Ernie and Bert in the radio

TANAMI blazars in the IceCube neutrino fields

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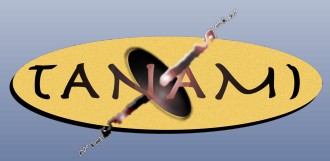
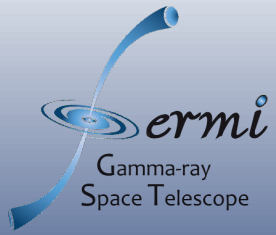
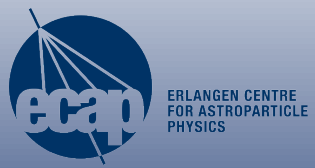
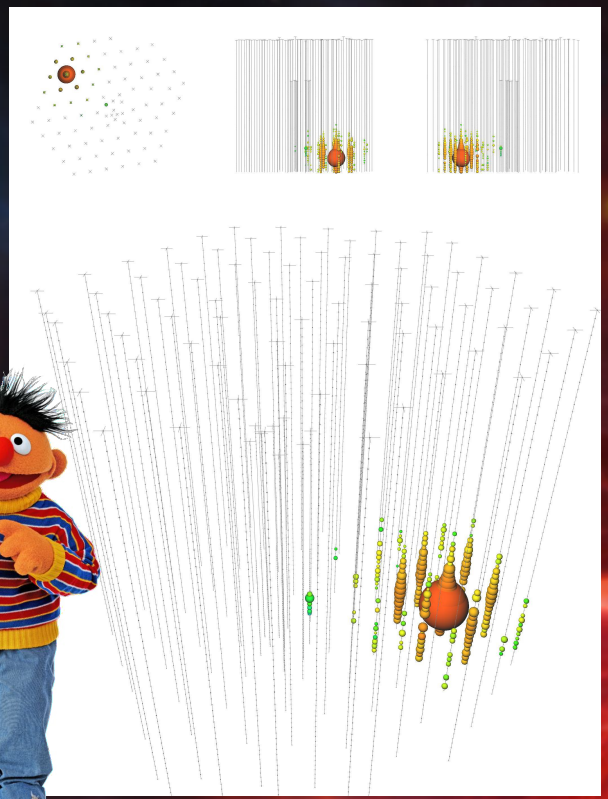
on behalf of the TANAMI and the Fermi*-LAT collaborations*

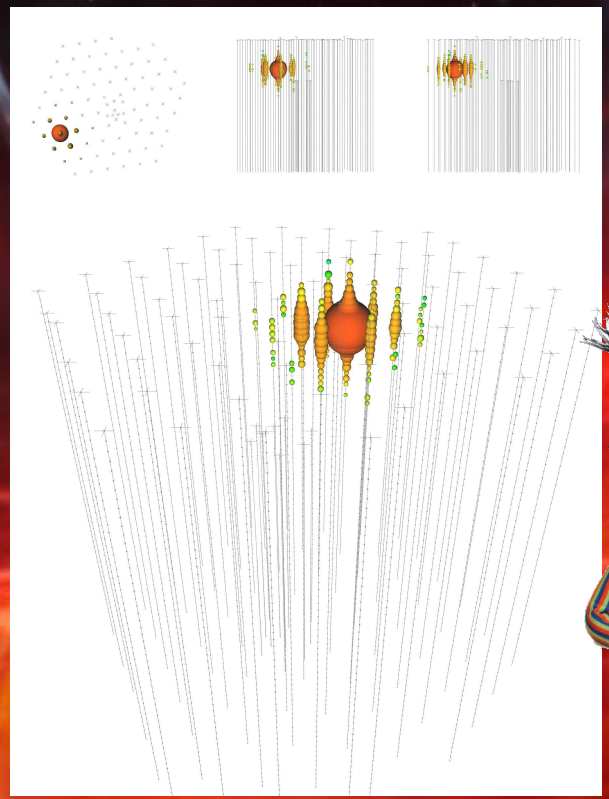






IceCube detection of PeV events

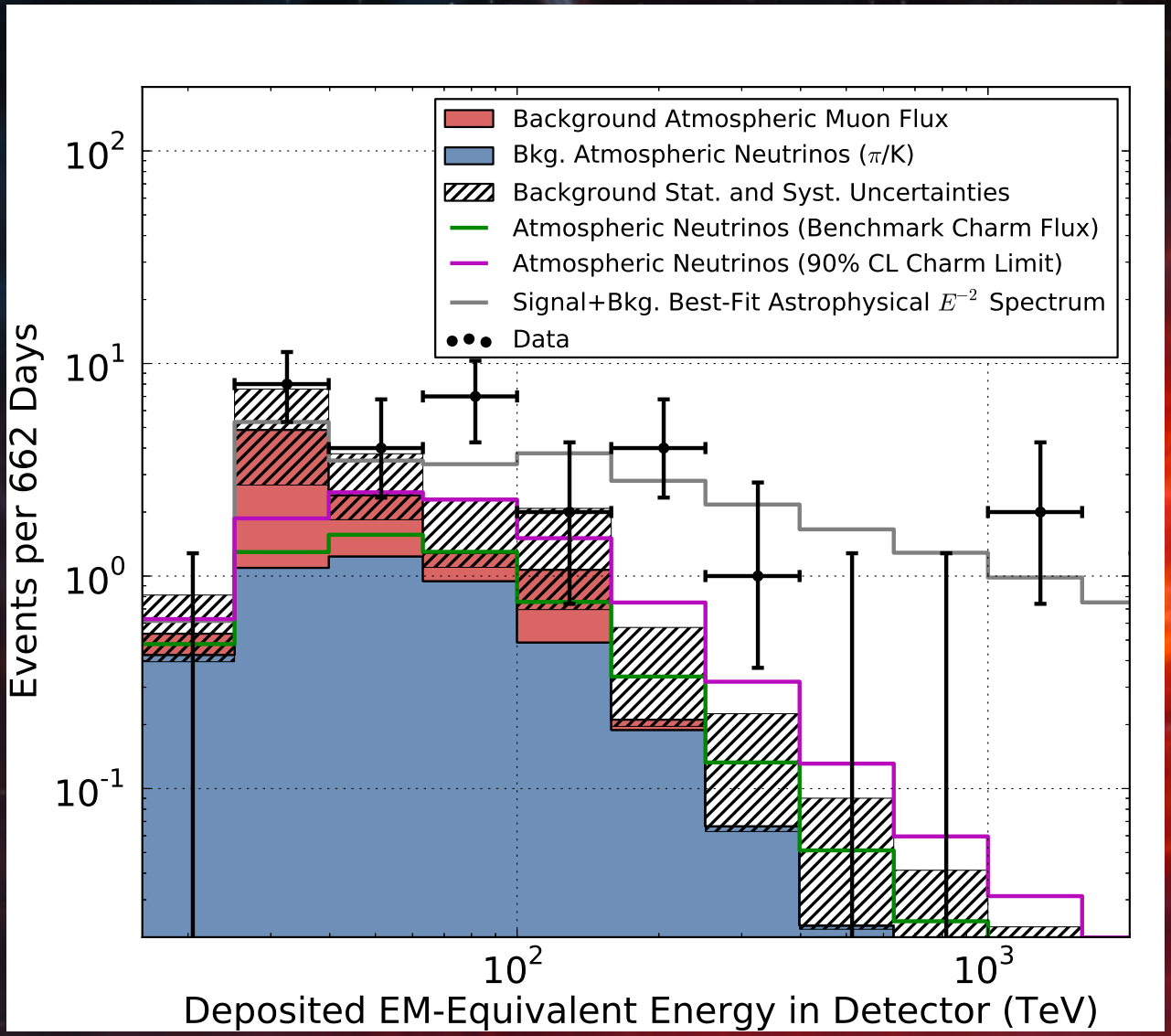




Events 20 and 14

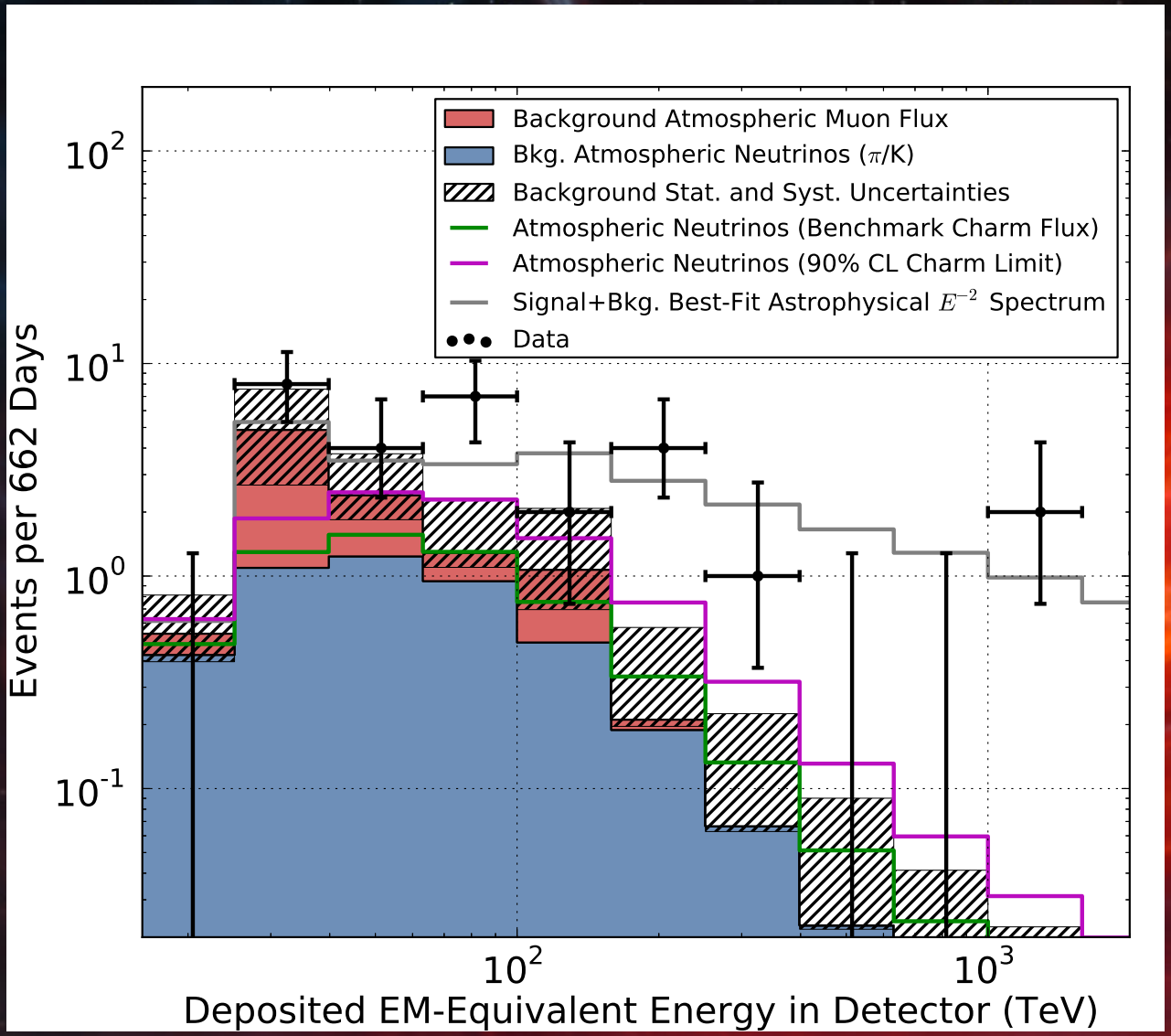
("Ernie" and "Bert", IceCube Collaboration, 2013, Science, 342)

Atmospheric neutrinos



(IceCube Collaboration, 2013, Science, 342)

Atmospheric neutrinos



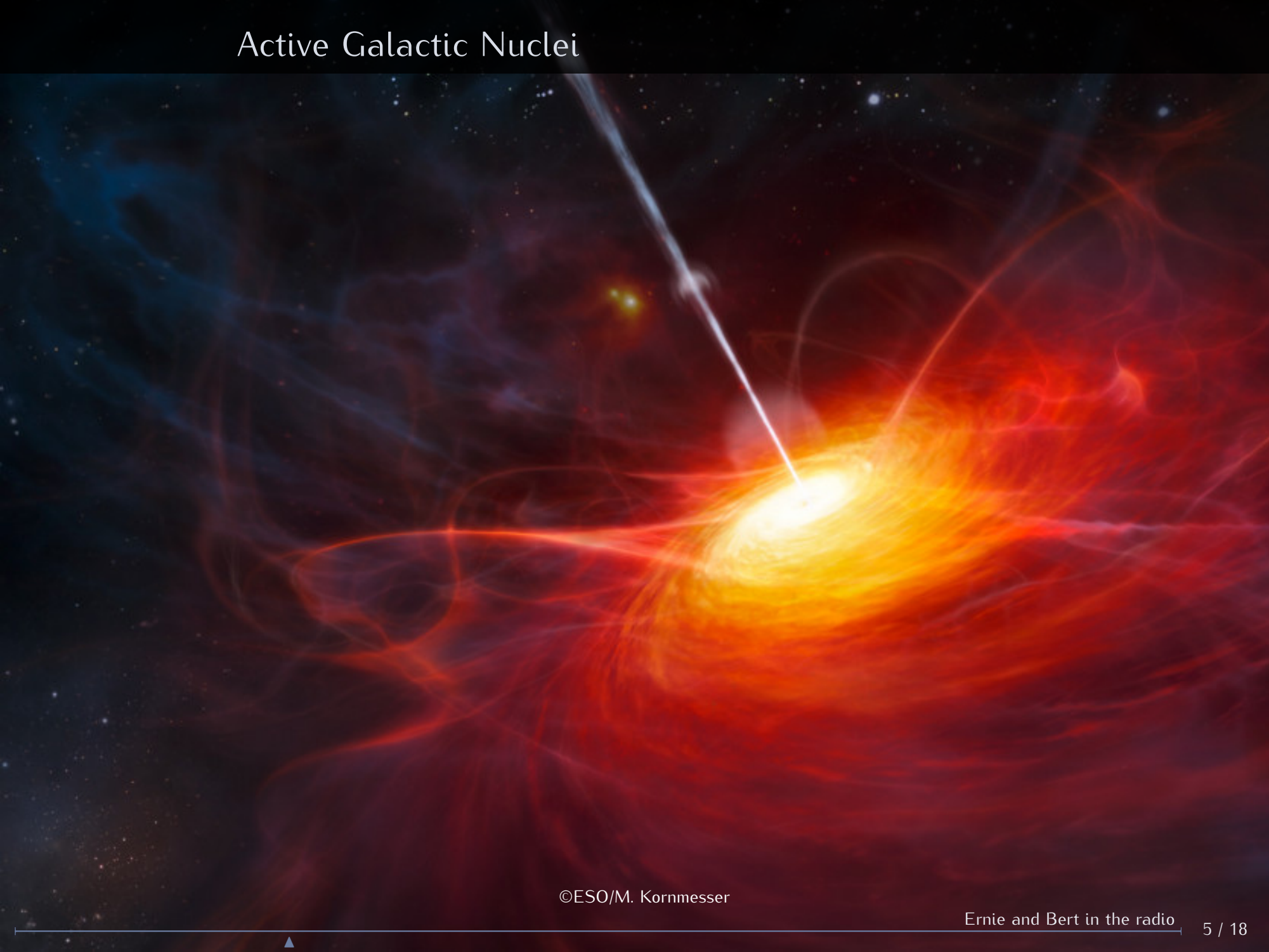
What are possible (astrophysical) sources of these events?

IceCube detection of PeV events

- Single source in Galactic center excluded (Adrián-Martínez et al., 2014, ApJL 786, L5)
- homogenous distribution
- Gamma-ray Burst (GRB) origin unlikely

→ candidate: active galaxies (Mannheim K., 1995, Astroparticle Physics 3, 295)

Active Galactic Nuclei



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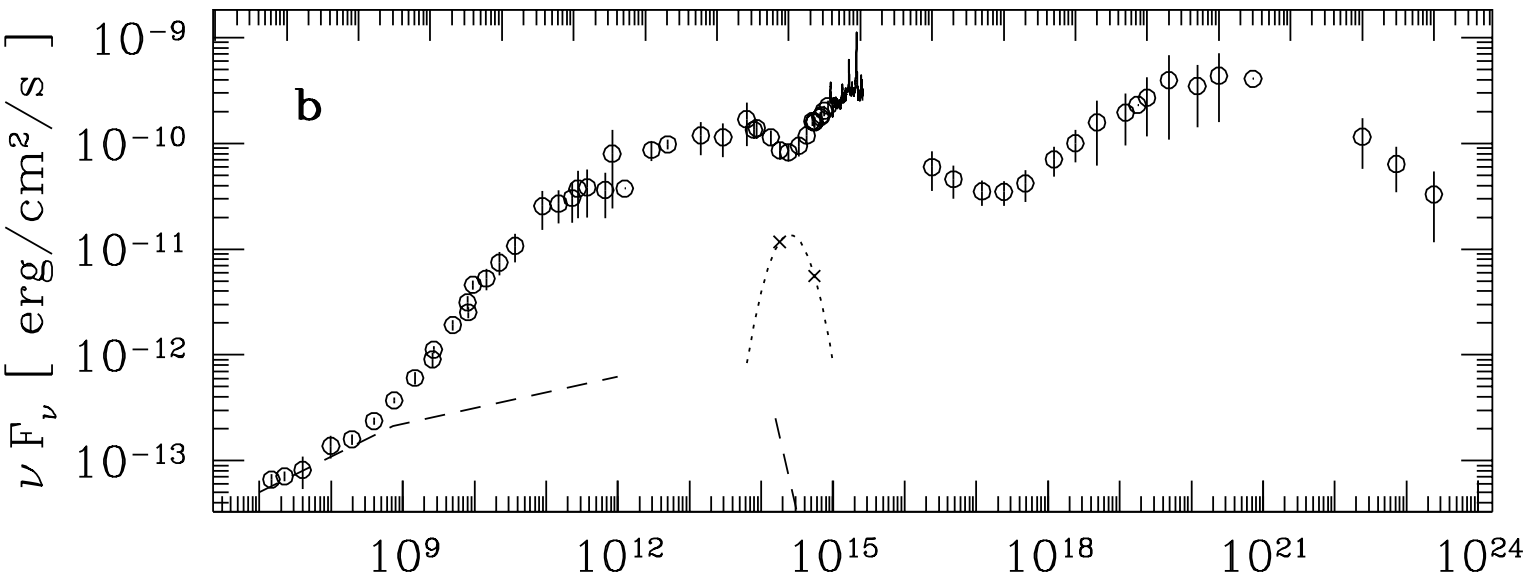
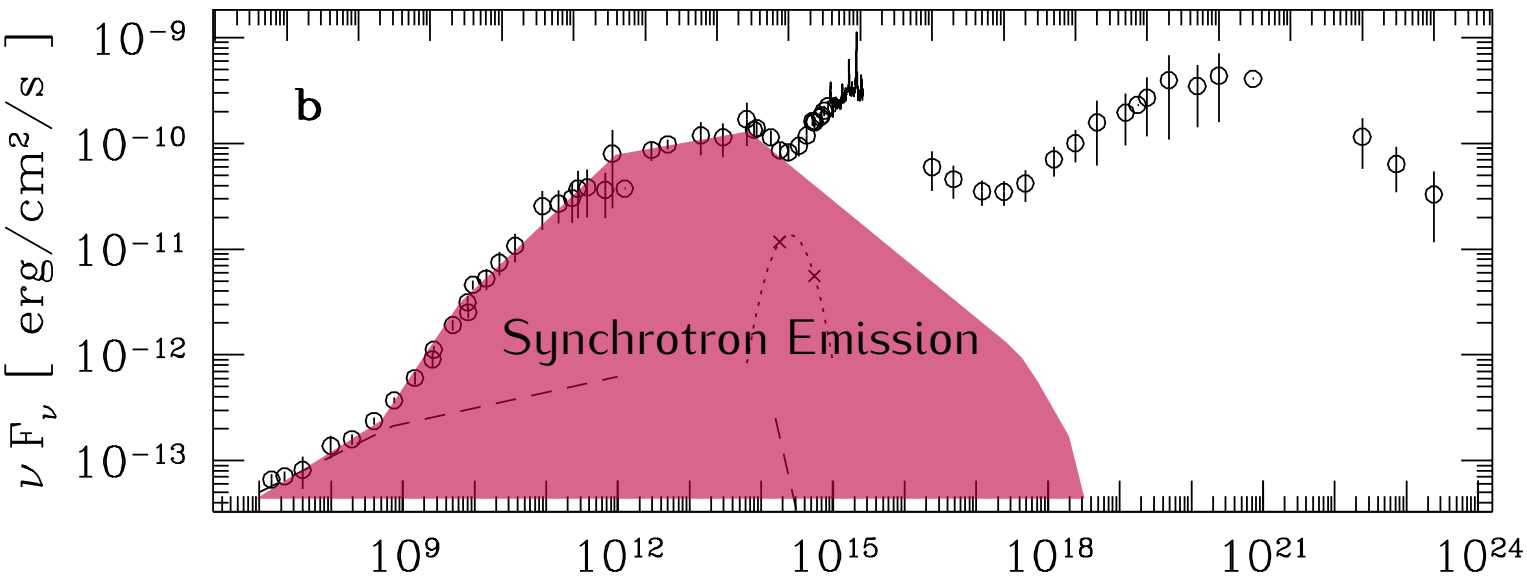
Blazar Spectral Energy Distribution



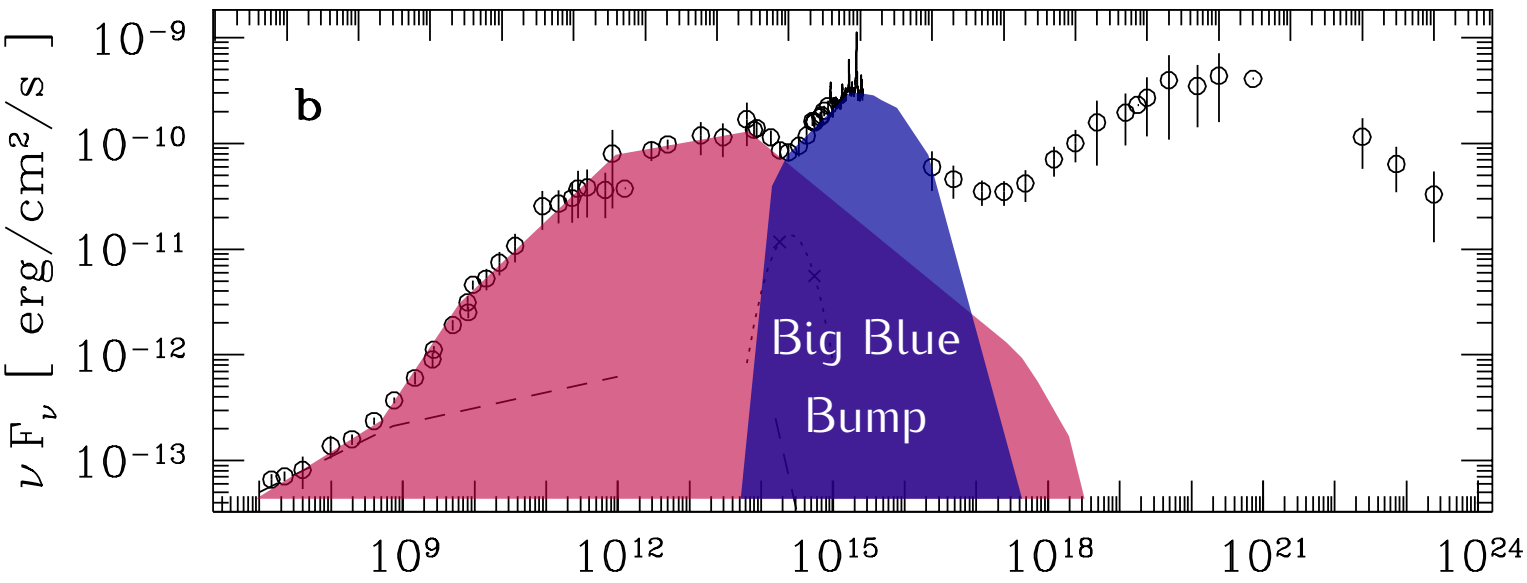
3C 273 (Türler et al., 1999, A&AS, 134, 89)

Blazar Spectral Energy Distribution



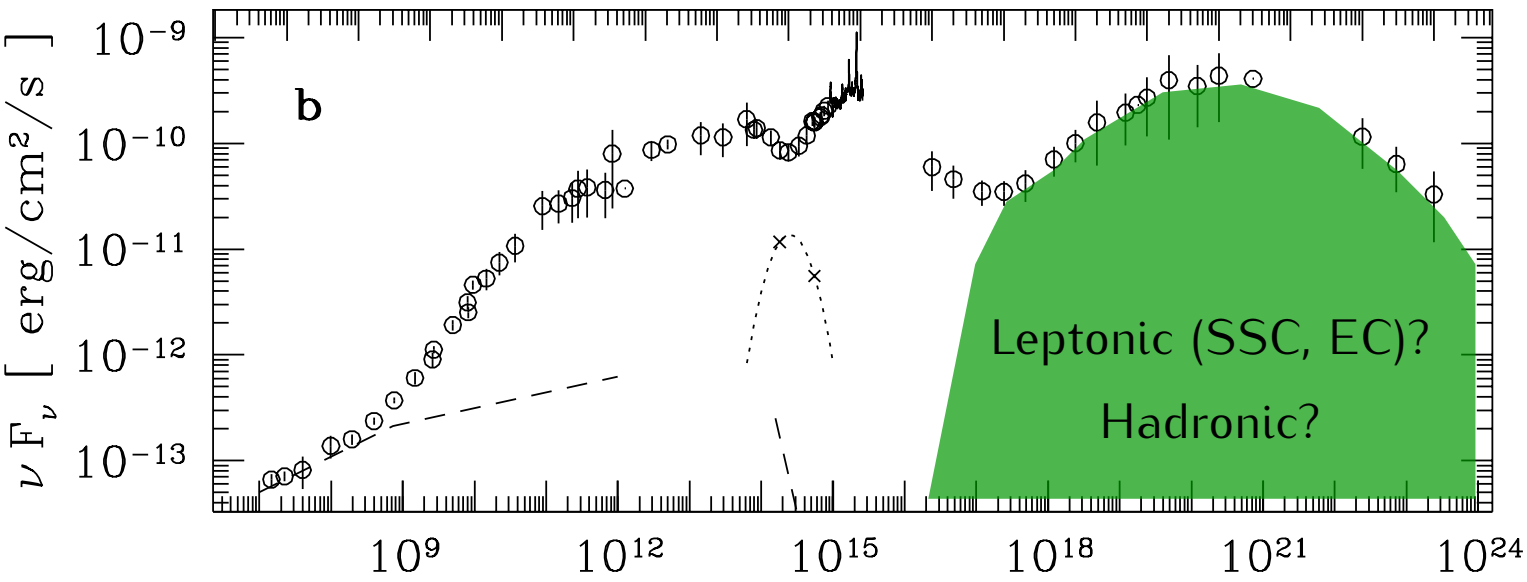
3C 273 (Türler et al., 1999, A&AS, 134, 89)

Blazar Spectral Energy Distribution



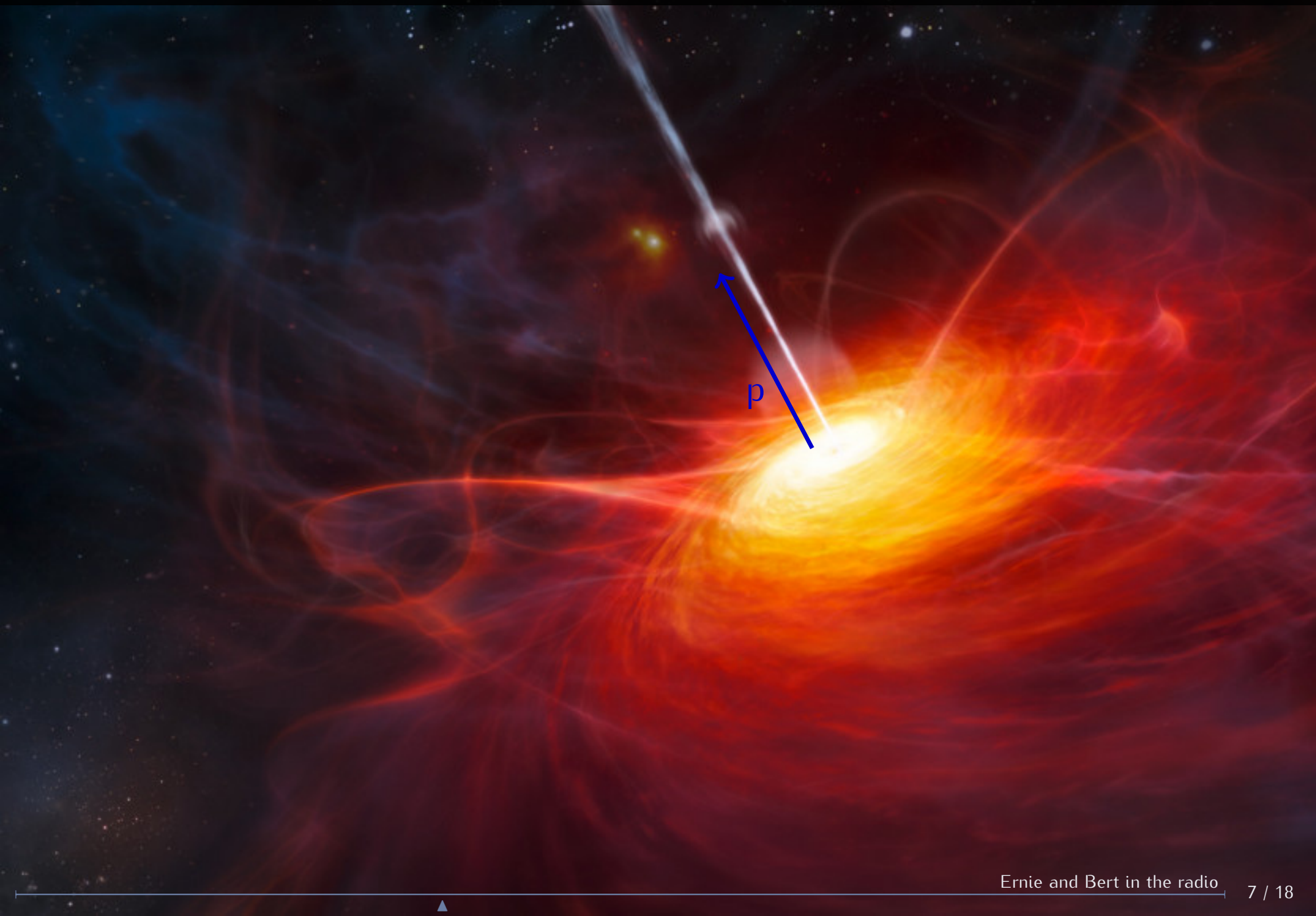
3C 273 (Türler et al., 1999, A&AS, 134, 89)

Blazar Spectral Energy Distribution

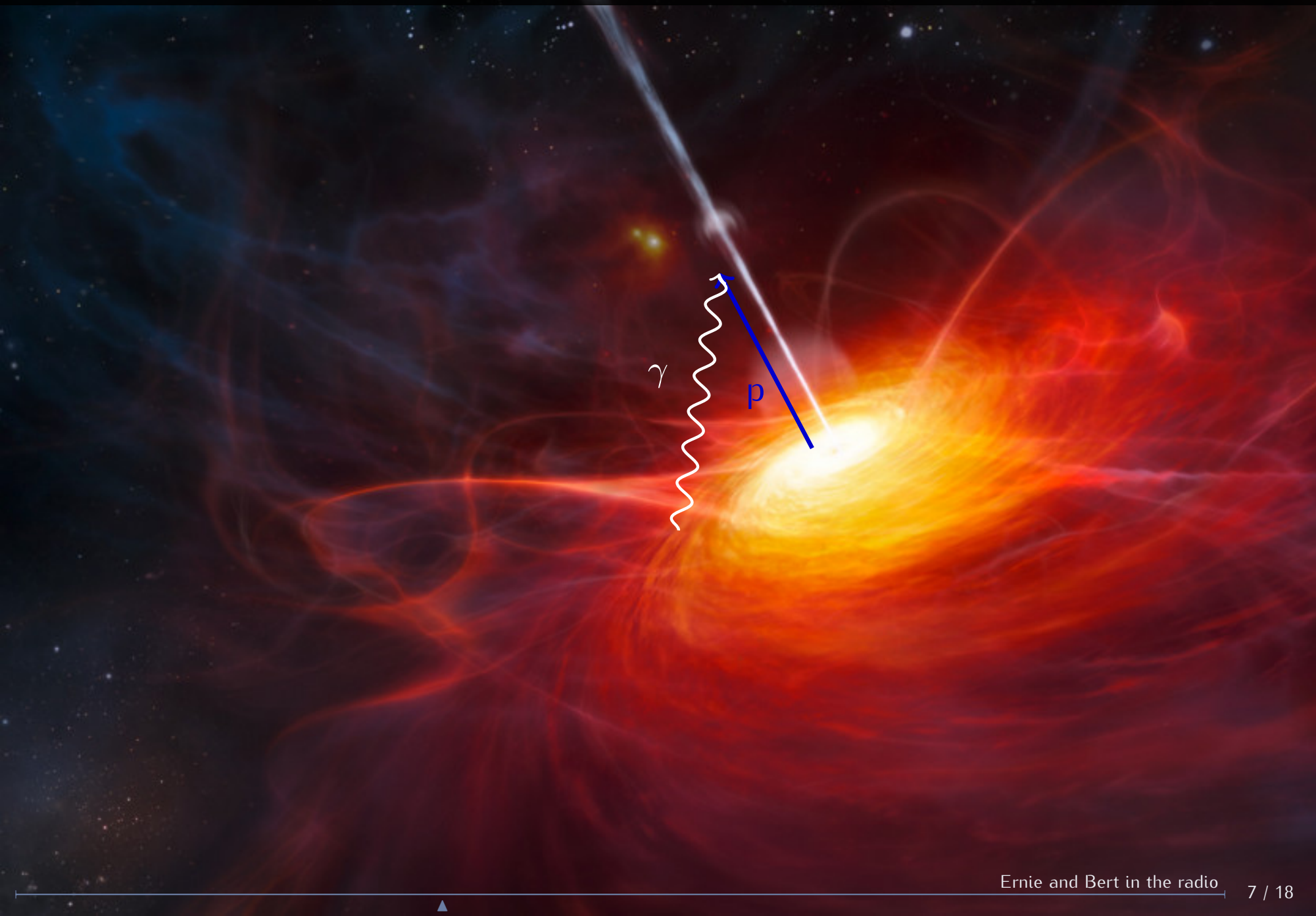


3C 273 (Türler et al., 1999, A&AS, 134, 89)

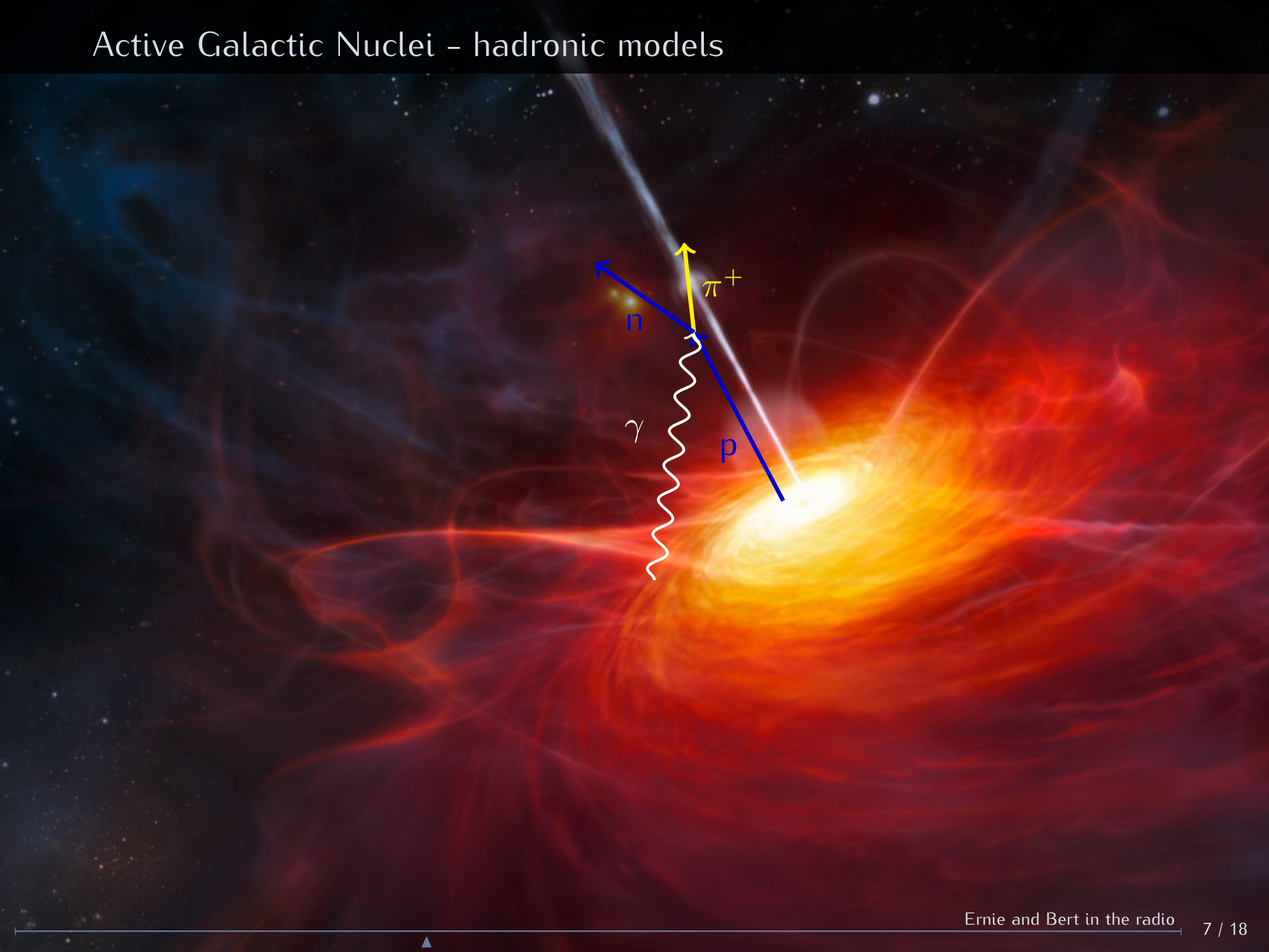
Active Galactic Nuclei - hadronic models



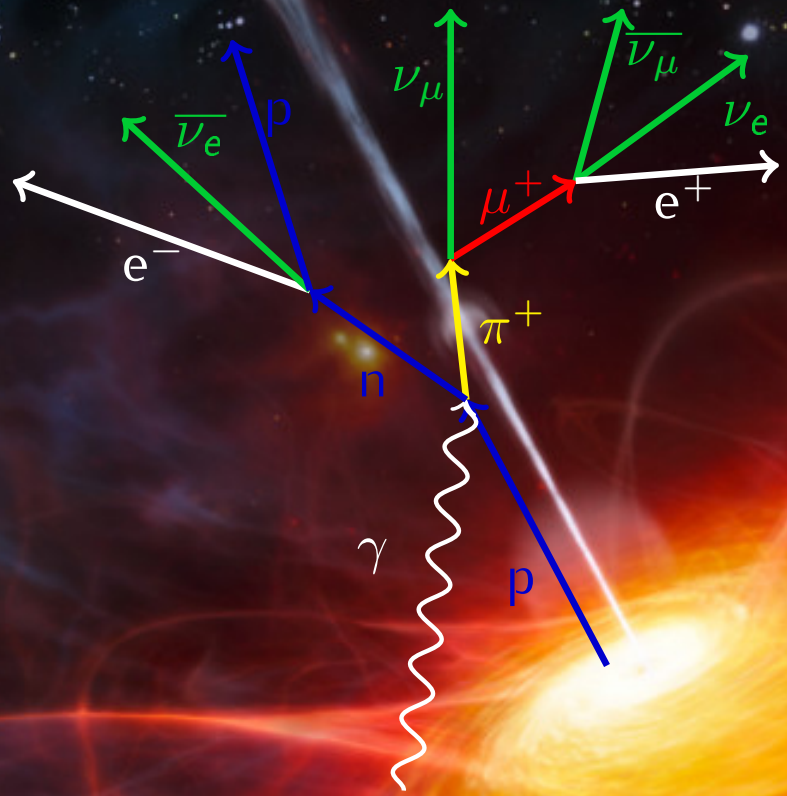
Active Galactic Nuclei - hadronic models



Active Galactic Nuclei - hadronic models



Active Galactic Nuclei - hadronic models



Tracking Active Galactic Nuclei with Austral Milliarcsecond Interferometry

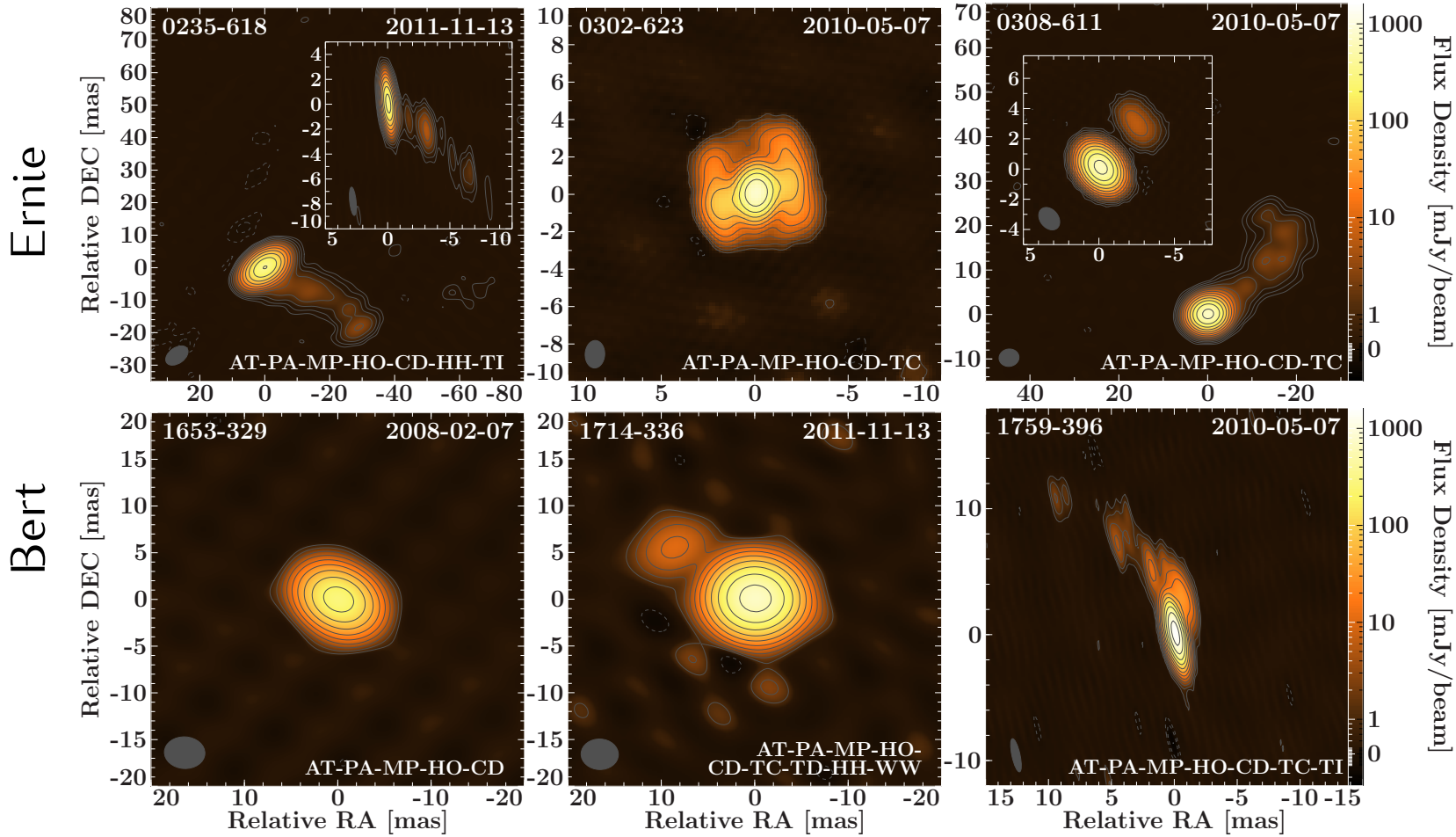
- VLBI monitoring at 8.4 & 22.3 GHz
- brightest γ-ray (GeV) and radio sources

http://pulsar.sternwarte.uni-erlangen.de/tanami Ojha et al. 2010, A&A, 519, A45

	Source	α [°]	δ [°]	z	Class.	θ [°]
Ernie	0235−618	39.2218△	−61.6043△	0.47♦	FSRQ♦	5.61
	0302−623	45.9610†	−62.1904†	1.35♦	FSRQ♦	5.98
	0308−611	47.4838†	−60.9775†	1.48♦	FSRQ♦	7.39
Bert	1653−329	254.0699△	−33.0369△	2.40◇	FSRQ◇	11.18
	1714−336	259.4001⋆	−33.7024⋆	?	BL Lac▲	7.87
	1759−396	270.6778•	−39.6689•	1.32■	FSRQ■	12.50

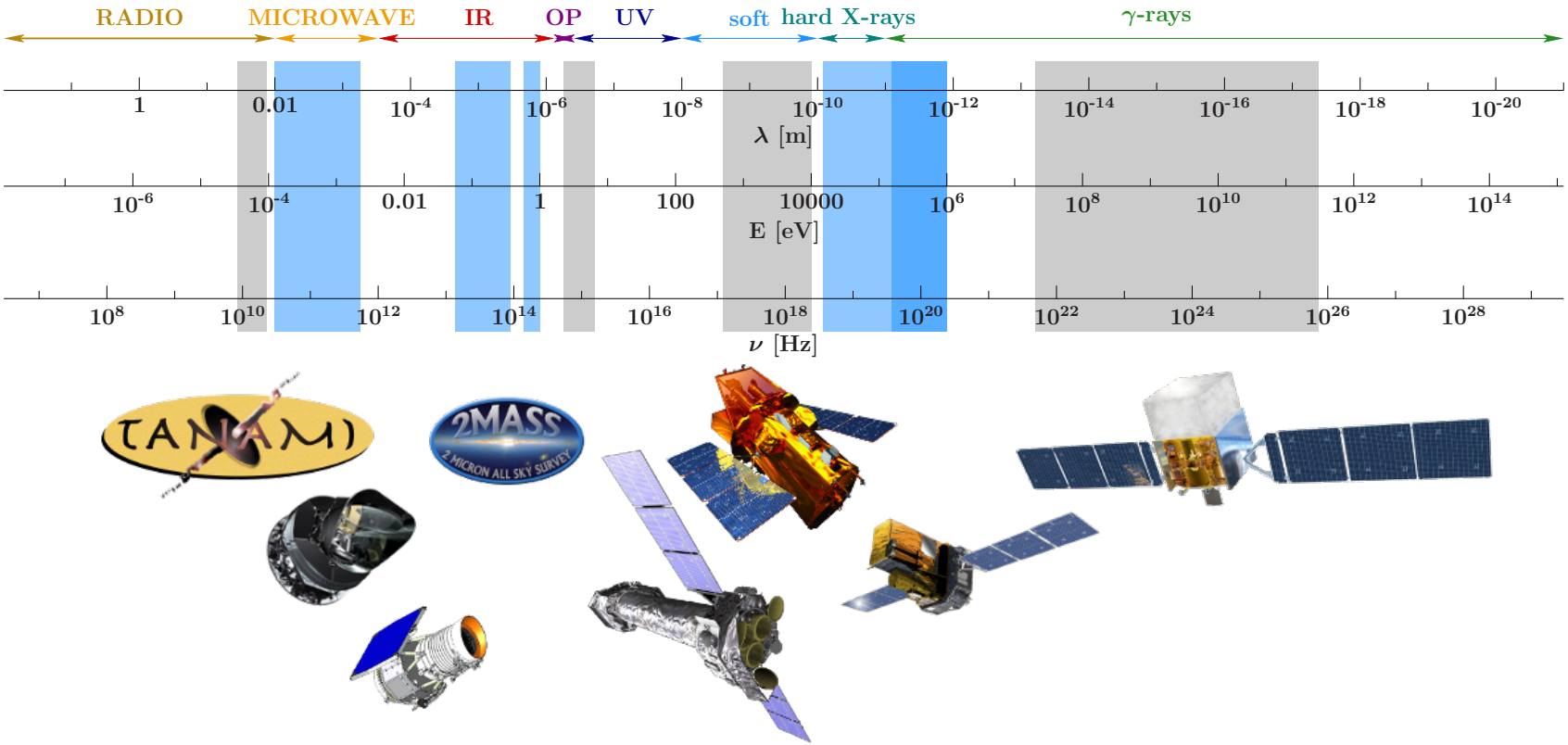
♦ Healey et al. (2008)
▲ Cutri et al. (2003)
† Lambert&Gontier (2009)
⋆ Immer et al. (2011)
• Fomalont et al. (2003)
▲ Véron-Cetty&Véron (2006)
■ Massaro et al. (2009)
◇ Masetti et al. (2008)

VLBI Images

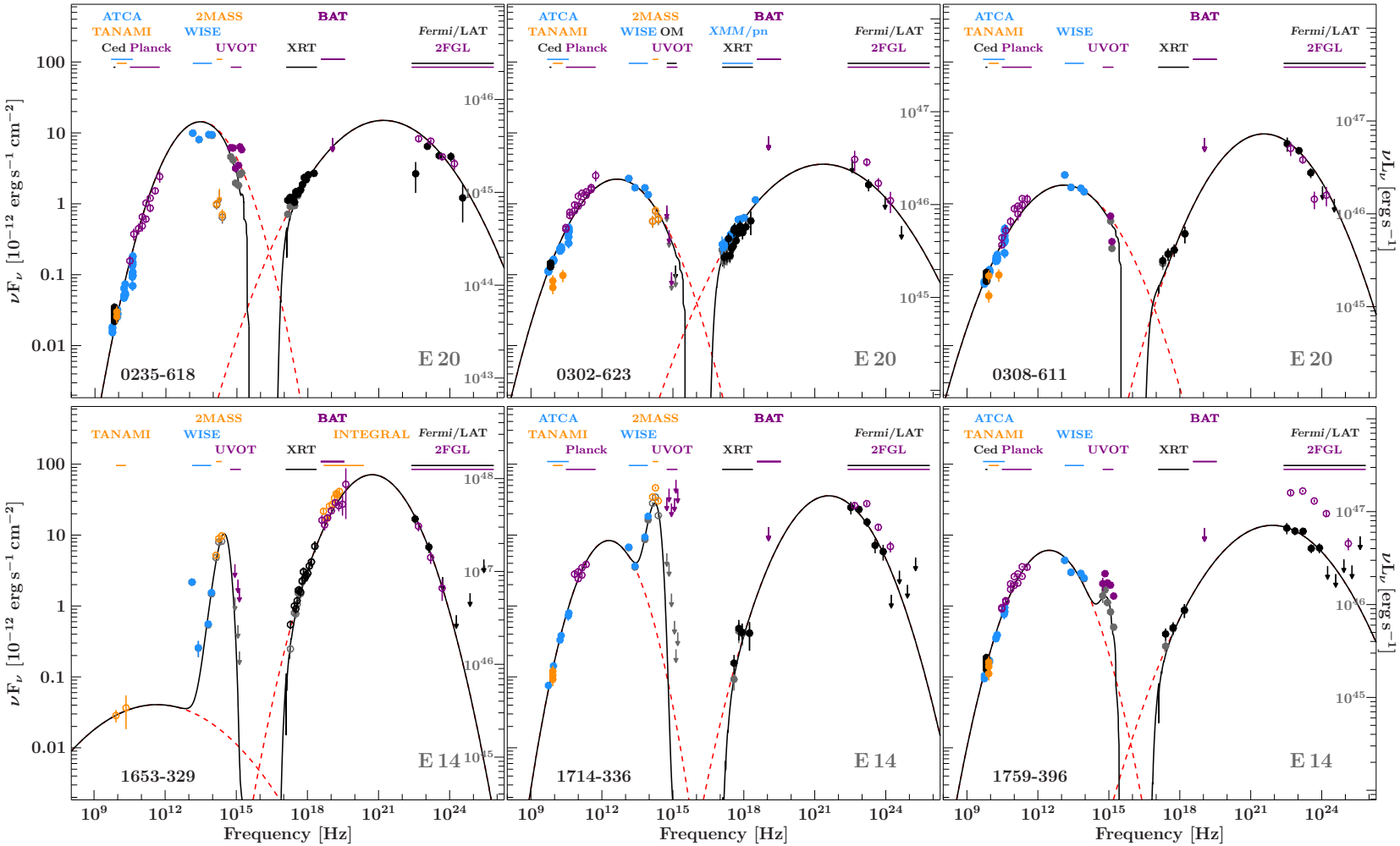


(Krauß et al., A&A, 2014, 556, L7)

Broadband coverage



Broadband spectra



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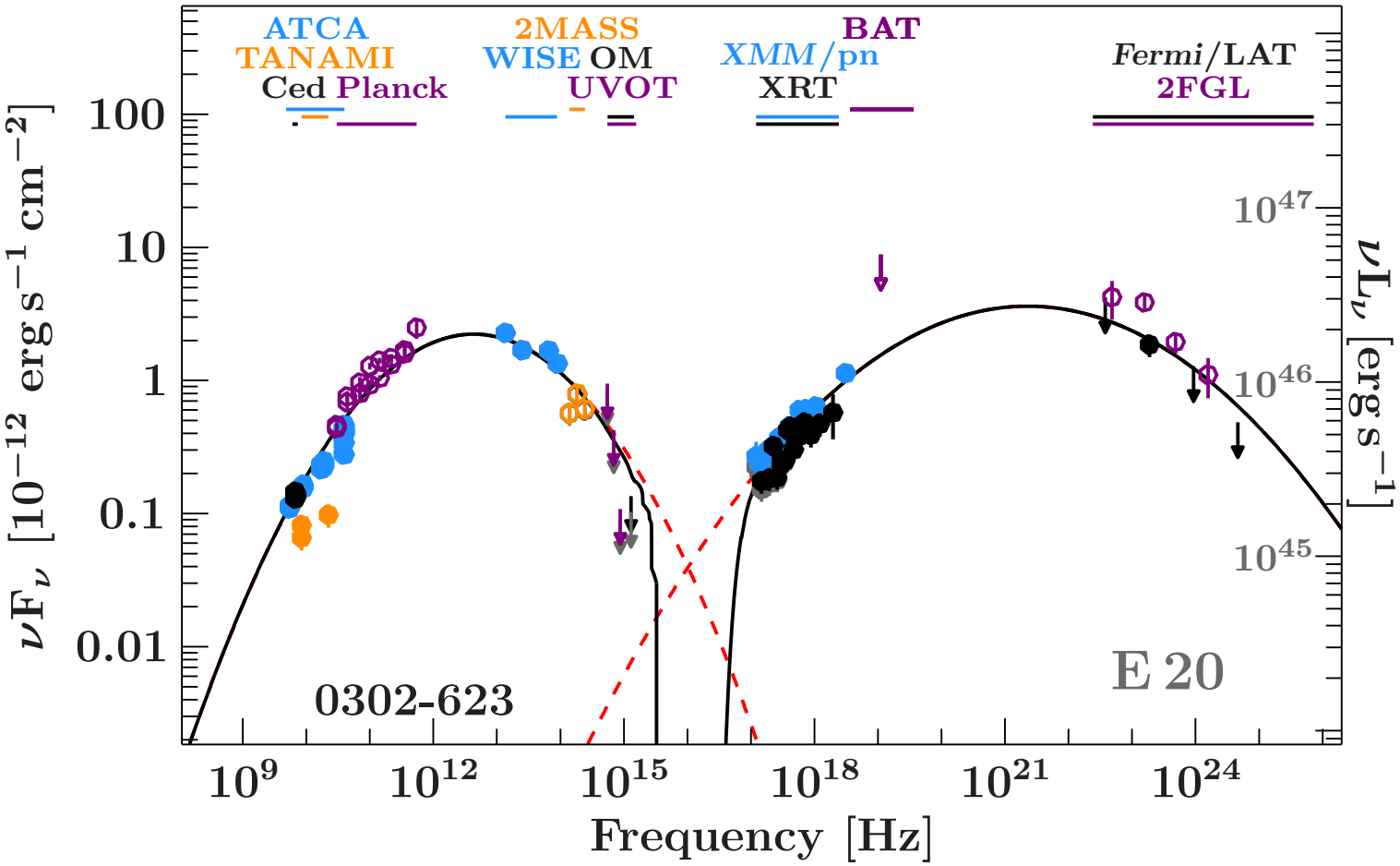
Broadband spectra



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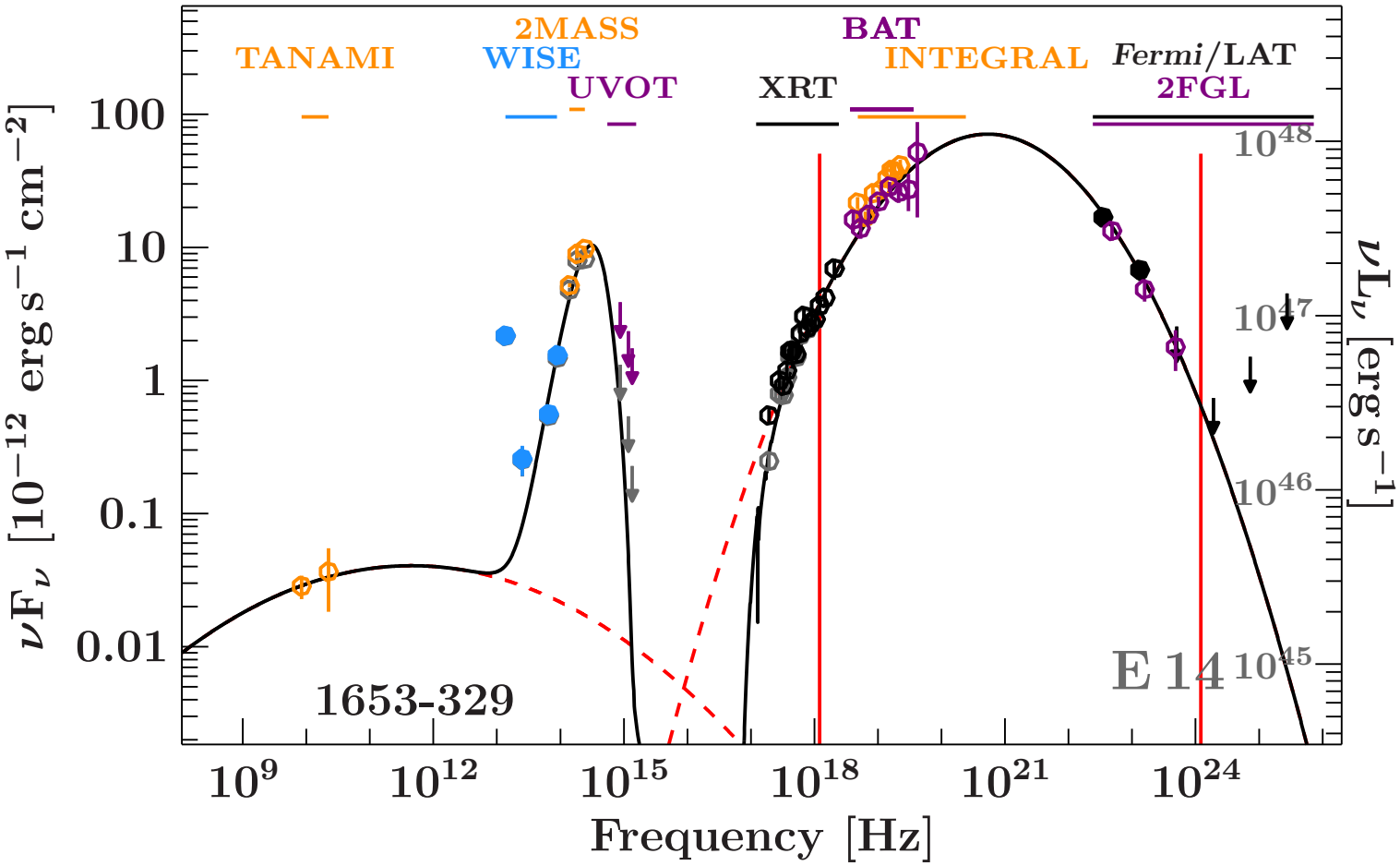
Broadband spectra



(Krauß et al., A&A, 2014, 556, L7)

Neutrino fluence

	source	$F_\gamma\,(\mathrm{erg\,cm^{-2}\,s^{-1}})$	events
Ernie	0235−618	$\left(1.0^{+0.5}_{-0.5}\right) \times 10^{-10}$	$0.19^{+0.04}_{-0.04}$
	0302−623	$\left(3.4^{+0.7}_{-0.7}\right) \times 10^{-11}$	$0.06^{+0.01}_{-0.01}$
	0308−611	$\left(7.5^{+2.9}_{-2.9}\right) \times 10^{-11}$	$0.14^{+0.05}_{-0.05}$
Bert	1653−329	$\left(4.5^{+0.5}_{-0.5}\right) \times 10^{-10}$	$0.86^{+0.10}_{-0.10}$
	1714−336	$\left(2.4^{+0.5}_{-0.6}\right) \times 10^{-10}$	$0.46^{+0.10}_{-0.12}$
	1759−396	$\left(1.2^{+0.3}_{-0.2}\right) \times 10^{-10}$	$0.23^{+0.50}_{-0.40}$
	Total		1.9 ± 0.4

- estimate of maximum neutrino fluence using broadband spectra, based on Mannheim, 1993, A&A, 269, 67
  → 1.9±0.4 neutrinos in 662 days

Neutrino fluence - caveats

- more realistic neutrino spectrum → lower number of neutrinos
- additional contributions from faint sources

⟶ AGN/blazars are able to explain the observed number of PeV neutrinos!

Conclusions

- neutrinos would provide unambigious evidence of hadronic processes
- six TANAMI sources could explain the observed neutrinos