Preliminary results of 2007 Suzaku, Swift, XMM-Newton and Chandra observations of PSR B1259-63.

M. Chernyakova (DIAS, Ireland),
Y. Uchiyama, T. Takahashi, F. Aharonian, J. Hinton, M. Kerschhaggl, D. Khangulyan, A. Neronov, E. Nichelli, H. Odaka

Key Question

Only 3 γ-ray loud (regular detected in TeV) binaries:

PSR B1259-63 (young pulsar +Be star)

LSI +61 303 (comp. source + Be star)

LS 5039 (comp. source + O star)

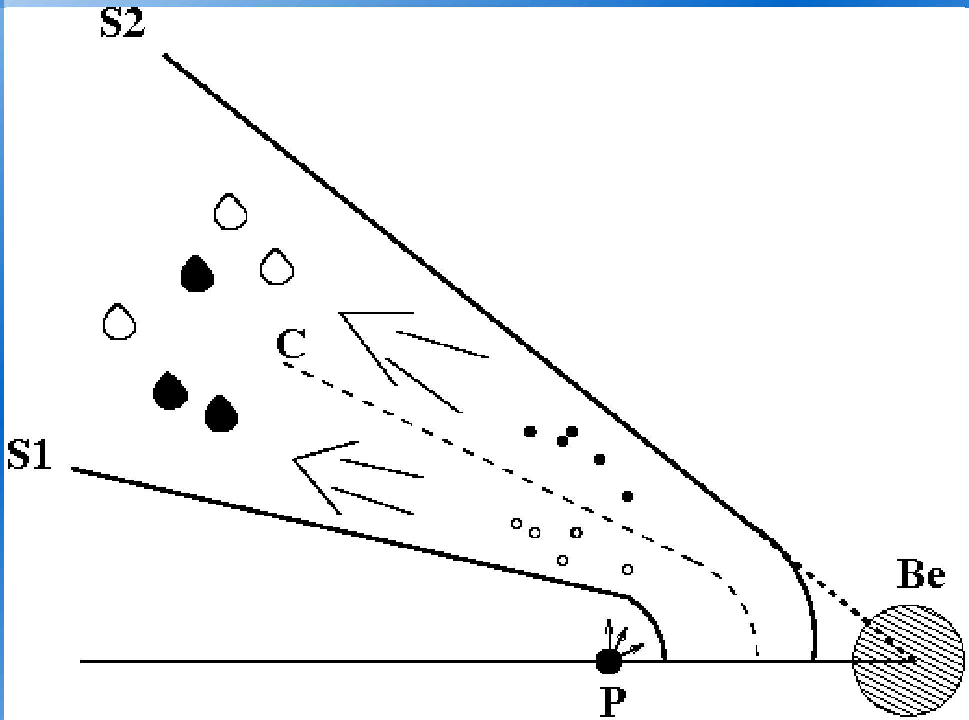
Origin of the high-energy emission?

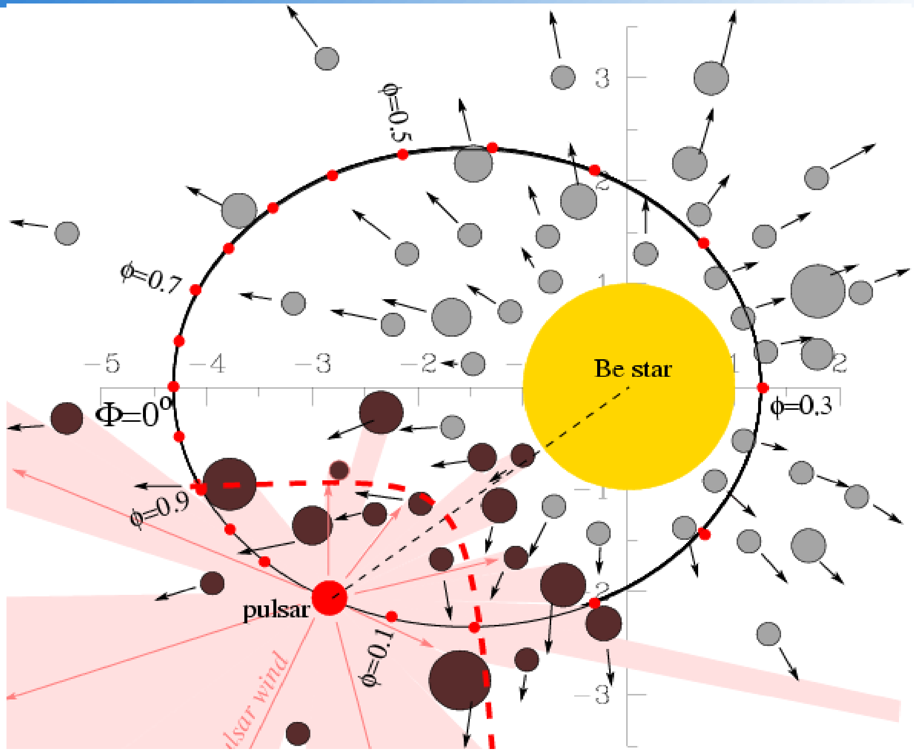
Special orientation, or

fundamentally different from other X-ray binaries?

Powered by rotation energy rather than accretion?

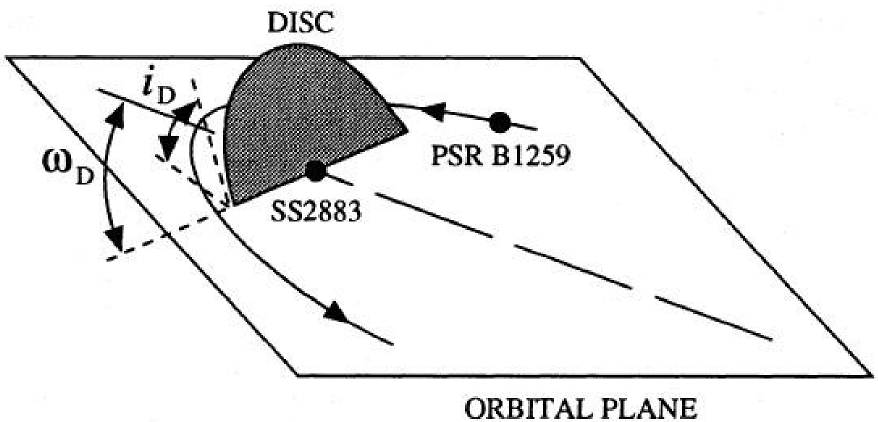
Winds collision





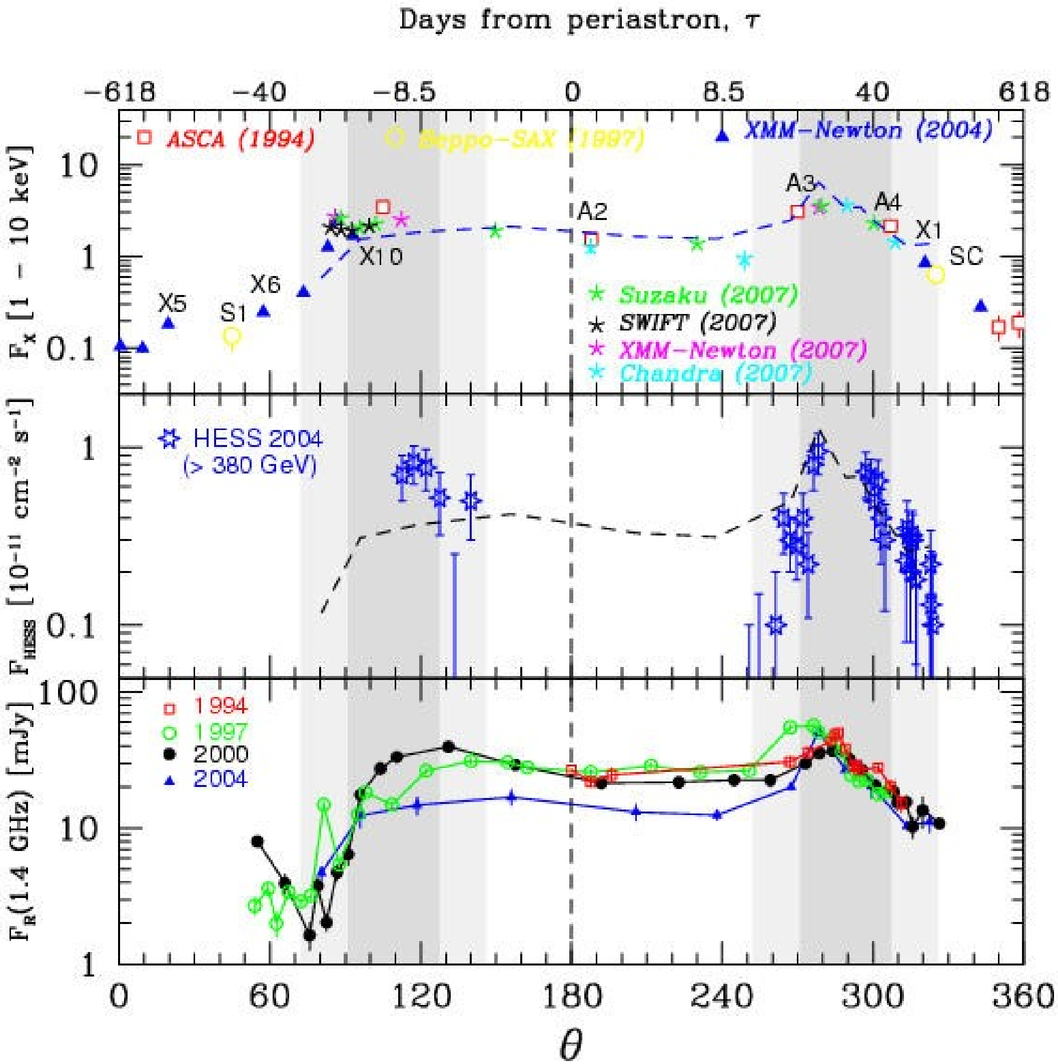
- Equating the dynamical pressures of the winds one finds the distance to the contact surface from the pulsar.
- Due to the intrinsic instabilities in the winds of massive stars clumps may form and change the well-ordered structure.
- Emission is due to the synchrotron, IC, bremsstrahlung, and proton-proton interactions.

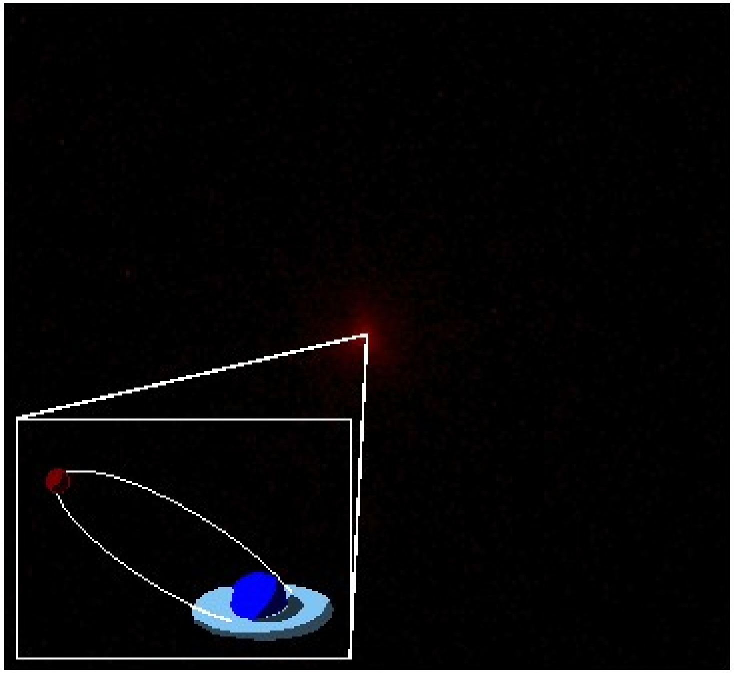
PSR B1259-63



- Orbital parameters
  - e=0.87
  - Porb=1236.8 days
  - $a=10^{13}$ cm
  - D ~ 2kpc
- Pulsar parameters
  - P=47.762 ms
  - dP/dt=2.28E-15
  - L_p=9E+35erg/s
- SS 2883 parameters
  - L_*=2.2E+38 erg/s
  - M~10M_{sun} T~27000 K

PSRB 1259-63



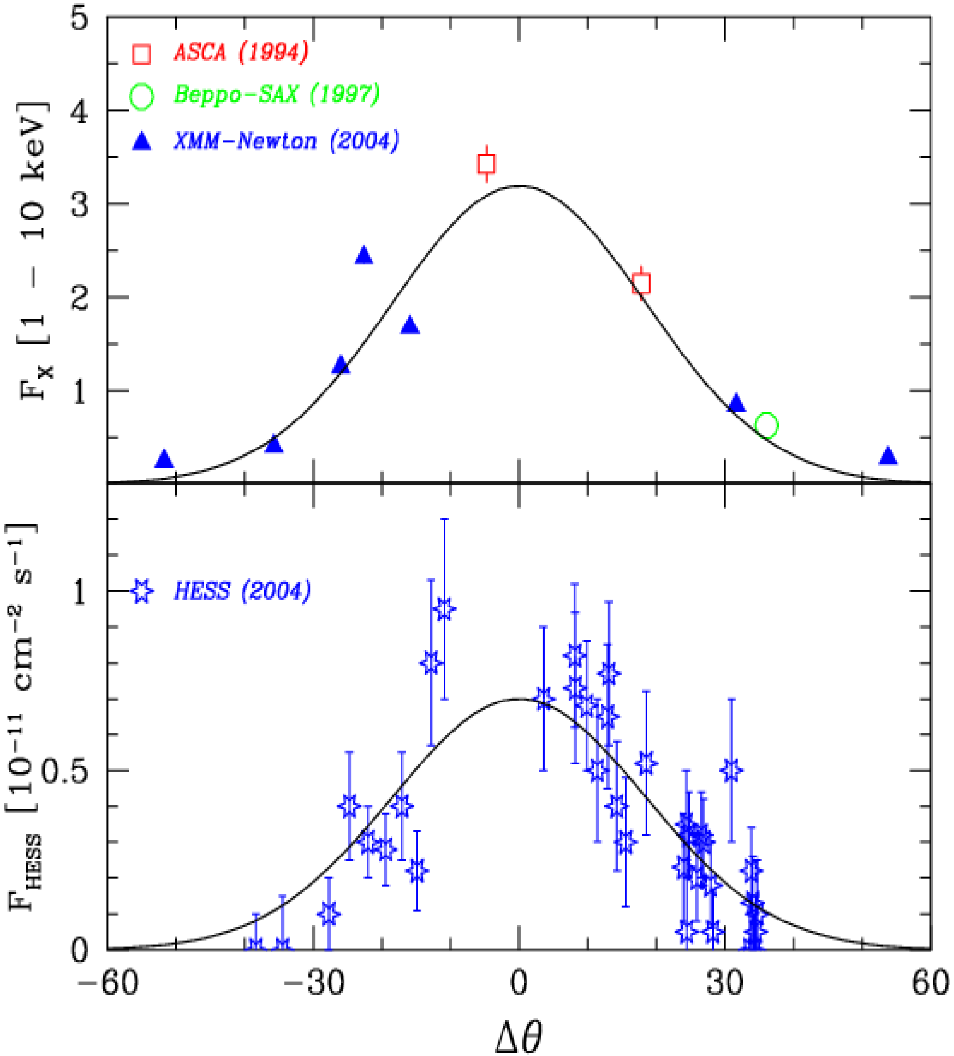


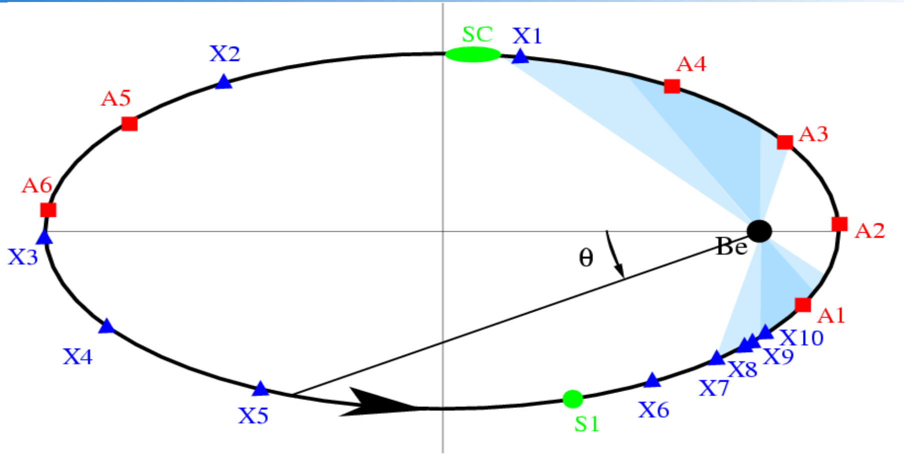
3.4 years orbital period. e~0.87

Rapid rise of the X-ray emission is correlated with the rise of the unpulsed radio emission.

Correlated variability ("*two bumps structure*") is seen in radio, X-ray and TeV bands.

Disk parameters and X-ray – TeV correlation





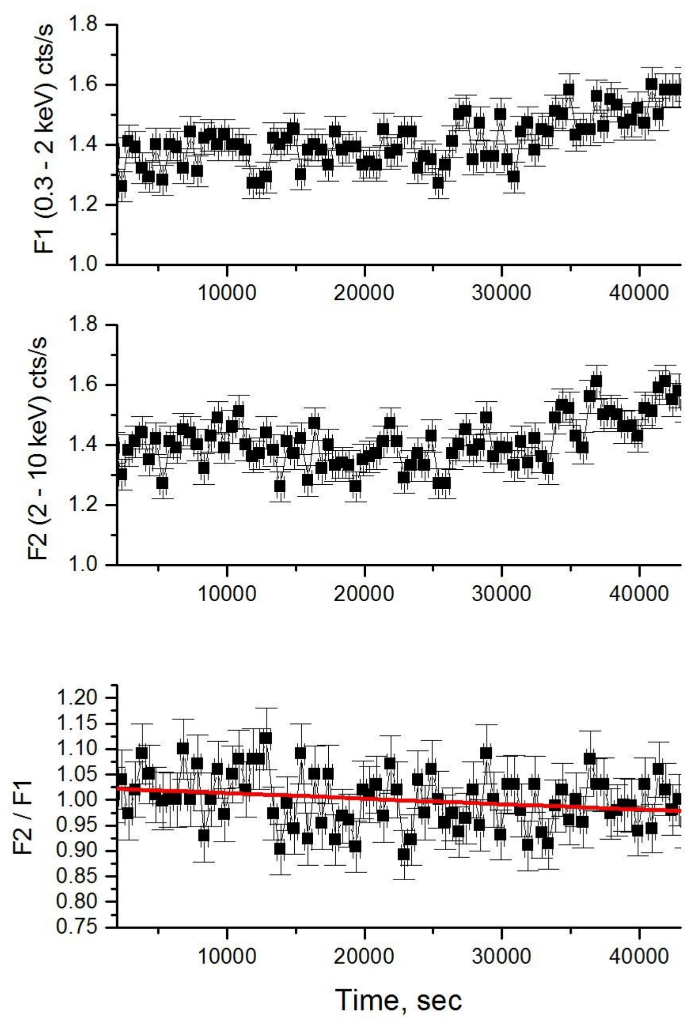
- Rise (decay) of the X-ray and TeV emission as the pulsar enters (leaves) the disk is described with a Gaussian:

$$F(\Theta) \propto \exp\left(\frac{-(\Theta - \Theta_{disk})^2}{2\Delta\Theta_{disk}^2}\right)$$

$$\Theta_{disk} = 109.1 \quad \Delta\Theta_{disk} = 18.5$$

Short Scale Time Behavior

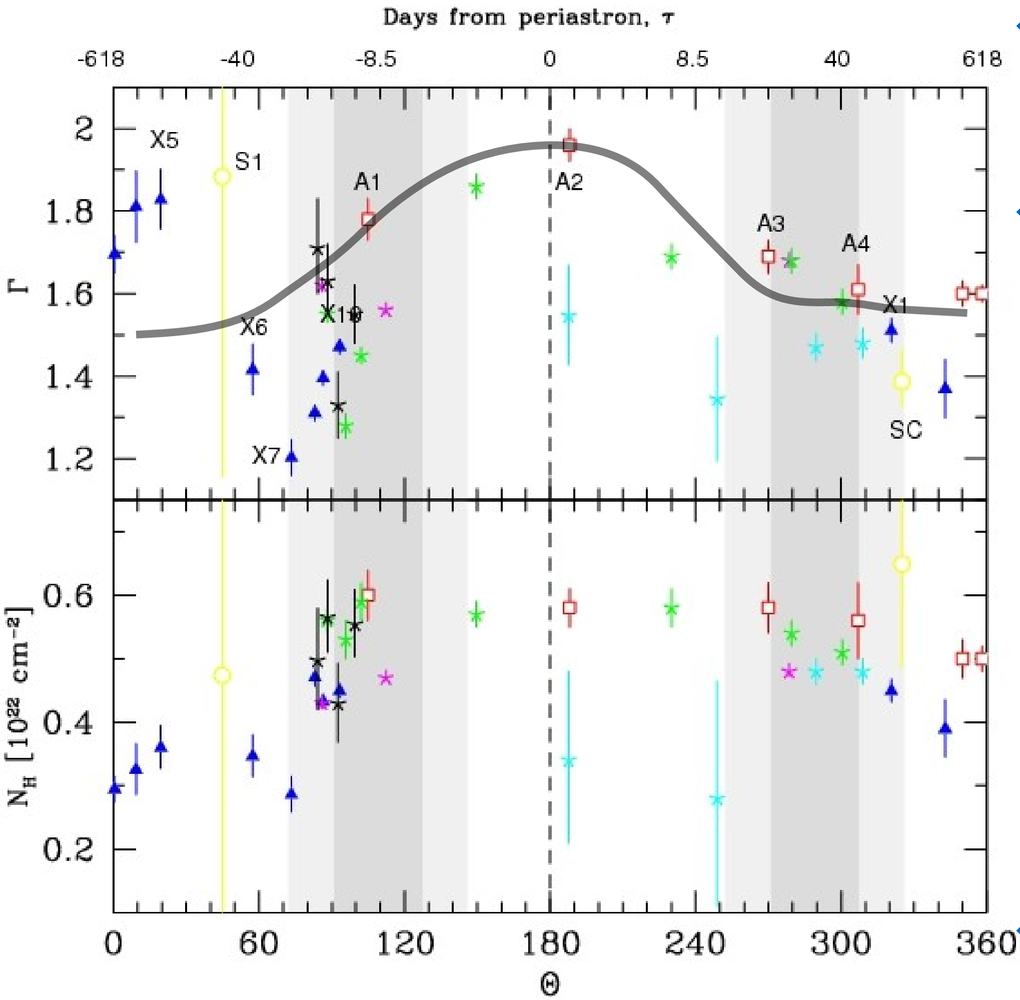
PN/*XMM* 16.07.2007 (θ=112)



- During 40 ksec of observation we observed a steady grow of flux without short scale variability.

- Linear fit to the hardness ratio gives a slope of $1.1\times10^{-6}\pm3.2\times10^{-7}$, i.e. softening by 0.04 in 40ksec.

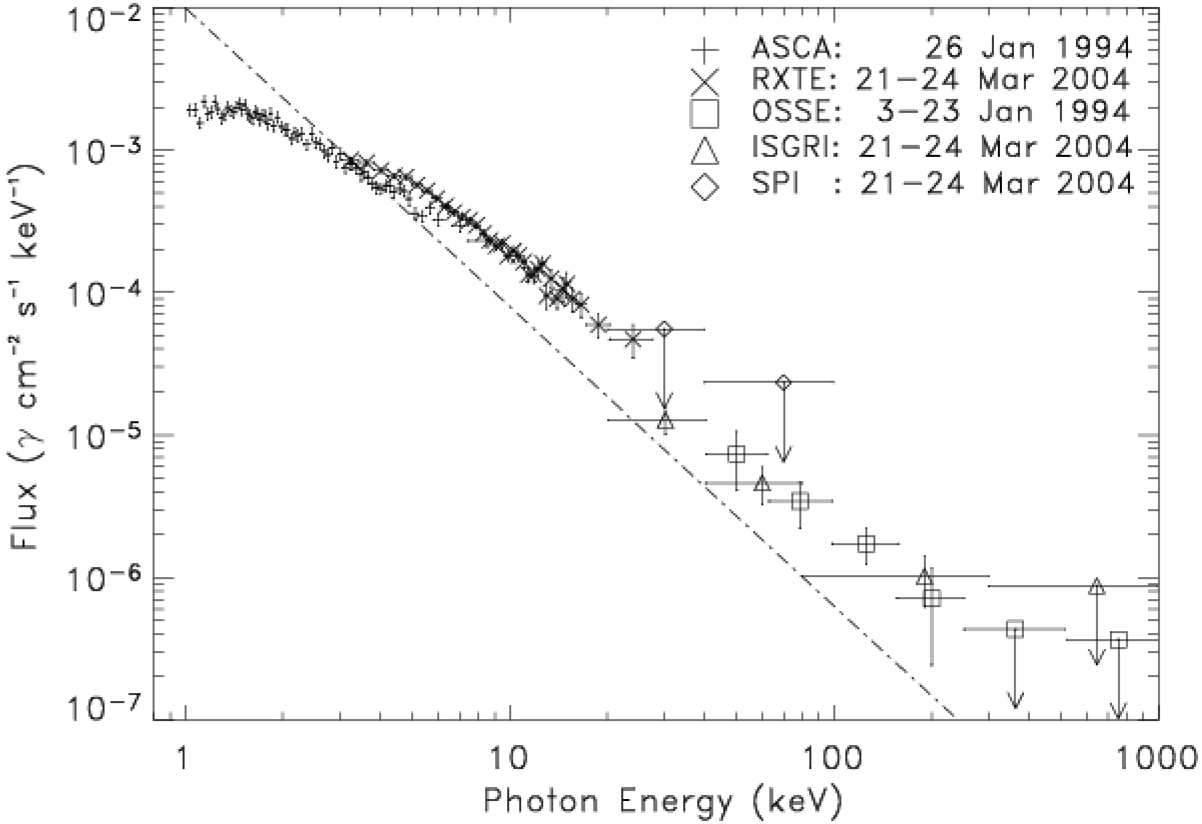
X-ray spectral properties



- Spectrum is well described by an absorbed power law.
- Contrary to what is expected in synchrotron (Tavani & Arons 97) model the X-ray spectrum hardens (reaching $\Gamma=1.2$), at the disk entrance, and becomes softer, as it penetrates into the disk, on *day time scales*.
- The N_H value correlates with the disk position.

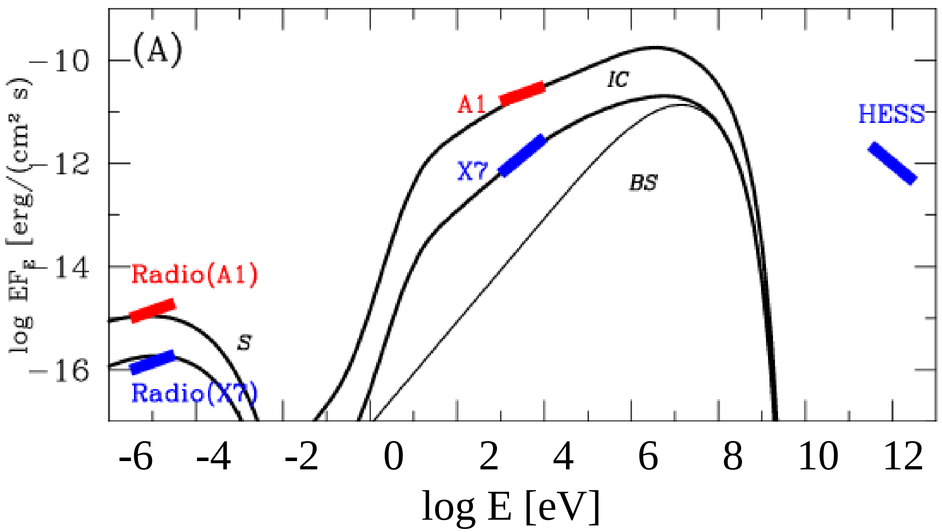
Hard X-ray – Gamma observations

Shaw et al. 2004



- Observations near the time of the second disk crossing are consistent with single power law (Γ=1.7) in 2–100 keV range (OSSE, INTEGRAL)

IC X-ray emission



The observed spectral variability is naturally explained in *IC model*

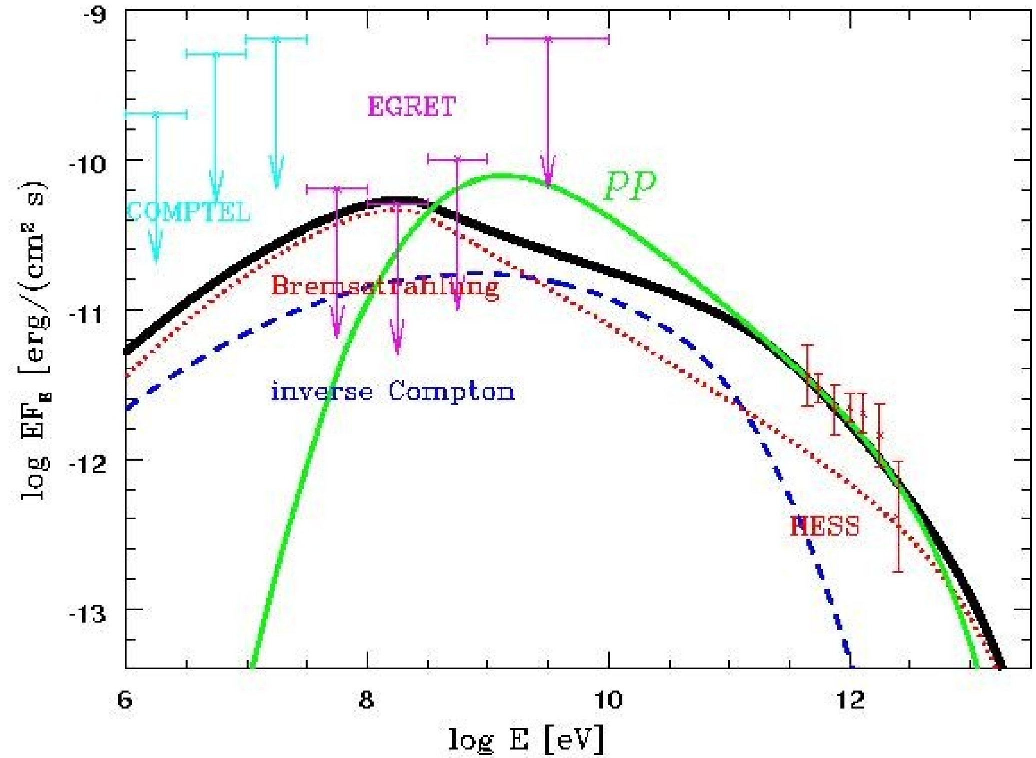
- $E_{ic}=4[E_e/10\text{MeV}]$ keV
- $t_{ic}=10^6[R/10^{13}\text{cm}]^2[10\text{MeV}/E_e]$ s
- $t_s=6\text{x}10^2[\text{B}/0.1\text{G}]^{-3/2}[\varepsilon_s/10\text{keV}]^{-1/2}$s

•.... *injection* of electrons with energies above 10 MeV at the moment of disk entrance would result in hardening, and subsequent softening of the X-ray spectrum on a day scale.

•Radio and X-rays are synchrotron and IC from the same population of electrons. --> An upper limit on magnetic field

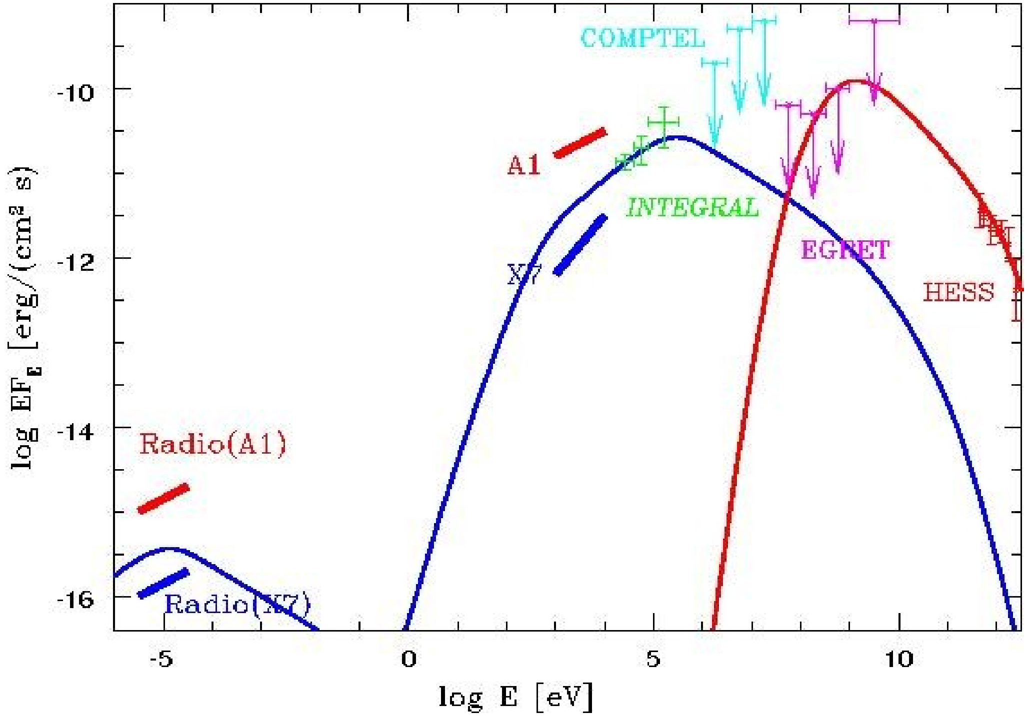
$B<0.1[R/10^{13}\text{cm}]$ G

TeV emission: IC, bremsstrahlung or proton-proton interactions?



- The observed TeV lightcurve can be reproduced in the IC model if *adiabatic loss dominates* or the *acceleration efficiency drops* at periastron (Khangulyan et al. 06).
- If the matter density is $n \sim 10^{11} cm^{-3}$, the bremsstrahlung energy loss is comparable to the IC loss (in KN regime) and proton-proton interaction time. TeV emission can be bremsstrahlung from the compact region of interaction of pulsar and stellar winds.

Radio-to-TeV emission from proton interactions?



If the *pulsar wind is proton-loaded*, TeV emission can result from decays of neutral pions produced in interaction of the pulsar and stellar wind protons.

Secondary electrons produced in pp interactions can be responsible for the observed radio (synchrotron) and X-ray (inverse Compton) emission.

- Radio – X-ray – TeV correlation is naturally explained, as well as
- Injection of electrons above 10 MeV at the moment of disk entrance.

Conclusions

- 2007 PSR B1259-63 observations revealed:
  - Stability of the X-ray orbital lightcurve.
  - Day scale variability during the disk passage.
  - Absence of the shorter time scale variability.
  - X-ray - radio lightcurves correlation.
- X-ray emission is dominated by inverse Compton, rather than synchrotron.
- Magnetic field in X-ray emission region is low, B<0.1G.
- 3 possible TeV emission mechanisms: *inverse Compton*, *bremsstrahlung* or pion decay emission.