Searching for Interstellar Archaeology signatures with Dyson Spheres on the stellar and galactic scale

Dick Carrigan
2014/5/27
with help from Nancy Carrigan

In pursuing SETI and interstellar archaeology remember the words of John Wellborn Root, a famous Chicago architect, who said "Reason should lead the way, and imagination take wings from the height to which reason has already climbed."

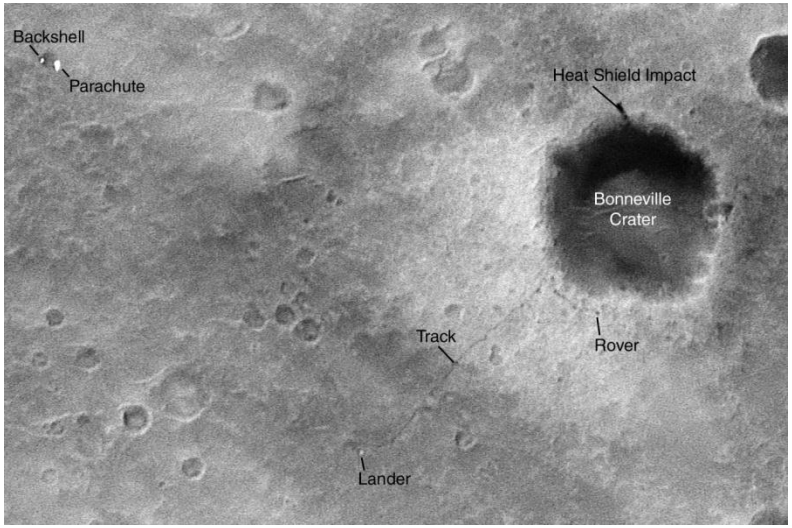
Nancy and Dick at Arecibo Observatory

Interplanetary Archaeology signatures have already been observed

pyramids from space station

Interplanetary Archaeology

(NASA photos)



Mars Rover but maybe robot anthropology

Organization of the talk

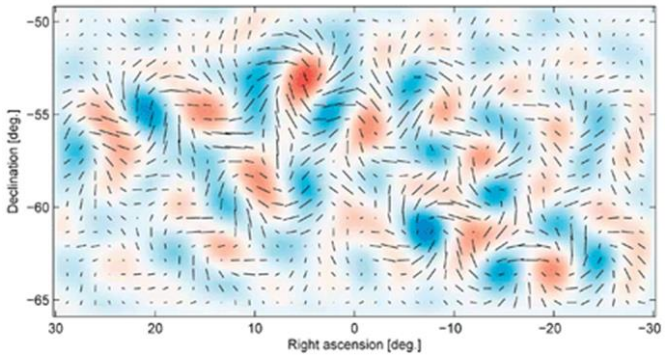
Interstellar archaeology

The backdrop: the origin of stars with
the big bang and inflation
and biological evolution

The Kardashev scale

The interstellar archaeology landscape
[1] SETI
[2] Exoplanet atmospheres
Stellar salting (I'll skip)
[3] Dyson sphere
Stellar engineering (skipping again)
[4] Galactic scale – Annis, Dyson

BICEP2 2014



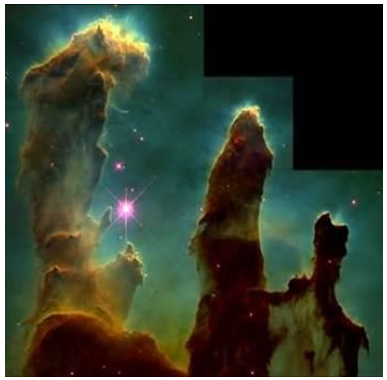
Guillermo Lemarchand

General ref: Guillermo Lemarchand, SETIQuest, Volume 1, Number 1, p. 3.
On the web at http://www.coseti.org/lemarch1.htm

The origin of stars

THE EAGLE'S CHILD

(Nancy Carrigan on seeing Internet pictures
taken by the Hubble telescope
of the birth of a star in the Eagle Nebula)



NASA – Pillars of Creation
Hubble, 1995, Hester & Paul
http://en.wikipedia.org/wiki/Eagle_Nebula

I saw, with my astonished eyes
a story told in ancient light--
celestial birth in distant skies
as our Sun-star once took flight.
This nameless star, egg-like it grew
in dull galactic primal dust
until it left the womb as new
stars and poems always must.

Has it, like Sun, a circling globe
with sea-fish, bird, and dexterous ape
who'se built a clever eye to probe
our mysteries? Does her mind escape
its bounds to ponder ancient light
and move a poet's pen to write?

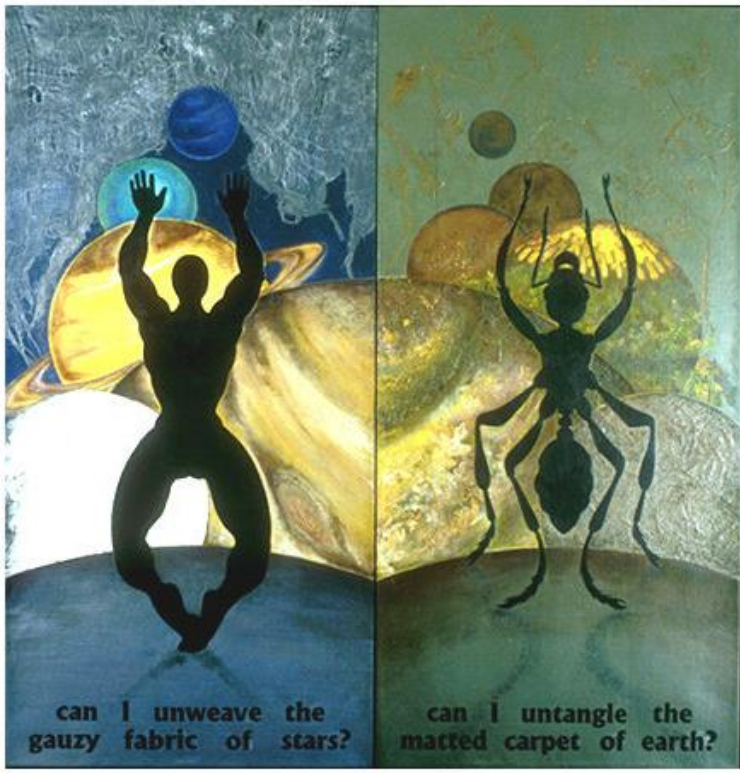
The Star Madonna
Nancy Carrigan

Evolution -The emergence of life and complex life on Earth and in the Universe

The missing panel:

What intelligence lies beyond?

Nancy Jean Carrigan



"Astrophysics and the Ant" Acrylic on Linen Nancy Jean Carrigan © 2000

Contact Nancy at: carrigans2@aol.com

Beside asking about the emergence of stars and life, Nancy also wonders about the contrasting variants of life. Her astronomer asks "*can I unweave the gauzy fabric of stars?*" while the ant ponders "*can I untangle the matted carpet of earth?*"

Ants to astronomers – how far? The Kardashev scale

Ants (10 W colony)

SETI (10^6 W)

Effect 1

planet (10^{16} W)

- exosolar planetary atmospheres.

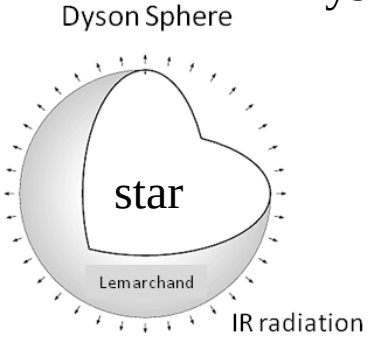
Effect 2

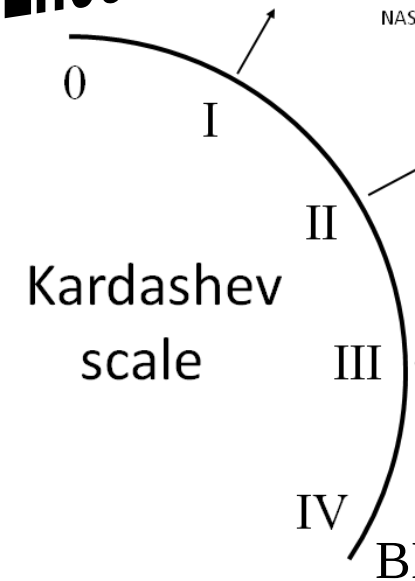
star ($4*10^{26}$ W Sun)

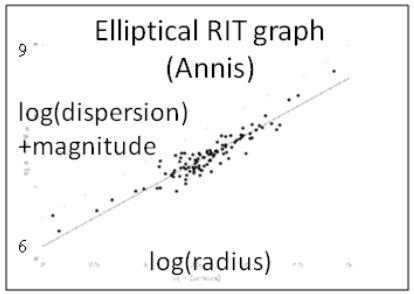
- Dyson sphere

Effect 3

Nikolai Kardashev







galaxy (10^{36} W)

Effect 4

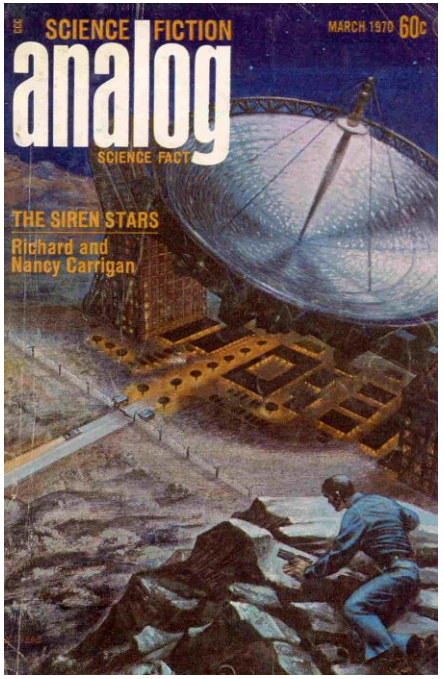
BIG BANG & INFLATION
(BICEP 2 -2014)

universe (10^{49} W)

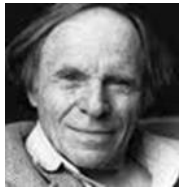
Effect 1

RADIO SETI PARADIGM: can span the galaxy but is there a **message** out there and **why**?

- In the sixties Nancy and I wondered about the possibility of dangerous messages and ended up writing a novel about it.
- Tarter: strong TV transmission out to one light year
- An advanced civilization may emit less stray radiation
- SETI may detect **cultural** as well as intentional signals.



Morrison



Cocconi

Jill Tarter

Degree of Difficulty

L_{SE} (*lifetime*) ~ civilization lifetime
P_{SE} (*power*) ~ 10^6 - 10^9 W
M_{SE} (*mass involved*) ~ not relevant

So far

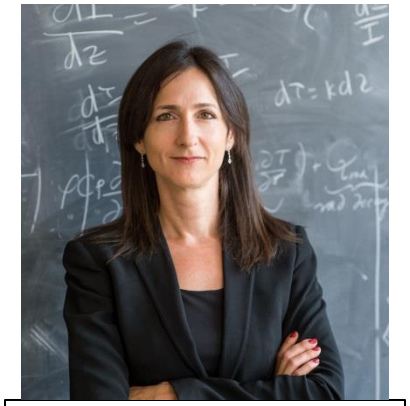
No signal!

Effect 2

Atmospheres of planets beyond our Sun - **type I Kardashev civilization**

As with Galileo and Jupiter's moons must first find exoplanets and then look for atmospheres and life impacts

Galileo 1610



Sara Seager
(photo –Justin Knight)

Lisa Kaltenegger

Have found some of the atoms and molecules of life around exoplanets

Progress on atmospheres- HD 189733b (63 ly)

Have found methane, H_2O, CO, and carbon dioxide (Swain, et. al., HD 189733b, ApJ **690**, L114, 2009)

too hot for even the hardiest life … unlikely that cows could survive here!"

Giovanna Tinetti

Swain et al., Nature 463, 617-618 (4 February 2010) have reported fluorescence from methane using a 3 m NASA Infrared Telescope Facility at Mauna Kea

Spitzer also saw silicon – the stuff of computer life – SiO_2 clouds

Signs of intelligence in exoplanet atmospheres

in earth atmosphere CO_2 up by 35% in industrial times

For interstellar archaeology want **unique cultural signal – freons (chlorofluorocarbons or CFCs)?**

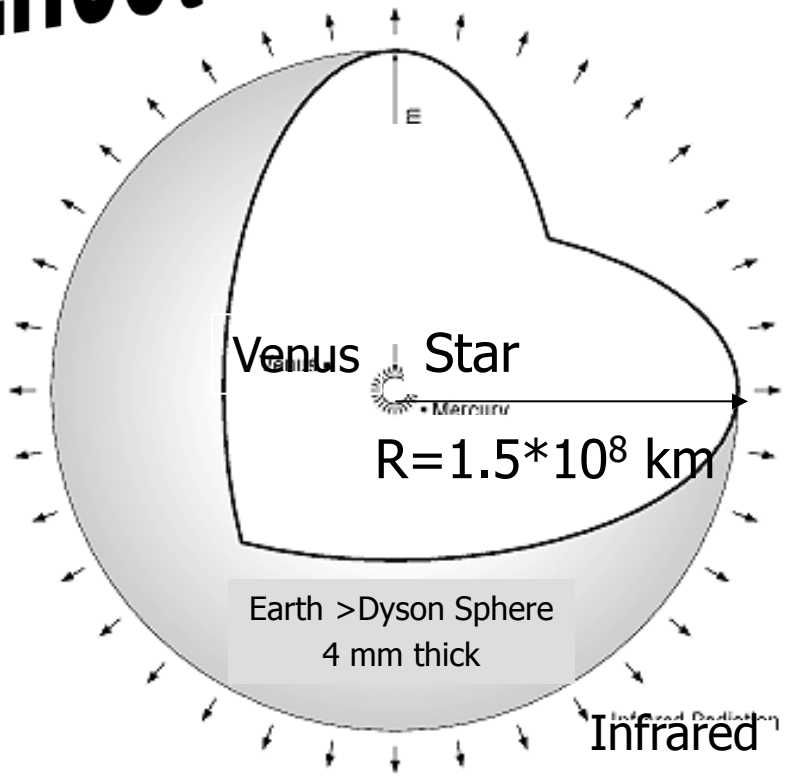
"CFCs are a very interesting idea to look for advanced civilizations," per Lisa Kaltenegger . …need exceptionally sensitive telescope. It might be feasible "in the far future with a flotilla of infrared telescopes in space".

Degree of Difficulty

Tough! 30 years out

L_a ~ atmospheric perturbation
P_a ?
M_a ~ 10^{15} kg (δ mankind CO_2)

Effect 3 Dyson sphere



Lemarchand, http://www.coseti.org/lemarch1.htm.

Rationale

harvest all star's visible energy

Types

pure – star completely obscured

partial

Signature

- infrared

stellar luminosity (distance problem)

Planck-like

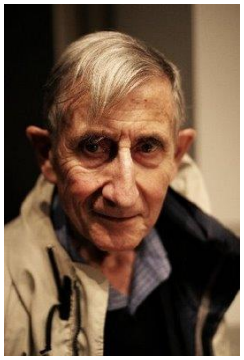
no star for pure DS

Energy to assemble - **BIG**

800 solar years to take Jupiter apart

Rigid Dyson sphere is unstable

instead cloud or shroud of smaller stuff



Freeman Dyson

Dyson, Science, 131, 1667 (1960), Dyson & Carrigan, Scholarpedia, 4(5):6647 (2009), http://www.scholarpedia.org/article/Dyson_sphere

IRAS

Requirement for Dyson Sphere search

all sky – useful

100 < T < 600 °K

Only all-sky survey at 12 μm before WISE

12, 25, 60, 100 μm micron filters

A main purpose – dust, mirror only 0.6 m

cirrus problems in 100, 60 μm

Performance

sensitivity – 0.5 Jy 12 – 60 μm,

1 Jy for 100 μm

250 K point sources

angular resolution – O(1')

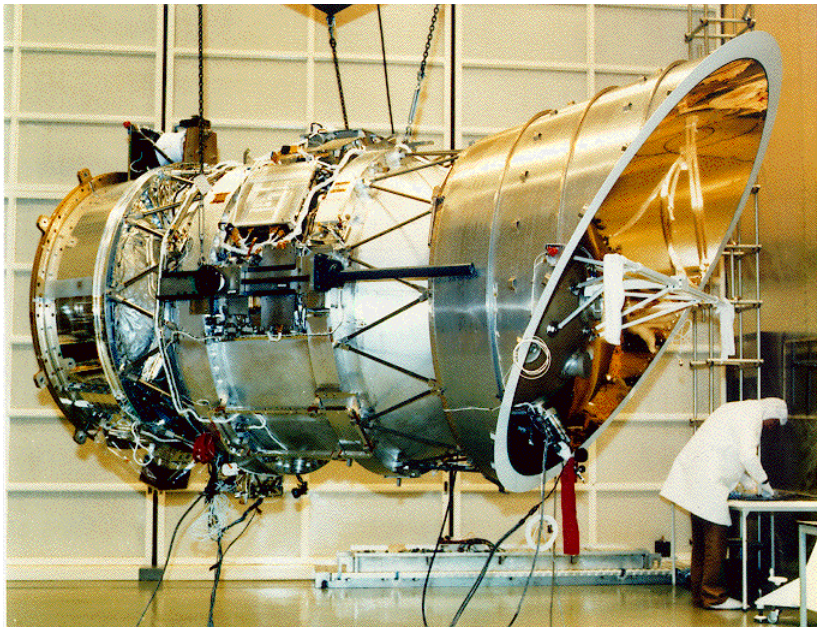
positional – 2 to 6" in-scan, 8 – 16" cross

Low Resolution Spectrometer (LRS)

sensitivity: 2 Jy in 12 – 24 μm filters

very useful Calgary LRS database

11224 sources



From Infrared Processing and Analysis Center, Caltech/JPL. IPAC is NASA's Infrared Astrophysics Data Center.

2MASS (ground based)

much more sensitive,

500 M point sources

IRAS 12 μm must be at least 10 Jy to register in the 2MASS 2.17 μm filter

SEARCH WITH IRAS LOW RESOLUTION SPECTROMETER

Calgary atlas – 11224 sources
FQUAL(12), FQUAL(25) > 1

Filter temperature cut:

$$T1 = c_0 + \sum_k c_k \left(f_{12} / f_{25} \right)^k$$

where k ranges over 4 const.
$100 \leq T1 \leq 600$ ºK

Select C, F, H, U, P ⟶
the classification scheme

Table I Calgary LRS Groups (Groups searched are underlined)

A	9.7 μm silicate absorption feature *typically O-rich AGB, thick cloud*
C	11 μm SiC dust emission *typically evolved C stars*
E	9.7 μm silicate emission feature *typically O-rich AGB, thick cloud*
F	flat, featureless spectrum *evolved O and C stars, little dust*
H	red continuum, 9.7 μm silicate abs or PAH *planetary nebulae of HII*
I	noisy or incomplete spectra
L	Spectra with emission lines above a continuum (few sources)
P	red continuum with sharp blue rise or 11.3 or 23 μm PAH feature *PAH*
S	Rayligh-Jeans optical tail (few) *stars earlier than M5 with little mass loss*
U	unusual spectra with flat continua *unknown*

Source flow through cuts

Fit LRS to Planck distribution

Visually scanned for:

- non-Planck shapes
- obvious spectral lines
- large data scatter
- visible stars with something else
- identification of the source
  - with a known object

Source flow through cuts	
Selection	Sources
IRAS sample	245,889
Calgary LRS sample	11224
FQUAL(12), FQUAL(25)>1	10982
100 ≤ Filter temperature ≤ 600 ºK	6521
Selecting C†, F, H(*), P(*), U	2240
IDTYPE = 0, 2, 3, 4	1527
Possible sources by direct scan	295
-Line(166),cl(40),T(14),H(9),np(1)	65
Statistical uncertainty <0.25	22
Somewhat interesting sources	16
Most interesting but with questions	3
* later eliminated, †C mostly lines	

Some Dyson sphere surrogates:

Stars are born and die in clouds of dust

← Protostars forming in Orion dust cloud (IRAS image)

Mira (Omicron Ceti) in visible (Hubble image) old, short-lived, circumstellar dust. Sum of many Planck spectra. Often have masers.

Also C stars, AGB and Post AGB (old)

Dyson sphere IRAS search - continued

Carrigan, ApJ, 698, 2075 (2009)

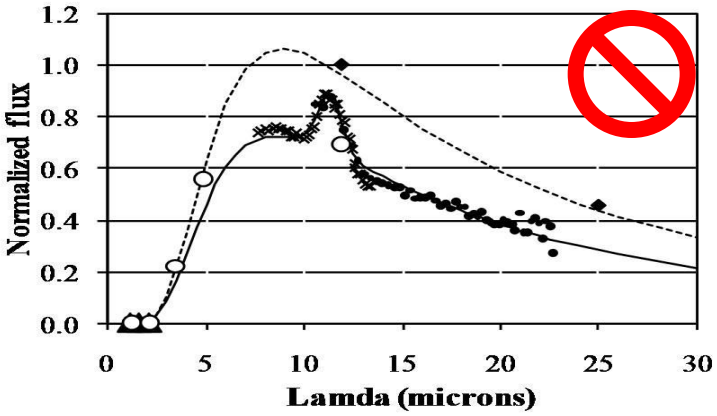
Low resolution spectrometer (LRS)

sensitivity: 2 Jy in 12 – 24 μm filters

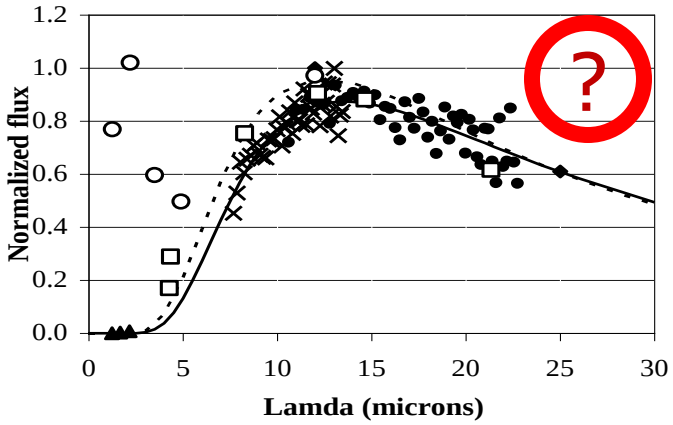
Calgary LRS database

11224 sources

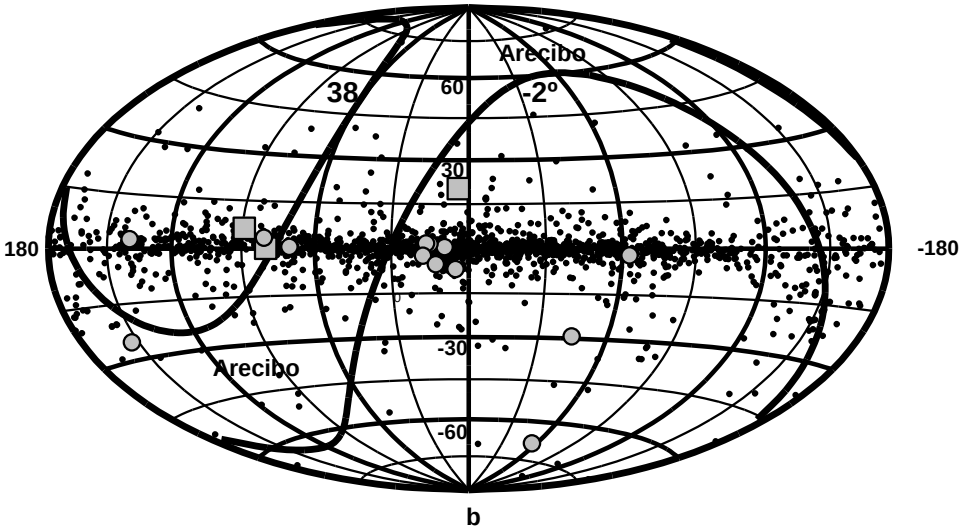
IRAS 17446-4048



IRAS 20369+5131



Dyson sphere summary



Results

3 faintly interesting, 13 poor

In retrospect, 6 sources near galactic center are curious.

Degree of Difficulty

Reach

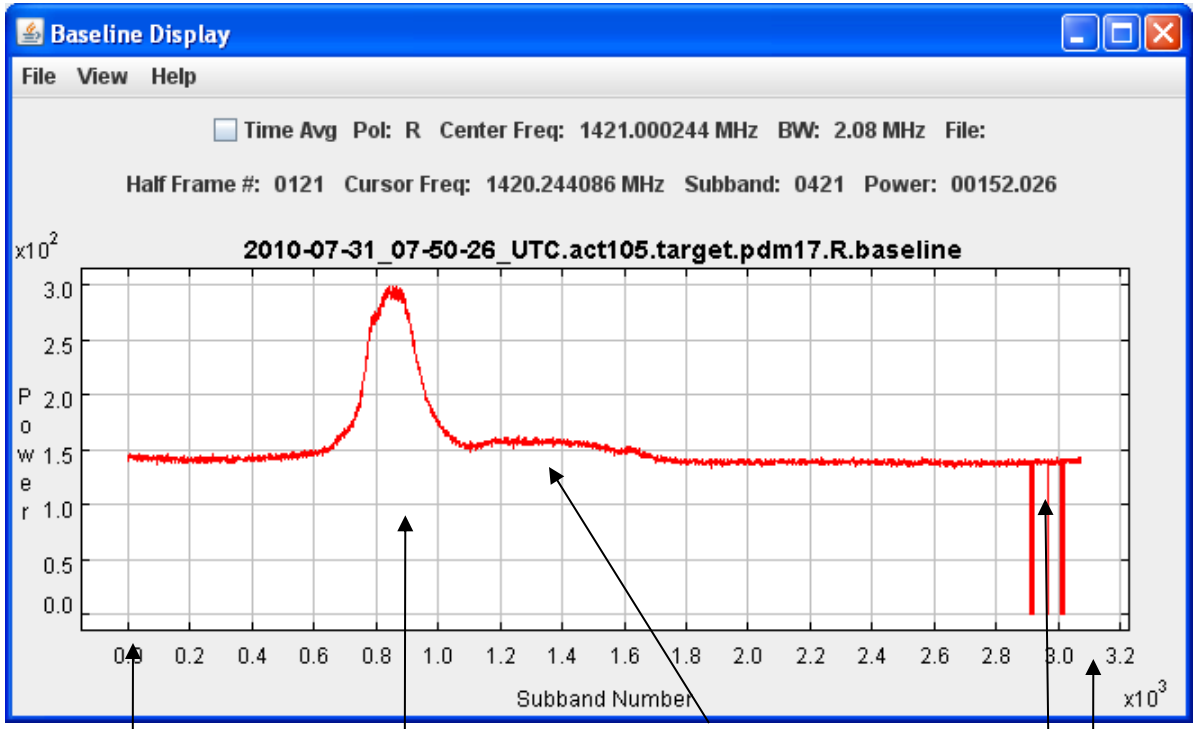
300 pc or ~ 1000 ly, not uniform on sky but no galactic bulge

L_{Dy} ~ Dyson sphere lifetime

P_{Dy} ~ $4*10^{26}$ W (star)

M_{Dy} ~ 10^{24} kg (~Earth)

Allen Telescope Dyson sphere investigation for radio SETI with Peter Backus, Jim Annis



1420

Neutral hydrogen
1420.536 MHz
Nom 1420.406

shoulder

1422

1421.969
Man-made interference

Allen telescope

IRAS 20369+5131
L = 89.09 b = 6.29

Cell phone frequencies go from
450 MHz to 1900 MHz

TV 50 – 1000 MHz

Effect 4

type III Kardashev civilization

Finding intelligence beyond our galaxy

Galaxy filled with stellar Dyson spheres, IR with visible Fermi void

Enrico Fermi

Fermi paradox

slow interstellar travel possible (can cross galaxy as it rotates) so where are space aliens?

Voyager 1 is now traveling at solar escape velocity. For 100 times the energy, the velocity could have been raised to 400 km/s or 10^{-3}c. 60 my to cross galaxy.

Quotes for spirals

Freeman Dyson: "a **type III Kardashev civilization** **(energy from a whole galaxy)** in our own galaxy would change the appearance of the sky so drastically that it could hardly have escaped our attention,"

Jim Annis: "It is quite clear that the Galaxy itself has not transformed into a type III civilization based on starlight, nor have M31 or M33, our two large neighbors."

Galactic scale artifacts

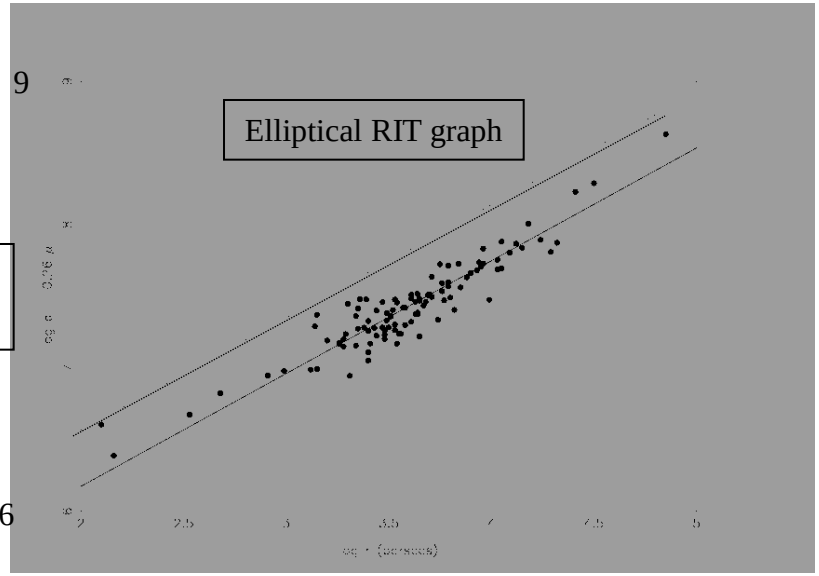
Possible model – galaxy filled with Dyson spheres

Actually just replication, slow interstellar travel

J. Annis, JBIS 52, 33 (99)

Outlier line is 1.5 magnitude or 75% in energy

No candidates in 106 galaxies



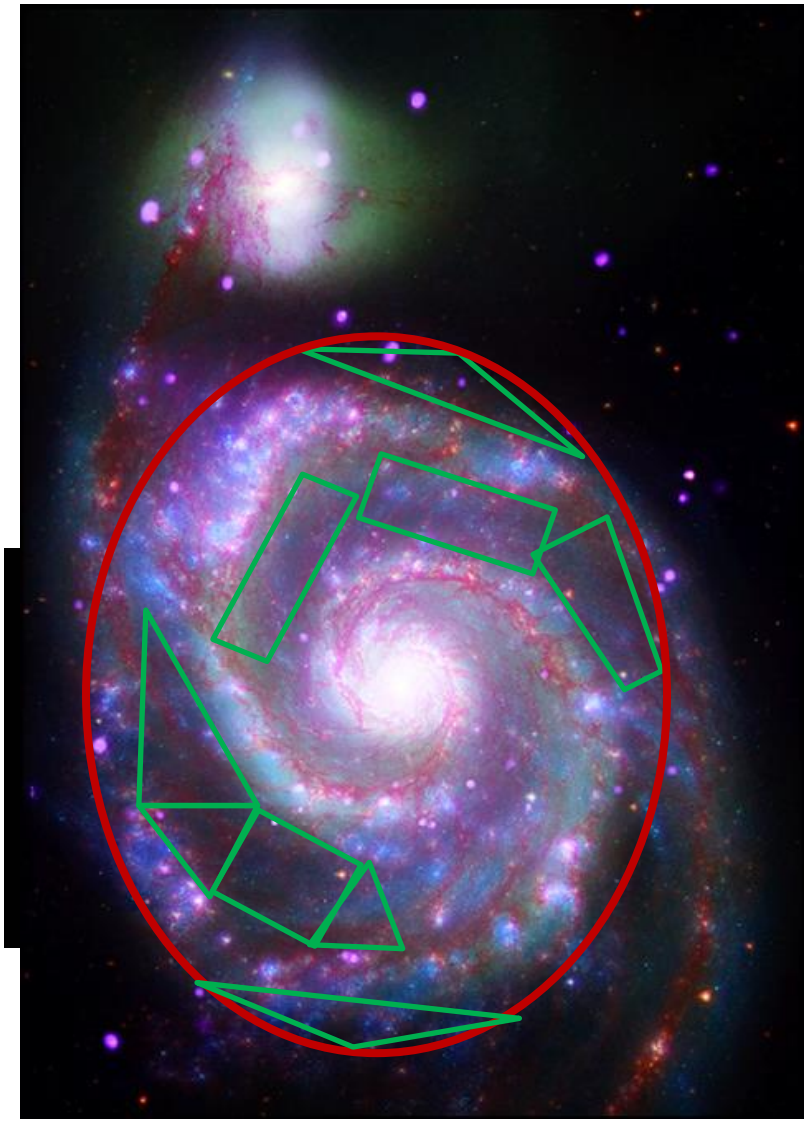
Degree of Difficulty

L_g ~ stellar lifetime

$P_g \sim 10^{37}$ W (stars in galaxy)

$M_g \sim 10^{36}$ kg (10^{11} planets)

Searching for Fermi/Dyson voids - spirals



Whirlpool galaxy M51 30 mly

Image is Spitzer – IR red

Green – optical Hubble

Purple – xray – Black Hole, Neutron stars

About 25% in relatively empty arms

< 5% unexplained voids or bubbles

IR does not follow voids

Jim Annis:

Instead try elliptical galaxies

Fermi voids in elliptical galaxies

Virgo A galaxy M87 (NGC 4486)

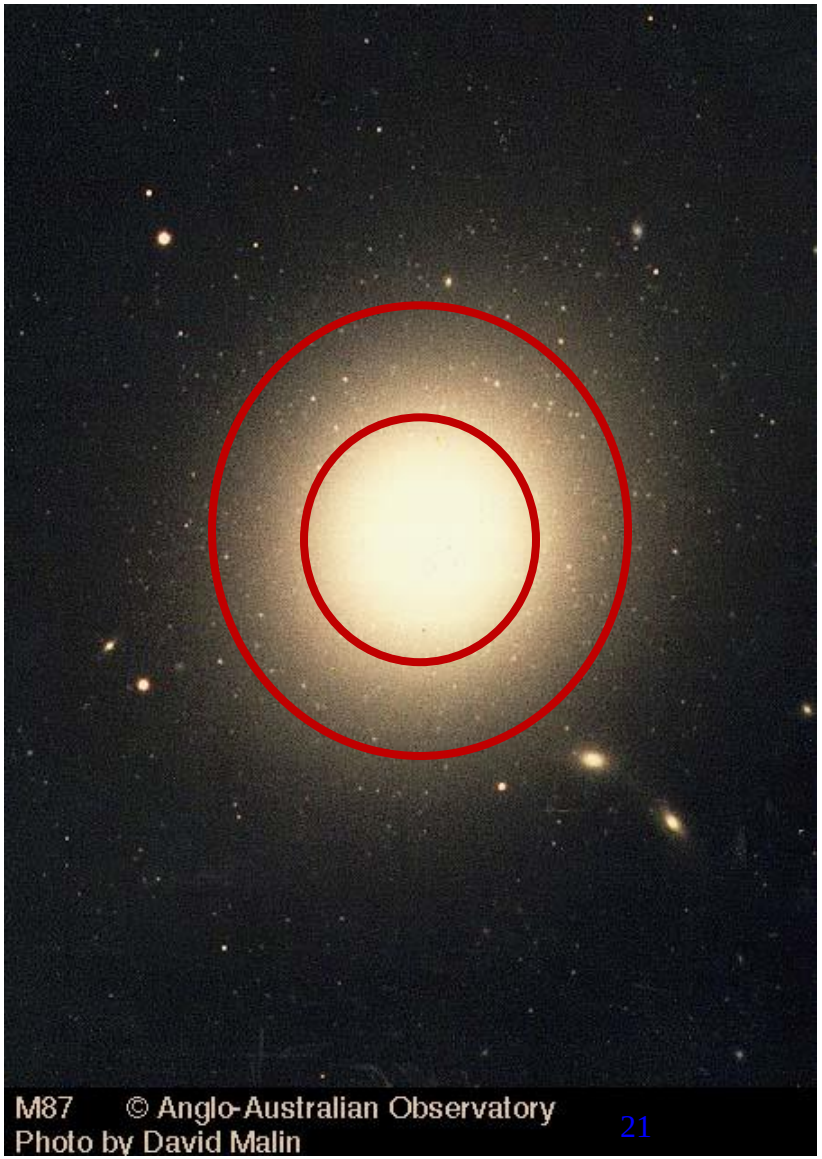
55 mly

Anglo-Australian Observatory

Seems quite uniform

ATLAS3D Slow rotator

Look for radial or azimuthal voids



Information and questions on elliptical galaxies

ATLAS3D Cappellari (2010) -260 non spiral galaxies based on integral field observations to give rotation

(see Reviews of Modern Physics, v86, Jan.–Mar. 2014, Corteau, Cappellari, et al.)

66% of the galaxies previously classified as elliptical were fast-rotating discs while conventional ellipticals are "slow rotators"

Sloan: Benardi et al., Astron.J. **125**, 1866 (2003)

Pedagogical: U. Maryland ASTR620: Galaxies - Fall 2013 - Richard Mushotzky

Questions

Can elliptical galaxies support intelligence?

Other reasons for voids

galactic habitable zone for elliptical galaxies - where to look for Fermi bubbles?

- First generation stars have low metallicity,
- stars formed from many generations of stars have high metallicity.
- Metallicity is important for planet formation
- Earth-like planets are high Z (silicates, etc.). High metallicity should correlate with planet formation.

Spiral galaxy habitable zone models exist

- Lineweaver etc. (2004) don't like ellipticals
- Prantzos (2006) modernizes estimates of earth-like planets
- Forgan and Rice (2010) – more sophisticated model and sterilization,
- Gowanlock (2010) – could extend to ellipticals

Inhomogeneities in ellipticals (e. g. voids or hot spots)

Kent: "if you have seen one spiral galaxy you have seen one, if you have seen one elliptical you have seen them all"

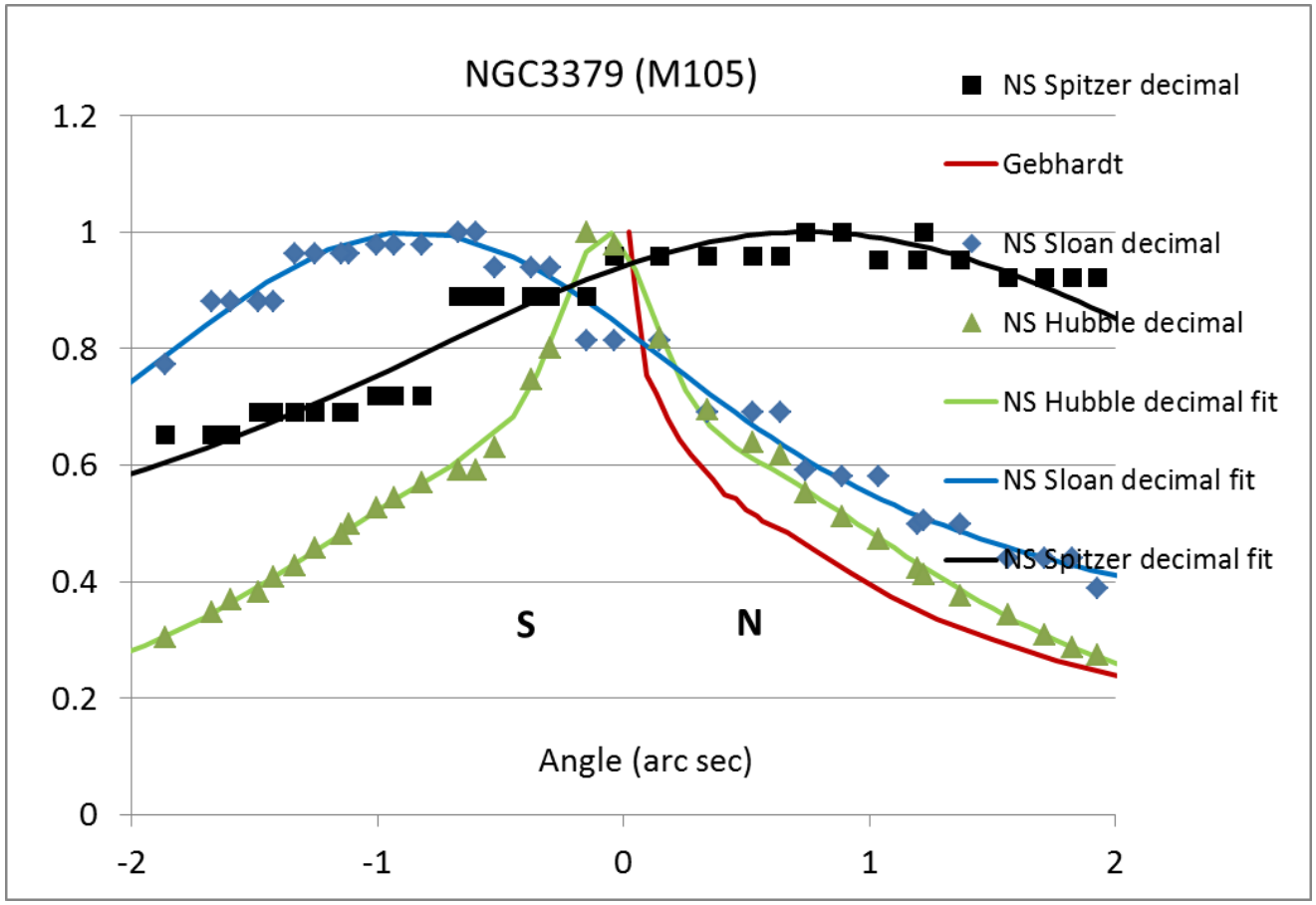
Factors giving rise to inhomogeneities:· rings happen, nearby globular clusters, surface brightness fluctuations, often due to stars, dust, e. g. dust lane warps.

Casual inspection of M32, M49, M60, M87, M89, and M105 showed few inhomogeneities. Most prominent non-uniform features are sequential rings. On M89 (NGC 4552) some density changes of O(10%) were O(40 pixels) across for 1000 pixels wide galaxy. These appear as both irregularities around the edge of the bright disc and beyond the edge. Some of the Hubble images are several thousand pixels across with the galaxy filling O(25%) of the image.

Equilibration time might be one billion years

The problems of pixelation

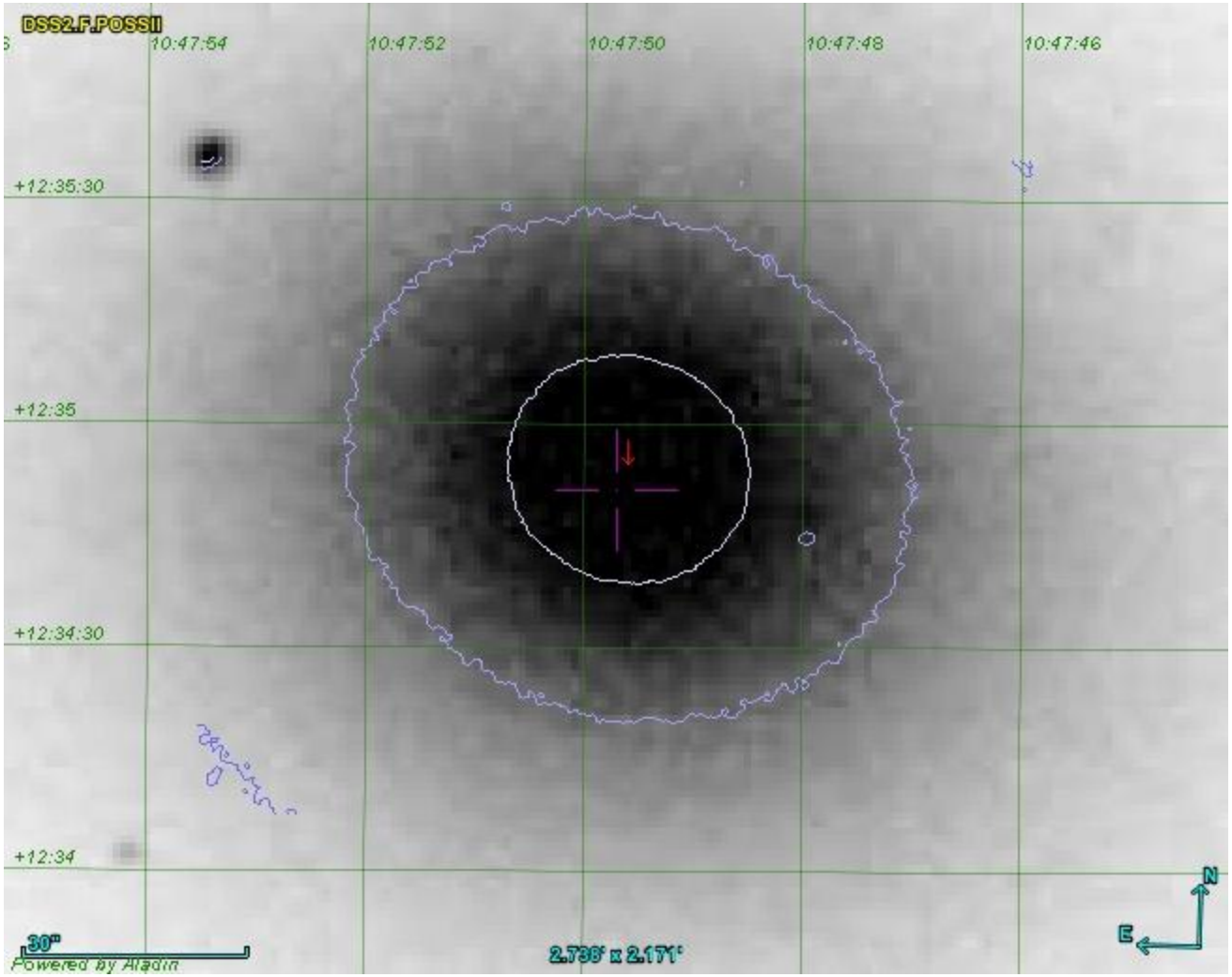
M105 -ATLAS 3D fast rotator 10.3 Mpc (32 Mly)



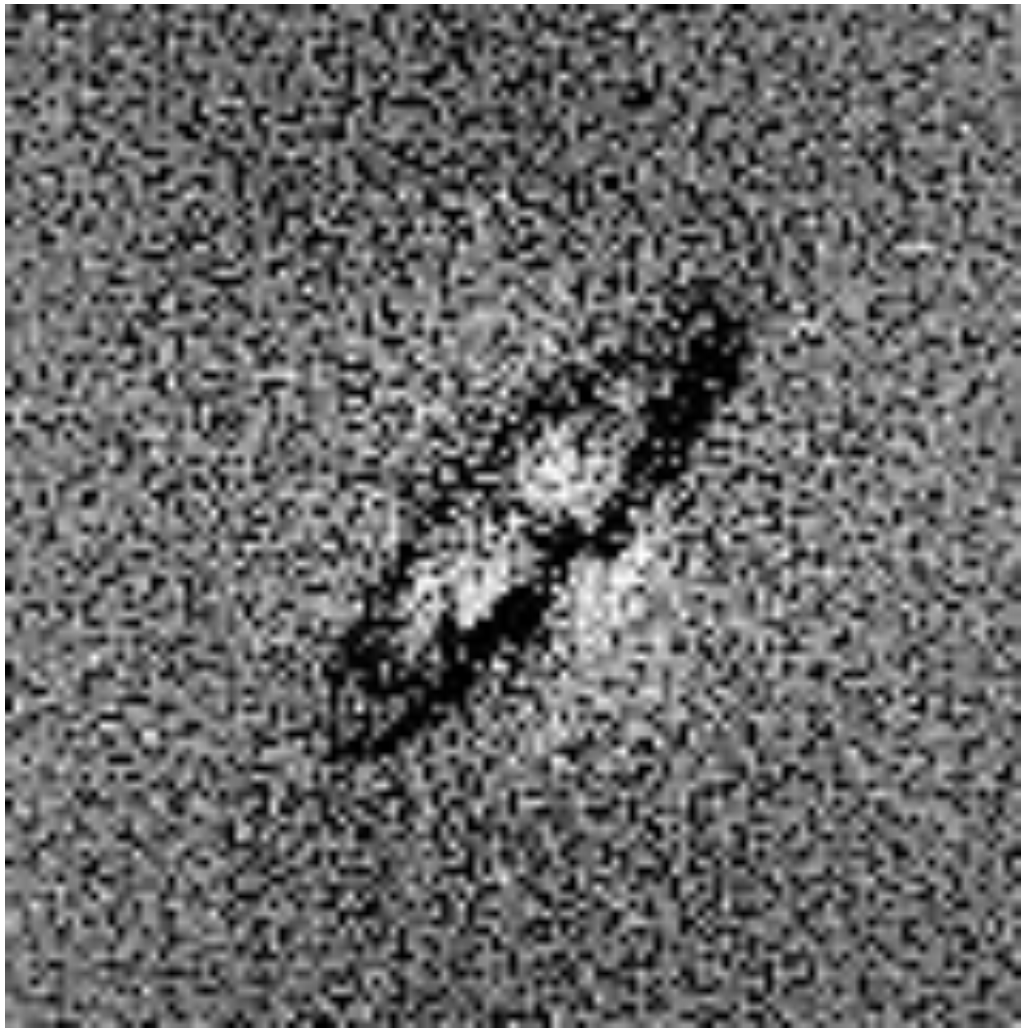
RESOLUTION

Sloan: 0.4″
2MASS: 2″
Hubble: 0.1″
WISE: 6.5″
Spitzer: 1.2″

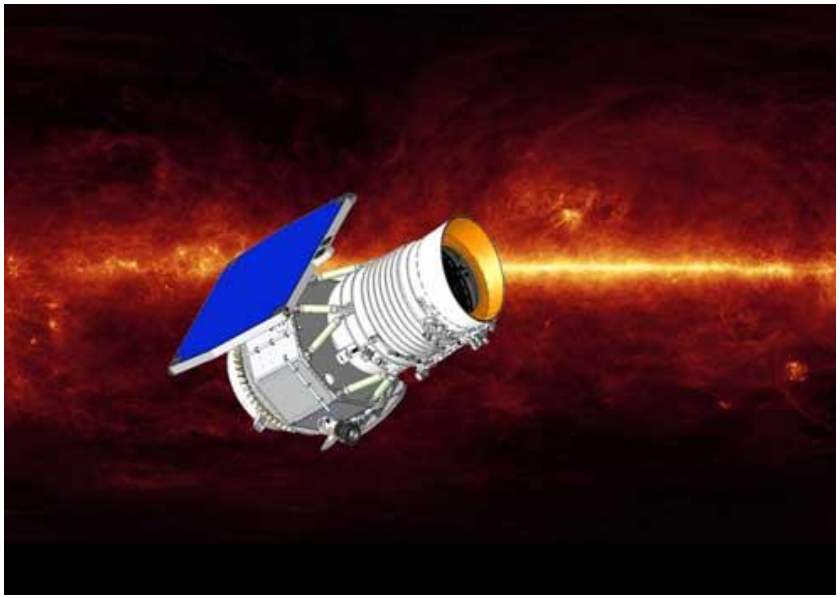
M105 – DSS – 30” per maj. div., 1” per pixel



M105 – Hubble image – 5” across, .045” pixels

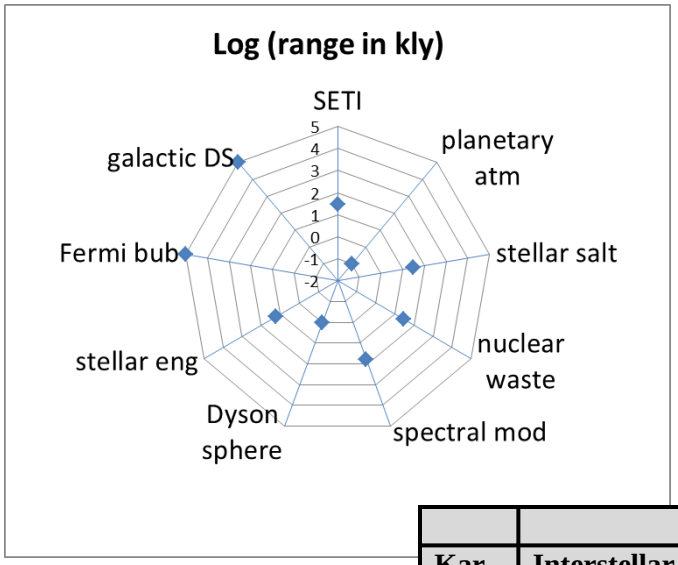


Jason Wright's SETI Institute talk Nov. 12, 2013



Jason Wright

Nov. 12 Abstract: If alien civilizations exist throughout the universe, many have had billions of years to develop technology, expand their population and energy supplies, and travel across their galaxies. Kardashev classified hypothetical advanced civilizations by the magnitude of their power supply, with Type II civilizations harnessing most of the energy output of their host star, and Type III civilizations using most of the power in their galaxy... This approach to SETI makes few assumptions about the behavior of alien civilizations…



Summary table

	Examples of Interstellar Archaeology						
Kar. num.	**Interstellar archaeology type**	**Reach (1000 ly)**	**L_c (lifetime)**	**L_c (kyrs)**	**Power Needs (W)**	**Mass Involved (kg)**	**Problems**
0	**SETI(radio)**	**to 0.25 now, 30 soon**	**civilization**	**5**	**10^6**		**often needs intent**
0	**planetary atmospheres**	**O(0.1)**	**atmospheric perturbation**	**O(0.1)**		**~10^{15}**	**ambiguity**
0	**stellar salting**	**~30**	**λ isotope**	**O(10^3)**		**10^8**	**natural signals**
0	**nuclear waste**	**~30**	**λ waste**	**O(10^1)**		**10^8**	**ambiguity**
I - II	**spectral modulation**	**60 (also ext. gal.)**	**civilization**	**5**	**10^{26}**	**10^{24}/yr**	**natural signals**
II	**Dyson sphere**	**to 1**	**civilization dyn. stab.**	**5**	**4*10^{26}**	**10^{25}**	**mimics**
II	**stellar engineering**	**20**	**~stellar lives**	**10^6**	**4*10^{26}**	**10^{30}**	**~~blue stragglers~~**
II.5 - III	**Fermi bubble**	**O(10^5)**	**0.1 galaxy crossing**	**10^4**	**10^{35}**	**10^{34}**	**confusing signature**
III	**galactic Dyson sphere ensemble**	**O(10^5)**	**galaxy crossing**	**10^5**	**10^{37}**	**10^{36}**	**dark galaxies**

Effect 1

Effect 2

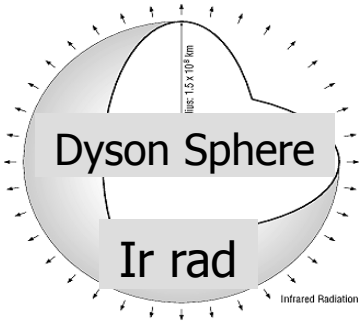
Effect 3

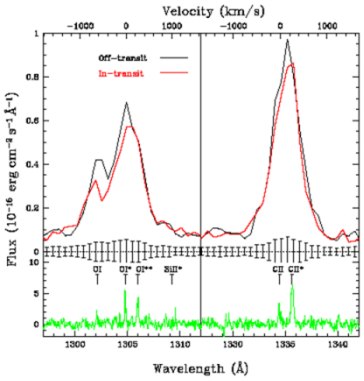
Effect 4

Summary

Interstellar archaeology:

- SETI cultural signals (**nearly possible**)
- Cultural planetary atmosphere signals (**look how fast we are screwing up our own**)
- Dyson sphere (tough)
- Type III Kardashev ala Annis (mere replication of DS, a turn of a galaxy, really hard)





We are at the stage of Galileo 400 years ago. The situation looks difficult but there are possibilities for progress.

Perhaps we can draw from the perspective of Chicago poet Larry Janowski : "I wish I were taller but when looking at the stars it doesn't matter."