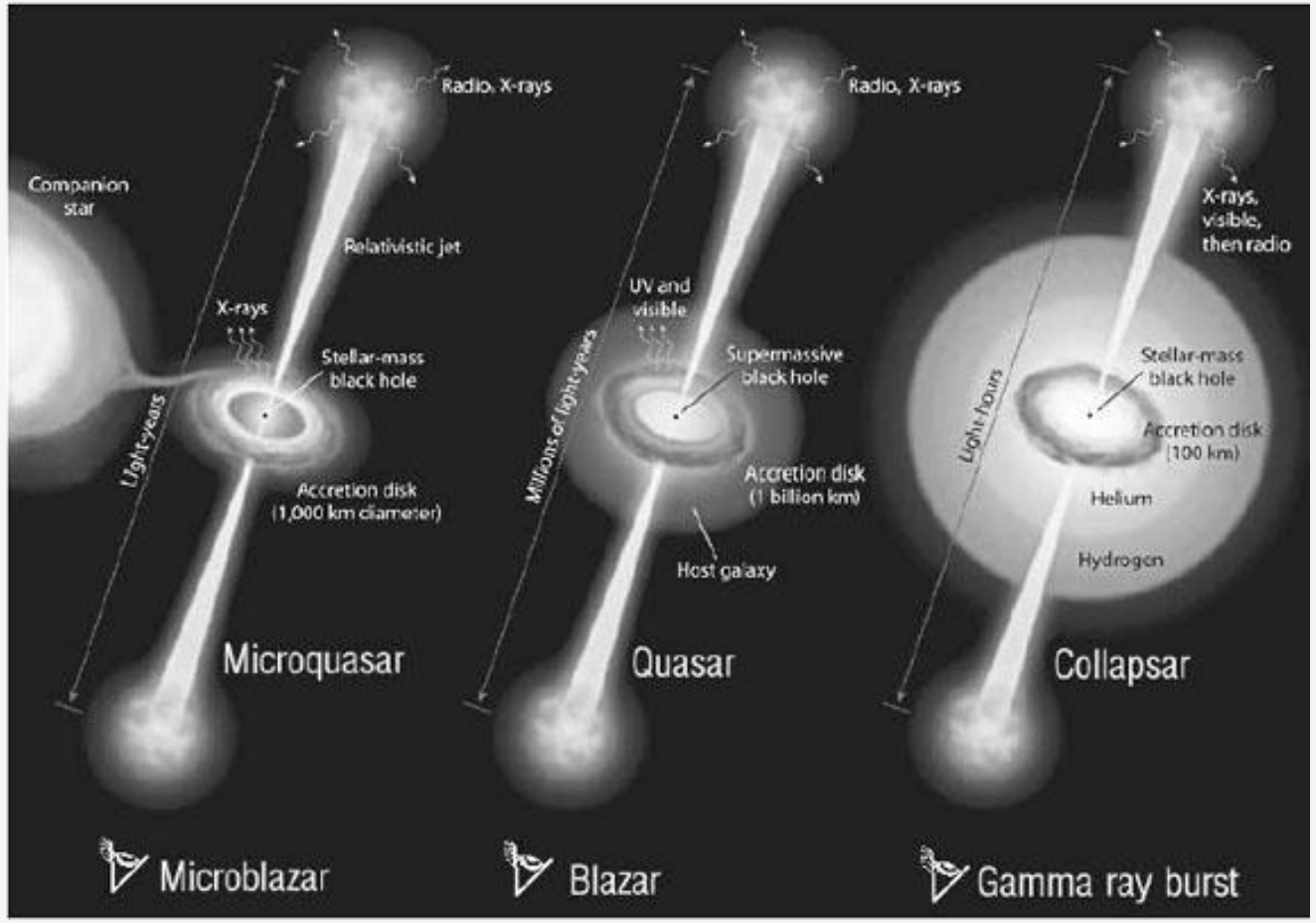
SIMILARITY AND DIVERSITY OF BLACK HOLE SYSTEMS

View from the Very High Energies

Elina Lindfors, Tuorla Observatory @ TT2016

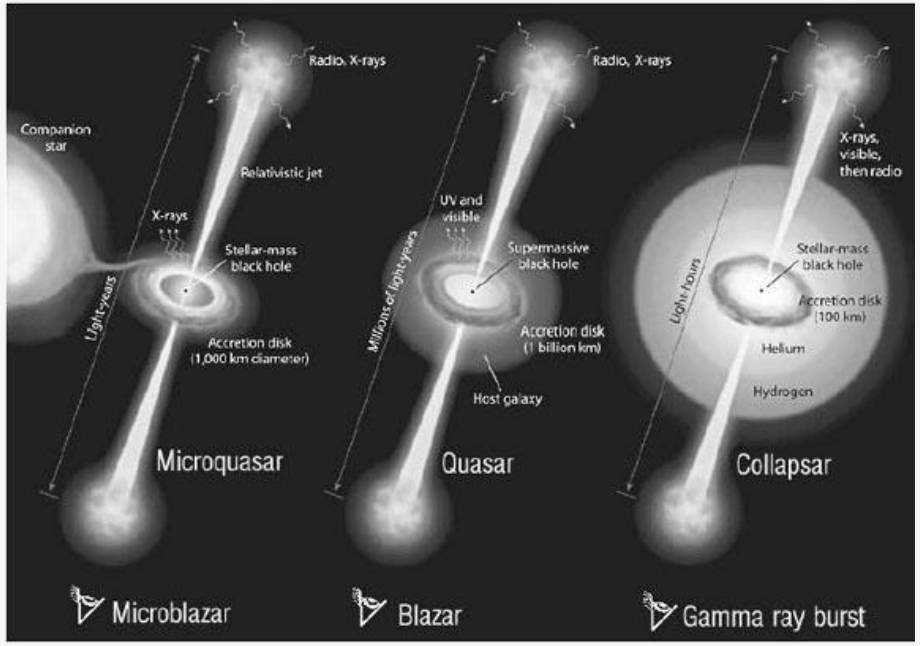
Classical view

Spinning black hole
Accretion disk
Collimated jets of particles



Mirabel & Rodriguez 2002

Looking at the big picture

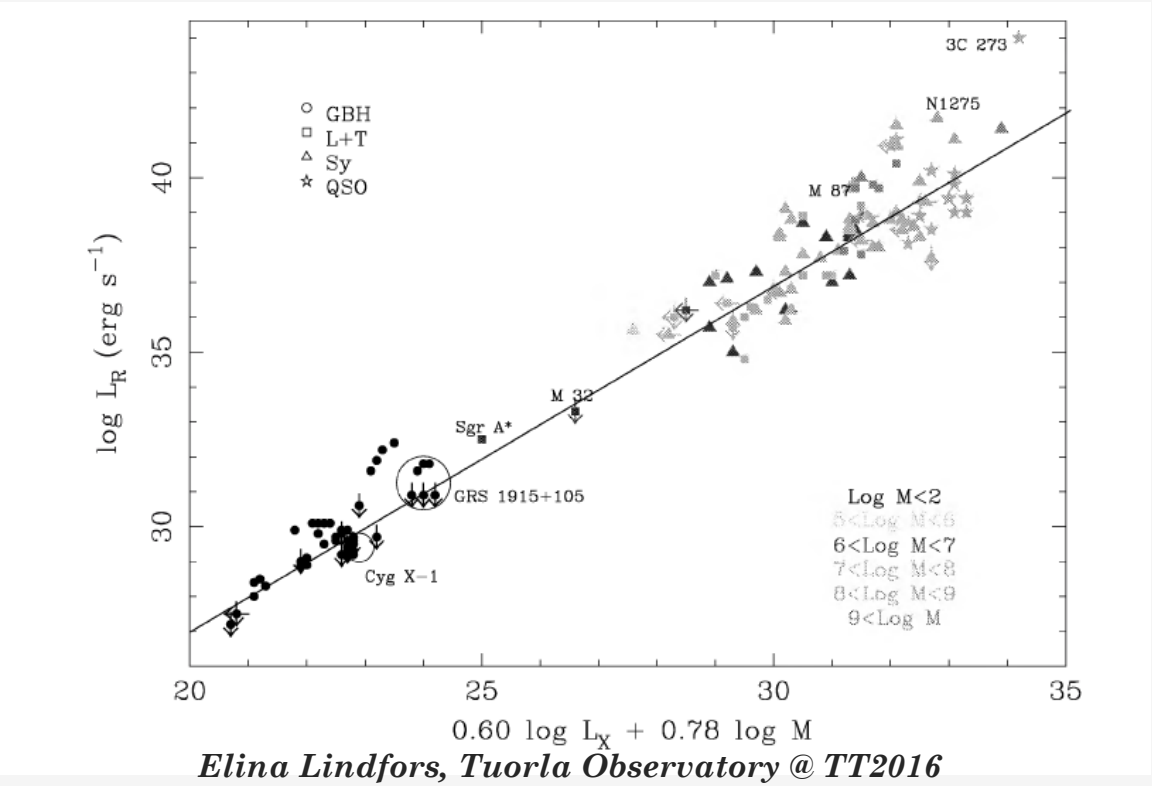


Central engines share the same basic astrophysical ingredients but vastly different mass scales

- What properties simply scale with the black hole mass? Could be sign of something fundamental?
- Does everything just scale?
- Same flaring mechanism?

Scalings

Fundamental plane of black hole activity (Merloni et al. 2002)
Active galaxies and galactic black holes: points in three dimensional space (L_R, L_X, M) lie on a plane



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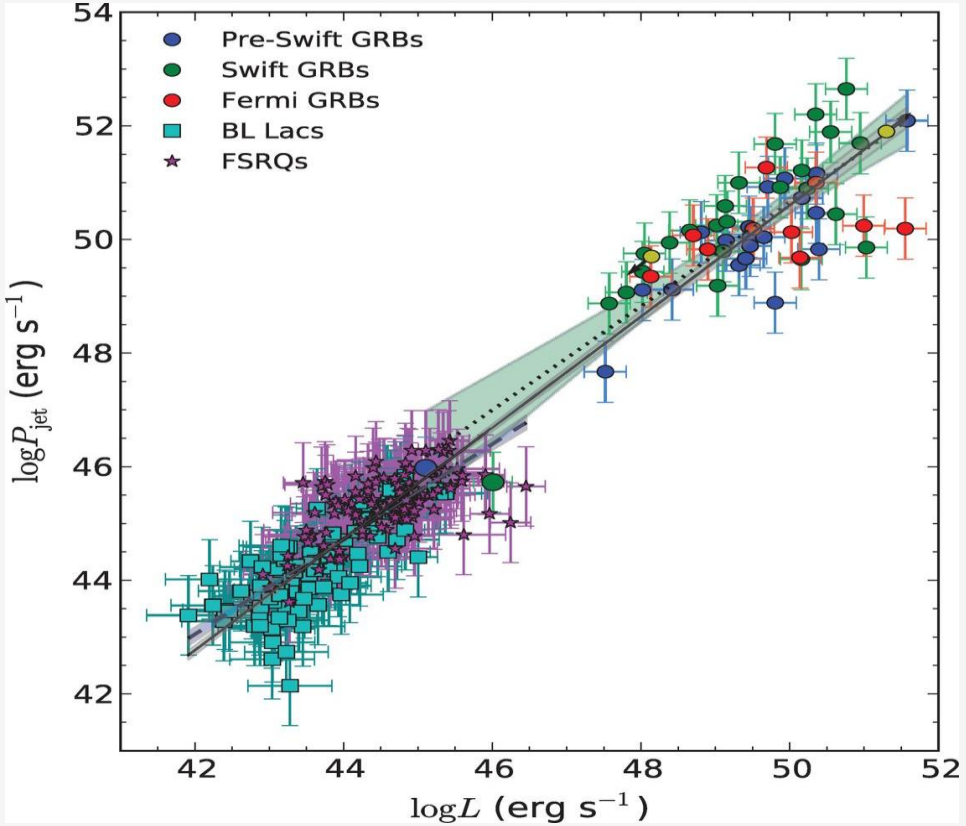
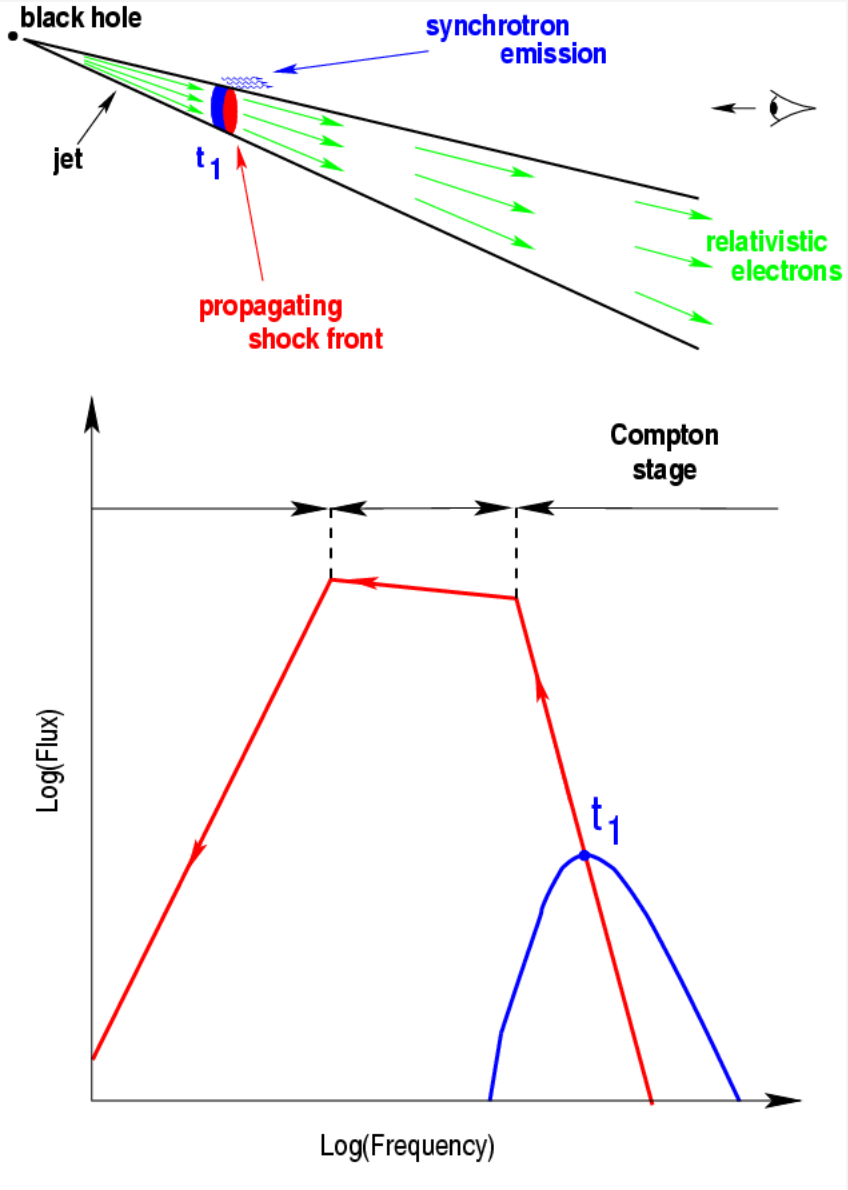
Collimation-corrected gamma-ray Luminosity vs. kinetic jet power in AGN and GRBs (Nemmen et al. 2012)

Jets created by black holes maintain the same coupling between the total power carried by the jet and power radiated away.



Flaring behavior

Radio to optical flares are shocks travelling in a jet, going through three stages of evolution



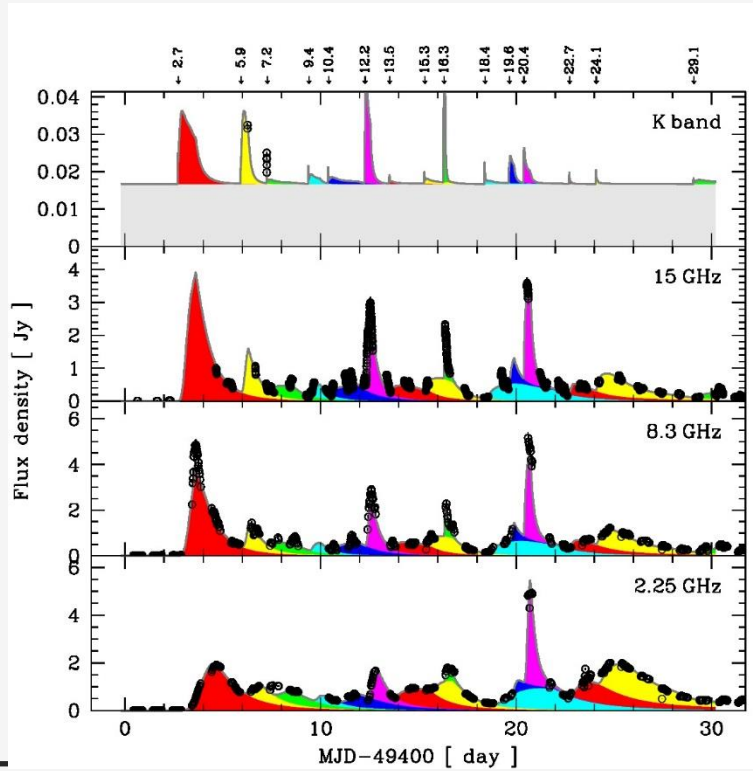
Credit: Marc Türler, ISDC

Flaring behavior

Decomposing the lightcurves to derive the evolution of the jet parameters.
Method developed by Türler et al. 2000

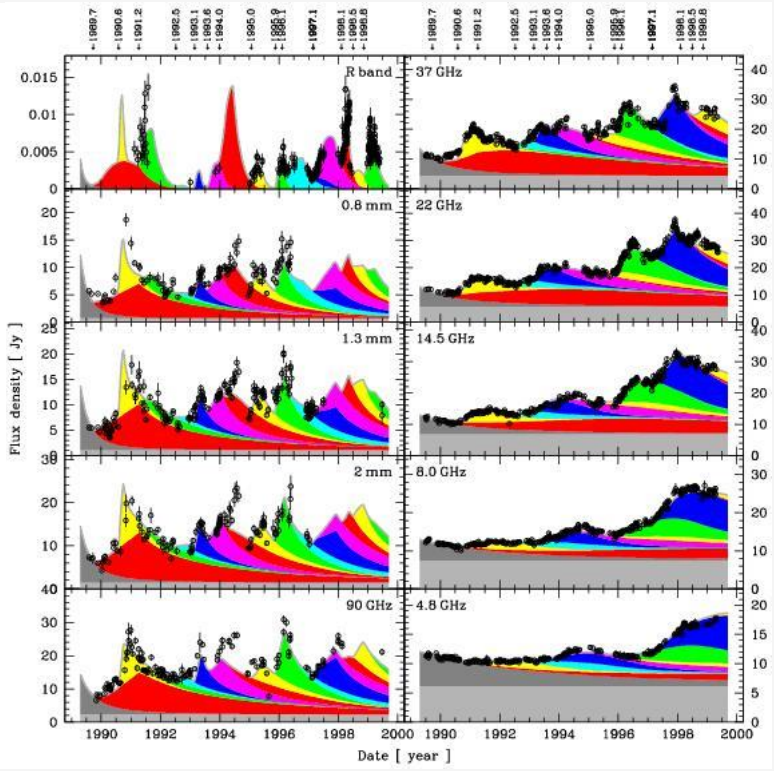
- Outbursts in blazar 3C279 and microquasar Cyg X-3 are well described by shock in jet model.
- Jet parameters derived were similar for both jets

Cyg X-3



Lindfors, Türler et al. 2007

3C279



Lindfors, Türler et al. 2006

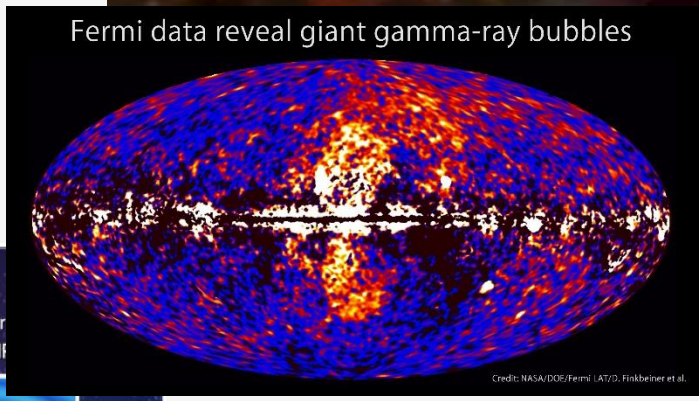
Recent Observations

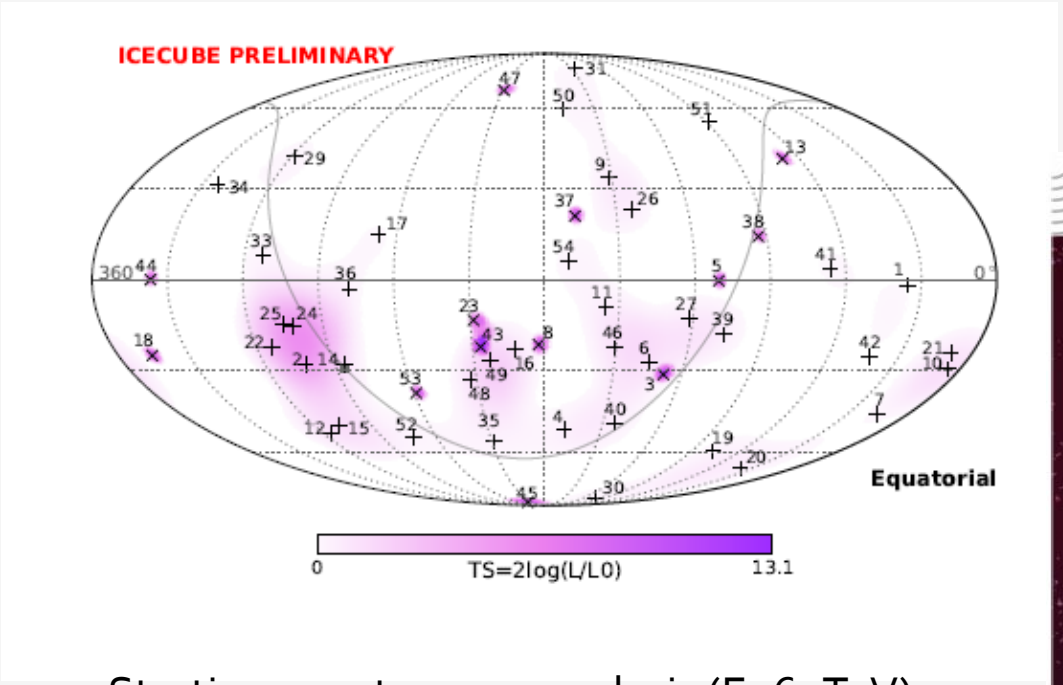
- Tidal disruption events
- Fermi bubbles
- New windows:

  -Very High Energy gamma-rays

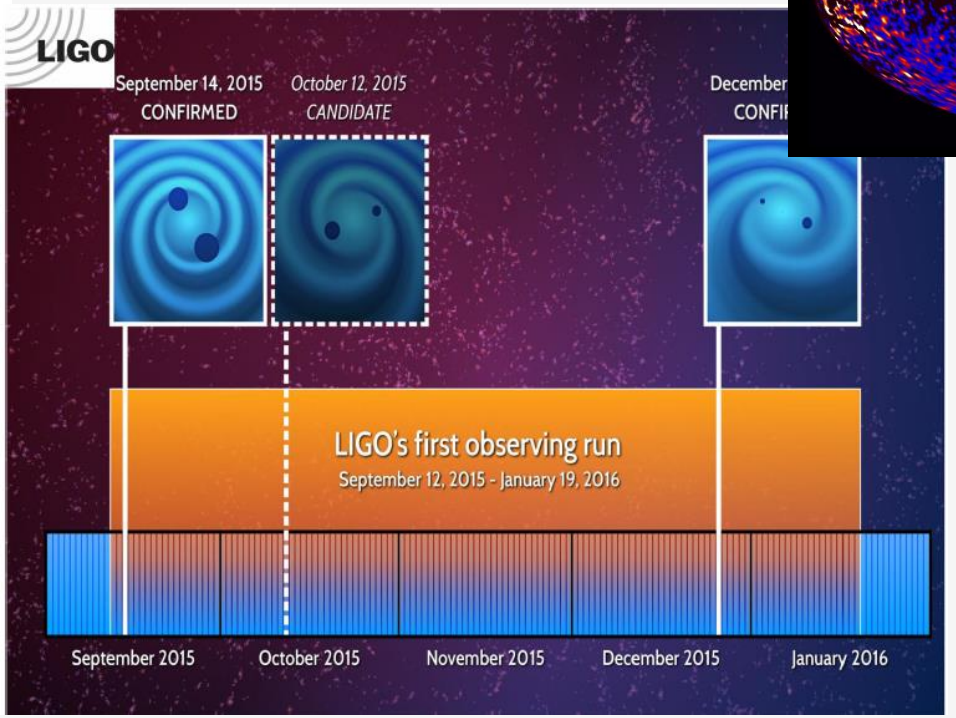
  -Neutrino Astronomy

  -Gravitational waves

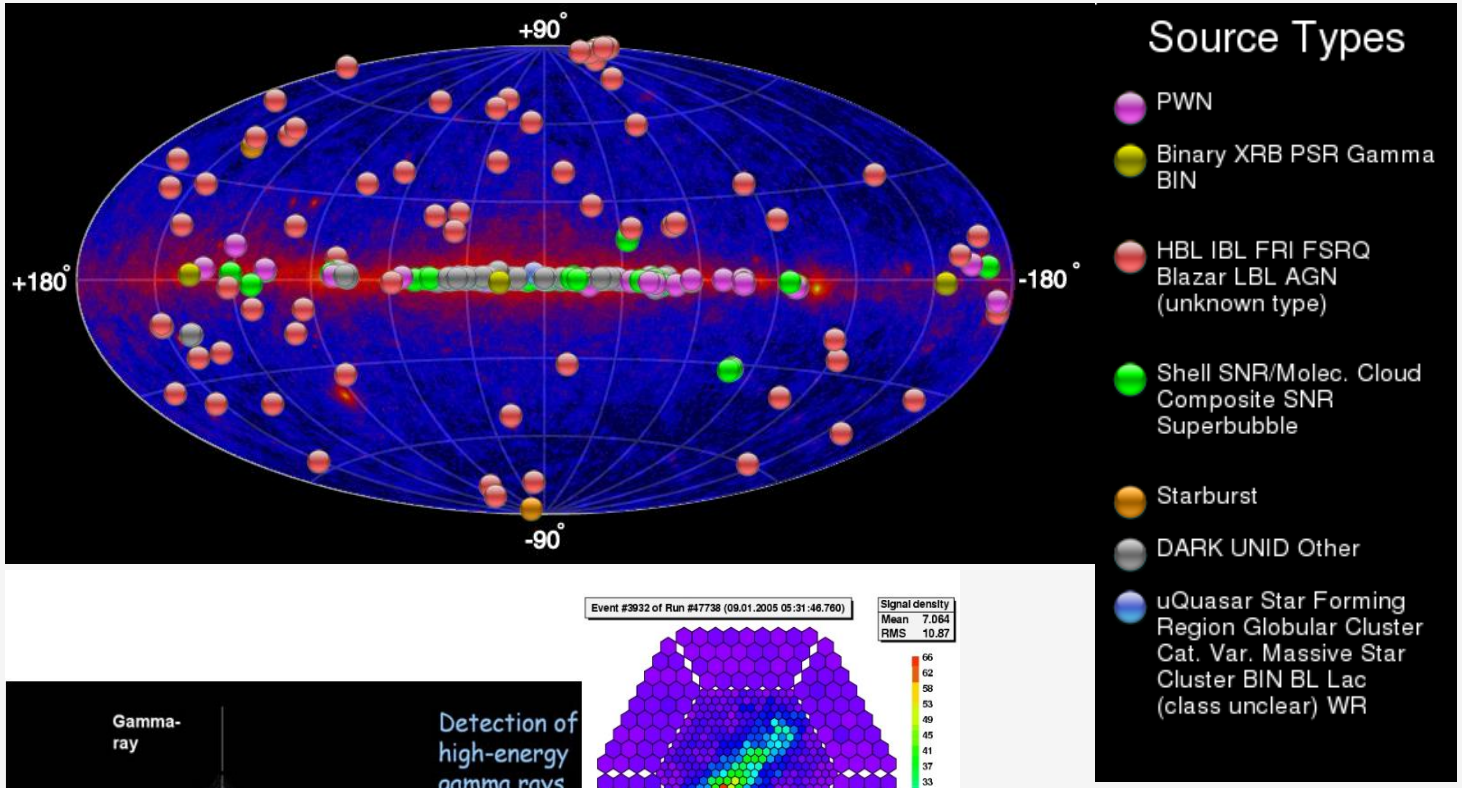


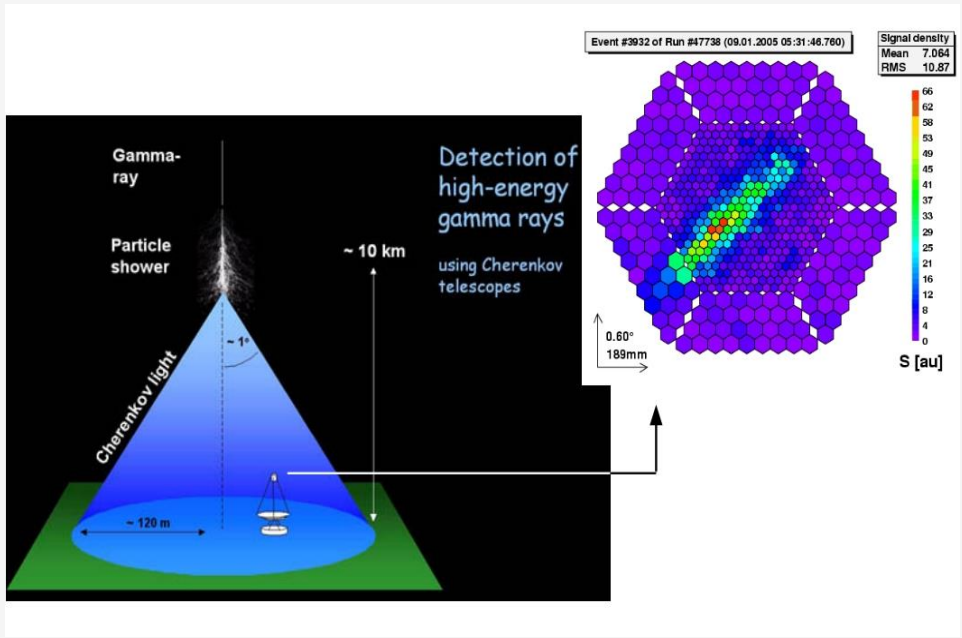


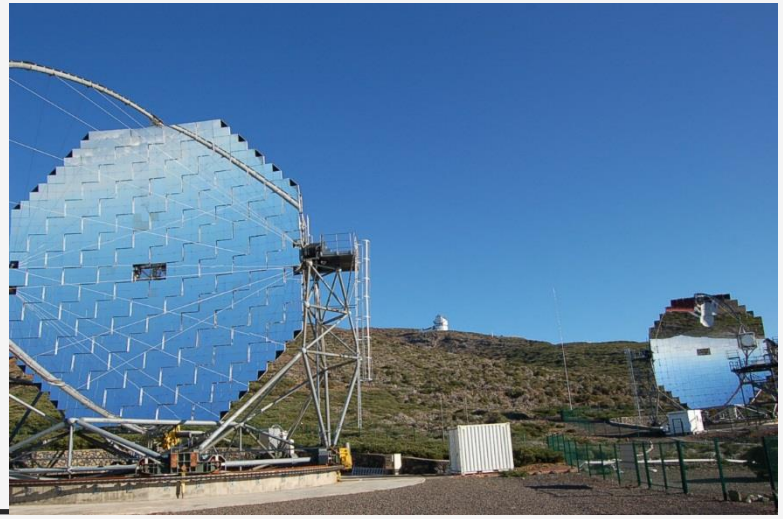
Starting event source analysis (E>60TeV)



View from the Very High Energies

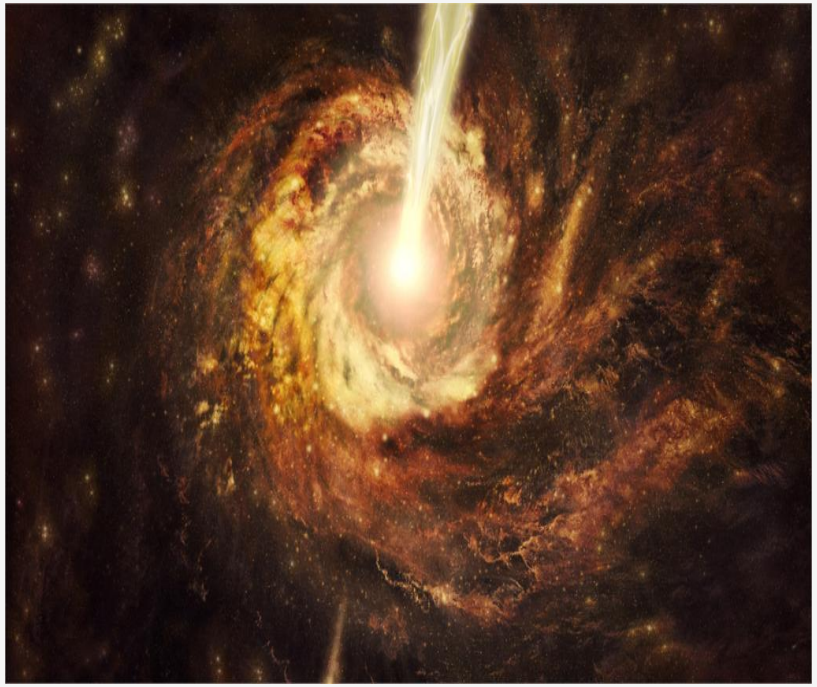






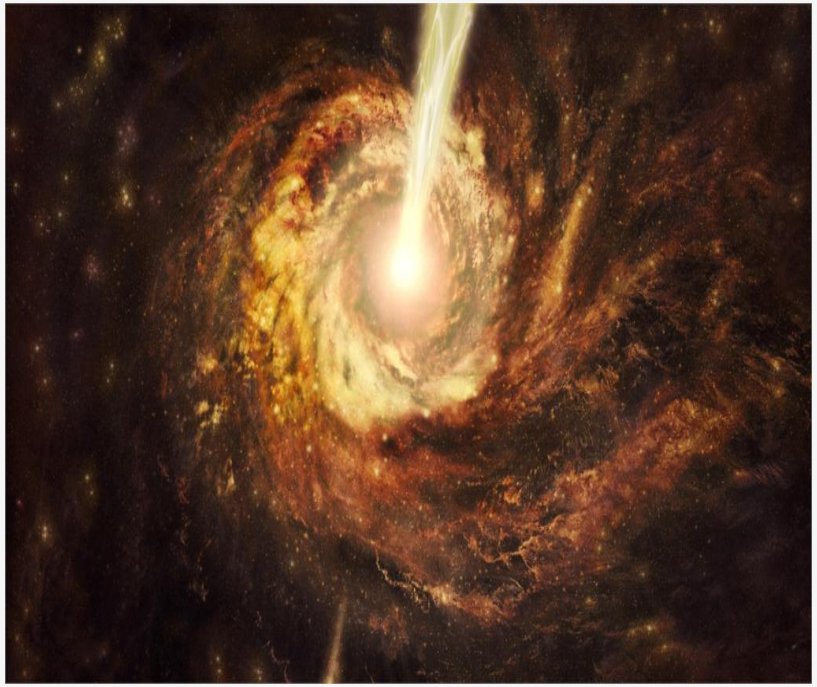
Elina Lindfors, Tuorla Observatory @ TT2016

Active Galactic Nuclei

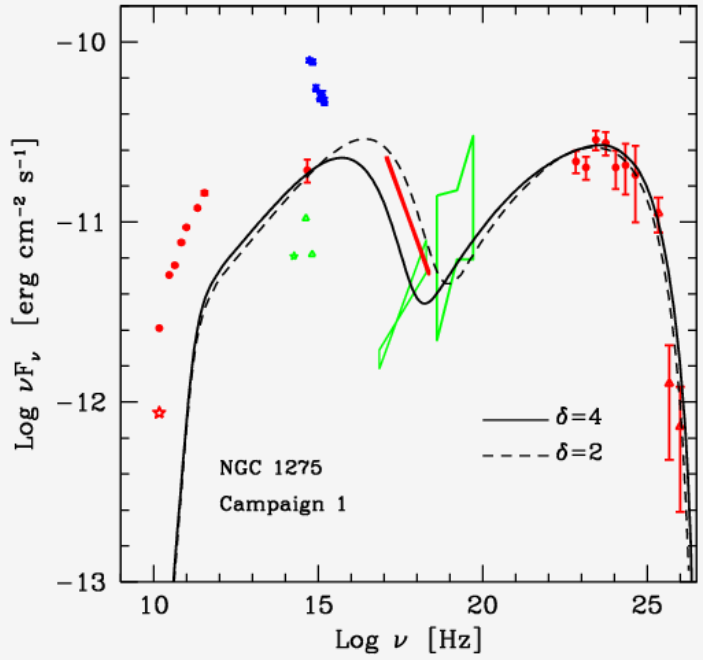


- The most numerous sources in the VHE gamma-ray sky
- Mostly blazars of High Synchrotron Peaking BL Lac type
- But diversity is increasing: radio galaxies, low synchrotron peaking sources
- Moreover starburst galaxies
- …and the center of our galaxy

Active Galactic Nuclei

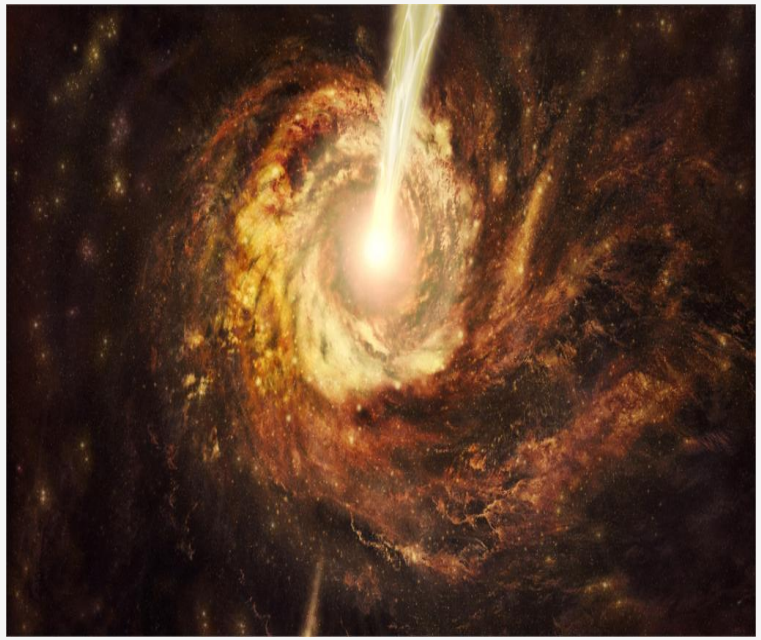


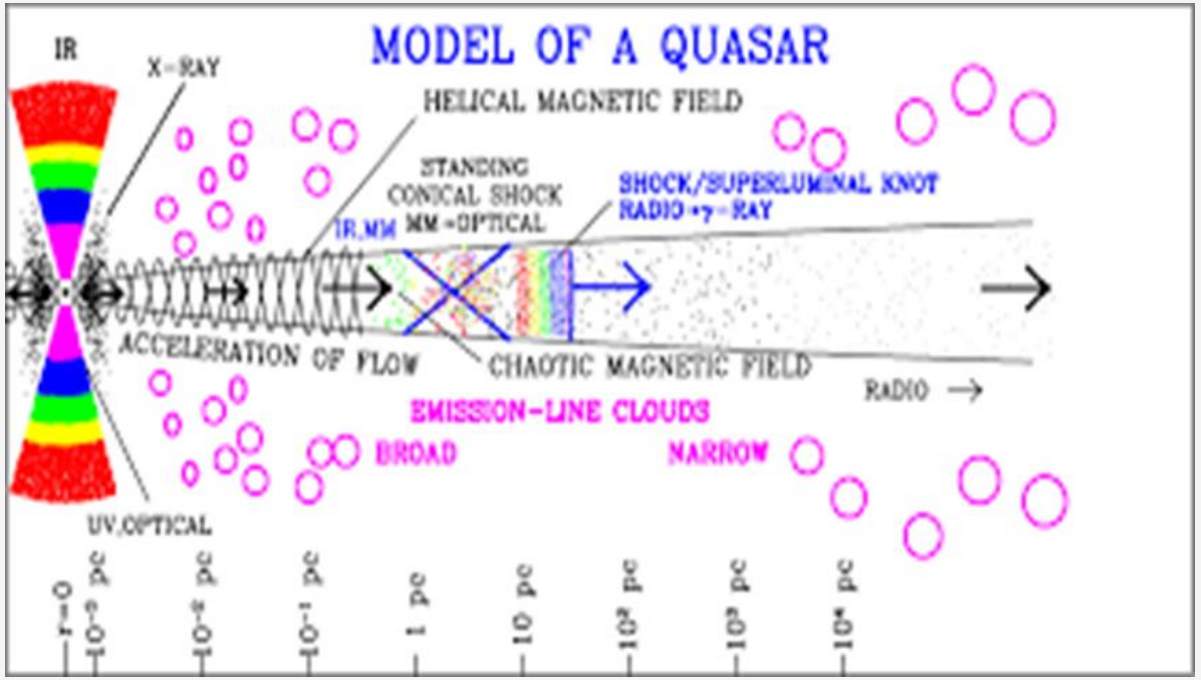
- Very High Energy gamma-rays: From the jet: synchrotron emission, inverse compton scattering
- Origin of the fast variability?
- Hadronic processes?
- Always the jet?



Blazars

- Fast variability seen in all types of VHE blazars (timescales down to minutes)
- Tempting to place the emission region close to the black hole
- But very difficult for VHE gamma-rays to escape

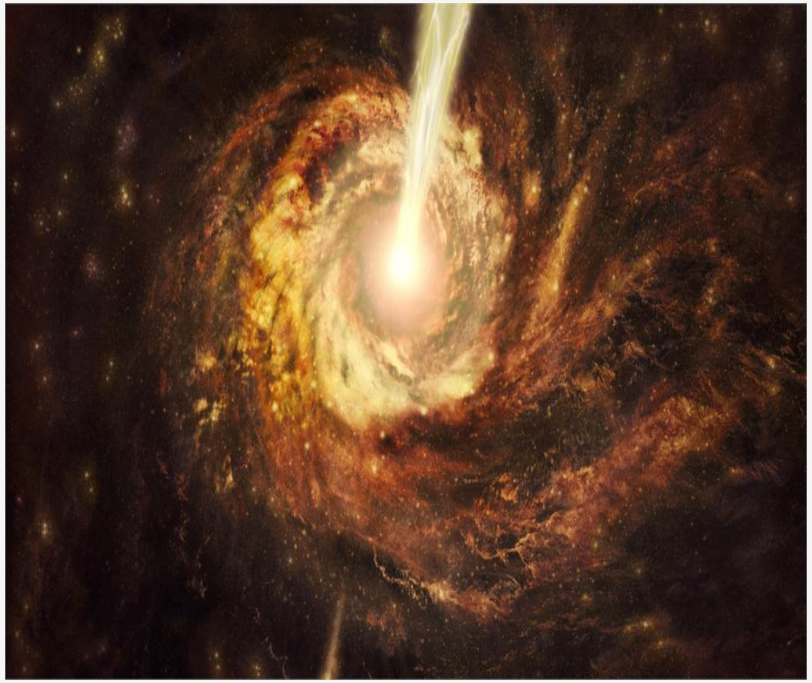




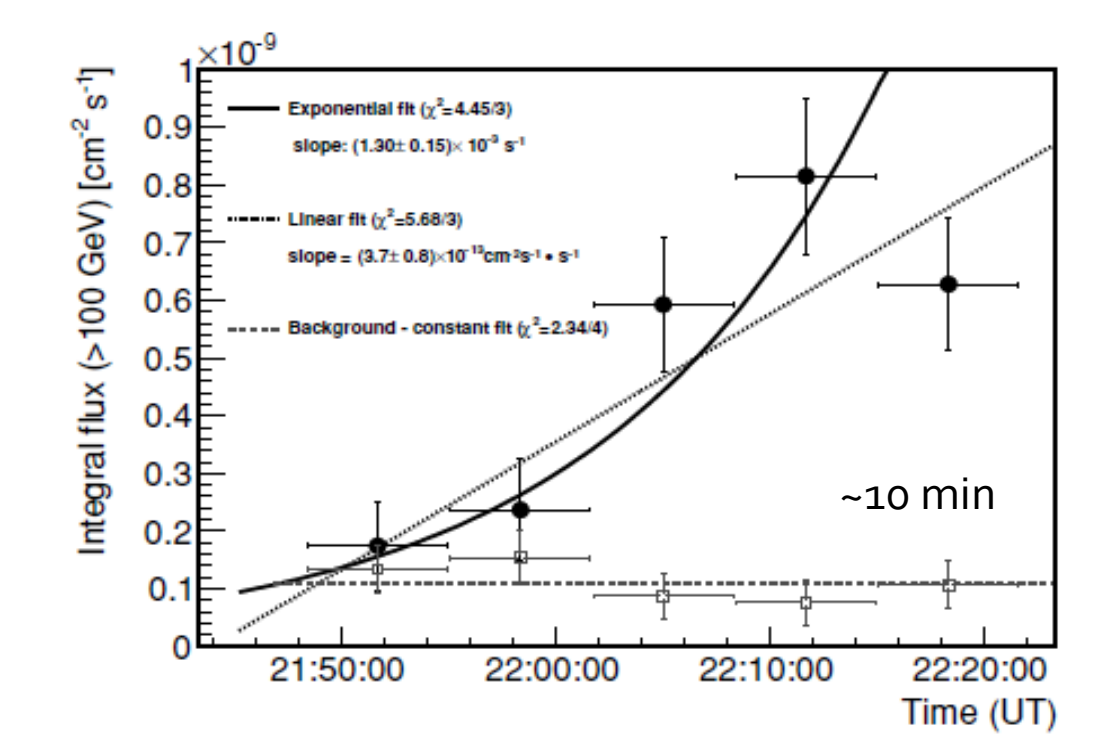
Blazars

Many possible models:

- strong recollimation of the jet
- very compact region embedded within large scale jets (spine-sheath, jets-in-jet, ring-of-fire)



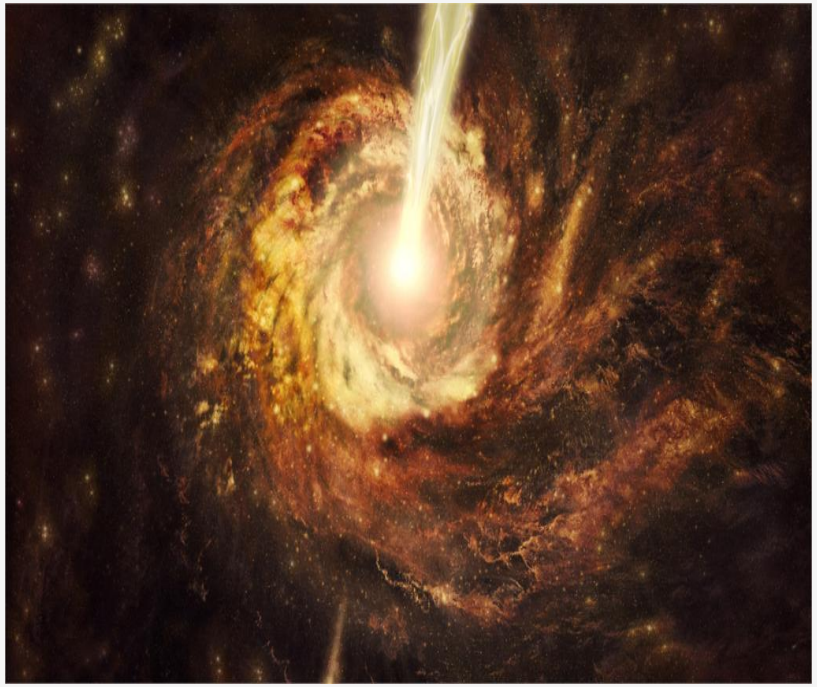
PKS1222+216

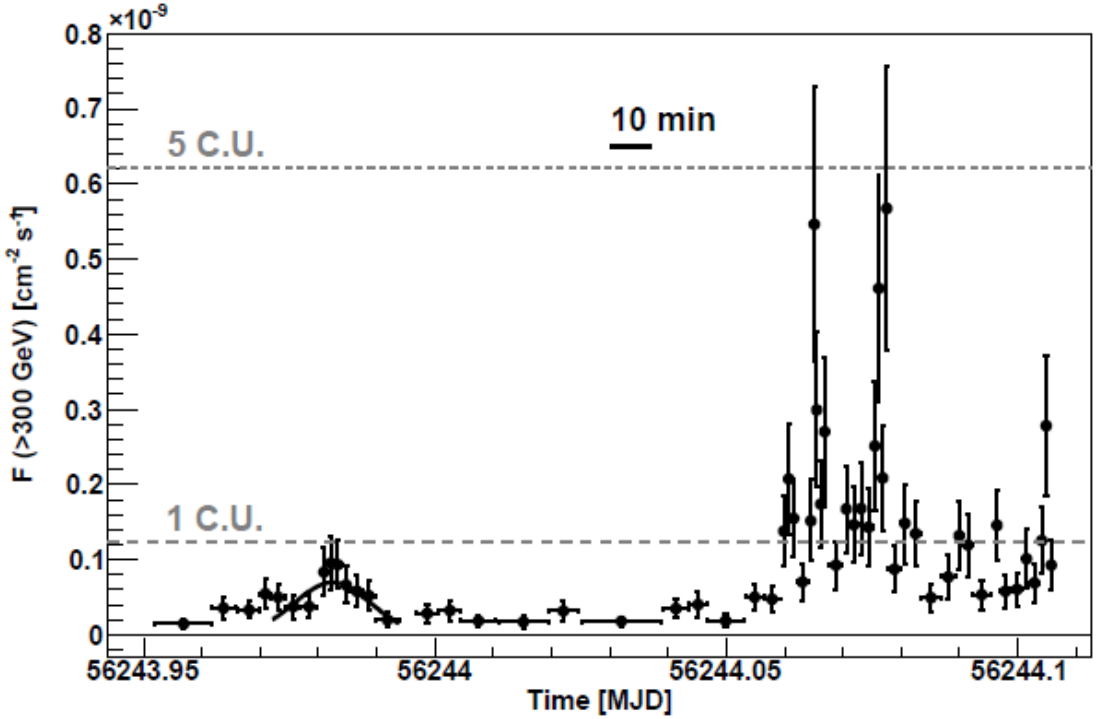


MAGIC Collaboration 2011

IC310

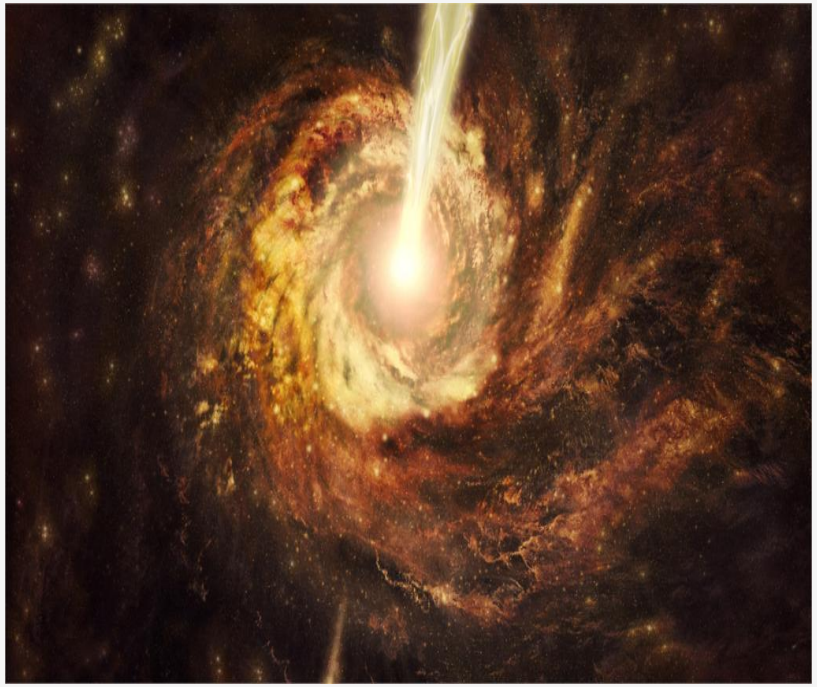
- In Perseus cluster; VLBA shows blazar like jet with viewing angle 10-20 degrees
- Variable in VHE band (MAGIC Collaboration 2014)
- Huge flare in Nov 2013



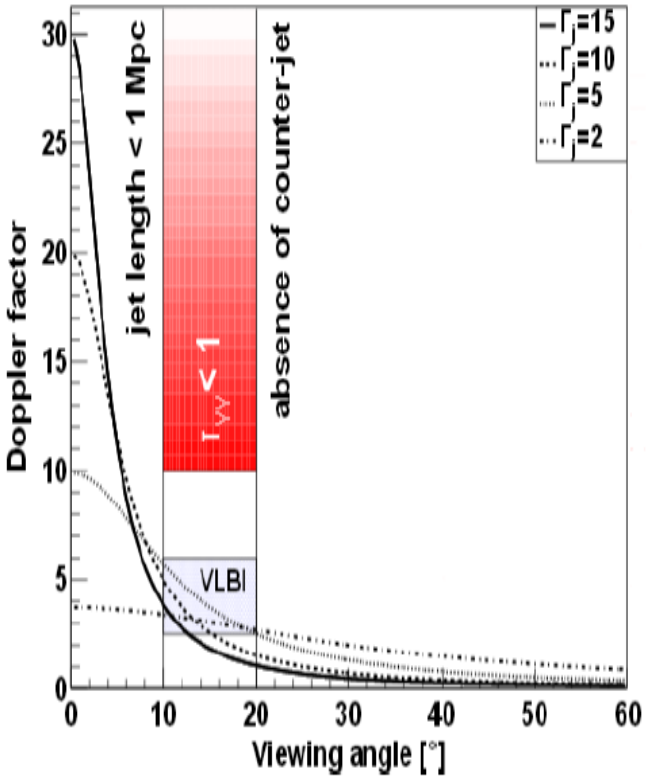


Aleksić et al. 2014, *Science*

IC 310



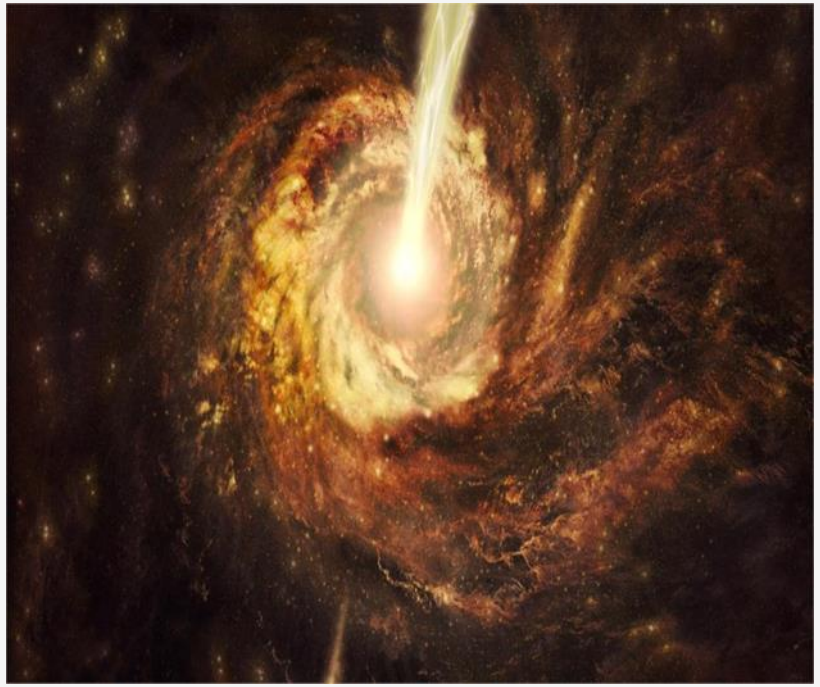
- $R < \delta c \tau_{\rm var} = \delta \cdot 0.2 \cdot R_{\rm G}$ (for 4.8 min, $M_{\rm BH} = 3 \times 10^8 M_\odot$ Aleksić et al. 2014, *Science*)
- Opacity problems: typically solved by $\Gamma \sim 50$ (Begelman et al. 2008)
- Here: $\delta \gtrsim 10$ required
- Possible production mechanism:
  - Jets-in-jet models based on magnetic reconnection? Giannios et al. 2010
  - Or star/cloud-jet interaction? Bednarek & Protheroe 1997, Barkov et al. 2010/2012



Aleksić et al. 2014, *Science*

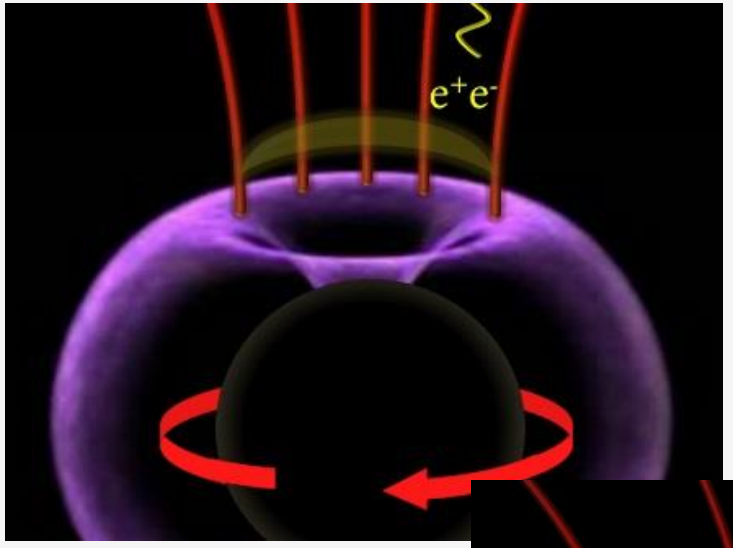
Total power of minijets exceeds the power of the jet?
One cloud produces single peak in LC?

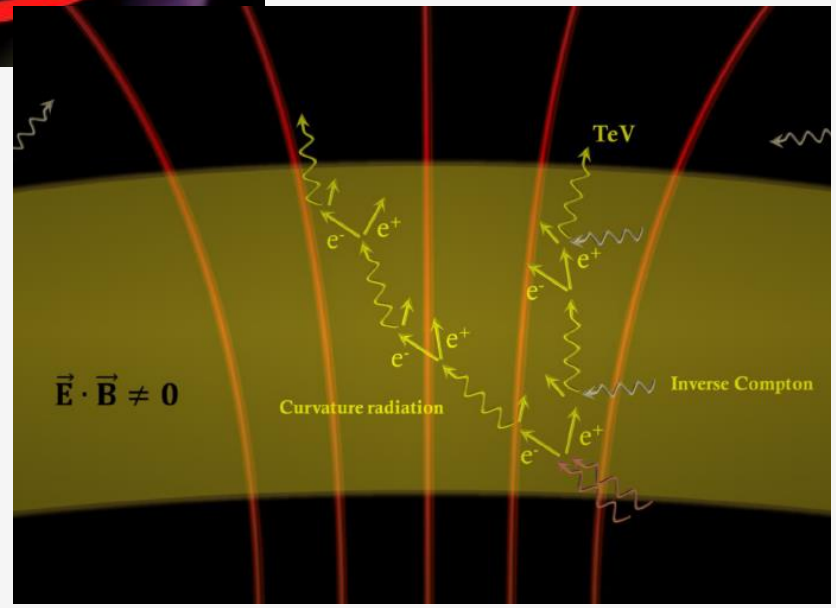
IC 310 Black hole lightning



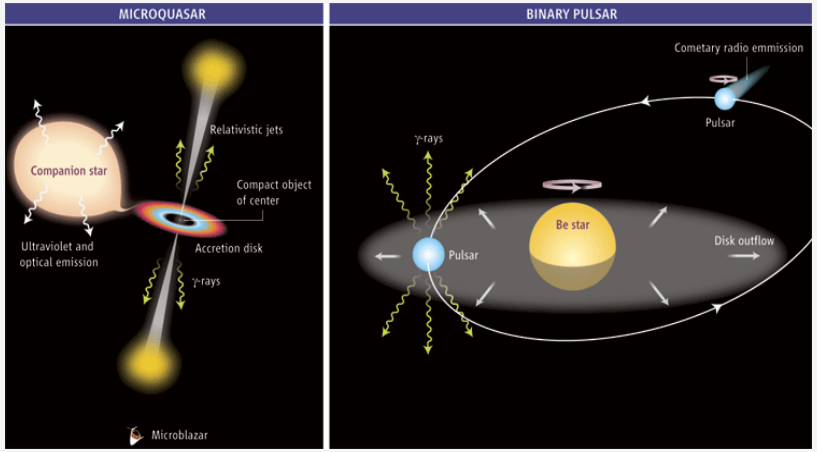
- Magnetospheric models:

  Curvature radiation, Inverse Compton





Microquasars



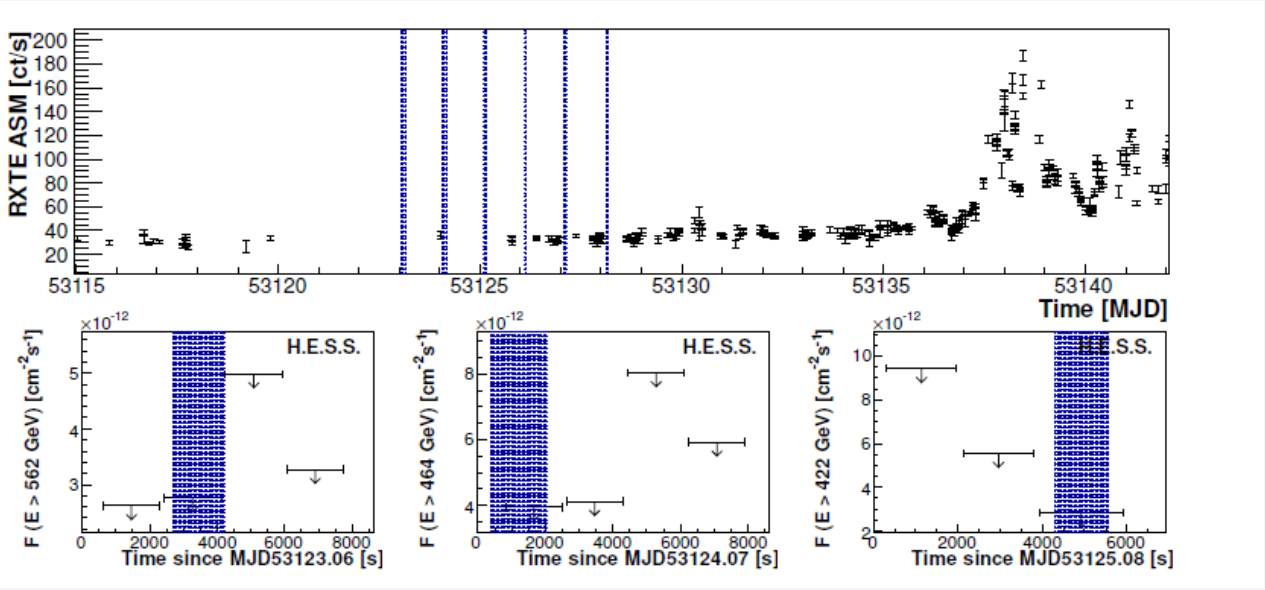
- Detections of VHE gamma-rays from LS5039 and LSI +61 303 (Aharonian et al., Science 309, 746 (2005), Albert et al. Science 312, 5781 (2006))
- Periodic emission, later observations favored binary pulsar model
- Observations of Cyg X-1 and Cyg X-3: no detection of VHE gamma-rays
- Observations of GRS 1915+105, Circinus X-1, V4641: no detection of VHE gamma-rays

Microquasars

Why dont we see them in the VHE gamma-rays?

They dont emit gamma-rays?

Observational bias?



HESS Collaboration, 2016, 1607.04613

Fermi (>100MeV) sees Cyg X-3 (variable emission) and now Cyg X-1, strong correlation of gamma excess with X-ray state: **the jet**

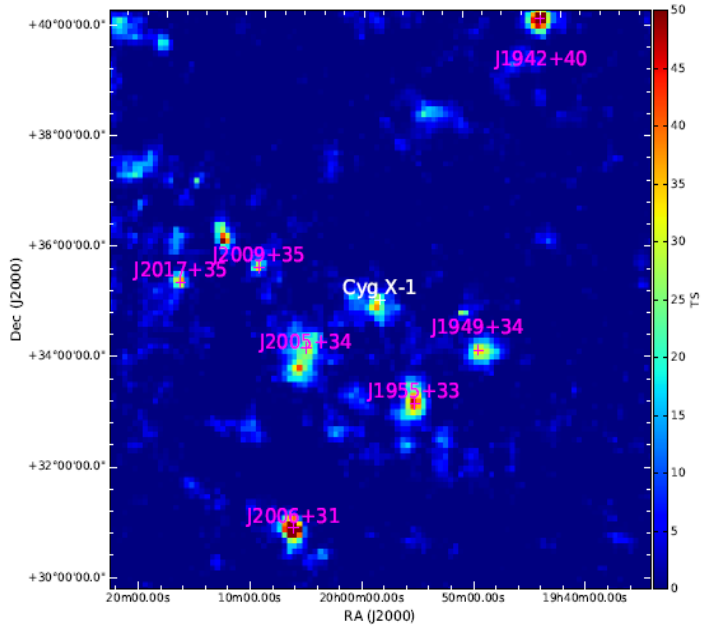


Fig. 2. 5° × 5° TS map centered at the nominal position of Cygnus X-1 above 1 GeV obtained when including only the 3FGL sources in the background model.

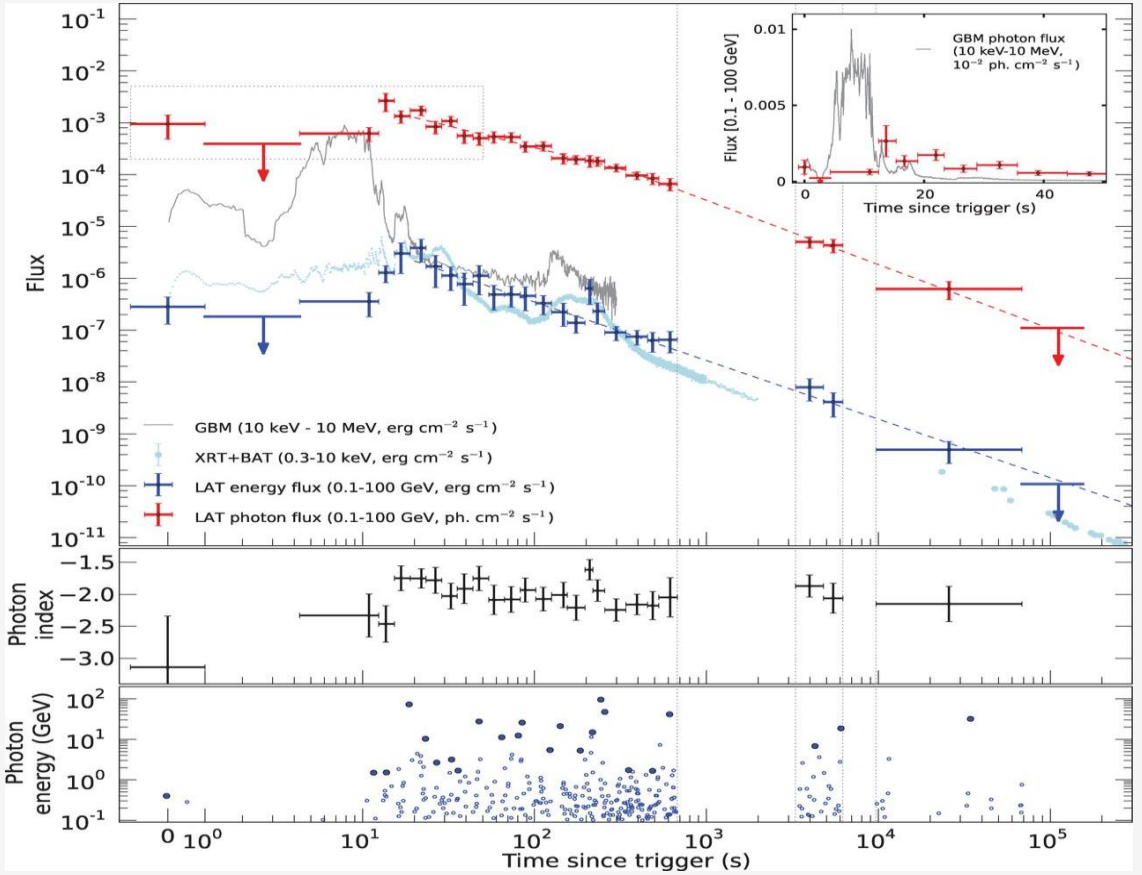
Zanin et al. 2016, 1605.05914

Gamma-ray bursts

This afternoon

On prospects for CTA: S. Inoue on Friday

- Late time VHE emission from GRB's seen by Fermi
- LAT sees ~5/yr GRBs with photons >1GeV

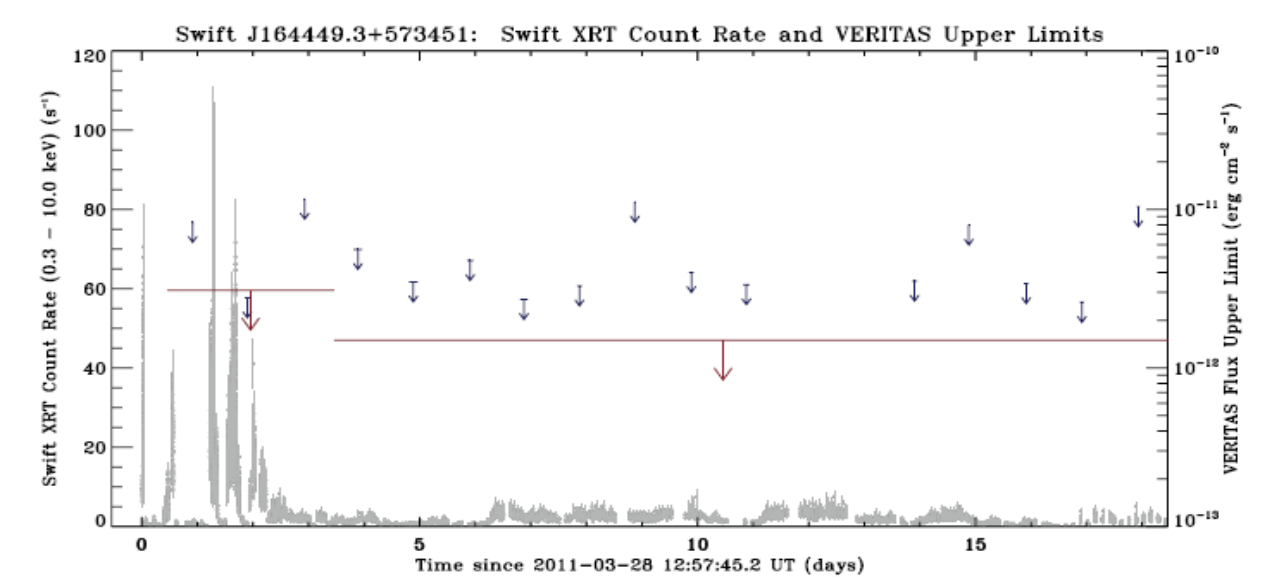


Fermi Collaboration 2014

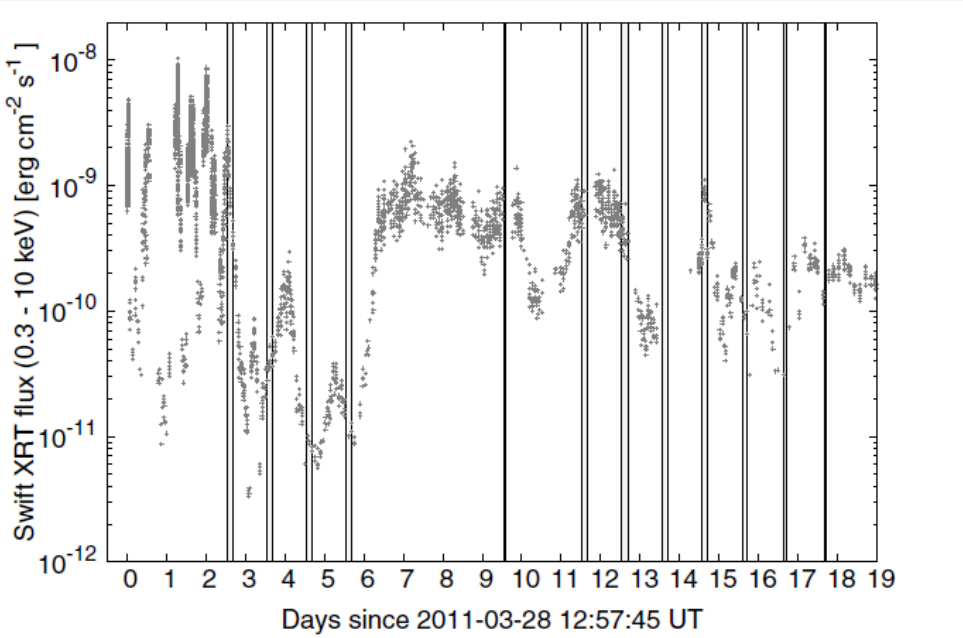
Tidal Disruption Events

- Swift 1644+57 is the only event that has been observed with IACTs
- Rather unlucky timing of the VHE observations
- The upperlimits not so constraining for the models

Talks on Tuesday



VERITAS Collaboration 2011



MAGIC Collaboration 2013

Similarity and Diversity

- Phenomenon related to black holes on Very High Energy gamma-rays are transient and/or extremely variable
- Huge observational challenge, many open questions
- Very High Energy emission mostly from the jets launched by the black holes
- But sometimes we see a lightning from the black hole?