X-ray Studies of Classical Novae

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Dai Takei
—Rikkyo University—
Harvard-Smithsonian Center for Astrophysics
An X-ray Study of Classical Novae

Dai Takei

Department of Physics, Graduate School of Science, Rikkyo University
3-34-1, Nishi-Ikebukuro, Toshima, Tokyo, 171-8501, Japan
takei@ast.rikkyo.ac.jp

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and all concerned ...

X-rays : Suzaku, XMM-Newton, and Swift operation teams
Chandra, Beppo-SAX, ASCA, ROSAT, and Einstein
Infrared : Kanata TRISPEC team in Hiroshima University
Optical : Variable star databases (AAVSO, VSNET, VSOLJ)
Worldwide amateur astronomers
Summary of the Ph.D. thesis

Scope: Classical novae are important in astrophysics
X-ray studies are necessary for understanding
But, it was difficult by their transient nature...

Method: 1. Data archive search
2. Target-of-Opportunity (ToO) observations
Point: Collaboration with amateurs and multi-satellites
Agenda: Five important challenges in astrophysics

Result: X-ray studies of five novae (~20% of the total)
Both expected and unexpected scientific results

Goal: Understanding the nature of classical novae!!
Classical Novae and X-rays

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

- **X-rays from CNe**
  - Soft X-rays ($< 1 \, \text{keV}$) from WD surface (a.k.a. SSS)
  - Hard X-rays ($> 1 \, \text{keV}$) from shocks in the ejecta
  - The system returns to a quiescent phase over time
Advent of Swift era

- **X-ray studies of CNe were quite difficult**
  - Rare event in post CNe explosions
  - Faint, variable, and transient behaviors
  - ToO observations were risky
- **Swift changed the game, completely !!**
  - X-ray snapshots for discovered CNe
  - Monitoring campaigns at a high cadence
  - Risk reduction for other observatories

Road to X-ray spectroscopy has opened
The golden age of CNe has arrived
Advent of Swift era

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Suzaku View : Classical Novae

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

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

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

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)
Objectives of Research

1. Classification of X-ray Emission
2. WD Atmosphere
3. Ejecta Chemistry
4. Reestablished Accretion
5. Discovery of Non-thermal Process
Reestablished Accretion

• **How early does an accretion proc. resume?**
  - An accretion process stops after a nova outburst
  - But, it is reestablished in the binary evolution

• **Get the evidence of an accretion proc.**
  - Some CNe occur in magnetized WDs (i.e., Polar, IP)
  - IPs are strong emitters of Fe lines (talk by T. Yuasa)

Fe XXV, Fe XXVI

White Dwarf
(CO-Type or ONe-Type)

$R_{\text{WD}} \sim 5000$ km

Fe I
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Result and Discussion:

- Radiation pressure inhibits an accretion proc.
  - Bright soft X-rays from the WD surface
- Accretion resumes when the fuels consumed
  - Inverse correlation between soft and Fe light curve
  - We confirmed the time-line of the binary evolution
Summary

1. Dawn of a golden age of classical novae
2. Recent studies impact on astrophysics
3. Suzaku brought me the Ph.D. degree!!

Please let me know if you are interested
dtakei@head.cfa.harvard.edu