Neutrinos from AGN and other Black-Hole-Disk-Jet-Systems

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- Galactic Sources: Black-Hole-Binary & Microquasars

Motivation

- no extragalactic ν-source found up to now

$\rightsquigarrow$ need new ideas for potential ν-objects

  - ◇ AGN

    old idea, but still exciting

  - ◇ AGN-like objects

    same physical structure

    $\Rightarrow$ Black-Hole-Disk-Jet-Systems

    - ○ Compact-Steep Sources (CSS)
    - ○ 5 GHz- Peakes Sources (GPS)
    - ○ galactic sources:
      - Black-Hole-Binarys
      - Microquasars

- for statistical reasons

  $\rightarrow$ limitation of number of observed objects

- distance for νs not important $\rightsquigarrow$ no limits on z

ν-production

- need hadrons for ν-production

  $\rightsquigarrow$ mostly protons (less mass)

- in jet of AGN-like objects ideal acceleration-environment

◇ acceleration via Fermi-process

need magnetic fields and shock waves

◇ $\pi^{\pm,\circ}$-production via

hadron-hadron-interaction or hadron-photon-interaction

◇ $\pi^{\pm,\circ}$-decay

$$\pi^+ \rightarrow \nu_\mu + \mu^+ \rightarrow \nu_\mu + \bar{\nu_\mu} + \nu_e + e^+$$

$$\pi^- \rightarrow \bar{\nu_\mu} + \mu^- \rightarrow \bar{\nu_\mu} + \nu_\mu + \bar{\nu_e} + e^-$$

$$\pi^\circ \rightarrow \gamma + \gamma$$

◇ μ-decay also from kaons $\rightsquigarrow$ νs

$\Rightarrow \frac{\Phi_{\nu_\mu}}{\Phi_\gamma} \sim \frac{2}{1}, \qquad \frac{\Phi_{\nu_e}}{\Phi_\gamma} \sim \frac{1}{1}$

- acceleration-direction of $\nu \parallel$ direction of p $\Rightarrow \parallel$ to jet

$\Rightarrow$ detectable ν-source if jet towards observer

$\rightarrow$ blazars and blazar-like objects

Radio-Source-Blazar-Connection

- catalogue of radio-sources with radio emission $>$1 Jy

  (Kühr, Witzel et al. 1981)

- studies of Kühr, Biermann, Witzel

  $\rightsquigarrow$ all FSRQ (flat spectrum radio sources) of this catalogue

  are blazars (AGN with jets towards us)

  what are FSRQ?

  slope of spectrum in radio range (here: ν = frequency)

  ν = 2.7 GHz – 5 GHz (λ = 11 cm – 6 cm)

  approximation with power law $S_\nu \sim \nu^{-\alpha}$

  $\rightsquigarrow$ spectral index $\alpha \leq +0.5$

- blazars are potential ν-sources,

  all FSRQ in Kühr-catalogue are blazars

$\Rightarrow$ all FSRQ are potential ν-sources

$\Rightarrow$ take prominent FSRQ/blazar-candidates out of Kühr-catalogue

Blazar-Example: Mkn 421

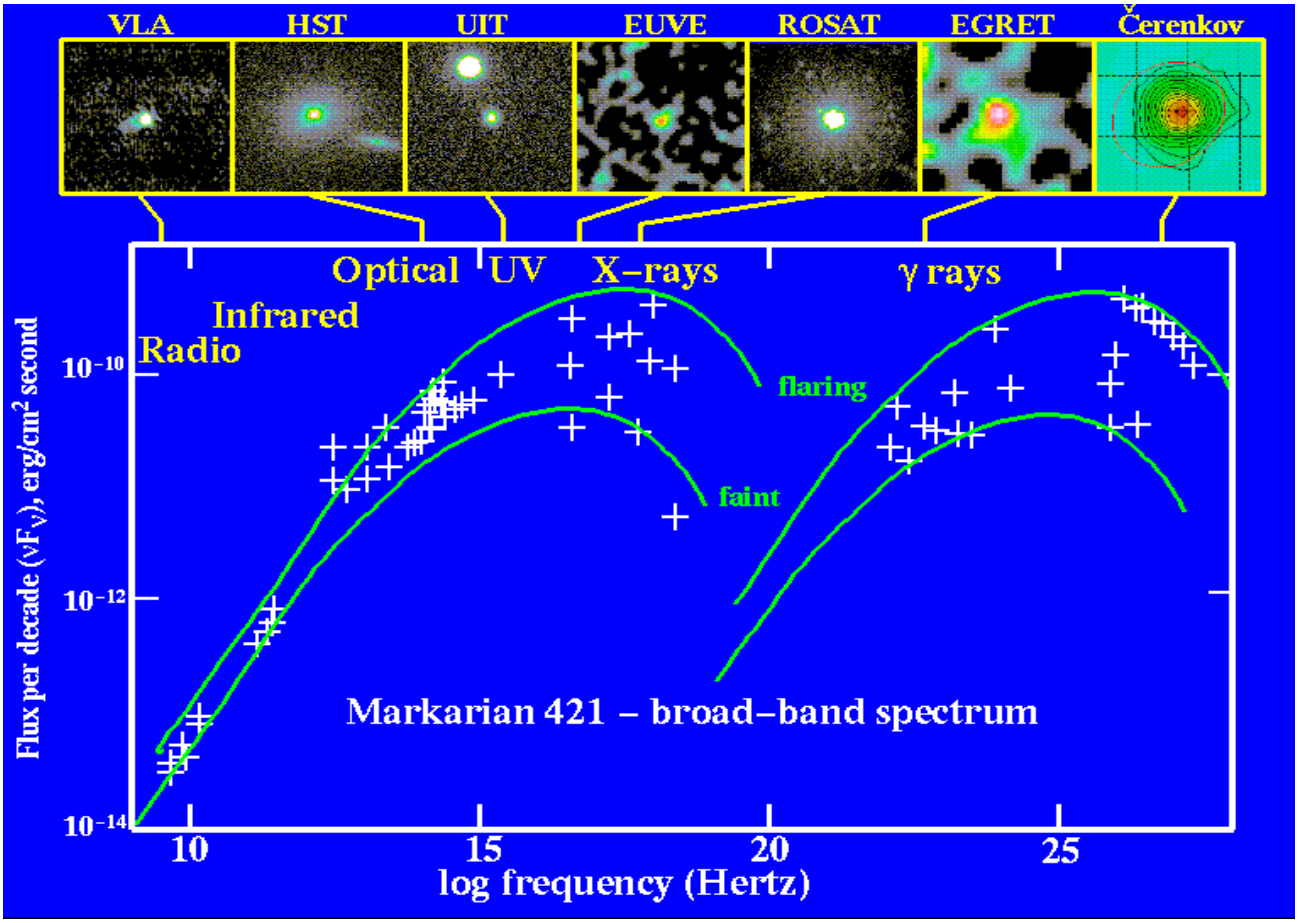

Fig. by Bill Keel

Known TeV-γ-Blazars

- up to now 8 TeV-γ-Blazars are found (all FSRQ),

  4 confirmed (= additional detection from other experiment)

source	z	max. energy of γ-ray-flux
confirmed		
Mkn 421	0.031	17 TeV (HEGRA-CTs)
Mkn 501	0.034	25 TeV (HEGRA-CTs)
1ES 1426+428	0.129	10 TeV (HEGRA-CTs)
		21 TeV (HEGRA-Array)
1ES 1959+650	0.047	(flare May/June 2002)
not confirmed		
1ES 2344+514	0.044	-
PKS 2155-304	0.116	-
3C66A	0.444	-
BL Lac	0.069	-

- photon-energy-spectra up to 25 TeV

$\rightsquigarrow$ need π^0-decay for this energy

pions are from hadron-interactions $\rightarrow$ charged pions

$\rightsquigarrow$ ν-production

TeV–X-Ray–Correlation I

- How to find TeV-γ-ray-blazars?

$\rightarrow$ different models for high photon production in jet:

(i) hadronic: π^0-decay

π^0 from hadron-interactions $\rightsquigarrow$ other $\pi^{\pm}$

$\rightarrow$ ν-production from $\pi^{\pm}$-decay

(ii) leptonic: synchrotron-self-compton process (SSC)

and boosting via inverse compton (IC)

find high X-ray emission (first peak= synchrotron peak)

for high TeV-γ-ray emission

(second peak= inverse compton peak)

$\rightarrow$ ν-production not necessarily implicated

TeV–X-Ray–Correlation II

- idea: leptons for (ii) from $\pi^{\pm}$-decay

  combines both high X-ray emission and ν-production

$\rightarrow$ so if high X-ray emission $\rightsquigarrow$ νs

!! but not vice versa

there could also be ν-production without high X-ray emission

see Mkn 421 multiwavelength campaign May 2001:

$\rightarrow$ NO correlation between TeV (HEGRA) and X-Ray (RXTE)

BUT in pure leptonic model correlation is required

$\Rightarrow$ proof for hadronic model (!) and idea is possible

- unfortunately ad hoc TeV-emission difficult to foresee

  multiwavelength campaigns and careful analysis necessary

$\rightsquigarrow$ no selection criteria (not handy enough)

- but to find certain amout of possible TeV-blazars/ν-sources

$\Rightarrow$ take blazars which are high in X-rays ($\sim$ 2 - 200 keV)

Special Blazars

blazars with special characteristics:

◇ Optically Violent Variable (OVV)

very high luminosity objects,

change in luminosity on very short timescales

$\rightarrow$ extreme physics on very small distances

production of huge amount of photons in short time $\rightarrow \nu$s

◇ Highly Polarized Quasars (HPQ)

high grade of polarisation (P $>$ 3 %)

$\rightarrow$ extreme magnetic fields

extreme acceleration of charged particles (protons) $\rightarrow \nu$s

5 GHz- Peakes Sources (GPS)

and Compact-Steep Sources (CSS)

- radio-sources (AGN-like)

  which are not necessarily included in Kühr-catalogue

  but 10% – 30% of radio-source population

	GPS	CSS
core size	$<$ 1 kpc	$<$ 1 - 20 kpc
radio spectra	convex	convex
peak	500 MHz – 10 GHz	$<$ 500 MHz
power $P_{1.4GHz}$	10^{25} W Hz^{-1}	$\sim 10^{25}$ W Hz^{-1}
spectral index α	$> +0.5$	$> +0.5$

- same structure like AGN at smaller scale:

  $\rightsquigarrow$ same ν-production

$\rightarrow$ younger stages of AGN $\rightsquigarrow$ source genesis & evolution

$\rightarrow$ closer look into the AGN-core,

no overlay with large-scale structures

$\Rightarrow$ νs if jets of GPS and CSS point towards us

Galactic Sources

- AGN-like objects

  $\rightsquigarrow$ same ν-production

- need jet pointing towards us

◇ Black-Hole-Binarys (BHB)

  - need high mass acceleration onto BH

    for high particle acceleration in jet

◇ Microquasars

  - miniature AGN

Conclusion

- AGNs and AGN-like objects are potential ν-sources
- 3 samples:
  - FSRQ (TeV-γ-emitter, OVV, HPQ)
  - GPS & CSS
  - galactic sources (BH-Binary, Microquasar)
- candidates with highest ν-potential

  $\rightarrow$ most active, high fluxes

  $\rightarrow$ jet needs to point towards us

- detailed source-listing

$\rightsquigarrow$ AMANDA internal report to come