Plasma evolution during Sgr A* flares

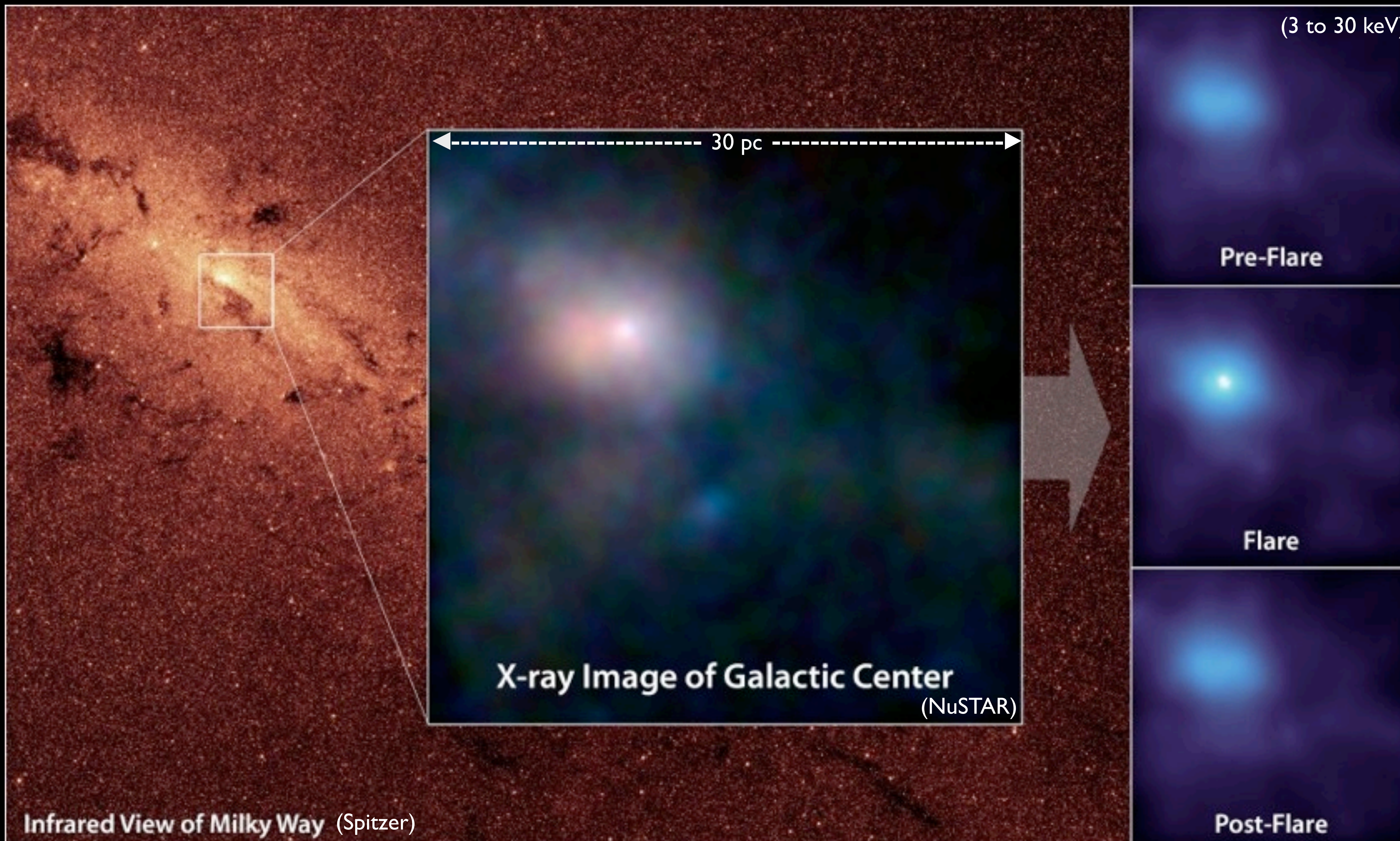

Image credit: NASA/JPL-Caltech

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Some motivations

Test general BH accretion; Understand Sgr A* specific nature

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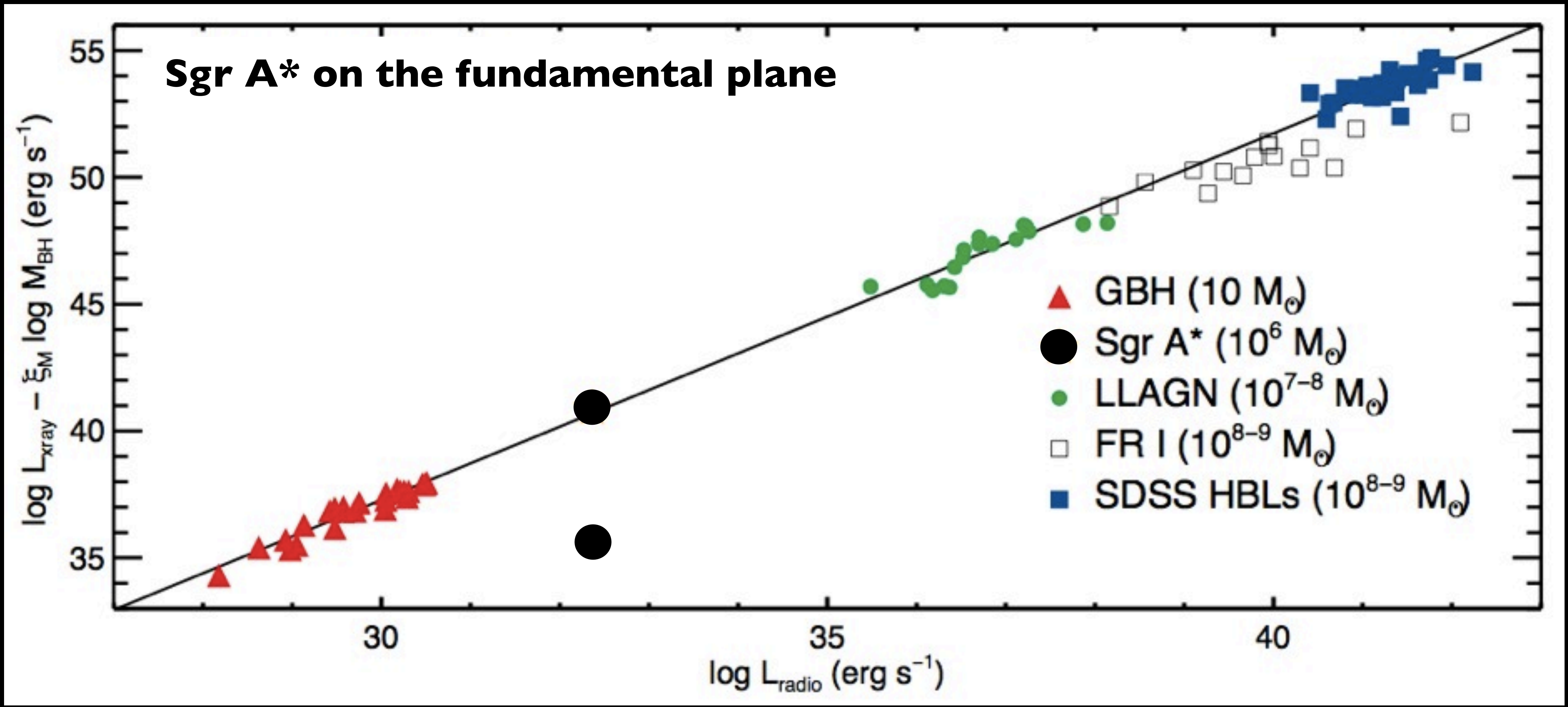

Plotkin et al., MNRAS 2012

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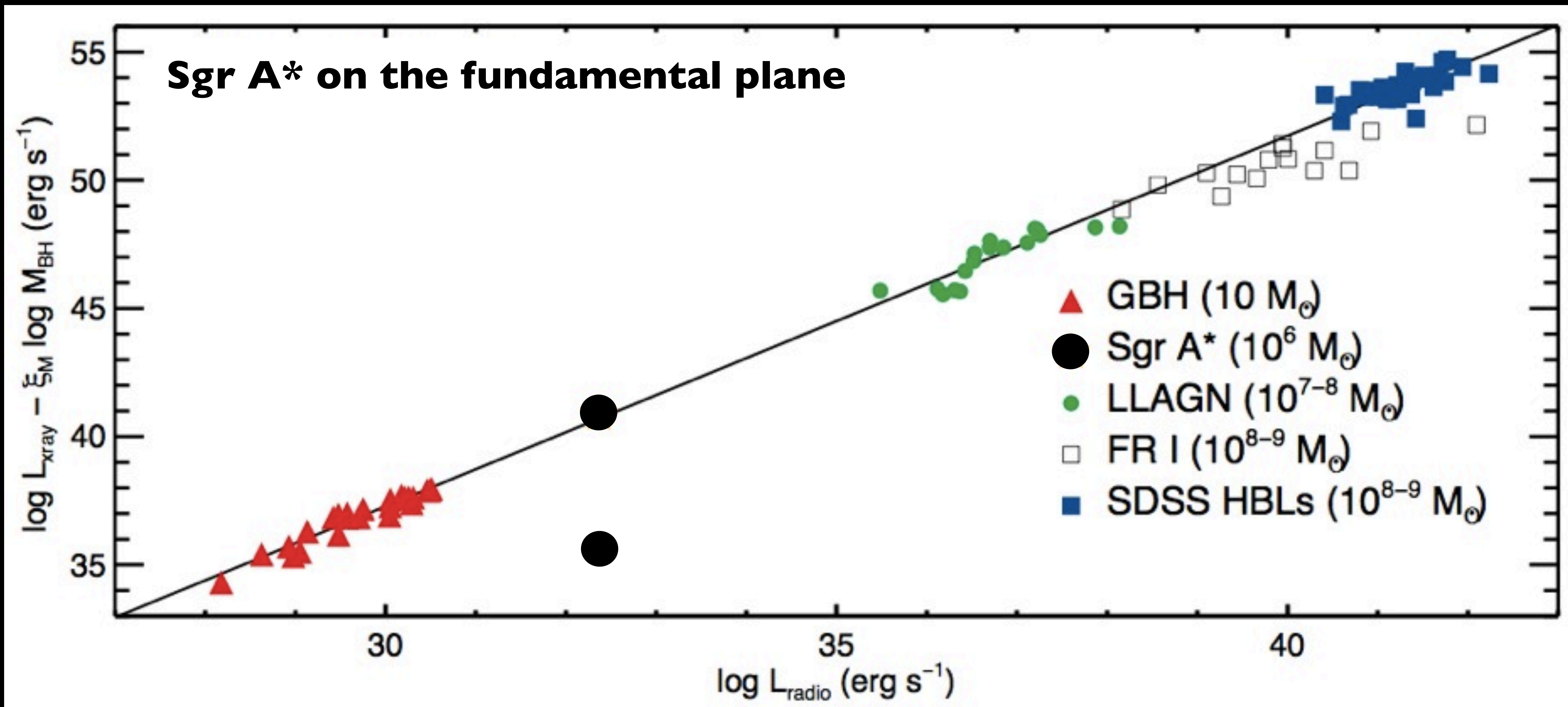
Test general BH accretion; Understand Sgr A* specific nature



Plotkin et al., MNRAS 2012

What is the particle distribution? Thermal/non-thermal plasma?
What are the physical processes triggering the flare events?
What is the energy budget?

Constraints on Sgr A*

Distance $\simeq$ 8 kpc , Mass $\simeq 4.3 \times 10^6 M_\odot$

(Reid 1993, Schodel et al. 2002, Eisenhauer et al. 2005, Melia 2007, Ghez et al. 2008, Gillessen et al. 2009)

$L_{bol} \simeq 100\ L_\odot \simeq 10^{-9}\ L_{Edd}$, $L_{X\text{-}ray} \simeq 10^{33}$ erg/s

(Narayan et al. 1998, Melia & Falcke 2001, Baganoff et al. 2003, Genzel et al. 2010)

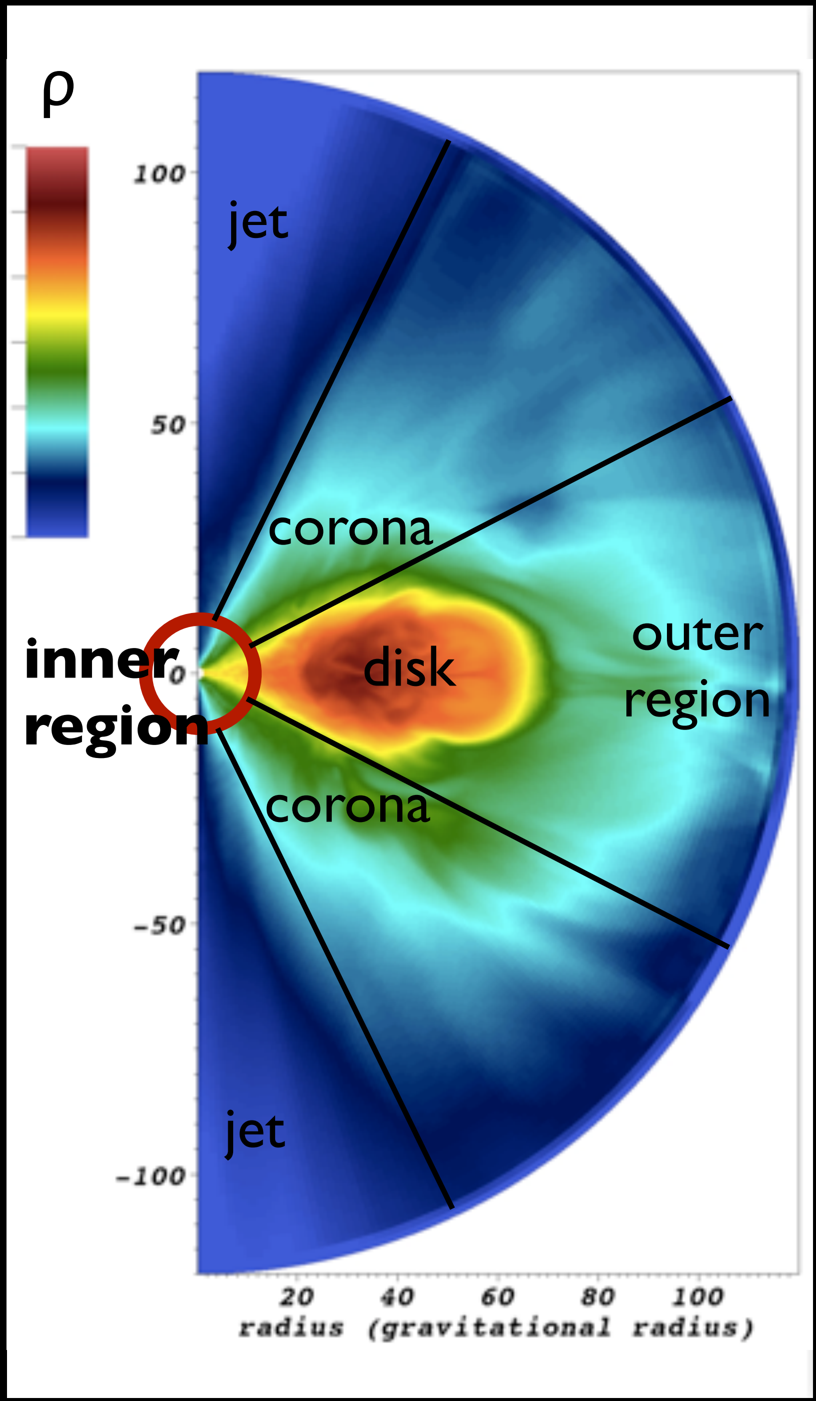
Accretion rate: 2×10^{-9} to $2 \times 10^{-7}\ M_\odot$/yr

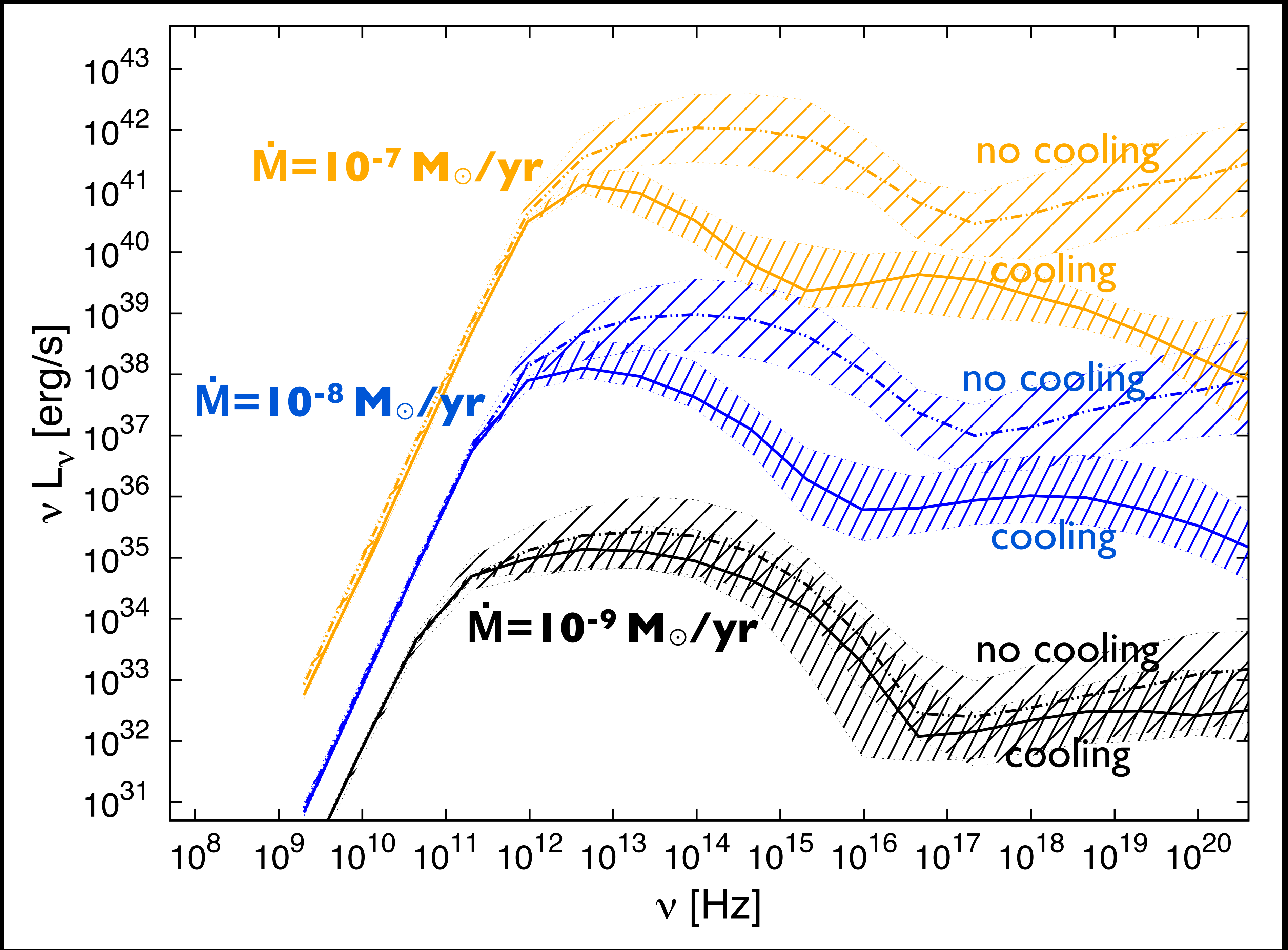
(Aitken et al 2000, Bower et al. 2003, Marrone et al. 2007)

Density < 10^8 cm^{-3} , B < few 100 Gauss

(Dexter et al. 2009, Moscibrodzka et al 2009, Dibi et al. 2012, Drappeau et al. 2013)

GRMHD simulation of accretion onto Sgr A* with Cosmos++ (Anninos et al. 2005; Fragile & Meier 2009)





(Dibi et al., MNRAS 2012)

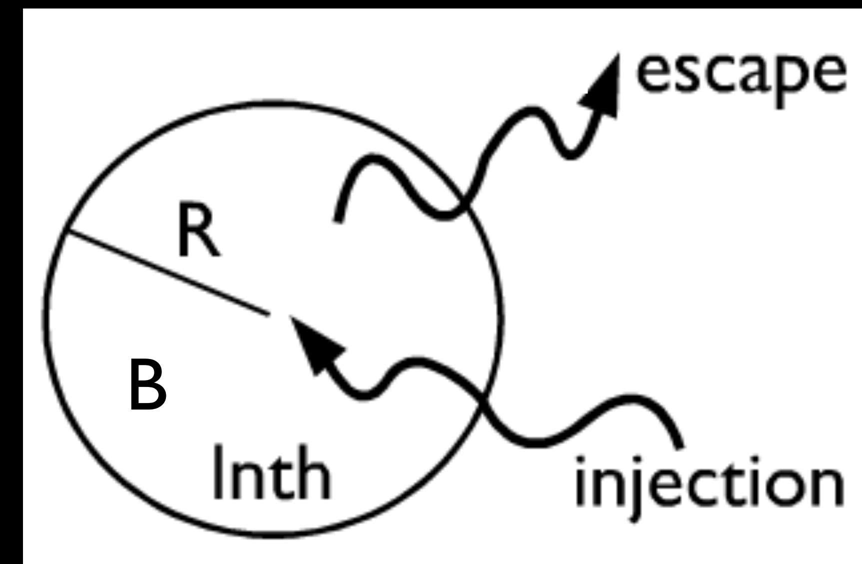
(Drappeau, Dibi, Markoff, Fragile, & Dexter, MNRAS 2013)

Models for Sgr A* inner plasma

Using Belm Code (Belmont, Malzac, & Marcowith 2008)

- Simplification: One single zone.

- Improvement: Particle distribution calculated self-consistently.



$R = 2\ Rg = 2GM/c^2$

(Melia et al. 2001; Eckart et al. 2004)

Thermal injection

Constant escape probability

Solve the kinetic equations:

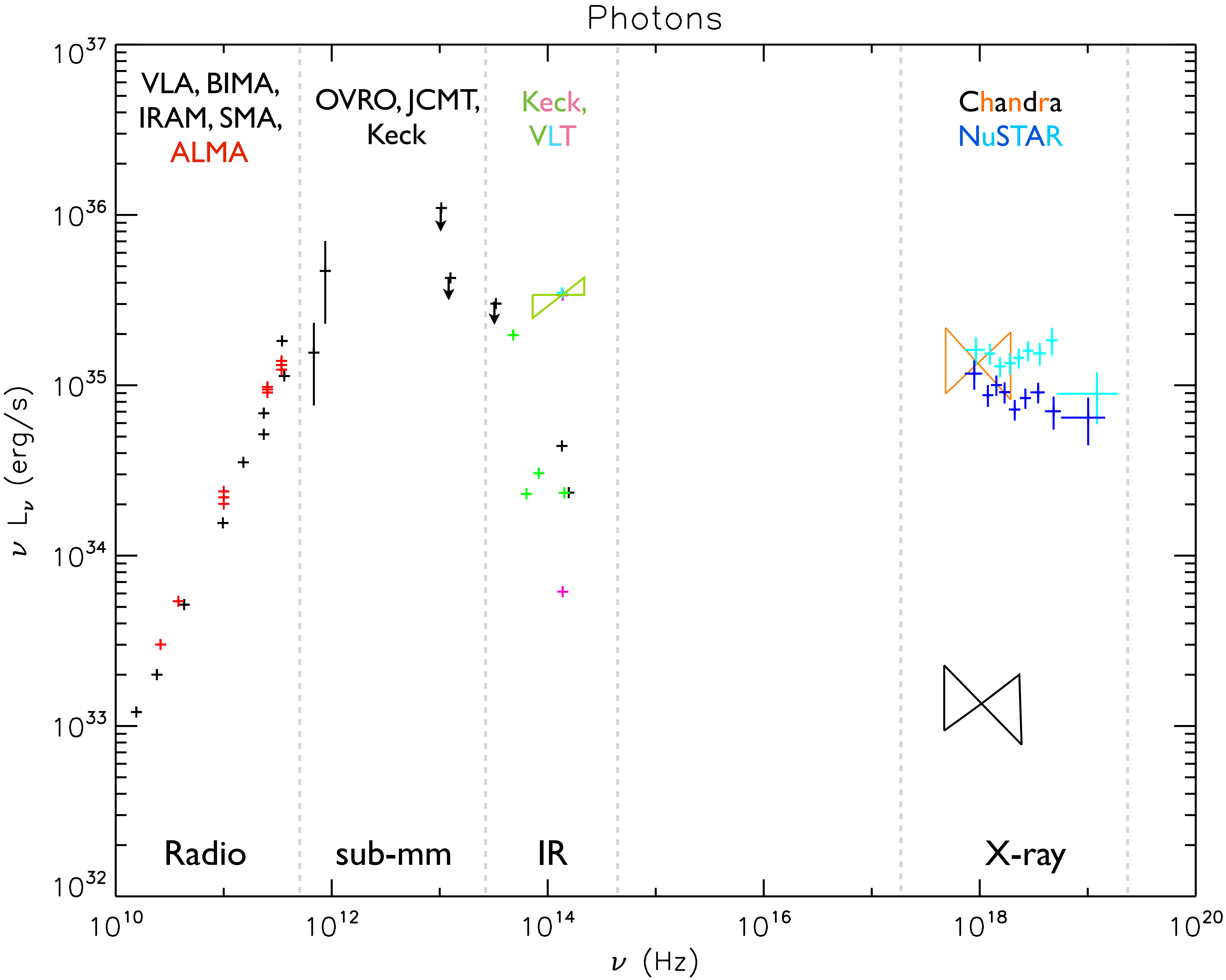
$$\partial_t N_\nu = S_\nu - L_\nu N_\nu + \partial_\omega [A_\nu N_\nu] + 1/2\, \partial^2{}_{\omega^2} [D_\nu N_\nu]$$

$$\partial_t N_{e\pm} = S_{e\pm} - L_{e\pm} N_{e\pm} + \partial_p [\gamma/p A_{e\pm} N_{e\pm}] + 1/2\, \partial_p [\gamma/p\, \partial_p (\gamma/p D_{e\pm} N_{e\pm})]$$

Source terms: injection, synchrotron emission, Compton scattering, annihilation/production, bremsstrahlung.

Loss terms: escape, synchrotron absorption, Compton scattering, pair production/annihilation, bremsstrahlung.

Sgr A* observational data



Falcke et al. 1998

Zhao 2003

Brinkerink & Falcke 2013

Serabyn et al. 1997

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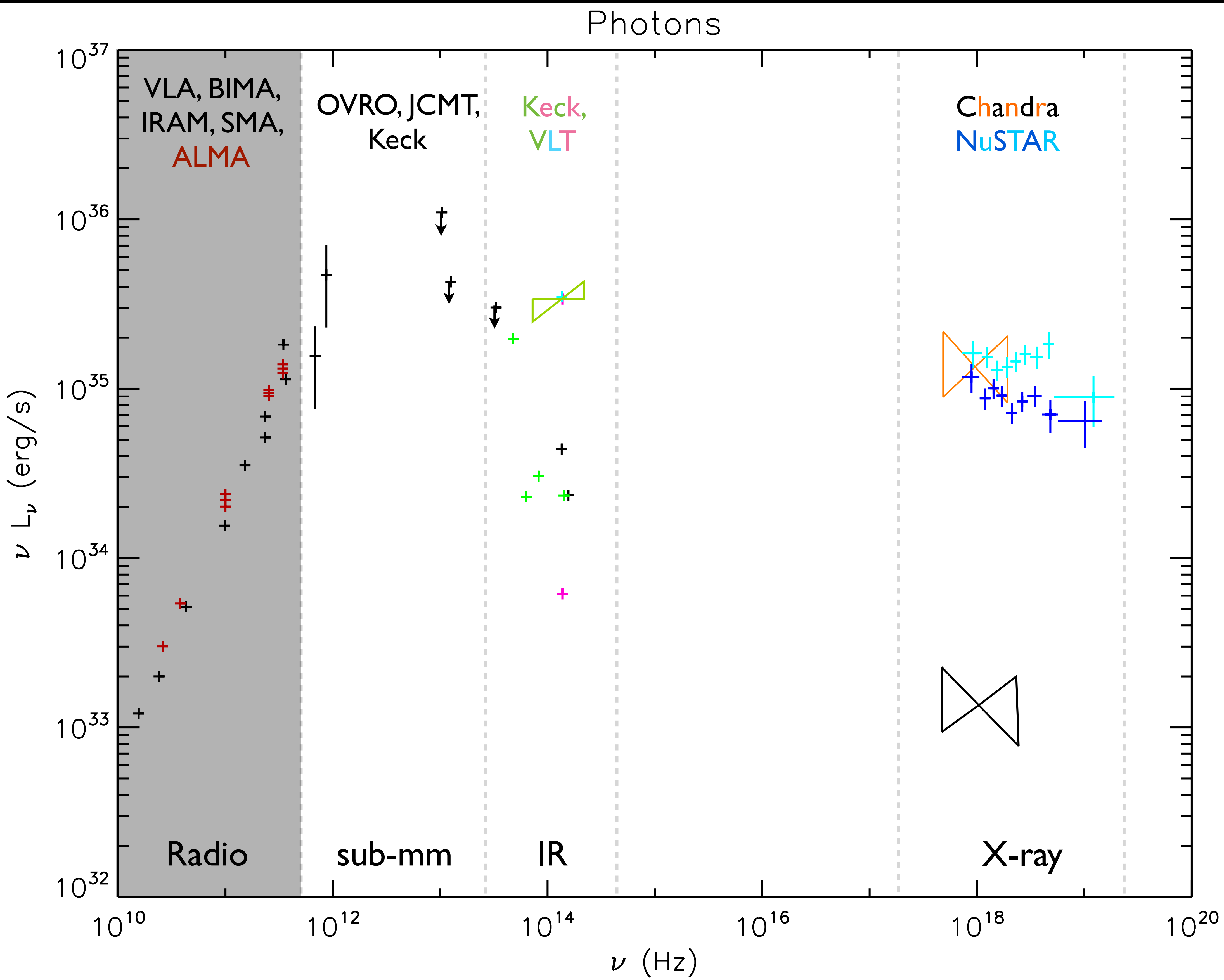

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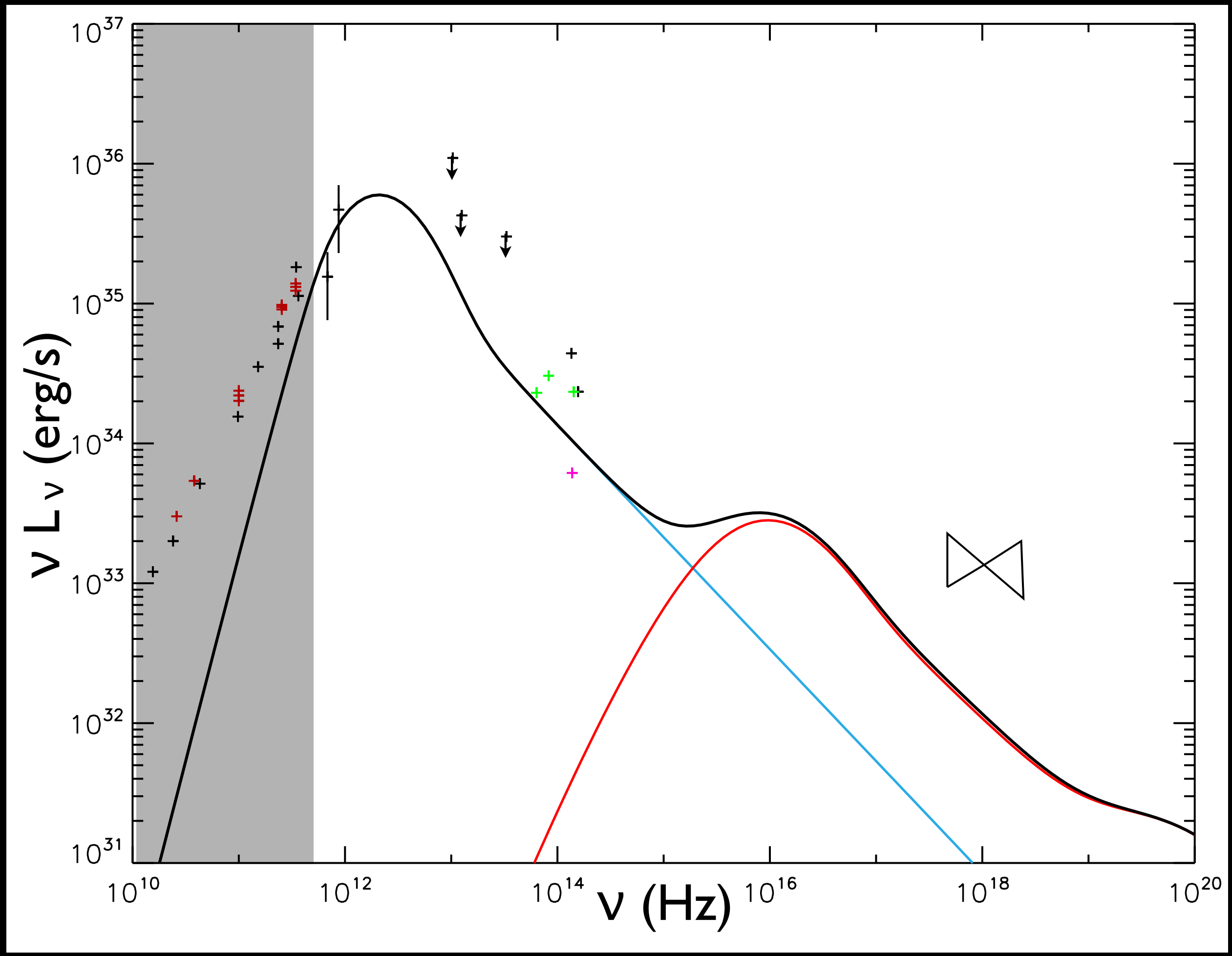
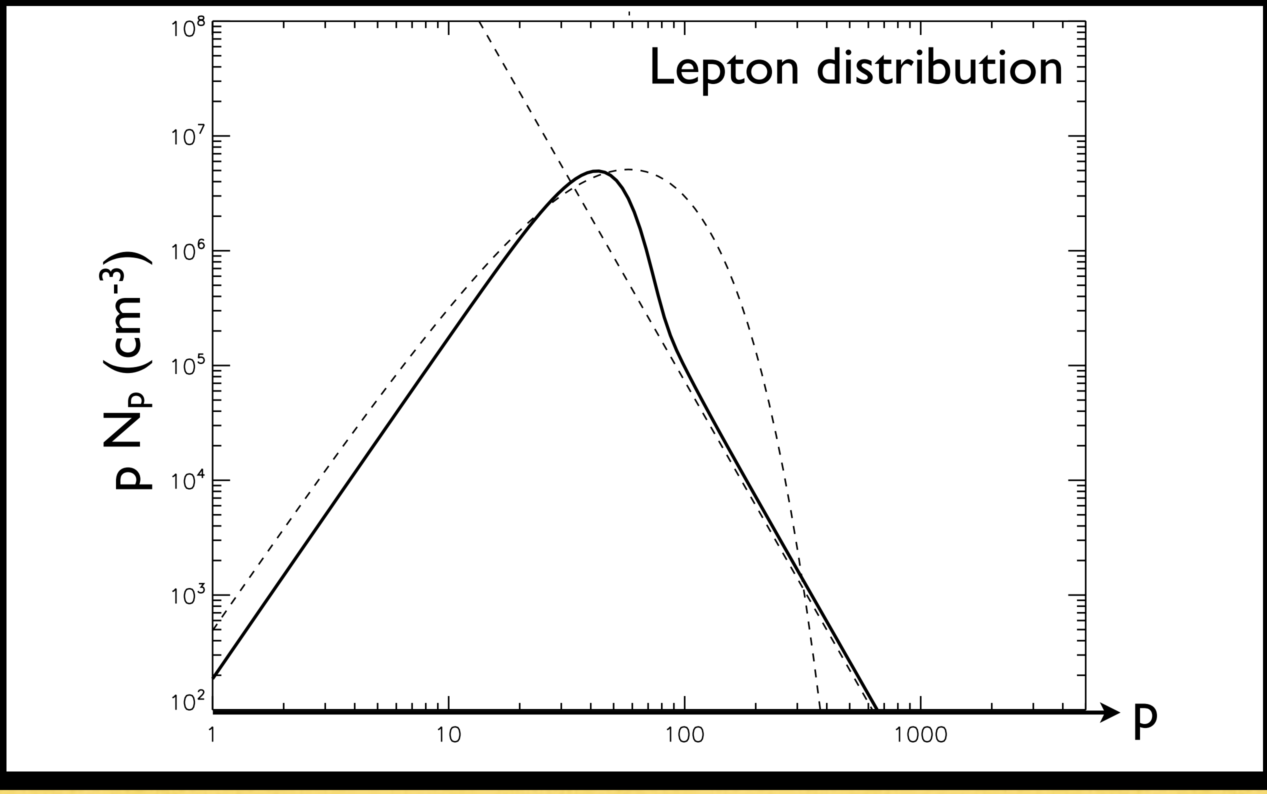
Sgr A* quiescent spectrum & distribution





No injection, P_{esc}=0

B ≃ 150 Gauss ($\epsilon_k/\epsilon_b \simeq 0.15$)

$n_e \simeq 5\times10^6$ cm^{-3}

L ≃ 1.4×10^{36}erg/s ($l_{th} = 2 \times l_{nth}$)

(Dibi et al., in prep.)

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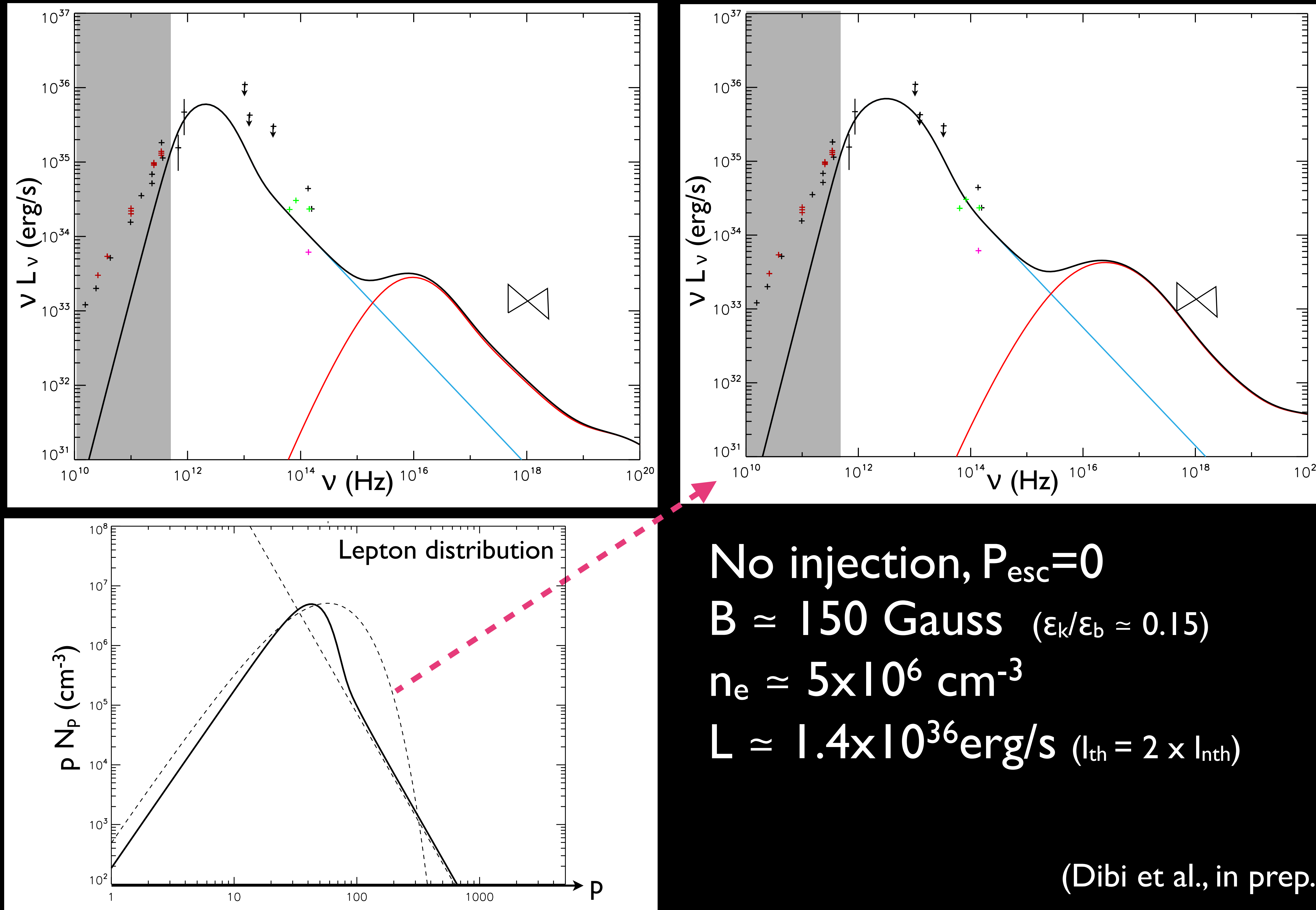

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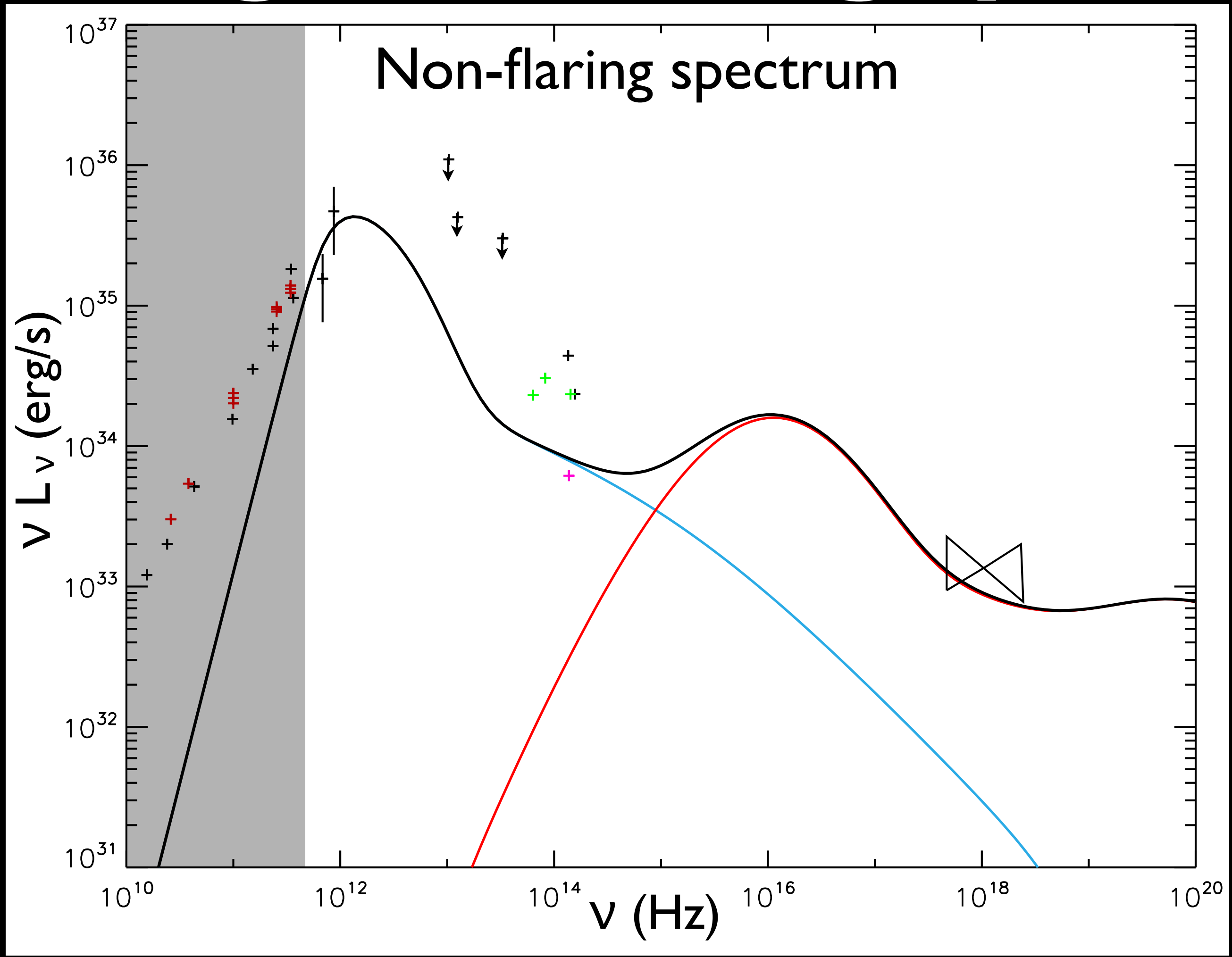
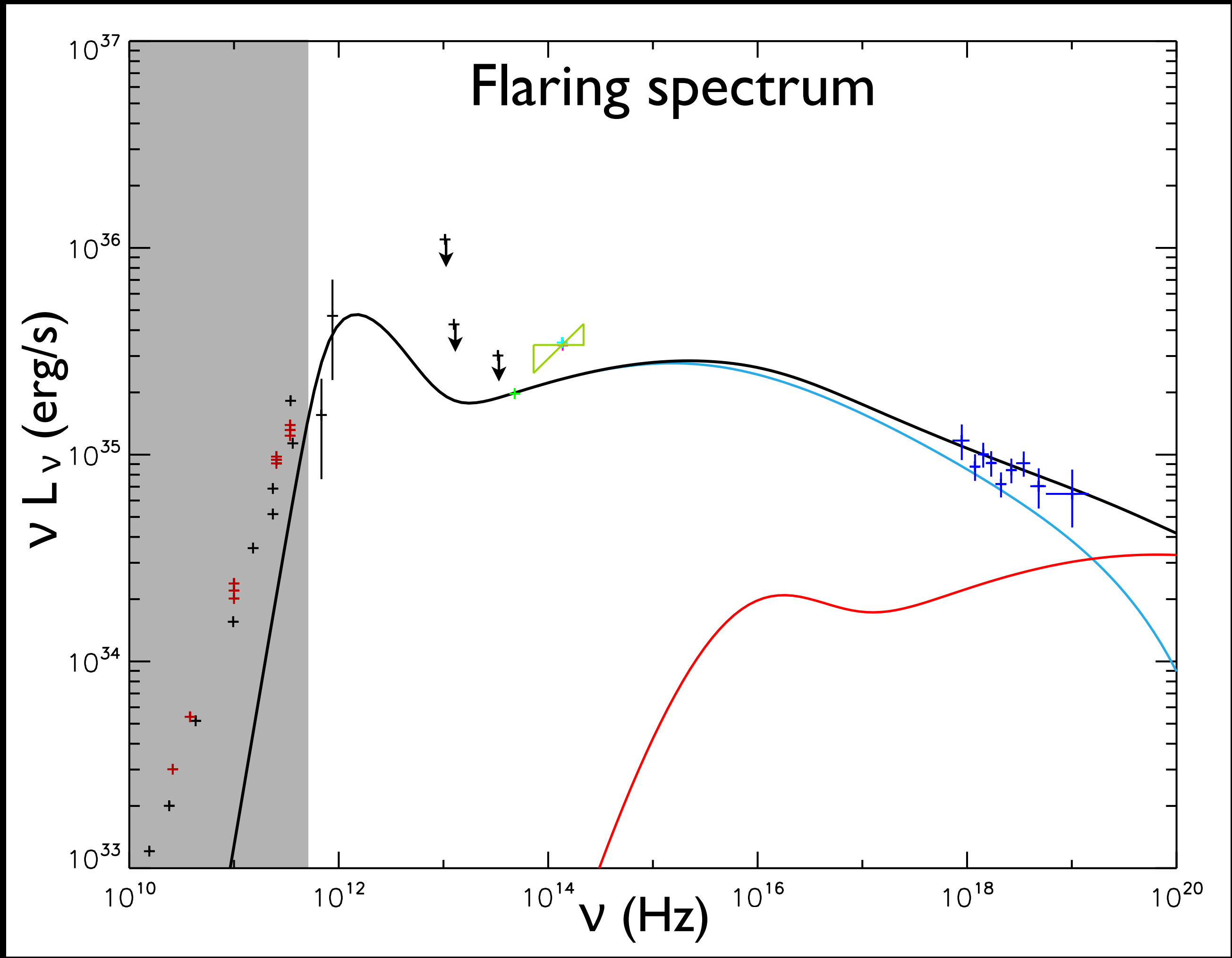
Sgr A* flaring spectrum and distribution





Injection and escape

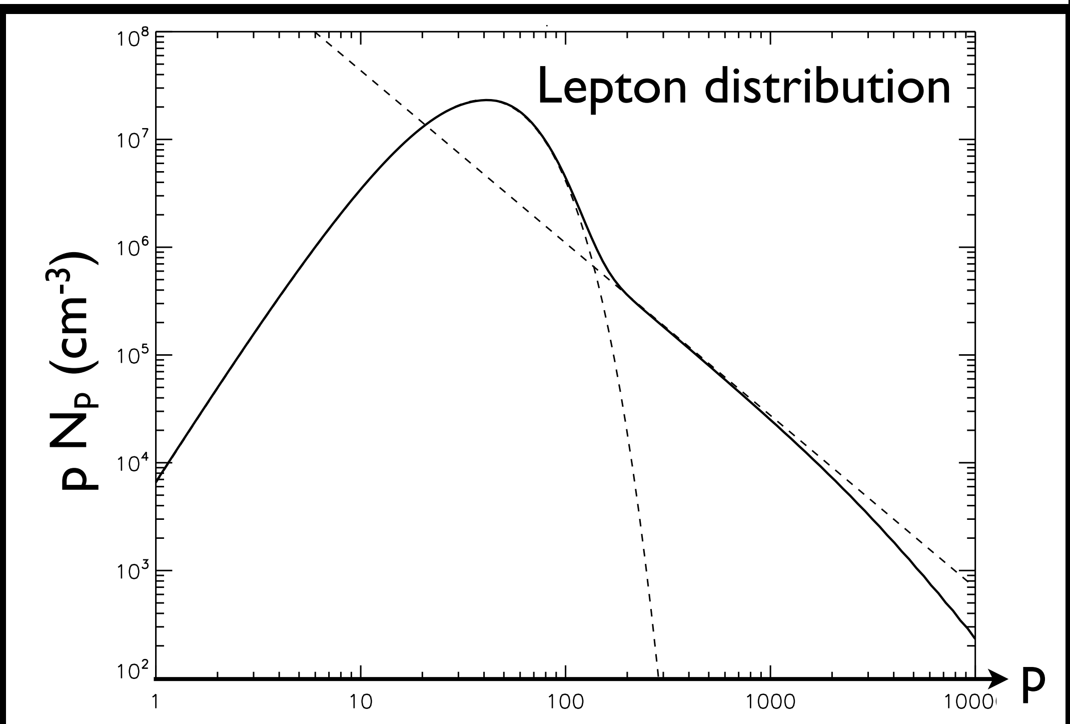
B ≃ 50 Gauss ($\varepsilon_k/\varepsilon_b \simeq$ 67-13)

L ≃ 1.0 - 4.1×10^{36}erg/s

constant injection, non-thermal component increases by a factor of six and flattens.

$n_e \simeq 3\times10^7$ cm^{-3}

(Dibi et al., in prep.)



Conclusions

- We expect that the accretion flow is injecting thermal electrons into the low magnetized inner plasma

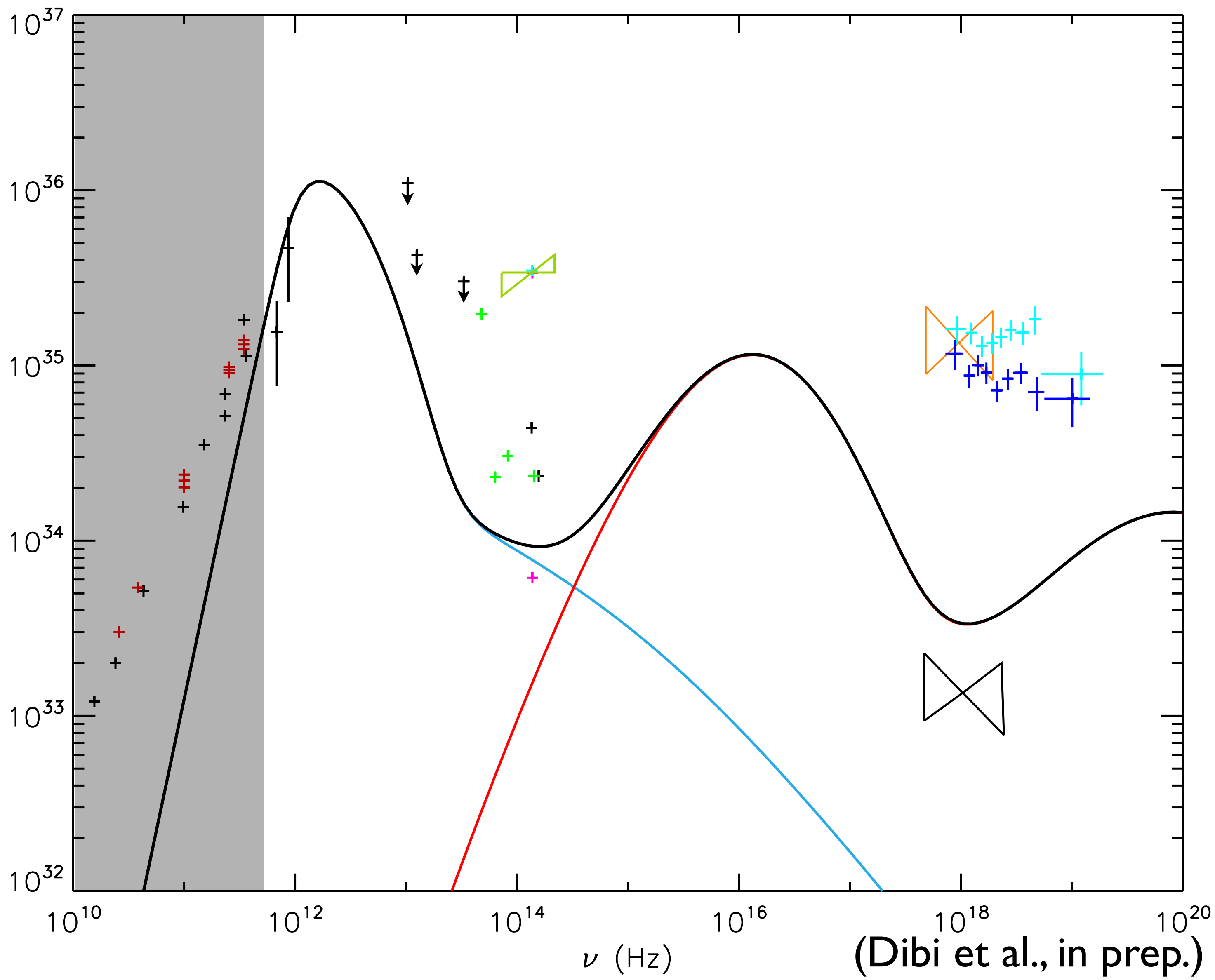
- Enhancement of the non-thermal heating process is responsible for the flaring event

- In preferred scenario, the particle distribution differs slightly from the usually assumed one

- The flare spectrum is best reproduced by non-thermal synchrotron with a cooling break (Agreement with Dodds-Eden et al. 2010)

Outlook/Future work

- Predicted quiescent Sgr A* spectrum with higher density plasma.



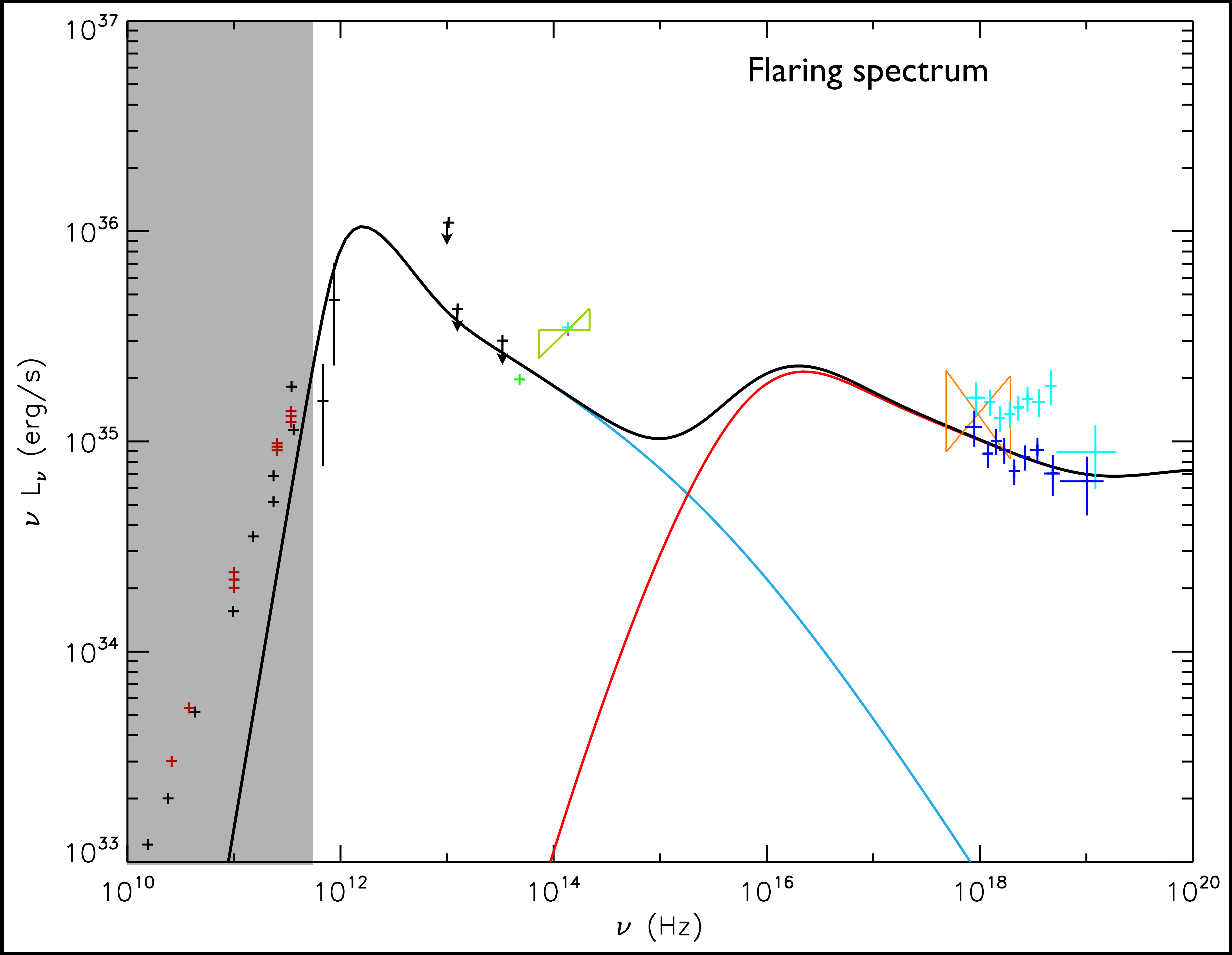
(Dibi et al., in prep.)

$n_e \simeq 1.4 \times 10^8$ cm^{-3}

- Use Flare statistics (J. Neilsen et al.) as a baseline to model the distributions.

Match simultaneous IR and X-ray flares to narrow down more the physics.

Move from single flare to families of flare events.



Flaring spectrum
10^{37}
10^{36}
10^{35}
10^{34}
10^{33}
$\nu \, L_\nu$ (erg/s)
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
ν (Hz)