Strong Field Neutron Stars with Astrosat

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Two Classes of Strong Field Neutron Stars

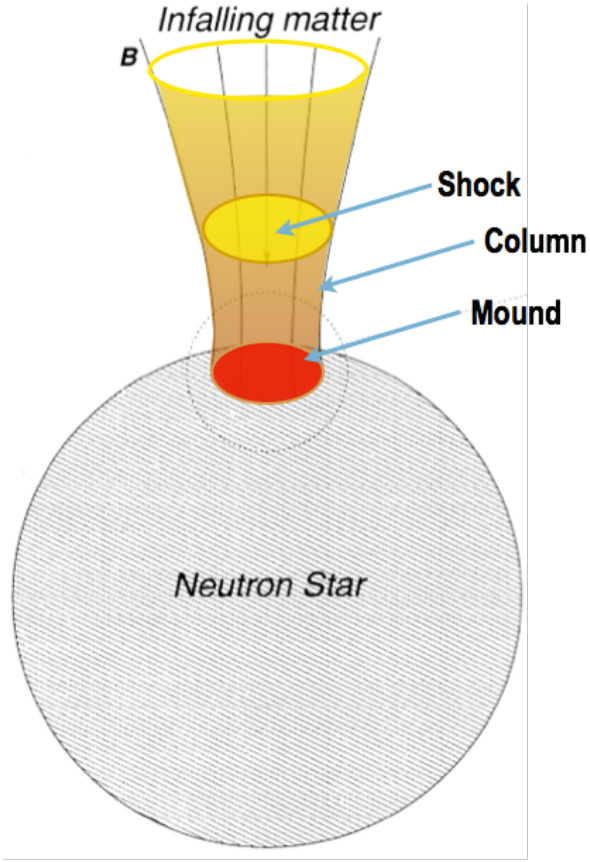
- Accreting X-ray Pulsars in High Mass X-ray Binaries
- Magnetars: isolated, magnetically powered neutron stars

Accreting X-ray Pulsars in HMXBs

- **Cyclotron Lines**
- Pulse profile studies
- Timing: disk-magnetosphere interaction
- Correlation of various properties with accretion rate

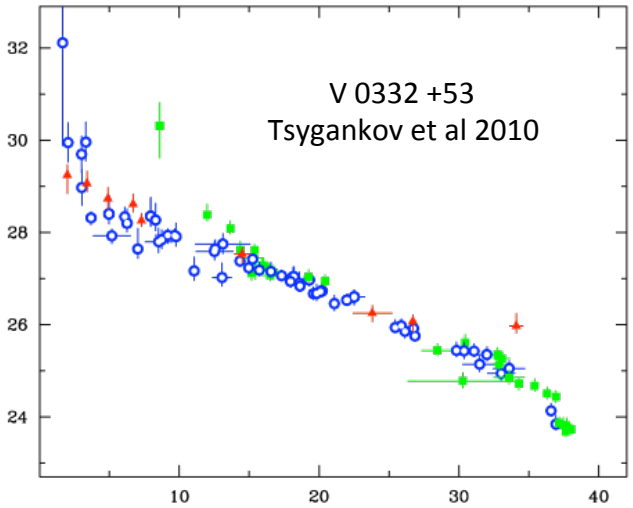
Cyclotron Lines (CRSF)

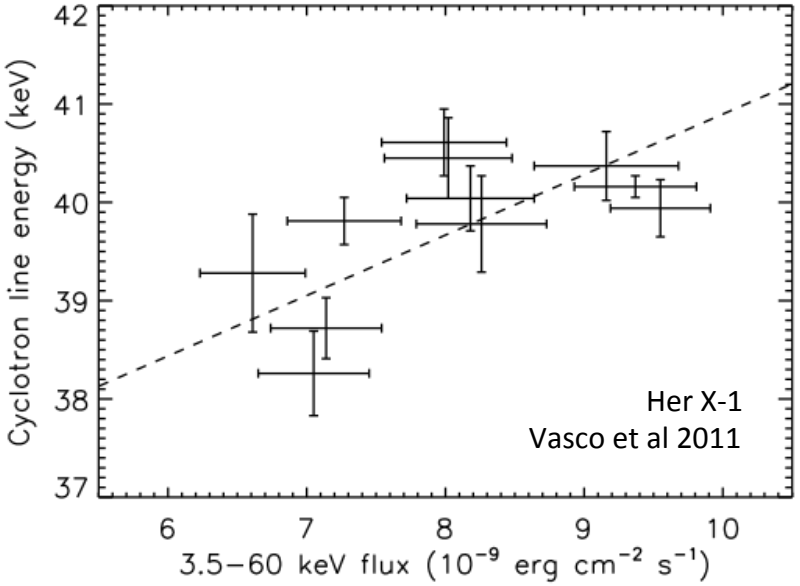
- Resonant scattering features from electrons in Landau levels: $E_c \approx 12\ B_{12}$ keV : estimate B
- Key unknowns:
  - Location of line formation, field geometry
  - Source and nature of the continuum
  - Distribution and dynamics of plasma
  - Short-term and secular evolution
- Important observational indicators
  - E_c vs L and pulse phase, line shape, harmonic spacing
  - Energy-resolved timing
  - Continuum shape, phase dependence



Polar accretion geometry

Luminosity dependence of CRSF

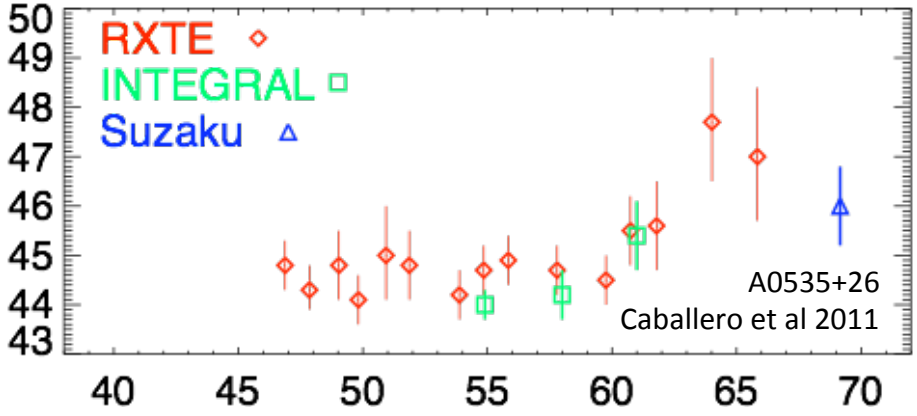


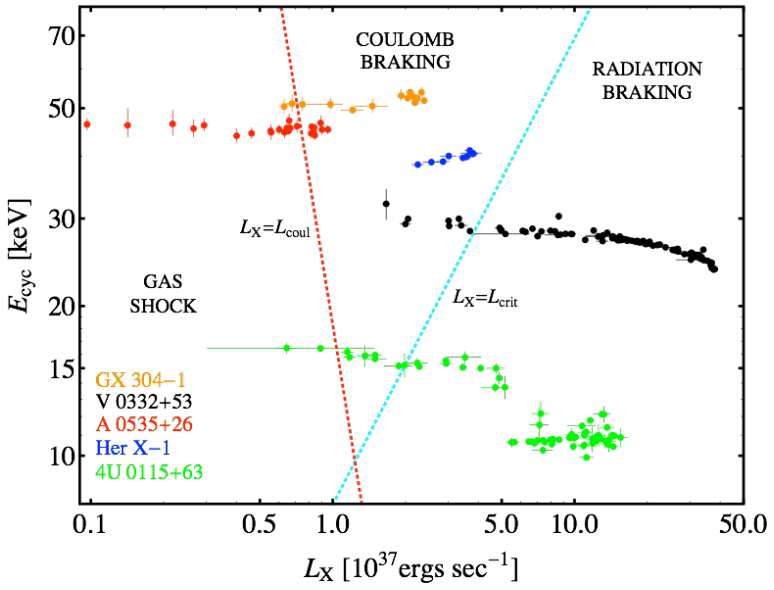


- +ve correlation
- -ve correlation
- No correlation

Different accretion regimes?

- Column model by Becker et al 2012



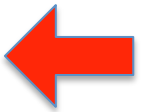


Correlation found to depend on continuum model used to fit the data (Ferrigno et al 2013)

Cyclotron Lines (CRSF)

ASTROSAT niche: wideband spectroscopy, high sensitivity, simultaneous timing.

- Determination of continuum shape
- Resolving line structure, harmonic ratios
- Phase resolved spectroscopy
- Time (flux, pulse, orbit) resolved spectroscopy
- Simultaneous variation of line and pulse profile
- Energy resolved timing
- Extend studies to weaker sources
- Find new cyclotron line sources

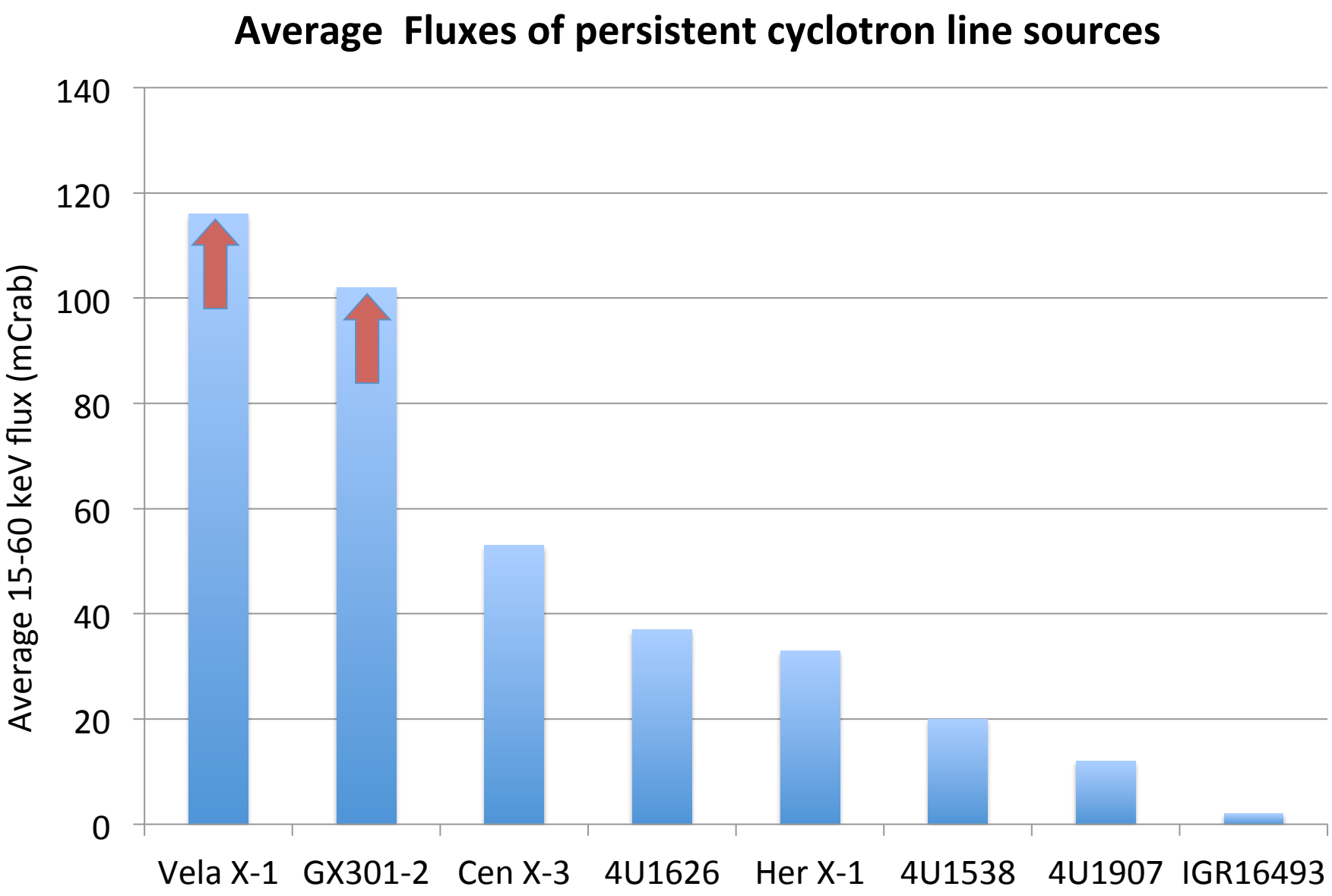


Astrosat will be a very capable observatory for cyclotron lines.

Baseline Science Proposal: 2 bright, persistent cyclotron line sources for phase resolved study at different luminosity states with SXT, LAXPC and CZTI

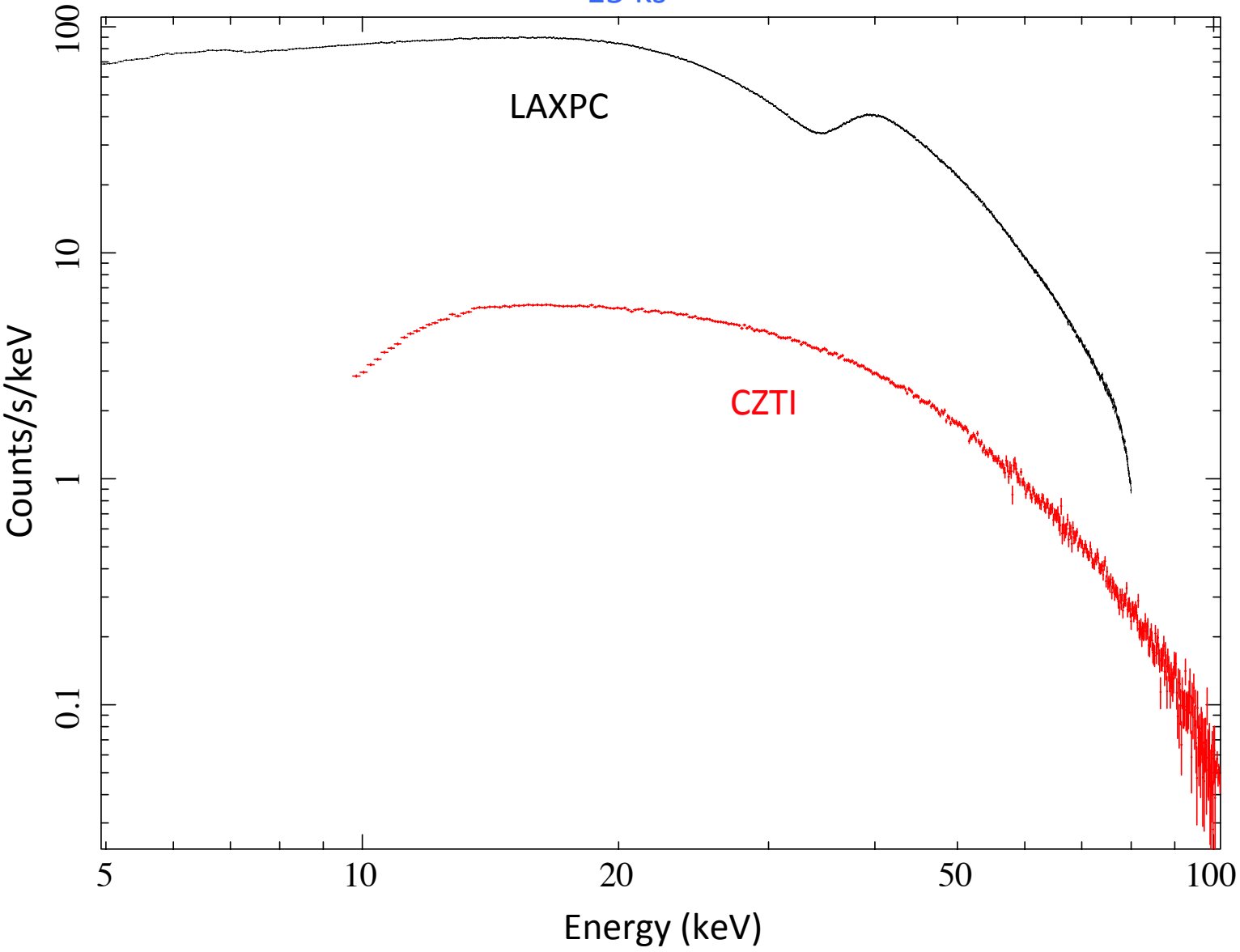
Vela X-1 : 4 observations of 50 ks each

GX301-2 : Luminosity variation (~10x) highly predictable (orbital) – 3 observations of 40, 30 and 50 ks

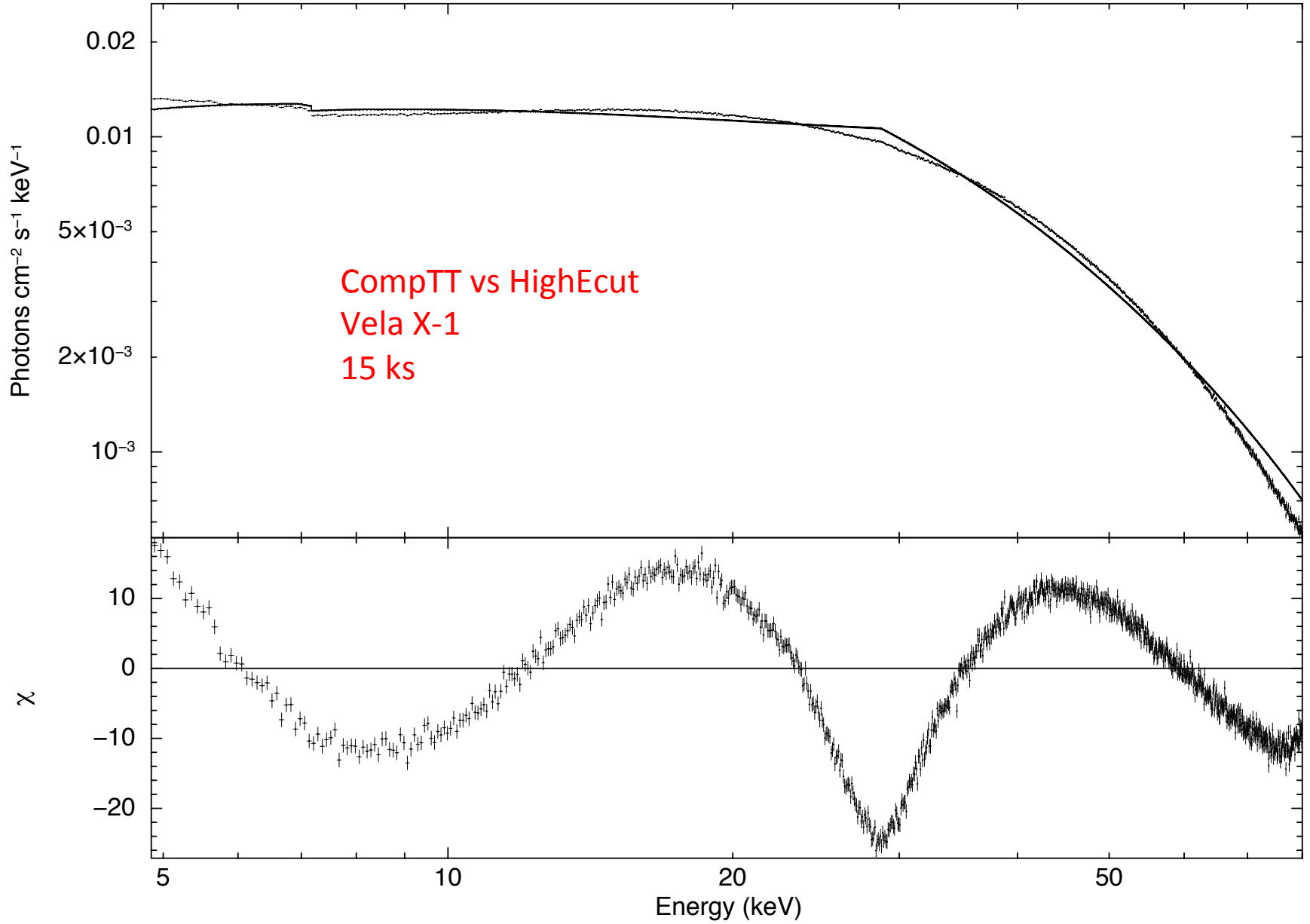

Average Fluxes of persistent cyclotron line sources
Average 15-60 keV flux (mCrab)
140
120
100
80
60
40
20
0
Vela X-1
GX301-2
Cen X-3
4U1626
Her X-1
4U1538
4U1907
IGR16493

Vela X-1

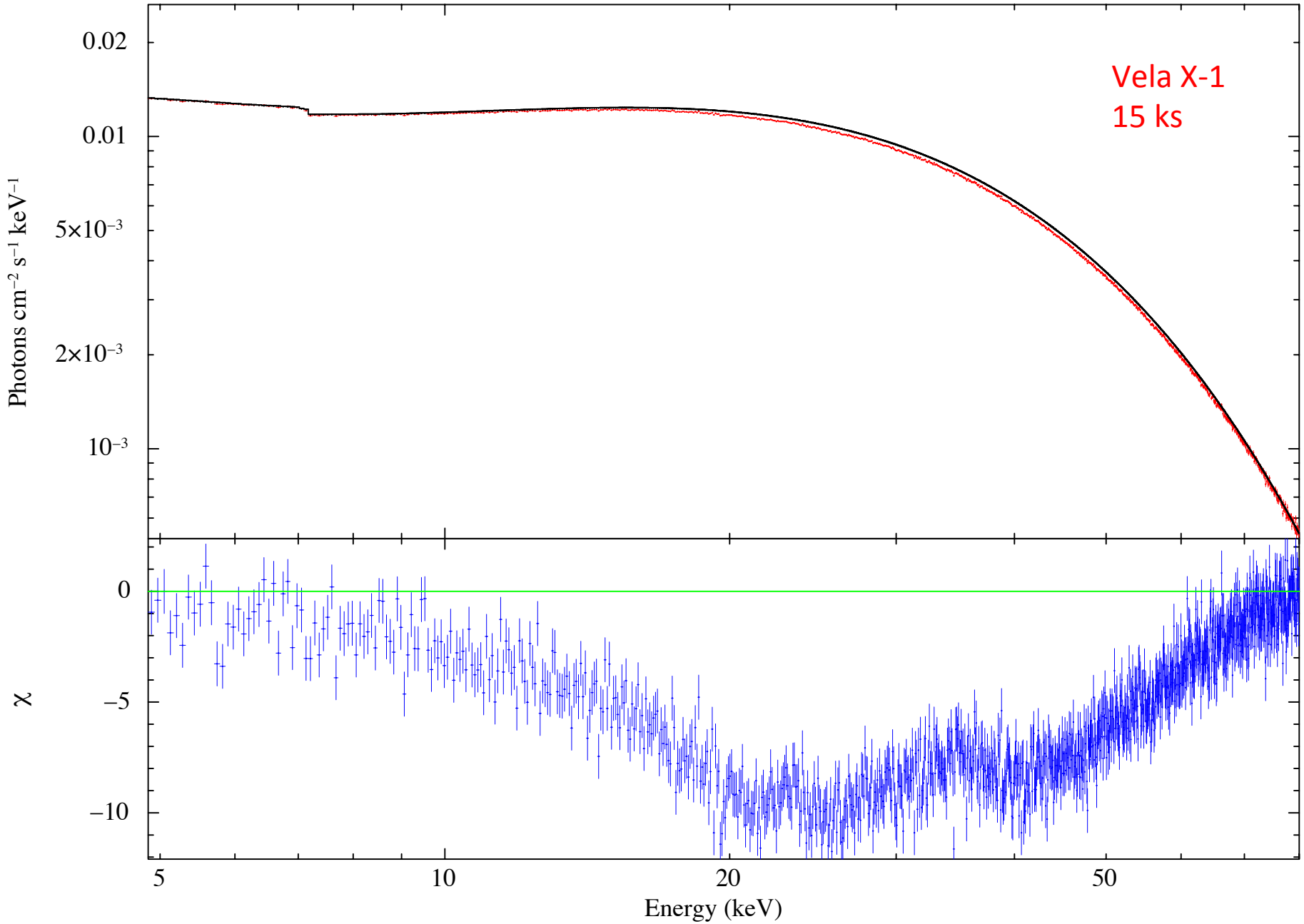
15 ks



Determining the continuum

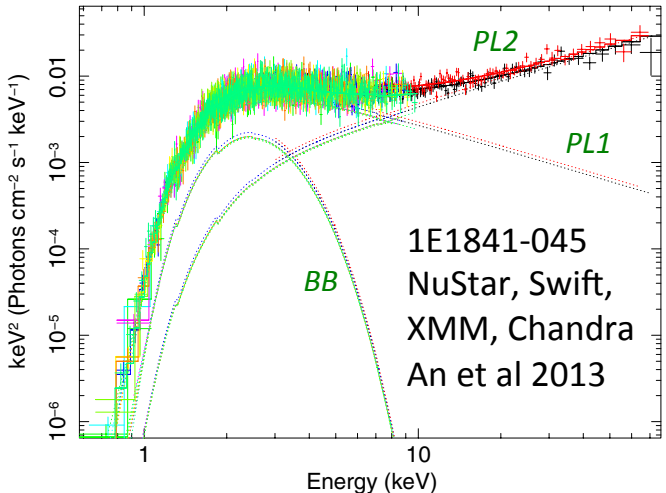


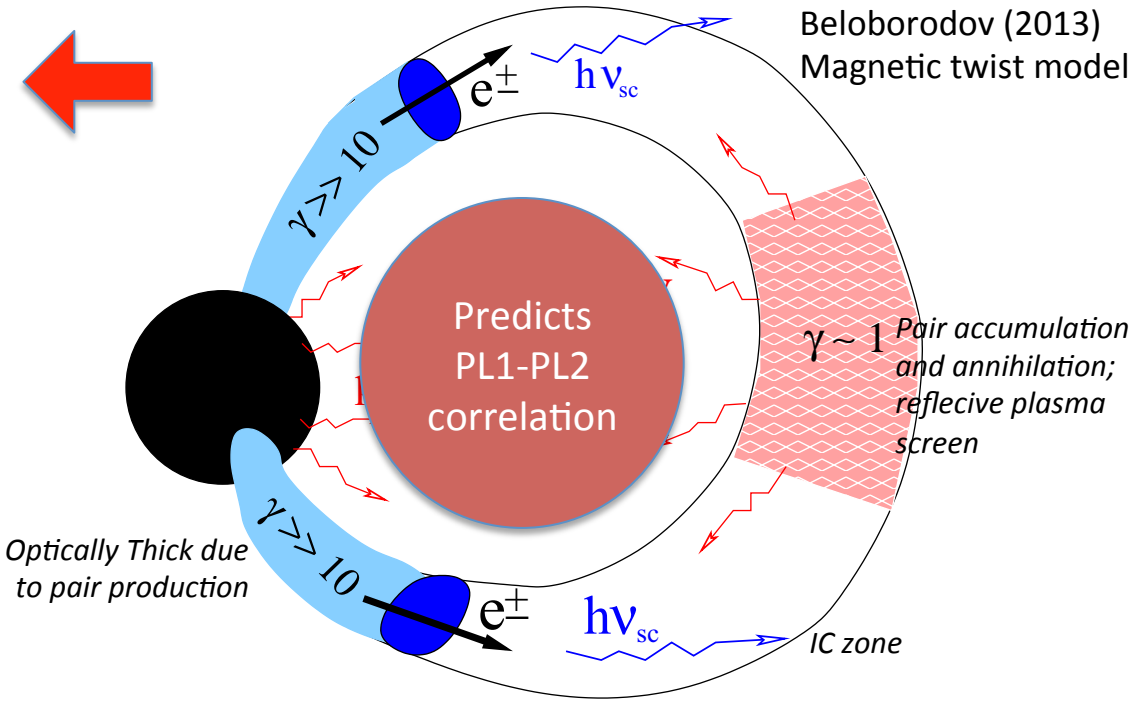
Detecting the line



Magnetars

- Key Issues
  - Energy Source: trapped magnetic free energy?
    - *B* estimate from spin down rate, proton cyclotron line
    - Long-term monitoring: *P* variations, glitches, outbursts
  - Emission Mechanism
    - Broadband spectra
    - Outburst profile





Magnetar proposal for Astrosat Baseline Science

- Two persistent magnetars, 100 ks each with SXT, LAXPC and CZTI: 1E1841-045 and 4U0142+61 to investigate correlated variability and beaming pattern of low energy and high energy power law components

- Follow up any bright Magnetar outburst that happens to occur during the baseline science period (All instruments).

1E1841-045 with Astrosat: 50 ks