X-ray Observations of Classical Novae

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Rikkyo University
Harvard-Smithsonian Center for Astrophysics
Talk Plan

1. Introduction (Motivation)
2. Classical Novae
3. Observational Results
4. Other Interests

Further reading:
• Cambridge Astrophysics Series, Classical Novae (Vol. 43)
  M. F. Bode and A. Evans, 2008
Talk Plan

1. Introduction (Motivation)  ~ 2 min
2. Classical Novae  ~ 3 min
3. Observational Results  ~ 4 min
4. Other Interests  ~ 2 min

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Suzaku X-ray Satellite

- **Two X-ray Instruments**
  - X-ray CCDs (0.2~12 keV)
  - Scintillators (15~600 keV)

- **Several Advantages**
  - High signal-to-noise ratio
  - Medium energy resolution
  - Low background level

- **Greatest Disadvantage**
  - Lack of imaging resolution

I was working as a calibration member...

Takei+08 (PASJ)

It is a new source!!

Suzaku

Position Error

E0102-72

Chandra

http://chandra.harvard.edu/photo/2000/0015multi/
Classical Novae and X-rays

- **Classical Novae (CNe)**
  - Binary (WD and Late-Type)
  - Sudden hydrogen fusion
  - Energy: $10^{45} \sim 10^{46}$ erg
  - $M_{\text{ejecta}}$: $10^{-4} \sim 10^{-6}$ $M_\odot$
  - $V_{\text{ejecta}}$: $10^2 \sim 10^4$ km/s
  - Rate: $10$/yr (discovered)

- **X-rays from CNe**
  - Soft X-rays (< 1 keV) from WD surface (a.k.a. SSS)
  - Hard X-rays (> 1 keV) from shocks in the ejecta
  - The system returns to a quiescent phase over time

http://photojournal.jpl.nasa.gov/archive/PIA09221.mov
Objectives and Strategies

Objectives

1. X-ray Spectroscopy
   only a few samples
   (weak, variable, transient)

2. Astrophysical Issues
   mass of white dwarfs
   binary system evolution
   discovery of unknowns

   Systematic Study

Strategies

1. Optical Discovery
   grate abilities of amateurs
   (IAUC, AAVSO, VSNET)

2. X-ray Snapshots
   excellent sky monitors
   (Swift, MAXI, and Fermi?)

3. Deep Observations
   latest X-ray spectrometers
   (Chandra, XMM, Suzaku)

The golden age of classical novae has arrived!
Suzaku View : Classical Novae

③ V2491 Cyg (2008.04)
- Takei et al. (2009), ApJL, 697, 54
- Takei et al. (2010), AN, 331, 183

② V458 Vul (2007.08)
- Tsujimoto et al. (2009), PASJ, 61, S69

④ V2672 Oph (2009.08)
- Takei et al., in prep.

⑤ U Sco (2010.01)
- Takei et al., in prep.

⑥ V1280 Sco (2007.02)
- Observed in AO-5

⑦ RS Oph (2006.02)
- Planned in AO-6

① Suzaku J0105-72 (2005.08)
- Takei et al. (2008), PASJ, 60, S231

http://skyview.gsfc.nasa.gov/cgi-bin/query.pl
ROSAT ALL-Sky X-ray Background Survey (0.73-1.56 keV)
The Impact of *Suzaku* on CNe

The highest energy X-rays ever detected from CNe

Discovery of non-thermal phenomena for the first time

Classical Nova V2491 Cygni

(Suzaku spectrum 9 days after the outburst)
Classical Nova V2491 Cygni

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Classical Nova V2491 Cygni

(Suzaku spectrum 9 days after the outburst)
Classical Nova V2491 Cygni

- Thin-thermal plasma ($\gamma = 0.1$)
- Power-law ($\gamma = 0.1$)

Flux (photons cm$^{-2}$ s$^{-1}$ keV$^{-1}$)

Energy (keV)

- X-ray CCDs
- Scintillator

Fe XXV
What is the origin ...?

• **Positron Annihilation in Novae?**
  - Novae produce radioactive isotopes  
    *(e.g., Clayton and Hoyle 1974, ApJL)*
  - Hard X-rays are expected in an outburst  
    *(e.g., Gomez-Gomar et al. 1998, MNRAS)*
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### Radioactive Isotope in CNe (proton-rich nuclei)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Lifetime</th>
<th>Novae</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{13}$N</td>
<td>862 s</td>
<td>ALL</td>
</tr>
<tr>
<td>$^{18}$F</td>
<td>158 m</td>
<td>ALL</td>
</tr>
<tr>
<td>$^{7}$Be</td>
<td>77 d</td>
<td>C-O</td>
</tr>
<tr>
<td>$^{22}$Na</td>
<td>3.75 y</td>
<td>O-Ne</td>
</tr>
<tr>
<td>$^{26}$Al</td>
<td>$10^6$ y</td>
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- e.g., Hernanz et al. 2001
- Gomez-Gomar et al. 1998
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<td>$^{13}$N</td>
<td>962 s</td>
<td>ALL</td>
</tr>
<tr>
<td>$^{18}$F</td>
<td>77 d</td>
<td></td>
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<tr>
<td>$^{7}$Be</td>
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<td>106 y</td>
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<td>10$^6$ y</td>
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$^{22}_{11}$Na: Neutron-deficient nuclei
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**Compton Degrad. Model**
(V2491 Cyg, $M_{\text{ejecta}} = 10^{-3} M_\odot$)

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<th>Energy (keV)</th>
<th>Photon Flux (photon cm$^{-2}$ s$^{-1}$ keV$^{-1}$)</th>
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<tr>
<td>10</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>100</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td>1000</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>10000</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>100000</td>
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- $t=9-10$ day
- $t=29-30$ day
- $t=49-50$ day
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CNe have a potential as non-thermal sources
A great sample for future theoretical works
Other Research Activities

• **Instruments (in Japanese lab.)**
  - X-ray Telescope with Adaptive Optics
  - X-ray Polarimeter
  - X-ray Interferometer

• **Simulation (begin in CfA)**
  - Hydrodynamic Code : FLASH
  - Radiative Transfer Code : MOCASSIN

• **Fundamental Studies**
  - Dynamics : Golf, Tennis, Ice Hockey
  - Fluid Dynamics : Beer, Piano, Violin
  - Statistics : Mahjong, Casino, Stocks
Summary

B306-C door is always open!!
Please let me know if you are interested in these works (or real Japanese teas)

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