The Contributions of Margarita Hernanz to Studies of the Classical Nova Outburst

HAPPY BIRTHDAY and many more!

Sumner Starrfield
Earth and Space Exploration
Arizona State University
{symbiotic floor}
15 June 2017

The Contributions of Margarita Hernanz to Studies of the Classical Nova Outburst

With a little help from her friends:

As of June 2017, Margarita has 398 publications. They are in a wide variety of areas from theory to observations to instrument building.

I will concentrate on the Nova studies. *

Theory

Gamma Ray

X-ray

*Full disclosure – we have 23 joint publications

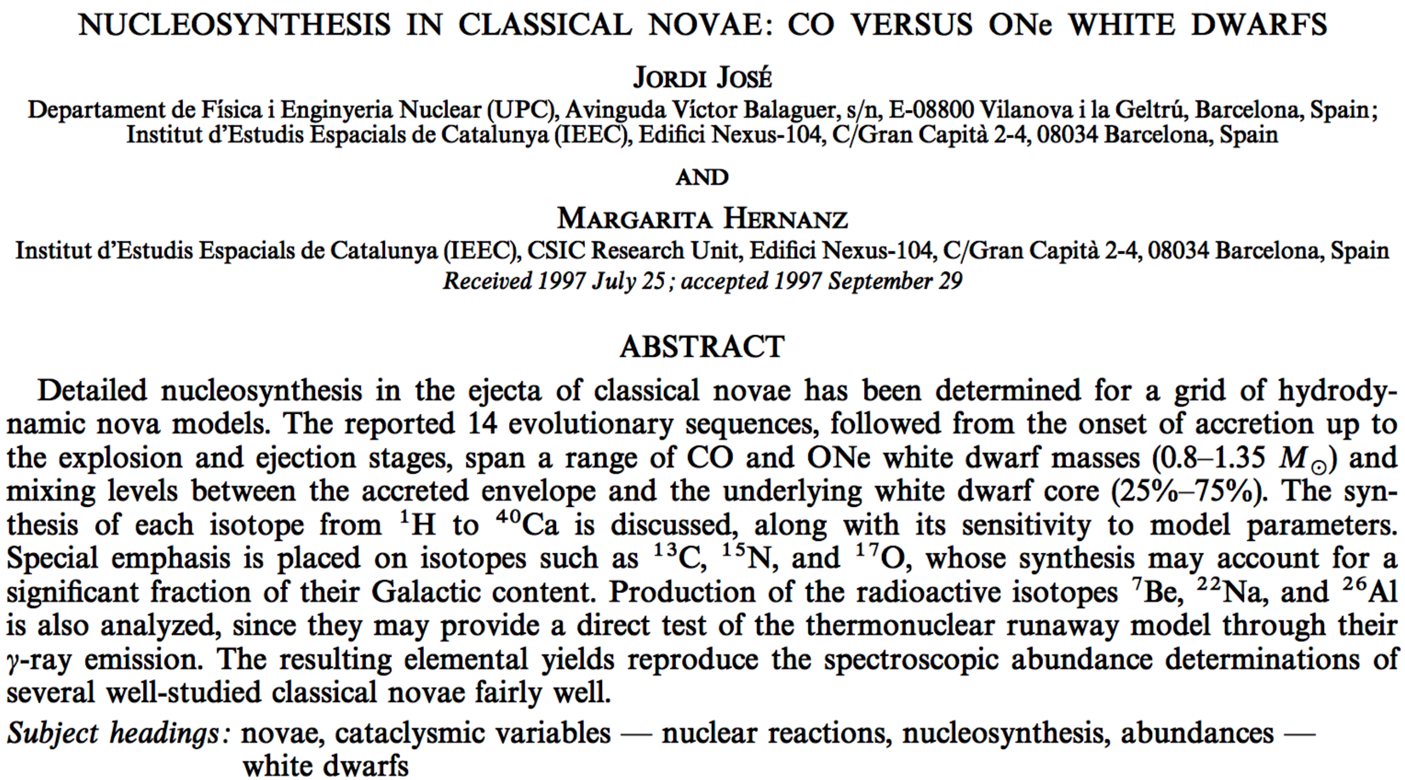
Sumnery*

- **Largest hydrogen (fusion) bomb in the universe**
- **A consequence of accretion onto white dwarfs where core matter is mixed with accreted matter and ejected**
- **Temperatures in the explosion sample the regime where cross sections can be directly measured in the lab**
- **Ejecta abundances depend strongly on nuclear physics**
- **Core composition of the white dwarf is either:**

  CO or ONe
- **Analyses of the ejected gases show non-solar abundances for <u>ALL</u> elements**
- **Possible galactic source of: ^{7}Li, ^{13}C, ^{15}N, ^{26}Al**
- **They are emitting VHE Gamma-rays**

*** [in case Jordi drags me off the stage]**

Margarita's most cited paper (275):


NUCLEOSYNTHESIS IN CLASSICAL NOVAE: CO VERSUS ONe WHITE DWARFS

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Received 1997 July 25; accepted 1997 September 29

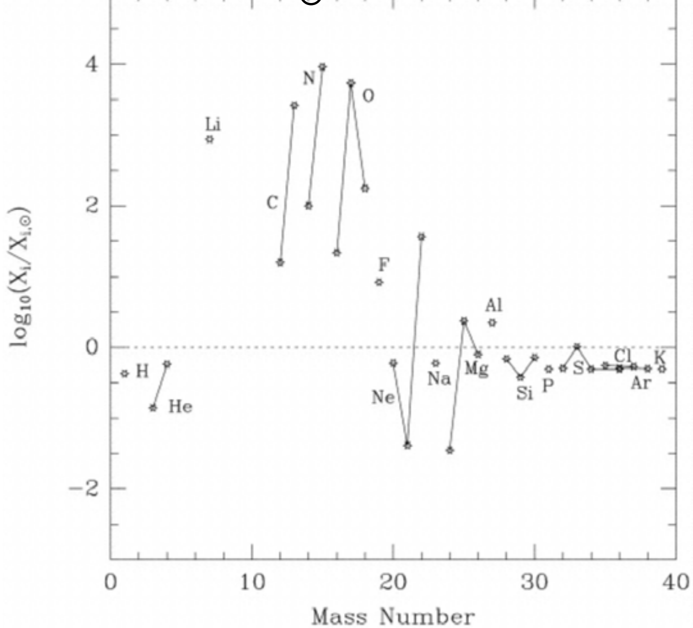
ABSTRACT

Detailed nucleosynthesis in the ejecta of classical novae has been determined for a grid of hydrodynamic nova models. The reported 14 evolutionary sequences, followed from the onset of accretion up to the explosion and ejection stages, span a range of CO and ONe white dwarf masses (0.8–1.35 $M_\odot$) and mixing levels between the accreted envelope and the underlying white dwarf core (25%–75%). The synthesis of each isotope from ^{1}H to ^{40}Ca is discussed, along with its sensitivity to model parameters. Special emphasis is placed on isotopes such as ^{13}C, ^{15}N, and ^{17}O, whose synthesis may account for a significant fraction of their Galactic content. Production of the radioactive isotopes ^{7}Be, ^{22}Na, and ^{26}Al is also analyzed, since they may provide a direct test of the thermonuclear runaway model through their γ-ray emission. The resulting elemental yields reproduce the spectroscopic abundance determinations of several well-studied classical novae fairly well.

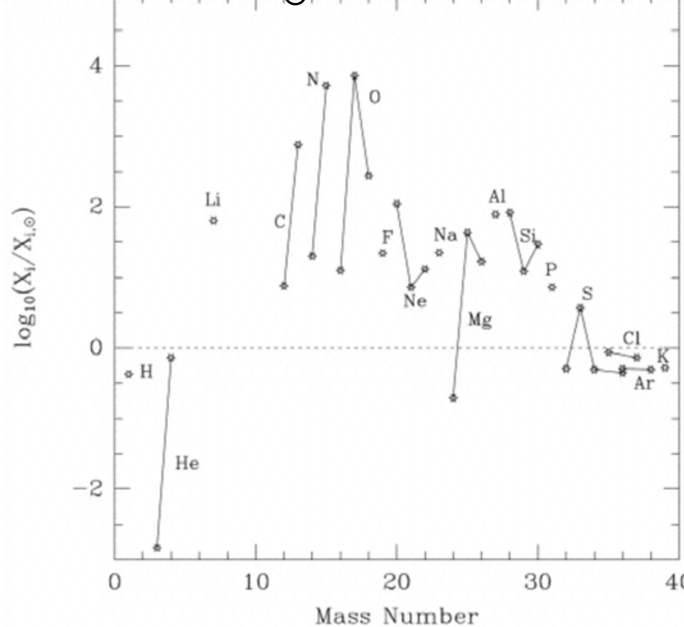
Subject headings: novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances — white dwarfs

Studied both carbon-oxygen and oxygen-neon core white dwarfs using SHIVA.
Detailed study of the synthesis of each isotope –especially the nuclear physics.
Emphasized the production of ^{7}Be, ^{22}Na, and ^{26}Al (a recurring theme!).
Tested the effects of white dwarf mass.
Used production plots to show which nuclei were produced by each outburst.

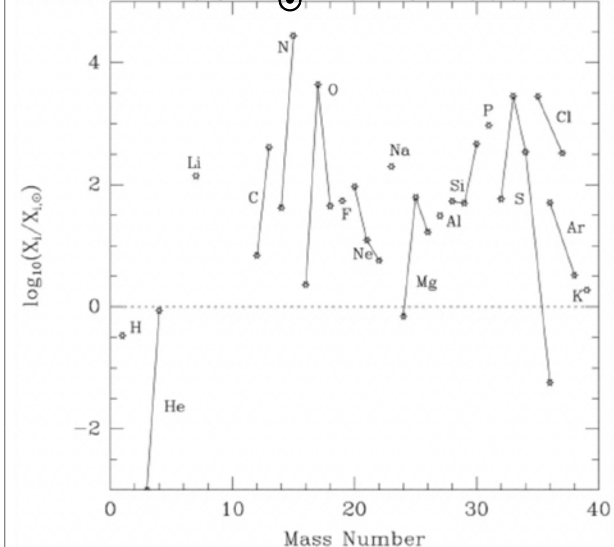
$1.15M_{\odot}$ CO Results



$1.15M_{\odot}$ ONe Results



$1.35M_{\odot}$ ONe Results



Initial ^{12}C abundance is important. The more carbon the faster the rise to the TNR with less mass and lower temperatures

"Also, the presence of a massive ONe white dwarf could be inferred from a significant detection of ^{19}F, ^{35}Cl, and even ^{31}P and ^{33}S in ejected nova shells."

THE ASTROPHYSICAL JOURNAL, 520:347–360, 1999 July 20

NUCLEAR UNCERTAINTIES IN THE NeNa-MgAl CYCLES AND PRODUCTION OF ^{22}Na AND ^{26}Al DURING NOVA OUTBURSTS

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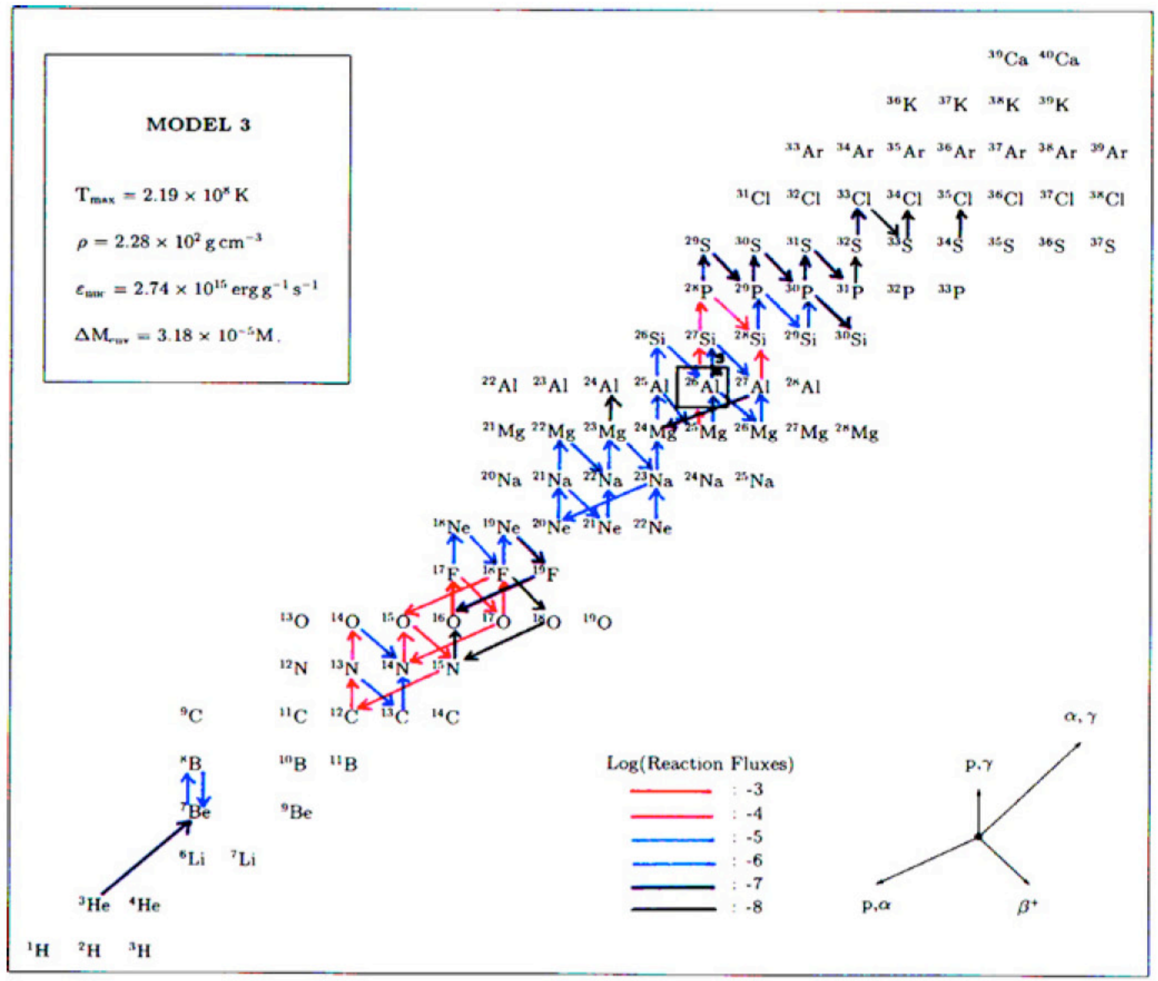
ABSTRACT

Classical novae eject significant amounts of nuclear-processed material into the interstellar medium. Among the isotopes synthesized during such explosions, two radioactive nuclei deserve particular attention: ^{22}Na and ^{26}Al. In this paper, we investigate the nuclear paths leading to ^{22}Na and ^{26}Al production during nova outbursts by means of an implicit hydrodynamic code that follows the course of the thermonuclear runaway from the onset of accretion up to the ejection stage. New evolutionary sequences of ONe novae have been computed, using updated nuclear reaction rates relevant to ^{22}Na and ^{26}Al production. Special attention is focused on the role played by nuclear uncertainties within the NeNa and MgAl cycles in the synthesis of such radioactive species. From a series of hydrodynamic models, which assume upper, recommended, or lower estimates of the reaction rates, we derive limits on the production of both ^{22}Na and ^{26}Al. We outline a list of nuclear reactions that deserve new experimental investigations in order to reduce the wide dispersion introduced by nuclear uncertainties in the ^{22}Na and ^{26}Al yields.
Subject headings: novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances

Nuclear Physics Uncertainties in the production of ^{22}Na and ^{26}Al.
Here they varied the nuclear reaction rates from lower to recommended to upper.
Included important discussions of the nuclear structure of ^{26}Al.
They predicted increased ^{22}Na over that from previous work– but it has still not been detected.
Need a nearby nova. Probably much less than 1 kpc.

Not from the previous paper but shows how the flows among the nuclei will affect the final abundances. The major cycles for hot hydrogen burning.

J. Phys. G: Nucl. Part. Phys. **35** (2008) 014024 J José and M Hernanz



The Astrophysical Journal, 560:897–906, 2001 October 20

SYNTHESIS OF INTERMEDIATE-MASS ELEMENTS IN CLASSICAL NOVAE: FROM Si TO Ca

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Received 2001 March 2; accepted 2001 June 22

ABSTRACT

Thermonuclear runaways driven by accretion into degenerate white dwarf cores are the source that power classical nova outbursts. In this paper, we identify the dominant nuclear paths involved in the synthesis of intermediate-mass elements, from Si to Ca, during such violent events. New evolutionary sequences of 1.35 $M_\odot$ ONe novae have been computed using updated nuclear reaction rates. The main nuclear activity in this region is powered by the leakage from the NeNa-MgAl region, where the activity is confined during the early stages of the explosion. We discuss the critical role played by ^{30}P(p,γ) in the synthesis of nuclear species beyond sulfur and point out the large uncertainty that affects its rate, which has dramatic consequences for studies of nova nucleosynthesis in the Si-Ca mass region.
Subject headings: novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances

Even higher mass nuclei with even newer rates:

Si to Ca

Uncertainty in rate of ^{30}P(p,gamma) is important

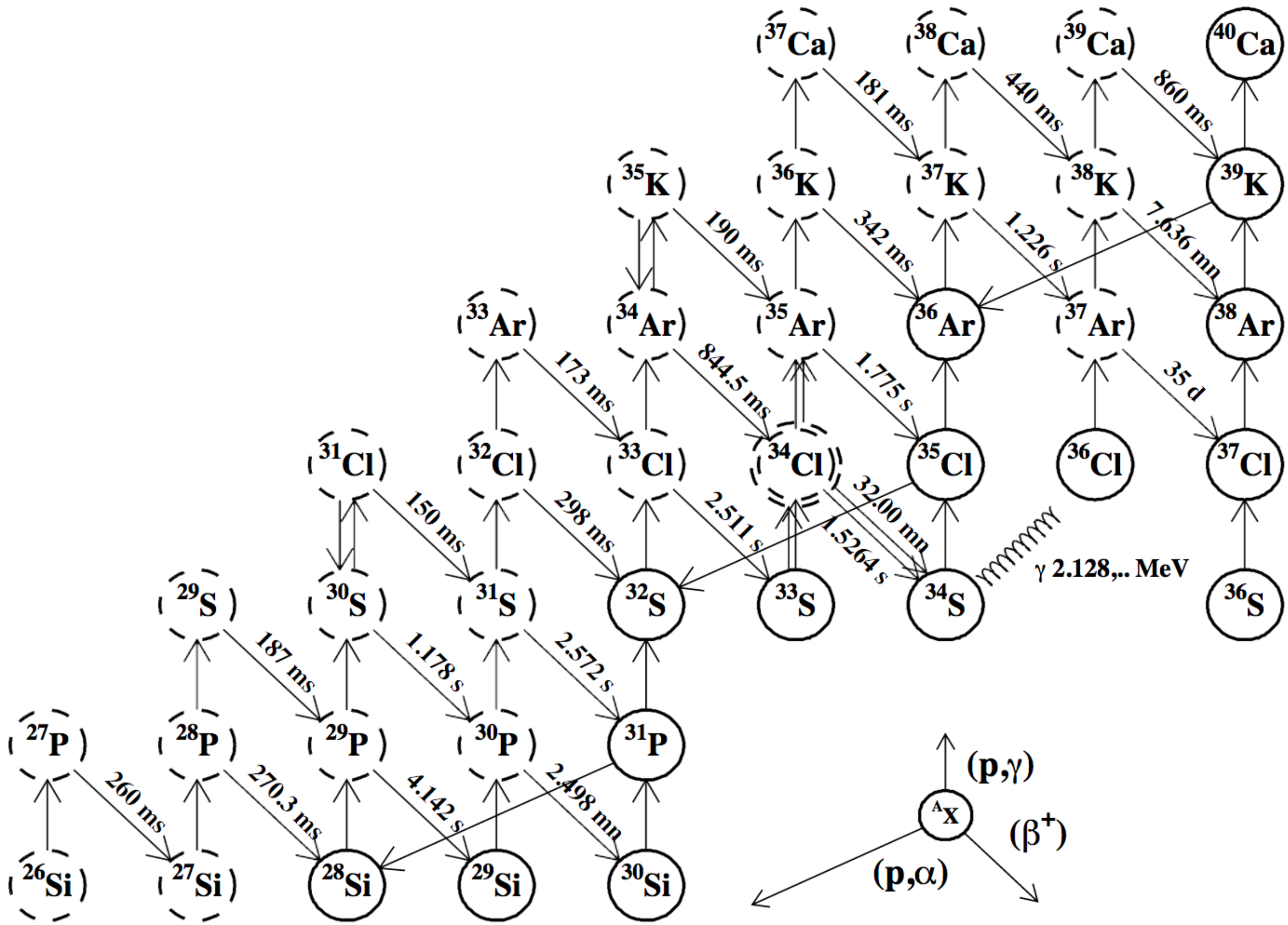

FIG. 1.—Main nuclear paths in the Si-Ca mass region

THE ASTROPHYSICAL JOURNAL, 465:L27–L30, 1996 July 1

ON THE SYNTHESIS OF ^{7}Li AND ^{7}Be IN NOVAE

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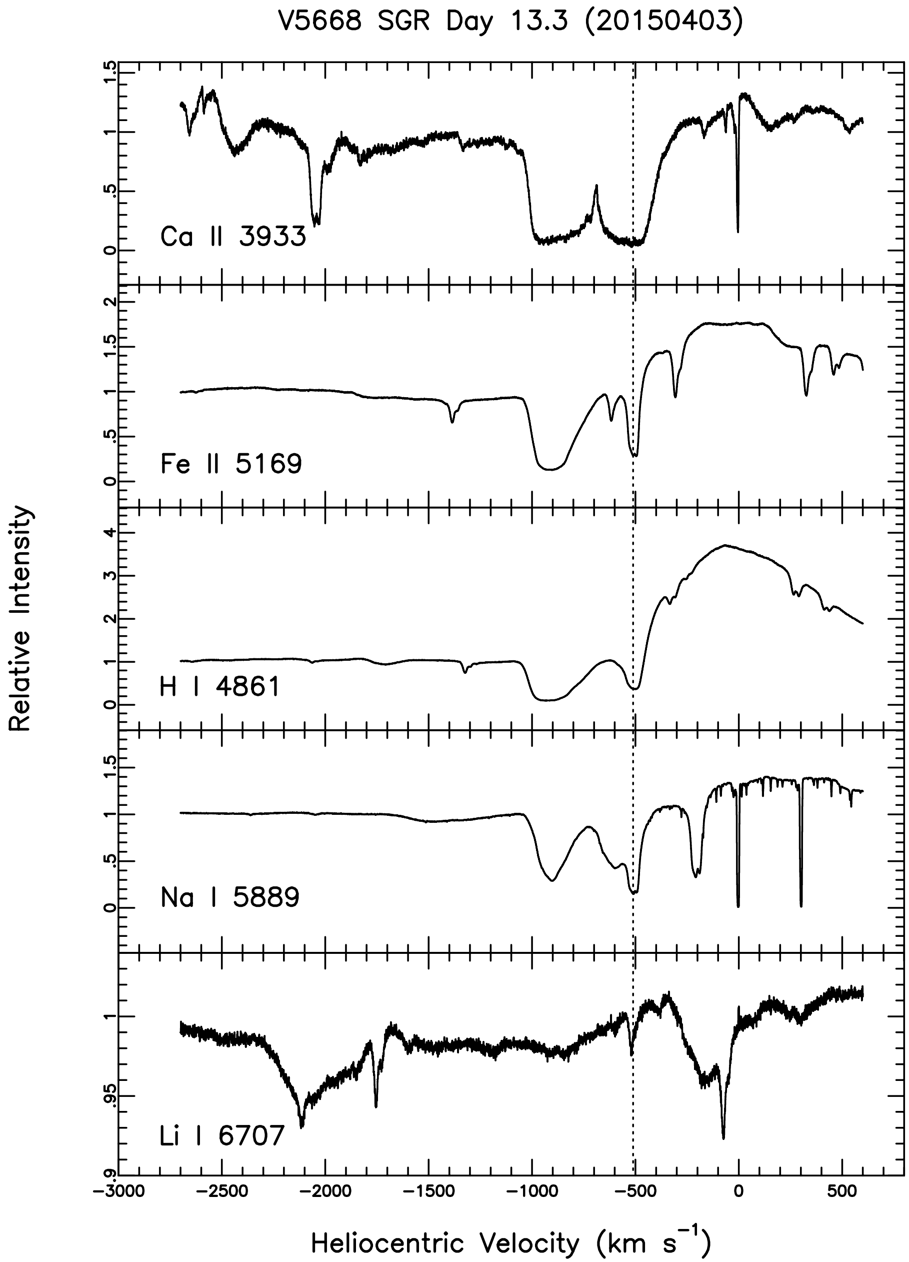
ABSTRACT

The production of ^{7}Li and ^{7}Be during the explosive hydrogen burning that occurs in nova explosions is computed by means of a hydrodynamic code able to treat both the accretion and the explosion stages. Large overproduction factors with respect to solar abundances are obtained, the exact value depending mainly on the chemical composition of the envelope. Although the final ejected masses are small, these results indicate that novae can contribute to the ^{7}Li enrichment of the interstellar medium. Furthermore, since ^{7}Be decays by emitting a gamma ray (478 keV), with a half-life of 53.3 days, the synthesis of ^{7}Li could be tested during the *INTEGRAL* mission.

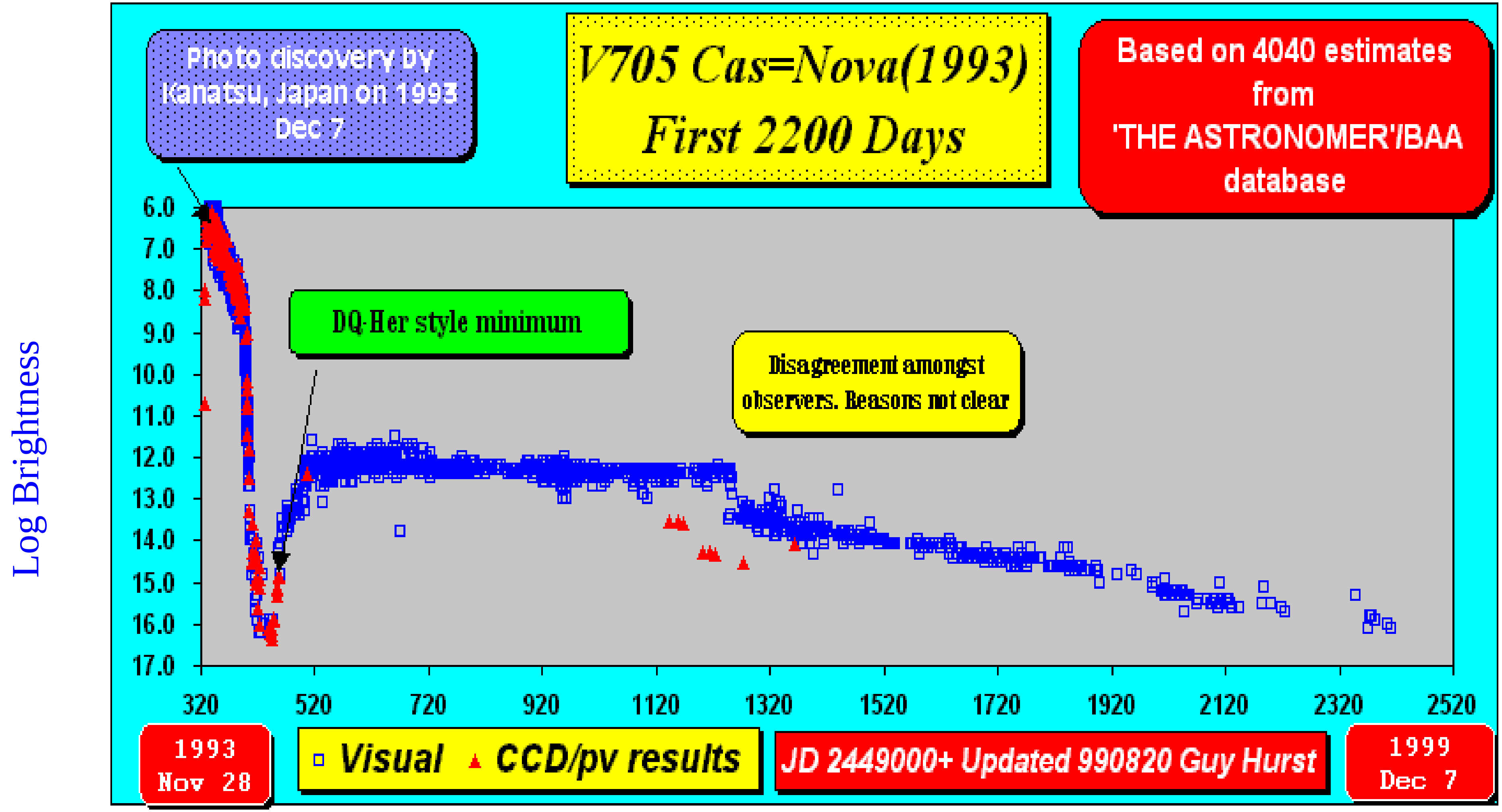
Subject headings: gamma rays: theory — novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances

46 2015 Nature 518 307 H 1.000 02/2015 A E R U
Hernanz, Margarita Astrophysics: A lithium-rich stellar explosion
A "News and Views" about the observational detection of Li and Be in Nova ejecta.

PEPSI on the
Large Binocular
Telescope
R~270,000
April 3, 2015



Novae Form Dust –in some cases lots of dust



ApJ 2004

THE IMPRINT OF NOVA NUCLEOSYNTHESIS IN PRESOLAR GRAINS

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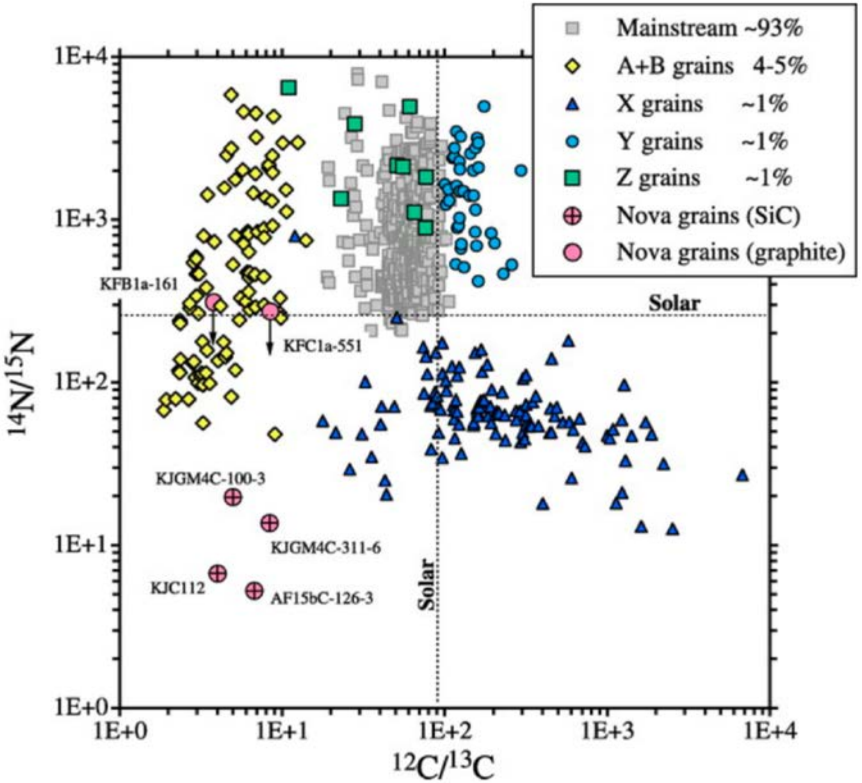
ABSTRACT

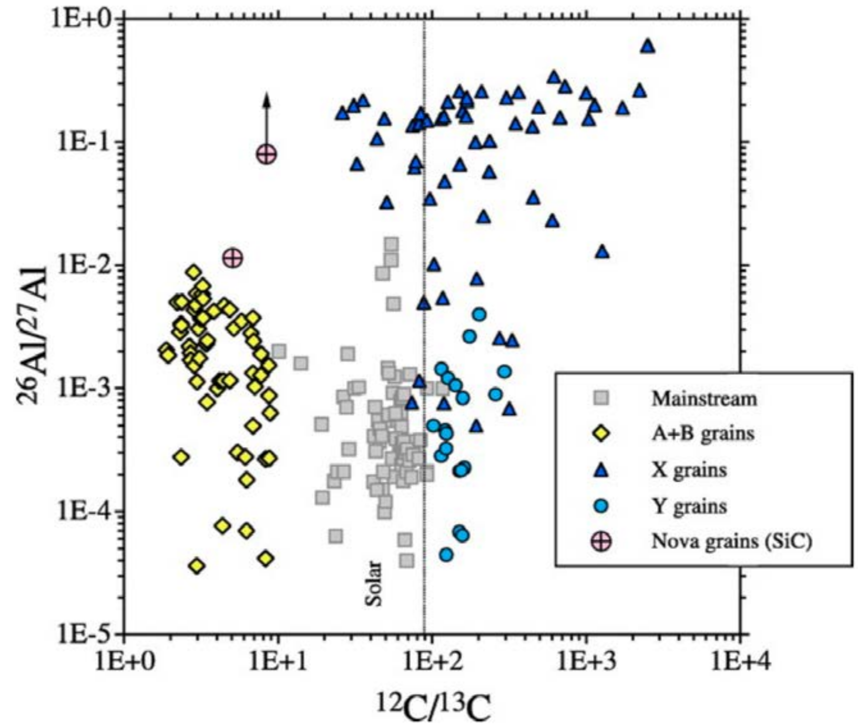
Infrared and ultraviolet observations of nova light curves have confirmed grain formation in their expanding shells that are ejected into the interstellar medium by a thermonuclear runaway. In this paper we present isotopic ratios of intermediate-mass elements up to silicon for the ejecta of CO and ONe novae, based on 20 hydrodynamic models of nova explosions. These theoretical estimates will help to properly identify nova grains in primitive meteorites. In addition, equilibrium condensation calculations are used to predict the types of grains that can be expected in the nova ejecta, providing some hints on the puzzling formation of C-rich dust in O > C environments. These results show that SiC grains can condense in ONe novae, in concert with an inferred (ONe) nova origin for several presolar SiC grains.

Subject headings: dust, extinction — novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances

Online material: color figures

We have known since DQ Her (1934) that some classical novae form grains. The shape of the light curve is obvious. Are there any grains on the earth that were formed by novae? This was not their first paper on the subject but was a detailed study of the physics. Very Important paper. It included equilibrium condensation calculations: How do we form carbon grains in an oxygen rich environment? O > C – O < C ??





Take predicted isotopic ratios and compare to laboratory measurements of those same ratios. Papers after this too.

THE ASTROPHYSICAL JOURNAL, 662: L103–L106, 2007 June 20

THE FIRST NOVA EXPLOSIONS

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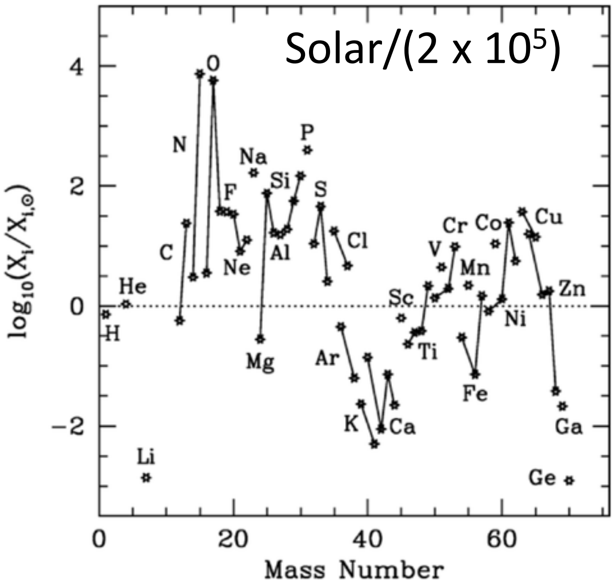
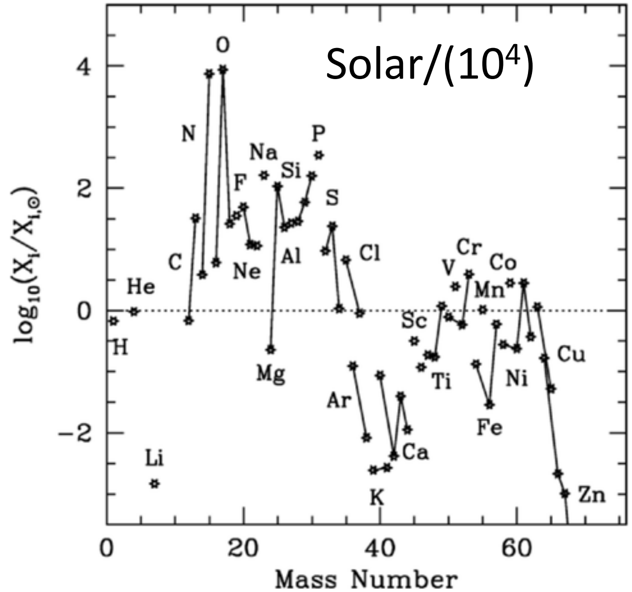
ABSTRACT

Classical novae are stellar explosions with an energy release that is only overcome by supernovae and γ-ray bursts. Theoretical and observational evidence suggests that these cataclysmic events are major sources of the Galactic ^{15}N, ^{17}O, and ^{13}C, and contribute to the abundances of ^{7}Li, and ^{26}Al, with a likely nucleosynthetic endpoint around Ca. However, there are reasons to believe that these nuclear signatures have changed during the overall Galactic history. In this Letter, the first that addresses the nature of nova explosions in the most primitive, low-metallicity binaries, we show that *primordial novae* eject more massive envelopes and display a larger nuclear activity than *classical novae*, leading to a new type of explosion, halfway between a supernova and a nova. The ejected shells from the most violent, massive primordial novae yield large excesses of Ti and a likely nucleosynthetic endpoint around Cu-Zn, signatures never before associated with a nova-like explosion. We conclude that the chemical abundance pattern of the nova ejecta is strongly modified at low metallicities and suggest that primordial novae are a possible birthplace of a rare variety of presolar grains whose origin remains uncertain.

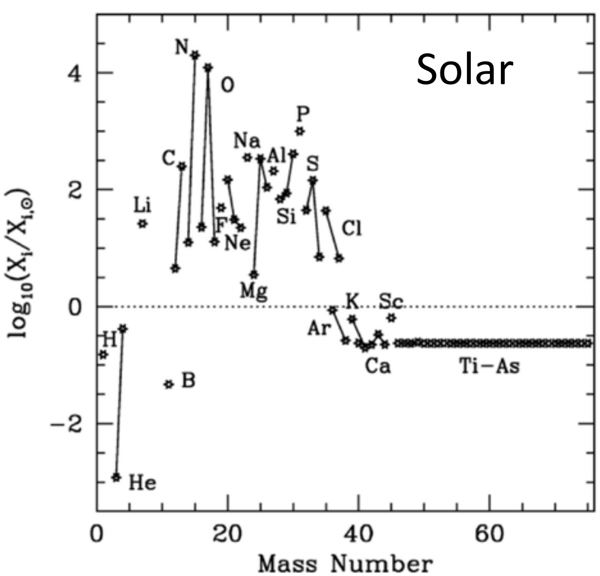
Subject headings: circumstellar matter — dust, extinction — Galaxy: abundances — novae, cataclysmic variables — nuclear reactions, nucleosynthesis, abundances

Here they investigate novae in low Z environments – really low Z. They find that the white dwarf accretes more matter (opacity is low so energy produced by accretion gets radiated more easily). Plus, they use the results of multi-D simulations and insert core material late in the evolution.



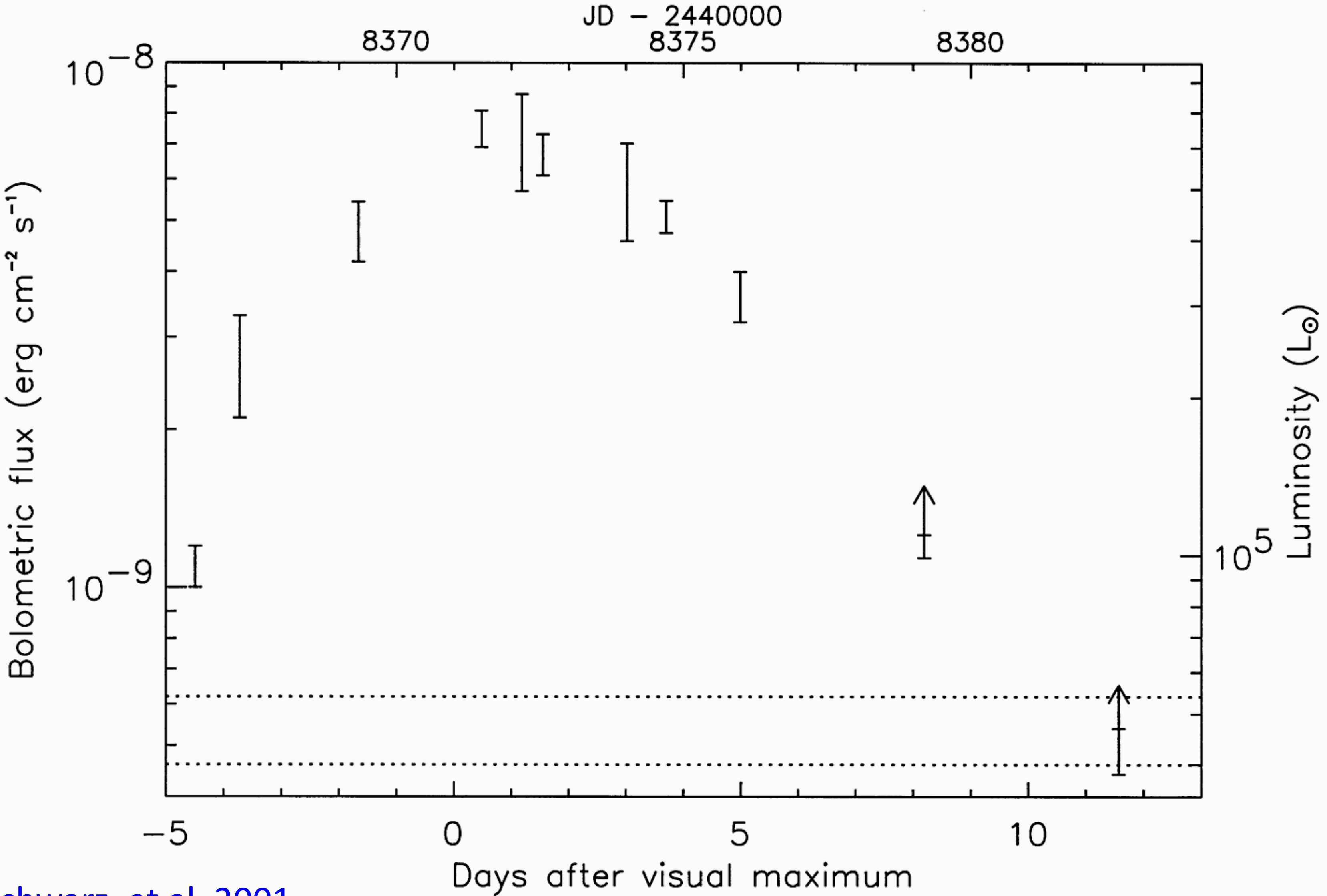


$Z_{LMC} < Z_{\odot}$
so a CN in the LMC should accrete more material and be more violent than a nearby nova.



Parameter	Model A	Model B	Model C
Composition...	Solar/2×10^5	Solar/10^4	Solar
Initial metallicity...	10^{-7}	2×10^{-6}	0.02
$X(^{12}C)_{initial}$...	1.52×10^{-8}	3.03×10^{-7}	3.03×10^{-3}
ΔM_{env} (10^{-5} $M_{\odot}$)...	1.65	1.25	0.656
t_{acc} (10^5 yr)...	1.00	0.753	0.380
t_{rise} (yr)...	2.71×10^4	4.21×10^3	3.01×10^2
T_{conv} (10^7 K)...	7.22	5.04	2.12
t_{peak}...	3.04 yr	99.84 days	1.10 hr
T_{peak} (10^8 K)...	3.77	3.55	3.08
ΔM_{ejec} (10^{-5} $M_{\odot}$)...	1.33	1.01	0.429
K_{ejec} (10^{45} ergs s^{-1})...	2.33	1.99	1.28
Z_{ejec} (%)...	19	26	78
Nucleosynthetic endpoint...	^{67}Zn	^{63}Cu	^{37}Cl

LMC 1991Super Eddington for 2 weeks. A CO nova



Schwarz et al. 2001

More Theory

A&A 439, 1057–1060 (2005)
DOI: 10.1051/0004-6361:20042587

Astronomy & Astrophysics

Envelope models for the supersoft X-ray emission of V1974 Cyg

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Abstract. The evolution of the soft X-ray emission of V1974 Cyg has been simulated by a white dwarf envelope model with steady hydrogen burning. The comparison of the results obtained from ROSAT observations with the results of our envelope models indicates that the post-outburst evolution of the nova can be explained by steady H-burning on either a 0.9 $M_\odot$ white dwarf with 50% degree of mixing between solar-like accreted material and the ONe degenerate core, or on a 1.0 $M_\odot$ ONe white dwarf with 25% mixing.

Key words. stars: individual: V1974 Cygni – stars: novae, cataclysmic variables – stars: white dwarfs – X-rays: binaries

Models for the soft X-ray emission of post-outburst classical novae

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Abstract. We developed a hydrostatic and stationary white dwarf envelope model for the study of the post-outburst phases of classical novae and their soft X-ray emission. We considered several white dwarf masses and chemical compositions typical of classical novae. Our results show that the luminosity, maximum effective temperature, and envelope masses depend on the white dwarf mass and on the chemical composition. Envelope masses for which equilibrium solutions exist are pretty small ($\sim 10^{-7}$–10^{-6} $M_\odot$), thus leading to a short duration of the soft X-ray emitting phase of classical novae, in agreement with most observations. The models we present provide a useful tool for the determination of the white dwarf properties from observable parameters in the X-ray range.

Key words. stars: novae, cataclysmic variables – stars: white dwarfs – X-rays: binaries

Hydrostatic envelope models
for post-explosion white dwarfs:
What are the conditions necessary
For X-ray emission?

T_{eff}, M_{env} all a function of WD mass

Varied the amount of mixing of core
with envelope.

Hydrostatic and stationary envelopes. Steady burning

Theory of Recurrent Novae:

The recurrent nova RS Oph: A possible scenario for type Ia supernovae

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Abstract

The recurrent nova RS Oph experienced an outburst in 2006, 21 years after its previous explosion in 1985, as expected. It was observed at almost all wavelengths, and important information about its properties is still being extracted. We present theoretical models of the explosion of this fascinating object, which indicate that the mass of the accreting white dwarf should be very close to the Chandrasekhar mass, to allow for such a short recurrence period. In addition, since models suggest that this nova ejects less mass than it accretes, it is an excellent candidate for a thermonuclear supernova explosion, in about $10^5 - 10^7$ years from now. We also analyze the emission of soft gamma-rays by RS Oph detected with the BAT instrument onboard Swift, and with the PCA onboard RXTE. We rule out that this emission has its origin in radioactive decays in the expanding nova envelope.

Key words: binaries: close, binaries: symbiotic, novae, cataclysmic variables, stars: individual (RS Oph), supernovae: general, nucleosynthesis, gamma-ray astronomy

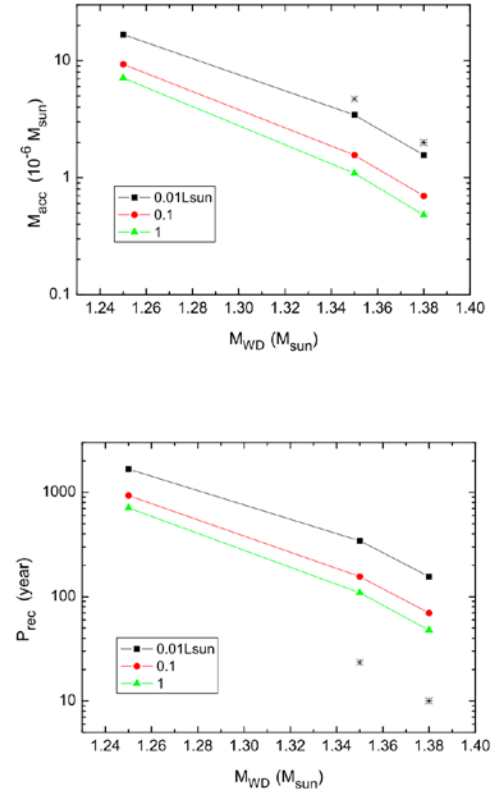

Fig. 1. Upper panel: accreted masses required to reach hydrogen ignition conditions and to power a TNR. Lower panel: recurrence periods for the same set of initial conditions as in the upper panel. Asterisks denote the values obtained for $\dot{M} = 2 \times 10^{-7} M_\odot$/year and $L_{wd}^{ini} = 10^{-2} L_\odot$.

<- Photobombed by 3 observers. At least.

How do we make the WD grow in mass as a result of the TNR? High mass accretion rate and no mixing with core. Massive WD helps too.

Margarita has also contributed to our understanding of High Energy emission from Classical and Recurrent Novae in outburst: Gamma -ray and X-ray.

Gamma-ray emission ("observed") in Novae occurs under 3 different mechanisms:

1. Radioactive decay:

Gamma-ray signatures of classical novae

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†Institute for Space Studies of Catalonia (IEEC)
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Abstract. The role of classical novae as potential gamma-ray emitters is reviewed, on the basis of theoretical models of the gamma-ray emission from different nova types. The interpretation of the up to now negative results of the gamma-ray observations of novae, as well as the prospects for detectability with future instruments (specially onboard INTEGRAL) are also discussed.

No detection yet

TABLE 1. Radioactive isotopes ejected by novae relevant for gamma-ray emission

Isotope	Lifetime	Main disintegration process	Type of γ-ray emission	Nova type
^{13}N	862 s	β^+–decay	511 keV line & continuum	CO and ONe
^{18}F	158 min	β^+–decay	511 keV line & continuum	CO and ONe
^{7}Be	77 days	e^-–capture	478 keV line	CO
^{22}Na	3.75 years	β^+–decay	1275 keV & 511 keV lines	ONe
^{26}Al	10^6 years	β^+–decay	1809 keV & 511 keV lines	ONe

TABLE 2. Radioactivities in novae ejecta (^{13}N and ^{18}F at 1h after T_{peak})

Nova	$M_{wd}(M_\odot)$	$M_{ejec}(M_\odot)$	KE (erg/g)	^{13}N ($M_\odot$)	^{18}F ($M_\odot$)	^{7}Be ($M_\odot$)	^{22}Na ($M_\odot$)
CO	0.8	6.2×10^{-5}	8×10^{15}	1.5×10^{-7}	1.8×10^{-9}	6.0×10^{-11}	7.4×10^{-11}
CO	1.15	1.3×10^{-5}	4×10^{16}	2.3×10^{-8}	2.6×10^{-9}	1.1×10^{-10}	1.1×10^{-11}
ONe	1.15	2.6×10^{-5}	3×10^{16}	2.9×10^{-8}	5.9×10^{-9}	1.6×10^{-11}	6.4×10^{-9}
ONe	1.25	1.8×10^{-5}	4×10^{16}	3.8×10^{-8}	4.5×10^{-9}	1.2×10^{-11}	5.9×10^{-9}

TABLE 3. SPI 3σ detectability distances (in kpc) for lines and continuum (see text for details about T_{obs}).

Nova type	$M_{wd}(M_\odot)$	511 keV line	478 keV line	1275 keV line	(170-470) keV
CO	0.8	0.7	0.4	-	0.4
CO	1.15	2.4	0.5	-	2.0
ONe	1.15	3.7	-	1.1	3.0
ONe	1.25	4.3	-	1.1	3.0

Predictions of gamma-ray emission as a function of time. Need a nearby nova –less than a kpc.

2. Shock Emission (detected by Swift (BAT) and RXTE for RS Oph):

Evidence for nonlinear diffusive shock acceleration of cosmic-rays in the 2006 outburst of the recurrent nova RS Ophiuchi

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ABSTRACT

Spectroscopic observations of the 2006 outburst of the recurrent nova RS Ophiuchi at both infrared (IR) and X-ray wavelengths have shown that the blast wave has decelerated at a higher rate than predicted by the standard test-particle adiabatic shock-wave model. Here we show that the observed evolution of the nova remnant can be explained by the diffusive shock acceleration of particles at the blast wave and the subsequent escape of the highest energy ions from the shock region. Nonlinear particle acceleration can also account for the difference of shock velocities deduced from the IR and X-ray data. The maximum energy that accelerated electrons and protons can have achieved in few days after outburst is found to be as high as a few TeV. Using the semi-analytic model of nonlinear diffusive shock acceleration developed by Berezhko & Ellison, we show that the postshock temperature of the shocked gas measured with *RXTE* PCA and *Swift* XRT imply a relatively moderate acceleration efficiency characterized by a proton injection rate $\eta_{\rm inj} \gtrsim 10^{-4}$.

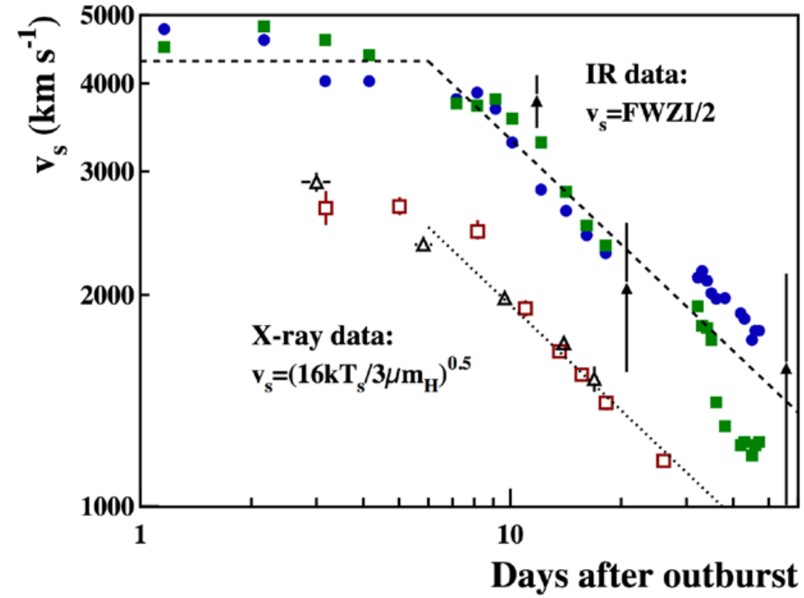


Fig. 1.— Time-dependence of forward shock velocity as deduced from FWZI of IR emission lines (filled symbols: squares and circles (Das et al. 2006), triangles (Evans et al. 2007)) and X-ray measurements of the postshock temperature (open symbols: triangles (Sokoloski et al. 2006), squares (Bode et al. 2006)). The lines are simple fits to the data (see text).

Plus Hernanz and Tatischeff 2012: Baltic Astronomy, 21, 62 where they also Considered the Fermi/LAT detections of novae

Large Area Telescope on FERMI

The Large Area Telescope on the *Fermi Gamma-ray Space Telescope* Mission 27

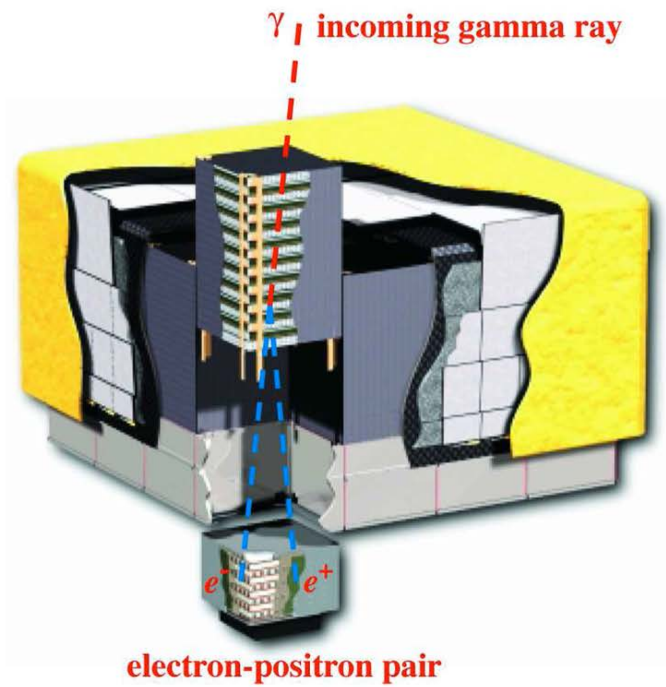
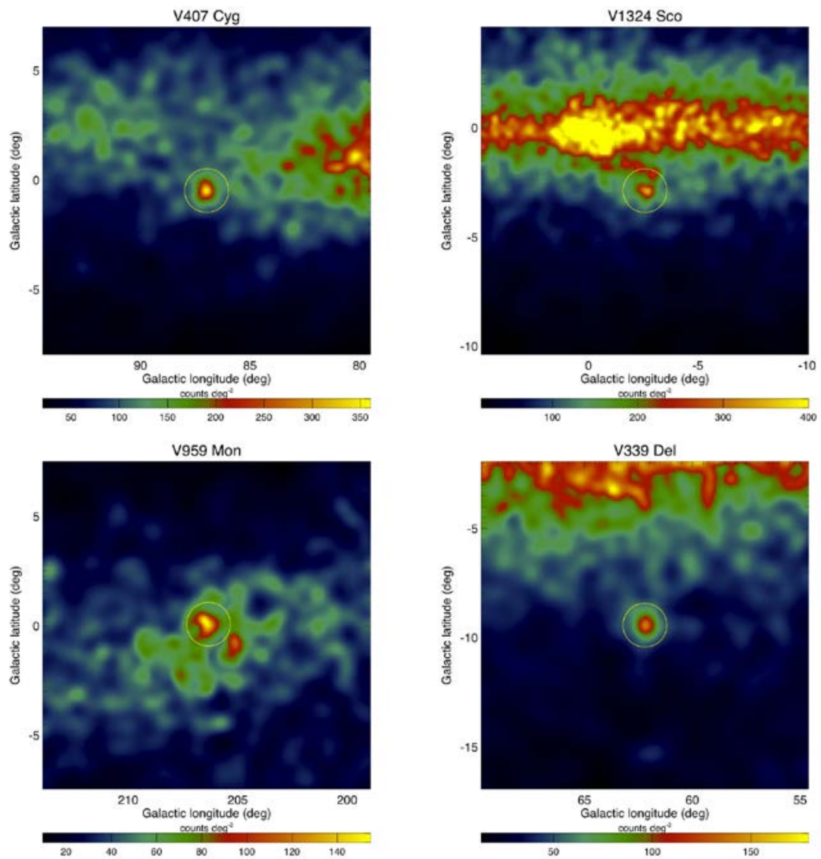
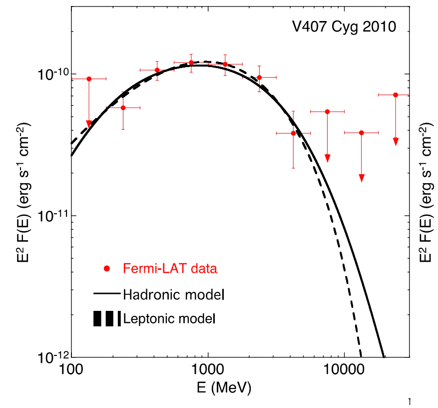


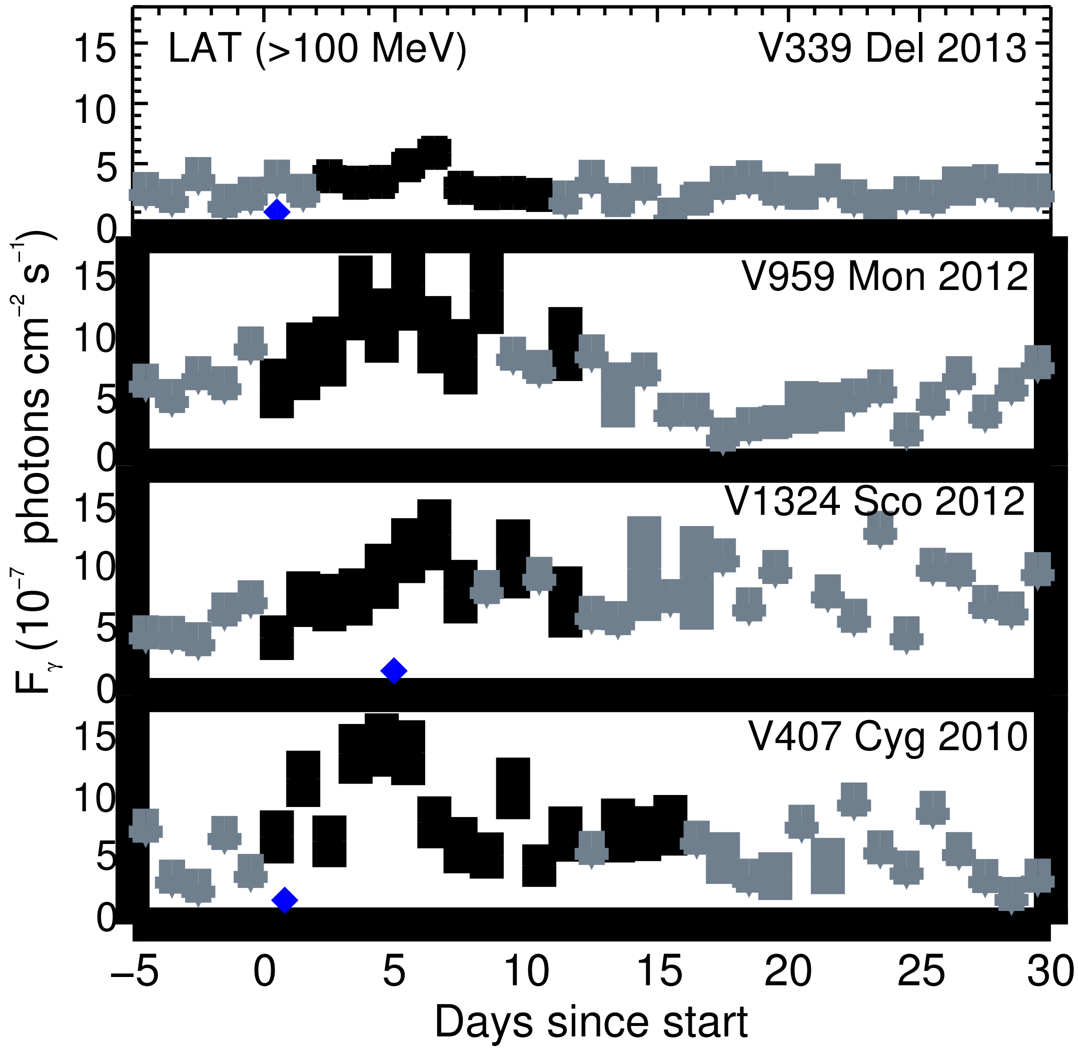
FIG. 1.— Schematic diagram of the Large Area Telescope. The telescope's dimensions are 1.8 m × 1.8 m × 0.72 m. The power required and the mass are 650 W and 2,789 kg, respectively.

Pair Conversion 30 times more sensitive than EGRET on Compton. Has now detected more than 6 Classical and 2 Recurrent Novae at E > 100 MeV. All novae emit VHE Gammas?

3. Most novae are emitting VHE gammas but the exact mechanism is not yet known:







Blue point marks the optical peak.   Not seen in V959 Mon because it was behind the Sun.

X-ray observations: One of her first papers was in Science:

A Classical Nova, V2487 Oph 1998, Seen in X-rays Before and After Its Explosion

Margarita Hernanz* and Glòria Sala

Classical nova explosions are very energetic and frequent phenomena caused by explosive hydrogen burning on top of an accreting white dwarf. Observations of the recent nova V2487 Oph 1998 by the X-ray Multi-Mirror satellite (XMM-Newton) provide evidence that accretion (probably on a magnetic white dwarf) was reestablished as early as 2.7 years after the explosion. In addition, positional correlation with a source previously discovered by the Röntgen Satellite (ROSAT) in 1990 suggests that the site of a nova explosion had been seen in x-rays before the outburst.

V2491 Cyg was also seen before outburst

THE EXTRAORDINARY X-RAY LIGHT CURVE OF THE CLASSICAL NOVA V1494 AQUILAE (1999 NO. 2) IN OUTBURST: THE DISCOVERY OF PULSATIONS AND A "BURST"

JEREMY J. DRAKE,[1] R. MARK WAGNER,[2] SUMNER STARRFIELD,[3] YOUSAF BUTT,[1] JOACHIM KRAUTTER,[4] H. E. BOND,[5] M. DELLA VALLE,[6] R. D. GEHRZ,[7] CHARLES E. WOODWARD,[7] A. EVANS,[8] M. ORIO,[9] P. HAUSCHILDT,[10] M. HERNANZ,[11] K. MUKAI,[12] AND J. W. TRURAN[13]

Received 2002 August 11; accepted 2002 October 14

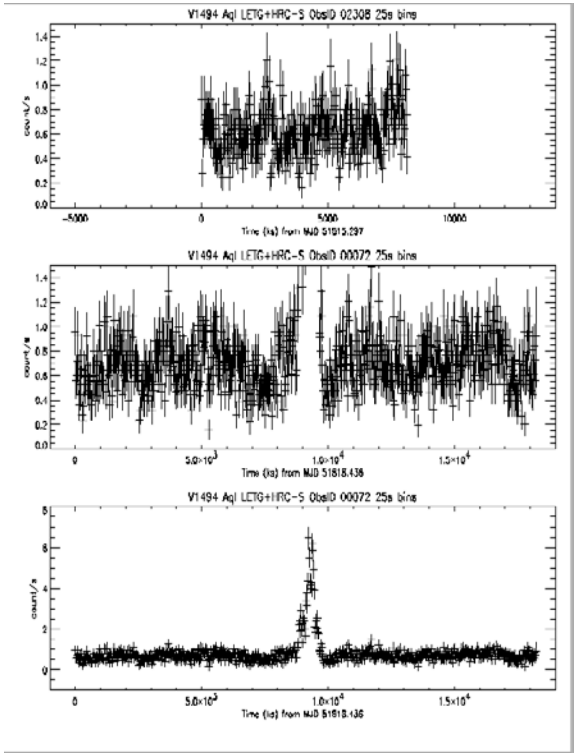
ABSTRACT

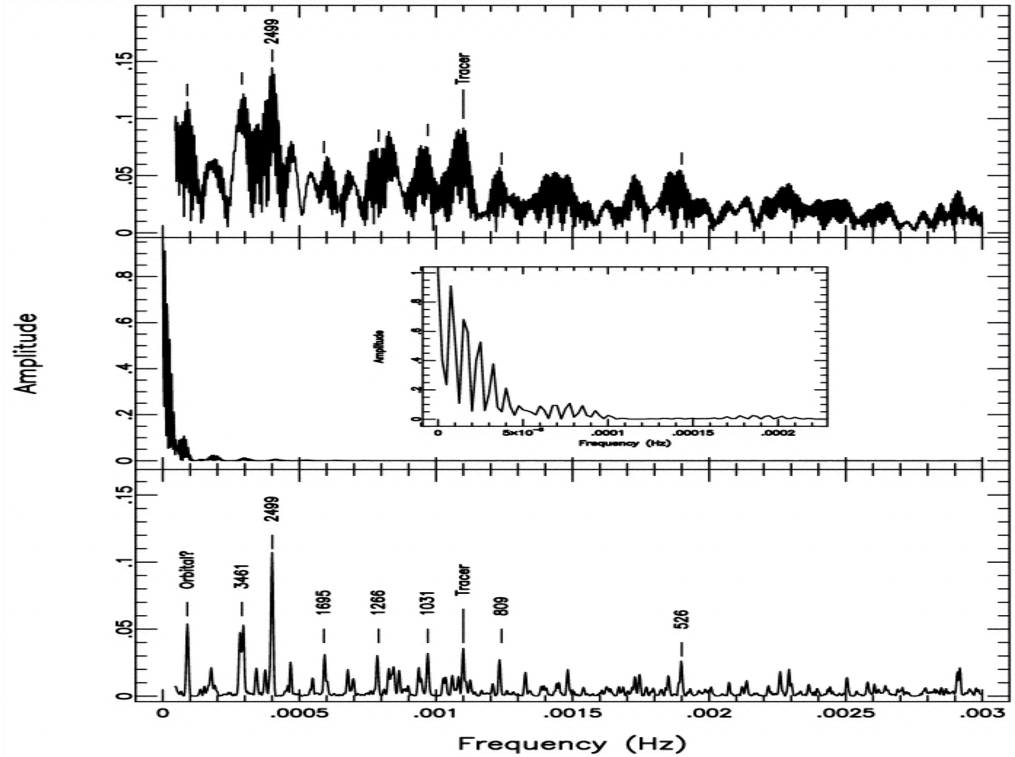
V1494 Aql (Nova Aql 1999 No. 2) was discovered on 1999 December 2. We obtained *Chandra* ACIS-I spectra on 2000 April 15 and June 7 which appear to show only emission lines. Our third observation, on August 6, showed that its spectrum had evolved to that characteristic of a Super Soft X-ray Source. We then obtained *Chandra* LETG+HRC-S spectra on September 28 (8 ks) and October 1 (17 ks). We analyzed the X-ray light curve of our grating observations and found both a short timescale "burst" and oscillations. Neither of these phenomena has previously been seen in the light curve of a nova in outburst. The "burst" was a factor of ~10 rise in X-ray counts near the middle of the second observation, and which lasted about 1000 s; it exhibited at least two peaks, in addition to other structure. Our time series analysis of the combined 25 ks observation shows a peak at ~2500 s which is present in independent analyses of both the zeroth-order image and the dispersed spectrum and is not present in similar analyses of grating data for HZ 43 and Sirius B. Further analyses of the V1494 Aql data find other periods present which implies that we are observing nonradial g^+ modes from the pulsating, rekindled white dwarf.

Subject headings: novae, cataclysmic variables — stars: individual (V1494 Aquilae) — stars: oscillations — white dwarfs — X-rays: binaries — X-rays: bursts

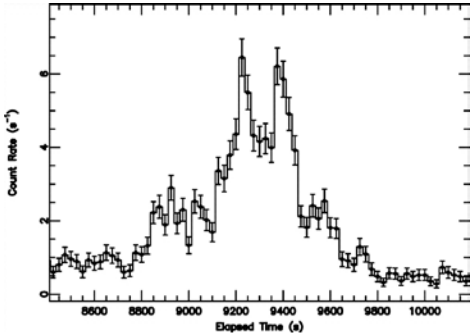
The second nova studied with CHANDRA. The first was V382 Vel (1999) –Burwitz et al. 2002. These were observed right after the launch.

The CHANDRA X-ray light curve of V1494 Aql (in its SSS Phase)





A blow-up of the X-ray "Burst"



Brief flux increase- 14 minutes

Variation unexplained

Does not look like variable absorption

A *CHANDRA* LOW ENERGY TRANSMISSION GRATING SPECTROMETER OBSERVATION OF V4743 SAGITTARII: A SUPERSOFT X-RAY SOURCE AND A VIOLENTLY VARIABLE LIGHT CURVE

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Received 2003 April 22; accepted 2003 July 25; published 2003 August 6

ABSTRACT

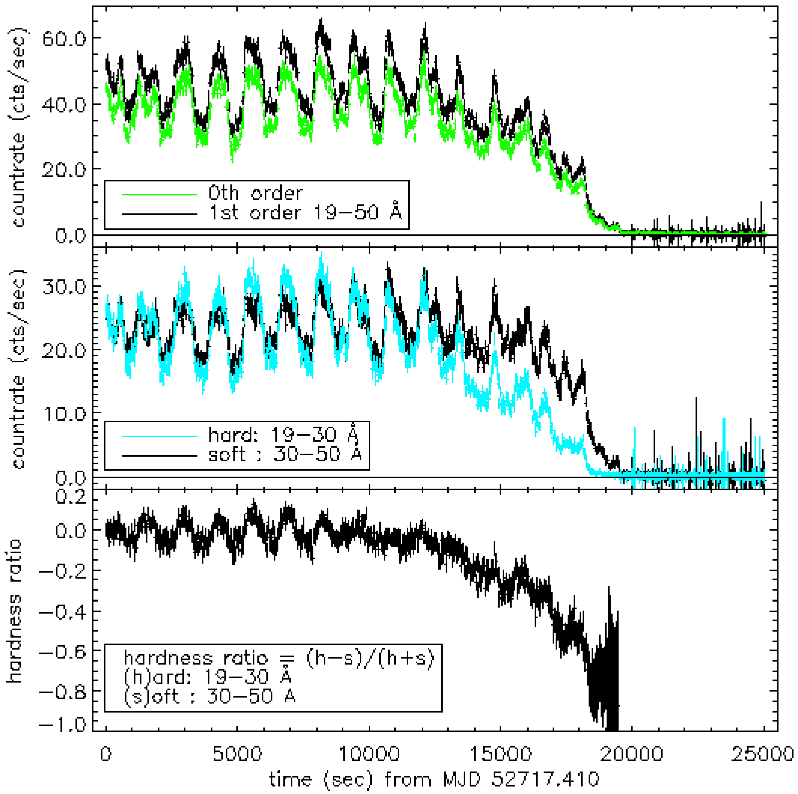
V4743 Sagittarii (Nova Sgr 2002 No. 3) was discovered on 2002 September 20. We obtained a 5 ks ACIS-S spectrum in 2002 November and found that the nova was faint in X-rays. We then obtained a 25 ks *Chandra* Low Energy Transmission Grating Spectrometer (LETGS) observation on 2003 March 19. By this time, it had evolved into the supersoft X-ray phase exhibiting a continuous spectrum with deep absorption features. The light curve from the observation showed large-amplitude oscillations with a period of 1325 s (22 minutes) followed by a decline in the total count rate after ~13 ks of observations. The count rate dropped from ~40 counts s^{-1} to practically zero within ~6 ks and stayed low for the rest of the observation (~6 ks). The spectral hardness ratio changed from maxima to minima in correlation with the oscillations and then became significantly softer during the decay. Strong H-like and He-like lines of oxygen, nitrogen, and carbon were found in absorption during the bright phase, indicating temperatures between 1 and 2 MK, but they were shifted in wavelength corresponding to a Doppler velocity of -2400 km s^{-1}. The spectrum obtained after the decline in count rate showed emission lines of C VI, N VI, and N VII, suggesting that we were seeing expanding gas ejected during the outburst, probably originating from CNO-cycled material. An *XMM-Newton* Target of Opportunity observation, obtained on 2002 April 4 and a later LETGS observation from 2003 July 18 also showed oscillations, but with smaller amplitudes.

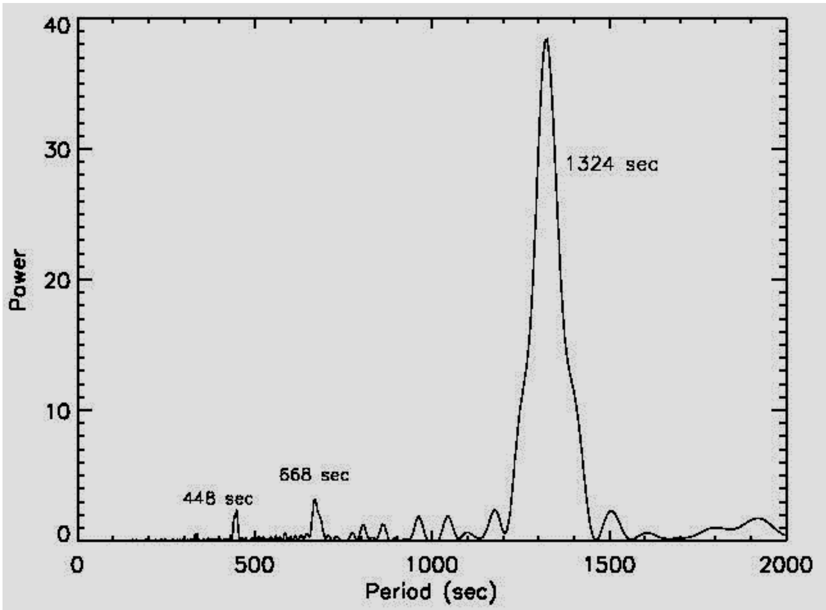
Subject headings: novae, cataclysmic variables — stars: individual (V4743 Sagittarii) — stars: oscillations — white dwarfs — X-rays: binaries

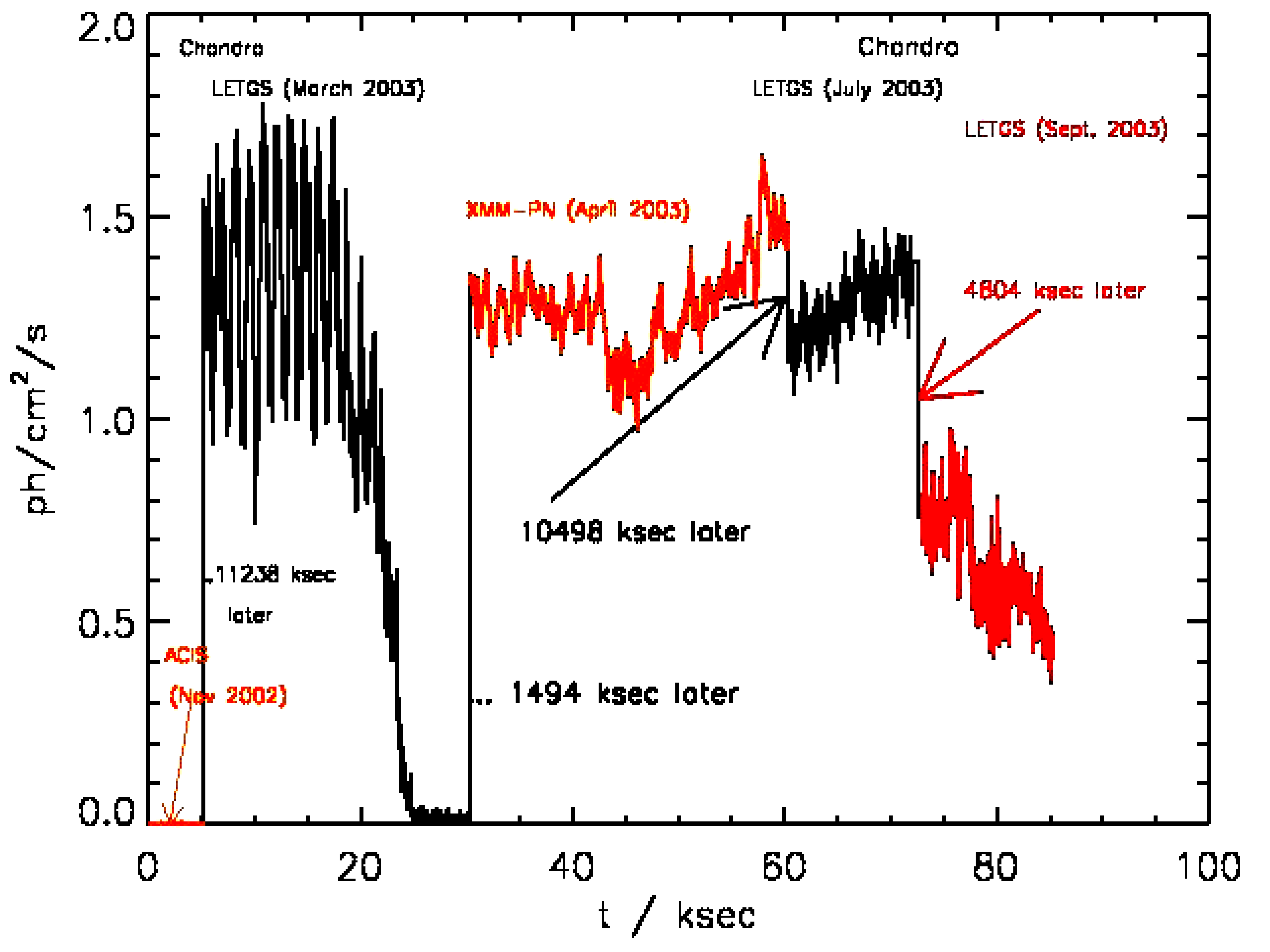
Another interesting nova studied in X-rays!

V4743 Sgr

1) The light curve exhibits oscillations with a period ~22min
2) After 15 ksec it begins to decline - first “hard” then “soft”
3) By 20 ksec it has dropped to nearly zero.







Chandra
LETGS (March 2003)
Chandra
LETGS (July 2003)
LETGS (Sept. 2003)
XMM-PN (April 2003)
4804 ksec later
10498 ksec later
..11238 ksec
later
ACIS
(Nov 2002)
... 1494 ksec later
ph/cm^2/s
t / ksec
0.0
0.5
1.0
1.5
2.0
0
20
40
60
80
100

XMM-NEWTON OBSERVATIONS OF NOVA SAGITTARII 1998

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Received 2003 October 1; accepted 2007 April 2

ABSTRACT

We report on X-ray observations of Nova Sagittarii 1998 (V4633 Sgr) performed with *XMM-Newton* at three different epochs, 934, 1083, and 1265 days after discovery. The nova was detected with the EPIC cameras at all three epochs, with emission spanning the whole energy range from 0.2 to 10 keV. The X-ray spectra do not change significantly at the different epochs and are well fitted for the first and third observations with a multitemperature optically thin thermal plasma, while lower statistics in the second observations lead to a poorer fit. The thermal plasma emission is most probably originated in the shock heated ejecta, with chemical composition similar to that of a CO nova. However, we cannot completely rule out reestablished accretion as the origin of the emission. We also obtain upper limits for the temperature and luminosity of a potential white dwarf atmospheric component and conclude that hydrogen burning had already turned off by the time of our observations.

Subject headings: novae, cataclysmic variables — stars: individual (V4633 Sagittarii) — white dwarfs — X-rays: binaries — X-rays: individual (V4633 Sagittarii)

Online material: color figures

Observations very late in the outburst. Still detected as an optically thin thermal plasma. Shock heating 3.5 years after outburst.

Pre-nova X-ray observations of V2491 Cygni (Nova Cyg 2008b)

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Received 23 January 2009 / Accepted 23 February 2009

ABSTRACT

Classical novae are phenomena caused by explosive hydrogen burning onto an accreting white dwarf. Only one classical nova had been identified in X-rays before the actual optical outburst occurred (V2487 Oph). The recently discovered nova, V2491 Cyg, is one of the fastest (He/N) novae observed to date. Using archival *ROSAT*, *XMM-Newton*, and *Swift* data, we show that V2491 Cyg was a persistent X-ray source during its quiescent time before the optical outburst. We present the X-ray spectral characteristics and derive X-ray fluxes. The pre-outburst X-ray emission is variable, and, at least in one observation, it exhibits a soft X-ray source.

Another nova detected in X-rays before the outburst. It was variable and ranged from soft to hard.

XMM-NEWTON X-RAY AND ULTRAVIOLET OBSERVATIONS OF THE FAST NOVA V2491 Cyg DURING THE SUPERSOFT SOURCE PHASE

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Received 2010 November 7; accepted 2011 March 21; published 2011 May 5

ABSTRACT

Two *XMM-Newton* observations of the fast classical nova V2491 Cyg were carried out in short succession on days 39.93 and 49.62 after discovery, during the supersoft source (SSS) phase, yielding simultaneous X-ray and UV light curves and high-resolution X-ray spectra. The first X-ray light curve is highly variable, showing oscillations with a period of 37.2 minutes after an extended factor of three decline lasting ~3 hr, while the second X-ray light curve is less variable. The cause of the dip is currently unexplained and has most likely the same origin as similar events in the early SSS light curves of the novae V4743 Sgr and RS Oph, as it occurred on the same timescale. The oscillations are not present during the dip minimum and also not in the second observation. The UV light curves are variable but contain no dips and no period. High-resolution X-ray spectra are presented for four intervals of differing intensity. All spectra are atmospheric continua with deep absorption lines and absorption edges. Two interstellar lines of O I and N I are clearly seen at their rest wavelengths, while a large number of high-ionization absorption lines are found at blueshifts indicating an expansion velocity of 3000–3400 km s^{-1}, which does not change significantly during the epochs of observation. Comparisons with the slower nova V4743 Sgr and the symbiotic recurrent nova RS Oph are presented. The SSS spectrum of V4743 Sgr is much softer with broader and more complex photospheric absorption lines. The ejecta are extended, allowing us to view a larger range of the radial velocity profile. Meanwhile, the absorption lines in RS Oph are as narrow as in V2491 Cyg, but they are less blueshifted. A remarkable similarity in the continua of V2491 Cyg and RS Oph is found. The only differences are smaller line shifts and additional emission lines in RS Oph that are related to the presence of a dense stellar wind from the evolved companion. Three unidentified absorption lines are present in the X-ray spectra of all three novae, with projected rest wavelengths 26.05 Å, 29.45 Å, and 30.0 Å. No entirely satisfactory spectral model is currently available for the soft X-ray spectra of novae in outburst, and careful discussion of assumptions is required.

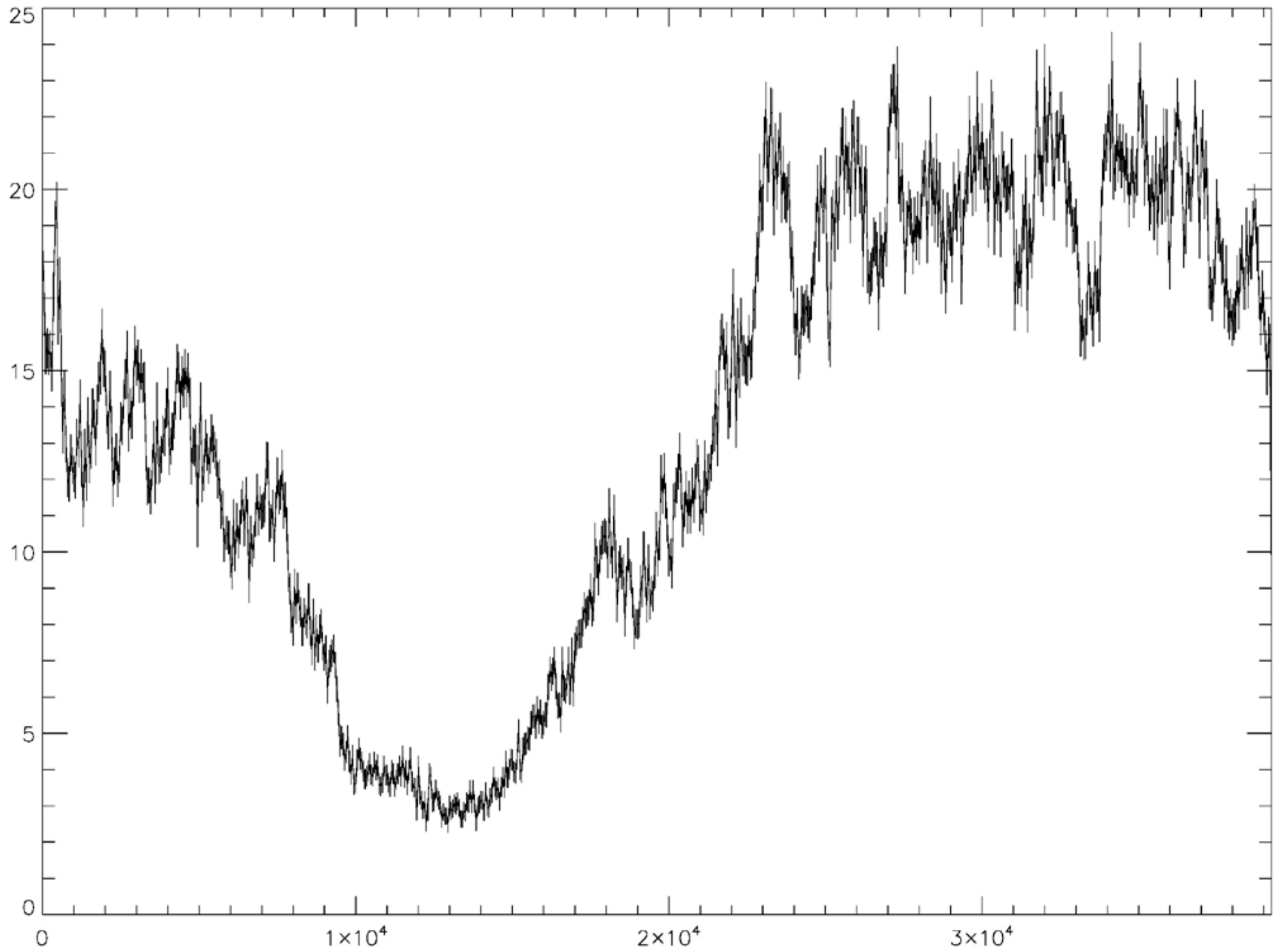
Key words: astronomical databases: miscellaneous – novae, cataclysmic variables – stars: individual (V2491 Cyg, RS Oph, V4743 Sgr)

Online-only material: color figures

Observed twice with XMM – extremely variable in the first observation and "flat" in the second. Detailed analysis of the X-ray spectrum showed that it was harder than that of V4743 Sgr.

V2491 Cyg XMM light Curve Day 39.9

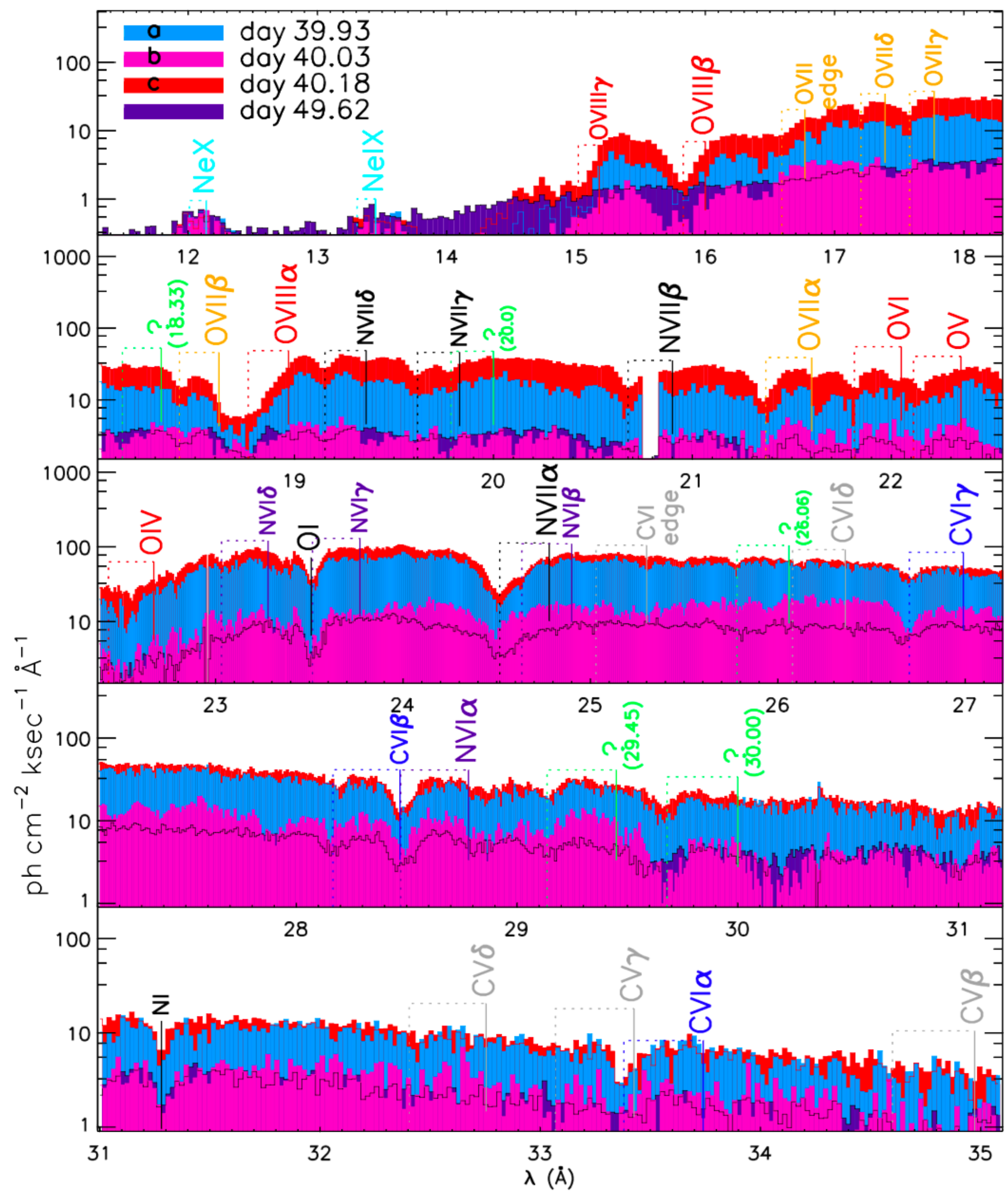
(next observation on day 49 (10 days later)-- it was “flat”)



Count Rate cts/sec

Time (Seconds)

V2491 Cyg Spectrum on 4 days: Ness et al.



COLLIMATION AND ASYMMETRY OF THE HOT BLAST WAVE FROM THE RECURRENT NOVA V745 Sco

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ABSTRACT

The recurrent symbiotic nova V745 Sco exploded on 2014 February 6 and was observed on February 22 and 23 by the *Chandra X-ray Observatory* Transmission Grating Spectrometers. By that time the supersoft source phase had already ended, and *Chandra* spectra are consistent with emission from a hot, shock-heated circumstellar medium with temperatures exceeding 10^7 K. X-ray line profiles are more sharply peaked than expected for a spherically symmetric blast wave, with a full width at zero intensity of approximately $2400\,\mathrm{km\,s^{-1}}$, an FWHM of $1200 \pm 30\,\mathrm{km\,s^{-1}}$, and an average net blueshift of $165 \pm 10\,\mathrm{km\,s^{-1}}$. The red wings of lines are increasingly absorbed toward longer wavelengths by material within the remnant. We conclude that the blast wave was sculpted by an aspherical circumstellar medium in which an equatorial density enhancement plays a role, as in earlier symbiotic nova explosions. Expansion of the dominant X-ray-emitting material is aligned close to the plane of the sky and is most consistent with an orbit seen close to face-on. Comparison of an analytical blast wave model with the X-ray spectra, *Swift* observations, and near-infrared line widths indicates that the explosion energy was approximately 10^{43} erg and confirms an ejected mass of approximately $10^{-7} M_{\odot}$. The total mass lost is an order of magnitude lower than the accreted mass required to have initiated the explosion, indicating that the white dwarf is gaining mass and is a Type Ia supernova progenitor candidate.

Key words: novae, cataclysmic variables – shock waves – stars: individual (V745 Sco) – X-rays: binaries – X-rays: stars

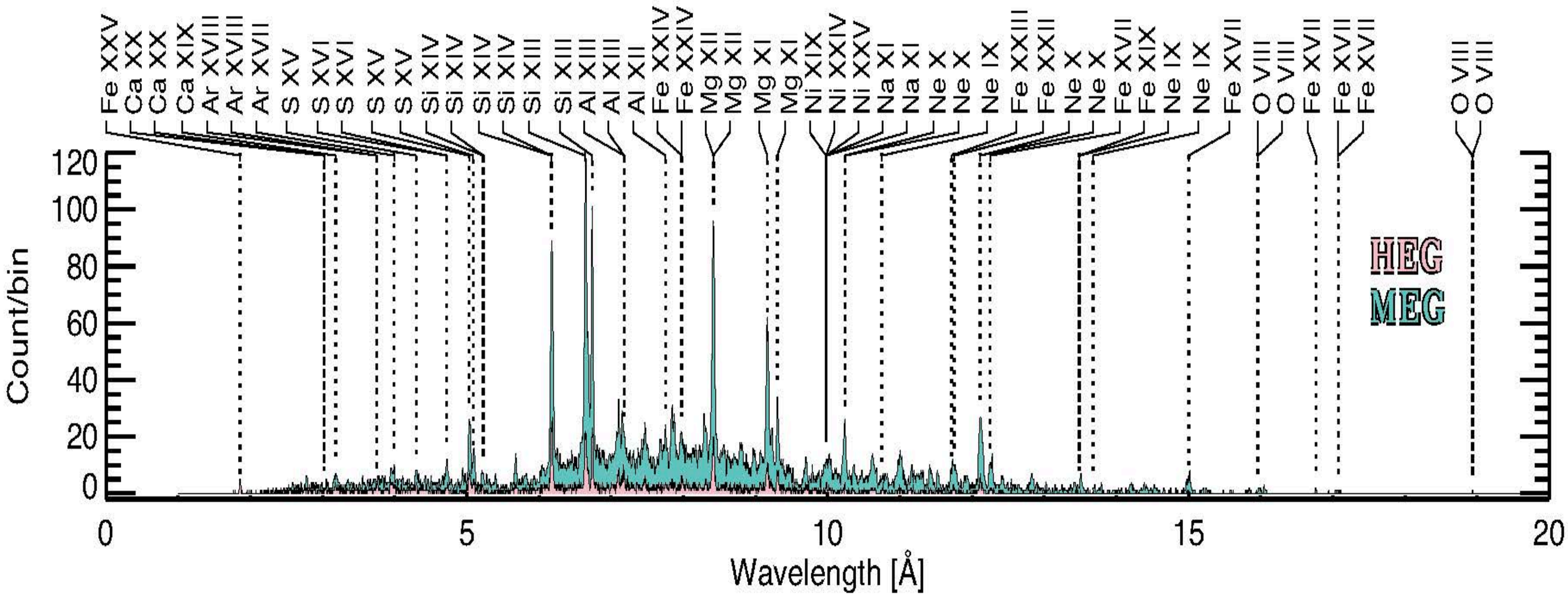
A Recurrent Symbiotic that was detected marginally by the Fermi/LAT and then observed with the Chandra grating spectrometers about 2 weeks later. Clearly, a shock spectrum. V_{ejec} about 2400 km/s. Not a spherical ejection.

V745 Sco

a Recurrent Nova with a giant Secondary

emitting VHE γ-Rays during its outburst in Feb/March 2014

Chandra HETG Spectrum 2 weeks after discovery:



Some of the elements:

O, Ne, Na, Mg, Al, Si, S, Ar, Ca, Fe

Lots of different ionization states.

Fe XXV
Ca XX
Ca XX
Ca XIX
Ar XVIII
Ar XVIII
Ar XVII
S XV
S XVI
S XVI
S XV
S XV

Si XIV
Si XIV
Si XIV
Si XIV
Si XIII
Si XIII
Al XIII
Al XIII
Al XII

Fe XXIV
Fe XXIV
Mg XII
Mg XII
Mg XI
Mg XI
Ni XIX
Ni XXIV
Ni XXV
Na XI
Na XI
Ne X
Ne X
Ne IX

Fe XXIII
Fe XXII
Ne X
Ne X
Fe XVII
Fe XIX
Ne IX
Ne IX
Fe XVII
O VIII
O VIII
Fe XVII
Fe XVII
Fe XVII

O VIII
O VIII

2017

A&A 601, A93 (2017)
DOI: 10.1051/0004-6361/201628957

Astronomy & Astrophysics

The supersoft X-ray source in V5116 Sagittarii

I. The high resolution spectra★

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ABSTRACT

Context. Classical nova explosions occur on the surface of an accreting white dwarf in a binary system. After ejection of a fraction of the envelope and when the expanding shell becomes optically thin to X-rays, a bright source of supersoft X-rays arises, powered by residual H burning on the surface of the white dwarf. While the general picture of the nova event is well established, the details and balance of accretion and ejection processes in classical novae are still full of unknowns. The long-term balance of accreted matter is of special interest for massive accreting white dwarfs, which may be promising supernova Ia progenitor candidates. Nova V5116 Sgr 2005b was observed as a bright and variable supersoft X-ray source by *XMM-Newton* in March 2007, 610 days after outburst. The light curve showed a periodicity consistent with the orbital period. During one third of the orbit the luminosity was a factor of seven brighter than during the other two thirds of the orbital period.
Aims. In the present work we aim to disentangle the X-ray spectral components of V5116 Sgr and their variability.
Methods. We present the high resolution spectra obtained with *XMM-Newton* RGS and *Chandra* LETGS/HRC-S in March and August 2007.
Results. The grating spectrum during the periods of high-flux shows a typical hot white dwarf atmosphere dominated by absorption lines of N VI and N VII. During the low-flux periods, the spectrum is dominated by an atmosphere with the same temperature as during the high-flux period, but with several emission features superimposed. Some of the emission lines are well modeled with an optically thin plasma in collisional equilibrium, rich in C and N, which also explains some excess in the spectra of the high-flux period. No velocity shifts are observed in the absorption lines, with an upper limit set by the spectral resolution of 500 km s^{-1}, consistent with the expectation of a non-expanding atmosphere so late in the evolution of the post-nova.

Key words. novae, cataclysmic variables – X-rays: binaries – X-rays: individuals: V5116 Sgr – X-rays: stars

A bright and variable SSS nearly 2 years after the outburst. Bright enough for grating spectra with XMM. Hot white dwarf atmosphere.

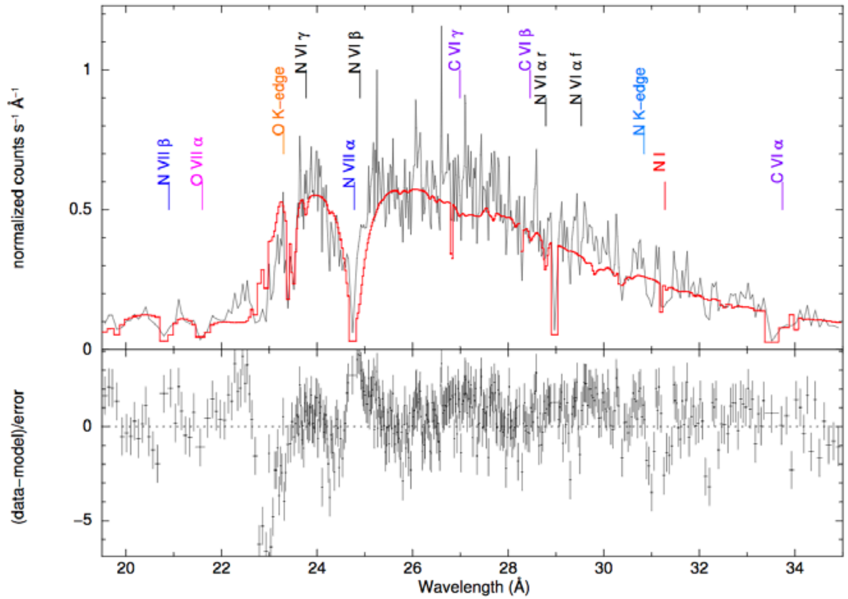

Fig. 7. RGS1 spectrum during the high-flux state (black), fit with the TBabs and TMAF atmosphere 003 models (red).

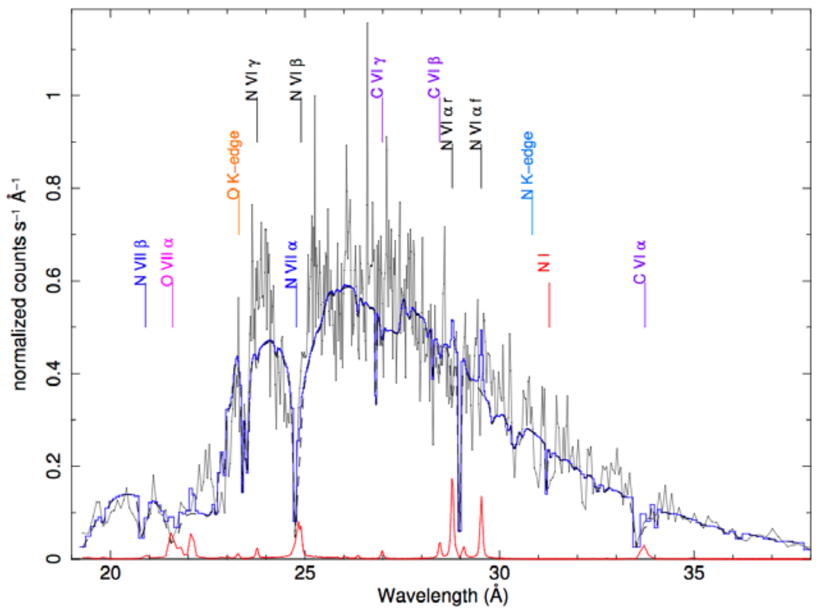

Fig. 8. RGS1 spectrum during the high-flux state (black), fit with the TBabs, TMAF atmosphere model 008 (green), and VAPEC plasma model (red). The total model is shown in blue. The VAPEC plasma model is taken with the same parameters as the best fit for the low-flux spectrum, and contributes to a better fit of the N VI β line.

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X-ray observations of classical novae: Theoretical implications

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Key words stars: novae, cataclysmic variables – stars: white dwarfs – X-rays: binaries

Detection of X-rays from classical novae, both in outburst and post-outburst, provides unique and crucial information about the explosion mechanism. Soft X-rays reveal the hot white dwarf photosphere, whenever hydrogen (H) nuclear burning is still on and expanding envelope is transparent enough, whereas harder X-rays give information about the ejecta and/or the accretion flow in the reborn cataclysmic variable. The duration of the supersoft X-ray emission phase is related to the turn-off of the classical nova, i.e., of the H-burning on top of the white dwarf core. A review of X-ray observations is presented, with a special emphasis on the implications for the duration of post-outburst steady H-burning and its theoretical explanation. The particular case of recurrent novae (both the "standard" objects and the recently discovered ones) will also be reviewed, in terms of theoretical feasibility of short recurrence periods, as well as regarding implications for scenarios of type Ia supernovae.

An excellent review of the results from X-ray studies of Classical Novae in outburst. Lots of physical insight.

The Contributions of Margarita Hernanz Conclusions:

- A Classical Nova Outburst is the result of accretion onto a white dwarf
- The properties of the outburst depend on
  - The mass of the white dwarf
  - The mass accretion rate
  - The chemical composition of both the white dwarf (if mixed) and the accreting matter
  - The luminosity of the white dwarf (its age and thermal history)
  - When mixing with the core occurs and how much mixing occurs
- Novae should be emitting Gamma-rays via 3 different mechanisms
  - Radioactive decay from ^{7}Be, ^{18}F, ^{13}N, ^{22}Na, continuum --but we need a nearby nova
  - Shock heated gas from the explosion seen in: RS Oph, V407 Cyg, V745 Sco
  - ??? VHE Gammas from "all" novae
- Novae are seen in X-rays before the outburst (V2491 Cyg and V2487 Oph)
- During the outburst they range from Hard to Soft. Studies of Soft X-ray emission allow the measurements of temperature and abundances.
- They are also quite variable during certain stages as SSS