Extreme SETI

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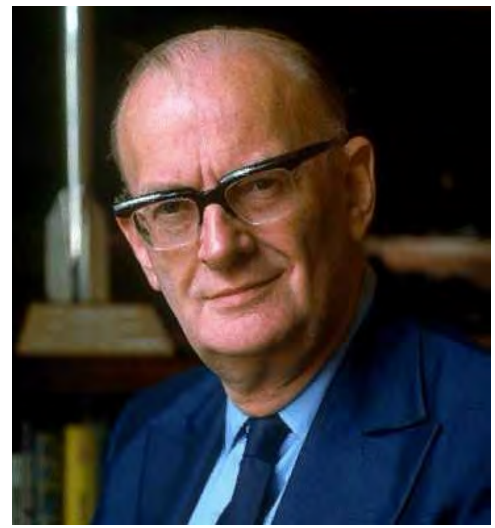
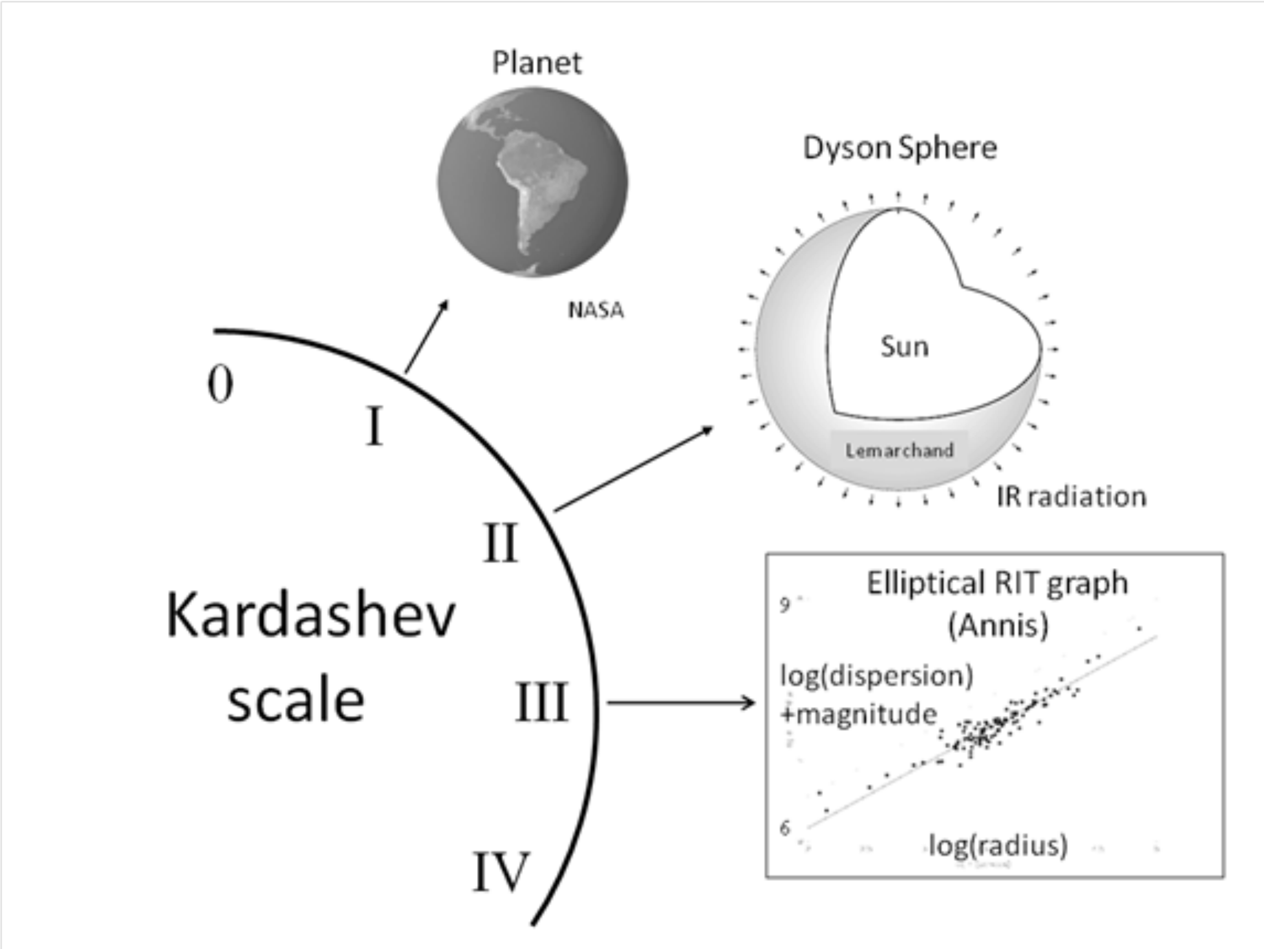


Big Thinks

Freeman Dyson and Nikolai Kardashev



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)

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**

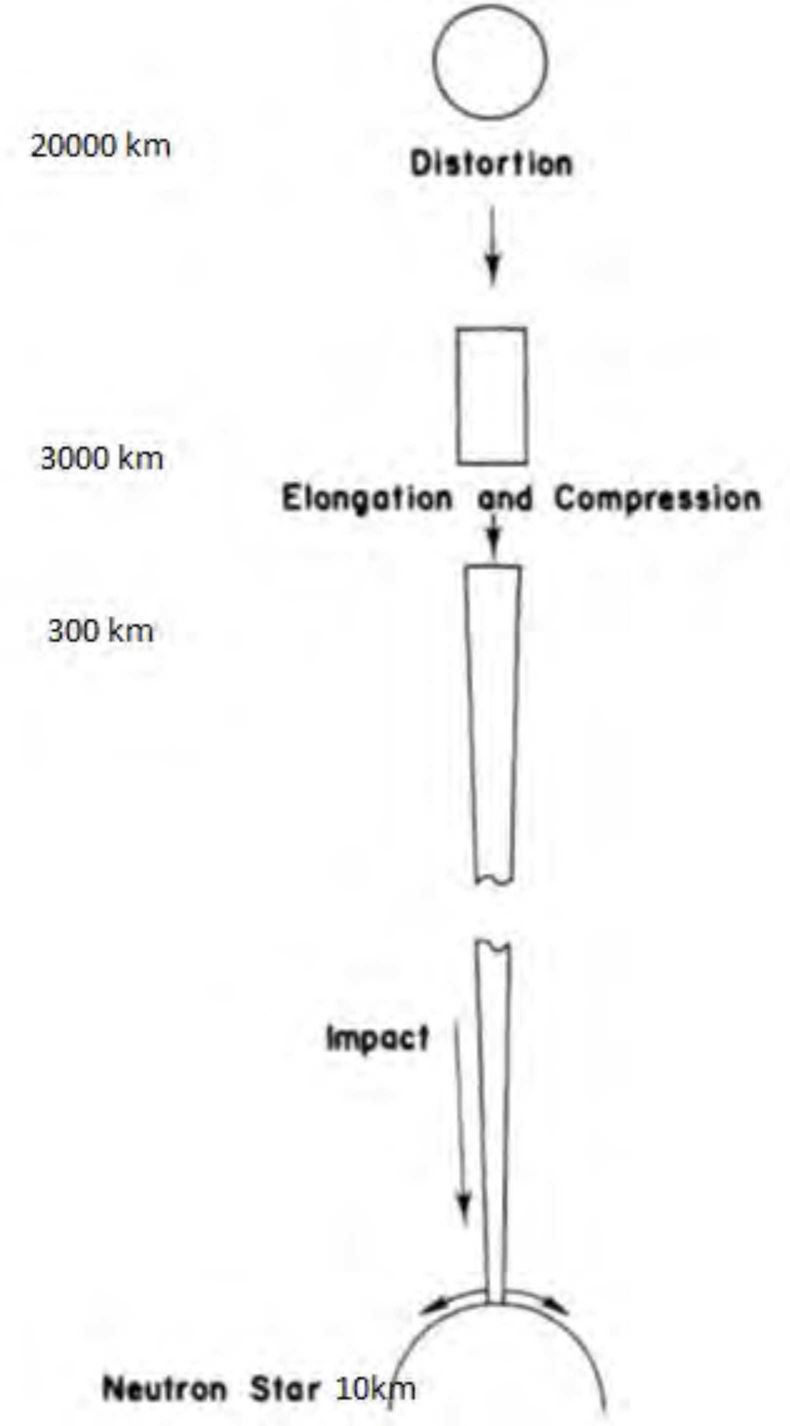
Ansatz

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?

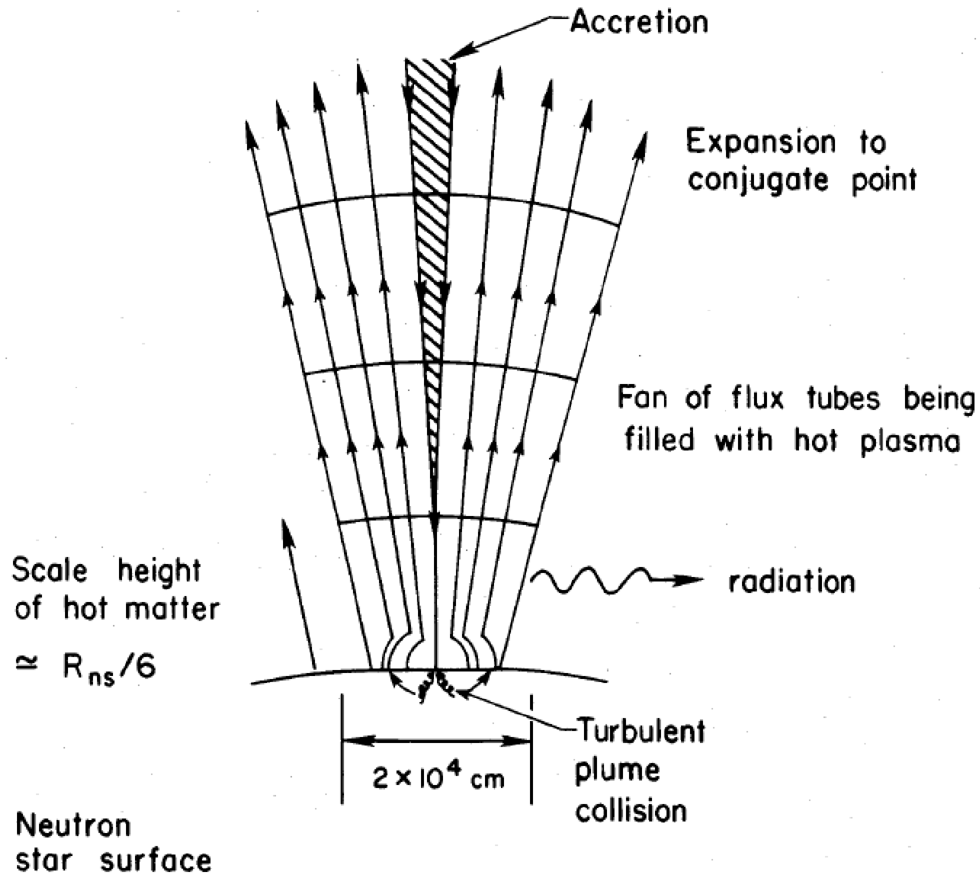
Science Fiction prose writers have been doing it for almost 80 years now, …..so what the hell!

Neutron Star
and
Black Hole Beacons

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



Colgate and Petsheck
Ap. J 1983



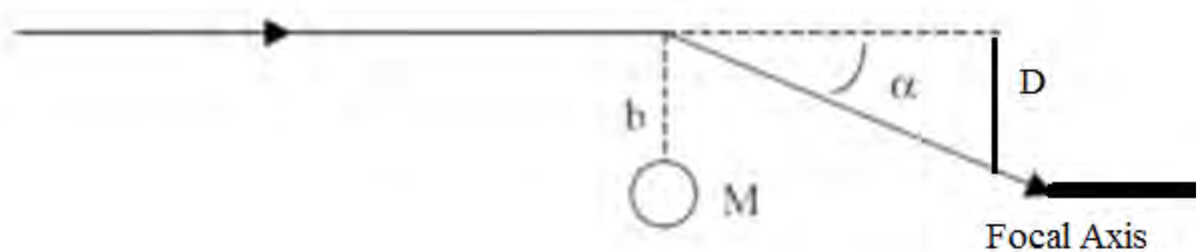
Impact energy $E = \frac{GM_{ns}m_{imp}}{R_{ns}}$.

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

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 → ∞

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

For visible light $\omega \sim 500\ TH_z$, M = 5 Solar Masses then

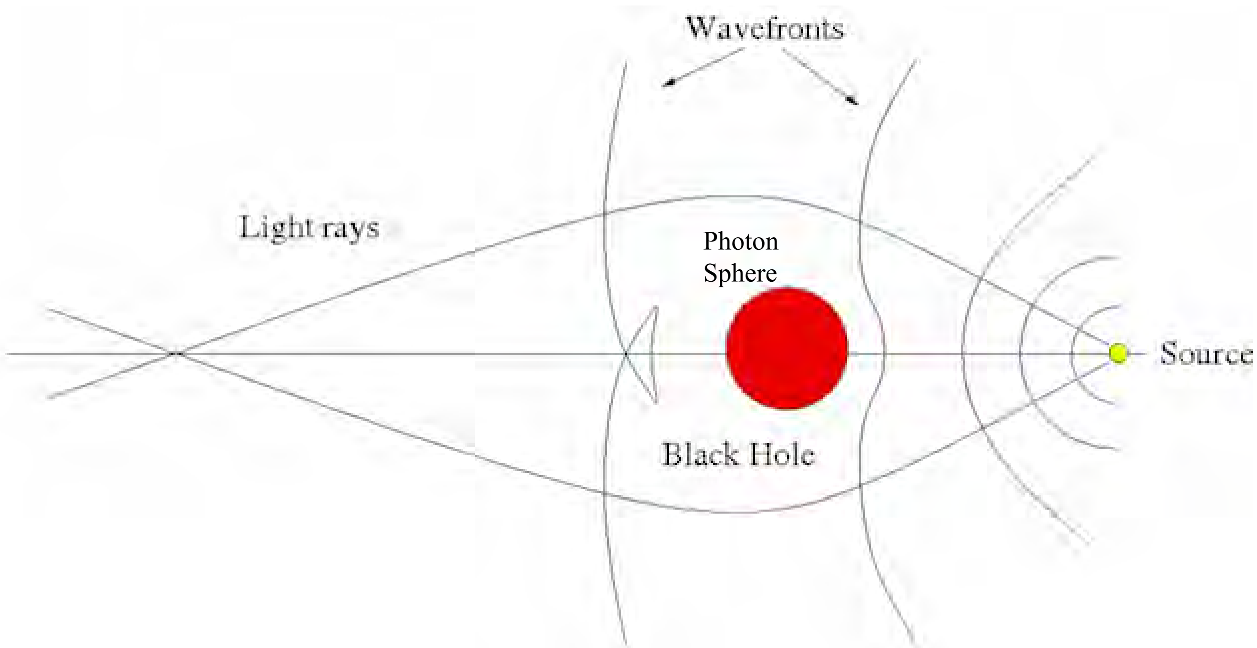
$\mu = 10^{17}$, so 1 watt in 10^5 terawatts out.

Three critical radii

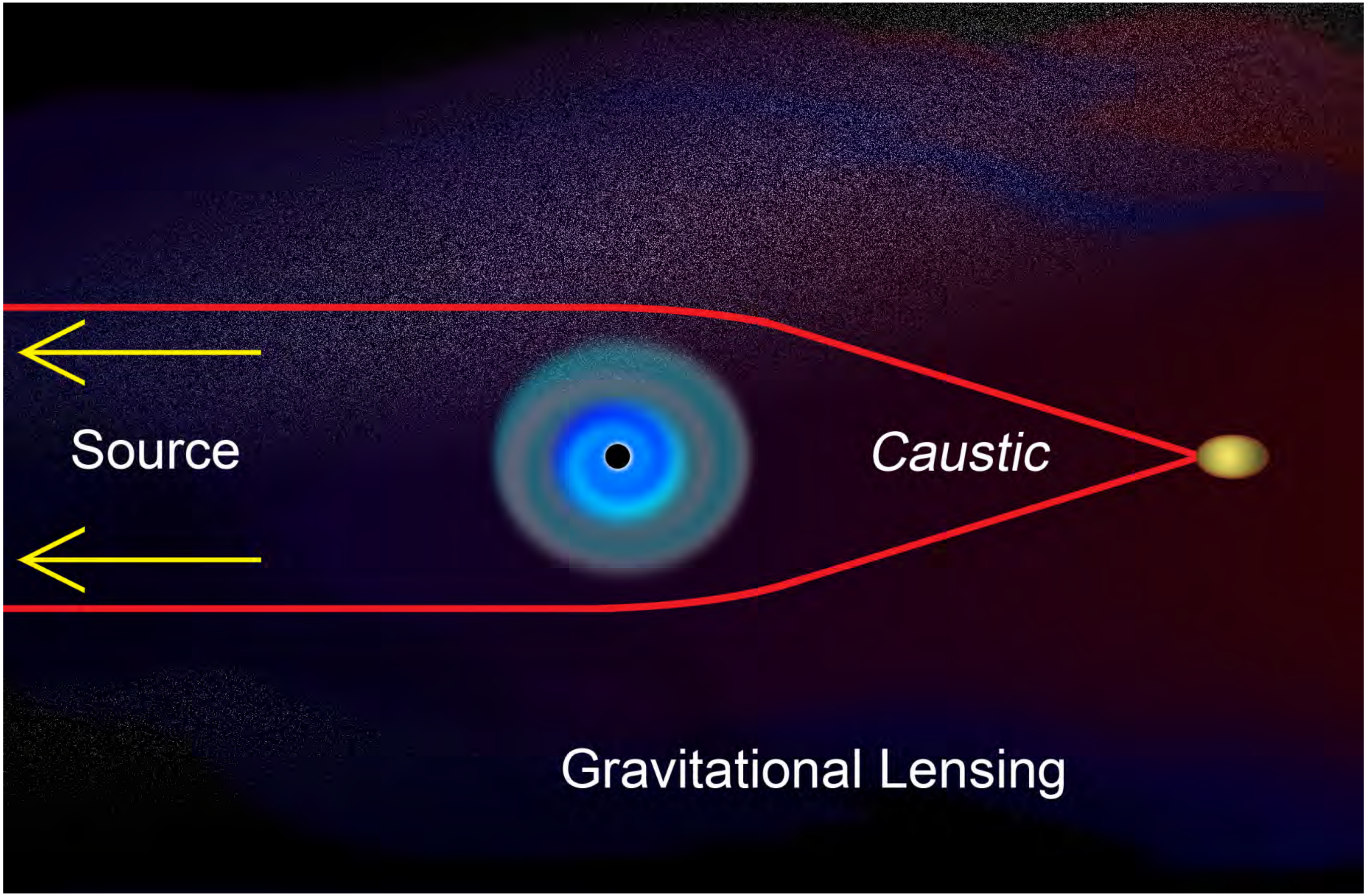
Highly non-Newtoian sphere = $10R_s$

Photon Sphere = $3R_s$

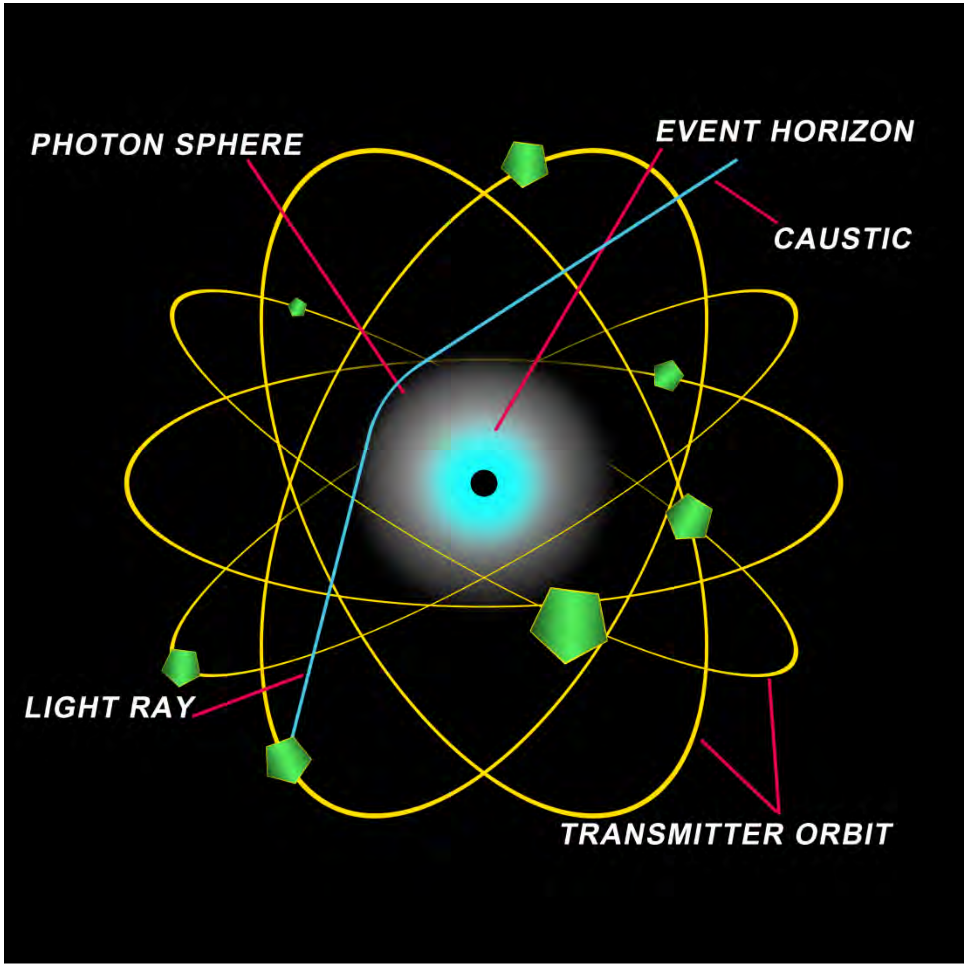
Event Horizon $R_s = \frac{2GM}{c^2}$



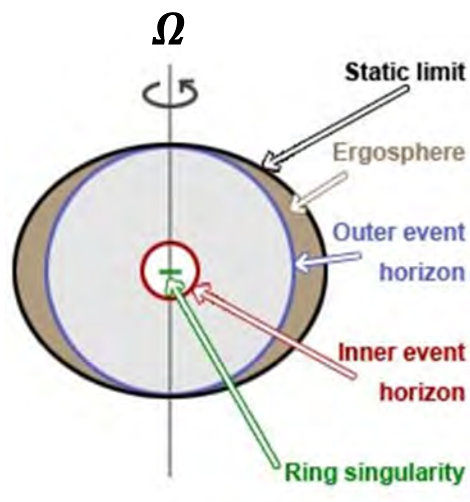
F. FRUTOS-ALFARO *ET AL.*


Source
Caustic
Gravitational Lensing

Gravitational Lensing Constellation



Kerr Black Hole Bomb Beacons



The rotational energy in the

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

Ω= angular speed of Outer horizon

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

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

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

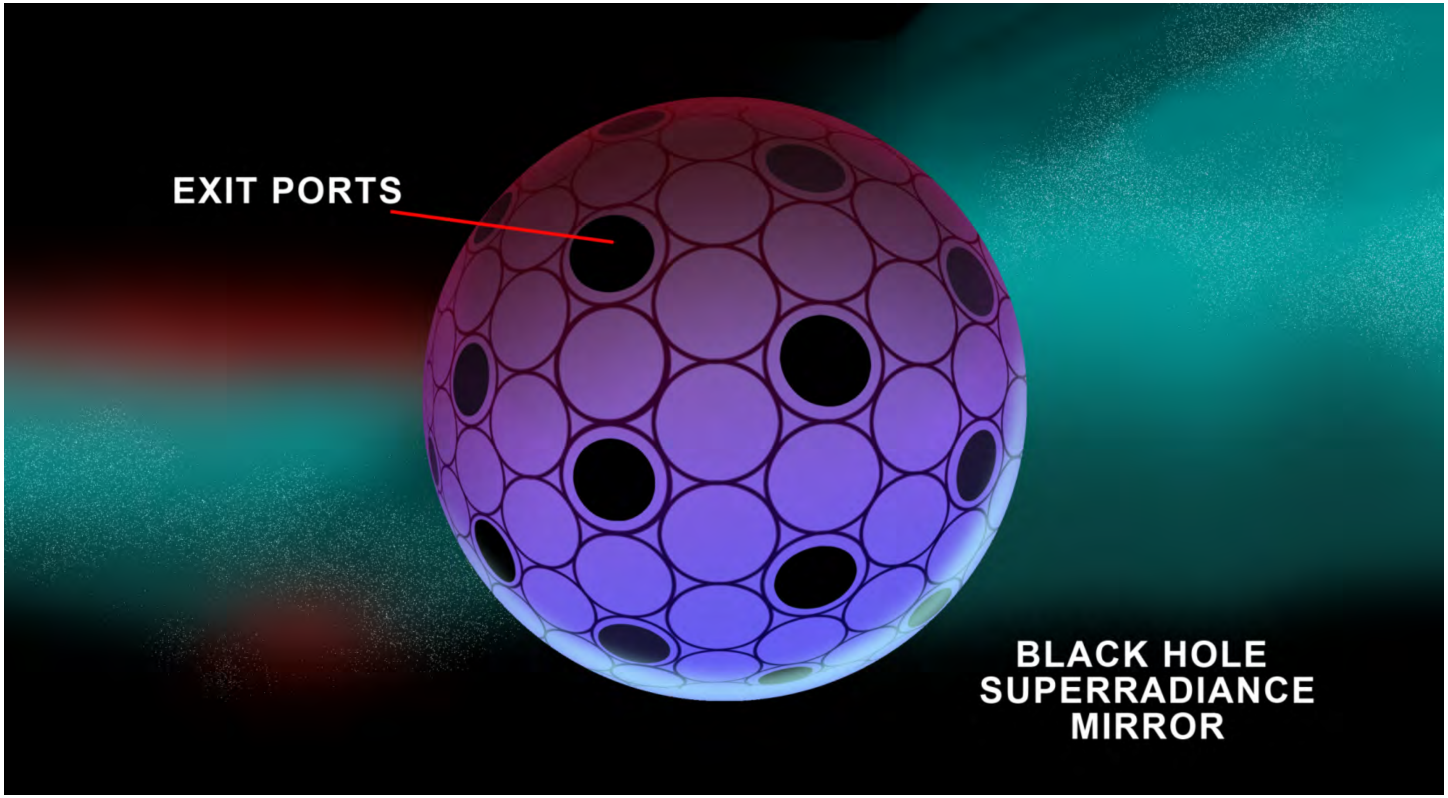
Where (t,r,θ,ϕ) are time and spherical coordinates , ω is the frequency, l is the spheroidal harmonic index and m is the azimuthal harmonics index.

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.

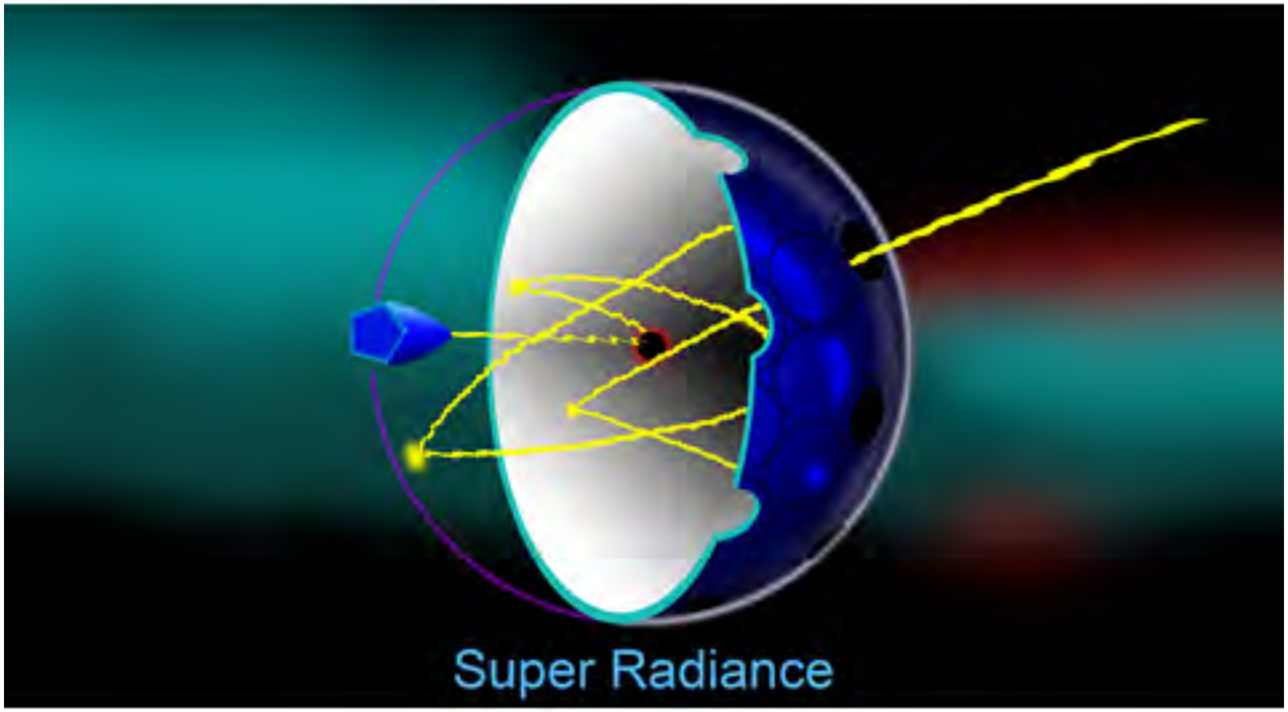
For a maximally rotating black hole (a = 1) Outgoing wave gains a small amount of energy on the condition that:

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

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!

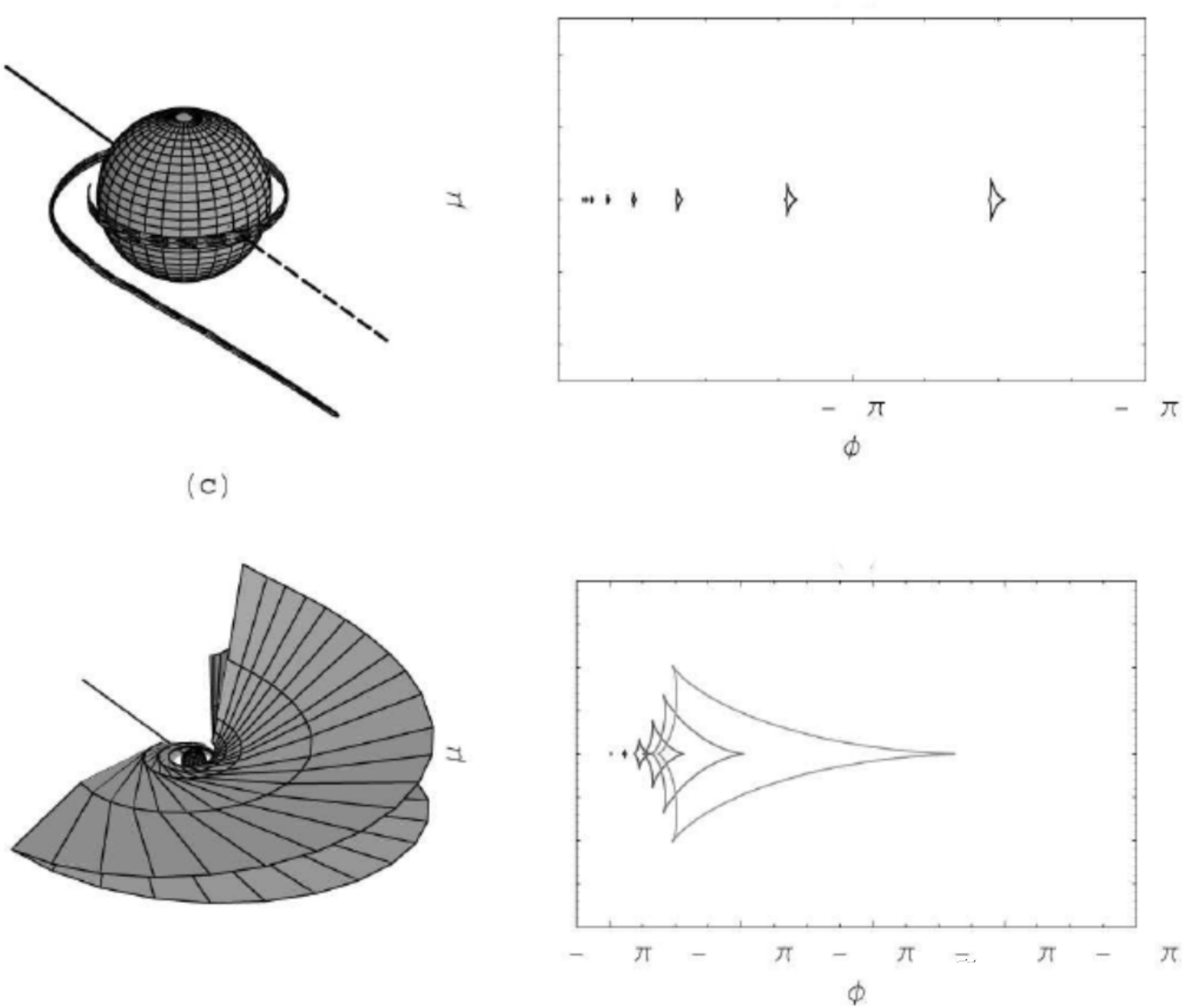


33 km mirror about a one solar mass black hole.


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



Supplementary Slide