Extreme SETI
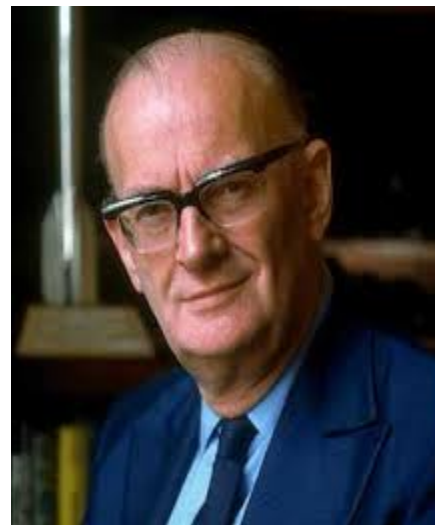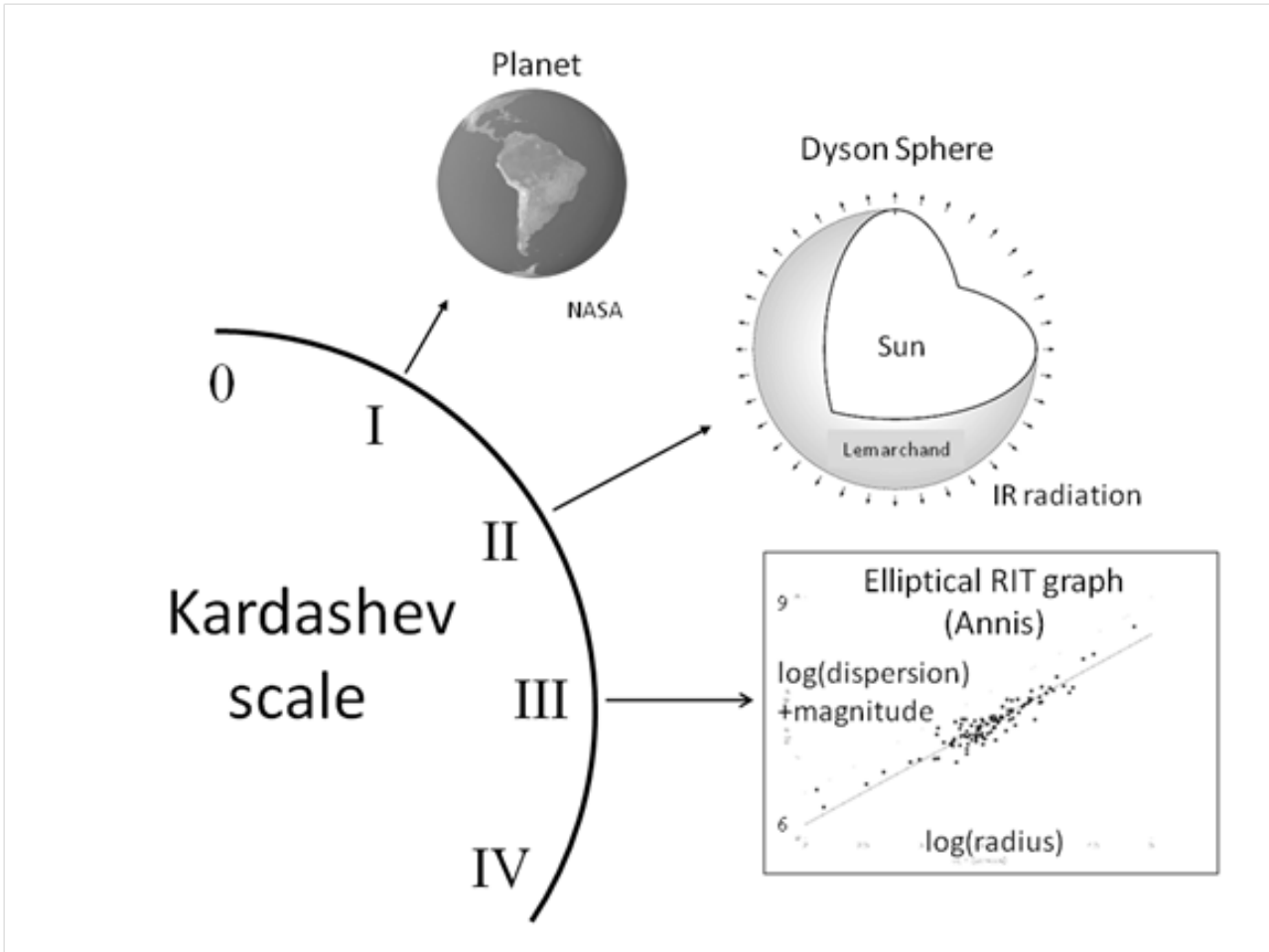# Albert Allen Jackson IV
Lunar and Planetary Institute, Houston, Texas

Big Thinks

Freeman Dyson and Nikolai Kardashev

Planet

NASA

Dyson Sphere

Sun

Lemarchand

IR radiation

Kardashev scale

0

I

II

III

IV

Elliptical RIT graph
(Annis)

9

log(dispersion)
+magnitude

6

log(radius)

Zubrin(Possible Propulsion Systems, 1995)

Type	Radiated at Source	Frequency	Detection
Radio*	80-2000 TW	10 – 48 kHz	Yes-Magsails ~ 100 to 1000 ly
Visible	120000 TW	IR	Yes – Antimatter Possibly at 300 ly
X-Rays	40000 TW	2 - 80 KeV	Marginal at ~10 ly-1000ly!
Gamma Rays	1 – 32 MeV	20-200 Mev	Maybe

*Includes bow shocks

Ansatz

Following the lead of Freeman Dyson and Nikolai Kardashev
I will take the civilization to be Kardashev 2, or K2.
These problems have been solved a K2 civilization.
1)K2 civilization have interstellar flight.
2)K2 civilizations can deploy an instrumentality that can 'engineer' a local
Astronomical environment.
 3) Whatever the problem ……. a K2 civilization can solve it.
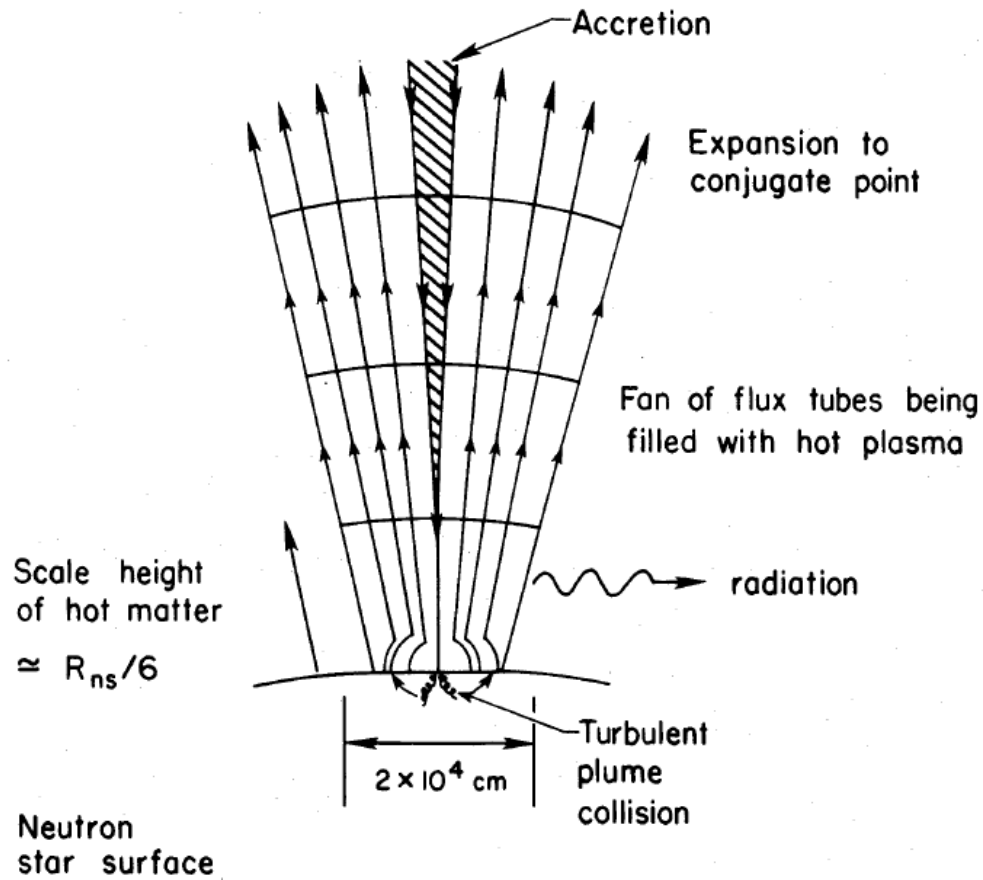Is all this possible?

Science Fiction prose writers have been doing it for almost 80 years now, …..so
what the hell!

Neutron Star
and
Black Hole Beacons

1.Bombing Neutron Stars
2.Black Hole Lensing
3. Kerr Black Hole Bombs

20000 km — Distortion

3000 km — Elongation and Compression

300 km

Impact

Neutron Star 10km
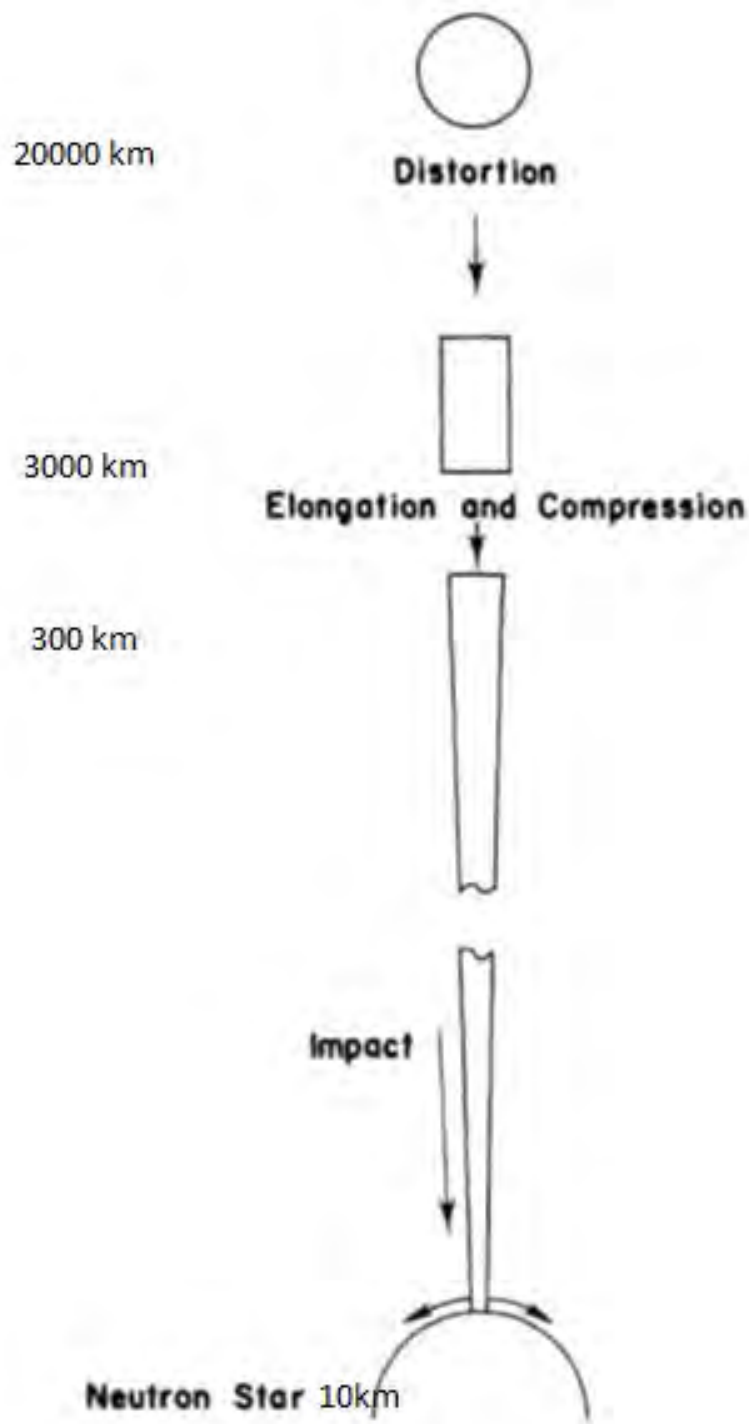
Colgate and Petsheck
Ap. J 1983

Impact energy $E = \dfrac{G M_{ns} \, m_{imp}}{R_{ns}}$.

For a ~ 1km impactor density of iron (8 gm/cm^3) E ~ $10^{36}(\dfrac{m_{imp}}{10^{16}}) ergs$

Colgate and Petsheck
Ap. J 1983

Gravitational Lensing

Source

$$R_{cross} \approx \frac{b}{\alpha}$$

For a week deflector and/or the source far away:

$$\alpha = \frac{4GM_{Sun}}{c^2 R_{Sun}} = 1.7 \text{ arcsec}$$

$$gain \approx \frac{2\sqrt{GM}}{D} \quad D \to 0 \; gain \; \to \infty$$

Wave Optics

Solve the wave equation

$$g^{\alpha\beta}\partial_{\alpha\beta}\phi = 4\pi T$$

On the Schwarzschild background

$$c^2 d\tau^2 = (1 - \frac{2GM}{r})dt^2 - (1 - \frac{2GM}{r})^{-1}dr^2 - r^2(d\theta^2 + \sin^2 d\varphi^2)$$

To get the amplitude

$$\emptyset = \frac{\pi w}{1 - e^{-\pi w}}\left[F_1^1(\frac{iw}{2}, \frac{iwyD^2}{2}\right]$$

$w = 4GM\omega$ and F_1^1 is a confluent Hypergeometric function

As D goes to 0 the amplification and $w \rightarrow \infty$

$$\phi\phi^* \approx \mu = 10^5 \left(\frac{M}{M_{sun}}\right)\left(\frac{\omega}{GH_z}\right)$$

For visible light $\omega \sim 500$ TH$_z$, M = 5 Solar Masses then
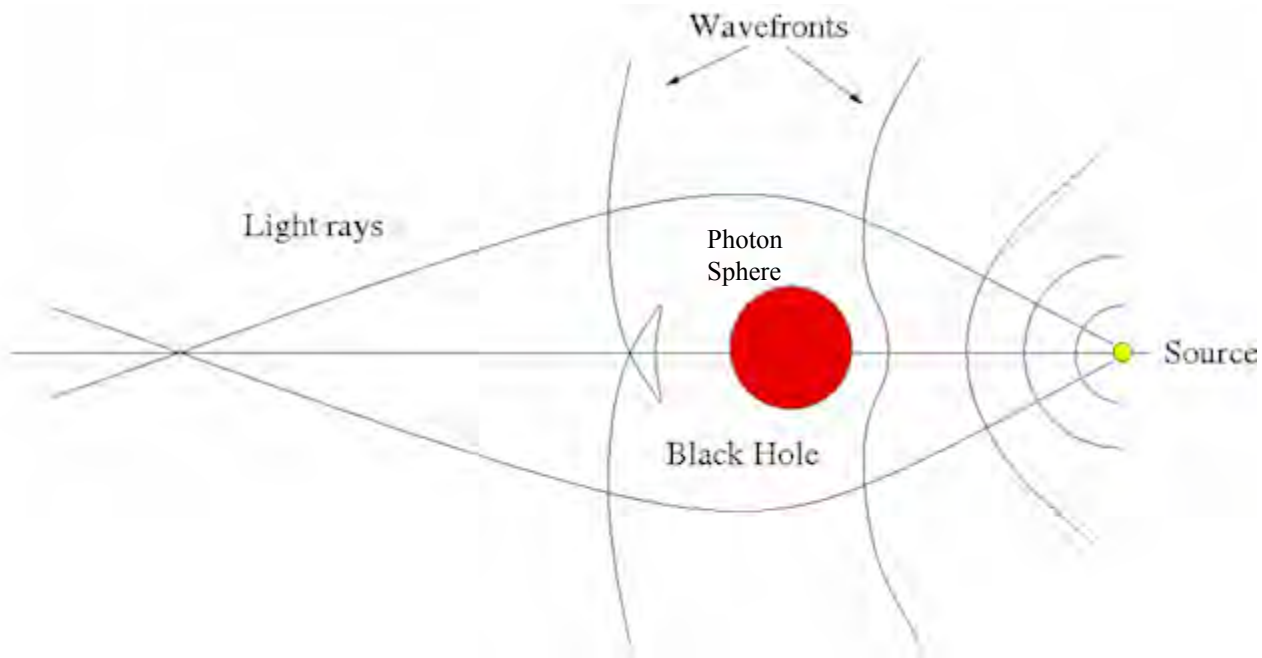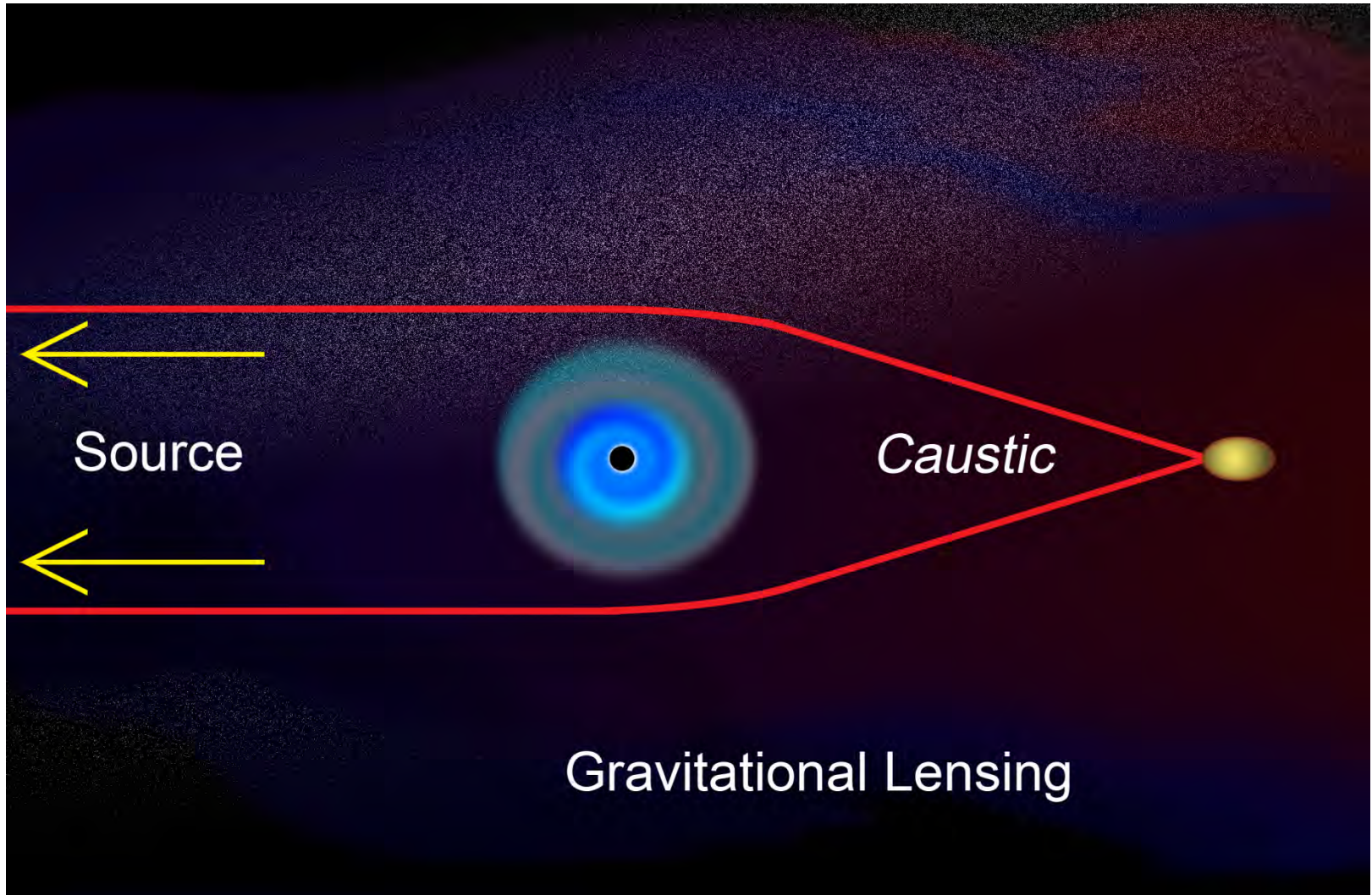
$\mu = 10^{17}$, so 1 watt in 10^5 terawatts out.

Three critical radii

Highly non-Newtoian sphere $= 10R_s$

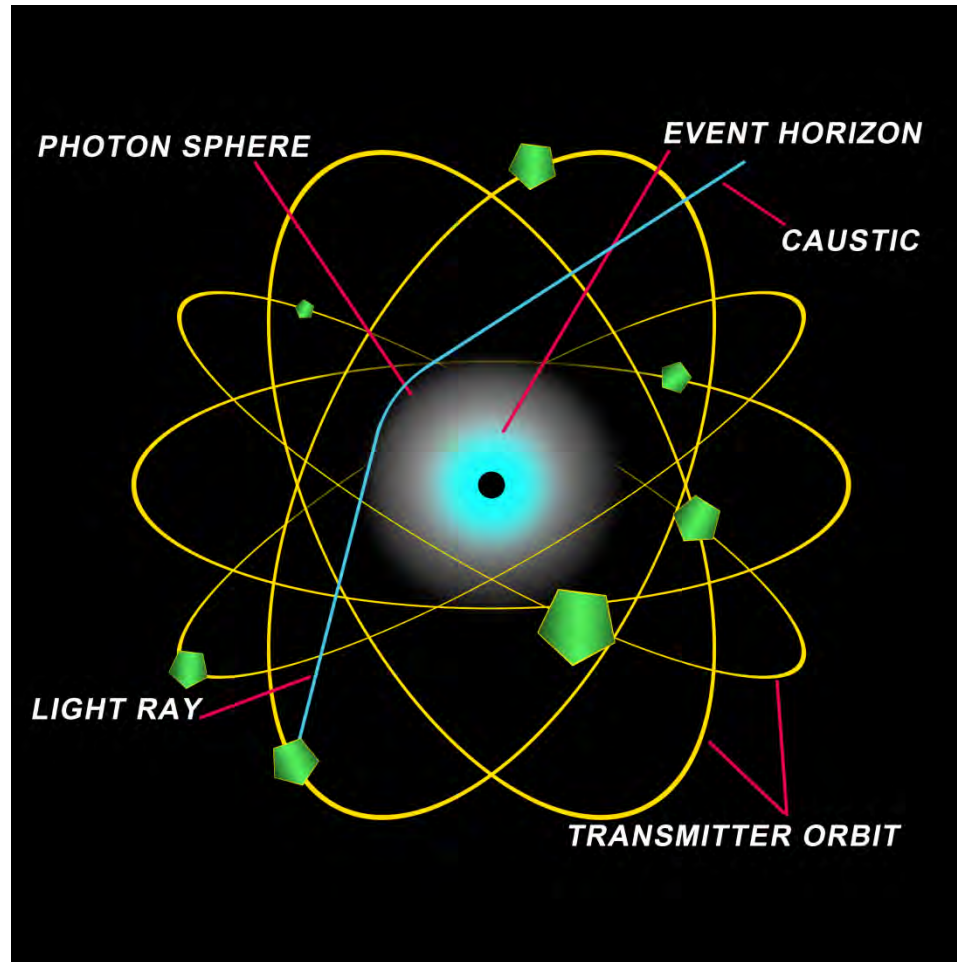Photon Sphere $= 3R_s$
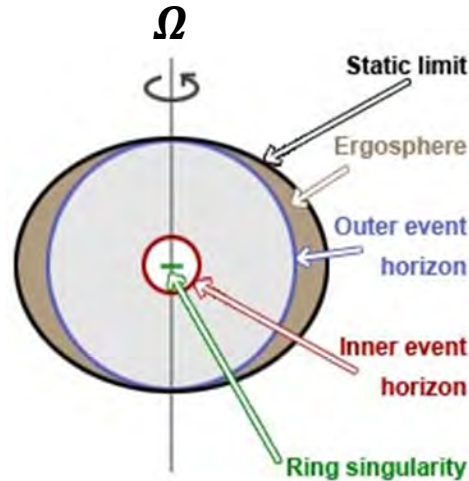
Event Horizon $R_s = \frac{2GM}{c^2}$

Wavefronts

Light rays

Photon
Sphere

Source

Black Hole

F. FRUTOS-ALFARO   *ET*   *AL.*

Source

Caustic

Gravitational Lensing

Gravitational Lensing Constellation

Kerr Black Hole Bomb Beacons

Ω

The rotational energy in the

Ergosphere of a Kerr BH ~ 10^{52} to 10^{54} ergs!

Ω = angular speed of Outer horizon

Note Angular Momentum (J) parameter $a = \dfrac{J}{Mc}$

The scalar wave equation on the Kerr background

$$g^{\alpha\beta}\partial_{\alpha\beta}\phi = 4\pi T$$

By separation of variables this has the solution

$$\phi = e^{-i\omega t}e^{lm\varphi}S_l^m(\theta)\frac{\Psi(r)}{r}$$

Where (t,r,θ,ϕ) are time and spherical coordinates, ω is the frequency, l is the spheroidal harmonic index and m is the azimuthal harmonics index.

Where (t,r,θ,ϕ) are time and spherical coordinates, ω is the frequency, l is the spheroidal harmonic index and m is the azimuthal harmonics index. When boundary conditions are applied for the ingoing and outgoing wave it found that the wave extracts a small amount of energy of the rotating hole. This is called superradiance. If one were to confine the radiation with a spherical mirror there will be exponential growth of the wave amplitude.

For a maximally rotating black hole (a = 1) Outgoing wave gains a small amount of energy on the condition that:

$$\omega \leq m\mathbf{\Omega} \ \text{ or } \omega \approx 16\frac{M_\odot}{M} \ KH_z$$

For a one solar mass rotating black hole (with a = 1) this is a wave length of about 19 km, extremely long wave length radio waves. The wave can be amplified with a mirror, theory shows for a one solar mass black hole, R_s = 3 km, optimum mirror radius = 33 km with an e-folding time of .06 seconds. In 13 seconds the energy content of a pulse in will be 10^{14} (the amplitude squared)! One watt in gives 1 terawatt (10^{12} watts) out!
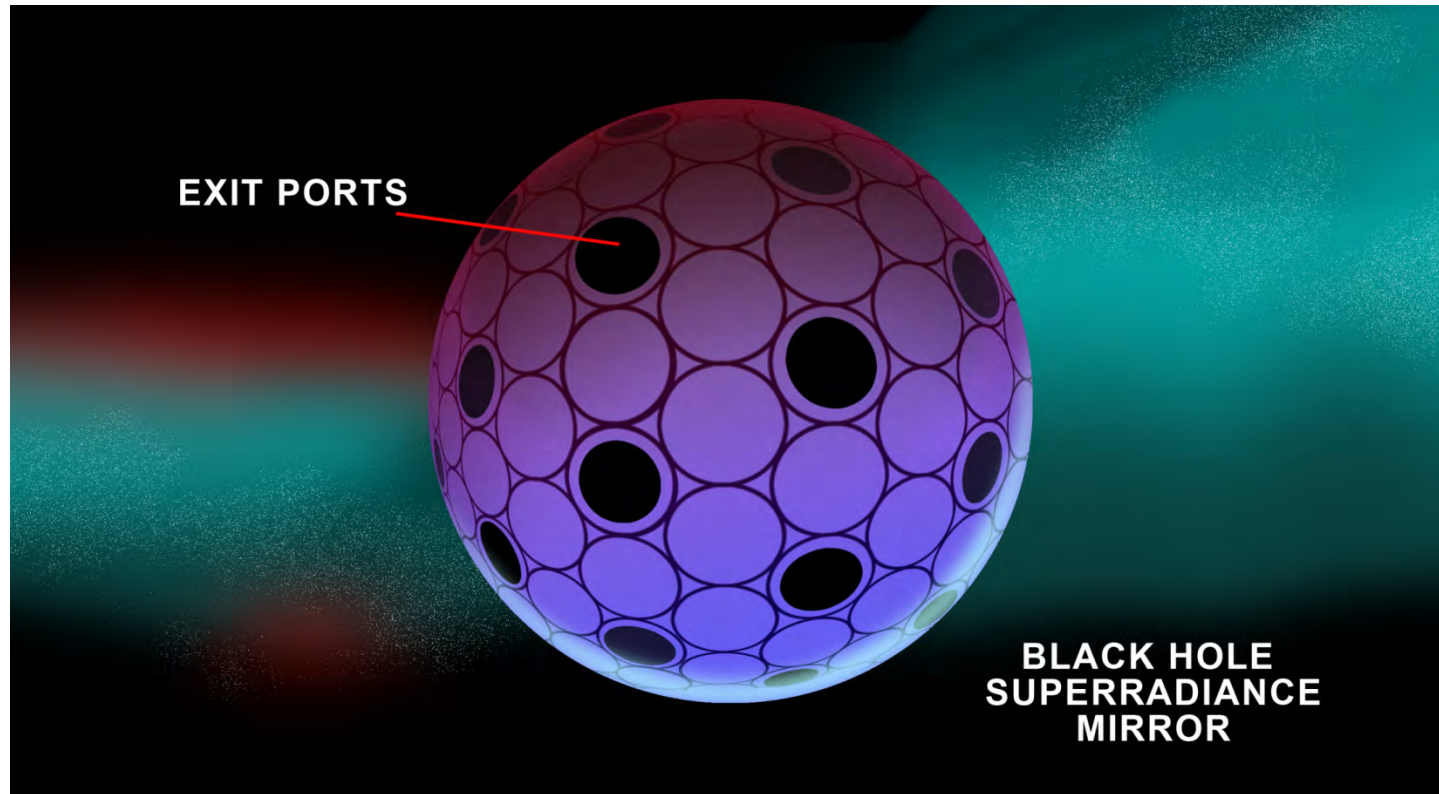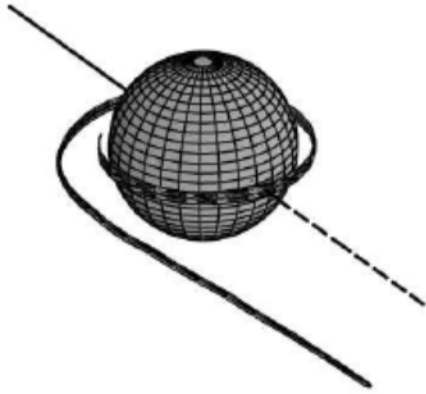
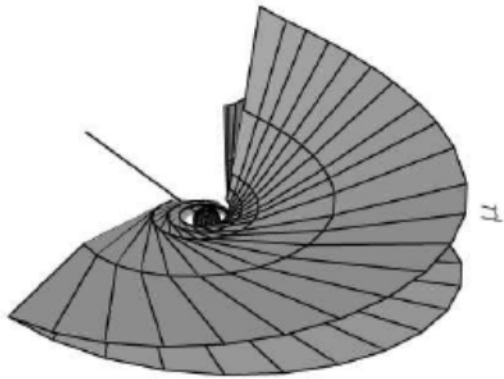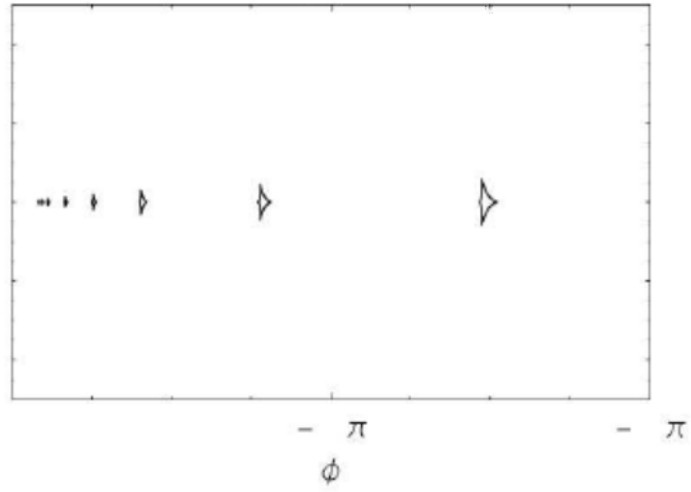33 km mirror about a one solar mass black hole.

Super Radiance
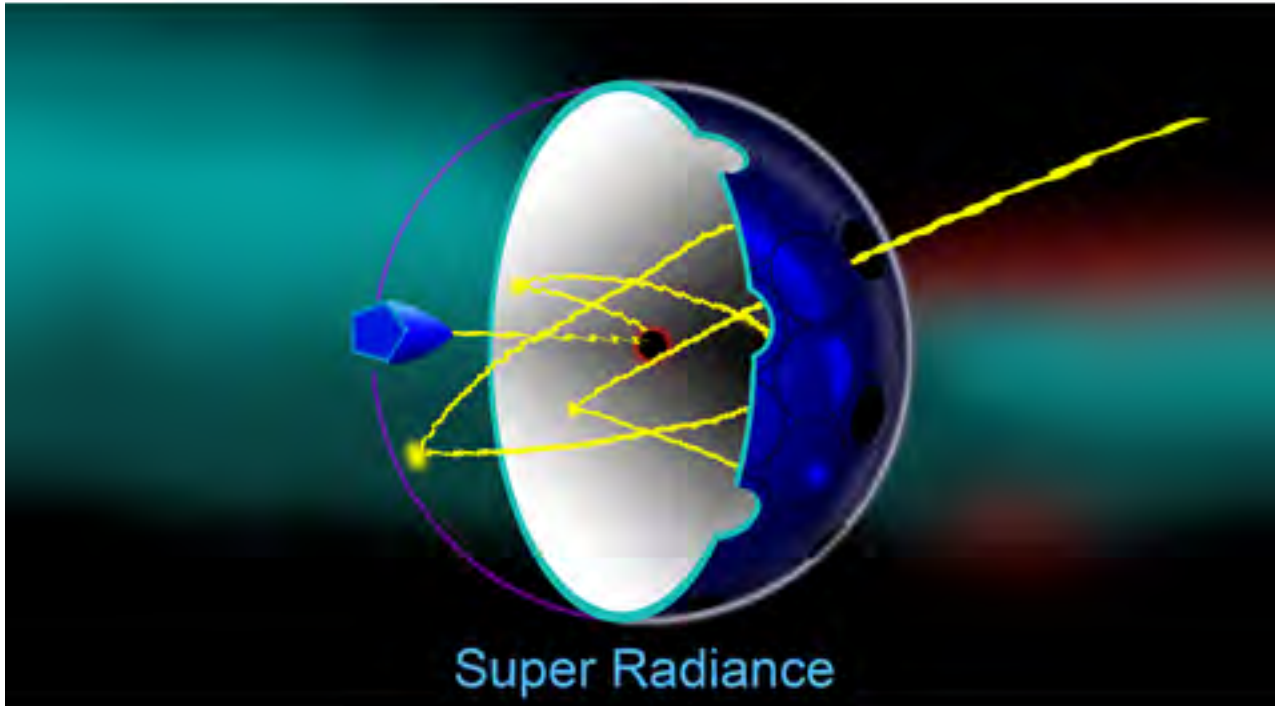
Conclusion

Source	Energy In	Energy Out	Spectrum
Neutron Star Impactor	1 KM Iron Sphere	10^{36} ergs	~10 kev X-rays
Black Hole Lens	1 watt	1 terrawatt (depends on the choice of wave length)	Visible (depends on the choice of wave length)
Black Hole Bomb	1 watt	10 terrawatt	Long wave Length Radio waves

(c)

Supplementary Slide
Extreme SETI