V2487 Oph 1998: a puzzling recurrent nova observed with XMM-Newton

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V2487 Oph = Nova Oph 98

Main interest / puzzling features

- Magnetic character: looks like an intermediate polar (X-ray spectrum)

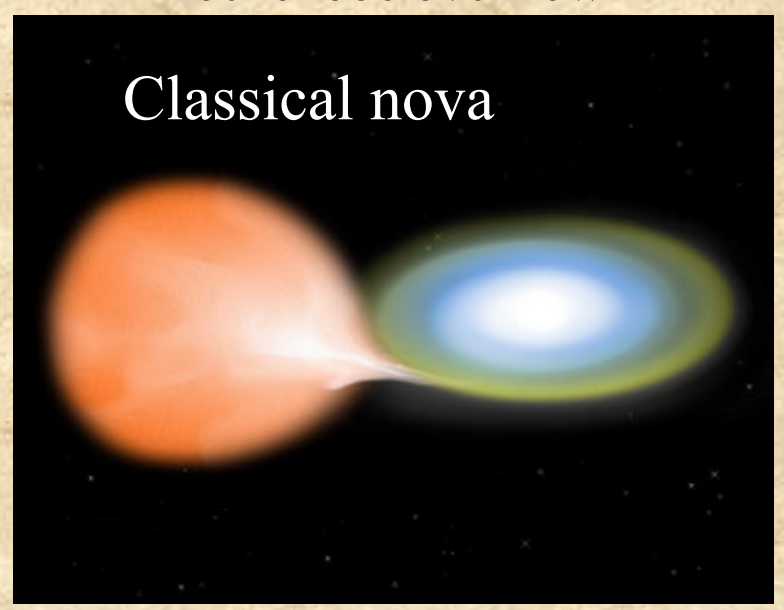
- Recurrent nova - P_{rec} = 98 years

Scenario of Nova Explosions: White Dwarfs in close binary systems

Cataclysmic variable:

WD + Main Sequence

Roche lobe overflow



P_{rec}~10^4-10^5 yr; P_{orb}~hr-day

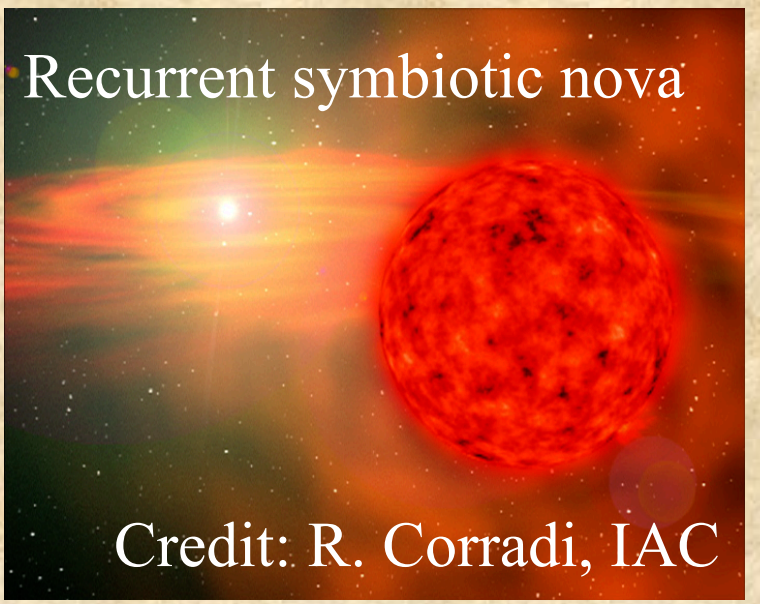
a~few 10^5 km~ few 10^{10}cm

rate ~35/yr in Galaxy

Symbiotic system:

WD + Red Giant

Accretion from a red giant wind (+disk?)



P_{rec}<100 yrs; P_{orb}~100's days

a ~ 10^{13}-10^{14} cm

rate ~10 known in Galaxy

Origin of X-ray emission

- Residual steady H-burning on top of the white dwarf:
  photospheric emission from the hot WD:
  $T_{eff} \sim (2\text{-}10)\times10^5$K (L$\sim10^{38}$erg/s) ⟶ ***supersoft X-rays***
  - ➢ duration related to H-burning turn-off time - remnant H-mass

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- Reestablished accretion: emission "as a CV"
  - ➢ non magnetic WD: accretion disk
  - ➢ magnetic WD: accretion through a truncated disk or directly onto the WD surface
  - ➢ (soft and) hard X-ray emission

X-ray observations of post-outburst novae:

recovery of accretion

➔tracing the properties of the binary system (**CV, symbiotic**) hosting the nova explosion

XMM-Newton observations of Nova Oph 1998 (post-outburst)

(XMM-Newton not available in 1998)

Target	Discovery date	Date of observation – Time after outburst	Detection
N Oph 1998 V2487 Oph	June 15	Feb. 25, 2001 – 986d, 2.7 yr Sep. 5, 2001 – 1178d, 3.2 yr Feb. 2002 – 1352d, 3.7yr Sept. 24, 2002 – 1559d, 4.3yr	YES *but no SSS*
N Oph 1998 V2487 Oph	June 15	Mar. 24, 2007 – 8.8yr *AO6 long exposure*	YES *but no SSS*

- Very fast nova – optical light curve with $t_2 = 6.3$ d and $t_3 = 9.5$ d

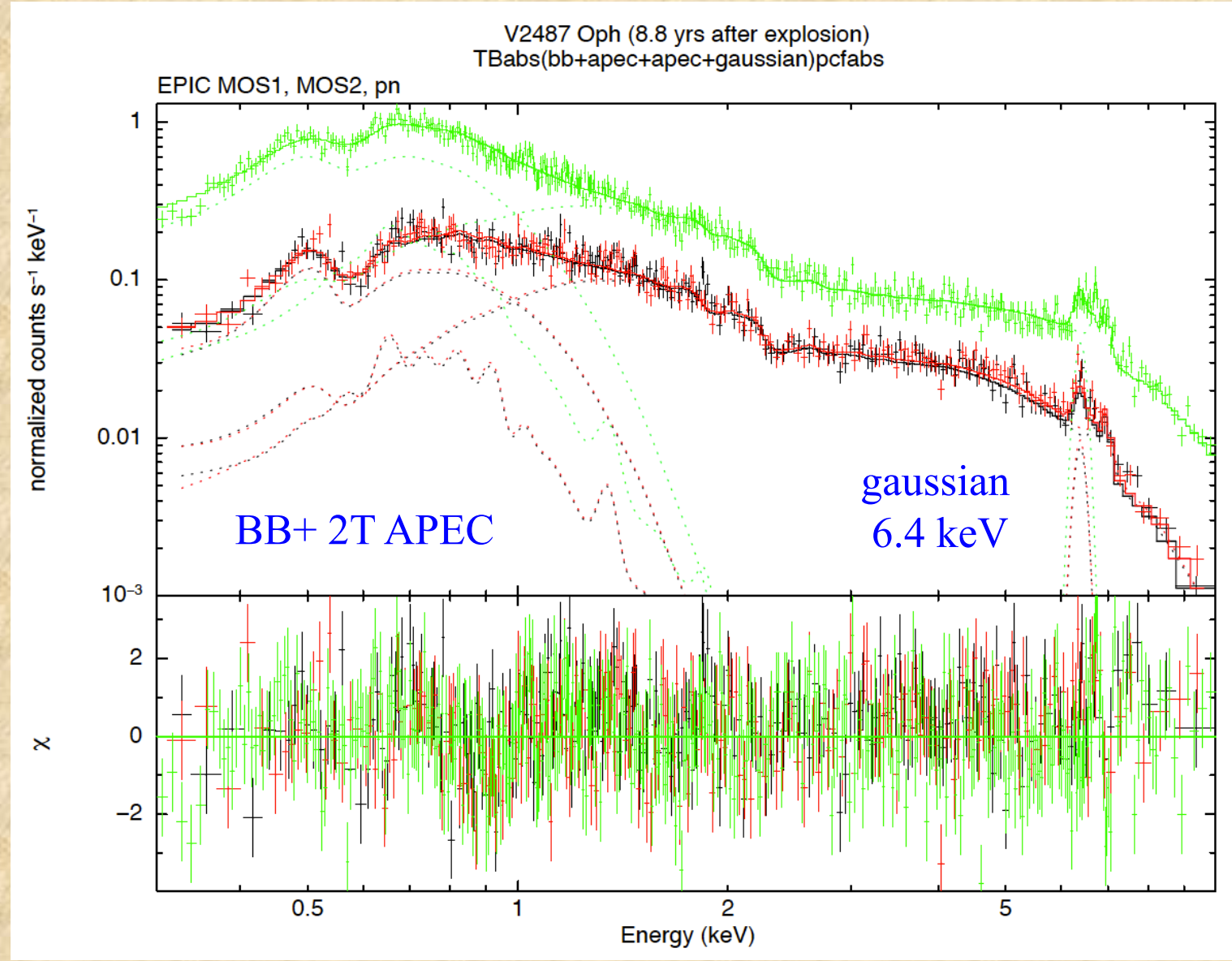
V2487 Oph (1998): 1st nova seen in X-rays before its explosion (ROSAT)

- Positional correlation with a source previously discovered by ROSAT (RASS) in 1990 suggests that the "host" of the nova explosion had been seen in X-rays before the outburst (Hernanz & Sala 2002, Science)

  → new case: V2491 Cyg (2008): previous ROSAT, XMM and SWIFT detections (Ibarra et al. 2009, A&A)

- Restablishment of accretion clearly seen in X-rays - 2.7 yrs after eruption – Fe K alpha fluorescence line at 6.4 keV

N Oph 1998 = V2487 Oph - 8.8yr post outburst



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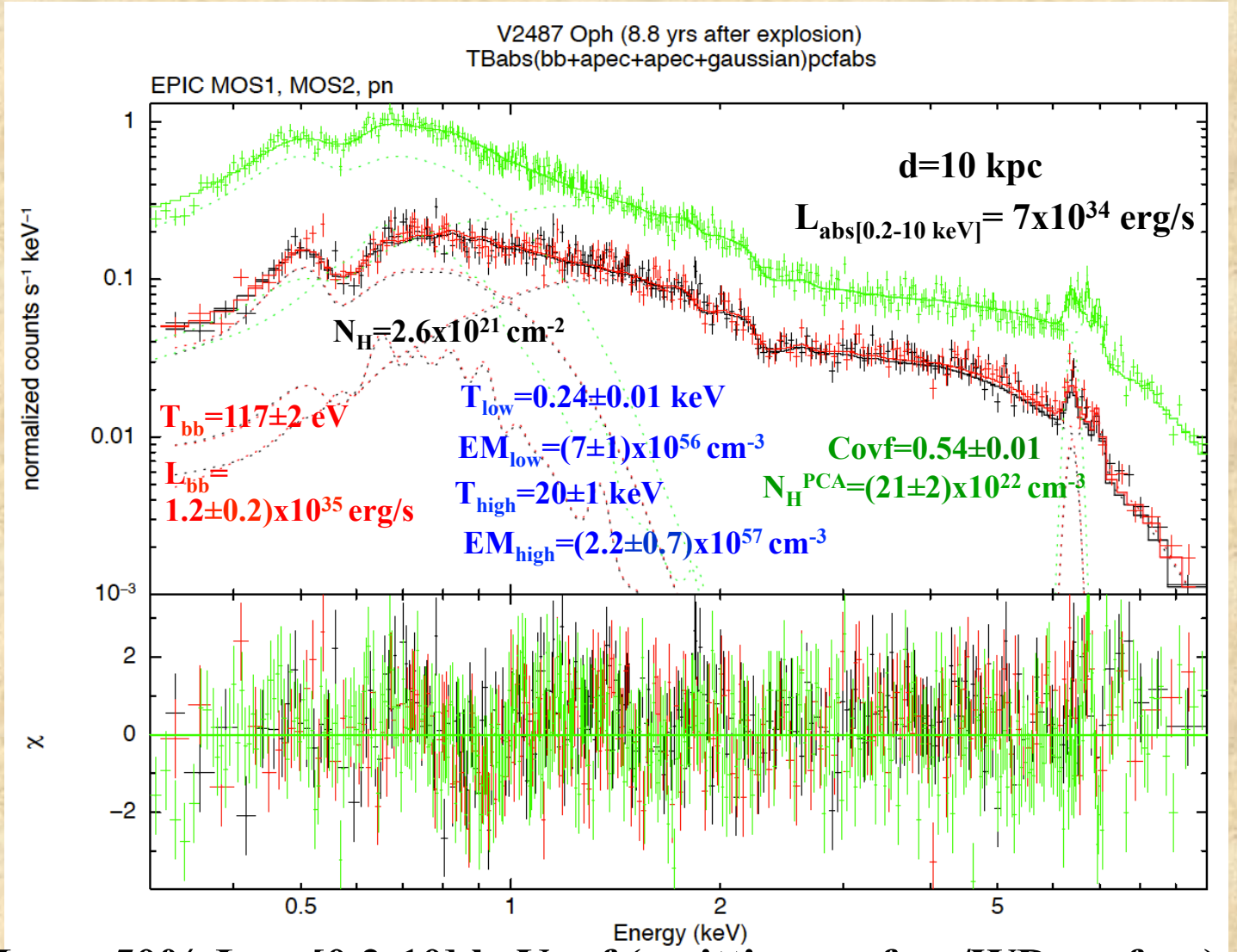

red. chisq=1.08
(1674/1548)

- L_{BB} ~ 50% L_{TOT}[0.2-10] keV - f (emitting surface/WD surface)~10^{-3-4} (hot spots?)

➢ Luminosity, spectral shape ..→ Intermediate polar? *need P_{spin} vs. P_{orb}*

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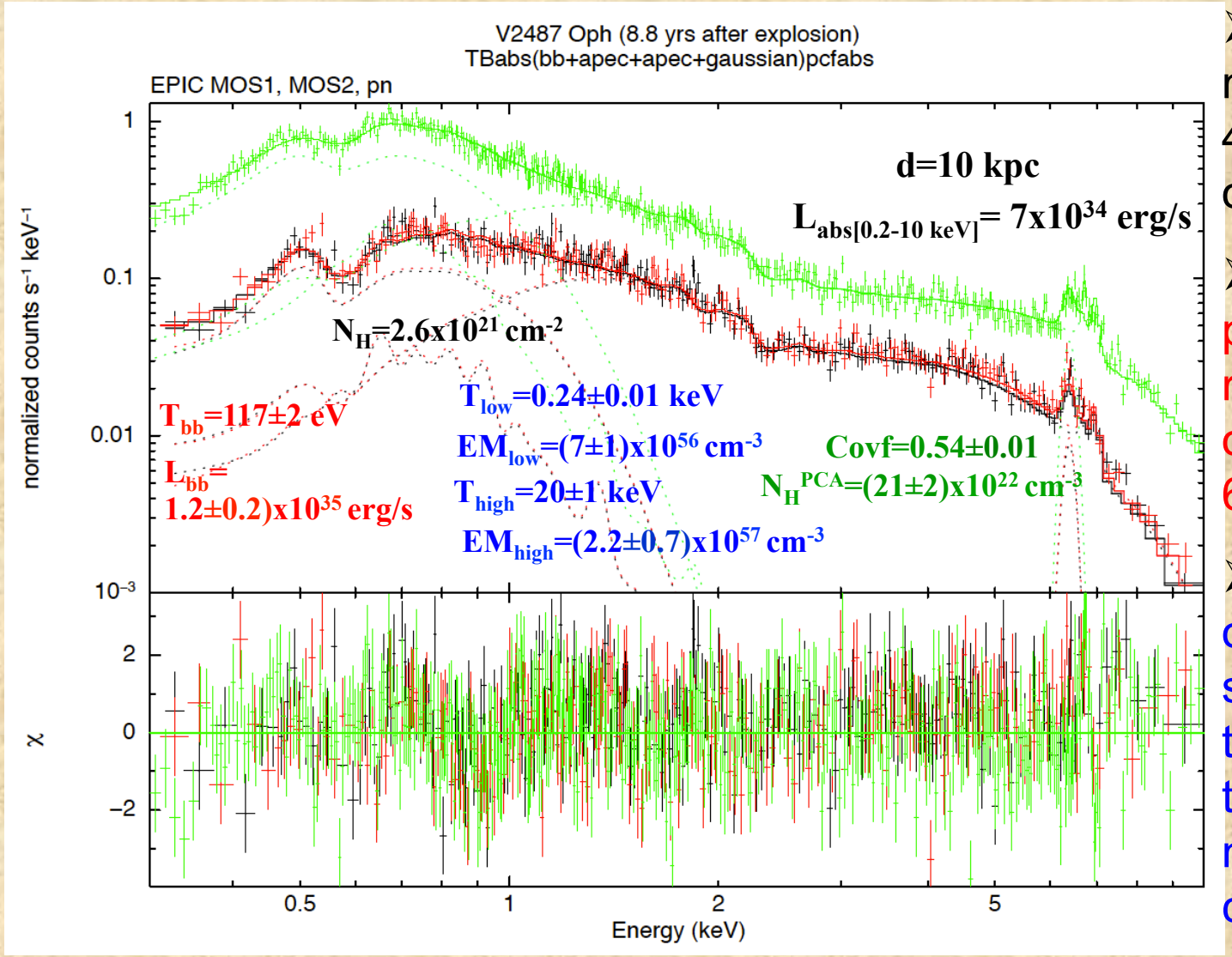

- Spectral model: similar to 4 previous observations
- No clear periodicities in X-rays – Hint of orbital period ≈ 6.5 hrs
- Optical observations seem to confirm the orbital P and the magnetic nature (but needs confirmation)

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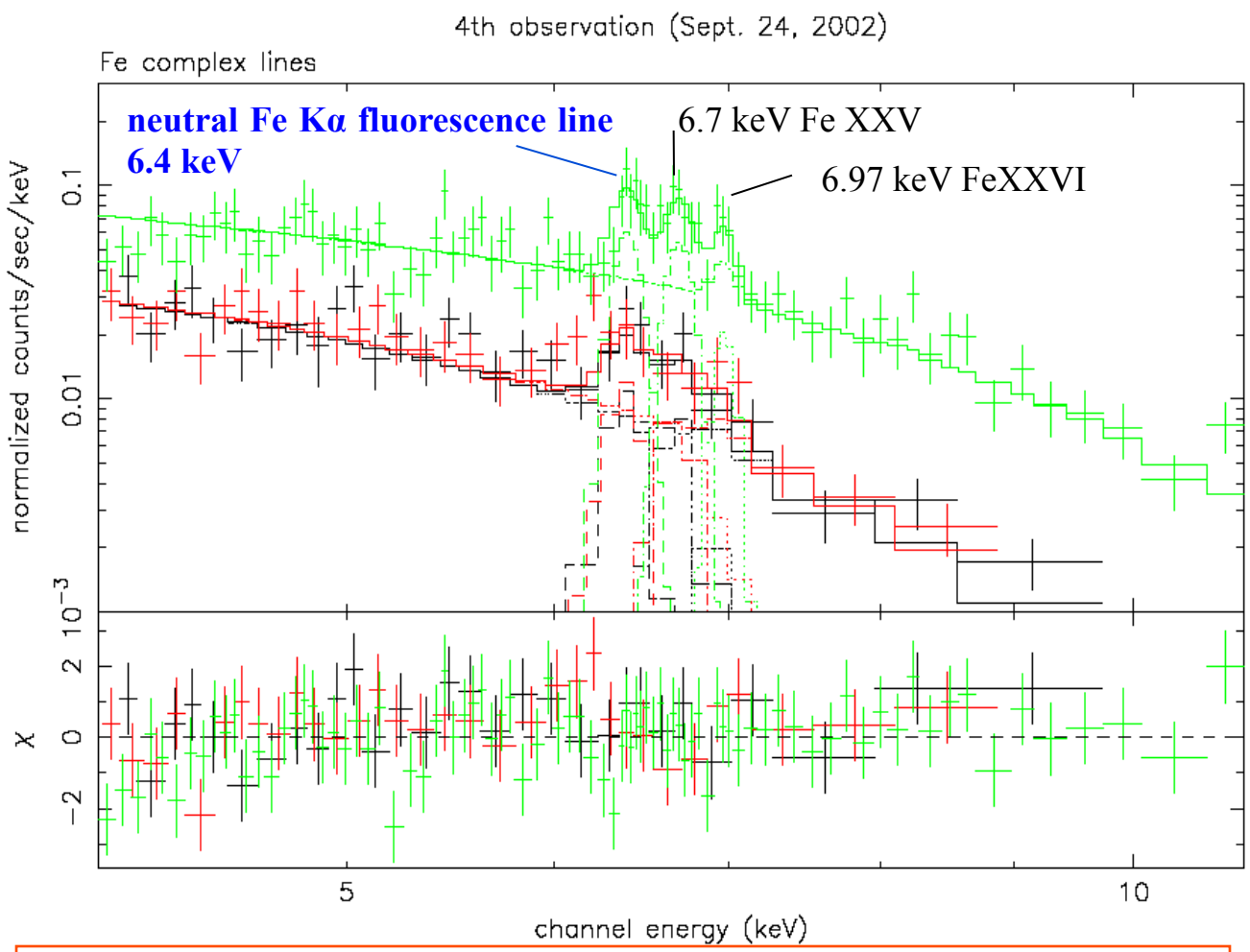
Nova Oph 1998 = V2487 Oph - 4.3 yrs post explosion



- Identification of three Fe Kα emission lines:
  ~neutral Fe: 6.4 keV
  He-like Fe: 6.68 keV
  H-like Fe: 6.97 keV

Fluorescent Fe Kα line at 6.4 keV reveals reflection on cold matter (disk and/or WD): accretion

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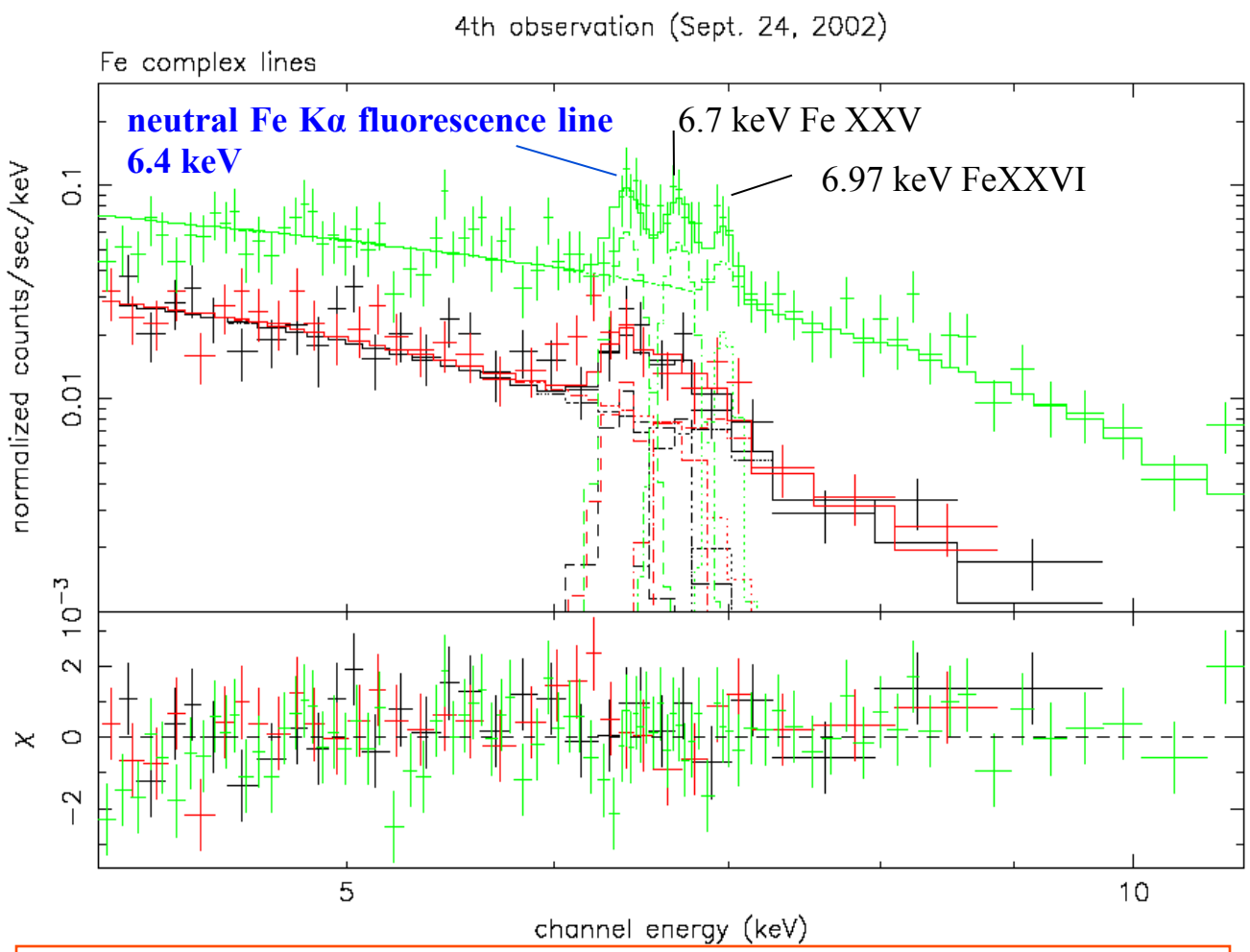

Fluorescent Fe Kα line at 6.4 keV reveals reflection on cold matter (disk and/or WD): accretion

- Identification of three Fe Kα emission lines:
  ~neutral Fe: 6.4 keV
  He-like Fe: 6.68 keV
  H-like Fe: 6.97 keV
- If T_{high} ~ (10-20) keV, He-like and H-like lines well reproduced & only 6.4 keV fluorescent line added

➢ *If complex absorption -partial covering absorber-* low (ISM)+ high N_H → T_{high}~(10-20) keV

Nova Oph 1998 = V2487 Oph Hard X-rays

- Detection with INTEGRAL/IBIS survey in the 20-100 keV band (Barlow et al. 2006, MNRAS): **kT=25 keV** ; flux compatible with our XMM-Newton results, but the IBIS spectrum has low S/N
  - large M_{WD} from large T_{high} – but T_{high} not well constrained

- Also detected with RXTE/PCA (Butters et al, 2011) as a possible IP, but not clear periodicities found

- Hints for large M_{WD} also from the optical light curve (Hachisu & Kato, 2002, ApJ)

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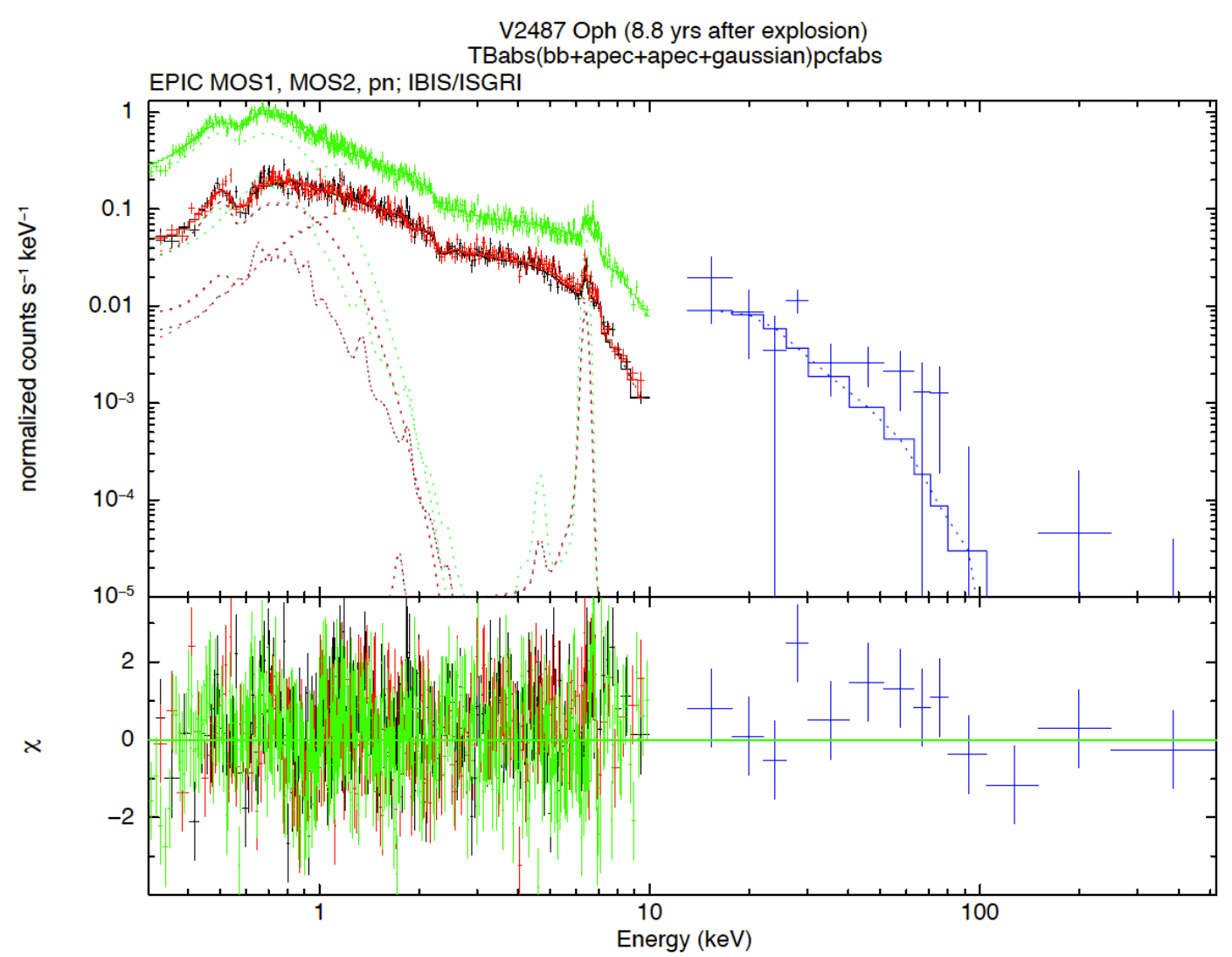

INTEGRAL IBIS/ISGRI data reduction: courtesy of S. Paltani

Other Novae in IPs

V4633 Sgr – a probable second asynchronous polar classical nova

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ABSTRACT

Photometric observations of V4633 Sgr (Nova Sagittarii 1998) during 1998–2005 reveal the presence of a stable photometric periodicity at $P_1 = 180.8$ min which is probably the orbital period of the underlying binary system. A second period was present in the light curve of the object for 6 yr. Shortly after the nova eruption it was measured as $P_2 = 185.6$ min. It has decreased monotonically in the following few years reaching the value $P_2 = 183.9$ min in 2003. In 2004 it was no longer detectable. We suggest that the second periodicity is the spin of the magnetic white dwarf of this system that rotates nearly synchronously with the orbital revolution. According to our interpretation, the post-eruption evolution of Nova V4633 Sgr follows a track similar to the one taken by V1500 Cyg (Nova Cygni 1975) after that nova eruption, on a somewhat longer time-scale. The asynchronism is probably the result of the nova outburst that led to a considerable expansion of the white dwarf's photosphere. The increase in the moment of inertia of the star was associated with a corresponding decrease in its spin rate. Our observations have followed the spinning-up of the white dwarf resulting from the contraction of its outer envelope as the star is slowly returning to its pre-outburst state. It is thus the second known asynchronous polar classical nova.

MNRAS, 2008

Other Novae in IPs

THE ASTRONOMICAL JOURNAL, 132: 608–613, 2006 August

NOVA V4743 SAGITTARII 2002: AN INTERMEDIATE POLAR CANDIDATE

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ABSTRACT

We present the results of 11 nights of CCD unfiltered photometry of V4743 Sgr (Nova Sgr 2002 No. 3) from 2003 and 2005. We find two periods of 0.2799 days (≈6.7 hr) and 0.01642 days (≈24 minutes) in the 2005 data. The long period is also present in the 2003 data, but only weak evidence of the shorter period is found in this year. The 24 minute period is somewhat longer than the 22 minute period that was detected from X-ray observations. We suggest that the 6.7 hr periodicity represents the orbital period of the underlying binary system and that the 24 minute period is the beat periodicity between the orbital period and the X-ray period, which is presumably the spin period of the white dwarf. Thus, V4743 Sgr should be classified as an intermediate polar (DQ Her star). About 6 months after the nova outburst, the optical light curve of V4743 Sgr seemed to show quasi-periodic oscillations, which are typical of the transient phase in classical novae. Therefore, our results support the previous suggestion that the transition phase in novae may be related to intermediate polars.

Other Novae in IPs

A&A 531, A22 (2011)
DOI: 10.1051/0004-6361/201116756

Astronomy & Astrophysics

Nova M31N 2007-12b: supersoft X-rays reveal an intermediate polar?⋆

W. Pietsch[1], M. Henze[1], F. Haberl[1], M. Hernanz[2], G. Sala[3], D. H. Hartmann[4], and M. Della Valle[5,6,7]

Results. The SSS emission started between 21 and 30 d after the optical outburst and ended between 60 and 120 d after outburst, making M31N 2007-12b one of the few novae with the shortest SSS phase known. The X-ray spectrum was supersoft and can be fitted with a white dwarf (WD) atmosphere model with solar abundances absorbed by the Galactic foreground. The temperature of the WD atmosphere seems to increase at the beginning of the SSS phase from ~70 to ~80 eV. The luminosity of M31N 2007-12b during maximum was at the Eddington limit of a massive WD and dropped by ~30% in the observation 60 d after outburst. The radius of the emission region is $\sim 6 \times 10^8$ cm. In the four bright state observations, we detected a stable 1110 s pulsation, which we interpret as the WD rotation period. In addition, we detect dips in three observations that might represent a 4.9 h or 9.8 h binary period of the system.
Conclusions. Nova envelope models with ≲50% mixing between solar-like accreted material and the degenerate core of the WD can be used to describe the data. We derive a WD mass of 1.2 $M_\odot$, as well as an ejected and burned mass of 2.0×10^{-6} $M_\odot$ and 0.2×10^{-6} $M_\odot$, respectively. The observed periodicities indicate that nova M31N 2007-12b erupted in an intermediate polar (IP) system. The WD photospheric radius seems to be larger than expected for a non-magnetic WD but in the range for magnetic WDs in an IP system.

Nova Oph 1998=V2487 Oph - Recurrent Nova

- Previous outburst in 1900 June 20, discovered in the Harvard College Observatory archival photograph collection *Pagnotta and Schaefer*, IAUC 8951, 200; 2009 AJ)

→ recurrent nova - P_{rec}=98 yrs

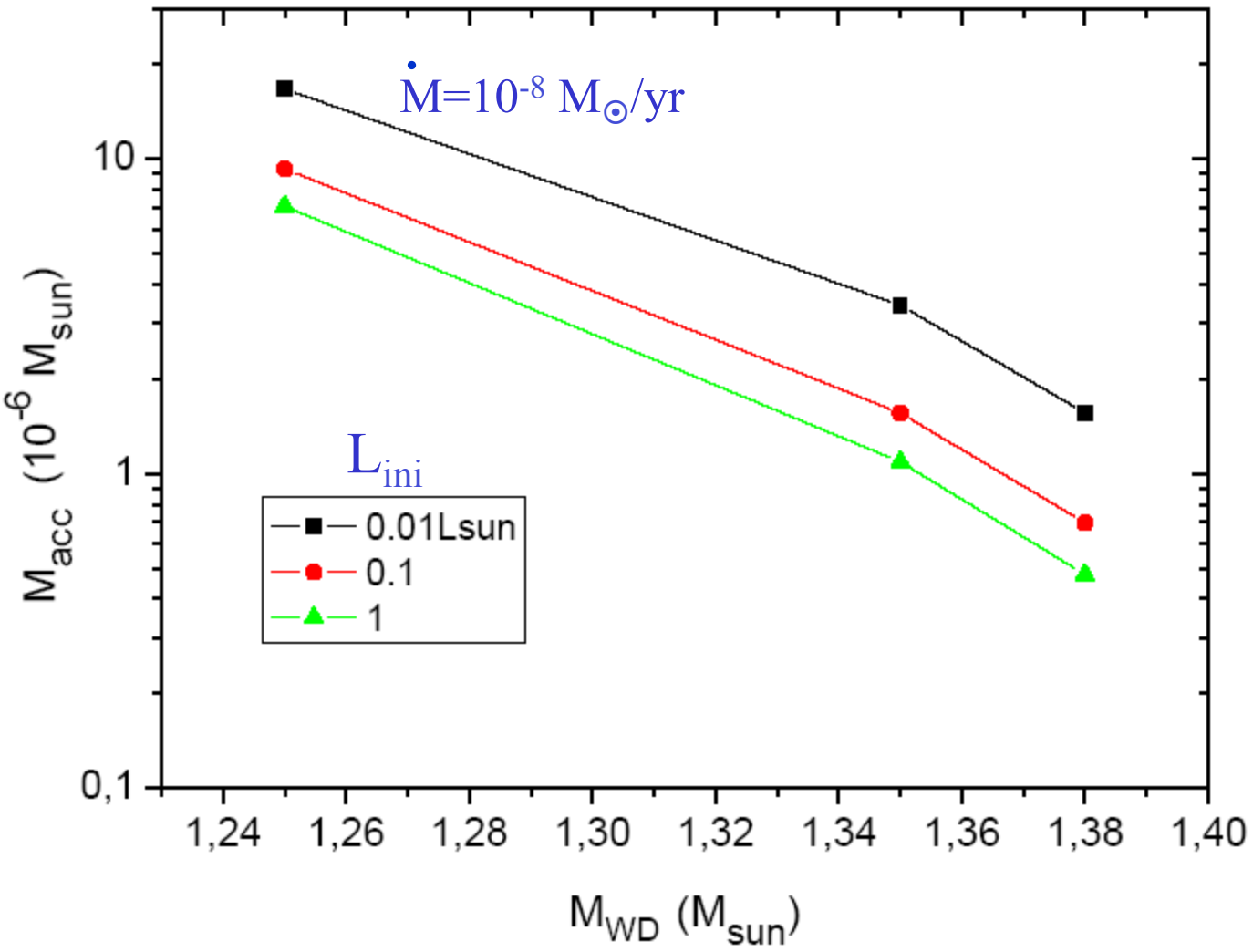
→M_{WD} very close to $M_{CHANDRA}$ → relevance for the SNIa scenario

➡ *challenge for theory to get recurrent nova explosions with such short time scales*

Recent nova in M31 (Henze et al. 2014), with P_{rec} = 1 yr ➔ even more challenging for theory

Accreted masses to reach H-ignition conditions

(hydrodynamic code)

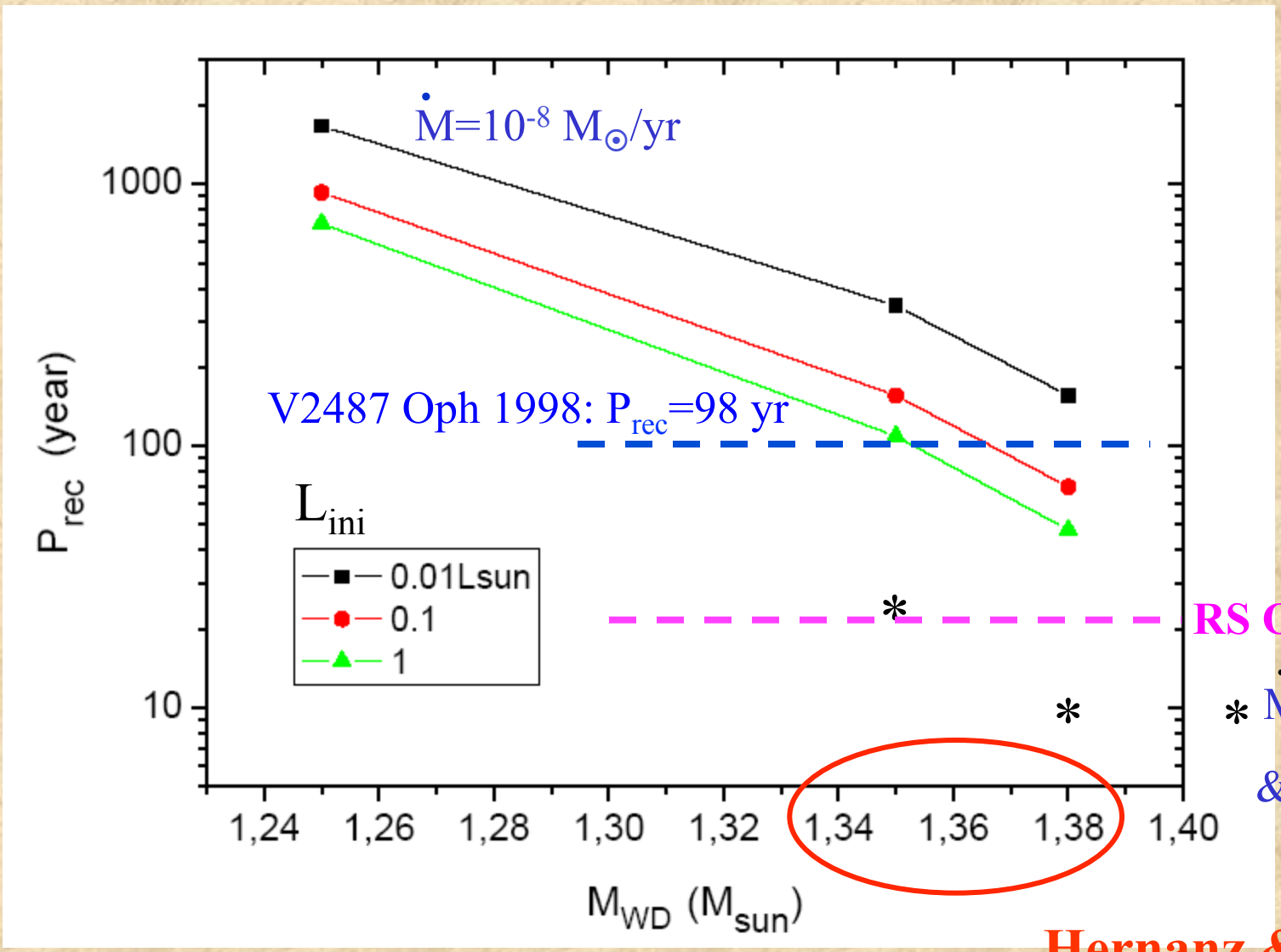


critical accreted mass does not depend only on M_{wd}

M_{wd} very close to $M_{CHANDRA}$

Hernanz & José 2008

Recurrence periods of novae



Hernanz & José 2008

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➡ X-ray emission CV-like ≠ RN scenario in symbiotics

• The nova – V2491 Cyg (2008) – has also been claimed to be recurrent. It was also a very fast nova, expected to be massive, very luminous in X-rays (Ibarra et al. 2009, A&A). It has also been detected in hard X-rays with Suzaku (Takei et al. 2009)

CONCLUSIONS

• **X-rays** are crucial to study the recovery of accretion in post-outburst novae: ***type of CV, mass of the WD***

• **Magnetic WD**: challenge for accretion – traditionally assumed to occur through an accretion disk in a non mag. WD. But some "magnetic novae" are known: V1500 Cyg (1975), V4633 Sgr (1998) – asynchronous polars as a consequence of the nova outburst (Lipkin & Leibowitz, 2008) - **V2487 Oph (1998)**

➔ also: V4743 Sgr 2002, M31N 2007-12b (Pietsch et al. 2011)

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• Massive WD: if T_{high}(plasma) is large and/or the nova is recurrent. Scenario for type Ia supernovae

➢ BUT challenging for theory: narrow parameter range: M_{wd} extremely large & accretion rate large to get $P_{recurrence} < 100$ yrs

➢ BUT M_{WD} should increase (OK: no mixing & SS emission)

➢ main caveat: not CO WDs but ONe (collapse instead of explo)