Observations of Recent Novae Visible on the Northern Hemisphere

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Contents

Current knowledge

The basics of the thermonuclear runaway theory of novae are confirmed by observations.

The processes by which novae eject material from the binary system remain poorly understood.

The complexity of the mass ejection leads to gamma-ray producing shocks internal to the nova ejecta.

The shocks are radiative and contribute significantly to the bolometric luminosity of novae.

Modern model of nova event

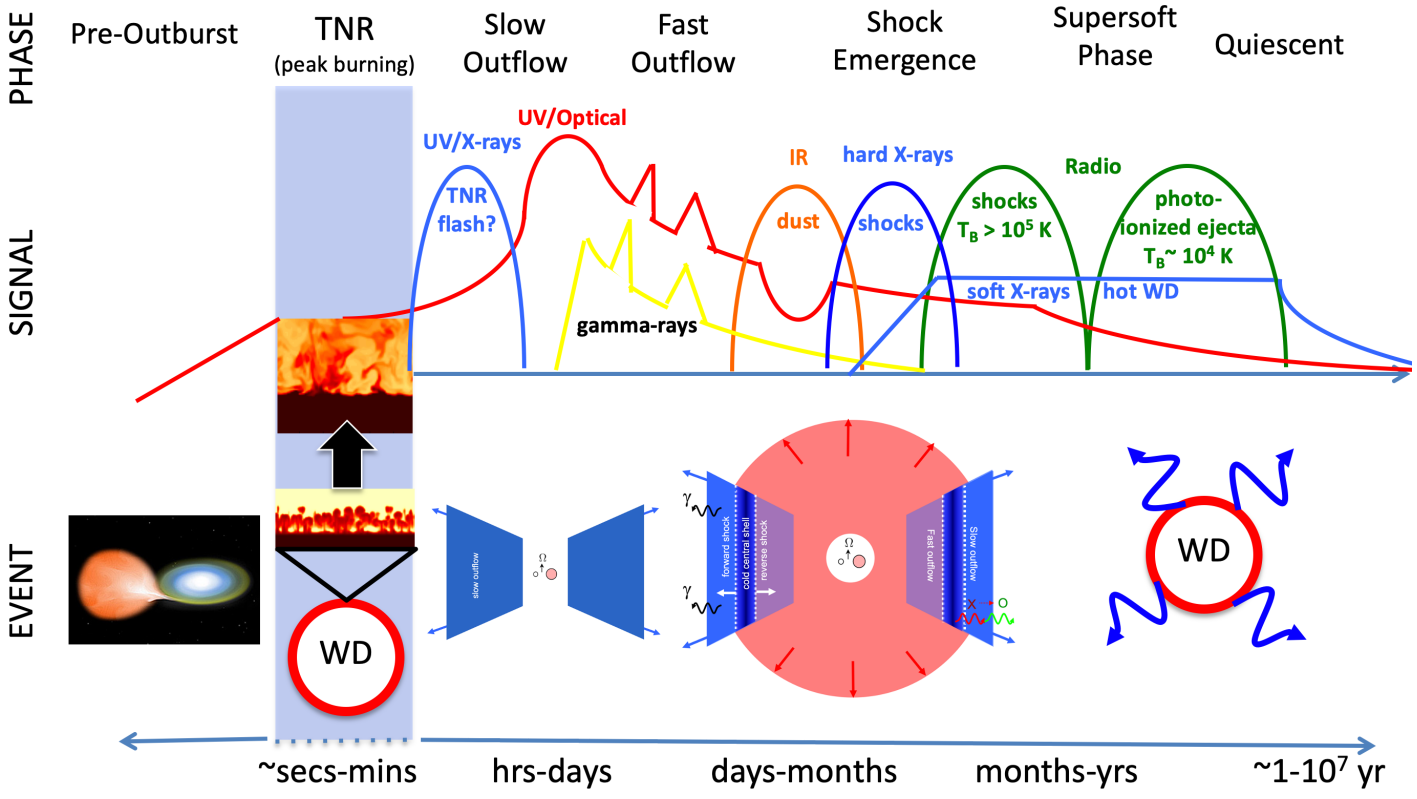


Figure: Schematic timeline of the physical processes and electromagnetic signals from novae. Figure from Chomiuk et al. 2020.

Simple model of nova ejection

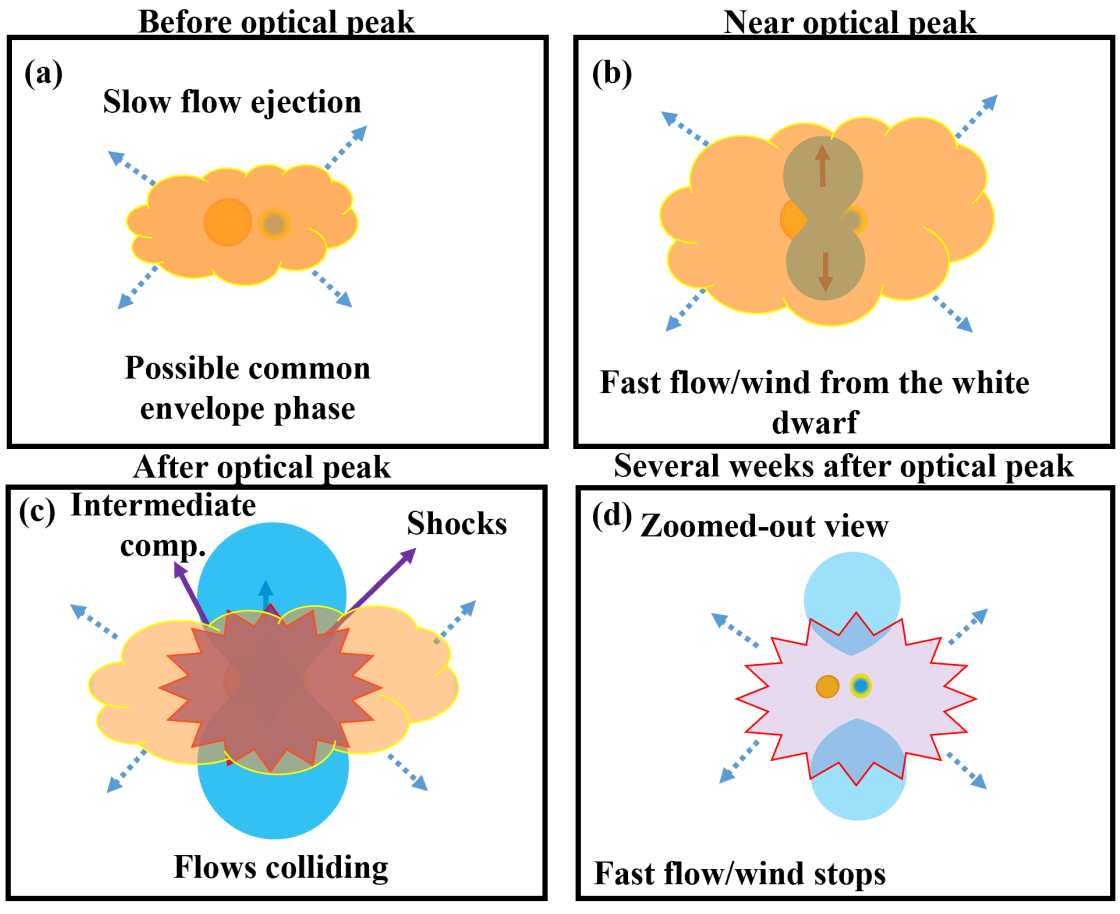


Figure: Figure from Aydi et al. 2020.

Variety of novae lightcurves

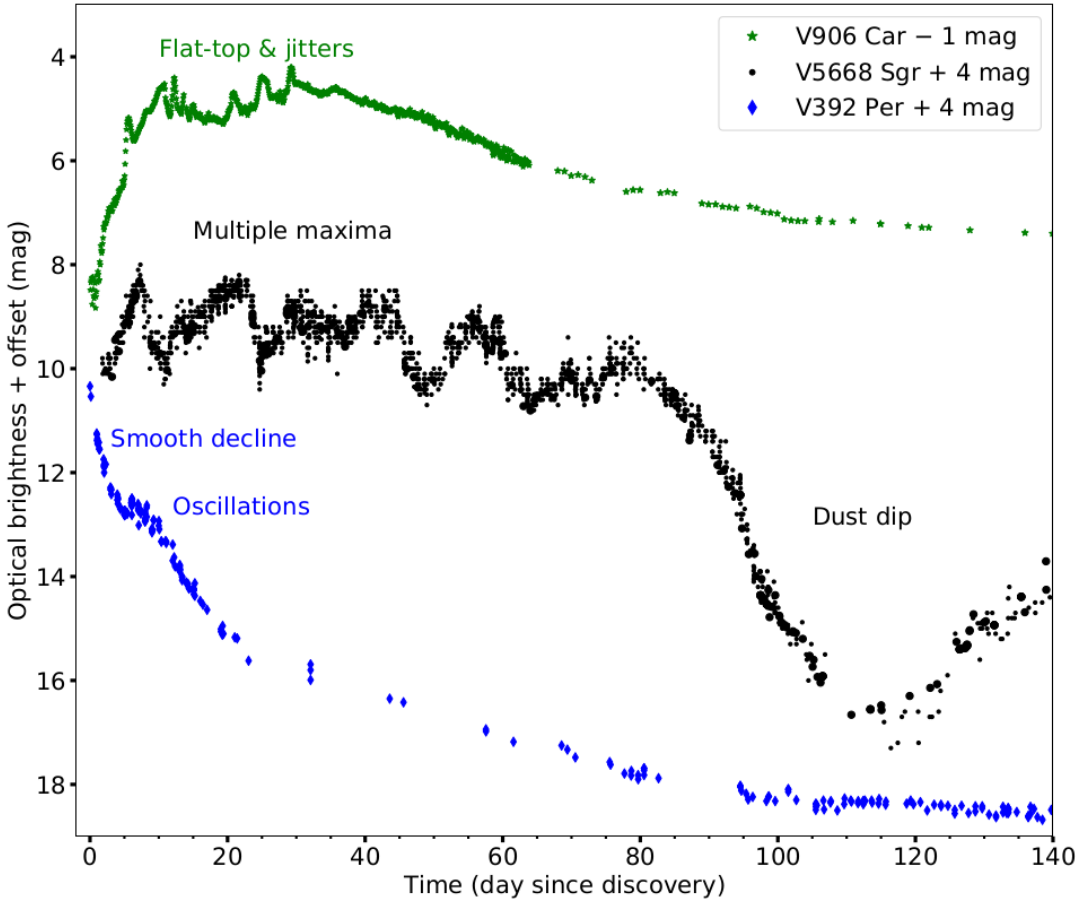


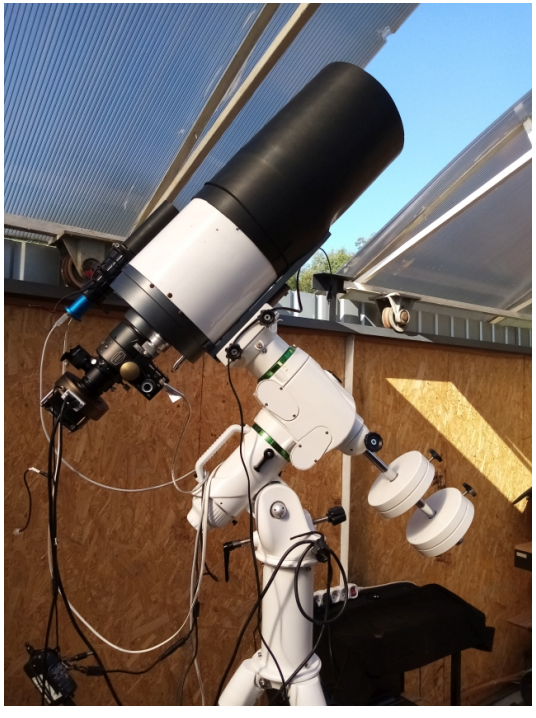
Figure: Figure from Chomiuk et al. 2020.

Instruments for photometry

C14

- Telescope Celestron Edge HD, focal reducer 0.7x, 356/3000 mm
- CCD camera MII G2-1600 + B V Rc Ic Clear filters, binning 2x2
- Scale 1.24 arcsec/px
- FOV = 13.4 x 8.9 arcmin
- Autoguiding on separate telescope
- Recording software - MaXimDL
- Data reduction - CoLiTecVS and MCV
- Observer - P. A. Dubovský at AO Kolonica Saddle

Instruments for photometry



M20

- Cassegrain-Maksutov on EQ6 mount, 200/2000 mm
- CCD camera MII G2-1600 + B V Rc Ic Clear filters, binning 2x2
- Scale 1.01 arcsec/px
- FOV = 22.50 x 15.00 arcmin
- Autoguiding on separate telescope using PHD2
- Recording software - Sequence Generator Pro v3.2.0.66
- Data reduction - CoLiTecVS and MCV
- Observer - T. Medulka at AO Kolonica Saddle

Instruments for photometry

Photolense 6cm

- Photolense 6 cm, 60/180 mm
- SBIG ST-10 Dual CCD Camera + B V Rc Ic Clear filters, binning 1x1
- Scale 7.53 arcsec/px
- FOV = 283 x 191 arcmin
- No autoguiding
- Recording software - MaXimDL
- Data reduction - CoLiTecVS and MCV
- Observer - S. Shugarov in Stará Lesná

Instruments for photometry

ZC600

- Zeiss Cassegrain in primary focus 600/2400 mm
- CCD camera Atik 383L + U B V Rc Ic filters, binning 2x2
- Scale 1.24 arcsec/px
- FOV = 25.9 x 19.5 arcmin
- No autoguiding
- Recording software - MaXimDL
- Data reduction - CoLiTecVS and MCV
- Observer - P. A. Dubovský remotely at M. R. Štefánik Observatory and Planetarium Hlohovec

Instrument for fast photometry

VNT

- Vihorlat National Telescope, modified Cassegrain 1000/9000 mm
- FLI PL1001E + B,V,Rc,Ic, Clear filters, binning 2x2
- Scale 1.10 arcsec/px
- FOV = 9.44 x 9.44 arcmin
- Autoguiding on separate telescope
- Recording software - MaXimDL
- Data reduction - CoLiTecVS and MCV
- Observer - P. A. Dubovský at AO Kolonica Saddle

Instrument for spectroscopy

C11

- Telescope Celestron CGEM 1100, focal reducer 0.66x, 280/1750 mm
- Spectrograph LISA (Shelyak Instruments)
- CCD camera ATIK-460ex, binning 1x1
- Resolution power 1000
- Autoguiding - off axis ATIK-317
- Recording software - MaXimDL
- Data reduction - ISIS, VisualSpec. PlotSpectra
- Wavelength calibration - standard A or B type star
- Instrumental response calibration - neon lamp + standard A or B type star

Nova Cas 2020 (V1391 Cas; TCP J00114297+6611190)

Main characteristics

- Was discovered on 2020-07-27.9302 UT by S. Korotkiy on images of NMW survey and classified as a Fe II type classical nova (ATel 13903, 13919, 13939, 13941, 13967, 13998).
- Interstellar reddening is strong E(B-V)=1.39 mag (ATel 13905)
- In the following months the nova showed a series of flares (each lasting days to a week) with the brightest flare peaking at V=10.8 on 2020-08-10.08.
- Simultaneous photometry and spectroscopy allowed us to express the spectra in absolute units and calculate the absolute flux in emission lines. No significant changes during the oscillation phase were observed. This is consistent with the shock powered scenario were important part of the nova luminosity is thermal radiation of the shocks formed in the envelope reprocessed in optical light. Several outflows of ejecta can produce multiple brightennings.

Photometry

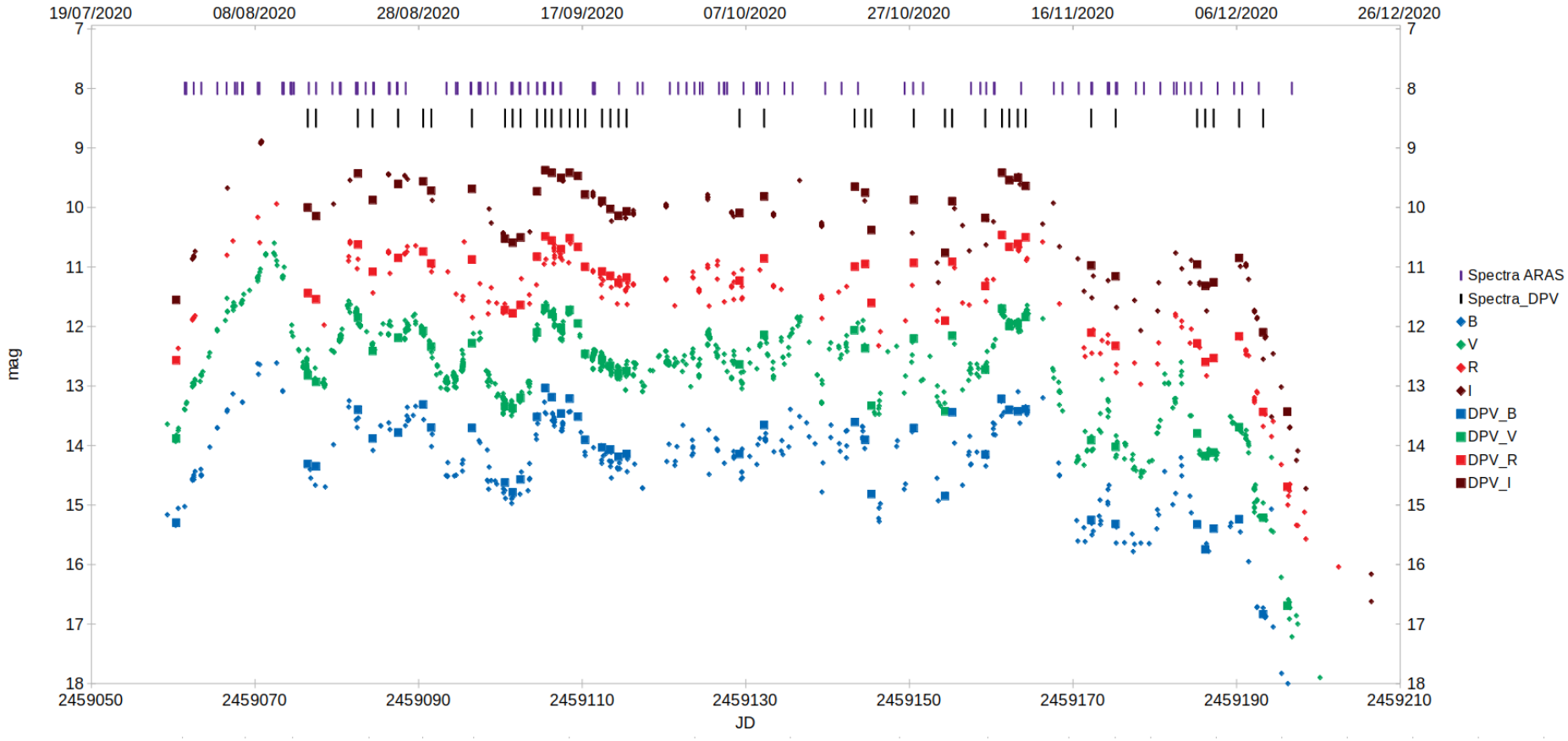


Figure: Available photometry from AAVSO database in B V Rc Ic bands. Our measurements are marked as DPV. Times of spectra acquisition are on the top.

Spectroscopy - Evolution of spectral lines (without Halpha)

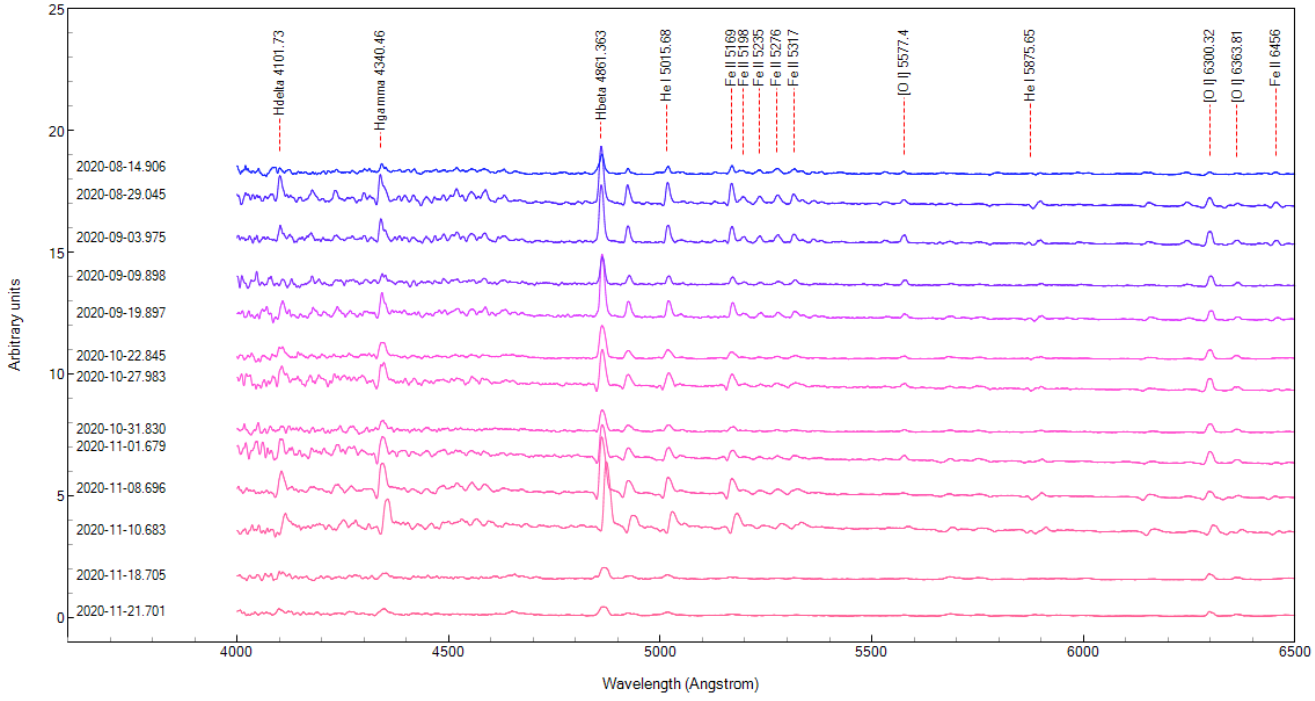


Figure: Selected low resolution spectra without the Halpha region. The spectra are dereddened using the value E(B-V)=1.39 for interstellar reddening. Arbitrary shift between all individual spectra is the same. So the changes in continuum are visible as different gaps between plotted curves.

Nova Per 2020 = V1112 Per

Main characteristics

- Nova Per 2020 has been discovered on Nov 25.807 UT as TCP J04291884+4354232 by Seiji Ueda and classified as a nova in ATel 14224 based on the presence of broad Balmer lines with P-Cyg absorptions on spectra recorded on Nov 26.05 UT.
- First spectra showed P-Cyg profiles in HeI and NII emissions. But already on the following night all HeI and NI lines have disappeared, replaced by FeII lines indicating that mass from the secondary component is now present in the ejecta. We missed this transition from He-N to FeII nova due to bad weather.
- But the dust formation event was well observed in January 2021.
- Interstellar reddening was determined measuring interstellar lines to be E(B-V)=0.77 mag.

Photometry

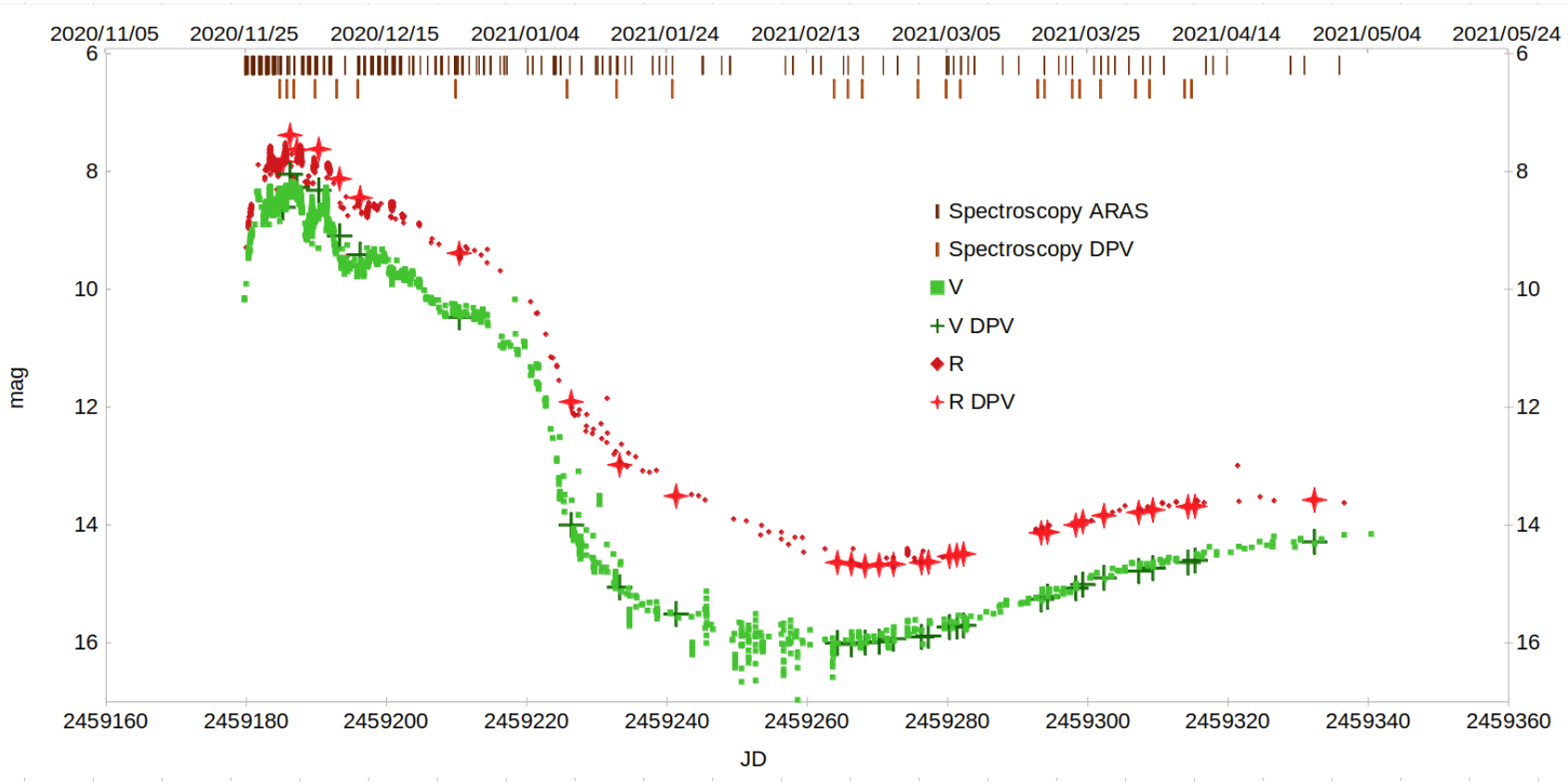


Figure: V and Rc band observations from AAVSO database + observations at Kolonica observatory marked as DPV. Times of spectra acquisition are identified on the top.

Spectroscopy - dust to nebular phase transition

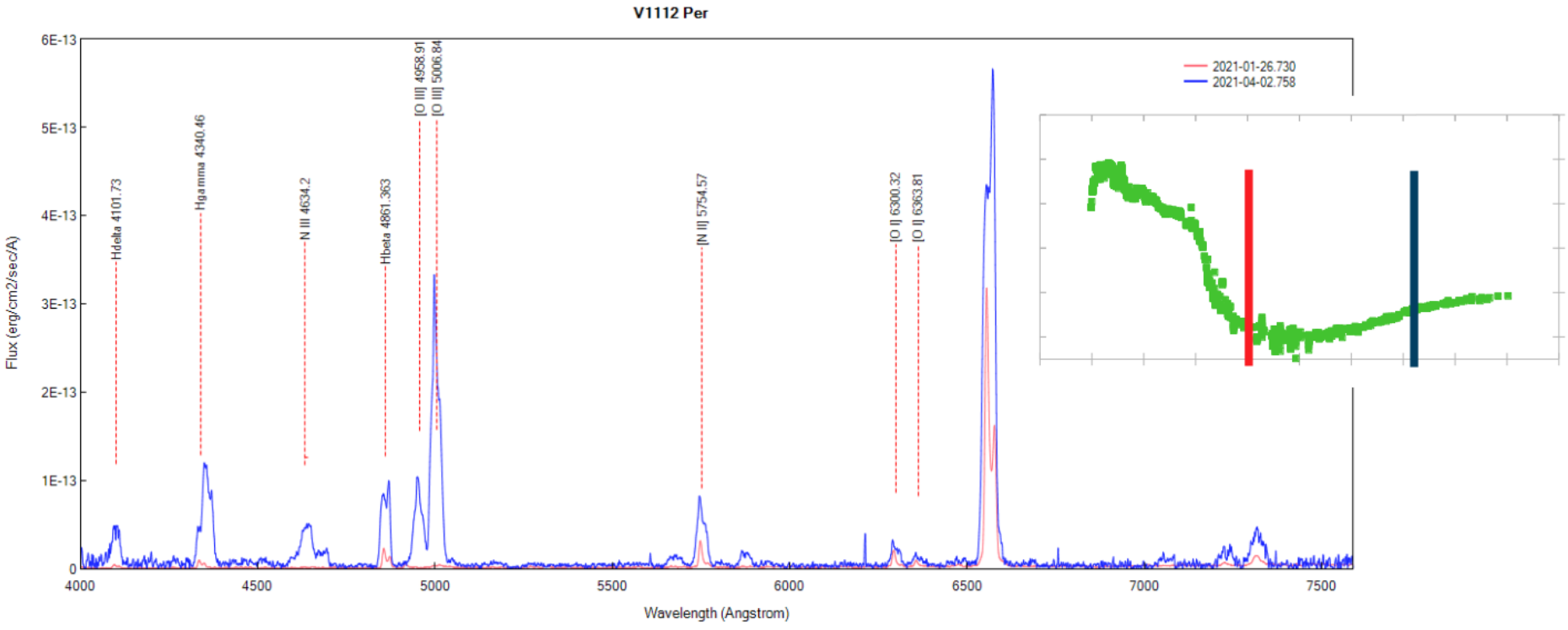


Figure: Note these spectra were taken around 15 mag in V band.

Nova Cas 2021 = V1405 Cas

Main characteristics

- Nova Cas 2021 has been discovered by Y. Nakamura on 2021-03-18.42 UT.
- The precursor was identified with known eclipsing variable CzeV3217. However the cataclysmic nature of the object is visible in TESS data showing sinewave with flickering.
- Also this nova evolved from higher excitation spectral lines to lower ones. HeII in 1 day HI, then typical FeII after the main optical peak.
- After the main peak of brightness several more were observed.
- Interstellar reddening is E(B-V)=0.55 mag.
- The distance of the precursor is known from GaiaDR3: 1.69 $\pm$ 0.07 kpc (i.e. m - M = 11.13 mag).
- The orbital period 0.1883907 d was known from the pre-outburst observations. Not measured after the outburst yet.

Photometry

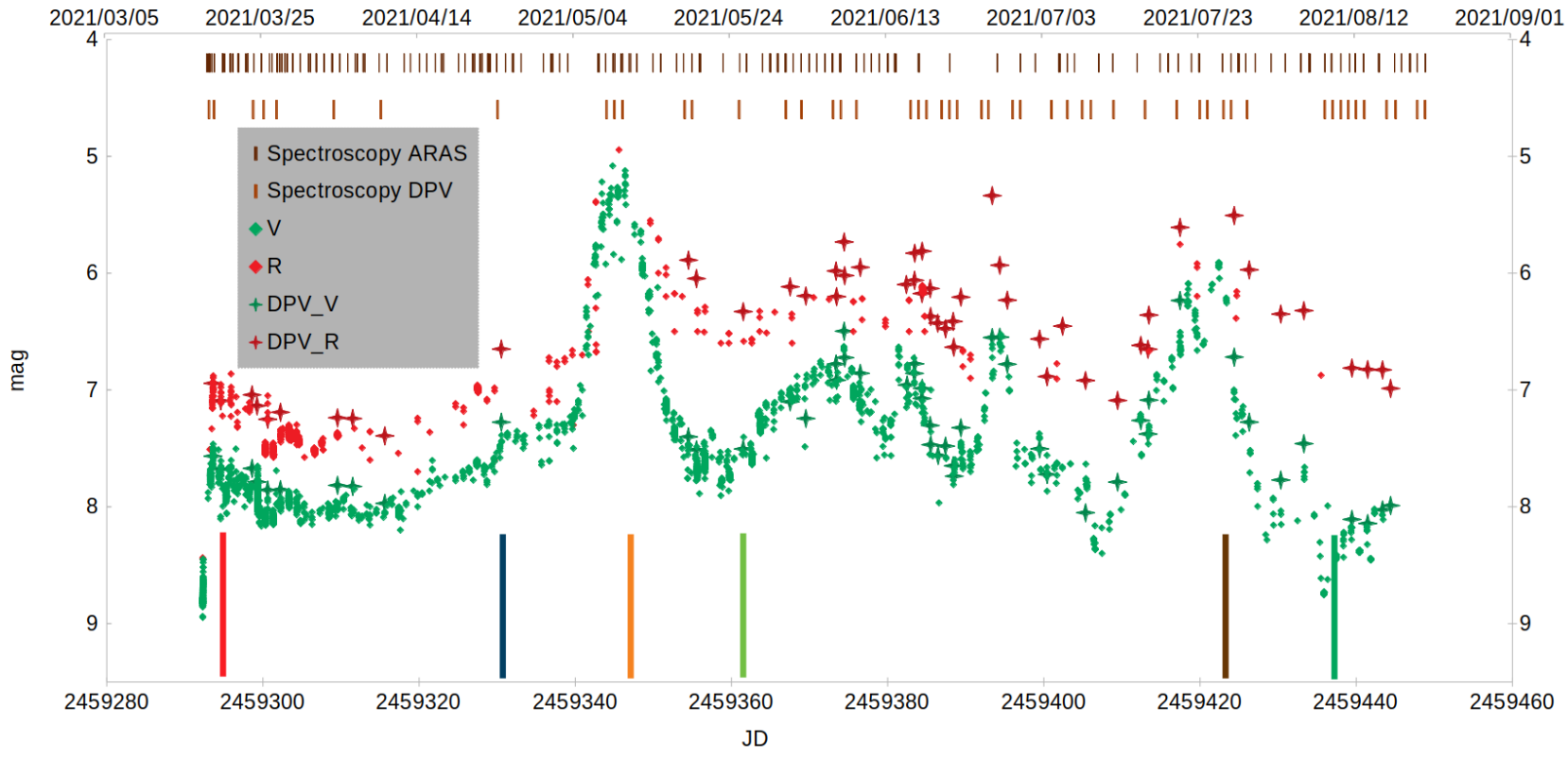


Figure: Available photometry and spectroscopy of V1405 Cas. Note the brightenning to naked eye visibility around April 09, 2021

Spectroscopy before the maximum brightness

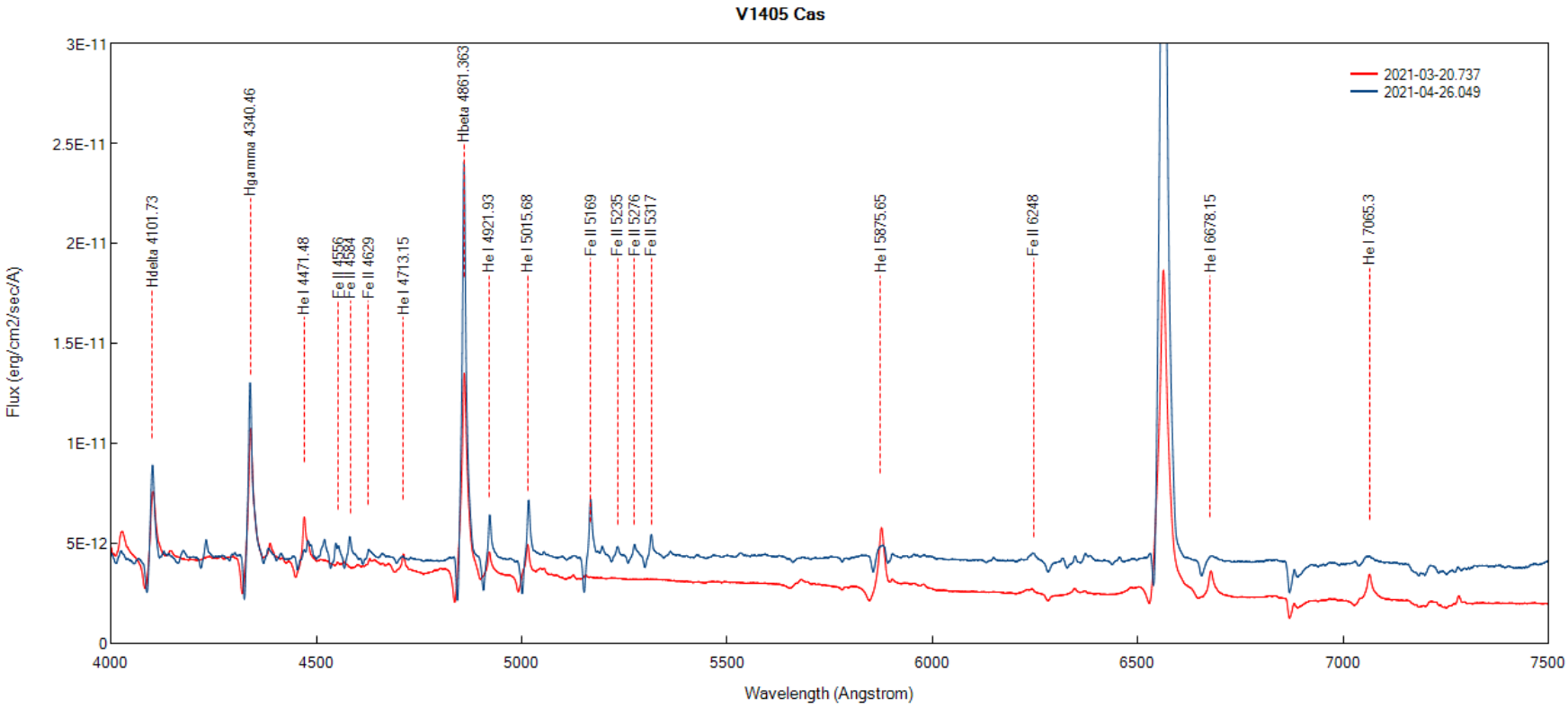


Figure: The appearance of FeII lines.

Spectroscopy - P Cygni profile at maximum brightness

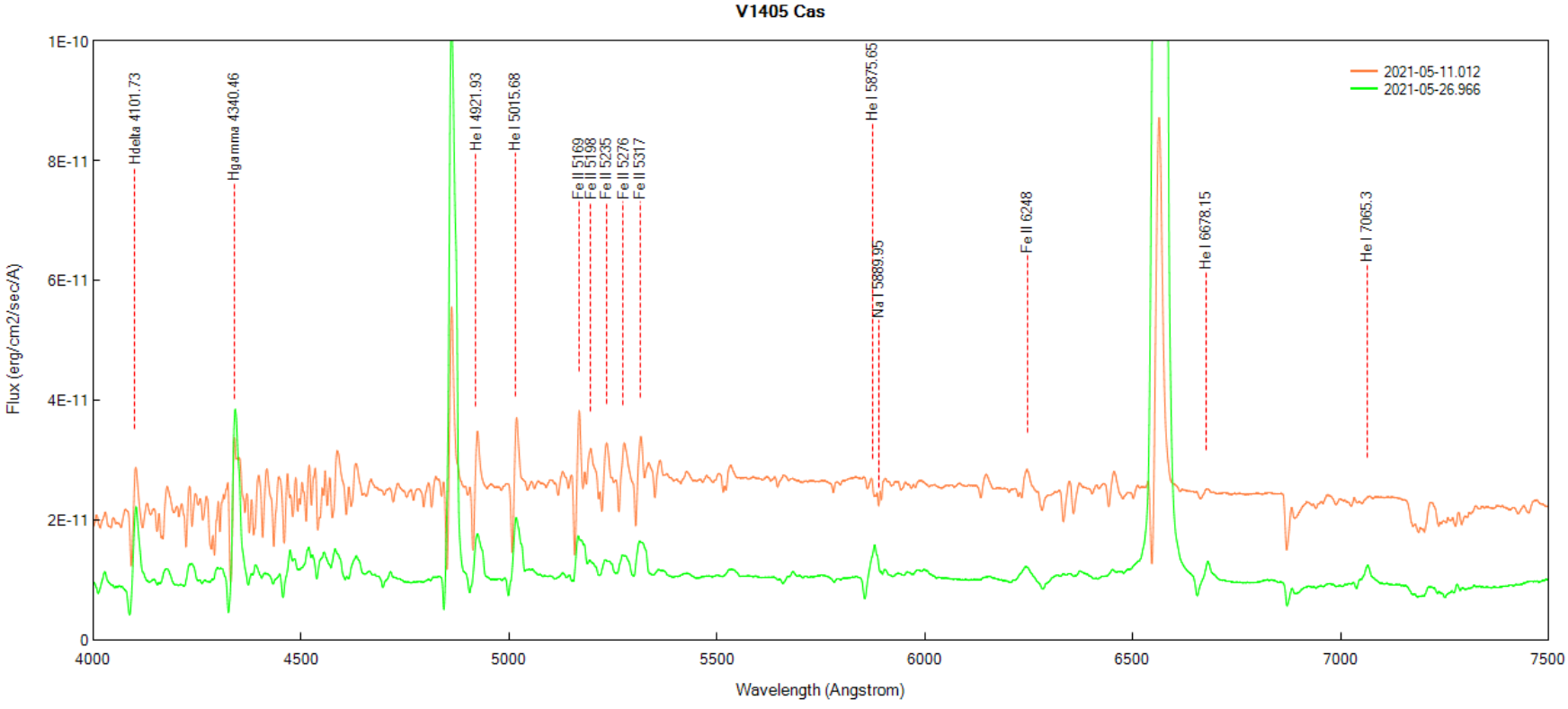


Figure: First Gamma-ray detection by Fermi Gamma-ray Space Telescope in data from 2021-05-20 15:01:17 to 2021-05-24 = The shocks are present

Spectroscopy - Oscillations phase

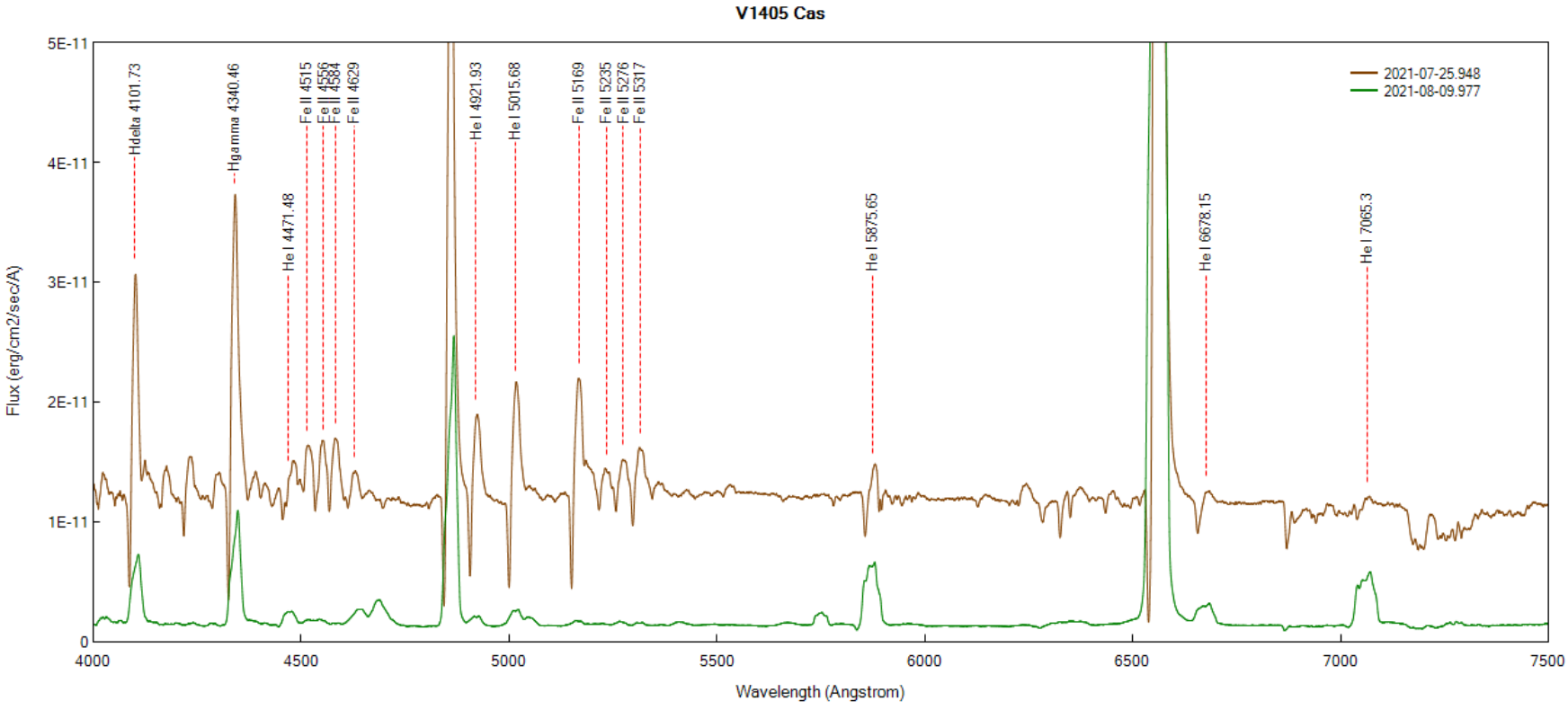


Figure: Reappearance of now broad HeI emissions = the slow outflow was accelerated.

Nova Her 2021 = V1674 Her

Main characteristics

- Nova Her 2021 was discovered at 8.4 mag on 2021-06-12.537UT by Seiji Ueda.
- The fastes nova: t_3 is likely around 3 d
- The progenitor is an intermediate polar with spin period 8.357 min. ATel 14720. This value is based on ZTF survey data .
- X-ray pulsations with spin period were detected in Chandra DDT observation made on July 10, 2021 (ATel 14776).
- Shugarov and Afonina (ATel 14835) reported the orbital period detection.
- Patterson et al. (ATel 14856) reported results of extensive set of time series observations confirming the presence of strong double-humped photometric signal at 0.15302(2) days, and another strong signal at 8.3586(3) minutes

Photometry

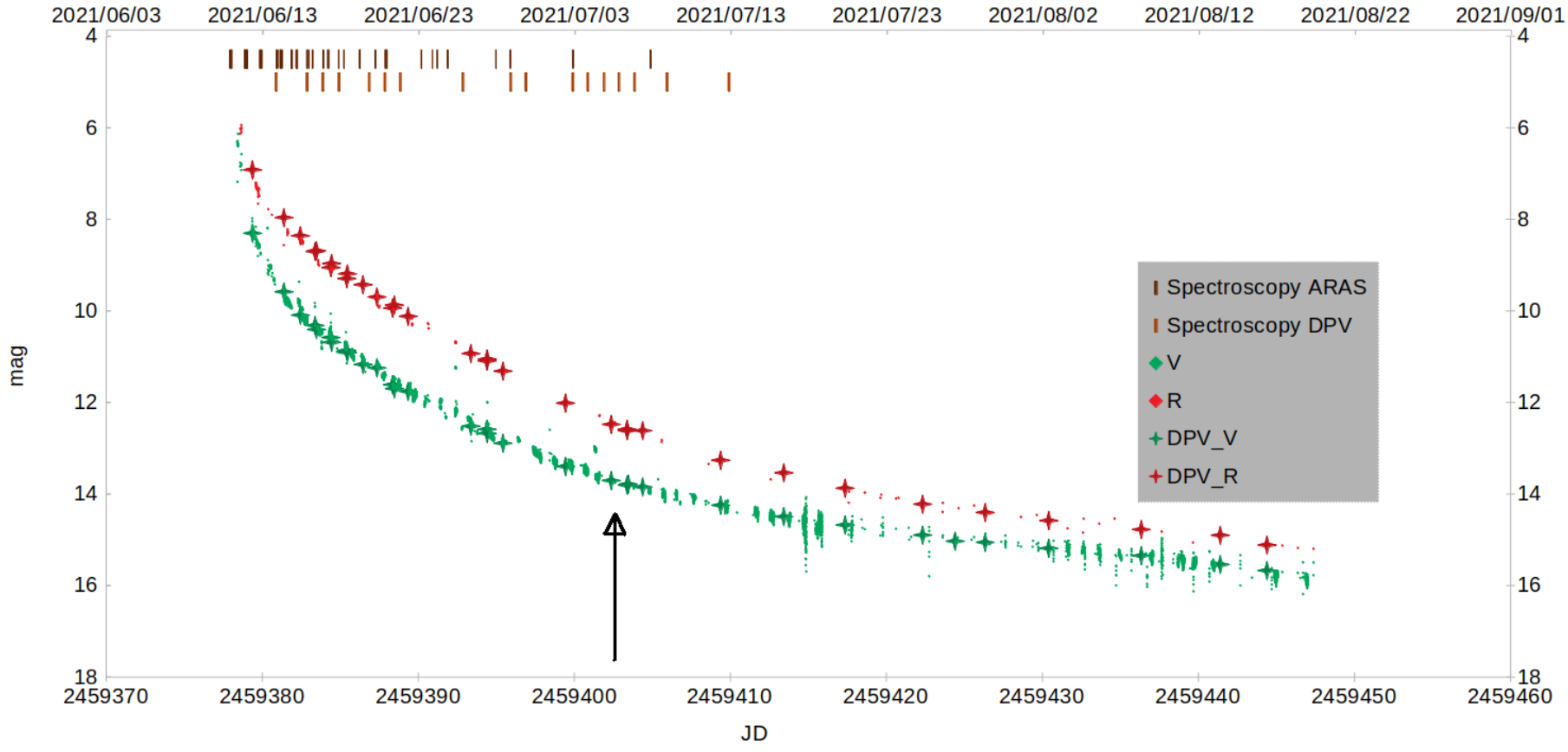


Figure: Photometry and spectroscopy of V1674 Her. The time of first appearance of orbital and spin signal is marked with black arrow

Period analysis - fast photometry with VNT telescope

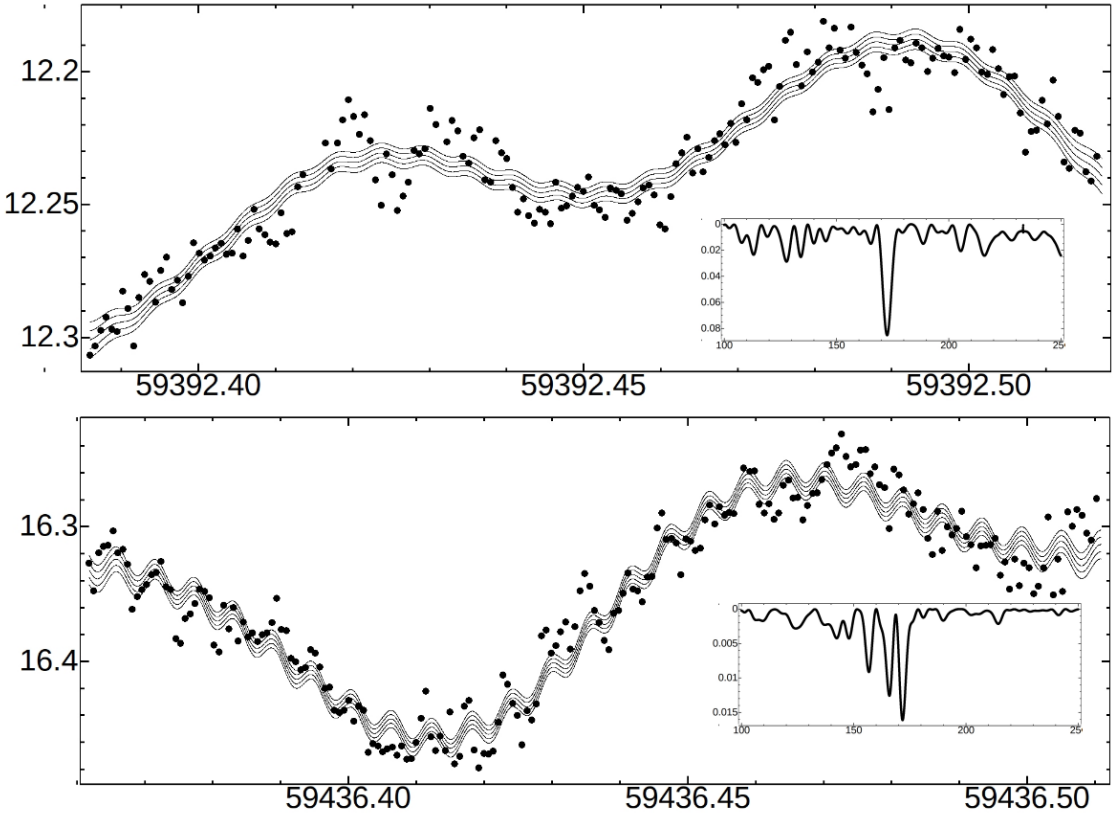


Figure: Top: multisinusoidal fit of the data from July 5, 2021 in V band with periodogram (small panel) showing the peak at the spin frequency. Bottom: data from August 7, 2021 in clear filter. Sideband frequencies $\omega - \Omega$ and $\omega - 2\Omega$.

Period analysis - Surprise!

Early detection of spin period signal

July 5, 2021 in V band observation, only 23 days after the outburst when the brightness of the nova was still 7 mag above the quiescent. The orbital wave was present as well.

Later, based on VNT observations in clear filter we could determine basic parameters of the intermediate polar

•	Period	Frequency
WD spin	$P_{spin} = 0.00580d$	$\omega = 172.4c/d$
Orbital motion	$P_{orb} = 0.1525d$	$\Omega = 6.5595c/d$

$P_{orb}/spin = 26.3$

So the object is well above the limit $P_{orb} = 10 * P_{spin}$ followed by almost all IPs above the period gap. Even if we take the half of the orbital period value.

Spectroscopy - Halpha profile evolution

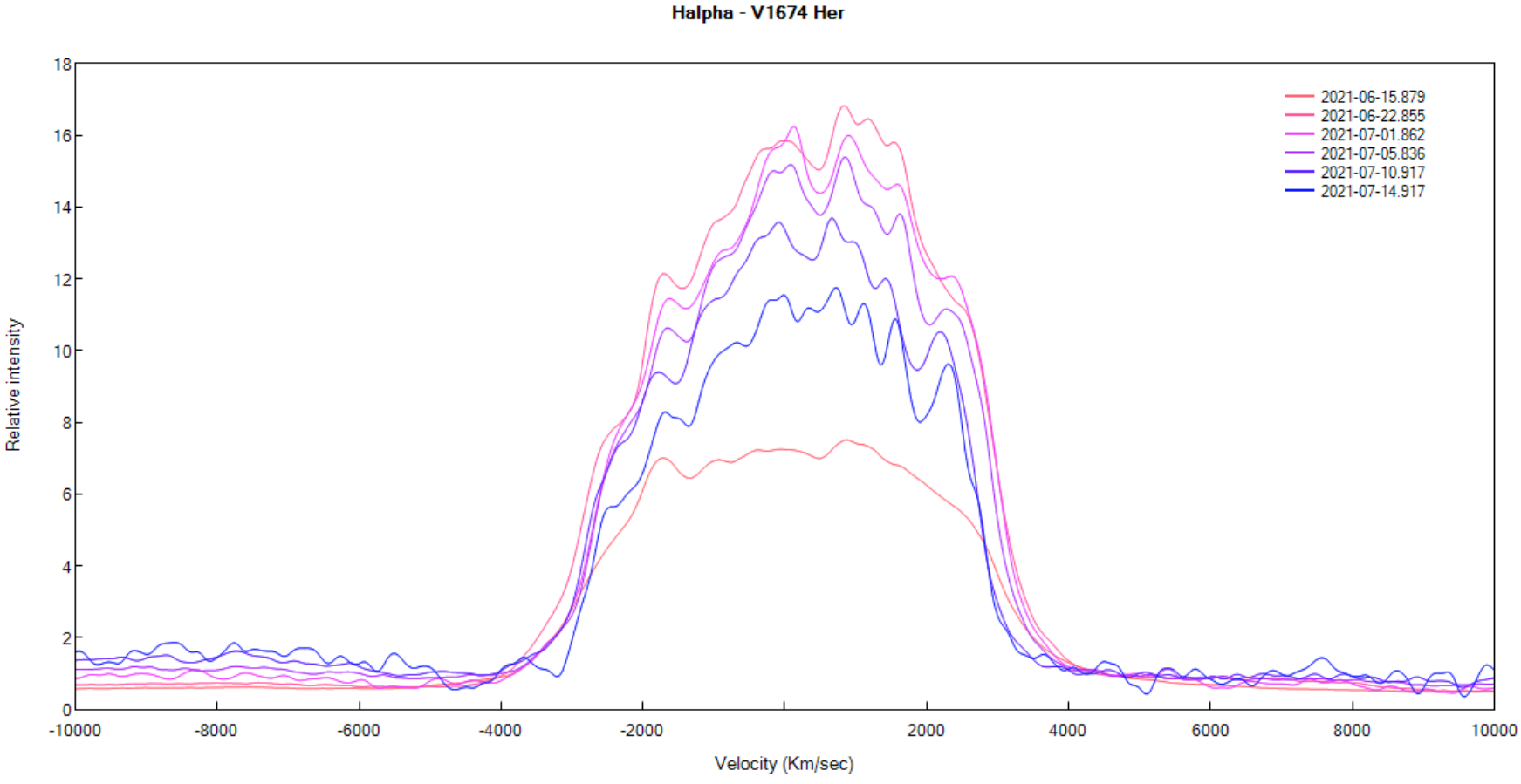


Figure: Fast outflow with velocities above 4000 km/s. Note that even in low resolution spectra details in the ejecta can be observed.

Nova Vul 2021 = V606 Vul

Main characteristics

- Nova Vul 2021 was discovered as optical transient TCP J20210770+2914093 on 2021-07-16.56 UT by K. Itagaki and classified spectroscopically as a classical nova by Munari et al. (ATel 14793).
- Thanks to early disvovery we could observe again the transition from He/N type to FeII type nova. This transition was well covered by our photometric an spectroscopic observations.
- The spectral evolution of nova V606 Vul is also consistent with the paradigm of early spectral evolution of novae presented by Aydi et al. (2020; ApJ, 905, 62), which suggests the presence of two physically distinct outflows, a slow and fast one, during the early weeks of a nova event.

Photometry

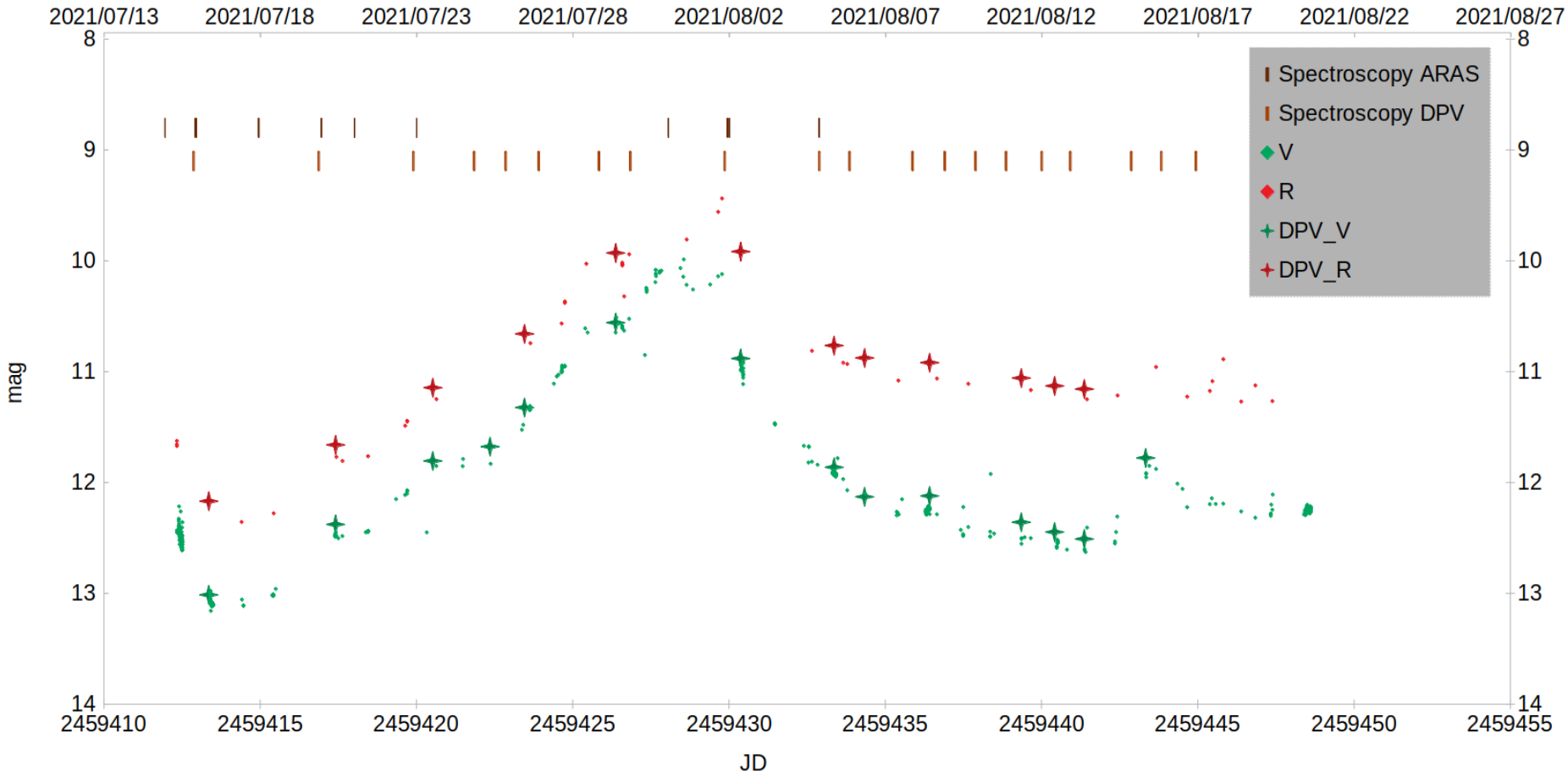


Figure: Photometry and spectroscopy of V606 Vul. First sign of oscillation phase is already visible.

Spectroscopy - transition from He/N type to FeII type nova

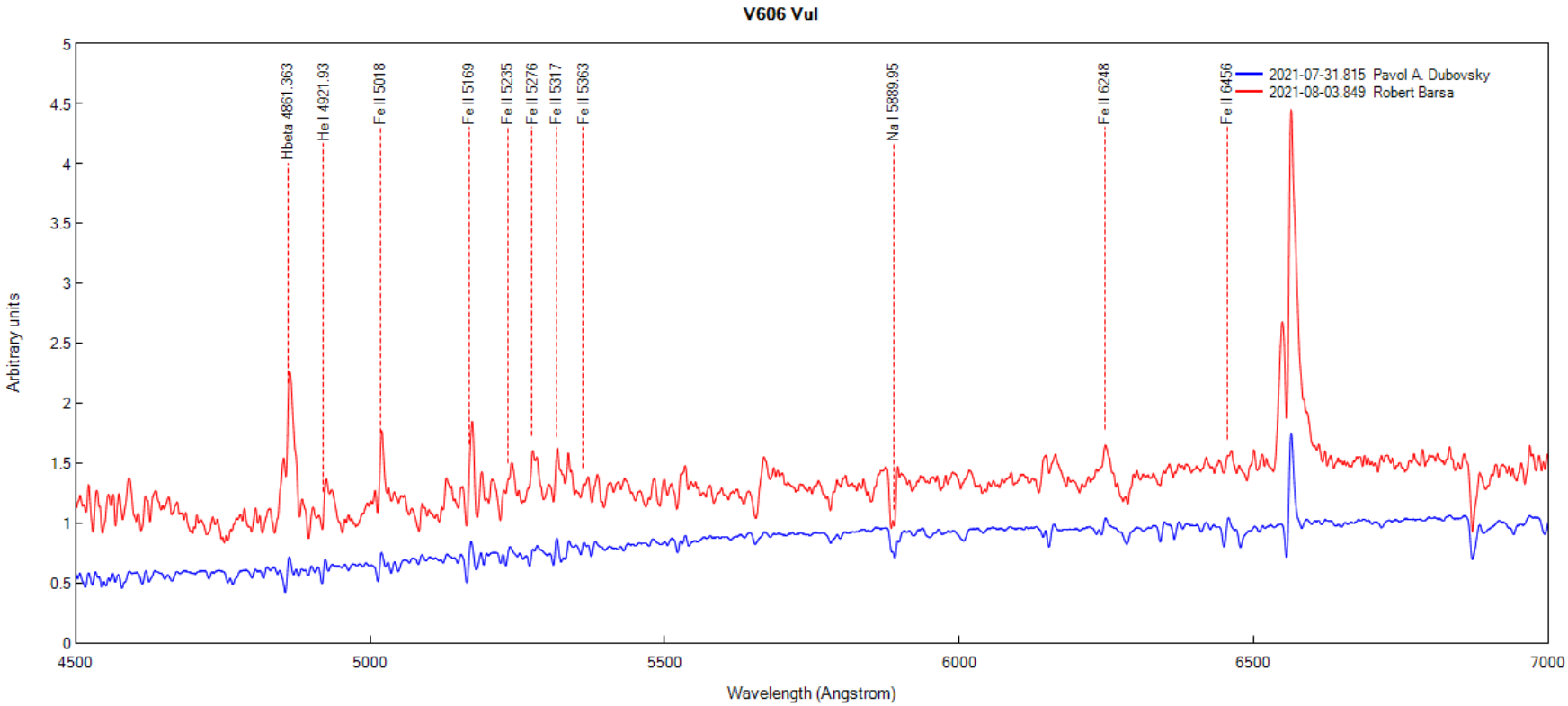


Figure: Spectra obtained during Variable astrocamp at AO on Kolonica Saddle.

RS Oph - symbiotic recurrent nova

Main characteristics

- The present outburst was discovered independently by visual observers Alexandre Amorim, Eddy Muyllaert and Keith Geary on 2021-08-8.93 UT at 5.0 mag.
- Previous outbursts have been recorded in 1898, 1933, 1958, 1967,1985 and 2006 with a probable outburst in 1945.
- The current outburst is following a similar fading trend to previous ones.

Photometry

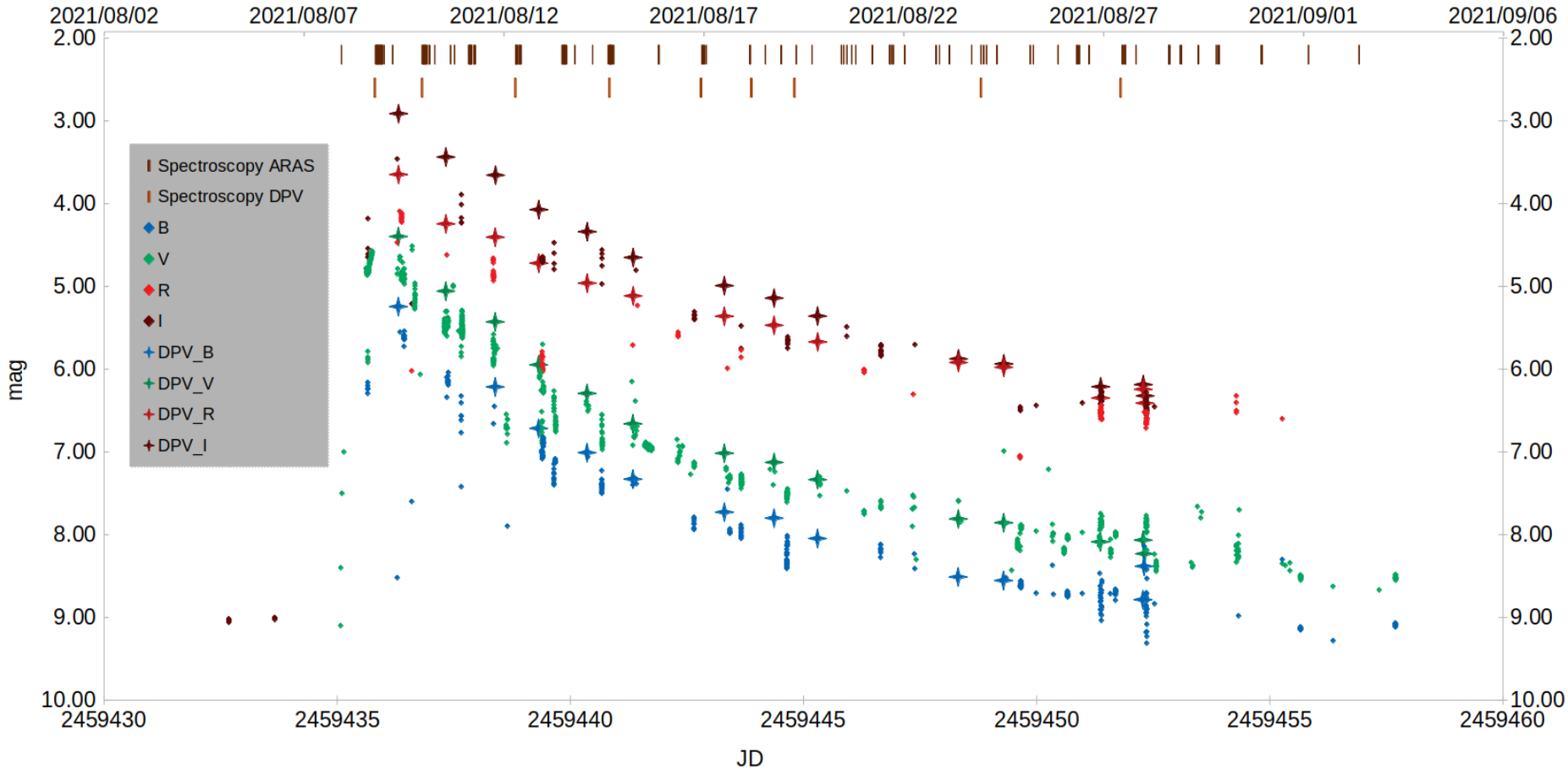


Figure: Photometry and spectroscopy of RS Oph.

Comparison of 5 nova lightcurves in the same time scale showing the variability of the nova event.

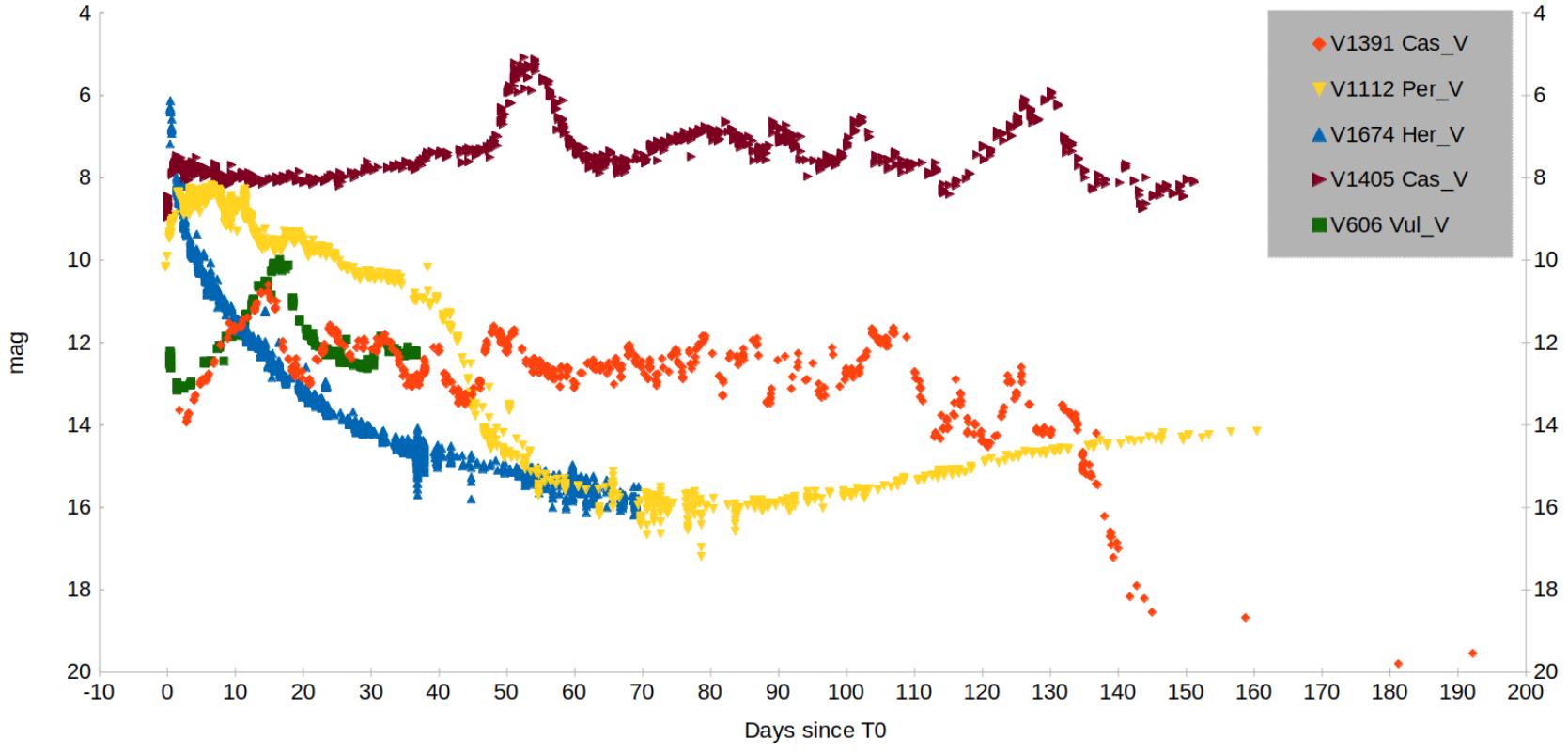


Figure: V band from AAVSO database

Conclusions

Better observational techniques and better observational coverage of the outbursts give us data with unprecedent amount and quality.

More novae are discovered before the maximum.

The maximum magnitude-rate of decline (MMRD) relation is questioned. Difficult to determine the t_2 or t_3 on some lightcurves.

Brightness oscillations looks common to almost all novae. They are probably related to the schocks in the ejecta.

The hybrid novae are common. Transitions He/N to FeII and reverse are observed. The model of slow and fast outflow with different geometry is generally accepted.

Conclusions

Remains unexplained the observation of spin period signal in V1674 Her at the stage when the vast majority of nova luminosity comes from the ejecta.

Challenge for the observers: We know the orbital period of V1405 Cas. Thus in the near future we will have the chance to measure the period change after the eruption.

Multiband observations from radio to gamma-ray - The best way to understand processes typical also for supernovae and active galactic nuclei. Novae are excellent nearby laboratories!

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Thank you for your attention