Study of accretion states with y-parameter variations in the ultra luminous X-ray source Holmberg IX X-1

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1. Introduction

Ultra Luminous X-ray sources (ULXs) are point sources found in nearby spiral galaxies with luminosity of L_X=$10^{39.5-41}$ erg/s, exceeding the Eddingnton limit L_{edd}=10^{39} for $10M_{\odot}$ black holes. Although their X-ray spectra have some similarity to those of black hole binaries (BHBs)[1], it is not yet clear whether their spectral evolution and states have firm analogies to those of BHBs[2]. Here we focus on the power-law (PL) like state, in which they exhibit hard PL-like spectrum with a mild cutoff around 10 keV[6]. This state is often explained by thermal Comptonization in a corona with a low electron temperature, kT_e∼1-5 keV, and a large optical depth, $\tau \geqq 10$ corona[5]. Our objective is to study the dependence of this Comptonization properties on the source luminosity.

3. Holmberg (Hol) IX X-1

Hol IX is a dwarf galaxy associated with the spiral galaxy M81 (∼3.4 Mpc). Our target is its X-1 (Fig,1). It is a typical ULX and known to reside often in the PL like state [3][4][5]. Therefore, Hol IX X-1 is suited for our study.

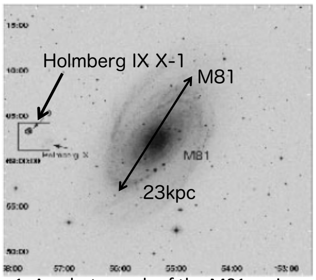

Fig.1: An photograph of the M81 region, where an X-ray image of Hol IX X-1 is superposed [4].

2. Previous study

Among a number of previous studies of Hol IX X-1, [3] explained the PL-state spectra with a sum of a disk emission and its Comptonization (Fig.2). As the luminosity changed, kT_e varied while the 1-5 keV slope (i.e. the y-parameter) was kept constant [3].

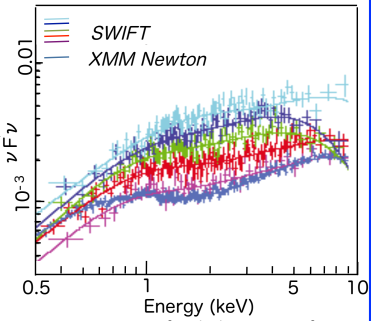

Fig.2: PL-state of Holmberg IX X-1 from previous observations [3].

4. *Suzaku* Observations

Using *Suzaku*, very long observations were conducted in 2012 Apr. (180 ks) and Oct. (220 ks). We analyzed the XIS0+XIS3 data taken on these two occasions. As shown in Fig.3, the average count rate increased by ∼40% in half a year. Also, there was ±10% variations within each obsercation (Fig.3).

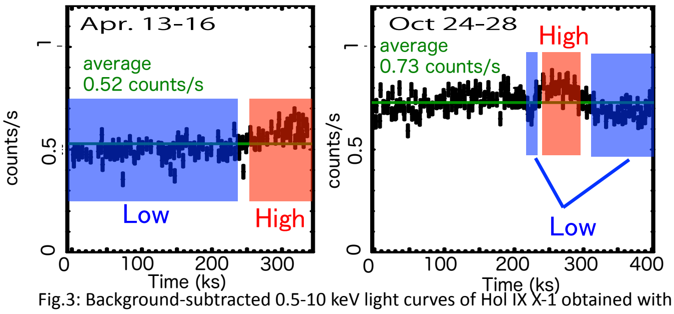

Fig.3: Background-subtracted 0.5-10 keV light curves of Hol IX X-1 obtained with the XIS in the two observations.

5. Spectral Analysis of the *Suzaku* spectra

We defined the High/Low phases as showed in Fig.3, and extracted the corresponding spectra (Fig.4).

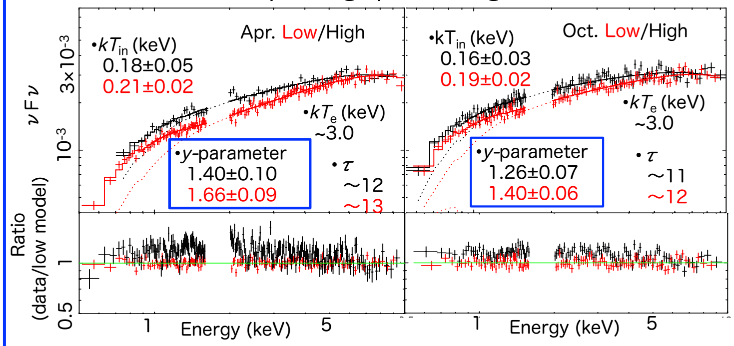

Fig.4: *Suzaku* XIS0+XIS3 spectra for the High/Low phases.

✧ The spectrum softened as the luminosity increased.
✧ The four spectra are successfully reproduced (Fig.4) by phabs(diskbb+nthcomp) where seed photons for Comptonization are assumed to come from diskbb.
✧The fit yields kT_e∼3 keV , τ =11-13, in agreement with [3].

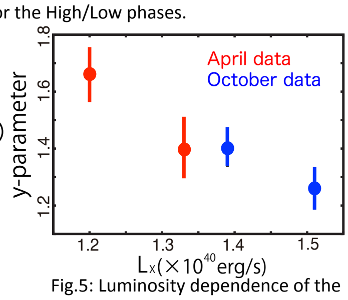

Fig.5: Luminosity dependence of the y-parameter.

✧As in Fig.5, the Compton y-parameter decreases with L_X.
✧Unlike [3], kT_e remained unchanged with errors of ± 90% as L_X varied by ∼30%.

6. Discussion

Coronae with a low kT_e and a high τ are found not only in Hol IX X-1, but also in the most extreme ULX, M82 X-1[5], in the neutron-star binary Aql. X-1 [7], and AGN Mrk 509 [8]. There can be common physics behind these "cool and thick" coronae.

From the measured L_X and estimated kT_{in}∼0.2 keV, L_{disk}∼ 1.4×10^{38} erg/s, Hol IX X-1 can be interpreted as a 100 $M_{\odot}$ BH accreting at ∼0.7 times of the Eddington value with its corona carrying a large fraction of the mass inflow, if we assume a Schwarzschild BH. However, note that other possibilities, e.g. super-Eddington emission, cannot be rejected as well.

7. Conclution

✧We analyzed the *Suzaku* data of Holmberg IX X-1.
✧Spectra were successfully explained with multi-color disk and thermal Comptonization by a corona with low kT_e and large τ.
✧The y-parameter decreased with luminosity, while kT_e remained rather unchanged.
✧A key to the ULX phenomenon may be "cool and thick" Compton coronae, found in various types of accreting X-ray sources.

❖Reference

[1] Makishima et. al 2000 [2] Mineshige et. al 2007 [3] Viertayanti et. al 2009
[4] La Parola et. al 2001 [5] Miyawaki et. al 2009 [6] Mizuno et. al 2007
[7] Sakurai et. al 2012 [8] Noda et. al 2011