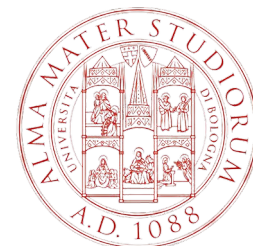


A VLBI investigation of high-energy neutrino-emitter candidates

Cristina Nanci

University of Bologna and INAF - Institute of Radio Astronomy

with M. Giroletti, M. Orienti, G. Migliori, J. Moldón, S. Garrappa,
M. Kadler, E. Ros, S. Buson, T. An, M. A. Pérez-Torres
et al.

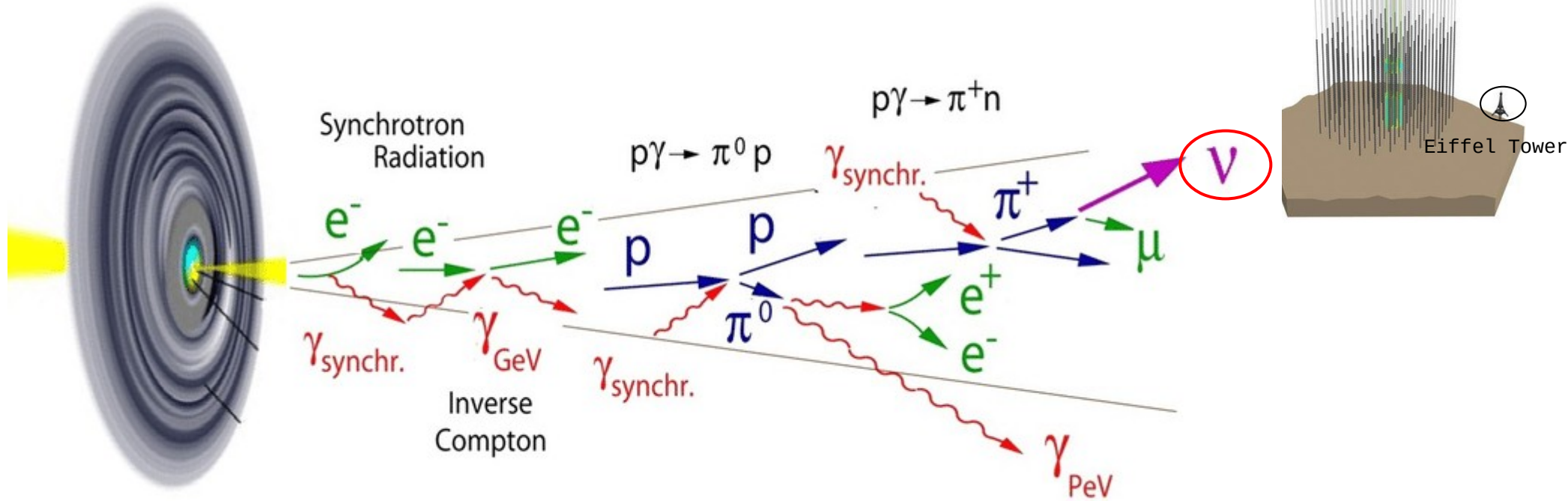


INAF IRA

15th EVN Symposium and Users' Meeting Providing the Sharpest View of the Universe

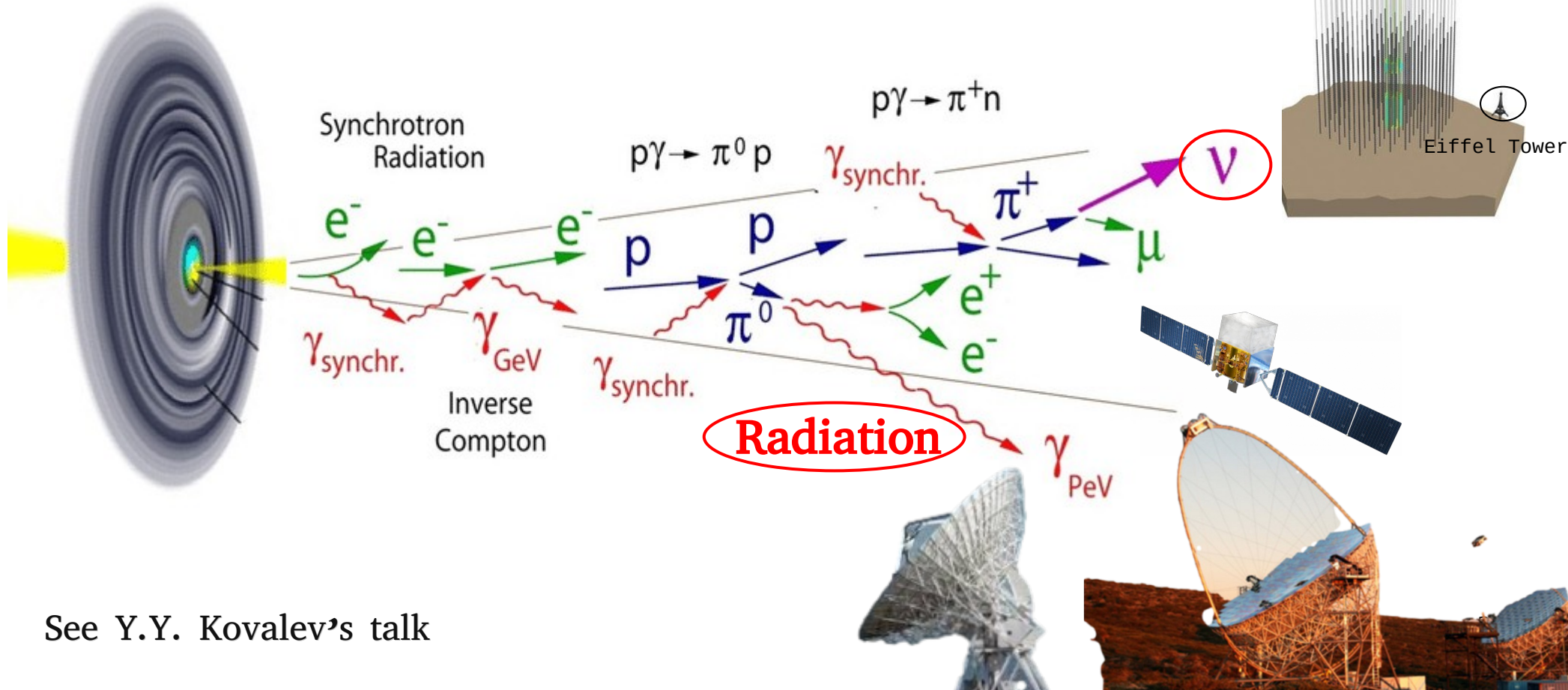
12 July 2022

Are neutrinos coming from BLAZARSs?



See Y.Y. Kovalev's talk

Are neutrinos coming from BLAZARSs?



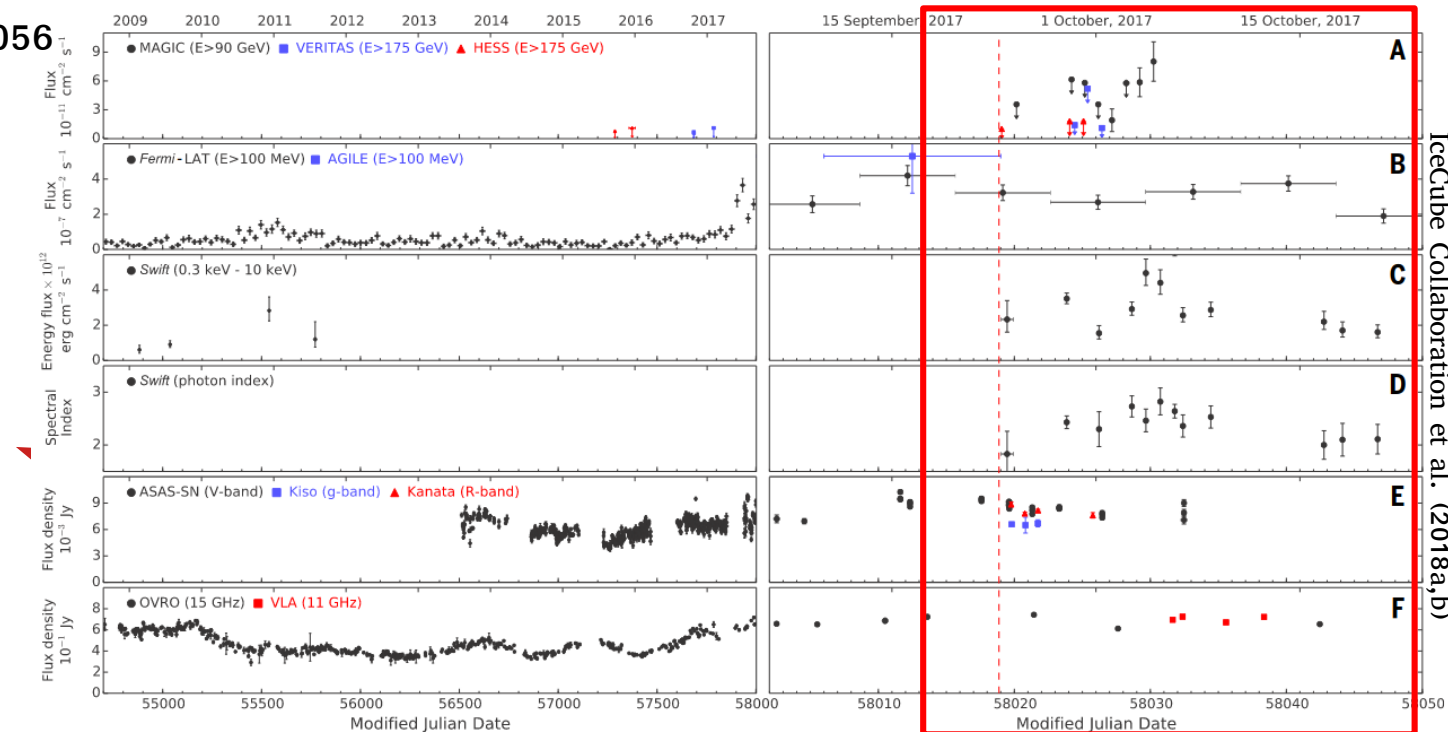
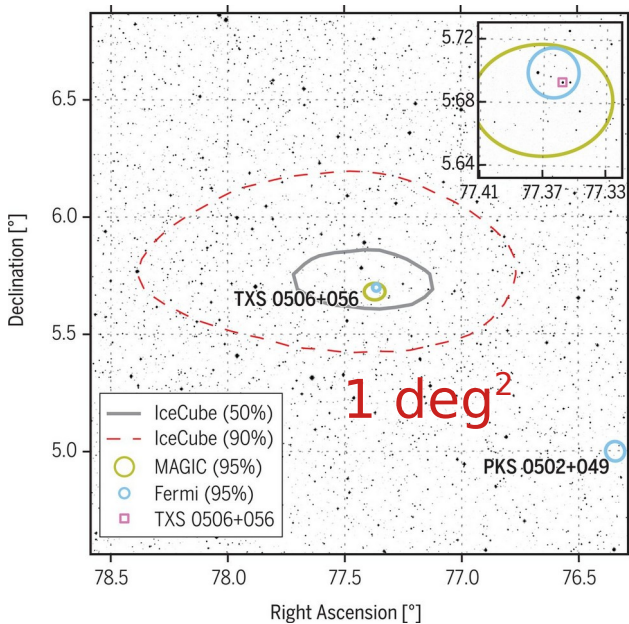
See Y.Y. Kovalev's talk

Sept. 2017: IC 170922A

- 290 TeV
- 56% probability to be of astrophysical origin
- In spatial and temporal coincidence with a flare from TXS 0506+056

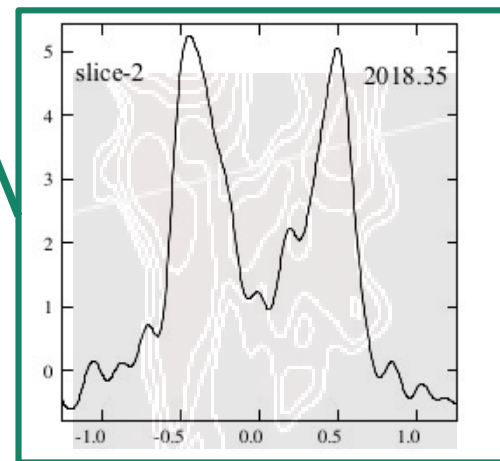
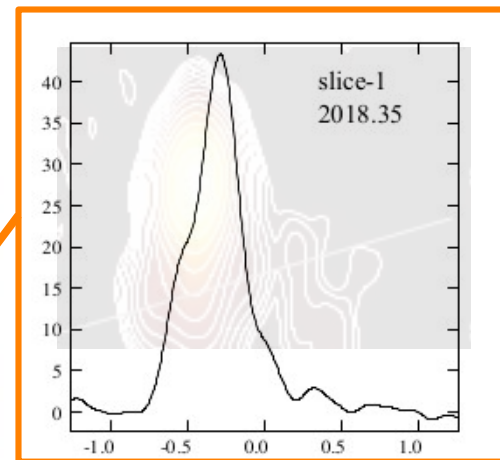
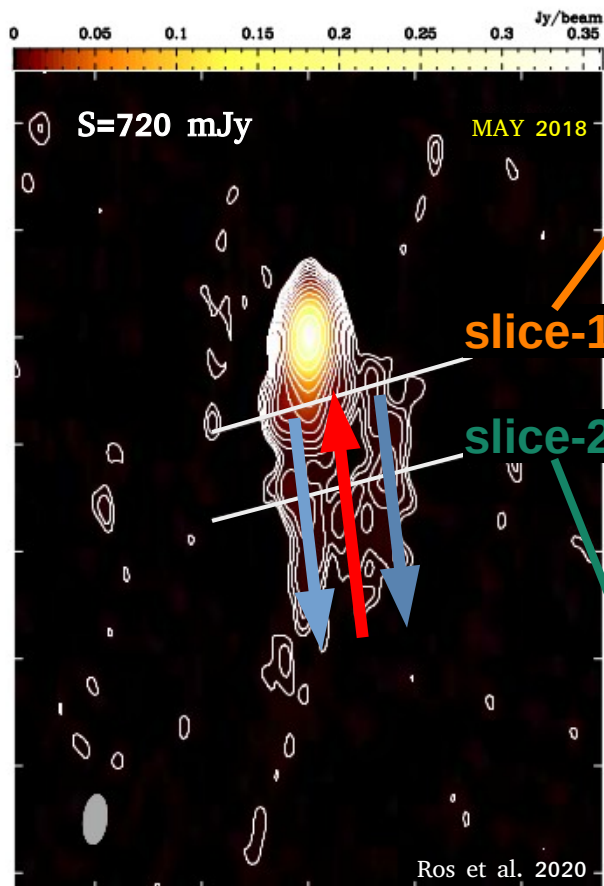
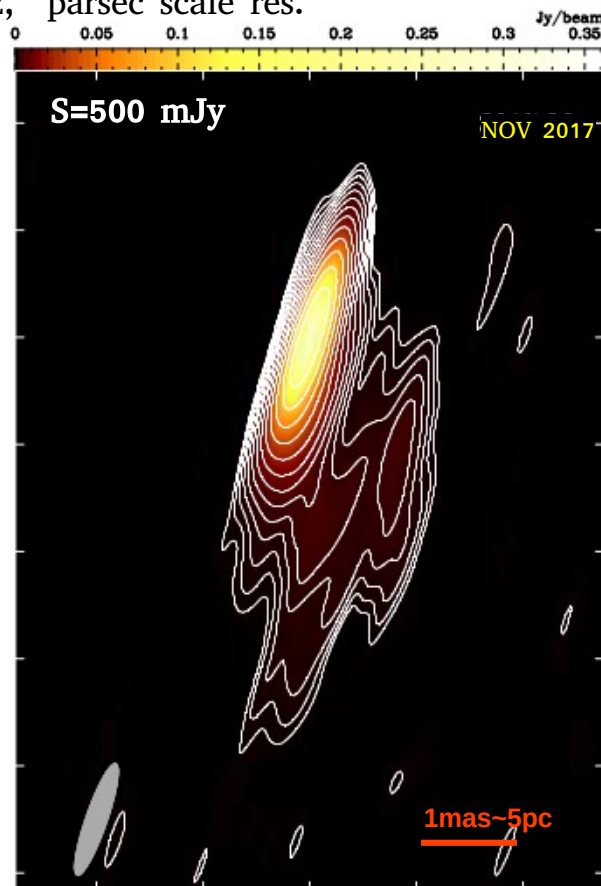


TXS 0506+056 flare at all the bands when the neutrino arrived



VLBI study on TXS0506+056 - I

43 GHz, parsec scale res.



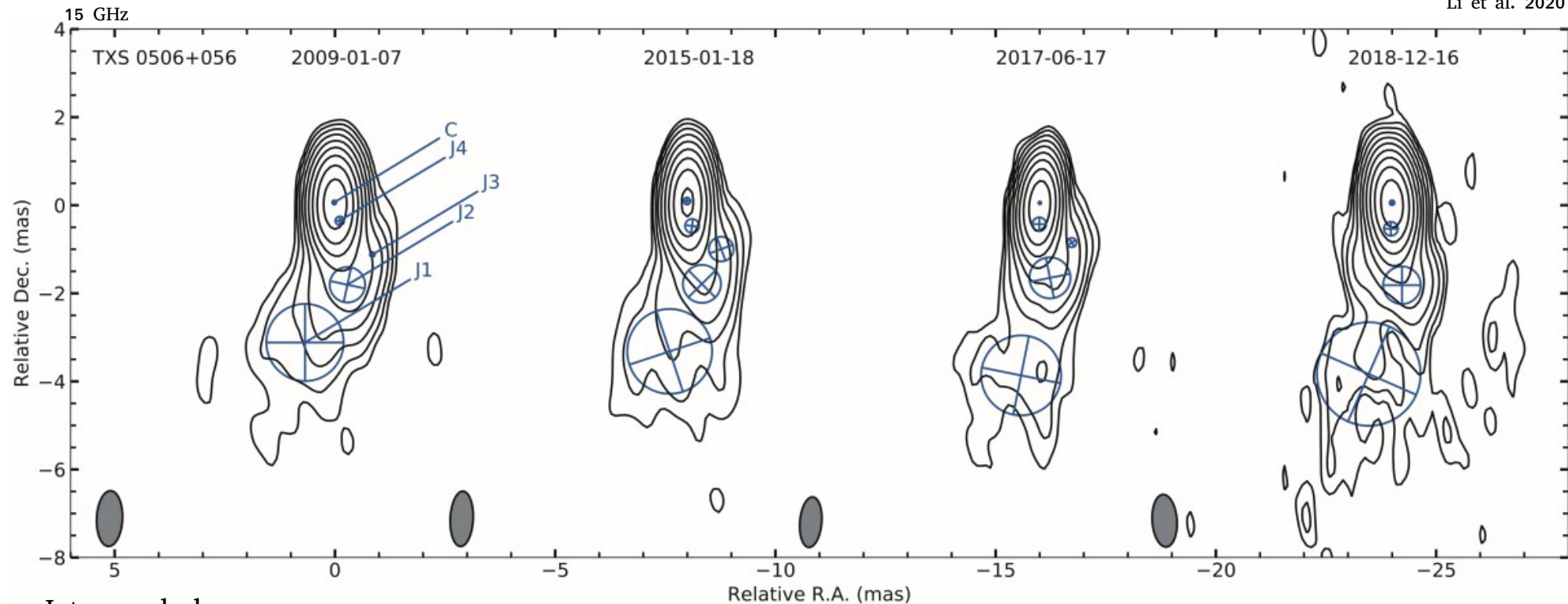
Surface brightness (mJy/beam)

Distance from the slice mid-point (mas)₅

Signature of layers in the jet → region of efficient neutrino production (Tavecchio et al. 2014, Righi et al. 2017)

VLBI study on TXS0506+056 - II

Li et al. 2020



- Jet morphology
- Jet component kinematics
- Brightness temperature, position angle evolution
- The flare occurred in the core (pc-scale)
- Magnetic field strength decreases after the neutrino event

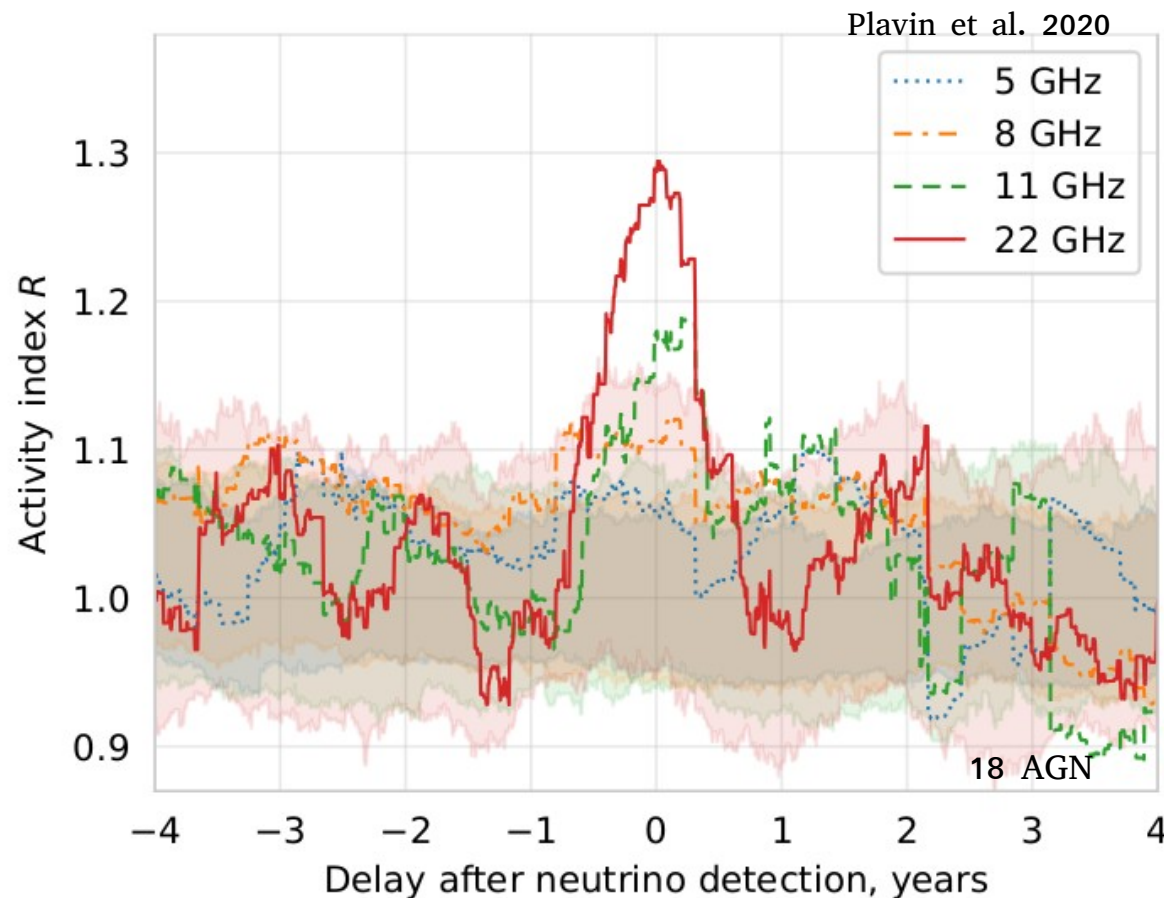
Conversion of magnetic energy → particle energy
→ ongoing particle acceleration

VLBI population studies

Plavin et al. 2020,2021

-significant **positional** association of
bright VLBI blazars with neutrinos

-significant **temporal** association of
VLBI flares with neutrinos



Our VLBI study

Search for other neutrino emitter blazars through VLBI follow-ups

Between 2019 and 2020

1. Characterization of the radio sources
2. Does neutrino emission correspond to **enhanced radio activity** ?
3. Can we see **recurring radio properties** linked to neutrino production?

Our VLBI study

Search for other neutrino emitter blazars through VLBI follow-ups

Between 2019 and 2020

+ 4 new VLBI follow ups of NEUTRINO events

on a total of ~ 8 events followed with VLBI and published so far

→ 10 radio sources candidate counterparts

→ 5 “best” candidates

- Blazar-like
- γ -ray associated

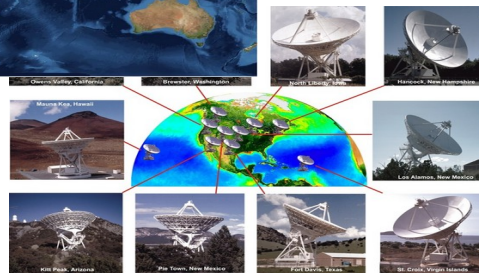
The VLBI networks

Credits: P. Boven



EVN

European VLBI Network



VLBA

Very Long Baseline Array



e-MERLIN

**Multi-Element Radio
Linked Interferometer
Network**

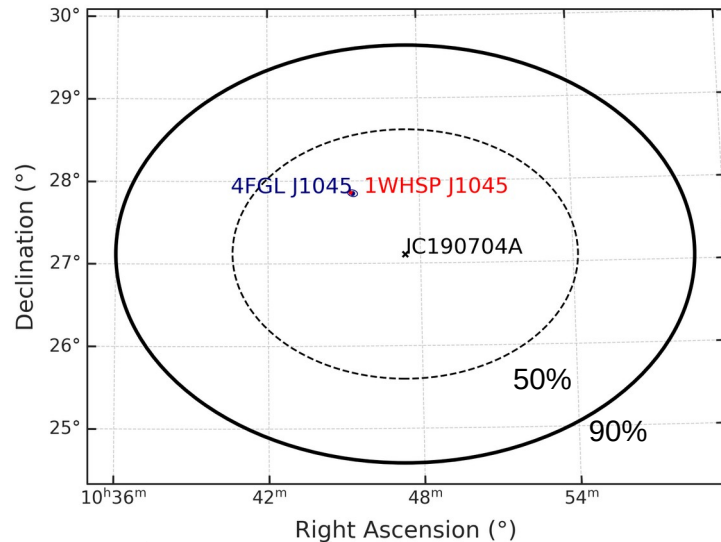


EAVN

East Asia VLBI Network

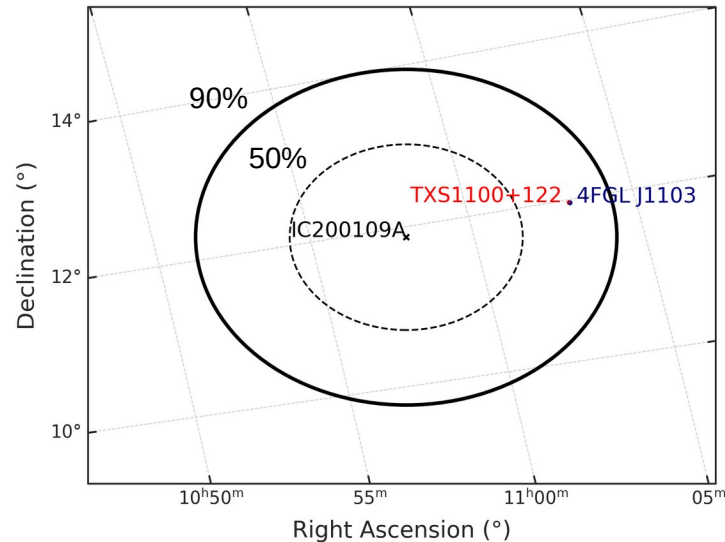
→ milliarcsec resolution → parsec resolution at z of our sources

IC190704A



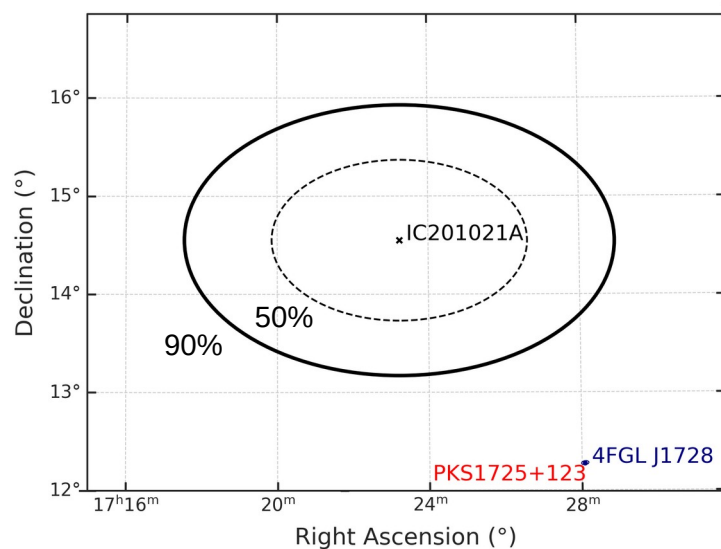
BRONZE
155 TeV
20 deg²

IC200109A



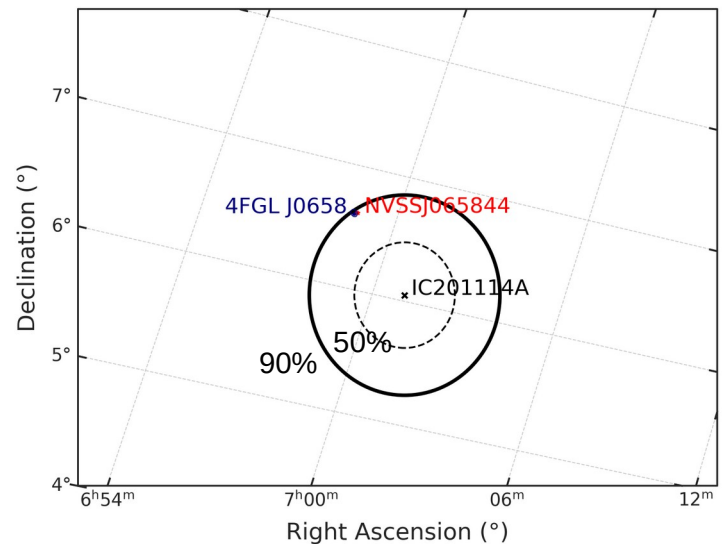
GOLD
375 TeV
26 deg²

IC201021A



BRONZE
105 TeV
6 deg²

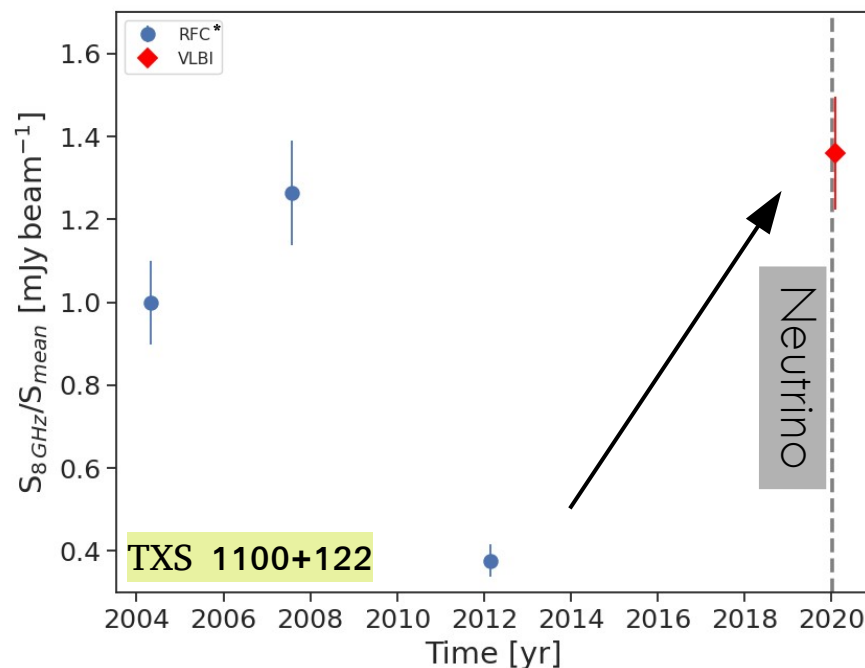
IC201114A



GOLD
214 TeV
4 deg²

Our VLBI study: Does neutrino emission correspond to **enhanced radio activity**?

1. **1WHSP J104516.2+275133** – IC 190704A → **FIRST VLBI OBSERVATION** → NO ARCHIVAL DATA for comparison
2. **TXS 1100+122** – IC 200109A → **VLBI OBSERVATION** → hints of enhanced activity
+ **RATAN-600** observations at 2.3, 5, 8, 11, 22 GHz (Kovalev et al.2020a)

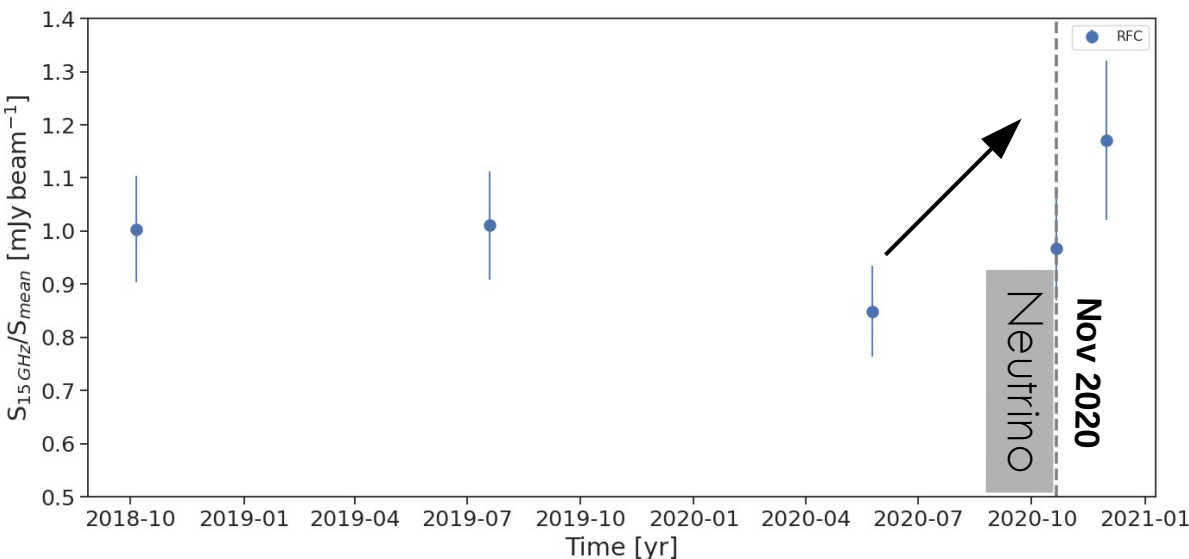


*Radio Fundamental catalog

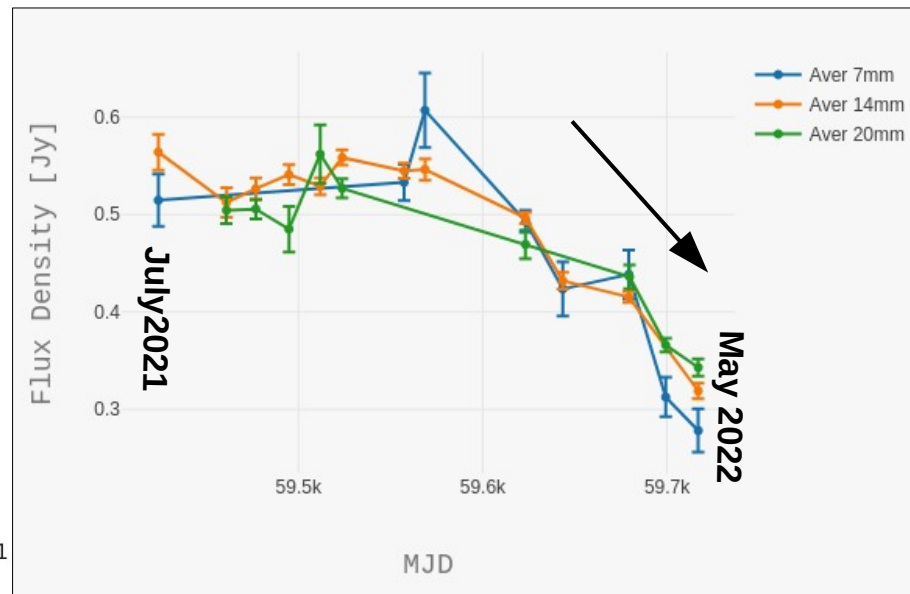
Our VLBI study: Does neutrino emission correspond to **enhanced radio activity**?

3. **PKS 1723+125** – IC 201021A → enhanced activity

MOJAVE*



TELAMON* – after IC 201021A



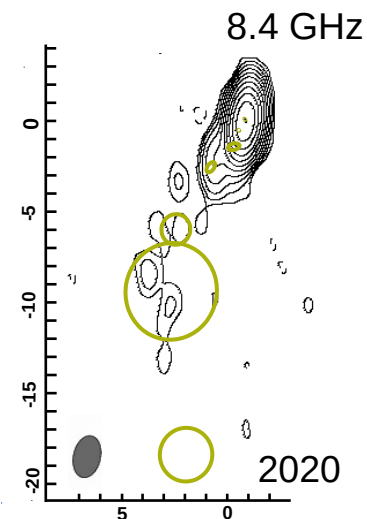
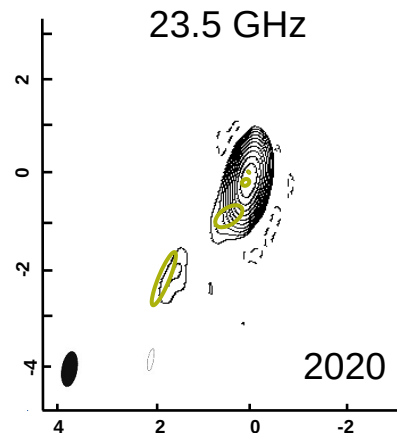
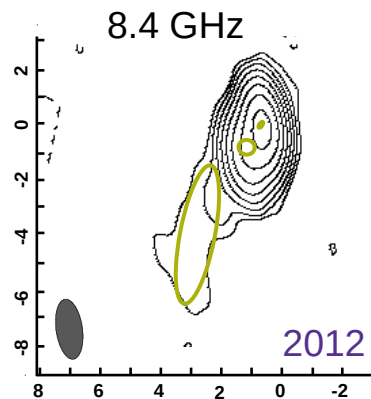
*Monitoring Of Jets in Active galactic nuclei with VLBA Experiments

*Effelsberg Monitoring of AGN Jets with Very-High-Energy Astroparticle Emissions (Kadler et al. 2021)

time →

Our VLBI study: Can we see **recurring radio properties** linked to neutrino production?

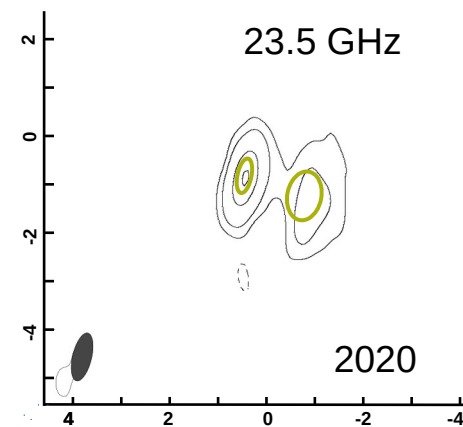
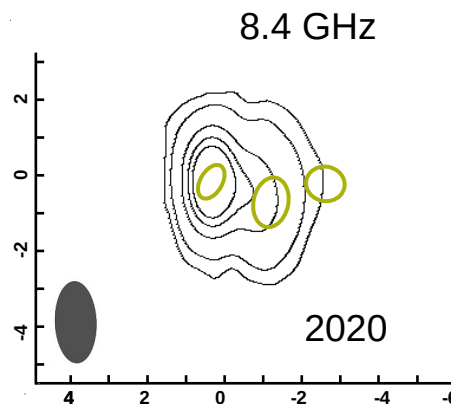
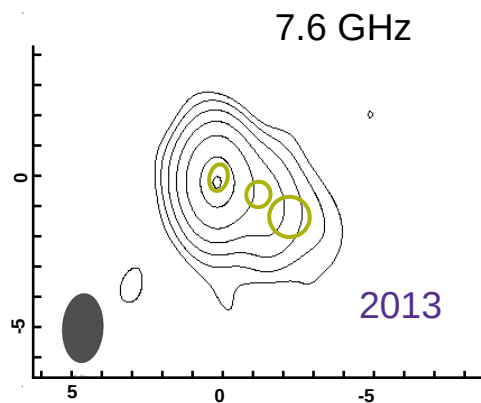
2. **TXS 1100+122**



Jet kinematics
and
morphology

→ will come
with
monitoring of
the sources

4. **NVSS J065844+063711**



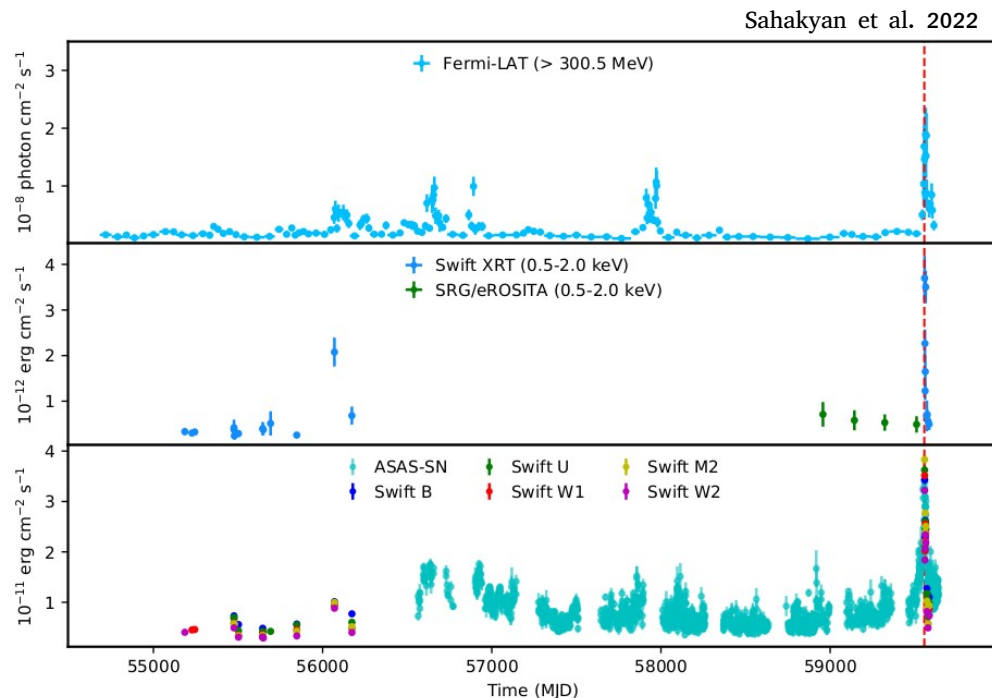
Our future VLBI study: new VLBI follow-ups

1. IC-211208A (bronze) – PKS 0735+17 ($z=0.424$)

→ in flare at the neutrino arrival

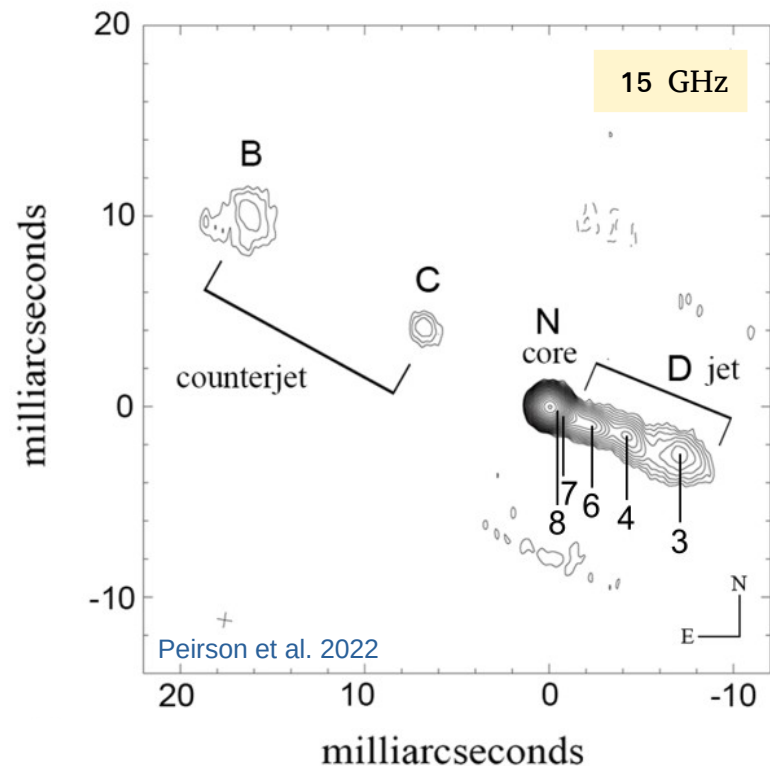
gamma rays (ATel #15099,#15129) X-rays (ATel #15102,#15108,#15109,#15113,#15130)

optical (ATel #15098,#15100,#15132,#15136,#15148) radio (ATel #15105 by Kadler et al.)



2. IC-220205A (bronze) – PKS 1431+134 ($z=0.247$)

→ lensed object, 1st blazar with counter jet



stacked image
of 23 epochs by
MOJAVE

Stay tuned...

Our future VLBI study: new VLBI follow-ups

1. IC-211208A (bronze) – **PKS 0735+17** ($z=0.424$)
→ in flare at the neutrino arrival
2. IC-220205A (bronze) – **PKS 1431+134** ($z=0.247$)
→ lensed object, 1st blazar with counter jet
3. IC-220205B (gold) – **PKS 1741-03** ($z=1.054$)
→ promising candidate according to Plavin et al. 2020
4. IC-220425A (gold) – **TXS 1749-101**
→ previous association with a 2018 neutrino event
GCN #23375
– **TXS 1742-078**
→ in flare at the neutrino arrival
GCN #31948

Stay tuned...

Summary

PAST..

- + **4** neutrinos follow-ups with VLBI (+ **10** radio candidates)
- VLBI classification of the cospatial sources
- Check of the state of activity at the neutrino arrival
- Working on the jet kinematics..

Nanci et al.2022



PKS 1725+123: ~ **enhanced** state of activity
TXS 1100+122: ~ hint of **enhanced** state of activity

..PRESENT..

+ **4 NEW** neutrinos follow-ups with VLBI

..FUTURE!

More neutrinos follow-ups to collect new insight and test the hypothesis of the connection between (radio properties of) blazars and neutrino events

- - EVN proposal submitted
- - e-MERLIN proposal submitted
- - VLBA proposal to be submitted at the next call

Thank you for your attention!