The TeV BL Lac 1ES 1426+428: spectrum and variability

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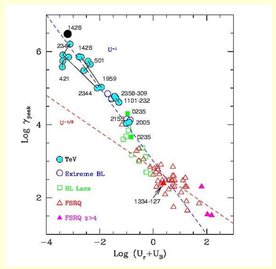
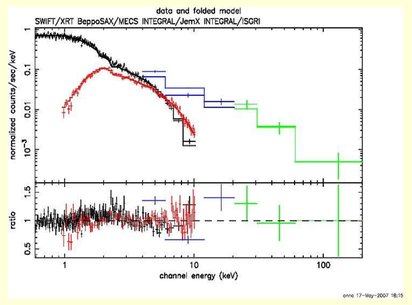
The BL Lac 1ES 1426+428 is an extreme object, with the hard synchrotron component peaking at energies at or above 100 keV, resembling the hard states of Mkn 501 and 1ES 2344+514. We have observed it with INTEGRAL: the detection confirms the earlier interpretation of the BeppoSAX observation. The source is a very extreme BL Lac, which might have the peak of synchrotron component at E > 10 keV in a "stationary" state, not only during huge flares like for instance MKN 501.
Here we collect all the available X-ray observations of this object, from the historical ones, to the one obtained with the current satellites: Chandra, XMM-Newton, SWIFT, RXTE, to determine if the variability pattern of this source is similar to other high peaked objects.

Trend of γ_{peak} with total energy density

From Ghisellini et al 2002, Wolter et al arXiv:0707557





INTEGRAL OBSERVATION + Older SPECTRA

JemX+ ISGRI (May 2006)

XRT/Swift (May 2005)

MECS/BeppoSAX (Feb 1999)

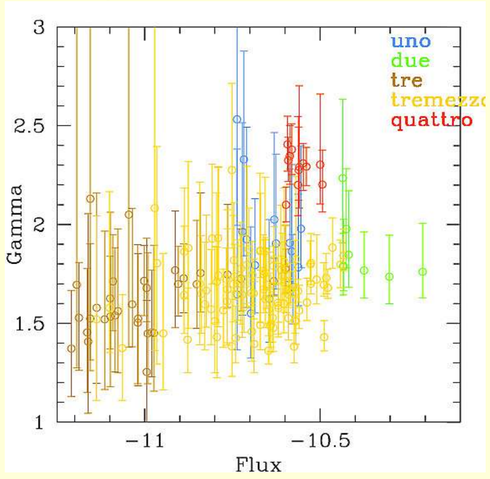
All the observations give consistently a slope of Γ = 1.9-2.0

Fluxes are a bit different: Factor of 2 between max min LOWEST is INTEGRAL!! F(2-10 keV) = 1.6 – 3.0 10^{-11}

(From Wolter et al. 2007 arXiv:07072735)

1ES1426_428 was observed by RXTE in a long series of observations
Again, we have no spatial resolution, but we consider that the PCA flux is due to 1ES1426+428 only (see contaminant box at right).
We plot flux vs. power law slope (Γ) with different colors according to the epoch of observation:

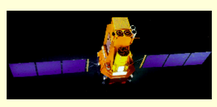
2000-04-30 2000-05-05
2001-05-18 2001-05-25
2002-03-07 2002-06-15
2004-02-01 2004-08-06

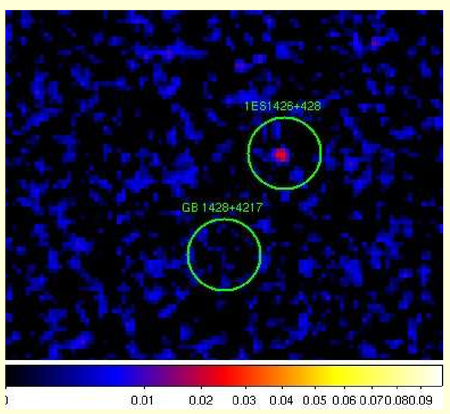


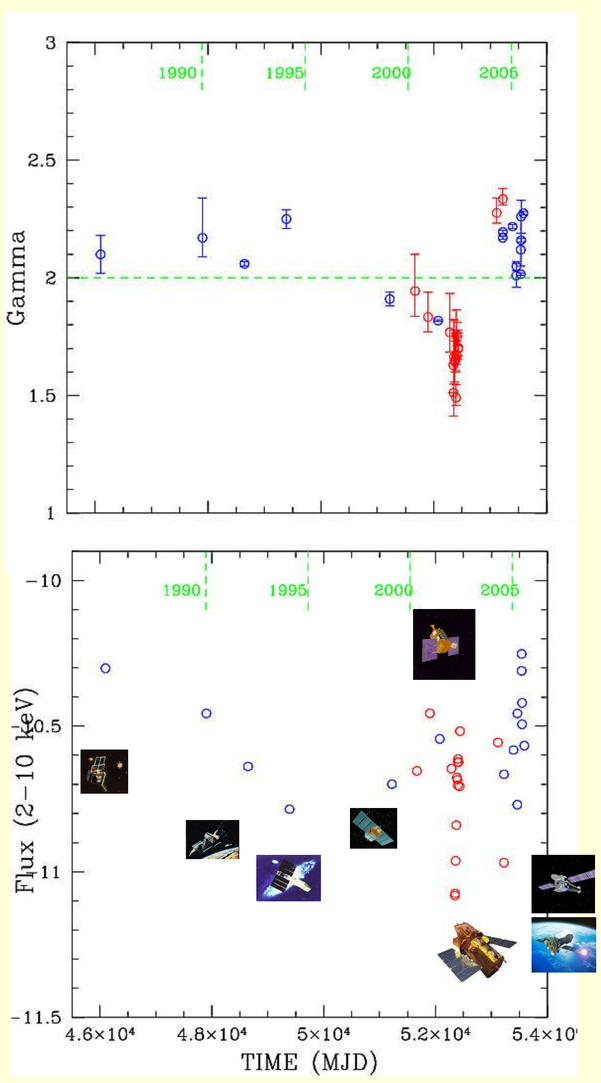
The spectrum and flux do not change much with time. The slope is around 2 (flat in $\nu F\nu$) or flatter.
Occasionally it becomes steeper.
The source seems to have long term trends: observations close in time are found mostly in the same zone of the graph.

PB: contaminant

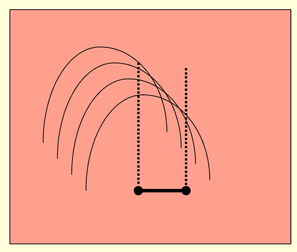
Given the BeppoSAX PDS field of view (about 1 degree radius, with triangular response) many sources might have contributed to the high energy flux. We identified the culprit with GB1428+422 @z=4.72 which lies at 41' from 1ES1426+428.
INTEGRAL does not detect it (but very high flux limit)
FURTHER: X-ray flux of GB1428 about factor 10 lower as shown also by this 3-6 keV JEM-X image (May 2006)



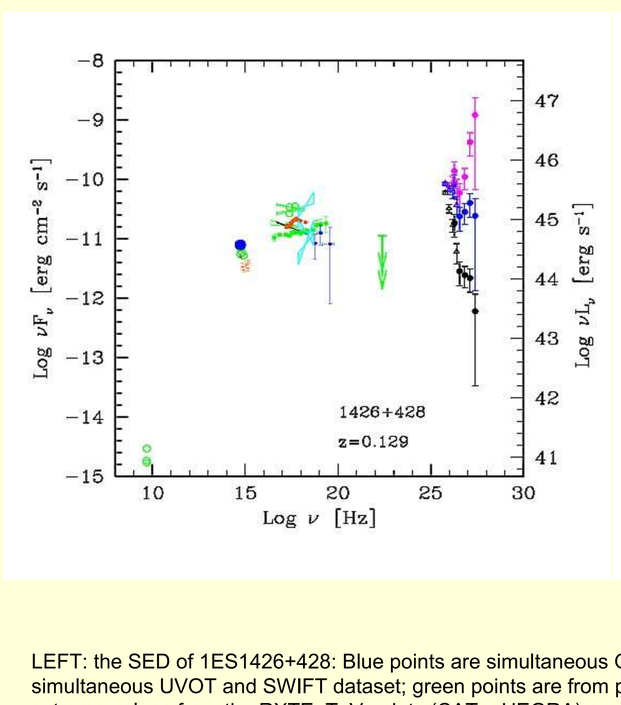




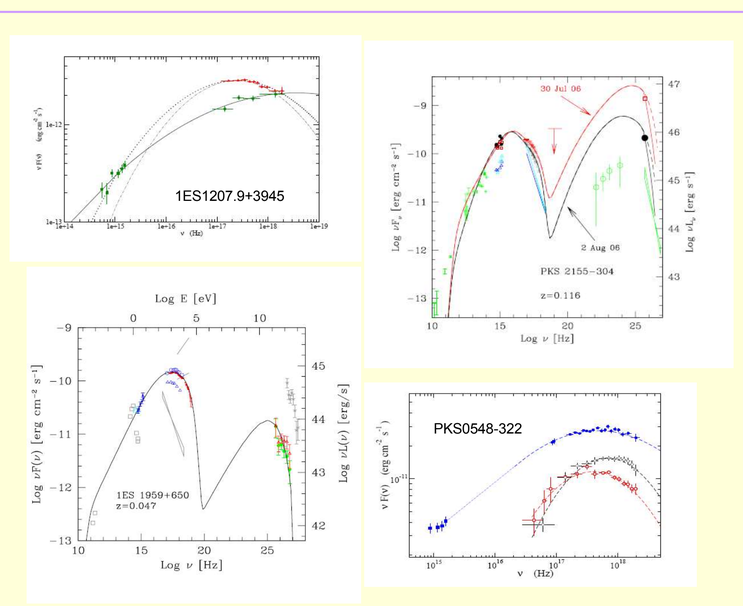
Historical light curve: slope of power law (TOP) and flux intensity (BOTTOM) as a function of time, from EXOSAT to Chandra and XMM-Newton. Blue circles are results from single observations. Red circles are an average over 10 subsequent pointings from RXTE, to avoid cluttering and reduce error bars.
Data from Sambruna et al 1997, Costamante et al 2001, Tramacere et al 2007, this work



STEEPER when BRIGHTER?



LEFT: the SED of 1ES1426+428: Blue points are simultaneous OM and ISGRI points from INTEGRAL; brown points are a simultaneous UVOT and SWIFT dataset; green points are from previous pointings (BeppoSAX; ASCA); cyan errorbars indicate extreme values from the RXTE. TeV points (CAT + HEGRA) are in black:De-reddened for IR EBL: mild (blue from Kneiske et al. 2004) or strong (magenta from Primack et al 2001)
RIGHT: a model of a homogenous one zone blob (Tavecchio private communication) is overplotted over the SED: it describes well the INTEGRAL points and the midly de-reddened TeV points. It is evident from the plot that in many occasions the slope of the X-ray spectrum, and therefore the position of the synchrotron peak, is very different (steeper, with peak at lower energies), while the flux of the sources changes only by a factor of few.



A few examples of HBL variability: most have the more typical behavior of HARDER when BRIGHTER, like Mkn421 and Mkn501, except 1ES1207.9+3945.
Maselli et al. 2008; Foschini et al 2007; Tagliaferri et al. 2008; Perri et al. 2007

1ES1426+428 is an "extreme" HBL, it has been detected in TeV, and has shown at various epochs a peak of the synchrotron component at energies above 1 keV.
Numerous observations with RXTE have shown that the slope of the power law is quite stable: mostly flat, sometimes steeper, implying that the peak moves to low energies.
The behavior is STEEPER when BRIGHTER, contrary to most known blazars (eg Mkn 421, see also panel at left).
However, the story is not so simple: PKS2155-304 sometimes shows the same SwB behavior (Foschini et al 2007) and even 1ES1426+428 is sometimes detected to vary like Mkn421 or Mkn501 (see eg. Massaro et al 2008).
It remains to be found what parameters drive the variability, for instance a difference in accretion rate, B field or Doppler factor might explain these changes.
It is also possible that different variability behaviour are present in the same source at different times.
A monitoring of the source over X-ray and TeV ranges will certainly help in finding the answer.