THE DARK MATTER-MASSIVE BLACK HOLE CONNECTION

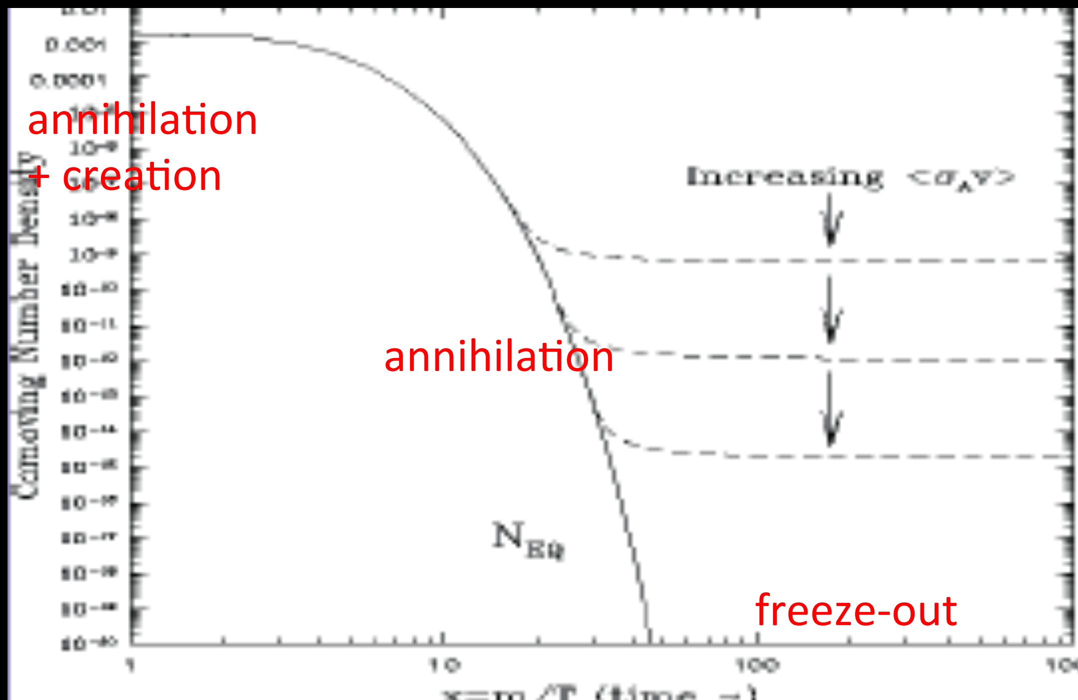
Joe Silk (IAP, JHU, BIPAC)

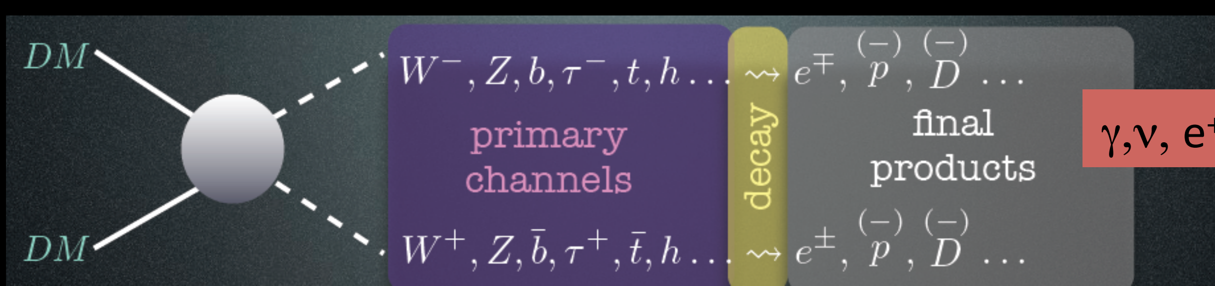
massive black holes are potential amplifiers of dark matter signals

PREDICTING $<\sigma v>$

generic WIMP $<\sigma_{ann} v> \sim \alpha_w^2/m_x^2 = \alpha_w^2/1\ \text{TeV}^2$

SUSY WIMP in thermal equilibrium: relic abundance if $<\sigma_{ann} v> \sim 3\text{x}10^{-26}\ \text{cm}^3/\text{s} \sim 0.23/\Omega_x$





Indirect detection
of high energy γ, ν, e^+…

Following the light Higgs discovery and the failure to find evidence for SUSY, the new frontier for particle physics is likely to be a 100 TeV collider

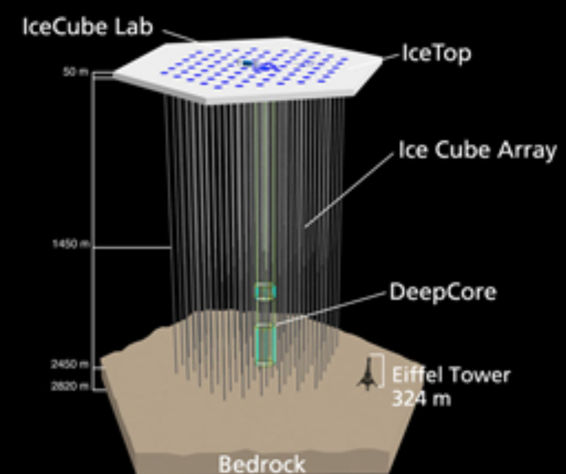
The new frontier for DM detection will shift from light DM (10-100 GeV) where the constraints are increasingly tight on heavy DM

unitarity constrains $\langle\sigma v\rangle \sim m_x^{-2}$: 0.1-30 TeV is a natural window

SUSY relic one of many DM candidates...

But equally natural is asymmetric DM for which m_x=5 GeV

lepton-like asymmetry: $\rho_B=\eta_B n_\gamma m_B$ $\rho_x=\eta_B n_x m_x$ No annihilations!



SUSY aside, minimal DM is attractive: m_x=10 TeV

SM + quintuple: neutral, stable, thermal freeze-out to give relic abundance & annihilation signatures!

SMBH OUTFLOWS CONTROL BARYONIC FEEDBACK

supermassive BH 10^6-10^{10} M_{sun}

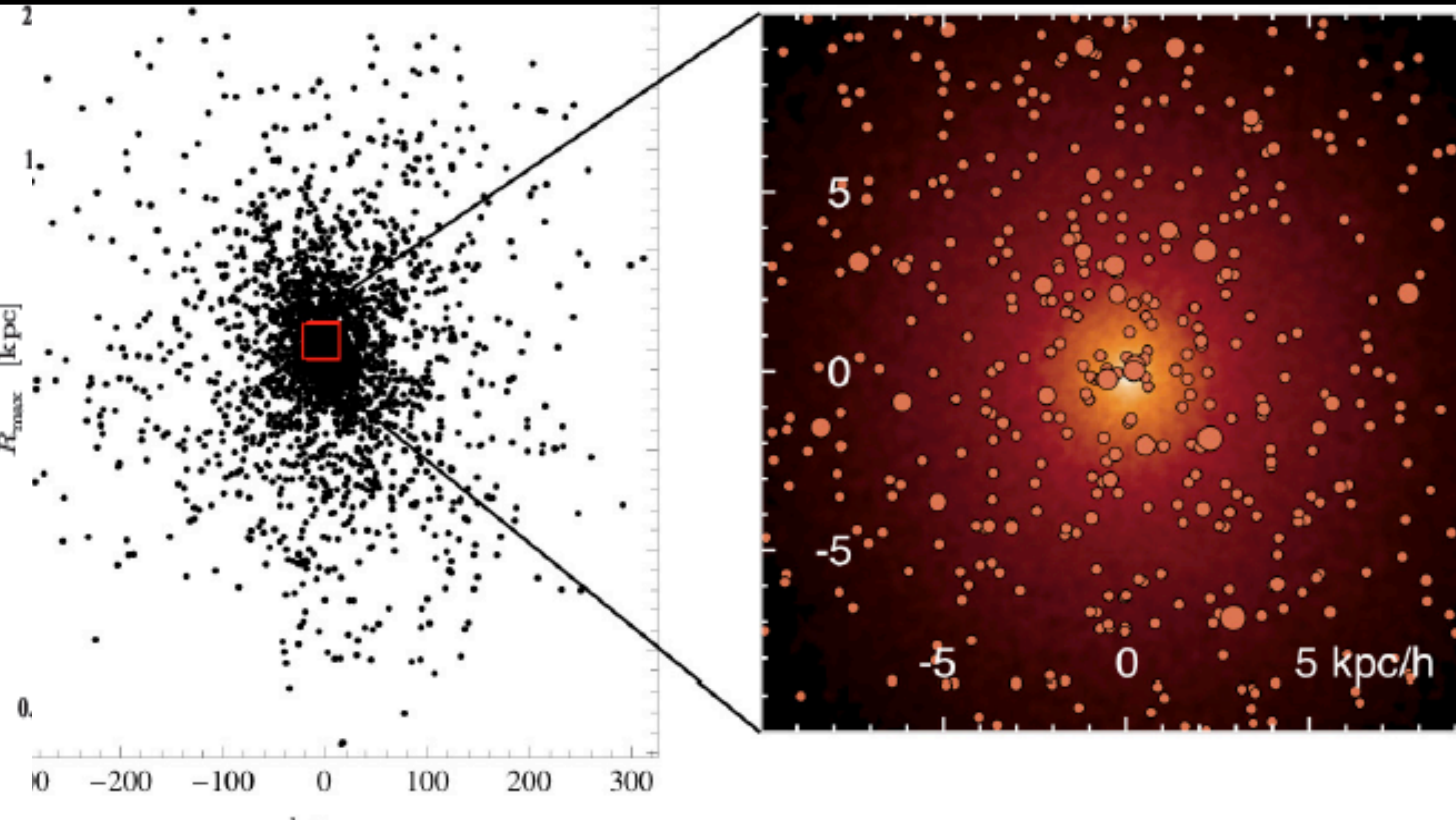
Peirani + 2013

Baryon fraction

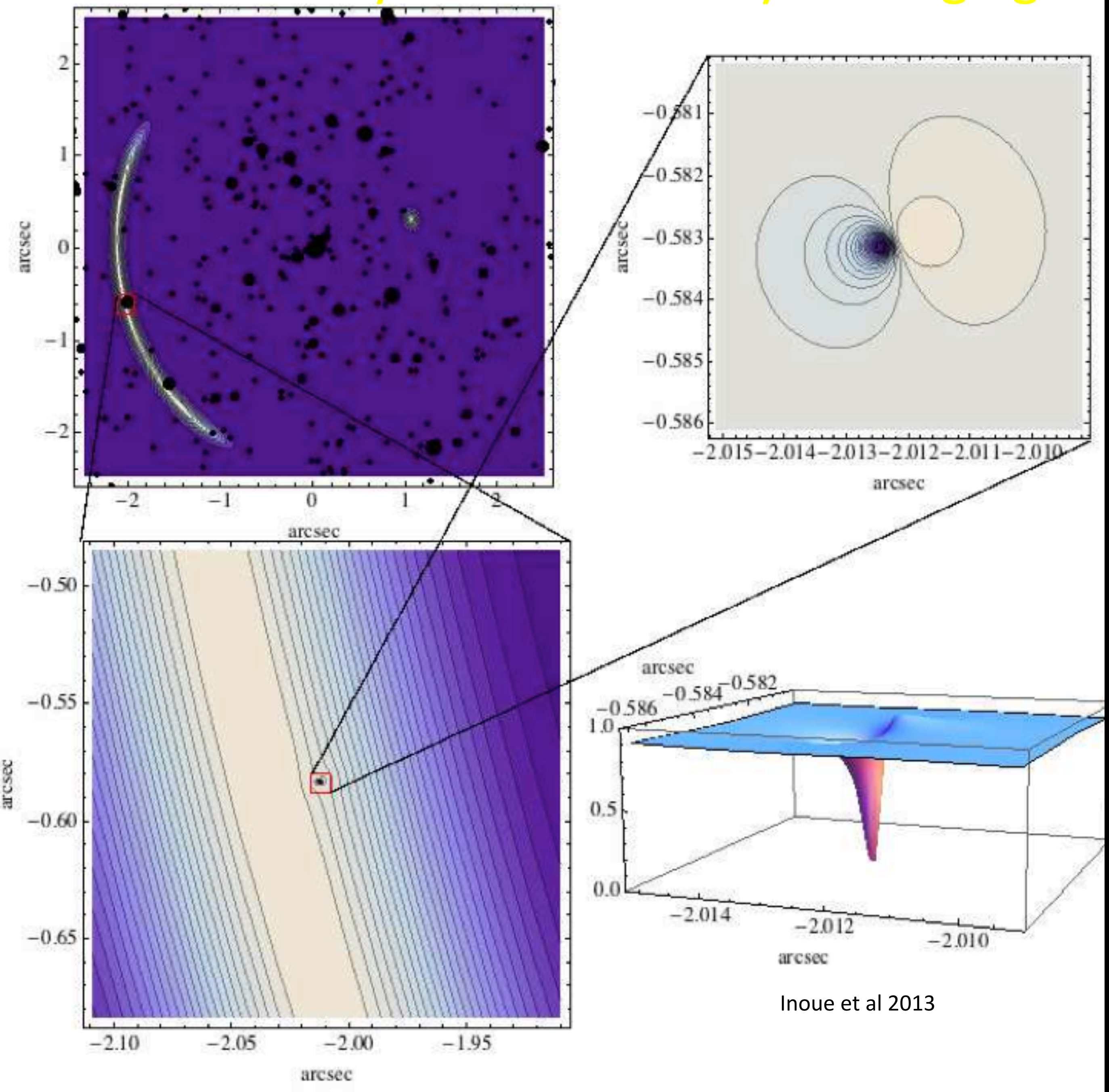
Duc + 2013

IMBH EXPEL BARYONS

Intermediate mass BH 10^3-10^6 M_{sun} predictions



A futuristic way to see IMBH by lensing against radio galaxies



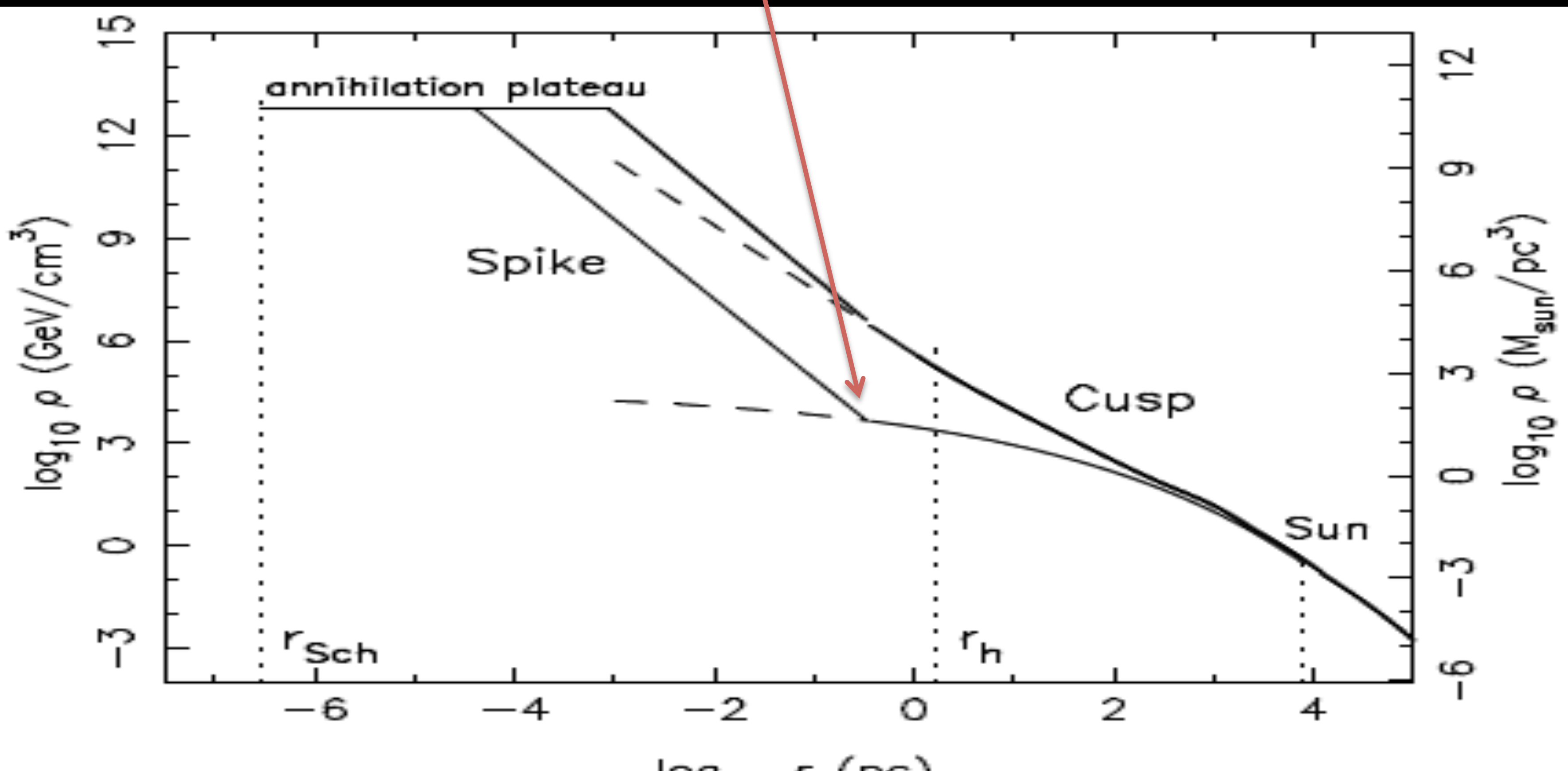
Inoue et al 2013

CDM cusp steepens by adiabatic growth of IMBH: $\rho \propto r^{-\gamma} \Rightarrow \rho \propto r^{-\gamma'}$, **with** $\gamma' = \frac{9-2\gamma}{4-\gamma}$

Annihilation rate is amplified within a radius $GM_{bh}/\sigma^2 \sim 0.003(M_{BH}/10^5 M_\odot)$pc

Density profile

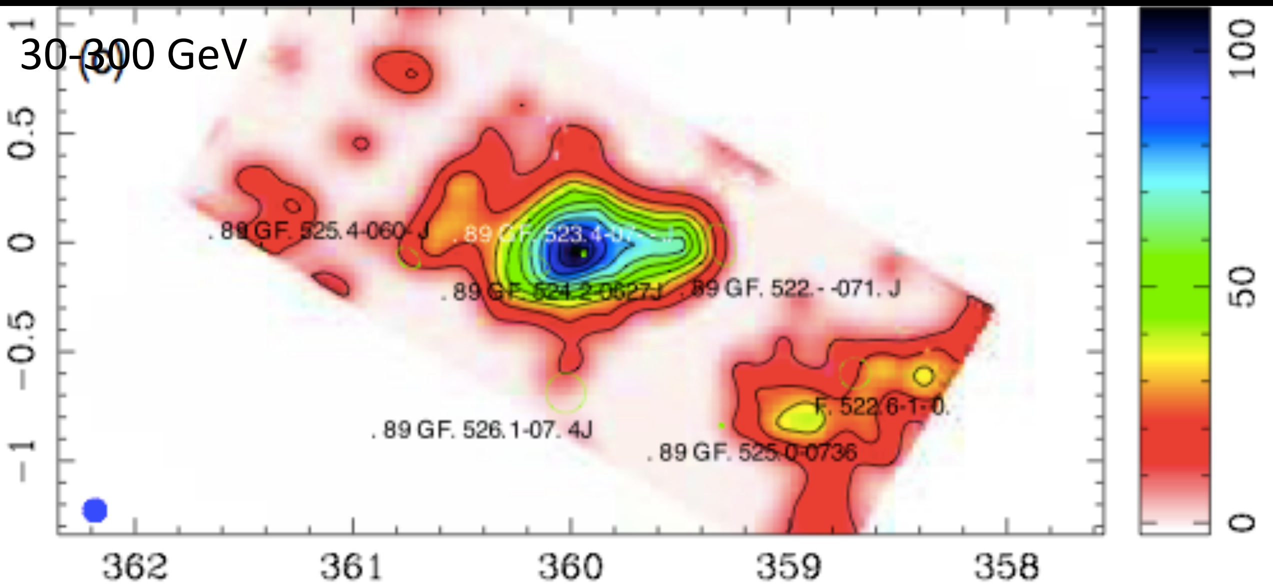
Plateau: $n_x(\mathbf{r})\langle\sigma v\rangle\, t_{BH} \sim 1$

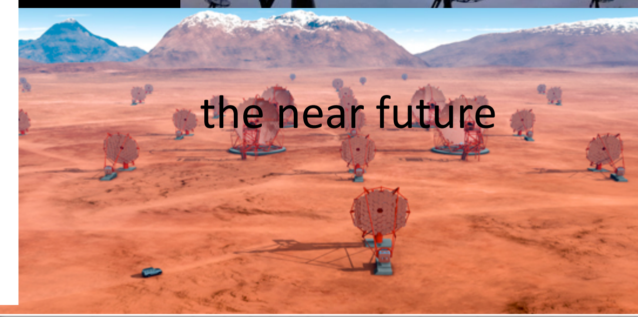


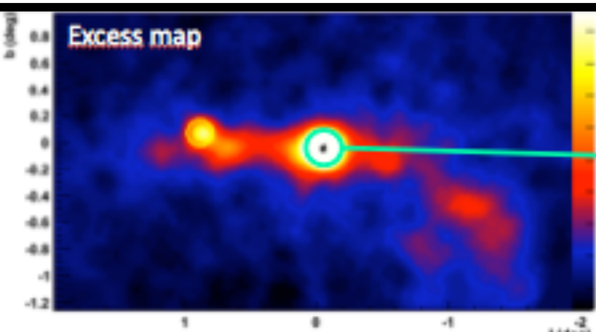
Gondolo + JS 1999, Gnedin & Primack 2004, Sadeghian, Ferrer + Will 2013

supermassive black hole at Galactic Center

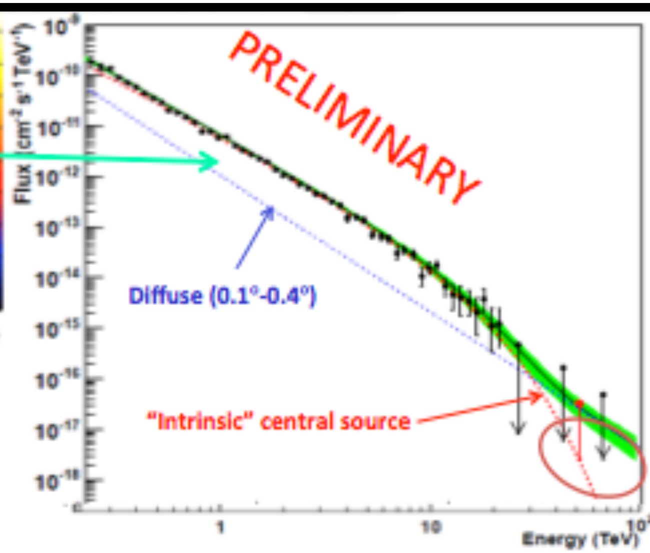
prediction for CTA: superexponential signature of TeV DM annihilations

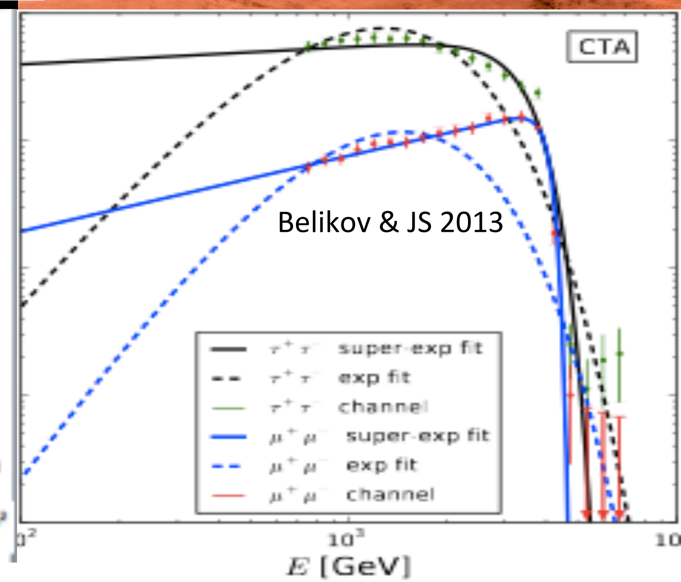




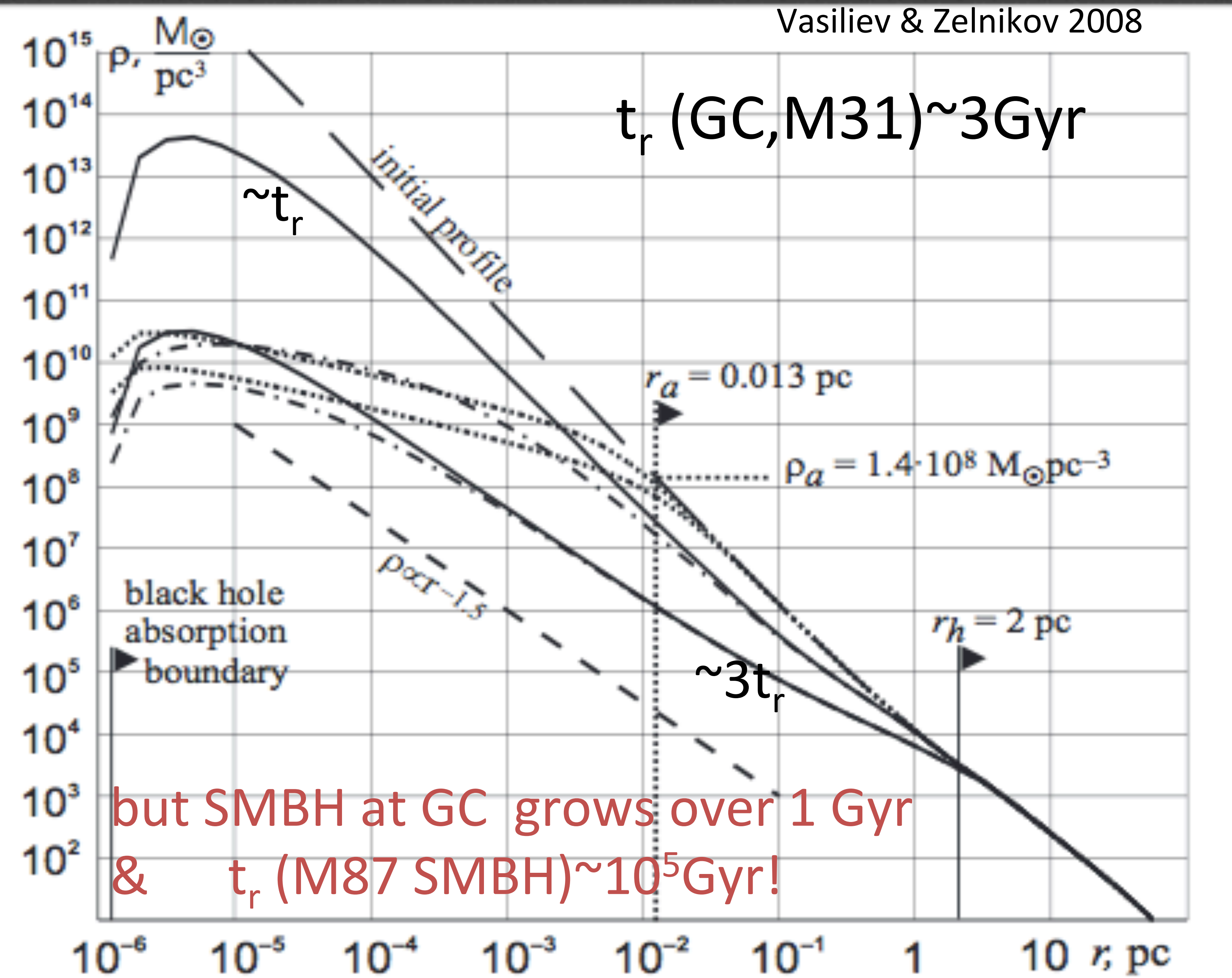


Vaiana + 2014





Does cusp survive? MAYBE!



NEARBY AGN

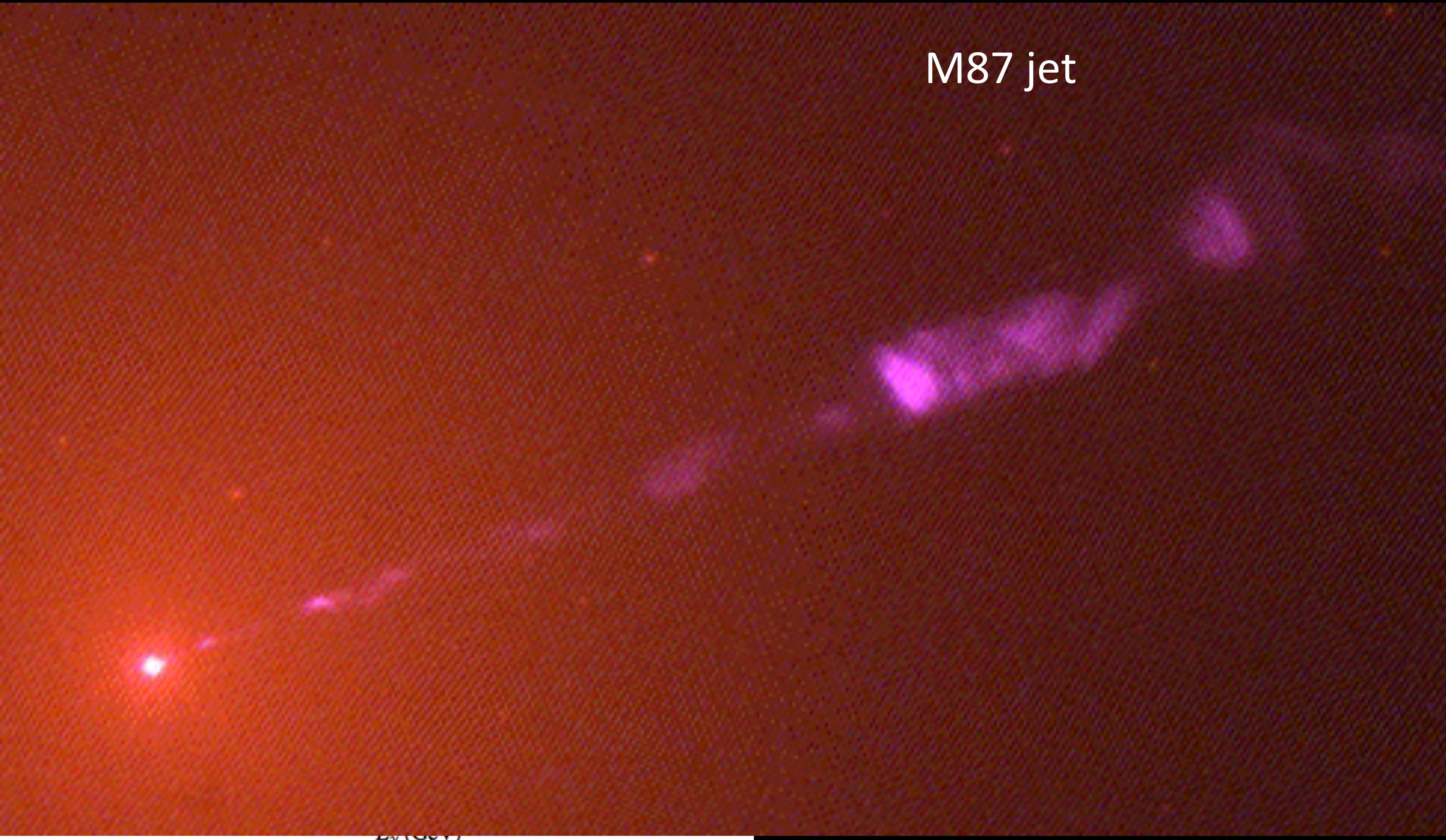
M87 is an attractive target

Distance 2000 x GC but M_{BH} 1500 x SagA*

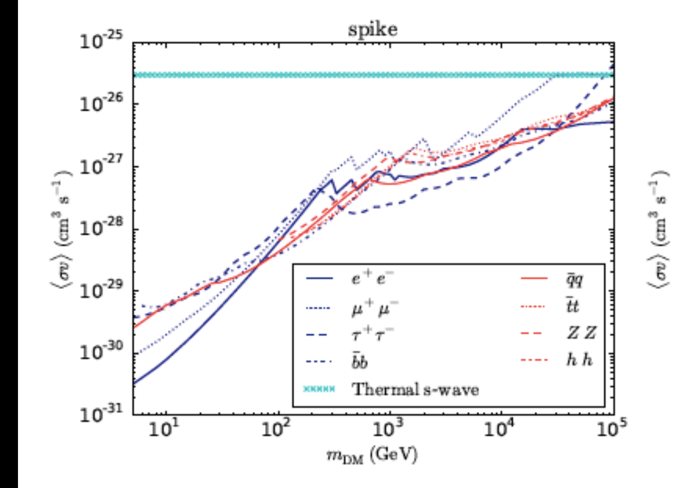
Flux ~ $n_x^2 \langle \sigma v \rangle (2r_p)^3$ ~ $M_{BH}^3 / \langle \sigma v \rangle$ for low $\langle \sigma v \rangle$

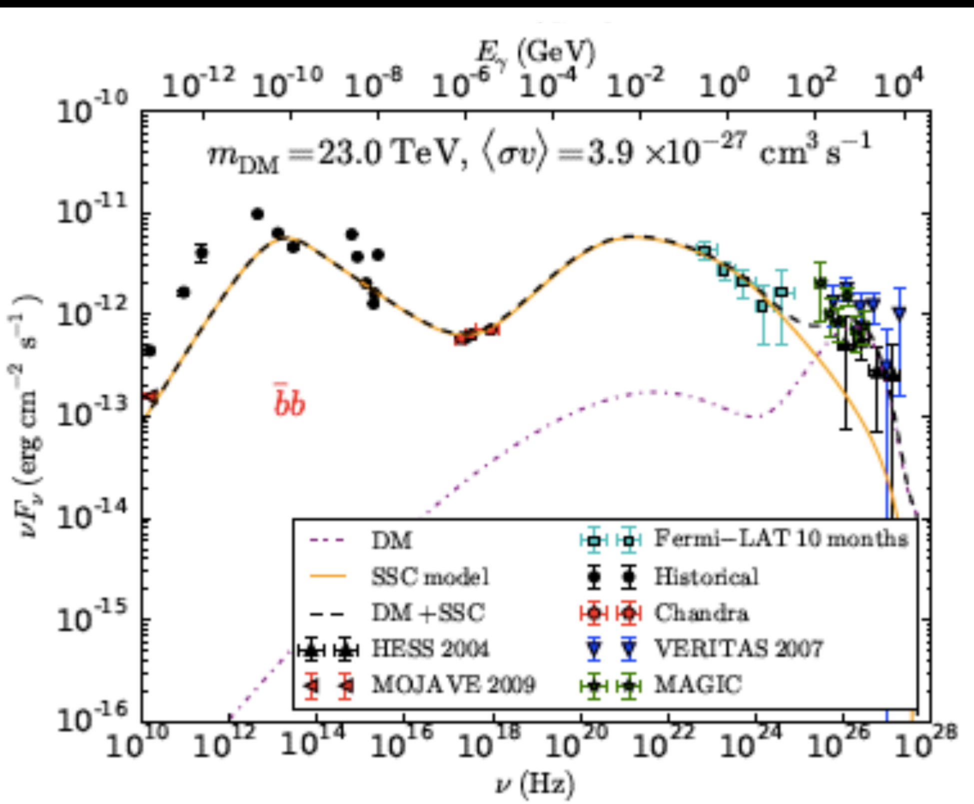
$n_x(\mathbf{r_p}) \langle \sigma v \rangle t_{BH}$ ~ 1

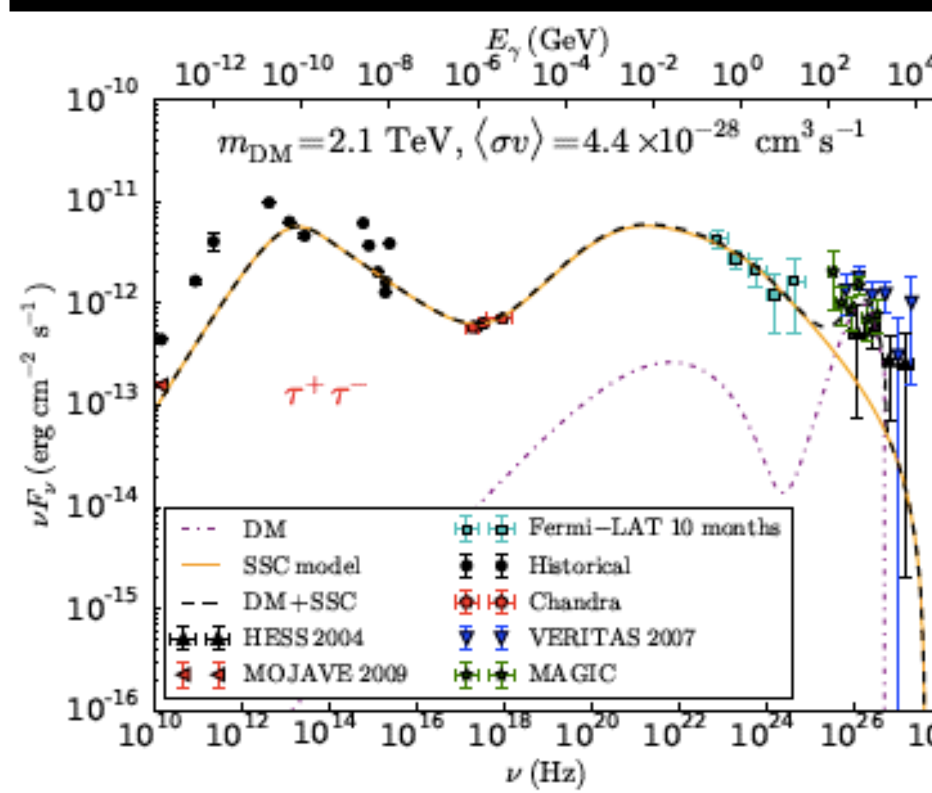
Dynamical heating of spike ~ 10^{14} yr vs 10^9 yr (GC) relativistic jets emanate from ergosphere, so high energy e,p collide with DM spike particles



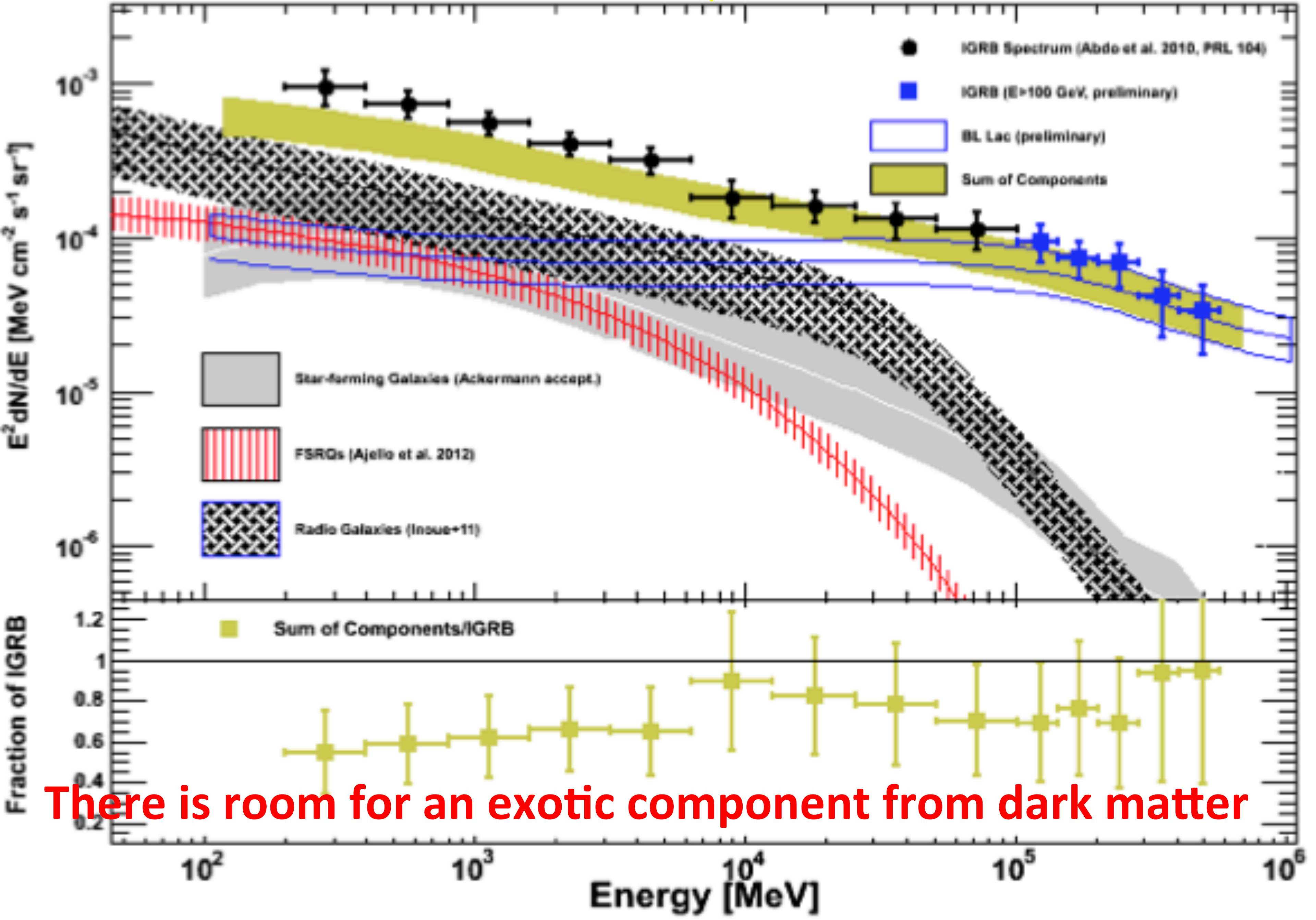
Lacroix, JS, CB 2015



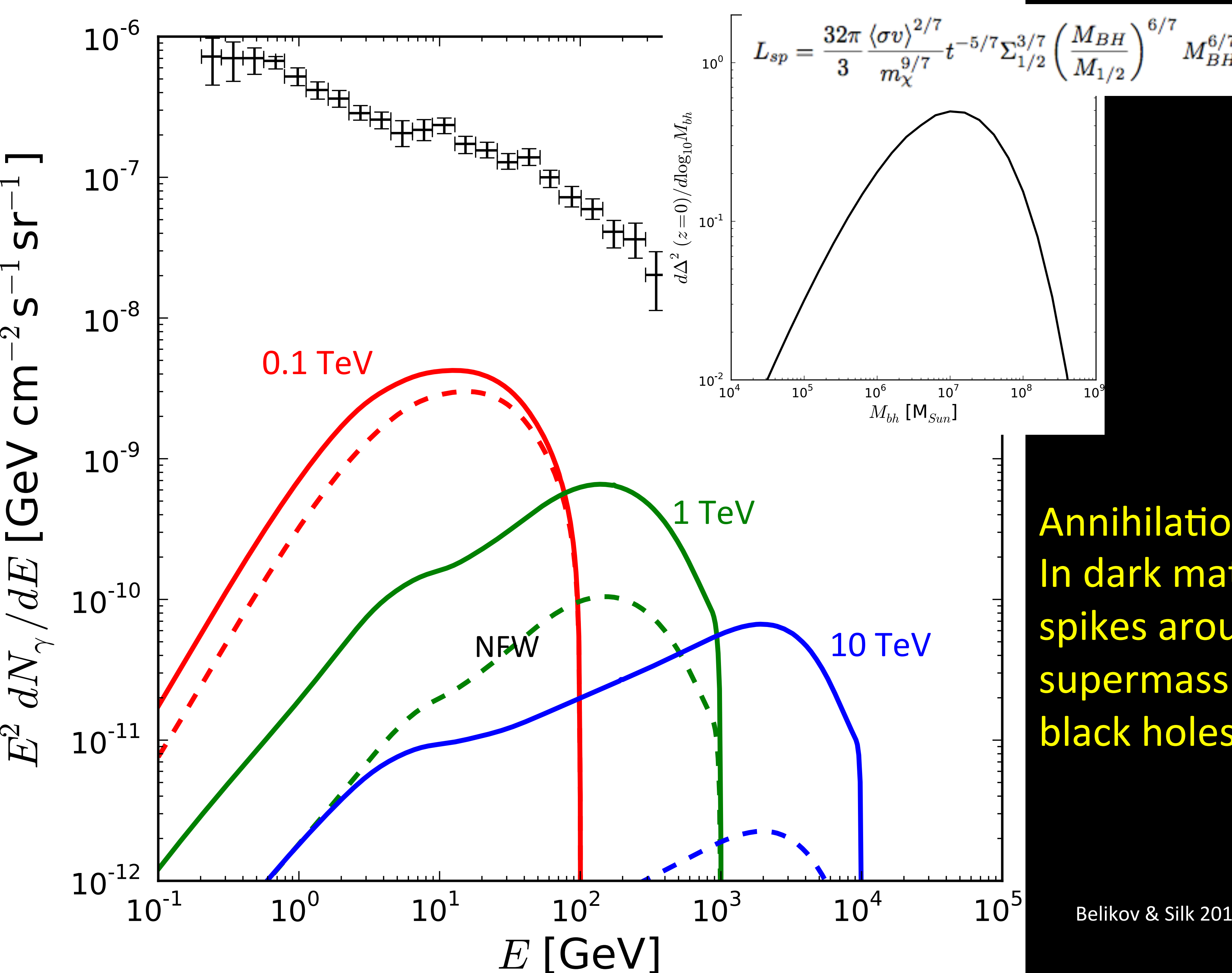




EXTRACALACTIC DIFFUSE γ RAY BACKGROUND



There is room for an exotic component from dark matter



Annihilations In dark matter spikes around supermassive black holes

Belikov & Silk 2013

BLACK HOLES AS PARTICLE ACCELERATORS

Piran & Shaham (1977)

Upper bounds on collisional Penrose processes near rotating black-hole horizons

Banados, Silk, & West (2009)

Black Holes as Particle Accelerators to Arbitrarily High Energy

Bejger , Piran, Abramowicz, Hakansonet (2012)

Collisional Penrose process near the horizon of extreme Kerr black holes

Harada et al.(2012)

Upper limits of particle emission from high-energy collision and reaction near a maximally rotating Kerr black hole

Zaslavskii (2012)

Acceleration of particles by black holes as a result of deceleration: ultimate manifestation of kinematic nature of BSW effect

Schnittman (2014, 2015)

Revised upper limit to energy extraction from a Kerr black hole

Berti, Brito, Cardoso (2015)

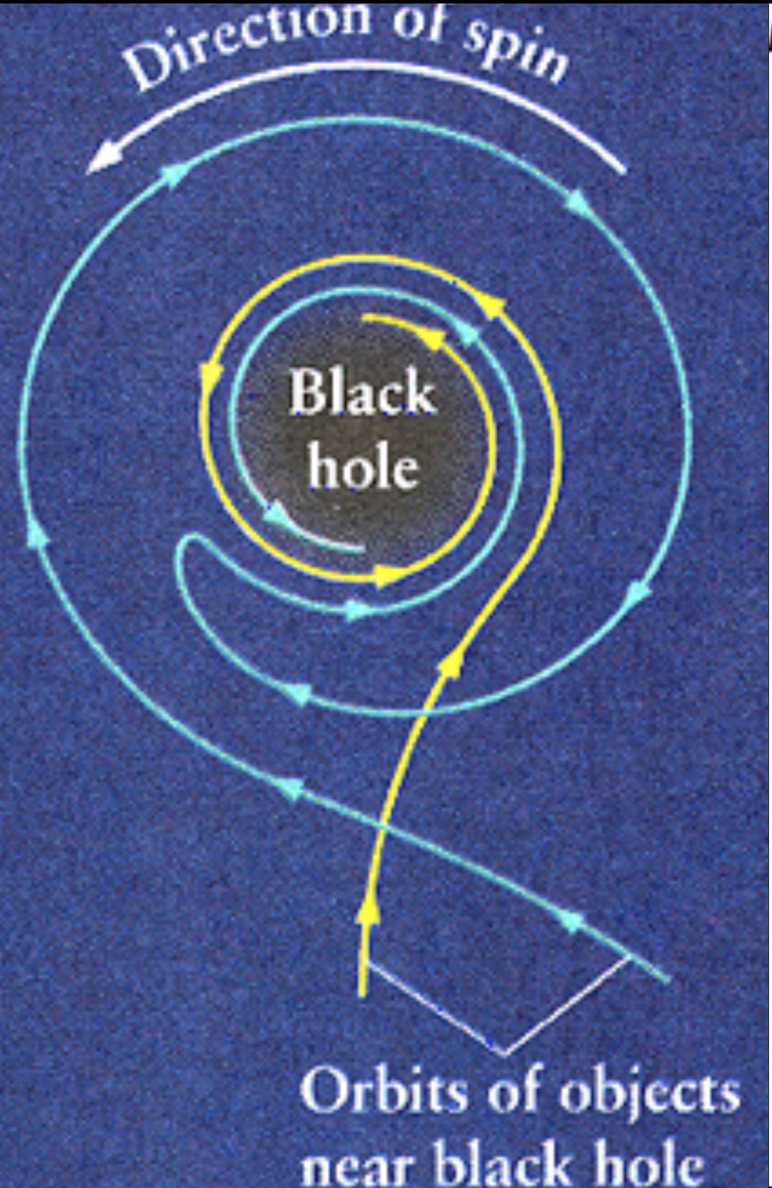
Energy debris from the collisional Penrose process

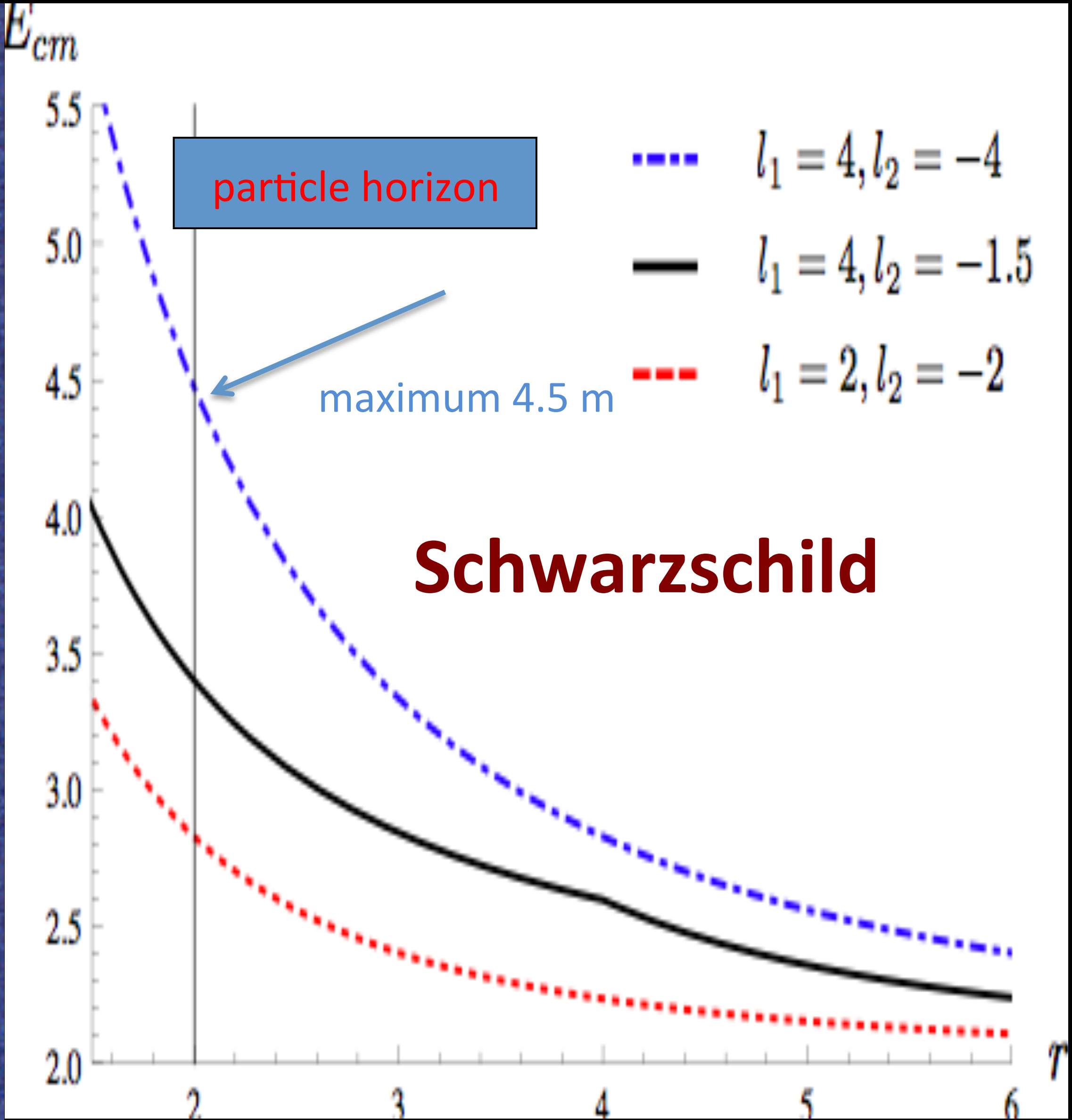
Zaslavskii (2014)

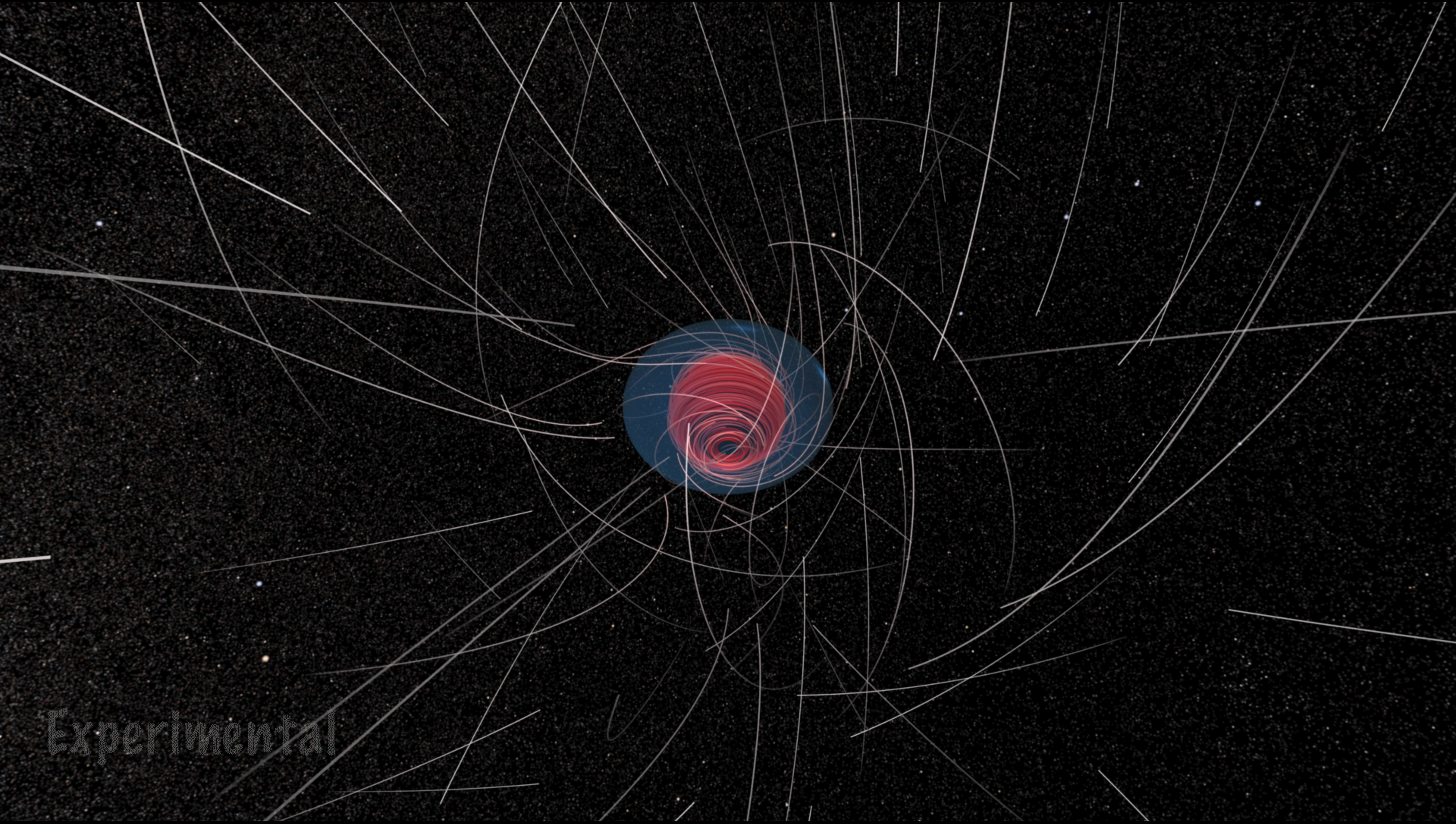
Unbounded energies of debris from head-on particle collisions near black

BLACK HOLES

THE ULTIMATE PARTICLE ACCELERATOR: dark matter cusp around black hole

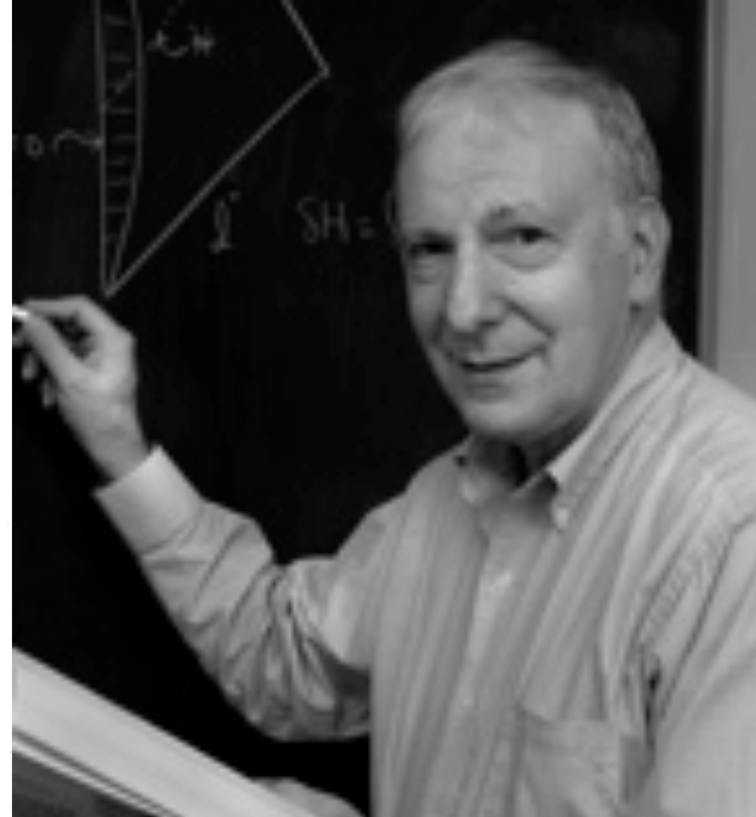





Experimental

Extraction of Rotational Energy from a Black Hole

THERE has been considerable interest recently in the question of the gravitational collapse of a massive body and of the possible astrophysical consequences of the existence of the "black hole" which general relativity predicts should sometimes be the result of such a collapse. In particular, the question has arisen whether the mass–energy content of a black hole could, under suitable circumstances, be a source of available energy. We now



ASTROPHYSICAL JOURNAL, 191:231–233, 1974 July 1

ENERGY LIMITS ON THE PENROSE PROCESS

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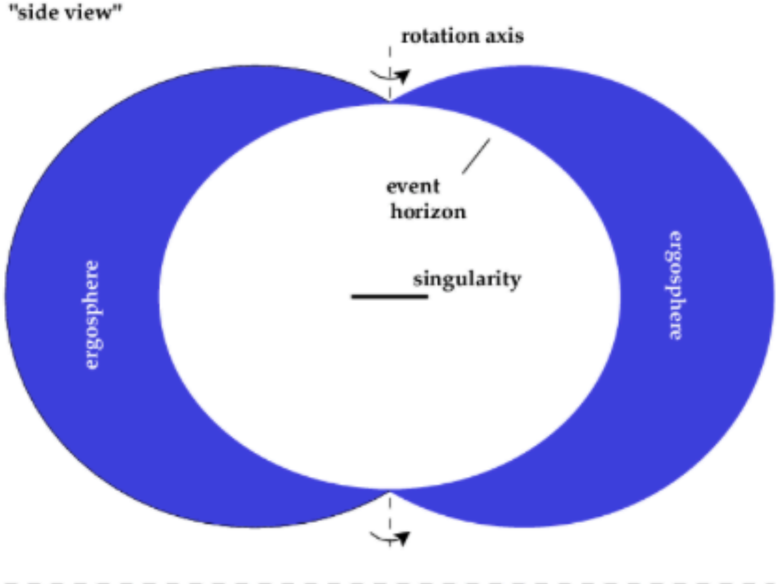
Department of Physics and Astronomy, University of Maryland, College Park

Received 1973 December 26

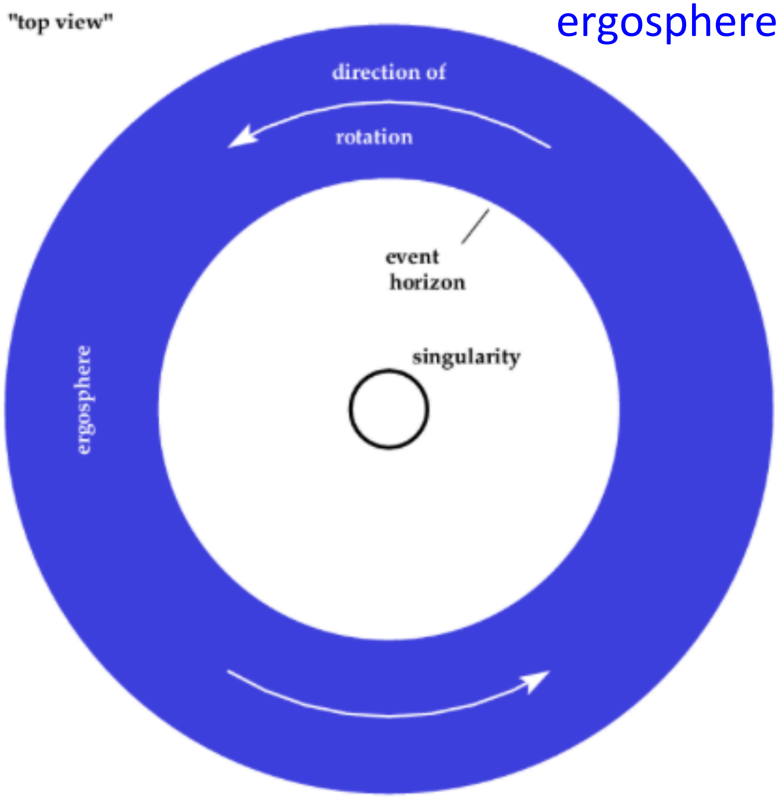
ABSTRACT

If a body in the vicinity of a rotating black hole breaks apart into two or more fragments, then under appropriate conditions the rotational energy of the black hole can be used to enhance the energy of one of the fragments (Penrose process). Wheeler and others have suggested that the Penrose process could serve as an energy mechanism for jets. In this paper we derive strict limits on the energies which can be achieved by the Penrose process. It is shown that in no case can one obtain energies which are greater by a significant factor than those which already could be obtained by a similar breakup process without the presence of a black hole.

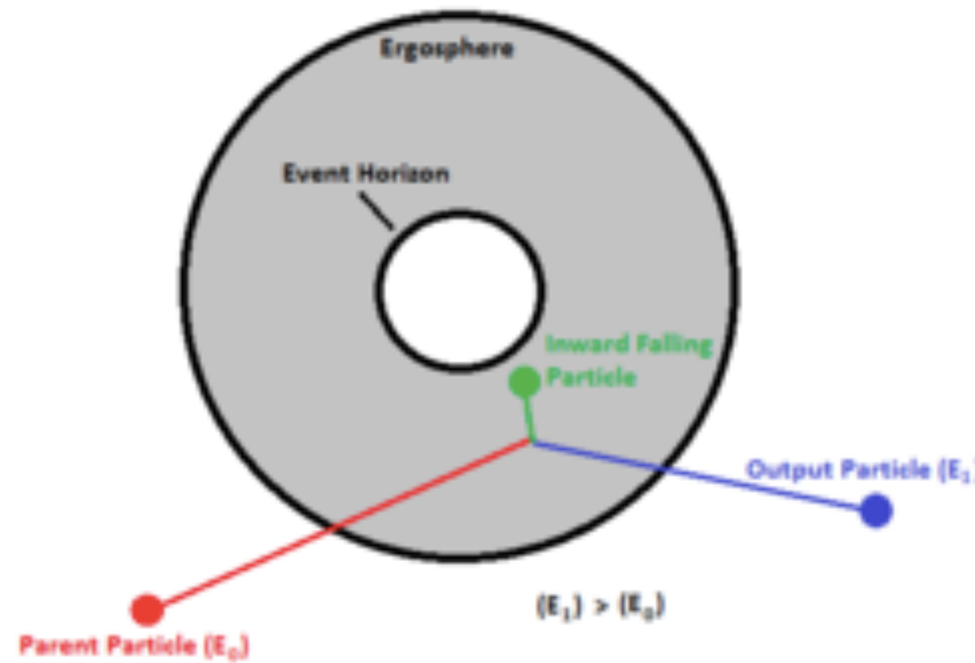


NEAR KERR BLACK HOLES

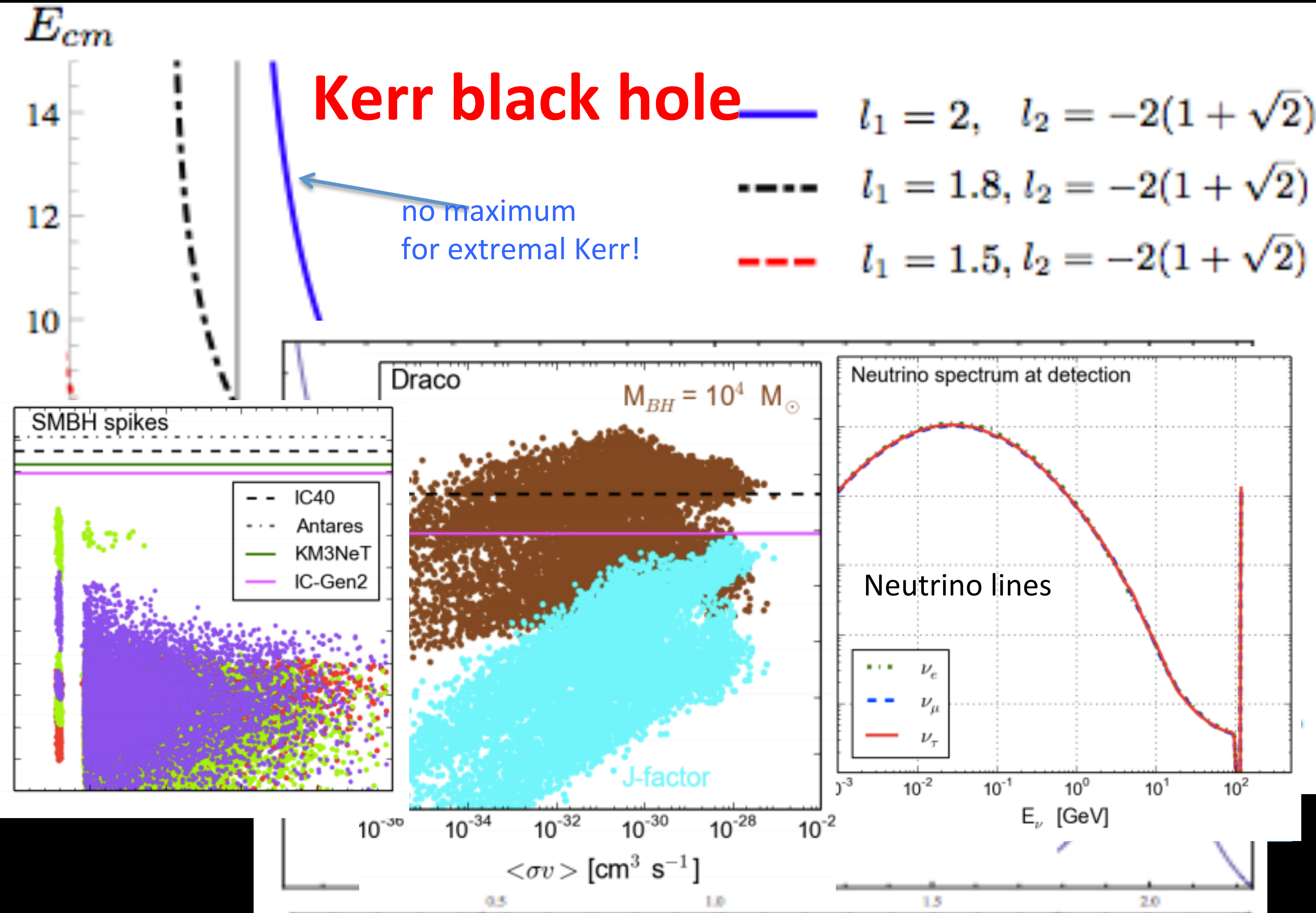
ergosphere

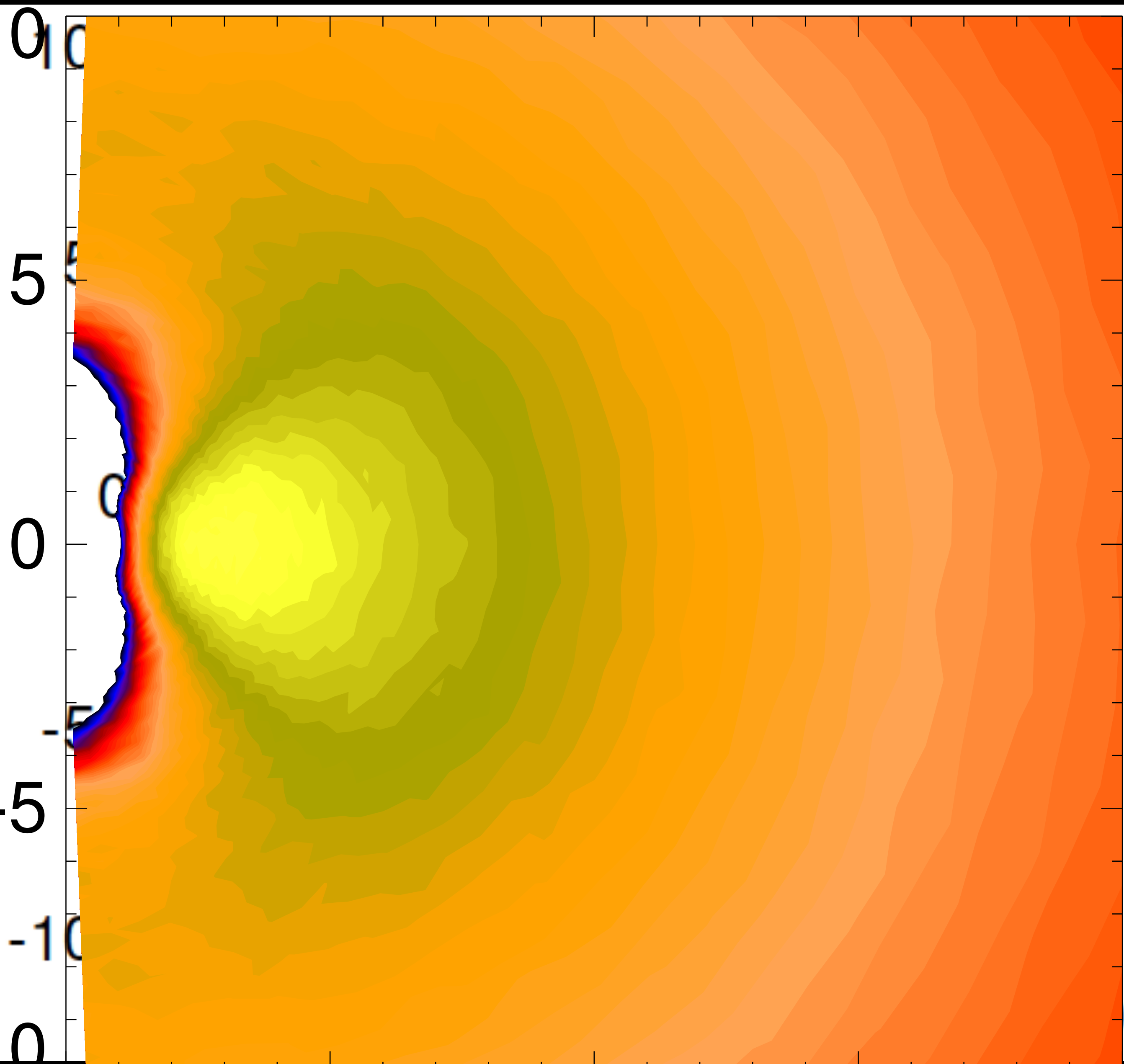


Penrose process

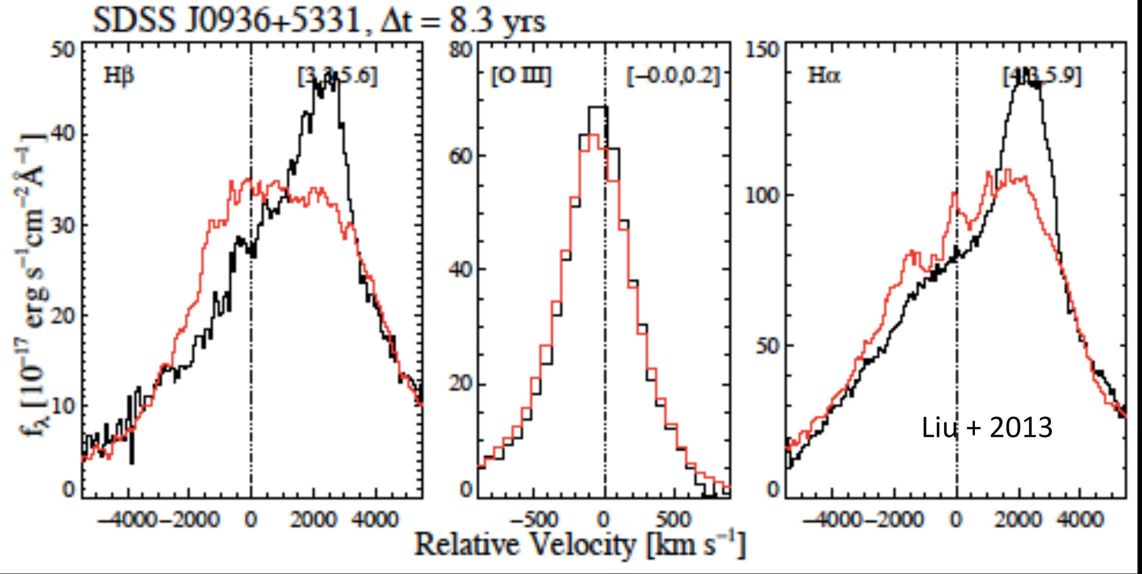


Rotating black hole can feed Penrose effect via DM particle collisions



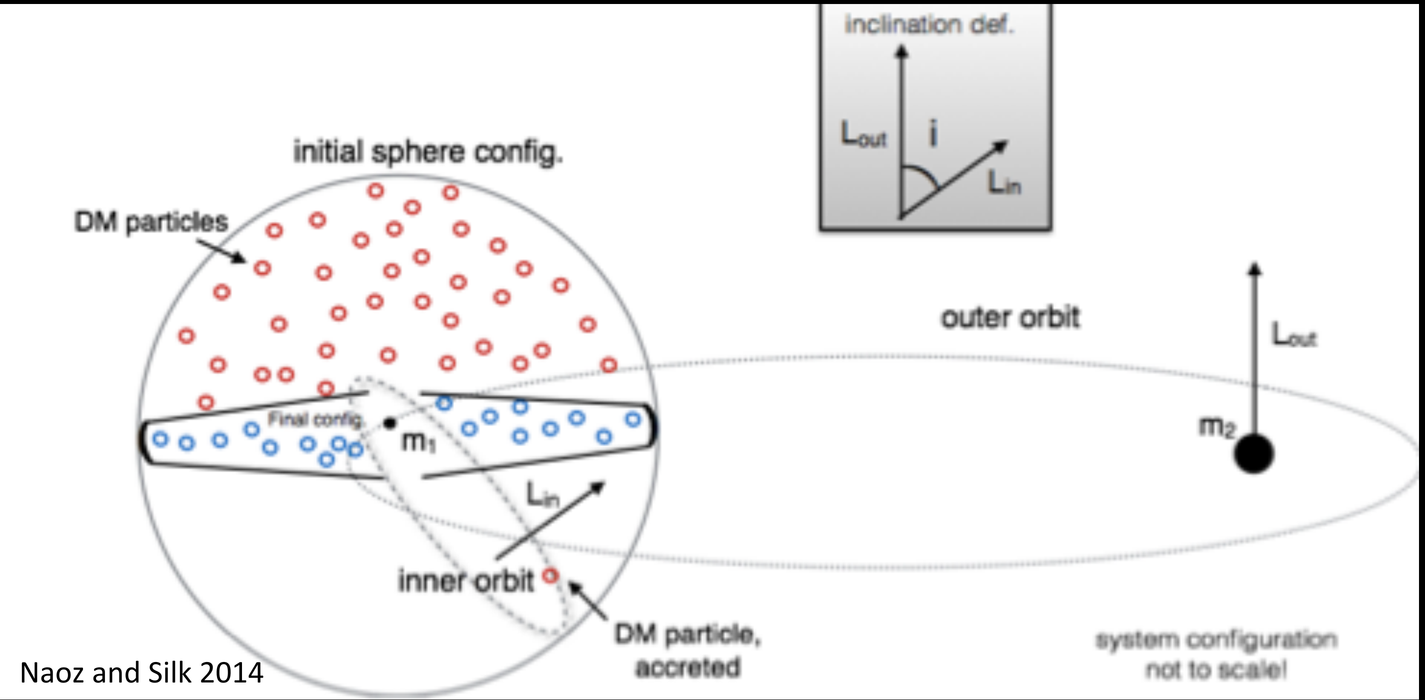


Frame dragging generates a torus



SMBH binaries in quasars may be common at parsec scales from Balmer line offsets

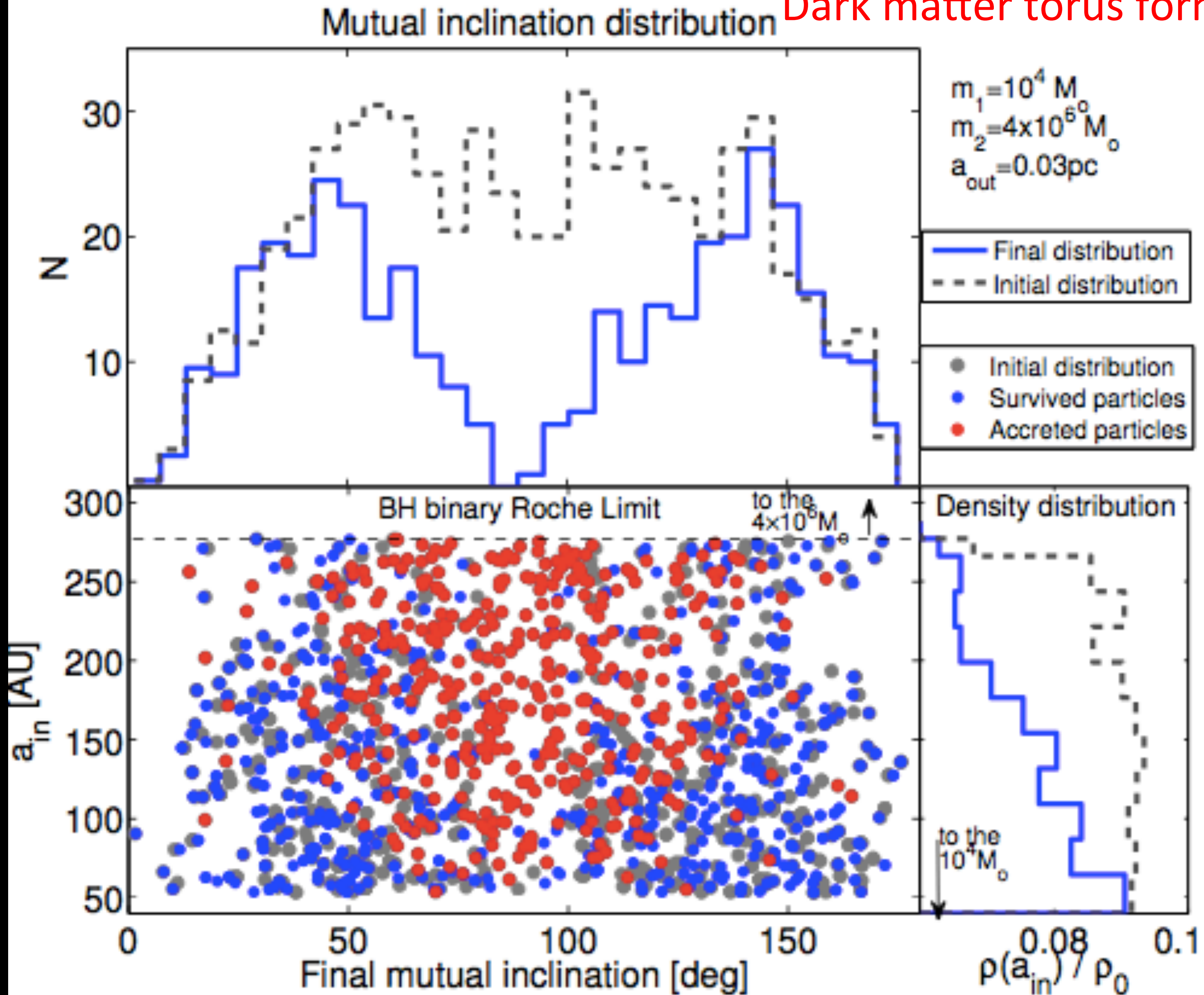
Kozai mechanism drives resonant infall of DM in eccentric orbits……..operates for binary black hole



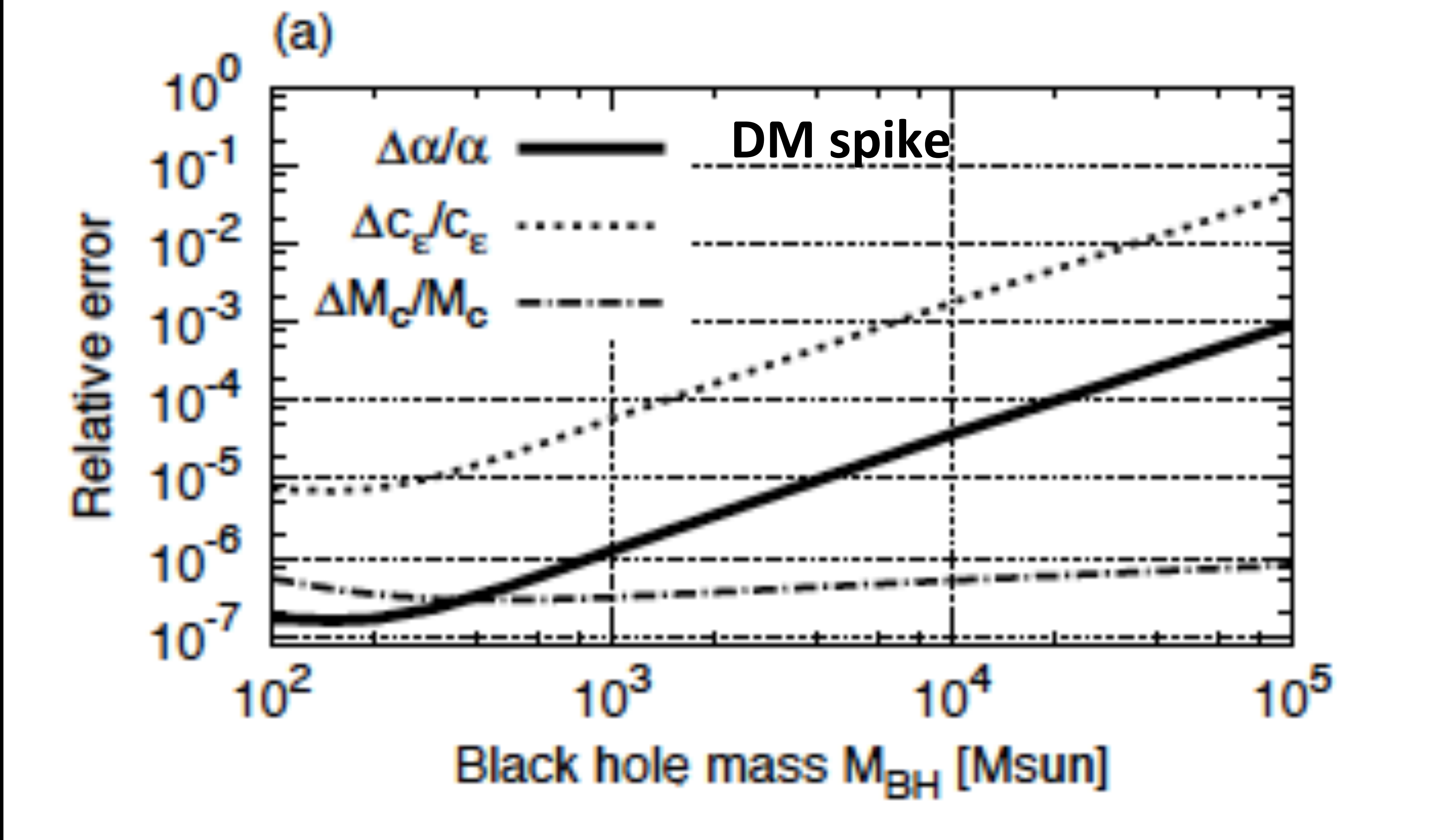
Naoz and Silk 2014

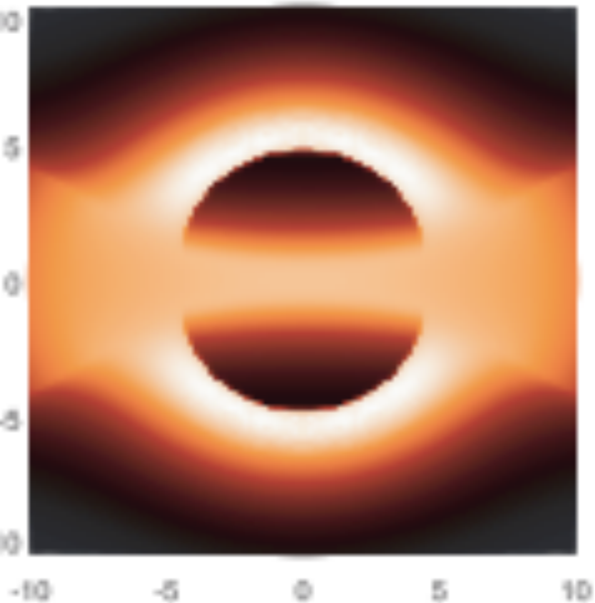
Naoz and Silk 2014

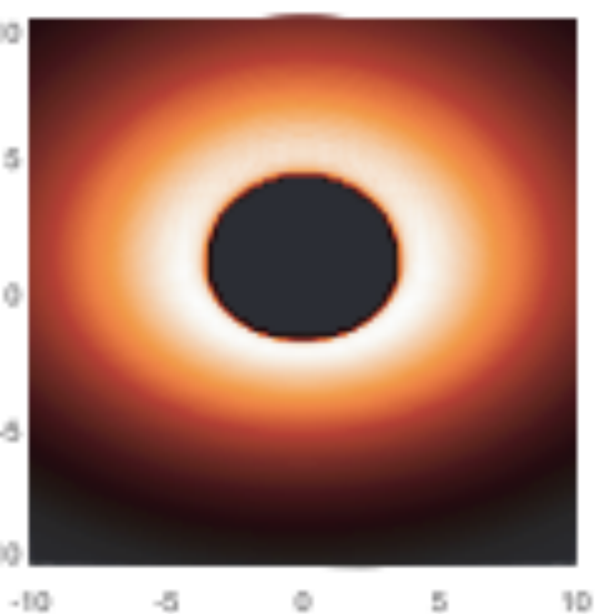
Dark matter torus forms



Graviatational wave inspiral: 5yrs, eLISA







Black hole shadow

Event Horizon Telescope

Simulated image at 1mm
of M87 or SagA* black hole

Resolve horizon scale
GM/c^2 at ~5 μ arcsec

M87 distance 2000 x GC
but M_{BH} 1500 x SagA*

Could one see a cloud of DM-generated pairs
undergoing synchrotron emission?

Huang + 2007

Ευχαριστώ

Και καλή τύχη για την Κυριακή!