university of groningen

The X-ray continuum spectrum and the Iron emission line in the neutron-star X-ray binary 4U 1636–53

Ming Lyu, Mariano Mendez, Andrea Sanna, Guobao Zhang

University of Groningen, kapteyn Astronomical Institute , Groningen, The Netherlands E-mail: *lyu@astro.rug.nl*

Objectives

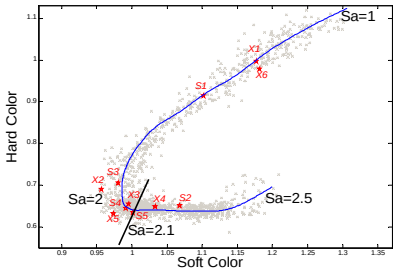
- **Investigate the properties of the spectrum of 4U 1636–53 as the source moves across the color-color diagram.**
- **Study the possible correlations between the different spectral component.**

Introduction

4U 1636–53 is a Low Mass X-ray Binary (LMXB) which shows full range of states (Altamirano et al. 2008). In this work, we use eleven medium-resolution X-ray observations, six with XMM-Newton plus RXTE (Sanna et al, 2013) and five with Suzaku, to study the spectral properties of 4U 1636–53 as the source moves across the color-color diagram (CCD).

We fitted the continuum spectrum with components that account for emission from the accretion disc (**Diskbb**), the neutron-star surface (**Bbody**), and a Comptonizing corona (**Nthcomp**). We also included a component that accounts for the iron emission line (either **Gaussian**, **Diskline**, **Laor**, or **Kyrline**, the latter with the spin parameter fixed to 0, 0.27 or 1).

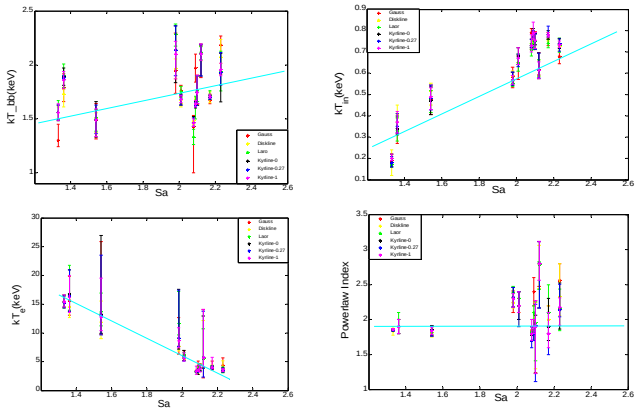
Color - Color diagram for 4U 1636-53



The red stars mark the position of the 5 Suzaku observations (S1-S5) and 6 XMM/RXTE observations (X1-X6). Each gray point represents the averaged Crab-normalized colors per RXTE observation. The position of the source on the diagram is parameterized by the length of the blue solid curve Sa. The black solid line corresponds to the position of the vertex (Zhang et al, 2011).

Results :

1. Temperature and Power-law Index



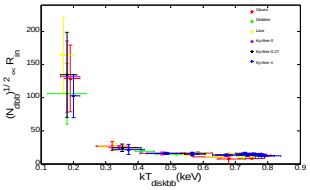
*Data is fitted with different Iron line models which are marked in different colors. The kyrline-0, kyrline-0.27 and kyrline-1 in the legend represent the Kyrline model with the spin parameter fixed to 0, 0.27 or 1, respectively. The (hand-drawn) solid lines in light cyan show the evolution of the parameters as a function of Sa.

From soft to hard state, the temperature of the blackbody stays more or less constant, or increases slightly, while the temperature of the inner disc increases from 0.2 keV in the hard state to about 0.8 keV in the soft state. The temperature of the corona behaves in the opposite way, dropping from 15 keV to less than 5 keV when the source goes from the hard to the soft state.

The power-law index of the corona emission (Nthcomp) remains more or less constant at around 1.9 – 2 across the hard and soft states.

Results:

2. Inner disc radius

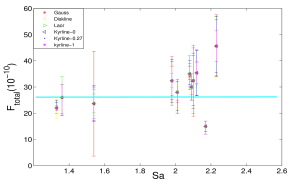


*The Suzaku obs 5 (S5) is excluded since its diskbb normalization is close to zero.

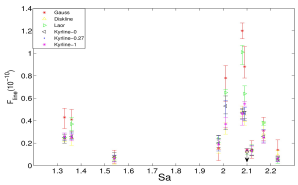
The inner radius of the disc decreases dramatically when the source evolves from the hard state into the soft state, and there it stays more or less constant, indicating the disc may have reached the ISCO (innermost stable circular orbit).

Results:

3. Flux evolution and correlations



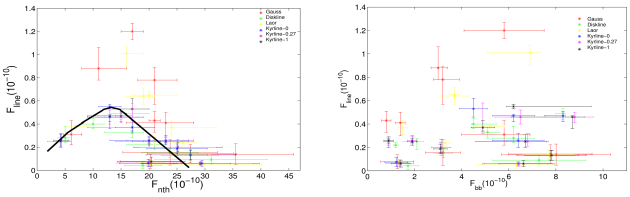
*The (hand-drawn) solid line in light cyan shows the (approximate) average flux of 4U 1636-53.



*The black arrow shows the upper limit of the flux in observation S4, where the line was not significantly detected.

The total (0.5-130 keV) unabsorbed flux (continuum+line) of the 11 observations remains more or less constant as a function of Sa.

The flux of the Iron line changes in a complex way. The line flux appears to peak at around Sa=2.1, which corresponds to the position of the vertex in the CCD.



* Due to the low significance, the iron line in S4 is not included in the diagrams. We added the (hand-drawn) black solid line in the left panel to indicate the trend described in the text.

Left panel: We found a weak positive correlation between the flux of Nthcomp and the flux of the Iron line when the Nthcomp flux is relatively low, and a weak anti-correlation as the Nthcomp flux increases. The maximum in this diagram happens when the source is at the vertex (Sa=2.1) in the CCD. Right panel: We found no correlation between the flux of the Iron line and the flux of blackbody component.

Conclusions

1. **The evolution of the spectral parameters agrees with the truncated disc model (Done et al, 2007).**
2. **The total flux remains constant while the Iron line flux evolves in a complex way.**
3. **We found that the flux of the Iron line first increases as the flux of Nthcomp increases; contrary to the expectations, when the source moves beyond the vertex in the color-color diagram the flux of the Iron line decreases as the flux of Nthcomp increases further.**

References

1. Altamirano, D.; van der Klis, M.; Méndez, M.; Jonker, P. G.; Klein-Wolt, M.; Lewin, W. H. G. (2008), X-Ray Time Variability across the Atoll Source States of 4U 1636-53, ApJ 685:436

2. Done, C.; Gierliński, M.; Kubota, A. (2007), Modeling the behaviour of accretion flows in X-ray binaries. Everything You always wanted to know about accretion but were afraid to ask, A&ARv 15:1

3. Sanna, A.; Hiemstra, B.; Mendez, M.; Altamirano, D.; Belloni, T.; Linares, M. (2013), Broad iron line in the fast spinning neutron-star system 4U1636-53, in press

4. Zhang, G.; Mendez, M.; Altamirano, D. (2011), The cooling phase of Type I X-ray bursts in 4U 1636-53, MNRAS 413:1913