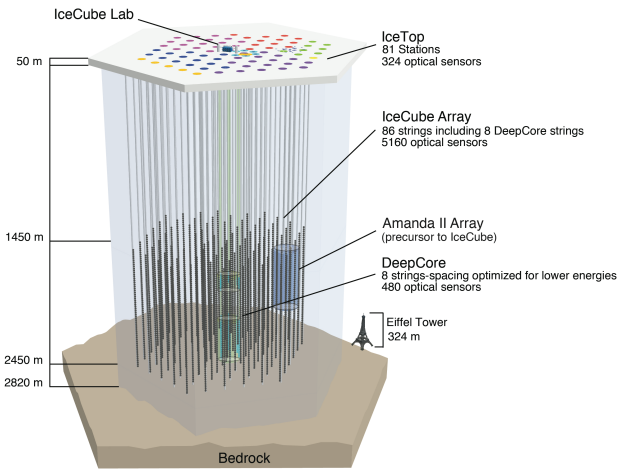


Astrophysical neutrinos and very high-energy astrophysics (with ASTRI and CTA)

Paolo Padovani, European Southern Observatory,

Garching bei München, Germany

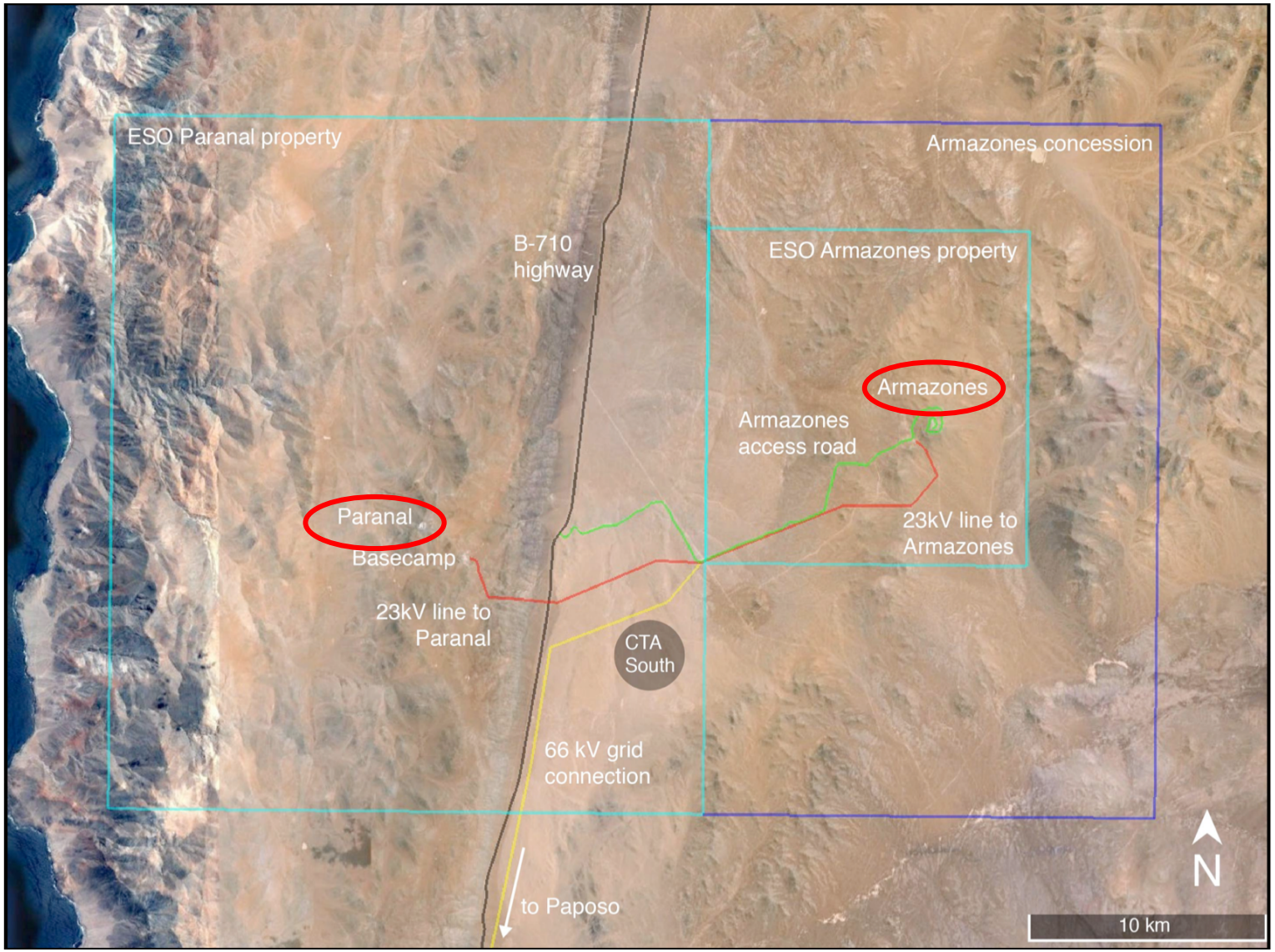
- Neutrino astrophysics
- Astronomical counterparts of IceCube neutrinos
- Strong synergy with very high-energy astrophysics

Energy notations

- 1 eV ≡ **2.42 10^{14}** Hz ≡ 12,400 Å
- 1 GeV (10^{9}) ≡ 2.42 10^{23} Hz (γ-rays) ≡ 1.24 10^{-5} Å
- 1 TeV (10^{12}) ≡ 2.42 10^{26} Hz (VHE γ-rays) ≡ 1.24 10^{-8} Å
- 1 PeV (10^{15}) ≡ 2.42 10^{29} Hz

- 1 GeV ≡ 1.602 10^{-3} erg
- 1 TeV ≡ 1.602 erg
- 1 PeV ≡ 1.602 10^{3} erg

Cherenkov Telescope Array (CTA)

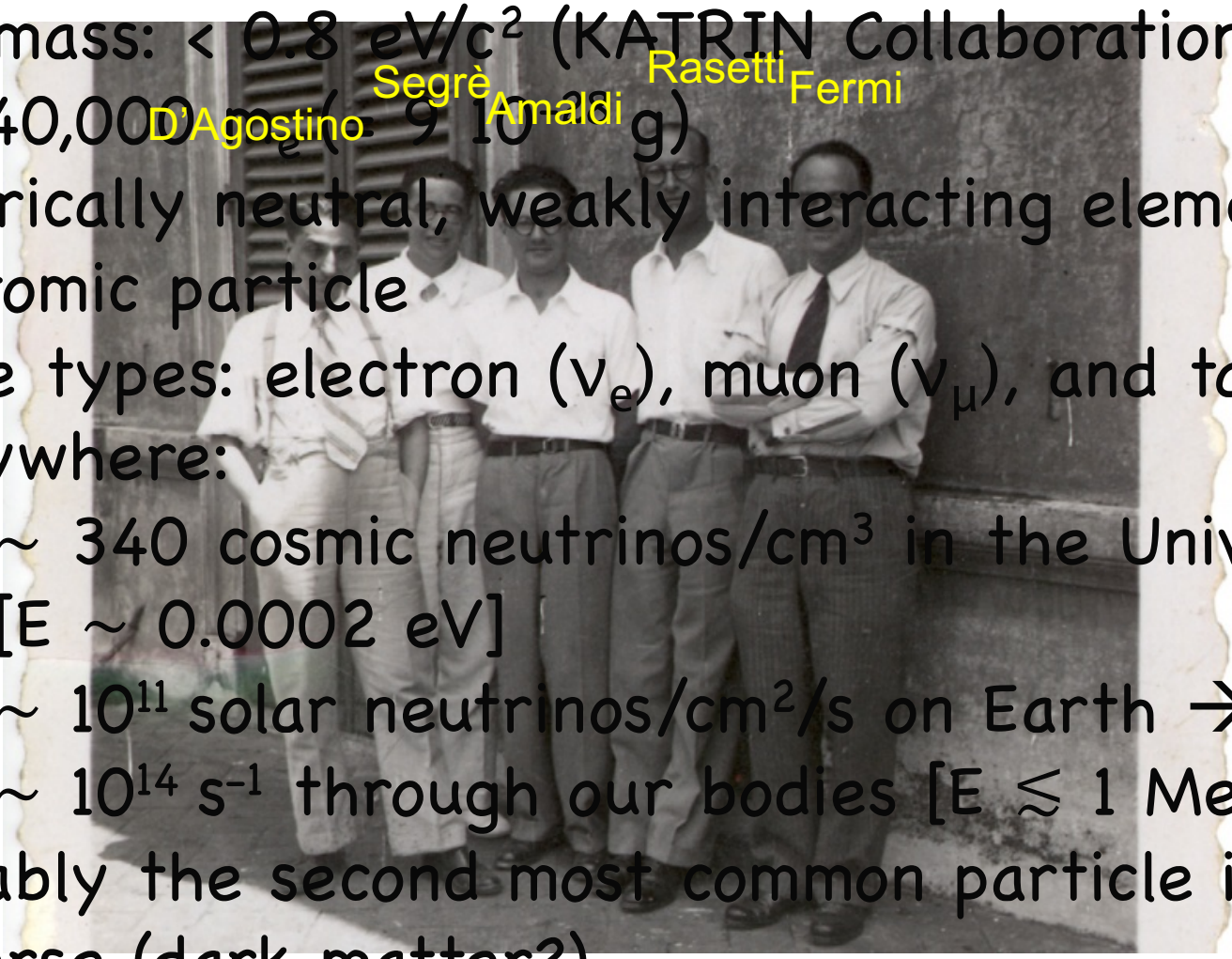


Neutrinos in a nutshell

- Italian for "little neutral one"
- Tiny mass: < 0.8 eV/c^2 (KATRIN Collaboration 2022), < 1/640,000 m_e (= 9 10^{-28} g)
- Electrically neutral, weakly interacting elementary subatomic particle
- Three types: electron (ν_e), muon (ν_μ), and tau (ν_τ)
- Everywhere:
  - ✓ ~ 340 cosmic neutrinos/cm^3 in the Universe [E ~ 0.0002 eV]
  - ✓ ~ 10^{11} solar neutrinos/cm^2/s on Earth → ~ 10^{14} s^{-1} through our bodies [E $\lesssim$ 1 MeV]
- Probably the second most common particle in the Universe (dark matter?)

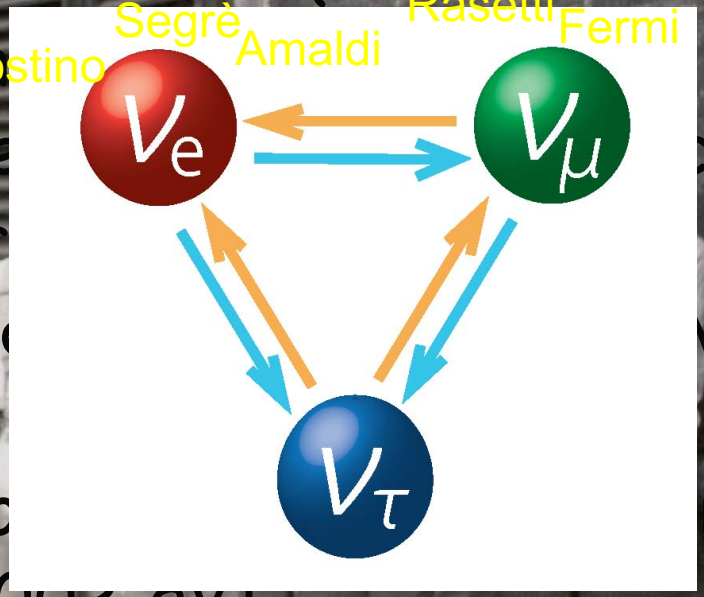
Neutrinos in a nutshell

- Italian for "little neutral one"
- Tiny mass: < 0.8 eV/c^2 (KATRIN Collaboration 2022), < 1/640,000 m_e ($< 9 \cdot 10^{-31}$ g)
- Electrically neutral, weakly interacting elementary subatomic particle
- Three types: electron (ν_e), muon (ν_μ), and tau (ν_τ)
- Everywhere:
  - ✓ ~ 340 cosmic neutrinos/cm^3 in the Universe [E ~ 0.0002 eV]
  - ✓ ~ 10^{11} solar neutrinos/cm^2/s on Earth → ~ 10^{14} s^{-1} through our bodies [E ≲ 1 MeV]
- Probably the second most common particle in the Universe (dark matter?)



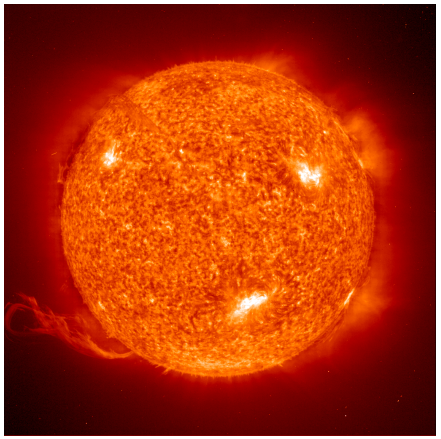
Neutrinos in a nutshell

- Italian for "little neutral one"
- Tiny mass: < 0.8 eV/c² (KATRIN Collaboration 2022), < 1/640,000 [illegible]
- Electrically ne[illegible]cting elementary subatomic par[illegible]
- Three types: [illegible] (ν_μ), and tau (ν_τ)
- Everywhere:
  - ✓ ~ 340 co[illegible]n the Universe [E ~ 0.0002 eV]
  - ✓ ~ 10^{11} solar neutrinos/cm²/s on Earth → ~ 10^{14} s^{-1} through our bodies [E ≲ 1 MeV]
- Probably the second most common particle in the Universe (dark matter?)



Neutrino astrophysics

The Sun

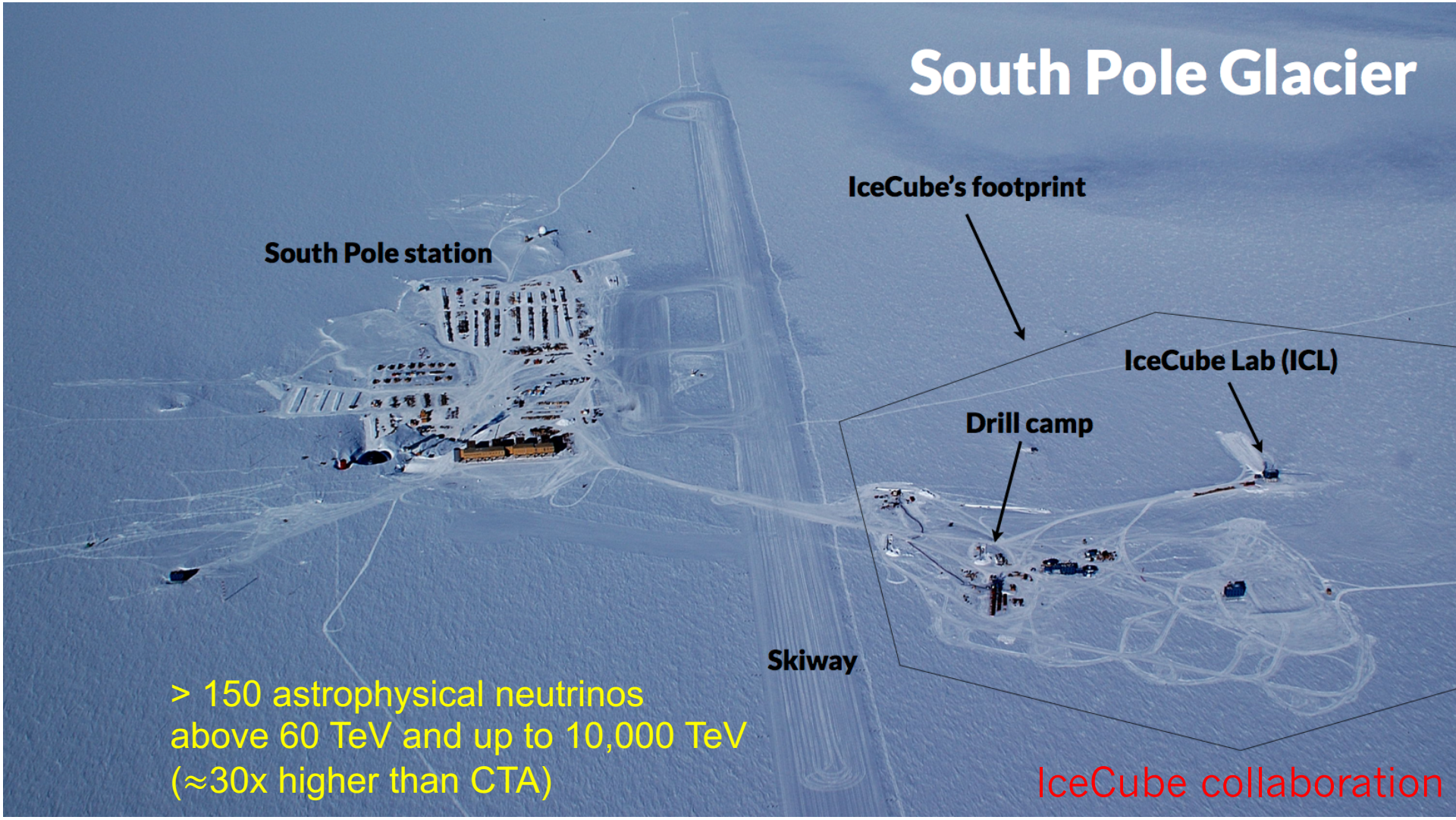


E < 1 MeV (nuclear fusion)

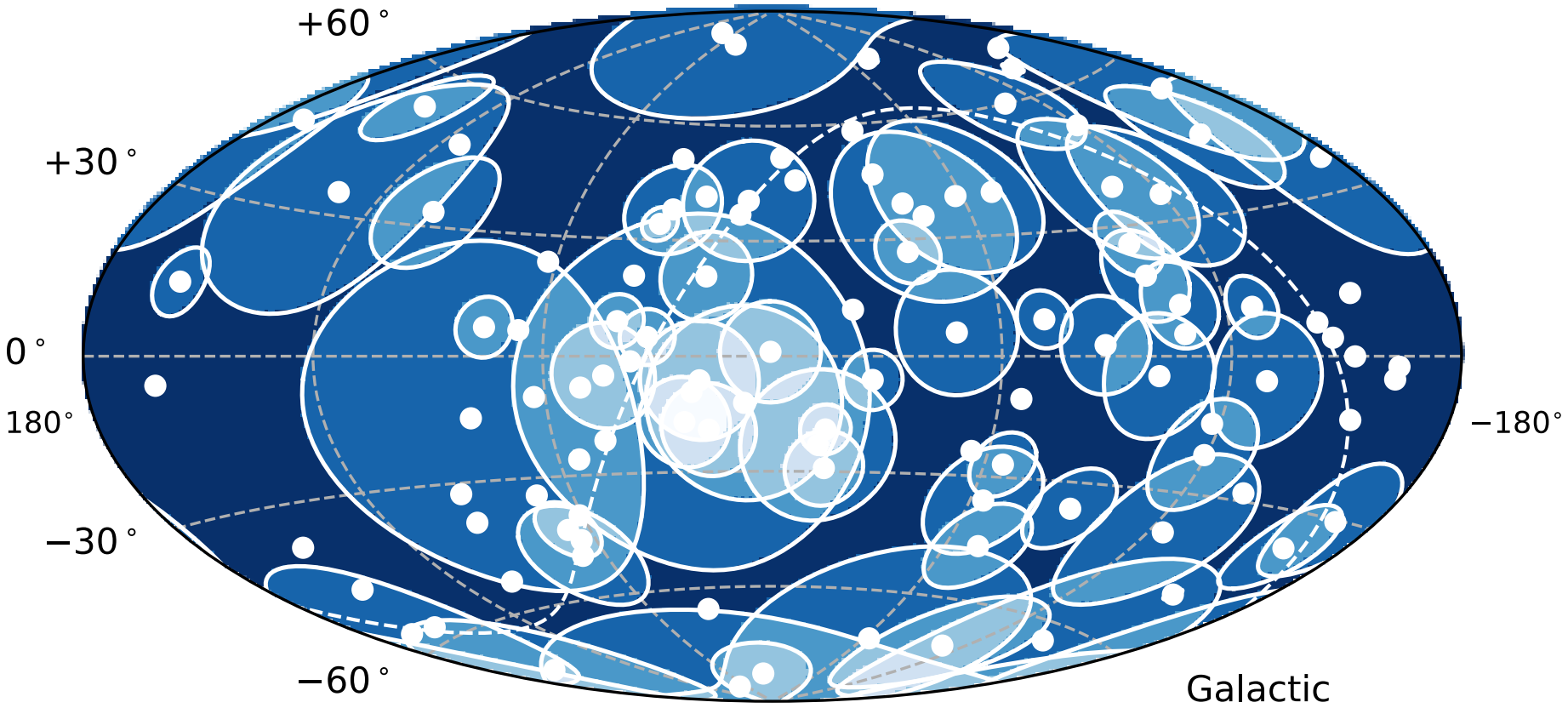
SN 1987A

E ~ 10 MeV (Supernova explosion)

The IceCube Neutrino Observatory



Neutrino sky distribution



The first (extragalactic) neutrino source

TXS 0506+056,
a blazar in γ-ray outburst
(a BL Lac) at z = 0.3365;
p−value (post-trial)
~ 3 – 3.5σ

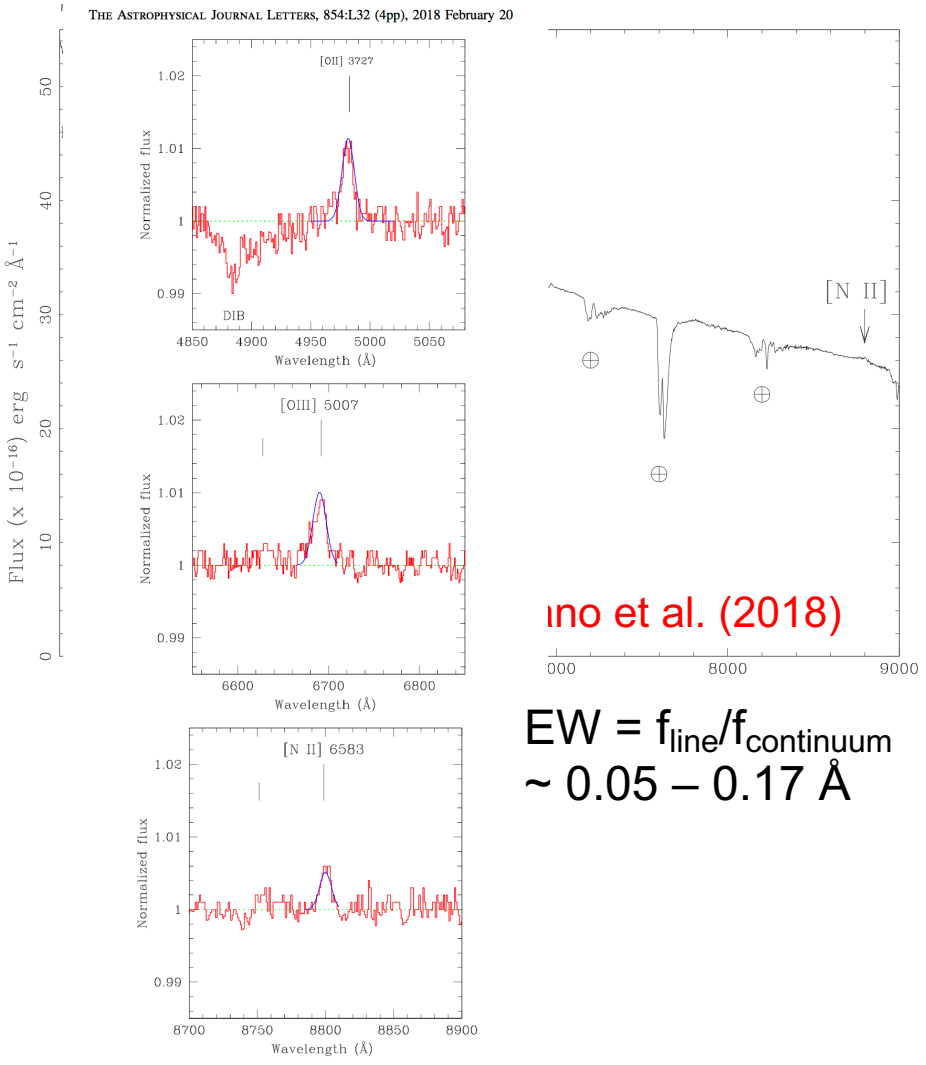
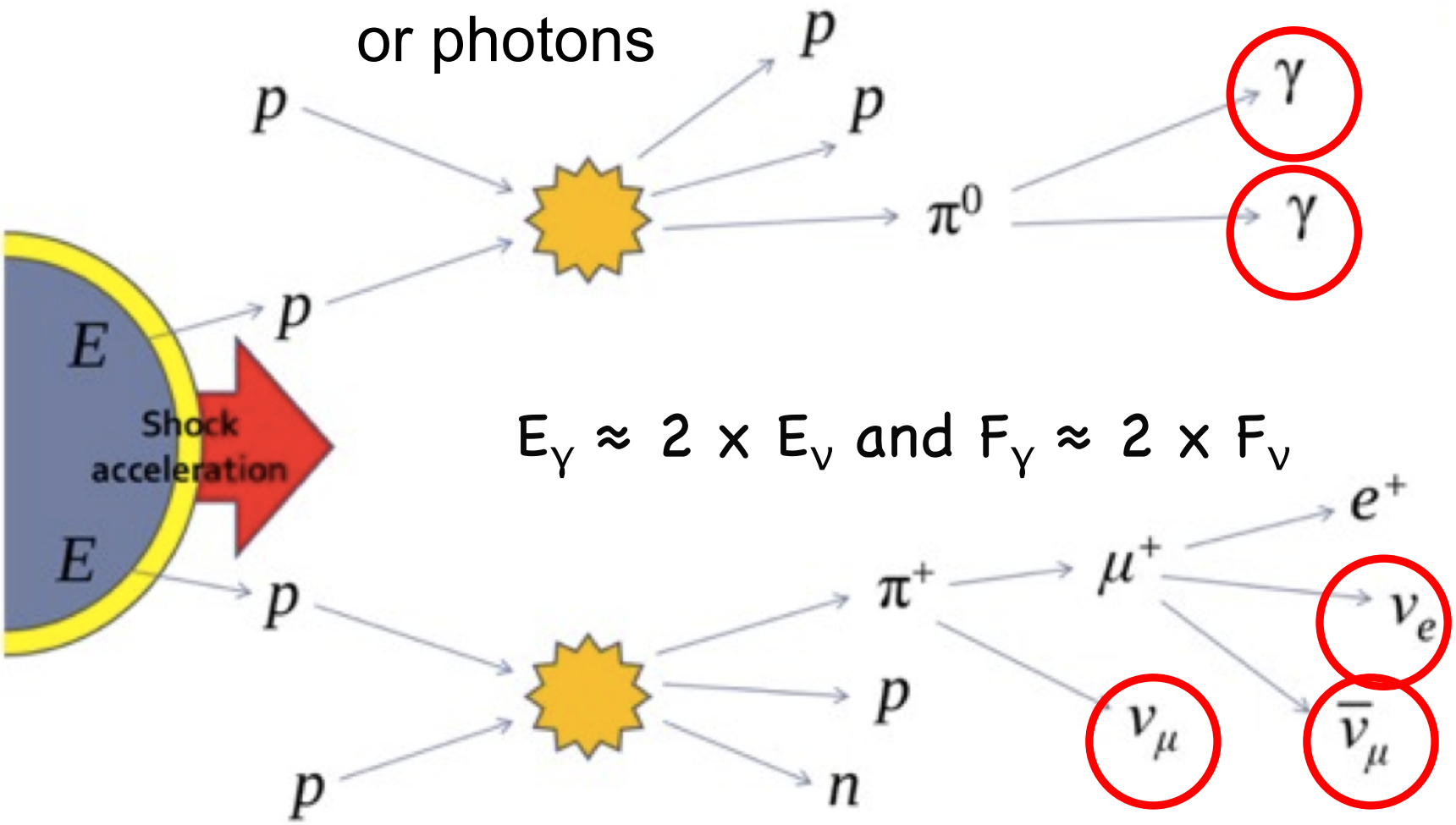


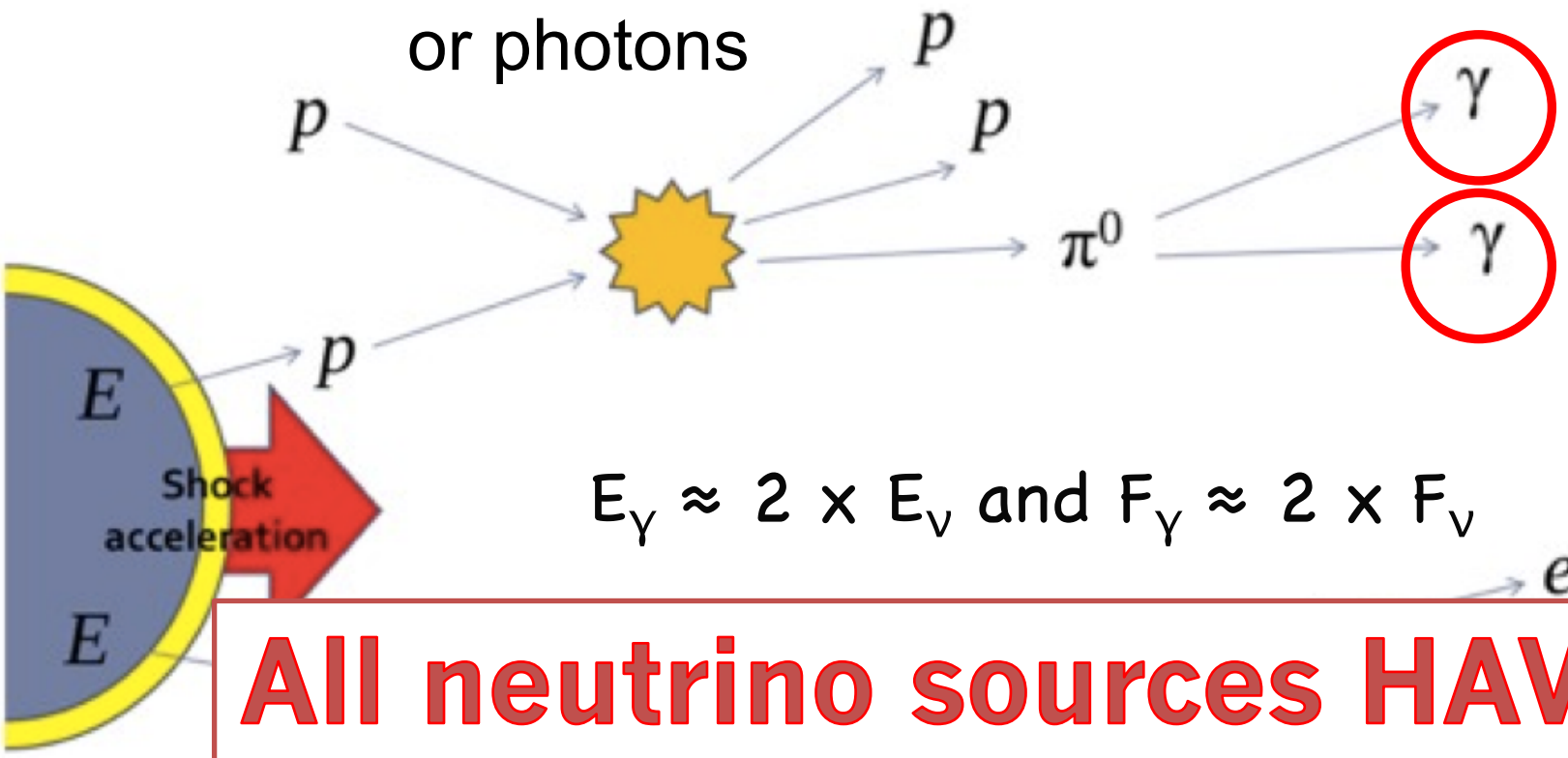
Figure 3. Close-up of the normalized optical spectrum (obtained with $R \sim 1300$) of TXS 0506+056 around the three faint detected emission lines. Top: the emission line at 4981.5 Å identified as [O II] 3727 Å (EW = 0.12 Å). Middle: the emission line at 6693.6 Å identified as [O III] 5007 Å (EW = 0.17 Å), Bottom: the emission line at 8800.5 Å identified as [N II] 6583 Å (EW = 0.05 Å). The short vertical bars indicate the fainter component of the doublet.

EW = $f_{line}/f_{continuum}$
~ 0.05 – 0.17 Å

High-energy neutrino physics

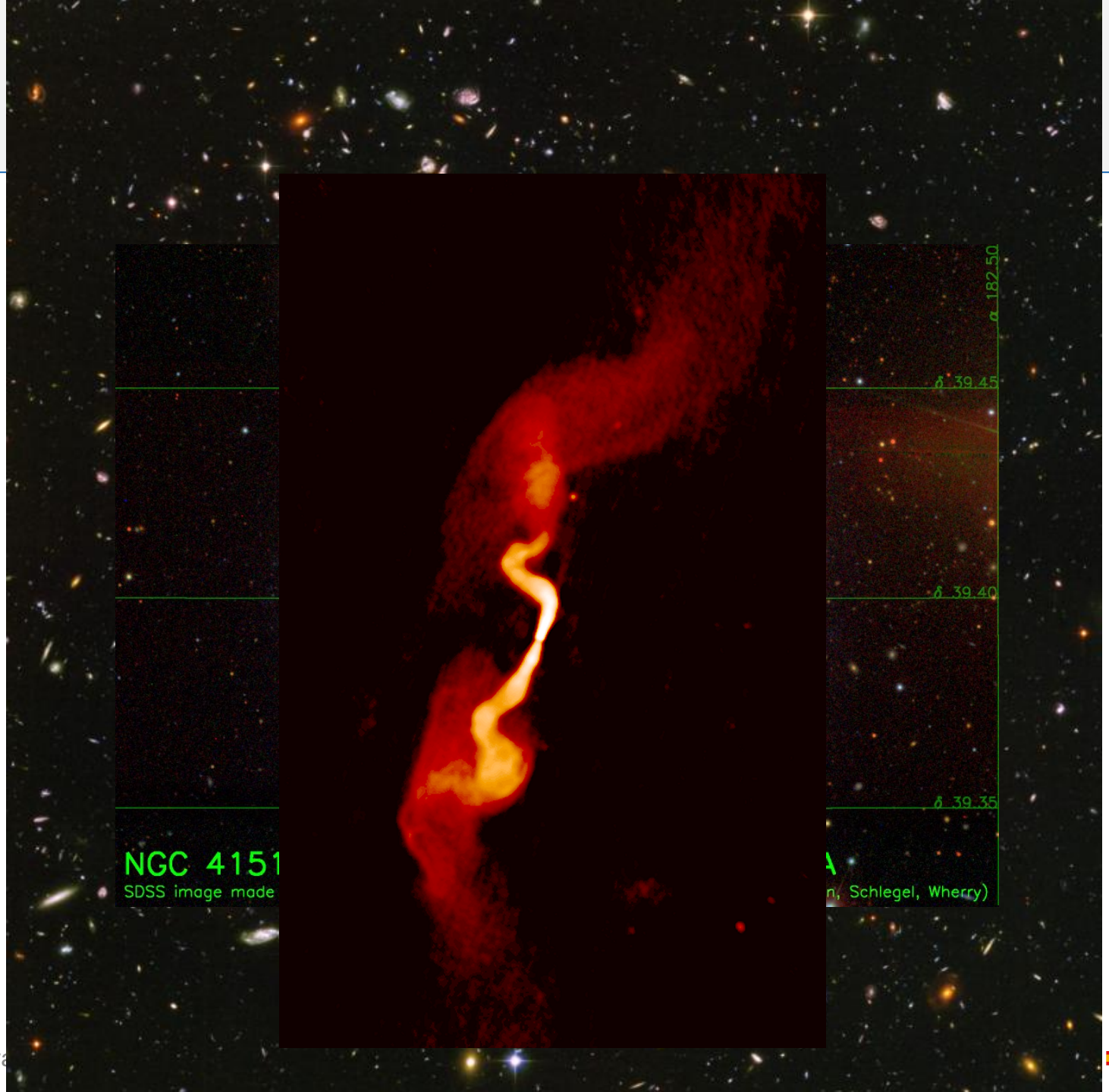


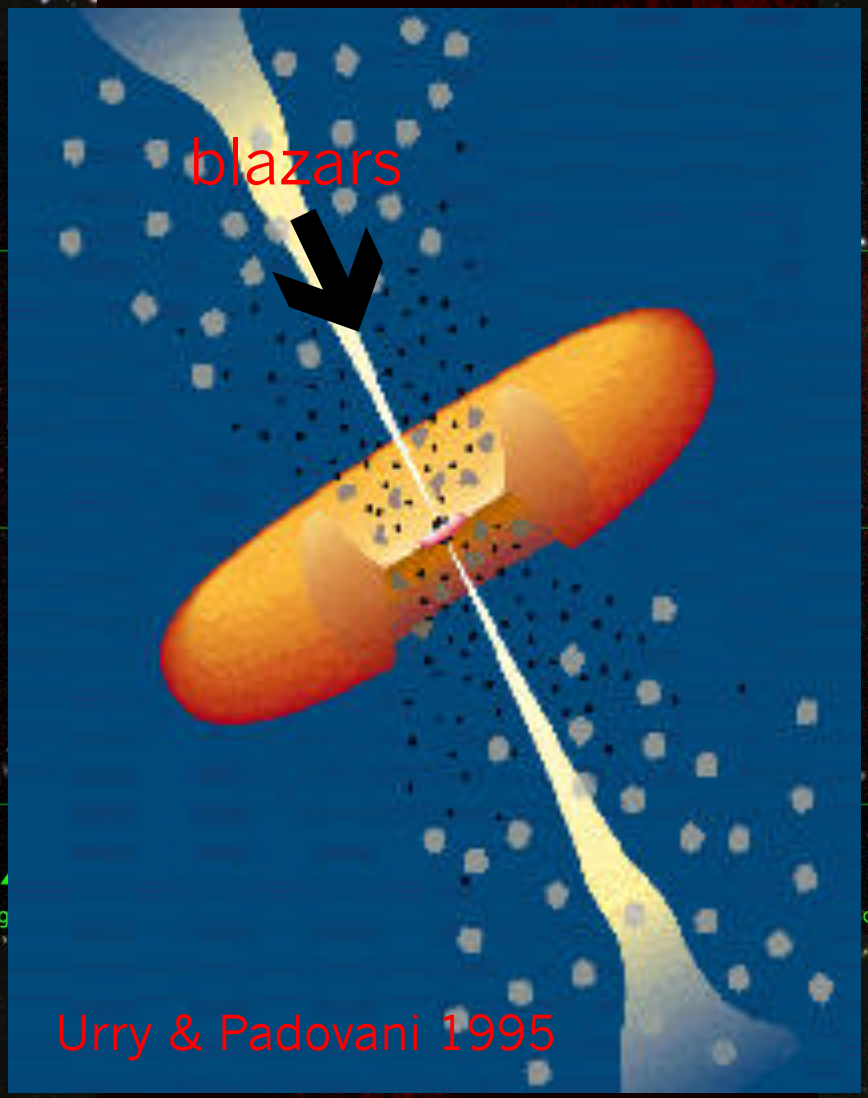
High-energy neutrino physics



$E_\gamma \approx 2 \times E_\nu$ and $F_\gamma \approx 2 \times F_\nu$

All neutrino sources HAVE to be (intrinsically) γ-ray sources!


α 182.50
δ 39.45
δ 39.40
δ 39.35
NGC 4151
SDSS image made
n, Schlegel, Wherry)



Less than 1 galaxy out of 100 000 is a blazar!

The status of IceCube detections after TXS 0506+056. 1. IceCube results

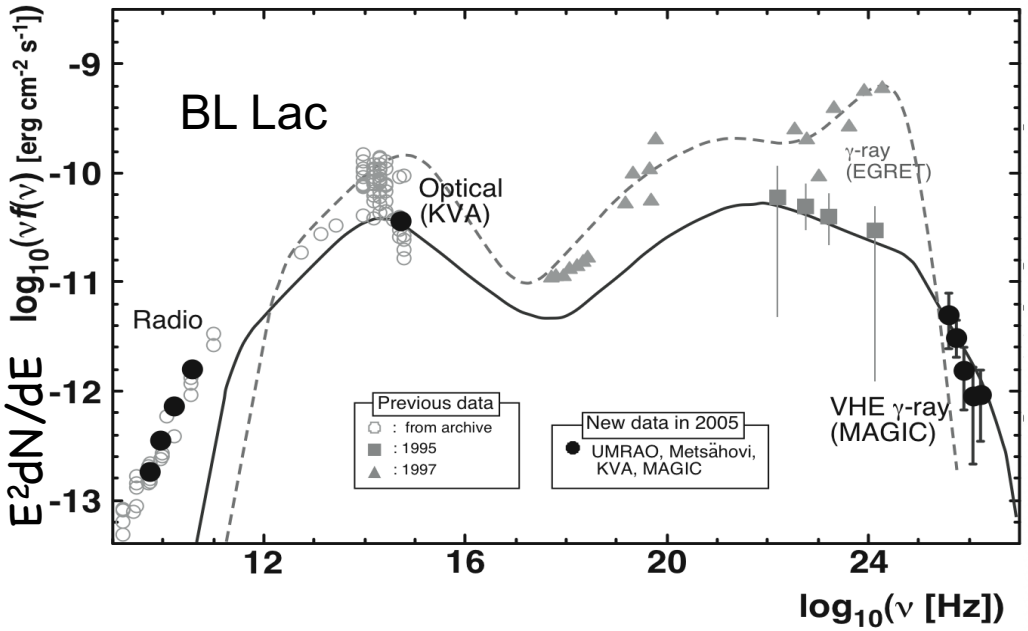
- 2.9σ detection from **NGC 1068** (Aartsen et al. 2020)
- 3.3σ combined excess in the northern sky due to **NGC 1068** and three blazars: **TXS 0506+056**, **PKS 1424+240**, and **GB6 J1542+6129** (Aartsen et al. 2020)
- 3.0σ cumulative time-dependent excess in the northern sky due to **NGC 1068, M87**, and two blazars: **TXS 0506+056**, and **GB6 J1542+6129** (Abbasi et al. 2021)

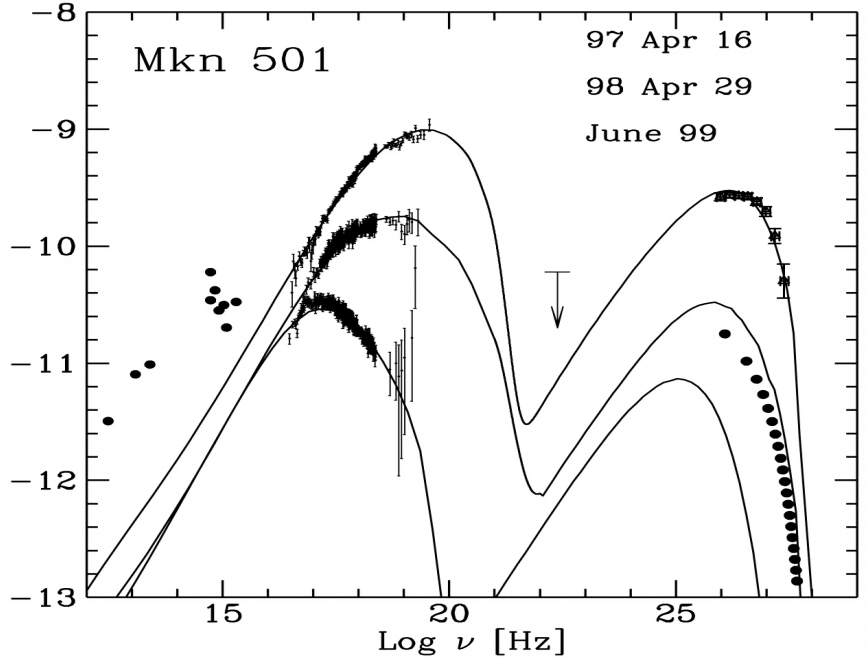
The status of IceCube detections after TXS 0506+056. 2. other results

- 3.2σ correlation excess for 47 γ-ray **blazars** [intermediate- and high-peaked sources (IBLs and HBLs): $\nu_{peak,synch} > 10^{14}$ Hz] (Giommi et al. 2020)
- 2.9σ correlation excess for strong very-long-baseline interferometry (VLBI)-selected AGN; four brightest associations are all **blazars** [low-peaked sources (LBLs: $\nu_{peak,synch} < 10^{14}$ Hz)] (Plavin et al. 2020)
- 3.0σ correlation excess for strong VLBI-selected AGN, different IceCube sample (Plavin et al. 2021)
- 2.6σ association between 5 neutrinos detected by ANTARES and an IceCube event for the **blazar MG3 J225517+2409** [HBL] (Albert et al. 2021)

The status of IceCube detections after TXS 0506+056. 2. other results

- 3.2σ correlation excess for 47 γ-ray **blazars** [intermediate- and high-peaked sources (IBLs and HBLs): $\nu_{peak,synch} > 10^{14}$ Hz] (Giommi et al. 2020)





- 2.0σ association between 3 neutrinos detected by ANTARES and an IceCube event for the **blazar MG3 J225517+2409** [HBL] (Albert et al. 2021)

The status of IceCube detections (after TXS 0506+056). 3. take home messages

1. Additional $\gtrsim 3\sigma$ associations (still missing the "magical" 5σ!)
2. Blazars keep popping up
3. Strong hints that only somewhat rare blazar sub-classes are involved (our group)
4. Consistent with overall result that blazars can explain only < 17 – 27% of the IceCube signal (IceCube collaboration 2017, 2019 + our group)

Why TXS 0506+056?

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **00,** L1 (2019) doi:10.1093/mnrasl/slz011

TXS 0506+056, the first cosmic neutrino source, is not a BL Lac

P. Padovani [1,2★] F. Oikonomou,[1] M. Petropoulou,[3] P. Giommi[4,5,6] and E. Resconi[7]

[1] *European Southern Observatory, Karl-Schwarzschild-Str 2, D-85748 Garching bei München, Germany*
[2] *Associated to INAF - Osservatorio Astronomico di Roma, via Frascati 33, I-00040 Monteporzio Catone, Italy*
[3] *Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08544, USA*
[4] *Agenzia Spaziale Italiana, ASI, via del Politecnico s.n.c., I-00133 Roma, Italy*
[5] *Institute for Advanced Studies, Technische Universität München, Lichtenbergstr 2a, D-85748 Garching bei München, Germany*
[6] *ICRANet, Piazzale della Repubblica 10, I-65122 Pescara, Italy*
[7] *Physik-Department, Technische Universität München, James-Frank-Str 1, D-85748 Garching bei München, Germany*

Accepted 2019 January 19. Received 2019 January 15; in original form 2018 September 21

ABSTRACT

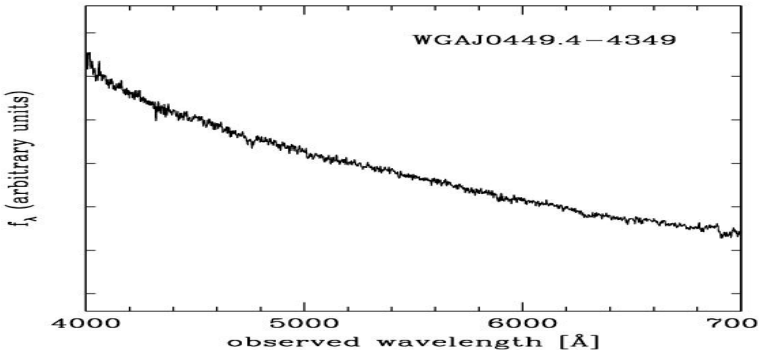
We present evidence that TXS 0506+056, the first plausible non-stellar neutrino source, despite appearances, is *not* a blazar of the BL Lac type but is instead a masquerading BL Lac, i.e. intrinsically a flat-spectrum radio quasar with hidden broad lines and a standard accretion disc. This reclassification is based on: (1) its radio and O II luminosities; (2) its emission line ratios; (3) its Eddington ratio. We also point out that the synchrotron peak frequency of TXS 0506+056 is more than two orders of magnitude larger than expected by the so-called 'blazar sequence', a scenario which has been assumed by some theoretical models predicting neutrino (and cosmic ray) emission from blazars. Finally, we comment on the theoretical implications this reclassification has on the location of the γ-ray emitting region and our understanding of neutrino emission in blazars.

Key words: neutrinos – radiation mechanisms: non-thermal – galaxies: active – BL Lacertae objects: general – gamma-rays: galaxies.

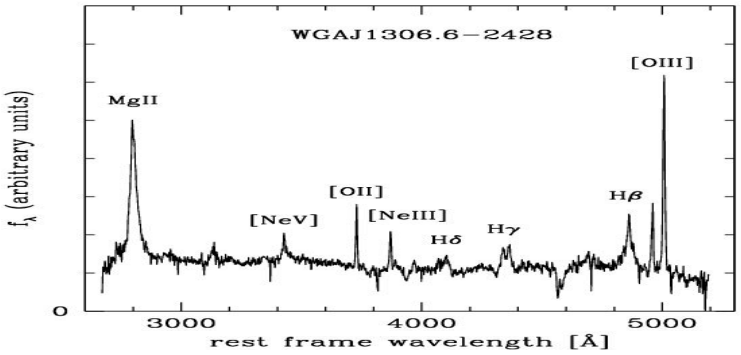
Why TXS 0506+056?

BL Lacs

Flat-Spectrum Radio Quasars



EW = $f_{line}/f_{continuum}$

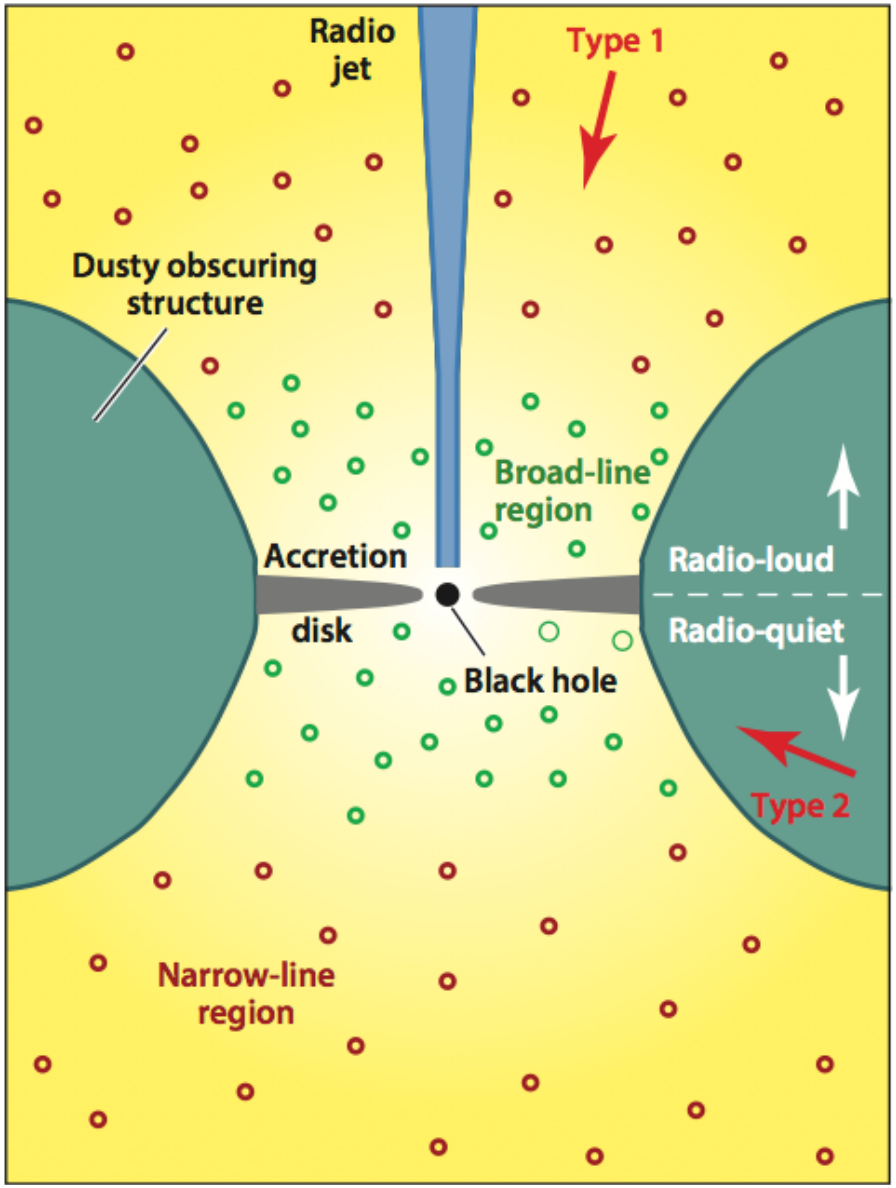


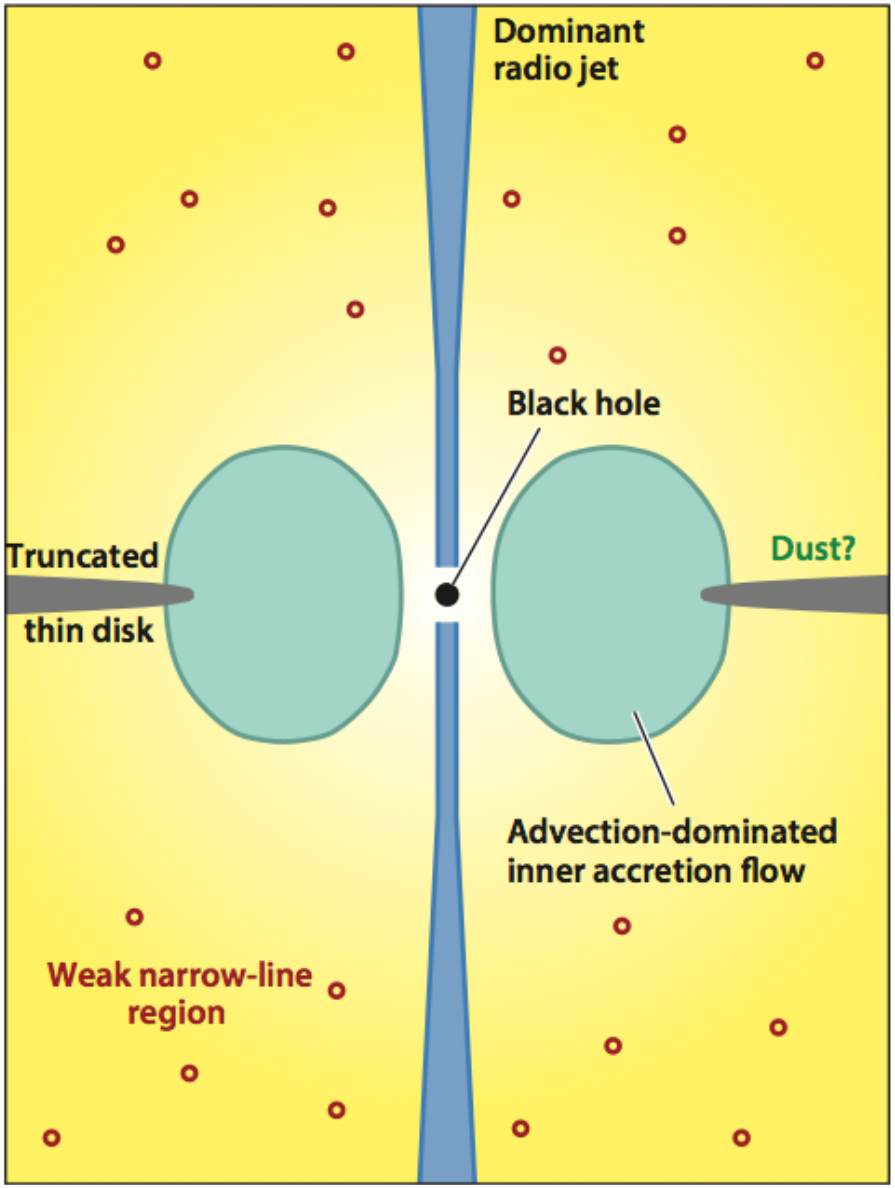
- Real BL Lacs: lines are intrinsically weak (EW low because lines are weak) → low-excitation galaxies (radiatively inefficient accretion)
- Masquerading BL Lacs*: lines are intrinsically strong but swamped by the jet (EW low because continuum is high) → intrinsically FSRQs, hence high-excitation galaxies (radiatively efficient accretion)
- TXS 0506+056 IS a masquerading BL Lac!

* Giommi, PP, et al. (2012)

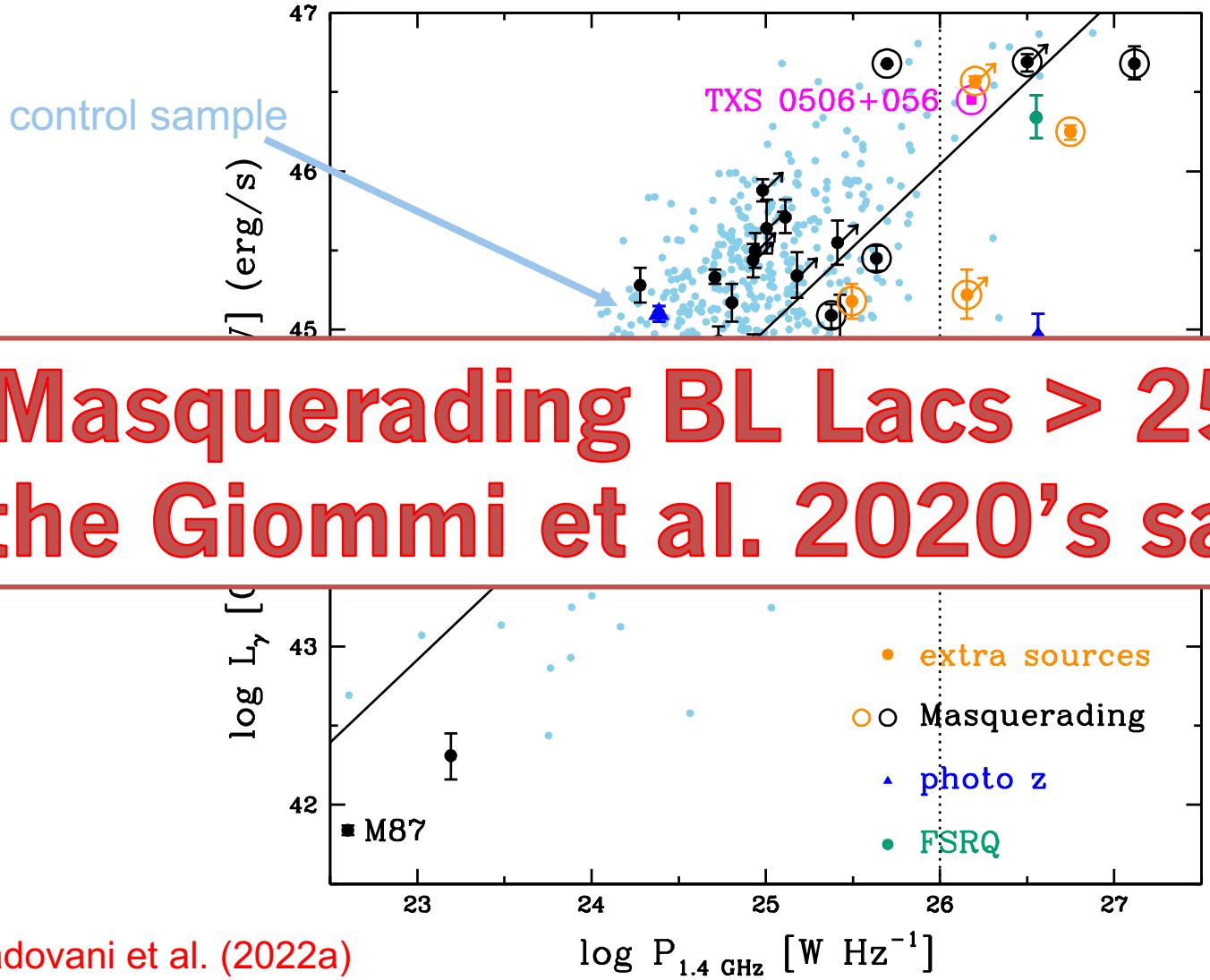
Why TXS 0506+056?

Heckman & Best 2014





Masquerading BL Lacs



Masquerading BL Lacs > 25% of the Giommi et al. 2020's sample

Padovani et al. (2022a)

More masquerading BL Lacs

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **511,** 4697–4701 (2022) https://doi.org/10.1093/mnras/stac376
Advance Access publication 2022 February 11

PKS 1424+240: yet another masquerading BL Lac object as a possible IceCube neutrino source

P. Padovani [1,2]★ B. Boccardi,[3] R. Falomo[4] and P. Giommi [5,6,7]

[1] *European Southern Observatory, Karl-Schwarzschild-Str 2, D-85748 Garching bei München, Germany*
[2] *Associated to INAF - Osservatorio di Astrofisica e Scienza dello Spazio, Via Piero Gobetti 93/3, I-40129 Bologna, Italy*
[3] *Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany*
[4] *INAF - Osservatorio Astronomico di Padova, vicolo dell'Osservatorio 5, I-35122 Padova, Italy*
[5] *Associated to Agenzia Spaziale Italiana, ASI, via del Politecnico s.n.c., I-00133 Roma, Italy*
[6] *Institute for Advanced Study, Technische Universität München, Lichtenbergstrasse 2a, D-85748 Garching bei München, Germany*
[7] *Center for Astro, Particle and Planetary Physics, New York University Abu Dhabi, United Arab Emirates*

Accepted 2022 February 8. Received 2022 February 8; in original form 2022 January 19

ABSTRACT

We show that the blazar PKS 1424+240, which has been recently associated by IceCube with a neutrino excess at the 3.3 σ level together with three other sources, is similar to the first plausible non-stellar neutrino source, TXS 0506+056, in being also a masquerading BL Lac object, i.e. intrinsically a flat-spectrum radio quasar with hidden broad lines and a standard accretion disc. We point out that these two sources share other properties, including spectral energy distribution, high powers, parsec scale properties, and possibly radio morphology. We speculate that the relatively rare combination of proton-loaded jets, possibly typical of high-excitation sources, and efficient particle acceleration processes, related to their relatively high synchrotron peak frequencies, might favour neutrino production in these two sources. GB6 J1542+6129, which has also recently appeared twice in a list of IceCube associations, seems also to belong to this rare blazar sub-class, which includes at most ≈20 *Fermi*-4LAC blazars.

Key words: neutrinos – radiation mechanisms: non-thermal – galaxies: active – BL Lacertae objects: general – gamma-rays: galaxies – radio continuum: galaxies.

And more…

MNRAS **000**, 1–12 (2022) Preprint 12 April 2022 Compiled using MNRAS LaTeX style file v3.0

A multi-messenger study of the blazar PKS 0735+178: a new major neutrino source candidate

N. Sahakyan,[1,2,3] ⋆ P. Giommi[4,5,6], P. Padovani[7,8], M. Petropoulou[9] †, D. Bégué[10], B. Boccardi[11], S. Gasparyan[1]

[1]*ICRANet-Armenia, Marshall Baghramian Avenue 24a, Yerevan 0019, Armenia*
[2]*ICRANet, P.zza della Repubblica 10, 65122 Pescara, Italy*
[3]*ICRA, Dipartimento di Fisica, Sapienza Università di Roma, P.le Aldo Moro 5, 00185 Rome, Italy*
[4]*Center for Astro, Particle and Planetary Physics (CAP3), New York University Abu Dhabi, PO Box 129188 Abu Dhabi, United Arab Emirates*
[5]*Institute for Advanced Study, Technische Universität München, Lichtenbergstrasse 2a, D-85748 Garching bei München, Germany*
[6]*Associated to Italian Space Agency, ASI, via del Politecnico snc, 00133 Roma, Italy*
[7]*European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748 Garching bei München, Germany*
[8]*Associated to INAF - Osservatorio di Astrofisica e Scienza dello Spazio, Via Piero Gobetti 93/3, I-40129 Bologna, Italy*
[9]*Department of Physics, National and Kapodistrian University of Athens, University Campus Zografos, GR 15783, Athens, Greece*
[10]*Bar Ilan University, Ramat Gan, Israel*
[11]*Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany*

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT

PKS 0735+178 is a bright radio and γ-ray blazar that is possibly associated with multiple neutrino events observed by the IceCube, Baikal, Baksan, and KM3NeT neutrino telescopes. The source was found to undergo a major flaring activity in γ-ray, X-ray, ultraviolet (UV) and optical bands. We present a long-term detailed study of this peculiar blazar to investigate the temporal and spectral changes in the multi-wavelength emission when the neutrino events were observed. The analysis of Swift-XRT snapshots reveal a flux variability of more than a factor 2 in about 5×10^3 seconds during the observation on December 17, 2021. In the γ-ray band, the source was in its historical highest flux level at the time of the arrival of the neutrinos. The observational comparison between PKS 0735+178 and other neutrino source candidates, such as TXS 0506+056, PKS 1424+240, and GB6 J1542+6129, shows that all these sources share similar spectral energy distributions, very high radio and γ-ray powers, and parsec scale jet properties. Moreover, PKS 0735+178, like all the others, is a masquerading BL Lac. We perform comprehensive modelling of the multiwavelength emission from PKS 0735+178 within one-zone lepto-hadronic models considering both internal and external photon fields and estimate the expected accompanying neutrino flux. The most optimistic scenario invokes a jet with luminosity close to the Eddington value and the interactions of ~ PeV protons with an external UV photon field. This scenario predicts ~ 0.067 muon and antimuon neutrinos over the observed 3-week flare. Our results are consistent with the detection of one very-high-energy neutrino like IceCube-211208A.

Key words: neutrinos – gamma-rays: galaxies – X-rays: galaxies – radiation mechanisms: non-thermal

1 INTRODUCTION

The discovery of a flux of very high-energy (VHE; > 100 GeV) neutrinos of astrophysical origin by the IceCube South Pole observatory[1] (Aartsen et al. 2013, 2020) and the first reliable association of Ice-

between VHE neutrinos and blazars (see Giommi & Padovani 2021, for a recent review).

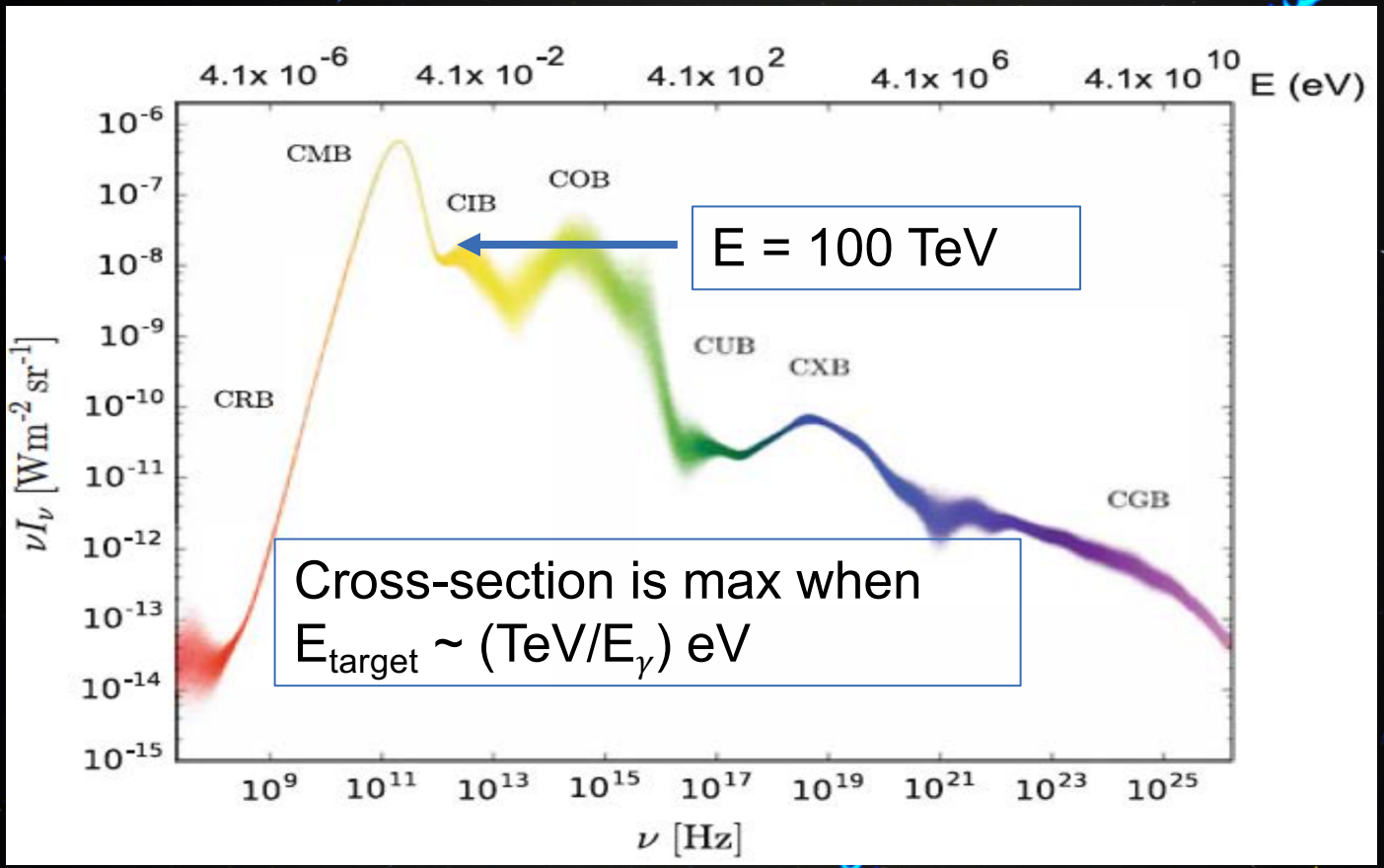
Blazars, a rare type of powerful Active Galactic Nuclei (AGN; Padovani et al. 2017) with a relativistic jet pointing at the Earth

So what?

With neutrinos we are now exploring an energy range which is, and will always be, **inaccessible** with photons at any redshift

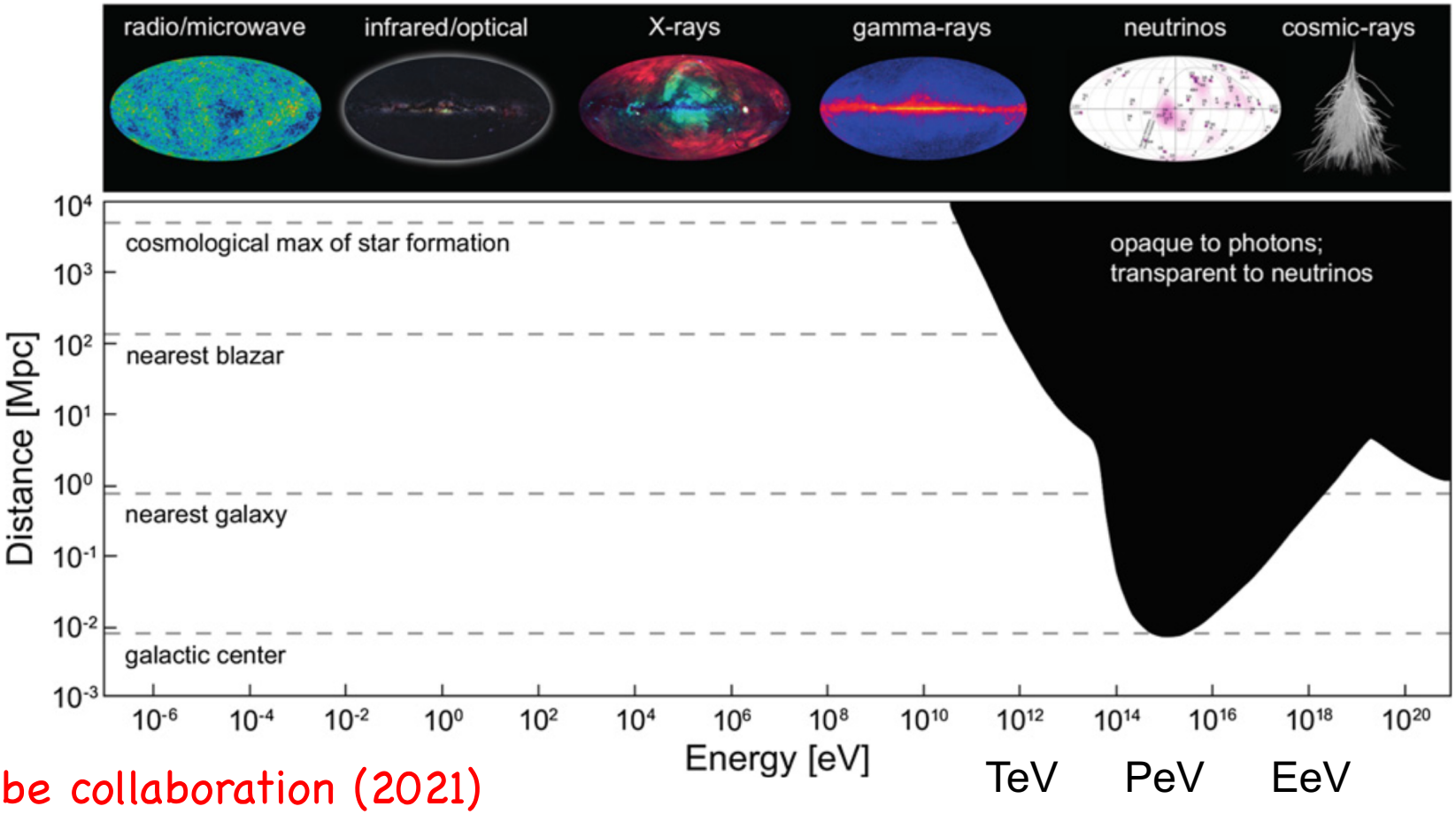
→ New window on very high-energy astrophysics

Extragalactic Background Light



Credit: NASA's Goddard Space Flight Center

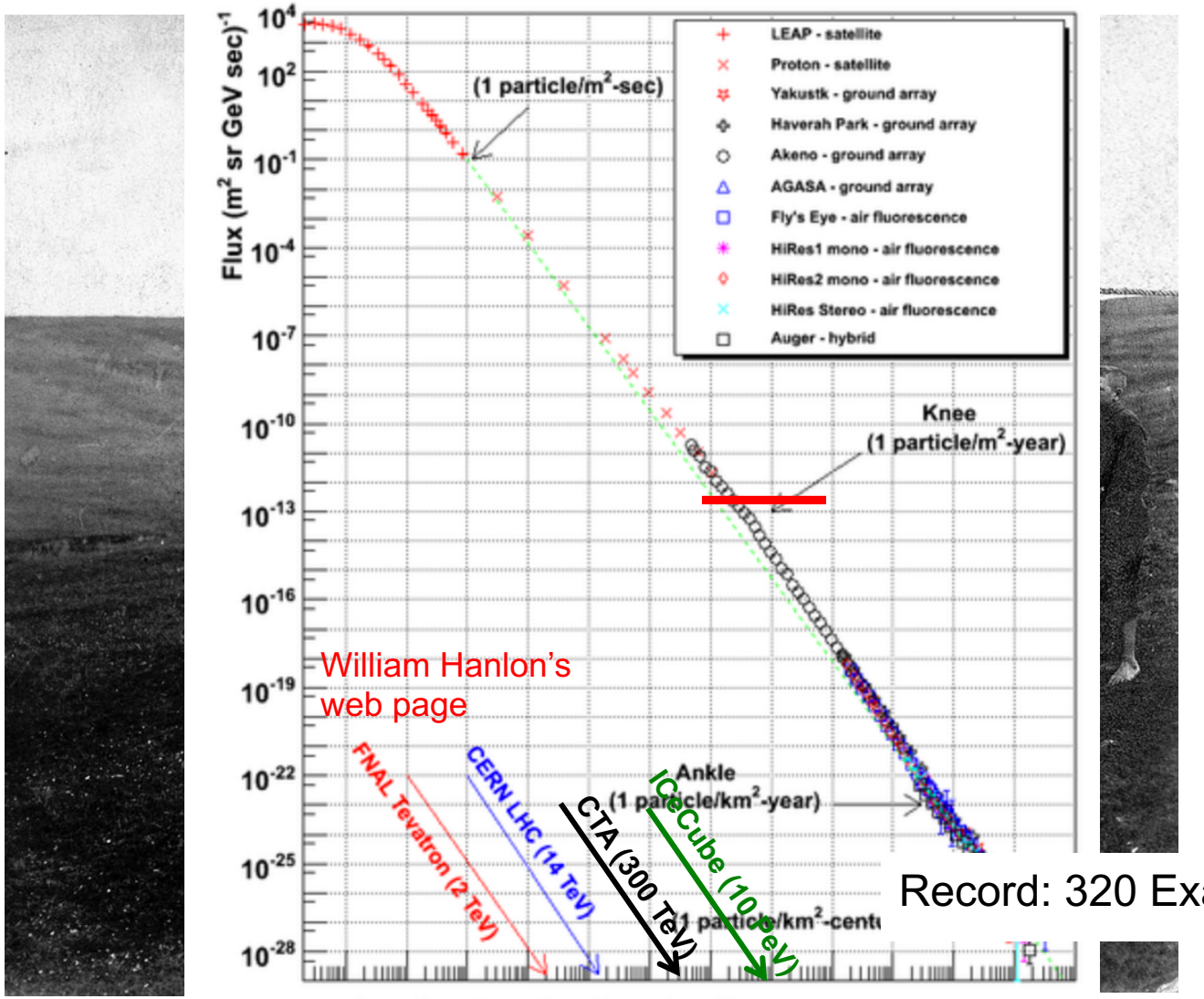
Photon Horizon



IceCube collaboration (2021)

Figure 1. Distance horizon at which the universe becomes non-transparent to electromagnetic radiation as a function of photon energy.

The mystery of cosmic rays

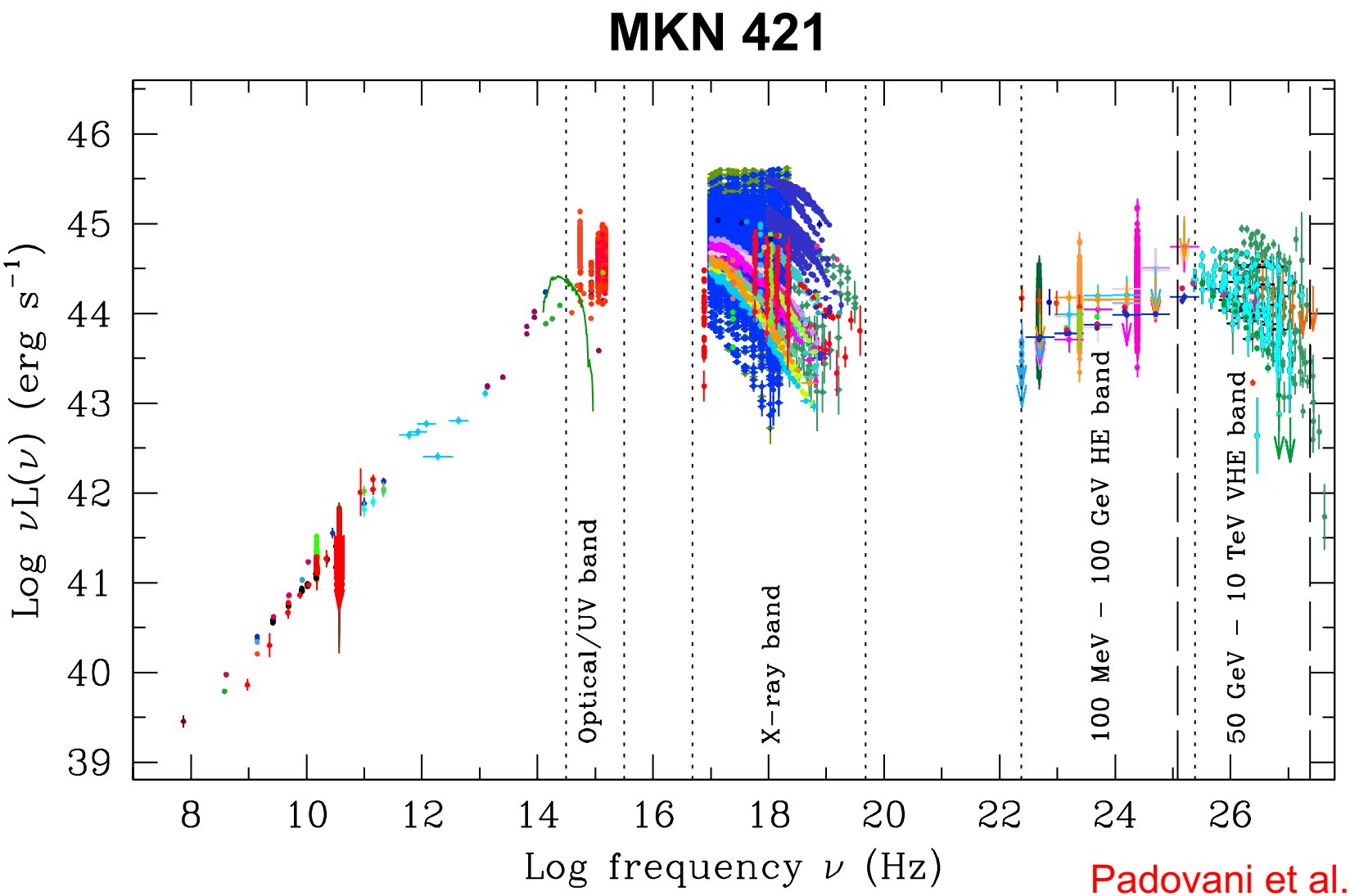


Record: 320 Exa eV!

Open issues

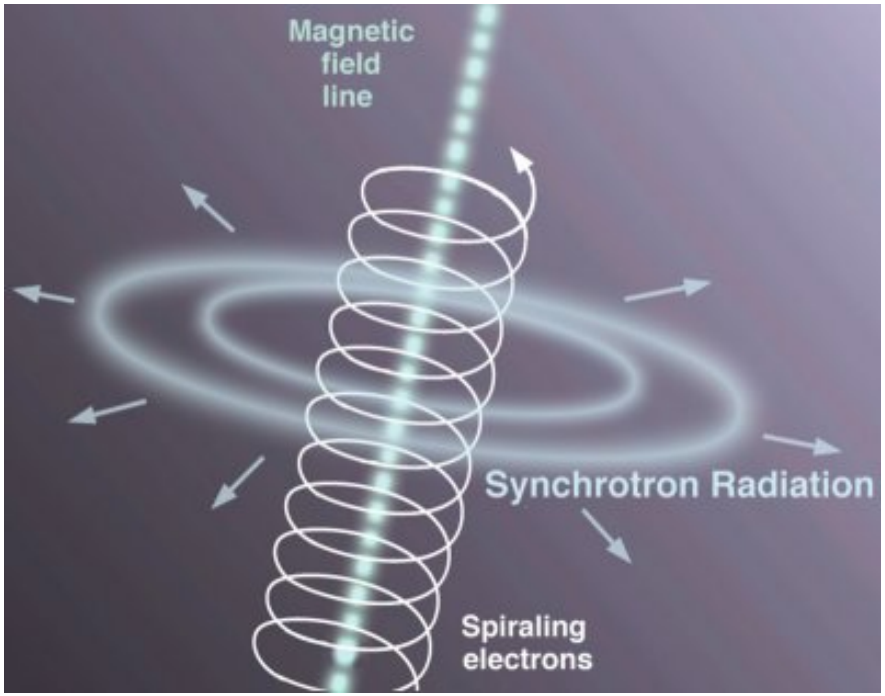
- No “smoking gun”!
- Blazars appear (*have*, I think!) to be involved but other classes have to be as well
- Still not clear which process is producing the γ-ray photons in blazars
- Still no hard evidence of high-energy protons

The synergy with VHE astrophysics: the issue of γ-ray photons



Padovani et al. (2017)

The synergy with VHE astrophysics: the issue of γ-ray photons

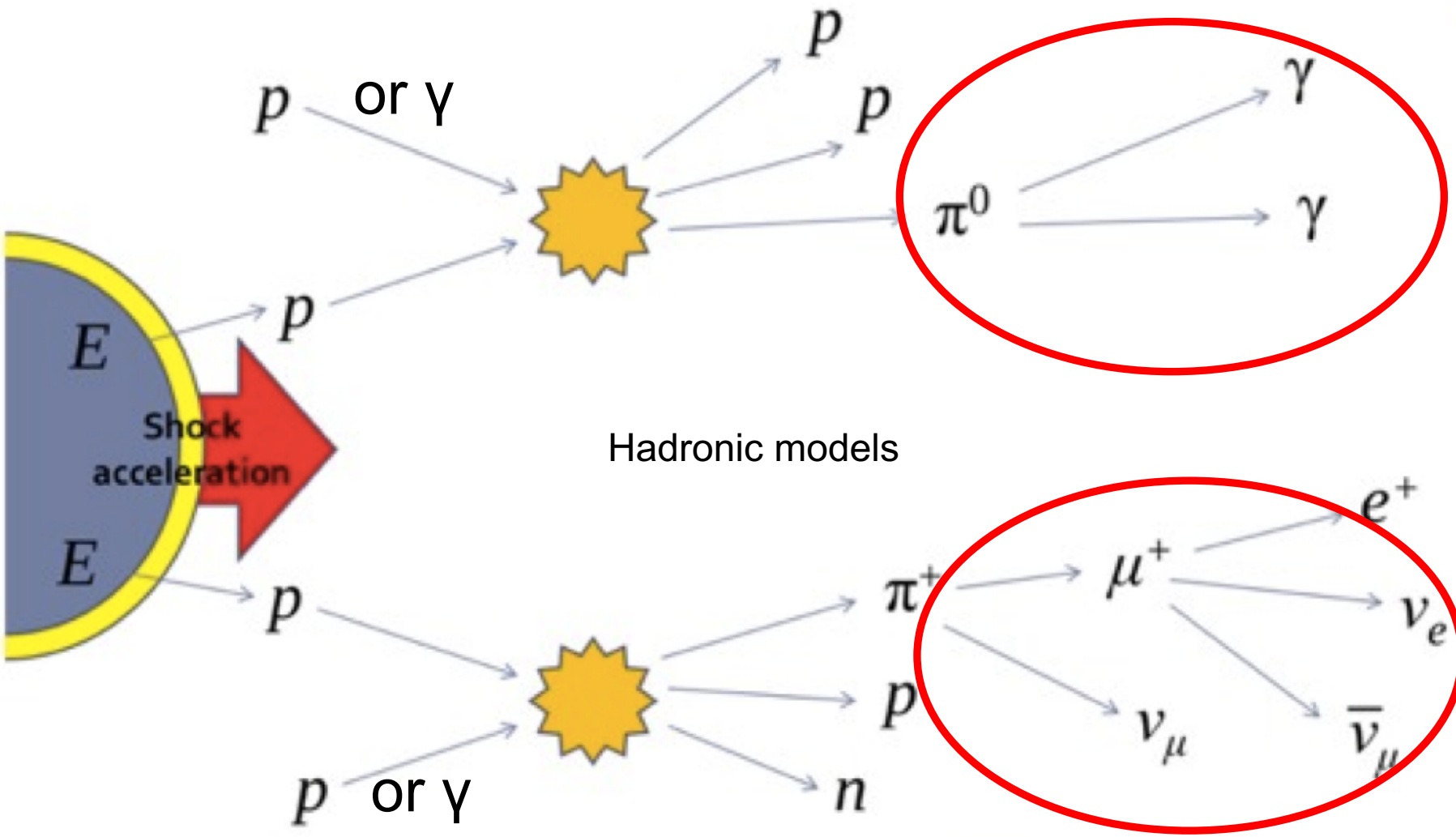


Inverse Compton emission

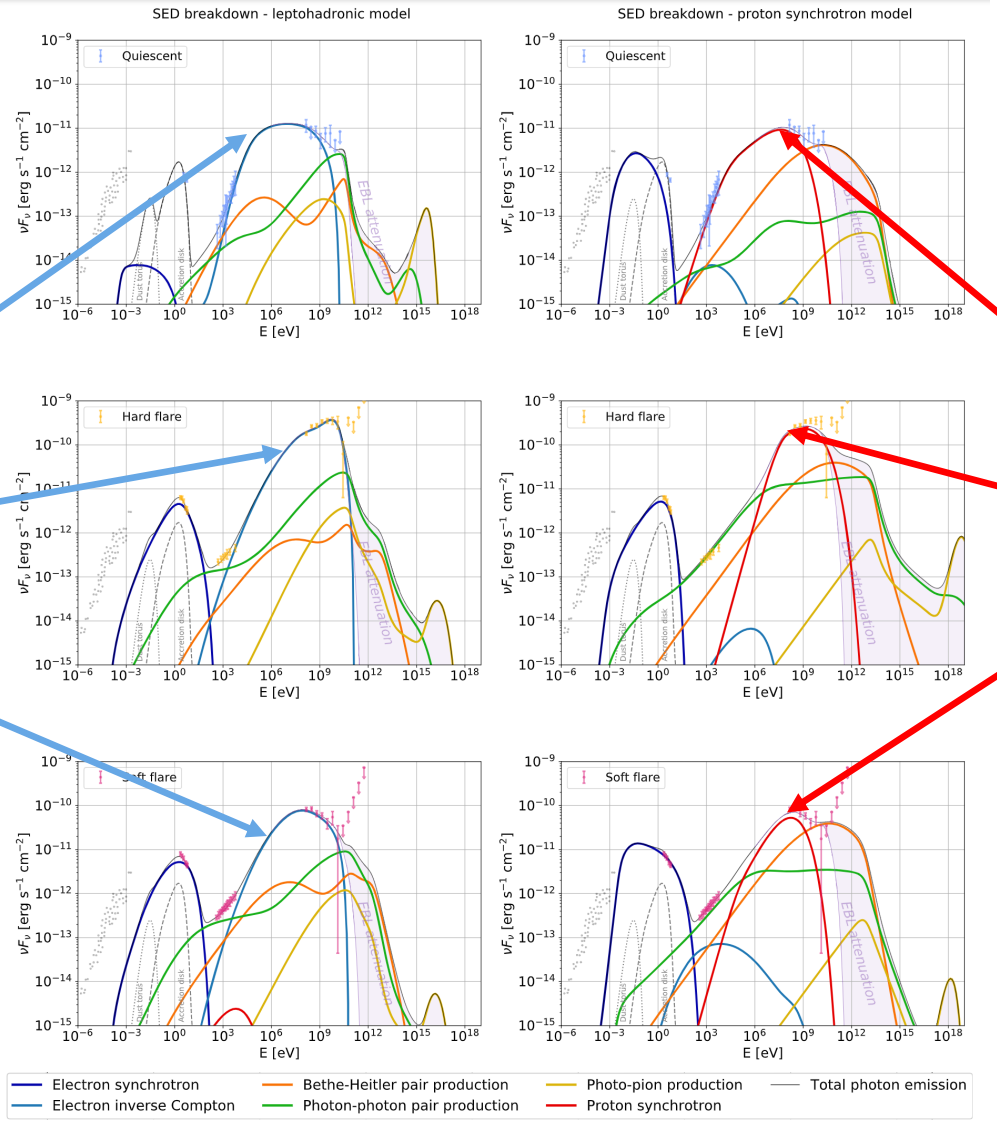
$$e^- + \gamma_{\text{low-energy}} \rightarrow \gamma_{\text{high-energy}}$$

Leptonic models

The synergy with VHE astrophysics: the issue of γ-ray photons



Leptonic vs. hadronic emission



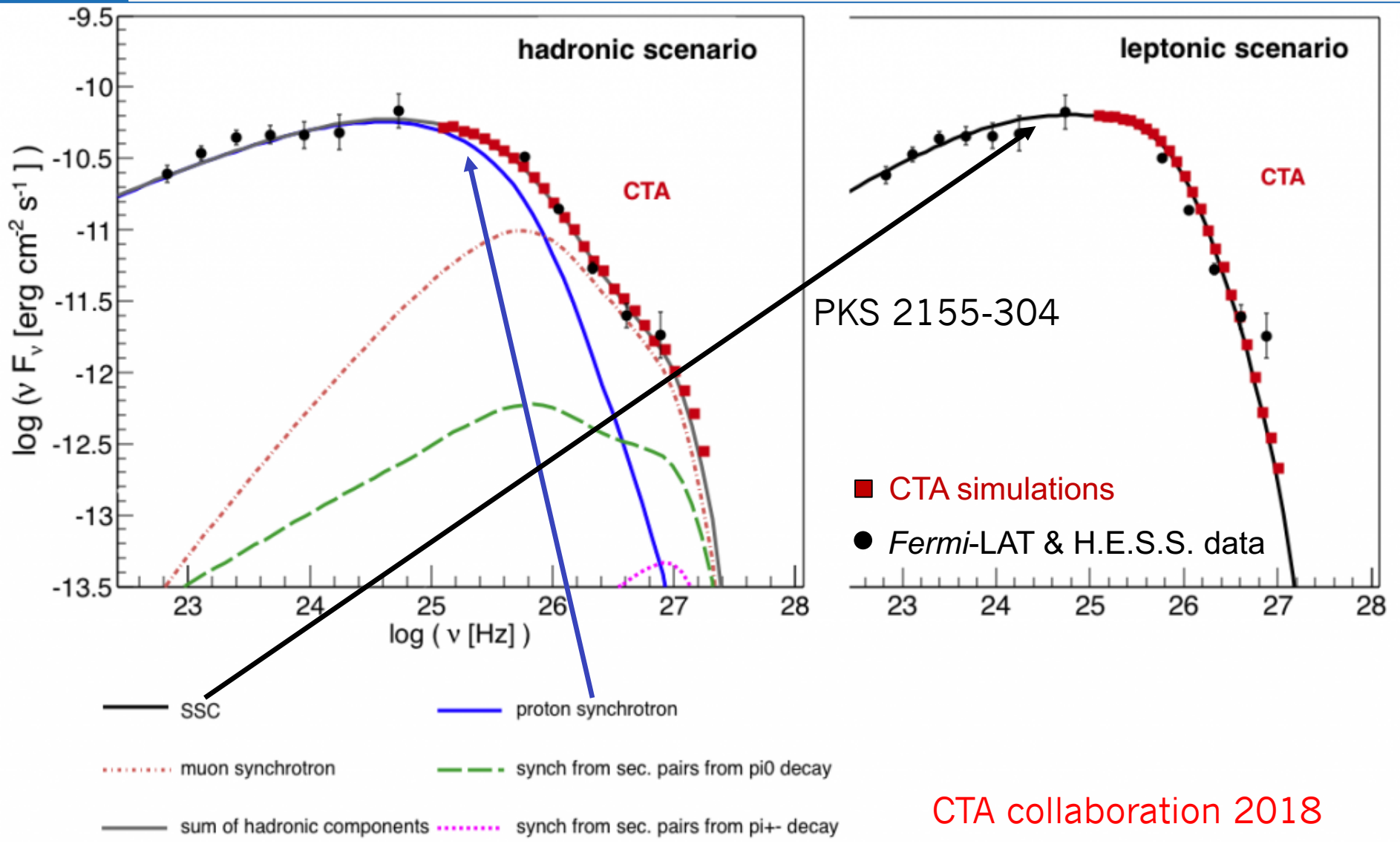
electron inverse Compton

proton synchrotron

PKS 1502+106

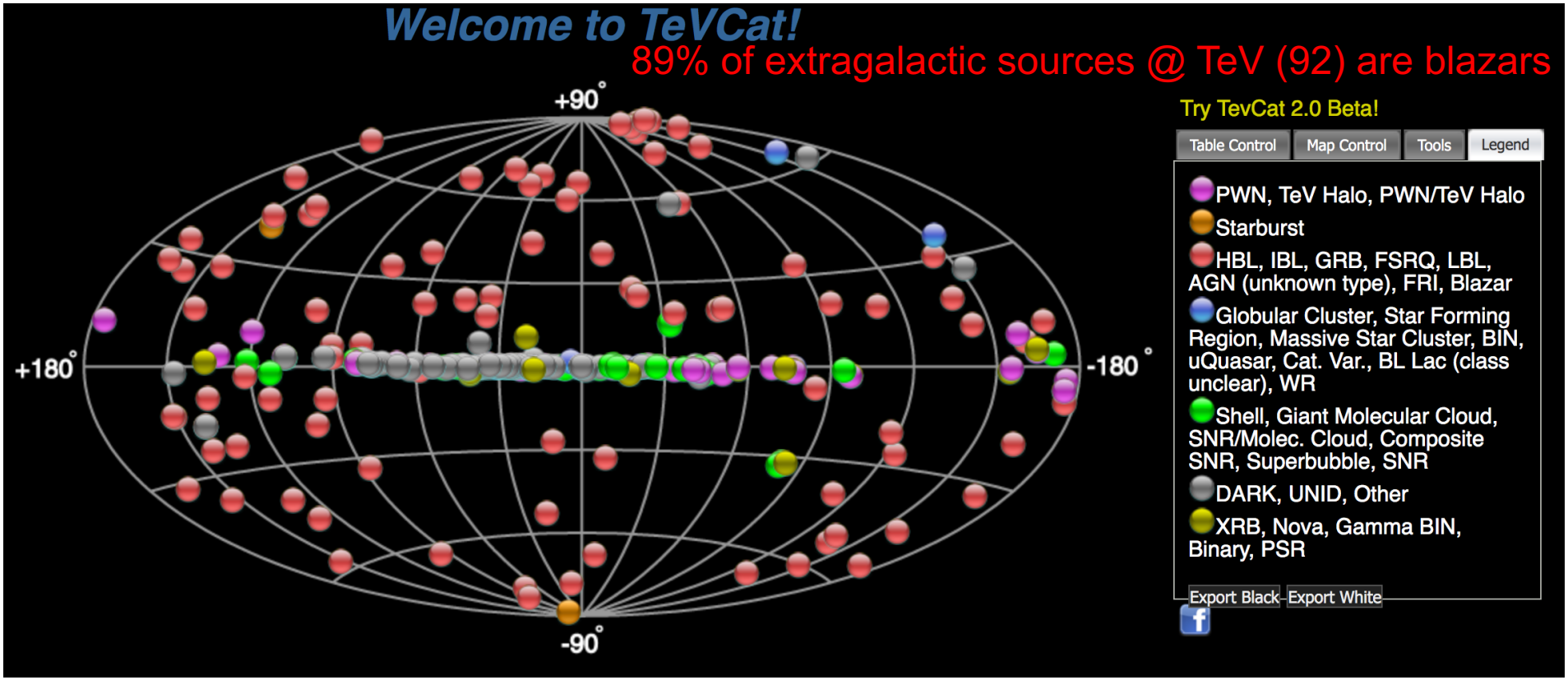
Rodrigues et al. 2021

CTA: leptonic or hadronic?

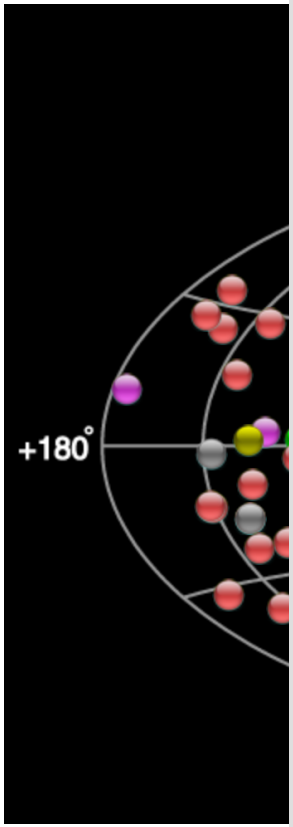


CTA collaboration 2018

CTA and blazars



CTA and blazars



THE ASTROPHYSICAL JOURNAL LETTERS, 815:L23 (8pp), 2015 December 20 doi:10.1088/2041-8205/815/2/L23

VERY HIGH ENERGY γ-RAYS FROM THE UNIVERSE'S MIDDLE AGE: DETECTION OF THE $z = 0.940$ BLAZAR PKS 1441+25 WITH MAGIC

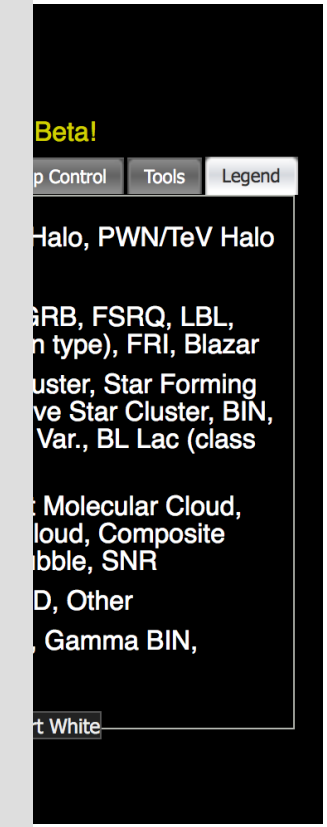
M. L. AHNEN[1], S. ANSOLDI[2], L. A. ANTONELLI[3], P. ANTORANZ[4], A. BABIC[5], B. BANERJEE[6], P. BANGALE[7], U. BARRES DE ALMEIDA[7,74], J. A. BARRIO[8], W. BEDNAREK[9], E. BERNARDINI[10,11], B. BIASUZZI[2], A. BILAND[1], O. BLANCH[12], S. BONNEFOY[8], G. BONNOLI[3], F. BORRACCI[7], T. BRETZ[13,75], E. CARMONA[14], A. CAROSI[3], A. CHATTERJEE[6], R. CLAVERO[15,16], P. COLIN[7], E. COLOMBO[15,16], J. L. CONTRERAS[8], J. CORTINA[12], S. COVINO[3], P. DA VELA[4], F. DAZZI[7], A. DE ANGELIS[17], B. DE LOTTO[2], E. DE OÑA WILHELMI[18], C. DELGADO MENDEZ[14], F. DI PIERRO[3], D. DOMINIS PRESTER[5], D. DORNER[13], M. DORO[7,19], S. EINECKE[20], D. EISENACHER GLAWION[13], D. ELSAESSER[13], A. FERNÁNDEZ-BARRAL[12], D. FIDALGO[8], M. V. FONSECA[8], L. FONT[21], K. FRANTZEN[20], C. FRUCK[7], D. GALINDO[22], R. J. GARCÍA LÓPEZ[15,16], M. GARCZARCZYK[10], D. GARRIDO TERRATS[21], M. GAUG[21], P. GIAMMARIA[3], N. GODINOVIĆ[5], A. GONZÁLEZ MUÑOZ[12], D. GUBERMAN[12], A. HAHN[7], Y. HANABATA[23], M. HAYASHIDA[23], J. HERRERA[15,16], J. HOSE[7], D. HRUPEC[5], G. HUGHES[1], W. IDEC[9], K. KODANI[23], Y. KONNO[23], H. KUBO[23], J. KUSHIDA[23], A. LA BARBERA[3], D. LELAS[5], E. LINDFORS[24], S. LOMBARDI[3], M. LÓPEZ[8], R. LÓPEZ-COTO[12], A. LÓPEZ-ORAMAS[12,76], E. LORENZ[7], P. MAJUMDAR[6], M. MAKARIEV[25], K. MALLOT[10], G. MANEVA[25], M. MANGANARO[15,16], K. MANNHEIM[13], L. MARASCHI[3], B. MARCOTE[22], M. MARIOTTI[17], M. MARTÍNEZ[12], D. MAZIN[7,23], U. MENZEL[7], J. M. MIRANDA[4], R. MIRZOYAN[7], A. MORALEJO[12], E. MORETTI[7], D. NAKAJIMA[23], V. NEUSTROEV[24], A. NIEDZWIECKI[9], M. NIEVAS ROSILLO[8], K. NILSSON[24,77], K. NISHIJIMA[23], K. NODA[7], R. ORITO[23], A. OVERKEMPING[20], S. PAIANO[17], J. PALACIO[12], M. PALATIELLO[2], D. PANEQUE[7], R. PAOLETTI[4], J. M. PAREDES[22], X. PAREDES-FORTUNY[22], M. PERSIC[2,78], J. POUTANEN[24], P. G. PRADA MORONI[26], E. PRANDINI[1,79], I. PULJAK[5], W. RHODE[20], M. RIBÓ[22], J. RICO[12], J. RODRIGUEZ GARCIA[7], T. SAITO[23], K. SATALECKA[8], C. SCHULTZ[17], T. SCHWEIZER[7], S. N. SHORE[26], A. SILLANPÄÄ[24], J. SITAREK[9], I. SNIDARIC[5], D. SOBCZYNSKA[9], A. STAMERRA[3], T. STEINBRING[13], M. STRZYS[7], L. TAKALO[24], H. TAKAMI[23], F. TAVECCHIO[3], P. TEMNIKOV[25], T. TERZIC[5], D. TESCARO[15,16], M. TESHIMA[7,23], J. THAELE[20], D. F. TORRES[27], T. TOYAMA[7], A. TREVES[28], V. VERGUILOV[25], I. VOVK[7], J. E. WARD[12], M. WILL[15,16], M. H. WU[18], R. ZANIN[22] (MAGIC COLLABORATION), M. AJELLO[29], L. BALDINI[30,31], G. BARBIELLINI[32,33], D. BASTIERI[19,34], J. BECERRA GONZÁLEZ[15,16,35,36], R. BELLAZZINI[37], E. BISSALDI[38], R. D. BLANDFORD[31], R. BONINO[39,40], J. BREGEON[41], P. BRUEL[42], S. BUSON[19,34], G. A. CALIANDRO[31,43], R. A. CAMERON[31], M. CARAGIULO[38], P. A. CARAVEO[44], E. CAVAZZUTI[45], J. CHIANG[31], G. CHIARO[34], S. CIPRINI[45,46,47], F. D'AMMANDO[48,49], F. DE PALMA[38,50], R. DESIANTE[39,51], L. DI VENERE[52], A. DOMÍNGUEZ[29], P. FUSCO[38,52], F. GARGANO[38], D. GASPARRINI[45,46,47], N. GIGLIETTO[38,52], F. GIORDANO[38,52], M. GIROLETTI[48], I. A. GRENIER[53], S. GUIRIEC[35,80], E. HAYS[35], J. W. HEWITT[54], T. JOGLER[31], M. KUSS[37], S. LARSSON[55,56], J. LI[18], L. LI[55,56], F. LONGO[32,33], F. LOPARCO[38,52], M. N. LOVELLETTE[57], P. LUBRANO[46,58], S. MALDERA[39], M. MAYER[10], M. N. MAZZIOTTA[38], J. E. MCENERY[35,36], N. MIRABAL[35,80], T. MIZUNO[59], M. E. MONZANI[31], A. MORSELLI[60], I. V. MOSKALENKO[31], E. NUSS[41], R. OJHA[35,61,62], T. OHSUGI[59], N. OMODEI[31], E. ORLANDO[31], J. S. PERKINS[35], M. PESCE-ROLLINS[31,37], F. PIRON[41], G. PIVATO[37], T. A. PORTER[31], S. RAINO[38,52], R. RANDO[19,34], M. RAZZANO[37,81], A. REIMER[31,63], O. REIMER[31,63], C. SGRO[37], E. J. SISKIND[64], F. SPADA[37], G. SPANDRE[37], P. SPINELLI[38,52], H. TAJIMA[31,65], H. TAKAHASHI[66], J. B. THAYER[31], D. J. THOMPSON[35], E. TROJA[35,37], K. S. WOOD[57] (FERMI-LAT COLLABORATION), M. BALOKOVIC[67], A. BERDYUGIN[68], A. CARRAMINANA[69], L. CARRASCO[69], V. CHAVUSHYAN[69], V. FALLAH RAMAZANI[68], M. FEIGE[70], S. HAARTO[71], P. HAEUSNER[70], T. HOVATTA[67,71], J. KANIA[70], J. KLAMT[70], A. LÄHTEENMÄKI[71,72], J. LEON-TAVARES[69], C. LOREY[70], L. PACCIANI[73], A. PORRAS[69], E. RECILLAS[69], R. REINTHAL[68], M. TORNIKOSKI[71], D. WOLFERT[70], AND N. ZOTTMANN[70]
[1] ETH Zurich, CH-8093 Zurich, Switzerland

ABSTRACT

The flat-spectrum radio quasar PKS 1441+25 at a redshift of $z = 0.940$ is detected between 40 and 250 GeV with a

+357 ($z = 0.944$), PKS 1441+25 is the most distant very high energy (VHE) blazar detected to date. The observations were triggered by an outburst in 2015 April seen at GeV energies with the Large Area Telescope on board *Fermi*. Multi-wavelength observations suggest a subdivision of the high state into two distinct flux states. In the band covered by MAGIC, the variability timescale is estimated to be 6.4 ± 1.9 days. Modeling the broadband

originating in the jet outside the broad-line region (BLR) during the period of high activity, while being partially within the BLR during the period of low (typical) activity. The observed VHE spectrum during the highest activity



CTA and blazars

- Our knowledge of blazar very high energy γ-ray emission is very biased and patchy
  - CTA will provide a systematic approach and will detect ~ 10 times more sources reaching higher energies

Summary

- We are witnessing the birth of extragalactic Neutrino Astronomy
- Various ≈ 3σ IceCube associations largely with blazars
- Neutrinos are providing a new window on very high-energy astrophysics (blazar jet physics) at energies forever inaccessible with photons
- CTA will be invaluable to prove (or disprove) the existence of hadronic processes in blazars and to provide an unbiased view of their ≈ TeV properties