X-ray astrophysics and CTA

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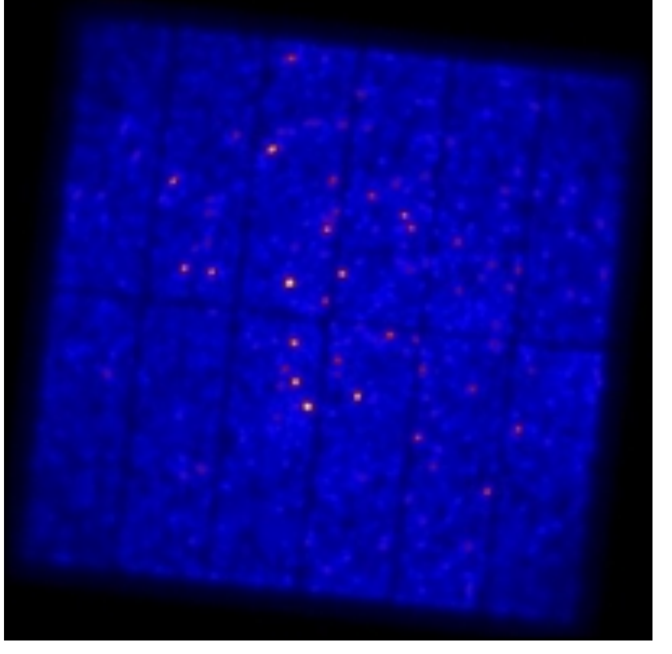
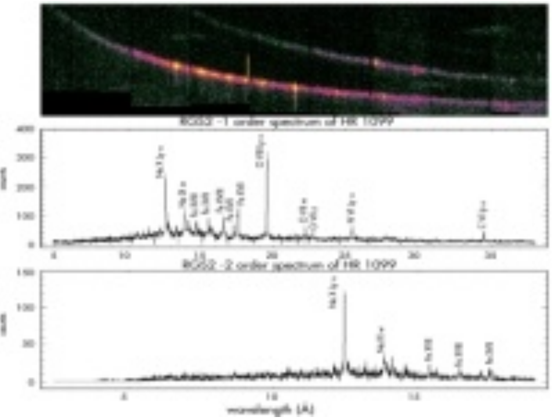
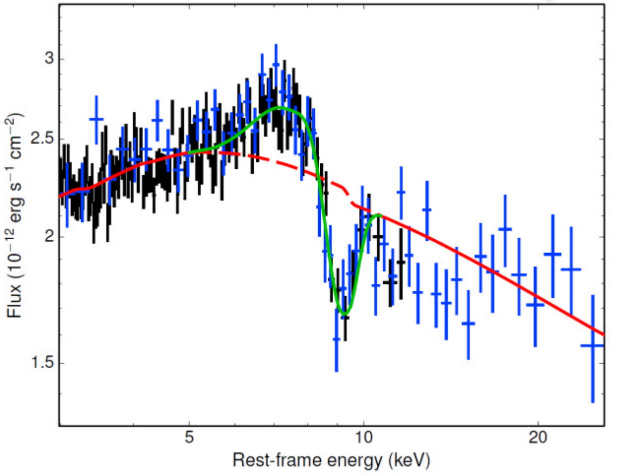
XMM-Newton: the most powerful X-ray satellite to date

Its high quality focusing mirrors (HEW~13") and battery of instruments enable it to achieve the following:

- Broad band imaging spectroscopy from 0.15 to 15 keV (0.8 - 80 Å)
- Investigate spectra of cosmic X-ray sources with a limiting flux of 10^{-15} erg cm^{-2} s^{-1}
- Perform sensitive medium-resolution spectroscopy with resolving powers between 150 and 800 over the wavelength band 5 - 35 Å (0.35 – 2.5 keV)
- Simultaneous sensitive coverage of the wavelength band 1700 to 6500 Å through a dedicated co-aligned optical monitor



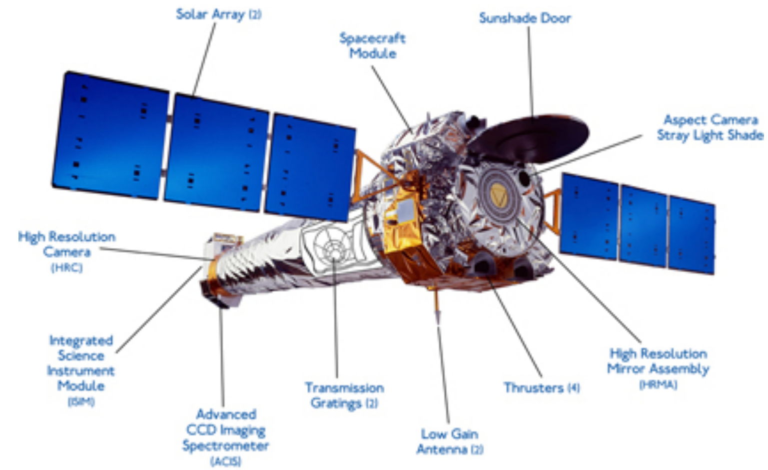


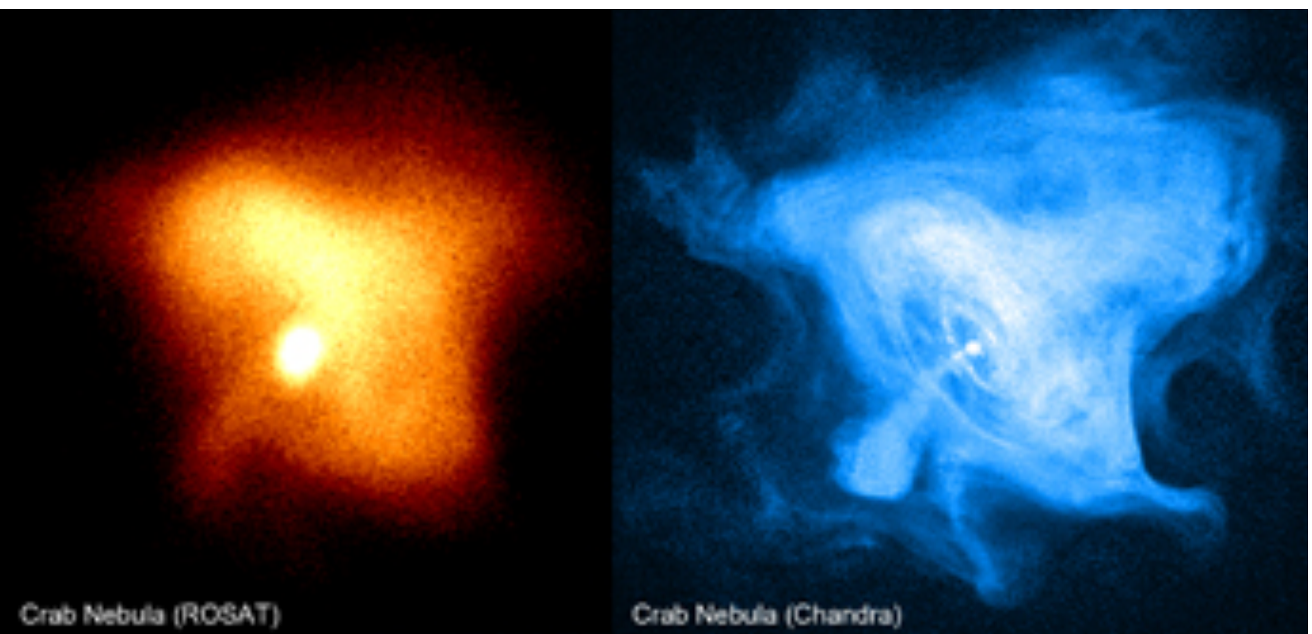


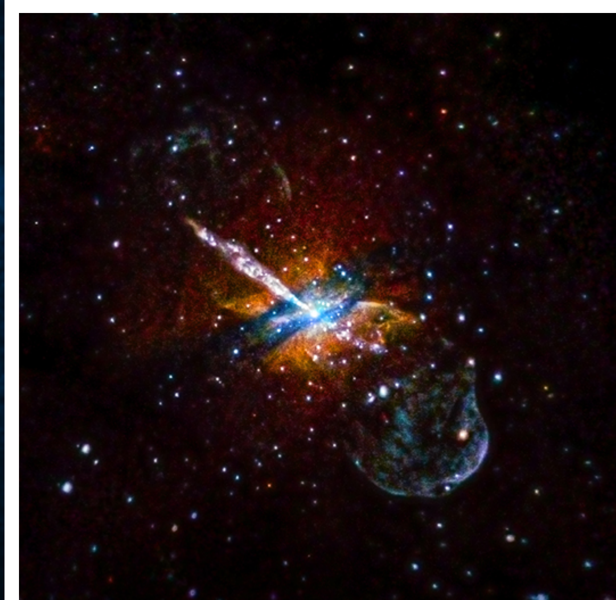
Chandra: the best X-ray imaging satellite to date

Chandra is sensitive essentially in the same energy band (0.2-10 keV) than XMM-Newton, with similar energy resolution (using CCD and grating), but:

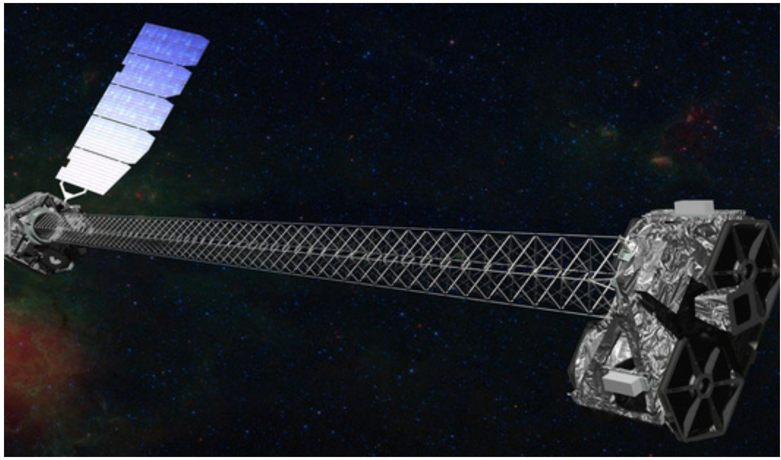
- Much better imaging capabilities (0.5 arcsec resolution)
- Less effective area





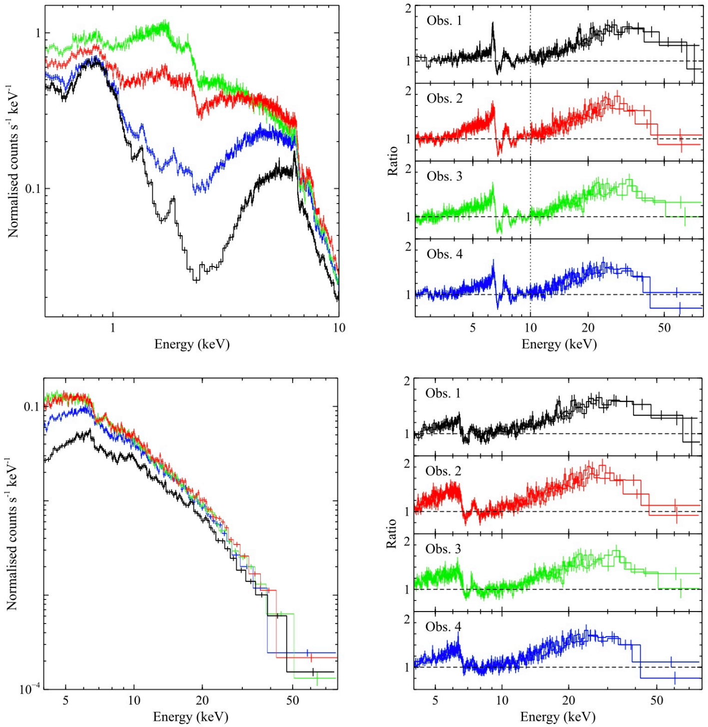


Nustar: the first hard-X-ray imaging satellite (3-80 keV)

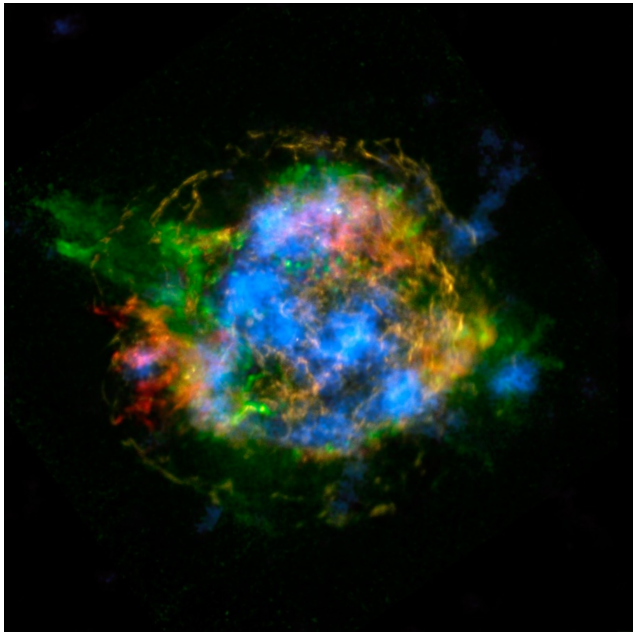


Nustar is sensitive in the energy band 3-80 keV with medium spectral resolution capabilities and an imaging capability with a spatial resolution of ~1 arcmin and energy resolution $\Delta E/E = 0.5$

Sensitivity (6–10 keV) 2×10^{-15} erg cm^{-2} s^{-1}
Sensitivity (10–30 keV) 1×10^{-14} erg cm^{-2} s^{-1}



Walton et al. 2014

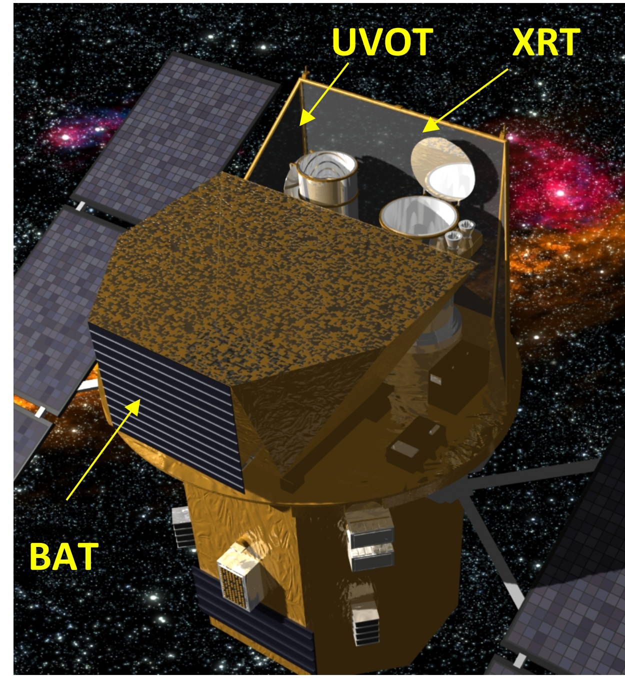


Swift – Time Domain Observatory

3 instruments, each with:

lightcurve, images, spectra

Rapid slewing spacecraft

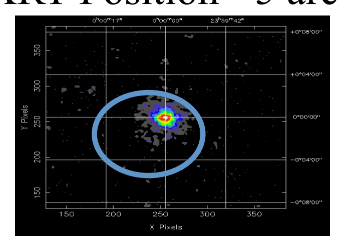


Instruments	energy band	pos. accuracy	effective area
BAT (2 sr):	15-300 keV,	2 arcmin,	5000 cm^2
XRT:	0.3-10 keV,	2 arcsec,	120 cm^2
UVOT:	170-600 nm,	<1 arcsec,	30 cm mirror

BAT Position - 2 arcmin

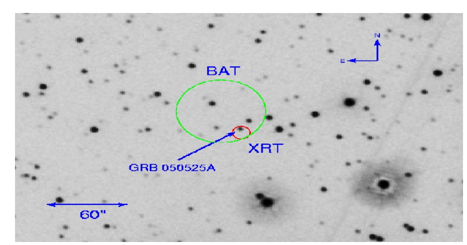
T<10 sec

XRT Position - 5 arcsec



T<90 sec

UVOT Position - < 1 arcsec

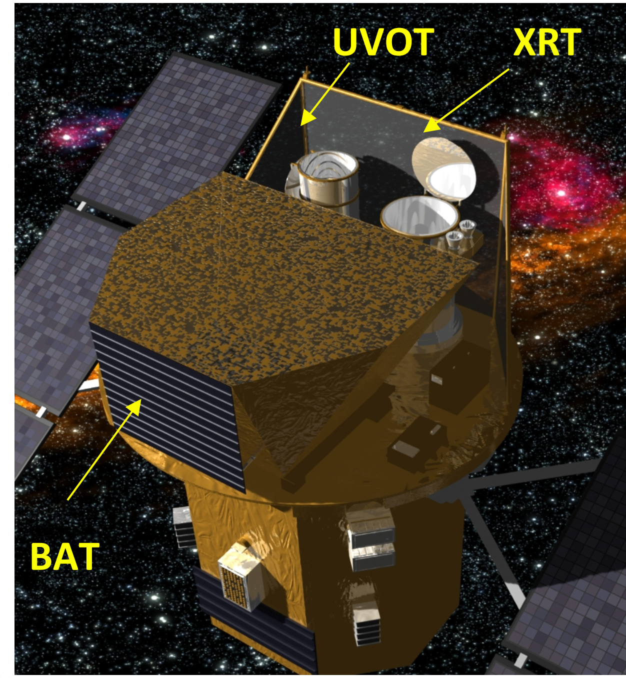


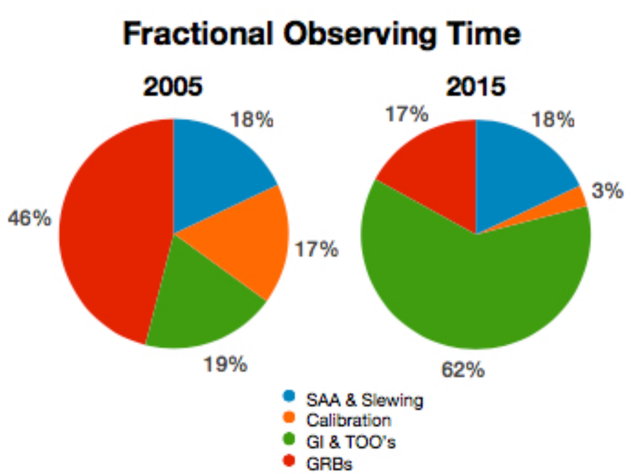
T<2 min

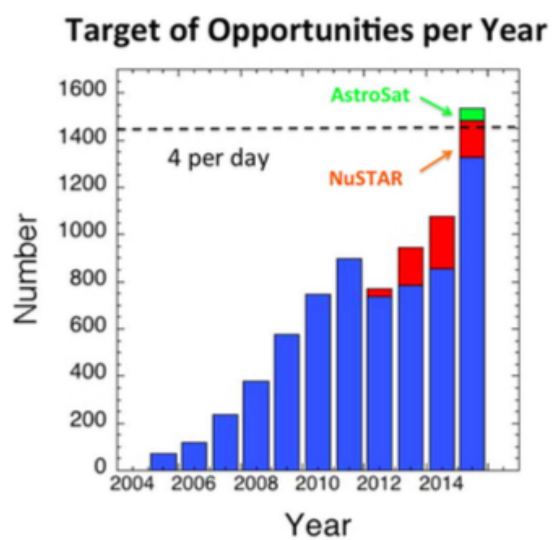
Swift – Time Domain Observatory

- **Gamma Ray Bursts**
  - >1000 GRB (10% short), most with arcsec positions
  - Hard X-ray prompt detection
  - Multiwavelength rapid (100 s) follow-up

- **Non-GRBs**
  - >350 transients detected by BAT
  - >6000 Target of Opportunities
  - Multiwavelength rapid (1 hr) response
  - Joint observations with NuSTAR, Fermi, PTF,
  - ASASSN, Kepler, WISE, LCOGT, Pan-STARRS
  - Surveys with all instrument

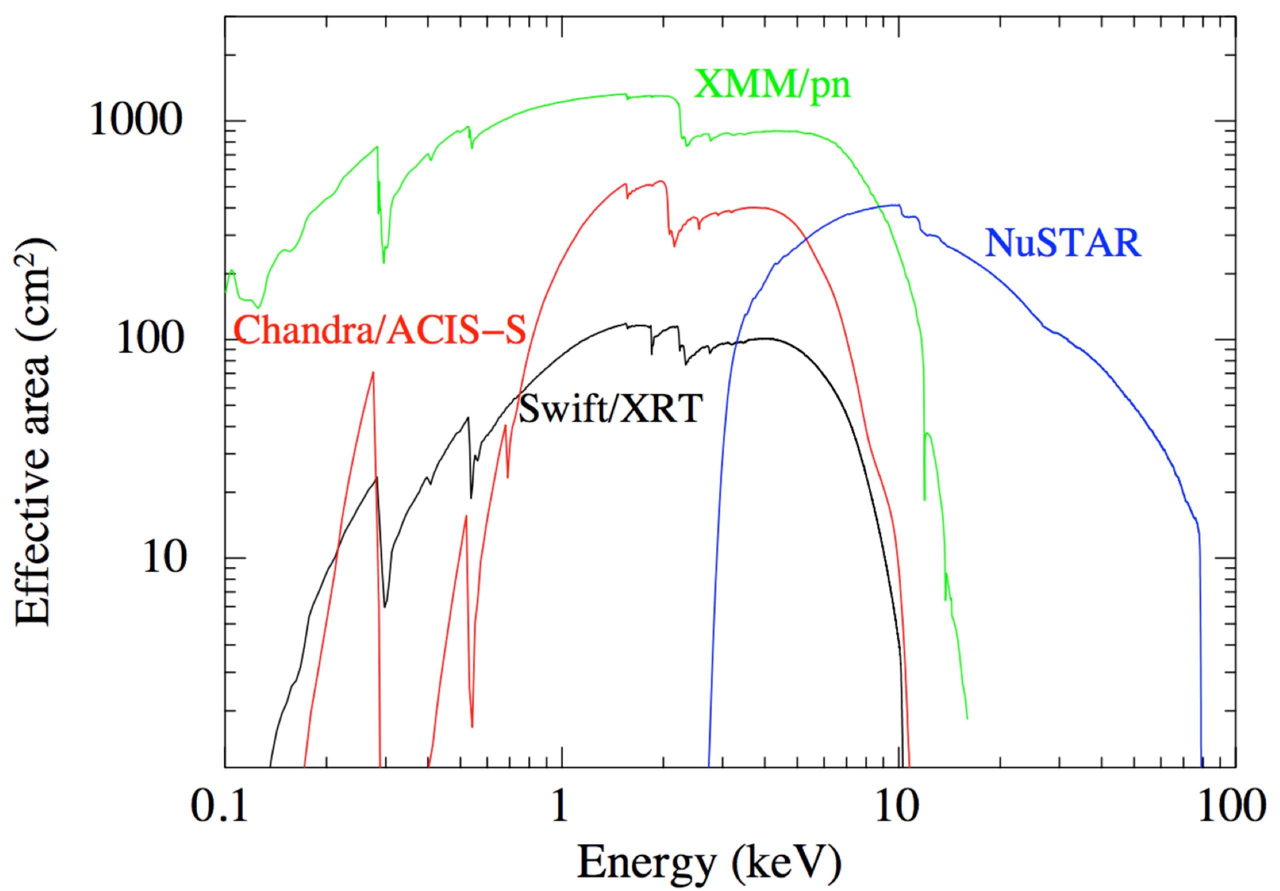






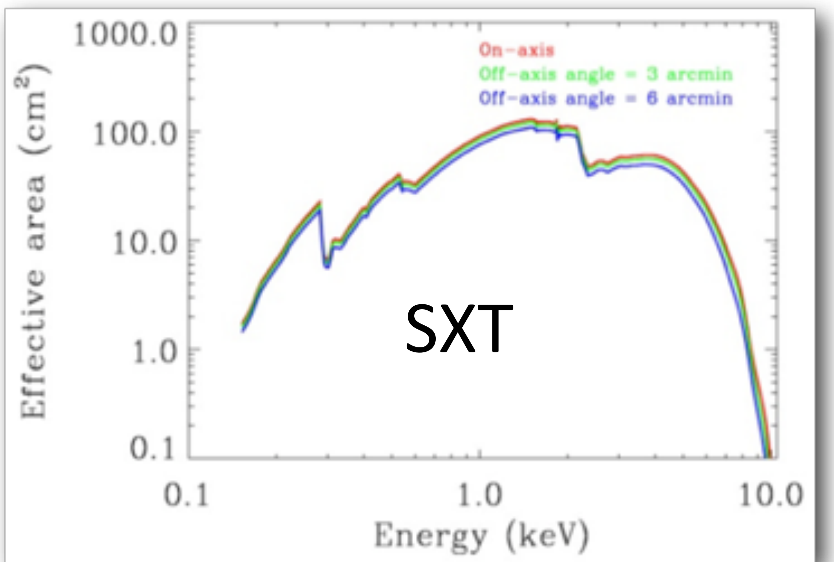
XMM-Newton, Chandra, Swift-XRT, Nustar

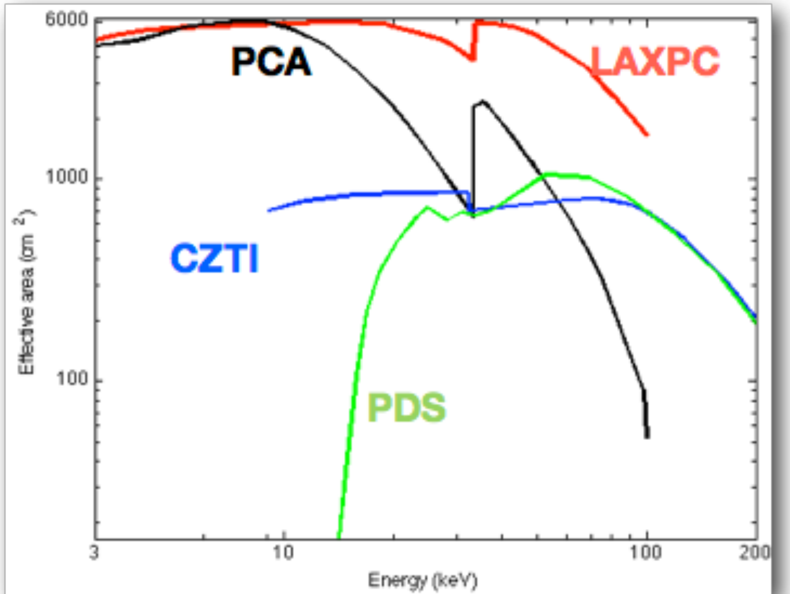
Effective area comparison



ASTROSAT

- **UVIT** 2 UV telescopes (38 cm, 130-550 nm)
- **SXT** Soft X Telescope (0.3-10 keV, ~100 cm^2 at 1.5 keV)
- **LAXPC** Large prop. Counter (3-80 keV, ~6000 cm^2)
- **CZTI** detector (10-100 keV, ~ 1000 cm^2)
- **SSM** All-sky monitor (2-10 keV, 10deg X 90deg, 24 mCrab 10 min)

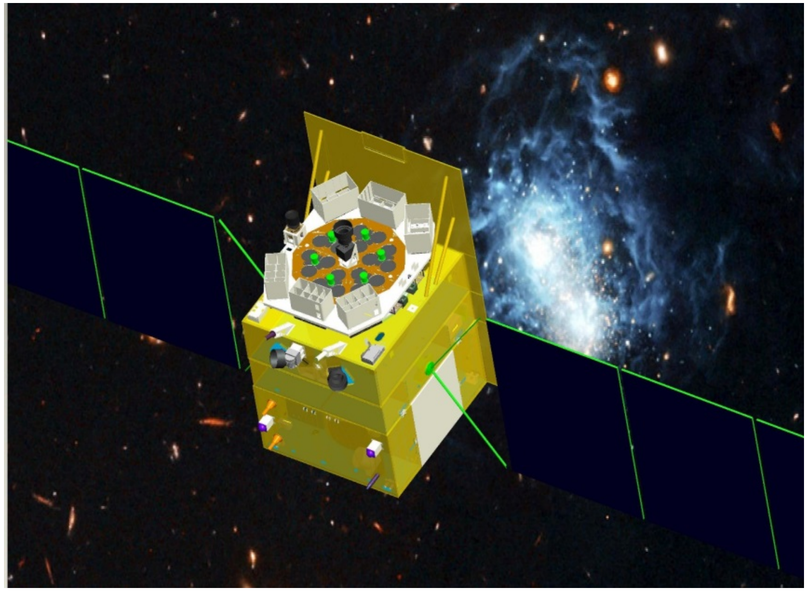




HXMT, MAXI & NICER

The Hard X-ray Modulation Telescope (HXMT) is China's first astronomical satellite

The main scientific objectives of HXMT are: scan the Galactic Plane to monitor transient sources, to study the dynamics and emission mechanism in strong gravitational or magnetic fields, to find and study GRBs



Three payloads:

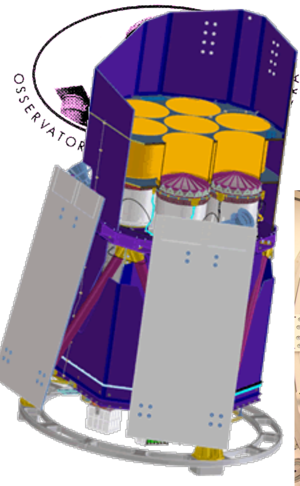
high energy X-ray telescope (20-250 keV, 5100 cm^2)
medium energy X-ray telescope (5-30 keV, 952 cm^2)
low energy X-ray telescope (1-15 keV, 384 cm^2)

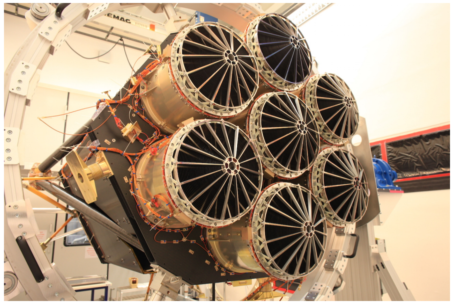
MAXI: monitoring X-ray transient in the 2-20 keV band from the space station

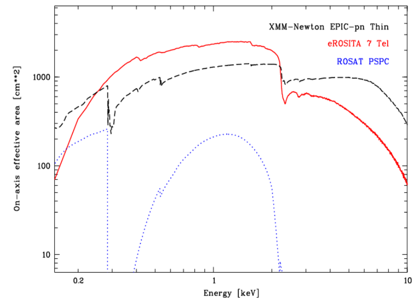
NICER: Neutron star Interior Composition Explorer, will provide high-precision measurements of neutron stars in the 0.2-12 keV band

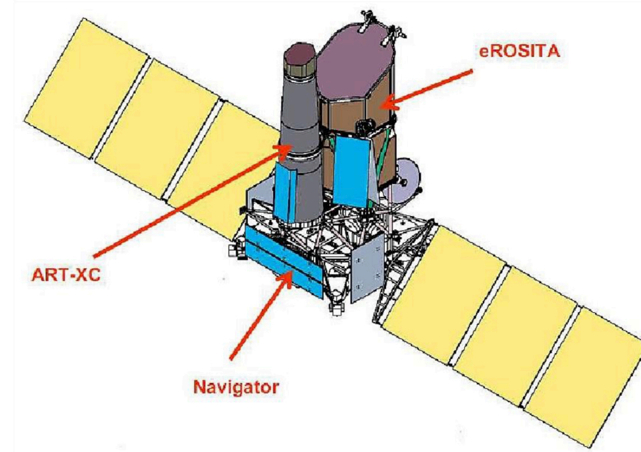
Spectrum-X-Gamma - eROSITA

To be launched in 2018

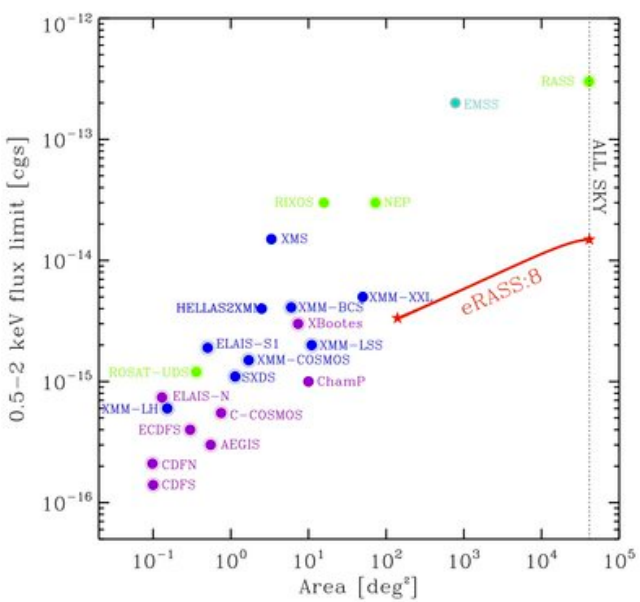








- 4 years all sky survey => ~3 million objects
- ~3.5 years of pointing observation



eROSITA

Energy range: 0.3-10 keV

Field of view: 1° diameter

Image quality: 16” HEW

Energy resolution 138 eV at 6 keV (pn-CCD)

ART-XC

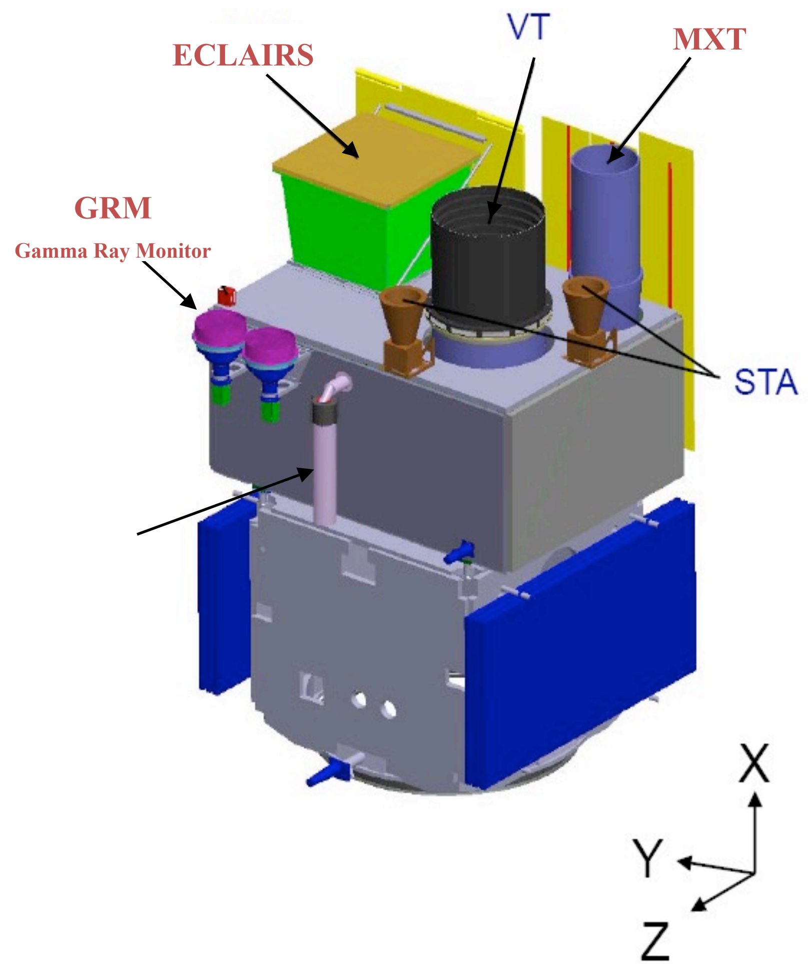
Table 1. Key parameters of ART-XC.

Energy range	6 – 30 keV
Field of view	∅34′
On-axis angular resolution	<1′
Energy resolution	12% at 14 keV
Effective area for pointed observations	450 cm^2 @ 8 keV
Grasp for survey	>40 deg^2 cm^2 @ 8 keV
Time resolution	1 ms

SVOM Satellite

To be launched in 2021?

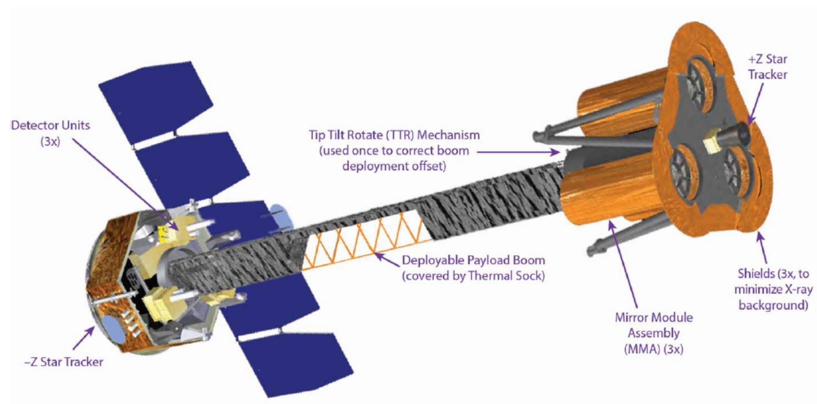
- Anti-Sun pointing and lower trigger energy range than Swift/BAT
- ECLAIRS (4-300keV)
- GRM (50keV-5MeV)
- VT (400-650nm + 650-950nm)
- MXT (0.3-7keV)
- Find nearby X-ray bright, low L GRBs (SN and GW connection) and high-z GRBs



IXPE

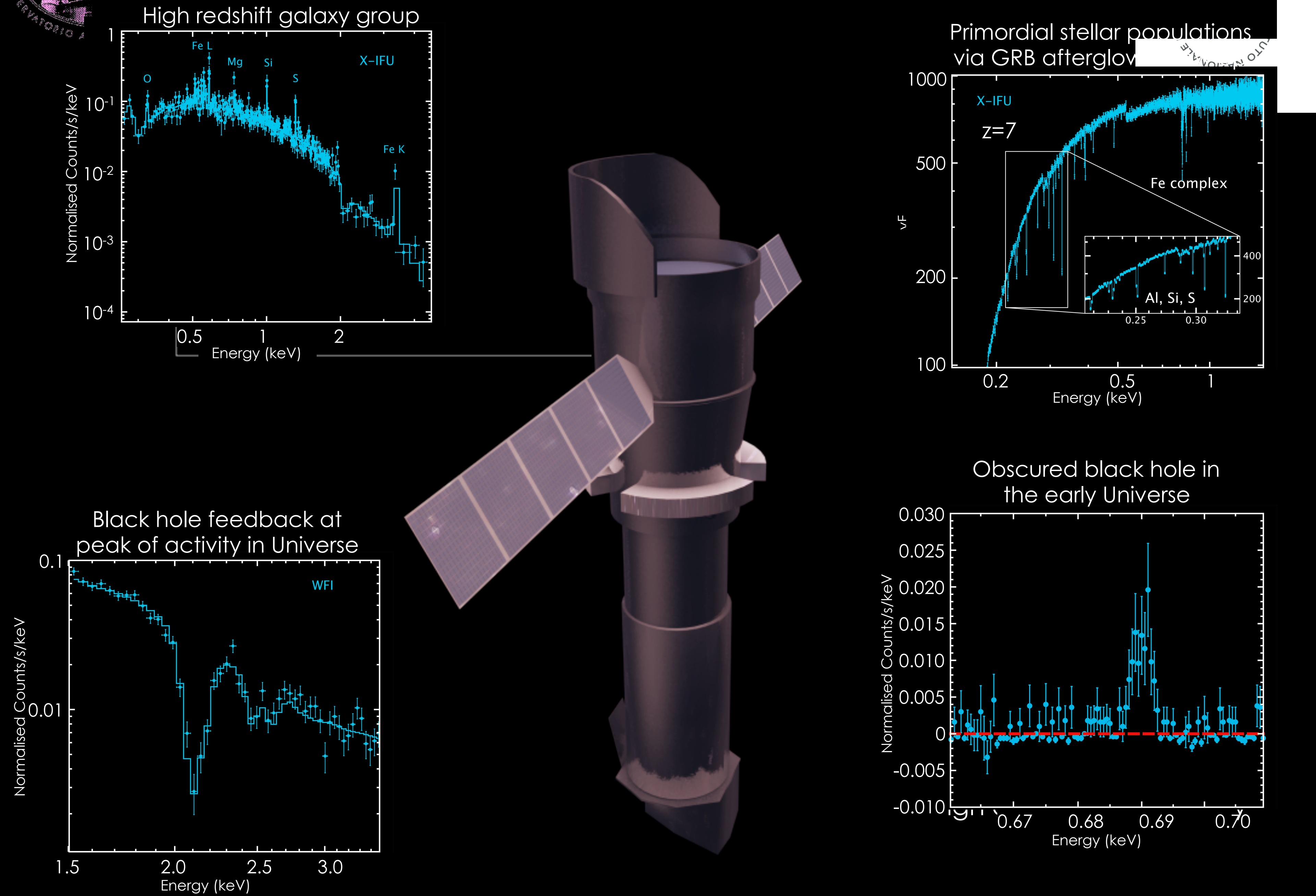
To be launched in 2021?

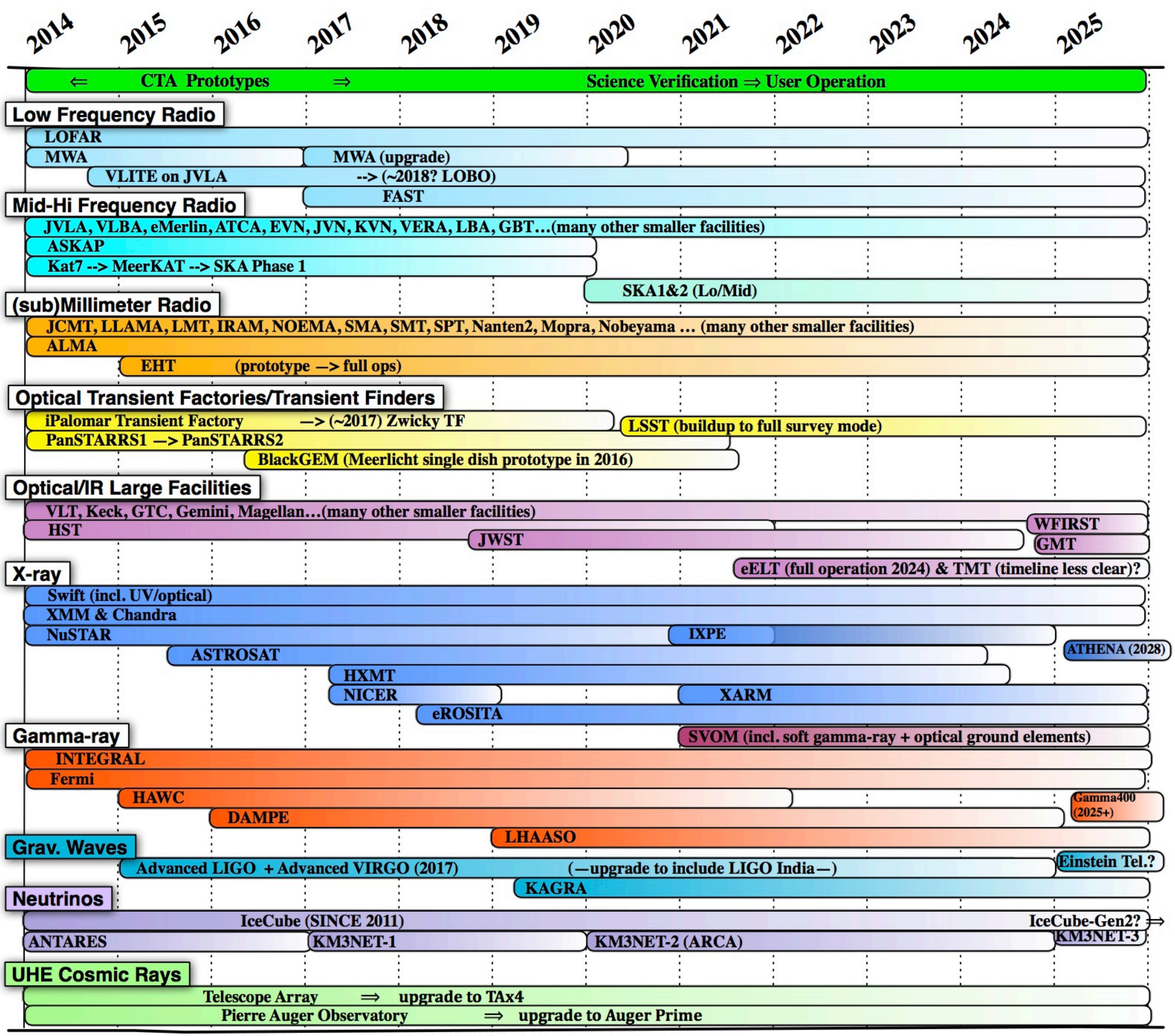
Polarisation sensitivity	1.8 % MDP for 2x10^{-10} erg/s cm^2 (10 mCrab) in 300 ks (CBE)
Spurious polarization	<0.3 %
Number of Telescopes	3
Angular resolution	28'' (CBE)
Field of View	12.9x12.9 $arcmin^2$
Focal Length	4 meters
Total Shell length	600 mm
Range Shell Diameter	24 shells, 272-162 mm
Range of thickness	0.16-0.26 mm
Effective area at 3 keV	854 cm^2 (three telescopes)
Spectral resolution	16% @ 5.9 keV (point source)
Timing	Resolution <8 μs
	Accuracy 150 μs
Operational phase	2 yr + extension (max 1 yr)
Energy range	2-8 keV
Background (req)	5x10^{-3} c/s/cm2/keV/det
Sky coverage, Orbit	50 %, 540 (0^o)



IXPE will open for the first time the X-ray polarimetry window: emission mechanism, geometry, orientation

The Athena Observatory

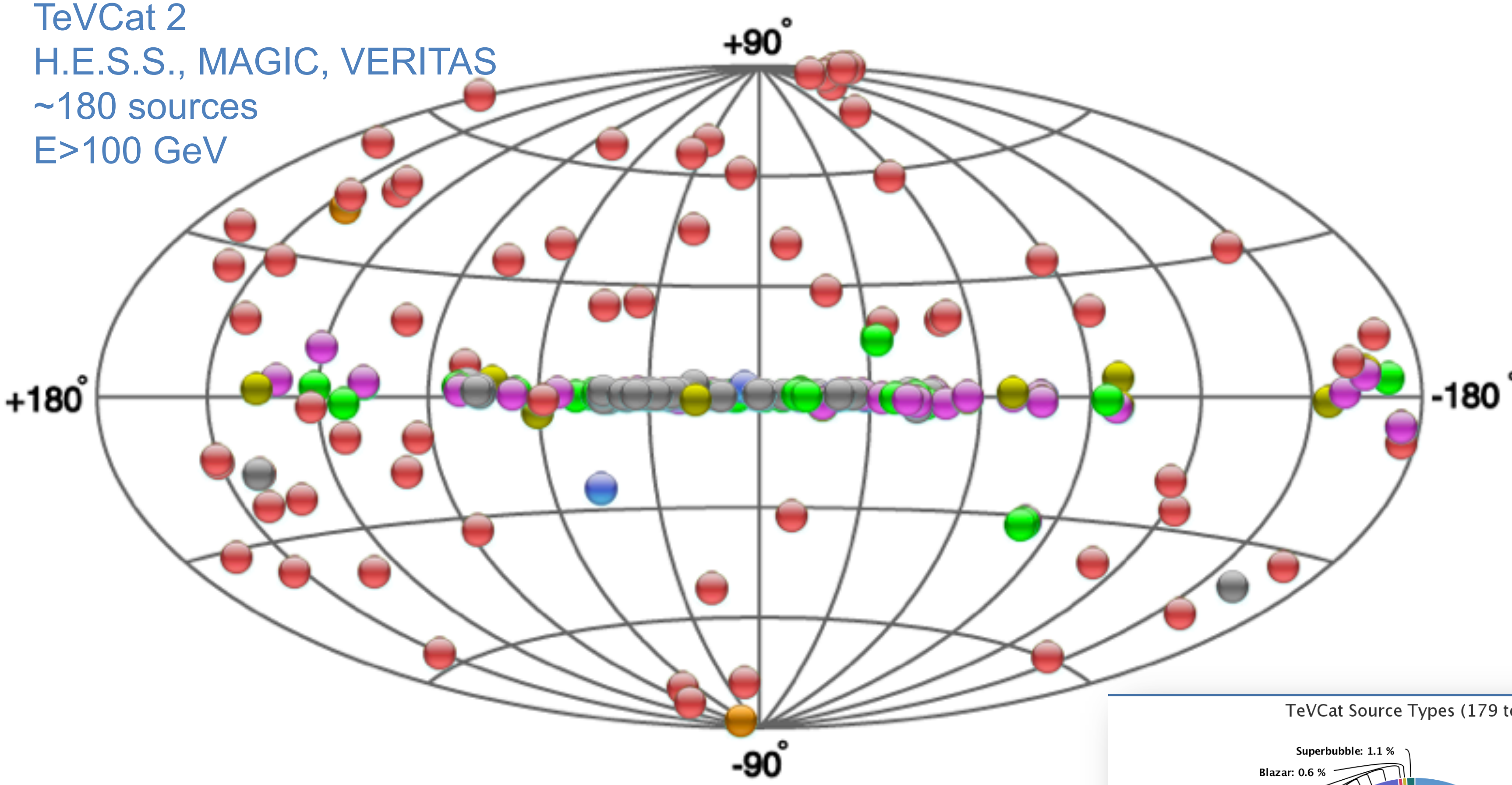


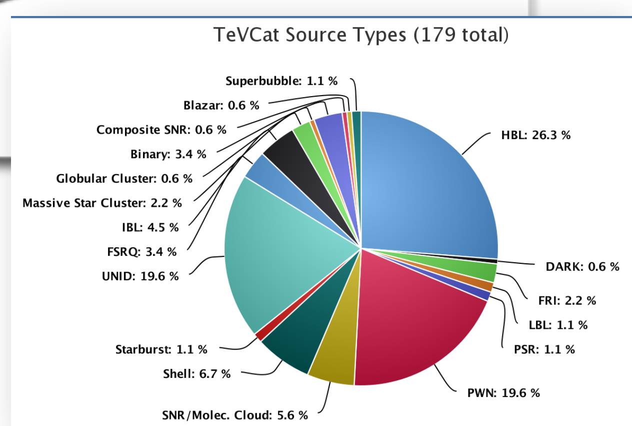


CTA consortium

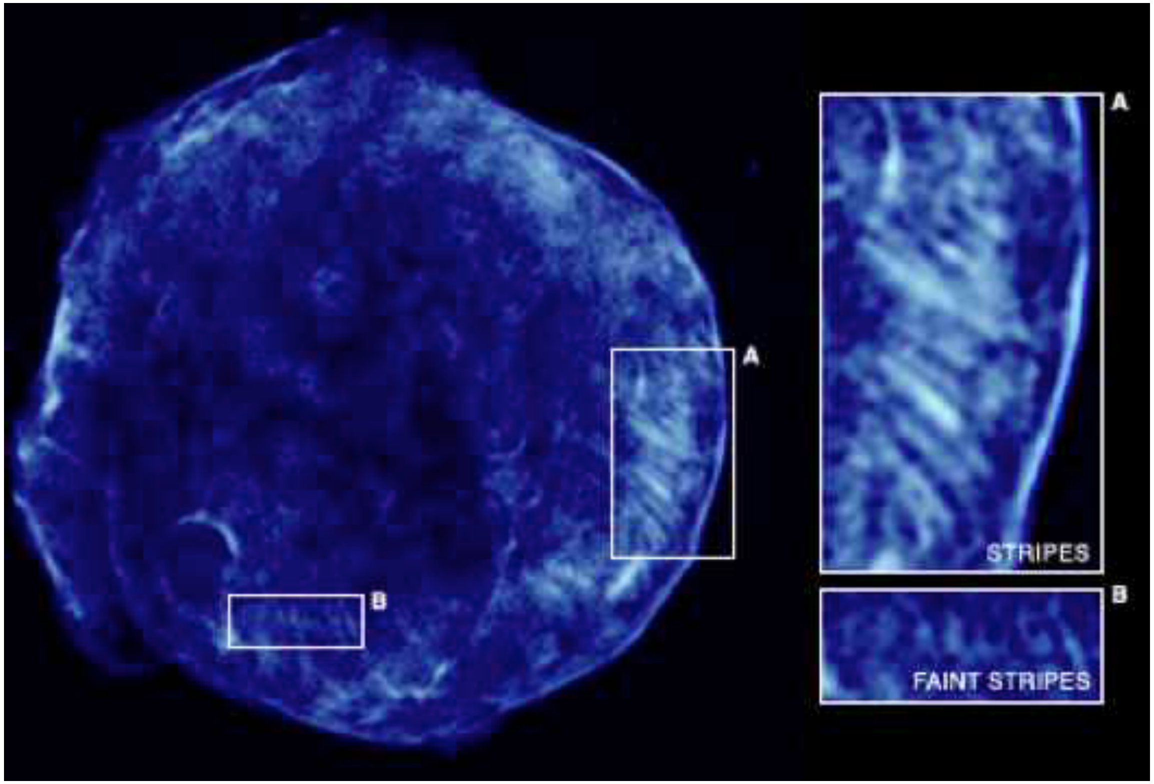
The TeV sky

TeVCat 2
H.E.S.S., MAGIC, VERITAS
~180 sources
E>100 GeV





Young SNR: most probable candidates for being Cosmic Rays accelerators

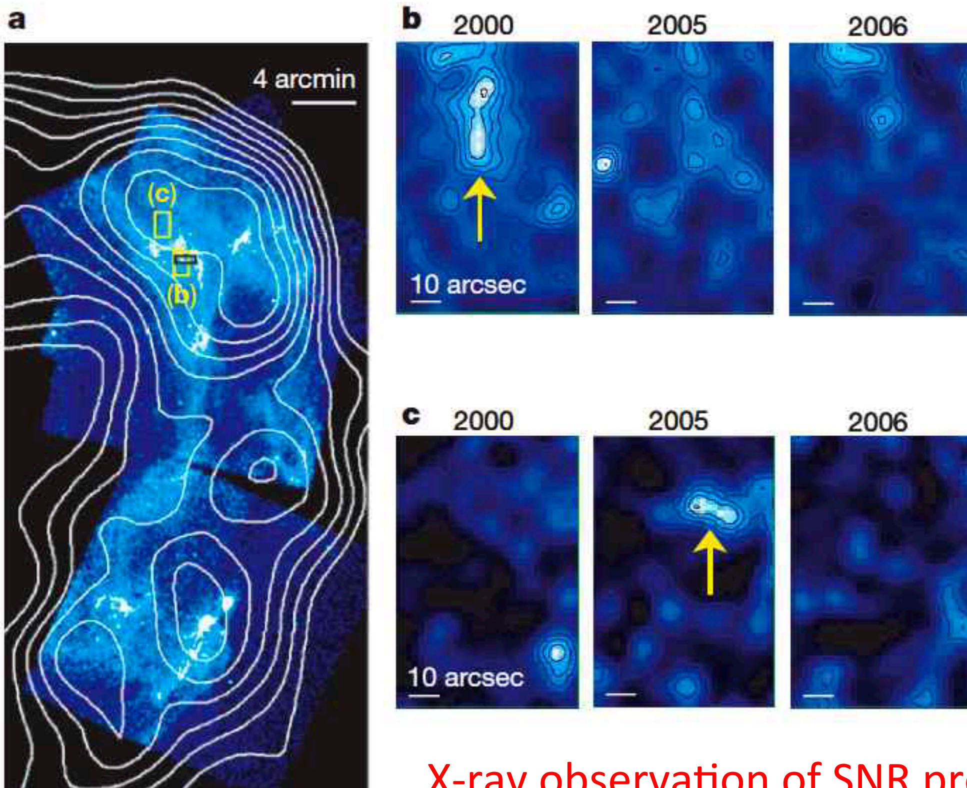


Deep Chandra 4-6 keV image of Tycho's SNR (Eriksen et al. 2011)

X-ray observation of SNR provide key parameters on the emitting plasma

In young SNR both thermal and non-thermal X-ray emission can be observed. The latter due to synchrotron radiation by VHE electrons accelerated at strong shock front. Synchrotron-emitting X-ray filaments provide key information about particle acceleration and magnetic field amplification processes

Young SNR: most probable candidates for being Cosmic Rays accelerators



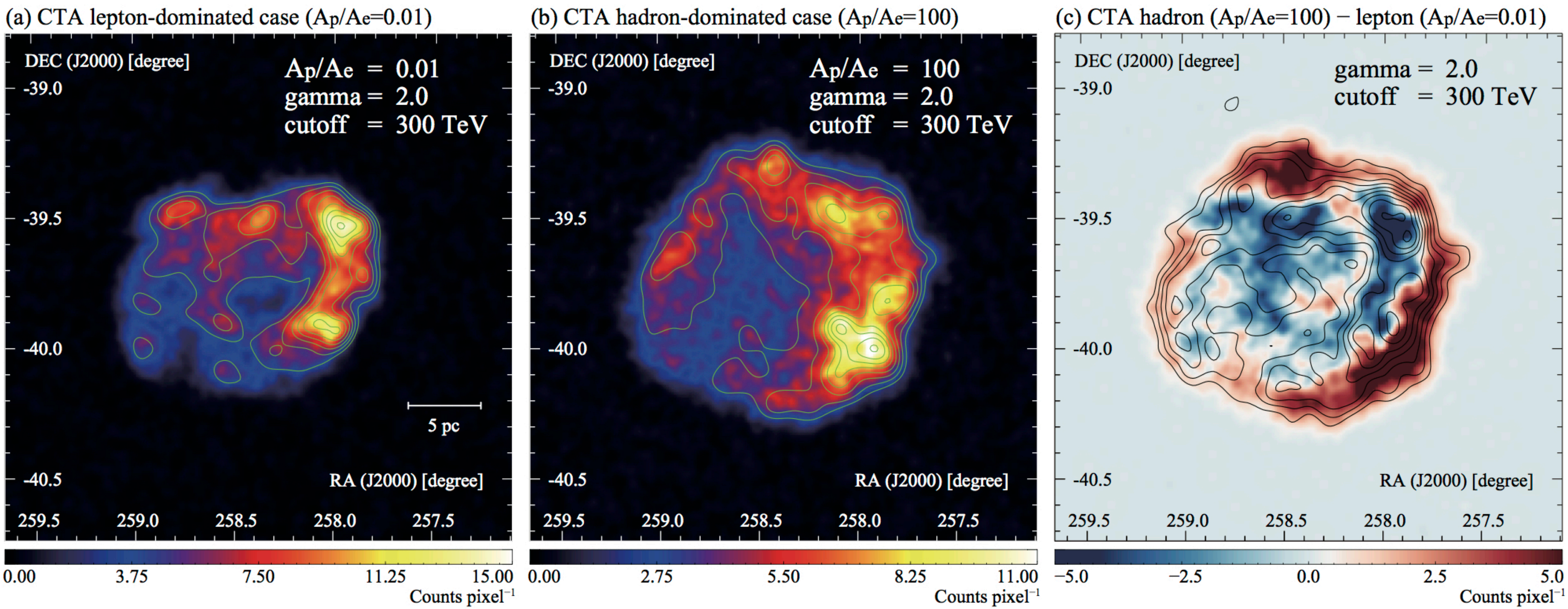
Chandra image of RX J1713-39 in the band 1-2.5 keV (panel **a** and **b**) or 3.5-6 KeV (panel **c**). In panel **a** the HESS contour >0.7 TeV are overlaid. Panel **b** and **c** show time variability of X-ray emission (Uchiyama et al. 2007)

X-ray observation of SNR provide key parameters on the emitting plasma

Rapid X-ray variability indicates that:

- the X-rays are produced by ultrarelativistic electrons through a synchrotron process
- electron acceleration does indeed take place in a strongly magnetized environment, indicating amplification of **B** by more than 100
- The X-ray variability also implies that we have witnessed the ongoing shock-acceleration of electrons in real time

Young SNR: most probable candidates for being Cosmic Rays accelerators



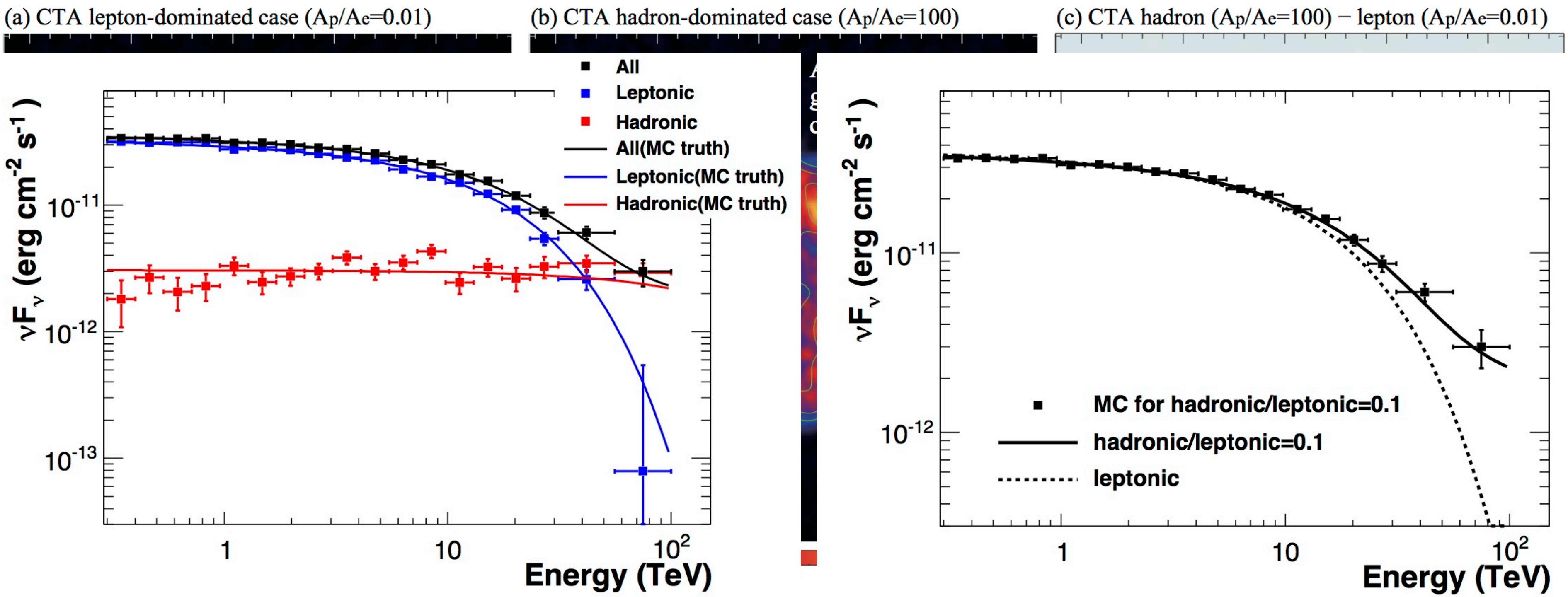
Acero et al. 2017

VHE gamma rays trace the non-thermal X-ray emission

Disentangle the emission mechanism of gamma-rays through information provided by their spatial distribution, spectra and time variations:

- Leptonic: low-energy photons up-scatetred by high-energy electrons
- Hadronic: π^0 −decay photons generated by accelerated protons colliding with surrounding gas

Young SNR: most probable candidates for being Cosmic Rays accelerators



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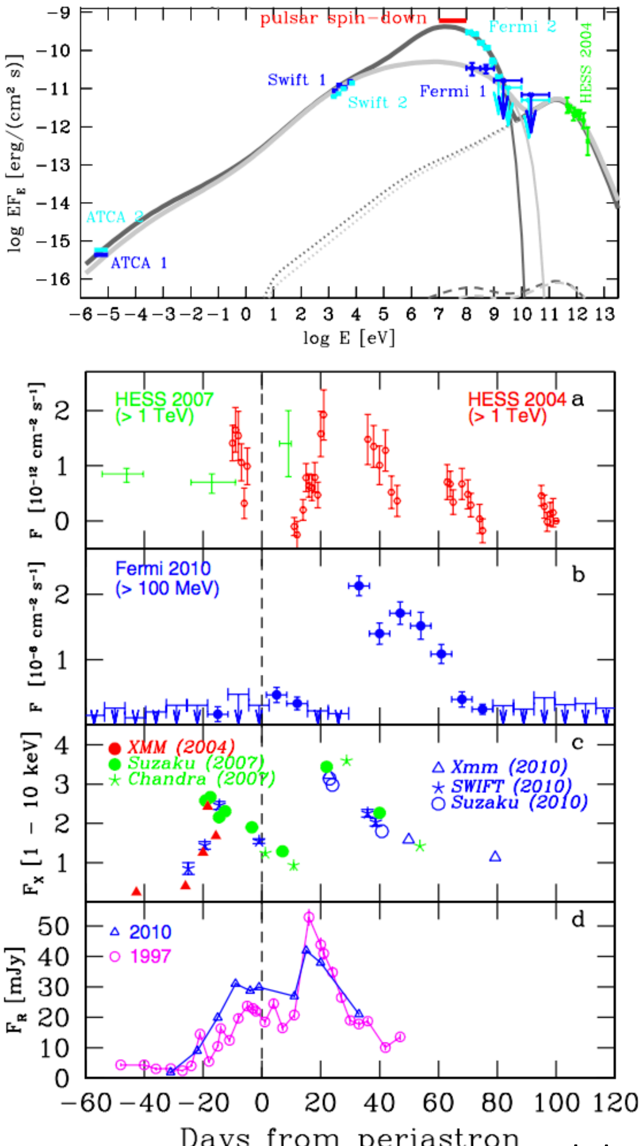
Gamma-ray Loud X-ray Binaries

PSR B1259-63



Abdo et al. 2011

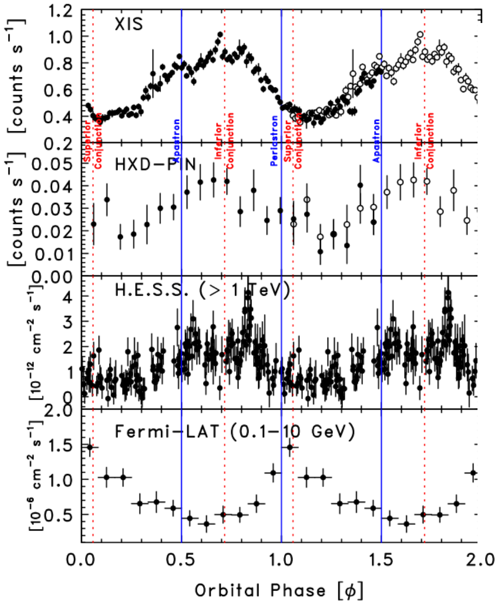
A young radio-pulsar (48 ms) orbiting a fast-rotating O-type star LS2883 (highly eccentric 3.4 yr orbit)

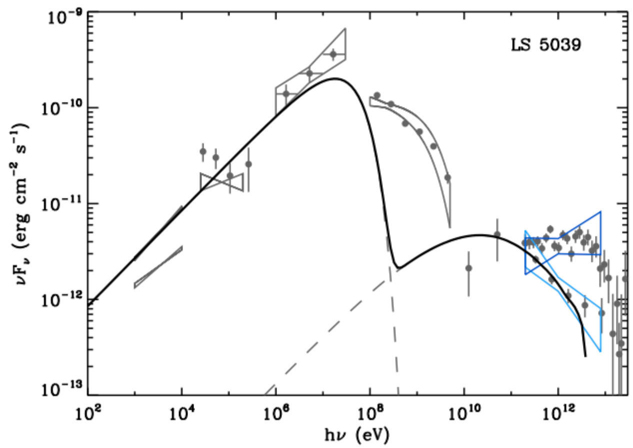
Electrons and positrons probably accelerated at an inner shock front of the pulsar wind:

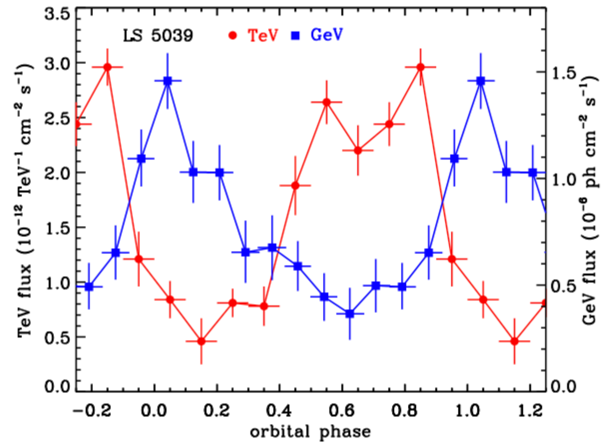
- X-ray emission probably due to synchrotron emission
- TeV emission could be then due to IC of the intense stellar photons by the same electrons-positrons population

Gamma-ray Loud X-ray Binaries

LS 5039, a HMXB with a 3.9 days period



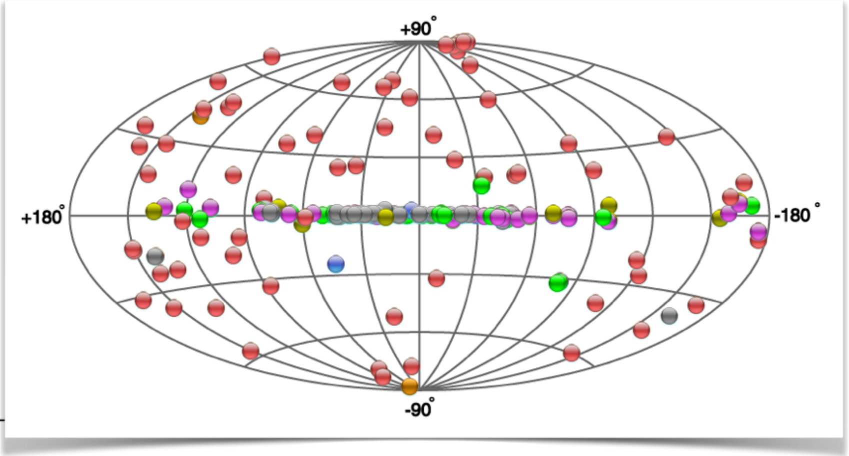




Abdo et al. 2009,
Takahashi et al. 2009,
Aharonian et al. 2006

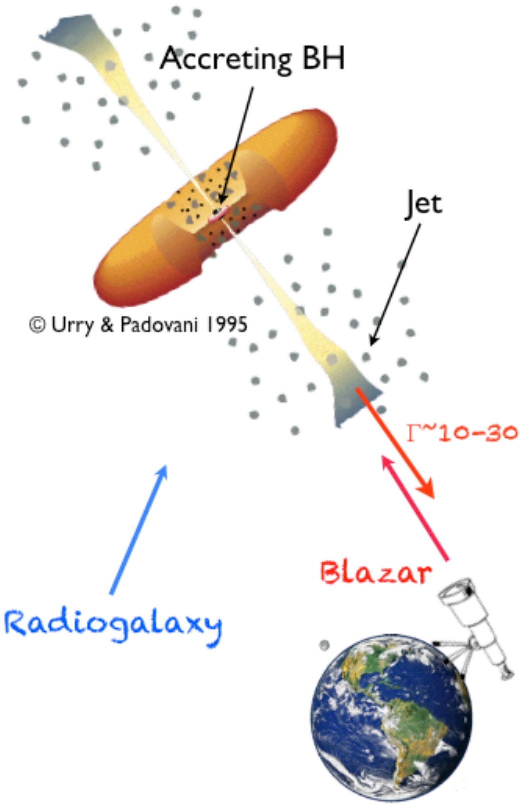
- X-ray emission likely due to synchrotron emission
- TeV emission can be due to IC of the intense stellar photons by the same electrons population (TeV emission affected by γγ absorption, not the GeV one)
- To simultaneous explain X-ray/TeV data one need an extremely efficient and rapid acceleration process

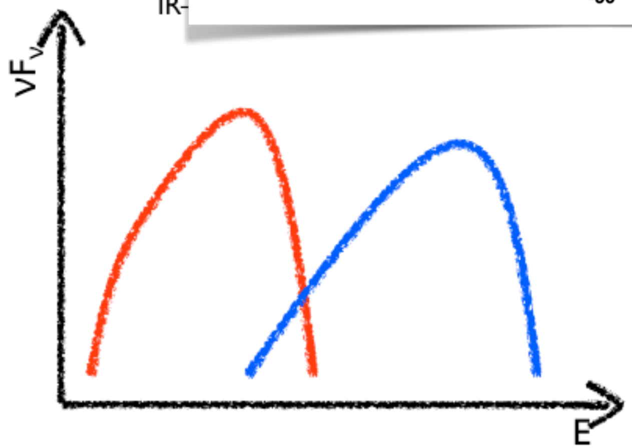
TeV extragalactic sources



IR-

Blazars in a nutshell





SED dominated by the relativistically boosted non-thermal continuum emission of the jet.

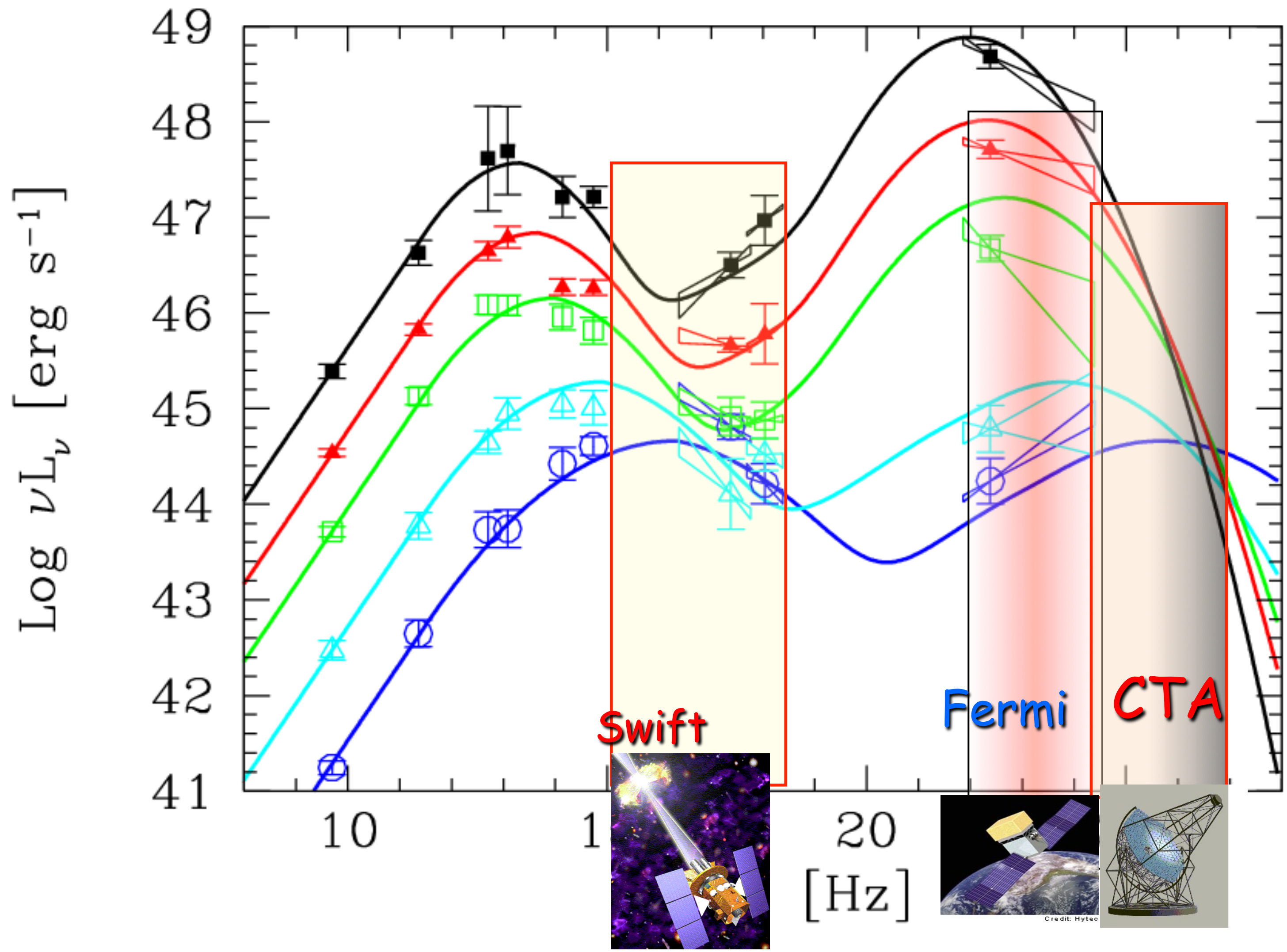
$$L_{\rm obs} = L'\delta^4 \qquad \delta = \frac{1}{\Gamma(1-\beta\cos\theta_{\rm v})}$$

$\delta \approx 10-20$

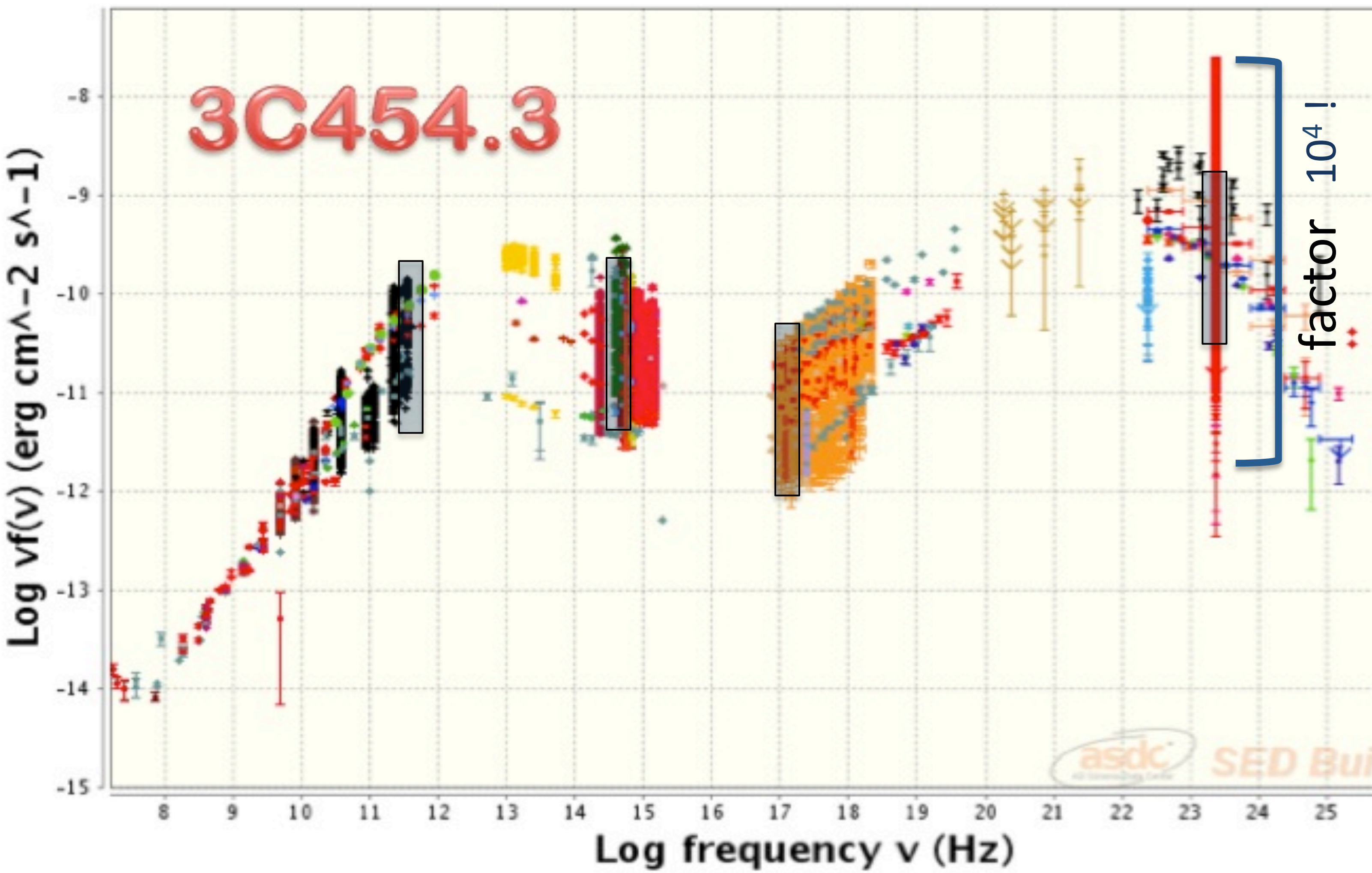
Synchrotron and IC in LEPTONIC models.

Also HADRONIC scenarios
(synchrotron or photo-meson) NEUTRINOS!

Blazars: basic phenomenology



Blazars: variability



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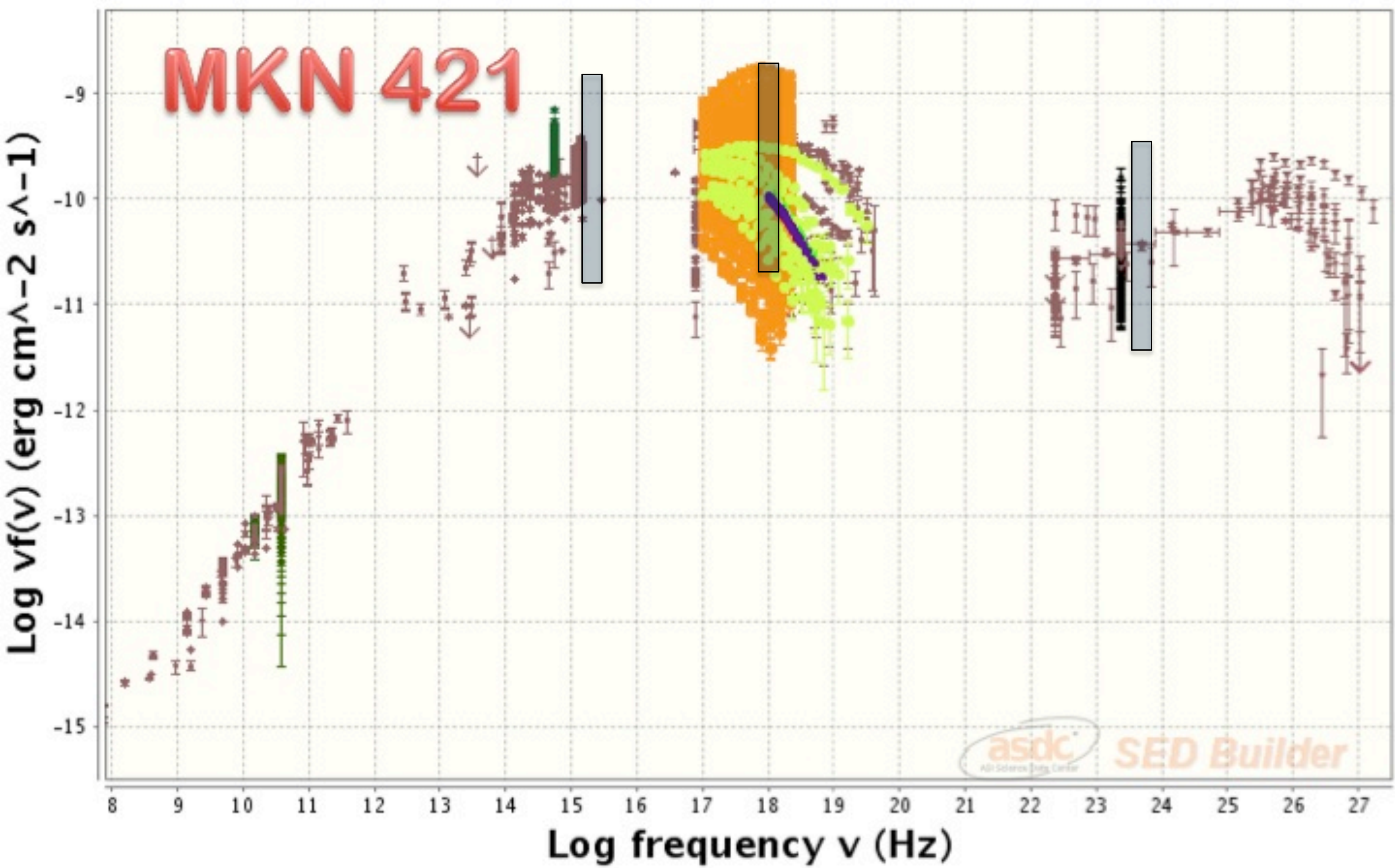
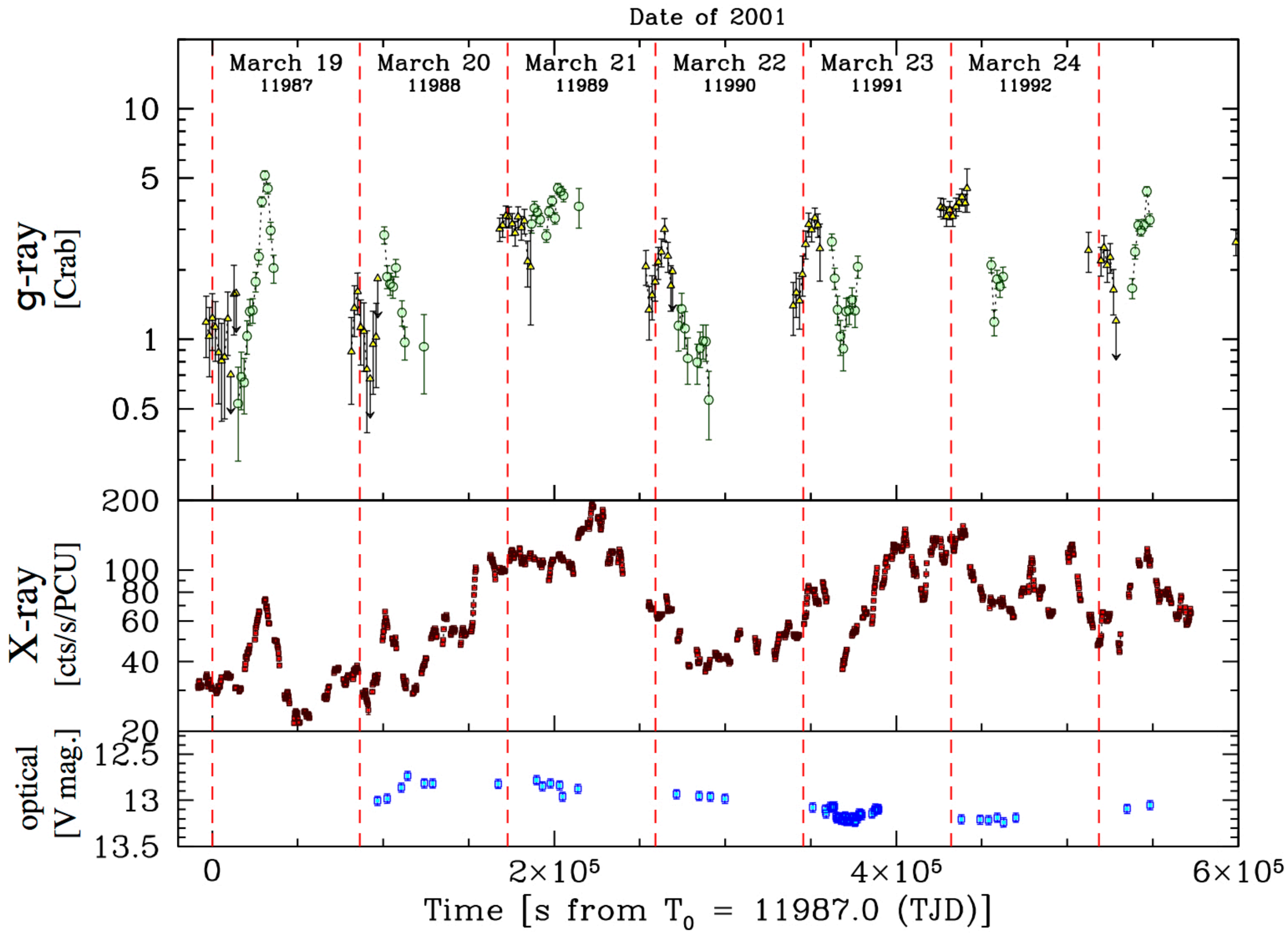


2014 Giommi presentation

MKN421: strong TeV variability correlated with X-ray



Fossati et al. 2008

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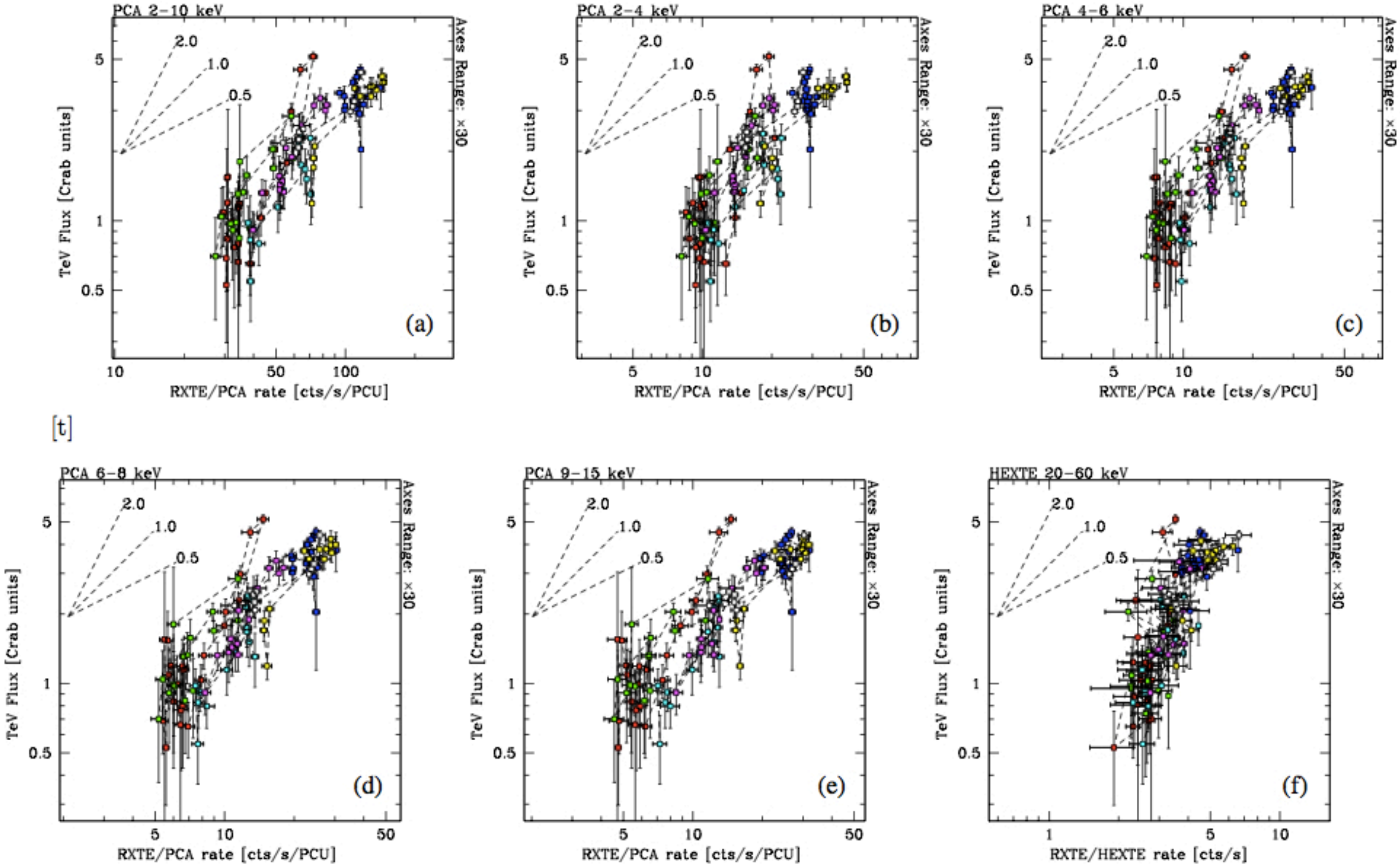
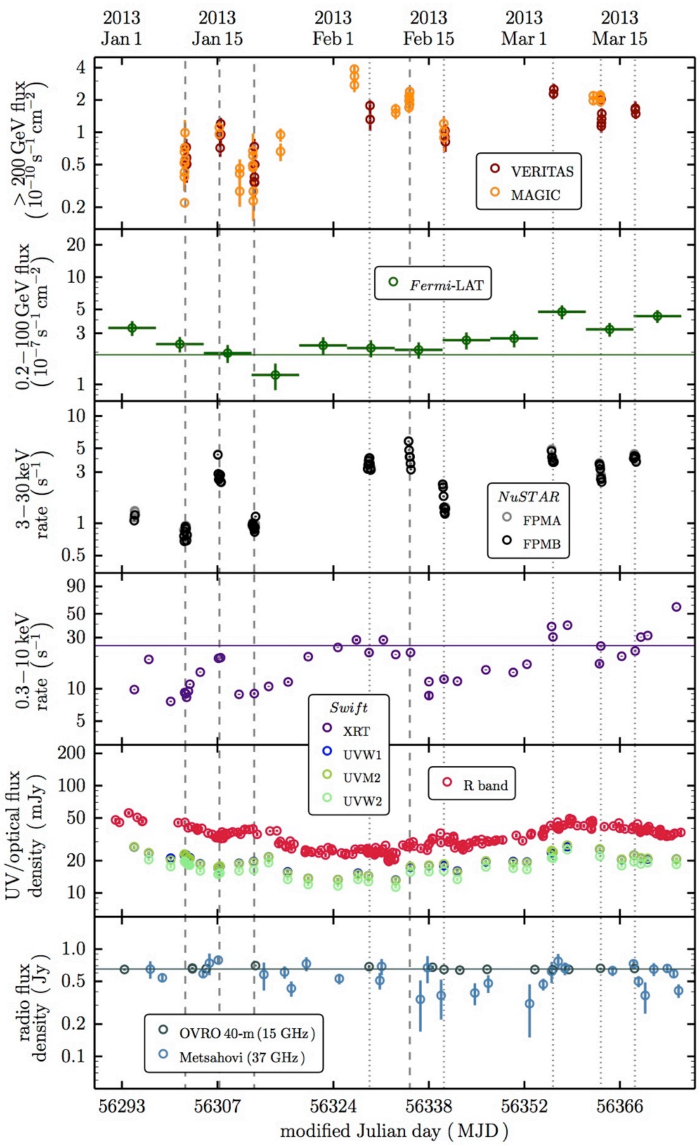
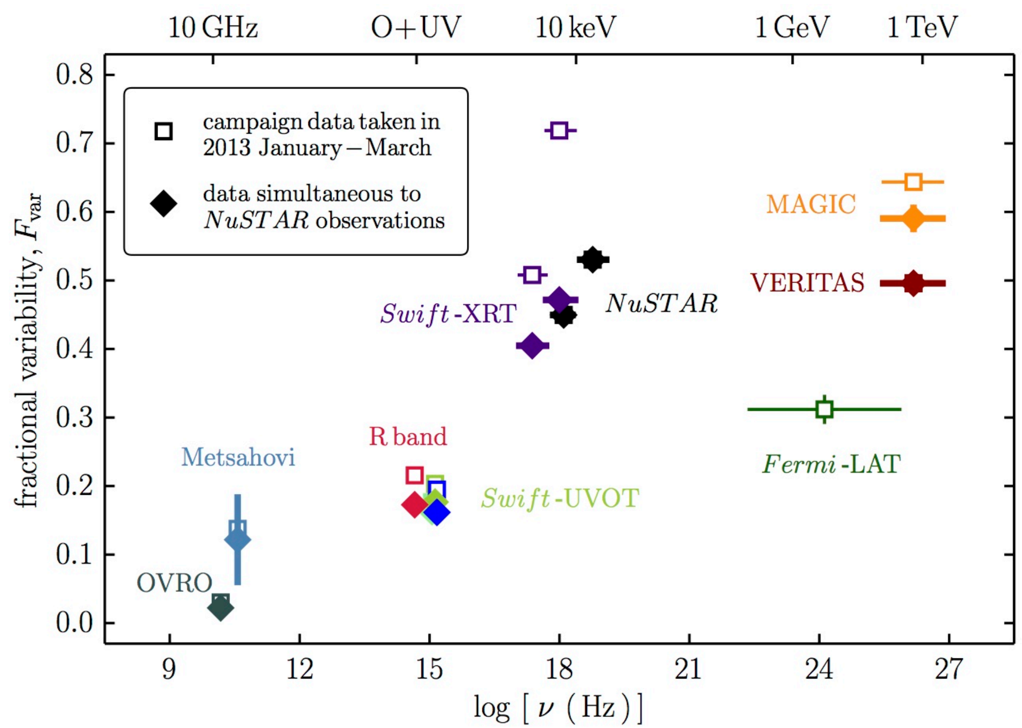


Fossati et al. 2008

MKN421: more recent MW campaigns





Balokovic et al. 2016

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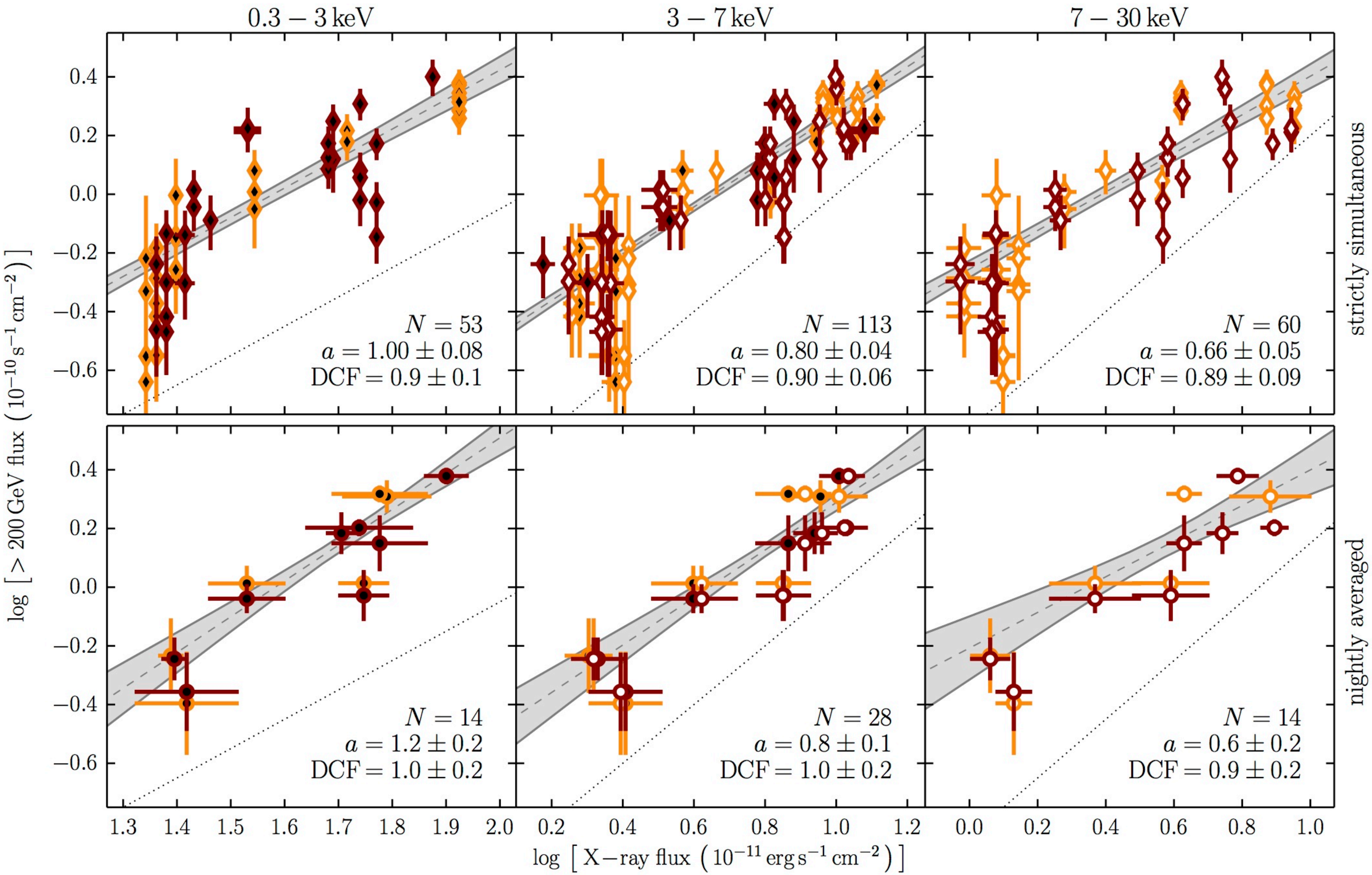

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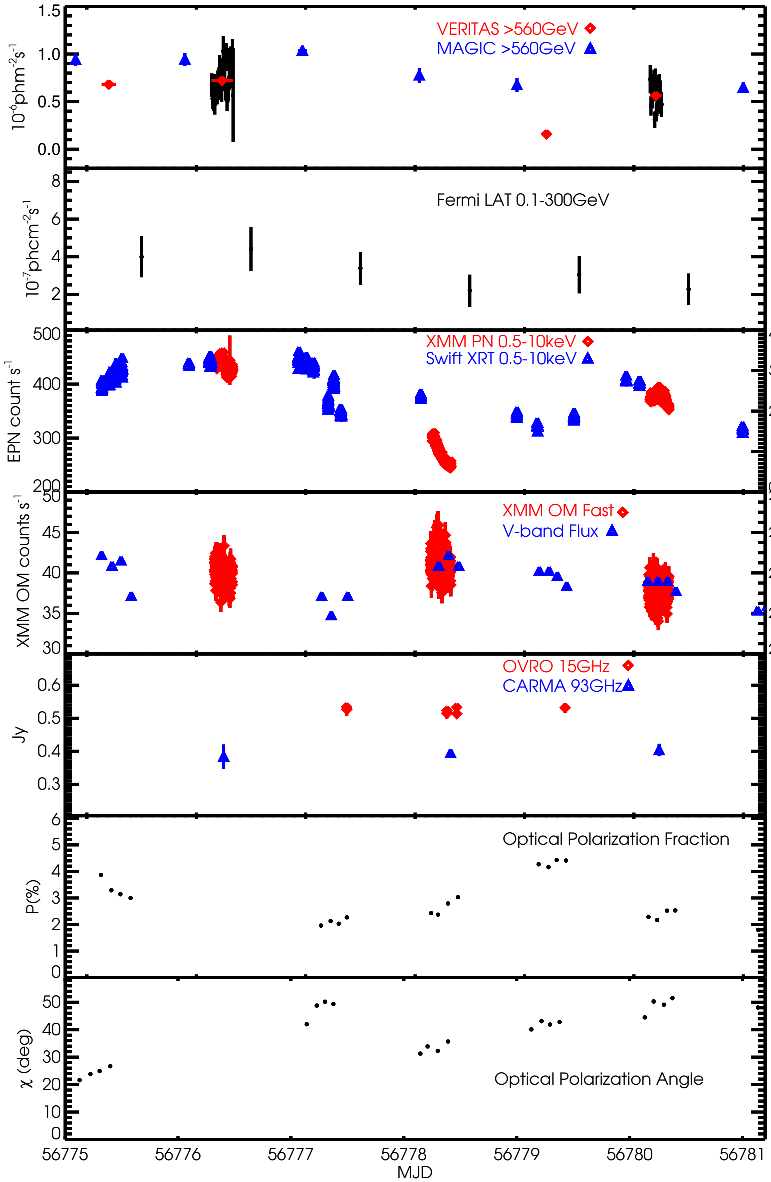
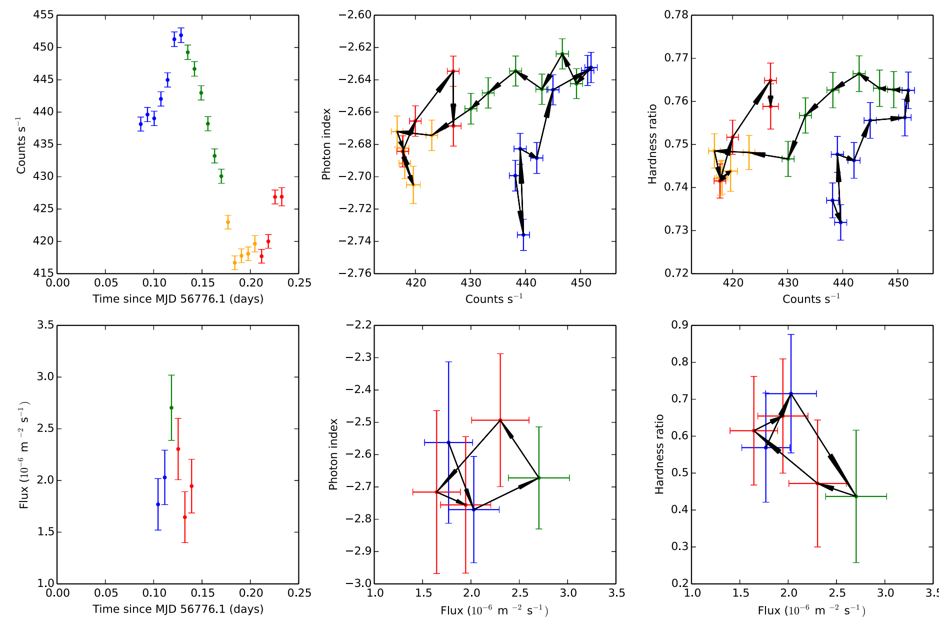
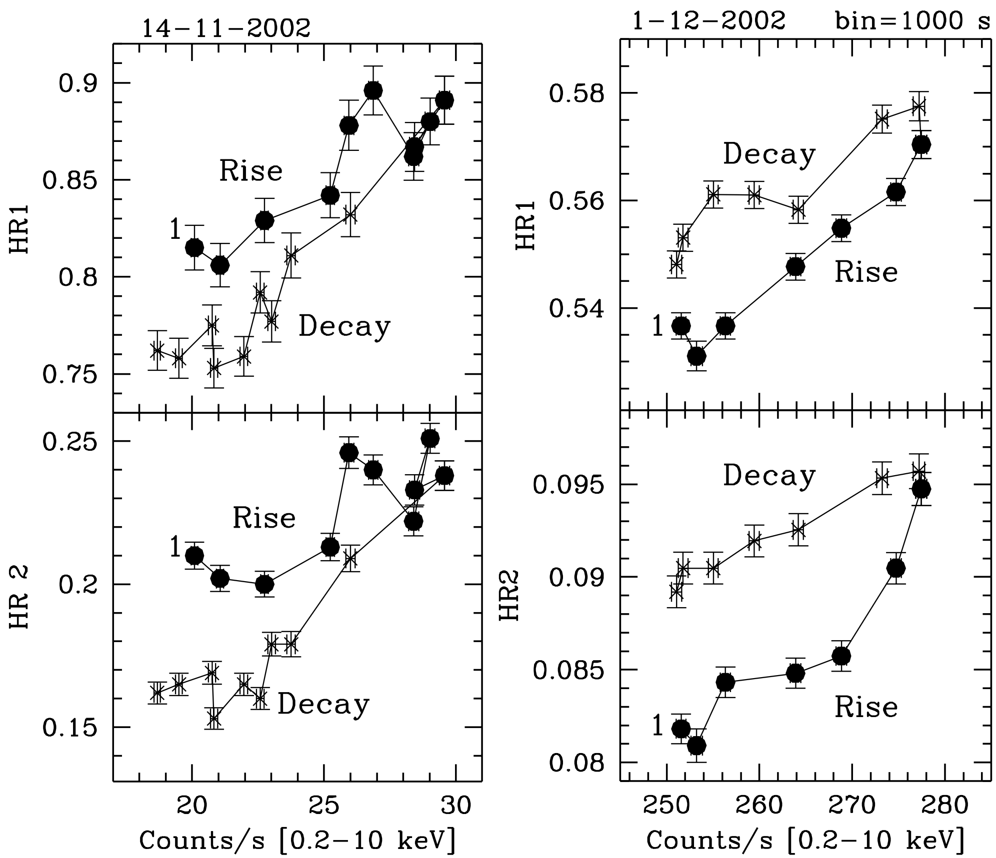


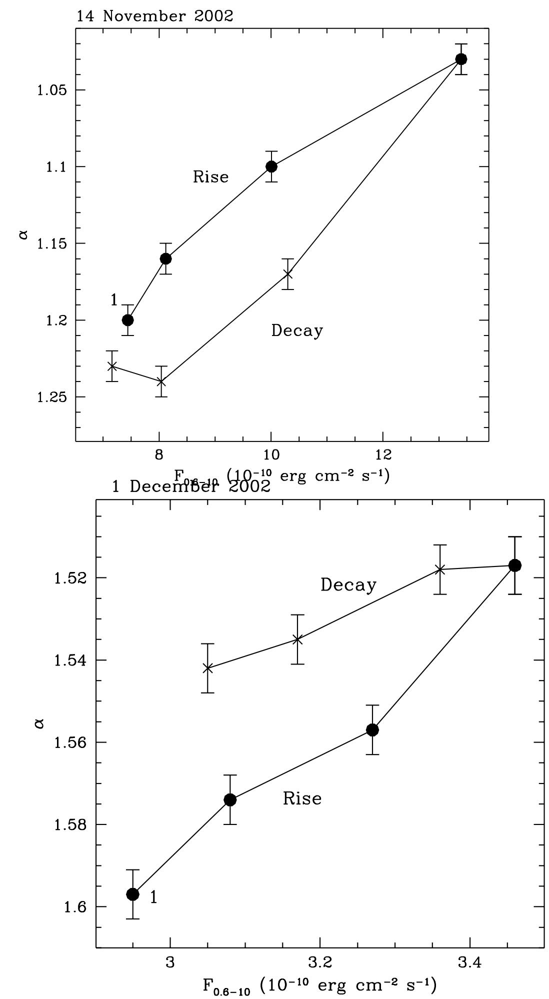


Give clues on timescales, eg. T_{cool}, t_{acc}, t_{inj}, $t_{dynamic}$

Abeyesekara et al. 2017

MN421: both clockwise and anticlockwise behaviour



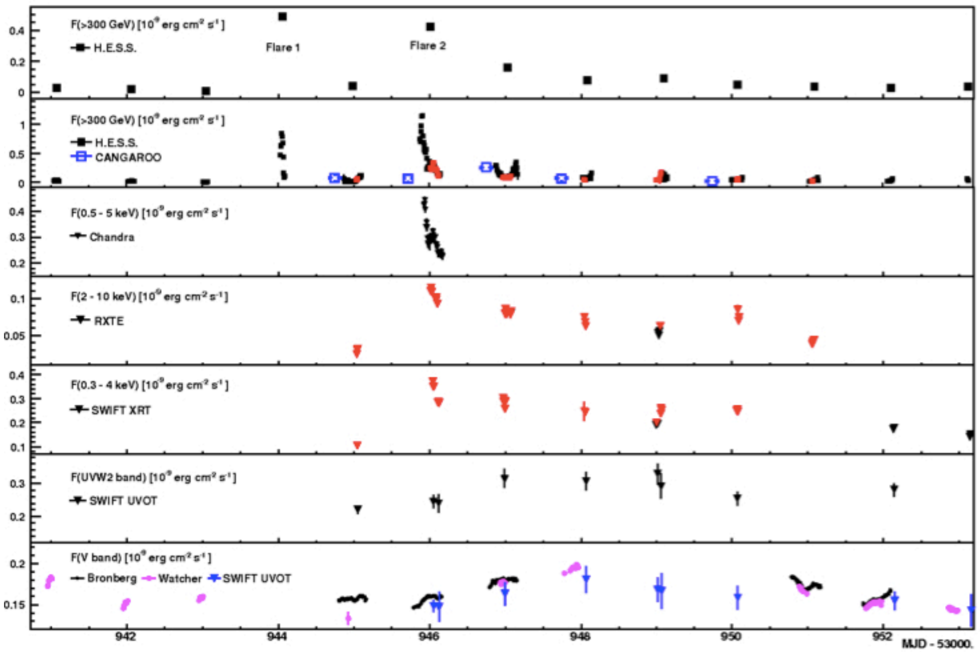


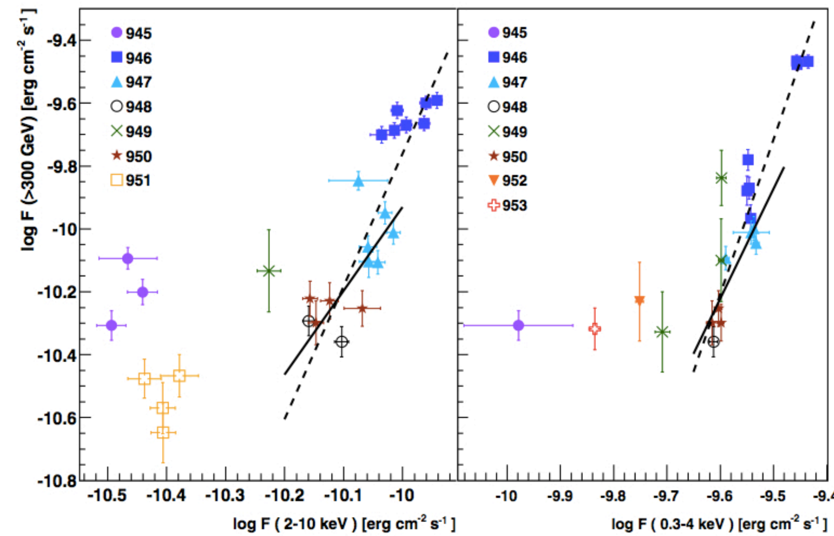
Explained as an effect of particle acceleration, cooling and escape timescales …

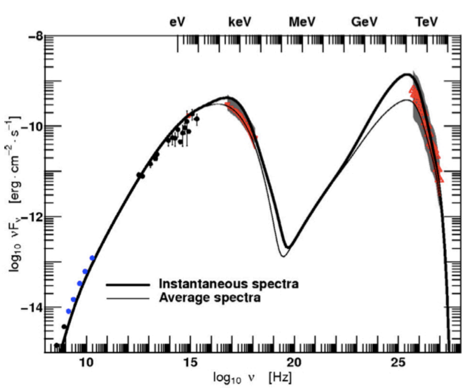
Simultaneous good quality TeV data are crucial to better constrain the various parameter

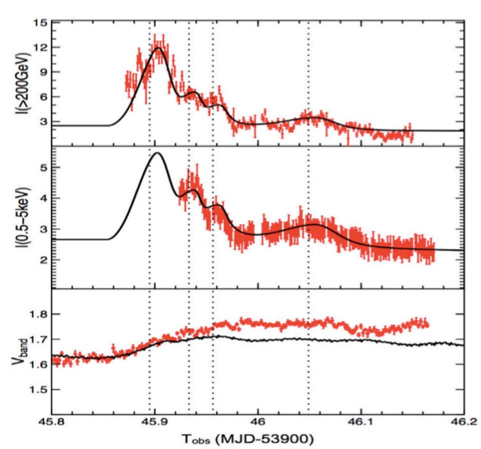
Ravasio et al. 2004
Brinkmann et al. 2003
Takahashi et al. 1996

Blazars: variability, PKS2155-304









Nightly averaged non-flaring SED => one zone SSC

Flaring SED and its evolution => multi-zone SSC models

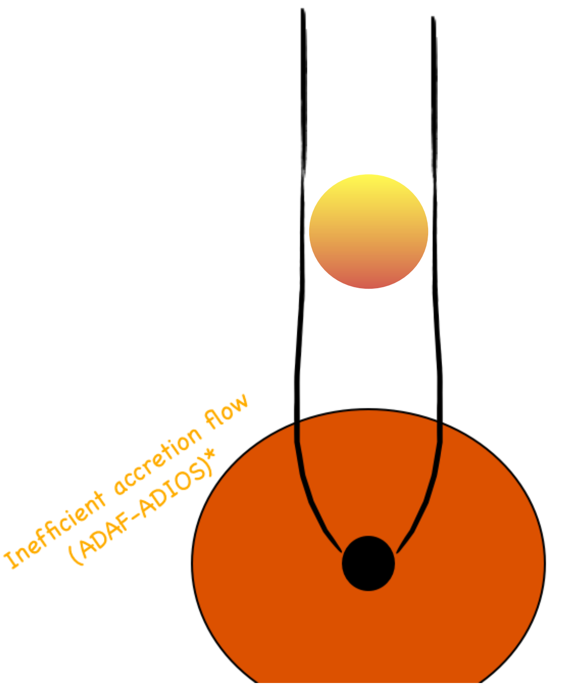
Time-dependet stratified jet

Abramowski et al. 2012

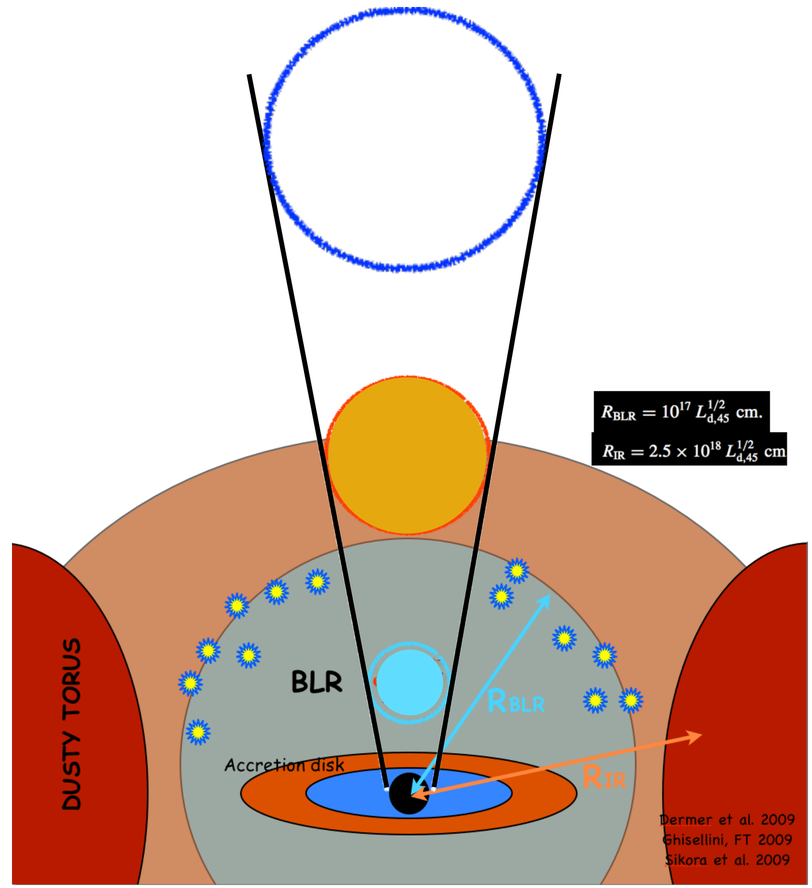
Blazars: the general framework

Blazars: the general framework

BL Lacs: "naked" jets



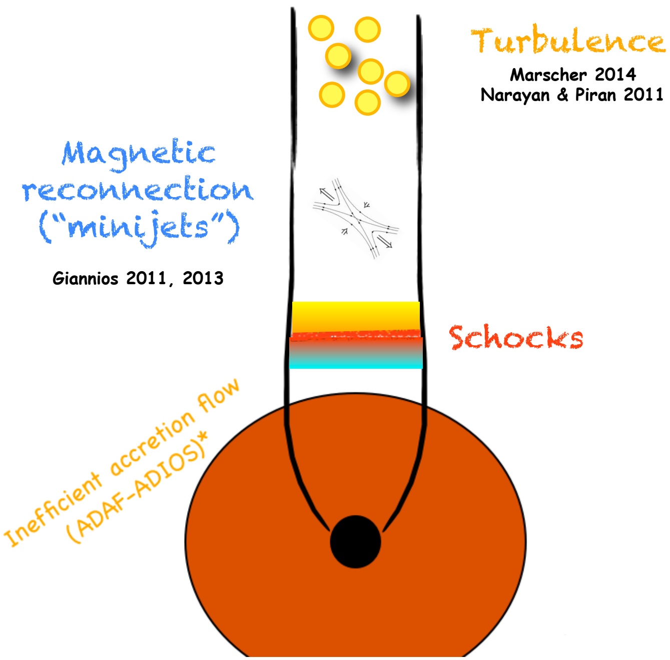
FSRQ: "dressed" jets



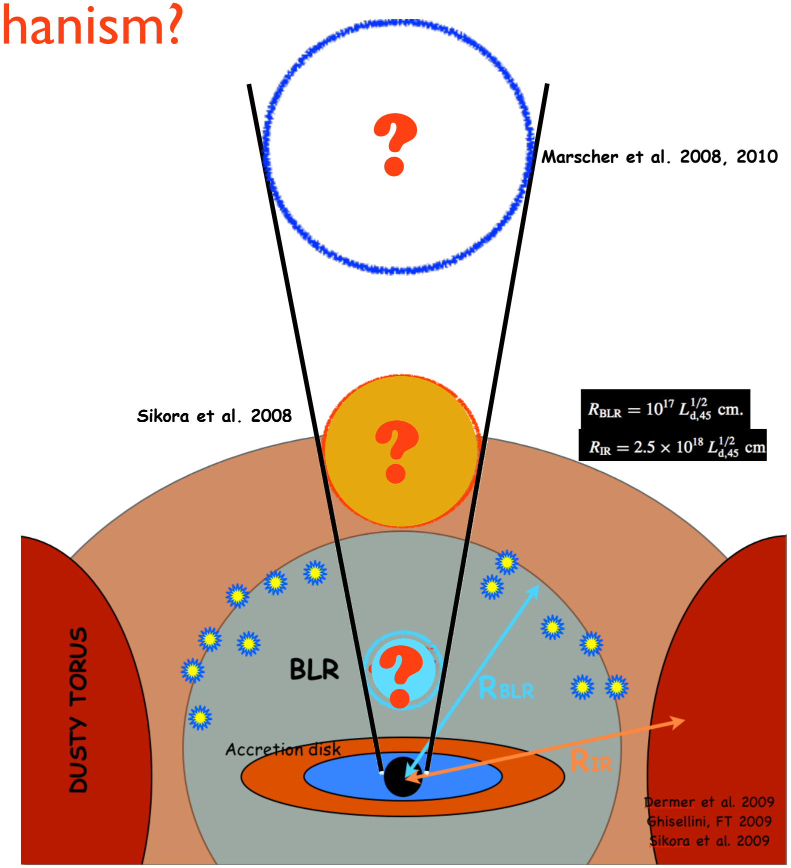
Blazars: current debate

Blazars: current debates

Dissipation/acceleration mechanism?



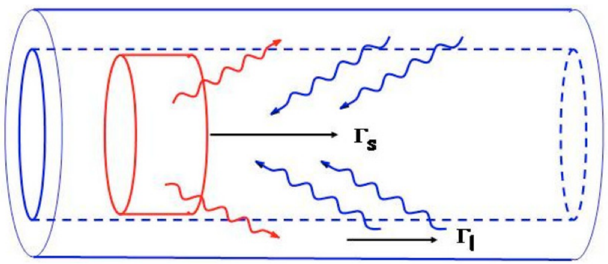
Location?



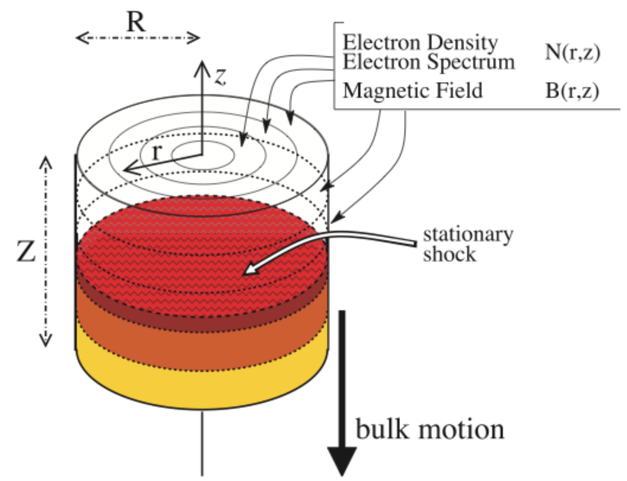
More refined schemes

More refined schemes

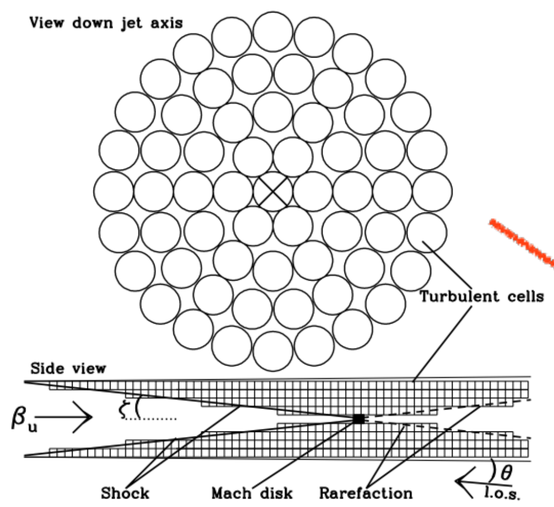
Ghisellini, FT & Chiaberge 2005



Chen et al. 2011



Marscher 2014



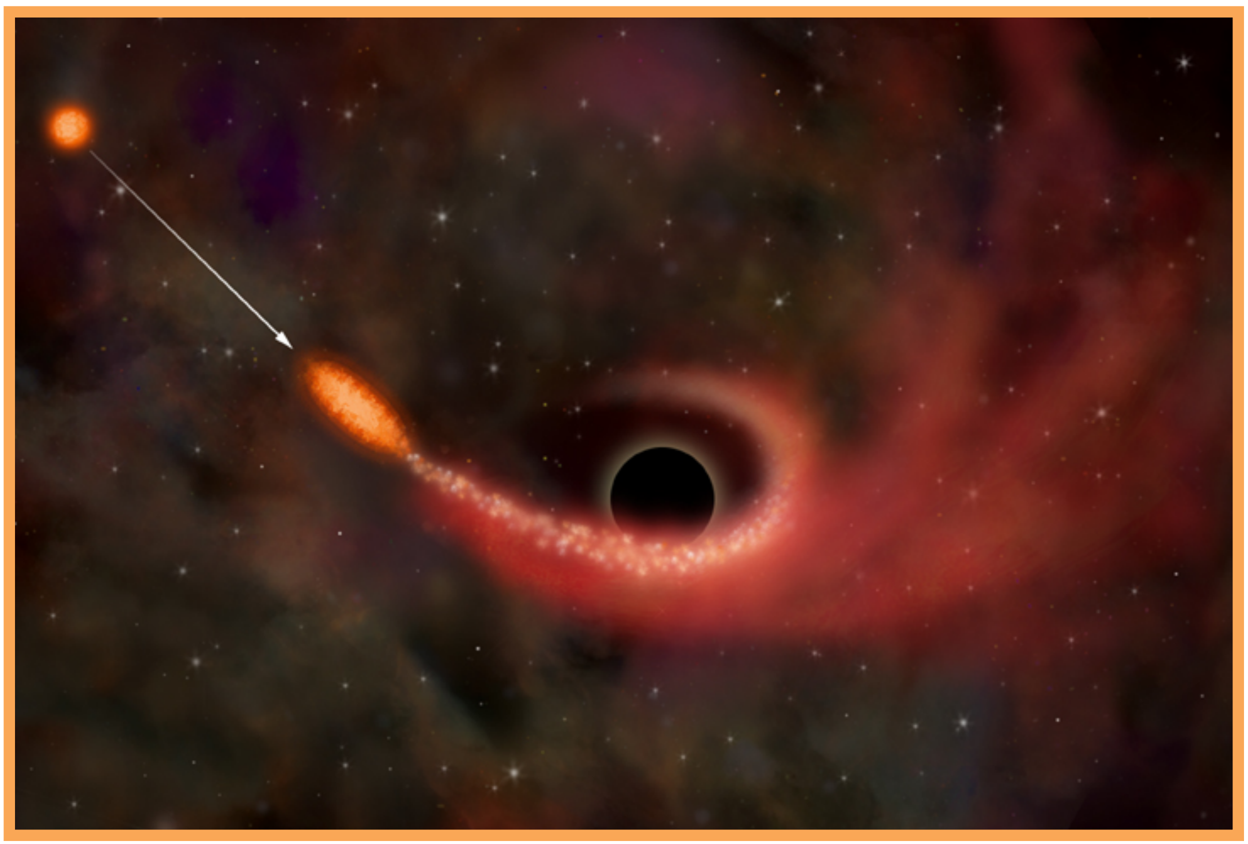
Polarization

Tidal disruption events

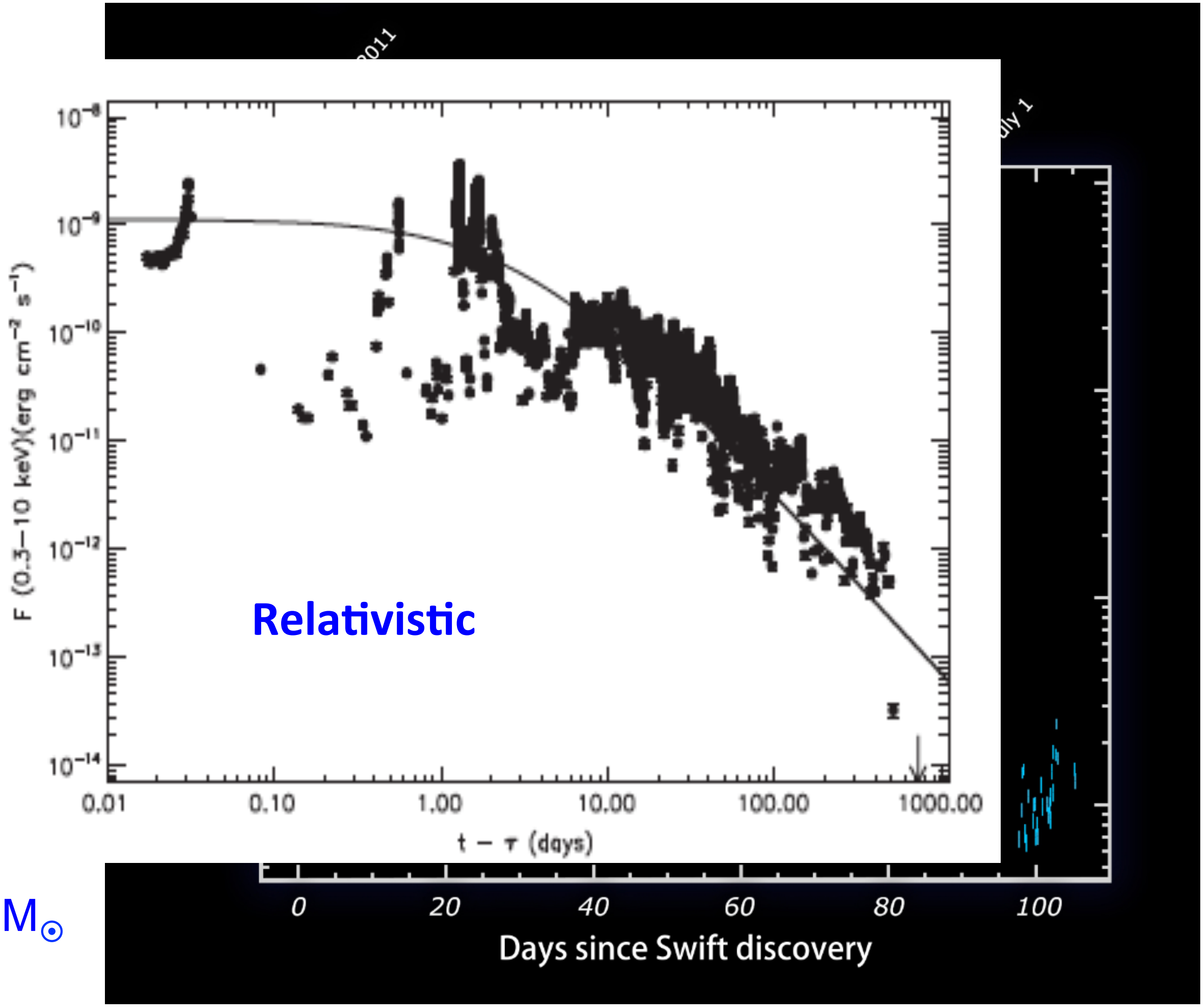
When a star orbits close to a massive black hole and its periastron distance reaches $R \sim R_*(M_{BH} / m_*)^{1/3}$, it will be disrupted and cause what is commonly referred to as a tidal disruption flare.

MASS FALLS BACK AT A RATE: $\dot{M} \propto t^{-5/3}$

Rees 88
Phinney 89



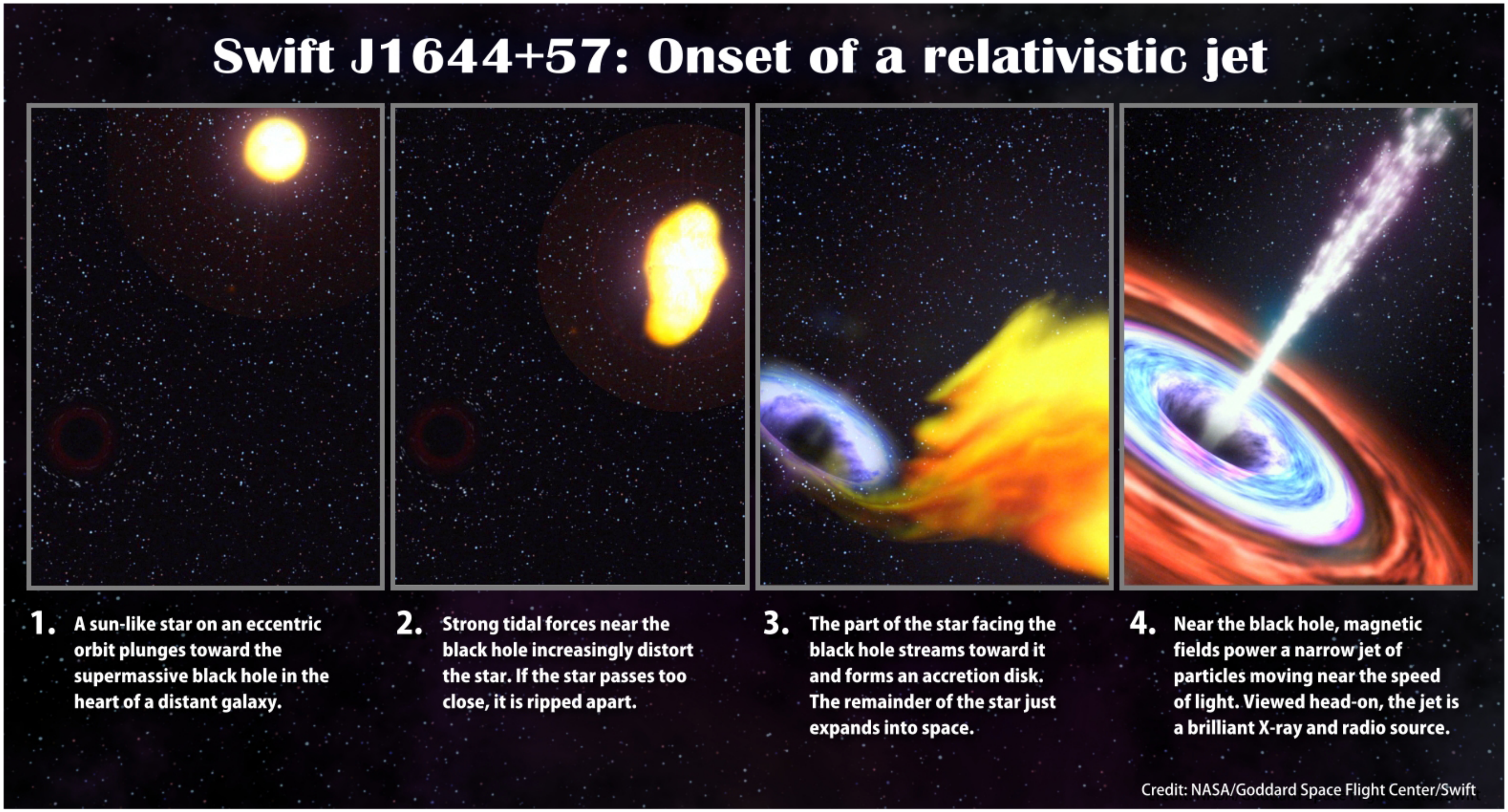
Swift 1644+57: XRT 4-months light curve



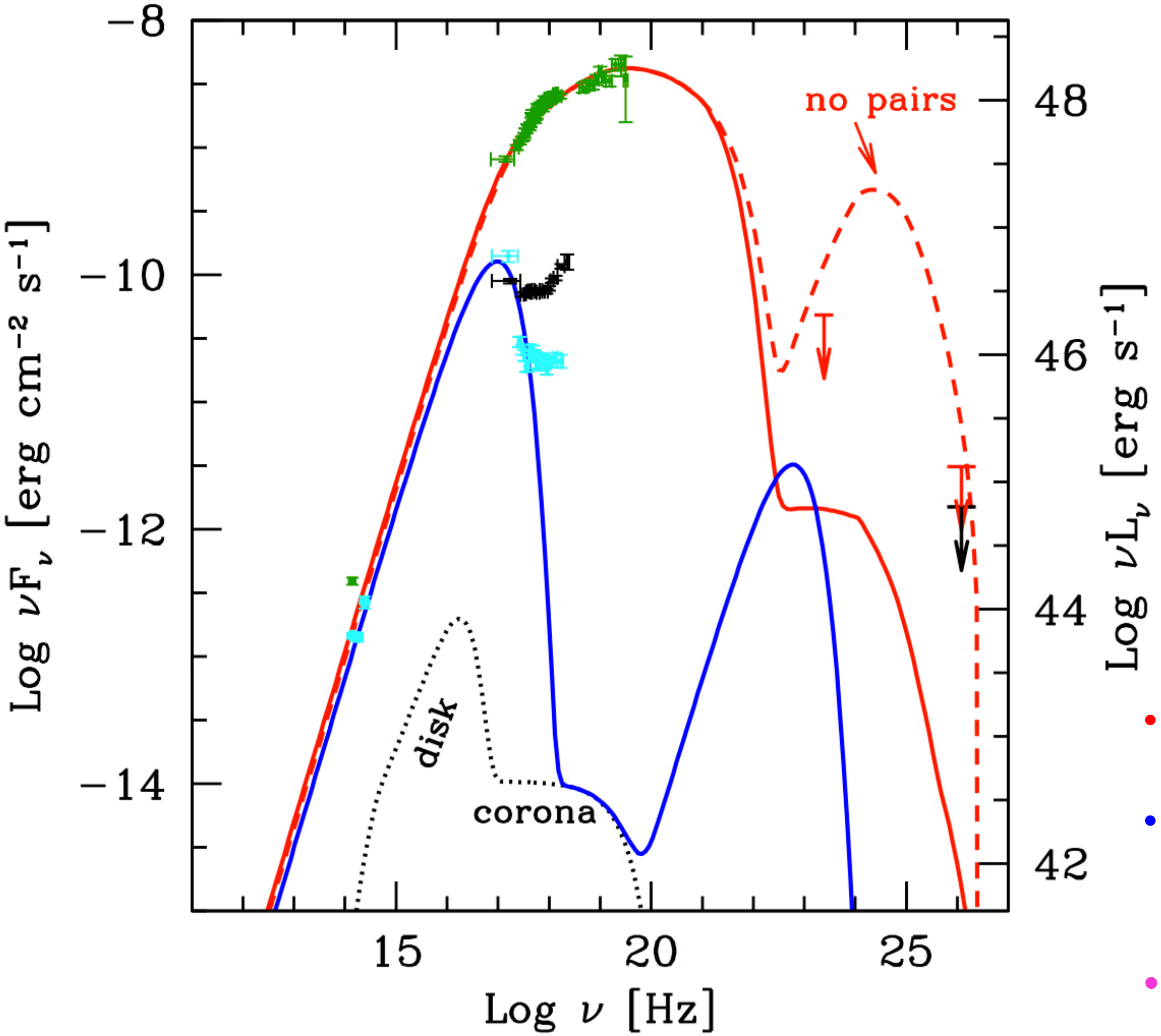
10^6-10^7 $M_\odot$

Burrows et al. 2011

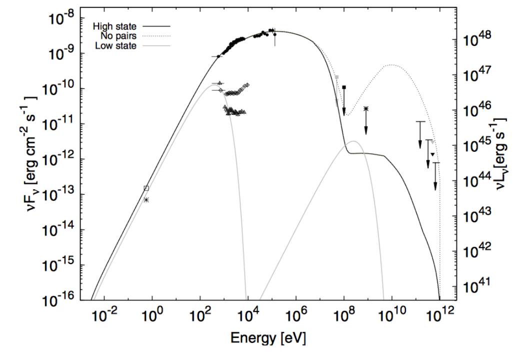
The onset of a jet from a TDE



A blazar model dominated by synchrotron emission



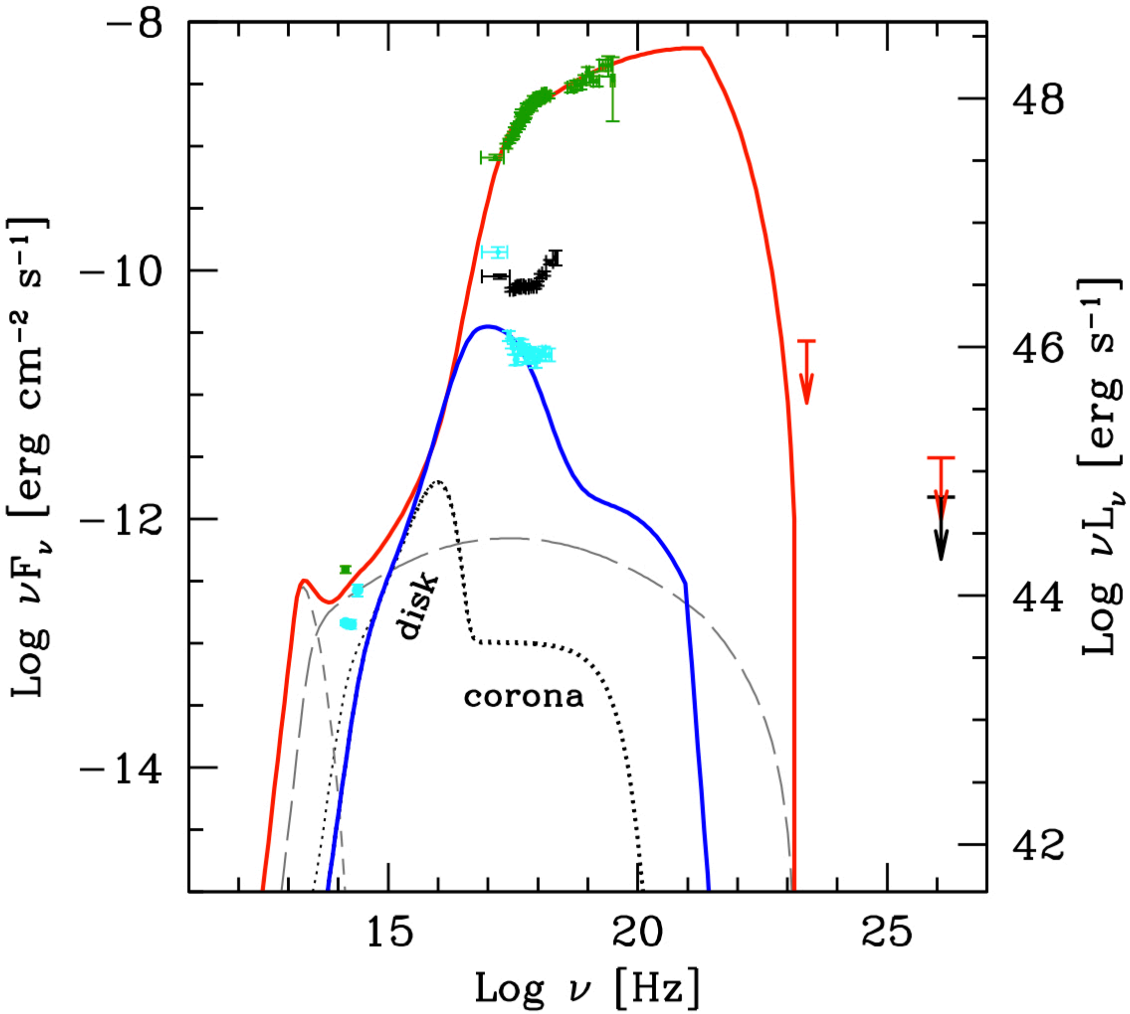
Burrows et al. 2011



Aleksic et al. 2013

- 10^6-10^7 $M_\odot$
- Optical/NIR => particle starved, magnetically dominated jet
- γ-TeV => γ-γ pair production => $\Gamma \leq 20$

A blazar model dominated by synchrotron emission+external Compton



matter dominated jet

Burrows et al. 2011
Bloom et al. 2011

Conclusions

X-ray observation provide information on the parameters characterising the emitting plasma that are directly related to the emission mechanisms at the base of the TeV emission

Simultaneous X-ray observations can be carried out with various satellites to date and more in the near future, both to properly studies the sources of interest, but also providing information on new transients and on sources while they are flaring