PRINCIPIUM

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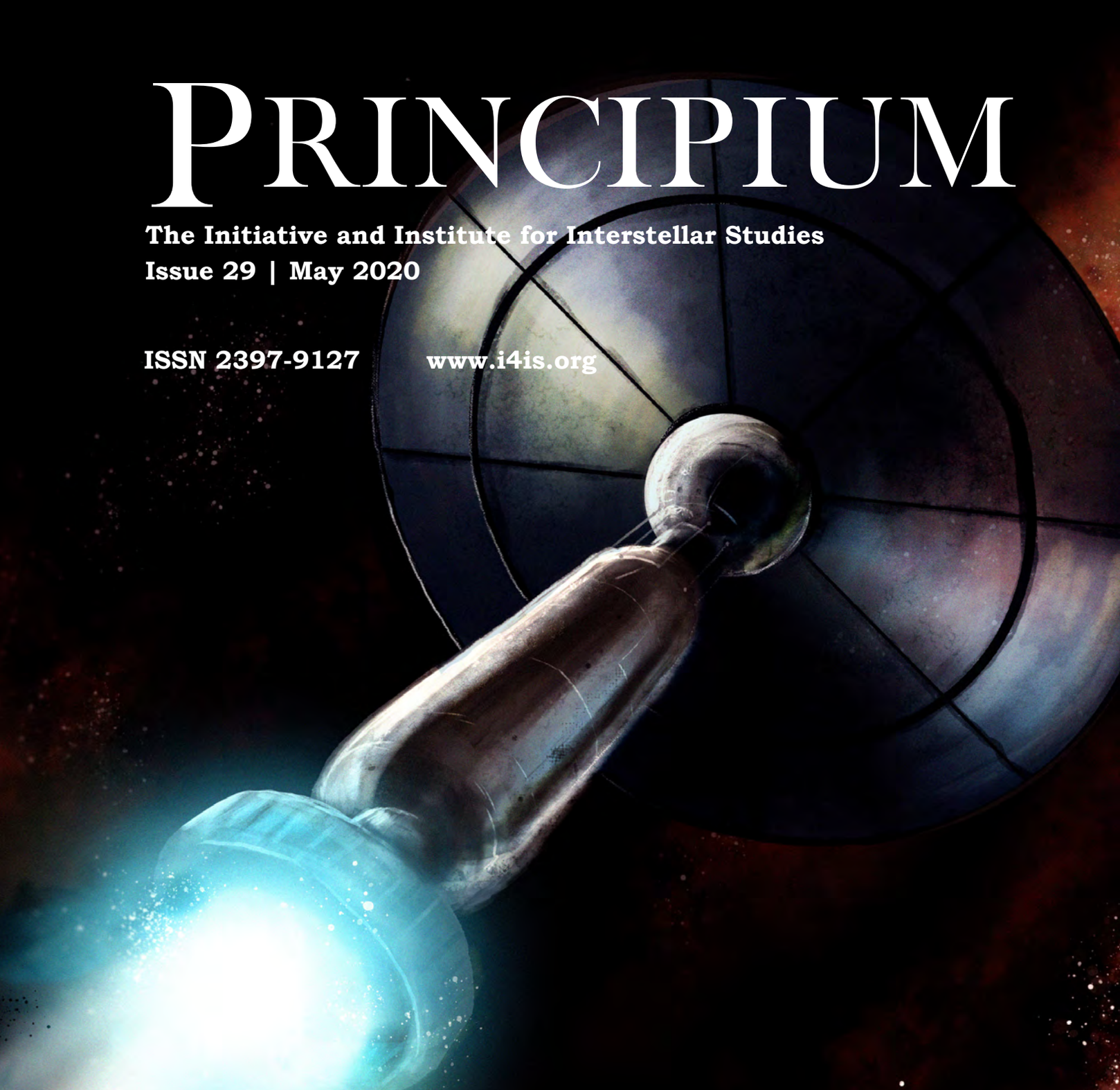

Scientia ad sidera
Knowledge to the stars

Editorial

Welcome to issue 29 of Principium, the quarterly about all things interstellar from i4is, the Initiative and Institute for Interstellar Studies.

The front cover image is a new visualisation of a Bussard ramjet by an old friend and colleague, Alex Storer (thelightdream.net). This year we mark the 60th anniversary of the publication of the paper *Galactic Matter and Interstellar Flight* by Robert W Bussard (Acta Astronautica, VI, pp 179-195, 1960), The distinguished spacecraft engineer and physicist Al Jackson celebrates this noble attempt to overcome the "tyranny" of Tsiolkovsky's rocket equation and evaluates its very considerable legacy - *The Interstellar Ram Jet at 60*.

The back cover image is of the Butterfly Nebula NGC 6302 taken by our old friend, the Hubble telescope.

The Lead Feature for this issue is the transcript of an interview with Cassidy Cobbs, Secretary of the Institute for Interstellar Studies (i4is-USA) and an evolutionary biologist working at the Memorial Sloan Kettering Cancer Center, New York. Robert Kennedy III, President of i4is-USA, suggested we interview Cassidy and it proved both entertaining and fascinating. We hope you agree. We intend to conduct occasional interviews like this with other specialists active in interstellar studies both within i4is and beyond. This interview is in two parts for the current and next issue of Principium, and in a single preprint already available in the members' area of our website.

We have the third and final report from the 70th International Astronautical Congress, Washington DC in October 2019. Members will have seen a preprint well ahead of this issue.

Our occasional contributor of thought provoking ideas, Dmitry Novoseltsev, brings us *Rings around earth-like exoplanets as possible artificial megastructures*. These have been imagined for our own planet, see the review of *Seveneves* by Neil Stephenson in P20.

Andreas Hein celebrates the life of Freeman Dyson (1923-2020), deviser of both profound mathematics and mind boggling structures - and a founder member of our Advisory Council.

The book *Religions and Extraterrestrial Life* by David Weintraub looks at the reaction we might expect to a successful SETI. John Davies reviews it and recommends it with a few reservations.

China has built the gigantic FAST radio telescope. We examine how this will work with the Breakthrough Listen SETI initiative.

And Terry Regan reports on the second phase of his model of the Mariner probes to Mars.

We report recent Interstellar News - see the full list in the new Contents page following this editorial.

In our next issue, P30 August 2020, we will have the concluding part of the interview with Cassidy Cobbs, a review of *Extraterrestrial Languages* by Daniel Oberhaus, a report of the i4is elective delivered at the International Space University, Strasbourg (completed just as we finalised this issue) and a commemoration of Al Worden (1932-2020).

If you have any comments on Principium, i4is or interstellar topics more generally, we'd love to hear from you!

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More in The i4is Members Page - page 13

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Please support us through membership of i4is. Join the interstellar community and help to reach the stars! Privileges for members and discounts for students, seniors and BIS members - details page 26. More at i4is.org/membership.

Please print and display our posters - in this issue our general poster on page 48 (white background) the student posters on pages 4 (black) and 31 (white).

All our poster variants at -

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And seek out our followers too!

Contact us on email via info@i4is.org.

Back issues of Principium, from number one, can be found at www.i4is.org/Principium.

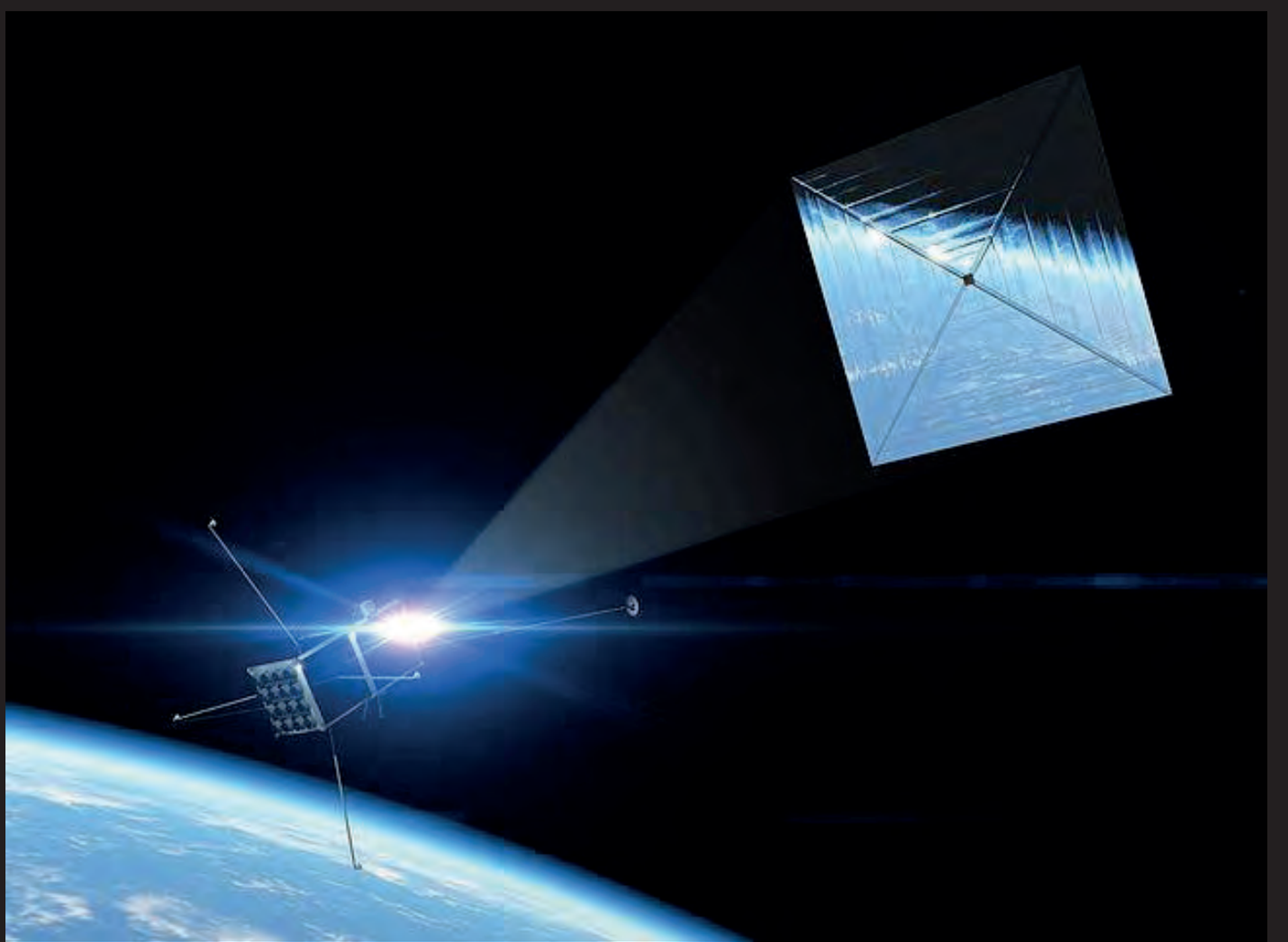
The views of our writers are their own. We aim for sound science but not editorial orthodoxy.

Contents

JOIN I4IS ON A JOURNEY TO THE STARS!

Do you think humanity should aim for the stars?

Would you like to help drive the research needed for an interstellar future...
... and get the interstellar message to all humanity?



The Initiative for Interstellar Studies (i4is) has launched a membership scheme intended to build an active community of space enthusiasts whose sights are set firmly on the stars. We are an interstellar advocacy organisation which:

- conducts theoretical and experimental research and development projects; and
- supports interstellar education and research in schools and universities.

Join us and get:

- member exclusive posts, videos and advice;
- free or discounted publications, merchandise and events;
- advanced booking for special HQ events; and
- opportunities to contribute directly to our work.

To find out more, see www.i4is.org/membership
90% discount for full time students!

Cassidy Cobbs - Bioscientist

interviewed by Robert Kennedy and John Davies

Cassidy Cobbs is an evolutionary biologist by training. A a student she participated in the discovery of a "lateral gene transfer event" between a fungus and an animal—that is, a seemingly humble fungus donated a gene complex allowing the second known instance of an animal's de novo production of carotenoid compounds. She was the lead author of *Carotenoids in unexpected places: Gall midges, lateral gene transfer, and carotenoid biosynthesis in animals* **(Molecular Phylogenetics and Evolution Elsevier doi.org/10.1016/j.ympev.2013.03.012 *) - see the midges discussion in this interview - and has contributed to research in related fields. Currently, she is a Scientific Liaison at Memorial Sloan Kettering Cancer Center (www.mskcc.org), New York, New York. She joined the Center as a Senior Research Technician in 2015 working in Sanger sequencing as part of the Integrated Genomics Operation core facility. With her lab she is now on the front line of the defence against Covid-19 in New York. Opinions expressed in this interview represent only her own point of view, and do not imply anything about those of her employer.**

Cassidy is the Secretary of the Institute for Interstellar Studies, the US-based part of our organisation. She was lead author of *Ecological Engineering Considerations for I.S.U.'s Worldship Project* **published in the Journal of the British Interplanetary Society Volume 68 (3/4), p 81-85, and supported the team delivering the Astra Planeta Final Report from the 2015 MSS Worldship Study at the International Space University (isulibrary.isunet.edu/doc_num.php?explnum_id=731).**

This article is the lightly-edited transcript of an interview with Cassidy conducted by Robert Kennedy III and John I Davies on 14th April 2020. In subsequent issues, we hope to bring further interviews with significant figures in i4is and interstellar studies.

This article appears in two parts in Principium 29 & 30 and in one part as a preprint in the i4is members area of the website.

John Davies (JD) top left, Robert Kennedy (K3) top right, Cassidy Cobbs bottom centre

* Search - scholar.google.com -for- *Carotenoids in unexpected places: Gall midges, lateral gene transfer and carotenoid biosynthesis in animals* - and use the link from - [PDF] academia.edu.

Section 1: Technology and language

The conversation is between -
K3: Robert Kennedy
JD: John Davies
CC: Cassidy Cobbs

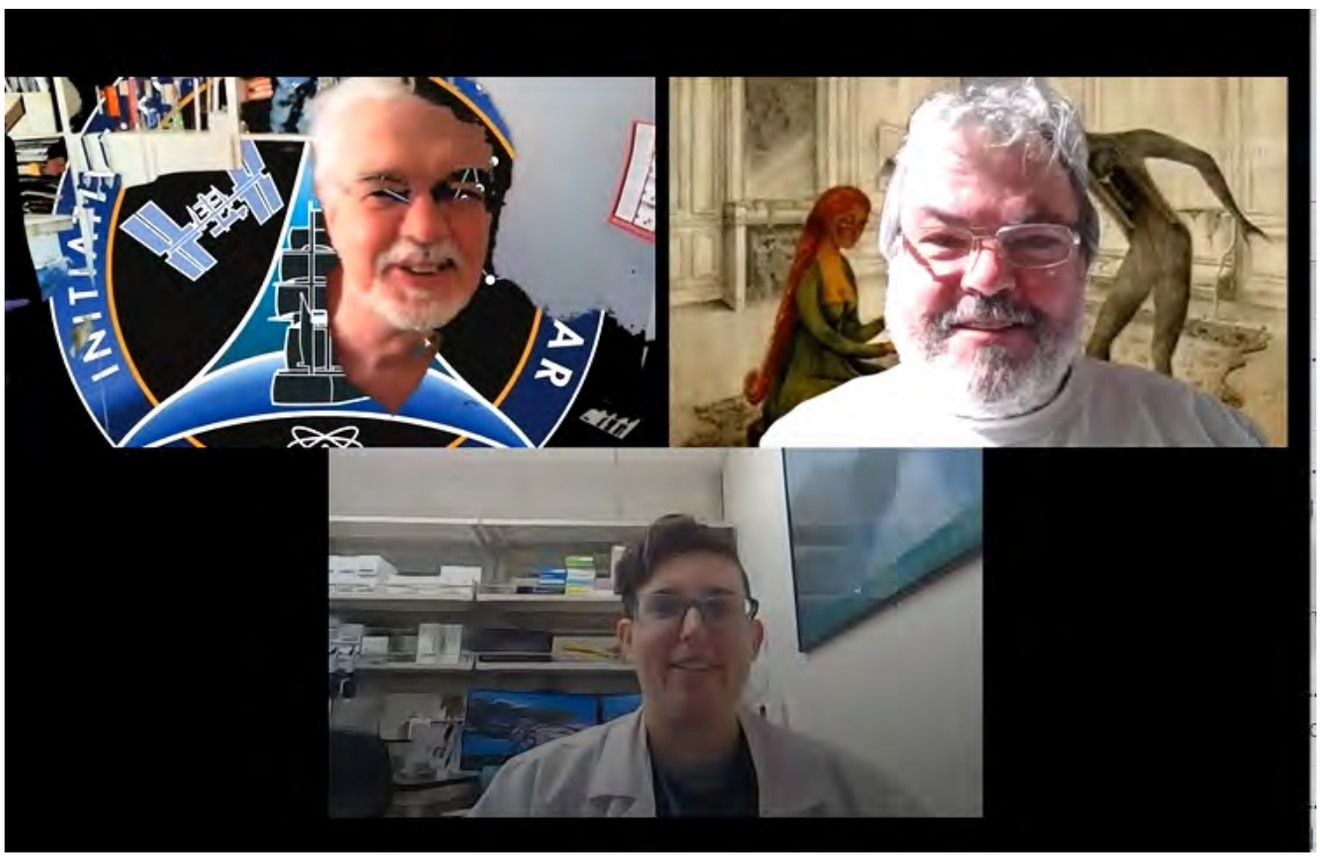
{Cassidy appears with a Zoom-inserted background}

K3:…it would be easier if you had a blue thing behind you like they use on TV

{then some messing about & experimentation}

JD:…Cassidy, you've distracted us now! {laughs}

K3: ……download smart virtual background package … hopefully this doesn't require administrative privileges…this is so cool if it works…oh John I see you're trying things



Caption: Vain attempt by JD to use Zoom background

JD: I'm trying to put the I4IS logo in, but it's got me as a ghostly figure {laughs}

K3: How cool

JD: I don't want to frighten people

K3: OK, now I know how to get here … Cassidy how are you fixed for time this morning?...

CC: I'm good.

JD: Sticking with my background. Right. I think Robert's got the longest list of questions, I've got a couple others to add to his. Are you recording, Robert?

K3: I am recording.

JD: I'll take copious notes!

K3: You shouldn't have to, that's why I'm recording so we can concentrate on the…umm…

…on the actual conversation.

As you can see, I suck at multi-tasking, so you know what? I'm gonna make an executive decision now, Cassidy, now that you've turned me on to this wonderful trick, I will utilize it henceforth, so let's get to … make this screen a little smaller … 'kay … one of the disadvantages of quarantine is of course in my case all my good computers are at work …

JD: I'm lucky, I've got the luxury of being retired, so the only computer I've got is the one here.

CC: I have the luxury of being an essential worker {laughs}

JD: It looks like a storeroom that you're in or is it a lab?

CC: It's a lab…{pans room with laptop camera}

JD: Oh yeah. Right. You know, that could be *anywhere*, what your sort of lab looks like, it could be…

CC: That's true…

JD: …Delhi, Tokyo, Melbourne…

CC: They all look the same.

K3: Let me grab this window …

JD: C'mon, Robert, let's get moving.

Caption: Cassidy shows us her lab

Robert's Questions

1. Tell us about yourself you can insert your own bio-blurb here; you should know I've made some fairly shameless plugs about you. What brought an Appalachian lady to hie herself to New York City? What were you doing before the pandemic?

2. As a transplanted denizen of the Big Apple, you are now living at Ground Zero of the Pandemic on Planet Earth. What is your life like these days? Please tell us how you reconfigured your lab to do coronavirus testing, and what working with that agent is like.

3. You have an unusual claim to fame. Tell us about this "lateral gene transfer event" you discovered - it is so cool. As a trained mycologist, tell us anything else about fungi that you think people aren't paying enough attention to.

4. What brought you to interstellar studies (besides me). How does interstellar work align with your long-term life goals? What paths of inquiry do you want to see in interstellar studies? What's not being explored adequately? If life ever returns to quasi-normal, what events (gatherings, size, purpose, location) would you like to see in our field?

5. Tell us about your outreach to bring more girls into science.

K3: yeah, yeah, we're burning daylight…the questions are visible, so…

K3: …thank you so much for your time,

JD: especially in the current situation.

K3: Our objective is to do some good for our charming – our quaint – little field, and also do it in a way that's salient, relative to current events, so first, why is a girl like you in the Big Apple? How did that happen?

CC: Um, good question. Well, they gave me a job here, so I came. Pretty much the gist. {laughs}

K3: Why was the Big…I mean, I was born and raised there, so New York is a state of mind. You must have been inclined to go there in the first place.

CC: I was in Nashville previously and I liked the city a lot but I was not going to find the kind of job that I wanted there so as I was hunting I was relatively location-independent. I looked a lot in the Bay Area, talked to / interviewed a couple places there but this ended up working out, kind of randomly. I didn't know anyone at this institute, I didn't know anyone in New York, but I guess they liked me so I moved in about two weeks from North Carolina to New York to start and I've been here five years.

K3: "Five years" has it been five years?

JD: Is your speech now North Carolina or New York or both or neither?

CC: I would say "neither". I never had much of a Southern accent. There was some active rebellion as a child to prevent developing one. Which were childish stereotypes which I have no problem admitting now, but my language patterns are set, so here we are.

JD: Right.

CC: I do still say "y'all" copiously.

JD: Oh do you? Right. That reminds me of the first Americans I knew when I was very young who were a bunch of Texans, the family a master sergeant in the US Air Force based nearby. They used to say, when we visited them, they used to say, "y'all come back!"

K3: Well, it's a useful word. It's a good Scots-Irish background {coughs} -- don't worry, seasonal allergies – you know, Indo-European languages make the distinction between polite and familiar which is usually done with plural and singular. Once plain old "you" became popular, they needed a way to distinguish the familiar "ye" so "y'all" and around here where I live not too far away they say "yoons" "you-uns"

JD: Right.

K3: that's pure Scots-Irish. That's old. Still around. So now, because they already use "ya'all" because they're being polite so how do you address plural yous, well that's simply, "all y'all".

{all laugh}

K3; which I find quite charming and I like to use. I like to pepper my New York-isms with nice Southern expressions, just like I like to pepper my Southern speech with Yiddish whenever I can. So, Cassidy, tell us about your professional background so the readers are up to speed on who you are, why you're working in this field.

CC: So I guess I've kind of wanted to be a wannabe scientist for a really long time, ever since my cat would bring mouse guts to my front porch so I would poke at them with a stick while my mother yelled at me to come get in the car so I could go to school…

JD: what to your front porch?

K3 & **CC:** "Mouse guts"!

K3: Disemboweled rodents.

CC: It was interesting. I'd never seen, like, a liver before. It was cool.

JD: I'm confused here. Our two countries divided by a common language. What are these things on the front porch? I'm just not understanding.

CC: So as a child, we had an outdoor cat, who would kill small animals, and who would bring their innards to the front porch to present to us as a gift.

JD: Oh right - moggy behavior.

CC: Yes. I was always very interested in poking around in the guts, seeing the organs. But we lived, we were quite rural and in general we spent a lot of time outdoors kind of appreciating the flora and fauna. My mother was, still is, an avid gardener, was a forestry major in college, so she had a great appreciation for the

forests, so we did lots of bird-watching and insect-catching. This was in the southern Appalachians which is home to some of the greatest diversity of salamanders in the world so we would I'm sure catch endangered salamanders {laughs}.

K3: um, greatest biodiversity in North America, period.

JD: Really?

CC: It was a great place to grow up with an interest in biology. I attended a high school specific for science and math and then you know I think in college I had a bit of a drive to expand my interests a bit which I think is common enough so I took as Robert knows some Russian some language classes linguistics.

K3: I don't think I knew about the Russian! Did you tell me about the Russian?

CC: Yeah!

K3: we went to that wonderful Polish restaurant *

JD: Now if you two are going to start talking Russian…

K3: Shoot, I should have greeted you in Russian. Kak vy pozhivaete?

CC: Nyet!

{all laugh}

CC: Um, but I eventually came back to biology, did my degree in that eventually, worked in a research lab at the North Carolina State University School of Veterinary Medicine. The lab was really fascinating, so they did, they studied, sort of immune-genomics and were looking at ways to knock down or knock out or human-ize the porcine immune system so that heart valves that were harvested from pigs for use in humans could be, you know, less immuno-genic. And it was very basic research. Essentially they were cloning pigs, and messing with immune genes to see what would happen. And that was really cool to be part of and learn about. I was still an undergraduate which of course meant part of my job was the most menial so I went to the slaughterhouse every week to collect fresh pig ovaries so we had oocyte donor cells for the cloning. Very glamorous. {laughs}

JD: Wow.

K3: That's the guts of the matter.

JD: I steered clear of biology, it was far too yucky.

CC: That's true. So after I graduated I moved to Nashville to Vanderbilt for graduate school lab where I joined a lab focusing on ecology and evolution, particularly mutualism and co-evolution.

So the main focus of the lab was actually aphids, they did a lot of aphid work. But my project ended up being studying mutualism between gall midges, which is a type of fly, a little fly, and a fungus.

JD: Ah…

CC: So, behaviorally, these midges would – we don't actually know a lot about how – but they would culture fungus on the surface of leaves of their favorite host plant. And the fungus would grow into this little gall over their eggs, it would protect the eggs from parasitoid predators, the eggs would then hatch, the larvae would eat the fungus, they'd mature, and move on with their lives. So there were different shapes of gall, some were sort of long and thin, so if you were a wasp looking to inject, to inject your eggs into a gall, because of a larger surface area, you would have less chance of actually hitting a midge egg to parasitize. But then there were some that were smaller but thicker so it would be harder to penetrate the fungal layer, and that was genetically passed so offspring of a mother that made a long thin gall also made long thin galls. We weren't sure how that was happening but there was clearly a genetic component to it. Because we had already been doing genomic work on midges, when the Moran Lab published evidence of a horizontal gene transfer from a fungus to aphids, there was reason to believe the midges may also have something like that because they were often orange. Their larvae were orange which is the color of carotenoids and this gene turned out to be a beta carotene synthesis gene which is not something…

JD: Amazing.

CC: …that animals can do. The vast majority of animals, aside from the few that have been discovered

* After the first i4is Foundations of Interstellar Studies Workshop (FISW) in June 2017, see Principium 18, August 2017 page 20-25 and JBIS Vol 71 No 8 August 2018 *Foundations of Interstellar Studies* NY.

now, can't synthesize their own beta carotene. So we looked at our genomic data and sure enough the genes were present in the gall midge as well. The phylogenetic analysis showed that it was from the same or at least a very related type of fungus that transferred the gene to the aphids so they were very closely related. And then we got to the level of being able to show that all three, there were three versions of the gene, and all of them were expressed. So they were producing RNA, they were active, they weren't just there, fossils of the…

JD: They weren't so-called "junk" DNA.

CC: Right. Exactly. They were using them for something. But, you know, as things happen in science I had to move on. That project remains in a sort of a "They're using them for something…!" stage. And what we hope is that "something" is that the carotenoids, which are known to have an effect on fungal growth, could be related to how they make their galls in the first place, how they shape them. But that's all very speculative.

JD: Right.

CC: So maybe someday someone will pick it up again.

K3: Getting even more speculative, since we hopped ahead to question 3, is there a general lesson yet that smart people should be paying attention to about a much closer relationship between fungi and higher animals?

CC: I mean, I'm not gonna, I don't have anything definitive to say about that. I've also, remember, been out of the literature for five years. But you know I think in general we're just beginning to appreciate how complex of a lifeform fungi are. They are often thought of as, well, yeah sure they're multicellular but they're basically just bacteria but different. But you know they're incredibly complex, their life cycles in some cases very simple and in some cases, outright insane. And I think that it's a realm as we continue to explore and find new species like we do of plants and animals we're going to find even more weird stuff. Their genomes are huge in a lot of cases. That's interesting because potentially they have a lot of room for adaptation should difficult things occur…

K3: Yeah. They have a big bag of tricks.

CC: They potentially have a big bag of tricks. I'm interested to see what we keep discovering. Some of them have genes that just aren't analogous to anything in the genomes we know. We don't know what they do, or what they're for, or why fungi have them, and I think that's really fun. So hopefully people you know continue to be excited about fungi.

JD: Magic phrase I remember I went to a lecture a couple years by Jocelyn Bell Burnell, you know the woman who did the pulsar thing, and she said, the best two words in science are "That's funny"*.

K3: Yeah, all great discoveries, "that's funny". True.

CC: So, the last five years have been a very different type of science for me. No longer quite so speculative. "We do not want anything to be funny in our lab." {all laugh} That would be a bad thing.

K3: That's gonna be a pull quote:

Section 2: We do not want anything 'funny' in our lab

CC: That has its own appeal, because we're constantly pushing the technological boundaries. You know, we always got to, because we do very high-quality work, and we do very high throughput work, we're always able to evaluate the newest instruments for genomics, the newest kits, the newest ideas. So even though I'm no longer in the business of discovering things, we learn new things all the time. And of course that's what's most important to me about science in general in any capacity. It's kind of just a different way of doing it. People sometime have a view of core facilities. In other fields - I don't know to what degree there are cores for astrophysics, but I know there are giant telescopes and particle accelerators that are shared-use facilities. Presumably there are technical experts also that run those things. Umm, and that's what we are. And sometimes that's looked down upon in science because it's not hypothesis-generating, it's technical.

* This is a personal memory of a speech given by Dame Jocelyn at William Perkin School, Feltham, London in 2017. I cannot find this in any published quote by her. However readers may be interested and amused by an after-dinner speech she gave to the New York Academy of Sciences in 1977- *PETIT FOUR*, S. Jocelyn Bell Burnell, Dec 1977 doi.org/10.1111/j.1749-6632.1977.tb37085.x - text at jila.colorado.edu/~ajsh/astr2030_12/sn/Bell.html.

But we're required to have such a thorough understanding of the biochemical processes, the biophysical processes, and the genetics and the genomics in general, that we can talk to anyone about their project, for the most part. Which is actually nice. I always like to say to when I'm talking to our new employees who are coming into a core, who have never worked in this environment, when I was in grad school—and this is the reason I ended up coming here in the first place— I did some transcriptomic work with our midges, RNA expression, RNA-Seq. I did a lot of, you know, made the libraries ourselves, I did the you know dirty coding, not good coding, to put the pipelines together for analysis, that kind of thing. You know, I thought I understood what was going on, what I was doing, but after being here and working in this facility for just six months, I was like, man, I knew nothing. I thought I understood what I was doing, but I was not even close. And that's why cores are important in general. When you're at a big-picture project in general it's very very difficult to learn all the minutiae. There's so many things to learn. And so that sort of collaborative nature is also the great part of working in a core because providing knowledge that you know don't always have time to learn all that stuff.

K3: You keep using the word "core", what sense are you using that word? C-O-R-E-core?

CC: C-O-R-E, yeah. So, in many research institutes, there are what are called "core facilities" which are funded usually by the institute itself. Well, three ways, by the institute itself, there are core facilities grants from the NIH (National Institutes of Health, a US federal body) but ours is actually from the National Cancer Institute, and then fee-for-service. So basically when you're talking about a field like genomics where there's a very high technical barrier to entry, to understanding what you're doing, and also the instruments themselves are very expensive, it behooves an institute to centralize its technology and its knowledge in a way that it's accessible to everyone, as opposed to each lab having to figure it out themselves. They don't really have the money or the time for that. So we have core facilities for all sorts of stuff.

JD: My other half {John's wife} worked on an early shared facility at the Royal Observatory Edinburgh (ROE) … she was a technician using a very early pioneer machine that took photographic plates in the days when astronomers used those and actually scanned them to digitize them essentially - and that, and a few other things that were happening at Edinburgh Astronomy Department eventually ended up with it being the centre for what became Astronomical Engineering in the UK, so basically any major new thinking - for example about new optical telescopes in UK astronomy - to a large extent will pass through the outfit that grew out of this ROE core facility. There are research astronomers there too but the astronomical engineering bit is a major function at Edinburgh. It's bigger than the Royal Greenwich Observatory, for example, in terms of astronomical engineering.

CC: Yeah, I think that's…

JD: that's exactly, it's a similar function.

CC: yeah, absolutely. So that's our idea. That's the point of us. People do pay, you know, we charge for our services, but we charge at cost, we don't make a profit, so it's definitely less expensive for investigators to work with us than to go to an outside company or to acquire all of the knowledge and the tech.

JD: You want to watch out that what happened to that sort of facility in the UK happens to you. Then somebody will say, "Oh, that's a potential profit-making organization, let's spin it out as a, and sell it off" and you end up paying more for the service because it's got privatised basically, and bingo, you've lost it. You know. There's supposed to be lots of competitors, but actually, no there aren't.

CC: Well, hopefully we'll remain mostly in-house.

JD. Right.

Section 3; The Sloan Kettering at "Ground Zero"

K3: So, that's a natural lead-in back to question 2. So, you're at Ground Zero—well, to New Yorkers "Ground Zero" means something special, so let's call it "new Ground Zero" until something better comes along—but you know the whole city's Ground Zero on Planet Earth for the pandemic…

…wow, there's the Zoom software trying to do its thing...

…What's life like these days? Do you feel like you're on the front lines? Tell us about that.

CC: You know, it feels, for everything that's going on, it feels remarkably normal in New York? Part of that is the neighborhood where I live is home to four or five major hospitals so we still have lots of foot traffic because we have lots of essential employees coming and going and living in the area. Yeah, um, a lot of stuff is closed, but the bodegas are still open, so I don't know what more you need anyway.

K3: No, I'd call that an essential service…*

CC: for sure

K3: …especially if it's serve-on-the-sidewalk.

{CC laughs}

K3: people gotta drink.

{CC laughs}

CC: We uh, you know, research activities were shut down on March 19th at our Institute {Cassidy note: we have reopened with strict guidelines for social distancing and infection control}, and everyone was sent home basically. Every lab gets an hour a day for one person to come in and do maintenance tasks, you know, check their liquid nitrogen tanks, make sure all their freezers are functioning, things like that. Labs that have mice—we have a really large mouse colony here—get two hours a day to come do essential animal care. We have a core facility where mice live, so there are veterinarians and animal care professionals that are still working and they do the basic cleaning and feeding and taking care of the mice. Things like that. So it's very limited access to the building right now unless the lab is doing some COVID-related activities. So our [the lab's] strength is really that we're capable of handling large numbers of samples. We have a number of {looks sideways and counts} one-two-three-four- five… like eight big liquid-handling robots.

K3: you mean those things that move a whole group of things like this? {dangles fingers} buzz-buzz-buzz Those?

CC: {nodding} right. Specialize in moving small volumes of colorless liquids.

K3: Right.

CC: We have a lot of those. So, our leadership worked really hard when the clinical lab here, Laboratory Medicine, needed us to develop a workflow that would work with us, which included, we needed a hood and a room for BSL-2,

K3: BSL-2, yes.

CC: which is Biosafety Level 2 and a way to safely process the samples. We had to buy two instruments which we got kind of immediately because the administration and the pharmaceutical companies, too, everybody's doing their best to push out reagents and instruments, everything you need to try to combat this. And we had as much support from the Institute as needed. So it took them about a week to go from, hey you think you can help with this to, OK here's a working protocol and set up and have the instruments and have the reagents and we're ready to go. There was a validation process, we had to be approved by the New York State Department of Health. We are not a clinical facility generally so this is out of the ordinary for us to be approved for something like this, but the situation is extraordinary. So it was important that testing passed pretty much as soon as possible. We did all the validation testing. It was fast, but it wasn't willy-nilly, I guess. It was still done as properly as possible. Since then, we've been running evening shifts, usually about 4 pm to 1 am, taking overflow samples from the clinical lab. I think at this point all of our samples have been employees, primarily clinical staff who have exposure risks and need to be cleared before they can go back to work. And then any staff are eligible for testing if they have symptoms, it's just priority is given to those who are clinical-facing then those who are essential but non-clinical and then everybody else.

* en.wikipedia.org/wiki/Bodega_(store) - and www.npr.org/sections/codeswitch/2017/03/10/518376170/new-york-city-bodegas-and-the-generations-who-love-them

We're running as many samples as they give us. Our busiest day we did almost four hundred, but that was exceptional. We normally process about one to two hundred a night. We could do more but there are other factors besides us. The swabs are actually in very short supply.

K3: Yeah, I saw that on CBS This Morning. They interviewed the guy up in Maine running the factory that makes mouth, it's actually a nasal swab not oral swabs…

CC: yeah.

K3: …not just your average Q-tip.

CC: No, no, they're not. And there's internal testing here and I'm sure many other places are also trying to validate using different types of material like – so mouthwash doesn't work great but sputum does pretty well if you can get it in a cup. Much better than just spit. So we're trying to validate things like that that would preclude using the swabs because {laughs} that seems to be our big limit right now. There's also a manpower limitation, how many appointments can you schedule in a day, safely? We are also working on antibody tests, via ELISA which will be essential for screening people who may have been asymptomatic but might have antibodies now and still be safe and able to come back to work even if they were never sick.

K3: Did you say "Eliza"?

CC: I did. E-L-I-S-A.

K3: All right.

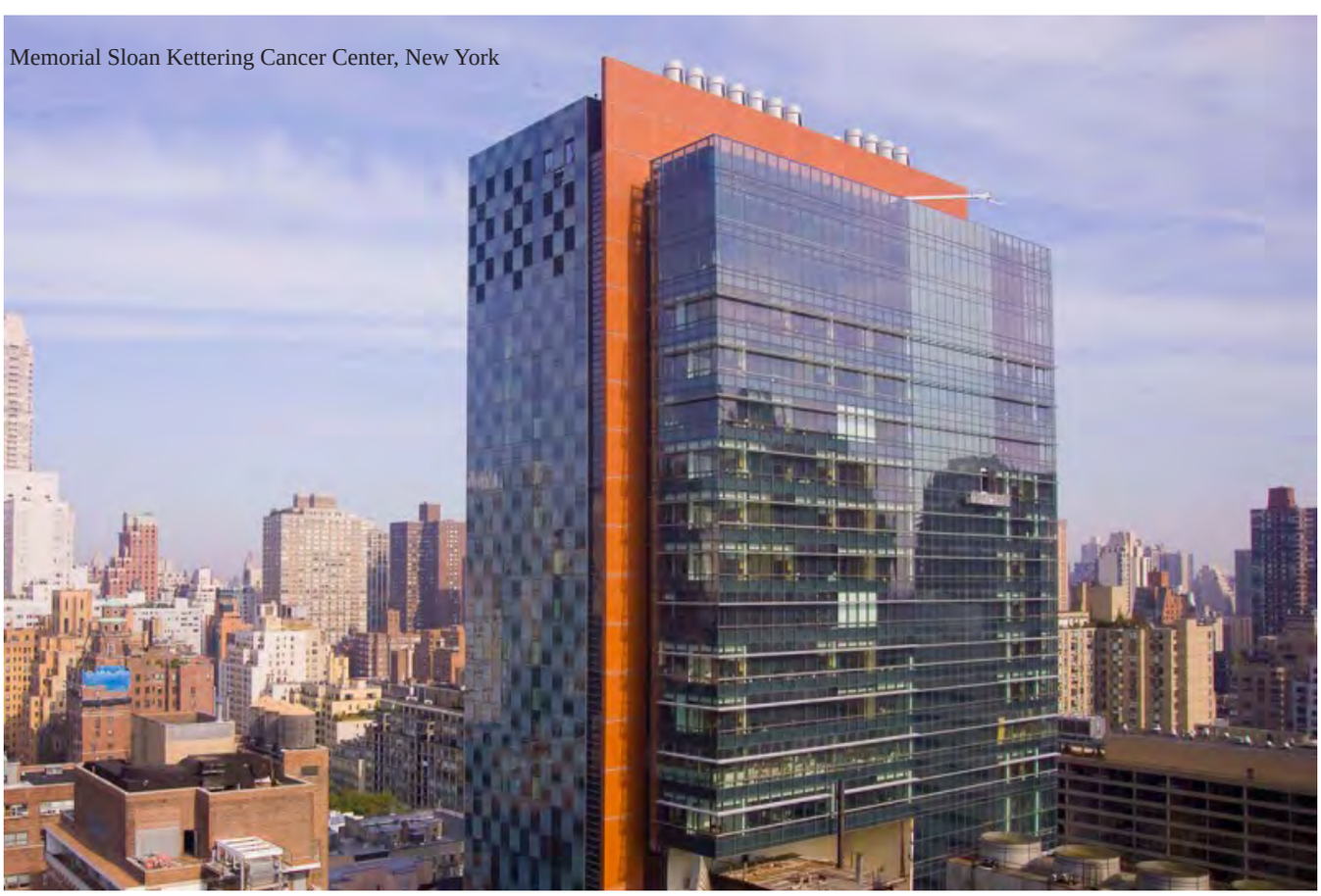
CC: It's an acronym. I can't remember what it stands for {CC: it's "enzyme-linked immunosorbent assay"}. We don't work in proteins a lot. It's a method for testing for the presence of antibodies, certain antibodies.

K3: A long time ago you and I talked about a paper involving the word MELISSA, which has the same string. Is it related?

CC: No, it is not.

K3: Argh, this is why the engineer is talking, interviewing the scientist, so we don't commit howlers.

{all laugh}


Memorial Sloan Kettering Cancer Center, New York

K3: How long? I mean I saw the governor {meaning New York Governor Andrew Cuomo} this morning. I think of myself as a New Yorker.

CC: That's fine.

K3: New York has plateaued, but many other places, most, by far most, in the country, have not because New York came from behind and became number one in the world basically because due to population density. Well, there's a bunch of those time bombs still waiting to happen.

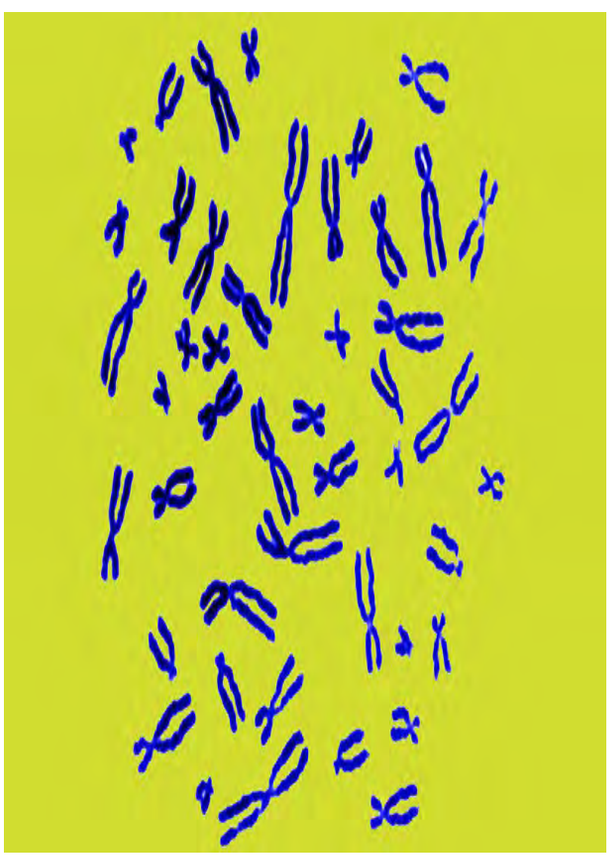
CC: True.

K3: So New York's plateaued. How long's this gonna go on? Are you ready? To do this for a year? I think I am…

CC: I guess we have to be…

K3: Well, yeah, what's our choice?

CC: …not really. Scientifically, yeah, we'll keep doing whatever we need to do. I suspect that things like research activities are gonna re-open before things like bars do. Because we can still take safety precautions like staggering shifts so that there aren't as many people in the building at one time. Mandating masks, I suppose. There are ways to decrease the risk. Screening people for antibodies so that you know who's ostensibly immune although we don't know how long immunity lasts…



duplicated chromosomes from a human male
MSKCC image

K3: Yeah, what's the latency of that though?

CC: We just don't know. There have been reports of re-infection, but it's hard to judge if there's true reinfection? Are they partial recoveries and relapses? Did they ever clear the virus in the first place? {shrugs gallically}. It's nuts.

JD: Maybe a false positive. Someone who's asymptomatic and gets tested, oh yeah, you've got it, all it takes is 1% of them.

K3: Apparently false negatives are a bigger problem orders of magnitude more than false positives. Those results from Korea? The human race better get that figured out soon because if this thing is shifting antigen {snorts} life's going to change permanently. That's my…. You know, I don't know how much of my stuff I've been sharing with you, Cassidy, but I've been thinking about this all my life. Life may change, permanently.

JD: From a purely amateur point of view it seems to me the clue to this thing in the long run is probably gonna be as much effective treatment as vaccination. Because vaccination only hits a particular genetic target. If the target moves, you've got to start again to a large extent, but if you have a treatment like a mild case of the flu because you've got things you can hit it with.

K3: Lemme, that's a good point John, let me modify—absent a prophylaxis, absent a therapy, life will change in fundamental ways, as it has before in the historical record. Read what really crashed the Roman Empire. Three big plagues, over 300 years, about 150 years apart. Not barbarians climbing over the walls, not Vandals running around. It was bugs. I dunno how much spare time you have for reading Cassidy - maybe a little thing about history's lessons… OK … well, we're kind of getting off topic. Ostensibly this is an interview about interstellar studies.

CC: Well…

That's all for this issue. More in P30, August, when Cassidy, Robert and John will discuss Interstellar biosafety and outreach, Diversity and SF in interstellar studies, and Cassidy's journey from School to Sloan Kettering.

Rings around earth-like exoplanets as possible artificial megastructures

Dmitry Novoseltsev

Our regular contributor, Дмитрий Новосельцев (Dmitry Novoseltsev), presents us with another of his challenging ideas – that the presence of rings around an Earth-like exoplanet may enable us to look for signs of a technologically advanced civilisation, that is, a "technosignature".

The Neil Stephenson novel, *Seveneves*, imagines such a ring. Take a look at *The Orbits of Seveneves - A book review with a touch of orbital dynamics, Part 2 - the orbits explained,* Sander Elvik, Principium 21, May 2018 (www.i4is.org/Publications/Principium).

Earlier 1] the author considered one of the possible directions of the search for optical technosignatures in the "New SETI" programs. The possibility proposed by the author 2] of using technogenic space debris in so-called kinetic jet engines (KJEs) during its mass development could allow us to observe the characteristic spectral markers of the combustion products from the high-energy materials in KJE targets around an inhabited and technologically advanced exoplanet.

This idea can be developed further. From the point of view of the working process of the KJE, the physical nature of the impactor transmitting the energy of the target does not matter much. This can be either an artificial object (including a fragment of technogenic debris), or a natural space body. The necessary condition is only a sufficiently high counterspeed of the impactor relative to the target.

In this regard, planetary rings are of particular interest.

By now, quite large rings around large exoplanets have already been discovered 3, etc]. The sensitivity of the astronomical instruments used is gradually increasing, which will allow smaller objects to be observed in the foreseeable future.

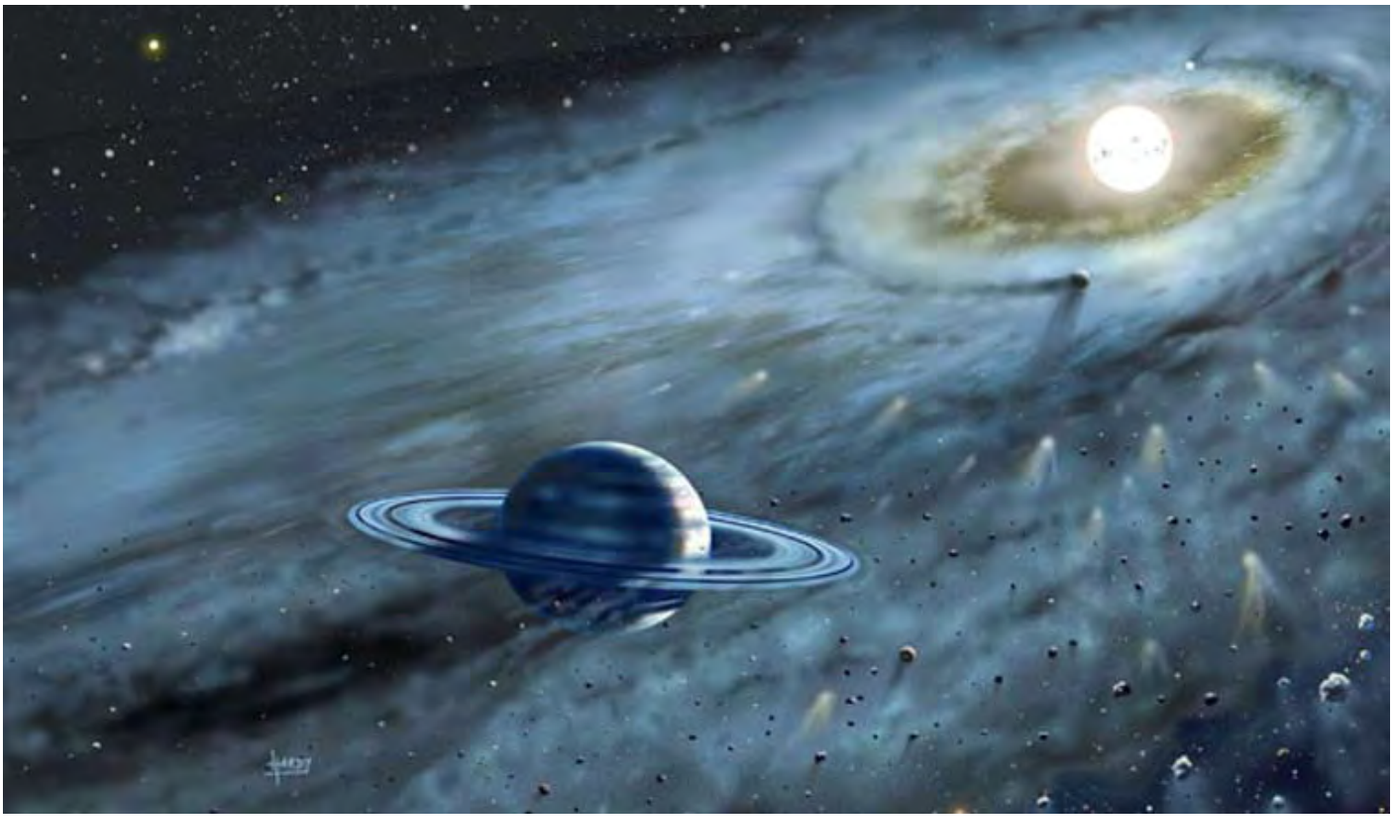
At the same time, for the terrestrial planets in our Solar system, and for Earth-like exoplanets, the presence of pronounced rings is unusual (although we expect that, in the distant future, natural rings may appear around Mars when its satellites are destroyed).

Further, we should note the somewhat speculative assumption that the development of a technological civilization may depend largely on external conditions.

For example, if there is free oxygen in the atmosphere, traditional carbon-based energy can only arise, in the absence of fossil fuels such as coal, peat and oil, through the use of renewable organic biomass and the products of its processing. It is possible that such "bio-carbon" energy, largely integrated with agriculture and forestry (and possibly with mariculture), would be more environmentally efficient than modern energy.

The situation is different with nuclear power, the development of which is ultimately determined by the concentration of a number of heavy elements in the upper layer of the planetary crust, and their availability. If they were several orders of magnitude less concentrated than on Earth, in the conditions corresponding to the middle of the 20th century, nuclear power would most likely not have been created: neither in wartime, due to the lack of available resources, nor in the post-war period, because of the low profitability. The theoretical possibility of nuclear power might well be known, but nuclear power plants would remain just as hypothetical as photon annihilation engines.

Under these conditions, the role of nuclear missile deterrence as a factor that excludes subsequent catastrophic global wars could be fulfilled instead, for example, by biological missile deterrence, which could also serve as a source for the development of traditional chemically-fuelled rockets and space technology. This might also make it possible to achieve a low planetary orbit in a comparable time frame, and to create artificial satellites, with the use of electric rocket engines, solar sails and other low-thrust engines, to begin research of the planetary system. However, the far reaches of the planetary system, where



Visualisation of a ringed planet - what the Fomalhaut dusty planetary system might look like from near the large planet.
Credit: © David A Hardy/www.astroart.org

solar panels are ineffective, would probably no longer be available for such a civilization, given that it appears to us to be impossible to organize such missions as the Voyager probes without appropriate sources of nuclear energy.

However, the situation could change completely if the hypothetical exoplanet described above is orbited by a ring comprised of small rock fragments. In such a case, after reaching the ring using the traditional means of rocket and space technology with chemical fuels, it would be further possible, with the use of KJE technology, to carry out many cheap and energy-efficient flights throughout the planetary system and beyond.

Previously, a number of authors 4, etc] have noted the advantage of having a natural satellite with relatively low gravity, such as the Moon, as an immediately achievable goal in space exploration, and as a base for the rapid growth and development of the technological and other potentials of a civilization, with an almost complete absence of environmental restrictions. It seems to this author that a circumplanetary ring provides much greater opportunities. (Here we can note the limitation of the classic Kardashev scale. There may be a situation where a technologically advanced civilization does not fully use the energy resources of the base planet, for environmental or other reasons, ie it does not formally correspond to type 1, but at the same time it actively uses the available resources of its natural satellites and rings.)

As is well known, in the recent past NASA considered a program to capture a small asteroid and transport it to near-earth or near-lunar orbit – the Asteroid Redirect Mission (ARM) or Asteroid Retrieval and Utilization (ARU) mission, later postponed 5]. Similar projects have also been considered by private companies in the framework of promising programs for the development of space resources. Such an operation for transporting an asteroid can in principle be carried out by traditional means of rocket and space technology, and, therefore, would be quite accessible to the hypothetical "non-nuclear" civilization described above.

In the future, the asteroid might be converted into small fragments – both directly and during the extraction of mineral raw materials from its substance – with the consequent formation of a ring of small rock fragments. Fragments of this ring could, in turn, be used as impactors for KRDs, which could significantly increase the volume and efficiency of transport operations in space.

Thus, the presence of a natural ring of small rock fragments orbiting a habitable exoplanet could provide a successful combination of circumstances from the point of view of the development of a technological civilization.

Such an artificial ring could also be one of the first and simplest, but also most effective, artificial astro-engineering megastructures created by a relatively young space civilization.

In either case, a cheap and mass-scale system for the launching of spacecraft from low planetary orbits into deep space becomes available to the civilization. This, in turn, would allow the civilization to carry out long-term and large-scale space exploration projects, such as "Catalysis" 6, 7], even with relatively limited resources.

In this regard, in the "New SETI" programs 8], focused on the search for technosignatures, it would be advisable to pay close attention to the observation of any detected earth-like exoplanets which display any signs of the existence of a ring of small rock fragments, in the available radio and optical bands. In the presence of the sorts of large-scale space activities described above, there would be likely to be an intensive exchange of signals between spacecraft, the exoplanet and its natural satellites, and these signals could potentially be detected by us. The spectral markers indicated earlier 1] for the use of CRD could perhaps be detected also.

References

1. Dmitry Novoseltsev. On a possible future direction for optical SETI. – Principium, Issue 27, November 2019. – pp. 4-6. i4is.org/wp-content/uploads/2019/11/Principium27-print-1911280846-comp.pdf

2. Новосельцев Д А, О возможности рациональной утилизации фрагментов околоземного космического мусора с использованием кинетических реактивных двигателей. - Всероссийская научная конференция "Космический мусор: фундаментальные и практические аспекты угрозы": Сборник трудов. / Серия «Механика, управление и информатика». - М.: ИКИ РАН, 2019. - стр. 217-229. iki.cosmos.ru/books/2019cos_mus.pdf

3. Hilke E. Schlichting, Philip Chang. Warm Saturns: On the Nature of Rings around Extrasolar Planets that Reside Inside the Ice Line. 19 Apr 2011. arxiv.org/abs/1104.3863

4. Кричевский С В, Освоение Луны: история, модель, сверхглобальный проект и экологичные технологии // Воздушно-космическая сфера. 2019. №3. С. 16-25. www.vesvks.ru/vks/article/osvoenie-luny-istoriya-model-sverhglobalnyy-proekt-16447

5. en.wikipedia.org/wiki/Asteroid_Redirect_Mission

6. Dmitry Novoseltsev. Engineering New Worlds: Creating the Future. Principium, Issue 17, May 2017, pp. 30-35. i4is.org/wp-content/uploads/2017/05/Principium17%201705170945.opt.pdf

7. Dmitry A Novoseltsev. The Catalysis Project: On the Possibility of Purposeful Expansion of Intelligent Life in the Galaxy. Evolution: Evolutionary Trends, Aspects, and Patterns. Volgograd: ‘Uchitel’ Publishing House, 2019. pp. 66-75. www.socionauki.ru/almanac/evolution_en/evol_6_en/

8. NASA and the search for technosignatures. A Report from the NASA Technosignatures Workshop. November 28, 2018. arxiv.org/ftp/arxiv/papers/1812/1812.08681.pdf.

PostScript

Currently, the author and the specialized small innovative company D-Start created by him, with the assistance of AmbaSat (developer and manufacturer of femtosatellites) and Interorbital Systems (developer and manufacturer of launch vehicles, operator of launch services), is implementing the "Impulse" project. The project involves preparing and conducting a flight test in 2020 of the current simplest functional model of the KJE analog. The project is implemented through crowdfunding.

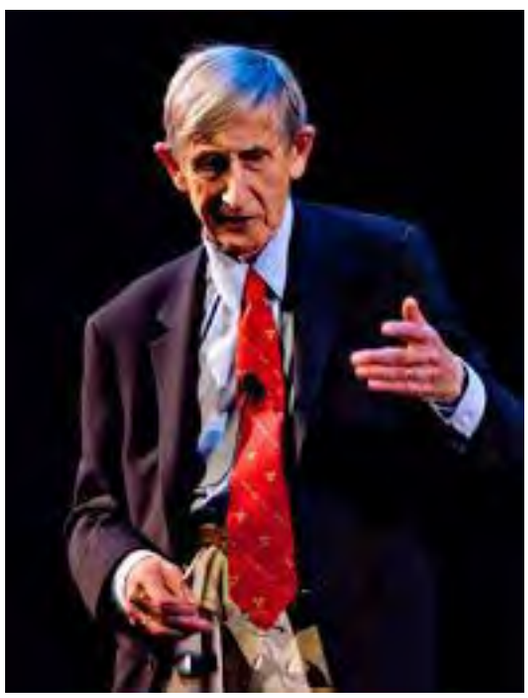
About the Author

Dmitry Novoseltsev (Дмитрий Новосельцев) is Deputy CEO of the Siberian Mechanical Engineering, Non-Profit Partnership (www.npsibmach.ru). He has a PhD in Technical Sciences, awarded by Omsk State Technical University, for his thesis “Vacuum, compressor technics and pneumatic systems”. He is a regular contributor to the Space Colonization Journal (jour.space).

Freeman Dyson (1923-2020)

Andreas Hein

A version of this tribute by i4is Executive Director, Andreas Hein, was published on the BIS website on February 29 2020



With great sadness, we received the message that Freeman Dyson has passed away. He was 96 years old. A distinguished physicist, Freeman Dyson was a member of the i4is Advisory Council for many years. Many obituaries have already appeared. In the following, I would like to honour Freeman by presenting his contributions to interstellar studies.

A master of exploratory thinking, his contributions to the field of interstellar studies are numerous. It is safe to say that he is one of the founders of our field. His contributions will remain a source of inspiration, a treasure trove of scientific creativity. Freeman was not afraid of entering into new domains, taking ideas, and combining them to generate novel concepts; audacious, but firmly grounded in existing physics, courageously extrapolating existing engineering. The back-of-the-envelope calculation as a showcase of human ingenuity. Just to mention a few:

– Orion interstellar spacecraft: In a landmark paper, he made the, to my knowledge, first detailed calculations on a crewed, nuclear bomb-driven spacecraft, capable of reaching other stars. The paper “Interstellar Transport” is a mandatory read for everybody interested in interstellar travel and a masterpiece in first-order feasibility analysis. Based on technologies of the 1960s, it includes even a possible date when we might be capable of developing such a spacecraft from an economic standpoint (He estimates 2168):

Dyson, F J (1968). Interstellar transport. Physics Today, 21(10), 41-45.

– Dyson Sphere: The megastructure, first proposed by Olaf Stapledon but turned into science by Dyson, encloses a star in order to harvest its energy. Speculative at first, the concept has stimulated subsequent research on looking for alien megastructures in our galaxy and even in millions of other galaxies. So far, no Dyson Spheres were discovered. But it shows how exploratory thinking can stimulate and guide observational science.

Dyson, F J (1960). Search for artificial stellar sources of infrared radiation. Science, 131(3414), 1667-1668

– Astrochicken: The idea of a kg-scale biological, self-replicating interstellar probe is again demonstrating how he combines ideas from different domains to create a new concept. The astrochicken blends microelectronics, biology, and artificial intelligence. It “would be launched by a conventional spacecraft into space, like an egg being laid into space. Astrochicken would then hatch and start growing a solar-energy collector. The solar collector would feed an ion drive engine that would power the craft. Once Astrochicken entered a planet’s vicinity, it would collect material from the moons and rings of the planet, taking in nutrients. It could land and take off using an auxiliary chemical rocket similar to that used by bombardier beetles. It would periodically transmit details of its journey when it could make radio contact with Earth.” en.wikipedia.org/wiki/Astrochicken

The seeds he has planted will continue to grow into futures, one day to the stars.

He will be greatly missed.

Andreas Hein, i4is

Current technological feasibility of self-replicating probes for interstellar exploration

Olivia Borgue

Olivia Borgue is working with Dr Andreas Hein, Executive Director of i4is, on a feasibility study of self-replicating probes. The significance of these for both interstellar exploration and for questions of SETI and the eternal Fermi paradox will be familiar to many Principium readers. The first serious studies were by the Hungarian-American polymath John von Neumann in the late 1940s but the idea of self-reproducing machines dates back to pre-industrial times. Here Olivia introduces us to the current state of the art and gives us a taste of work in preparation for publication by herself and Andreas.

Self-replicating probes have been proposed for various purposes related with space exploration as they would allow for an exponential growth in the number of interstellar probes and would enable a rapid exploration of space or rapid bootstrapping of space infrastructure.

Despite their potential benefits, concepts for self-replicating probes have been proposed in the literature for decades but remain a hypothetical concept to date. It has been actually argued that every corner of the Milky Way and even beyond could be explored with self-replicating probes in a relatively short time. The general concept is a machine that is able to replicate itself using materials that are available and accessible out in space, such as materials available on planets, moons or asteroids. The probe explores space and transmits data back to Earth, in the meantime it looks for a suitable destination where it lands and harvests the material it needs to build copies of itself, which, will perform the same replication and data collection/transmission functions.

Although the existence of a self-replicating machine has been formally proven, an actual construction, even in the form of computer programs is difficult and computationally expensive and actual construction has not been yet accomplished. The only physically realized concepts which relate to self-replication pertain to self-assembling systems. These systems are collections of passive elements that self-assemble under external agitation or naturally occurring physical forces. Such is the case of the self-replicating systems proposed by Penrose (1959), a machine comprising four different components that are assembled by following tracks, see Figure 1.

Figure 1. Self-replicating machines proposed by Penrose (1959)

Self-reconfigurable robots have been largely investigated and, in most cases, modular components are all connected (either physically or by a communications link), and the topology of that connection changes as a function of time or the task requirements, such is the case of the systems proposed by Zykov et al (2005, 2007), Figure 2.

Figure 2. Self-assembling systems proposed by Zykov et al (2005, 2007).

However, these alternatives use prefabricated parts that are assembled to form copies of themselves. For useful applications related to space exploration, physical self-replicating machines would need to possess high computing power and sophisticated manufacturing capabilities.

Conceptual papers about self-replicating systems for space applications were proposed by Bond and Martin (1986), for the Daedalus concept or Freitas (1989), for the REPRO concept.

These authors proposed large (hundreds to thousands of tons) self-replicating spacecraft for interstellar exploration that would land in Jovian planets for the establishment of resource harvesting and self-replication factories. However, no concrete system architecture for a self-replicating probe has been proposed.

The advent of novel manufacturing technologies such as 3D-printing / additive manufacturing, enables the possibility to manufacture a wide range of components onboard a space probe in a compact and resource efficient manner.

In a recent study, Olivia Borgue and Andreas Hein performed a technology analysis of the systems onboard a self-replicating probe to assess their feasibility in the context of current state-of-the-art technologies. The study revealed that every system onboard a self-replicating probe can be, theoretically, self-replicated. However, considering the current technology development of the replication and resource harvesting module, the manufacturing systems necessary to fabricate every component onboard can itself be difficult to manufacture.

A self-replicating probe able to be manufactured in the next 10 years would not be 100% self-replicating, instead, several components must be carried from Earth, limiting the replication cycles.

However, launching a partially self-replicating probe to replicate itself a finite number of times can still have economic benefits.

The results of this study will soon be submitted to the Journal Acta Astronautica.

References

Penrose, L. S. (1959). Self-reproducing machines. Scientific American, 200(6), 105-117.

Bond, A., & Martin, A. R. (1986). Project Daedalus reviewed. Journal of the British interplanetary society, 39, 385-390.

Freitas Jr, R. A. (1980). A self-reproducing interstellar probe. Journal of the British Interplanetary Society, 33(7), 251-264.

Zykov, V., Mytilinaios, E., Adams, B., & Lipson, H. (2005). Self-reproducing machines. Nature, 435(7039), 163-164.

Zykov, V., Mytilinaios, E., Desnoyer, M., Lipson, H., 2007. Evolved and designed self-reproducing modular robotics. IEEE Trans. Robot. 23, 308–319.

Interstellar News

John I Davies reports on recent developments in interstellar studies

More Interstellar Objects and more controversy

Interstellar Objects(ISOs) remain at the focus of both observational and theoretical study and there is still no consensus on many issues which they raise.

The continuing mystery of the tumbling and accelerating 1I/'Oumuamua and the difficulty of reconciling these two behaviours still attracts attention. Mashchenko* in the Monthly Notices of the Royal Astronomical Society remarked that "the contributions to f_r [the accelerating force from outgassing] at different rotation phases would all cancel out".

In March, Wired magazine journalist Daniel Oberhaus asked "Should Earthlings Chase 'Oumuamua Into Interstellar Space?" (www.wired.com/story/should-earthlings-chase-oumuamua-into-interstellar-space/). It cites our Acta Astronautica paper *Project Lyra: Catching 1I/'Oumuamua – Mission opportunities after 2024* (doi.org/10.1016/j.actaastro.2020.01.018 open at arxiv.org/abs/1902.04935) at some length and quotes authors Adam Hibberd (see also his piece about reaching the third ISO), Marshall Eubanks and Andreas Hein. It also cites others on the subject, notably including Seligman and Laughlin of Yale. Both Eubanks and Seligman sense that the unique 1I/'Oumuamua will deserve close inspection if it remains one of a kind in a few years time.

Recent Interstellar Papers in JBIS

The January 2020 issue, a General Interstellar Issue, was dedicated to papers from last year's second Foundations of Interstellar Studies workshop, FISW 2.

The Continuing Mysteries of 1I/'Oumuamua - A personal view

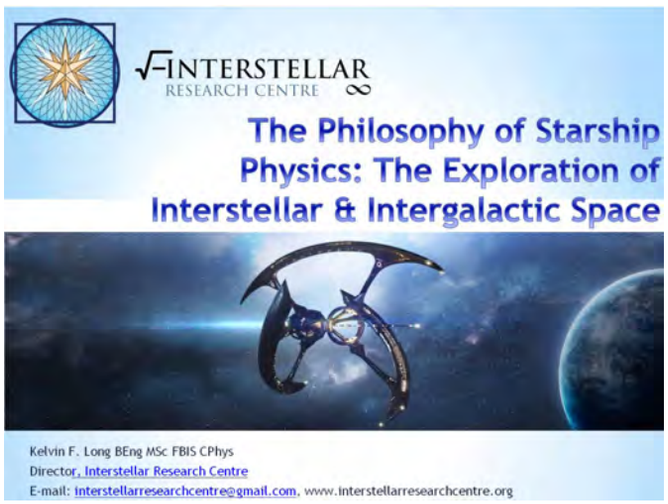
- It's an elongated object maintaining structural integrity - thus limiting the choice of material composition and excluding the "dirty snowball" of a conventional comet (which 2I/Borisov seems to be).
- It's tumbling motion shows no significant variation over the period of observation - thus there is no net torque being applied to it.
- Therefore the anomalous acceleration must be the result of a net force acting at its centre of mass.
- To produce such a force by outgassing (also invisible) requires a mechanism which precisely tracks the angle of incidence of solar radiation (since this is the same angle as the Sun's gravity).
- A material composition which has this precise radiation-tracking property is unknown to current science

John Davies

* *Modelling the light curve of 'Oumuamua: evidence for torque and disc-like shape*, Sergey Mashchenko, Monthly Notices of the Royal Astronomical Society, Volume 489, Issue 3, November 2019, Pages 3003–3021, doi.org/10.1093/mnras/stz2380 open at www.researchgate.net/profile/Sergey_Mashchenko/publication/333678739_Modeling_the_light_curve_of_Oumuamua_evidence_for_torque_and_disc-like_shape/links/5d07c696458515ea1a6d4d7f/Modeling-the-light-curve-of-Oumuamua-evidence-for-torque-and-disc-like-shape.pdf

The Philosophy of Starship Physics

One of the last events at BIS HQ, London, before the lockdown was a broad ranging presentation by our co-founder and former executive director, Kelvin Long titled *The Philosophy of Starship Physics: The Exploration of Interstellar and Intergalactic Space*. Kelvin has kindly shared his presentation with us so you can get a small flavour of his talk.



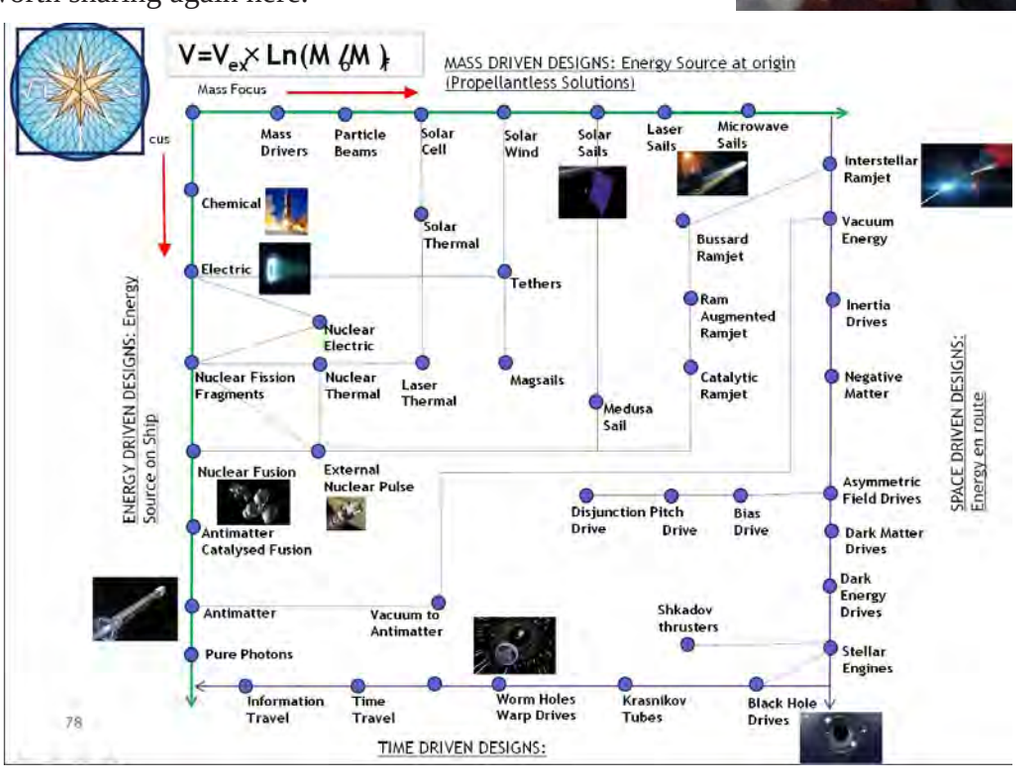
The seven objectives of his Interstellar Research Centre range from The Nature of Homo Sapiens via Interstellar Travel to the nature of Consciousness. He introduced his new book of essays and a number of recently published monographs. He took us rapidly through the history of interstellar studies from Sanger and Shepherd in the 50s to the present day, notably the founding of Project Icarus in 2009. His taxonomy of propulsion is an old favourite, well worth sharing again here.

Some old themes such as temporal spaghettification came with new ideas (to this reporter) including the Bronstein Hypercube, a topological description of the relations of the physical theories of Galileo, Newton, Minkowski, Maxwell, Einstein (special and general theories) and others. Some distance above my head but Bronstein seems to have provided a way of looking at the interrelations - and sometimes conflicts - between these theories.

Kelvin's top 5 predictions before 2050 include inspiring events - a precursor mission beyond 1,000 AU, a threat to Earth, exoplanets, physics of a new energy source and new SETI discoveries. This was a stimulating coverage of just some of things currently occupying Kelvin's fertile mind. The event was live-streamed but has not yet appeared in the members area of the BIS website.

BIS President Gerry Webb pays close attention to Kelvin's talk

Credit: John Davies



Taxonomy of Propulsion

Credit: Kelvin Long

Data Mining for SETI

A NASA press release last month (April 2020) draws attention to *Earth-Size, Habitable Zone Planet Found Hidden in Early NASA Kepler Data* (www.nasa.gov/press-release/earth-size-habitable-zone-planet-found-hidden-in-early-nasa-kepler-data). This reminds of a point made by Robert Kennedy III in *A Modest Proposal for Photometric SETI*, Principium 11 | November 2015 "... we might be able to find the fingerprints of a Type I civilization simply by data mining the archives from missions such as Kepler and its successors".

SOLAR ONE – A Proposal for The First Manned Interstellar Spaceship

Alberto Caballero, an Intelligence and Security specialist, has proposed a novel, and controversial, approach to interstellar propulsion. He suggests using aspects of three existing or near-term technologies - the US Navy CFR fusion reactor, a larger version of NASA's Sunjammer light sail, and a continuous-wave version of the Teramobile laser system (engrxiv.org/qcrxa/download?format=pdf). Alberto's idea featured in Space Daily (www.spacedaily.com/reports/Solar_One_A_proposal_for_the_first_manned_interstellar_spaceship_999.html) but received a blunt response in a Tweet for Les Johnson (NASA Principal Investigator and long prominent in interstellar studies) tweeted "Space Daily, how could you? A laser sailcraft can't carry its own laser to push itself! (Newton is rolling over in his grave!) [translation: the propulsion system won't work]." . We'll keep an eye on this, of course.

Virus cancellations and postponements

The Covid-19 pandemic has not disturbed the internal processes of i4is significantly so far. We are all in good health as of early May and we necessarily work at a distance since we are spread across the world, mostly but not exclusively, Europe and North America.

However this annoying virus, as well as continuing horrible effects on life, health and the world economy. Here are the various cancellations we see - starting with events involving i4is people most closely -

- We would have been at a Royal Holloway University of London event for schools in March. This has been cancelled. UK schools currently open only for vulnerable children and the children of key workers.
- i4is at the Royal Institution - 2020: In July we would have delivered our third workshop for the 13-15 and 16-18 age groups. The Royal Institution has decided to cancel the summer school programme this year. There may be some virtual version but this may have to be our own event only.
- Foundations of Interstellar Studies Workshop 2020 FISW 2.5 is currently being rescheduled. We will keep you informed.
- We were planning two events for this summer, Starship Engineering 2020 and a wider-ranging Summer School, both at the British Interplanetary Society (BIS). London. The BIS HQ and staff are working from home until further notice and the HQ building is closed. All events are now moved online (www.bis-space.com)
- The big event of the astronautical year, the International Astronautical Congress 2020, will now happen in curtailed virtual form. The International Astronautical Federation (IAF) announces "The 71st International Astronautical Congress – The CyberSpace Edition will take place in your homes and offices around the world during 12 – 14 October 2020." (www.iafastro.org/events/iac/iac-2020). We will report on this in our November issue, P31.
- Last month's (March) 51st Lunar and Planetary Science Conference (www.hou.usra.edu/meetings/lpsc2020) of the Lunar and Planetary Institute (www.lpi.usra.edu), part of the Universities Space Research Association (www.usra.edu) was cancelled. More information at the websites.
- The COSPAR 2020 Scientific Assembly is postponed to January 2021(www.cospar2020.org). COSPAR is the Committee on Space Research of the International Science Council (ISC).

BIS Chief Executive appointed

Our ancestor organisation, the British Interplanetary Society has now appointed a Chief Executive Officer, replacing the outgoing Executive Secretary, Gill Norman. Elizabeth Anderson will parallel Gill in June and July. More at - www.bis-space.com/2020/05/12/24686/new-chief-executive-officer.

We look forward to working with Elizabeth and her team in future.

3rd Annual Interstellar Probe Exploration Workshop

The 3rd Annual Interstellar Probe Exploration Workshop organised by the Johns Hopkins University Applied Physics Laboratory is scheduled for November 17–19, 2020 in Baltimore, USA. More at - interstellarprobe.jhuapl.edu. We'll keep you posted on its status.

KEEP AN EYE ON OUR FACEBOOK PAGE

Our Facebook page at - www.facebook.com/InterstellarInstitute - is the place for up to date announcements of our work and of interstellar studies in general. It's a lively forum much used by our own Facebookers and others active in our subject area.

Here's a recent posting from our Executive Director -

.

Acta Futura - Interstellar Edition

Acta Futura is a peer-reviewed open access on-line journal from ESA's Advanced Concepts Team. The new issue will include papers from the ESA's first ever Interstellar Workshop, as reported in Principium News Feature: *Interstellar Workshop of the European Space Agency.* Principium Issue 26 | August 2019. Several of these papers are from i4is team members. Here is the partial list as currently known -

The Path to Interstellar Flight Lubin, P and Hettel, W

Project Icarus: Designing a Fusion Powered Interstellar Probe Swinney, R W and Freeland II, R M and Lamontagne, M

Radiation Conditions in Relativistic Interstellar Flight Semyonov, O G

World Ships: Feasibility and Rationale Hein, A M, Smith, C, Marin, F, and Staats, K

Artificial Gravity in Interstellar Travel Hall, T W

Language Development During Interstellar Travel McKenzie, A and Punske, J

Considerations on Life Support Systems for Interstellar Travel: a Regenerative Story Volponi, M and Lasseur, C

Growing Plants in Human Space Exploration Enterprises Medina, F J

Papers are already accessible at - www.esa.int/gsp/ACT/acta_futura/issue12.

Centauri Dreams - the JHU-APL *Interstellar Probe*

The Johns Hopkins University Applied Physics Laboratory (JHU-APL) proposal for an *Interstellar Probe* has featured in Paul Gilster's invaluable Centauri Dreams (www.centauri-dreams.org) -

A New Shape for the Heliosphere www.centauri-dreams.org/2020/03/23/a-new-shape-for-the-heliosphere-2/

- about the astrophysical results expected.

The 1000 AU Target www.centauri-dreams.org/2020/03/24/the-1000-au-target

- about the mission and instrumentation.

The JHU-APL Interstellar Probe has also been much featured in Principium, notably reports from IAC 2019 *An Interstellar Probe for the next Heliophysics Decadal Survey, Interstellar Probe: Cross-Divisional Science Enabled by the First Deliberate Step in to the Galaxy* in Principium 28,November 2019 page 24, *Interstellar Probe: Humanity's First Deliberate Step into the Galaxy by 2030* pages 29-30 and *The Physics of Heat Shielding During an Oberth Manoeuvre* page 26 in the same issue. The latter was also inspiration for *How low can you go? - The Benkowski equation* by Adam Hibberd and John Davies in issue 27 page 40 and *The Equation used in the Benkoski Paper, A Derivation* by Adam Hibberd in Issue 28, February 2020, page 41.

Energy Limits to Gross Domestic Product on Earth

In this new paper (arxiv.org/abs/2005.05244) i4is Executive Director Andreas Hein and Jean-Baptiste Rudelle of Zenon Research Center, Paris, challenge the assumption that economic growth at current rates can be sustained beyond the 21st century. They conclude that the overall size of Earth's global economy is facing an upper limit purely due to energy and thermodynamic factors. The greenhouse effect and heat dissipation from energy consumption with a 2% annual GDP growth, the upper limit will combine to limit growth within a few centuries. They assume large-scale deployment of carbon-neutral energy sources. Even the possibility of massive deployment of new energy sources such as fusion power will mean that unless GDP can be decoupled from energy consumption, thermodynamics alone will limit the size of Earth's economy and further economic growth will require expanding economic activities into space.

In a striking passage they state "*Kick starting a large space economy will require decades and upfront funding. To rely on its own momentum, this space economy will need to reach a certain critical size way before we approach Earth's own GDP limit.*" citing Mark Hempsell - *A History of Space and Limits to Growth*, JBIS, v51, #9, 1998*.

Jean-Baptiste has created a pop-science video to explain the paper. It's in French but select closed caption and auto-translate: www.youtube.com/watch?v=BkBp1uzOyfk&t=1s.

Limitless Space Institute

The Limitless Space Institute (LSI), earlier the Limitless Propulsion Institute, (www.limitlessspace.org) is a new venture led by Harold "Sonny" White, Director, Advanced Research & Development. Its aim is "...to inspire and educate the next generation to travel beyond our solar system and to support the research and development of enabling technologies that will allow for interstellar human space exploration". Sonny was Advanced Propulsion Theme Lead at NASA Houston where he led work on advanced propulsion technologies including EMdrive and Alcubierre drive. President of LSI is Brian K Kelly, former Director, Flight Operations at NASA Houston. LSI founder Kam Ghaffarian is building on the success of Stinger-Ghaffarian Technologies Inc. LSI will offer grants, fund and lead applied research - and offer a range of student programmes at school and university level. LSI featured in Wired magazine - www.wired.com/story/nasas-emdrive-leader-has-a-new-interstellar-project.

"Prospectives in Deep Space Infrastructures, Development, and Colonization"

Dennis M Bushnell and Robert W Moses of NASA Langley have developed a study as part of the NASA scientific and technical information (STI) program which looks at cost reduction benefits of reusable rockets and their effect on commercial and colonisation-related activities and the nature of space developments beyond GEO.

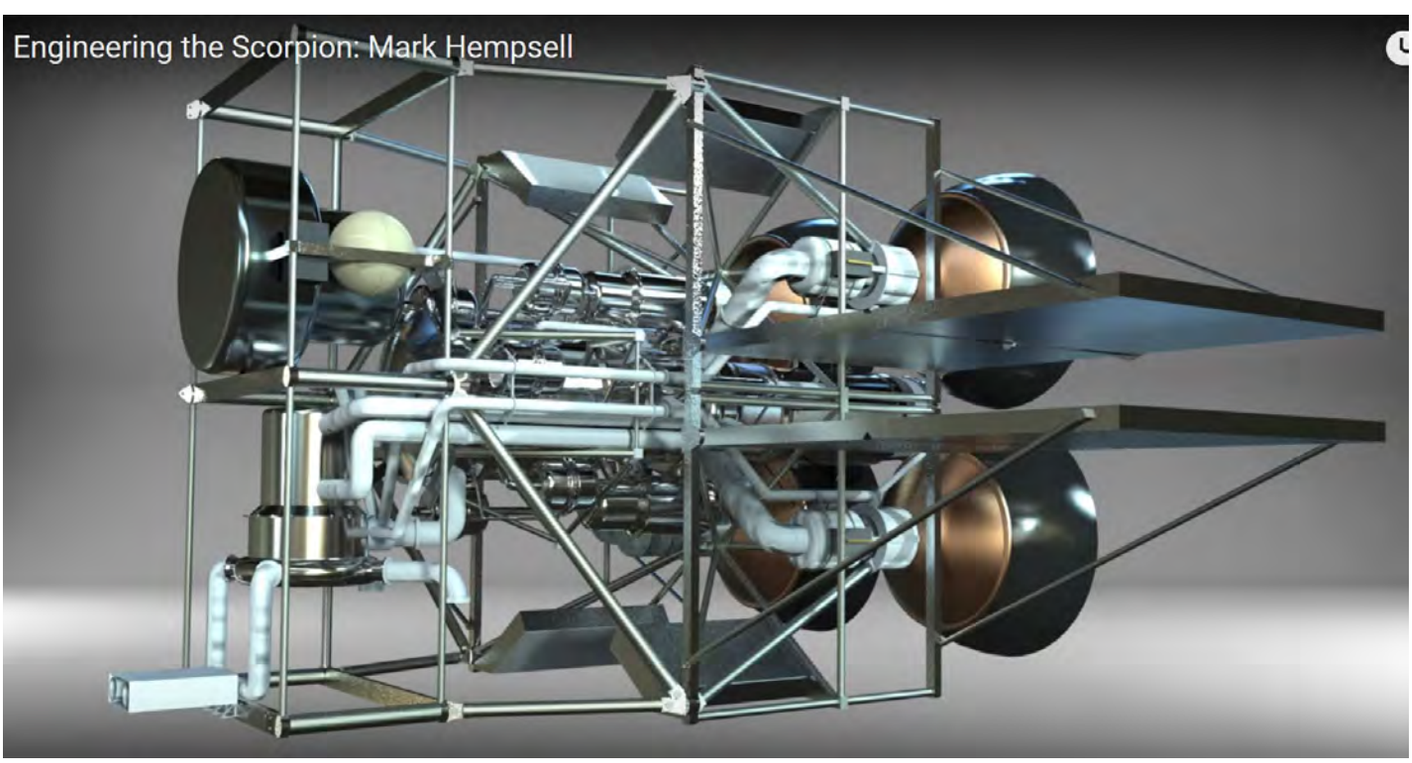
The paper is at - ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20200001142.pdf,

* *A History of Space and Limits to Growth*, JBIS, v51, #9, 1998
C M Hempsell, Aerospace Engineering, University of Bristol
Abstract: The history of thinking that links expansion into space as a means of overcoming limits to human growth goes back to Tsiolkovsky at the start of the century. As astronautics progressed the theme has been refined both from the general philosophic viewpoint and in specific engineering proposals. Until the 1970's the writing seems to have been individuals working largely in isolation, but after Apollo the various articles show an interacting body of opinion of mostly American authors into a "school" of thinking who see this as the long term justification for the development of mankind's capabilities in space. During the 1980's a second school, centred more on British authors, arose using more quantitative analysis based on various modelling techniques. This school saw the issue as more urgent and a justification for more specific engineering proposals such as the HOTOL launch system.

SCORPION: a Design Study for a General Purpose Space Transportation System

The Scorpion is a spacecraft concept by Mark Hempsell, Hempsell Astronautics Ltd and the BIS. It is intended to be a multirole human space transport system supporting high earth orbit, lunar and interplanetary flight. Mark's study objective was to explore what is possible with realisable technology to contrast with what we currently achieved, to illustrate the working of Martin's law ("politics first – money second – technicalities last") within the space industry. The spacecraft is 107 m long with a dry mass of 230 tonnes, has a crew of 6 people and can be spun to provide artificial gravity. Prime propulsion is provided by a hybrid thermal/electrical fission nuclear propulsion system, called Serpent-H, which has a thrust of 200 tonnes and an exhaust velocity of 12.7 km/sec. Mark was due to present his study at BIS HQ. Given that this is not currently possible he has produced an excellent video explanation youtu.be/d_s0FS06WNQ.

Here are a couple of stills from the video showing the Scorpion spacecraft in LEO and the Serpent-H nuclear propulsion system, which is based on ideas by Mark's colleague at Reaction Engines and BIS, Alan Bond.



MSS20 M8-ISR INTERSTELLAR STUDIES - 27 April - 7 May 2020
Schedule at 2020-04-23

	Monday 27 April	Tuesday 28 April	Wednesday 29 April	Thursday 30 April	Friday 1 May
					PUBLIC HOLIDAY
9:00 to 10:00	M8-ISR-L01 Introduction to Interstellar Studies Elective	M8-ISR-L07 Spacecraft Systems	M8-ISR-L12 Advanced Propulsion Systems 2	M8-ISR-L17 The Case for Interstella	
	Welch/Hein/Swinney	A Hein	R Swinney	J Davies	
10:15 to 11:15	M8-ISR-L02 Background to Interstellar Studies and Scaling the Problem	M8-ISR-L08 Worldship Conceptual Design	M8-ISR-L13 Artificial Intelligence on Worldship Missions	Assignment work	
	R Swinney	O Borgue	J Davies		
11:30 to 12:30	M8-ISR-L03 Introduction to Worldships	M8-ISR-L09 Artificial Intelligence for Worldships	M8-ISR-L14 Worldship Population Dynamics		
	A Hein	J Davies	F Marin		
12:30 to 14:00	*Lunch*	*Lunch*	*Lunch*	*Lunch*	
14:00 to 15:00	M8-ISR-L04 Introduction to Assignment	M8-ISR-L10 Worldships in Science Fiction	M8-ISR-L15 Interstellar Travel using Einstein Physics	Group Meeting	
	A Hein	S Caroti	D Fries		
15:15 to 16:15	M8-ISR-L05 Precursor Missions	M8-ISR-L11 Advanced Propulsion Systems 1	Assignment work	Assignment work	
	R Swinney	R Swinney			
16:30 to 17:30	M8-ISR-L06 Destinations	Assignment work			
	R Swinney				
	Monday 4 May	**Tuesday 5 May**	**Wednesday 6 May**	**Thursday 7 May**	**Friday 8 May**
9:00 to 10:00	Group Meeting	Group Meeting	Group Meeting	Assignment work	PUBLIC HOLIDAY
10:15 to 11:15	Assignment work	M8-ISR-L16 Worldship Documentary	Assignment work		
		M Madsen			
11:30 to 12:30		Assignment work			
12:30 to 14:00	*Lunch*	*Lunch*	*Lunch*	Paper submission deadline: 12:00	
14:00 to 15:00	Assignment work	Assignment work	Assignment work	Presentations (14:00 - 16:00)	
15:15 to 16:15				Welch/Hein/Swinney, etc.	
16:30 to 17:30					

i4is at the International Space University

This annual i4is Elective again took place, this time, for obvious reasons, online 27 April to 8 May -

MSS20 M8-ISR INTERSTELLAR STUDIES

The elective student projects were -

- Exoplanet settlement
- Rogue planet settlement
- Life extension
- Hibernation

Much more about this in the next issue and in Members Newsletters. ISU have also kindly provided videos of our presentations which will appear in the member area of our website.

Two ISU students are also preparing papers based on their principal Master projects - Bussard ramjet and interstellar deceleration. More about both the Elective and these two projects in our next issue.

Observational Constraints on the Great Filter

A recent paper (arxiv.org/ftp/arxiv/papers/2002/2002.08776.pdf) by Jacob Haqq-Misra, Ravi Kumar Kopparapu and Edward Schwieterman* looks at how easily we might detect the effects of the postulated "Great Filter". The Great Filter was first named by Robin Hanson (mason.gmu.edu/~rhanson/greatfilter.html) in 1998 but similar thoughts have occurred to others over the years since Enrico Fermi first asked "Where are they?" in the 50s (en.wikipedia.org/wiki/Fermi_paradox). As Haqq-Misra et al put it in this paper "...absence of evidence for extraterrestrial technology suggest that there is at least one extremely improbable evolutionary step somewhere from the origin of life to galactic-scale settlement". Have we yet reached that step on Earth? The paper suggests constraints on our ability to detect evidence of the effects of the Great Filter. Current SETI looks for both technosignatures (such a radio signals) and biosignatures (such as presence of key biochemicals). The paper takes the view that "If planets with technosignatures are abundant, then we can increase our confidence that the hardest step in planetary evolution—the Great Filter—is probably in our past. But if we find that life is commonplace while technosignatures are absent, then this would increase the likelihood that the Great Filter awaits to challenge us in the future."

The paper has been accepted for publication in Astrobiology.

* Blue Marble Space Institute of Science, NASA Goddard and University of California at Riverside respectively

More Gleanings from *TVIW – update*

Our colleagues at The Tennessee Valley Interstellar Workshop (TVIW) offer a steady stream of interesting titles and links in their Interstellar Updates. Here are just a few we noticed -

- Inverse design of lightweight broadband reflector for efficient lightsail propulsion (May 18 update)
- Dynamic Orbital Slingshot for Rendezvous with Interstellar Objects (May 8)
- The Astrobiological Copernican Weak and Strong Limits for Extraterrestrial Intelligent Life (April 9)
- The Solar System: Favored for Space Travel (April 1)

Subscribe via tviw.us/interstellar-updates and tell us of any which interest you - and why.

SunSpaceArt

Our friend and colleague Helen Schell is doing more online in recent circumstances. The SunSpaceArt site (www.sunspaceart.org) features the work of Helen and 12 other artists, funded by the UK STFC (stfc.ukri.org). She has been creating space related art for some years. Her theme here is 'The Human Spaceship – I believe art and science must collaborate for humanity to fully understand that we live in a space-faring society and are witnessing the most astounding change in 'being-human' through astronomy and space exploration in the 21st century.' (www.sunspaceart.org/team/helen-schell). Helen has been creating space related art in many forms since 2007. She inspires us to think onwards and upwards!

Helen with her work '*Solar Observatory*'
'Credit: Helen Schell

Three great Helens - left to right

Dr Helen Elizabeth Mason - Department of Applied Mathematics and Theoretical Physics, University of Cambridge (www.damtp.cam.ac.uk/person/hm1)

Helen Sharman - Astronaut - Department of Chemistry, Imperial College London (www.helensharman.uk)

Helen Schell - artist (thenewbridgeproject.com/portfolio/helen-schell))

Credit: Helen Schell

The i4is Members Page

The i4is membership scheme launched in December 2018 and we are now adding new members-only material to the website regularly. This page features currently available content and what is planned. Membership of i4is draws together all who aspire to an interstellar future for humanity. Your contribution, together with the voluntary work of our team and their donation of their own expenses, helps us to take the vital early steps toward that goal.

You need to login with your i4is identity to access members content. If you are not yet a member you can sign up via - i4is.org/membership - or simply find out more about membership. We'll keep you up to date as we add to this content, both in the next issue of Principium and in our members' email newsletter.

Members Newsletter

Members have received two Newsletters since the last issue of Principium -

- 1 April: Newsletter: i4is Annual Report, mini-research projects and more...
- 6 May: Newsletter: Share a One Year Free Trial with a friend, and much more...

The **Annual Report** is a 32 page summary of the past year and, for this first edition, a brief history of i4is since its foundation in late 2012.

We suggested six **Mini-Research Projects** -

Concepts for decelerating interstellar probes

Settling rogue planets

Settling exoplanets

Hibernation and interstellar travel

Life extension and interstellar travel

Artificial intelligence on a world ship: concepts

These parallel the topics we set for the students of the Masters of Space Studies course at the international Space University, Strasbourg last month. If you have time and are inspired by these then please get in touch.

To members who have been with us for more than one year we offered a single-use code that they can share with a friend, giving them a **One Year Free Trial** on their new membership of the Initiative for Interstellar Studies (i4is.org/members/free-trial/). We hope that many of you will take this up especially on behalf of the rising generation in full time education who are now eligible, in subsequent years, for a further discount of membership to £5, just over $6 and just under €5.

And we mourned the passing of **Al Worden**, Apollo 15 command module pilot and a lesson to all of us of both pride in his achievements and modesty in manner. We also lost **Freeman Dyson FRS**, a pioneer of interstellar studies and a founding member of the i4is Advisory Council. We have an appreciation of Freeman Dyson in this issue and we will commemorate Al Worden in our next issue.

Al Worden opened our late HQ in 2017.

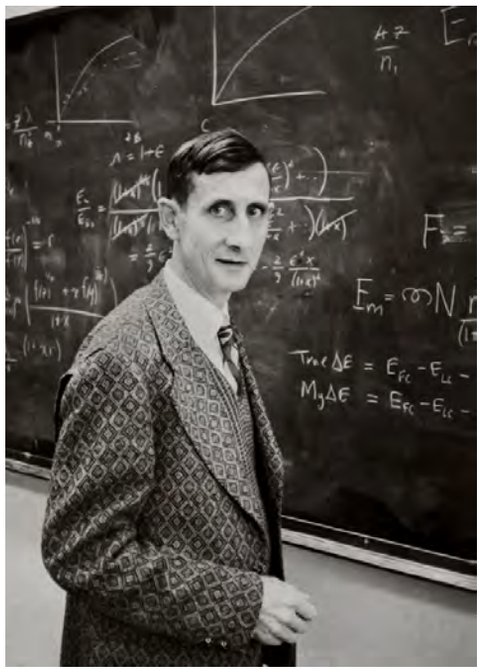
Kieran is now studying physics at the University of Oxford.

Freeman Dyson FRS (1923-2020) "Progress in science is often built on wrong theories that are later corrected. It is better to be wrong than to be vague."

Dyson (www.theguardian.com/science/2020/mar/01/freeman-dyson-obituary) was a visionary in theoretical physics, an innovator in engineering on the grand scale and a pioneer of interstellar studies.

He was long a member of the Advisory Council of the Initiative and Institute for Interstellar Studies.

A tribute to Freeman Dyson by the Executive Director of i4is, Dr Andreas Hein, appears elsewhere in this issue of Principium.



Freeman Dyson at Princeton, 1972.

Credit: William E Sauro/The New York Times

Principium preprints

Several of the articles in this issue of Principium have already been available in draft form to members as Principium Preprints including Part 3 of our report of The Interstellar Papers from the 70th International Astronautical Congress 2019 and the new idea from Dmitry Novoseltsev, *Rings around earth-like exoplanets as possible artificial megastructures.* Look out for more preprints and send us your comments - info@i4is.org as always.

Become active in i4is

We need all your talents - computing, maths & physics are important but many other talents are needed. The time and the unique skills of our members and, especially, our active volunteers are vital to all we do.

We listed some of the major contributors of time, brains and effort in the Members pages in the last two Principium issues - Tam O'Neill, Satinder Shergill, Paul Campbell, Tishtrya Mehta, Robert G Kennedy III PE, Alex Storer, Zachary Burkhardt, Angelo Genovese, Nikolaos Perakis, Samar AbdelFattah, Robert Matheson, Adam Hibberd, Conor MacBride, Terry Regan, Elena Ancona, Efflam Mercier and David A Hardy.

Take a look at P27 (November 2019) and P28 (February 2020) to see the breadth of these contributors to our work.

We need more - and an even wider diversity of occupations, talents, backgrounds and nations - to help us to do more in pursuit of that interstellar vision. Whatever skills and interests you have we would love to hear from you. You will find us a friendly and welcoming bunch! Contact us via info@i4is.org and we'll get back to you.

Help us to grow!

Tell your friends and colleagues. Share a One Year Free Trial with a friend if you have been with us for at least one year (see your personalised link in your 6 May Newsletter). And our student discount is now 90%!

Print our general poster on page 48 (white background) and the student posters on pages 4 (black background) and 31 (white background). All four posters are at i4is.org/i4is-membership-posters-and-video/

And finally

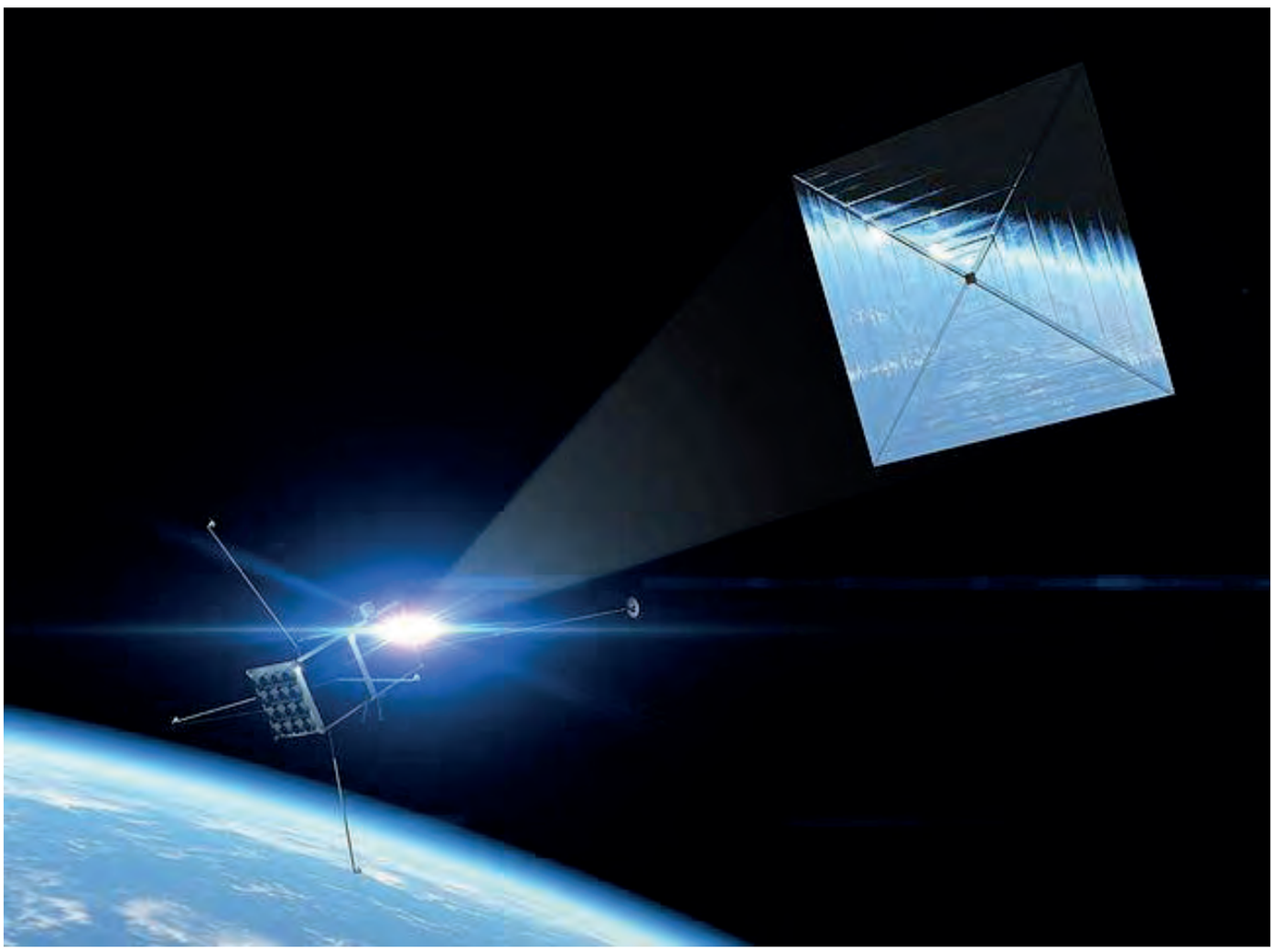
We hope all i4is members, Principium readers, the interstellar studies community and all we know and love are getting through this time of trouble for humanity.

If our interstellar vision can add a little long-term hope to the situation that can do a little good.

JOIN I4IS ON A JOURNEY TO THE STARS!

Do you think humanity should aim for the stars?

Would you like to help drive the research needed for an interstellar future...
... and get the interstellar message to all humanity?



The Initiative for Interstellar Studies (i4is) has launched a membership scheme intended to build an active community of space enthusiasts whose sights are set firmly on the stars. We are an interstellar advocacy organisation which:

- conducts theoretical and experimental research and development projects; and
- supports interstellar education and research in schools and universities.

Join us and get:

- member exclusive posts, videos and advice;
- free or discounted publications, merchandise and events;
- advanced booking for special HQ events; and
- opportunities to contribute directly to our work.

To find out more, see www.i4is.org/membership
90% discount for full time students!

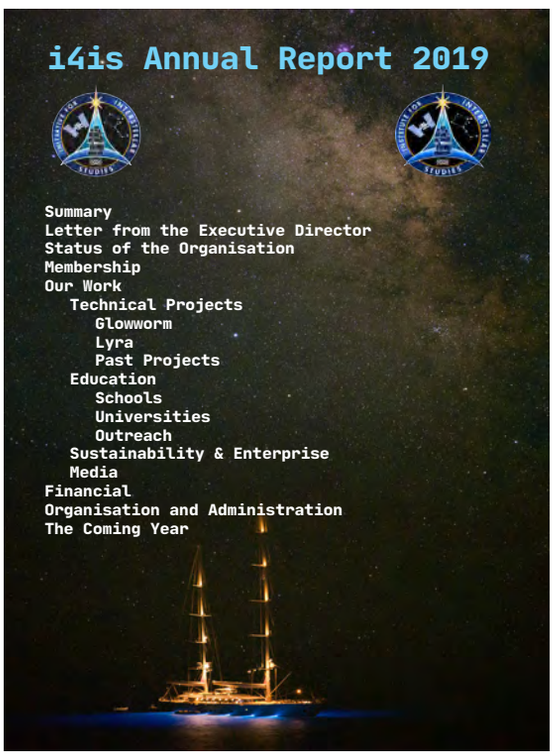
Become an i4is member

Patrick J Mahon

How becoming a member of i4is helps our work and delivers exclusive benefits to you

We are a growing community of enthusiasts who are passionate about taking the first steps on the path toward interstellar travel now. The best way to support the mission of i4is is to become a subscribing member. You will be directly supporting the interstellar programme. If you wish to, and have the time, we would love you to get actively involved with our projects. But we appreciate that not everyone who shares our interstellar vision has the time or resources to do this.

In addition to supporting the programme, members have access to privileged content. Most recently, we have added an outline of several focused interstellar research projects which those members with some time on their hands during the current global lockdown due to coronavirus might be interested to explore, along with a copy of our first Annual Report to members, published on 31 March. Other exclusive content includes our reports from the Second Foundations of Interstellar Studies Workshop last June, further papers from which have just appeared in the Journal of the British Interplanetary Society, presentations given by i4is members, and 'The Interstellar Minimum', a test paper to explore your knowledge of starship engineering.



Early drafts of Principium articles are also shared with members before general publication of each issue.

More details are on the i4is members' page, also in this issue of Principium. You will get access to all this content, and much more, if you choose to join.

We send a regular news email exclusively to members, containing the latest news on interstellar developments and our own activities.

To see the other benefits of membership, or to join, please go to i4is.org/membership.

Join i4is now and help us build our way to the Stars!

News Feature: 70th International Astronautical Congress 2019
The Interstellar Papers - Part 3

Reported by John I Davies

Here is a third and final brisk trot through what we saw and heard at the 70th IAC in Washington DC 21-25 October. We distributed print issues of Principium 26 at the event including the timetable in that issue. More from this massive event in the last two issues P27, November 2019, and P28, February 2020.

The quoted links to papers and presentations are accessible to all IAC 2019 participants. I have looked for versions of the papers on open access and quoted links where I found them. Please get in touch via Principium@i4is.org if you find more.

We must again thank the IAF Media Office for press access to the Congress. Delegate fees would have been a significant expense in addition to the travel and accommodation overheads, which we donated personally, our normal practice since the foundation of i4is. We are and will remain a low-overhead organisation.

Tuesday 22 October	**SETI 2: SETI and Society**	**IAC reference: IAC-19/A4/2/**	**iafastro.directory/iac/browse/IAC-19/A4/2/**

Co-Chair: Prof John Elliott, Leeds Beckett University, United Kingdom;

Co-Chair: Dr Michael A G Michaud, International Academy of Astronautics, United States;

SETI and International Space Law

Prof Andrea Harrington Air University (USAF Air Command and Staff College) United States

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,1,x54045.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,1,x54045.show.pptx

Open paper: None found

Dr Harrington is a space lawyer with the US Air Force Staff College. She summarised the current state of international space law, starting with the Outer Space Treaty, in the context of non-terrestrial claims on what is currently assumed to be “the province of all mankind”. This might become a “Fundamental Change of Circumstances” (*Rebus sic santibus*) as envisaged in overarching international law. The Vienna Convention on the Law of Treaties. She concluded that International Space Law and International Law in general do not limit activities in the search for ETI but that this law may be substantially modified and may trigger negotiations for new legal provisions. This might, in some circumstances justify terminating or withdrawing from a treaty - or for suspending the operation of a treaty - including the provisions against nuclear weapons and WMDs in general. But she warned with a reference to Robert Bolt’s play *A Man for All Seasons,* where Sir Thomas More says "If you cut down all the laws, where will you hide, the laws all being flat? If we cut down all the laws, can we stand upright in the winds of change that will blow?"

Evo-SETI quartics yielding ET Civilizations' Energy

Dr Claudio Maccone International Academy of Astronautics (IAA) and Instituto Nazionale di Astrofisica (INAF) Italy

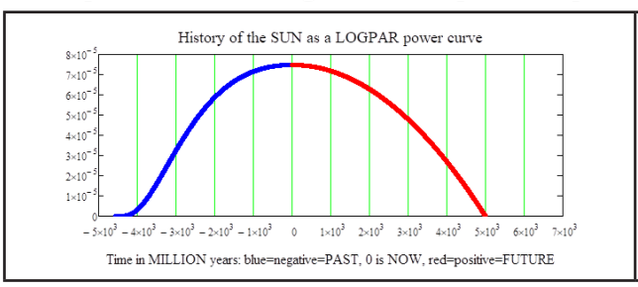
IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/1/manuscripts/IAC-19,A4,1,18,x49763.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,2,x49155.show.ppt

Open paper: URL

Dr Maccone presented his body of work on Mathematical SETI, referring to his 2012 book of that title (www.springer.com/gp/book/9783642274367) and both earlier and later work. He first looked at the concept of "energy of a lifetime" for a civilisation. He introduced Evo-SETI Quartics (fourth degree polynomials) representing a log-normal probability density covering the time from an advanced ET Civilisation's birth to its death. This represents the total power used by the civilisation in its lifetime. He quoted the general quartic equation - poly4(t) = $at^4 + bt^3 + ct^2 + d\,t + e$.

He showed some example curves starting with a simple example representing the lifetime of the Sun.



Sun input dates - birth = -4.5 gigayear (Gy), peak=0, death=+5 Gy.

Credit: C Maccone

This brief account by your less mathematical reporter gives only a flavour of his presentation. Dr Maccone's work appears in Acta Astronautica, numerous occasions of the International Astronautical Congress, the International Journal of Astrobiology and the Journal of the British Interplanetary Society (JBIS) and is cited in over 40 open papers in the Cornell University site arxiv.org.

Dr Maccone is a member of the Advisory Council of i4is.

SETI and Post-Detection: Towards a New Research Roadmap

Prof Kathryn Denning York University Canada

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,4,x52210.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,4,x52210.show.pptx

Open paper: none found

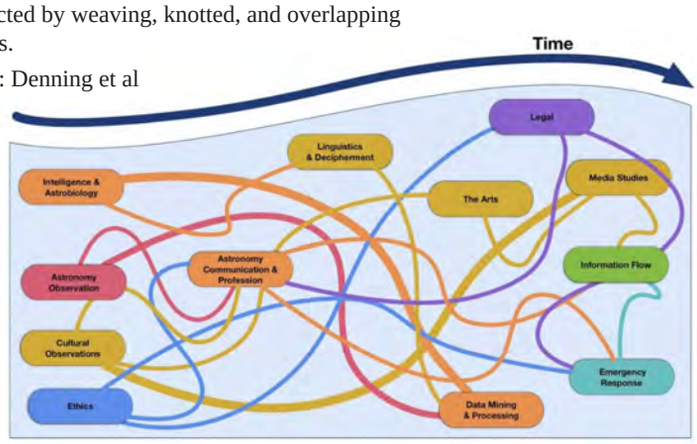
Prof Denning is an anthropologist. She and her co-authors (astronomers, an economist and data scientist, a legal expert, anthropologists and SETI/technosignatures researchers) see a need for substantial research to support post-detection policy and thus the requirement for a research roadmap. They believe that a number of factors demand this -

- extraordinary increase in technosignature search capacity
- increased detection sensitivity
- changes in society including wider discussion of ETI, changing norms about data and transparency, views on trust in scientific thinking and on scientific responsibility

So post-detection needs re-framing and this is a multiple discipline study in IAA SETI and elsewhere.

Streams of work during the process of discovery, connected by weaving, knotted, and overlapping threads.

Credit: Denning et al



The History of the IAA SETI Permanent Committee - 1980 to 1989

Ms Lori Walton Tigerstar Geoscience Canada

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,5,x52248.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,5,x52248.show.pptx

Open paper: none found

Ms Walton summarised the present role and structure of the International Academy of Astronautics (IAA) - SETI Permanent Committee. She cited the influences of early post war space fiction on its origins. Her

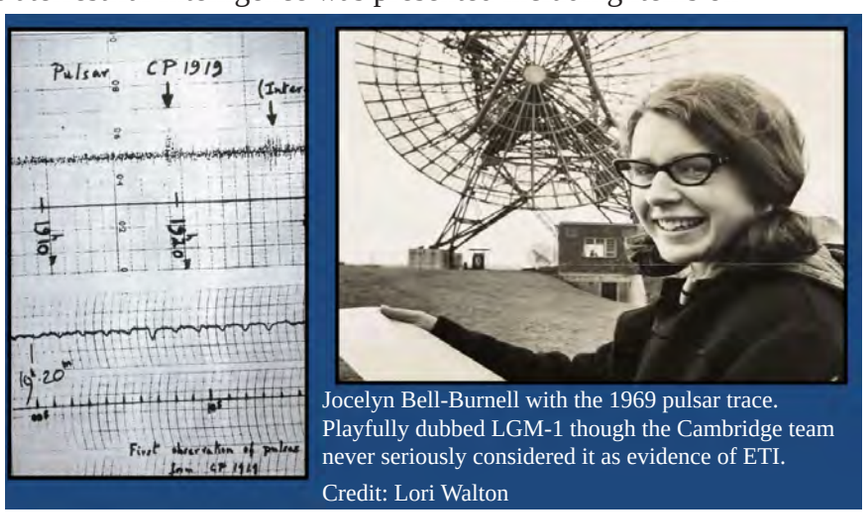
Examples of US and UK early post war space fiction.

The 1950 film Destination Moon (en.wikipedia.org/wiki/Destination_Moon_(film)) and a modern magazine celebrating the 1950s character, Dan Dare (en.wikipedia.org/wiki/Dan_Dare) in series technically advised by Arthur C Clarke.

paper presented at this IAC extends the history presented at the 2015 IAC, *The History of the IAA SETI Permanent Committee – The Early Years* (tinyurl.com/The-History-of-the-IAA-SETI-Pe) describes the first serious international consideration of SETI from the first SETI-centric paper at an IAC in 1956 (Haley, A G, 1956, Space Law and Metalaw – A Synoptic View. Harvard Law Record 23, Nov 8, 1956)*.

Turning to the 1980-1989 period - in the early 1980s the existence of "extremophiles" in deep ocean hydrothermal vents extended the range of environments in which life might be found. The 9th IAA International Review Meeting on SETI was at IAC 1980 in Tokyo. 1984 was a busy year with the founding of The SETI Institute (en.wikipedia.org/wiki/SETI_Institute) and the first Bioastronomy Commission Symposium in Boston. Ms Walton's list of SETI Committee members in 1986 includes names which are likely to be familiar and perhaps legendary to those interested in interstellar studies including Ronald N Bracewell, Nikolai S Kardashev, Anthony T Lawton and Anthony R Martin.

The 1988 IAC at Bangalore, India, a declaration of Principles Regarding Activities Following the Detection of Extraterrestrial Intelligence was presented including items on verification, data dissemination, first public announcement and protection of radio frequencies by the World Administrative Radio Council of the International Telecommunication Union. This was subsequently approved by the Board of Trustees of the IAA, and by the Board of Directors of the International Institute of Space Law (IISSL) in April 1989. The Declaration notably included the statement that “No response to a signal or other evidence of extraterrestrial intelligence should be sent until appropriate international consultations have taken place".



Jocelyn Bell-Burnell with the 1969 pulsar trace. Playfully dubbed LGM-1 though the Cambridge team never seriously considered it as evidence of ETI.

Credit: Lori Walton

*Andrew G Haley, 1904-1966, a pioneer in the early years of the IAF. Brought law (metalaw as he called it) to SETI management & early space technology. airandspacelaw.olemiss.edu/team/resources/andrew-haley.

Lessons from Studying Nonhuman Animal Communication

Dr Denise Herzing United States

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,6,x53336.pdf

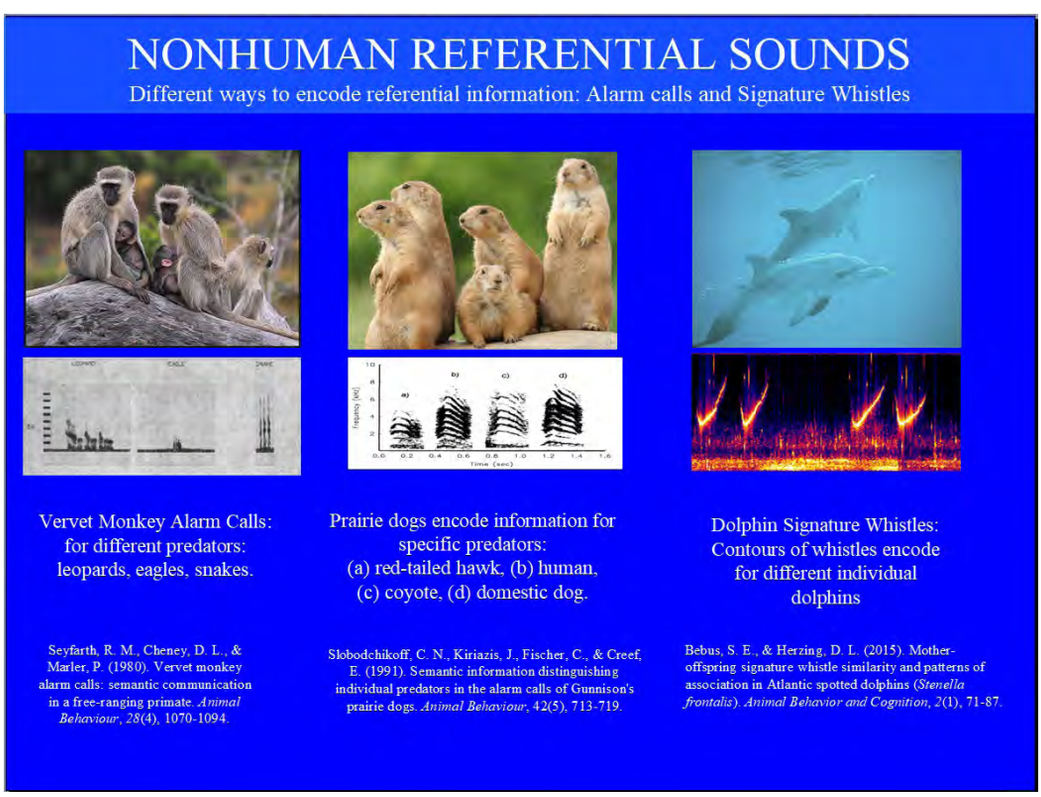
IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,6,x53336.show.pptx

Open paper: None found

Dr Denise Herzing is Research Director and Founder at the Wild Dolphin Project, Florida, and a member of the Associated Faculty of the Department of Biological Sciences, Florida Atlantic University, with 32 years experience researching dolphin behaviour. She asserts that the study of non-human animal communication systems can potentially provide insight into the post detection and analysis of alien signals in the future. In studying animal communication the "raw" signal must be taken together with metadata such as age, sex, relationships and behavioural context. While details will be different, context of this sort will be relevant in interpreting ETI signals. Dr Herzing gave numerous examples of both intra-species and inter-species animal communications. Striking examples include individual identity in dolphin whistles, both sender and recipient (analogous to this reporter to the inclusion of source and destination IP address in Internet protocols).

Some communications are mutually interpretable. Common examples are those between humans and sheepdogs and the alarm calls of prey species. By contrast Orcas encode echolocation clicks in the background noise of the ocean when hunting dolphins, who have high frequency hearing,

Sophisticated decoding tools such as neural networks have been used for some time in this sort of analysis*. Dr Herzing considered the implications for SETI of this terrestrial research. Even if clues about how an ETI communicates exist, clues about non-human communication systems on Earth may be of value. Animal examples also suggest looking at signals beyond single pulses such as sequences in larger time series and searching for both simultaneous signals on different channels (such as optical and radio) or for sequential radio signals.



examples of nonhuman referential (labelling) sounds Credit: Herzing

* *Quantifying complex patterns of bioacoustic variation: Use of a neural network to compare killer whale(Orcinus orca) dialects*, Deecke et al (1999)

www.marinemammal.org/wp-content/pdfs/Deecke%20et%20al.%201999.pdf

InCosmiCon: A New Italian-Peruvian project about SETI and Big History

Dr Paolo Musso University of Insubria Italy

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,7,x51377.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,7,x51377.show.pptx

Open paper: www.researchgate.net/publication/339294965_InCosmiCon_A_New_Italian-Peruvian_project_about_SETI_and_Big_History

Dr Musso presented a joint paper with 21 authors from Italy, Argentina and Peru describing a joint project based on the Italian SETI program and a Peruvian Oxford Templeton Visiting Fellowship from the Ian Ramsey Centre for Science and Religion at Oxford University and the John Templeton Foundation (most famous for the annual Templeton Prize for achievements in the field of spirituality, including those at the intersection of science and religion). The name InCosmiCon (Intelligence in the Cosmic Context) expresses the objective of the authors to investigate the topic of intelligent life in the universe, both from the point of view of classic SETI and from the more general framework of Big History (bighistory.org), inspired by Dr Claudio Maccone, Chairman of the IAA SETI Committee. They ask questions about the significance of intelligence in the cosmic context (see paper presented at IAC 2017 by Maccone and Russo, *La Vida en el Universo: The Oxford Templeton Visiting Fellowship to Perua about Seti And Bioastronomy* iafastro.directory/iac/paper/id/38131/abstract-pdf/IAC-17,A4,2,3,x38131.brief.pdf?2017-04-08.19:29:58). Work includes the involvement of students from Amazonian cultures at Nopoki, an institution bridging western and native Amazonian culture, possibly providing a model for a positive interaction with hypothetical extraterrestrial civilisations. Work also extends into mainstream philosophy notably the work of Quine (en.wikipedia.org/wiki/Word_and_Object). The analogy of terrestrial inter-cultural dialogue with SETI is clear, though there is no intention to attempt communication in the present programme.

Dr Musso invited us to "get on board" using a an image from popular culture Credit: Musso (and, no doubt, the BBC)

K-Pop to the stars: The export of Korean pop music as an analog for embedded cultural artifacts in messages to extraterrestrial intelligence

Mr Daniel Oberhaus United States

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,8,x54279.pdf

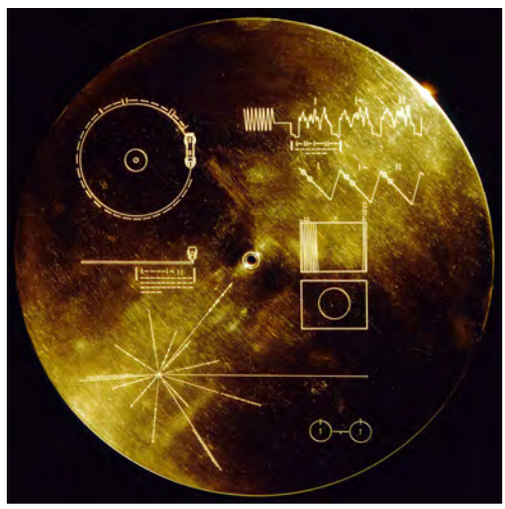
IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,8,x54279.show.pptx

Open paper: none found

Daniel Oberhaus is a staff writer at Wired with a background in philosophy. He is a science and technology journalist whose work has appeared in The Atlantic, The Guardian, BBC, Popular Mechanics, Motherboard, Slate, The Baffler, Nautilus, Vice, The Awl, The Outline, Supercluster and other publications. He is the author of Extraterrestrial Languages, MIT Press, October 2019 (mitpress.mit.edu/books/extraterrestrial-languages). He suggests that the cultural technology used to manufacture K-Pop is useful in analysing cultural artefacts embedded in our own interstellar messages. K-Pop is clearly designed to appeal to non-Korean cultures so he suggests we look at the cultural content of these intended interstellar messages as examples of cultural technology and thereby form a view of their likely efficacy.

The golden records aboard the Voyager 1 and 2 spacecraft launched in 1977 included mathematical and astronomical information which might be assumed to be universal and cultural items which are clearly specific to terrestrial civilisations. There have been several subsequent such intended interstellar messages

- for example the music from the 2017 Barcelona electronic music festival Sónar at its 25th anniversary (www.theguardian.com/music/2017/nov/21/the-vinyl-frontier-why-do-we-keep-sending-music-to-outer-space-sonar-festival). Oberhaus sees two problems - for the receiver of these messages, separating cultural content from scientific and mathematical material - and for the transmitter, selecting which cultural items to include. He concentrates on the latter, our selection. He suggests that a degree of selection bias* is inevitable but that it is possible to make this an intentional part of the message rather than an unintentional side-effect.



Cover of the Voyager Golden Record.
Credit: NASA/JPL

Taking inter-cultural communication on Earth as analogous to inter-cultural communication on an interstellar scale, Oberhaus believes that a deliberately cross-cultural form of entertainment like K-pop may be instructive. Songs and music videos are deliberately released not just in target languages but including target-specific chord progressions, colour of eyeshadow, appropriate hand gestures and camera angles. At least one K-pop producer has a manual! The result is market penetration from the relatively close example of China to the notoriously culturally-resistant US market. Oberhaus grants that this analysis is necessarily imperfect given the inevitably greater biological distance to an ETI but he suggests that cross-cultural studies could yield for "a quantitatively rigorous selection of diverse cultural artefacts for interstellar messages" so that selection bias, by being deliberate, assists the interstellar intelligibility of messages.

Chomsky in the cosmos: Lessons from neurolinguistics for the design of messages for extraterrestrial intelligence

Mr Daniel Oberhaus United States

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,9,x54271.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,9,x54271.show.pptx

Open paper: none found

Oberhaus is a staff writer at Wired, see previous item, *K-Pop to the stars*. He believes messages intended for interstellar consumption are not necessarily best expressed in mathematics and the sciences, as has been assumed. He cited an early dispute between Lancelot Hogben, an early populariser of mathematics and science*, and Arthur C Clarke. Clarke advocated sending images** .

Several artificial languages have already been invented for ETI communication. Oberhaus cited -

- Lincos — Design of a Language for Cosmic Intercourse, North-Holland 1960 (see also Freudenthal www.bigear.org/CSMO/PDF/CS05/cs05p35.pdf)
- LINCOS 2.0 Alexander Ollengren (Astrolinguistics: Design of a Linguistic System for Interstellar Communication Based on Logic, Springer 2012) - based on Church's Lambda Calculus (the basis of Lisp - en.wikipedia.org/wiki/Lisp_(programming_language))
- COSMIC CALL Yvan Dutil, Stephane Dumas (www.plover.com/misc/Dumas-Dutil/messages.pdf)

The nature of human language has been much examined, Oberhaus suggests that the idea of an innate Universal Grammar (en.wikipedia.org/wiki/Noam_Chomsky#Universal_grammar) leading to the idea that language is fundamentally a way of ordering our thoughts. And that human communication is a secondary purpose recently supported experimental evidence in neurolinguistics. Early AI researchers saw parallels

* Oberhaus uses the term selection bias (en.wikipedia.org/wiki/Selection_bias). In this context cultural bias (en.wikipedia.org/wiki/Cultural_bias) might be a more appropriate term.

** Hogben may be less familiar than Clarke. He was the author of Mathematics for the Million (1936) and Science for the Citizen (1938) en.wikipedia.org/wiki/Lancelot_Hogben#Writer. But he also wrote for JBIS - Hogben, Lancelot. "Astroglossa or First Steps in Celestial Syntax." Journal of the British Interplanetary Society 11.6 (1952): 258-274.

between CETI* and AI (reminding this reporter of Turing's "politeness principle" in determining whether an apparently intelligent machine is really thinking - see Ossie Hanfling quoted in *Sending ourselves to the stars?* Principium | Issue 13 | May 2016 page 17).

Oberhaus advocates an approach similar to Ollongren (second generation Lingua Cosmica) using a metalanguage (akin to the Lambda Calculus) to add meaning to a large selection of natural language and thus urges the necessity of further research on metalanguage design for extraterrestrial communication.

Mathematician Devises Radio Code 'Mars Could Understand'

Broadcast To All Planets Requested

But Other Scientists Doubt Feasibility

LONDON, Dec. 25 (UP) — Lancelot Hogben, the famous mathematician, has devised a series of radio messages which he believes ought to draw a reply from Mars or any other of the planets on which there may be intelligent beings.

Mr. Hogben calls his messages "astroglossa" (or astral language) and has prepared them in the form of lessons to be beamed for some time from the earth to the bodies of the solar system and beyond.

If there is a civilization anywhere which has reached our level or surpassed it, Mr. Hogben thinks it will understand the pattern of his radio messages and be able to enter into communication.

Other Radios Doubted

Arthur Clarke, chairman of the British Interplanetary Society, immediately advised Mr. Hogben his organization did not believe the beings of the solar system (if any) could use radio or their signals already would have been picked up by earth.

But Mr. Hogben, author of "Mathematics for the Million" thinks the experiment worth making, especially since scientists expect that in the next few decades advances in electronics will make it possible to beam communication directly to the heavenly bodies.

Wants Chat With Martian

The mathematician said he had no desire to visit Mars personally but it might be a good idea to have a few chats with the Martians before sending rockets hurtling across 30,000,000 miles of space for a possible unfriendly reception.

Mr. Hogben said he based his series of radio messages on a theory of numbers which would suggest to intelligent receivers that an intelligent agency was behind the dots and dashes. This, he believes, would start the Martians or residents of other planets trying to break down what would appear at first to be a simple code.

The mathematician agreed that his lessons were in the nature of a fantasy, but he defended them on the ground that if contact with other worlds ever was established, it would be greatly beneficial to our earth.

Mathematician Devises Radio Code 'Mars Could Understand'

Broadcast To All Planets Requested

But Other Scientists Doubt Feasibility

UP story from 1952 with refutation by Arthur C Clarke who as "... chairman of the British Interplanetary Society, immediately advised Mr Hogben his organization did not believe the beings of the solar system (if any) could use radio or their signals already would have been picked up by earth."

Credit: Oberhaus and UP.

The Morality of Interstellar Messaging

Ms Julia DeMarines University of California, Berkeley United States

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/1/manuscripts/IAC-19,A4,1,17,x55025.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/1/presentations/IAC-19,A4,1,17,x55025.show.pptx - note that the body of this presentation is in Prezi format

Open paper: not found but see references in shc.academia.edu/ChelseaHaramia/CurriculumVitae

Dr Chelsea Haramia, Spring Hill College, is the credited principal author of this paper. Jointly authored with Ms DeMarines. Their subject is moral philosophy applied to METI (messaging to extraterrestrial intelligence - en.wikipedia.org/wiki/Active_SETI). They characterise METI International (en.wikipedia.org/wiki/METI_(Messaging_Extraterrestrial_Intelligence)) and other proponents of METI as acting without international coordination, enforceable regulation, or representation of future generations. They draw as parallel with the US military in its role of asteroid defence which operates within a framework of regulation and enforcement, with a clear chain of command and a system of penalties for aberrations (without claiming that this framework has no flaws). METI presents dangers to both those who could act to curb it (for example governments or litigators) and who cannot (for example future humans or those without access to litigation). The risks may be unlikely to mature but the consequences if they do are potentially catastrophic. We should therefore regulate METI internationally, enforceably and with an eye to the long term future.

* Communication with Extraterrestrial Intelligence.

SUBSEQUENT REPORTS ARE BASED ON IAF PUBLICATION NOT IN-PERSON REPORTING

SETI@home: A Detailed Analysis and Study

Mr Adarsh Agrawal R V College of Engineering India

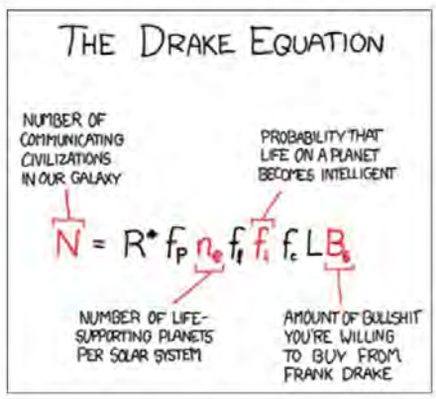
IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/manuscripts/IAC-19,A4,2,11,x54741.pdf

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,11,x54741.show.pptx

Open paper: not found

Mr Agrawal summarises the technology behind SETI@home - samples from radio telescopes in a 2.5 MHz band at the 1420 MHz hydrogen line*, divided into easily transmitted packages, each to multiple "home" systems, results returned to the coordinating system at UC Berkeley. This brings a large number of relatively modest systems together to form a very highly distributed "supercomputer". He looks into the background assumptions, such as the narrow band of frequencies and the necessary anthropomorphic assumptions. He notes -

- the Drake equation (with wit!)
- the Fermi Paradox - and quotes from an analysis of explanations from it from Tim Urban (waitbutwhy.com/2014/05/fermi-paradox.html)



A satirical view of the Drake Equation

Credit: Agrawal / Ursa Astronomical Association (www.ursa.fi)

Mr Agrawal clearly anticipated that the future of SETI@home was uncertain. He believed that SETI@home should continue in a modified form. Sadly UC Berkeley announced the end of SETI@home on 31 March 2020 (setiathome.berkeley.edu/forum_thread.php?id=85267). They stated that "the volunteer computing part of SETI@home will stop distributing work and will go into hibernation" having "analysed all the data we need for now" and because "It's a lot of work for us to manage the distributed processing of data. We need to focus on completing the back-end analysis of the results we already have, and writing this up in a scientific journal paper".

"We (do not) come in peace": The images of extraterrestrial life in contemporary conspiracy theories

Mr Alfredas Buiko Vilnius University Lithuania

IAC paper: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,12,x48796.show.pptx

IAC presentation: iafastro.directory/iac/proceedings/IAC-19/IAC-19/A4/2/presentations/IAC-19,A4,2,12,x48796.show.pptx

Open paper: none found

Mr Buiko is a member of the Philosophy Department at the University of Vilnius and the author of *Anapusinio Dievo samprata Karlo Bartho religijos filosofijoje* (The Conception of Otherworldly God in Karl Barth's Philosophy of Religion), 2017, in the Lithuanian journal *LOGOS - A Journal of Religion, Philosophy, Comparative Cultural Studies and Art*. He suggests that contemporary conspiracy theories characterise ETIs as malign - either as evil conspirators with government or as diabolical rulers using governments as "front organisations". He aims to analyse and describe ET conspiracy theories and their possible sources - and to try to predict the reactions of conspiracy theorists to a discovery of ETI.

* the 1420 MHz hydrogen line is a quantum transition, and thus a spectral line, for the hydrogen atom. First observed in 1951 (antena.fe.uni-lj.si/literatura/Razno/Diplome/Radioteleskop/zgodovina/nature%20physics%20portal%20-%20looking%20back%20-%20The%20hydrogen%2021-cm%20line.pdf) it has applications in measuring velocities and thus the recession of the galaxies. Otherwise this is a quiet part of the radio astronomy spectrum and thus an assumed "water hole frequency" for transmissions from ETIs en.wikipedia.org/wiki/Water_hole_(radio).

He characterises three image types of such ETs.

These are -

- idealised humans "Nordics" - largely benign
- "Greys" (en.wikipedia.org/wiki/Grey_alien)
- “Reptilian” as identified by conspiracy theorist David Icke (en.wikipedia.org/wiki/David_Icke#Reptoid_hypothesis)

He stresses that these are an overlapping but distinct set from the typical aliens suggested by proponents of UFOs (en.wikipedia.org/wiki/Unidentified_flying_object#Ufology). There appear to be strong parallels with anti-Semitic conspiracy theories and claims that the Apollo landings were faked. On the whole Mr Buiko concludes that conspiracy theorists are sceptical of all "official" information and would perhaps be the least affected by evidence of ETIs. He gives 28 references ranging from religion-based theories to essentially anti-government thinking, particularly in the USA.

Note on use of Wikipedia

John I Davies - editor of Principium

In this report, and elsewhere in this issue of Principium and in other issues of our periodical, we cite Wikipedia articles to help clarify concepts and proposals, identify significant individuals and cater for the wide range of levels of skill and experience in our readership. We have found Wikipedia to be the most useful general source fulfilling this need.

Here are some guidelines we use when citing Wikipedia articles -

- If the Wikipedia citation is in a source we trust then it passes the first test. However –
- We never rely on Wikipedia as the sole source of any fact
- We trust our own judgement, remembering that anyone can edit any Wikipedia article
- If it really matters we use the references in the Wikipedia article, believing them on the following rough scale -
  - Peer-reviewed articles by well-known experts - for example an article by Freeman Dyson in *Nature* - are perhaps the highest level of plausibility. But even Dyson can be wrong - ask yourself - "What is the scientific consensus?"*
  - Other material in respected peer-reviewed journals such as Acta Astronautica and the Journal of the British Interplanetary Society.
  - Articles in respected newspapers such as the Financial Times, the Economist and the Guardian in the UK, the New York Times, the Wall Street Journal, the Los Angeles Times and the Washington Post in the USA. Other countries no doubt have similarly respected papers.
  - Pieces on trusted electronic platforms such as the BBC.
  - Items in the respected general science and technology magazines such as Scientific American and New Scientist.

Other electronic sources such as our own website, i4is.org, also tviw.us, www.centauri-dreams.org and www.bis-space.com are also trustworthy, we believe.

Wikipedia has its own guidelines -

en.wikipedia.org/wiki/Wikipedia:Researching_with_Wikipedia

- which is "semi-protected so that only autoconfirmed users can edit it".

* but even the scientific consensus can be wrong. Remember the Phlogiston Theory!

The Interstellar Ram Jet at 60

A A Jackson

Principium readers are likely to be familiar with the fusion ramjet proposed by Robert Bussard in 1960. In this anniversary year Al Jackson revisits this ground-breaking attempt to defeat the tyranny of Tsiolkovsky's rocket equation. It's a tour through the work of brilliant minds - Bussard himself, his predecessors and his successors. Since Tsiolkovsky set the bounds for reaction propulsion we have been trying to defeat it. like Bussard, or avoid it like the current workers on laser-push propulsion.

Al is a retired NASA engineer and a long-standing contributor to interstellar studies. He presented papers at both our Foundations of Interstellar Studies workshops, New York 2017 and Gloucestershire UK 2019.

A version of this article appeared recently on Paul Gilster's interstellar blog, Centauri Dreams (www.centauri-dreams.org/2020/04/03/the-interstellar-ramjet-at-60/).

Introduction

Writers of science fiction prose noticed the difference between interplanetary flight and interstellar flight stronger than anyone. Various methods of faster-than-light, FTL, were invented in the 1930s, John Campbell even inventing the term ‘warp drive’. Asimov’s Galactic Empire is only facilitated by FTL ‘jump-drives’. Slower than light interstellar travel made an appearance in Goddard and Tsiolkovsky’s writings in the form of ‘generation ships’, usually called World Ships now.

As far as I know the first engineer to look at the very basic physics, quantitative calculations, of relativistic interstellar flight was Robert Esnault-Pelterie, he made relativistic calculations before 1920, these were published in his book L'Astronautique, 1930. The first derivation of the relativistic rocket equation occurs in Esnault-Pelterie writings. This was long before Ackeret in 1946, J Ackeret, Zur Theorie der Raketen, Helvetica Physica Acta, 19, p 103 (1946). The classical mass ratio rocket equation of Tsiolkovsky showed the difficulty of space travel, the relativistic rocket equation showed that interstellar flight was even more difficult. Eugen Sänger, who had been interested in interstellar flight in the 1930s, addressed the interstellar mass ratio problem in 1953 with a paper on photon rockets, Zur Theorie der Photonenraketen. (Vortrag auf dem 4. Internationalen Astronautischen Kongreß in Zürich 1953). Sänger, more than almost anyone before him studied the hard physics of anti-matter rockets and relativistic rocket mechanics. Using the most energetic energy source, antimatter, would require tons of it in a conventional rocket. There was sore need of a better method.

Bussard

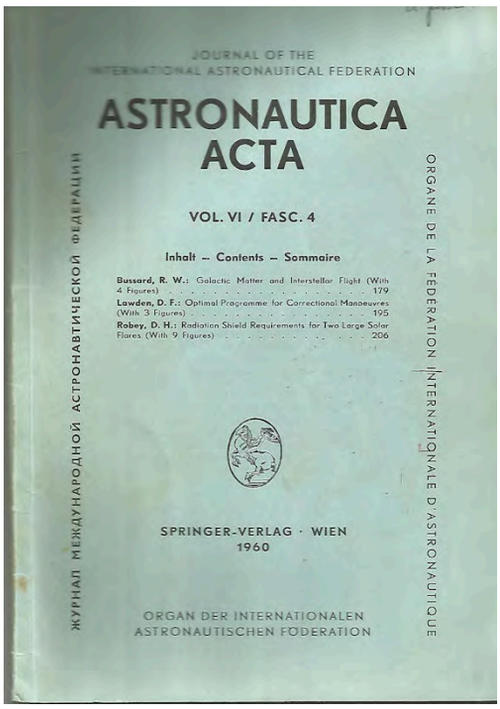
Robert W Bussard was a rangy man who looked like he walked the halls of power. I had dinner with him at a San Francisco section of the American Institute of Aeronautics and Astronautics meeting in 1997. We had invited Poul Anderson, author of *Tau Zero*, Anderson and Bussard had never met. Over dinner Bussard told me he started working on nuclear propulsion at Los Alamos in 1955 , he and R DeLauer wrote the first monograph on atomic powered rockets in 1959 [1]. He also said he had been looking at work at Lawrence Radiation Laboratory in 1959.

Bussard said he had always been interested in interstellar flight, one day at breakfast, at Los Alamos he got tortilla rolled up with scrambled egg in it. That cylinder made him think of a fusion ram starship! I have to wonder if that story is true, seems he had been looking at Livermore’s lab papers he probably saw project Pluto, the nuclear powered atmospheric ramjet.

Bussard sat down in 1959 and wrote the paper “Galactic matter and interstellar flight” published in Astronautica Acta in 1960. This paper is thoroughly technical; Bussard summarizes Ackeret, Sänger and Les Shepherd’s studies of interstellar flight [2]. Sänger had shown that even using antimatter one still had a mass ratio problem with a conventional rocket. Bussard presents an amazing new concept that solved the mass ratio problem [3]. He notes that one can scoop interstellar hydrogen and fuse it to produce a propulsion

system. His treatment is rigorously special relativistic, using conservation of energy and momentum he derives the equations of motion of an interstellar ramjet. He accounts for the energy production and propulsion efficiency of the vehicle in general terms. He uses the most energetic fusion mechanism the proton-proton fusion reaction which converts .0071 of the rest mass of collected protons to energy. Bussard derives the property that the ramjet will need to be boosted to an initial speed.

Robert Bussard in 1959 with his Astronutica Acta issue.



Bussard discusses the engineering physics problems; the difficulty of using the p-p chain is enormous. He notes that interstellar hydrogen can be unevenly distributed there being rich and rarefied regions. He gives a simplified model for scooping and sometimes it is missed that he mentions magnetic fields as a 'collector'. Bussard also notes radiation loses and radiation hazards during the operation of the ramjet.

Sagan

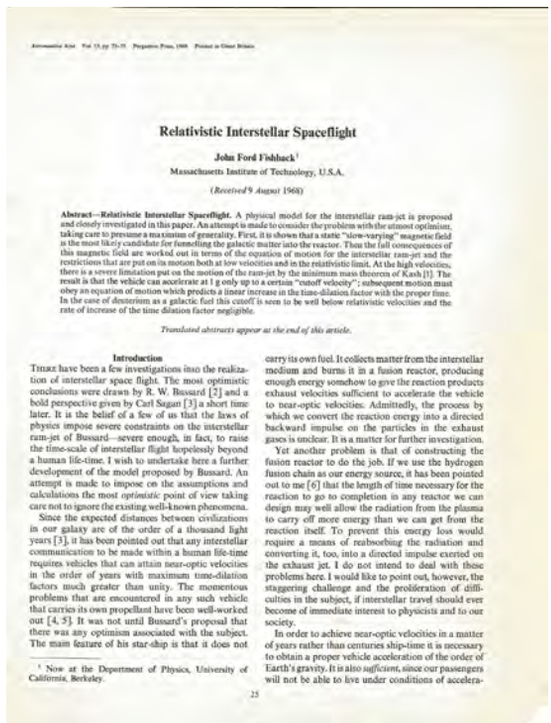
The Bussard Ramjet got a boost in 1963 when Carl Sagan noted that there was a solution to the mass ratio problem for interstellar flight [4]. Sagan summarized this paper in *Intelligent Life in the Universe* in 1966 [5], probably the best popularization of the Ramjet. Sagan also noted that ships accelerating at one gravity could circumnavigate the universe, ship proper time, in about 50 years. Sagan references Sänger in the paper version [4] and the calculation of the mechanics of a 1 g starship. As far as I know the 1957 paper of Sänger [6] is the first exposition of constant acceleration starship and the consequences of time dilation when extreme interstellar distances are traveled. Bussard mentioned, very briefly, a magnetic field as a scoop, Sagan, describes such a collector in a more elaborated though qualitatively way.

Fishback

John Ford Fishback published his MIT bachelor's thesis in Astronautica Acta in 1969 [7], this was supervised by Philip Morrison. Morrison and Cocconi were the fathers of radio SETI. Morrison seems to have taken an interest in Sagan's mention of Bussard's ramjet. Not sure if it was Morrison or Fishback who suggested the study. The paper is a remarkable marshalling of electrodynamics, charged particle motion, plasma physics, the physics of materials and special relativity. Fishback constructs a model for the magnetic scoop field taking into account the fraction of hydrogen ingested and reflected. Using conservation laws Fishback derives the most detailed equations of motion accounting for mass and radiation loses that had been published anywhere. In the scooping process Fishback accounts for the statistical distribution of the gas in the galaxy. Fishback derives a relativistic expression for ship proper acceleration with 'drag'. An important consequence, expressed for the first time, is the mechanical stress on the scoop field magnets. He derived an upper limit on the maximum Lorentz factor that can be obtained as a ramjet accelerates at 1 g for a long time due to stress on the source of the scoop field.

John Ford Fishback in 1967 and first page of his paper in Astronautica Acta.

(Unfortunately Fishback took his own life in 1970 at the age of 23).



Relativistic Interstellar Spaceflight

John Ford Fishback[1]

Massachusetts Institute of Technology, U.S.A.

(*Received* 9 *August* 1968)

Abstract—**Relativistic Interstellar Spaceflight.** A physical model for the interstellar ram-jet is proposed and closely investigated in this paper. An attempt is made to consider the problem with the utmost optimism, taking care to presume a maximum of generality. First, it is shown that a static "slow-varying" magnetic field is the most likely candidate for funnelling the galactic matter into the reactor. Then the full consequences of this magnetic field are worked out in terms of the equation of motion for the interstellar ram-jet and the restrictions that are put on its motion both at low velocities and in the relativistic limit. At the high velocities, there is a severe limitation put on the motion of the ram-jet by the minimum mass theorem of Kash [1]. The result is that the vehicle can accelerate at 1 g only up to a certain "cutoff velocity"; subsequent motion must obey an equation of motion which predicts a linear increase in the time-dilation factor with the proper time. In the case of deuterium as a galactic fuel this cutoff is seen to be well below relativistic velocities and the rate of increase of the time dilation factor negligible.

Translated abstracts appear at the end of this article.

Introduction

There have been a few investigations into the realization of interstellar space flight. The most optimistic conclusions were drawn by R. W. Bussard [2] and a bold perspective given by Carl Sagan [3] a short time later. It is the belief of a few of us that the laws of physics impose severe constraints on the interstellar ram-jet of Bussard—severe enough, in fact, to raise the time-scale of interstellar flight hopelessly beyond a human life-time. I wish to undertake here a further development of the model proposed by Bussard. An attempt is made to impose on the assumptions and calculations the most *optimistic* point of view taking care not to ignore the existing well-known phenomena.

Since the expected distances between civilizations in our galaxy are of the order of a thousand light years [3], it has been pointed out that any interstellar communication to be made within a human life-time requires vehicles that can attain near-optic velocities in the order of years with maximum time-dilation factors much greater than unity. The momentous problems that are encountered in any such vehicle that carries its own propellant have been well-worked out [4, 5]. It was not until Bussard's proposal that there was any optimism associated with the subject. The main feature of his star-ship is that it does not carry its own fuel. It collects matter from the interstellar medium and burns it in a fusion reactor, producing enough energy somehow to give the reaction products exhaust velocities sufficient to accelerate the vehicle to near-optic velocities. Admittedly, the process by which we convert the reaction energy into a directed backward impulse on the particles in the exhaust gases is unclear. It is a matter for further investigation.

Yet another problem is that of constructing the fusion reactor to do the job. If we use the hydrogen fusion chain as our energy source, it has been pointed out to me [6] that the length of time necessary for the reaction to go to completion in any reactor we can design may well allow the radiation from the plasma to carry off more energy than we can get from the reaction itself. To prevent this energy loss would require a means of reabsorbing the radiation and converting it, too, into a directed impulse exerted on the exhaust jet. I do not intend to deal with these problems here. I would like to point out, however, the staggering challenge and the proliferation of difficulties in the subject, if interstellar travel should ever become of immediate interest to physicists and to our society.

In order to achieve near-optic velocities in a matter of years rather than centuries ship-time it is necessary to obtain a proper vehicle acceleration of the order of Earth's gravity. It is also *sufficient*, since our passengers will not be able to live under conditions of accelera-

[1] Now at the Department of Physics, University of California, Berkeley.

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Martin

In 1971 [8] and 1973 [9] Tony Martin reviewed Fishback's paper making useful clarifying observations. Martin provides details of calculation that Fishback leaves to the reader of the relation of the fraction of particles that are magnetically confined to the reactor intake as a function of the confining field and the starship's speed. In his second paper Martin corrects a numerical error by Fishback showing that the cutoff speed due to the stress properties of the magnetic source is 10 times larger than was calculated. Martin also gives a nice calculation of the size of the magnetic scoop field. Fishback and Martin's papers account for the 'drag' due to reflected particles this result seems unknown to later critics of the ramjet.

Whitmire

I met Dan Whitmire in 1973 when we were both working on doctorates in physics at the University of Texas at Austin. Dan and I were talking about interstellar flight one day and I showed him Bussard's paper. Dan was in the nuclear physics group at Texas and took an immediate interest in the problem with proton-proton fusion as had been pointed out by Bussard and Martin. Dan came up with an ingenious solution. Carry Carbon on board the starship and use it as a catalyst to implement the CNO fusion cycle [10]. The CNO process is 10^{18} times faster than the PP chain at the fusion reactor temperatures under consideration. This reduces the fusion reactor size to 10s (and more) of meters in dimension. Since Carbon cycles in the process, in theory, one would only need to carry a small amount; however it is not clear how under dynamic conditions that one would recover all the catalysis needed.

Later Developments

The above are the core studies of the interstellar ramjet. Hybrid methods occurred to several researchers. Alan Bond [11] proposed a vehicle that carried a separate energy source yet scooped-up interstellar hydrogen not as fuel but simply as reaction mass, this is the augmented interstellar ramjet. Conley Powell [12] presented a refined analysis of this system. The author [13] presented a study using antimatter added to the scooped reaction mass for propulsion as an augmented method. Relevant to the augmented ramjet is antimatter combined with matter for propulsion studied by Forward and Kammash [14, 15].

T A Heppenheimer published a paper in the Journal of the British Interplanetary Society [16] noting the problems with the p-p chain for fusion without citing Dan Whitmire's solution. Heppenheimer notes radiation losses but does not cite Whitmire and Fishback who addressed the problems of bremsstrahlung and synchrotron radiation in the reactor and the scoop field.

Matloff and Fennelly [17] have interesting papers on charged particle scooping with superconducting coils. Cassenti looked at several modifications and aspects of the ramjet [18].

Recently Semay and Silvestre-Brac 21, [22] re-derived the equations of motion of the interstellar ramjet, first done by Bussard and Fishback. They find some new extensions with solutions of the relativistic equations for distance and time.

Dan Whitmire and the author [23] removed the fusion reactor by taking the energy source out of the ship and placing it in the solar system. If one scoops hydrogen but energizes it with a laser system it is possible to make a ramjet that is smaller and less massive. Such a system probably has a limited range similar to laser pushed sails.

An excellent survey of interstellar ramjets and hybrid ram systems are topics in the books by Mallove and Matloff [24] and recent monograph by Matloff [25] , see these books and the references listed in them. See also Ian Crawford's paper [26].

The Interstellar Ramjet in Science Fiction

It seems the Bussard Ramjet first appeared in a Larry Niven short story "The Warriors" 1966. Later Niven used the Ramjet in his other fiction, inventing, I think, the term Ram Scoop. However I think best known use of the Ramjet is Poul Anderson's *Tau Zero* [26]. The core story in *Tau Zer*o is not the Interstellar Ram Jet but the constant acceleration circumnavigate-the-universe calculation first done by Eugen Sänger. My guess is that Anderson only saw Carl Sagan's exposition on this in *Intelligent Life in the Universe*. The Greek letter 'Tau' was introduced by Hermann Minkowski in 1908, it is the time measured by the travelers in the *Leonora Christina*, while the time measured by people back on earth is t , special relativistic time dilation leads to (ship time)/(Earth Time) going to almost zero. Accelerate at one g for 50 years and one covers a distance of about 93 billion light years that is roughly the size of the universe.

The Bussard Ram *Leonora Christina* sets out for Beta Virginis, approximately 36 light years away. A mid-trip mishap robs the ship of its ability to slow down. Repairs are impossible unless they shut down the ramjet, but if the crew did that, they would instantly be exposed to lethal radiation. There's no choice but to keep accelerating and hope that the ship will eventually encounter a region in the intergalactic depths with a sufficiently hard vacuum so that the ramjet could be safely shut down. They do find such a region and repair the ship. Anderson then introduces the mother of all twists. The *Leonora Christina* as accelerated for so long that the crew discover relative to the universe a cosmological amount of time has elapsed. The universe is not 'open' but fits the re-collapse model, it is going for the big crunch. I know of no other science fiction novel with more extreme problem solving that this Hard SF story.

Anderson's cosmology for Tau Zero seems to come totally from George Gamow [28]. Gamow and his students did pioneering work on early time cosmology, an elaboration of earlier work done by Georges Lemaître. Poul Anderson, when he wrote the novel, may have been aware that Big Bang cosmology had evolved beyond Gamow's models …. However having his starship eventually orbit the 'Cosmic Egg' or Yelm was a solution to the crew's problem. Alas even in Gamow's cosmology the 'Yelm' is the universe so no way to 'orbit' it. Poetic license for the sake of a Ripping Yarn! (An intersecting exercise is to see what the trajectory of the *Leonora Christina*'s plot problem is in current accelerating universe cosmology.)

After Niven and Anderson the Bussard Ramjet became common currency in science fiction, that has somewhat faded some. Recently a fusion ramjet, SunSeeker is an integral part of the Bowl of Heaven series by Greg Benford and Larry Niven [29].

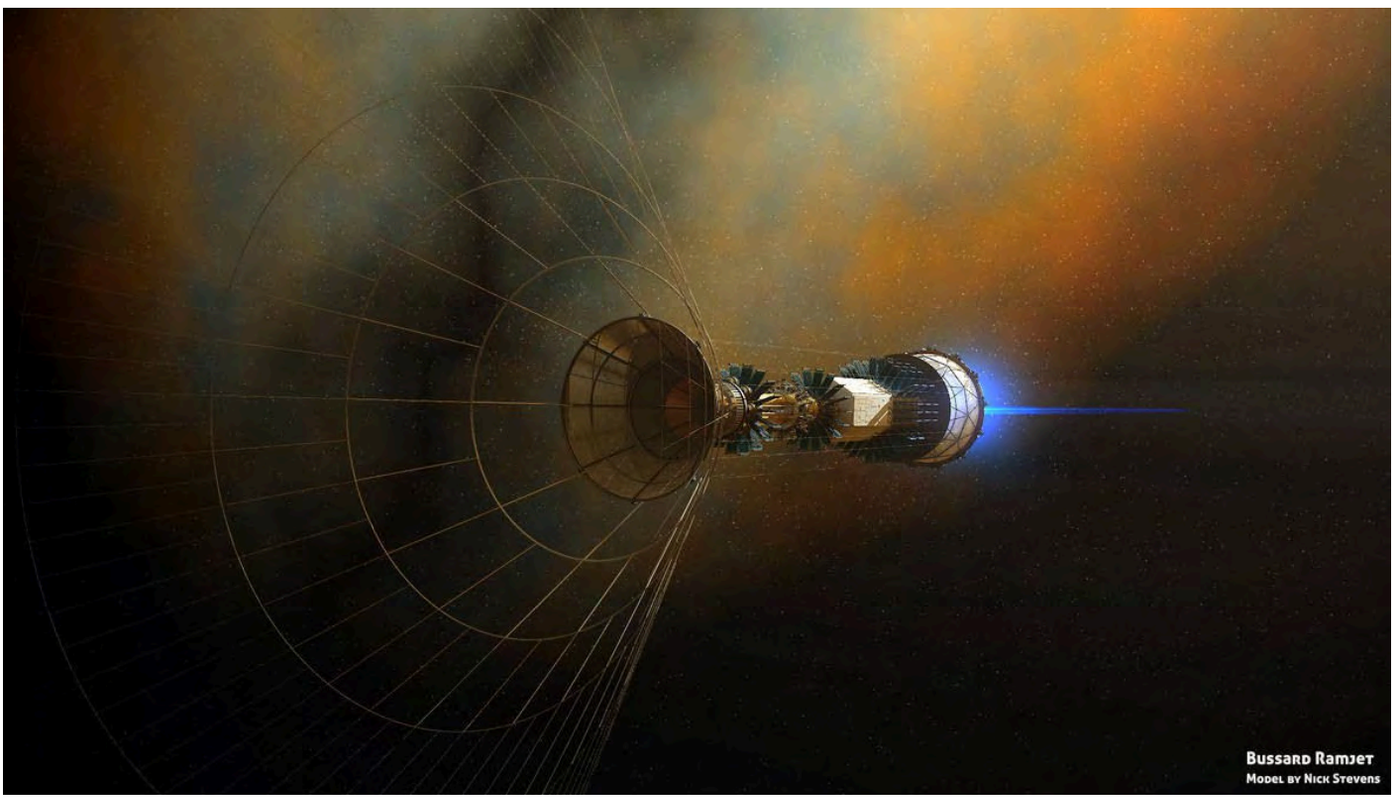
Final Thoughts

There seems a thread of pessimism about the Bussard Ramjet centered around drag on the ramjet due to interaction with the scoop field. This is an issue that Fishback deals with in his analysis , he shows one cannot just use a dipole magnetic field, a more complex collector field is needed. Fishback and Martin do show there is a fundamental physics limitation. Even using the strongest material theoretically possible there is an upper limit to a mission Lorentz factor, probably equal to 10,000. Above this one will bust the scoop coil due to magnetic stress. The cosmological peril of the *Leonora Christina* is not physically possible.

The main show stopper for the ramjet is the engineering physics. There is no way with foreseeable technology to build all the components of an interstellar ram scoop starship. Several aspects should be revisited. (1) The source of the magnetic scoop field , Fishback [7] derived one, Cassenti elaborated another idea [20], (2) the fusion reactor, the aneutronic fusion concept is direct conversion of fusion to energy [30] , (3) hybrid systems, especially laser-boosted ramjets.

Since basic physics does not rule a ramjet out it is possible that an advanced civilization might build one. Freeman Dyson [31] pointed out many times that what we could not do might be done by some advanced civilization as long as the fundamental physics allows it. An interesting consequence of this is interstellar ramjets may have been built and might have observable properties. Doppler boosted waste heat from the ships might be observable. Plowing into HII regions in the galaxy a starship's magnetic scoop field might produce a bow-shock which might be observable. Isolated objects in this galaxy with Lorentz factors in the thousands would be unusual and if they are accelerating even more unusual.

The idea of picking up your fuel along the way in your journey across interstellar space may be the optimal solution to the mass ratio problem in interstellar flight, therefore the interstellar ramjet warrants more technical study.



Appendix

Because Robert Bussard sketched a ramjet with a physical 'funnel' …all the many illustrations I have seen since seem to have some kind of 'cow catcher' on the front. Tho it is reasonable that such a structure is the source of an electromagnetic device I think it more likely that the 'scoop' field will be produced by a magnetic configuration that directs the incoming stream into the mouth of the reactor without any extra funnel-like forward structure. Here is a rough schematic done for me by artist Doug Potter. There is a 'blub' representing the magnetic source field (maybe the parabolic magnetic field calculated by Fishback) a reactor section and an exhaust. Not a very elegant representation of the ramjet but a suggested configuration.

References

1. Bussard, R W, and R D DeLauer. Nuclear Rocket Propulsion, McGraw-Hill, New York, 1958.

2. L R Shepherd, Interstellar Flight, JBIS, 11, 4, July 1952.

3. R W Bussard, Galactic matter and interstellar flight, Astronaut. Acta 6 (1960) 179–195.(citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.691.7932&rep=rep1&type=pdf).

4. C Sagan, Direct contact among galactic civilizations by relativistic interstellar spaceflight, Planet. Space Sci. 11 (1963) 485–498. (ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19630011050.pdf).

5. Sagan, Carl; Shklovskii, L S (1966). *Intelligent Life in the Universe*. Random House.

6. Sänger, E, Zur Flugmechanik der Photonenraketen. Astronautica Acta 3 (1957), S 89-99.

7. Fishback J F, Relativistic interstellar spaceflight Astronaut. Acta 15 25–35, 1969. (dspace.mit.edu/bitstream/handle/1721.1/102711/25183118-MIT.pdf).

8. Anthony R Martin; Structural limitations on interstellar spaceflight, Astronautica Acta, 16, 353-357, 1971.

9. Anthony R Martin; Magnetic intake limitations on interstellar ramjets, Astronautica Acta18, 1-10, 1973

10. Whitmire, Daniel P , "Relativistic Spaceflight and the Catalytic Nuclear Ramjet", Acta Astronautica 2 (5-6): 497–509, 1975. (citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.492.6775&rep=rep1&type=pdf).

11. Bond, Alan, An Analysis of the Potential Performance of the Ram Augmented Interstellar Rocket, Journal of the British Interplanetary Society (JBIS), Vol. 27, p.674,1974.

12. Powell, Conley, Flight Dynamics of the Ram-Augmented Interstellar Rocket, JBIS, Vol. 28, p.553.

13. Jackson, A A, Some Considerations on the Antimatter and Fusion Ram Augmented Interstellar Rocket, JBIS, v33, 117, 1980. (www.researchgate.net/profile/Albert_Jackson/publication/252428385_Some_Considerations_on_the_Antimatter_and_Fusion_RAM_Augmented_Interstellar_Rocket/links/568bb95708ae1975839f922e.pdf).

14. R L Forward, "Antimatter Propulsion", JBIS, 35, pp. 391–395, 1982.

15. Kammash, T, and Galbraith, D L, ''Antimatter-Driven-Fusion Propulsion for Solar System Exploration,'' Journal of Propulsion and Power, Vol. 8, No. 3, 1992, pp. 644 – 649. (pdfs.semanticscholar.org/d700/9dd33021a83b9eeedc4f3b48256842f34fc0.pdf).

16. Heppenheimer, T A (1978). "On the Infeasibility of Interstellar Ramjets". JBIS. 31: 222.

17. Matloff, G L, and A J Fennelly, "A Superconducting Ion Scoop and Its Application to Interstellar Flight", JBIS, Vol. 27, pp. 663-673, 1974.

18. Matloff, GL, and A J Fennelly, "Interstellar Applications and Limitations of Several Electrostatic/Electromagnetic Ion Collection Techniques", JBIS, Vol. 30, pp. 213-222, 1980.

19. Matloff, G L, and A J Fennelly , B N, Design Considerations for the Interstellar Ramjet, 44th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 2008.

20. Cassenti, B N, The Interstellar Ramjet, 40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, 2004.

21. Claude Semay and Bernard Silvestre-Brac,The equation of motion of an interstellar Bussard ramjet, European Journal of Physics 26(1):75, 2004. (freemanu1.free.fr/intersideral/references/SEMAY-2005-03-JOURNAL.pdf).

22. Claude Semay and Bernard Silvestre-Brac, Equation of motion of an interstellar Bussard ramjet with radiation loss, Acta Astronautica 61(10):817-822, 2007.

23. Whitmire, D and Jackson, A, "Laser Powered Interstellar Ramjet," JBIS Vol. 30pp. 223-226. 1977 (www.researchgate.net/profile/Albert_Jackson/publication/253524015_Laser_Powered_Interstellar_Ramjet/links/568bb8ba08aebccc4e1c06e6/Laser-Powered-Interstellar-Ramjet.pdf).

24. Mallove, E F, and G L Matloff, *The Starflight Handbook*, Wiley, New York, 1989.

25. Matloff, G, *Deep-Space Probe*s, Praxis Publishing, Chichester, UK, 2000.

26. Ian A Crawford, Direct Exoplanet Investigation Using Interstellar Space Probes In book: *Handbook of Exoplanets* Publisher: Springer Editors: H J Deeg, J A Belmonte, July 2017.

27. Anderson, Poul. *Tau Zero*. New York: Lancer Books (1970).

28. George Gamow, *The Creation of the Universe* (1952).

29. Benford, G and Niven, L, Bowl of Heaven Series, Macmillan.

30. Benford, G, Private communication.

31. Dyson, F J, 1966, The search for extraterrestrial technology, in Marshak, R E (ed), Perspectives in Modern Physics, Interscience Publishers, New York, pp. 641–655.

About the Author

Dr Albert Allen Jackson IV graduated from the University of North Texas with a BA in Mathematics and an MA in Physics. He joined NASA in 1966 and was a Lunar module simulation training instructor in the Apollo Program. He went on to a PhD at the University of Texas at Austin. He worked on space technology in a number of engineering companies and universities including 17 years as Principal Scientist at Lockheed/Martin. He is now retired but very busy! - including being a Visiting Scientist at the Lunar and Planetary Institute, a division of the Universities Space Research Association (www.lpi.usra.edu).

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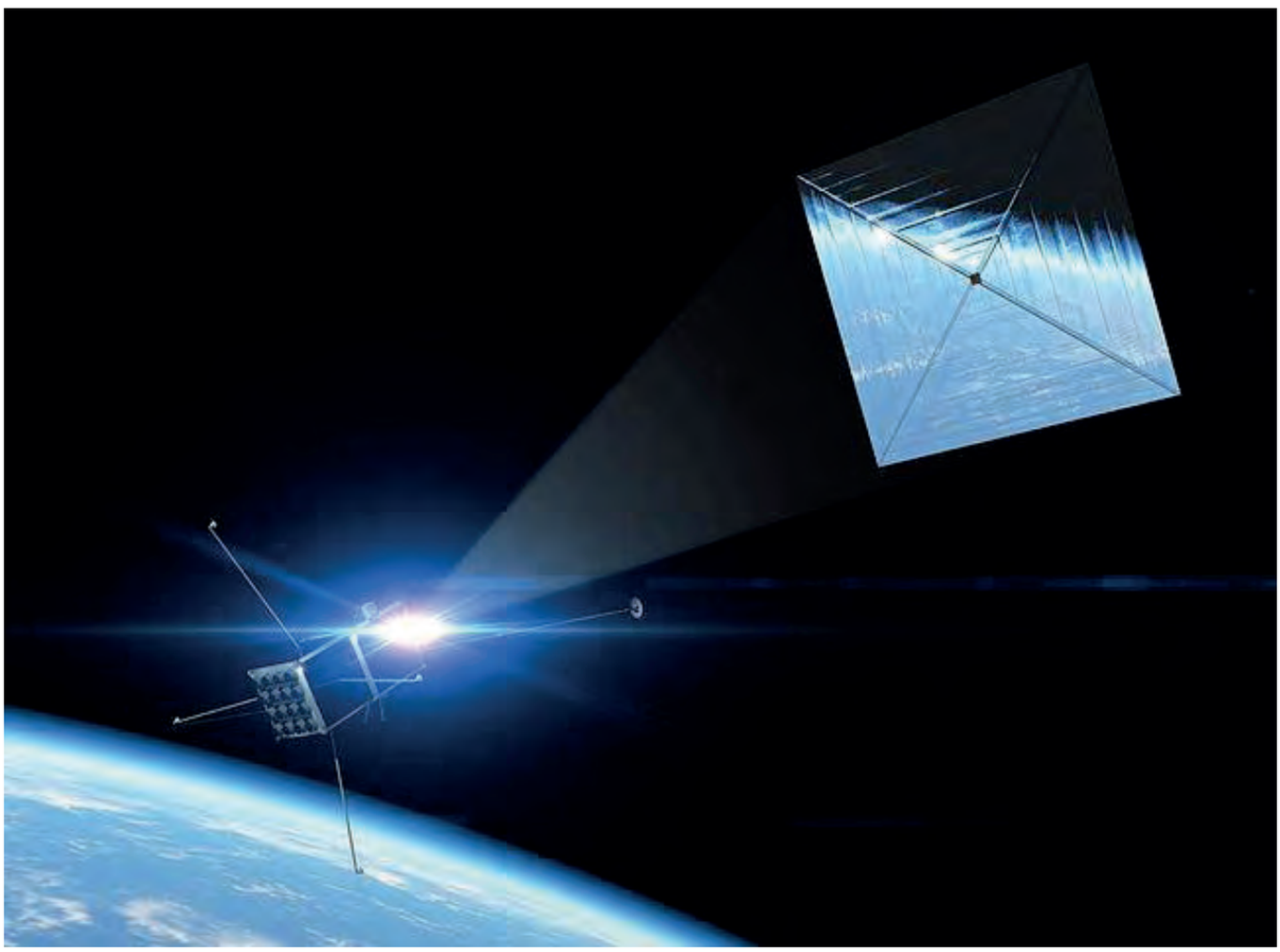

The Initiative for Interstellar Studies (i4is) has launched a membership scheme intended to build an active community of space enthusiasts whose sights are set firmly on the stars. We are an interstellar advocacy organisation which:

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News Feature - From the Website - i4is.org

John I Davies

Here's a selection of new things to be found on our ever changing website. Some of this content is *exclusive to members*. Logon or join via i4is.org/membership.

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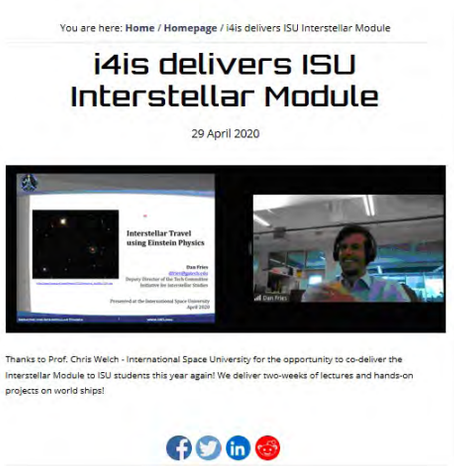

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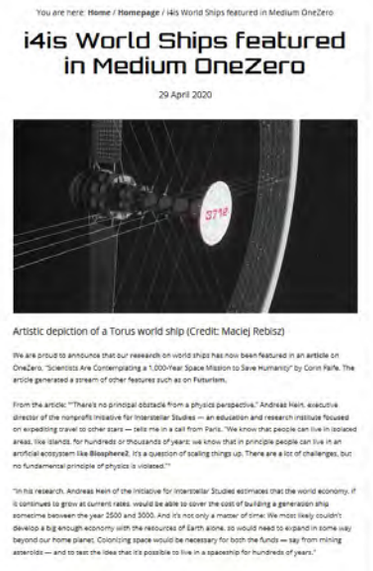
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i4is World Ships featured in Medium OneZero

29 April 2020

Artistic depiction of a Torus world ship (Credit: Maciej Rebisz)

We are proud to announce that our research on world ships has now been featured in an article on OneZero. "Scientists Are Contemplating a 1,000-Year Space Mission to Save Humanity" by Corin Faife. The article generated a stream of other features such as on Futurism.

From the article: ""There's no principal obstacle from a physics perspective," Andreas Hein, executive director of the nonprofit Initiative for Interstellar Studies — an education and research institute focused on expediting travel to other stars — tells me in a call from Paris. "We know that people can live in isolated areas, like islands, for hundreds or thousands of years: we know that in principle people can live in an artificial ecosystem like Biosphere2. It's a question of scaling things up. There are a lot of challenges, but no fundamental principle of physics is violated.""

"In his research, Andreas Hein of the Initiative for Interstellar Studies estimates that the world economy, if it continues to grow at current rates, would be able to cover the cost of building a generation ship sometime between the year 2500 and 3000. And it's not only a matter of time: We most likely couldn't develop a big enough economy with the resources of Earth alone, so would need to expand in some way beyond our home planet. Colonizing space would be necessary for both the funds — say from mining asteroids — and to test the idea that it's possible to live in a spaceship for hundreds of years."


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Project Lyra featured in Wired

28 April 2020

Sail-based probes arriving at 'Oumuamua (Credit: Maciej Rebisz)

Our new Project Lyra research was featured in Wired magazine. Project Lyra assesses the feasibility of missions to interstellar objects such as 'Oumuamua and Borisov.

From the article, which features Adam Hibberd and Marshall Eubanks of our Project Lyra team: "We now know such a mission, at least in principle, is achievable," says software developer Adam Hibberd, a volunteer with the initiative who built the software to design Project Lyra's trajectory. "The possible scientific return would be tremendous and might fundamentally alter our understanding of our place in the universe."

"'Unfortunately we can't just launch any year we like," says Hibberd. "To make missions feasible using current technology, we are reliant on Jupiter taking up a certain point in its 12-year orbit around the sun, and so the opportunities follow approximately a 12-year cycle.'"

"Marshall Eubanks, the chief scientist at Space Initiatives, a company working on small satellite systems, and a coauthor of the new Project Lyra paper, sees the mission as a stepping stone toward more ambitious interstellar missions. For example, Breakthrough Starshot, an interstellar mission bankrolled by the billionaire Yuri Milner, wants to use giant lasers to send a fleet of thumbnail-sized probes to our closest stellar neighbor, Alpha Centauri. Eubanks says that an interstellar mission to 'Oumuamua would

Project Lyra featured in Wired

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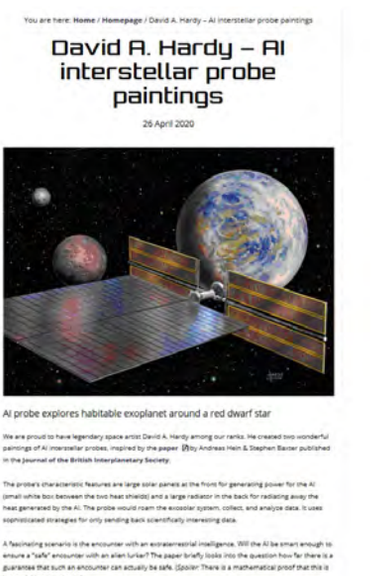
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David A. Hardy – AI interstellar probe paintings

26 April 2020

AI probe explores habitable exoplanet around a red dwarf star

We are proud to have legendary space artist David A. Hardy among our ranks. He created two wonderful paintings of AI interstellar probes, inspired by the paper by Andreas Hein & Stephen Baxter published in the Journal of the British Interplanetary Society.

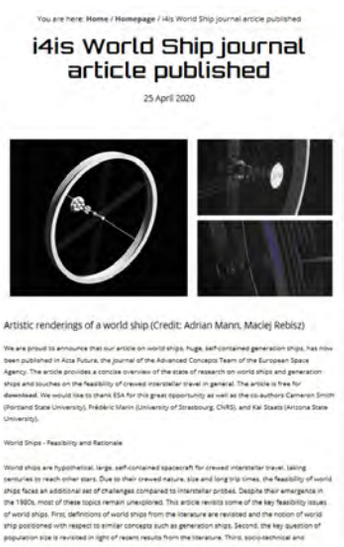
The probe's characteristic features are large solar panels at the front for generating power for the AI (small white box between the two heat shields) and a large radiator in the back for radiating away the heat generated by the AI. The probe would roam the exosolar system, collect, and analyze data. It uses sophisticated strategies for only sending back scientifically interesting data.

A fascinating scenario is the encounter with an extraterrestrial intelligence. Will the AI be smart enough to ensure a "safe" encounter with an alien lurker? The paper briefly looks into the question how far there is a guarantee that such an encounter can actually be safe. (Spoiler: There is a mathematical proof that this is impossible to guarantee.)

David A Hardy – AI interstellar probe paintings

27 April 2020

/i4is.org/david-a-hardy-ai-interstellar-probe-paintings/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i4is World Ship journal article published

25 April 2020

Artistic renderings of a world ship (Credit: Adrian Mann, Maciej Rebisz)

We are proud to announce that our article on world ships, huge, self-contained generation ships, has now been published in Acta Futura, the journal of the Advanced Concepts Team of the European Space Agency. The article provides a concise overview of the state of research on world ships and generation ships and touches on the feasibility of crewed interstellar travel in general. The article is free for download. We would like to thank ESA for this great opportunity as well as the co-authors Cameron Smith (Portland State University), Frédéric Marin (University of Strasbourg, CNRS), and Kai Staats (Arizona State University).

World Ships - Feasibility and Rationale

World ships are hypothetical, large, self-contained spacecraft for crewed interstellar travel, taking centuries to reach other stars. Due to their crewed nature, size and long trip times, the feasibility of world ships faces an additional set of challenges compared to interstellar probes. Despite their emergence in the 1960s, most of these topics remain unexplored. This article revisits some of the key feasibility issues of world ships. First, definitions of world ships from the literature are revisited and the notion of world ship positioned with respect to similar concepts such as generation ships. Second, the key question of population size is revisited in light of recent results from the literature. Third, socio-technical and

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26 April 2020

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exclusive to members


You are here: Home / Homepage / Newsletter: i4is Annual Report, mini-research projects and more...

Newsletter: i4is Annual Report, mini-research projects and more...

1 April 2020

Dear John,

We have just published the i4is Annual Report 2019. This is the first annual report to members of the Initiative for Interstellar Studies and the Institute for Interstellar Studies. All members receive this report and it can be downloaded here

Explore the Report

The i4is Membership Survey is closing very soon. If you have not already filled it out you can do so here. Your feedback allows us to create the membership scheme that our members want. We have tested the form and on average it should take around 5 minutes to complete.

Take the Survey

Please note that all answers are optional, so feel free to answer as many or as few as you wish. If you have any queries about this survey, please don't hesitate to contact us at membership@i4is.org.

Many thanks from Tam O'Neill and the i4is membership team.

Here are some new items for you to explore:

Interstellar mini-research project topics

Since our last newsletter the world has changed considerably. Our Executive Director and Technical Research Committee chair, Andreas Hein, has compiled a list of short (~2 weeks) research projects that you can work on if you have some free time over the coming weeks. These projects are real research topics that address important research gaps in the interstellar field. Their titles are:

Newsletter: i4is Annual Report, mini-research projects and more…

1 April 2020

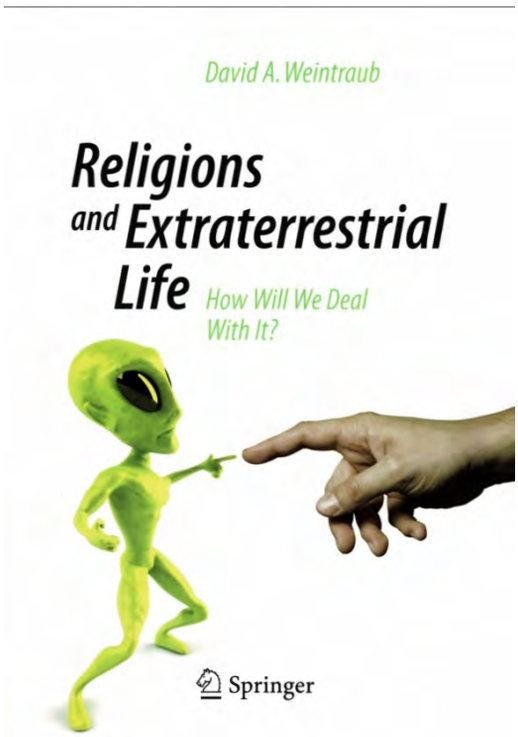
i4is.org/newsletter-i4is-annual-report-2019/

Book Review: Religions and Extraterrestrial Life

David A Weintraub

John I Davies

Religious belief has been a common feature of human cultures. There have been, and are, cultures which have rejected or suppressed it but it seems fulfil a widespread need for our species. Religions offer answers to the big questions of "Life, the universe and everything" (copyright D Adams) so how do they answer the possibility of Extraterrestrial Intelligence (ETI)? And how would they respond to the discovery of ETI? in his 2014 book, Religions and Extraterrestrial Life: How Will We Deal with It? David A Weintraub attempts to answer these questions.



Beginning with some history, Weintraub tells us that Aristotle's physics supported an Earth-centric cosmology. At the time this may have seemed self-evident to most observers but there were other views. His successor Epicurus (famously the advocate of the atomic theory of matter) argued that there was "nothing to hinder the infinity of worlds". Aristotle's view dominated western thinking until the 15th-16th century. When observation started to provoke dissent from the Earth-centric view in Europe the Church attempted to suppress it, of course. Weintraub points out that Copernicus only published *Dē revolutionibus orbium coelestium* (On the Revolutions of the Heavenly Spheres) from his deathbed. However, the heliocentric theory won and not even the most devout Catholic now support the Earth-centric view. And once Galileo and his successors pointed telescopes at the planets the possibility that they were Earth-like had to be considered.

Western theologians invoked the omnipotence of the Christian God and Weintraub cites David Rittenhouse (1732-1796) who speculated that "if God wanted to create multiple worlds, he could", though Leibniz (1646-1716) had earlier argued for multiple worlds from an astronomical point of view. Pluralism grew, for example Herschel expected to find living things on the Moon.

Weintraub attaches particular importance to the views of Tom Paine (1737-1809) who, in *The Age of Reason*, wrote -

> Though it is not a direct article of the Christian system, that this world that we inhabit is the whole of the habitable creation, yet it is so worked up therewith, from what is called the Mosaic account of the Creation, the story of Eve and the apple, and the counterpart of that story, the death of the Son of God, that to believe otherwise, that is, to believe that God created a plurality of worlds, at least as numerous as what we call stars, renders the Christian system of faith at once little and ridiculous, and scatters it in the mind like feathers in the air. The two beliefs cannot be held together in the same mind, and he who thinks that he believes both, has thought but little of either. (www.ushistory.org/PAINE/reason/reason12.htm)

Religions and Extraterrestrial Life:
How Will We Deal with It?

Autor: David A Weintraub, published Springer 2014

David Weintraub is Professor of Astronomy, Vanderbilt University (my.vanderbilt.edu/davidweintraub).

So "to believe that God created a plurality of worlds" is incompatible with the founding myths of Christianity. Weintraub applies Tom Paine's "litmus test" to many theological attitudes to ETI, not just Christian ones.

As the 19th century progressed astronomers were able to determine that advanced life probably did not exist in the Solar System, despite Lowell's perceived canals on Mars. Weintraub does not mention Wells' "intellects vast and cool and unsympathetic" on Mars.

Weintraub's analyses of the major religions are the core of his book. He starts with Judaism. Though there is little in Jewish scripture about ET life, he believes that most varieties of Judaism would have no difficulty with the discovery of ETI. In one of the few SF references he quotes William Tenn's Bulbas, Jews from Rigel IV, whom terrestrial Jews accept as co-religionists on the basis that "There are Jews and there are Jews, Bulbas belong to the second category".*

He treats Roman Catholicism at some depth. He remarks that recent RC theologians have had little trouble accommodating ETIs despite, in his view, failing Tom Paine's litmus test. They struggle with the idea that if Christ is not to be incarnated on multiple planets than only humans can achieve salvation.

Orthodox Christianity seems to take a range of views on ETI. Originally very Earth-centric and Christ-centric, modern orthodox theologians have accepted the possibility of ETI but there remain fundamentalists who go further than the most conservative Roman Catholics, rejecting not only the possibility of ETI but much of modern science.

The Church of England is famously a "broad church". Its Episcopalian (in Scotland) and Anglican siblings elsewhere - and the Church in Wales - are, in some cases, even broader. Weintraub notes the rejection of Paine's test by cosmologist E A Milne FRS who found no contradiction between Christ's unique incarnation on Earth and a Christian message to the cosmos (in Modern Cosmology and the Christian Idea of God). Others have also argued that there are many routes to salvation. However Anglican (very Anglican!) novelist C S Lewis speculated that only humanity may be "fallen". (This looks to this writer like a suggestion that other intelligent beings inhabit a "garden of Eden", presumably one per planet - there seem to be parallels with the James Blish story, see below). Weintraub accuses Lewis of wanting to have it both ways. (We might call this "cakeism", as practised by Boris Johnson "My policy on cake is pro having it and pro eating it.") . Others have simply suggested that we should not bother our little heads about the issue.

Weintraub identifies the other theological descendants of Luther and Calvin as "Mainline Protestant Christianity" with the central principle of Sola Scriptura (by scripture alone). 20th century movements such as the "process theology" deriving from Alfred North Whitehead have seen God as being involved in the process of the universe rather than being wholly immutable. This allows them to retain an Earth-centric understanding of the Christian founding myths but to allow that ETIs can achieve redemption by means other than Christ. This is a very diverse group and there is a corresponding range of responses to the ETI question. One, the United Church of Christ, comprising the former Evangelical Church, Reformed Church and the Congregational Churches, is a loose group but its President, John H Thomas, asserted in 2008 that "there are good reasons to think that life, even intelligent life, exists throughout the universe".

Weintraub differentiates the Christians he characterises as Evangelical and Fundamentalists. Here the common core is a personal relationship with Christ. One of their most prominent preachers, Billy Graham, appeared to be relaxed but unspecific about potential ETIs. Some of these churches would proselytise any ETIs we found. More recently Evangelical and Fundamentalist churches have adopted a more pronounced opposition to the idea of ETIs, seeing this as a "slippery slope" to the acceptance of evolution - which they strongly reject. Some have gone as far as to invoke the Fermi Paradox as evidence of the non-existence of ETIs†. Weintraub concludes that the appearance of ETIs would "devastate" Evangelicals and Fundamentalists.

* William Tenn's story *On Venus, Have We Got a Rabbi!* has a decidedly non-human alien saying "I, Yitzhak ben Pinchas, am the direct descendant of Melvin Cohen, the assistant manager of a supermarket in Paramus, New Jersey" (www.tabletmag.com/sections/arts-letters/articles/on-venus-have-we-got-a-rabbi). Much of the humour is about aspects of Jewish culture I do not know but even if you only get half the jokes it's still very funny.

† the views of cosmologist Frank Tipler on the Anthropic Principle in his *The Physics of Christianity* and elsewhere which appear to have some religious roots, are not mentioned by Weintraub.

He briefly discusses the views of Unitarians, Quakers and Christian Scientists. This looks like an arbitrary grouping to this writer, varying from "flying saucer" theology to an austere solitary personal relationship with a virtually undescribed god. For Mormons, he places ETIs as others in the chain of "sparrow's flight" transitions between existences.

Islam, Weintraub asserts, has no problem with ETIs, an Imam of the 7th century CE writing "God created thousands and thousands of worlds and thousands and thousands of humankind". For most Islamic theologians science is an Islamic duty helping to understand God's creation. There are some tricky, but probably trivial, issues of course such as the direction of Mecca from Epsilon Eridani. But perhaps all of this is subsidiary to the Islamic principle of surrender to the divine will.

Hinduism's succession of incarnated lives with the opportunity to achieve good and bad karma seems equally applicable to ETIs and multiple worlds would not be a problem for Hindus. All sentient beings could aspire to the final release from the cycle,

Buddhism he characterises as a sort of "protestant" Hinduism with an infinite cosmology. He finds no "science phobia" in any variety of Buddhism. Some streams of Buddhism even envisage conversation between disembodied humans and ETIs (which comes close to the idea of AGIs and transcendent humans).

Jainism and Sikhism, also deriving from Hinduism, are quite distinct. One pacifist and the other decidedly not. But both would actively welcome ETIs. Finally Baha'is see harmony between science and religion and would see ETIs as a natural part of their cosmology.

Weintraub winds up by asking if we, collectively, are ready for ETI. He notes early astronomy as an essential part of religion. The enquiries of cosmology and theology have obvious parallels*. Nevertheless he considers that we are not ready. And certainly some sets of beliefs would struggle with the revelation of an ETI.

Conclusion

Weintraub provides an excellent survey of religions thinking about ET life and intelligence. His largely historical approach means that the common threads of their cosmologies are not as visible as they might be. He also omits what used to be called "primitive" religions. The cosmology of native Australians might have been of interest. Other major omissions include the essentially religious beliefs of Confucians and the religions of defunct civilisations, some of which, such as those of South America, may not be quite defunct.

His extensive references are clearly valuable - though I followed up only a few.

A substantial central section about exoplanets is necessarily out of date and could have been shorter and more generalised.

Weintraub does not deal much with science fiction, apart from the Bulbas, of course. So everything from the spiritual tribulations of Father Ruiz-Sanchez, SJ, in James Blish's *A Case of Conscience* to the lampooning works of the fictional Oolon Colluphid (Where God Went Wrong, Some More of God's Greatest Mistakes and Who is this God Person Anyway?) invented by Douglas Adams, are absent.

As are Fred Hoyle's speculations about ETIs inhabiting interstellar space in *The Black Cloud* - these ETIs being astounded to find even our limited intelligence in the hostile environment of a planetary surface.

All reservations aside, this is a thought provoking book and a fine introduction to an important aspect of the great "what if?" question which arises if SETI is successful.

* are there also some parallels between eschatologies - myths of the end of the world - and the second law of thermodynamics?

About the Reviewer

John Davies has been editor of Principium since Issue 9, May 2015. He is a retired mobile telecoms consultant and a former software and electronic engineer. He describes his own religious views as "sentimental Church of England atheism".

The FAST radio telescope works with Breakthrough Listen to push SETI forwards

Patrick Mahon

Patrick Mahon reports on a recent arXiv preprint setting out how a huge new Chinese radio telescope could help answer some of SETI's most important questions

In the last issue of Principium, I reviewed The Contact Paradox [1], Keith Cooper's excellent book on the Search for Extra-Terrestrial Intelligence, or SETI. I was therefore intrigued when John Davies forwarded me details of a recent paper on the topic of SETI that had been deposited on arXiv, the open-access repository where academics share preprints of their papers before they've been peer-reviewed. The paper, titled *Opportunities to Search for Extra-Terrestrial Intelligence with the Five-hundred-meter Aperture Spherical radio Telescope* [2], discusses proposals to use the largest single aperture radio telescope in the world, recently opened in South West China, to make real advances in SETI, working with the Breakthrough Listen Initiative [3], whose Executive Director, Pete Worden, formerly the Director of NASA Ames, who visited i4is back in November 2017*. The paper is co-authored by 33 scientists and engineers working at 14 institutions spread across six countries, so this is truly an international collaboration.

Central to the paper is the use of FAST – the Five hundred metre Aperture Spherical radio Telescope. This facility was built in southwest China between 2011 and 2016 and on achieving First Light in September 2016, became the largest single-aperture radio telescope in the world. If you're wondering what it looks like, think of a larger version of the Arecibo radio telescope built in Puerto Rico in the early 1960s. Like

The FAST telescope - image courtesy of the SETI Institute (www.seti.org/seti-institute/worlds-biggest-radio-ear). The SETI Institute are to be commended for the openness of their communications – www.seti.org/education-outreach/communications.

* see *NEWS FEATURE Dr Pete Worden, Breakthrough Initiatives, at i4is HQ* Patrick Mahon, Principium 20, February 2018

that, it's built into a huge natural depression in the ground, which has been covered in metal, and pointing upwards towards a receiving antenna constructed at the focus. Unlike Arecibo, where the metal covering the ground is fixed in place, FAST uses an active surface whose elements can be moved, enabling the telescope to focus on a wider area of the sky than its predecessor. It's worth noting, though, that although the telescope dish has a diameter of 500 metres, as the name indicates, its maximum effective aperture is 300 metres. That still makes it larger than Arecibo, but its size shouldn't be over-emphasised.

The main reason why the paper's authors believe that FAST will be able to advance SETI substantially is its sensitivity. They estimate this to be 2.5 times higher than Arecibo, due to a combination of the larger aperture, more complex design and more advanced instrumentation and signal processing capabilities. This should enable two different kinds of advances. First, they can perform the usual 'narrow-band' searches (ie searching for an artificial radio signal whose frequency varies only by a few Hertz, which differentiates it from most natural astrophysical sources) at much higher resolution. Second, they can undertake searches for different types of artificial signals, previously too complicated to be detected. These include wide-band artificially dispersed pulses (where the different frequencies in the pulse arrive on Earth at different times, requiring the ability to correlate them in time), and signals with artificial modulation of the carrier wave (eg amplitude modulation or frequency modulation, as is done with AM or FM radio signals on Earth) to encode additional information in the signal. In both cases, the combination of the telescope's higher sensitivity, and the use of advanced machine learning techniques (some of which have been pioneered by Breakthrough Listen), should enable the detection of SETI signals which up to now would not be detectable.

The last major question discussed in the paper is the choice of targets for these early searches. They tested some of their proposed approaches by focusing the telescope last September on the potentially habitable exoplanet GJ273b, a super-Earth which orbits the red dwarf Luyten's Star, some 12.2 light years away. This test showed that the equipment worked and indicated that they could achieve the signal sensitivity they were aiming for. The forthcoming surveys will have two distinct targets. The first is the whole of the Andromeda galaxy, M31, which they will search for signs of any Kardashev type II or type III civilisations (that is, civilisations that can harness all the energy produced by their own star, or by all the stars in their galaxy, respectively). The second is a subset of the potentially habitable exoplanets identified by NASA's Transiting Exoplanet Survey Satellite (TESS) mission, launched in April 2018. TESS is expected to find up to 250 new super-Earths orbiting bright red dwarfs. Since these will be new discoveries, not available to previous SETI surveys, the project team see them as ideal candidates for a SETI search using FAST.

The paper does not make clear an intended timescale for the project, but i4is will watch out for early results from what looks to be an important new advance in the SETI field.

References:

[1] Keith Cooper, The Contact Paradox: Challenging our Assumptions in the Search for Extraterrestrial Intelligence, Bloomsbury Sigma, 2019.

[2] Di Li et al, 'Opportunities to Search for Extra-Terrestrial Intelligence with the Five-hundred-meter Aperture Spherical radio Telescope', arxiv.org/abs/2003.09639 , 24 March 2020. Forthcoming in Research in Astronomy and Astrophysics.

[3] Details of the Breakthrough Listen Initiative are available on their website at breakthroughinitiatives.org/initiative/1 .

Opportunities to Search for Extra-Terrestrial Intelligence with the Five-hundred-meter Aperture Spherical radio Telescope

Contents

Mariner 2 spacecraft model
part 2: The initial construction phase

Terry Regan

Terry Regan, our lead model-maker continues the story he began in issue 26 about his scratch-built model of the Mariner 2 spacecraft which went to Venus in 1962. Having explained his essential prior research last time, he now takes us though initial construction. He tells us that he was building this model using the very limited plans that are available and he warns us that "there may be a few discrepancies here and there". The finished object will, we are confident, be up to Terry's own high standards.

History

Mariner 2 was the first ever robotic space craft to be sent to Venus to carry out basic research. Launched from Cape Canaveral on August 27 1962 by a two stage Atlas Agena rocket, this was the first ever man made vehicle to be sent to a planet. So what happened to Mariner 1? Mariner 1 was launched on the 22nd July 1962 on an Atlas Agena two stage rocket to go to Venus, at 93 seconds into flight the guidance system malfunction and it started to veer off course. At 293 seconds into its flight the vehicle was destroyed by the Range Safety Officer.

The Mariners 1 and 2 were simplified versions of the block 1 spacecraft of the Ranger program that was sent to crash into the moon. The Mariner probe consisted of a 100 cm (39.4 inches) hexagonal bus (ie the main spacecraft) with two solar panels. The scientific instruments on board were two radiometers one for the microwave and one for infrared, a micrometeorite sensor, a solar plasma sensor, a charged particle sensor and a magnetometer.

The Model.

To start the build, the best place is the main body known as the bus; this will be the reference where all the other parts would be attached. A hexagonal piece was cut out of a sheet of 0.02” (0.50 mm) plastic card with 0.08” (2.mm) slots cut in each corner; the slots are for the six legs, more about that later. Next I cut six 23 mm x 20 mm 0.08” (2 mm) thick card, these are the side pieces and glued to the base and checking every thing is square as in photo M2 016.

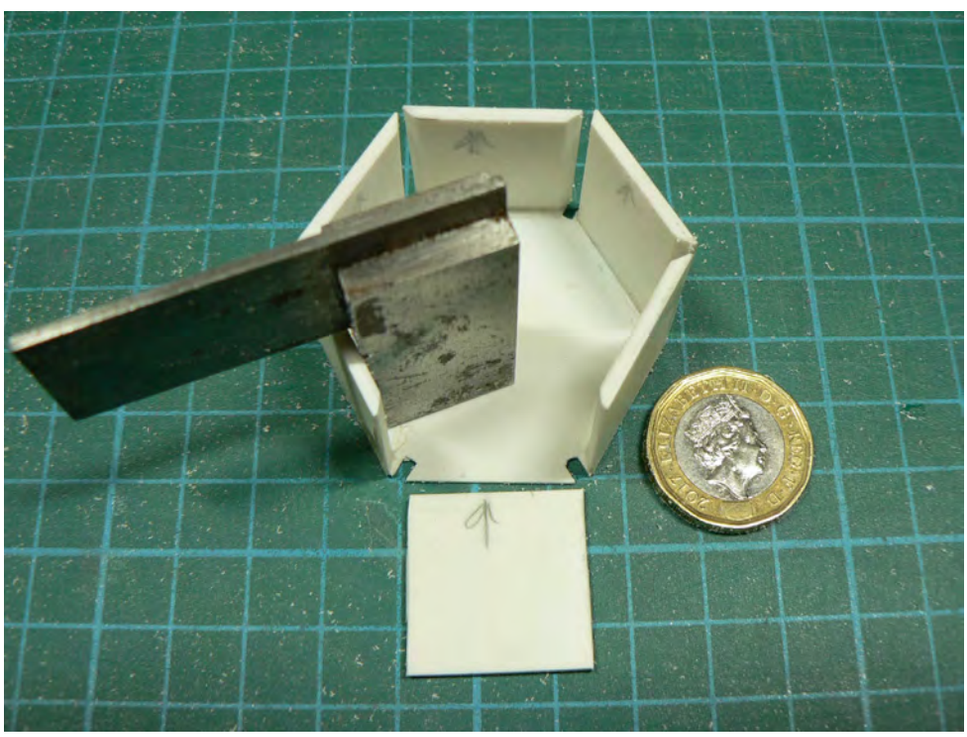


photo M2 016 - The coin is a UK pound about 23mm

Next job was to strengthen the side panels with again 0.08” (2 mm) card and also slot in six 2 mm card between each of the panels to get the gaps exactly right as in photo M2 021.

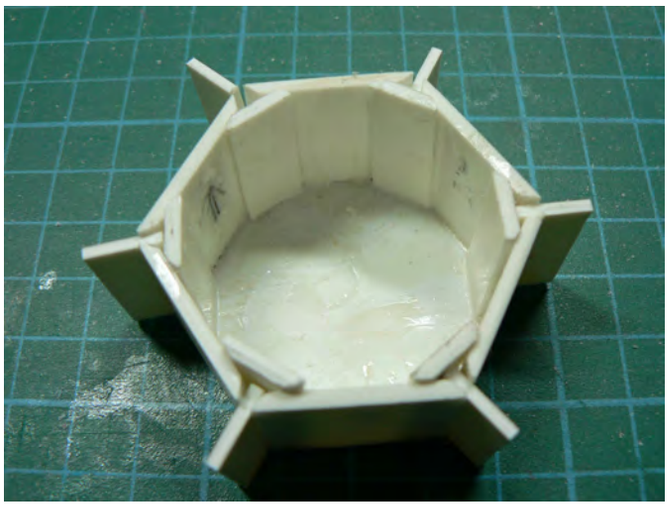
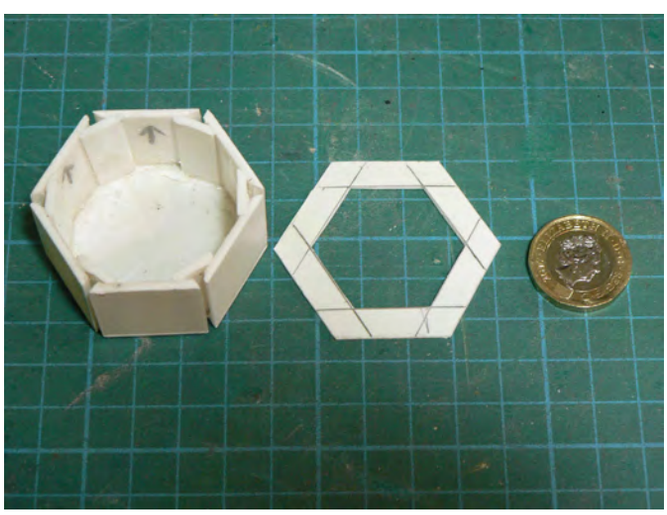
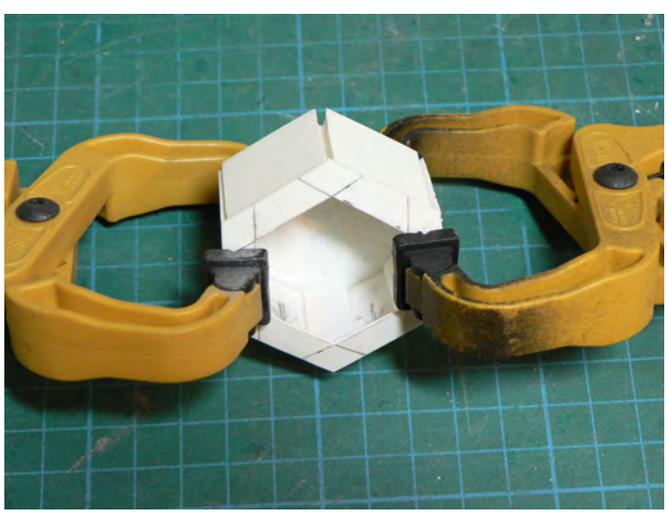


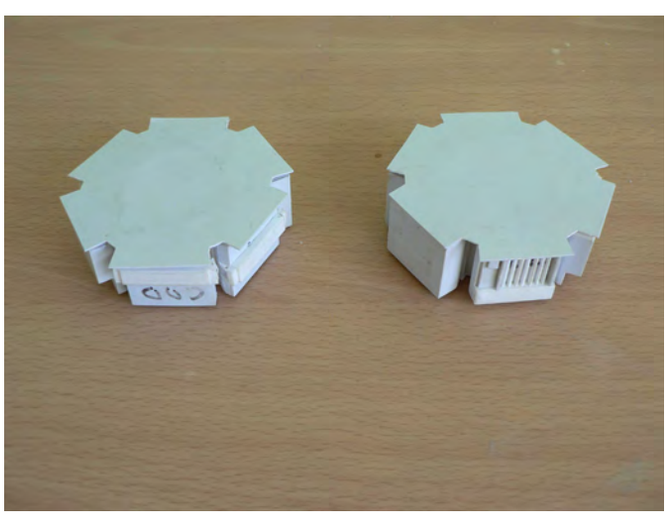
photo M2 021

Then another hexagonal piece, this time with the centre cut out (this is for the rocket motor / nozzle) and glue this to the bottom of the bus, clamp and left to dry as in photos M2 023 and 24. So the size of the bus is 45 mm by 45 mm.





M2 023 and 24 - left and right



M2 089 - the completed bus

Now that the bus is complete the next step is to make the six instrument boxes that are fitted to each side of the bus. This is where confusion set in, the boxes are wider than the bus mounts and with no information available explaining the shape of the boxes I had to study the photos and discovered in one photo that each side of the boxes were tapered slightly inwards as in photo M2 041.

photo M2 041

All the boxes are 25 mm tall by 25 mm long but four are at different depths but what I can say is that there is a Temperature Control lower Box and a Cosmic Dust Detector . The other boxes are not labelled. I started by making the Temperature Control box using strips of plastic and arranging them to represent louvres as in photo M2 042, and then I worked on the Cosmic Dust Detector box using the drawings I had.

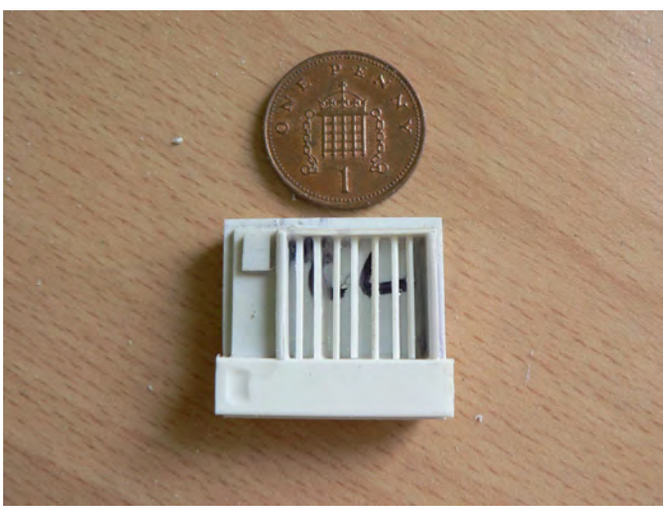


photo M2 04:. the coin is a UK penny about 20mm

Two other boxes had what look like external trunking so again strips of plastic were formed and fitted. When mounting the boxes I found that all the photos and drawings I had fitted completely differently to each other. So I resorted to the hand drawn plans, so who is right, the hand drawn plans or the two replica model hanging in the two museums - and even those two were mounted differently? Once I had glued the boxes the next step was to make the top cover, this part is the Temperature Control Shield, using 20th" plastic card, cut and shaped and glued, this would be the base for the framework that holds the antenna support brackets.

In Part 3 I will be talking about antennas and radars.

NEXT ISSUE

Concluding part of interview with Cassidy Cobbs
Book Review: Extraterrestrial Languages by Daniel Oberhaus
Report of the 2020 i4is elective at the International Space University, Strasbourg
Al Worden (1932-2020)

and more!

Cover Images

Front Cover: Alex Storer (thelightdream.net) kindly developed this image at the request of Principium editor John Davies in anticipation of the anniversary of the Bussard paper and Al Jackson's piece, *The Interstellar Ram Jet at 60*, in this issue. Alex aimed for a hand-painted effect while still using his regular digital toolkit. We hope Dr Bussard would have approved!

Back Cover: The indefatigable Hubble telescope was conceived in the 1960s, launched in the 1990s and remains our species' most reliable provider of spectacular images and visual-spectrum information about our universe. The final servicing mission to the Hubble in 2009 installed the new Wide Field and Planetary Camera 3. This image of the Butterfly Nebula NGC 6302 about 4,000 ly away was one of the results. 4,000 ly is the back yard to astronomers but a challenging distance to our current exploration technologies!

Credit: NASA / ESA

www.nasa.gov/multimedia/imagegallery/image_feature_2526.html

sci.esa.int/web/hubble/-/34998-demise-in-ice-and-fire-heic0407

Mission

The mission of the Initiative for Interstellar Studies is to foster and promote education, knowledge and technical capabilities which lead to designs, technologies or enterprise that will enable the construction and launch of interstellar spacecraft.

Vision

We aspire towards an optimistic future for humans on Earth and in space. Our bold vision is to be an organisation that is central to catalysing the conditions in society over the next century to enable robotic and human exploration of the frontier beyond our Solar System and to other stars, as part of a long-term enduring strategy and towards a sustainable space-based economy.

Values

To demonstrate inspiring leadership and ethical governance, to initiate visionary and bold programmes co-operating with partners inclusively, to be objective in our assessments yet keeping an open mind to alternative solutions, acting with honesty, integrity and scientific rigour.

Editors: John I Davies, Patrick J Mahon
Deputy Editor: Andreas M Hein
Layout / Proofing: John I Davies, Carol Wright, Lindsay A Wakeman

The Initiative for Interstellar Studies is a pending institute, established in the UK in 2012 and incorporated in 2014 as a not-for-profit company limited by guarantee.
The Institute for Interstellar Studies was incorporated in 2014 as a non-profit corporation in the State of Tennessee, USA.

Front cover: Bussard ramjet
Credit: Alex Storer
Back cover: Butterfly Nebula NGC 6302
Credit: Hubble / NASA / ESA

i4is.org

Scientia ad sidera
Knowledge to the stars