How can a magnet hide its signature line? The case of 4U 1901+03 and 2S 1417-624.

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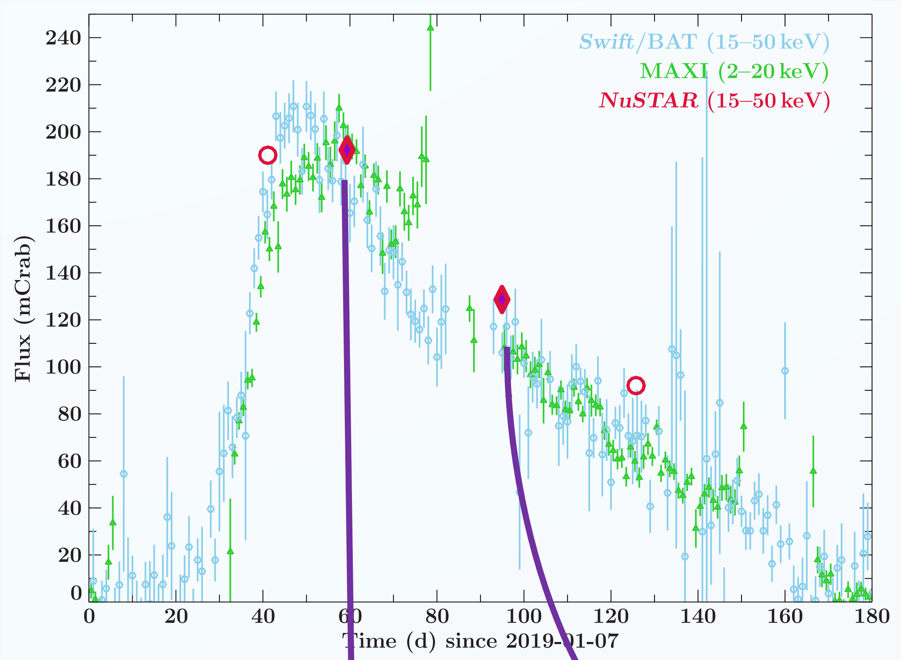
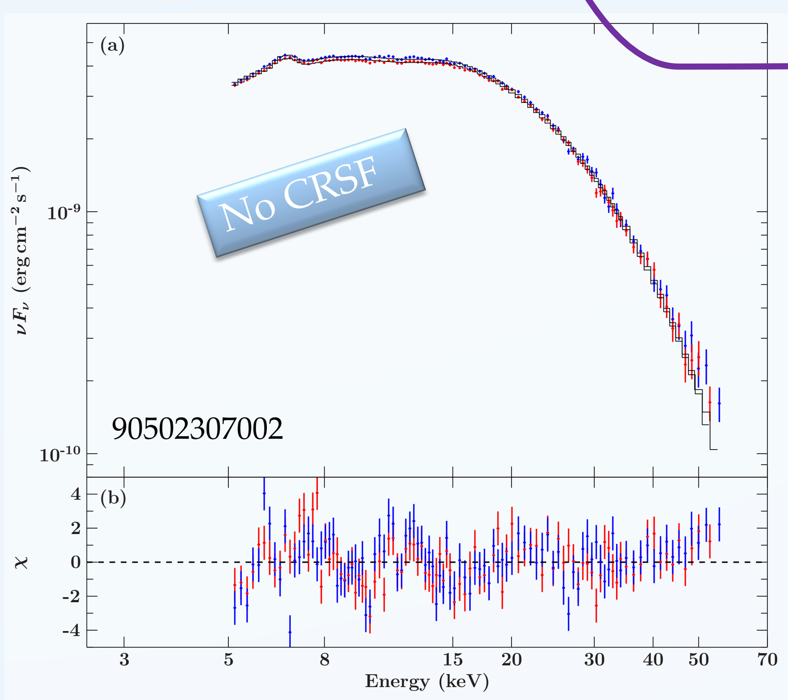
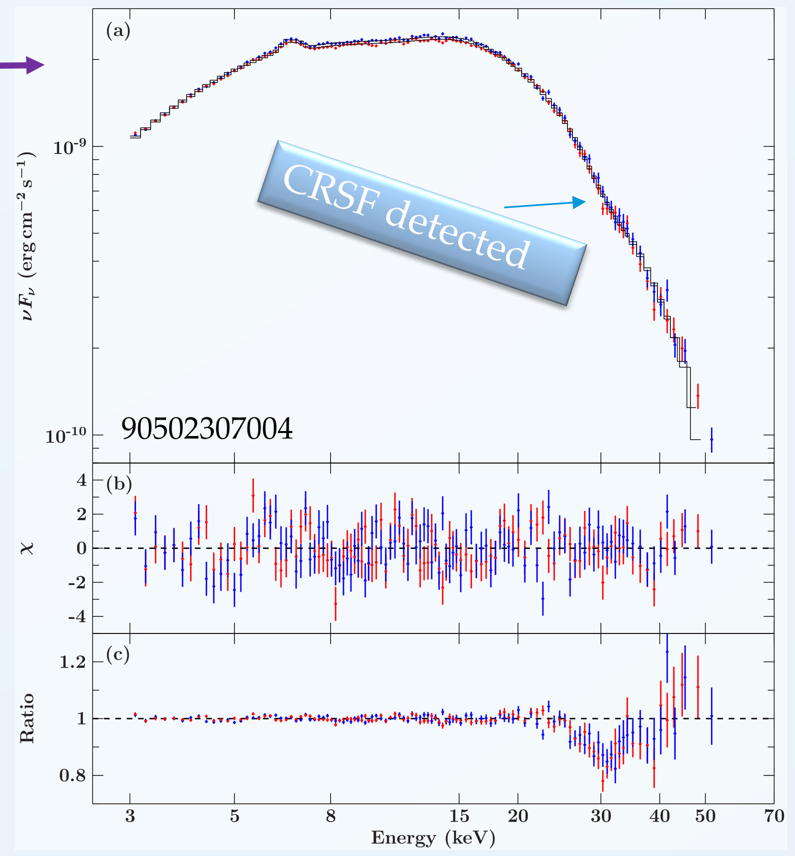
4U 1901+03



The plot shows the *Swift*/BAT, MAXI, and *NuSTAR* fluxes in units of mCrab in their respective energy band. From the 4U 1901+03 January 2019 outburst, the first one after almost 16 years of quiescence. We monitored the outburst with *NuSTAR* and obtained data at different luminosities.
The spectral-shape is complex, with a strong absorption line around 10keV, the nature of which is still under debate (e.g., Reig & Milonaki 2016).



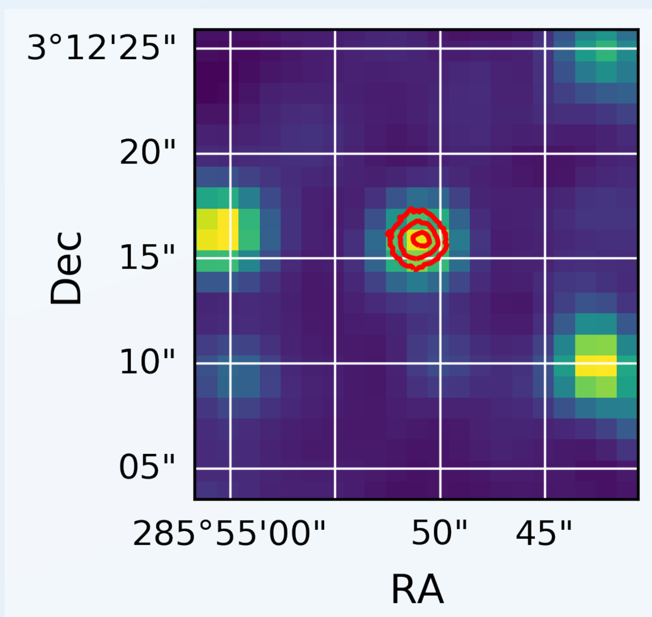


As example we show two spectra: during the peak of the outburst (ObsID 90502307002) and during the decline (ObsID 90502307004).
The spectrum during the peak of the outburst can be very well described by a `cutoffpl` continuum modified by a neutral absorption column (`tbnew`), an iron Kα flourescence line, and the known '10keV'-feature in absorption (modeled by `gabs`). **No evidence for a CRSF is found**.

The spectrum during the decline, on the other hand shows **a clear absorption feature around 30keV**, which we interpret as a CRSF (Coley et al., ATel #12684). The line is significant at over 99%. The analysis is currently ongoing to understand how the subtle changes in accretion rate and continuum spectra create conditions where a CRSFs can be observed.

Identifying the mass donor

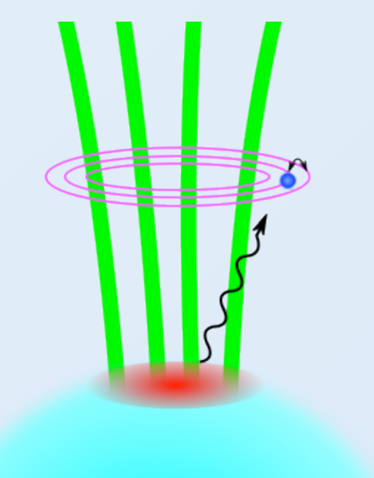
Because of the rare outbursts of 4U 1901+03 the counterpart was not known before this outburst. Using improved locations, in particular based on *Chandra*/HRC data, the counterpart was identified to be a Be star (UKIDS J190339.39+031215.6; Hemphill et al., Atel #12556, Strader et al., Atel #12554), confirming the high-mass X-ray binary nature of the source. The plot on the right shows the HRC contours superimposed on the 2MASS image, clearly identifying the counterpart.



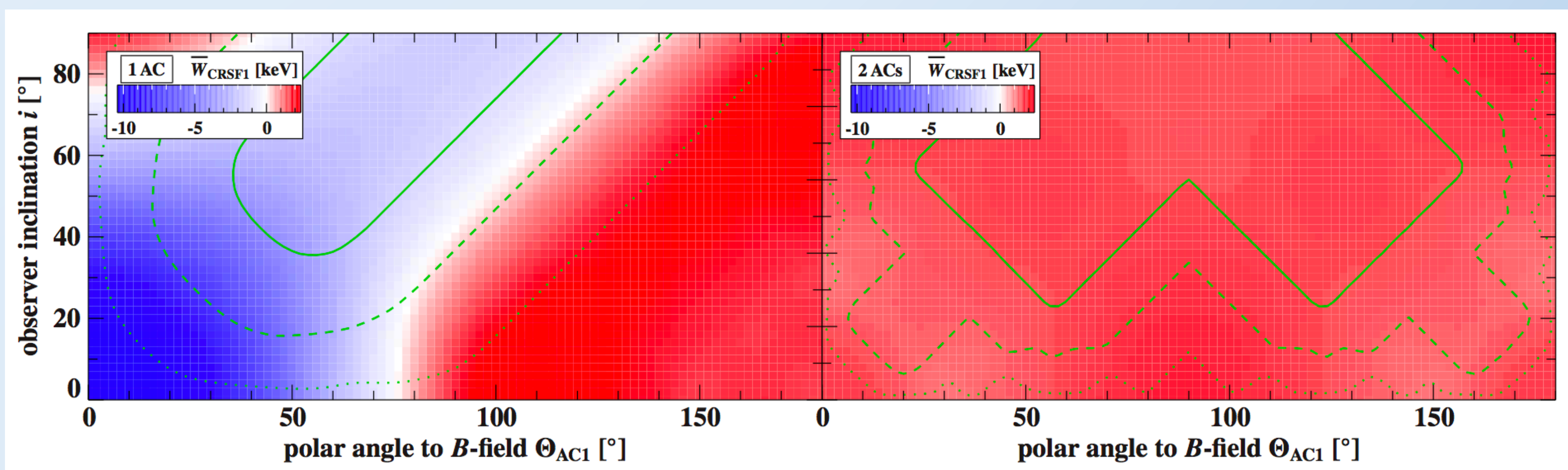
Cyclotron lines are formed in the strong magnetic fields of neutron stars. **But they don't always show up in the spectra! Why?**

Possible **dependence** on **flux** (4U 1901+03) or complex **geometry** (2S 1417-624).

New calculations show that it is **difficult** to create a significant observable CRSF for typical geometries.



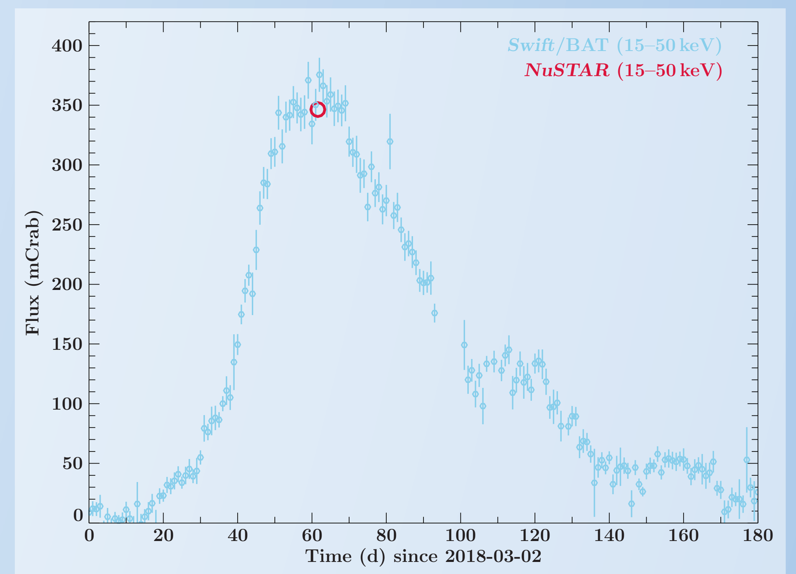
Cyclotron resonant scattering features (CRSFs) or cyclotron lines for short are produced by resonant scattering of photons with quantized electrons in strong magnetic fields. The movement of the electrons is quantized into Landau levels perpendicular to the magnetic field, giving rise to discrete features in the hard X-ray spectrum. The energy of the CRSF is directly related to the magnetic field strength in the line forming region via $E_{CRSF} = 11.57 / (1+z) \times 10^{12}$ G, where *z* is the gravitational redshift close to the surface of the neutron star.



The above plot shows the equivalent width of the fundamental CRSF, based on theoretical calculations (Falkner et al., subm.). Blue indicates an absorption line, while red indicates a line observed in emission. The left-hand panel shows the results for only one accretion column, the right-hand panel the case for two antipodal columns, as function of observer inclination and B-field angle with the respect to the rotational axis. As can bee seen, in the antipodal case no CRSF is produced in absorption regardless of geometry, indicating that if a source shows a CRSF a different geometry must be present.

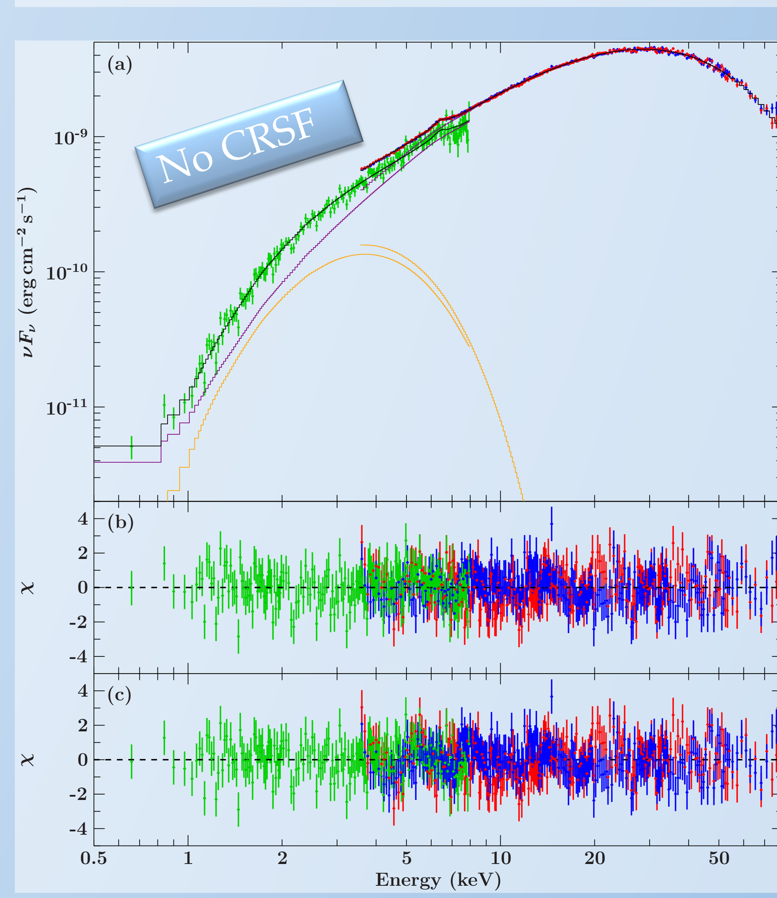
2S 1417-624

The plot shows the March/April 2018 outburst of 2S 1417-624, as seen by *Swift*/BAT It was the brightest outburst seen from this source so far. We triggered one *NuSTAR* observation simultaneous with *Swift* and captured the brightest phase of the outburst, as shown in the plot.

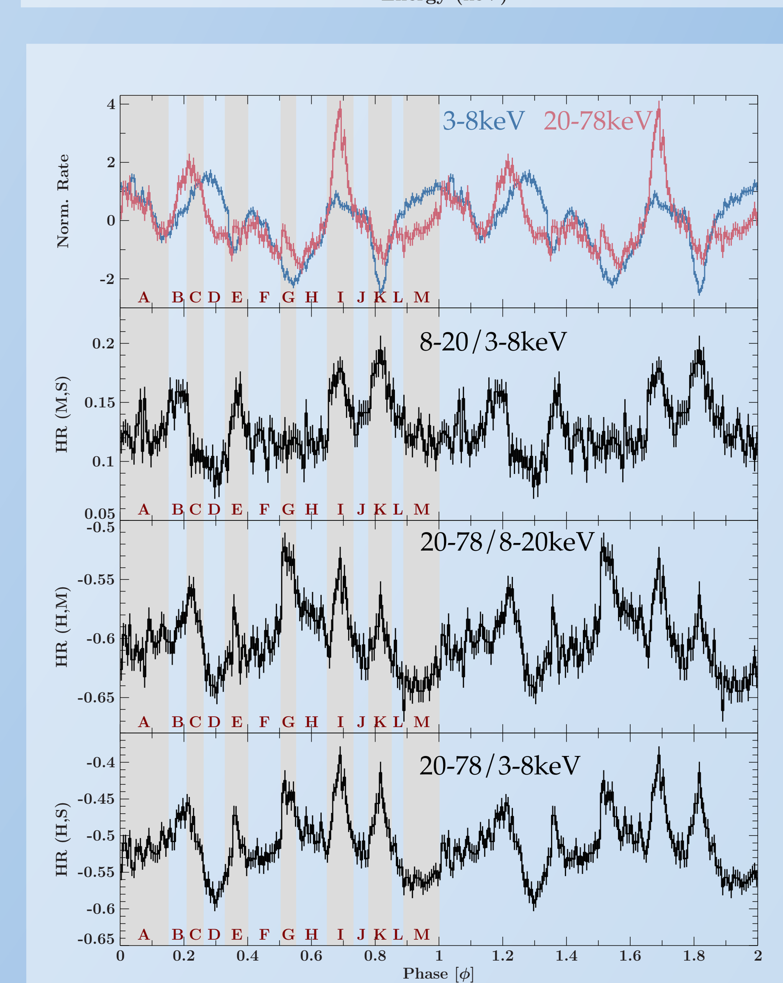


The broad-band X-ray spectrum as measured by *Swift*/XRT and *NuSTAR* can be well described with a typical, phenomenological continuum model consisting of power-law with an exponential cutoff at high energies (`cutoffpl`), a thermal blackbody (`bbody`), neutral absorption (`tbnew`) and fluorescence lines from iron Kα and Kβ (χ^2/dof =1.08, see panel *c*). Other continuum models like `highecut`, `FDcut` or NPEX provide a similar good fit (panel *b* for the `highecut` model).

We **do not find any evidence for a CRSF** for any continuum model, the spectrum appears very smooth.



The pulse period is 17.45702±0.00004 s (at MJD 58250) and the pulse profile is complex and energy dependent.
We are looking at three energy bands 3–8 keV (S, blue), the 8–20 keV band (M), and the 20–78 keV (H, red) and their pairwise hardness ratios.
As can be seen, the hardness of the source changes dramatically and quickly multiple times during one rotation of the neutron star.



This pulse-resolved behavior indicates a very complex accretion geometry with multiple (possibly even more than two!) accretion columns contributing to the observed flux. As shown in the central panel, CRSFs might vanish when more than one column is observed at any given time, possibly explaining the lack of a CRSF in 2S 1417-624.

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