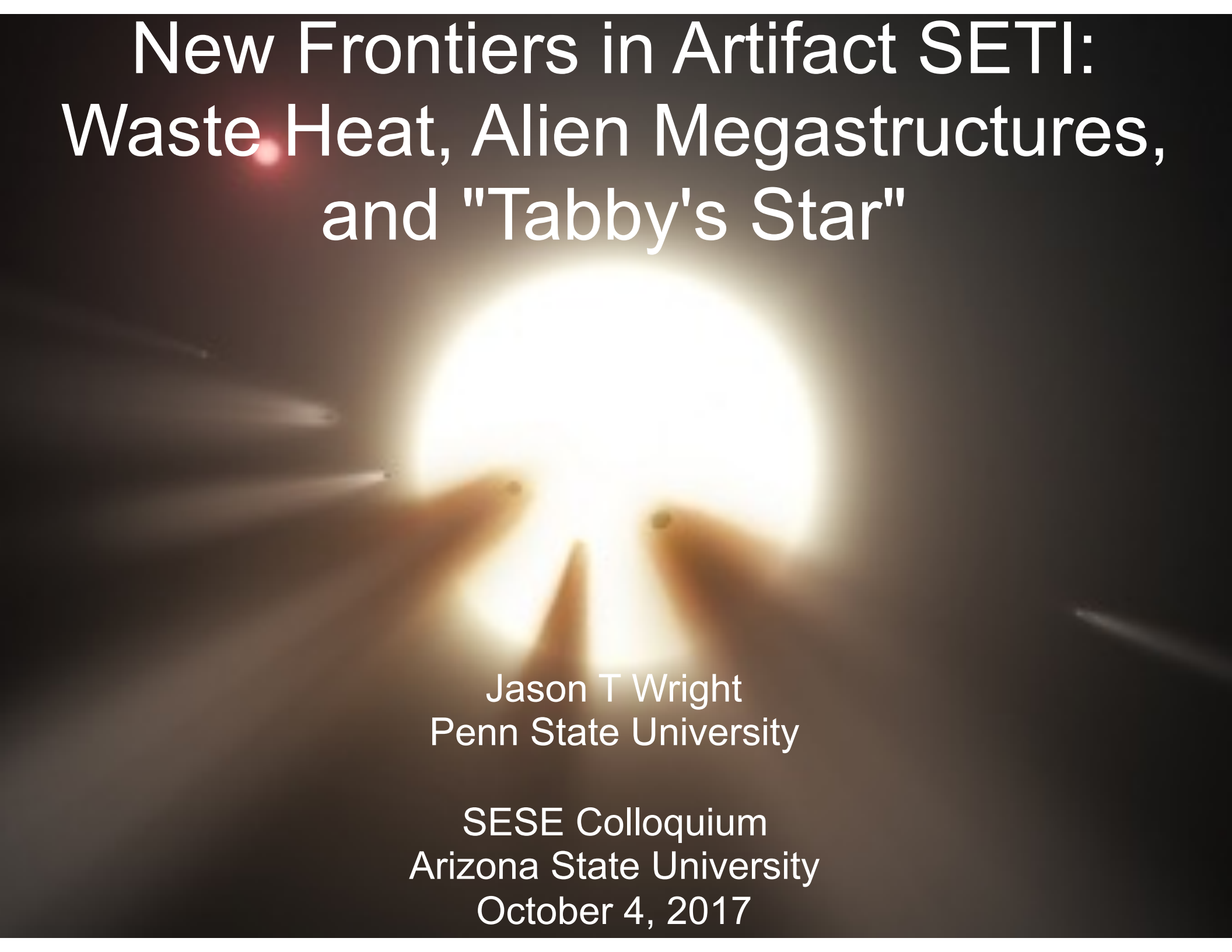
New Frontiers in Artifact SETI: Waste Heat, Alien Megastructures, and "Tabby's Star"



Jason T Wright
Penn State University

SESE Colloquium
Arizona State University
October 4, 2017

Contact (Warner Bros.)

What is SETI?

- “The Search for Extraterrestrial Intelligence”
- A field of study, like cosmology or planetary science
- SETI Institute:
  - Research center in Mountain View, California
  - Astrobiology, astronomy, planetary science, radio SETI
  - Runs the Allen Telescope Array
- Berkeley SETI Research Center:
  - Hosted by the UC Berkeley Astronomy Department
  - Mostly radio astronomy and exoplanet detection
  - Runs SETI@Home
  - Runs the $90M Breakthrough Listen Project

Communication SETI

The birth of Radio SETI

1960 — Cocconi & Morrison suggest interstellar communication via radio waves

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†
Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation; (2) origin of life; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

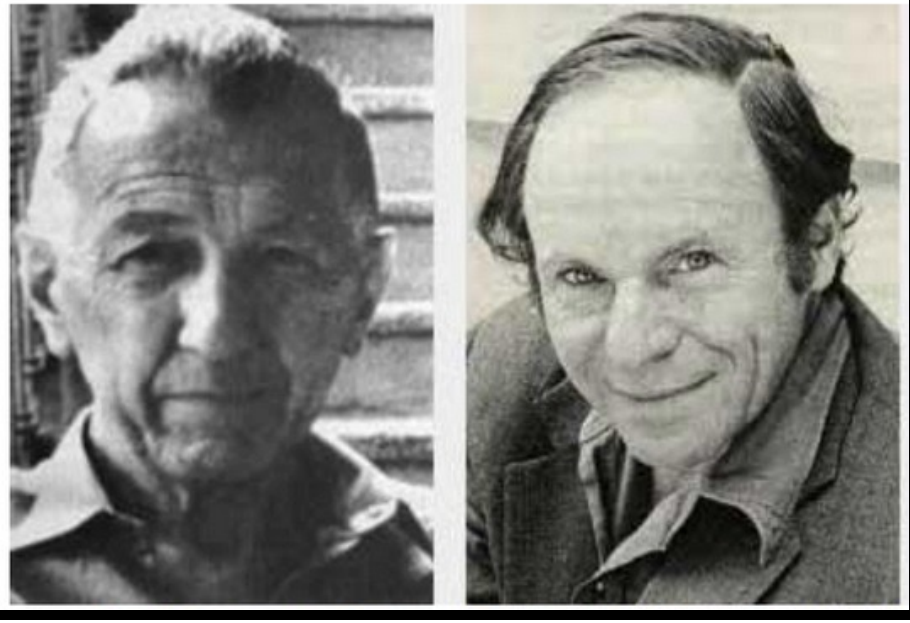
To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We
they established a channe
would one day become kn
look forward patiently to t
the Sun which would make
society has entered the c
What sort of a channel wou

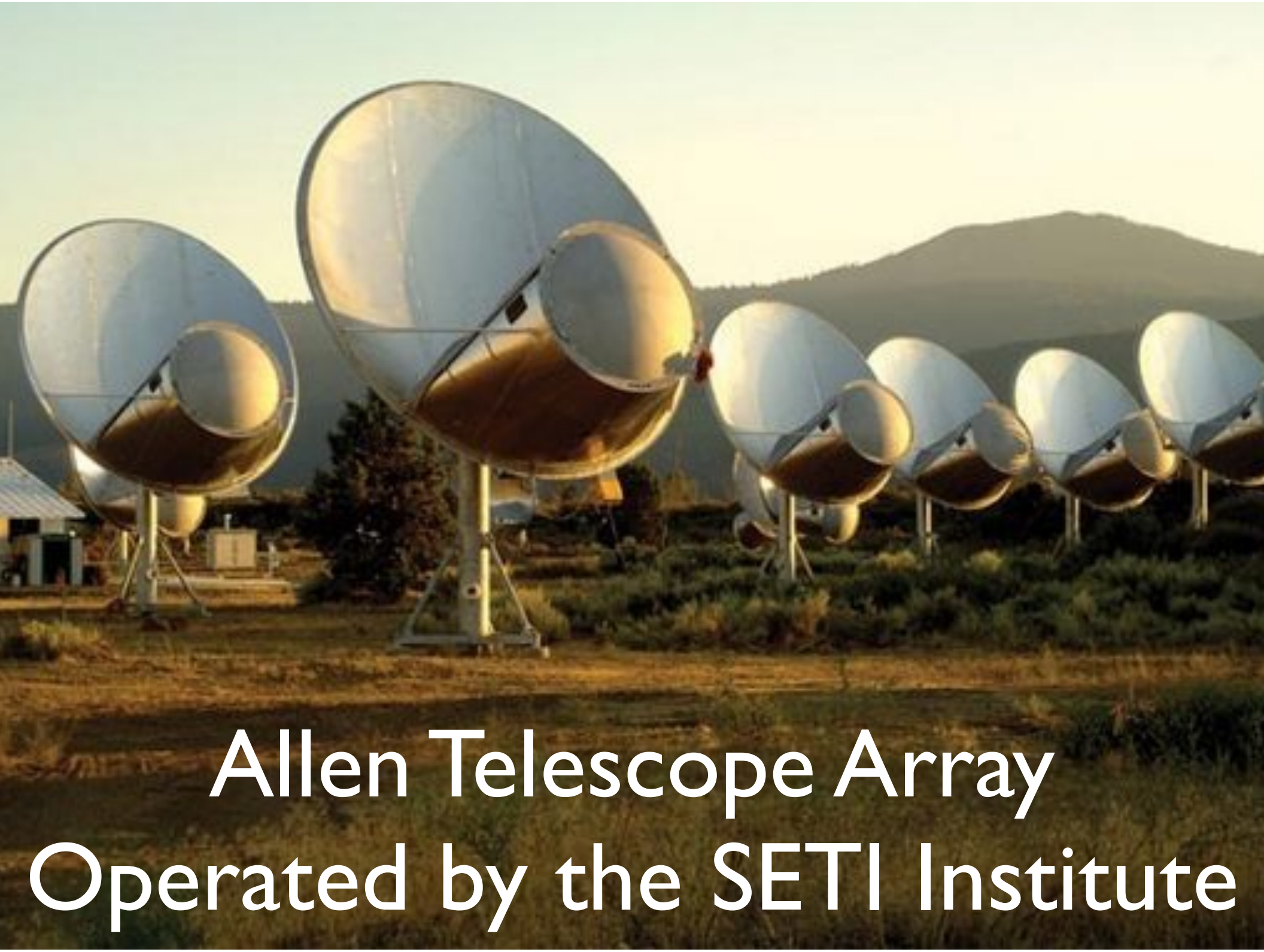
The Optimu

Interstellar communicat
plasma without dispersion i
is practical, so far as we
magnetic waves.

Since the object of thes
is to find a newly evolved
that the channel used w
minimum burden of freque

* Now on leave at CERN, Geneva.
† Now on leave at the Imperial College of Science and Technology, London, S.W.7.




Allen Telescope Array
Operated by the SETI Institute

Stephen Hawking and Yuri Milner Announce $100M Initiative to Seek ET

Milner, a tech start-up entrepreneur and philanthropist, is partnering with scientists around the world to search for life among the stars

By Lee Billings | July 20, 2015

SETI—the Search for Extraterrestrial Intelligence—has been one of the most


Green Bank Telescope
Operated by the
National Radio Astronomy Observatory

Artifact SETI

Dyson (1960)

Energy-hungry civilizations might use a significant fraction of available starlight to power themselves

Energy is never "used up", it is just converted to a lower temperature

If a civilization collects or generates energy, that energy must emerge at higher entropy (e.g. mid-infrared radiation)

This approach is general: practically any energy use by a civilization should give a star (or galaxy) a MIR excess

IRAS All-Sky map (1983)

The discovery of infrared cirrus complicated Dyson sphere searches.

Credit: NASA GSFC, LAMBDA

Carrigan reported on the Fermilab Dyson Sphere search with IRAS:
Lots of interesting red sources: carbon stars, AGBs, HII regions
No aliens

THE ASTROPHYSICAL JOURNAL, 698:2075–2086, 2009 June 20 doi:10.1088/0004-637X/698/2/2075

IRAS-BASED WHOLE-SKY UPPER LIMIT ON DYSON SPHERES

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Received 2008 November 17; accepted 2009 April 6; published 2009 June 8

ABSTRACT

A Dyson sphere is a hypothetical construct of a star purposely shrouded by a cloak of broken-up planetary material to better utilize all of the stellar energy. A clean Dyson sphere identification would give a significant signature for intelligence at work. A search for Dyson spheres has been carried out using the 250,000 source database of the *IRAS* infrared satellite which covered 96% of the sky. The search has used the Calgary database for the *IRAS* Low Resolution Spectrometer (LRS) to look for fits to blackbody spectra. Searches have been conducted for both pure (fully cloaked) and partial Dyson spheres in the blackbody temperature region $100\,\mathrm{K} \leqslant T \leqslant 600$ K. When other stellar signatures that resemble a Dyson sphere are used to eliminate sources that mimic Dyson spheres very few candidates remain and even these are ambiguous. Upper limits are presented for both pure and partial Dyson spheres. The sensitivity of the LRS was enough to find Dyson spheres with the luminosity of the Sun out to 300 pc, a reach that encompasses a million solar-type stars.

Key words: astrobiology – extraterrestrial intelligence – infrared: stars – stars: carbon – stars: fundamental parameters

Paper I: Motivation

The Astrophysical Journal, 792:26 (16pp), 2014 September 1 doi:10.1088/0004-637X/792/1/26

THE Ĝ INFRARED SEARCH FOR EXTRATERRESTRIAL CIVILIZATIONS WITH LARGE ENERGY SUPPLIES. I. BACKGROUND AND JUSTIFICATION

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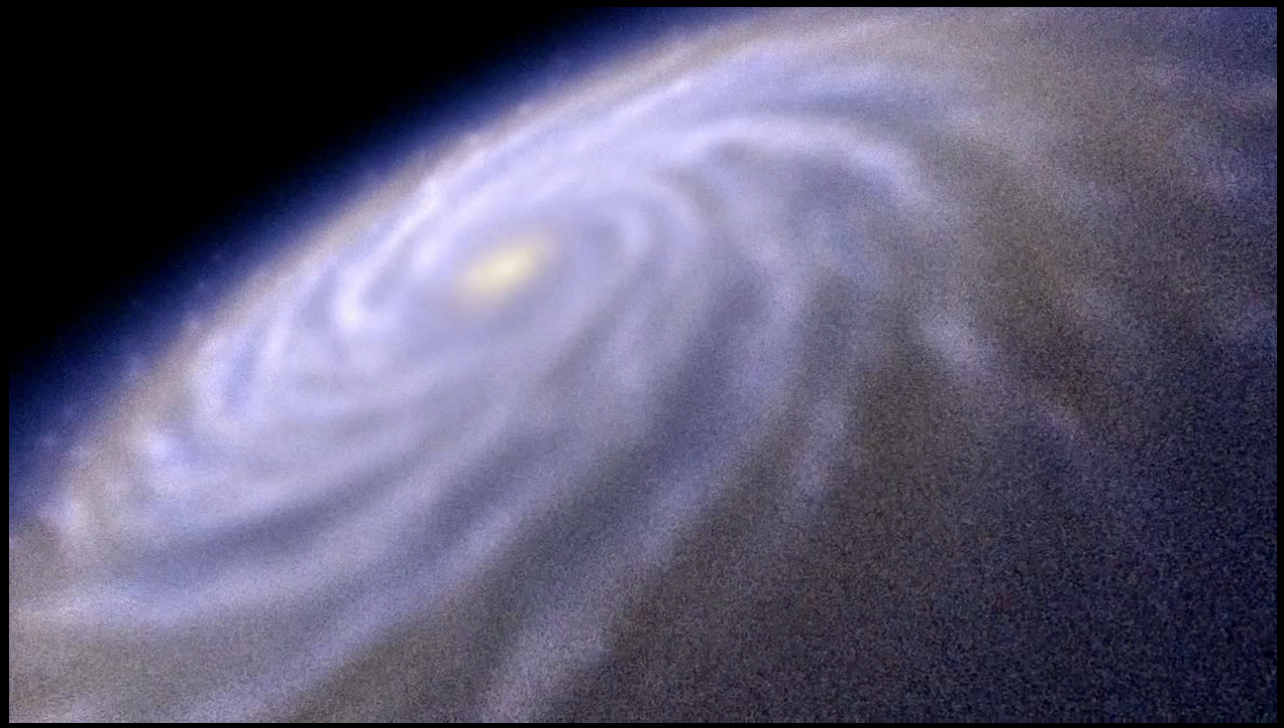
Received 2014 June 24; accepted 2014 June 24; published 2014 August 12

Maximum galaxy-filling time is a few galaxy rotations

- Even *slow* colony ships (30 km/s) that rarely launch (every 10,000 years) will lead to exponential growth of number of settlements
- Once expansion spans significant fraction of galaxy (~100 million years) galactic rotation, shear, and random stellar velocities will "mix" civilization into a galaxy in a few rotations

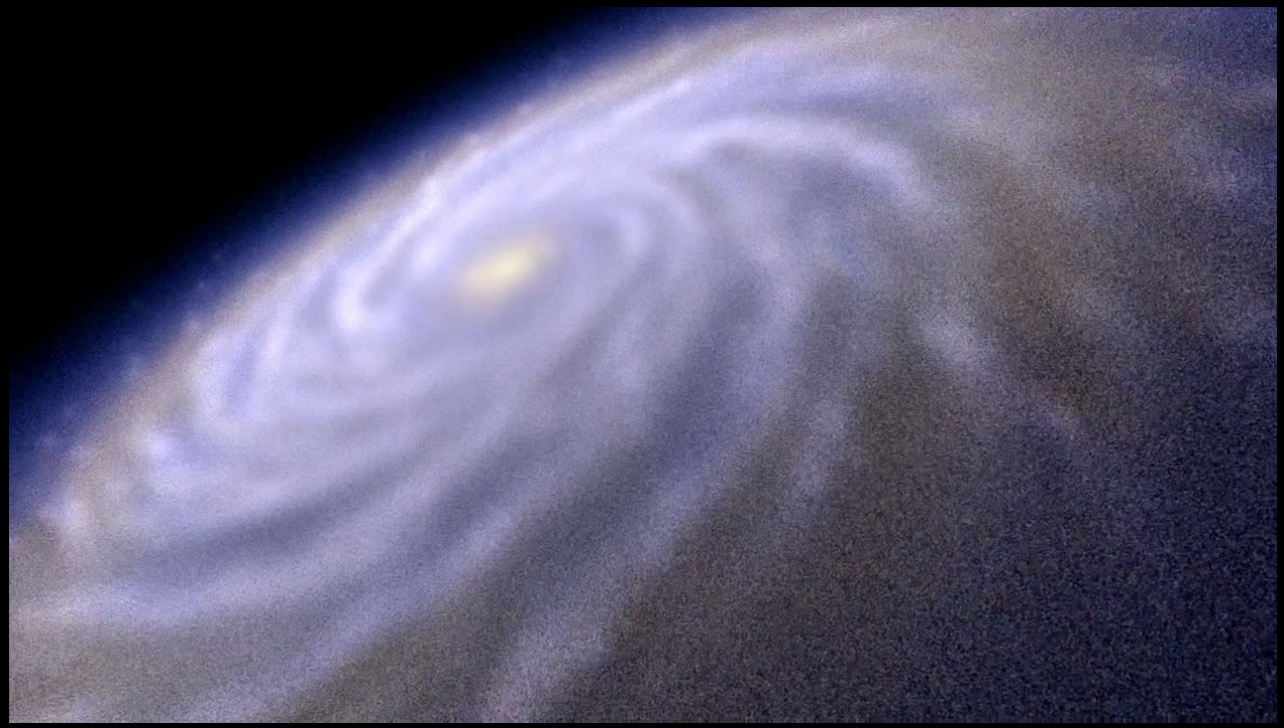


Credit: Elena D'Onghia, Mark Vogelsberger – Harvard FAS Supercomputer Odyssey, Thiago Ize – Scientific Computing and Imaging (SCI) Institute – University of Utah

Maximum galaxy-filling time is a few galaxy rotations

Corollaries:

- Nearly all galaxies should have zero spacefaring civilizations or be filled with them
- Either the Milky Way is filled with spacefaring ETIs or we are the first



Credit: Elena D'Onghia, Mark Vogelsberger – Harvard FAS Supercomputer Odyssey, Thiago Ize – Scientific Computing and Imaging (SCI) Institute – University of Utah

Galaxy-spanning civilizations: all or nothing?

This argument formed the basis of Michael Hart's argument that we must be alone in the MW, because they have not already colonized the Solar System

...but unless spacefaring life is unique to Earth...

If Hart is correct:
Other galaxies should be filled with advanced civilizations.
A search for K3's will eventually succeed

If Hart is incorrect:
The Milky Way should be filled with K2's.
A search for K2's will eventually succeed

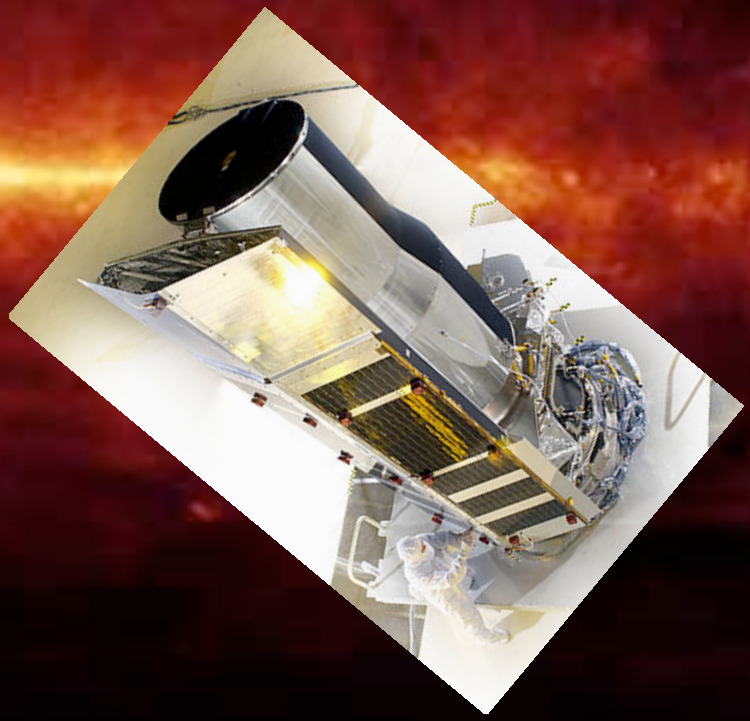
We should test Hart's thesis by pursuing *both* routes

Communication SETI

1964 —Kardashev classifies extraterrestrial civilizations by their total power supply (i.e. potential for transmission power)

Type I: Can harness a planet's entire energy supply (K1)
Type II: Can harness a star's entire output (K2)
Type III: Can harness an entire galaxy's output (K3)

Ĝ: Glimpsing Heat from Alien Technologies



Paper II: Strategy

The Astrophysical Journal, 792:27 (12pp), 2014 September 1 doi:10.1088/0004-637X/792/1/27

THE Ĝ INFRARED SEARCH FOR EXTRATERRESTRIAL CIVILIZATIONS WITH LARGE ENERGY SUPPLIES. II. FRAMEWORK, STRATEGY, AND FIRST RESULT

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Received 2013 October 21; accepted 2014 June 23; published 2014 August 12

Search for galaxies with 75-95% obscuration

Placing a Limit on Star-Fed Kardashev Type III Civilizations

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A civilization that uses the bulk of a galaxy's starlight for it's own power requirements is a remarkably obvious entity. This is because galaxies naturally obey scaling laws between the surface brightness, the radius of the stellar distribution, and the thermal velocities of the stars. The latter two quantities reflect the mass and its resulting gravitational potential, while the former is the result of this same mass emitting light as stars. If a civilization takes that light for it's own purposes, the scaling laws are broken, and the galaxy becomes an outlier on plots showing the scaling laws. For a sample of 137 galaxies, no such outliers are found.

Dynamical masses are compared to luminosities to find high M/L galaxies

WISE is very sensitive to waste heat

THE DISCOVERY OF Y DWARFS USING DATA FROM THE WIDE-FIELD INFRARED SURVEY EXPLORER (WISE)

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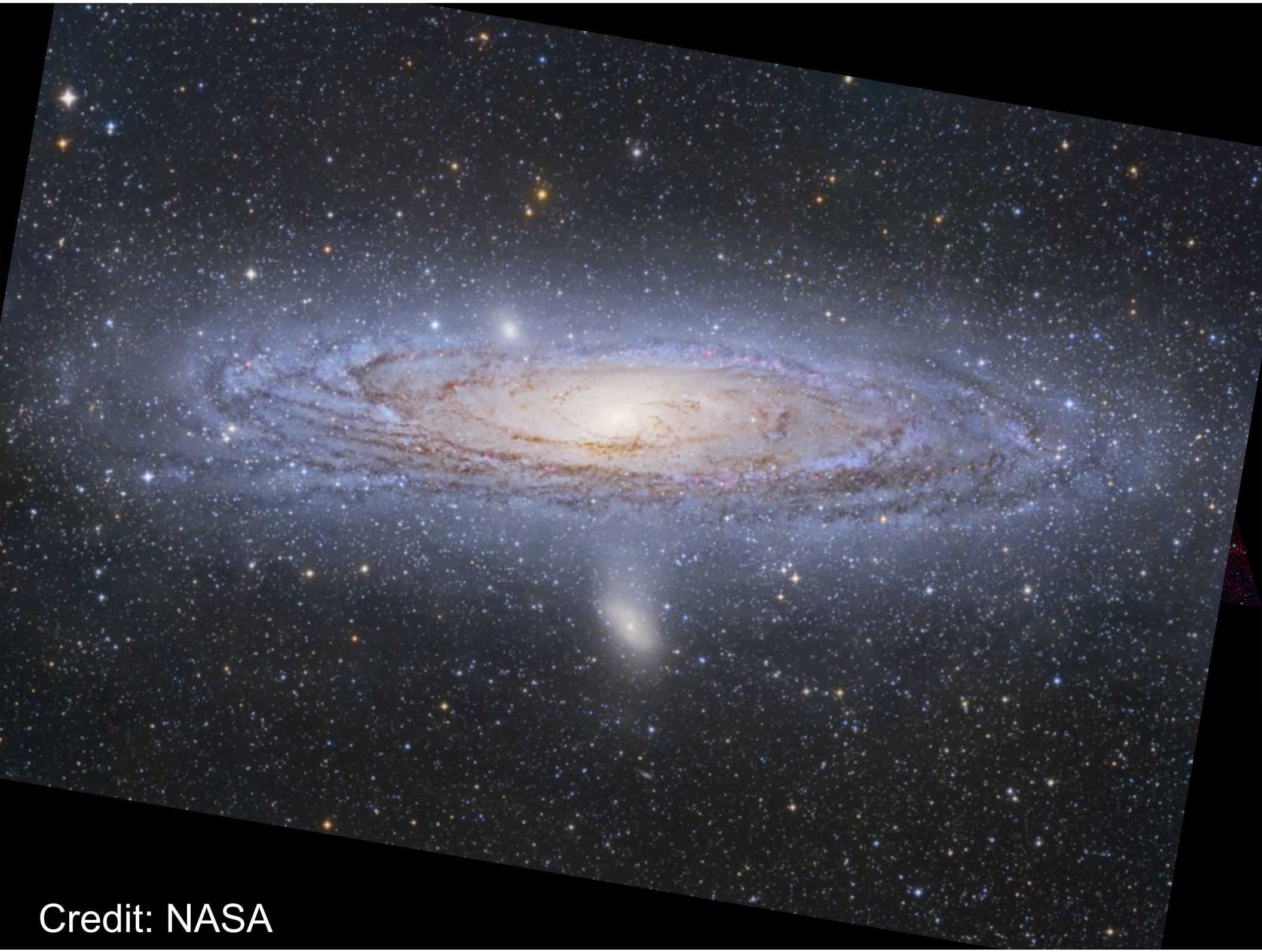
Draft version August 24, 2011

ABSTRACT

We present the discovery of seven ultracool brown dwarfs identified with the Wide-field Infrared Survey Explorer (WISE). Near-infrared spectroscopy reveals deep absorption bands of H_2O and CH_4 that indicate all seven of the brown dwarfs have spectral types later than UGPS J072227.51−054031.2, the latest type T dwarf currently known. The spectrum of WISEP J182831.08+265037.8 is distinct in that the heights of the J- and H-band peaks are approximately equal in units of f_λ, so we identify it as the archetypal member of the Y spectral class. The spectra of at least two of the other brown dwarfs exhibit absorption on the blue wing of the H-band peak that we tentatively ascribe to NH_3. These spectral morphological changes provide a clear transition between the T dwarfs and the Y dwarfs. In order to produce a smooth near-infrared spectral sequence across the T/Y dwarf transition, we have reclassified UGPS 0722−05 as the T9 spectral standard and tentatively assign WISEP J173835.52+273258.9 as the Y0 spectral standard. In total, six of the seven new brown dwarfs are classified as Y dwarfs: four are classified as Y0, one is classified as Y0 (pec?), and WISEP J1828+2650 is classified as >Y0. We have also compared the spectra to the model atmospheres of Marley and Saumon and infer that the brown dwarfs have effective temperatures ranging from 300 K to 500 K, making them the coldest spectroscopically confirmed brown dwarfs known to date.


Credit: NASA


Roger Griffith (PSU)
WISE (NASA)

Results of our search

DRAFT VERSION APRIL 13, 2015
Preprint typeset using LaTeX style emulateapj v. 08/22/09

THE Ĝ INFRARED SEARCH FOR EXTRATERRESTRIAL CIVILIZATIONS WITH LARGE ENERGY SUPPLIES. III. THE REDDEST EXTENDED SOURCES IN *WISE*

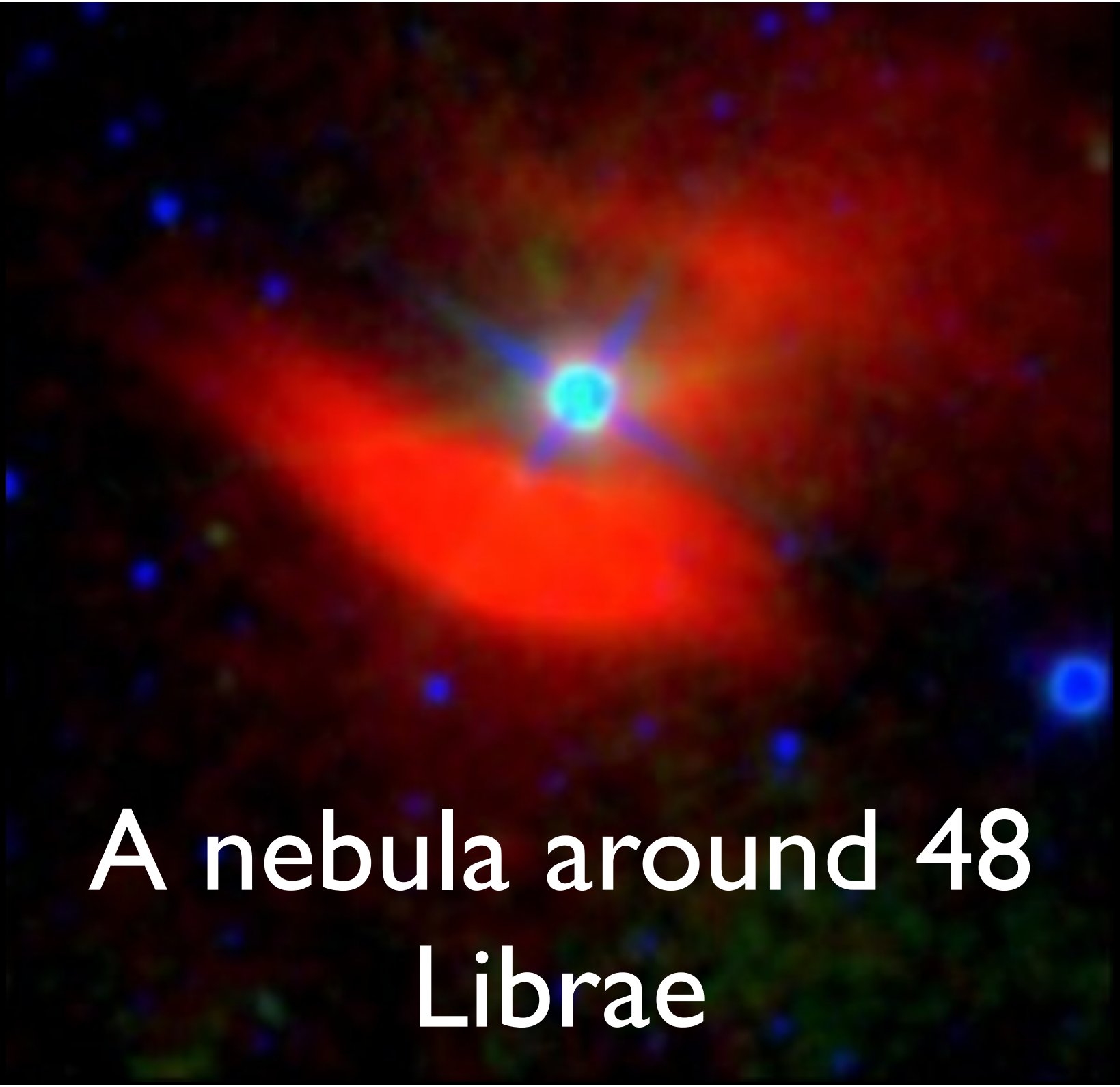
ROGER L. GRIFFITH[1,2], JASON T. WRIGHT[1,2], JESSICA MALDONADO[3], MATTHEW S. POVICH[3], STEINN SIGURÐSSON[1,2], BRENDAN MULLAN[4]

Draft version April 13, 2015

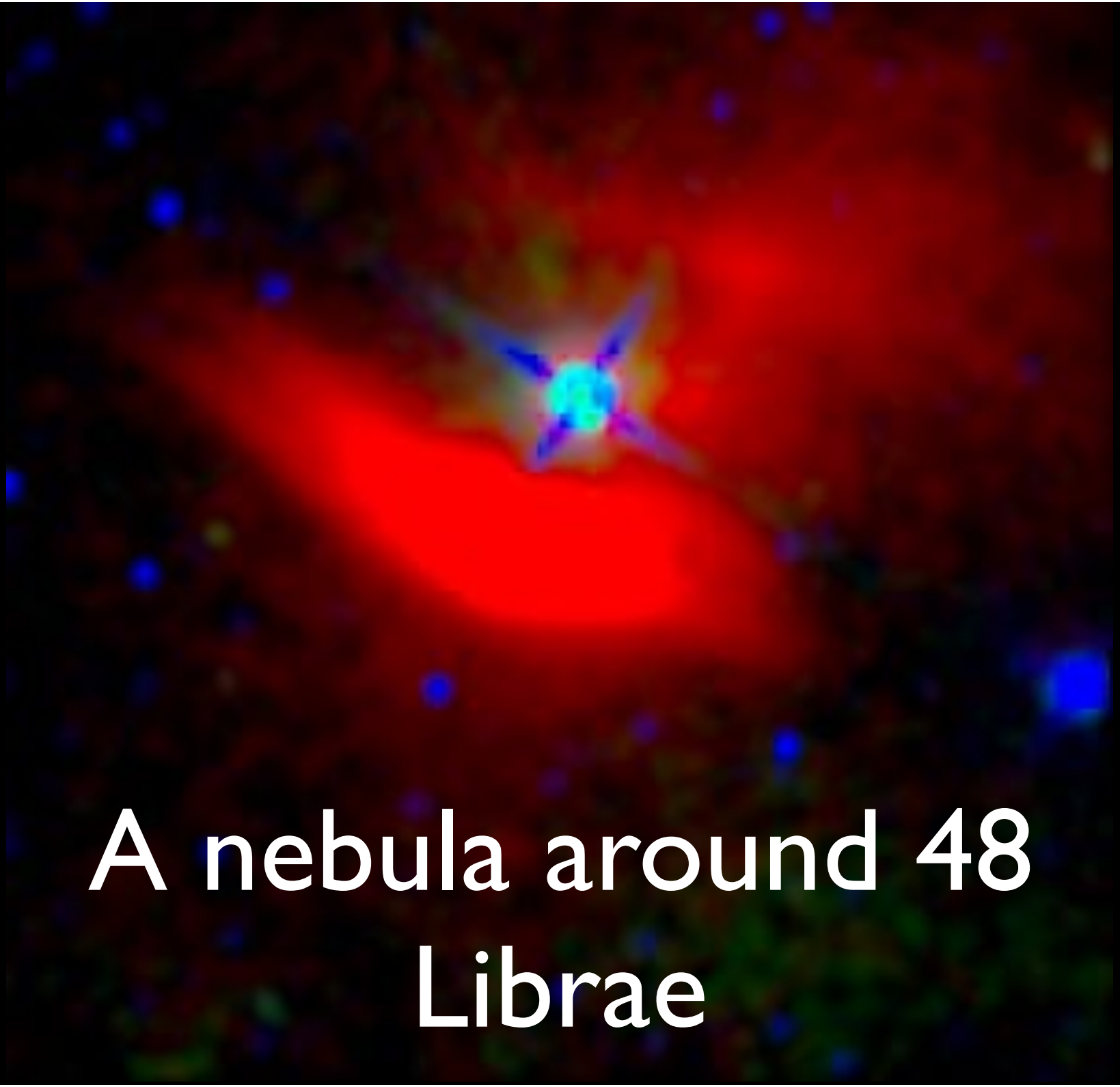
- MIR-bright K3's are very rare among ~100,000 resolved galaxies in WISE catalog
- Only 50 candidates using > 50% of starlight, (including Arp 220) all probably starbursts
- This result is newly enabled by *WISE*

Referee comment on Davis (1955) (First upper limit on Solar neutrino production)

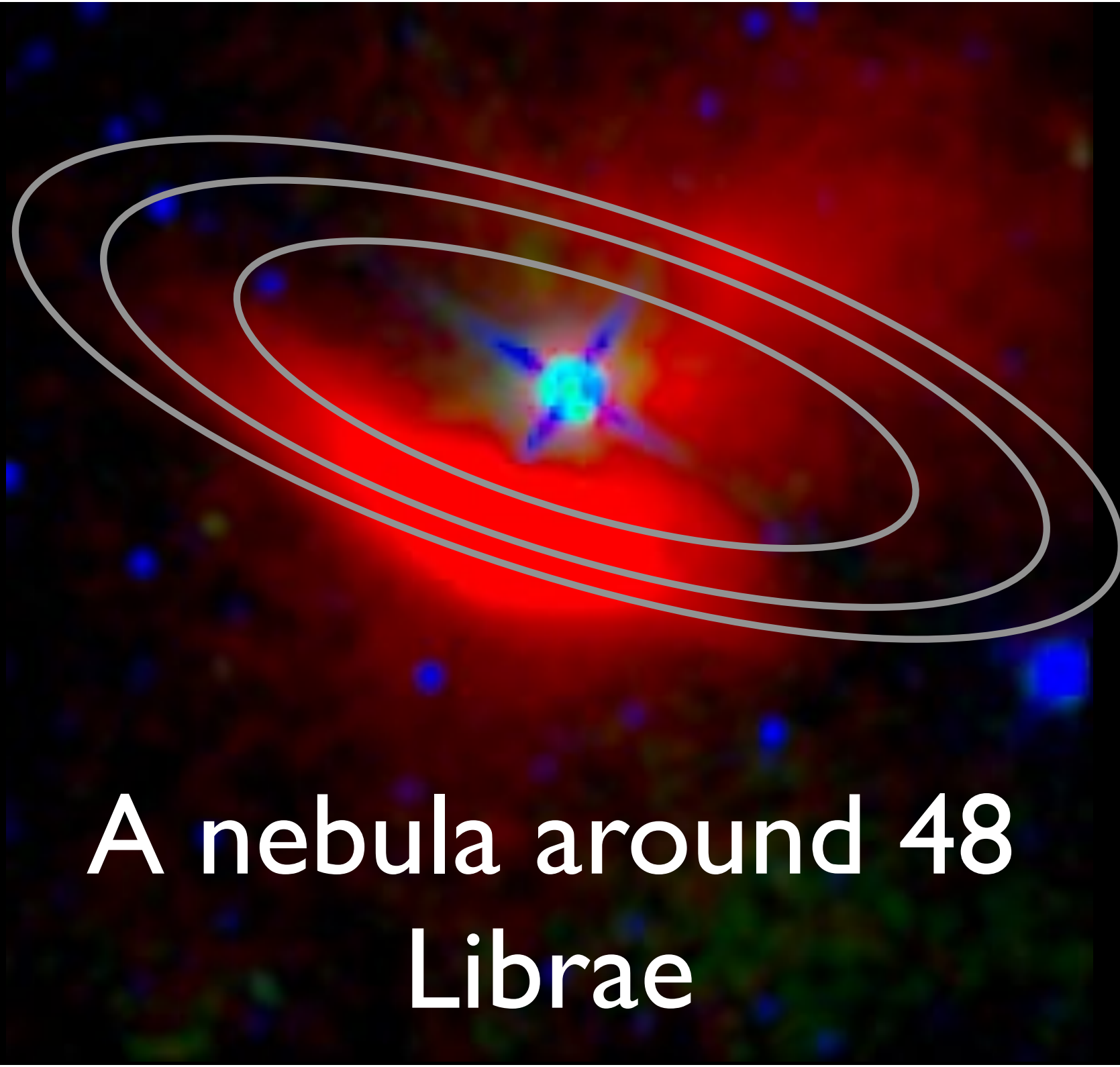
Any experiment such as this, which does not have the requisite sensitivity, really has no bearing on the question of the existence of neutrinos. To illustrate my point, one would not write a scientific paper describing an experiment in which an experimenter stood on a mountain and reached for the moon, and concluded that the moon was more than eight feet from the top of the mountain.



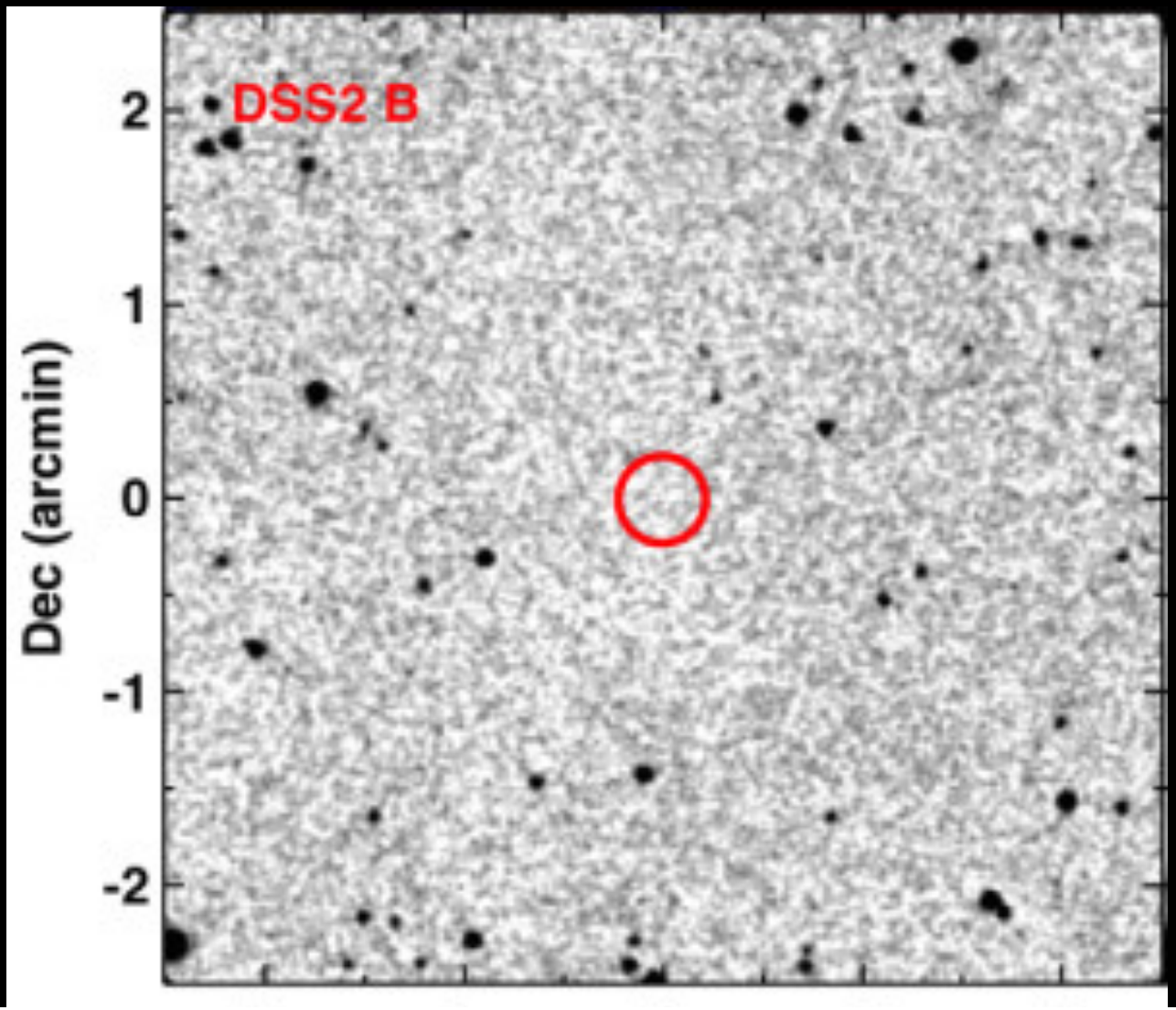
A nebula around 48 Librae



A nebula around 48 Librae

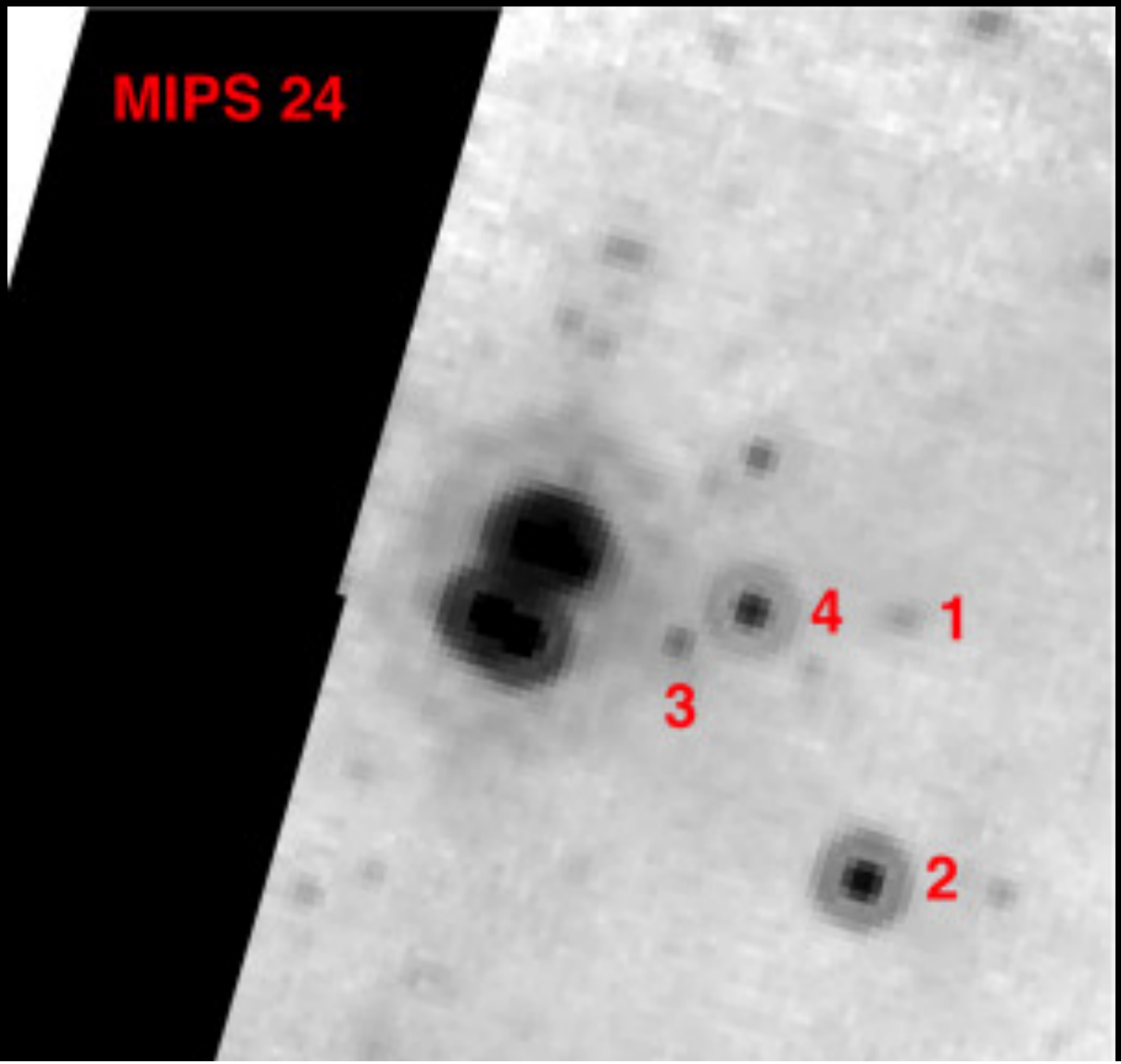

A nebula around 48
Librae

Mysterious optically dark MIR sources



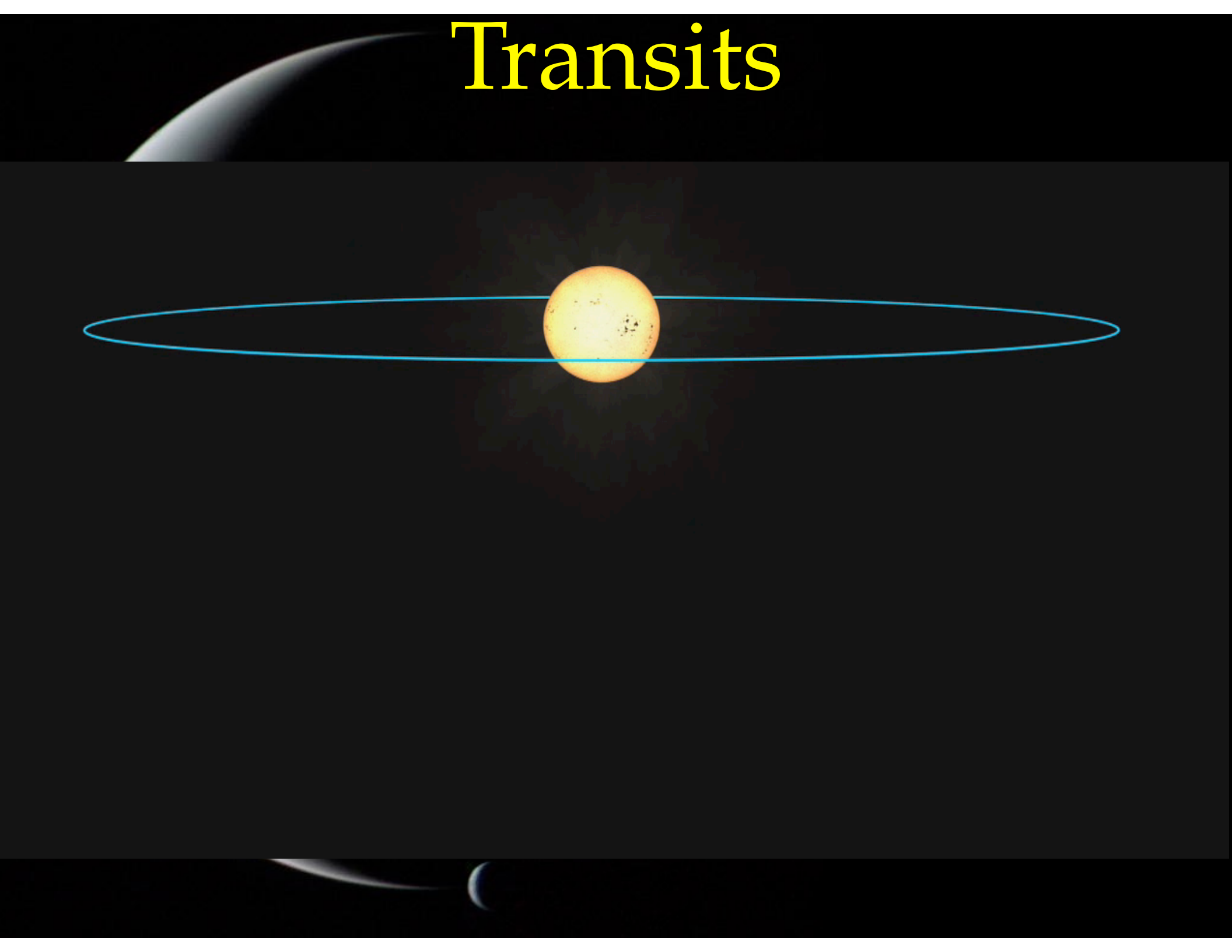
Mysterious optically dark MIR sources

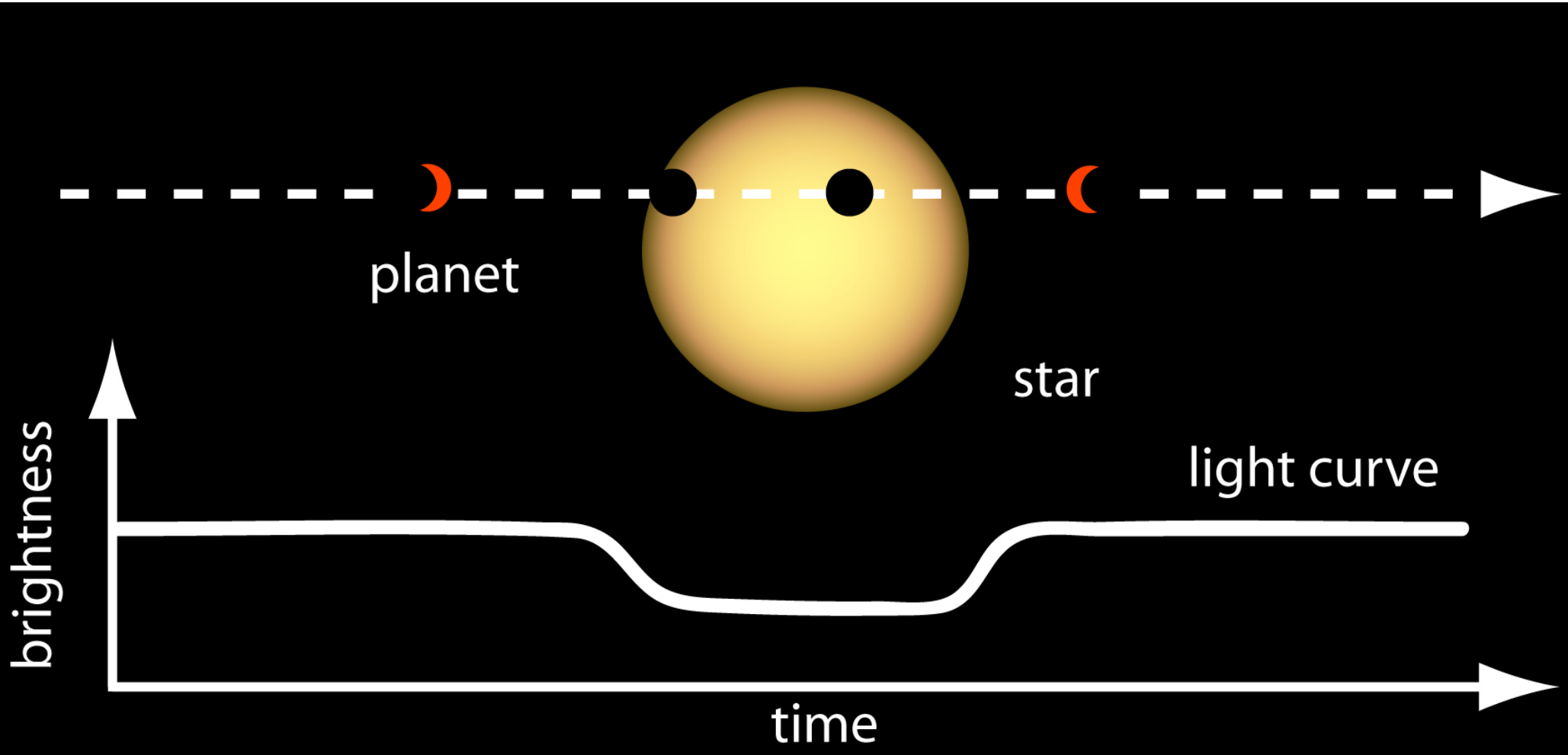
Mysterious optically dark MIR sources



Artifact SETI produces interesting astronomy even with a null result (for aliens)

Transits





Kepler searched >100,000 stars for transits

Megastructure aspect
vs.
Planet aspect

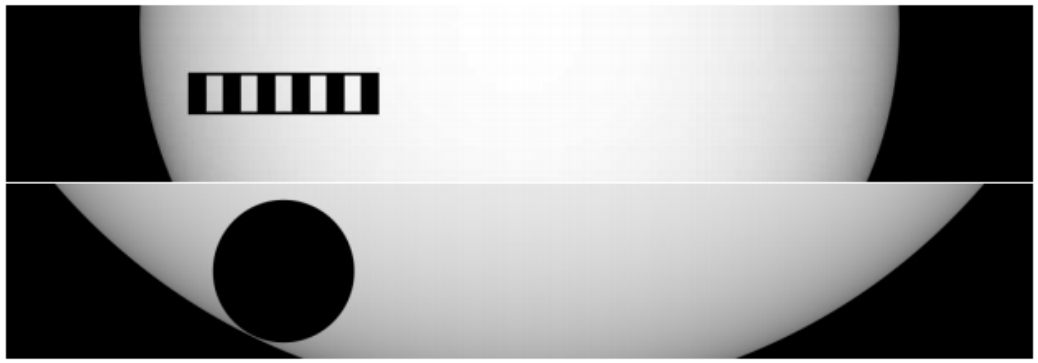
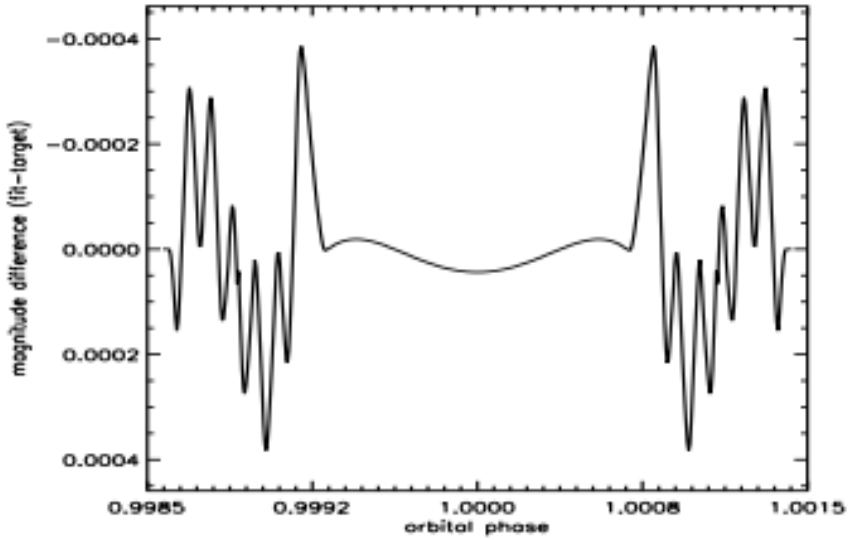


Fig. 6.— Transiting objects: A louver-like 6-screen object (upper strip) and the best-fit spherical planet and star (lower strip, same scale as upper strip). The fit gives a transiting sphere of 2.08 $R_{Jupiter}$ at $b = 0.79$ and a star with $u_1 + u_2 = 0.57$, $u_1 - u_2 = 0$ and $R_\star = 1.85\ R_\odot$. $u_1 - u_2$ set to zero, and a non-significant radius increase of 0.6%. Fitting object oblateness f, either with zero or 90° obliquity to maintain lightcurve symmetry, converges to solutions not significantly different from the case $f = 0$.

Difference between planet light curve and megastructure light curve



Arnold (2005)

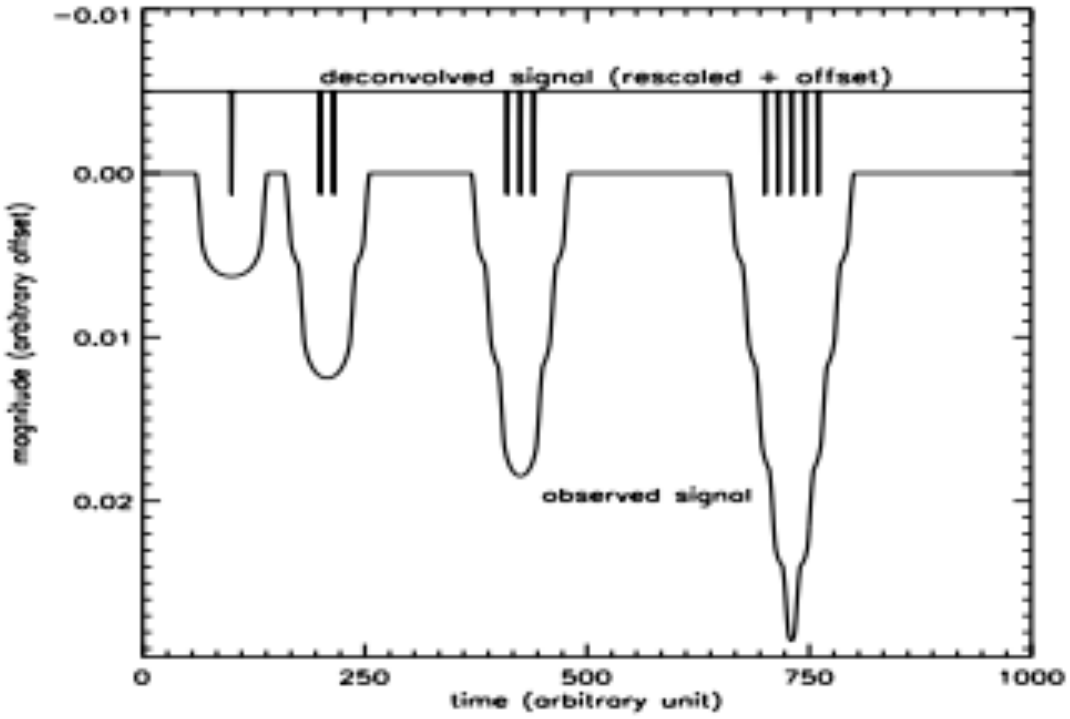


Fig. 8.— Example of multiple transits generated by eleven objects, grouped in prime numbers (1, 2, 3 and 5 objects). Note that the time between transits also increases as a prime numbers series. Each object has a Saturn-like cross-section and transits the star HD209458 with an impact parameter $b = 0.5$. Here, due to objects size and space between them, only 5 objects can be simultaneously in front of the star for a given observer. The first transit of a single object allows to deconvolve the transits of multiple objects (upper curve).

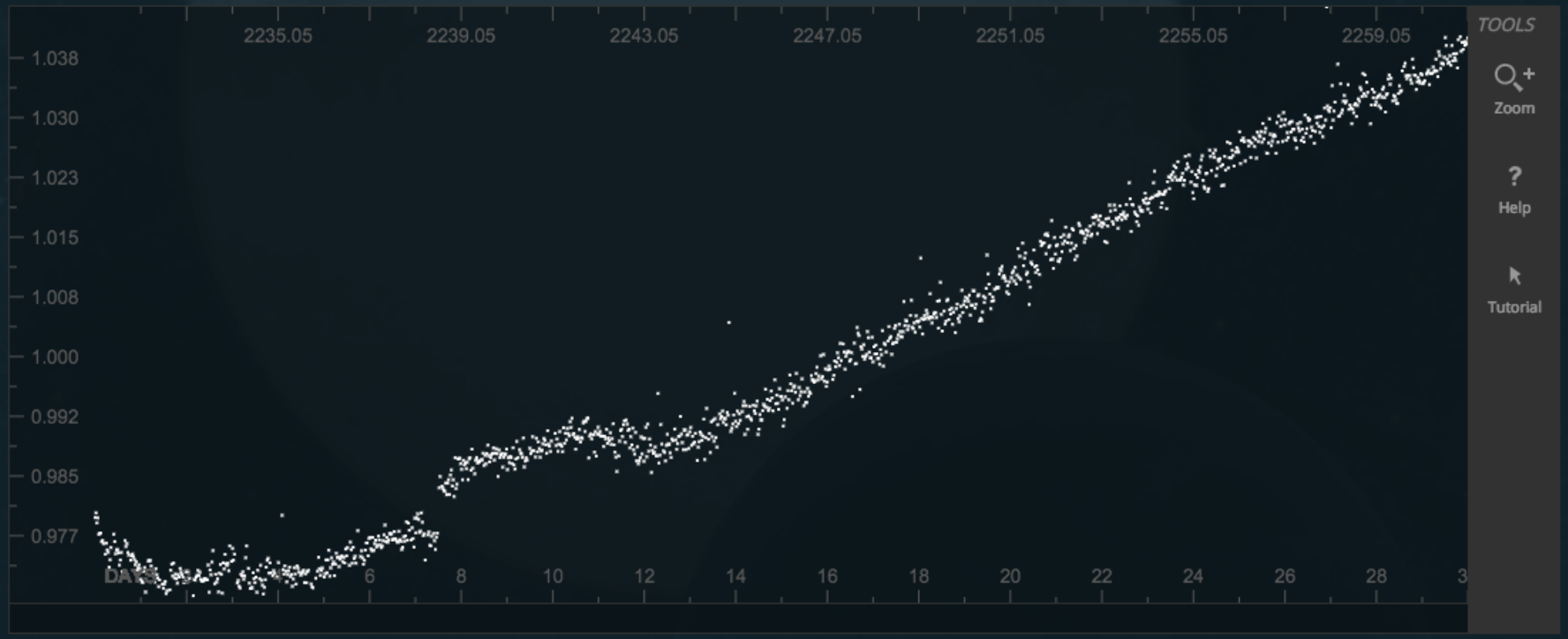
Arnold also predicted *Kepler* might discover variable-depth "beacons"

But *Kepler* didn't see any of those…

…right?!?

Do you see a transit?

If so, highlight it on the light curve below!



Star Information

Magnitude 15.224 Type N/A Temp N/A Radius N/A

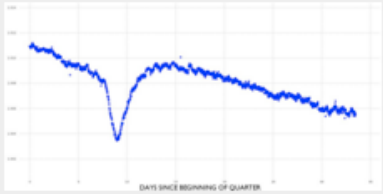
No Transits

The Zooniverse is a collection of web-based citizen science projects that use the efforts of volunteers to help researchers deal with the flood of data that confronts them.

KID 8462852 - Quarter 8, Quarter 16 and Quarter 17

Started by cappella

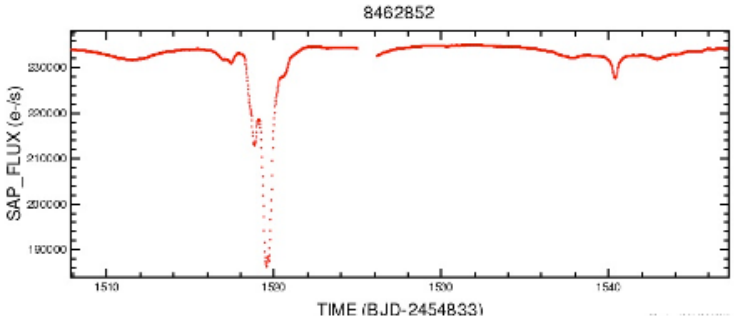
Sign in to watch



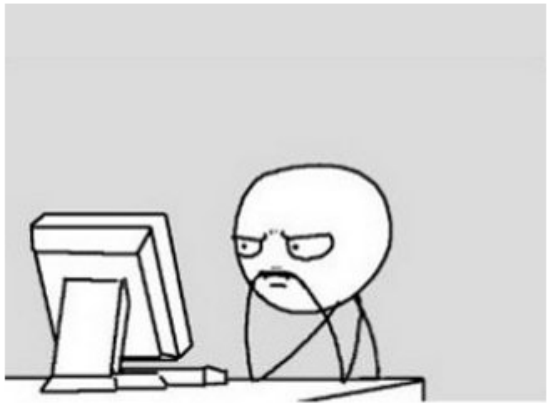
APH10115382

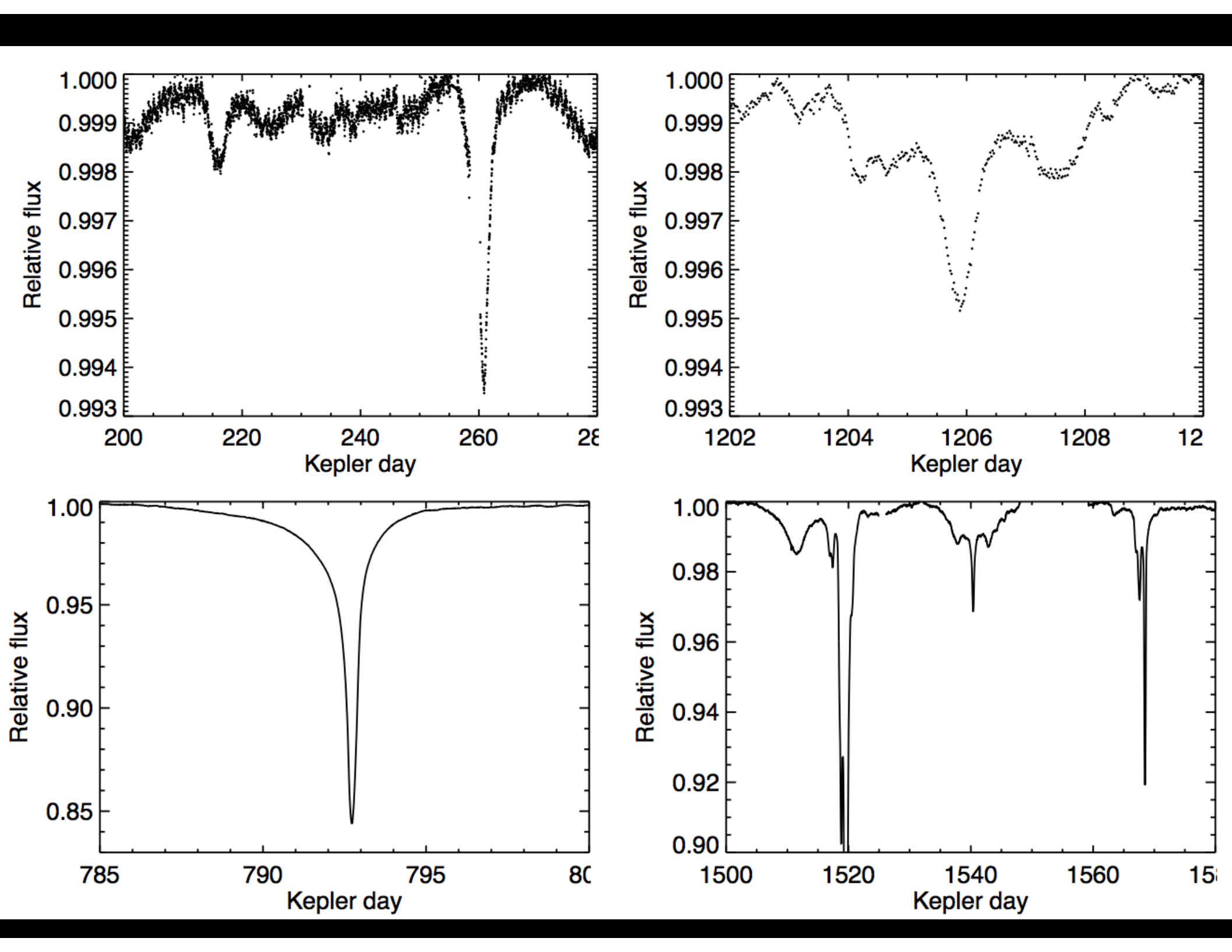
nighthawk_black *over 2 years ago*

Indeed strange, the eclipse profile in Q16 looks largely the same in SAP_FLUX:



I can't quite reconcile the smaller dips at 140 (Q1), 792 (Q13) and 1540 (Q16) as secondaries to make this an eccentric EB. Nothing to match smaller dip 1540 is found near 813, unless it occurred early and was lost in the data break from 802-808...




1.000
0.999
0.998
0.997
0.996
0.995
0.994
0.993
Relative flux
200
220
240
260
Kepler day
1202
1204
1206
1208
1.00
0.95
0.90
0.85
785
790
795
1.00
0.98
0.96
0.94
0.92
0.90
1500
1520
1540
1560

Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 2 September 2015 (MN LATEX s

Planet Hunters X. KIC 8462852 – Where's the flux? *†

T. S. Boyajian[2], D. M. LaCourse[3], S. A. Rappaport[1], W. M. J. Best[13], F. Ciesla[20], B. Csák[14], T. J. Dupuy[22], D. Fabrycky[4], D. A. Fischer[2], D. Gandolfi[5,6], S. Goodman[3], G. Handler[11], K. Heng[19], A. Hoekstra[3], K. J. Jek[3], G. Kennedy[12], H. Korhonen[8,9], J. Kovács[14], T. Kozakis[21], M. C. Liu[13], A. Moor[7], K. Olah[7], P. Saha[17,18], J. Schmitt[2], Gy. Szabo[14,15,16], R. Szabo[7], K. Vida[7], J. Wang[2], M. Wyatt[12],

ABSTRACT

Over the duration of the *Kepler* mission, KIC 8462852 was observed to undergo irregularly shaped, aperiodic dips in flux down to below the 20% level. The dipping activity can last for between 5 and 80 days. We characterize the object with high-resolution spectroscopy, spectral energy distribution fitting, and Fourier analyses of the *Kepler* light curve. We determine that KIC 8462852 is a main-sequence F3 V/IV star, with a rotation period $\sim$ 0.88 d, that exhibits no significant IR excess. In this paper, we describe various scenarios to explain the mysterious events in the *Kepler* light curve, most of which have problems explaining the data in hand. By considering the observational constraints on dust clumps orbiting a normal main-sequence star, we conclude that the scenario most consistent with the data in hand is the passage of a family of exocomet fragments, all of which are associated with a single previous breakup event. We discuss the necessity of future observations to help interpret the system.

THE ASTROPHYSICAL JOURNAL
LETTERS

KIC 8462852: THE INFRARED FLUX

Massimo Marengo[1], Alan Hulsebus[1], and Sarah Willis[2,3]

Published 2015 November 19 • The Astrophysical Journal Letters, Volume 814, Number 1

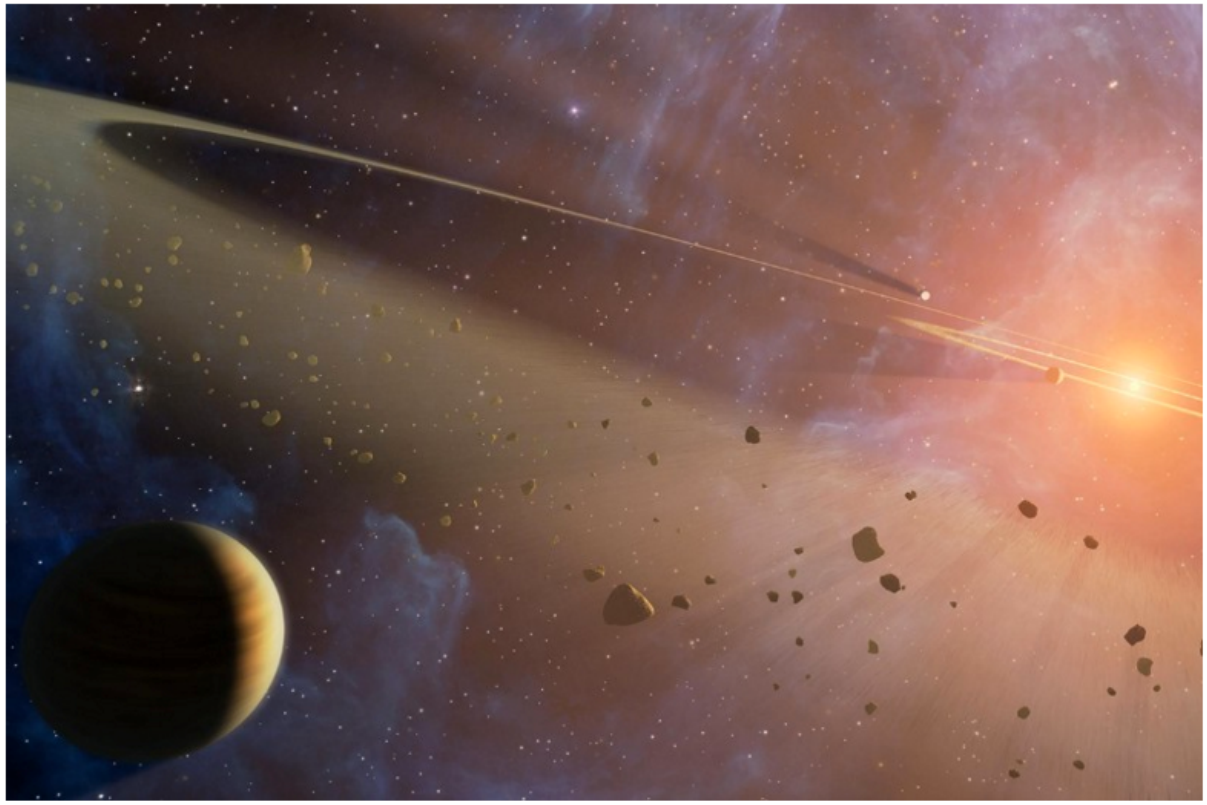
Abstract

We analyzed the warm *Spitzer*/IRAC data of KIC 8462852. We found no evidence of infrared excess at 3.6 μm and a small excess of 0.43 ± 0.18 mJy at 4.5 μm below the 3σ threshold necessary to claim a detection. The lack of strong infrared excess 2 years after the events responsible for the unusual light curve observed by *Kepler* further disfavors the scenarios involving a catastrophic collision in a KIC 8462852 asteroid belt, a giant impact disrupting a planet in the system or a population of dust-enshrouded planetesimals. The scenario invoking the fragmentation of a family of comets on a highly elliptical orbit is instead consistent with the lack of strong infrared excess found by our analysis.

New Scientist

DAILY NEWS 18 September 2015

Citizen scientists catch cloud of comets orbiting distant star



(Image: NASA)

A crowdsourced group of planetary detectives may have spotted a massive cloud of comets orbiting a distant star.

NASA's exoplanet-hunting Kepler space telescope spent four years carefully watching the same patch of sky, looking for any stars that dipped in brightness. These dips happen when an orbiting planet crosses in front of the star, and measuring their size and timing provides astronomers with data about the planet.

Most Kepler data is processed automatically by algorithms looking for repeating patterns, but a website called Planet Hunters lets citizen scientists inspect the data by eye in an effort to spot anything unusual.

Dr. Tabetha Boyajian
Yale University

Dr. Tabetha Boyajian
Yale University

Dr. Andrew Siemion
Berkeley SETI
Research Center

Ross Andersen
@andersen

Following

Last night I had dinner with the director of Berkeley's SETI Research Center. We had a fun talk: theatln.tc/1LZqhDx

The Atlantic

The Return of SETI

The Search for Extraterrestrial Intelligence is newly flush with cash —and ambition.

View on web

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2	4

10:57 AM - 29 Sep 2015

The Most Mysterious Star in Our Galaxy

Astronomers have spotted a strange mess of objects whirling around a distant star. Scientists who search for extraterrestrial civilizations are scrambling to get a closer look.

ROSS ANDERSEN | OCT 13, 2015 | SCIENCE

The light pattern suggests there is a big mess of matter circling the star, in tight formation. That would be expected if the star were young. When our solar system first formed, four and a half billion years ago, a messy disk of dust and debris surrounded the sun, before gravity organized it into planets, and rings of rock and ice.

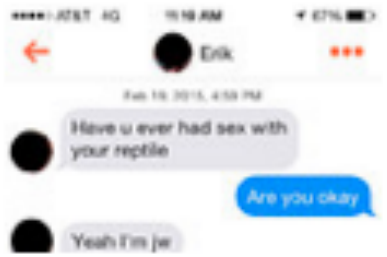
But this unusual star isn't young. If it were young, it would be surrounded by dust that would give off extra infrared light. There doesn't seem to be an excess of infrared light around this star.

It appears to be mature.

And yet, there is this mess of objects circling it. A mess big enough to block a substantial number of photons that would have otherwise beamed into the tube of the Kepler Space Telescope. If blind nature deposited this mess around the star, it must have done so recently. Otherwise, it would be gone by now. Gravity would have consolidated it, or it would have been sucked into the star and swallowed, after a brief fiery splash.

"It looked like the kind of thing you might expect an alien civilization to build."

Boyajian, the Yale Postdoc who oversees Planet Hunters, recently published a paper describing the star's bizarre light pattern. Several of the citizen scientists are named as co-authors. The paper explores a number of scenarios that might explain the pattern—instrument defects; the shrapnel from an asteroid belt pileup; an impact of planetary scale, like the one that created our moon.



Have Scientists Really Found An "Alien Megastructure" Around A Distant Star?

The leading theory is that the weird light patterns around the star can be explained by a family of comets, but extraterrestrial activity still hasn't been ruled out.

posted on Oct. 15, 2015, at 7:27 p.m.

Alex Kasprak
BuzzFeed Staff

Kelly Oakes
BuzzFeed Staff, UK

The Late Show with Stephen Colbert
10/29/2015 (Seth MacFarlane, Neil DeGrasse Tyson)

SCIENCE SPACE

Why it's so hard for astronomers to discuss the possibility of alien life

The internet went crazy this week over a strange star observed by NASA's Kepler spacecraft

By Loren Grush on October 16, 2015 12:10 pm @lorengrush

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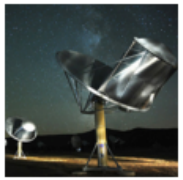
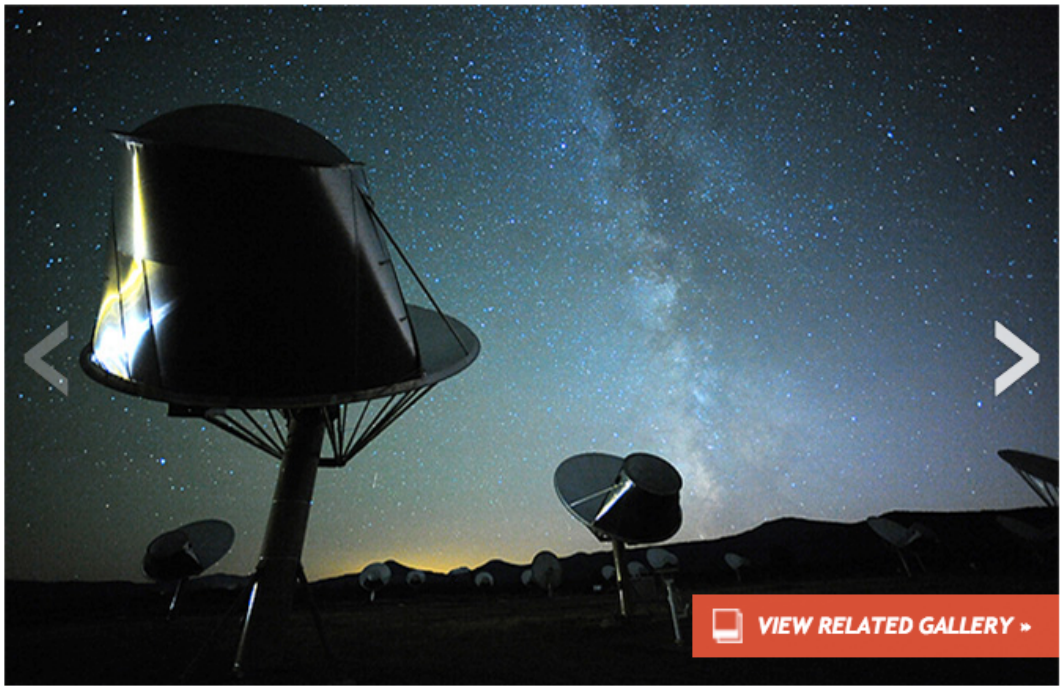
Water On Mars: Everything You Need To Know

Has Kepler Discovered An Alien Megastructure?

Is Stephen Hawking Right About Hostile Aliens?

ALIEN LIFE & EXOPLANETS

Alien Megastructure? SETI Spies No Intelligent Signals

NOV 6, 2015 03:05 PM ET // BY IAN O'NEILL



The SETI Institute's Allen Telescope Array (ATA) was recently used to seek out artificial signals from Tabby's Star. Alas, no signal was detected.

SETI INSTITUTE

After all the public excitement surrounding the star KIC 8462852 **and its weird transit signal as spotted by NASA's Kepler Space Telescope**, the SETI Institute decided to expedite plans to point a powerful radio antenna at the nearby star in the hope of detecting *any* artificial transmissions emanating from that location. Sadly (or not, depending on how you view the discovery of an intelligent alien civilization living in our cosmic backyard), the first pass drew a blank.

DNEWSvideo

Seeker Daily: What It's Like Living In Dubai

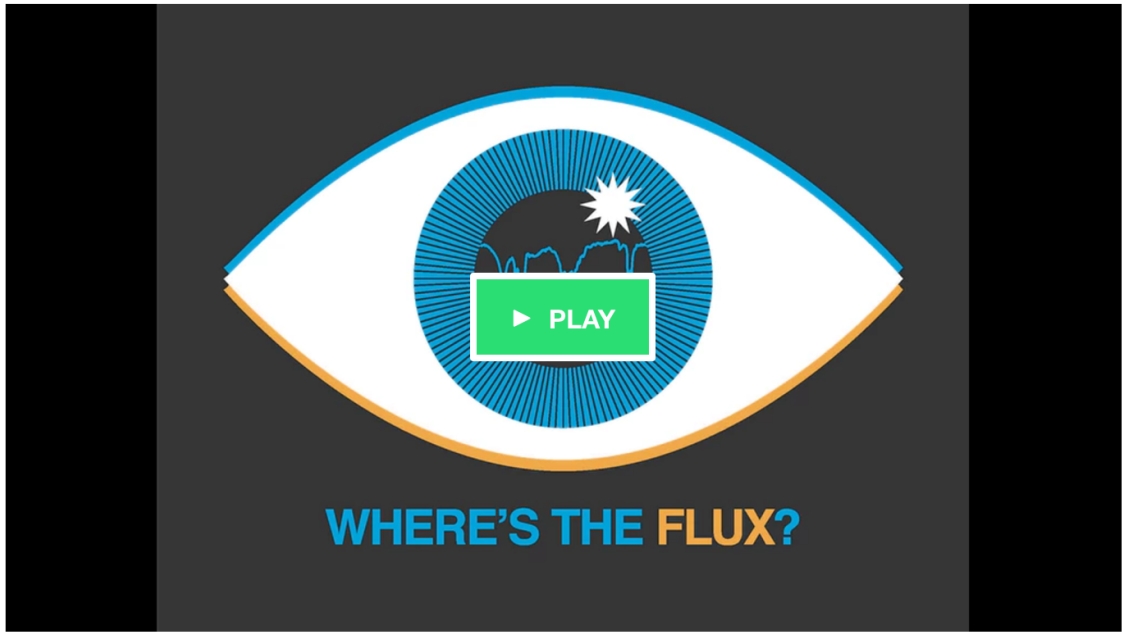
DNews: Can Tougher Corals Save Reefs

https://www.kickstarter.com/projects/608159144/the-most-mysterious-star-in-the-galaxy

Bookmarks | Google Calendar | Inbox – astrowright... | Light Curve Genera... | News | Professional | Refe

Campaign | Updates 38 | Comments 236 | Community

About this project

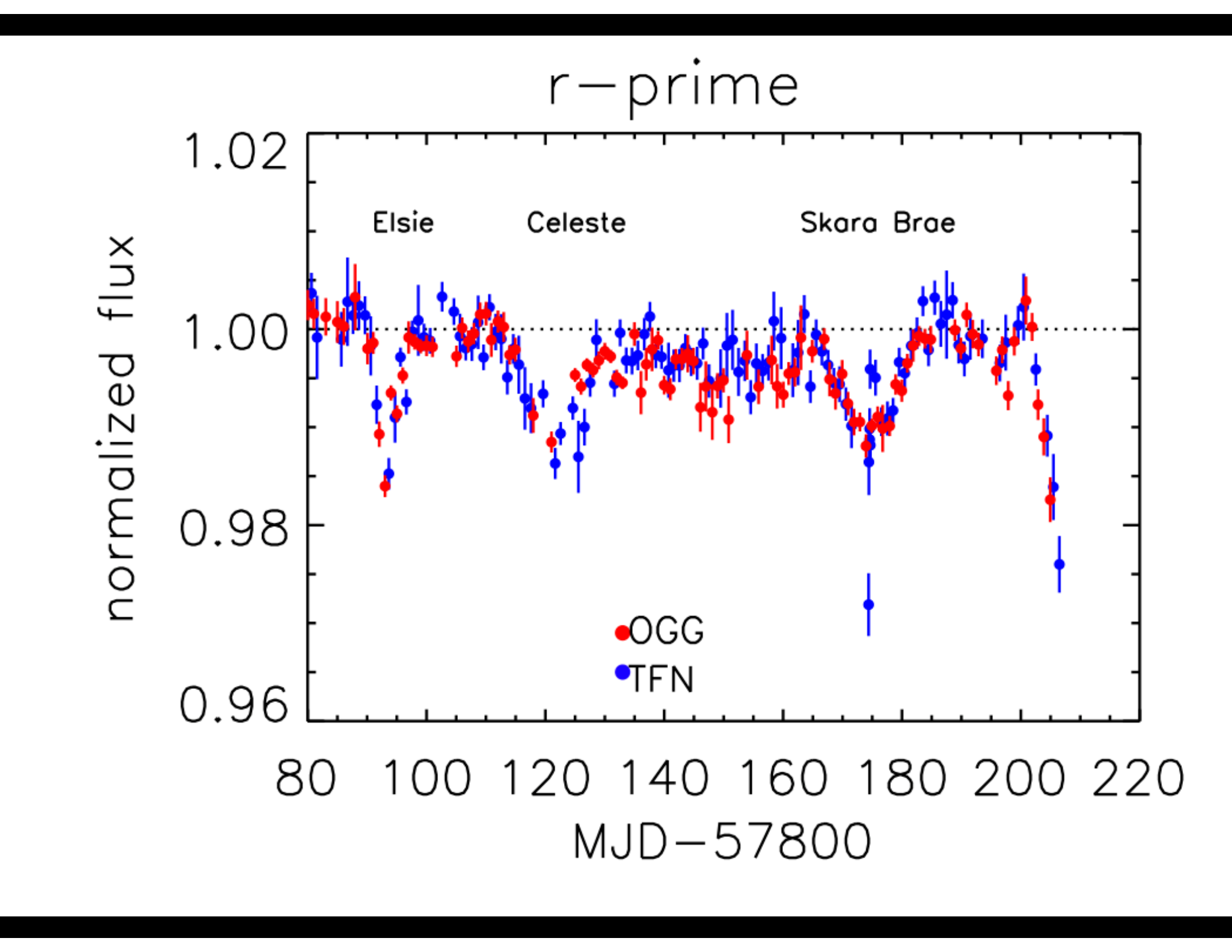


The most mysterious star in the Galaxy

New Haven, CT | Space Exploration | Project We Love

$107,421

pledged of $100,000 goal


r−prime
1.02
1.00
0.98
0.96
normalized flux
Elsie
Celeste
Skara Brae
OGG
TFN
80
100
120
140
160
180
200
220
MJD−57800

So what could it be?

- Tomorrow, 11-noon, ISTB4 692
- Tabby herself: 4pm PSF lobby (refreshments 3:45)

Communication and Artifact SETI are complementary

Artifact SETI
hard-pressed to prove phenomena cannot be natural

Communication SETI
must cast an impossibly wide net
(frequencies, duty cycles, bandwidth, power, targets...)

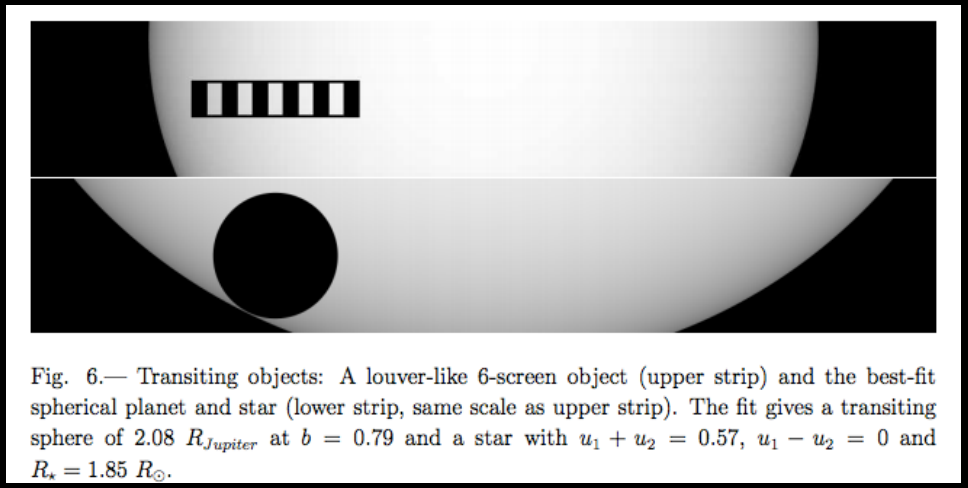
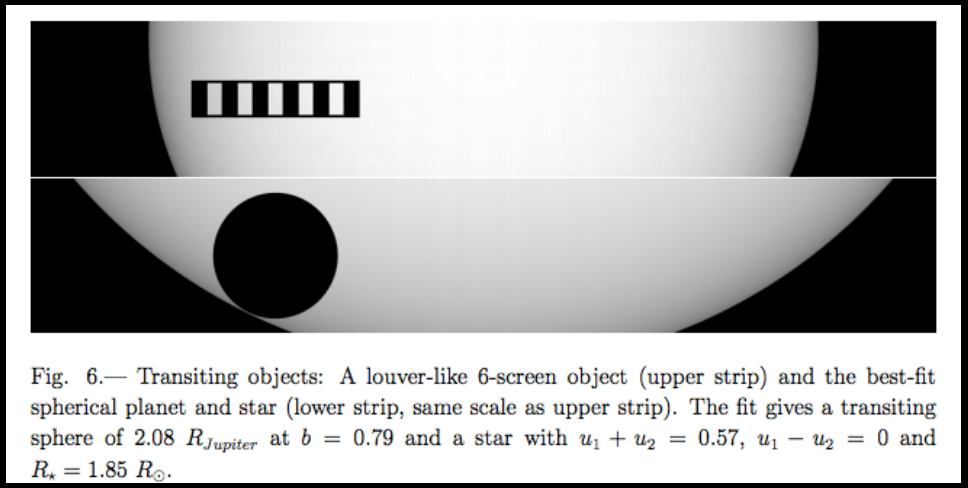


Fig. 6.— Transiting objects: A louver-like 6-screen object (upper strip) and the best-fit spherical planet and star (lower strip, same scale as upper strip). The fit gives a transiting sphere of 2.08 $R_{Jupiter}$ at $b = 0.79$ and a star with $u_1 + u_2 = 0.57$, $u_1 - u_2 = 0$ and $R_\star = 1.85\ R_\odot$.

Communication and Artifact SETI are complementary

Artifact SETI provides candidates → Communication SETI identifies candidates as alien



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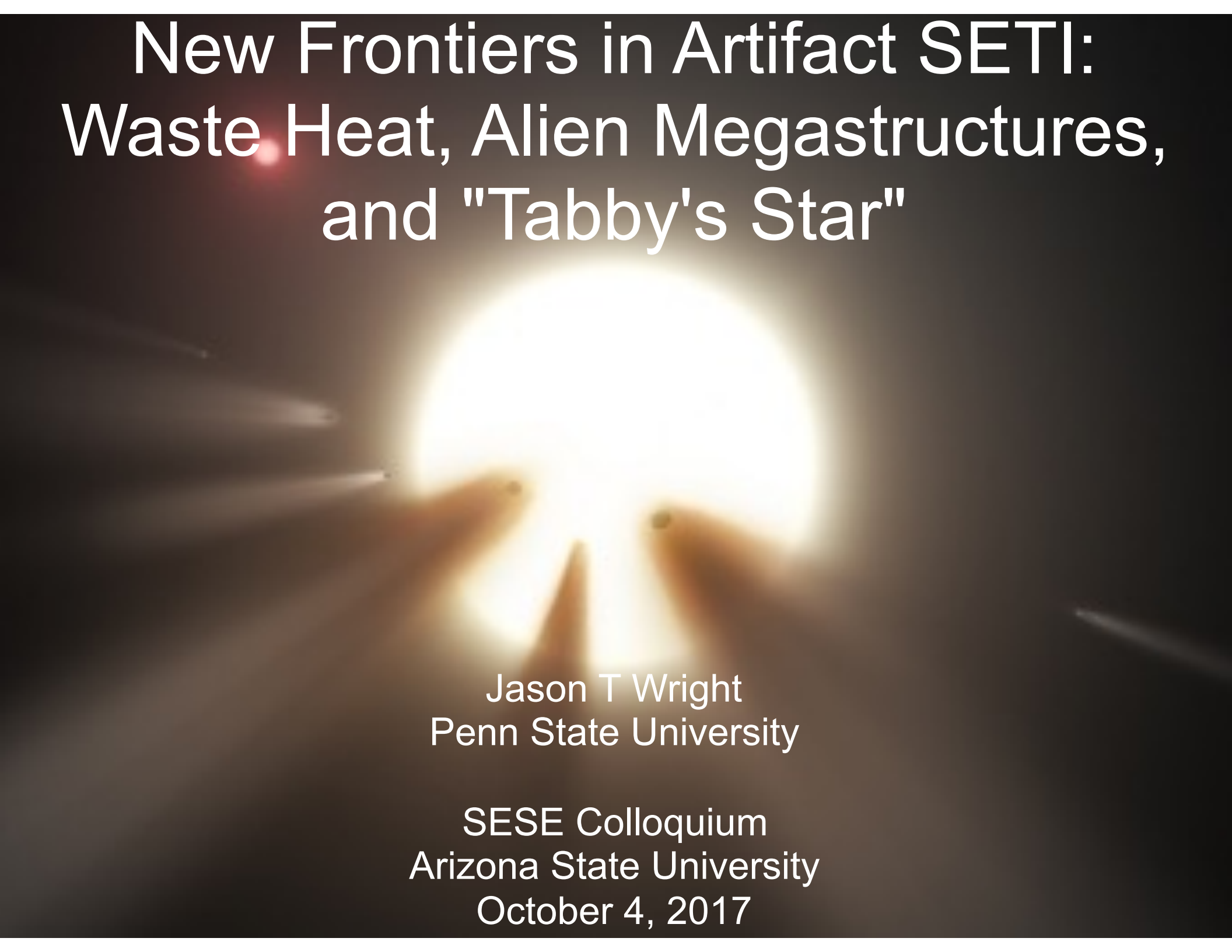
New Frontiers in Artifact SETI: Waste Heat, Alien Megastructures, and "Tabby's Star"



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SESE Colloquium
Arizona State University
October 4, 2017