Studying symbiotic stars and classical nova outbursts with small telescopes

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1. Interacting binaries with the white dwarf accretor:
   Symbiotic Stars & Cataclysmic Variables:
   Configuration, basic properties, outbursts

2. Composite spectrum during outbursts:
   Examples: V339 Del & AG Peg

3. Multiwavelength modeling the SED

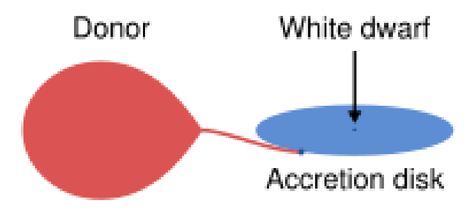
4. Conclusion:
   The role of small telescopes in the research
   of SySt & CVs outbursts

T.L., September 25, 2018

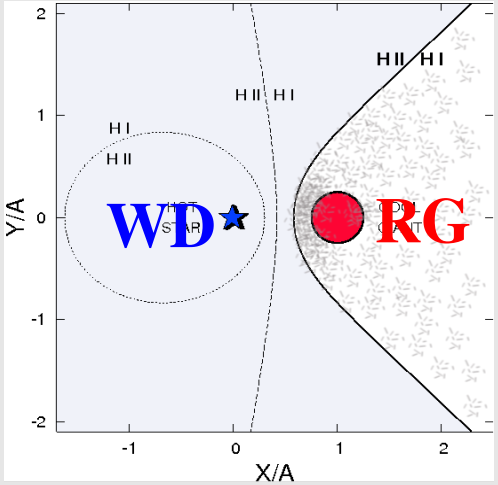
Configuration and basic parameters
CVs & SySt

Binary	Porb	Donor	Accretor	MTM	(dM/dt)acc	Outburst
CVs	hours	MS	WD	L_1	10^{-8}-10^{-10}	nova
SBs	years	RG	WD	wind	10^{-7}-10^{-8}	Z And-type

MTM – mass transfer mode
(dM/dt)acc in M_{Sun}/year

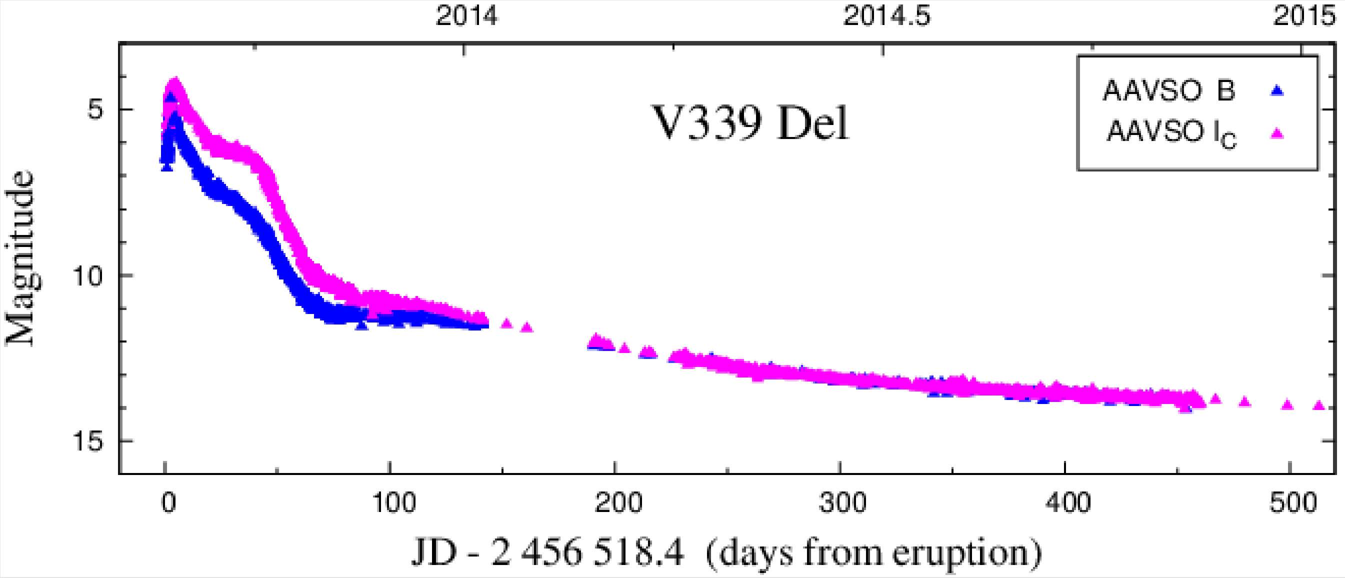


A ~ a few solar radii



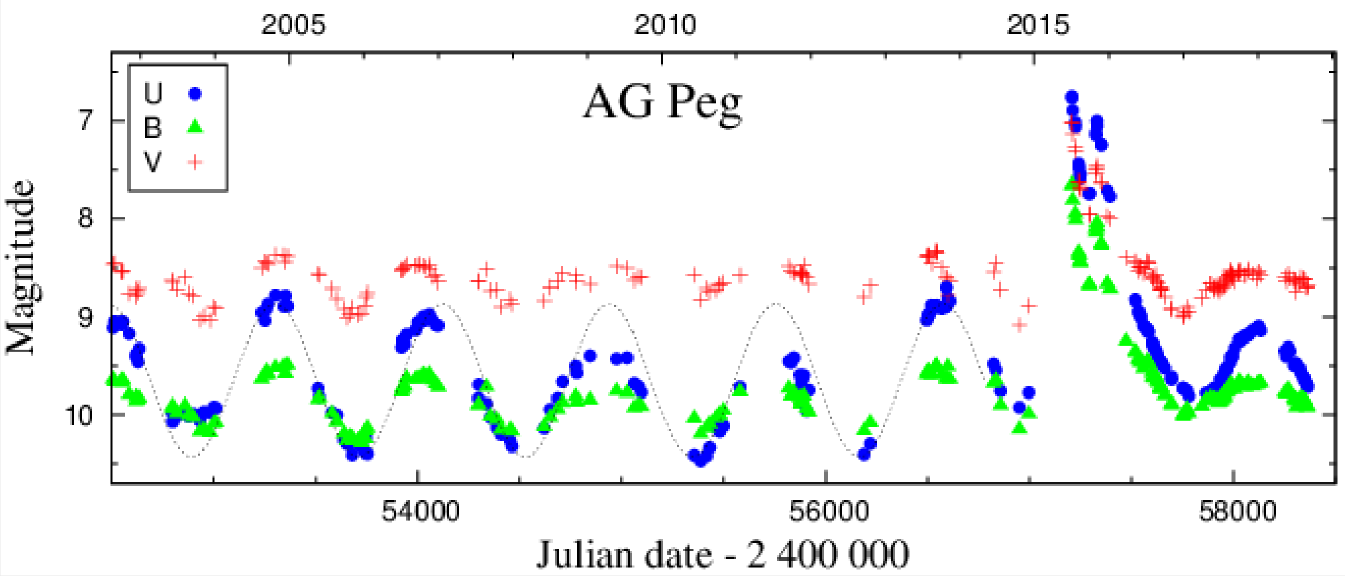
A ~ a few AU (or more)

Outbursts of CVs and SySt: Photometric evolution



Classical nova V339 Del

$\Delta m \sim 12 - 13$ mag
$L \sim 10^{39}$ erg/s $> L(\mathrm{Edd})$
Mass outflow
$\sim 10^{-4}\ M_s$/year

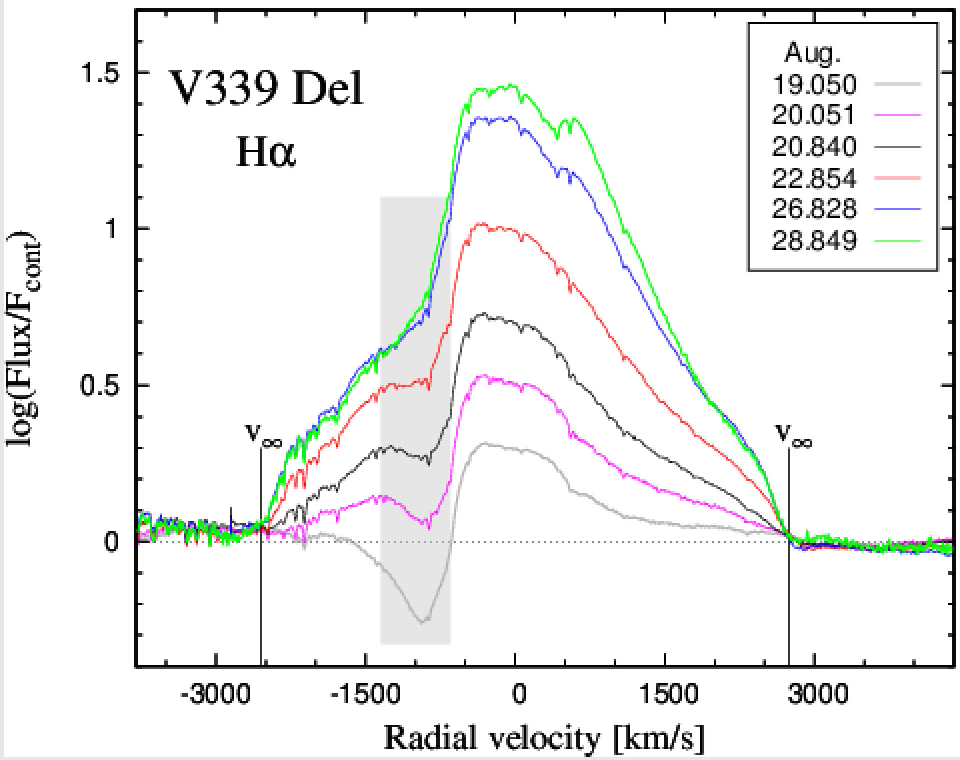


Classical SySt AG Peg

$\Delta m \sim 1 - 3$ mag
$L \sim 10^{37}$ erg/s $< L_{\mathrm{Edd}}$
Mass outflow
$\sim 10^{-6}\ M_s$/year

Major diversity: violence of outbursts

Outbursts of CVs and SySt: Spectral lines

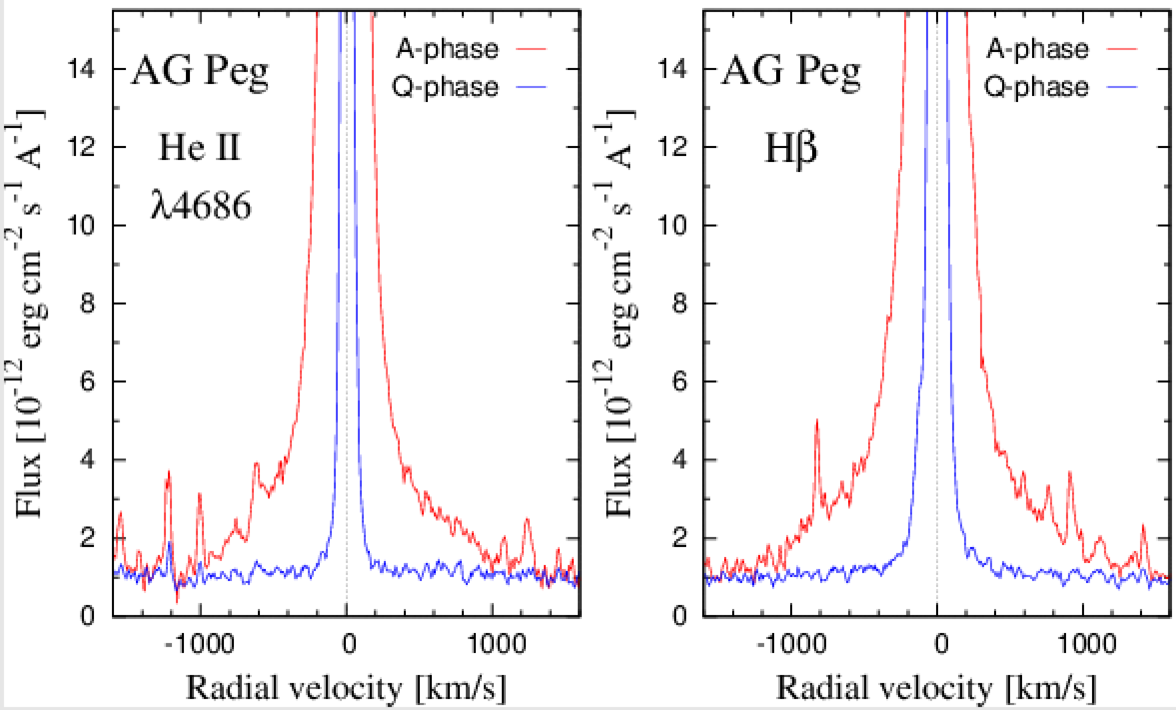


V339 Del: $v_\infty \sim 3000$ km/s

ARAS database:

- Observatory de la Toubiére; 0.355 m tel.; eShel; ATIK 460EX
- Castanet Toloson Observatory; 0.2 m Newton tel.; eShel; ATIK 460EX

Skopal et al., 2014



AG Peg: $v_\infty \sim 1200$ km/s

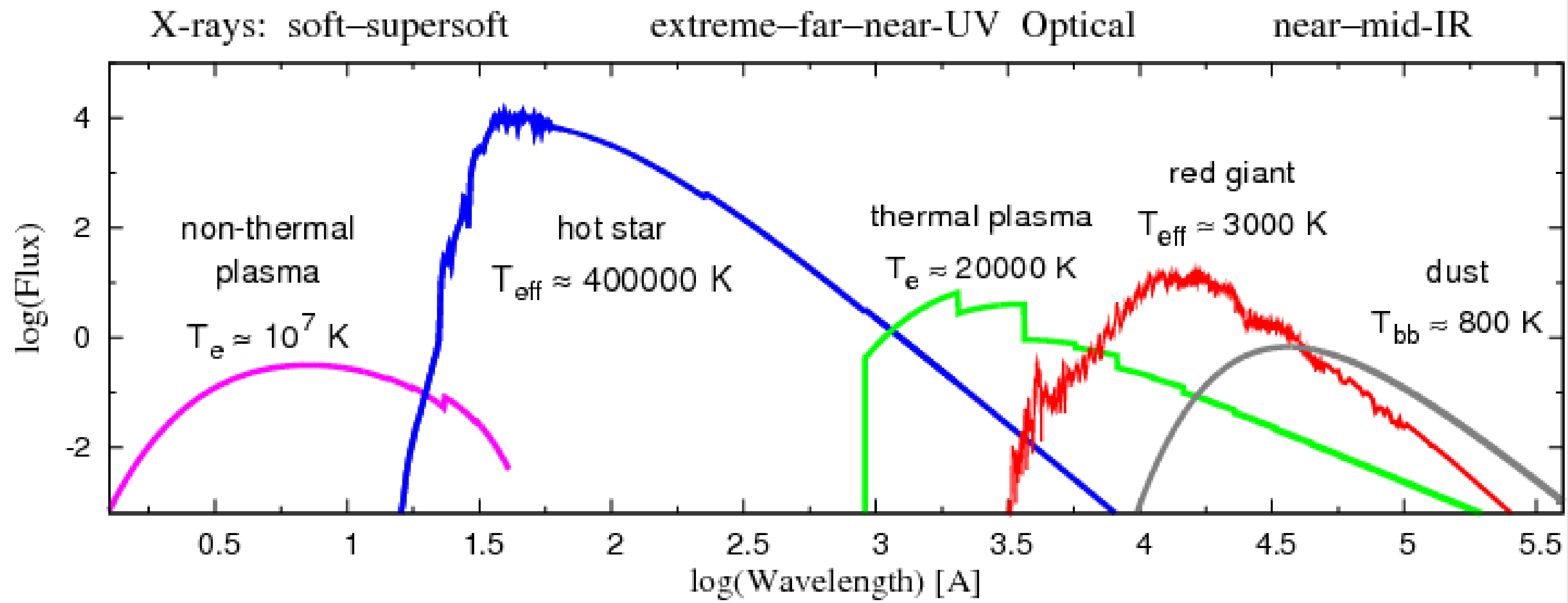
Stará Lesná Observatory,
0.6 m Cassegrain telescope;
eShel spectrograph;
ATIK 460EX CCD camera

Skopal et al., 2017

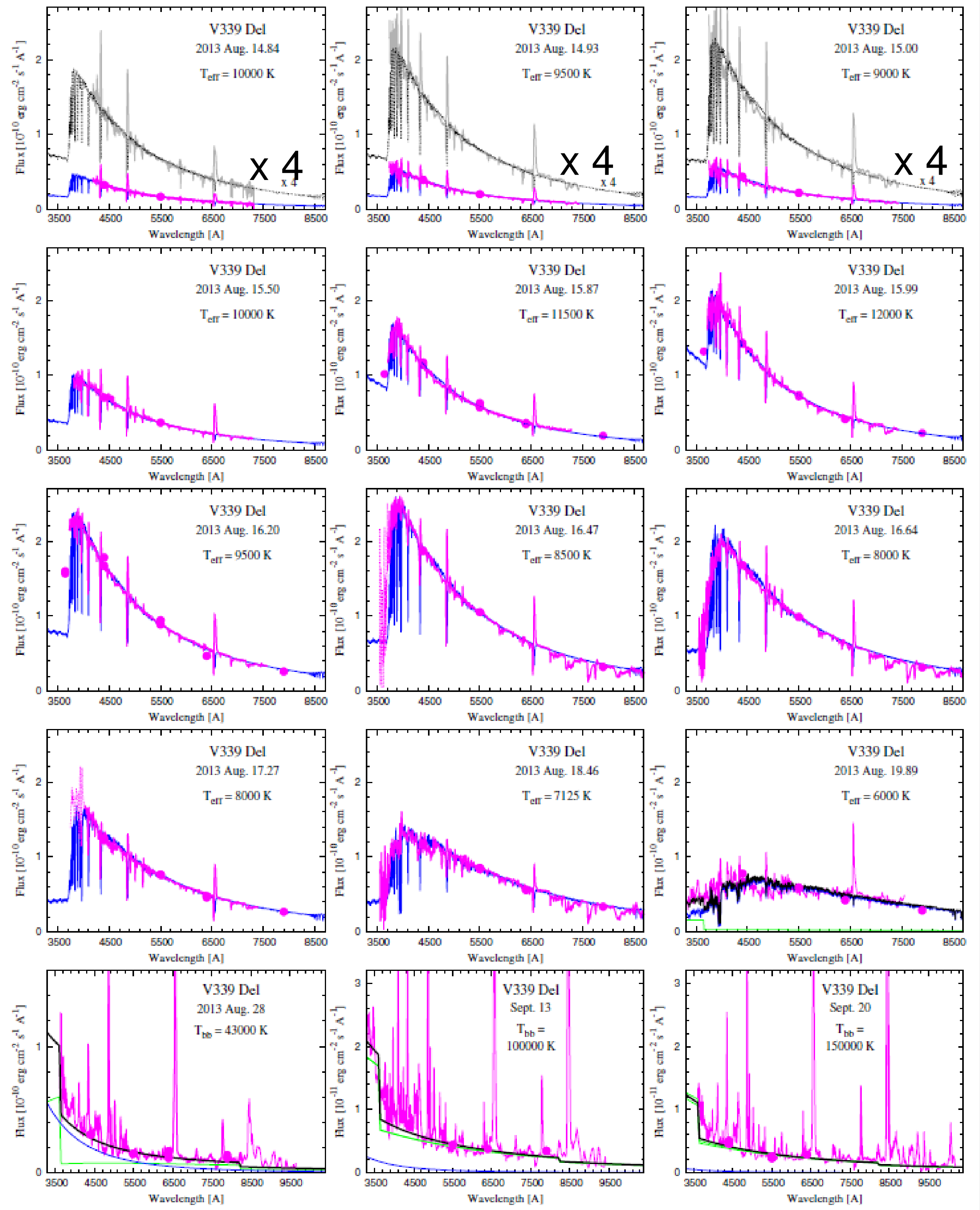
Composite continuum of Novae & SySt

The spectrum consists of different components of radiation

$$F(\lambda) = F_H(\lambda) + F_N(\lambda) + F_G(\lambda) + F_D(\lambda)$$



Aim: disentangling the composite spectrum to obtain physical parameters of individual components of radiation



Nova Delphini V339 Del:

Aug. 14 – Aug. 20, 2013

Fireball stage: $F(\lambda) = F_H(\lambda)$

Magenta: observations

Blue line: Atm. Models

Green line: Nebular radiation

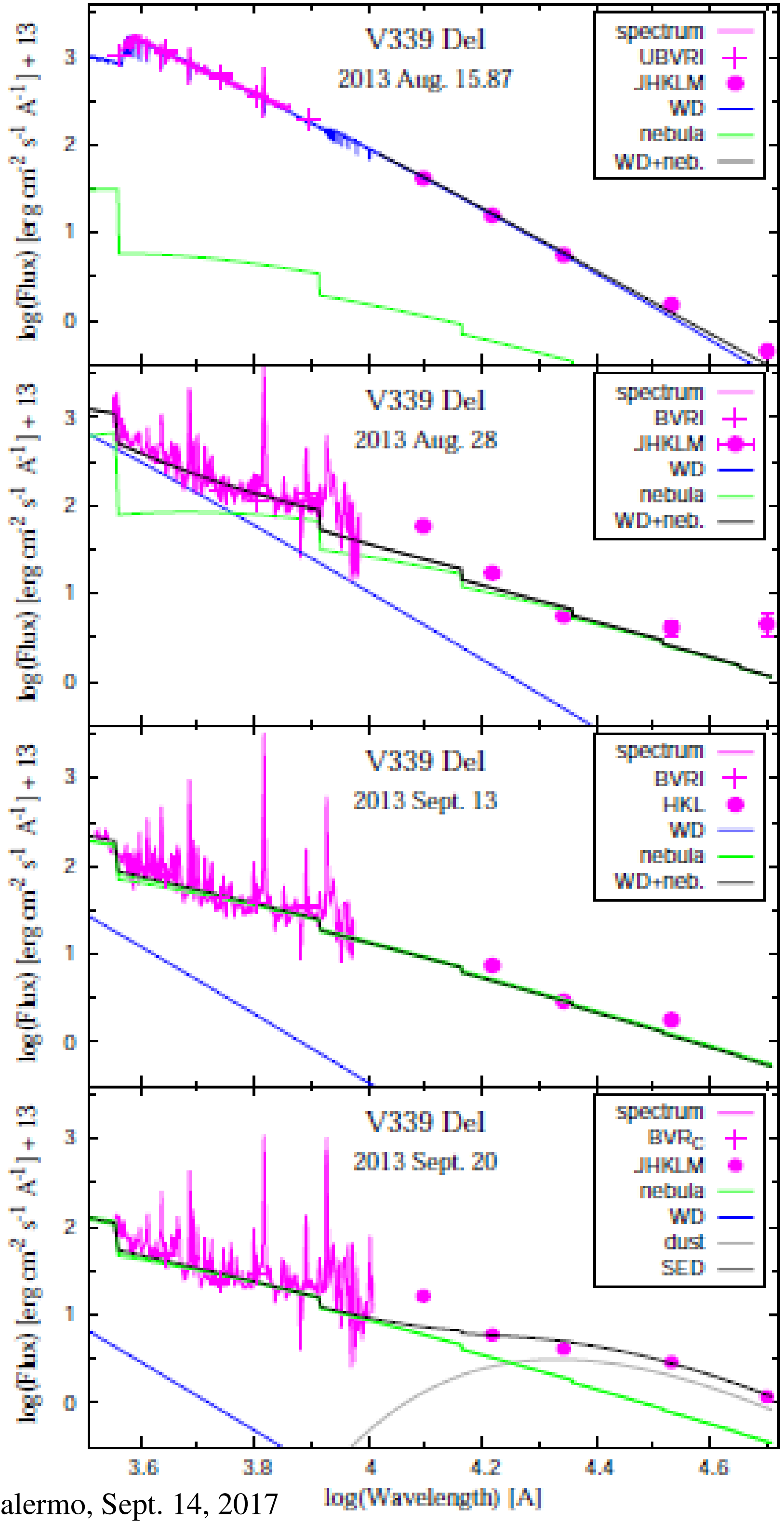
- Private station in Rouen; 0.36 m t.
- Santa Maria de Montmagastrell Observatory; SC16 tel.;
- Durtal Observatory; 0.51 m tel.
- Observatoire du Pilat; 0.25 m tel.
- Private station in Idaho Falls; 0.25 m tel.;
- Fujii Kurosaki Observatory; 0.4 m tel.

Aug. 20 – Sept. 24, 2013

Harder spectrum:

$F(\lambda) = F_H(\lambda) + F_N(\lambda)$

T.L., September 25, 2018



Palermo, Sept. 14, 2017

day-1.3: Aug. 16: $T_{eff} = 11{,}500$ K

Fireball phase $R_{WD} = 102$ Ro

$L = 6.3 \times 10^{38}$ erg/s

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day-14: Aug. 28: Te = 15,000 K

Transition phase $EM = 1.8 \times 10^{62}$ cm^{-3}

$T_{BB} \sim 43{,}000$ K (?)

$L \sim 10^{39}$ erg/s (from EM)

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day-30: Sept. 13: Te = 40,000 K

$EM = 1.4 \times 10^{62}$ cm^{-3}

$T_{BB} \sim 100{,}000$ K (?)

$L \sim 10^{39}$ erg/s (from EM)

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day-37: Sept. 20: Te ~ 50,000 K

Emergence of dust $EM = 1.0 \times 10^{62}$ cm^{-3}

$F(\lambda) =$ $T_{BB} \sim 150{,}000$ K (?)

$F_H(\lambda)+F_N(\lambda)+F_D(\lambda)$ $L \sim 10^{39}$ erg/s (from EM)

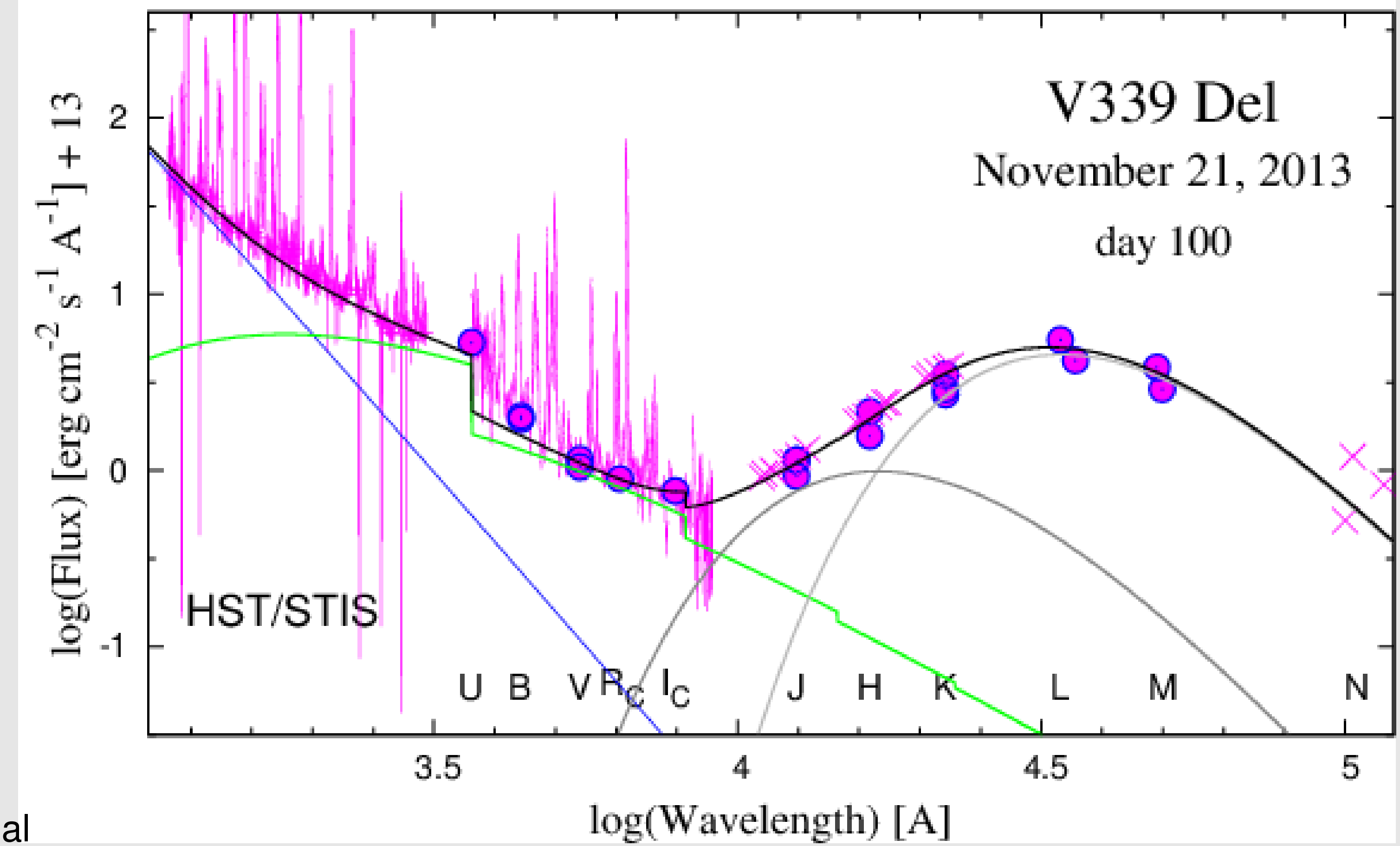
$T_{dust} \sim 1350$ K

SSS-phase: day-100, November 21, 2013: UV – IR SED

Nebula: $T_e = 40000 \pm 5000$ K, EM = 3.3×10^{60} $(d/3kpc)^2$ cm^{-3} .

Dust: $T_{D1} \sim 850$ K, $L_{D1} \sim 2.5 \times 10^{37}$ $(d/3kpc)^2$ erg/s;

$T_{D2} \sim 1700$ K, $L_{D2} \sim 2.8 \times 10^{36}$ $(d/3kpc)^2$ erg/s

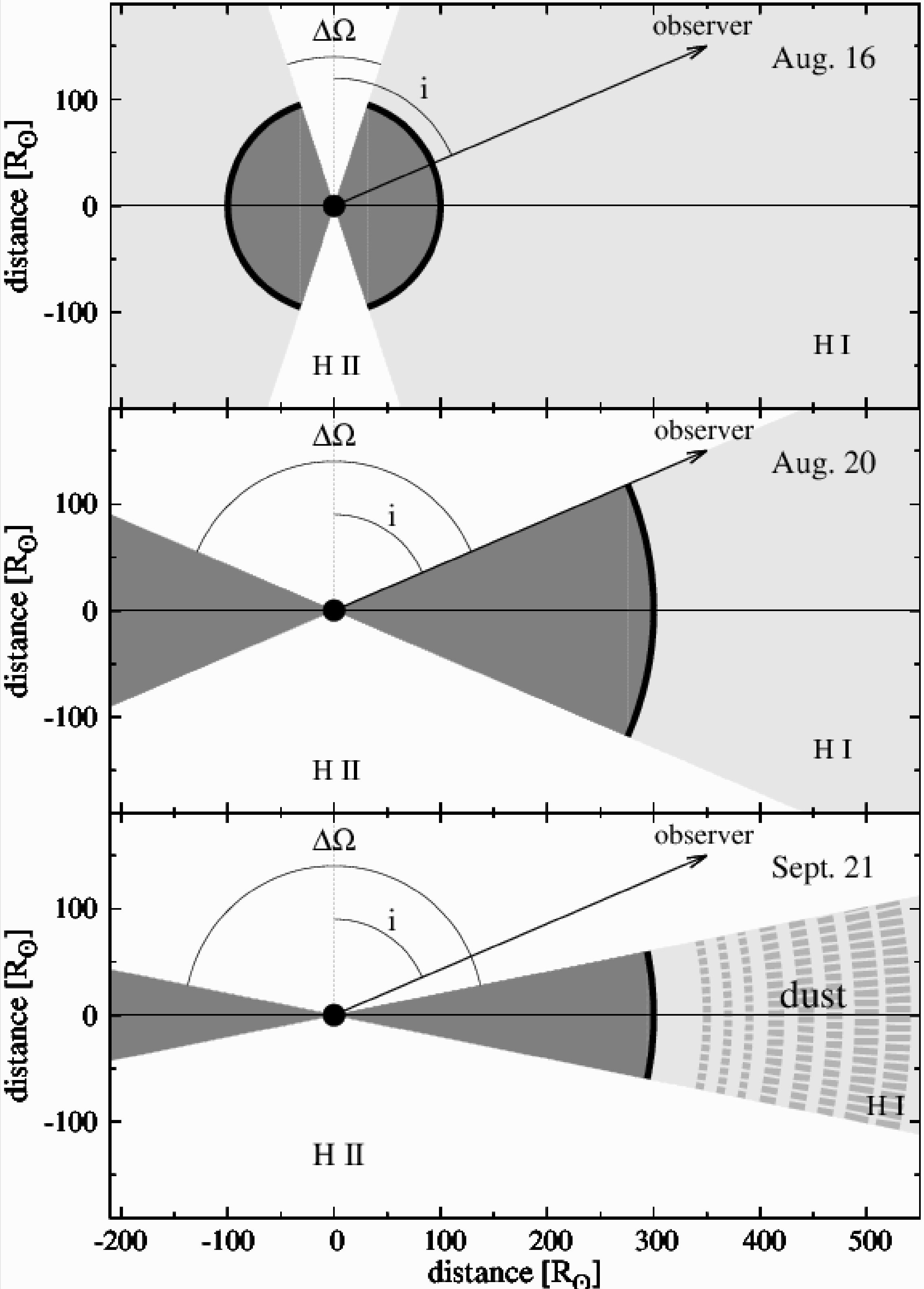


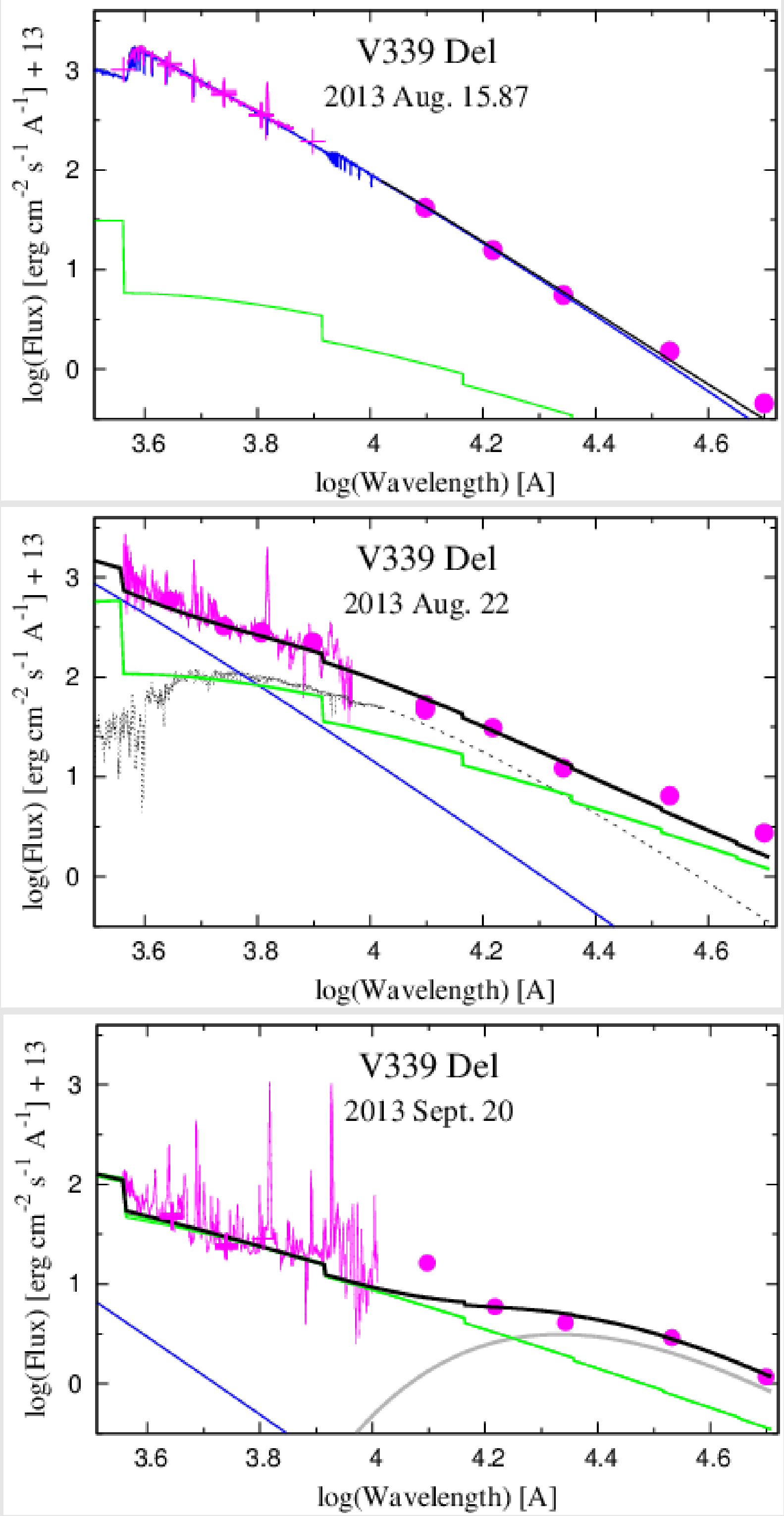
credit: A. Skopal

Data sources: Gehrz+15; Shore+16; Evans+17; AAVSO and ARAS databases.
HST/STIS: from MAST; ID: 13388, PI: Schwarz, G.J., reported by Shore+16

CLASSICAL NOVA

V339 Del

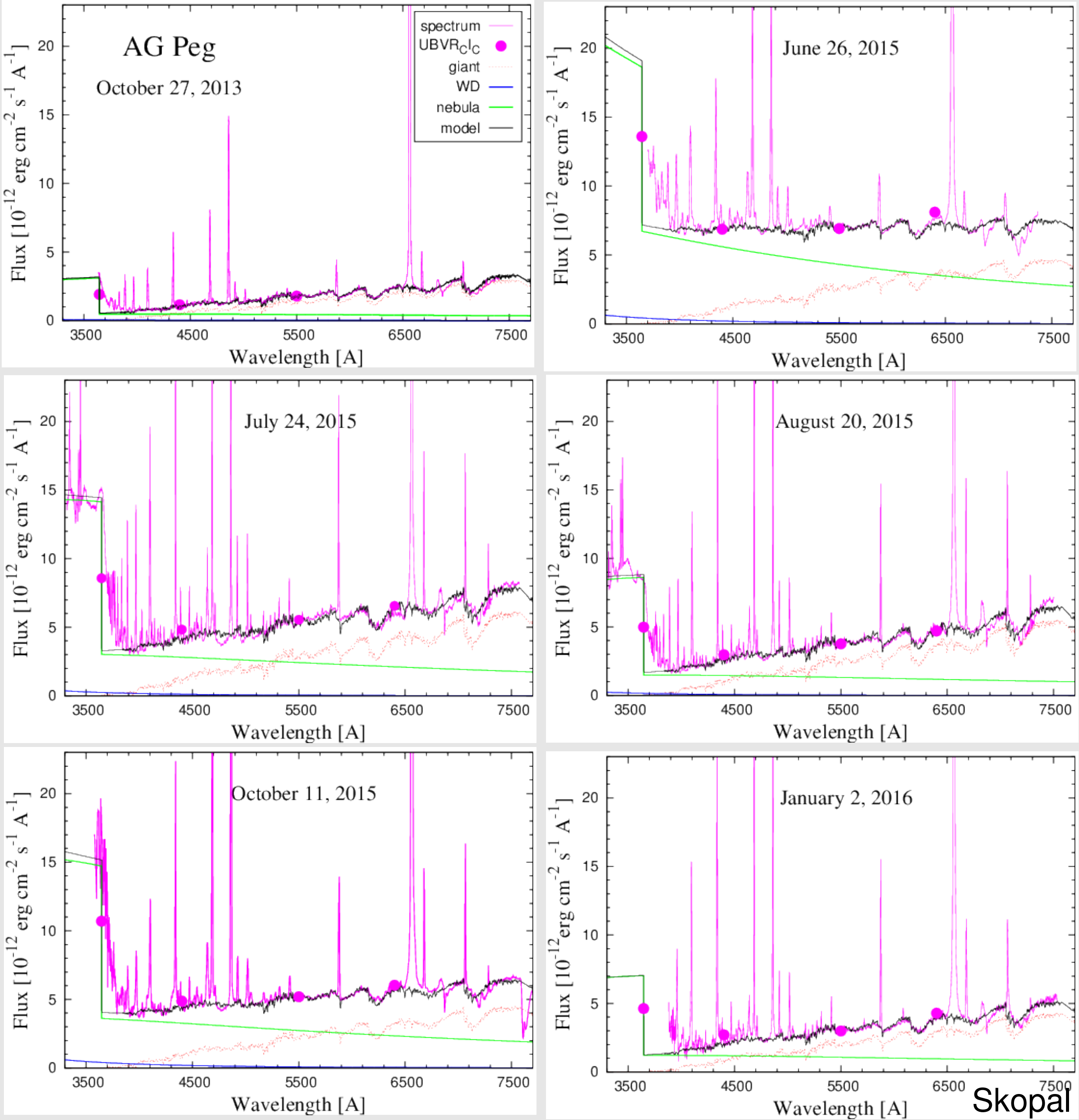




Skopal et al. (2014)

The 2015 outburst of AG Peg

Models SED: $F(\lambda)=F_N(\lambda)+F_G(\lambda)+\cancel{F_H(\lambda)}$



Skopal et al., 2017

Observations by small telescopes:

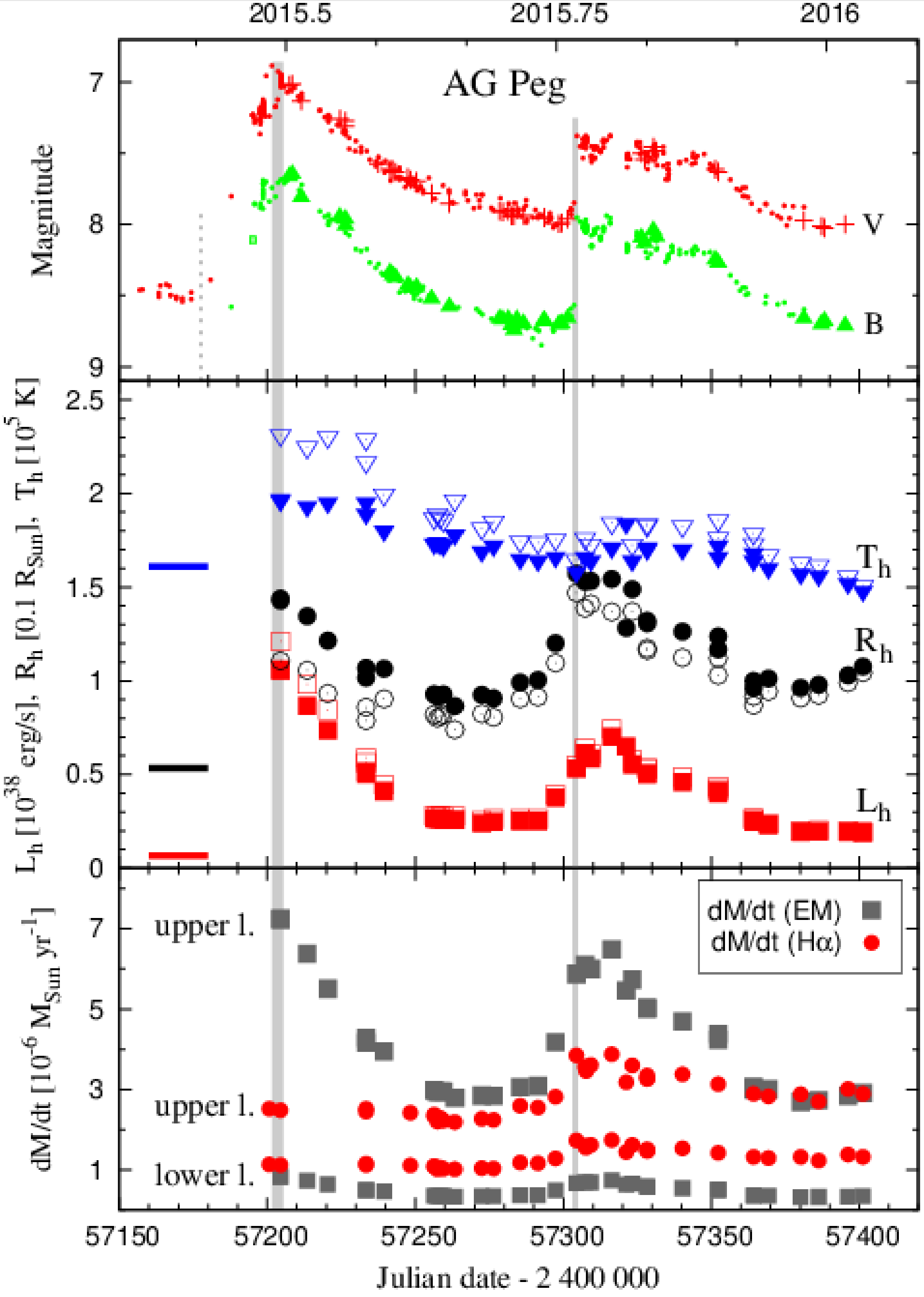
- Santa Maria de Montmagastrell Observatory; SC16 tel.;
- Private stations Manhattan and Grand Lake; 0.25 m S-C tel.
- Observatoire de Haute-Provence; 0.2 m N-tel. (Orion N200 f/5)
- Private station in L'Aquila; 0.2 m S-C tel. F/10.
- Fujii Kurosaki Observatory; 0.4 m S-C tel. F/10 (Meade).
- Observatory de la Couyére; 0.355 m S-C tel. (Meade).
- West Challow Observatory; 0.28 m S-C tel. (Celestron C11).

Magenta line: Observations

Orange line: Red Giant

Green line: Nebular radiation

Fundamental parameters of the burning WD from models SED



Skopal et al., 2017

2015 outburst of AG Peg was of the Z And-type

L_{WD} R_{WD}, T_{WD} from models SED

- T_{WD} from the ratio F_{4686} / $F_{H\beta}$
- L_{WD} from the emission measure (EM)
- R_{WD} from $L_{WD} = 4\pi R_{WD}^{2}\, \sigma\, T_{WD}^{4}$

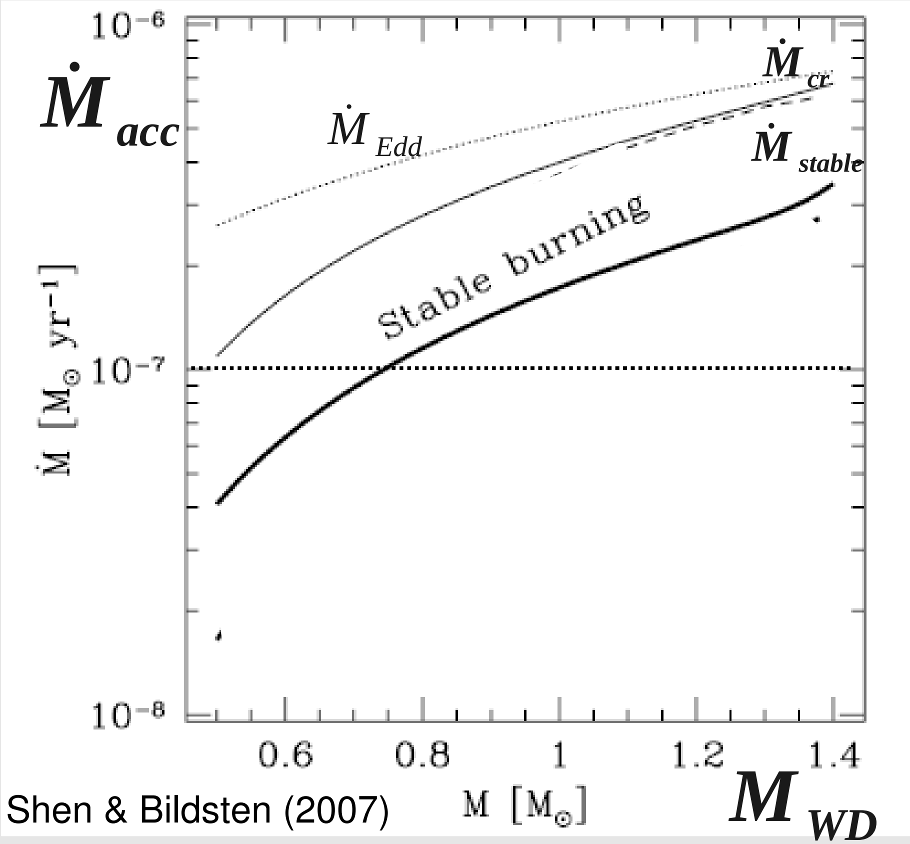
Mass outflow rate dM/dt from EM and the β-law wind

dM/dt ~ a few x 10^{-6} M_{sun}/year

Outbursts by mass-accreting WD

$$L_{WD} = L_{nucl} + L_{acc} = \eta X \dot{M}_{acc} + (1-\alpha) G \frac{M_{WD} \dot{M}_{acc}}{2 R_{WD}}$$

$$\eta = 6.3 \times 10^{18}\, erg/g, \quad X \equiv 0.7$$



Shen & Bildsten (2007)

$\dot{M}_{acc} < \dot{M}_{stable}$: No stable H-burning (shell flashes only)

Material is accumulated up to $P_{cr} \sim 10^{20}$ dyne/cm^2 .

If $P > P_{cr}$, --> nova explosion (TNR).

SySt: Accretion powered (EG And, CQ Dra).

$L = 10^0 - 10^2$ solar units

$\dot{M}_{stable} < \dot{M}_{acc} < \dot{M}_{cr}$: Steady H-shell burning

$(\dot{M}_{acc} = \dot{M}_{burning})$, L ~ a few x 10^3 solar units

SySt: Quiescence of e.g., Z And, AG Peg, SY Mus.

$\dot{M}_{acc} > \dot{M}_{cr}$: Mass-loss, increase of L to/around L_{Edd}

SySt: Z And-type outbursts, e.g., Z And, CI Cyg, AG Peg (2015).

Conclusion

Bright explosions of accreting WDs in a SySt or CV are very good targets for the science with small telescopes

- high cadence of observations
- prompt feedback to alerts
- important supplement to measurements with satellites and/or large telescopes
- direct and simple approach to the data (ARAS, AAVSO,...)

Spectroscopy & photometry of bright transients with small telescopes can contribute to worthy science

Thank you for your attention