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Fermi
Gamma-ray Space Telescope

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Observations of the Microquasar Cygnus X-3 by Fermi LAT

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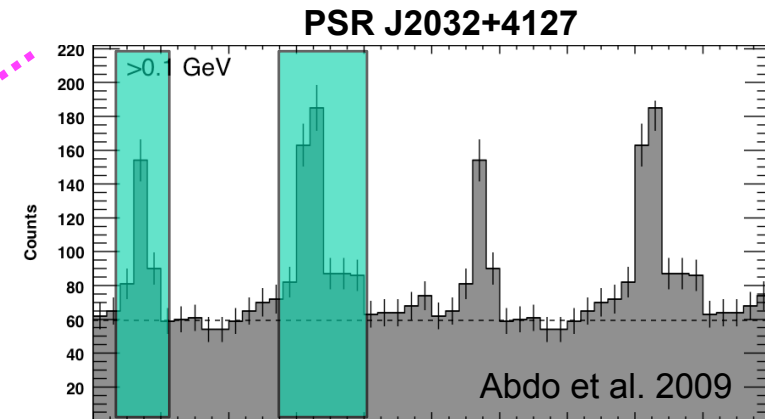
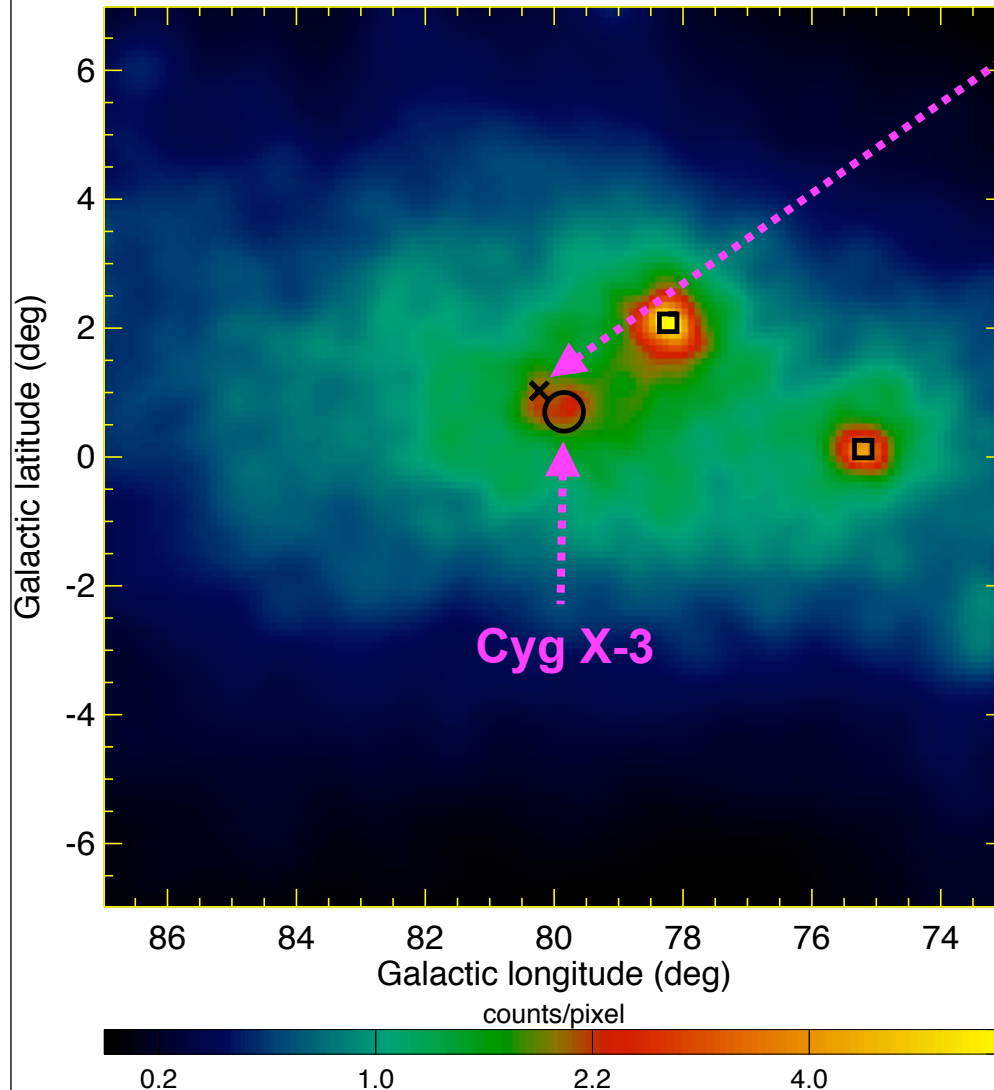
Paper submitted (embargo on all results)

Cygnus X-3



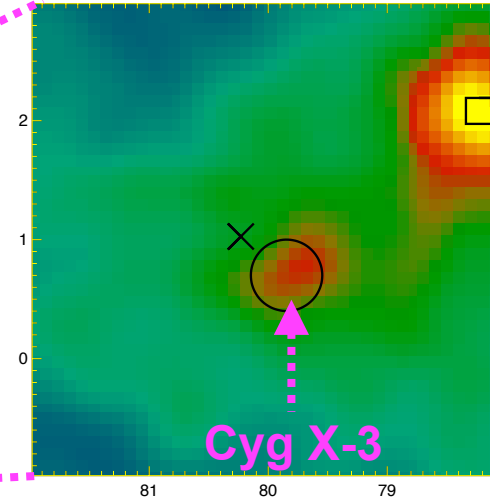
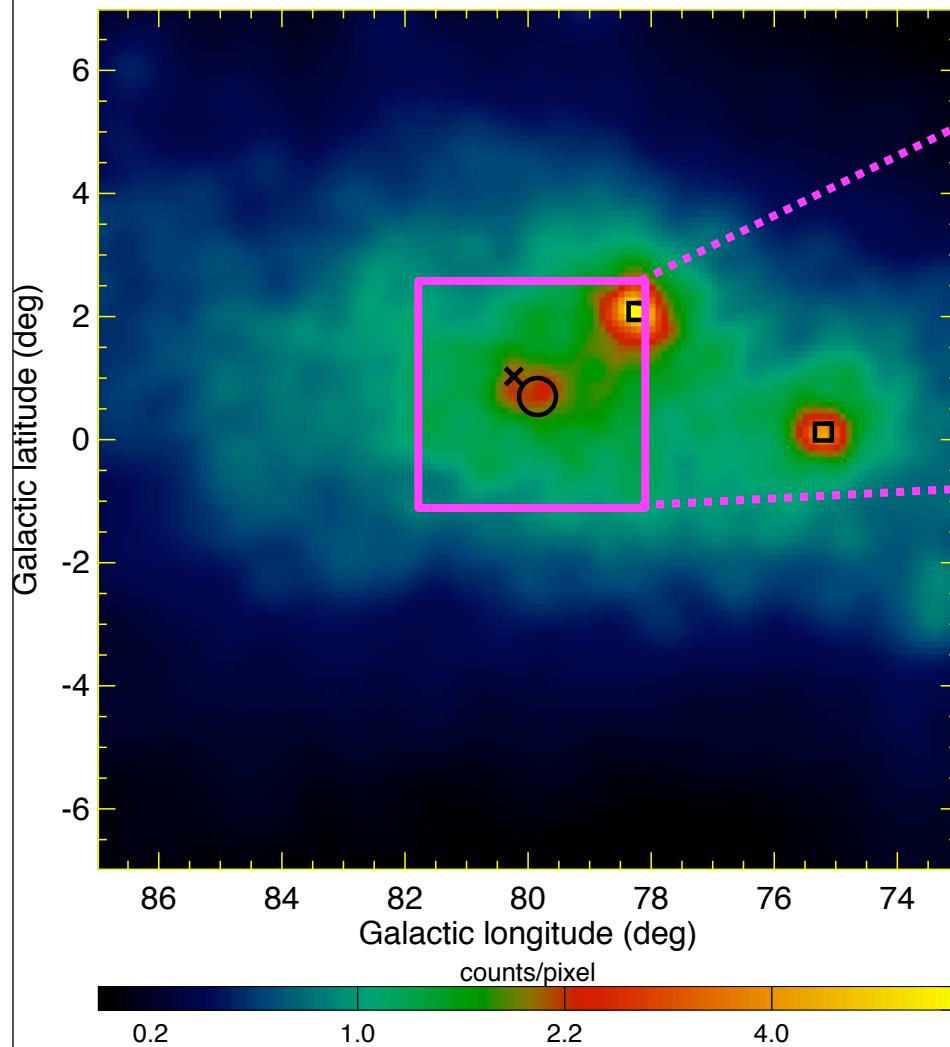
- **High Mass X-ray Binary** with a **Wolf Rayet companion star**, **short orbital period** (4.8 hours), distance ~ 7 kpc
- Compact object is probably a **black hole** but may be a **neutron star**
- Frequent radio outbursts associated with relativistic jets resolved in radio: **microquasar**
- **Long history** of “detections” from MeV to PeV (EeV?) in the 70s and early 80s, not confirmed later. **Motivated the development of high energy astronomy**
- AGILE report detection of a transient source in Cygnus region
- What can Fermi-LAT say about this ?

The Cygnus region



- **A crowded and complex field** with strong diffuse emission and 3 bright pulsars, incl. PSR J2032+4127 (cross) only 30' from Cyg X-3 (circle)
- **Turning off** the pulsar by selecting the LAT photons by phase: keep 80% of LAT exposure

The Cygnus region



- No off-pulse detection of PSRJ2032+4127
- A bright source at the location of Cyg X-3: $\sim 29 \sigma$
- Average flux (>100 MeV): 1.19 ± 0.06 (sta) ± 0.37 (sys) 10^{-6} ph s $^{-1}$ cm $^{-2}$
- Soft spectrum: PL index: 2.70 ± 0.05 (stat) $+ 0.20$ (syst)

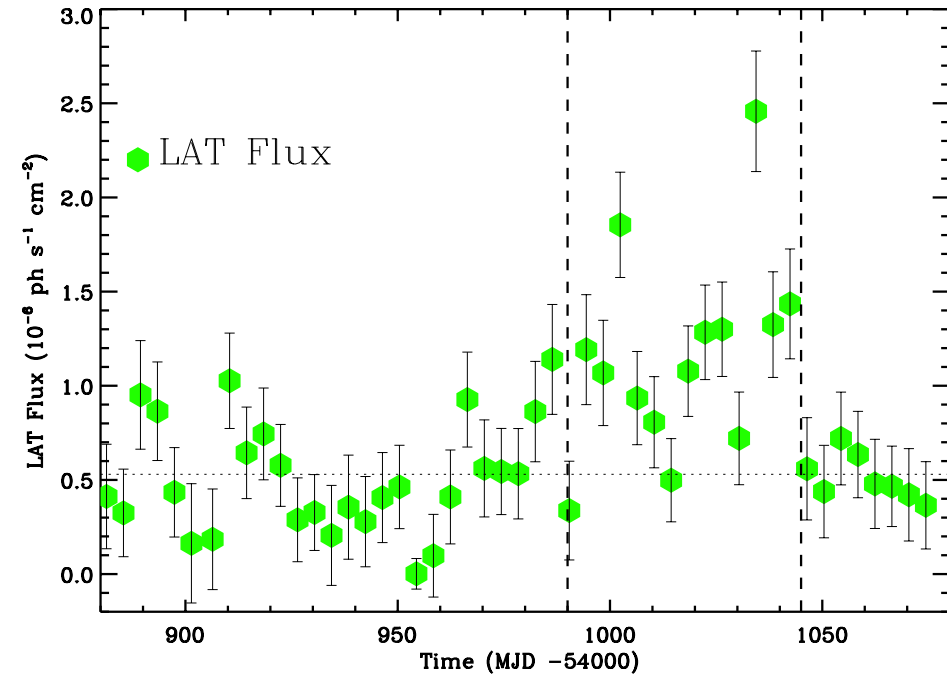
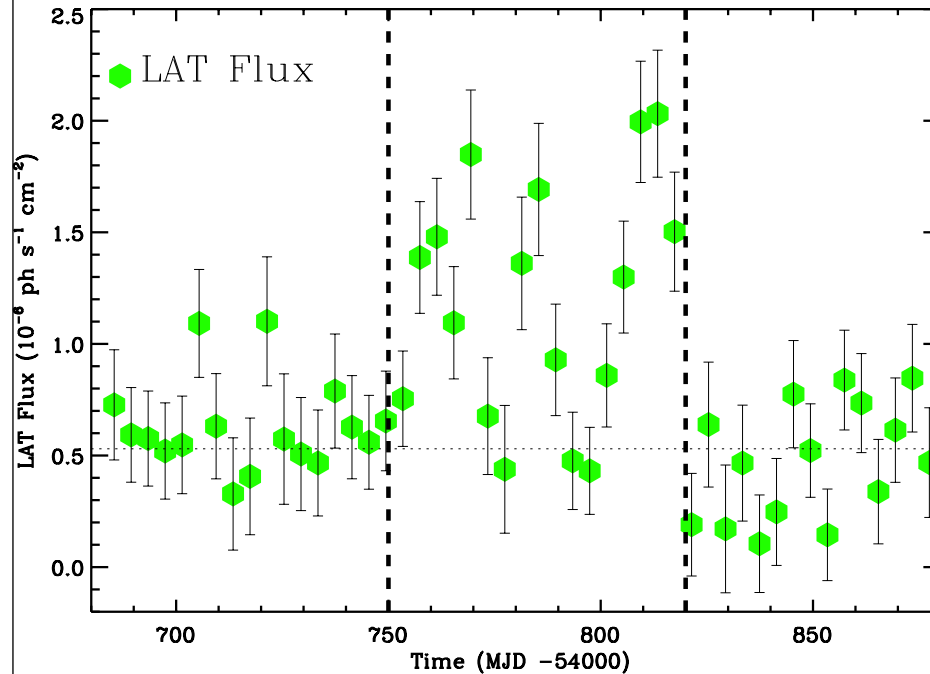
Fermi light-curve of the LAT source



2008 Aug

2009 Feb

2009 Sep



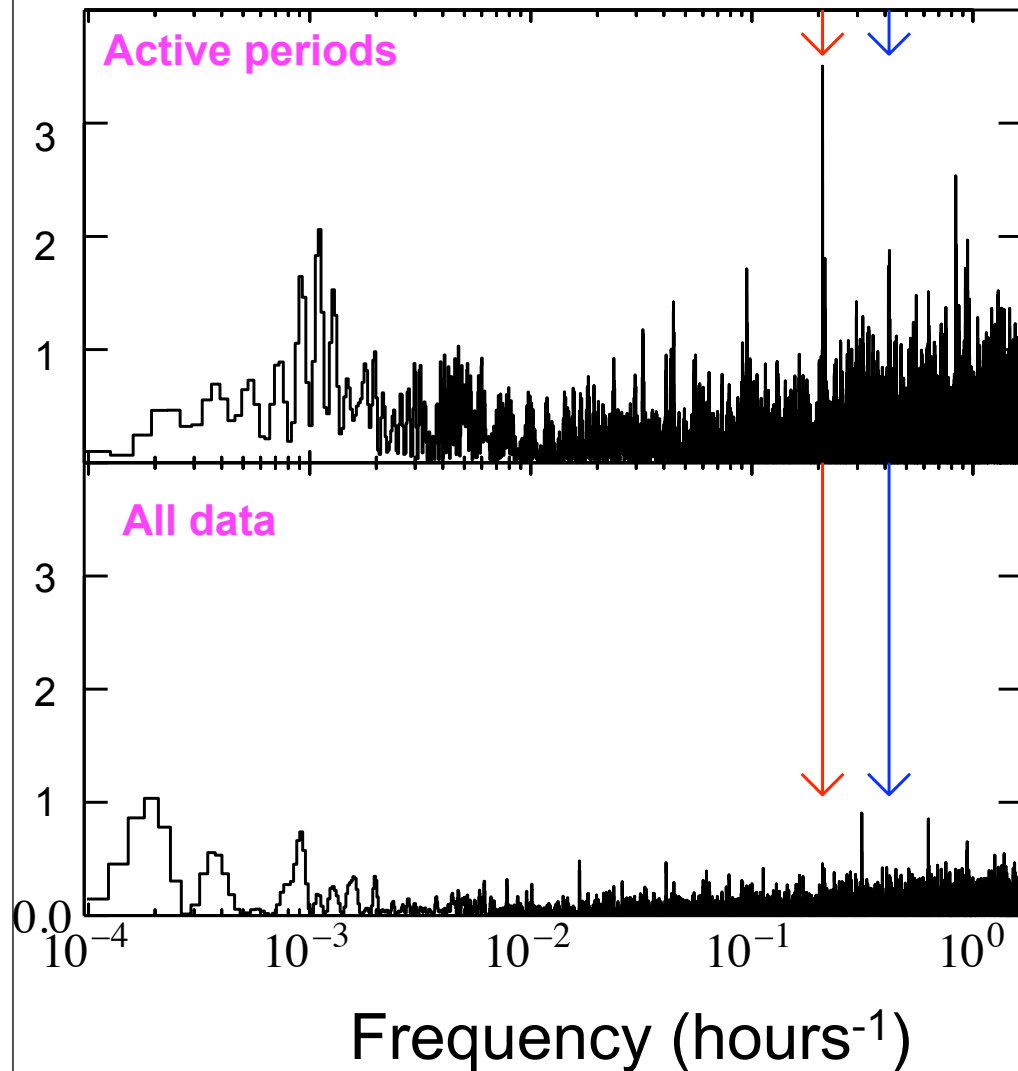
- The LAT source is variable with two main active periods : Oct to Dec 2008 and June to Aug 2009
- Active phases seem consistent with one or several flares
- Peak flux can be as high as 2×10^{-6} ph s $^{-1}$ cm $^{-2}$, corresponds to Gamma-ray luminosity $L_{\gamma} \sim 5 \times 10^{36} (d / 7 \text{ kpc})^2 \text{ erg s}^{-1}$

Orbital period search



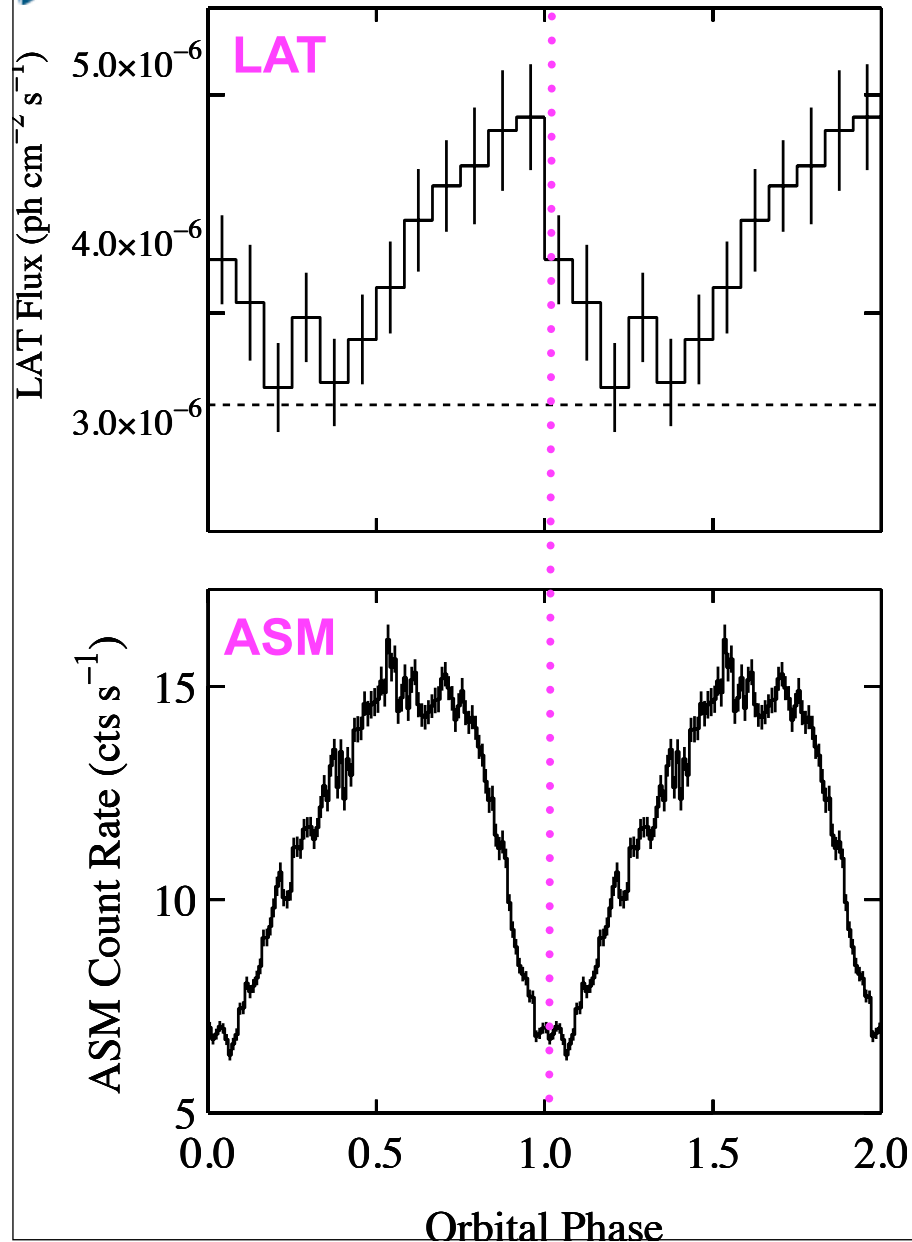
Power in 10^{-13}
(ph cm $^{-2}$ s $^{-1}$) 2

ν_{Orb} $2\nu_{\text{Orb}}$



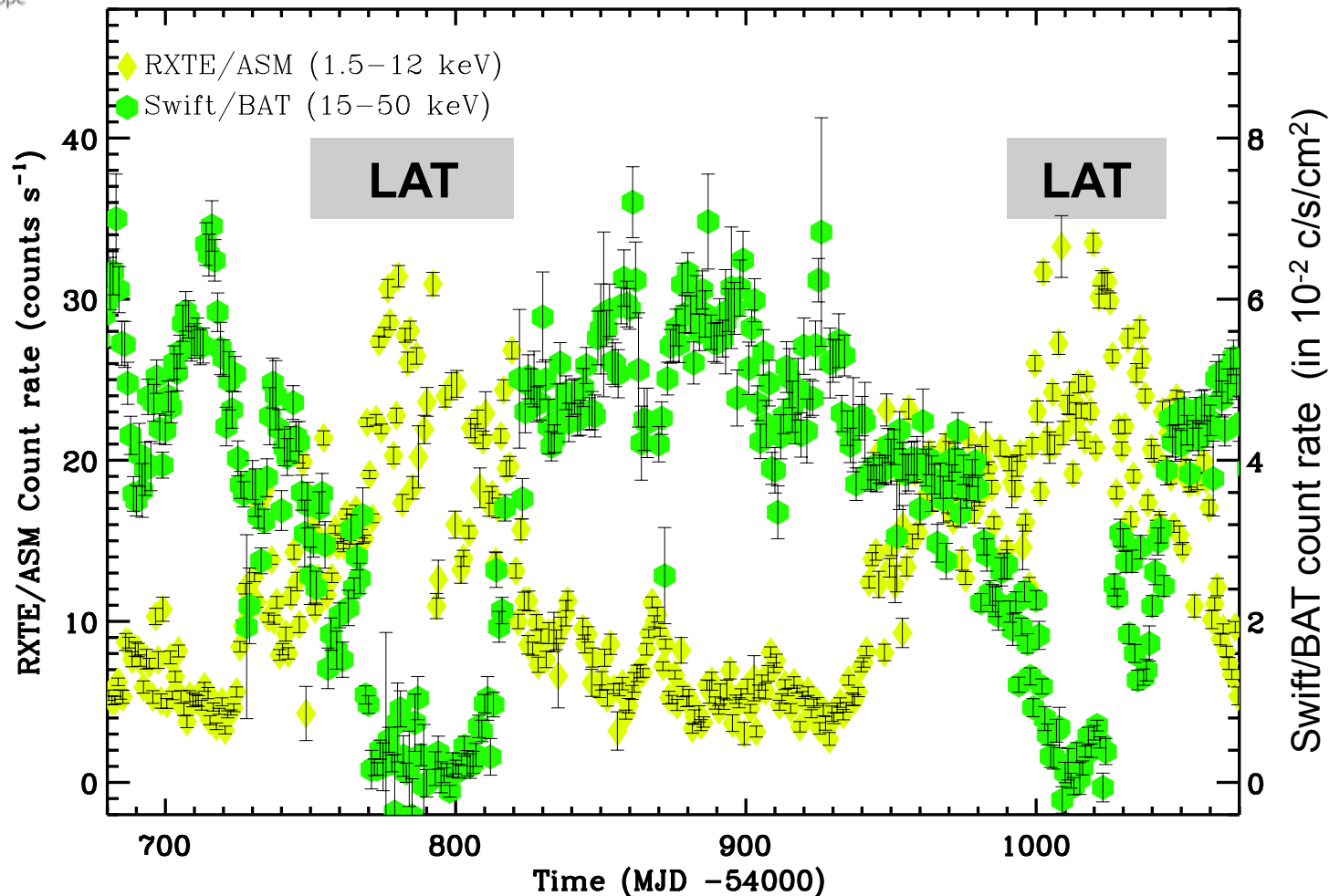
- **Cyg X-3 orbital period = 4.8 hours (red arrows)**
- **Data points weighted by their exposure**
- **No significant orbital modulation in the entire dataset**
- **Significant detection of Cyg X-3 orbital period in the two active periods (probability of a false detection $\sim 2 \cdot 10^{-9}$)**
- **Identification of the LAT source with Cyg X-3 !!**

Folded light-curves of Cyg X-3



- **RXTE/ASM and LAT: same asymmetric shape: slow rise followed by a faster decay**
- **LAT data: consistent with a 100 % modulation**
- **Important: the LAT maximum is shifted by 0.3 to 0.4 in phase from X-ray maximum**

LAT detection of Cyg X-3 in the soft state



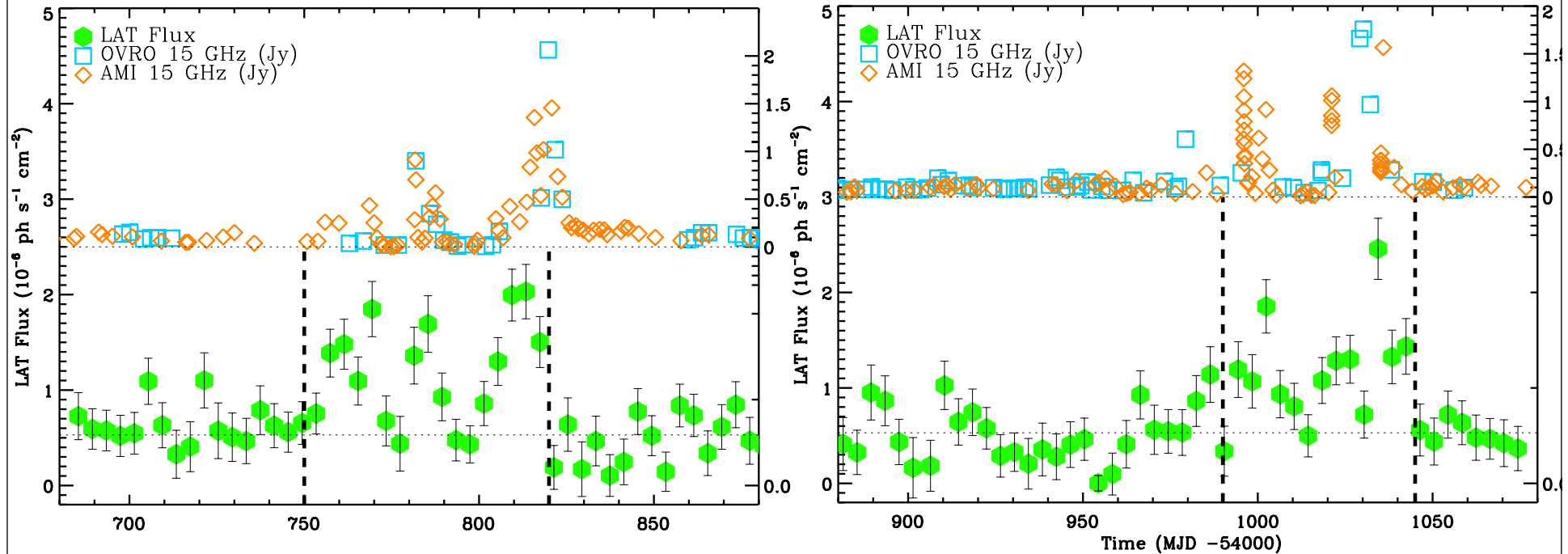
- The two active periods of Cyg X-3 as seen by LAT correspond to the soft X-ray state of Cyg X-3
- Connection to the ultra-soft state associated with relativistic ejections



2008 Aug

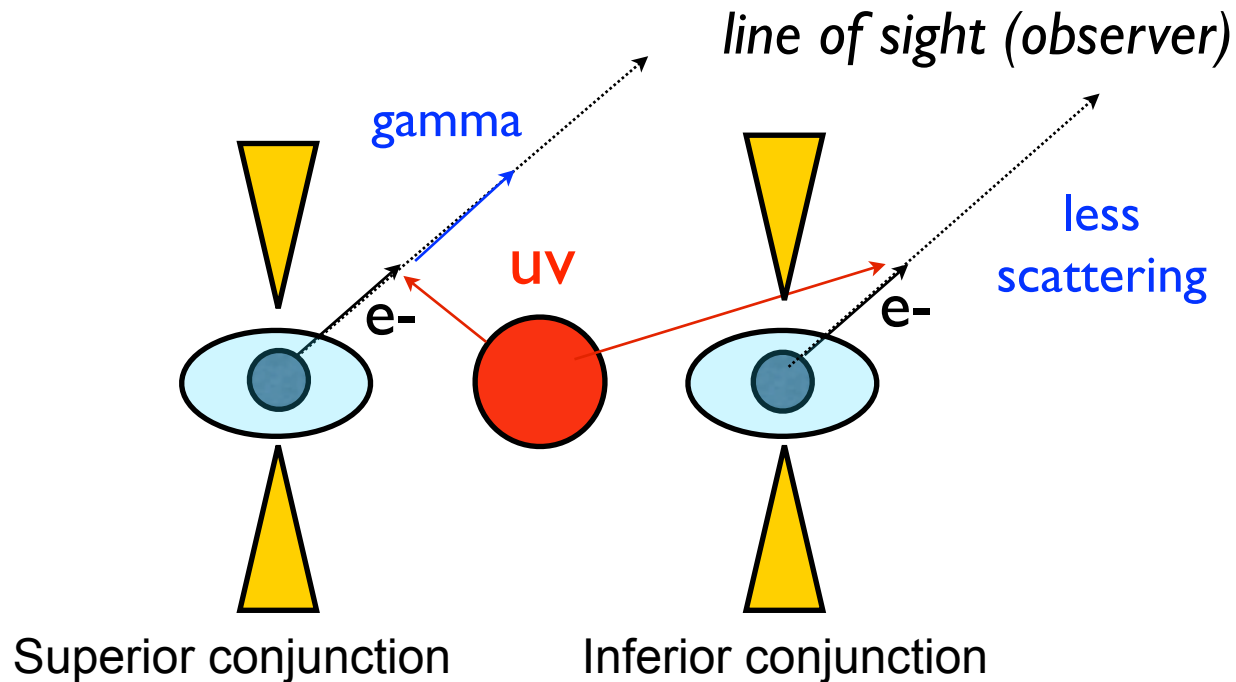
2009 Feb





2009 Sep



- The LAT active periods of Cyg X-3 occur close to radio (AMI + OVRO) flares
- Positive correlation as indicated by the discrete cross-correlation function
- Lag of the radio light-curve not well constrained: 5 +/- 7 days

Origin of the modulation



- 
 γ -rays can not originate too close to accretion disk (pair production)
- 
but within system: Modulation due to inverse Compton (IC) scattering on UV photons. More IC at superior conjunction (head-on collisions)
- 
Consistent with X-ray minima and phasing of orbit (Hanson et al. 00)
- 
e- in corona (= base of jets?). Extension of hard X-ray power-law to 100 MeV consistent with Fermi (but steepening).



- **Detection of a LAT source positionally consistent with Cyg X-3**
- **Identification with Cyg X-3** secured by the detection of its orbital period. First detection of a microquasar at high energy
- **Variability in gamma-rays** : associated with the soft X-ray state and also with periods of relativistic ejection events. **Clear link with relativistic jets ejection events.**
- **Gamma-ray emission = inverse Compton** of stellar photons on electrons in corona (=base of jets ?)
- **Maximum gamma-ray modulation when X-ray ~ minimum** : consistent with IC emission at superior conjunction.
- **WR wind + compact binary -> huge density -> hadronic interactions ? Cosmic rays protons in microquasars ?**