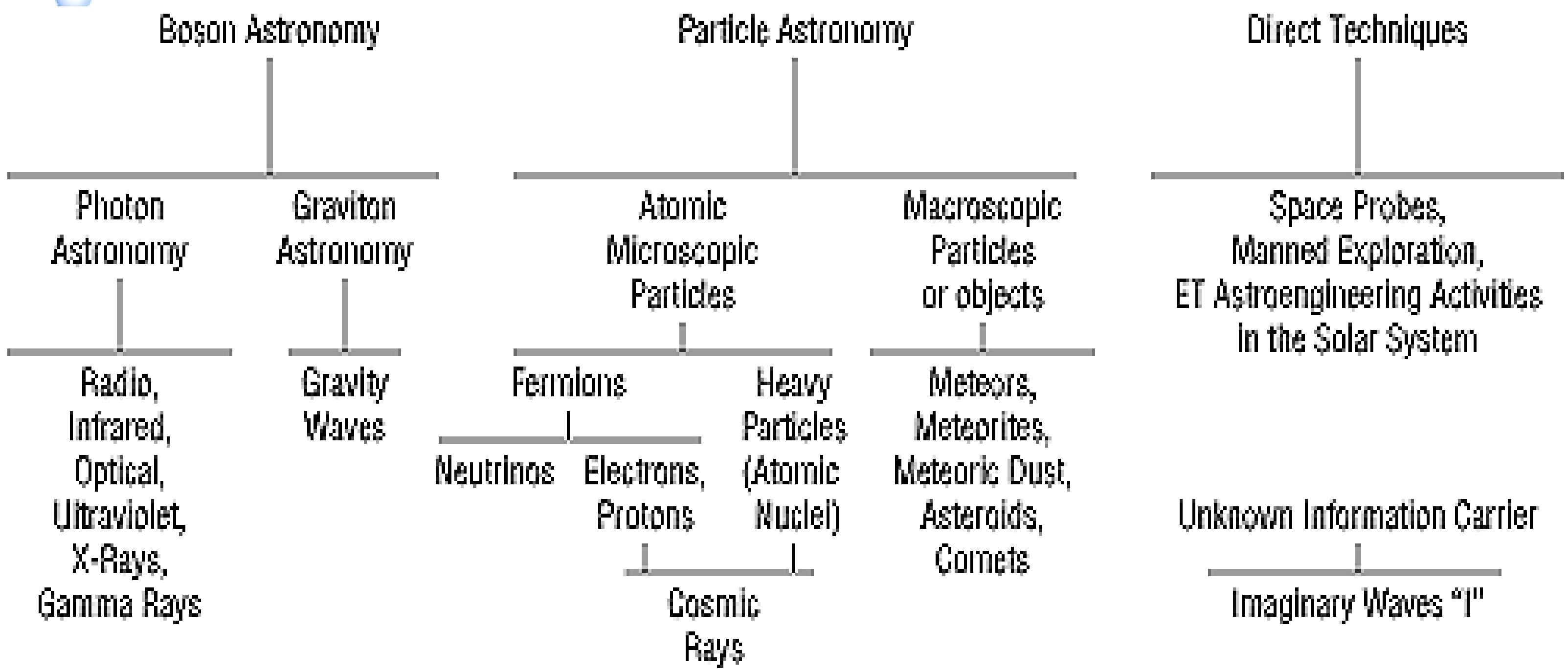
PARTE 5:
OTRAS BÚSQUEDAS E IDEAS SETI (¿Qué y cómo?)

¿Qué más Y cómo buscar ETI? A: Depende de nuestros intrumentos, inteligencia/conocimiento y**... ¿suerte?**

Observación: **¡Presente y futuro éxito de SETI empieza AHORA, era de la Información y Big Data!**



1. ¿Dónde y cómo buscar a ET-I en espectro?

- **SETI (normal signals): Radio, Microwave-21cm line, VIS-optical,...**
- **SETI (alternative signals): IR, UV,...X-ray,γRays, ν's, GW's...?**

El espectro es grande,y ¿otras partículas ``mensajeras''?!

Fotones ~0.005% del Universo, m-E conocida sólo 5% (Dark ETI?)

Propiedades (Kardashev-Sagan-Zubrin, Ω-Barrow, P-E+ λ):

- **Normal SETI:** **Radio-óptica-> Señal+Comunicación (alcance limitado), VISIBLE-óptico->Detección directa de objetos.**
- **SETI (otras longitudes de onda, complementarias):**

IR-> Actividades, nivel tecnológico,...

UV->Estructuras, materiales,...

X-ray, $\sqrt{3}$-ray,...-> Utilidad desconocida (¿llamada de atención? ¿invisibilidad?)

$$K=\left(\frac{1}{10}\right)\log_{10}\left(\frac{P}{10\,MW}\right) \qquad \lambda=\frac{h}{p}\sim\frac{hc}{E}$$

Búsquedas complementarias

Artefactos:

- Telescopios
- Cosmic colliders
- Constructos y megaestructuras
- Exotica y otros (DS, SRP, ISHIPS,...)

Exoplanetas + Exolunas:

- Sup. Hints.
- Atm. Hints.
- Otras "hints".

Señales no estándar:

- Violaciones de leyes físicas conocidas (empíricas).
- Quantum entanglement? La naturaleza ES cuántica E~f

★ **Ejemplo de estas búsquedas**
(SETI en Berkeley University):
arXiv0811.3046v2
astropulse+Fly's Eye/Allen TA uses

★ 7 búsquedas en IR, VIS-OP, RADIO
Ideas: fuente de µs-ms radio pulses son PBH, hyperflares from neutron stars, cosmic strings ó...ETI!

Otra lista (basada en arxiv./1001.5455):

En exoplanetas:

- Compuestos/ isótopos no naturales (freón, Tc, Pm, SHE,...)
- Sondeo UV (NUV,DUV,...)-metales en sup./atm.
- Residuos de calor tecnológico (Tierra+0.01%)

En estrellas:

- Stellar salting
- Ingeniería estelar
- Estructuras artificiales
- Ratios isotópicos
- Nuclear waste
- Modulación espectral en púlsares (arXiv 1311.4608) y estrellas (hard)

En galaxias (K3):

- Violaciones o anomalías en la relación Tully-Fisher (B-L plot, Brightness vs rot.velocity)
- Creación de burbujas de Fermi, vacíos, señales láser, IR u ópticas varias.

IDEA: Señal fuerte IR.
Annis searches →137 sample
+ Ĝ seti -recently, outliers candidates...

BÚSQUEDA DE ARTEFACTOS

ARQUEOLOGÍA DE ETI→Complementaria a comunicación (en bajo ancho de banda, a priori).

BÚSQUEDAS DE ARTEFACTOS

¿OVNIs, estrellas de la muerte? No...¿Sí? ``Casi'' o... tal vez.

- Esferas/enjambres de Dyson (Dyson shells, 1960)
- Self replicating probes (von Neumann's)
- Interestellar probes/starships/stellar stations/...Death Stars?

¿Cómo? Generalmente Direct Imaging y/o IR signal. Advanced Civilizations (AC)→fuerte señal IR. Peligro: falsos positivos por causas/fuentes naturales u otras hipótesis no ETI. Dyson: "La energía no se incrementa, sólo se convierte a T inferior(pérdida por calor)" -Requiere TD básica, no nueva física alienígena desconocida.

Idea 1 (ejemplo): Esferas de Dyson y otras (mega)-estructuras alrededor de estrellas, BH's,... Referencias: arXiv 1503.04376 (white D, DS), arXiv 1112.5519 (K3 civ.) **Detección vía tránsito/curva de luz (anomalía), direct imaging ó IR signal.** Nota: **GAIA dará distancias a posibles WISE+Spitzer candidates; reciente falso positivo provocado por nube cometaria (Planet Hunters).** Similar a búsqueda de estaciones solares (Arnold 2005) vía tránsito. **Posible señal UV (metal).** Shkadov thruster idea: arxiv 1306.1672.

Idea 2 (ejemplo): Detección de interstellar subluminal starships via reflexión relativista (arxiv 1203.3980)**, estudios ancho de banda para SRP** (arxiv 1111.6131)**.**

Idea 3 (ejemplo reciente): búsquedas de K3 en el IR (transgalácticas) Ĝ=Glimpsing Heat from Alien Technologies (Penn Univ.) WISE+Spitzer+TF y morfología galáctica (varios artículos).

OTRAS ideas (SETI exótica)

Neutrino SETI (GW SETI, X SETI, iSETI):
arXiv 0803.0409 Muon Collider and SETI
arXiv 0105127 Some uses of neutrino telescopes
arXiv 0805.2429v3 Galactic Neutrino Communication

Idea básica:
K2/K3 AC requieren ``sincronización de relojes"
Haz de neutrinos, coherente y colimado podría servir.
Usar resonancia en M(Z)/2=45.6 GeV~10^{25}Hz!
$\nu\nu \rightarrow Z \rightarrow \nu\nu$ Detección difícil, ...Pero posible en
~km^3 ν-telescopes! (Current Future ν-Astronomy!).
Alternativa con resonancia de Glashow en
$E(G)=m(W)^2/2m(e^-)$~6.3PeV
(señal inconfundible NO NATURAL)
Mediante superbeam (o medio desconocido):
antinetrino+$e^- \rightarrow W^-$

YeV SETI/Planck-scale collider SETI o búsqueda de Cosmic Colliders,UHE neutrinos (XeV,YeV,WeV,...).
arXiv 1503.01509 SETI AT PLANCK ENERGY: WHEN PARTICLE PHYSICISTS BECOME COSMIC ENGINEERS

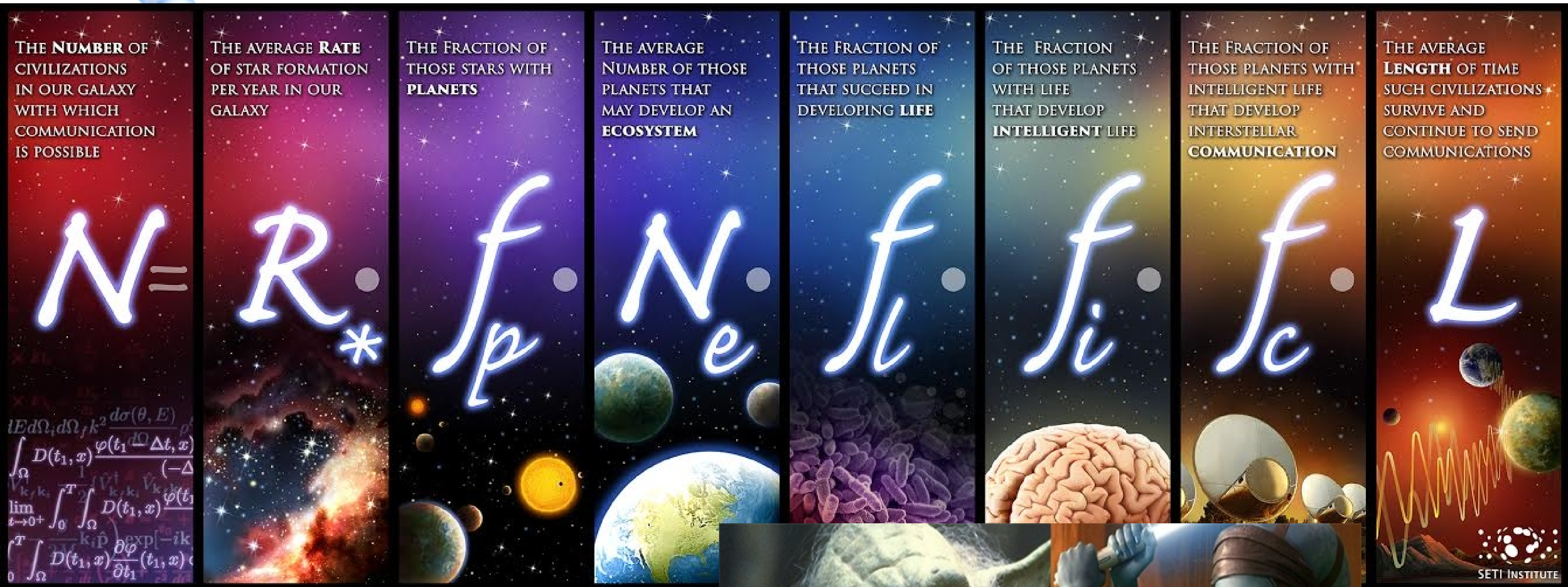
Ideas básica:
ETI como físicos + Ĉerenkov y Askaryan effect neutrinos/radio signals

Complementario:
Ĉerenkov/Gamma ray telescopes (como ¡CTA!)

Otras ideas: futura Astronomía/Astrofísica/Cosmología (SETI como "subfield" interdisciplinar). Are we alone? Paradoja de Fermi/Gran Silencio

¡Requieren solución multidimensional/multibanda/multidisciplinar!

¡MUCHAS GRACIAS POR VUESTRA ATENCIÓN!



BACK-UP SLIDES (parte 5):

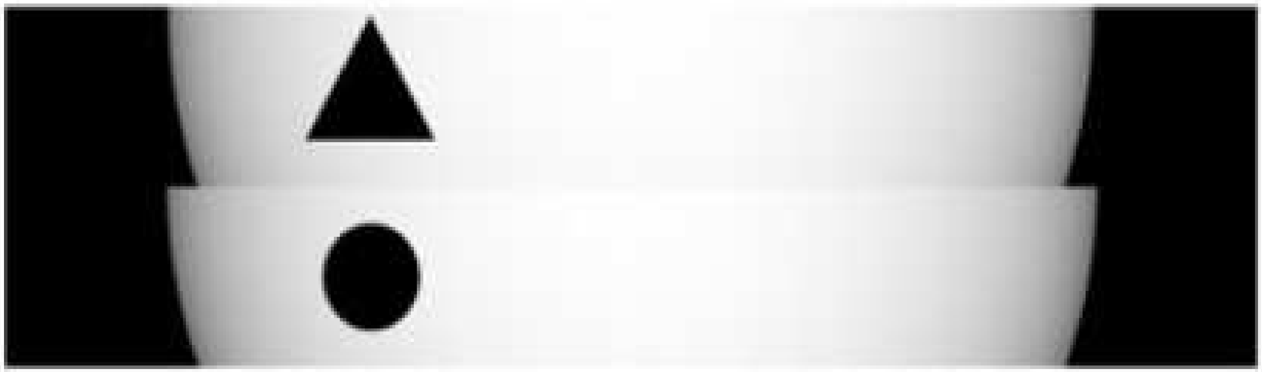
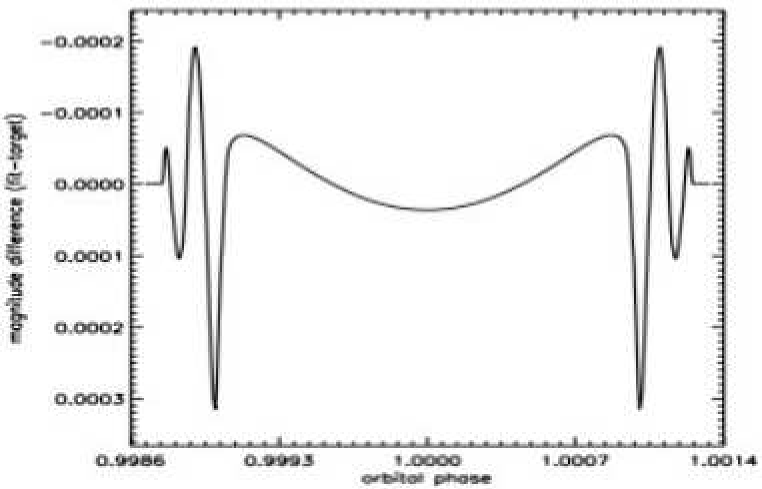


Fig. 1.— Transiting objects: A triangular equilateral object (upper strip) and the best-fit spherical planet and star (lower strip, same scale as upper strip). The star model for the triangle transit is HD209458 with limb darkening coefficients $u_1 + u_2 = 0.64$ and $u_1 - u_2 = -0.055$ (Brown et al. 2001). The triangle edge length is 0.280 stellar radius. The object impact parameter is $b = 0.176$ (transit center). The best-fit sphere has an impact parameter of $b = 0.19$ and a radius of $r_p = 1.16\ R_{Jupiter}$. Best-fit star has $u_1 + u_2 = 0.66$, with $u_1 - u_2$ set to zero, and a non-significant radius increase of 0.5%. Fitting object oblateness f, either with zero or 90° obliquity to maintain lightcurve symmetry, converges to solutions not significantly different from the case $f = 0$.



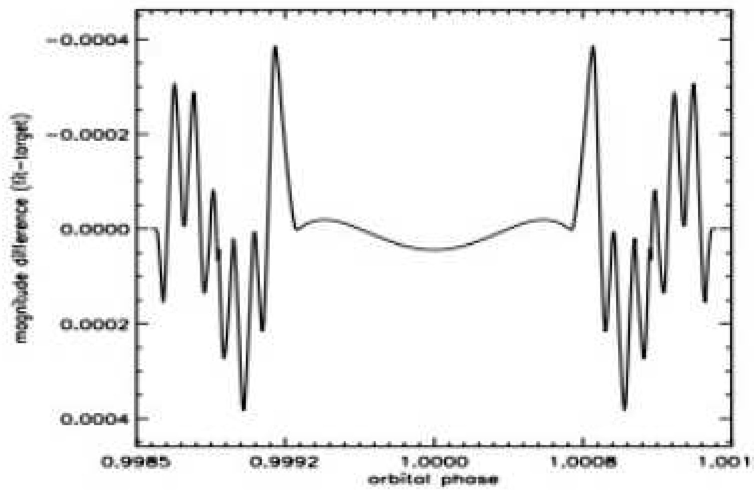


Fig. 6.— Transiting objects: A louver-like 6-screen object (upper strip) and the best-fit spherical planet and star (lower strip, same scale as upper strip). The fit gives a transiting sphere of 2.08 $R_{Jupiter}$ at $b = 0.79$ and a star with $u_1 + u_2 = 0.57$, $u_1 - u_2 = 0$ and $R_* = 1.85\ R_\odot$.

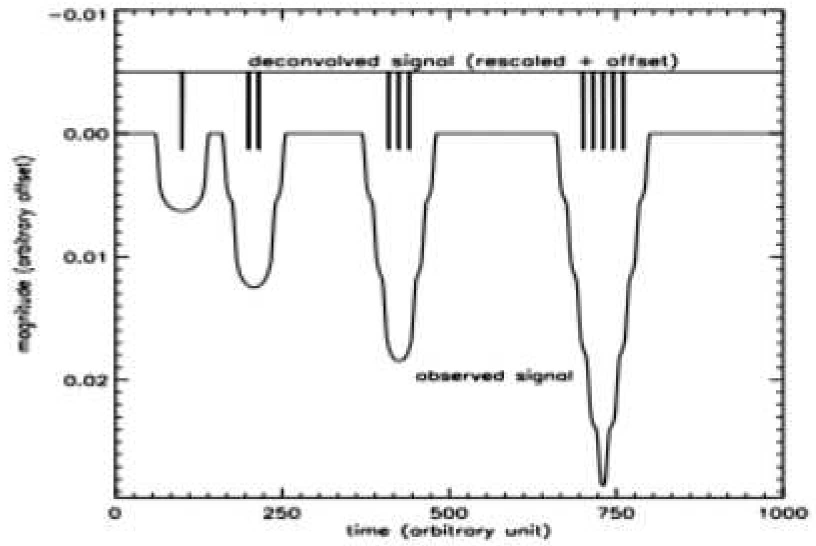
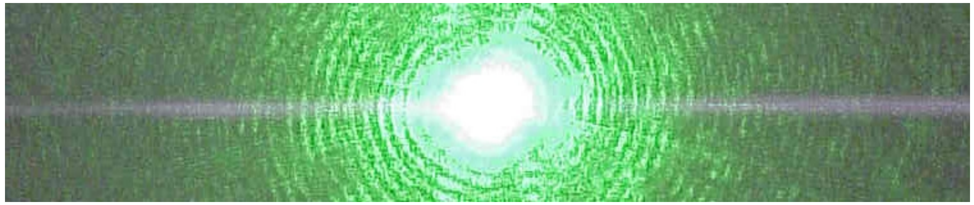
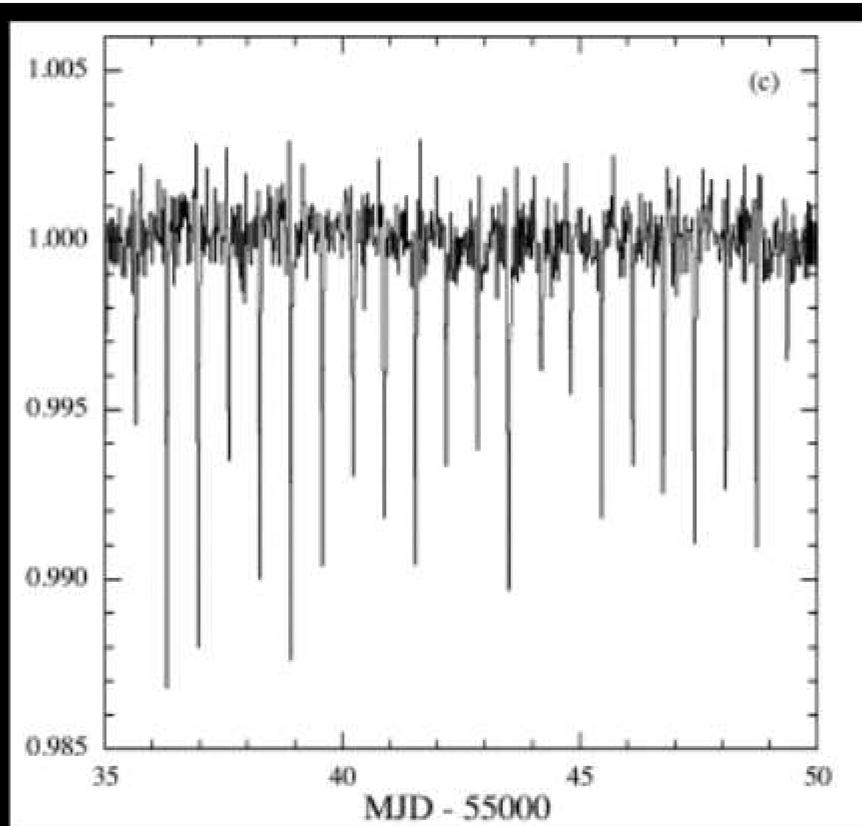


Fig. 8.— Example of multiple transits generated by eleven objects, grouped in prime numbers (1, 2, 3 and 5 objects). Note that the time between transits also increases as a prime numbers series. Each object has a Saturn-like cross-section and transits the star HD209458 with an impact parameter $b = 0.5$. 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).





KIC 12557548 (Rappaport et al. 2012)

KIC 8462852: THE INFRARED FLUX

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

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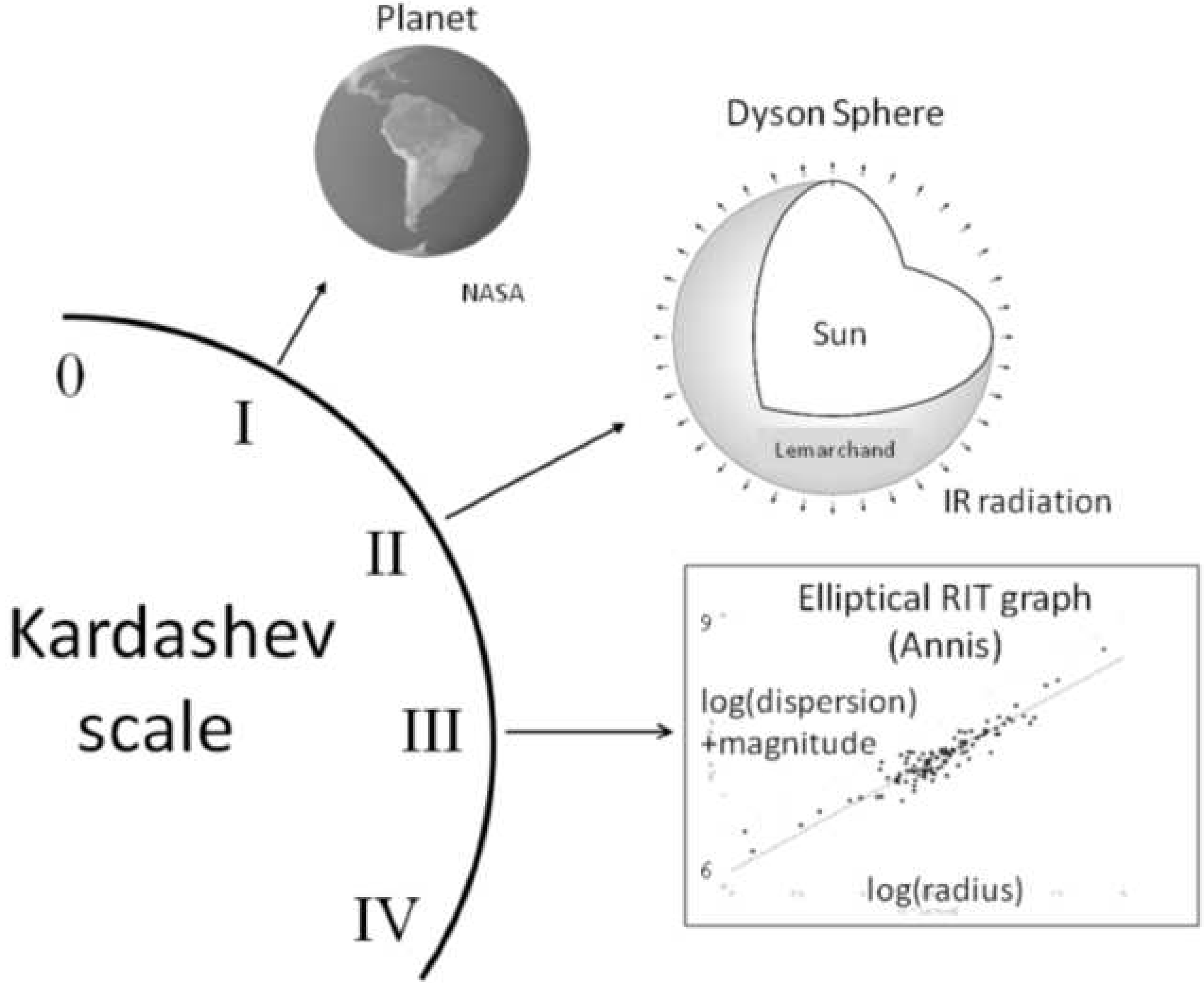
Article PDF

+ Article information

Abstract

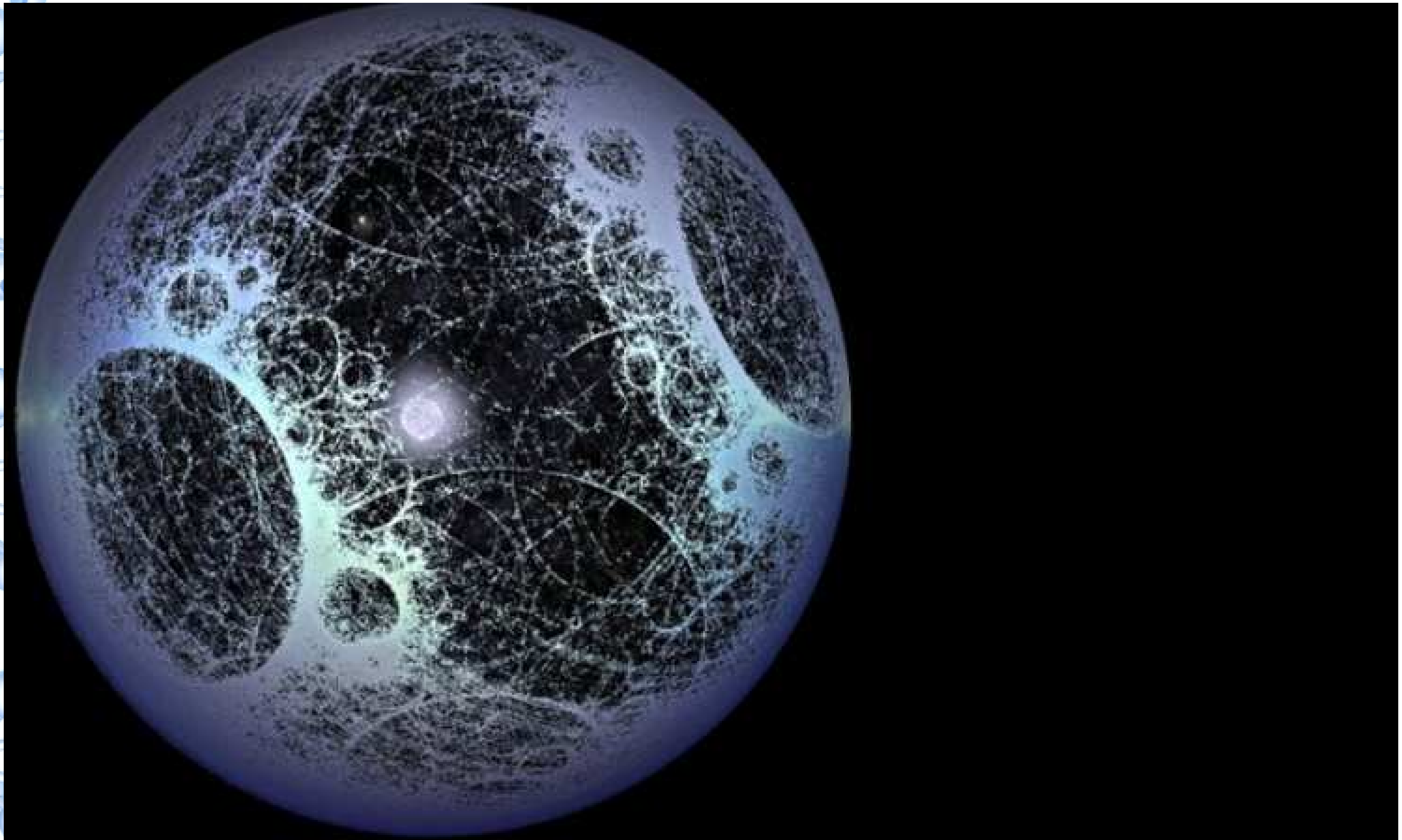
We analyzed the warm *Spitzer*/IRAC data of KIC 8462852. We found no evidence of infrared excess at 3.6 μm and a small excess of 0.43 ± 0.18 mJy at 4.5 μm below the 3σ threshold necessary to claim a detection. The lack of strong infrared excess 2 years after the events responsible for the unusual light 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.


Planet
NASA
Dyson Sphere
Sun
Lemarchand
IR radiation
0
I
II
III
IV
Kardashev
scale
Elliptical RIT graph
(Annis)
9
log(dispersion)
+magnitude
6
log(radius)

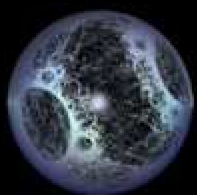
A galaxy full of Dyson spheres would be an example of a true K3 civilization

Such a galaxy would appear as a very red, extended source

Fanciful illustrations of Dyson Spheres


Dyson (1960); image by Steve Bowers

Dyson "spheres" will be difficult to distinguish from "natural" Galactic sources without spectra



GAIA will eventually provide distances (and so luminosities) for most candidates

- Zero parallax: Extragalactic sources —follow up as galaxies
- Giant star luminosity: Likely dusty giant star, low priority
- Stellar luminosity: Excellent candidate for follow-up:
  - Mid-infrared spectra to check for dust
  - Position in galaxy to check for association with star forming region


Ĝ: Glimpsing Heat from Alien Technologies
Phase I: K3 search of resolved galaxies
Phase II: K2 search of point sources
Phase III: K3 search of unresolved galaxies

Next steps

- Spectroscopic follow up of best galaxy candidates
- Matches with other catalogs will produce list of point sources consistent with Dyson spheres
- GAIA will segregate Dyson sphere candidates into three categories:
    - Extragalactic (likely AGN or dusty galaxies)
    - Dusty giant stars
    - ~Solar luminosity objects for further study
- Produce list of "reddest" objects in all of the WISE colors
- Return "cleaned" catalog to IPAC to remove artifacts from public catalog
- Search other unusual or rare objects (such as HI galaxies or red spirals) for excess waste heat

Kardashev Scale	Barrow Scale
KI – energy consumption at ~ 4 x 10^{19} erg s^{-1}	BI – manipulates objects of its own scale ~ 1 m
KII – energy consumption at ~ 4 x 10^{33} erg s^{-1}	BII – manipulates genes ~ 10^{-7} m
KIII – energy consumption at ~ 4 x 10^{44} erg s^{-1}	BIII – manipulates molecules ~ 10^{-9} m
	BIV – manipulates individual atoms ~ 10^{-11} m
	BV – manipulates atomic nuclei ~ 10^{-15} m
	BVI – manipulates elementary particles ~ 10^{-18} m
	BΩ – manipulates space-time's structure ~ 10^{-35} m

Table 1. Energetic and Inward civilization development

Kardashev's (1964) types refer to energy consumption; Barrow's (1998, 133) types refer to a civilization's ability to manipulate smaller and smaller entities. In section 3, we combine those two scales.

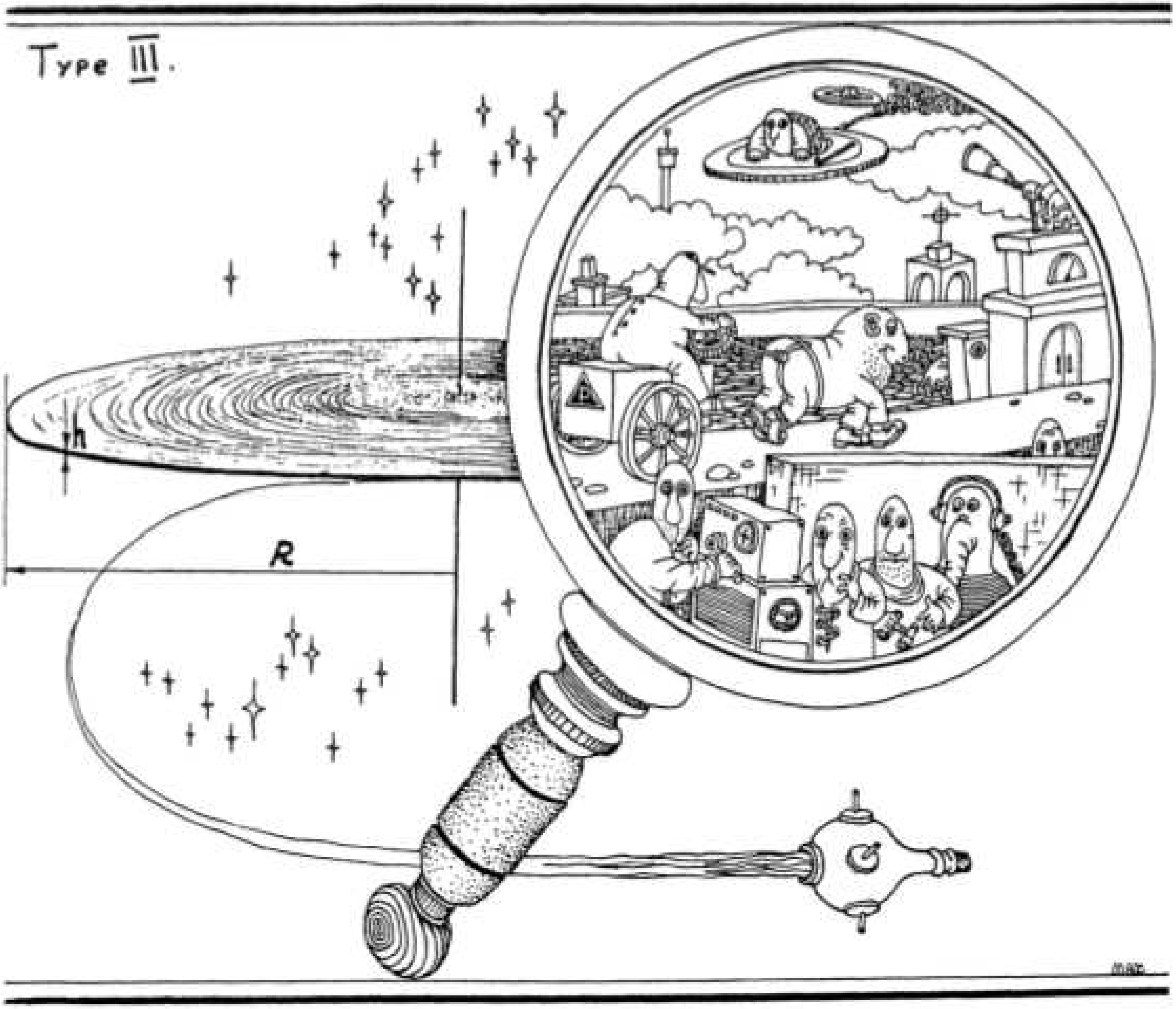


FIGURE 1. A general view of a Type III Supercivilization (cartoon by I. Maximov).

Examples of Interstellar Archaeology								
Kar. num.	Interstellar archaeology type	Ref.	Reach (1000 ly)	L_c (lifetime)	L_c (kyrs)	Power Needs (W)	Mass Involved (kg)	Problems
0	SETI(radio)	[25]	to 0.25 now, 30 soon	civilization	5	10^6		often needs intent
0	planetary atmospheres	[39]	O(0.1)	atmospheric perturbation	O(0.1)		$\sim 10^{15}$	ambiguity
0	stellar salting	[43]	~30	λ isotope	$O(10^3)$		10^8	natural signals
0	nuclear waste	[46]	~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	[5]	to 1	civilization dyn. stab.	5	$4*10^{26}$	10^{25}	mimics
II	stellar engineering	[12]	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	[23]	$O(10^5)$	galaxy crossing	10^5	10^{37}	10^{36}	dark galaxies

Description	White Dwarf			Dyson Sphere		
	Mass ($M_\odot$)	Luminosity ($L_\odot$)	Radius (km)	Radius (km)	Temperature (K)	Gravity (m/s^2)
Most suitable WD	0.88	1.6×10^{-4}	6.5×10^3	3.1-4.4 $\times 10^6$	308-260	12-6.1
Most massive suitable WD	1.03	1.5×10^{-4}	5.3×10^3	3.4-4.2 $\times 10^6$	289-260	12-7.9
Most luminous suitable WD A	0.80	2.9×10^{-4}	7.1×10^3	4.1-4.2 $\times 10^6$	310-308	6.2-6.0
Most luminous suitable WD B	1.01	2.9×10^{-4}	5.5×10^3	4.1-4.7 $\times 10^6$	310-290	7.8-6.0
System with largest possible habitable DS	1.02	2.3×10^{-4}	5.4×10^3	3.6-4.8 $\times 10^6$	310-272	10.2-6.0
System with smallest possible habitable DS, containing the least massive and least luminous suitable WD	0.34	3.8×10^{-5}	11.7×10^3	1.9-2.1 $\times 10^6$	271-260	12-10.2

Table 1: Properties of some particular suitable white dwarfs and the associated potential Dyson Sphere ranges. The radius, temperature and gravity data are given from the smallest to the largest suitable Dyson Sphere for a given white dwarf. The most suitable white dwarf is highlighted in Figure 6.

Table 2
Accelerator power to reach $\sigma_{\rm Planck}$

Beams	Limiting interaction[a]			Υ[b]		Υ/t_H		Υ/Myr		Notes
	Process	$\sigma(s_{\rm Planck})$[mb]	$\mathcal{O}[\sigma(s)]$	(erg)	($M_\odot c^2$)	(erg s^{-1})	($L_\odot$)	(erg s^{-1})	($L_\odot$)	
pp	$p+p\to\pi+$anything	~ 2000	$\ln^2 s$ (?)	1×10^{56}	70	3×10^{38}	7×10^4	4×10^{42}	1×10^9	(c)
$p\gamma$	$p+\gamma\to\pi+$anything	~ 7	$\ln^2 s$ (?)	4×10^{53}	0.2	9×10^{35}	200	1×10^{40}	3×10^6	(d)
$e^\pm e^-$	$e^\pm+e^-\to e^++e^-+e^++e^-$	1500	$\ln^3 s$	9×10^{55}	50	2×10^{38}	5×10^4	3×10^{42}	7×10^8	(e)
$\mu^\pm\mu^-$	$\mu^\pm+\mu^-\to\mu^++\mu^-+e^++e^-$	1000	$\ln^3 s$	6×10^{55}	30	1×10^{38}	3×10^4	2×10^{42}	5×10^8	(e)
$\gamma\gamma$	$\gamma+\gamma\to e^++e^-+e^++e^-$	0.00645	1	4×10^{50}	2×10^{-4}	9×10^{32}	0.2	1×10^{37}	3000	(g)
	$\gamma+\gamma\to$ hadronic	~ 0.02	$\ln^2 s$ (?)	1×10^{51}	7×10^{-4}	3×10^{33}	0.7	4×10^{37}	1×10^4	(d)
$p\nu$	$p+\nu\to$ anything	0.059	$\sqrt{s}^{0.36}$	3×10^{51}	0.002	8×10^{33}	2	1×10^{38}	3×10^4	(h)
$\nu_i\bar{\nu}_j$	$\nu_i+\bar{\nu}_j\to\ell_i+\bar{\ell}_j$	2.2×10^{-7}	1	1×10^{46}	7×10^{-9}	3×10^{28}	8×10^{-6}	4×10^{32}	0.1	(i)
$\nu_i\nu_j$	$\nu_i+\nu_j\to\nu_i+\nu_j$	7.0×10^{-8}	1	4×10^{45}	2×10^{-9}	9×10^{27}	2×10^{-6}	1×10^{32}	0.03	(i)

[a] The cross sections are evaluated at $s=E^2_{\rm Planck}$.

[b] The total energies needed are calculated from eqn. 5 assuming that $n_{\rm events}=1$, $\kappa=0.1$, and $\sigma_{\rm natural}=\sigma_{\rm Planck}$.

[c] Cross section as estimated from Olive & Particle Data Group (2014) (Section 50); the inelastic cross section is of order half of this. The $\ln^2 s$ dependence is expected in "black disk" models of nucleons. The Froissart bound is frequently interpreted as leading to a $\ln^2 s$ dependence as $s\to\infty$. But the size of the $\ln^2 s$ term, as well as the possibility of a slightly more rapidly growing term, are disputed. See, for example, Azimov (2011); Block & Halzen (2011); Fagundes et al. (2013); Anisovich et al. (2013a,b).

[d] Uses the Olive & Particle Data Group (2014) fits to the hadronic interaction cross sections.

[e] Formulae for cross sections summarized in Budnev et al. (1975). See also the discussion on muon accelerators in Ginzburg (1996).

[g] From Brown et al. (1973).

[h] From Gandhi et al. (1998).

[i] From Roulet (1993).