Effelsberg Monitoring of AGN Jets with VHE Astroparticle Emissions

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Abstract

The TELAMON program is using the Effelsberg 100-m telescope to monitor the radio spectra of active galactic nuclei (AGN) under scrutiny in astroparticle physics, namely TeV blazars and candidate neutrino-associated AGN. The large Effelsberg dish can yield superior radio data over other programs for very-high-energy (VHE) emitting blazars, which are often faint radio sources. We perform high-frequency observations every 2-4 weeks at multiple frequencies up to 44 GHz. We aim to characterize the radio variability of very-high energy emitting AGN jets and trace dynamical processes in the pc-scale jets of blazars related to high-energy flares or neutrino detections. Our sample covers about 40 sources and is dominated by high synchrotron peaked objects. Here, we introduce the TELAMON program and present first results since fall 2020.

Example Source: S2 0109+22

For each monitored source, we derive continuous dynamic spectra and light curves. Figure 1 shows as an example the source S2 0109+22 which exhibits flaring activity with a continuous increase in flux density over about 100 days both at 14mm and 7mm. Our sampling rate is well suited to sufficiently resolve such time scales. The spectral gap at 30 GHz will be filled by coordinated ATCA observations for all our sources south of +30° declination.

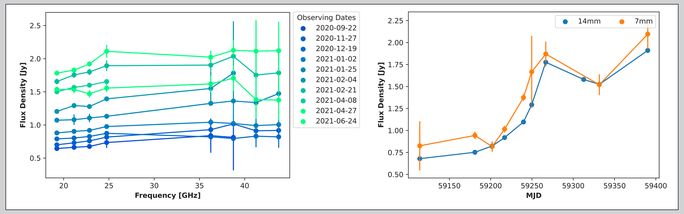


Figure 1: Example results of spectra (left) and light curves (right, averaged over all subbands) for the source S2 0109+22.

Neutrino Candidate Blazars Follow-up

The TELAMON target list is dynamically updated with new neutrino detections. Figure 2 shows the first radio spectral measurements of NVSS J065844+063711 three days after the detection of the positionally coincident event IC 201114A. Quite often, the uncertainty regions of neutrino events are too large for high-confidence associations. In such cases, radio data of sources in the field can yield additional independent information to judge possible associations. TXS 2016+386 is such a case inside a large error box. Fig. 2 (right) shows radio flaring (first at 7 mm and later an increase also at 14 mm) after the neutrino detection.

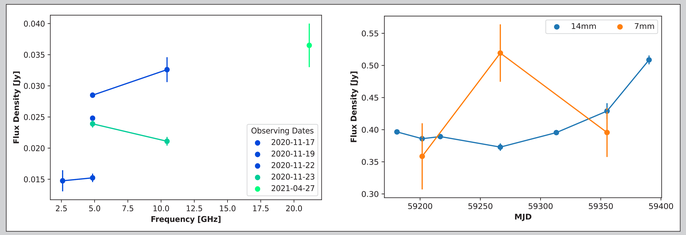


Figure 2: Radio spectral measurements of the neutrino-candidate source NVSS J065844+063711 (left) and lightcurve of the source TXS 2016+386 averaged over all subbands (right).

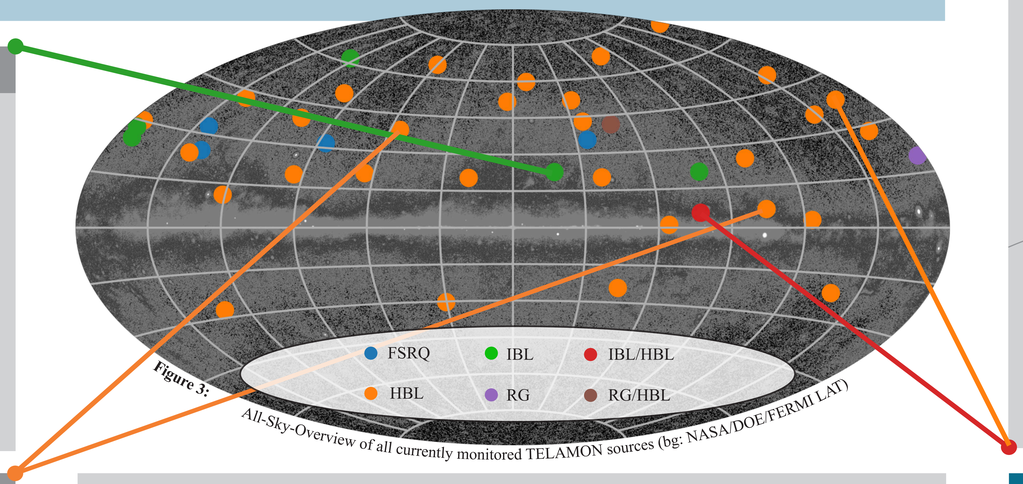


Figure 3: All-Sky-Overview of all currently monitored TELAMON sources (bg: NASA/DOE/FERMI LAT)

Table 1: List of all TELAMON sources with Redshift, Class and measured Flux Density averaged over all subbands at 14mm

J200 Name	Alternative Name	Class[a]	S^{b}_{14mm} [mJy]	Redshift
0035+5950	1ES 0033+595	HBL	75	0.086
0112+2244	S2 0109+22	IBL	1100	–
0214+5144	TXS 0210+515	HBL	150	0.049
0221+3556	S3 0218+35	FSRQ	500	0.68466
0222+4302	3C 66A	HBL	1000	0.34
0232+2017	1ES 0229+200	HBL*	40	0.1396
0303-2408	PKS 0301−243	HBL	200	0.2657
0316+4119	IC 310	RG/HBL	150	0.0189
0416+0105	1ES 0414+09	HBL*	50	0.287
0507+6737	1ES 0502+675	HBL	50 (1)	0.341
0509+0541	TXS 0506+056	IBL/HBL	1750	0.3365
0521+2121	RGB J0521+212	IBL	375	–
0650+2502	1ES 0647+250	HBL	100	–
0658+0637	NVSS J065844+063711	HBL	125	–
0811+0237	1RXS J081201.8+023735	HBL*	50 (1)	0.1721
0913-2103	MRC 0910−208	HBL*	135 (1)	0.198017
0955+3551	3HSP J095507.9+355101	HBL*	10	0.557
1015+4926	1ES 1011+496	HBL	225	0.212
1058+2817	GB6 J1058+2817	HBL	100	0.4793
1104+3812	Mrk 421	HBL*	375	0.031
1136+7009	Mrk 180	HBL	175	0.045278
1145+1936	3C 264	RG	325	0.021718

J2000 Name	Alternative Name	Class[a]	S^{b}_{14mm} [mJy]	Redshift
1217+3007	ON 325	HBL	450	0.131
1221+2813	W Comae	IBL	475	0.102
1221+3010	1ES 1218+304	HBL*	68	0.184
1230+2518	ON 246	IBL	400	0.135
1422+3223	OQ 334	FSRQ	775	0.681
1427+2348	OQ 240	HBL	400	0.647
1428+4240	1ES 1426+428	HBL*	30	0.129
1443+2501	PKS 1441+25	FSRQ	150	0.94
1518-2731	TXS 1515−273	HBL	225	0.1281
1542+6129	GB6 J1542+6129	IBL	115	0.507
1555+1111	PG 1553+113	HBL	300	0.49
1653+3945	Mrk 501	HBL*	1000	0.034
1728+5013	I Zw 187	HBL*	125	0.055
1743+1935	1ES 1741+196	HBL*	175	0.084
1813+3144	B2 1811+31	FSRQ	100	0.117
1943+2118	HESS J1943+213	HBL*	∼ 20 (2)	–
1958-3011	1RXS J195815.6−301119	HBL*	100 (1)	0.119329
1959+6508	1ES 1959+650	HBL*	225	0.048
2018+3851	TXS 2016+386	HBL	400	–
2158-3013	PKS 2155−304	HBL	325	0.116
2243+2021	RGB J2243+203	HBL*	115 (1)	0.119329
2347+5142	1ES 2344+514	HBL*	150	0.044

[a] FSRQ: flat-spectrum radio quasar - LBL: low-peaked BL Lacl - IBL: intermediate-peaked BL Lac - HBL: high-peaked BL Lac (extreme blazars are marked as HBL*)
RG: Radio galaxy; [c] Median flux densities from our first 9 months of observations at 14 mm wavelength, or estimated from 1) NED, 2) Gregory & Condon, 1991

Collaboration with Multiwavelength Partners

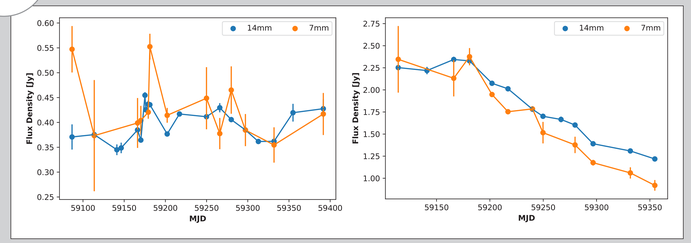
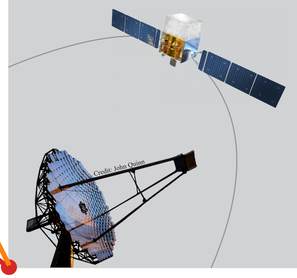


Figure 4: TELAMON light curves (averaged over all subbands) of Mrk 421 (left), and TXS 0506+056 (right)



Our samples includes many sources that are main targets of TeV telescopes like MAGIC and VERITAS. The two example sources shown in Fig. 4 (Mrk 421 and TXS 0506+056) show strong radio-jet variability in between gamma-ray observations. Moreover we are coordinating our observations with Fermi-LAT, FACT, H.E.S.S., MAGIC and VERITAS AGN monitoring groups. Along with multiwavelength colleagues, we are presenting light curves, spectra and SEDs of TXS 0506+056 and Mrk 421 at this conference.

Outlook

- »Building up a statistical database to test the significance of radio-flaring activity correlated with neutrino emission in blazars
- »Coordination with VLBI monitoring observations of TeV- and neutrino-candidate blazars as part of the MOJAVE VLBA and TANAMI LBA programs
- »Coordination of a complementary ATCA program that will observe all our sources south of +30° declination (including the 30 GHz band).
- »Contribution to multiwavelength SED studies of AGN in joint studies with our partners: Fermi-LAT, FACT, H.E.S.S., MAGIC, and VERITAS.