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CONNECTING SCIENCES

Can primordial Black Hole Dark Matter explain the γ-ray excess at the Galactic Centre?

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in collaboration with
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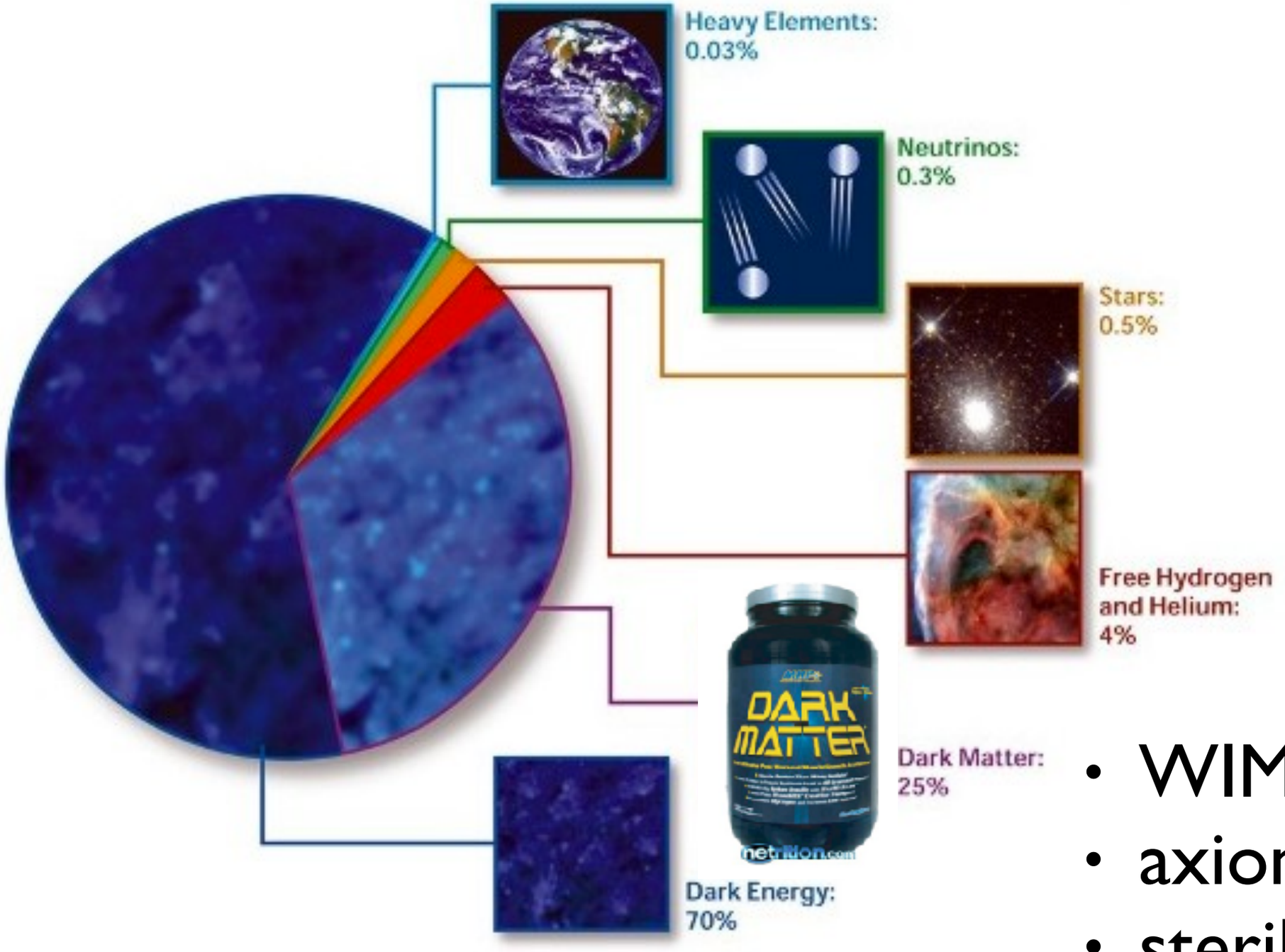
Planck 2017
Warssaw

- Motivation
  — LIGO g-wave events → primordial BHs?
  — Fermi LAT → Galactic Centre Excess?
- Constraints on PBHs
- Energy spectrum and morphology of the signal of Galactic PBH
- Summing up problems, troubles and uncertainties
- Always look on the bright side of life — PBH can explain GCE
- Takeaway messages



- WIMP
- axion
- sterile neutrino
- …zilla

Why not primordial BHs?

Primordial Black Holes as Dark Matter: motivation & constraints

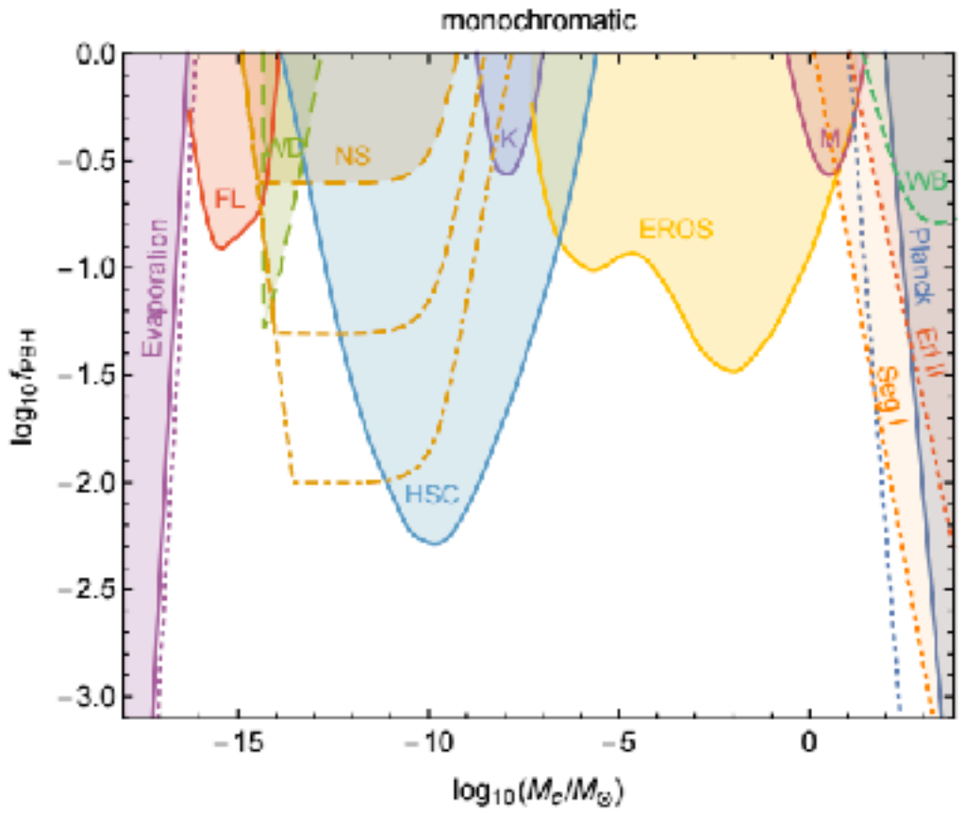
Motivation

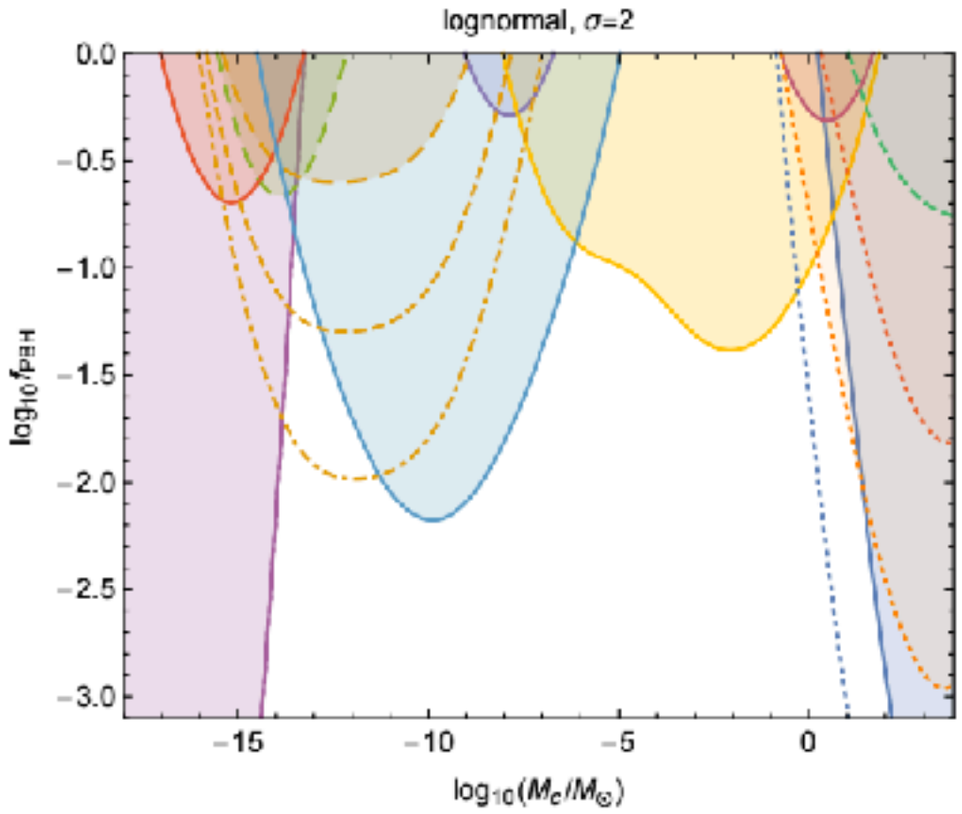
- LIGO boosted the experimental motivation (so far)

Gravitational wave event	Detection time (UTC)	Publication date	Location	Luminosity distance	Energy	Source
GW150914	2015-09-14 09:50:45	2016-02-11	Uncertain, probably in Southern sky	410 Mpc (1,300 Mly)	3 $M_\odot \times c^2$; 5.4×10^{47} joules (5.4×10^{54} erg; 5.4×10^3 foe) [NB 1]	Merger of a 36 $M_\odot$ black hole with a 29 $M_\odot$ black hole, detected by LIGO
GW151226	2015-12-26 03:38:53	2016-06-15	Uncertain	440 Mpc (1,400 Mly)	1 $M_\odot \times c^2$; 1.8×10^{47} joules (1.8×10^{54} erg; 1.8×10^3 foe) [NB 2]	Merger of a 14 $M_\odot$ black hole with a 8 $M_\odot$ black hole, detected by LIGO

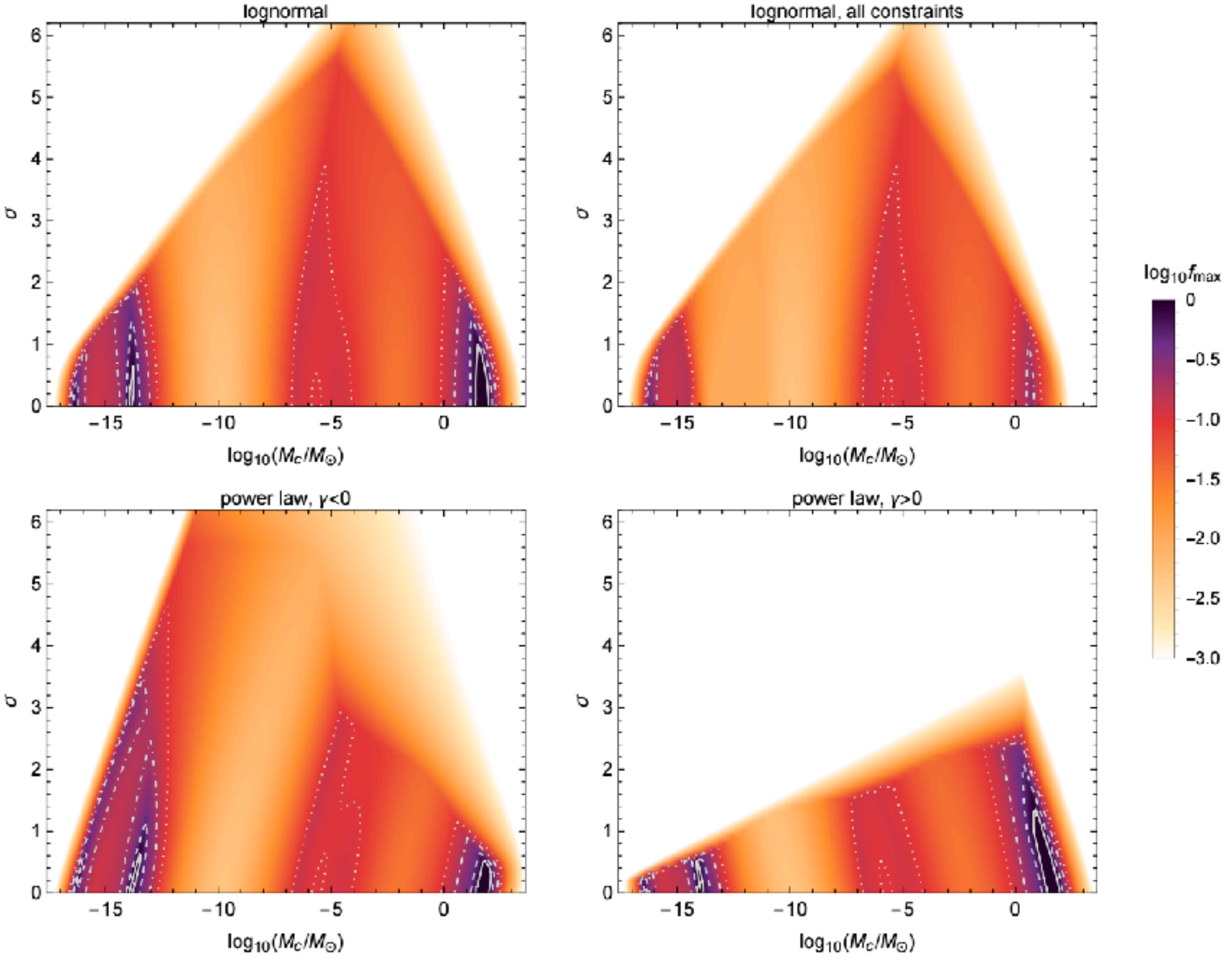
- Theoretically motivated by models of inflation
  For example, Kannike, Marzola, Raidal & Veermäe [1705.06225]

- BHs radiates due to ‘eating’ of gas/plasma
  — many constraints!





Carr, Raidal, Tenkanen, Vaskonen & Veermäe [1705.05567]



Carr, Raidal, Tenkanen, Vaskonen & Veermäe [1705.05567]

Galactic Centre (γ-ray) Excess

Galactic Centre Excess

Hooper & Goodenough [1010.2752]

↓

~500 papers

↓

a paper from the Fermi collaboration,
Ackermann et al [1704.03910]

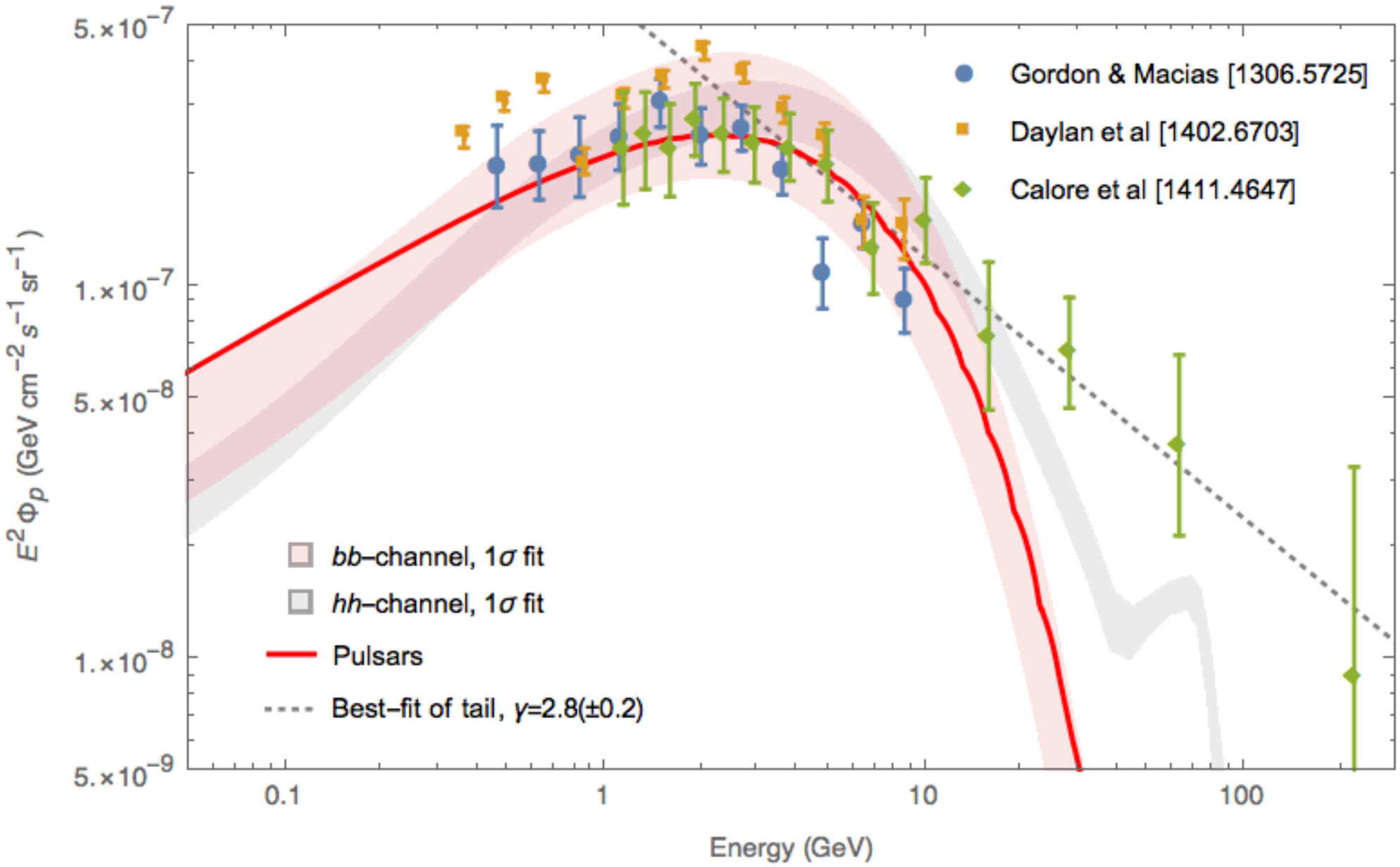
Distributed in energy, maximum around 1-5 GeV

Extended morphology, central symmetric (?),

$$F \propto r^{-2.6\pm0.2}$$

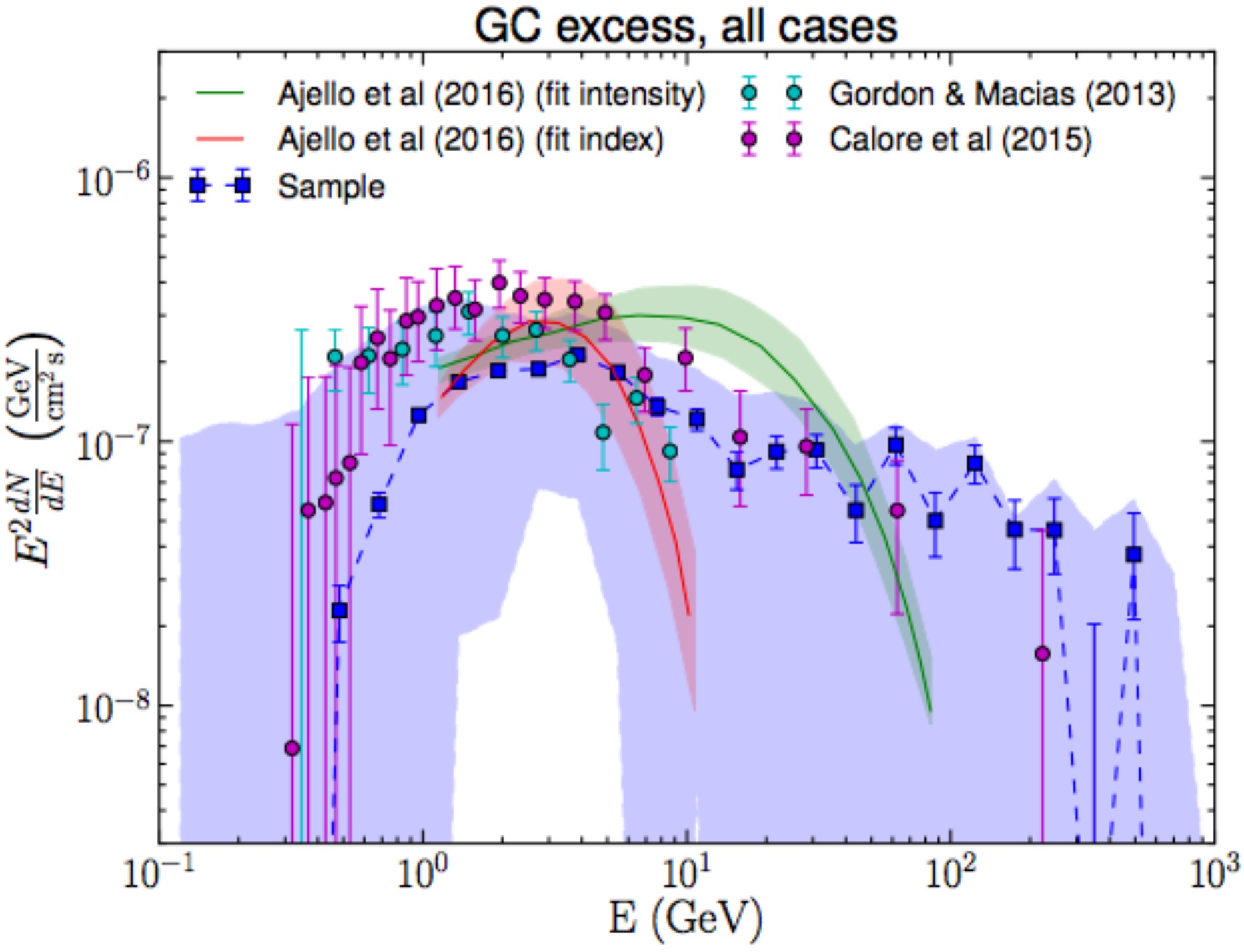
NB! The GCE signal is only few % of the total

GCE: energy spectrum



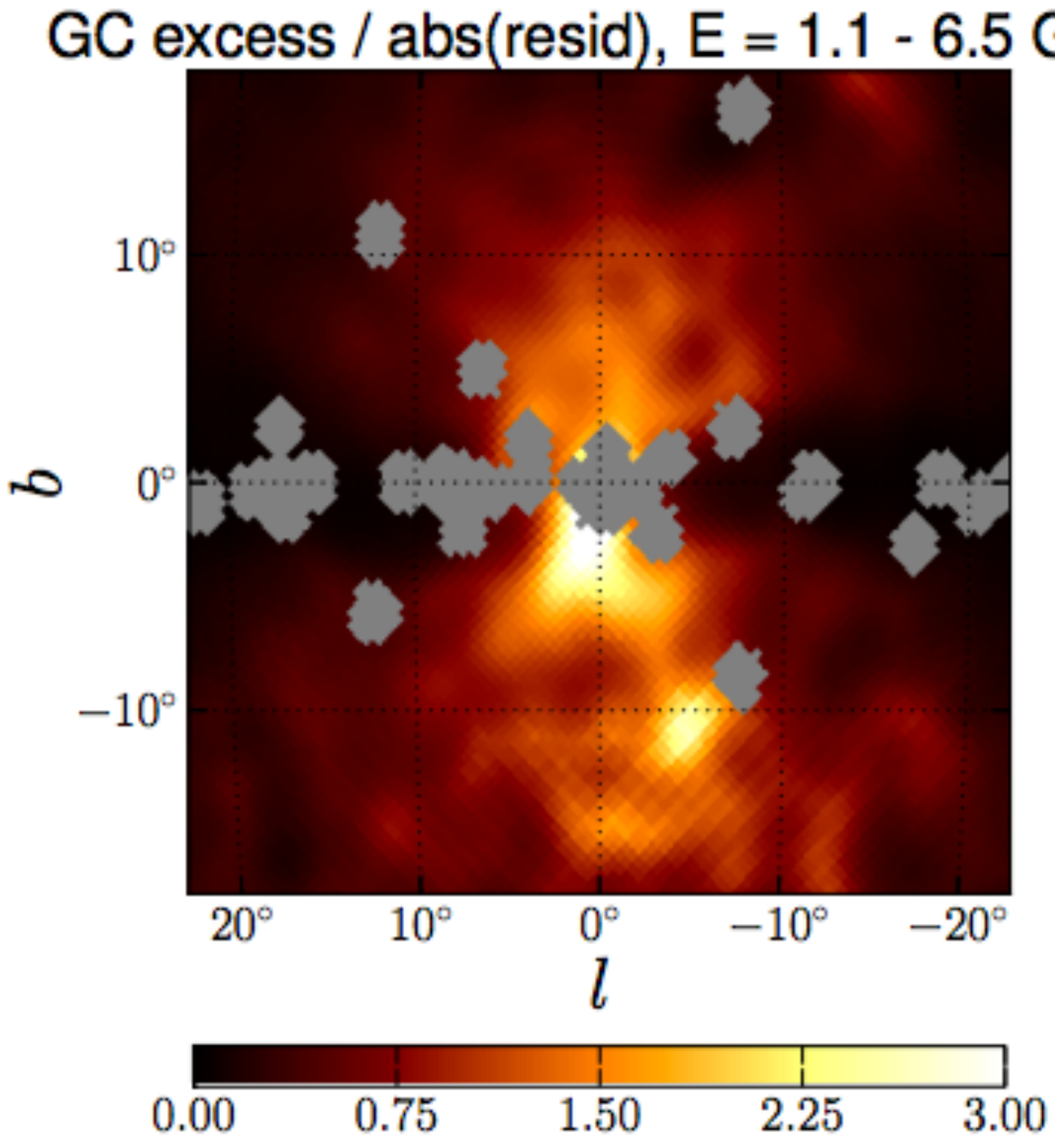
Hektor, Hütsi & Raidal [appearing soon]

GCE: energy spectrum



Ackermann et al [1704.03910]

GCE: morphology



Ackermann et al [1704.03910]

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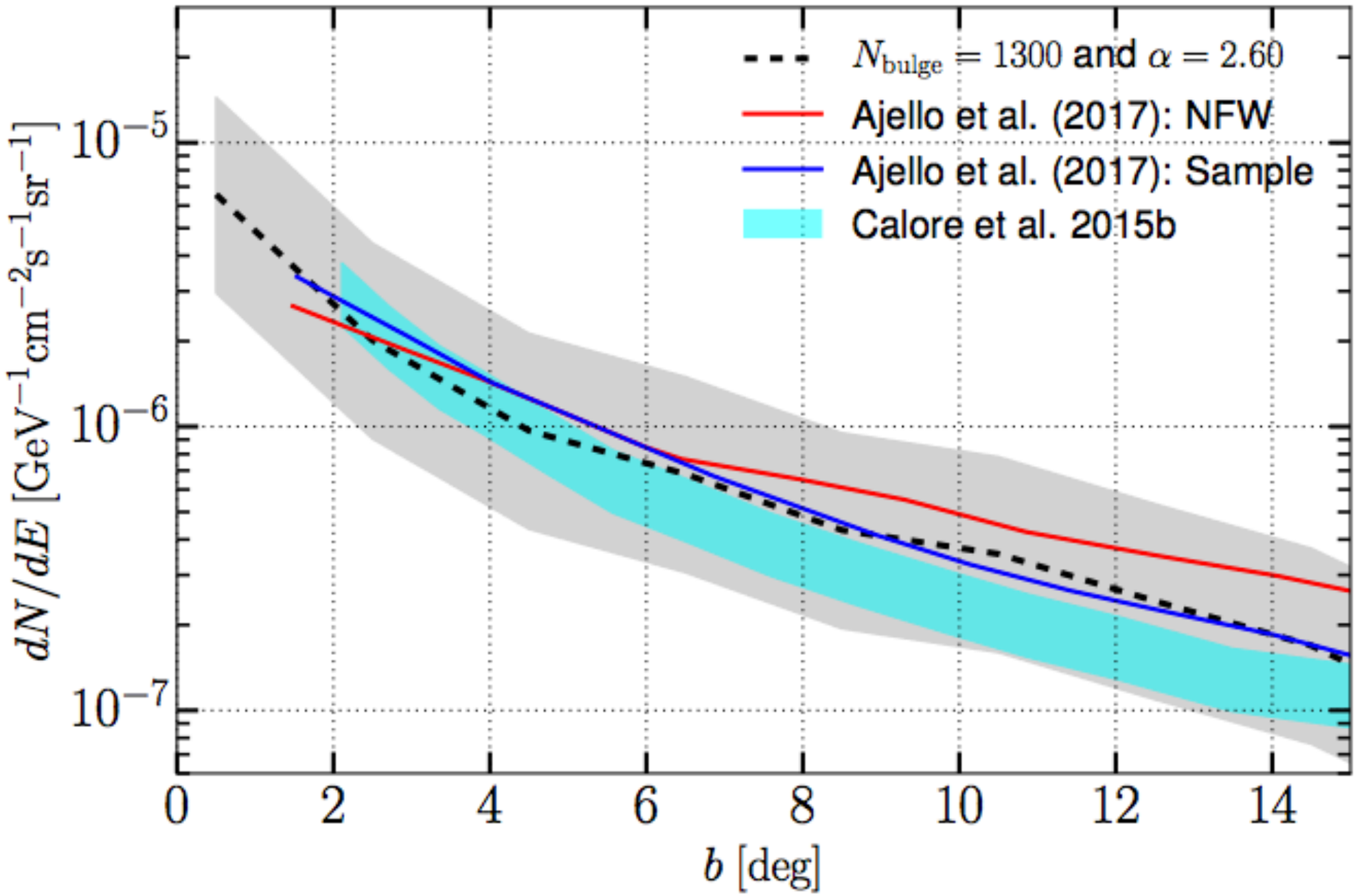


Ajello et al [1705.00009]

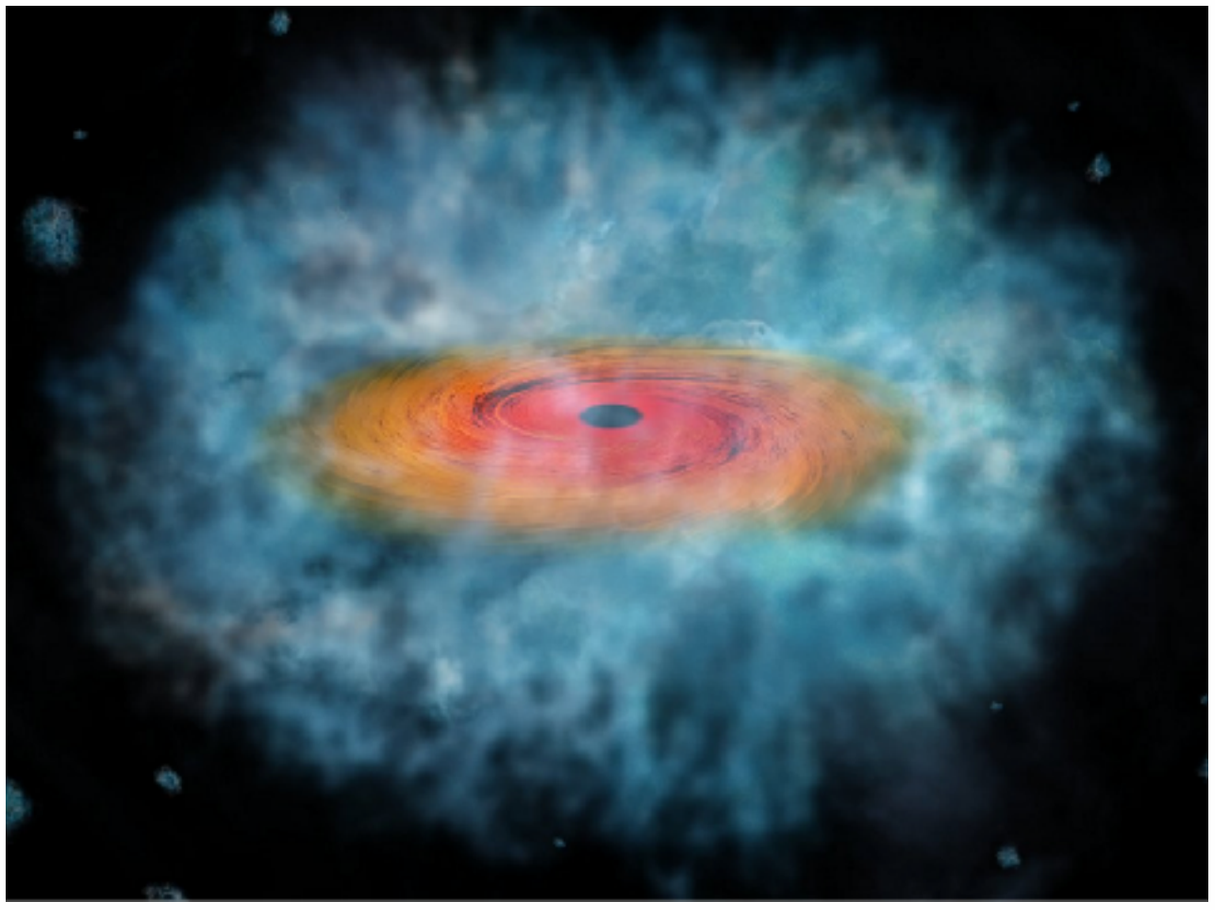
Does BH radiate γ-rays?

Radiation of BH

- BH radiates due to the dissipation of accretion (gas/plasma)
- PBHs are typically isolated and 'starving' ($L_{tot} \ll L_{Edd}$)

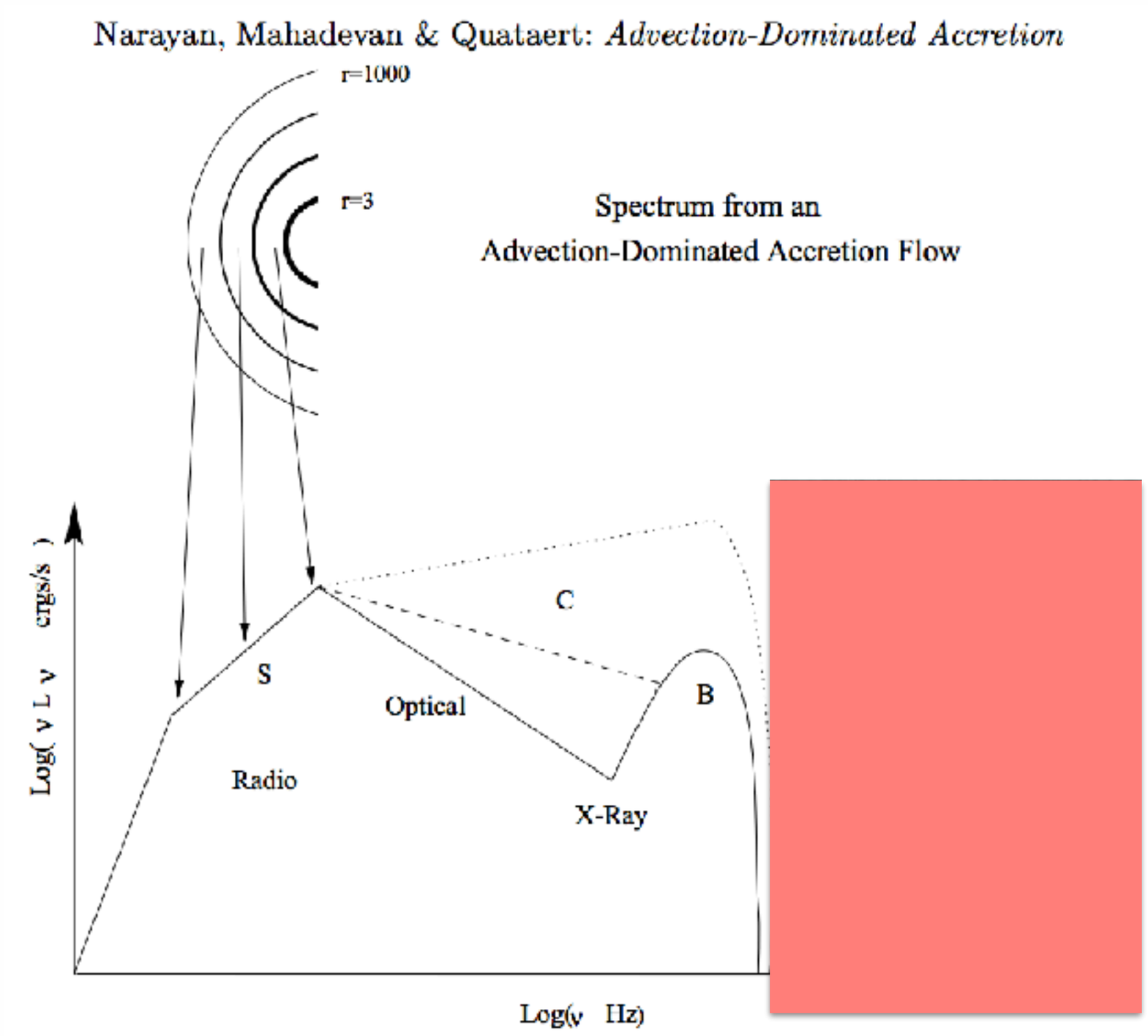
  → ADAF, $L_{tot} < 0.01\ L_{Edd}$
- The bolometric luminosity of BH

$$L_B \propto (n_{gas}\, v^{-3})^{\alpha},\ \ 1<\alpha<2$$



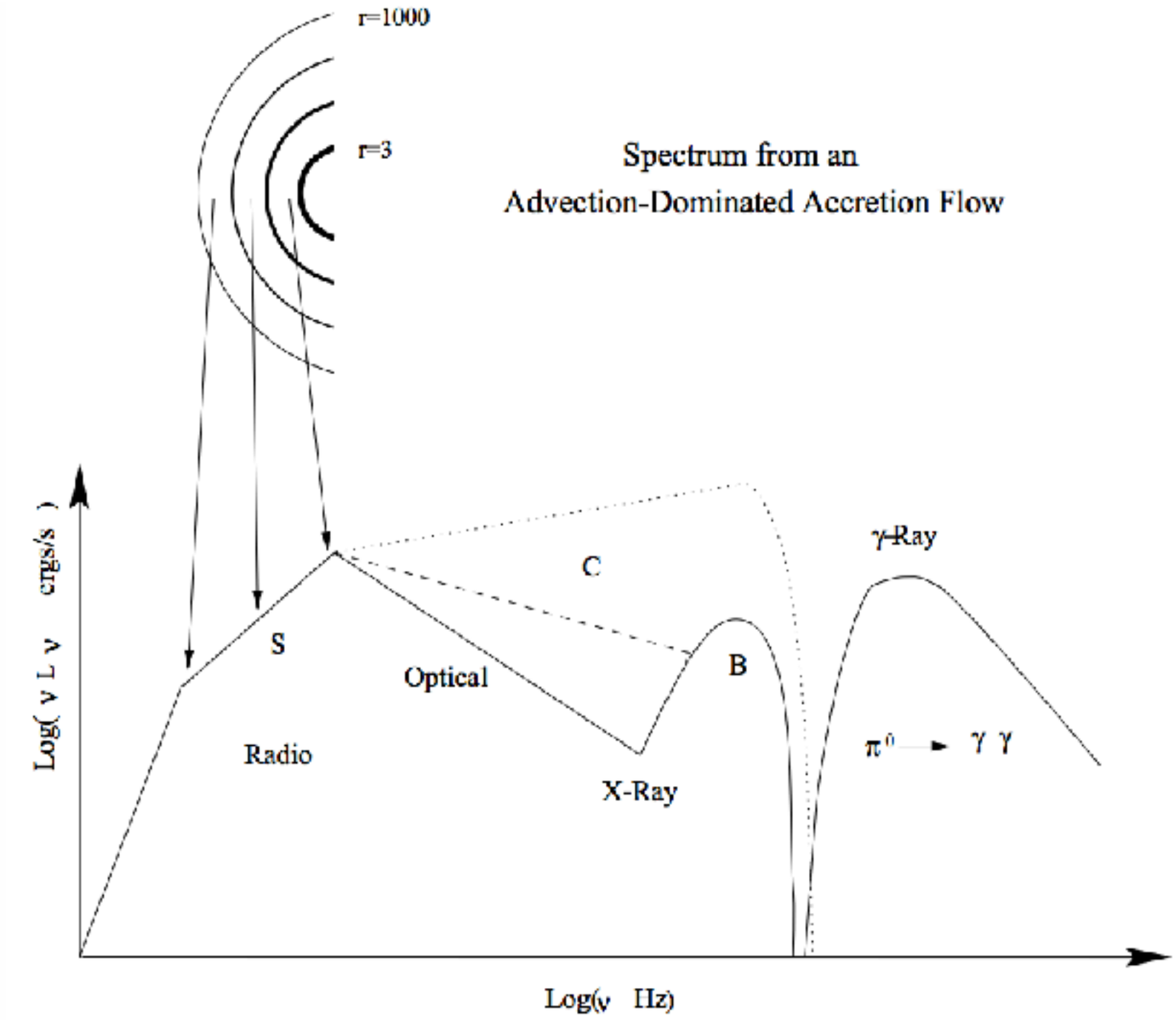
Credit: NASA/CXC/M. Weiss

Radiation spectrum of ADAF



Narayan, Mahadevan & Quataert [astro-ph/9803141]

Radiation spectrum of ADAF



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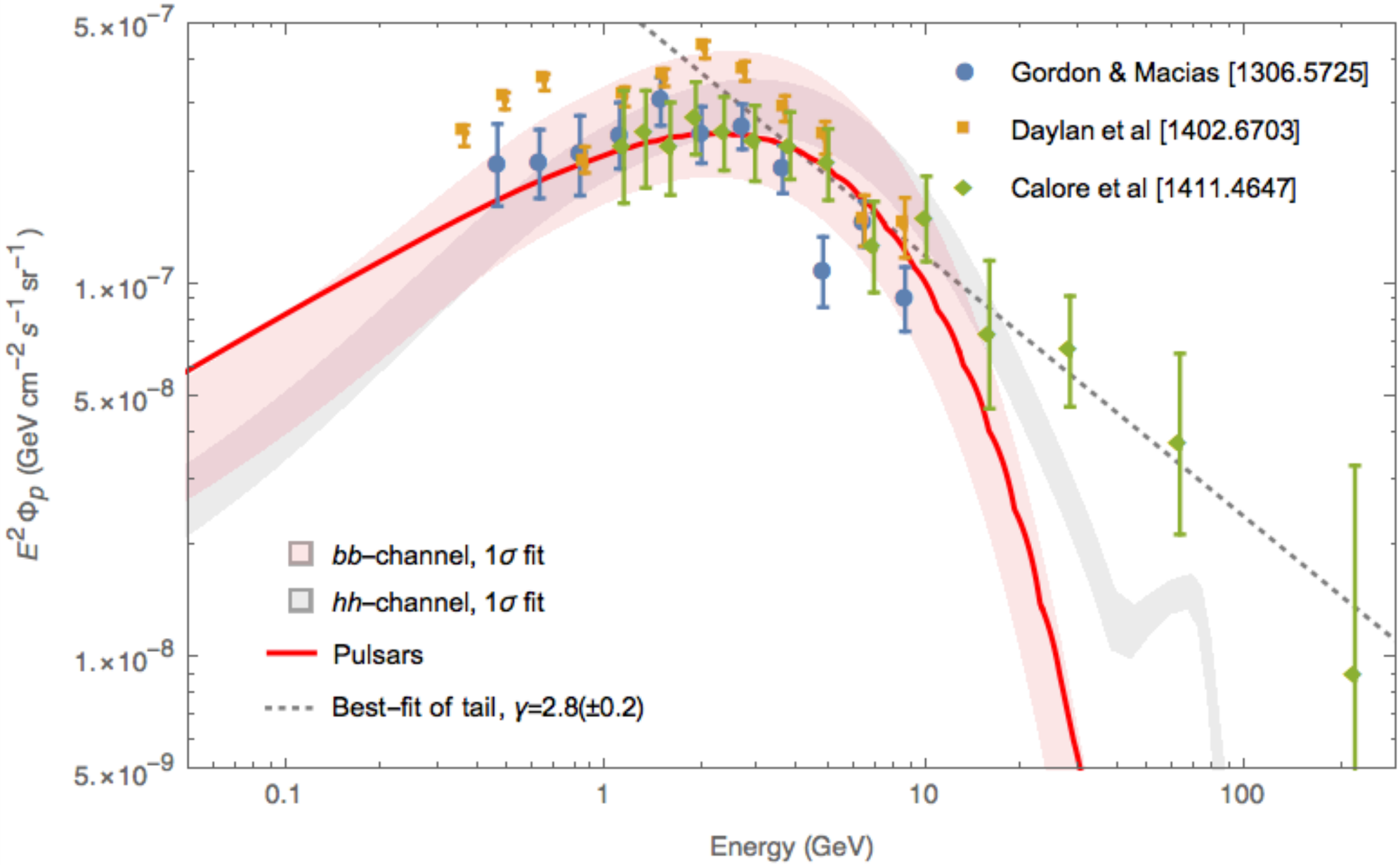
Let's put this to the picture…



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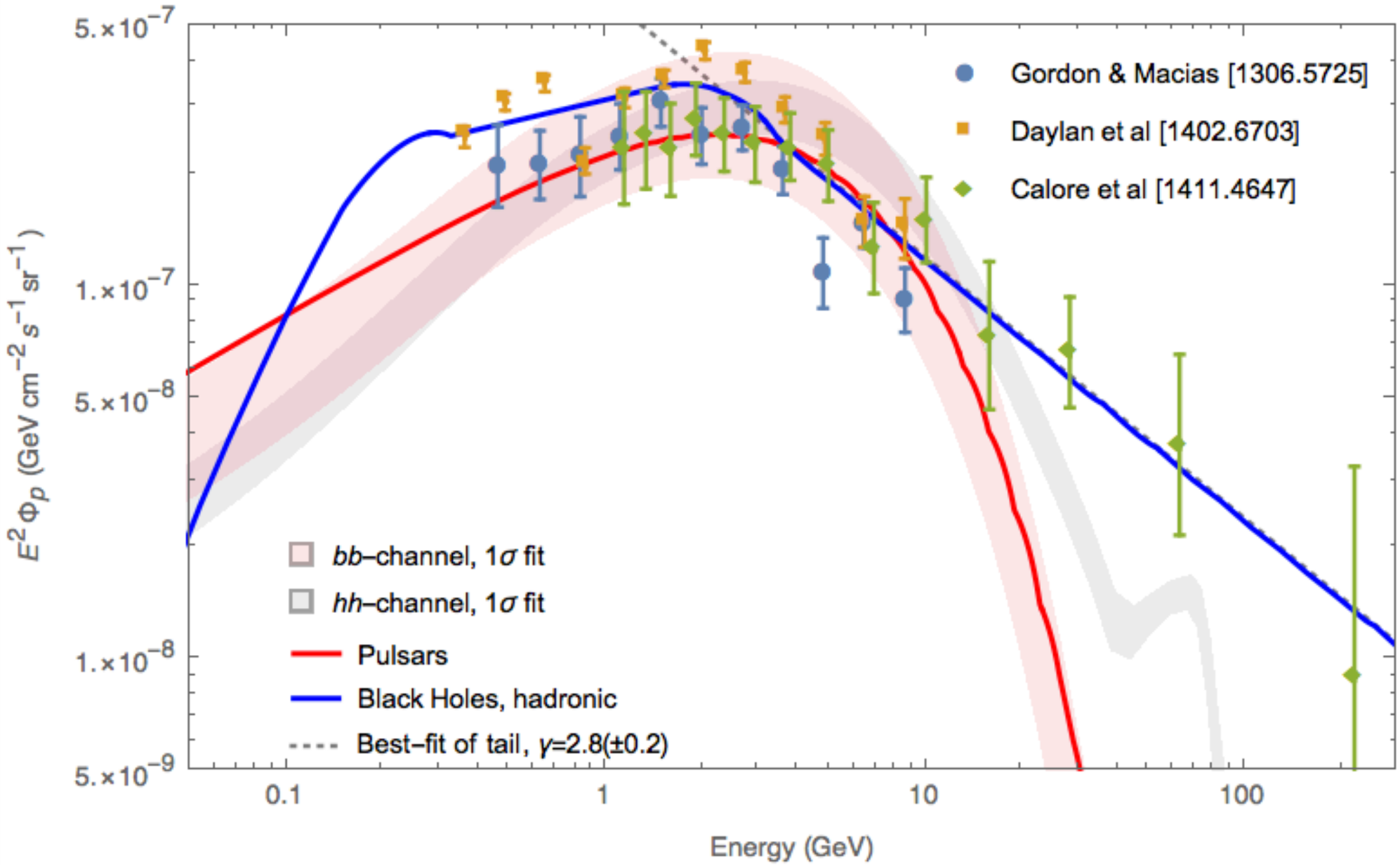

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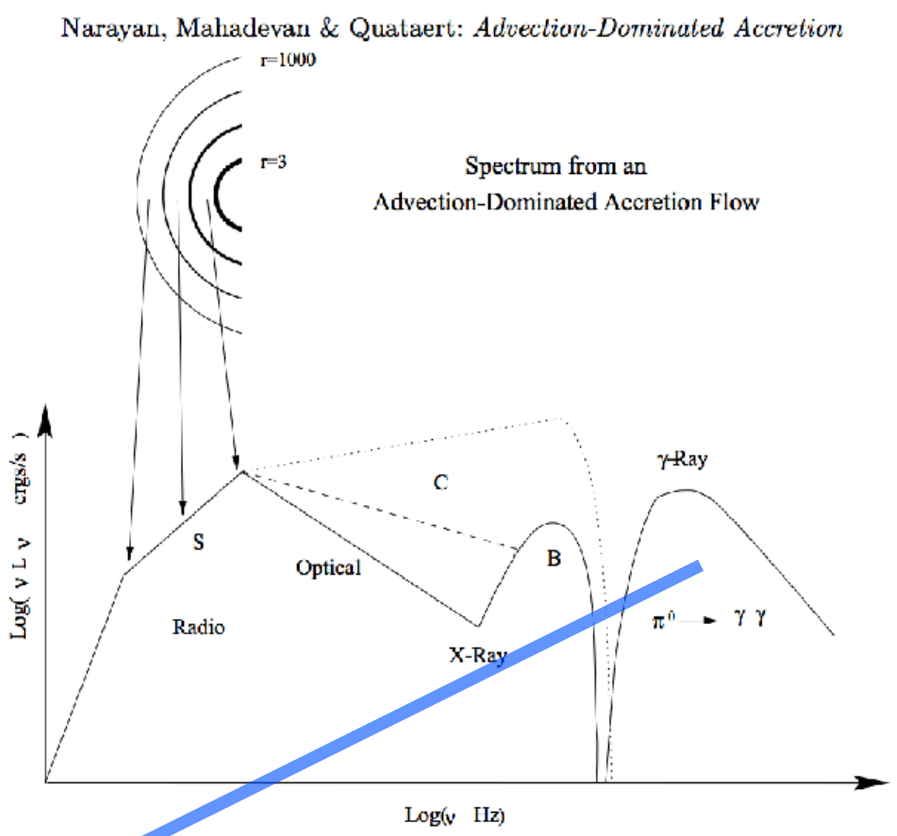

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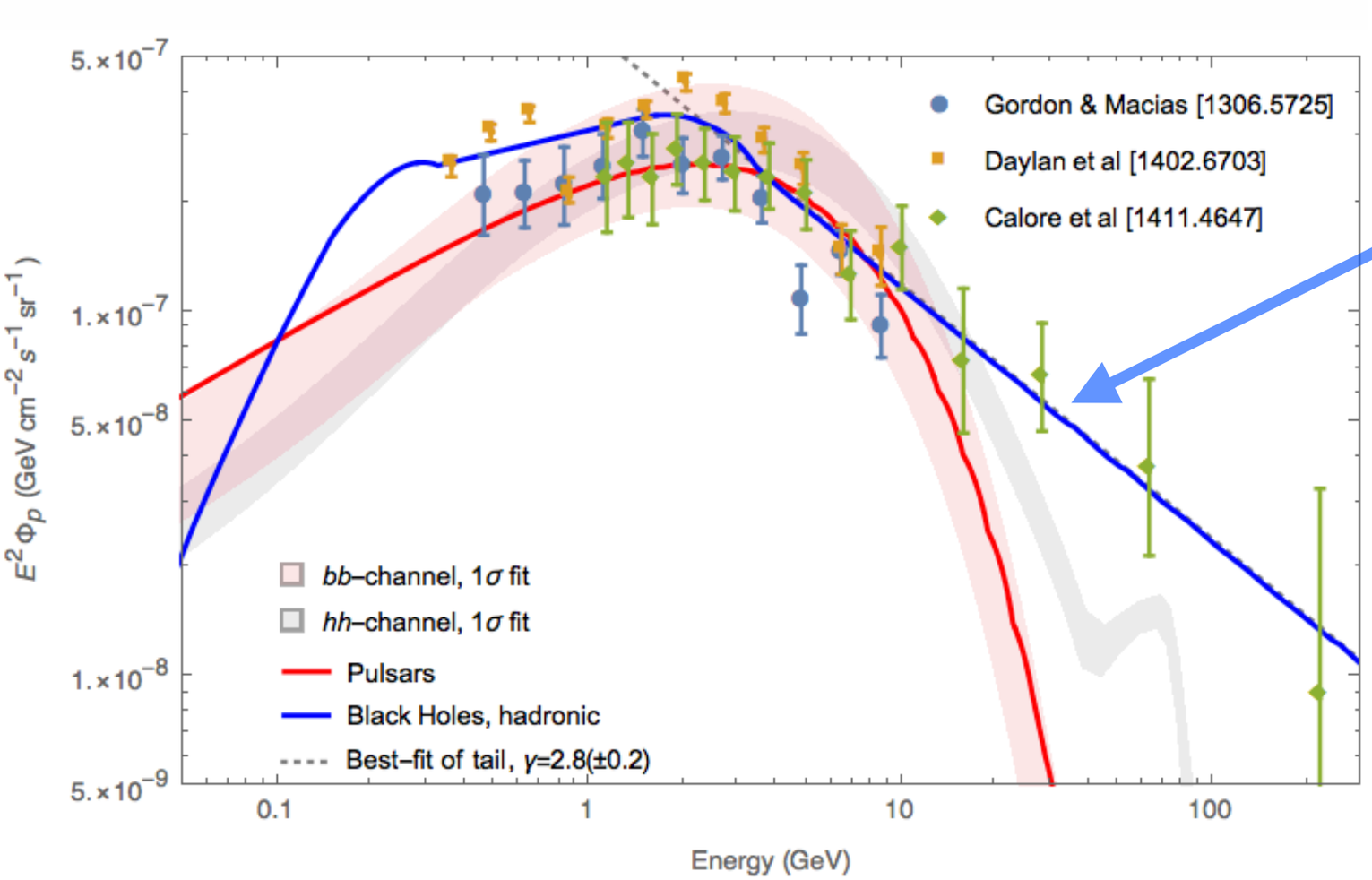

The morphology & total luminosity

Radiation of BH

$$L_B = \eta(\dot{m})\,\dot{m}c^2$$

$$\dot{m} = \lambda\,\dot{m}_{\rm Bondi},\ \lambda \simeq 0.01$$

$$\dot{m}_{\rm Bondi} = 4\pi(GM)^2\rho_{\rm gas}(v^2+c_s^2)^{-3/2} \simeq 4\pi(GM)^2\rho v^{-3}$$

$$\eta(\dot{m}) = \begin{cases} 0.1, & \dot{m} > \dot{m}_{\rm crit} \\ 0.1\,\dot{m}/m_{\rm crit}, & \dot{m} < \dot{m}_{\rm crit} \end{cases}$$

$$\dot{m}_{\rm crit} \simeq (10^{-2}\ldots10^{-3})\,\dot{m}_{\rm Edd}$$

$$L_B \propto (\rho_{\rm gas}v^{-3})^{\alpha},\ \alpha = 1\ldots2$$

$$L_{\rm NuSTAR} \simeq 0.01 L_B$$

$$L_{\rm Fermi} \simeq 0.06 L_B$$

Summing up problems, troubles and uncertainties

$$j(x,y,z) \propto n_{\rm PBH}(x,y,z)\ \left(\rho_{\rm gas}(x,y,z)\ v_{\rm disp}(x,y,z)^{-3}\right)^{\alpha}$$

Distribution of BHs:
NWF? Stellar clusters?

Distribution of gas:
H2 only? all?
analytic model? numeric data?

Relative dispersion of BHs and gas
NB! Very sensitive!
Total potential + solve Jeans equations?
observational data + DM simulations?

Summing up problems, troubles and uncertainties

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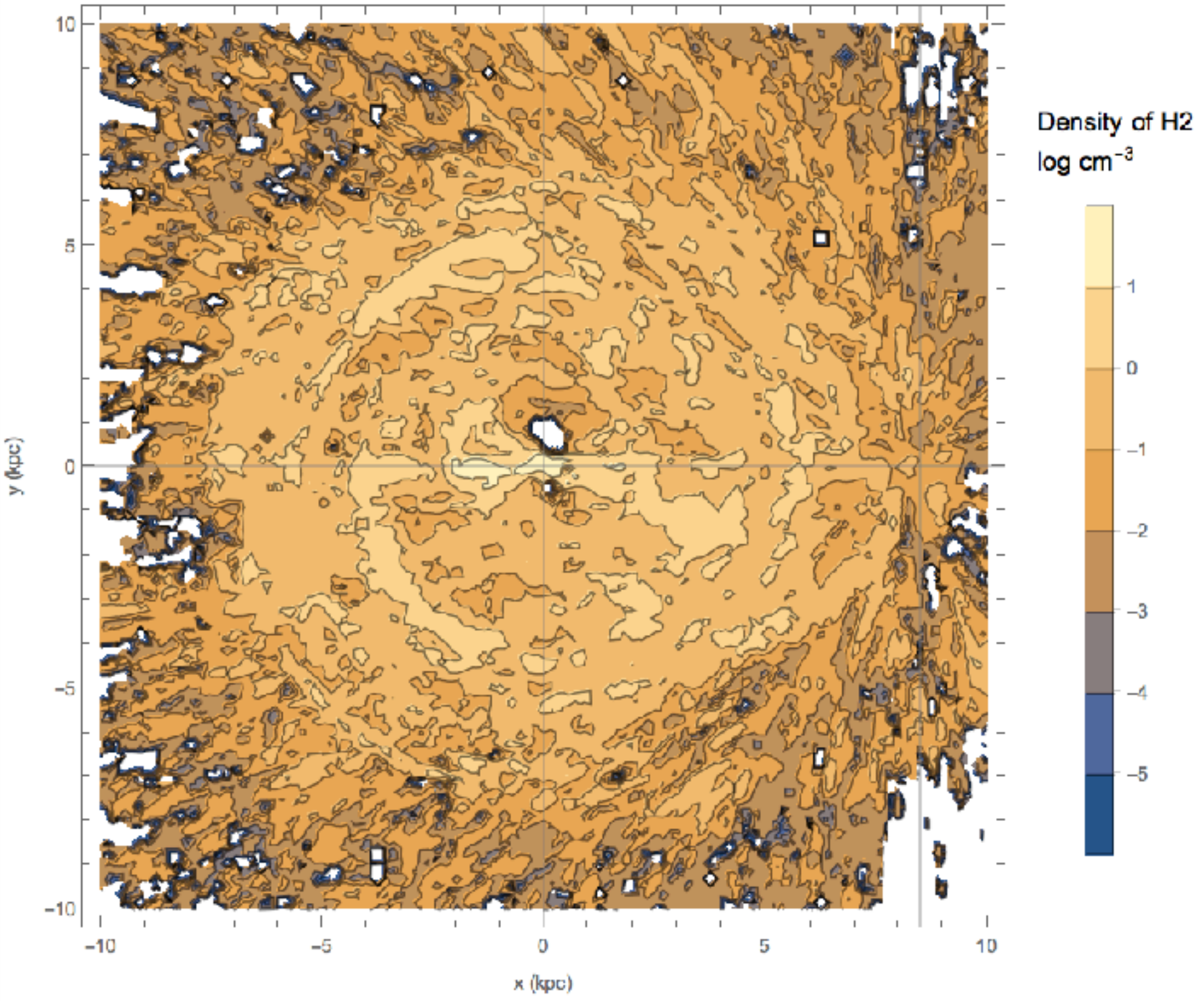
Distribution of H2



Pohl et al [0712.4264]

Morphology of the signal

- Calculations — Monte Carlo (with some analytical tests):

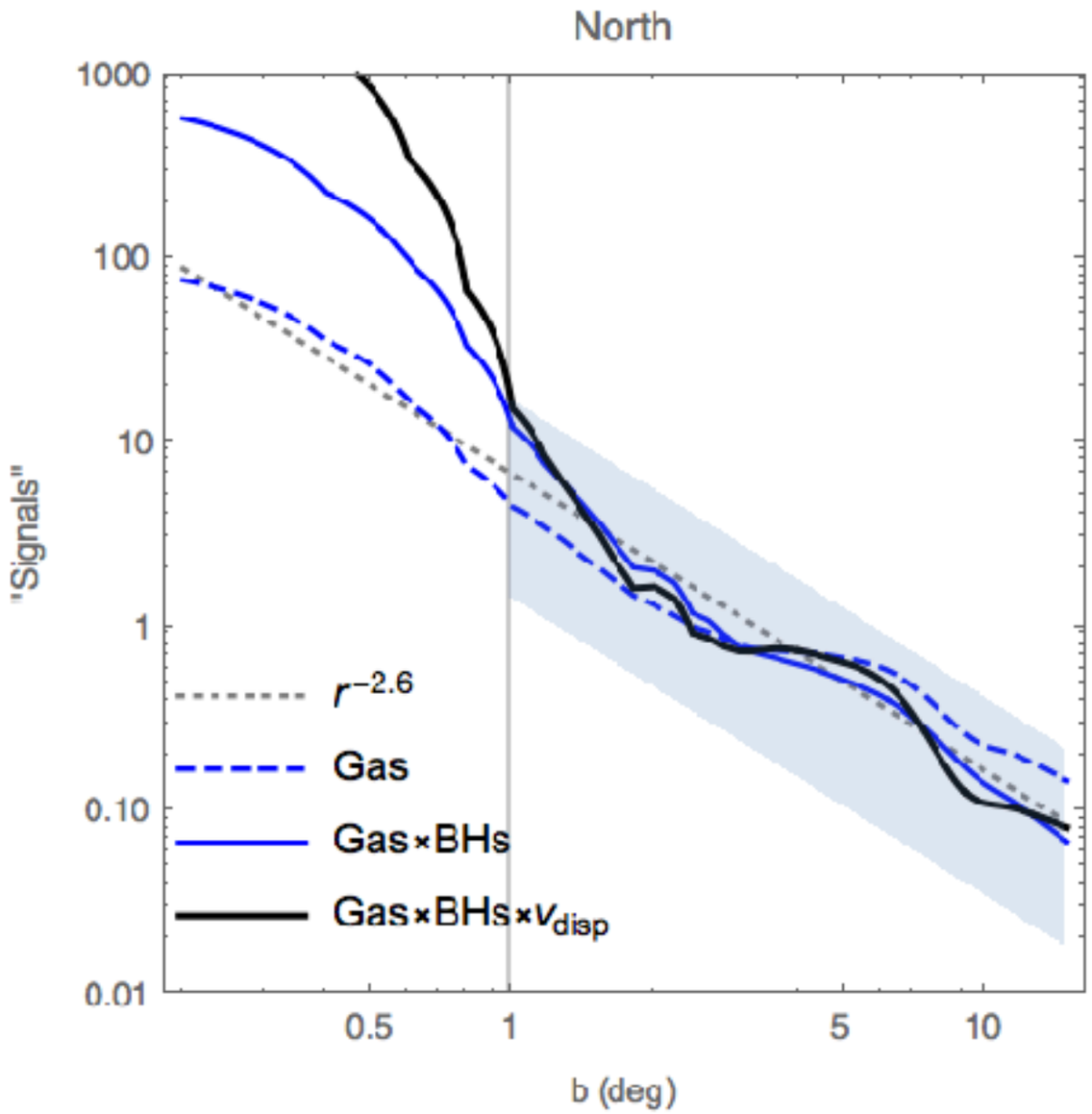
  — due to $j \propto v^{-3\alpha}$, the MC samples vary strongly

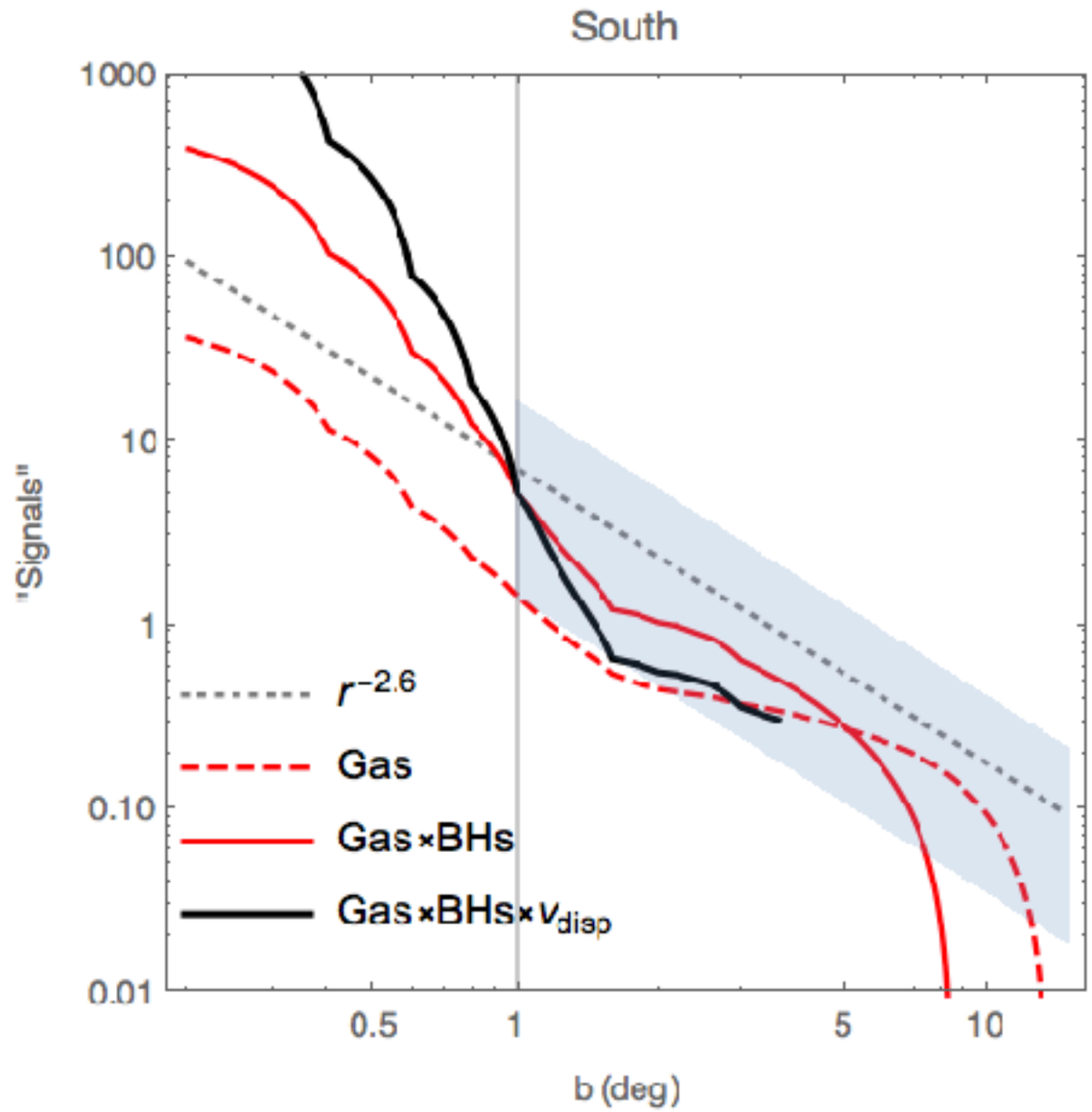
  — some bright sources can appear above the NuSTAR point source constraint

- The distribution of molecular gas (Pohl et al [0712.4264]) has north/south (b>0/b<0) asymmetry

- 'Technicalities': H2 is measured by CO lines, what is the relation factor X_{CO} between CO and H2? Many different models

Morphology of the signal





Takeaway messages

- PHS can provide all DM in the dark corners of some models
- The energy spectrum of PBH fits GCE
- The morphology of the PHB signal has many uncertainties: distribution of gas and PBHs, velocity dispersion
- Fitting the PHB signal against GCE:
  — (too) bright central region (b<1 deg)
  — asymmetry between the north and south (b>0 / b<0)

- **Future:** finish a preprint, try different H2 datasets, looking for better models of velocity dispersion etc

Thank you!