Recent results of extragalactic GeV/TeV-band studies

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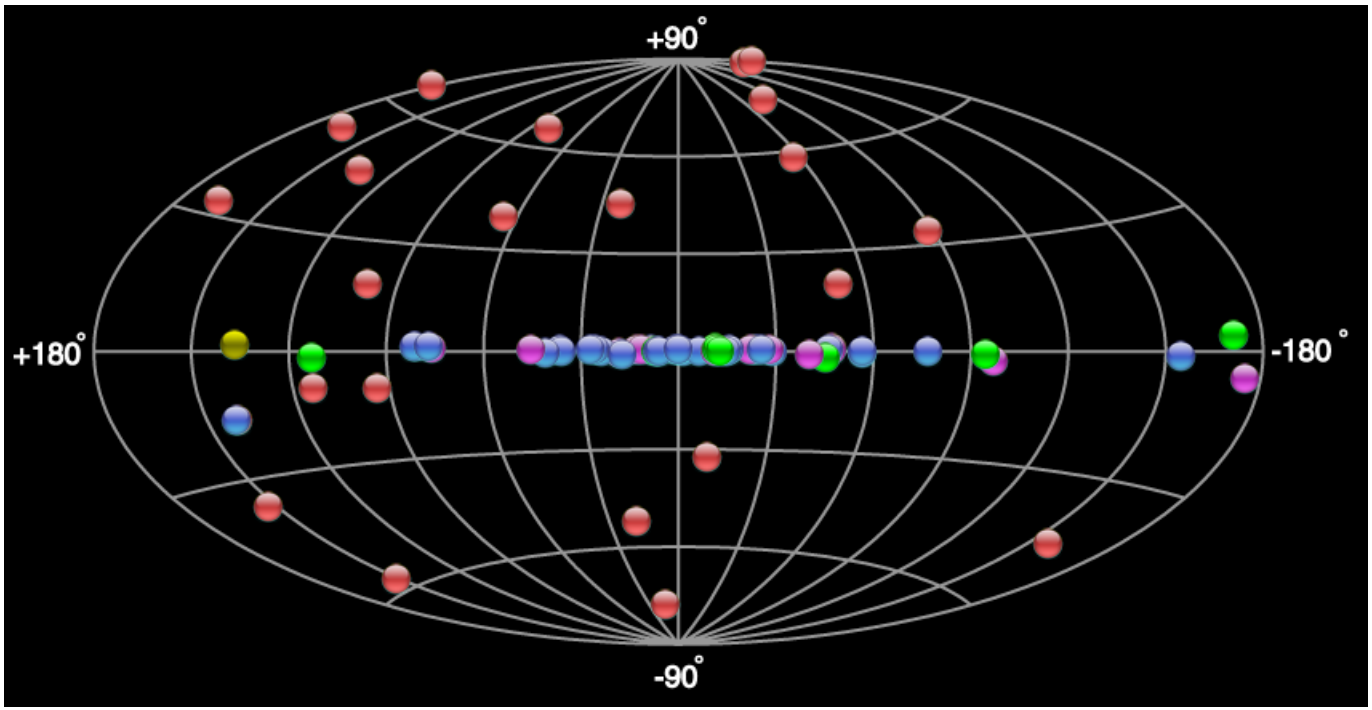
The TeV sky



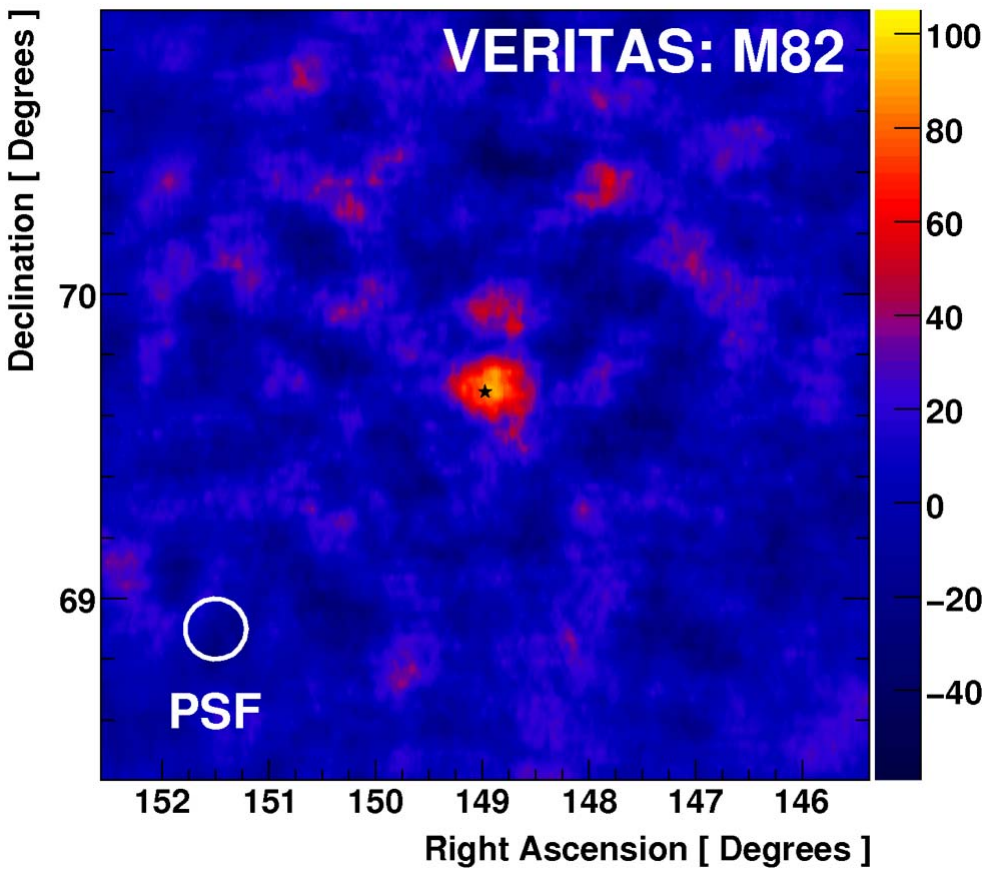
Source Types

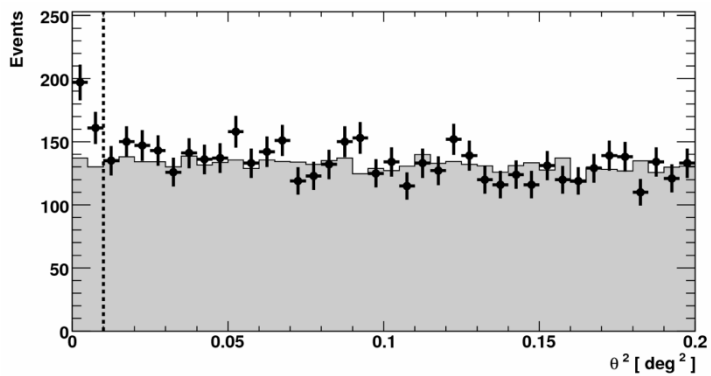
- Shell
- Plerion PWN
- XRB PSR
- DARK
- MQS Cat. Var. UNID Other BIN WR
- Starburst HBL IBL FRI FSRQ LBL

Topics

- Starburst galaxies
- Clusters, dark matter, etc.
- AGN
  - EBL
  - Spectral modeling
  - Variability
  - Multi-λ correlations
  - Location of emission zone

VERITAS Discovery of VHE Gamma-rays from M82



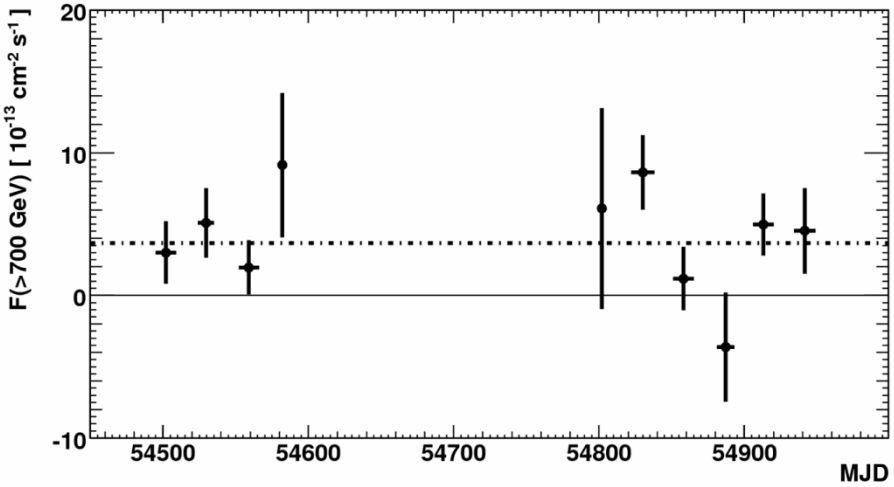


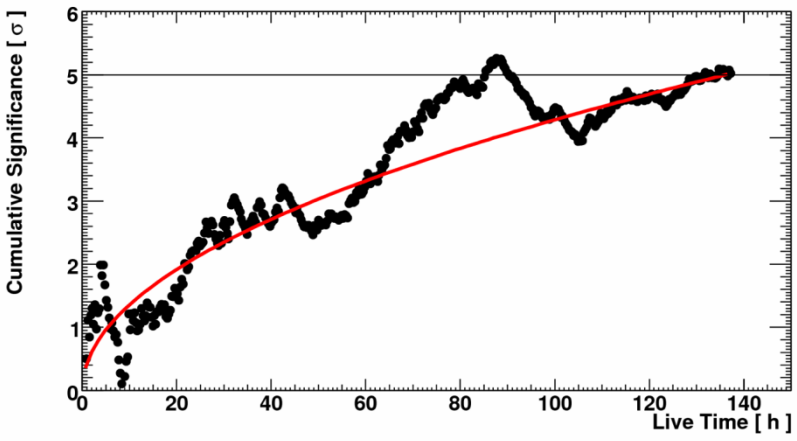
M82: archetypal starburst galaxy

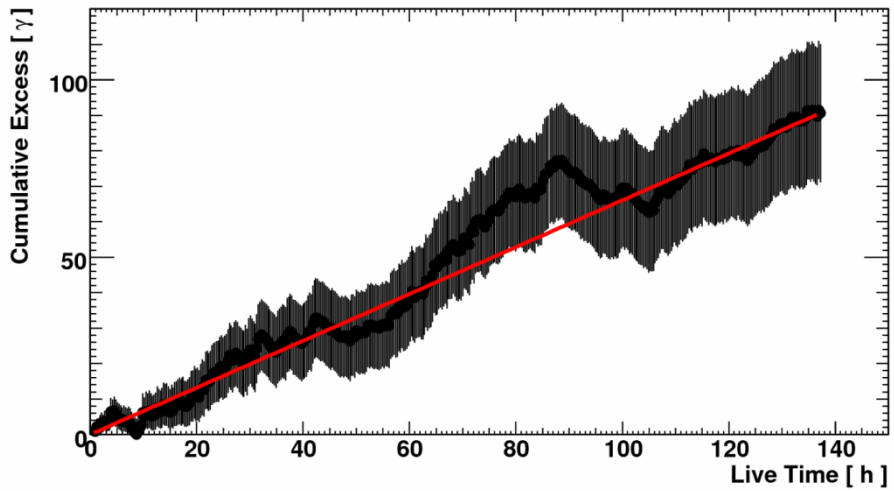
0.1-0.3 SN/yr

M 82: A Steady VHE Flux

- Among weakest-ever VHE sources
- $F(>700\ \text{GeV}) = (3.7 \pm 0.8_{\text{stat}} \pm 0.7_{\text{syst}}) \times 10^{-13}\ \text{cm}^{-2}\ \text{s}^{-1}$
  - 0.9% of Crab Nebula (>700 GeV)
  - Gamma-ray rate: 0.7 / hour
- No variations in monthly flux
  - $\chi^2 = 11.5$, 9 d.o.f.; $P(\chi^2) = 0.24$
  - Factor of "a few" variations not ruled out
- Steady signal accumulation

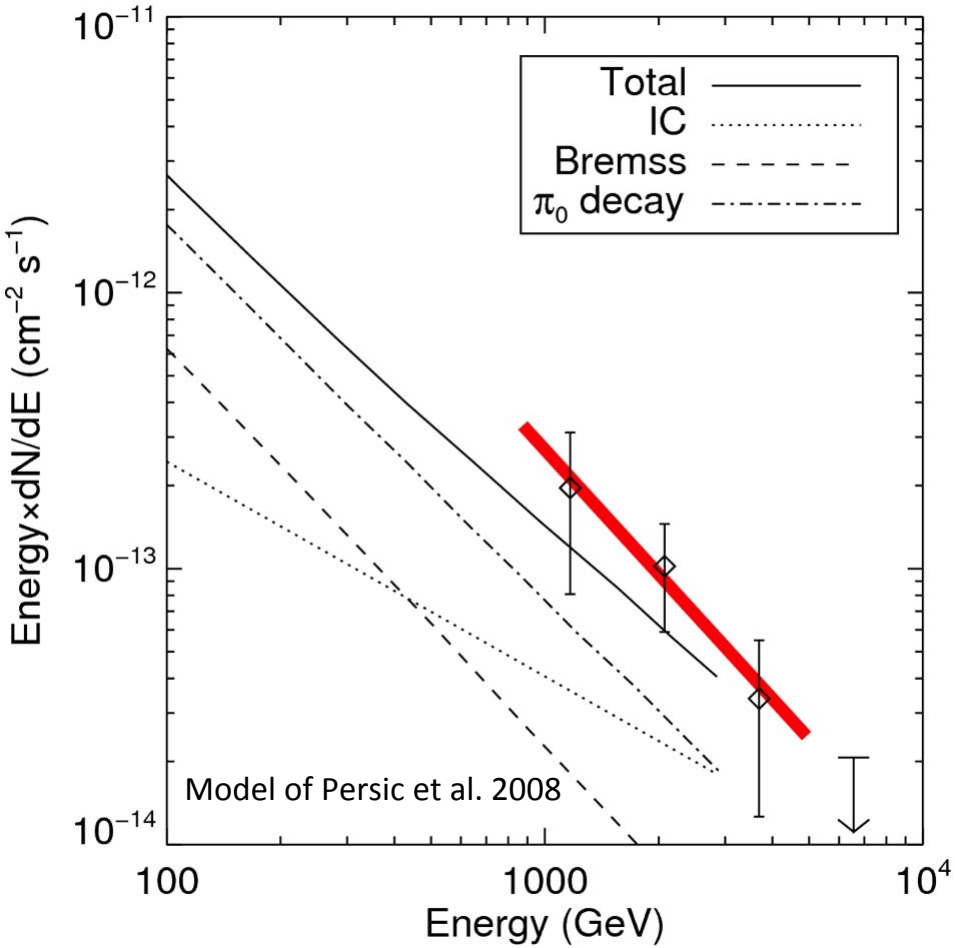






The VHE Gamma-Ray Spectrum

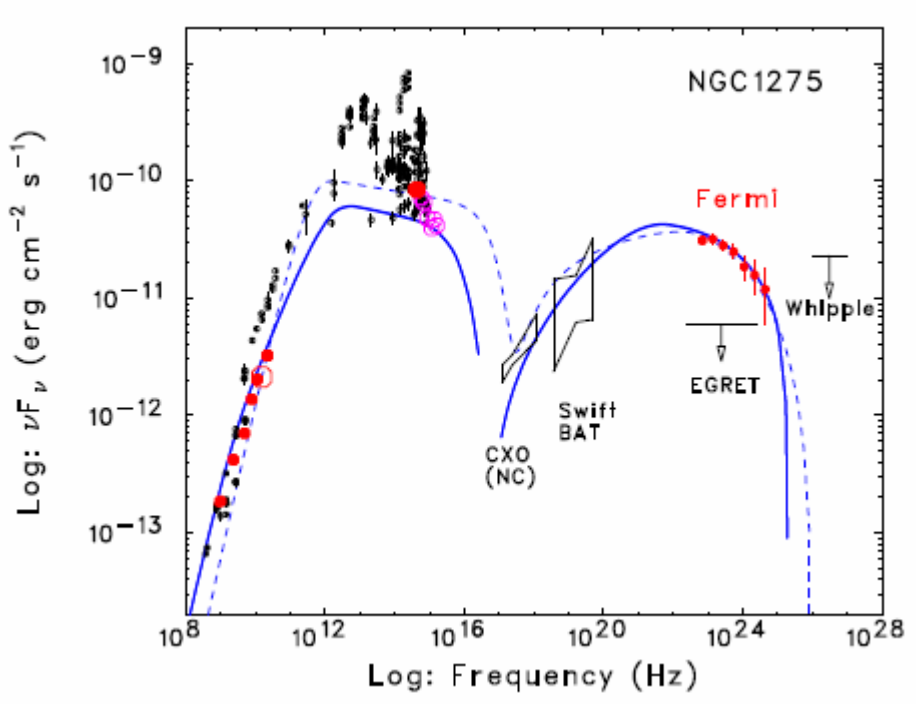
- Fit Range: 875 GeV to ~5 TeV
  - Fit to dN/dE ~ (E / TeV)$^{-\Gamma}$
  - $\Gamma = 2.5 \pm 0.6$
- VHE flux close to predictions
  - Incl. both leptonic & hadronic channels
    - Pohl 1994
    - Völk et al. 1996
    - Persic et al. 2008
    - de Cea del Pozo et al. 2009
- CR source rate ~ SN rate

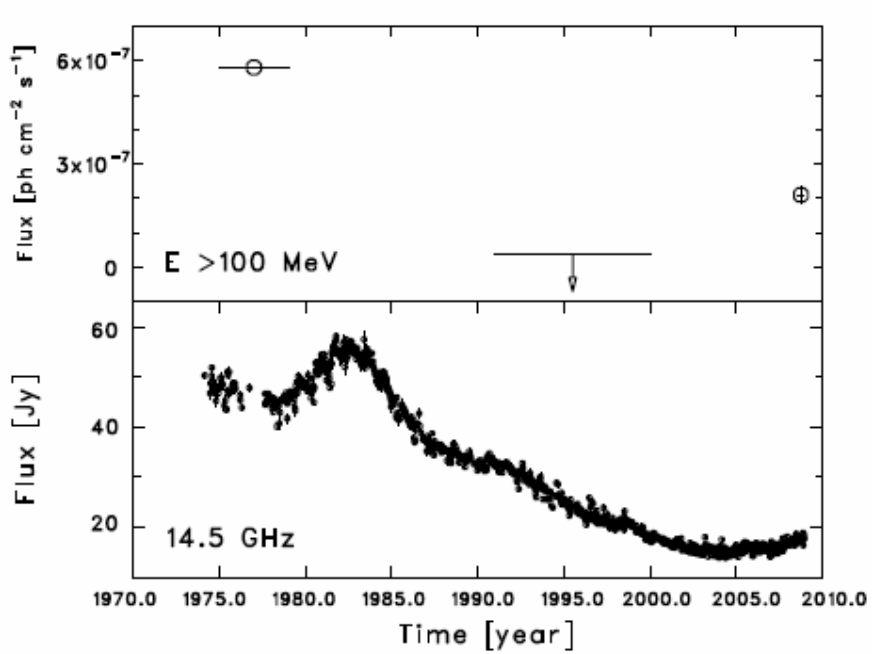


Clusters, dark matter, etc.

- **No detection from either**
- **Upper limits get tighter**
  - **Coma cluster: CR energy < 20% of thermal energy**
- **Efficient sources**
  - **Cluster, dark matter, and AGN at the same time**

NGC 1275 (aka 3C84 and Perseus A)

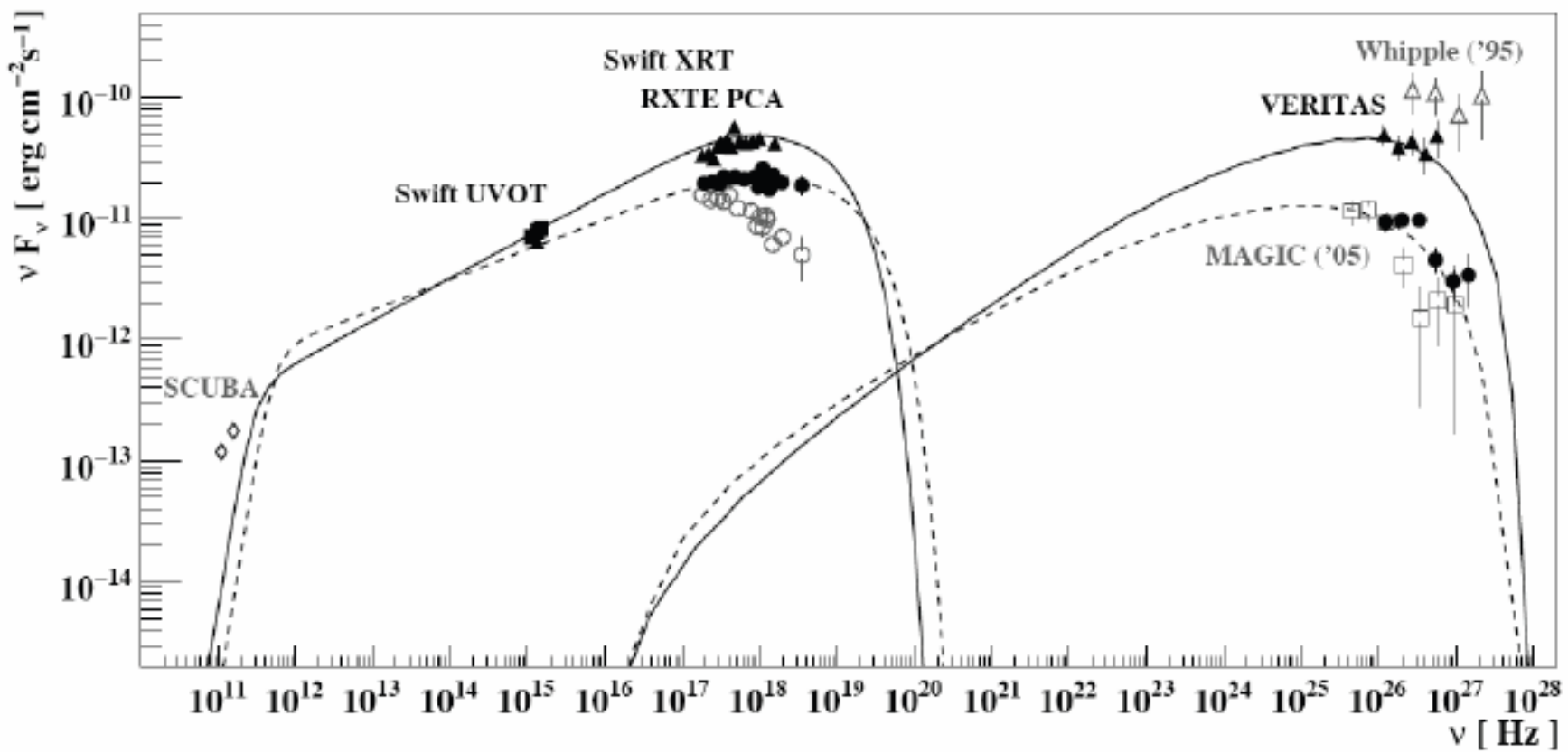




Fermi detection

Variability → it's the AGN (Seyfert 2, NLRG?)

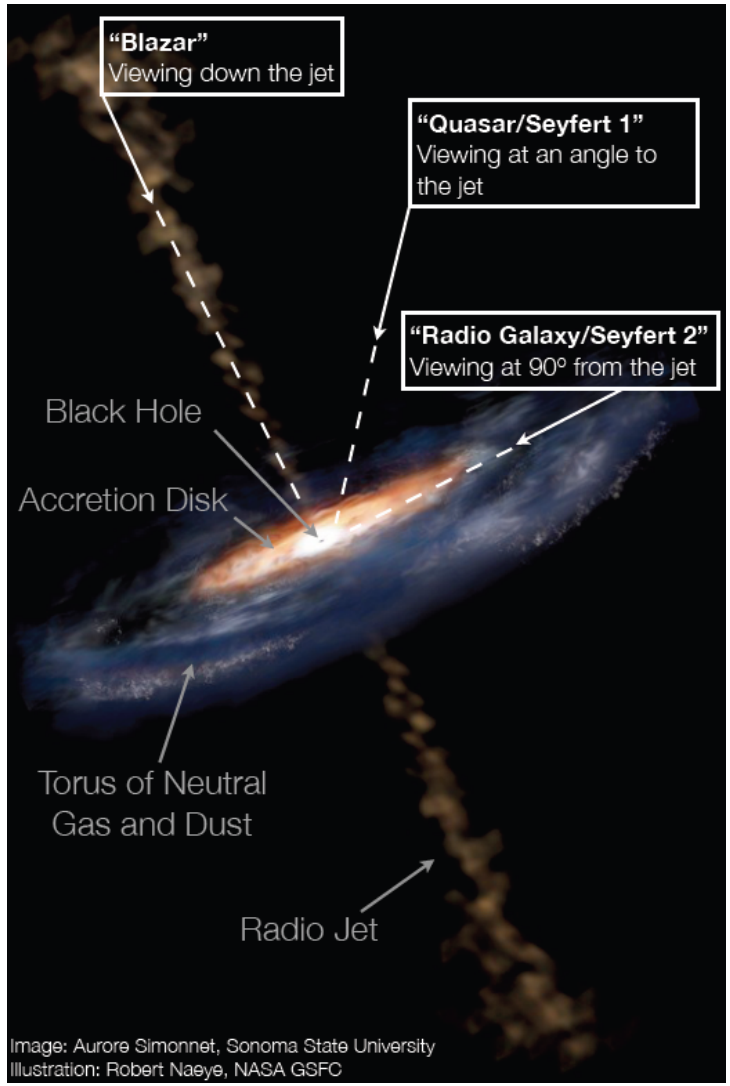
AGN



Typical spectral energy distribution: BL Lac object 1ES 2344+514

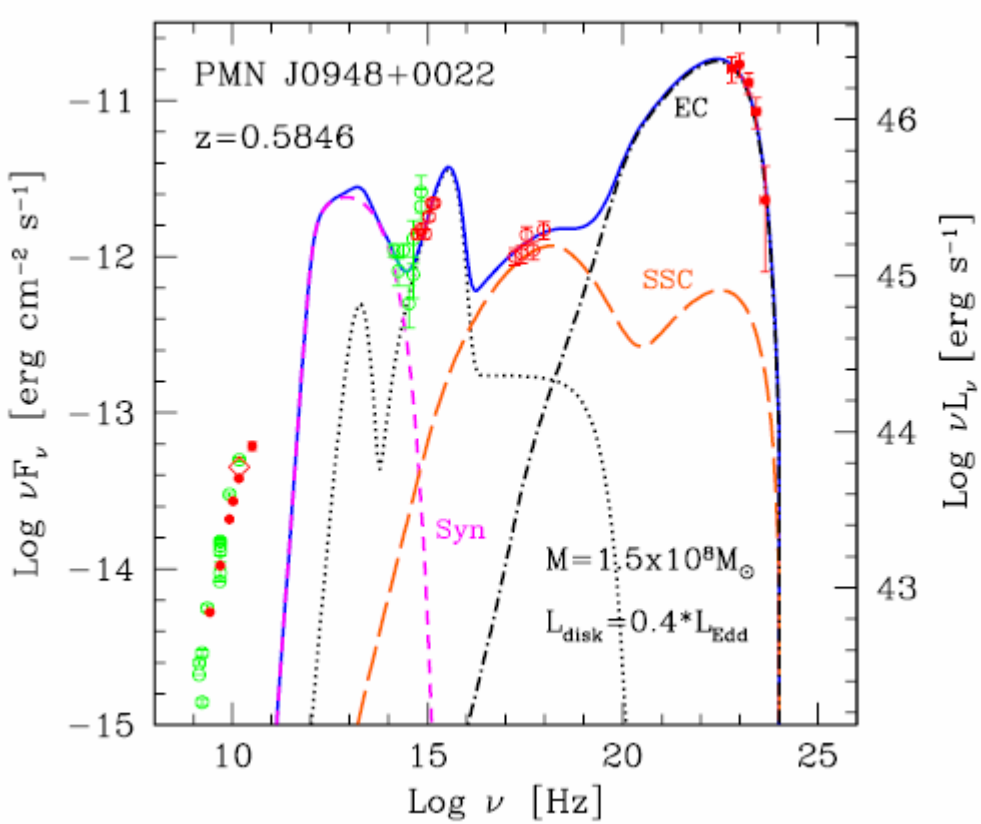
AGN types

- **Quasars**
  - **Strong internal photon field**
  - **GeV sources**
- **Radio galaxies**
  - **Seen from the side**
  - **Weak Doppler boosting**
  - **Can be close**
  - **→ good spatial resolution**
- **BL Lac objects**
  - **Weak internal photon field**
  - **Bright TeV-band sources**



GeV AGN

- Narrow-line quasar
- Small BH (~10^8 M_{sol})
- near Eddington accretion
- Is Eddington ratio a classification criterion?



GeV AGN

Spectral break at 2 GeV

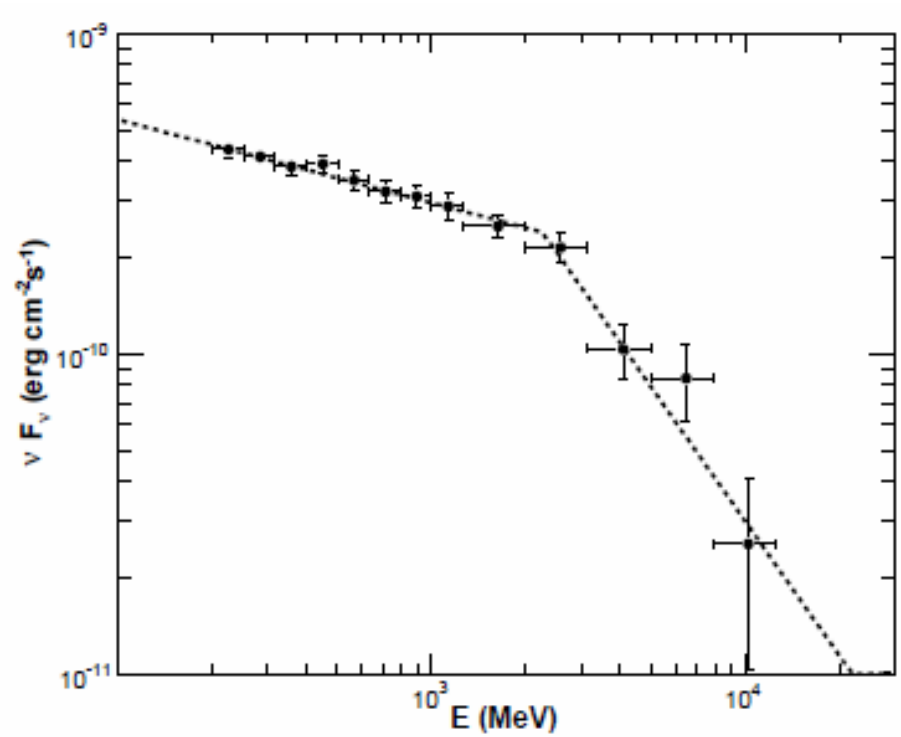
Unlikely cooling effect

Acceleration spectrum?

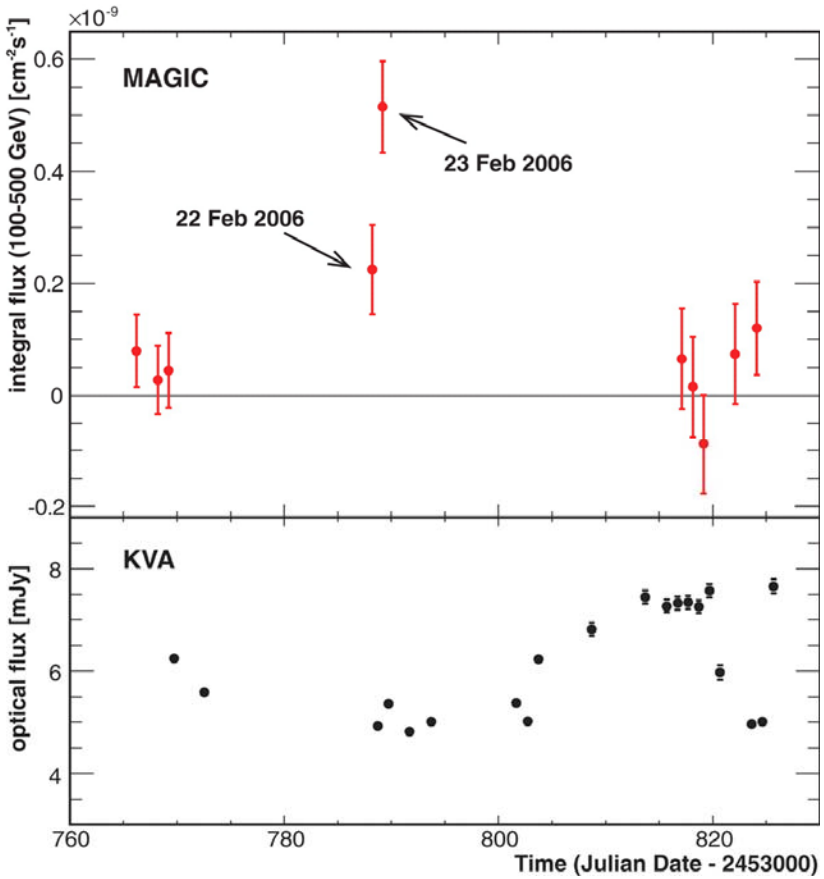
Internal absorption?

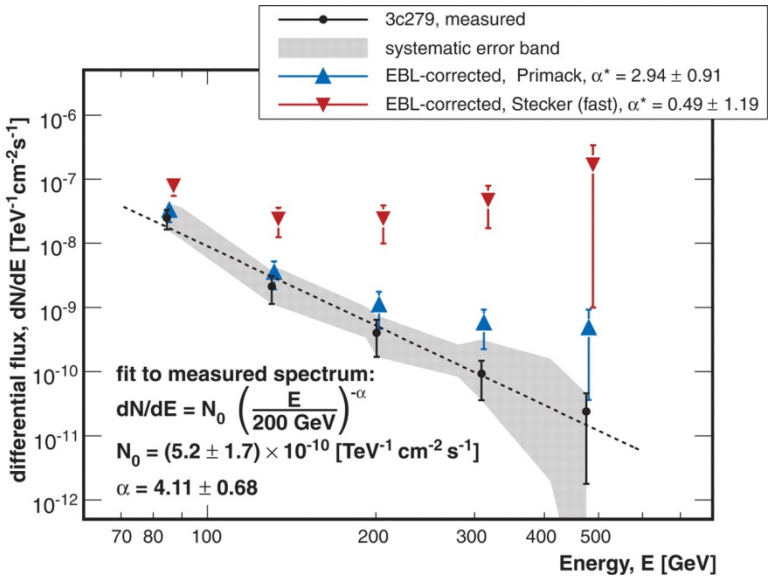
(should be at 20-50 GeV)

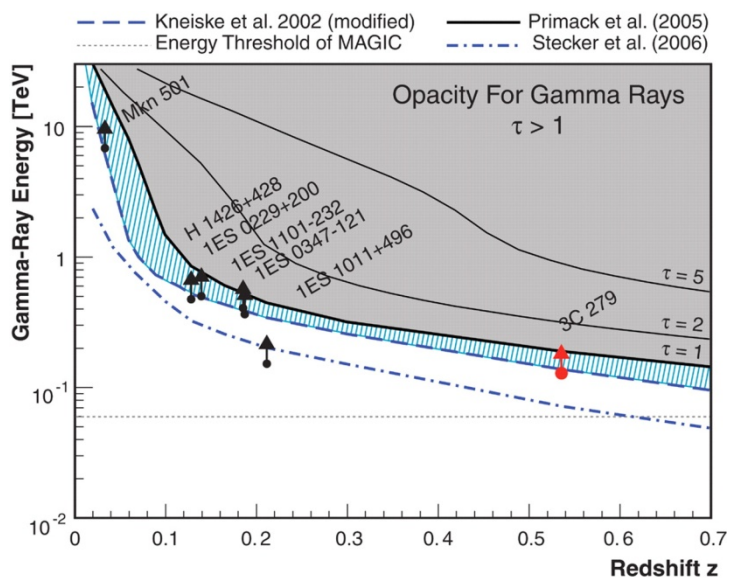
FSRQ 3C454.3



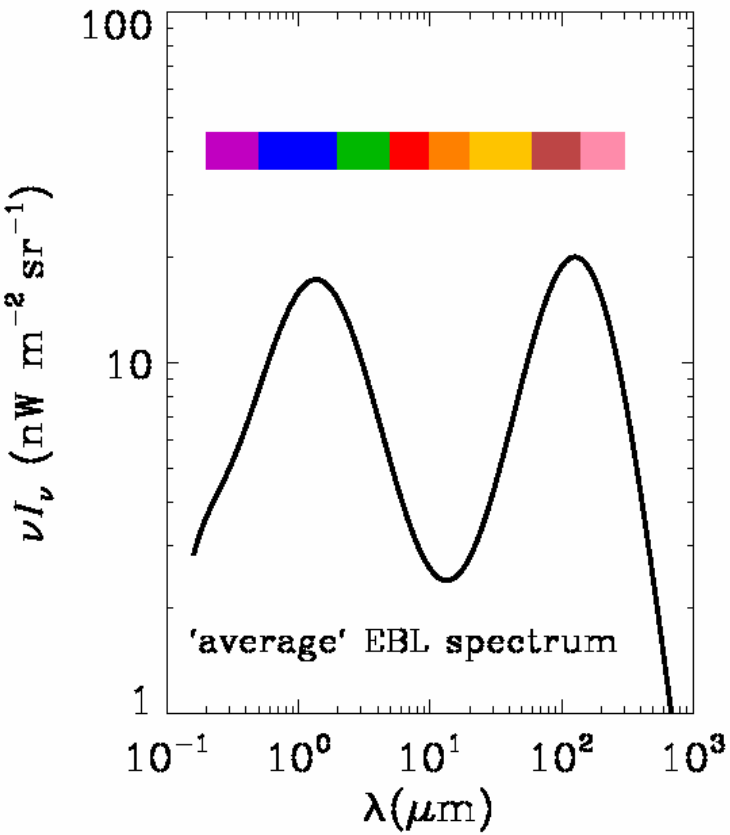
3C279: a FSRQ at redshift ~0.5

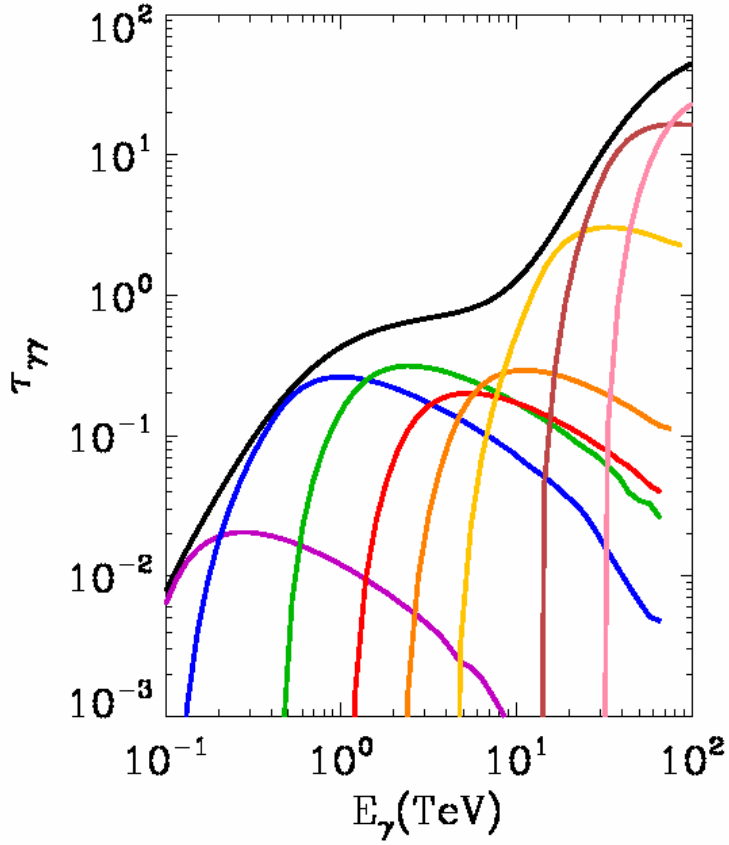




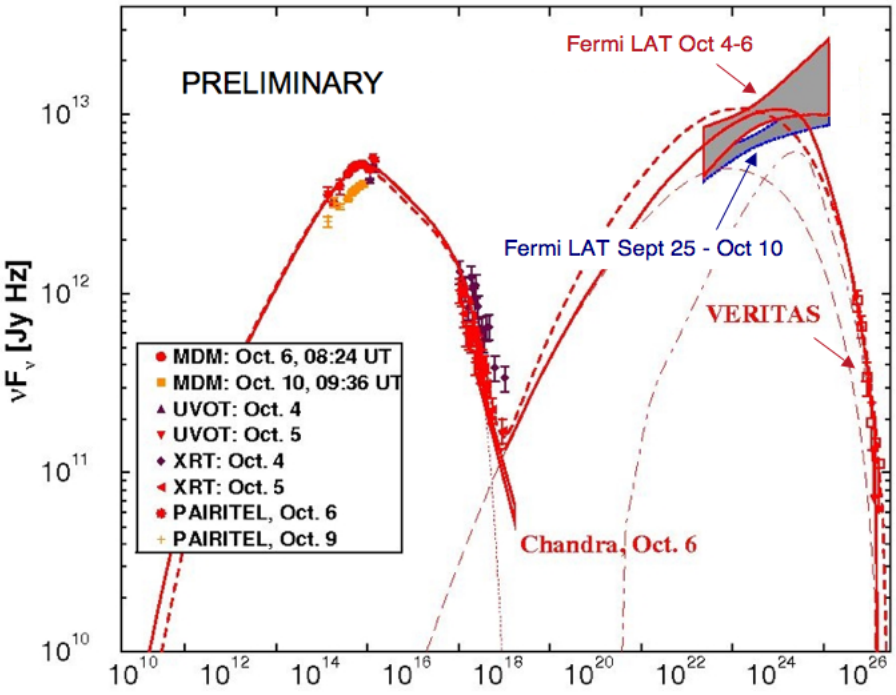


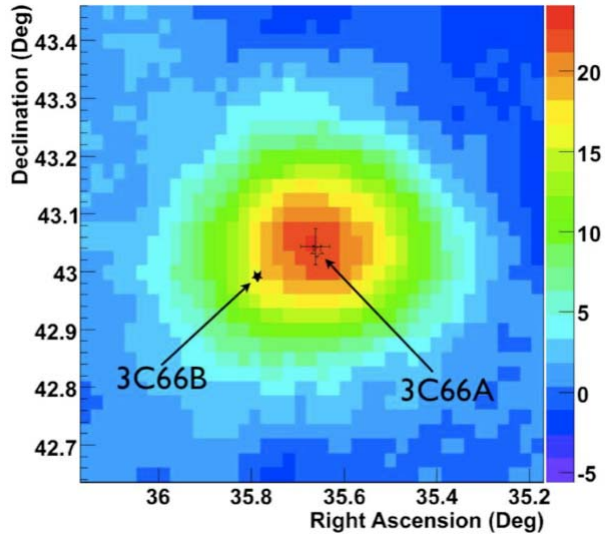
EBL absorption

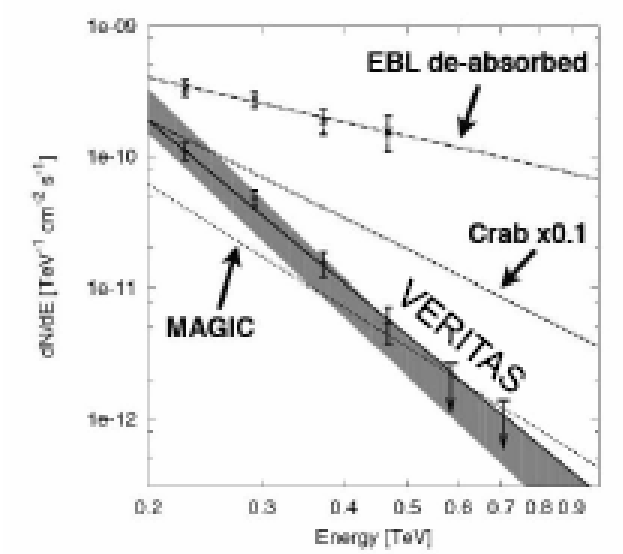




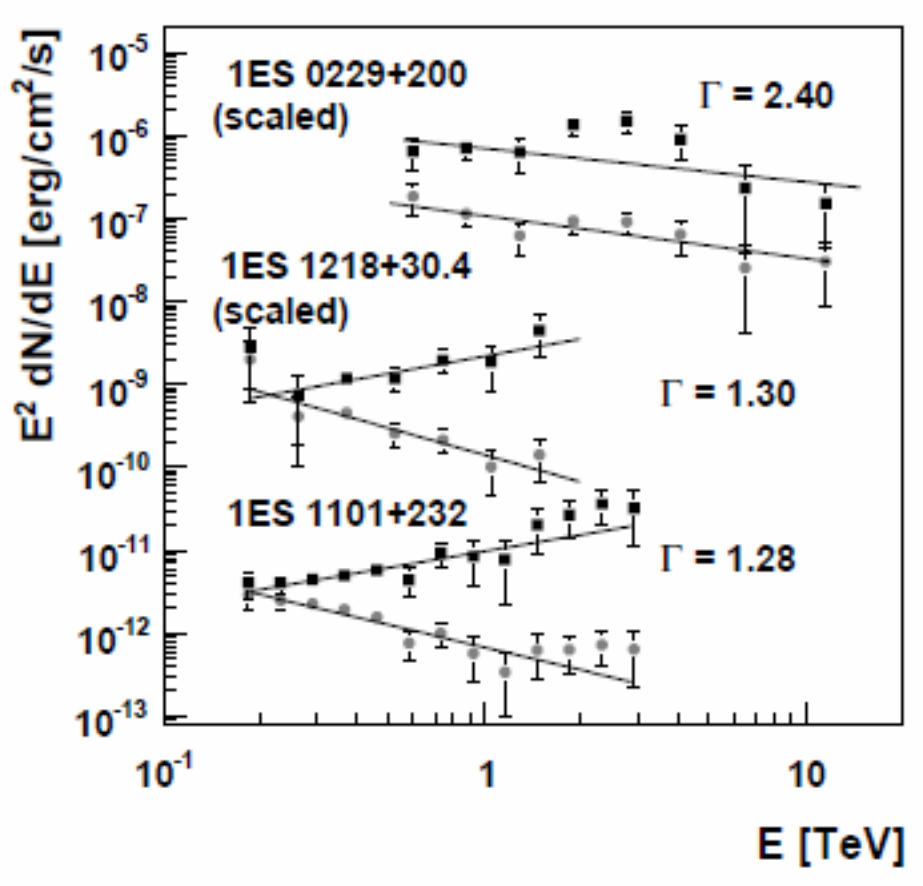
EBL absorption: IBL 3C66A

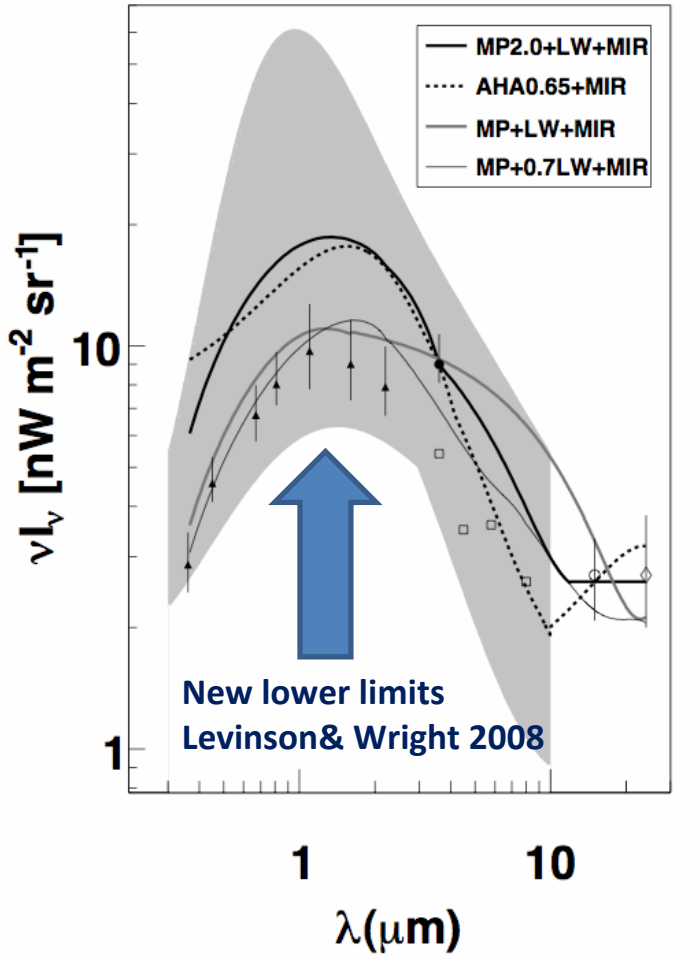






EBL absorption



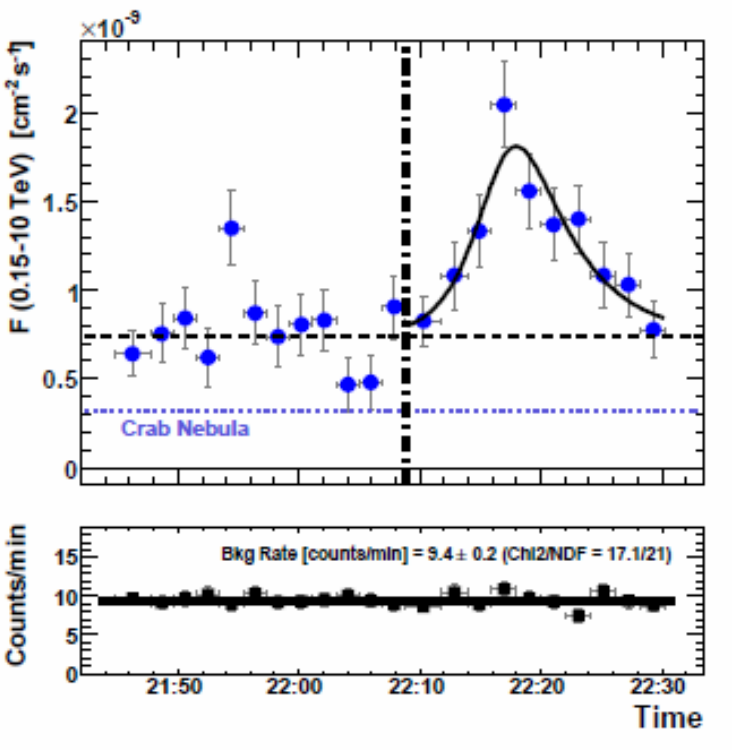


Very hard intrinsic spectra required!

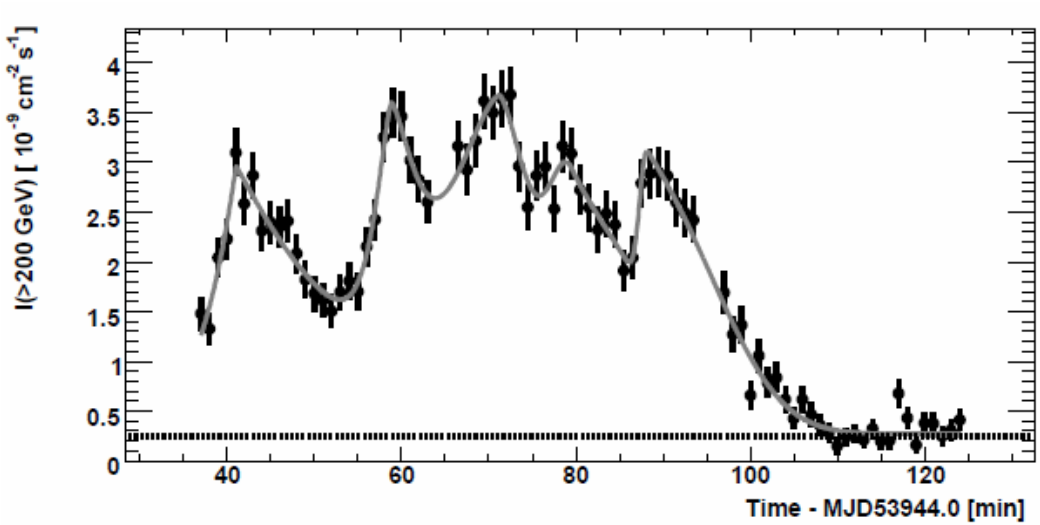
Variability

TeV-band variability on minute timescales

Mrk 501 (MAGIC)



PKS 2155-304 (HESS)



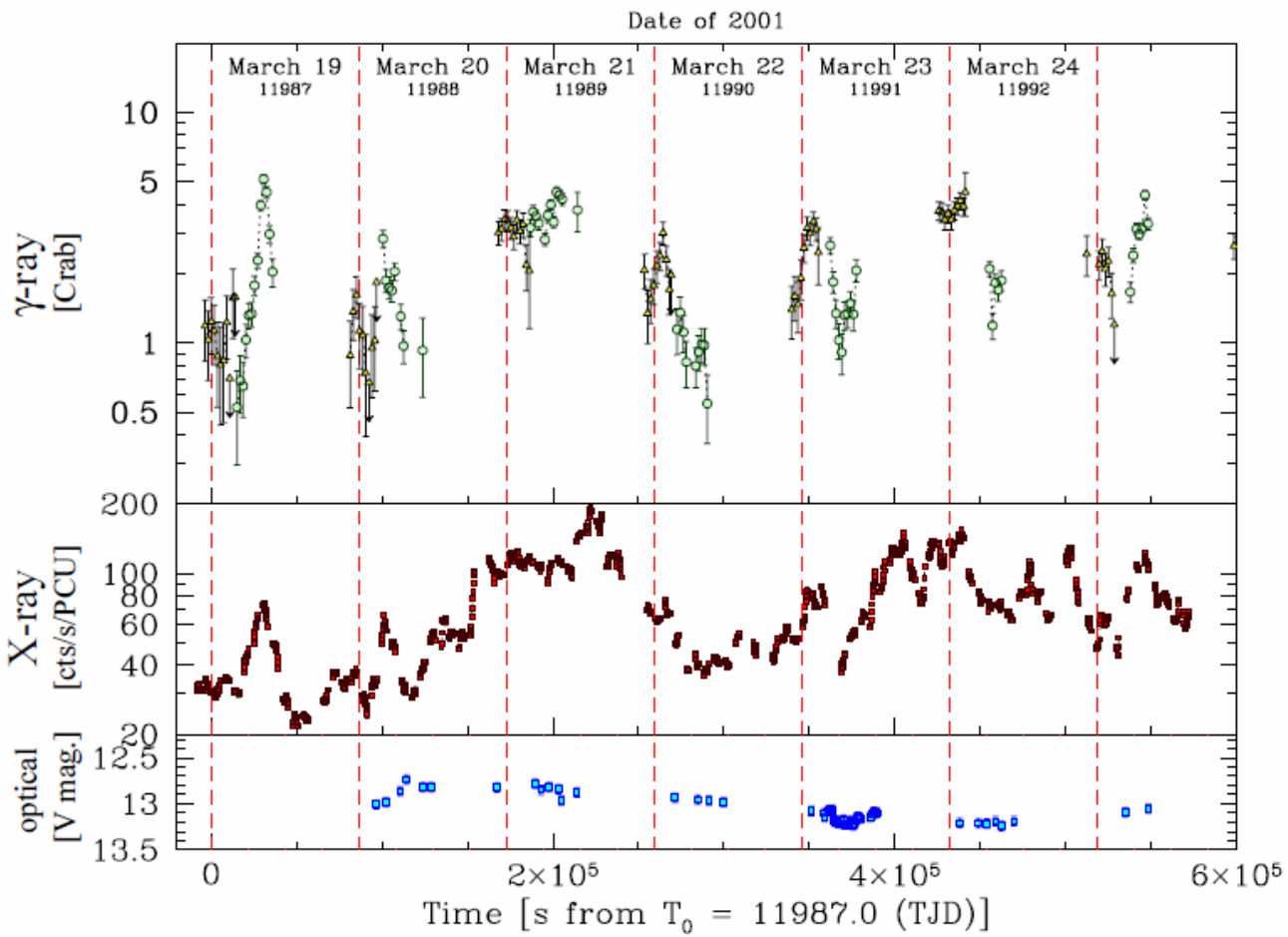
Causality constraint on source size!

Correlations

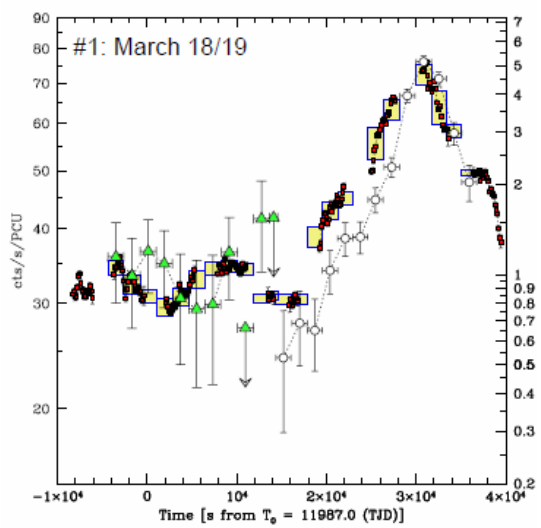
Mrk 421

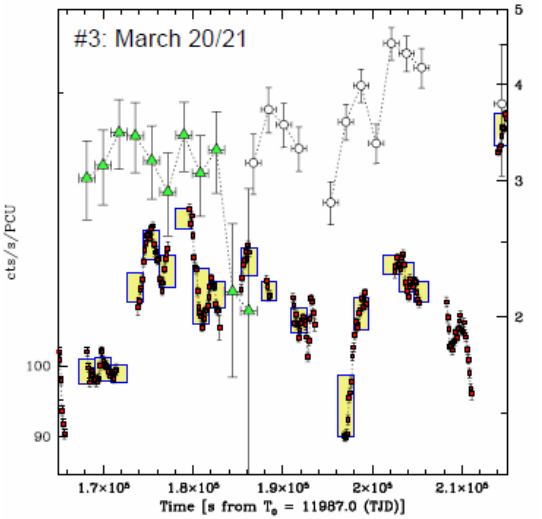
2001 campaign

(Fossati et al. 2008)

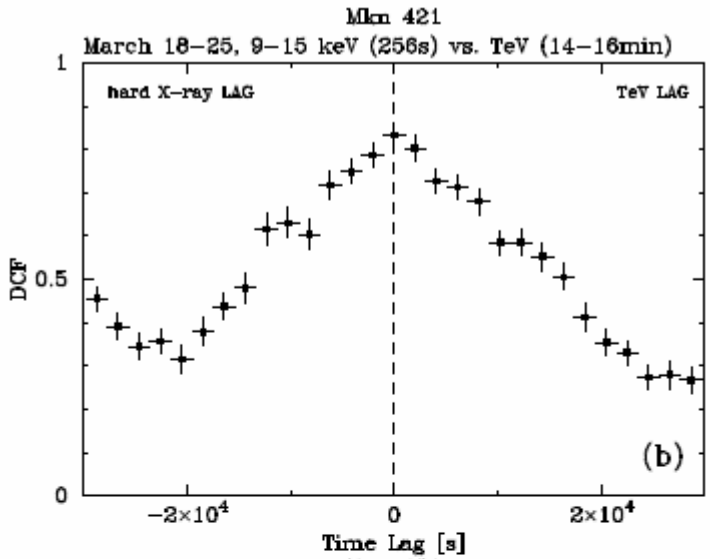


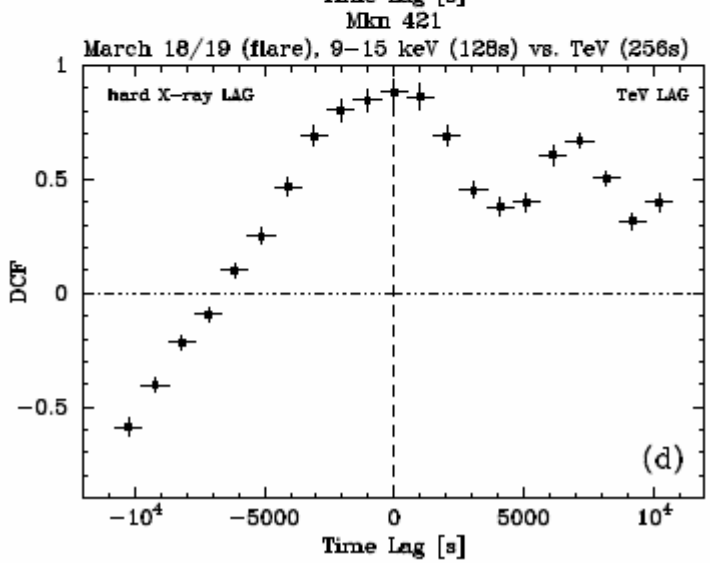
Correlations



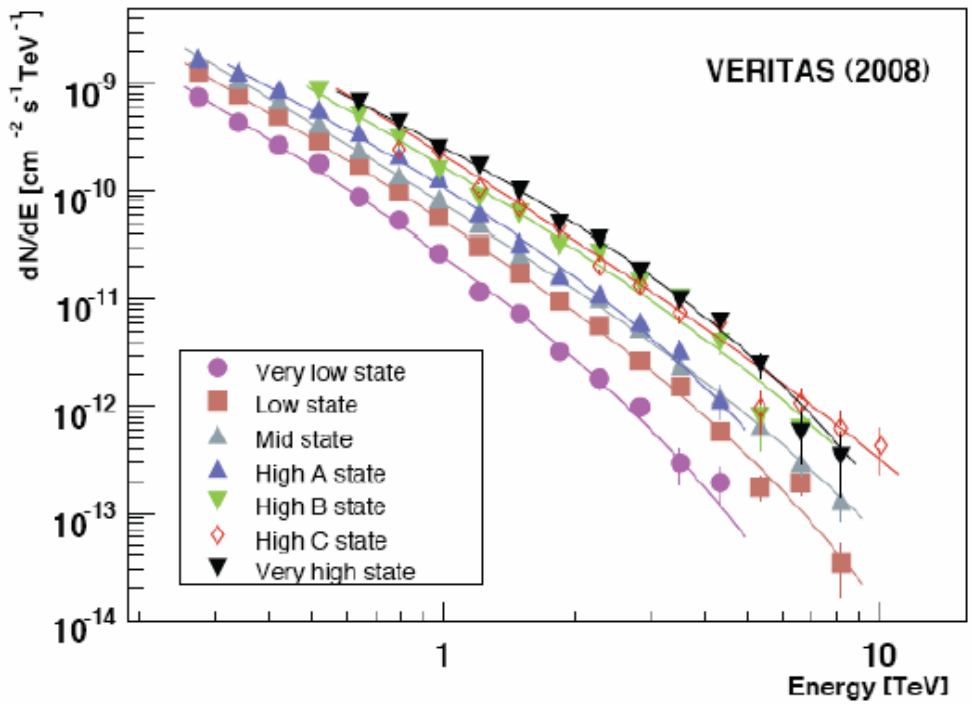


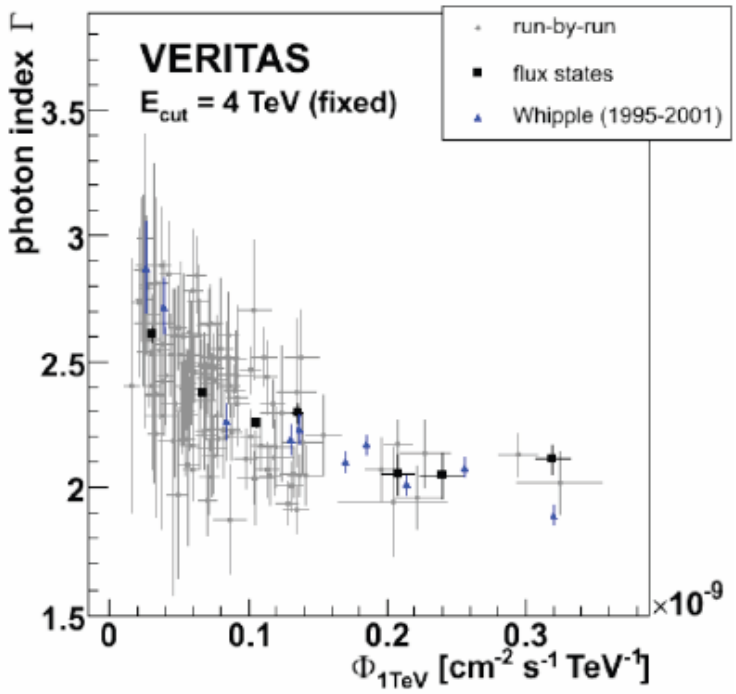
Yes
Or
no?





Correlations



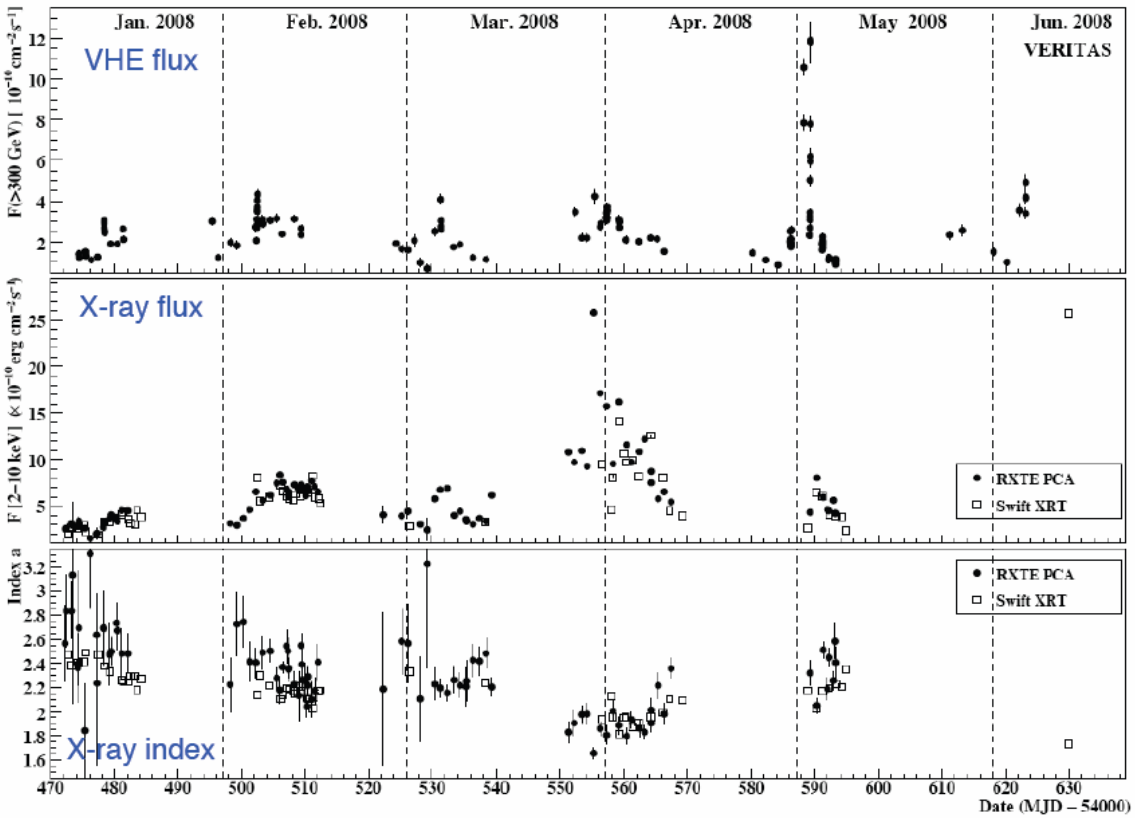


Mrk 421: newer data

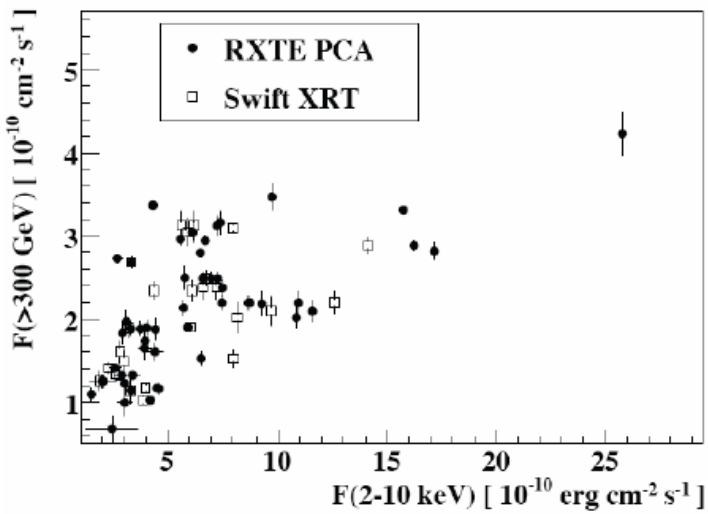
spectral hardening correlated with VHE flux

Donnarumma et al. 2008

Correlations

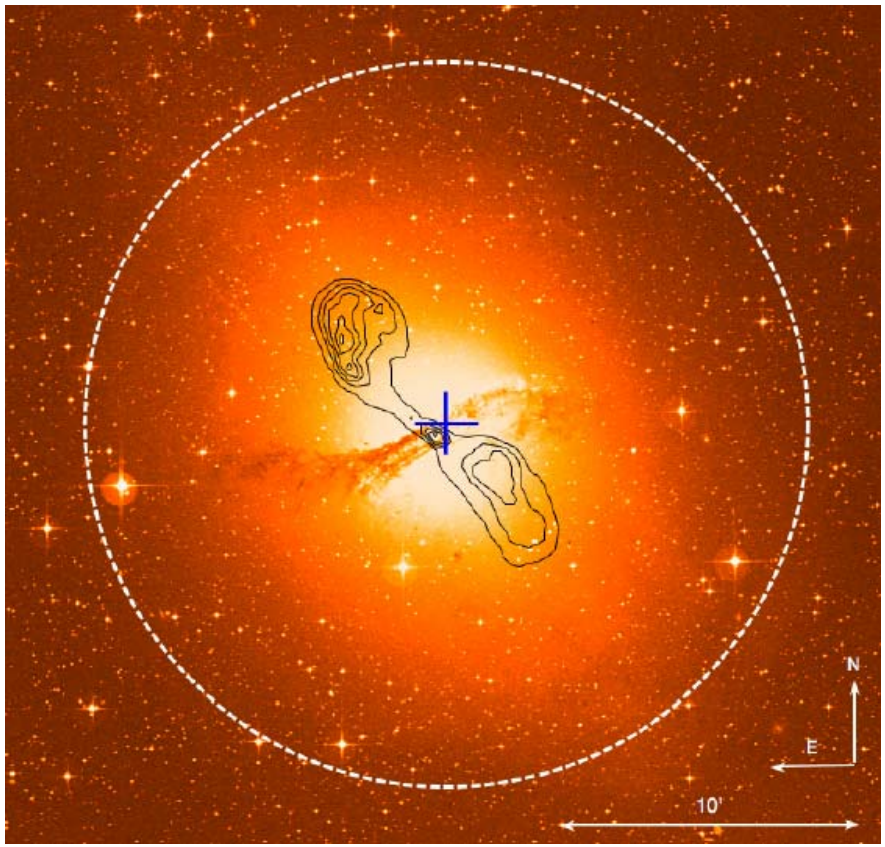


Mrk 421
5-h overlap window



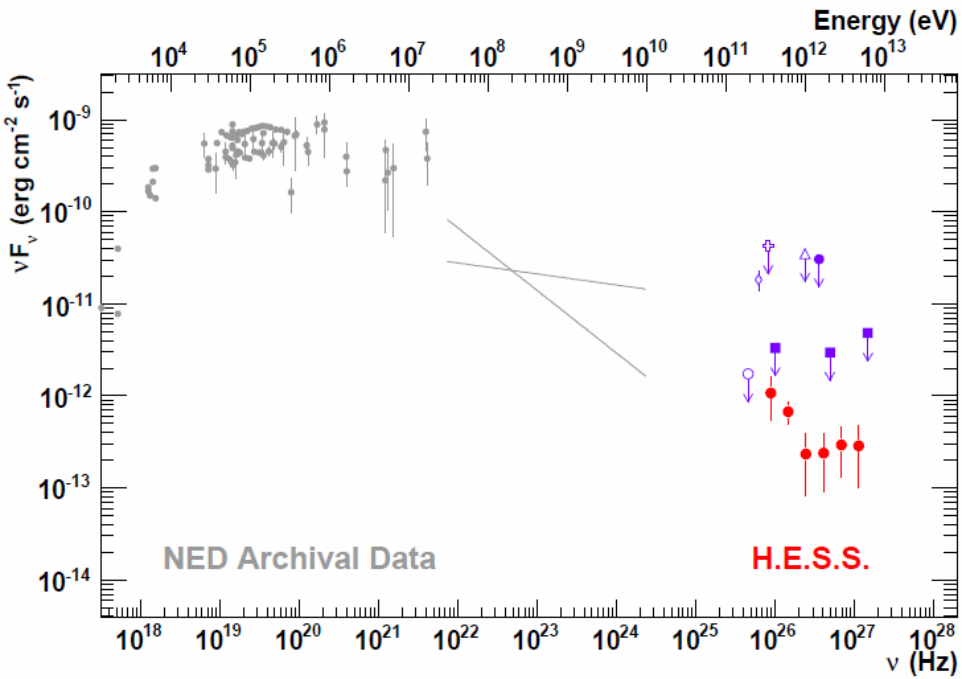
One-to-one correlations vs. common trend

Radio galaxies

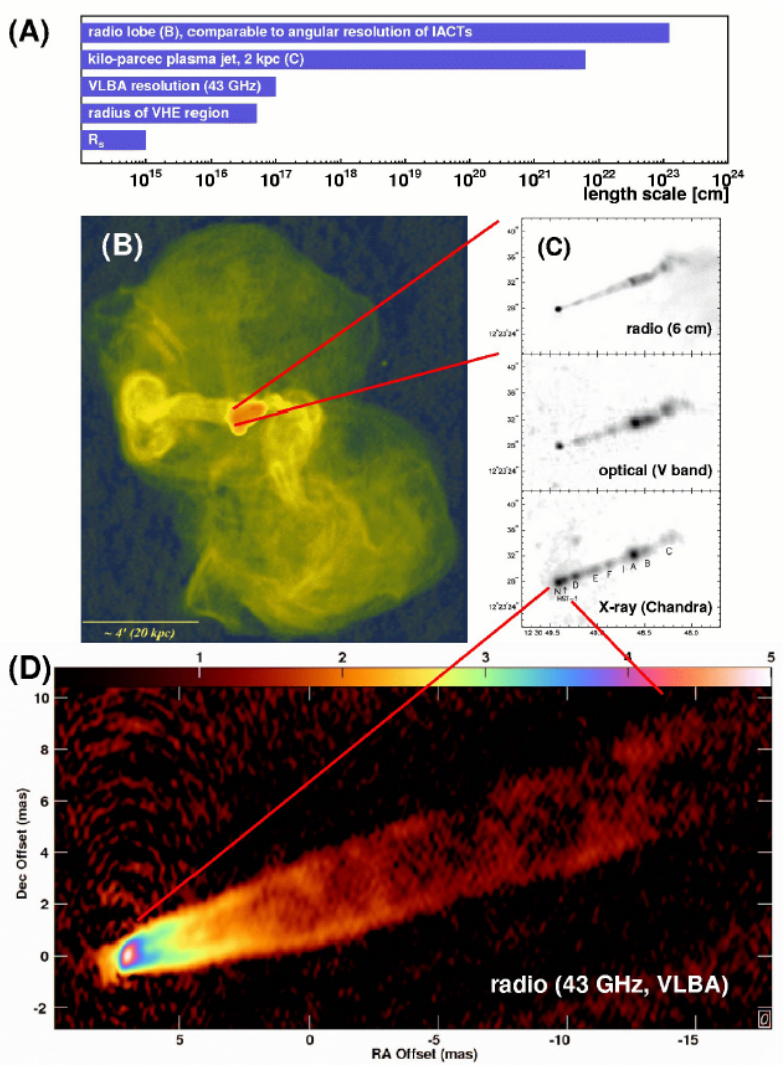


Centaurus A (HESS)

Distance only 3 Mpc



M87

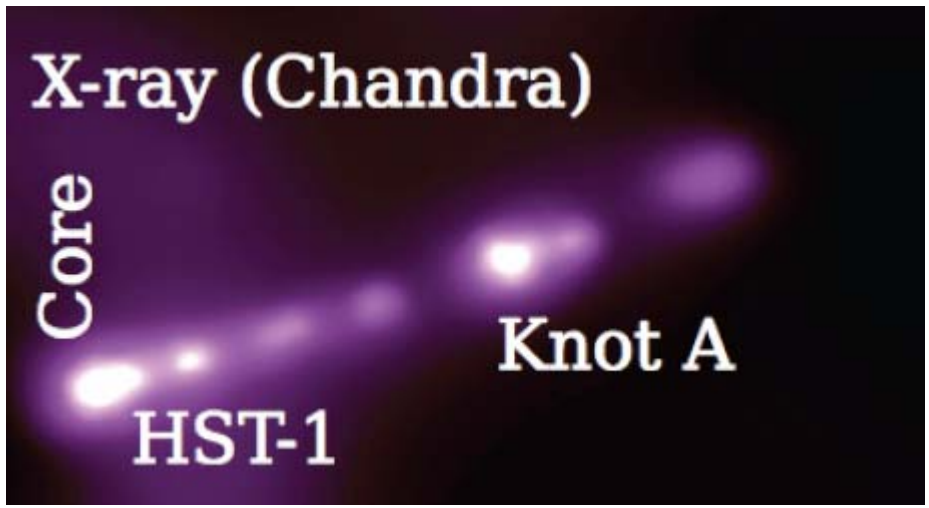


Jet angle 15-30 degrees

Superluminal motion v=2c

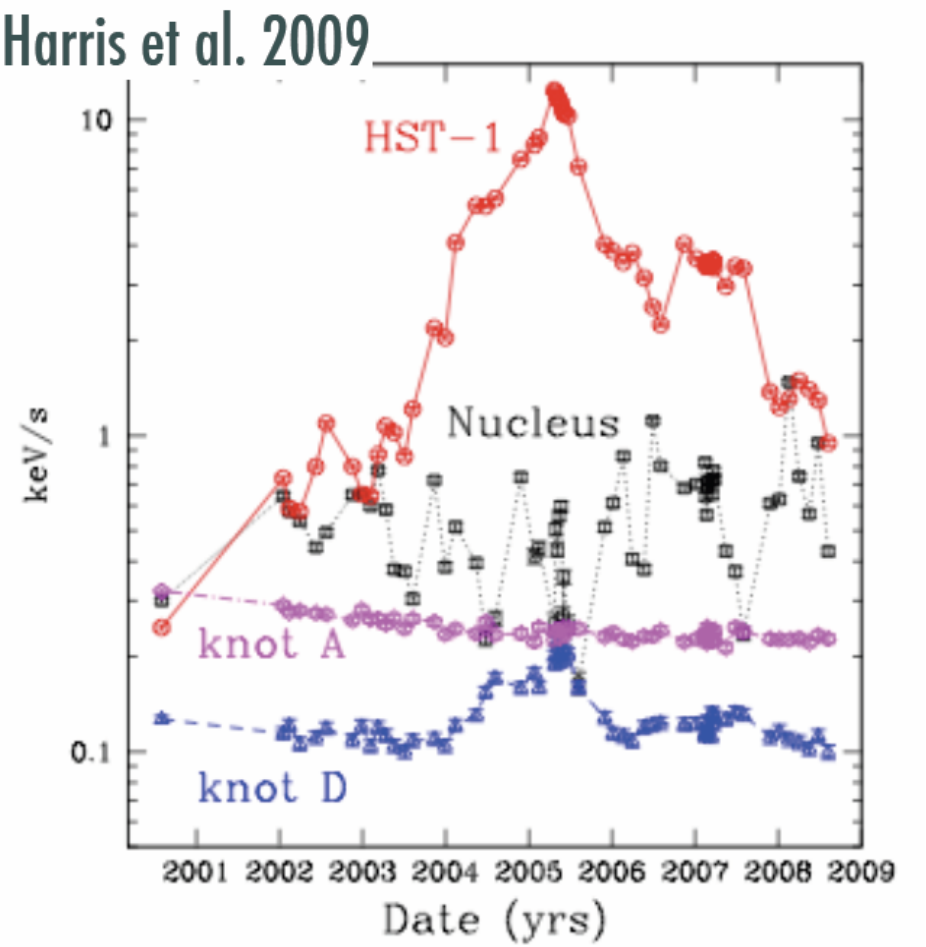
$M_{BH} = 6*10^9$ M_{sol}

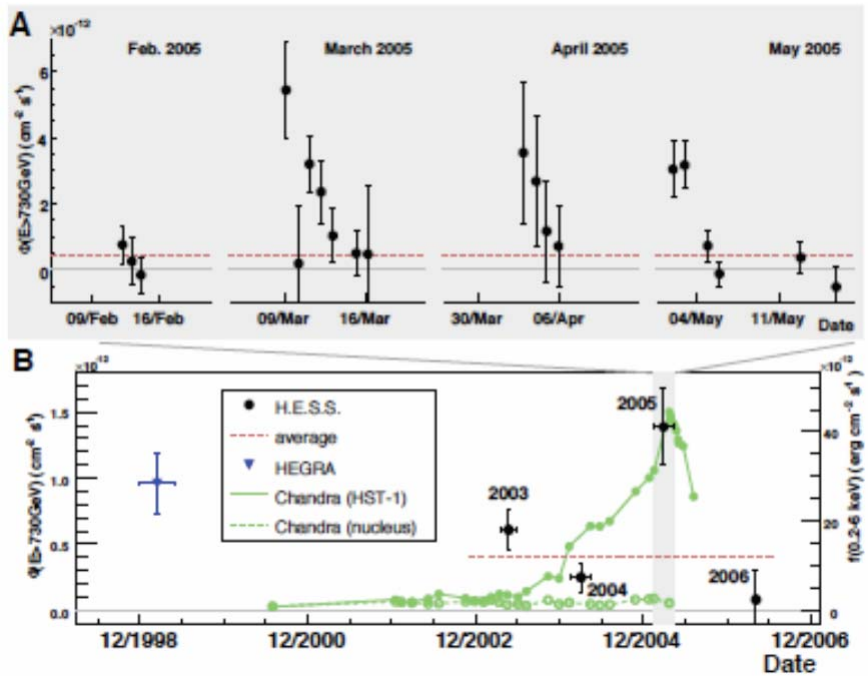
Distance 16 Mpc

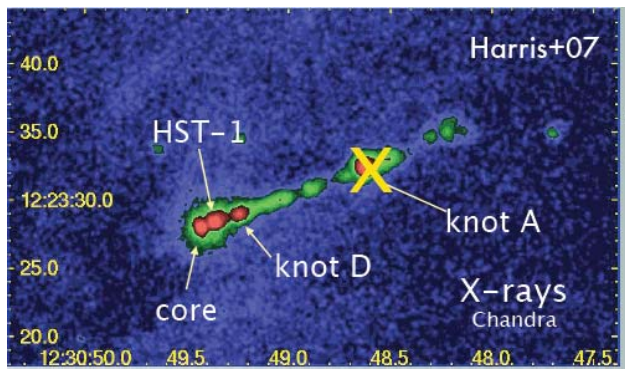


M87

Harris et al. 2009

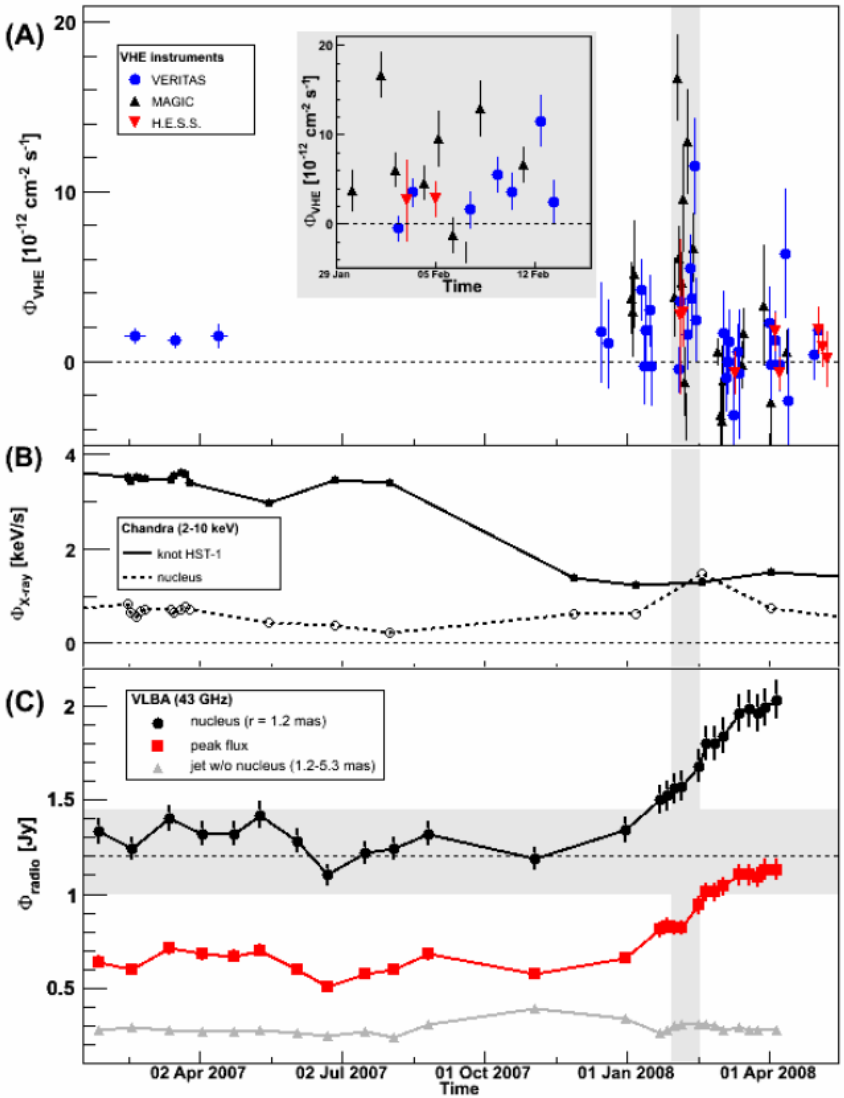


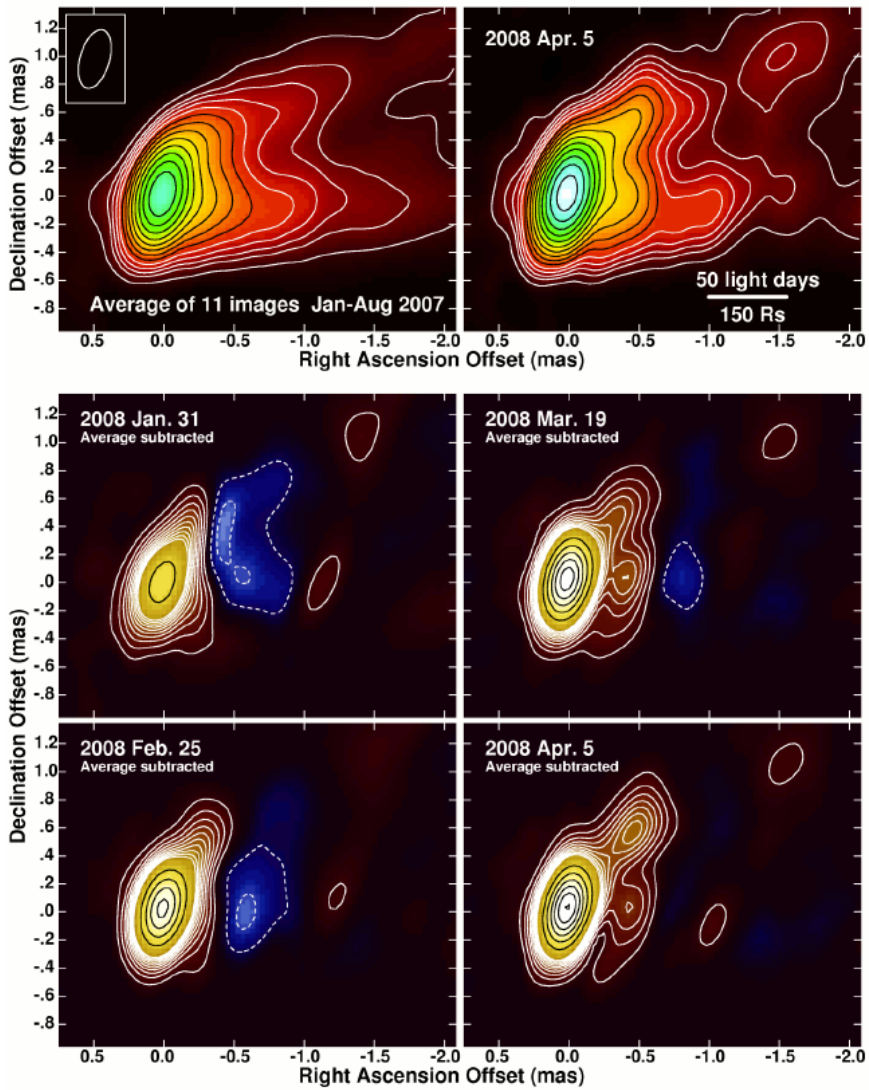




Fast variability
→ Knot A
as VHE γ-ray
source unlikely

M87: 2007-08 campaign





M87: conclusions

- **Rapid TeV flare with t_{var} ~ 1 day**
- **X-rays: HST 1 in low state, core at record high**
- **VLBA: A flare at core (30 x 60 R_S)**
- **VHE flare region much smaller than 30 R_S**
- **TeV emission originating close to core?**