High energy neutrinos from Seyfert galaxies

Elisa Resconi
Technical University of Munich
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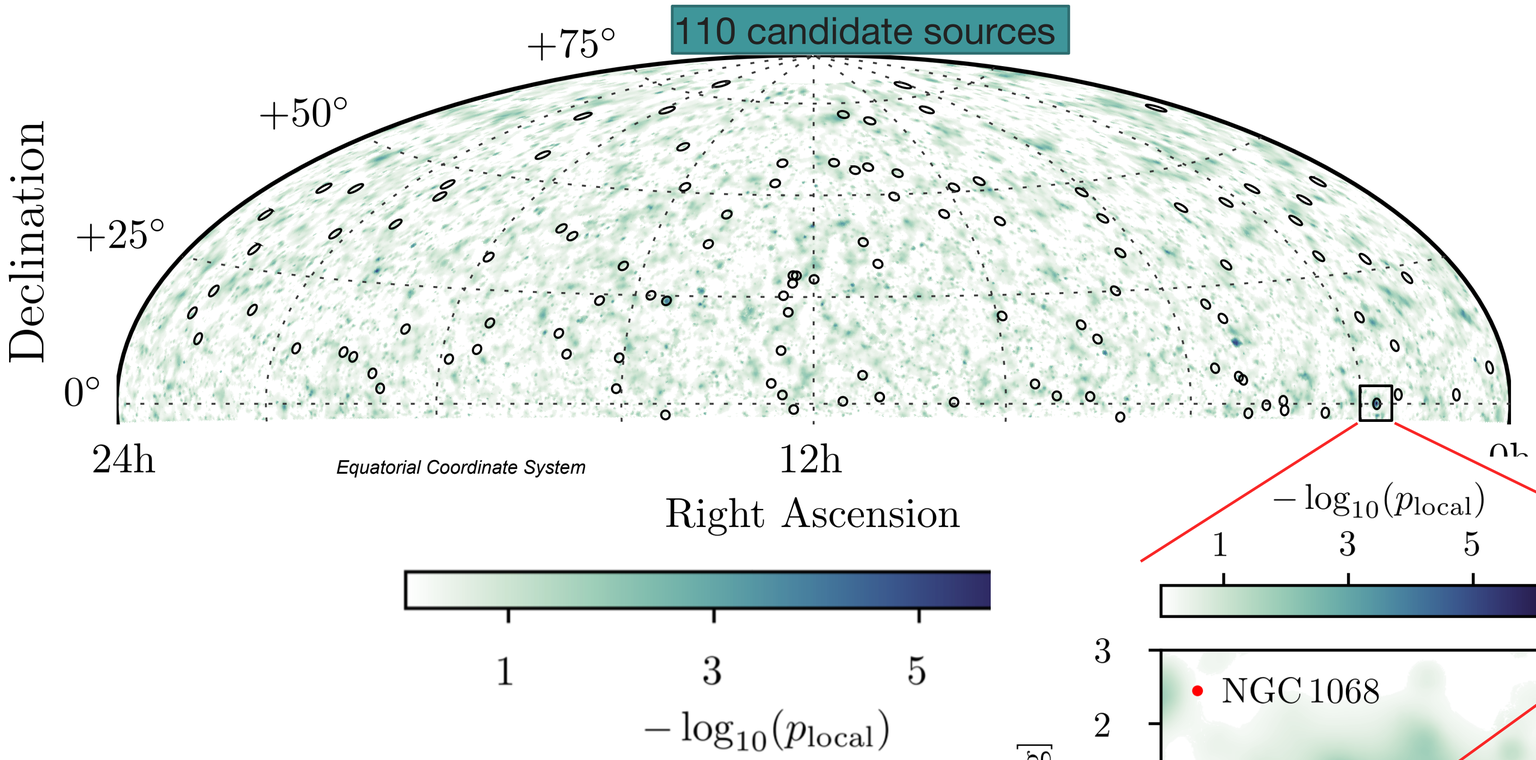
based on P. Padovani, C. Bellenghi, ER et al., in preparation

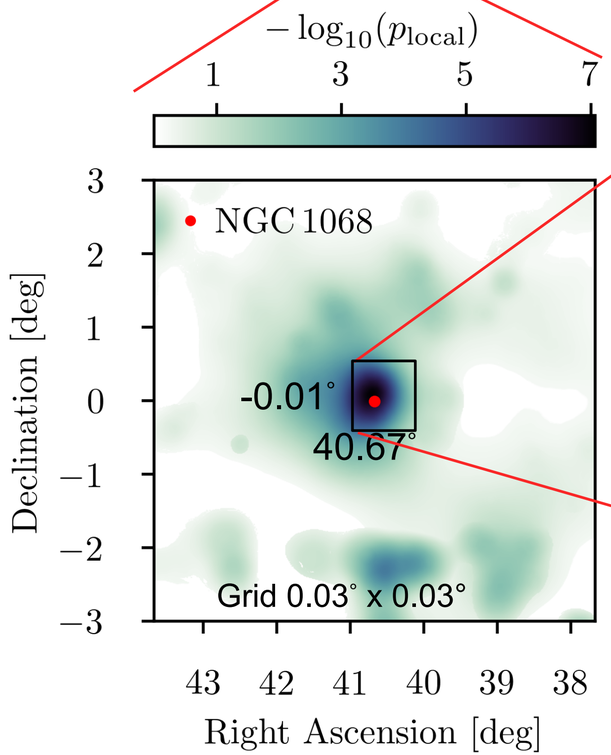
Evidence of neutrino emission from NGC 1068

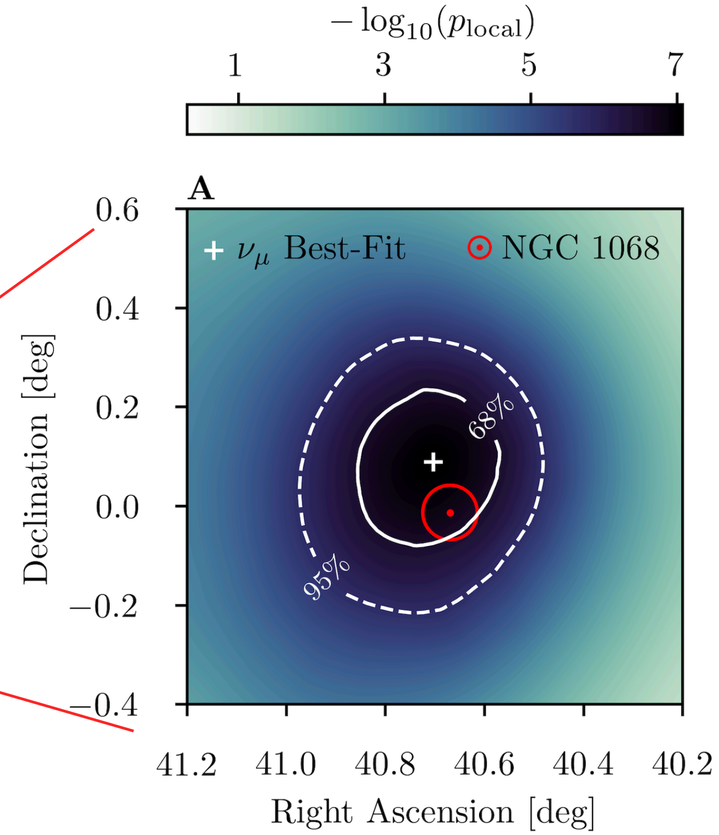
110 candidate sources

The IceCube Coll., ***Science*** 378 (2022)

Global significance **4.2σ**





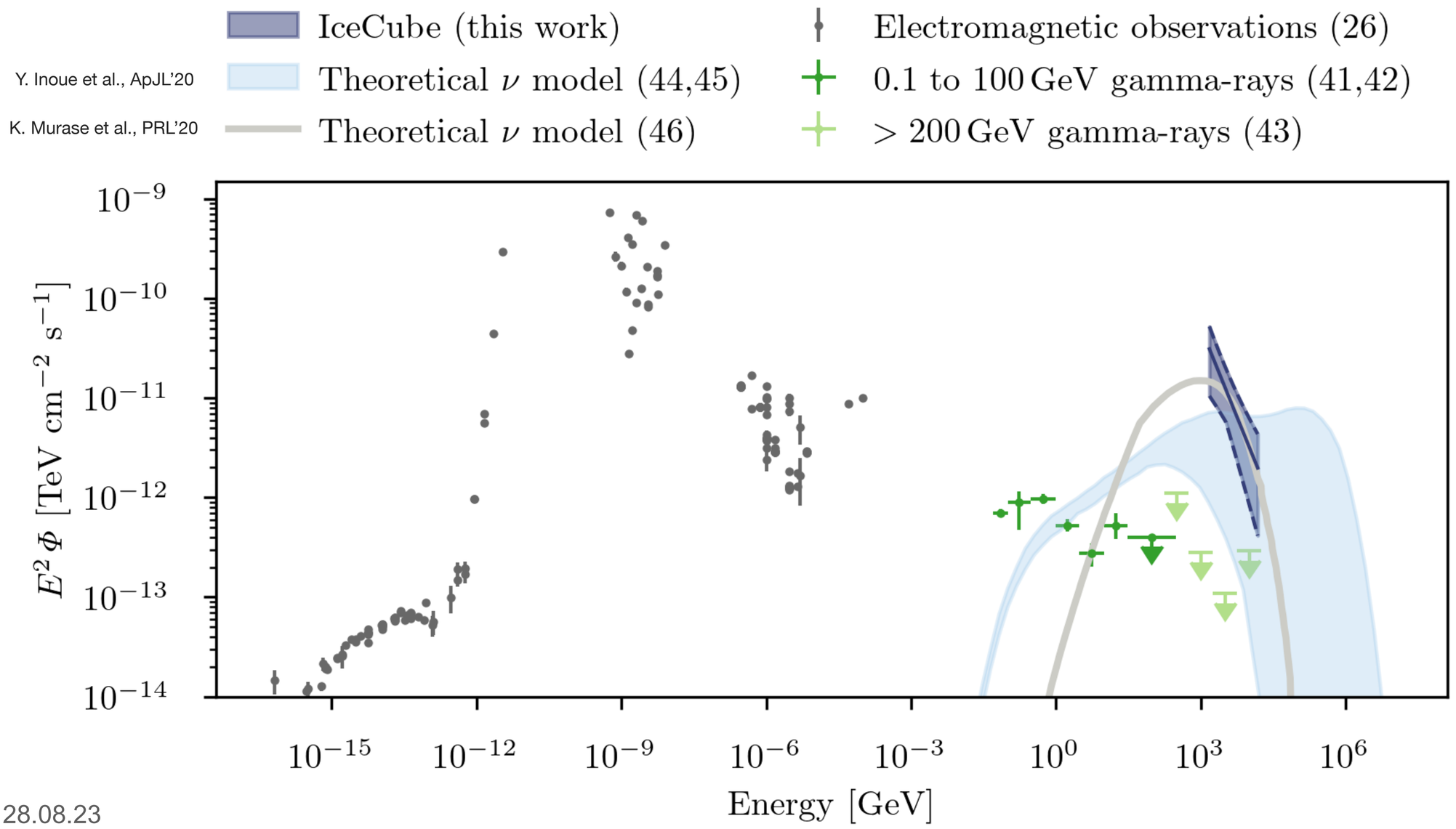


At the NGC1068 location:

- Astrophysical neutrino events = 79^{+22}_{-20}
- Spectral index = 3.2 ± 0.2

The multiwavelength picture

The IceCube Coll., ***Science*** 378 (2022)

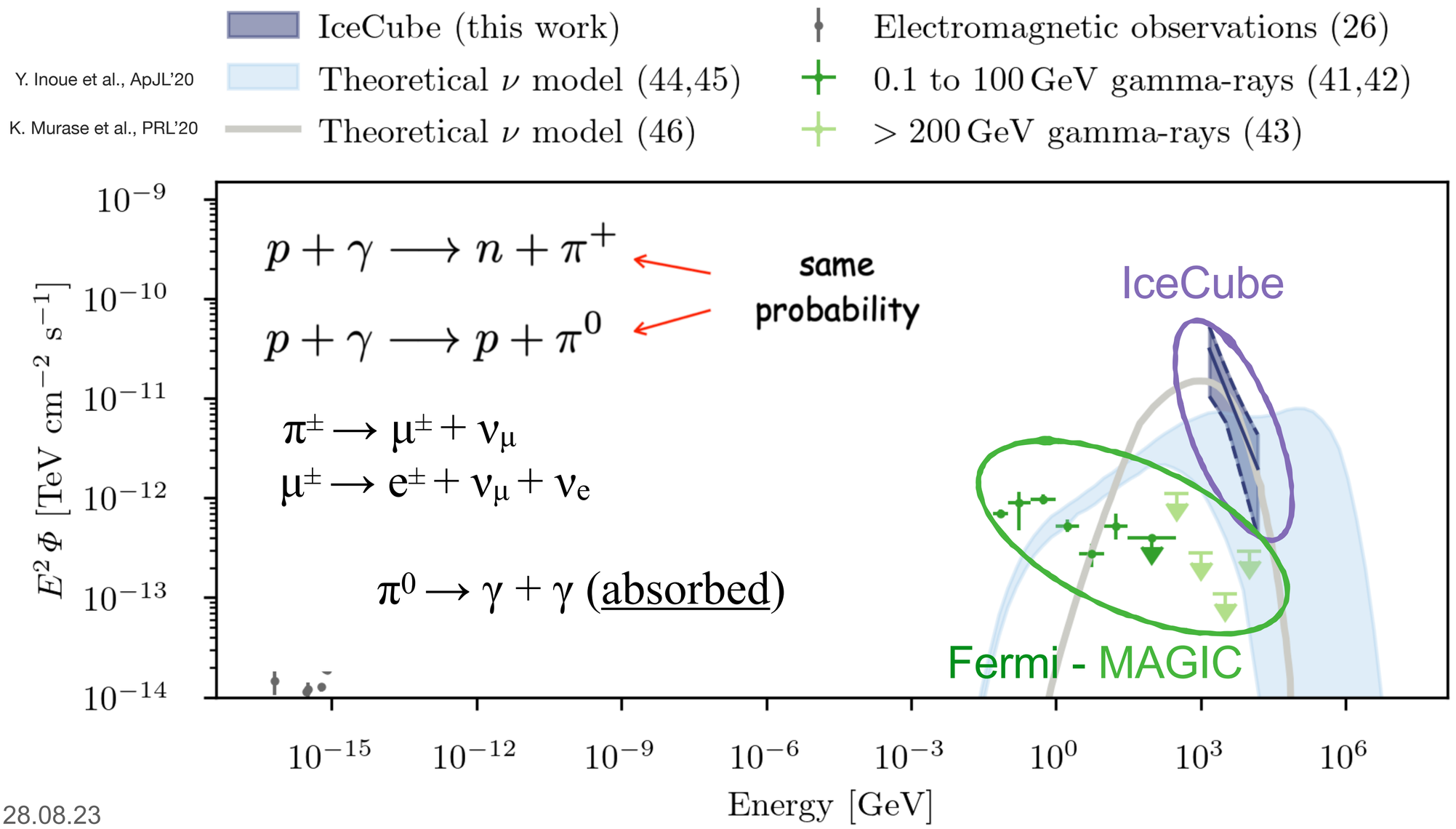


Y. Inoue et al., ApJL'20

K. Murase et al., PRL'20

Gamma ray flux << neutrino flux: how?

The IceCube Coll., ***Science*** 378 (2022)



NGC 1068: one of the nearest and most studied Seyfert 2

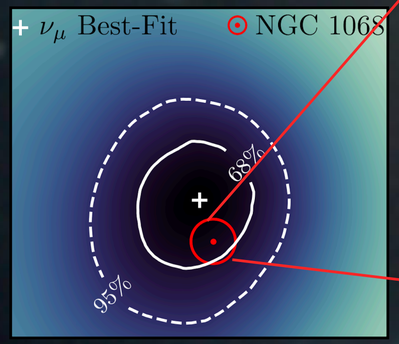
Halo

AGN

Circumnuclear disk (CND)
~200 pc in radius

Bar connecting CND and starburst ring

Starburst activity:
~2 kpc starburst ring



IceCube can’t resolve different emission components

NASA/JPL-Caltech/Roma Tre Univ.

Emission powers different components

P. Padovani et al., in preparation

	Scale	Power (erg/s)	L_γ (erg/s)	L_ν (erg/s)
Star formation	> Kpc	$10^{44.5}$	$\sim 10^{40.9}$	$\sim 10^{40.6}$
Jet	~ Kpc	$10^{42.9\pm1}$	$\sim 10^{41.7}$ (M87-like) [absorbed]	$\sim 10^{41.4}$
Outflow	~ 100 pc	$10^{41.4\pm1.0}$	$< 10^{39.5}$	$< 10^{39.2}$
BH vicinity	~ 0.03 millipc (~ 50 R_S)	$10^{44.7\pm0.5}$	?	?

Total: $\sim 10^{41.5}$

Observed: $10^{40.92\pm0.03}$ $10^{42.1\pm0.2}$

$$L_\nu = 1.4 \cdot 10^{42}\ \mathrm{erg/s}$$

Black Hole vicinity

Seyferts: radio quiet AGN

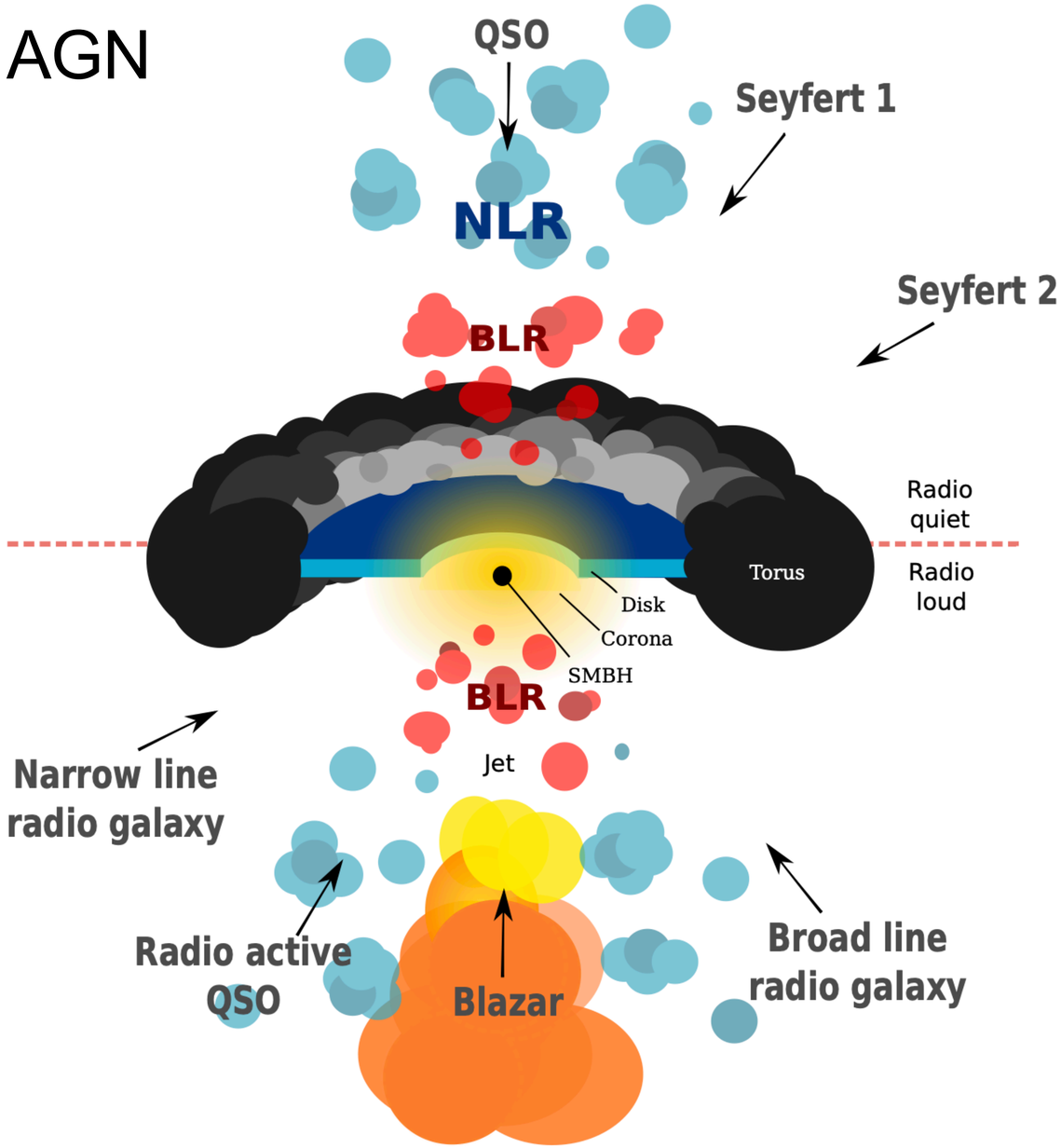


image from L. Baronchelli

Seyferts = radio quiet Active Galactic Nuclei

jet not dominant

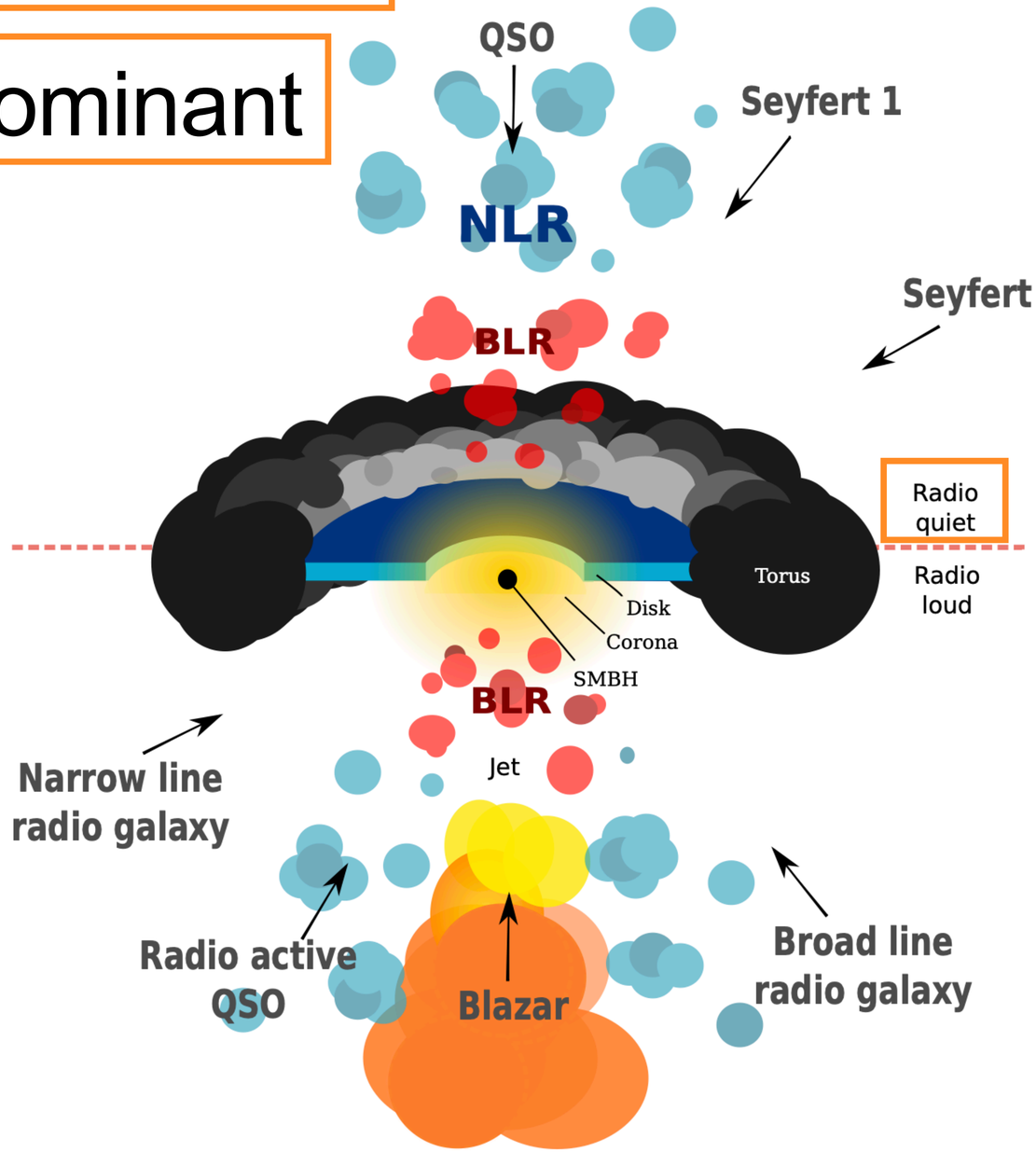


image from L. Baronchelli

Seyferts = radio quiet Active Galactic Nuclei

non-stellar activities

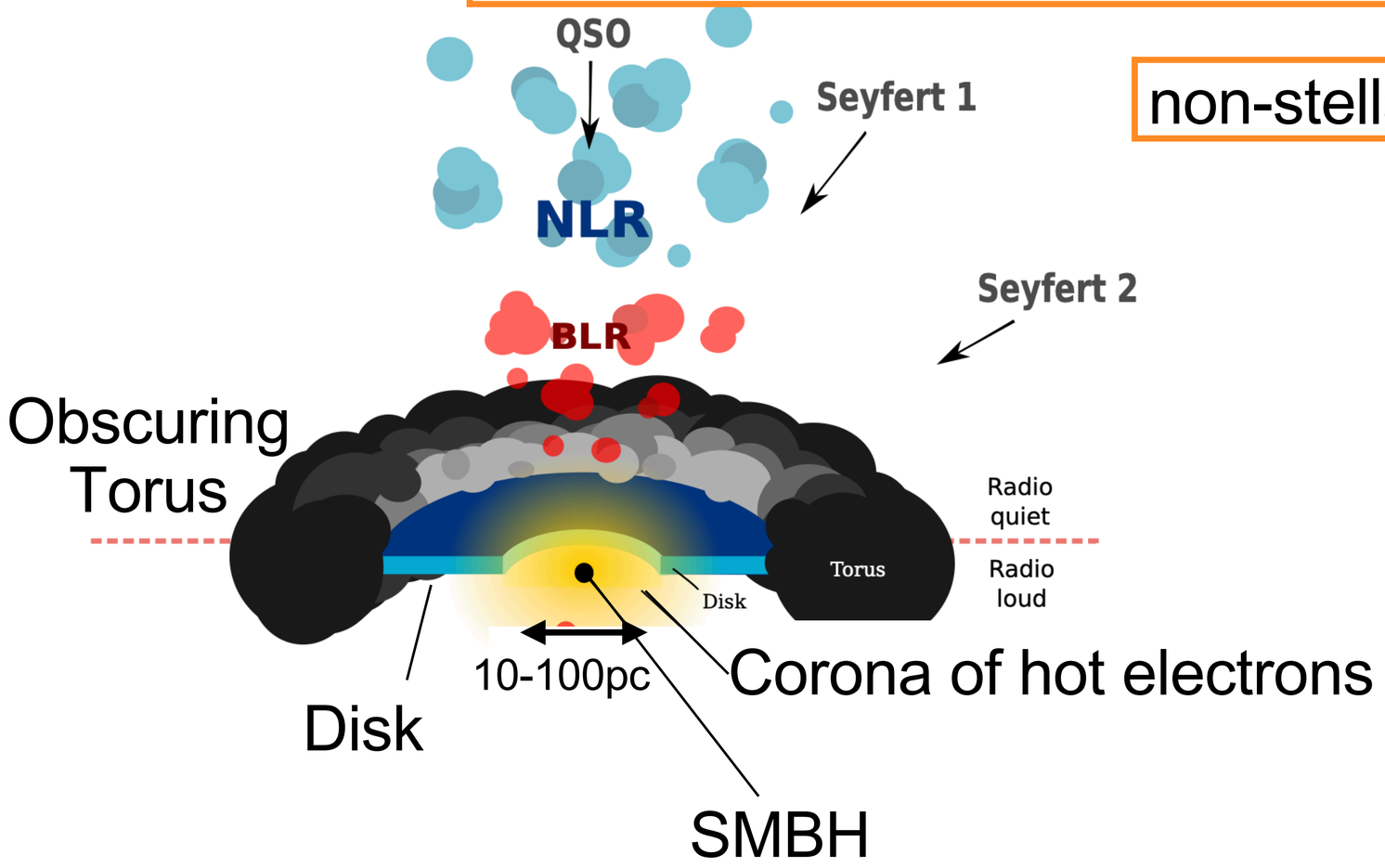
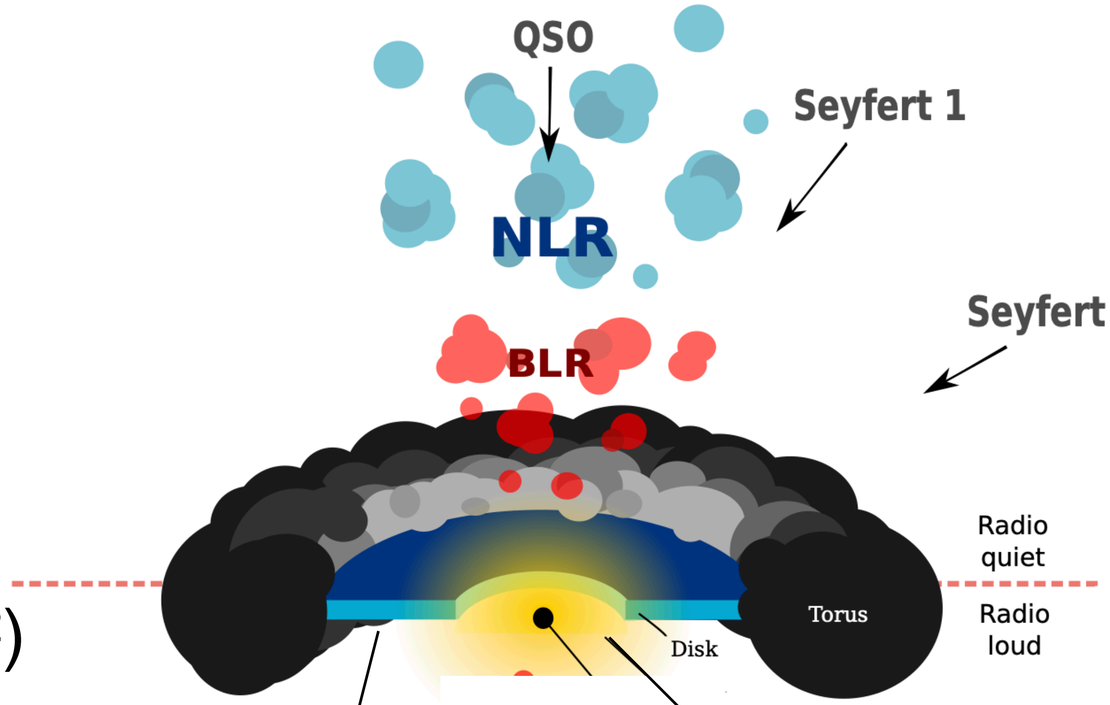


image from L. Baronchelli

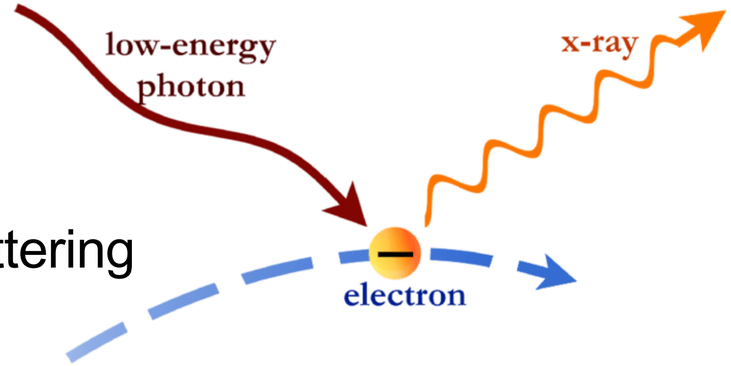
The Corona of hot electrons (and protons?)



Compton thick
($N_H > 10^{24}$ atoms cm^{-2})

Disk: photons at optical and UV wavelengths

Corona of hot electrons (X-ray)



Inverse Compton Scattering

image from L. Baronchelli

The scenario

see also Y. Inoue et al., ApJL'20, K. Murase et al., PRL'20, B.

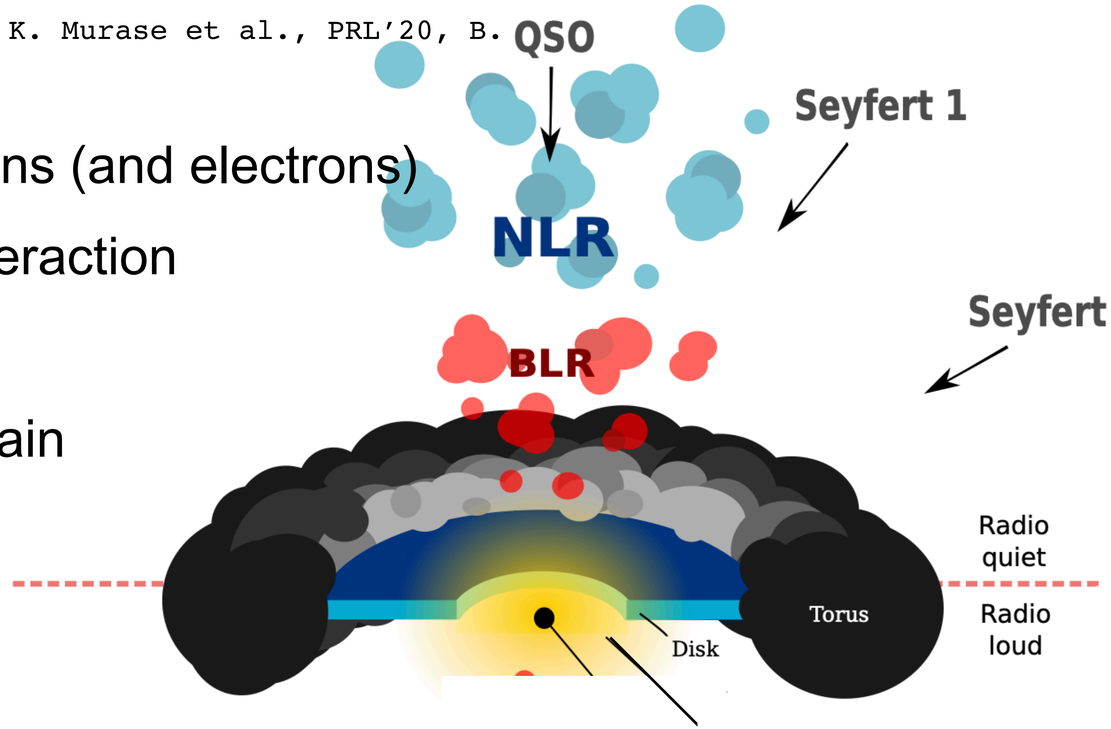
Step 1: acceleration of protons (and electrons)

Step 2: p-γ (but also p-p) interaction

e.g., $E_p \sim 100$ TeV

target γ ~ X-ray domain

(Corona component)



Corona of hot electrons (X-ray)

Step 3: mesons production

Step 4: γ-ray —> degraded into MeV region

neutrinos stream through

Note: the Fermi-LAT component most probably associated to the starburst component

see Eichmann et al., Astrophys. J. 939 (2022)

image from L. Baronchelli

The scenario

see also Y. Inoue et al., ApJL'20, K. Murase et al., PRL'20, B.

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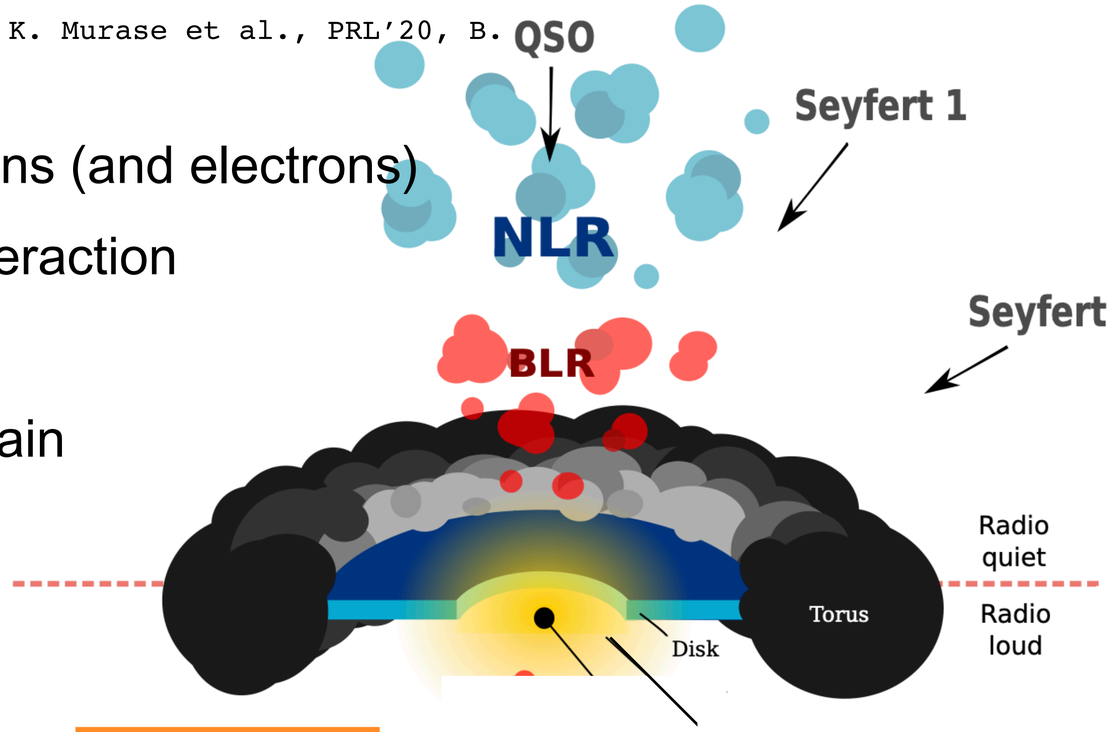

Corona of hot electrons (X-ray)

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neutrinos stream through

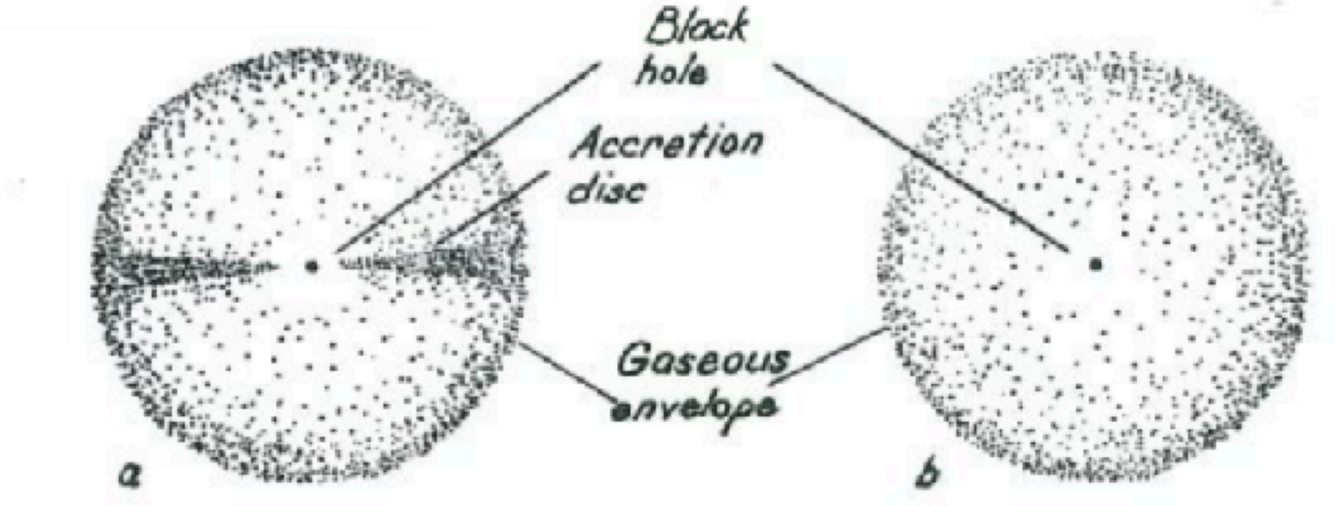
The smoking gun signature we need to validate the neutrino interpretation and search for additional neutrino sources.

image from L. Baronchelli

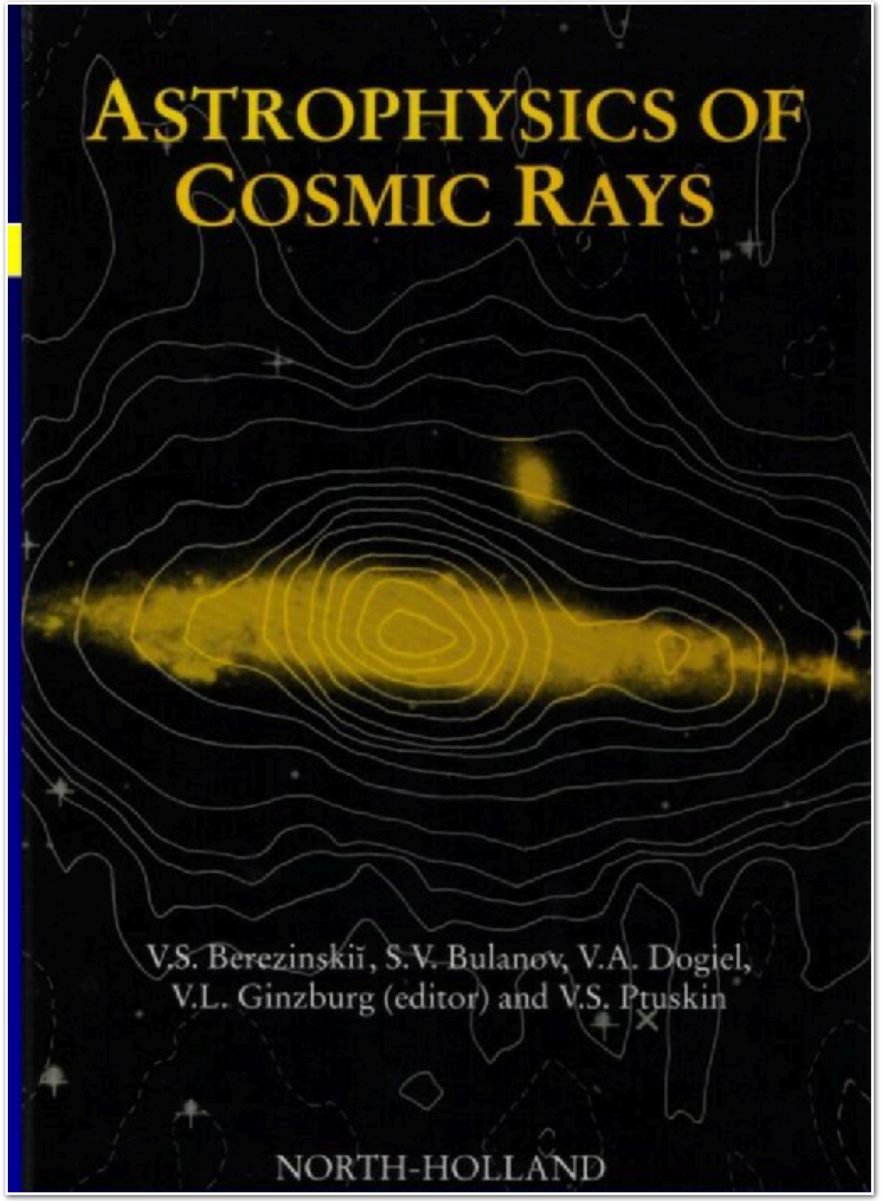
The ‘Hidden’ source idea

§9. Hidden sources

In the example of a massive black hole in a cocoon we encountered a model of a hidden source: an object which contains particles accelerated to high energies, but is not seen in high-energy electromagnetic radiation (X-ray and (or) gamma-ray radiation).



Berezinsky, Ginzburg, MNRAS 1981
Silberberg, Shapiro 1982



Conclusions, questions and a proposal

IceCube association to NGC1068 pointing to:

- **Primary Proton Acceleration near SMBH**: What are the mechanisms driving this acceleration?
- **Interactions in Compact and Obscured Regions**: How do interactions occur in such a dense environment? Are there any General Relativity corrections to factor in?
- **Hot Corona's Photon Field**: What is the origin, composition, and morphology of the corona emitting the photon field?
- **Gamma-Ray Showering**: Due to confinement, gamma-rays cascade down to the MeV range. What implications does this have?
- **Lack of MeV Telescopes**: The absence of telescopes in the MeV range raises challenges for confirmation. How can we address this limitation?

Key Anticipation in 1981 by V. Berezinsky who laid the groundwork for this scenario.

Consider the proposal of designating Seyfert galaxies with a neutrino component as "**Berezinsky galaxies**".