A Systematic X-ray Study of Dwarf Novae with Suzaku

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1. INTRODUCTION

Dwarf novae (DNe) are semi-detached close binary systems consisting of a late-type star and a white dwarf (WD) with weak magnetic fields (< 10^5 G). The gas from the secondary star fills the Roche lobe and flows onto the WD. The accreting gas has an angular momentum and forms an accretion disk around the WD. Accretion disk has two stable states, either the hydrogen gas in the disk is neutral (~10^3 K) or fully ionize (~10^4 K). These states correspond to the quiescent and outburst state, respectively. The transition between the two states is caused by thermal instability of the accretion disk[1][2][3]. Some DNe also show super-outbursts, which are brighter and longer than normal outbursts. This is caused by thermal and tidal instability of the disk[4][5].
The gas in the inner edge of the accretion disk has a Kepler rotation. On the other hand, the rotation velocity of the WD surface is slow in general. Therefore, when the gas falls onto the WD surface, the gas is decelerated by strong frictional force, and the kinetic energy is dissipated into thermal energy. This region, called the boundary layer, is heated to ~10^8 K and emits EUV and X-rays [6][7].

2. MOTIVATION

Outbursts of DN occur suddenly. Thus, it is not easy to schedule X-ray observations in time to capture these phenomena. Therefore, there are not so many X-ray data sets during outbursts, in particular, those taken with an energy resolution of the CCD detector or better. From this reason, the X-ray behavior of DNe in outburst is not well known yet.

Our Goals

①To reveal differences in X-ray characteristics during the quiescence and outburst.
②To determine the state of DNe by only using the X-ray data.

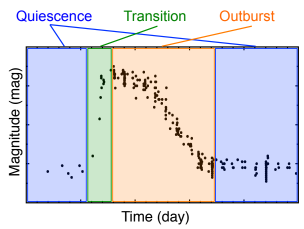
3. OBSERVATION

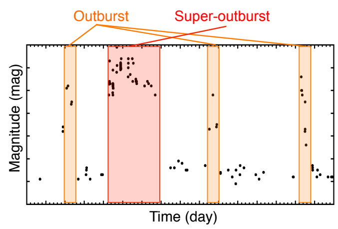
3-1. Data Selection

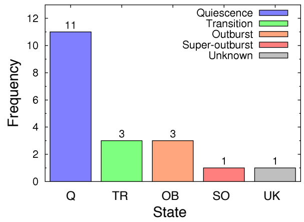
- We present the X-ray data observed with ***Suzaku*** satellite.
- We used *"Catalogue of Cataclysmic Binaries, Low-Mass X-Ray Binaries, and Related objects" Edition 7.20* [8] .

1. Selected DNe from Catalogue of Cataclysmic Binaries[9] (1094 objects → 610 objects)
2. Selected DNe that are included in the field of view of XIS (23 DNe, 29 observations)
3. Removed proprietary data (17 DNs, 23 Obs.)
4. Removed following data
   a) Those with a nature different from DN by individual studies[10] (1 object)
   b) Those in globular clusters and unresolvable from other sources by Suzaku (1 object)
   c) Undetected by XIS due to the count rates (2 objects)
5. Finally, we obtained 13 DNe and 23 observation. Four DNe have multiple observations in different states.

3-2. Definition of states







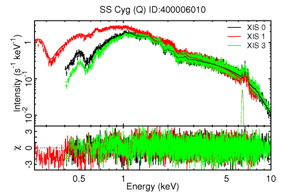
Our data

Quiescence .... 11 observations
Transition .... 3 observations
Outburst .... 3 observations
Super-outburst .... 1 observations
Unknown .... 1 observations

4. ANALYSIS & RESULTS

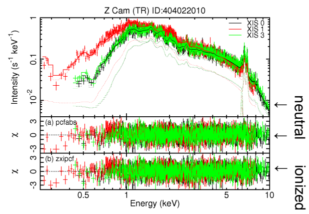
- In order to explain the X-ray spectrum of the DNe, we have used isobaric cooling flow model[11].
- This is the model that assumes the accreting gas cools as a steady flow in an equal pressure and emits optically-thin plasma radiation from each temperature layer.
- The parameters are T_{max}, T_{min}, Abundance, and Mass accretion rate.
- T_{min} was fixed to ~10 eV, which is the temperature of the WD surface.

Quiescence



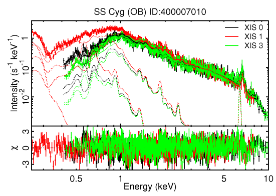
All 11 spectra were fitted well with *the cooling flow model* in the 0.25—10.0 keV band.

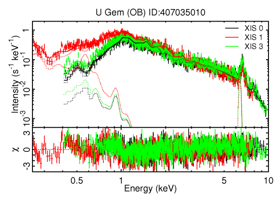
Transition



The spectra show a significantly stronger absorption than the interstellar absorption. We added *a partial covering absorption component to the cooling flow model*, which reproduced the spectra successfully.

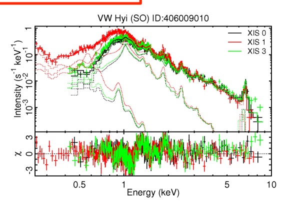
Outburst





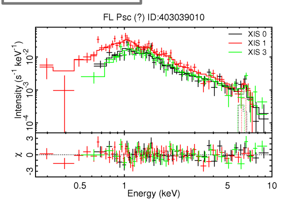
We could fit the spectra with *the cooling flow model only in the 2.0—10.0 keV band*. We found soft excess, which was not found in the quiescent data. To explain this excess, we added *a single or two temperature thermal plasma model*. The number of additional components is different between the SS Cyg and U Gem. The former requires two plasma components (0.18 keV & 0.62 keV), while the latter requires one component (0.12 keV).

Super-outburst



Spectral features are similar to those in of the outbursts. The spectrum required *two additional thermal plasma components to the cooling flow model*. Furthermore, we changed the *T_{min} in the cooling flow model to ~1.26 keV* to have an improved reduced χ^2.

Unknown



The spectrum could be explained by *the cooling flow model* in the 0.25—10.0 keV band.

5. DISCUSSION

① To reveal differences in X-ray characteristics during the quiescence and outbursts.

In the quiescence state, the X-ray spectra were explained well with the standard cooling flow model, indicating that the X-rays are from the boundary layer. *During the transition state*, the X-rays are from the same region, but an additional absorber, such as an outflow, appears causing a partial covering. *During the outbursts*, plasma emission is added to the standard model, which is considered to be from a region different from the boundary layer. *During the super-outburst*, the change in T_{min} may indicate that the plasma structure changes in the boundary layer.

② To determine the state of DNe by only using the X-ray data.

We found X-ray spectral features are distinctive in each state, and X-ray spectra can be used to determine which state a DN is in; indeed, one of the DNe in our sample has little optical coverage and its state is unknown. However, its X-ray spectrum was well fitted only with the cooling flow model, that suggests that this source was in the quiescent state.

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