V392 Per – A dwarf nova turned regular nova

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with: D. Chochol, S. Shugarov, A. Skopal, Š. Parimucha, P. Dubovský, and V. Šimon

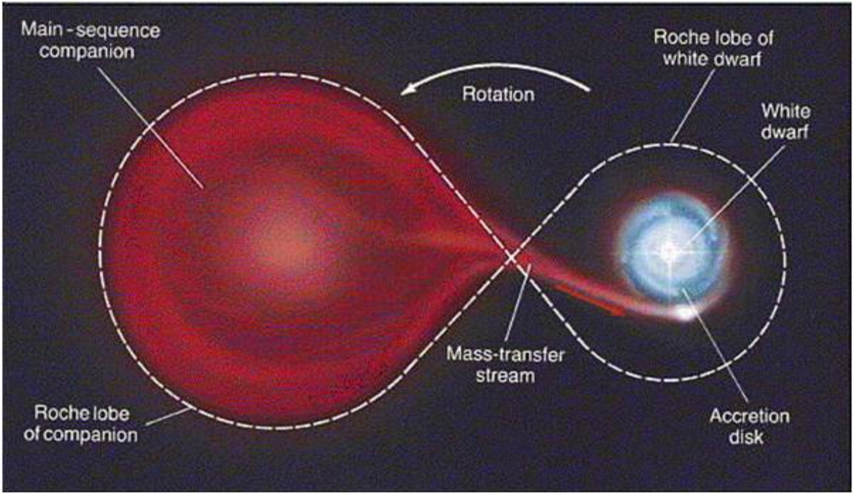
Bezovec online, Oct 2, 2020

Outline

What's the difference

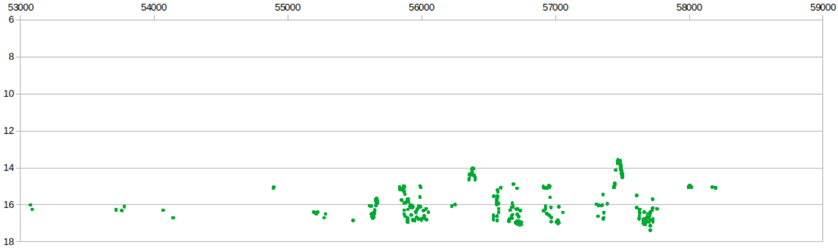
Classical Novae (CN):	Dwarf novae (DN):
White dwarf (WD) + red giant	WD + late type MS/subgiant
$P_{\rm orb} \sim 3\,$h$-2\,$d	$P_{\rm orb} \sim 1\,$h$-15\,$h
Solar luminosities	
RL overflow, TN runaway	Disk instability, sudden accretion
Brightness rises $16-19\,$mag	Brightness rises $2-8\,$mag
Energy release $\sim 10^{37}$ J	
Outburst $\sim$few $10^4\,L_\odot$	
	Outburst duration up to $\sim 14\,$d
$v_{\rm ej} \sim$few $10^2 - 10^3\,$km s^{-1}	
recurrence in $30-100\,$kyr	recurrence in months$-$years

Classical novae



Discovery

Discovered: April 29, 2018 by Nakamura



AAVSO V mag observations of dwarf nova V392 Per

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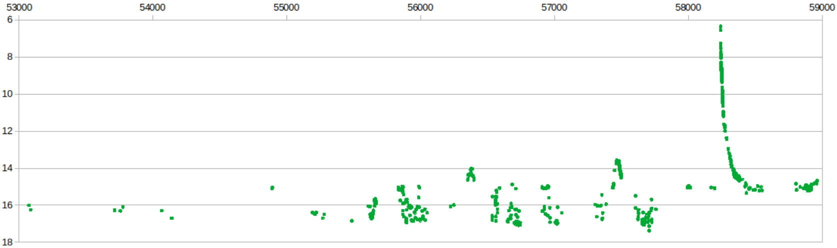


AAVSO V mag observations of dwarf nova V392 Per

Discovery

The real change

Before (map)

Discovery

The real change

Before (map)

After (May 5, 2018)

Individual data sources

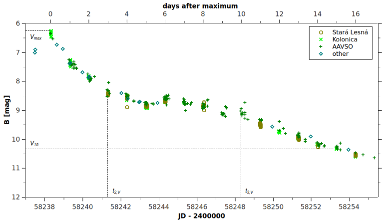
Photometry:

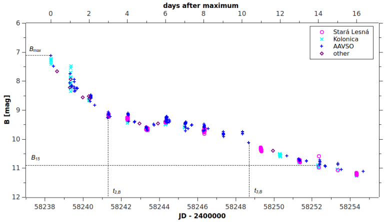
- $UBVR_CI_C$ photometry on 0.6m and 0.18m @ Stará Lesná
- BVR_CI_C on 1.0m, 0.35m, and 0.5m @ Kolonica
- BVR_CI_C on 1.25m and 0.5m @ Crimea
- added AAVSO, VSNET, ATel individual data

Spectroscopy:

- $R \sim 38000$ on 1.3m @ Skalnaté Pleso
- $R \sim 11500$ on 0.6m @ Stará Lesná
- added $R \sim 500 - 5000$ ARAS spectra

Rate of decline

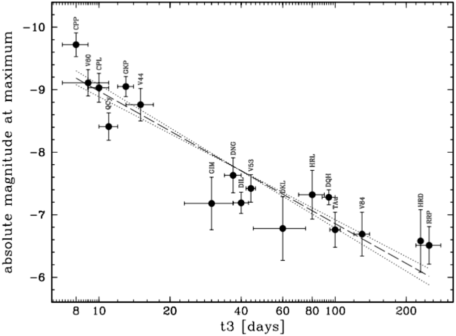




$$V_{max} = 6.24\,\text{mag} \qquad B_{max} = 7.12\,\text{mag}$$
$$V_{15} = 10.30\,\text{mag} \qquad B_{15} = 10.84\,\text{mag}$$
$$t_{2,V} = 3\,\text{d} \qquad t_{2,B} = 3\,\text{d}$$
$$t_{3,V} = 10\,\text{d} \qquad t_{3,B} = 10.5\,\text{d}$$

Absolute brightness

1. Maximum Magnitude Rate of Decline (Selvelli & Gilmozzi, 2019)
   $MV_{max} = (2.12 \pm 0.20) \log t_{3,V} - 11.08 \pm 0.33$
   $MV_{max,1} = -8.96 \pm 0.53$



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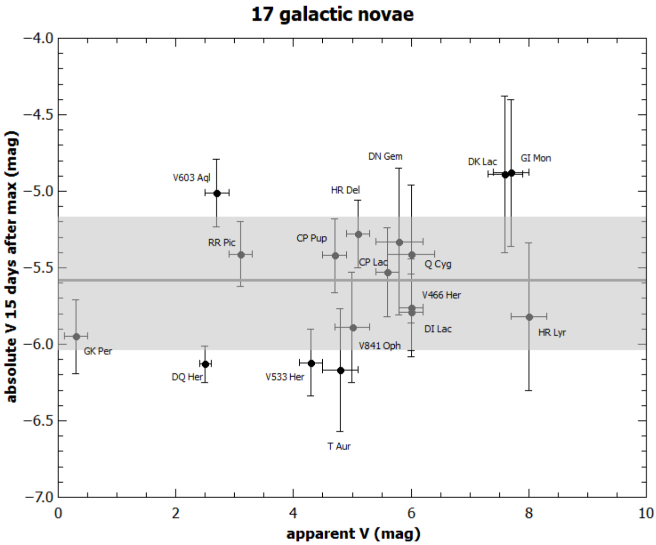

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2. all novae have the same absolute magnitude 15 days after maximum (ibidem): $MV_{15} = -5.58 \pm 0.41$
   $V_{15} = 10.30$, $\Delta V = 4.06$
   $MV_{max,2} = -9.64 \pm 0.41$

$$\rightarrow MV_{max} = -9.30 \pm 0.57$$

Color excess

1. observed $(B - V)_{max} = 0.88$ vs. intrinsic $(B - V)_0 = 0.23 \pm 0.06$ (van den Bergh & Younger, 1987)

$$\mathbf{E(B - V) = 0.65 \pm 0.06}$$

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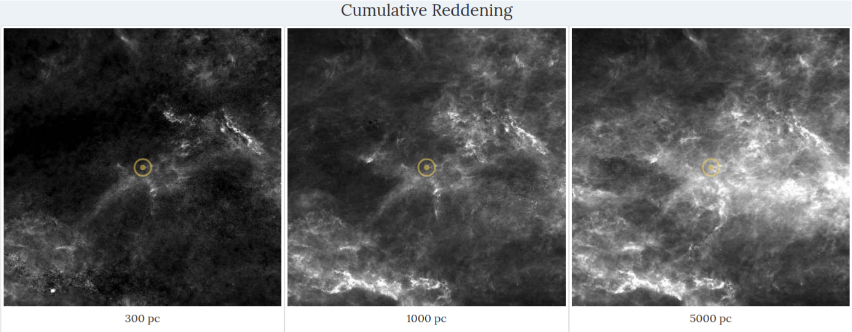
3. from 3D dustmap (Green et al., 2019)

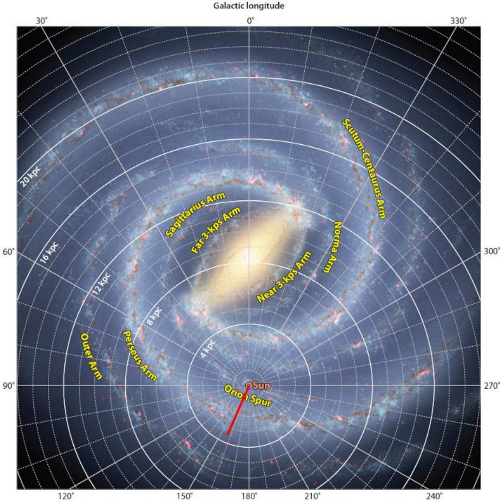
Color excess

Thick interstellar clouds (http://argonaut.skymaps.info/)



Color excess

Galactic coordinates of V392 Per: $l = 157.99184^\circ$, $b = 0.90224^\circ$



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4. EW of DIBs 5780Å, 5797Å, 6614Å and KI line (Tomov et al., 2018)

$$\mathbf{E(B-V) = 1.18 \pm 0.10}$$

Distance

Adopted mean value:	$E(B-V) = 0.90 \pm 0.13$
Corresponding absorption:	$A_V = 2.79 \pm 0.28$
Distance modulus:	$V_{max} - MV_{max} = 15.54 \pm 0.20$

Distance to the nova: $d = 3.55 \pm 0.60\,\mathrm{kpc}$

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Note:
Direct distance from Gaia DR2 parallax: $3.886^{+0.975}_{-0.649}$ kpc
Schaefer (2018): $4.161^{+2.345}_{-0.440}$ kpc
Bailer-Jones et al. (2018): $3.416^{+0.750}_{-0.533}$ kpc

Distance

Schaefer (2018):

> *The many variations on the 'maximum-magnitude-rate-of-decline' (MMRD) relation are all found to be poor, too poor to be usable, and even to be non-applicable for 5-out-of-7 samples of nova, so the MMRD should no longer be used.*

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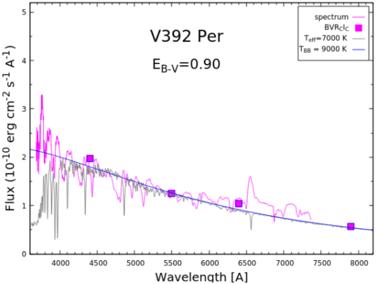
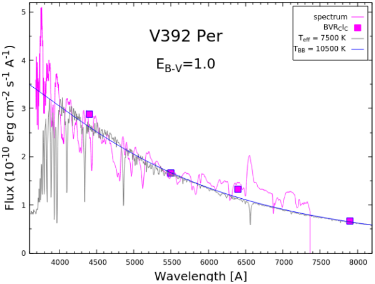
Schaefer (2018):	This work:
$V_{\mathrm{max}} = 5.6,\ t_2 = 2\,\mathrm{d},\ t_3 = 4\,\mathrm{d}$	$V_{max} = 6.24,\ t_2 = 3\,\mathrm{d},\ t_3 = 10\,\mathrm{d}$
$A_V = 1.6,\ E(B-V) = 0.52$	$A_V = 2.79,\ E(B-V) = 0.90$
$d = 3.981\,\mathrm{kpc}$	$d = 3.548 \pm 600\,\mathrm{kpc}$
$d_{GAIA} = 4.161^{+2.345}_{-0.440}\,\mathrm{kpc}$	$d_{GAIA} = 3.416^{+0.750}_{-0.533}\,\mathrm{kpc}$

Atmospheric model

SED similar to recurrent nova U Sco & classical nova GK Per





$R_{atm} = 356\,\mathrm{R}_\odot$	$R_{atm} = 354\,\mathrm{R}_\odot$
$M_{V,atm} = -8.70\,\mathrm{mag}$	$M_{V,atm} = -8.99\,\mathrm{mag}$
$R_{bb} = 258\,\mathrm{R}_\odot$	$R_{bb} = 234\,\mathrm{R}_\odot$
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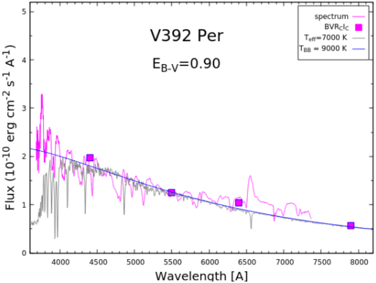

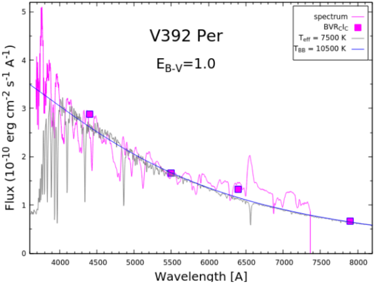

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Best fit consistent with E_{B-V}, SED & derived M_V:

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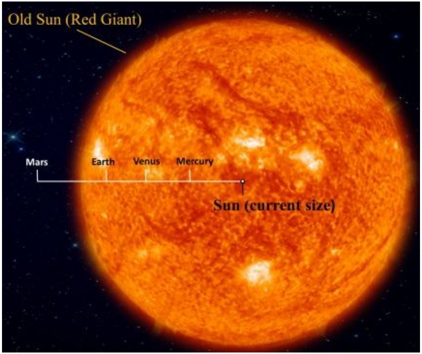
For comparison Sun as red giant:

$R \sim 256\,\mathrm{R}_\odot$
$L \sim 4\,800\,\mathrm{L}_\odot$



Mass of the white dwarf

1. from t_3 (Selvelli & Gilmozzi, 2019) $M_{WD} = 1.488 - 0.388 \log t_3$

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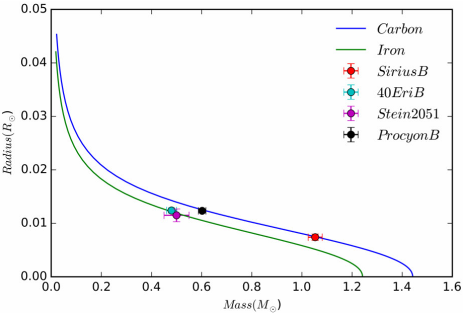

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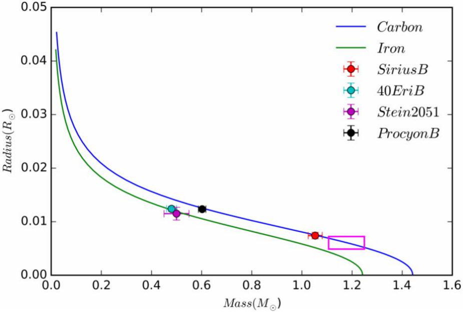

Line identification

First spectra: April, 29.894 (R. Leadbeater) $\rightarrow$ CN with iron curtain

Line identification

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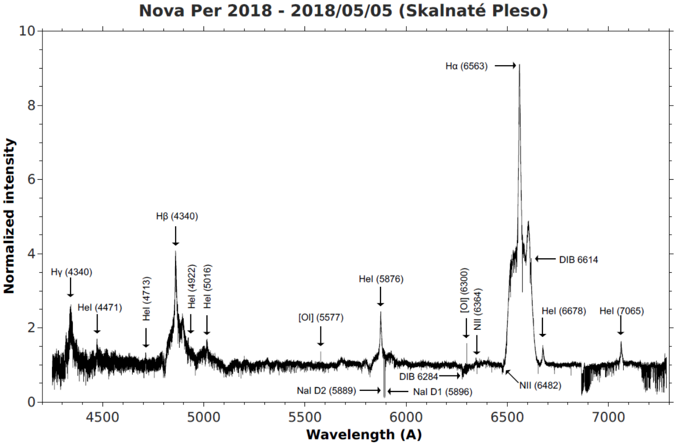
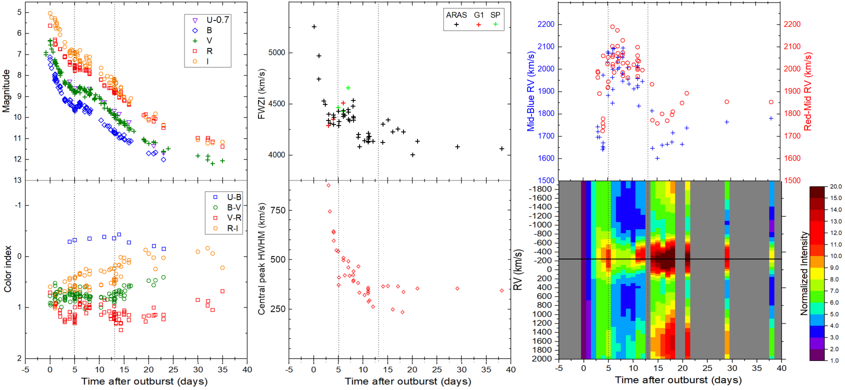
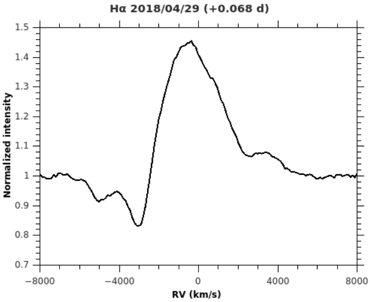


Nova evolution



Disentangling of Hα profile



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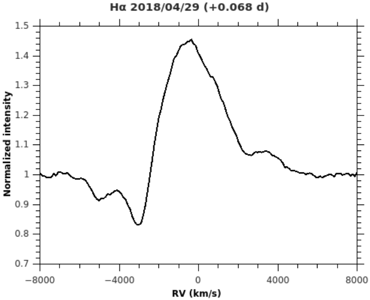

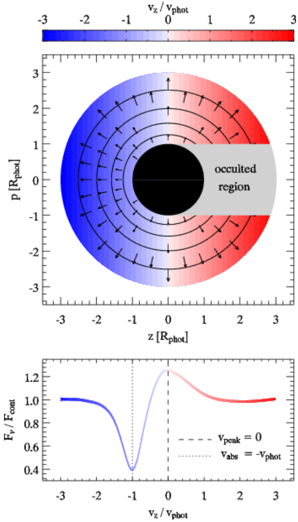

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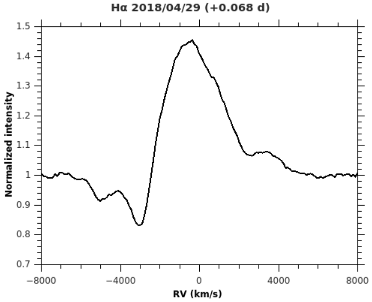

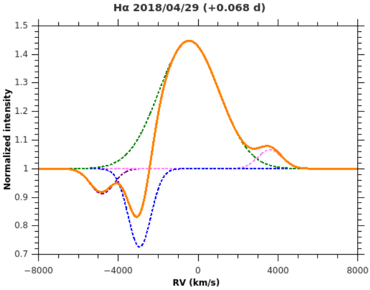

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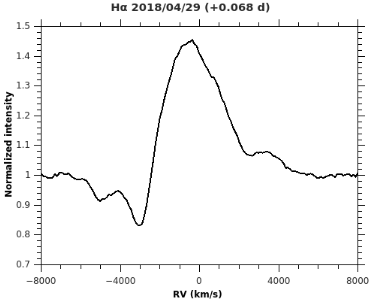
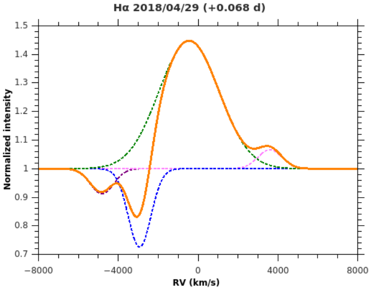
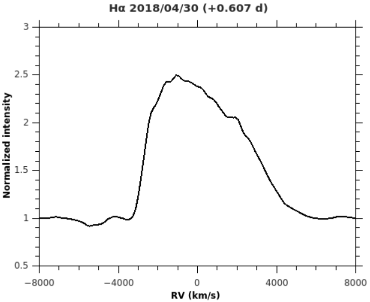
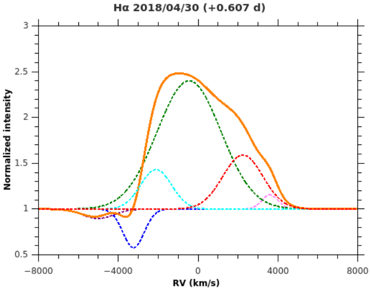




approaching outer polar outflow receding outer polar outflow
approaching spherical outer envelope ellipsoidal outer nebula
total profile

Disentangling of Hα profile

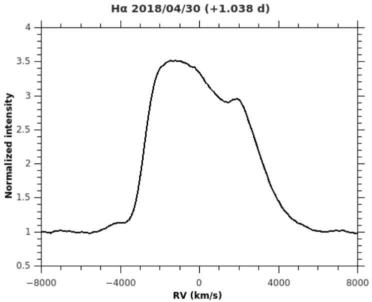


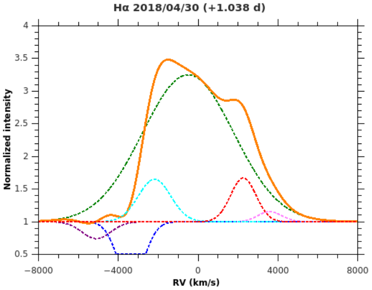


New:

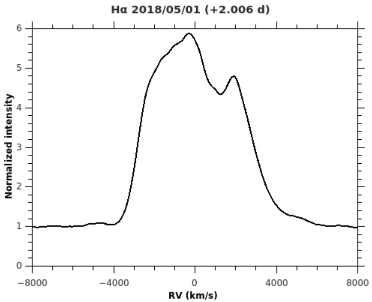
approaching inner polar outflow   receding inner polar outflow

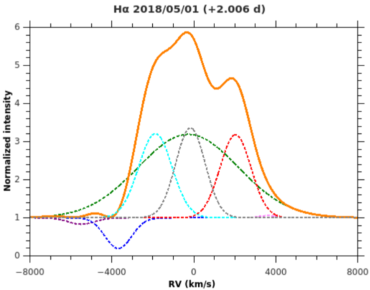
Disentangling of Hα profile





Disentangling of Hα profile

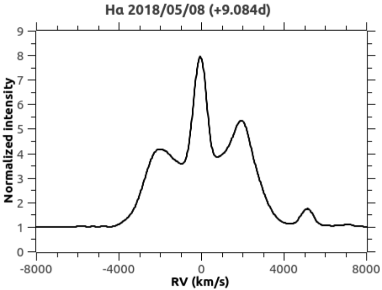


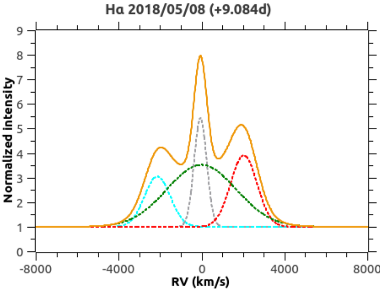


New:

equatorial inner ring

Late Hα profile

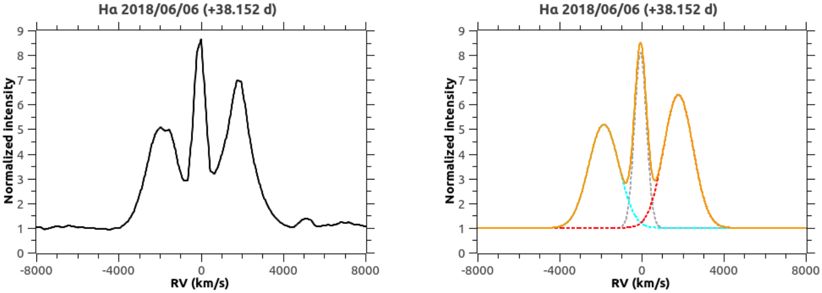




New:

~~approaching outer polar wind~~ ~~receding outer polar wind~~

Late Hα profile



New:

ellipsoidal ~~outer~~ nebula

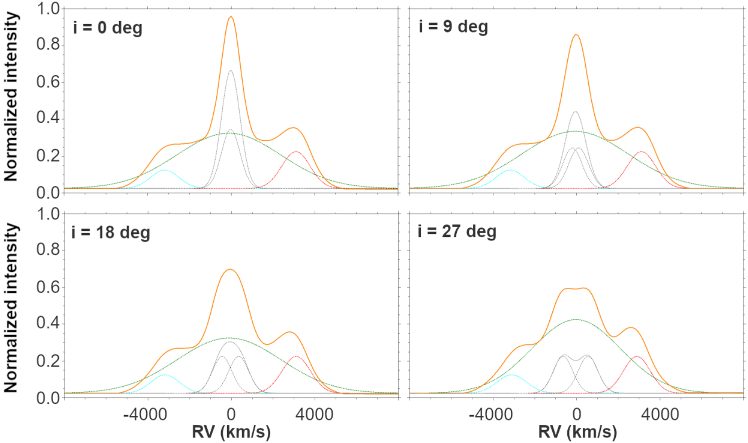
Late Hα profile

Why is the central peak important?

Late Hα profile

Why is the central peak important?

Actually made of two components:



3D model

Shape - morpho-kinematic 3D modeling of spatially resolved astrophysical nebulae (Steffen et al., 2011)

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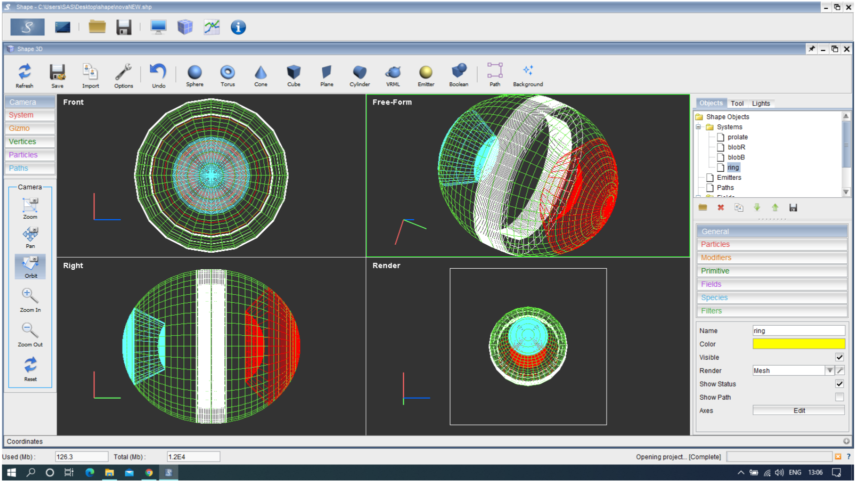
- geometrical 3D structures
- physical parameters of structures (density, velocity...)
- Doppler projection to the observation plane
- spectral profile synthesis
- object 3D rendering

3D model


Shape - C:\Users\SAS\Desktop\shape\novaNEW.shp
Shape 3D
Refresh
Save
Import
Options
Undo
Sphere
Torus
Cone
Cube
Plane
Cylinder
VRML
Emitter
Boolean
Path
Background
Camera
System
Gizmo
Vertices
Particles
Paths
Camera
Zoom
Pan
Orbit
Zoom In
Zoom Out
Reset
Front
Free-Form
Right
Render
Objects
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Shape Objects
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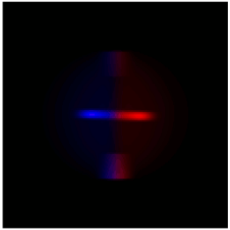
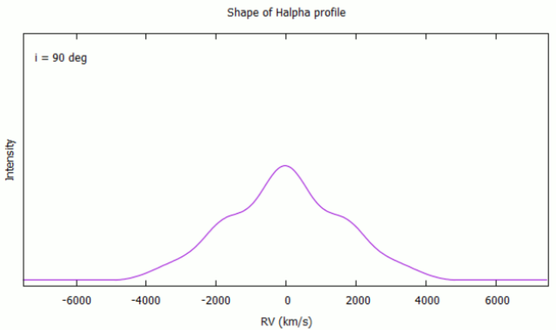
prolate
blobR
blobB
ring
Emitters
Paths
General
Particles
Modifiers
Primitive
Fields
Species
Filters
Name
ring
Color
Visible
Render
Mesh
Show Status
Show Path
Axes
Edit
Coordinates
Used (Mb) :
126.3
Total (Mb) :
1.2E4
Opening project... [Complete]
ENG
13:06

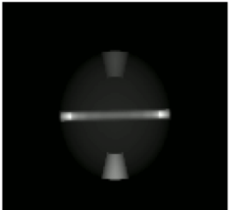
Inclination and the spectral profile

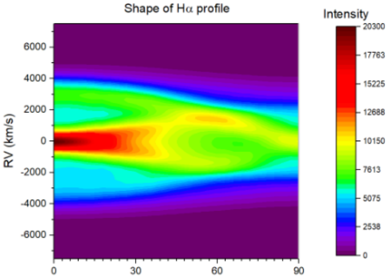
Doppler strength
(side view)





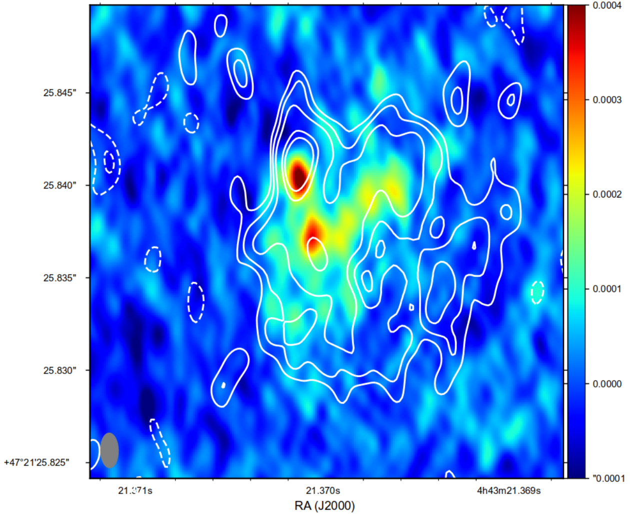
Intensity
(front view)





Radio observation

Linford et al., 2019:



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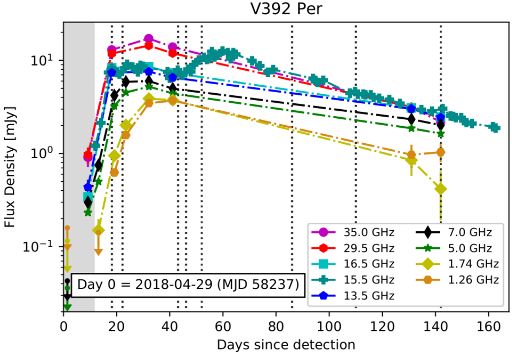
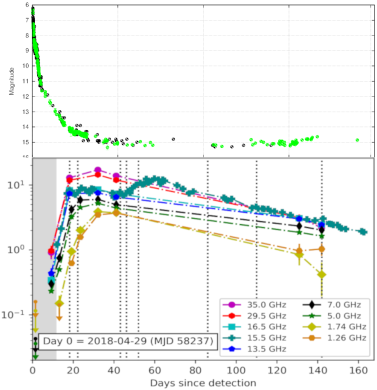


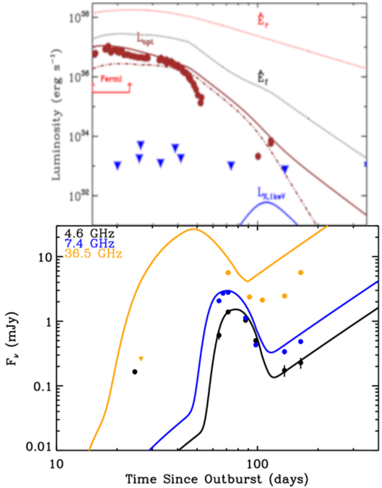
Figure 4: *Preliminary VLA and AMI-LA light curve of V392 Per. The green crosses (15.5 GHz) are from AMI-LA. All other data were obtained with the VLA. The gray region indicates the time when the nova was detected by the Fermi Gamma-ray Space Telescope. The vertical dashed lines indicate observations with the VLBA or EVN.*

Re-brightening (@15.5 GHz) - shock $\sim$ 46 d after maximum

Visual vs. radio

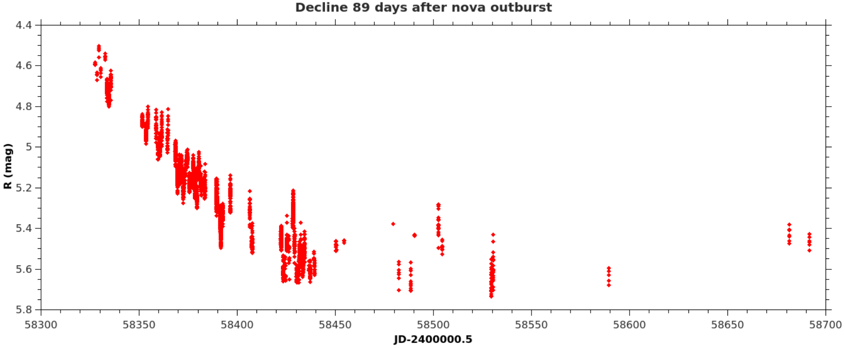


V392 Per

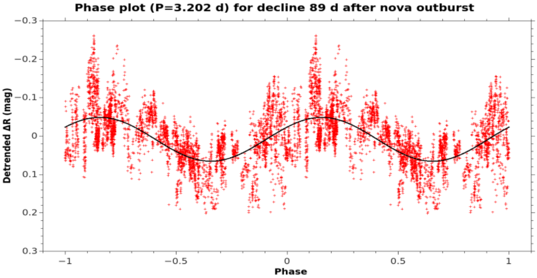


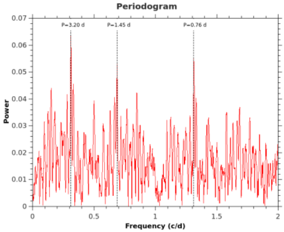
V1324 Sco

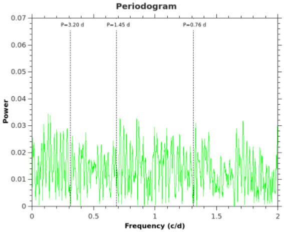
Decline variability



Periodogram

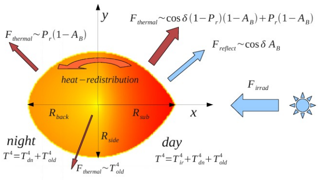


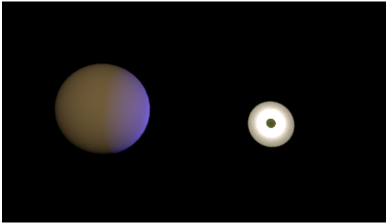




Phase and color

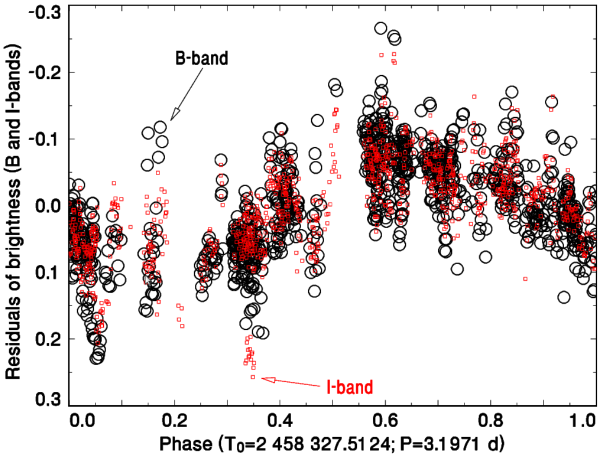
Discrete temperature spots?



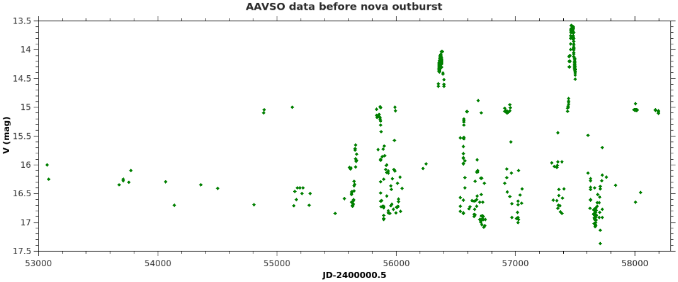


Phase and color

Discrete temperature spots? **NO**.



Historical (super)outbursts



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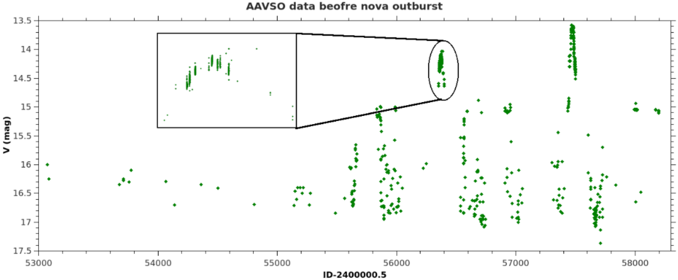

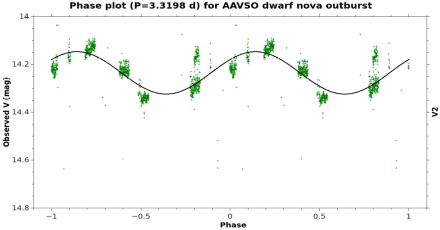

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- Periodic brightness variation in dwarf novae (SU UMa) after superoutburst event
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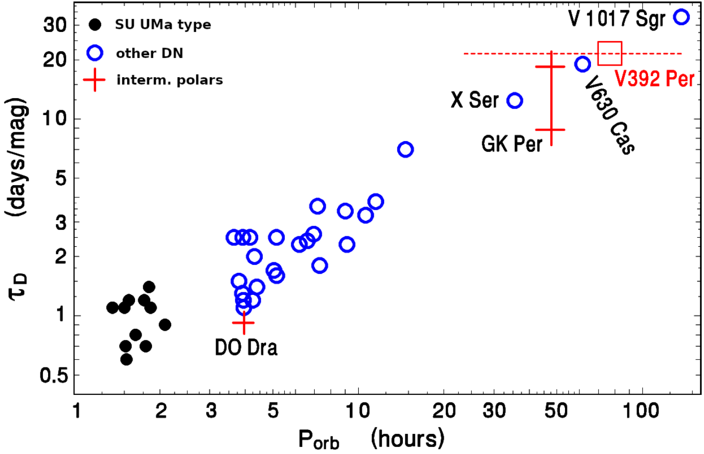
- Other issue: nearly pole-on system

Decline vs. orbital period

Decline rate in day for 1 magnitude (see Bailey, 1975): $\tau_{\rm D} = 9.2 P_{\rm orb}$



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Thank you for listening!