small telescopes on novae: still worth ?

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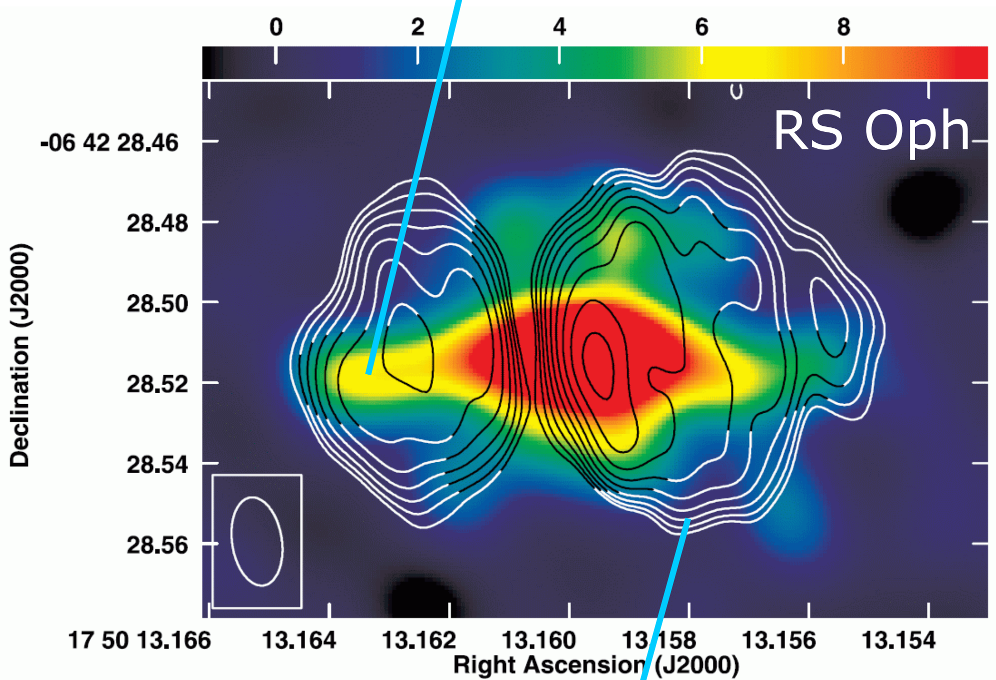
- over recent years, modeling and theoretical efforts on novae have been dominated by spectacular advances in the

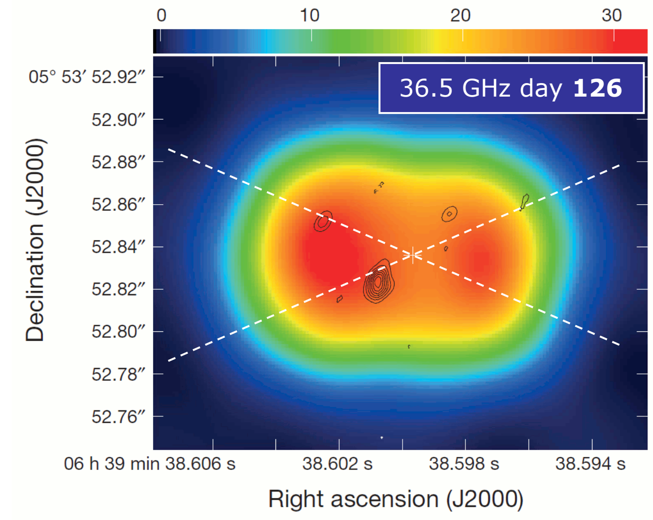
  X-rays
  γ-rays
  radio

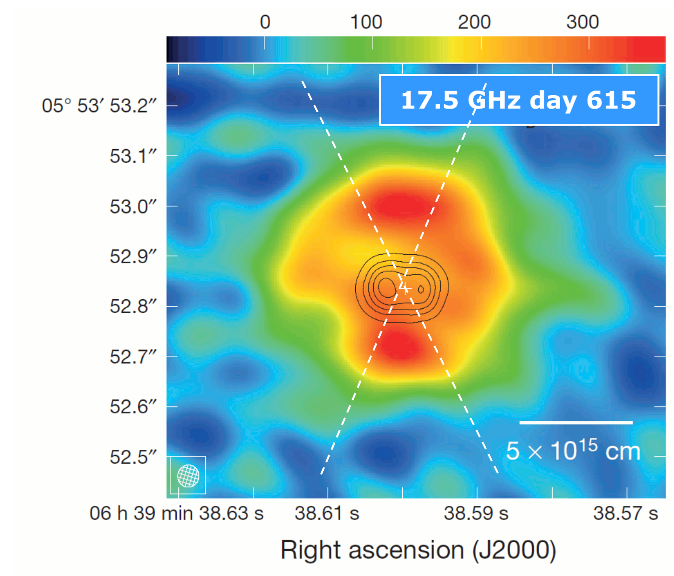
- a situation similar to when the IUE satellite opened the window on the **ultraviolet** in the 1980/1990ies

VLA 43 GHz thermal plasma

V959 Mon VLA







VLBI 1.7 GHz synchrotron

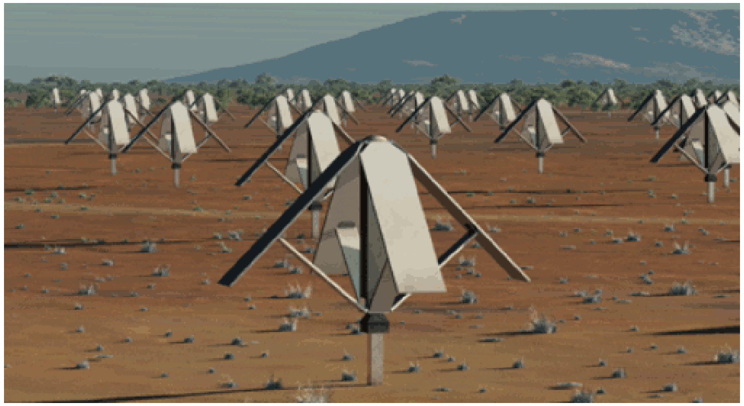
Sokoloski et al. 2008

Chomiuk et al. 2014

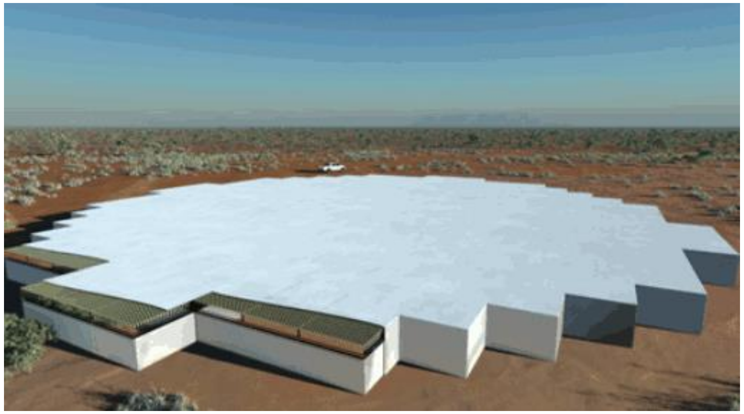
SKA Square Kilometer Array

Australia

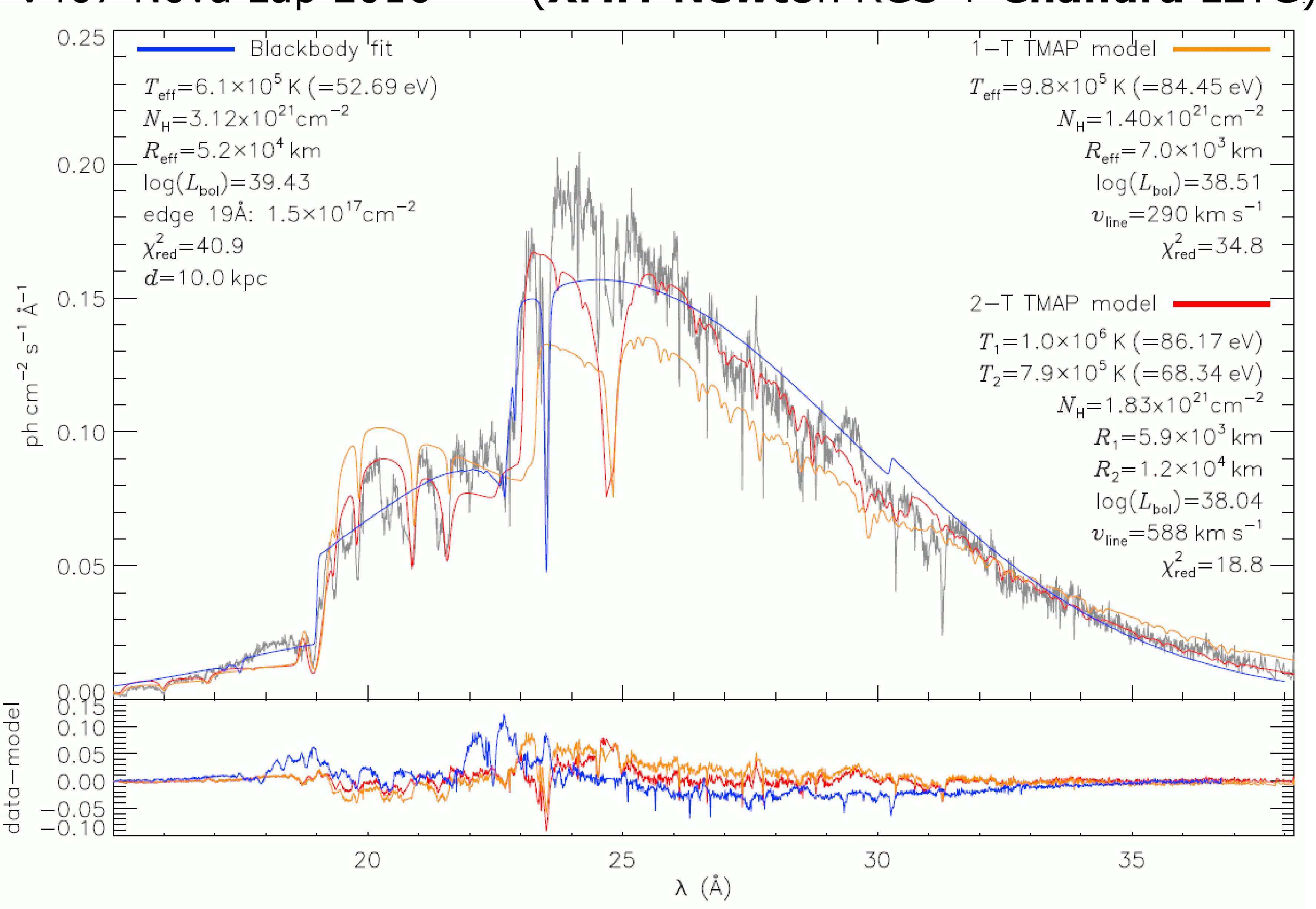
South Africa



precursors

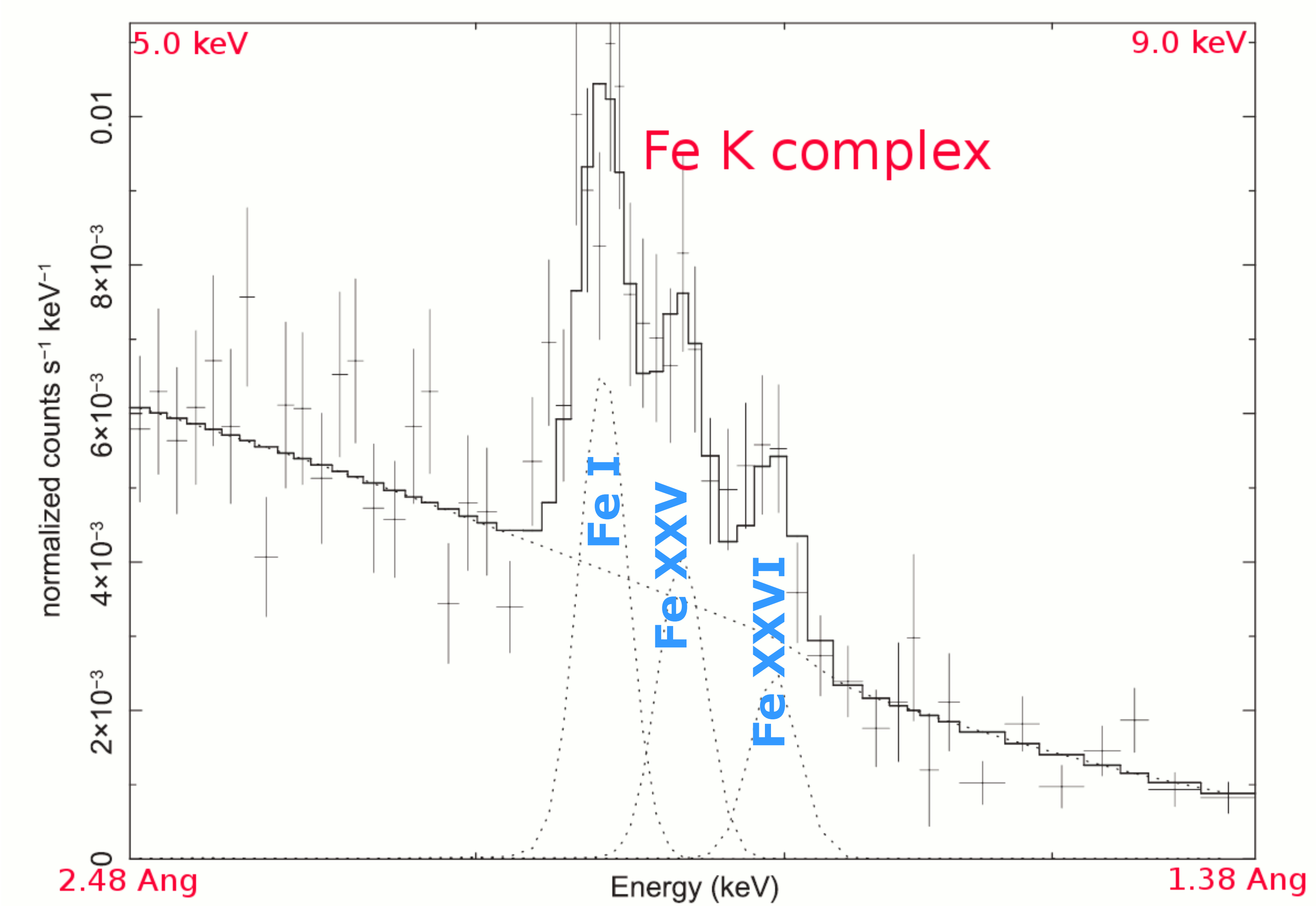


V407 Nova Lup 2016 (**XMM-Newton** RGS + **Chandra** LETG)



Zemko et al 2018

V2491 Cyg (**Suzaku** XSI spectrum)



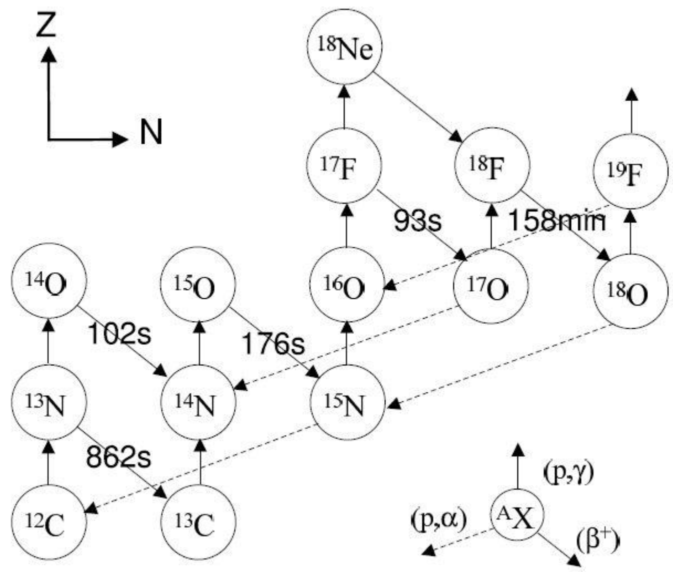
Zemko et al. 2015

pre-Fermi common view about γ-rays from novae (**MeV**)

<u>electron-positron annihilation</u>, with positrons coming from the β^+ decays

17F → 17O	**τ = 93 sec**	
14O → 14N	**τ = 104 sec**	
15O → 15N	**τ = 176 sec**	
^{13}N → ^{13}C	**τ = 862 sec**	
^{18}F → ^{18}O	**τ = 158 min**	

ejecta still opaque to g-rays



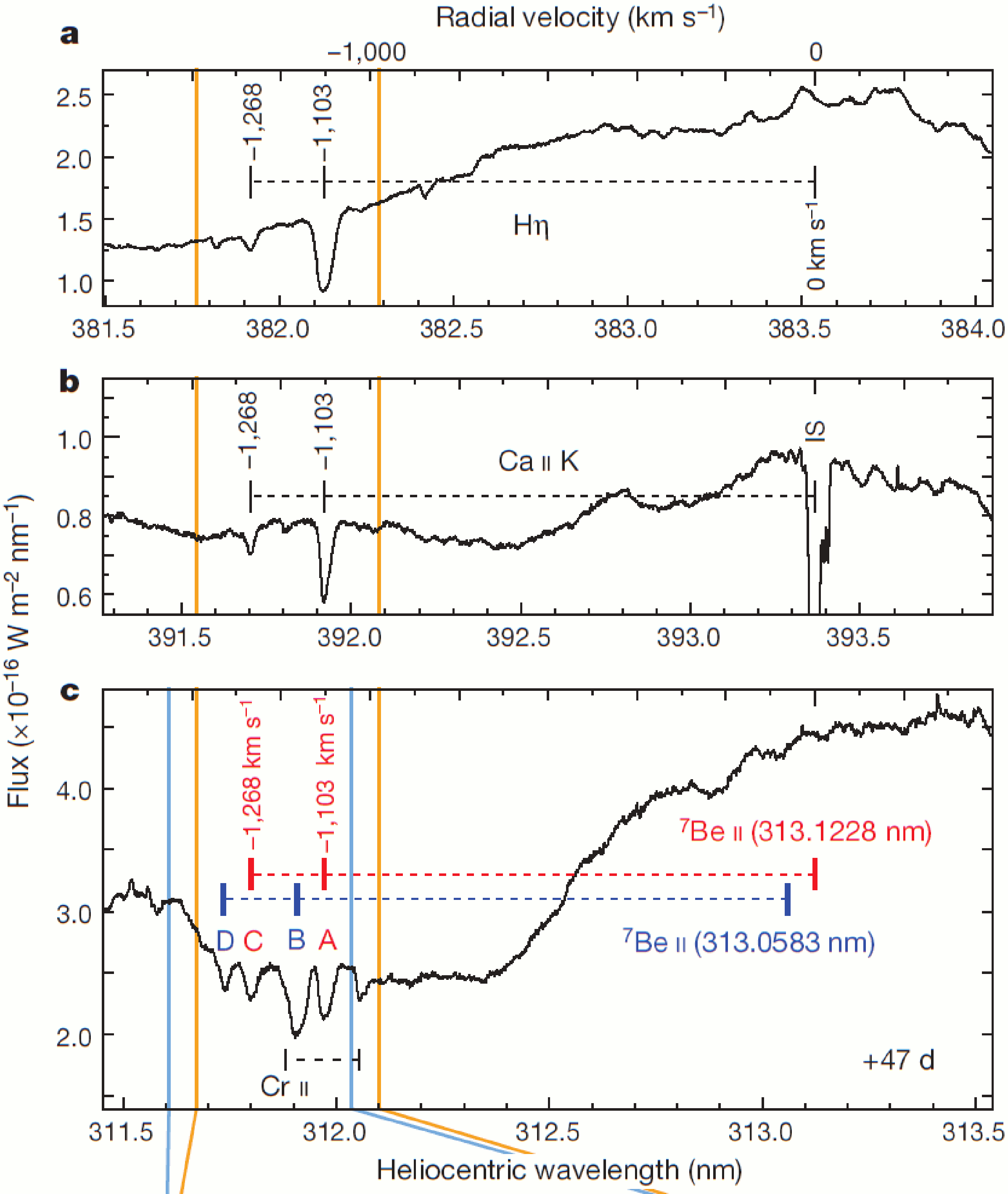
^{7}Be decay to ^{7}Li release of a **0.478 MeV** photon — **τ = 77 days**

^{22}Na decay to ^{22}Ne by β^+ emission and release of a **1.275 MeV** photon — **τ = 3.75 years**
→ annihilation leading to a **0.511 MeV** photon

^{26}Al decay to ^{26}Mg by β^+ emission and release of a **1.809 MeV** photon — **τ = 10^6 years**
→ annihilation leading to a **0.511 MeV** photon

Hernanz (2008)

Nova Del 2013



^{7}Be doublet at

3131.228 Å
3130.583 Å

Subaru + HDS

Tajitsu et al. 2015

Cescutti & Molaro 2018

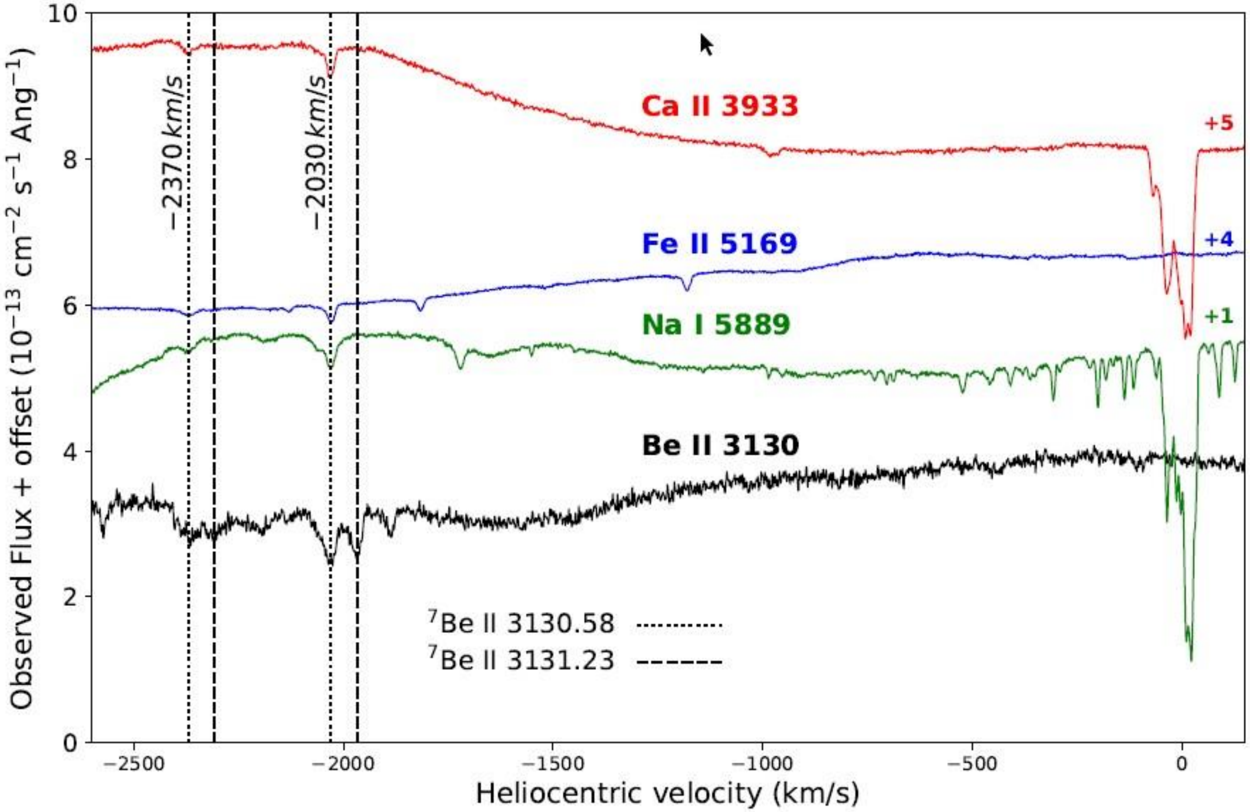
[Be/Fe]= +4/+5 dex

M_{ej} = 10^{-5} M_{sun}

M_{Li} = 3 10^{-9} M_{sun}

20 novae yr^{-1} over last 10^{10} yrs

$(M_{Li})_{Galaxy}$ = 600 M_{sun} in the Galaxy



V407 Lup
ASASSN-16kt

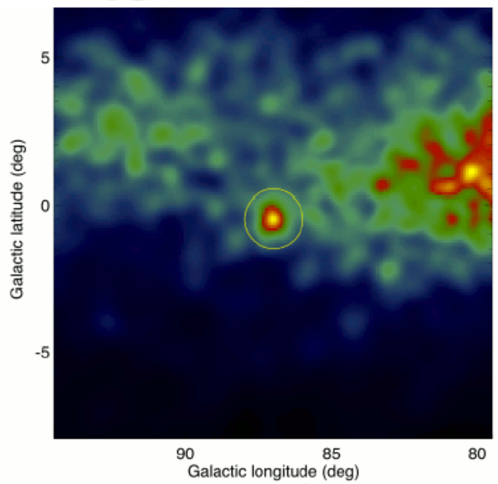
VLT + UVES

Izzo et al. 2018

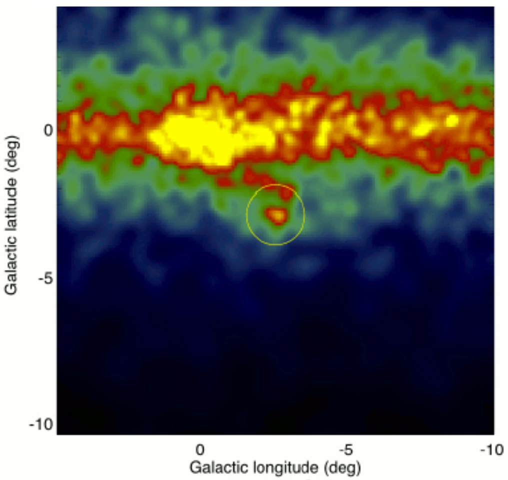
Fermi satellite and **GeV** γ-rays

$L_{\gamma\text{-rays}} = 100\ L_{sun}$

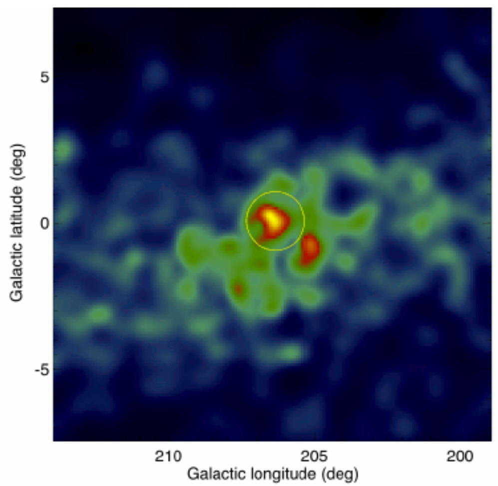
V407 Cyg (giant+WD) 2010



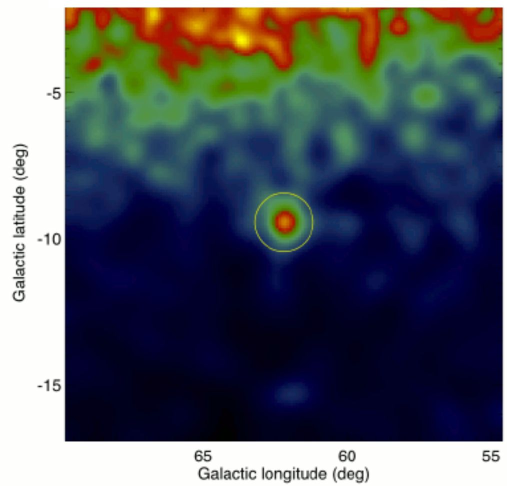
V1324 Sco (giant+WD) 2012



V959 Mon (dwarf+WD) 2012

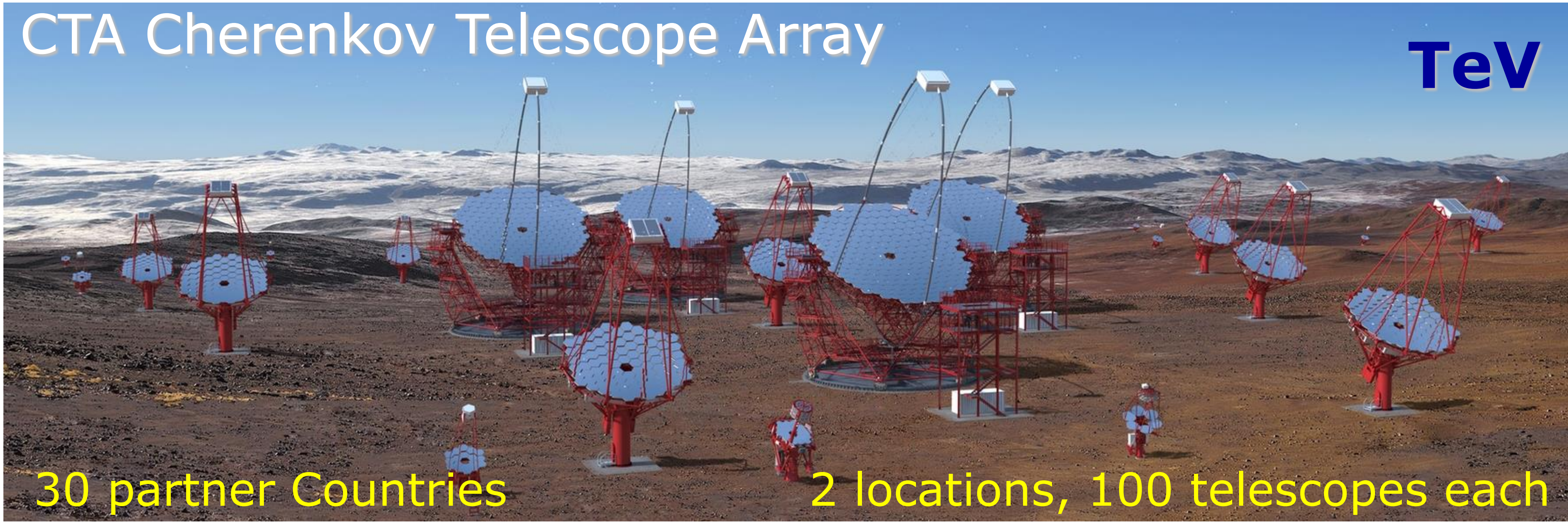


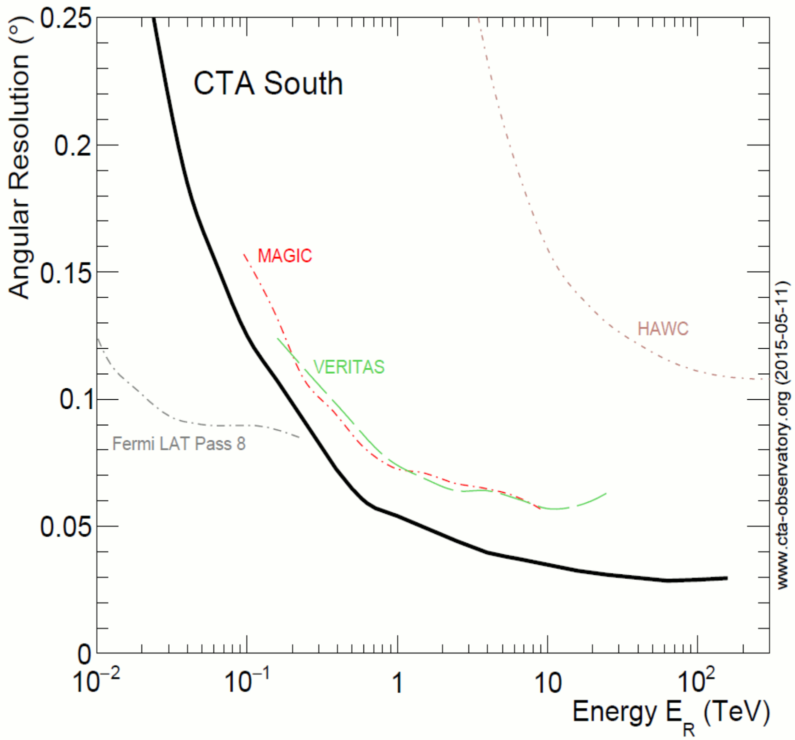
V339 Del (dwarf+WD) 2013

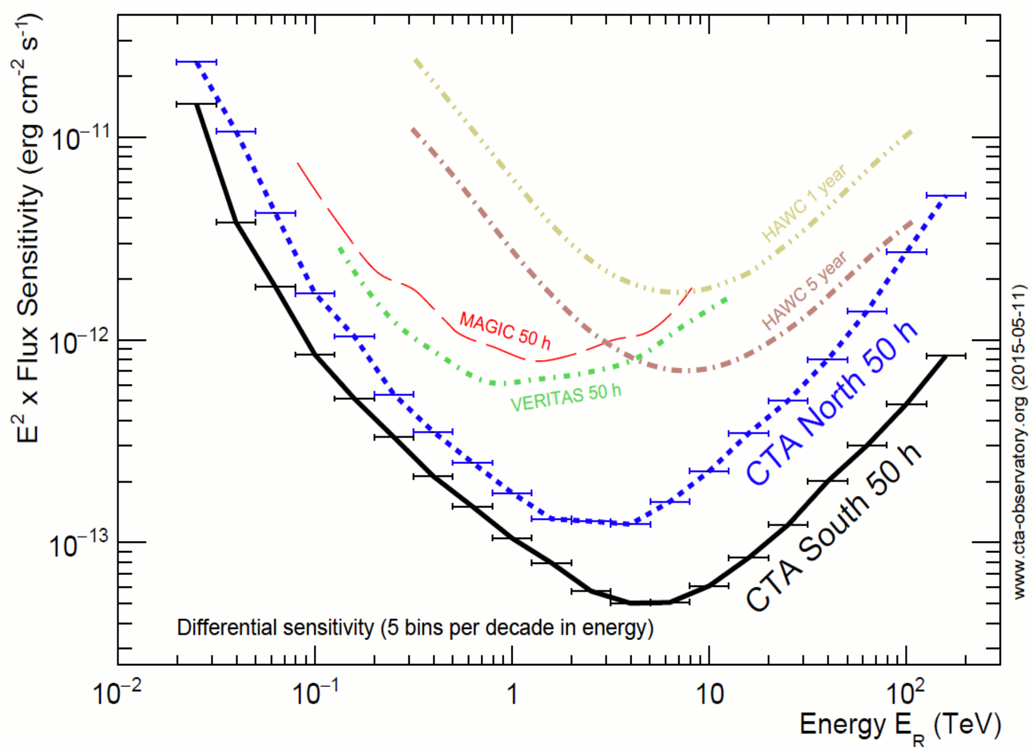


Ackermann et al. 2014

Nova	V407 Cyg 2010	V1324 Sco 2012	V959 Mon 2012	V339 Del 2013
Duration (days)	22	17	22	27
L_γ (10^{35} erg s^{-1})	3.2	8.6	3.7	2.6
Total energy (10^{41} erg)	6.1	13	7.1	6.0


CTA Cherenkov Telescope Array
TeV
30 partner Countries
2 locations, 100 telescopes each


CTA South
MAGIC
VERITAS
HAWC
Fermi LAT Pass 8
Angular Resolution (°)
Energy E_R (TeV)
www.cta-observatory.org (2015-05-11)


E^2 x Flux Sensitivity (erg cm^-2 s^-1)
HAWC 1 year
HAWC 5 year
MAGIC 50 h
VERITAS 50 h
CTA North 50 h
CTA South 50 h
Differential sensitivity (5 bins per decade in energy)
Energy E_R (TeV)
www.cta-observatory.org (2015-05-11)

CTA Precursors

Astri Miniarray →
(Italy, Brazil, South Africa)

2014, Etna Volcano Sicily

and what about the optical/NIR ?

it seems to me there is tendency for studies of novae based only on optical/NIR data:

- to deal with novae only on an object-by-object base
- to work individually or in small groups
- to force new observational results into old known classes and make use of seasoned relations/calibrations/classes
- lacking investment in theory explaining optical properties

to rub salt into the wound, traditional relations/measurements provided by optical observations are vulnerable to critics:

- existence of MMRD relations (i.e. $M_V = \alpha \log t_n + \beta$) questioned by Gaia DR2 (Schaefer arXiv 1809.00180)
- definition and measurements of rate of decline (t_2,t_3) and expansion velocity questioned by Özdönmez et al. (2018)

as a consequence:

- optical/NIR seems to contribute less and less to the "**big picture**" on novae
- it is (very) rare for optical data to take the lead in any paper where also radio, X-rays or γ-rays data are presented
- several of the adopted calibrations/classifications/classes/etc. are 30 or even 60 yrs old

yet:

- energy distribution of novae during the optically-thick phase peaks in the optical
- and meter-class optical/NIR telescopes are still the easiest to access daily for long time intervals

it is worth noticing that:

- communities at other wavelengths coordinate their efforts and collaborate much more than in the optical
- the inspiring example of [Swift-nova-cv]

and so ?

- optical/NIR standard observations of novae are no doubt worth and should be continued no matter what

however

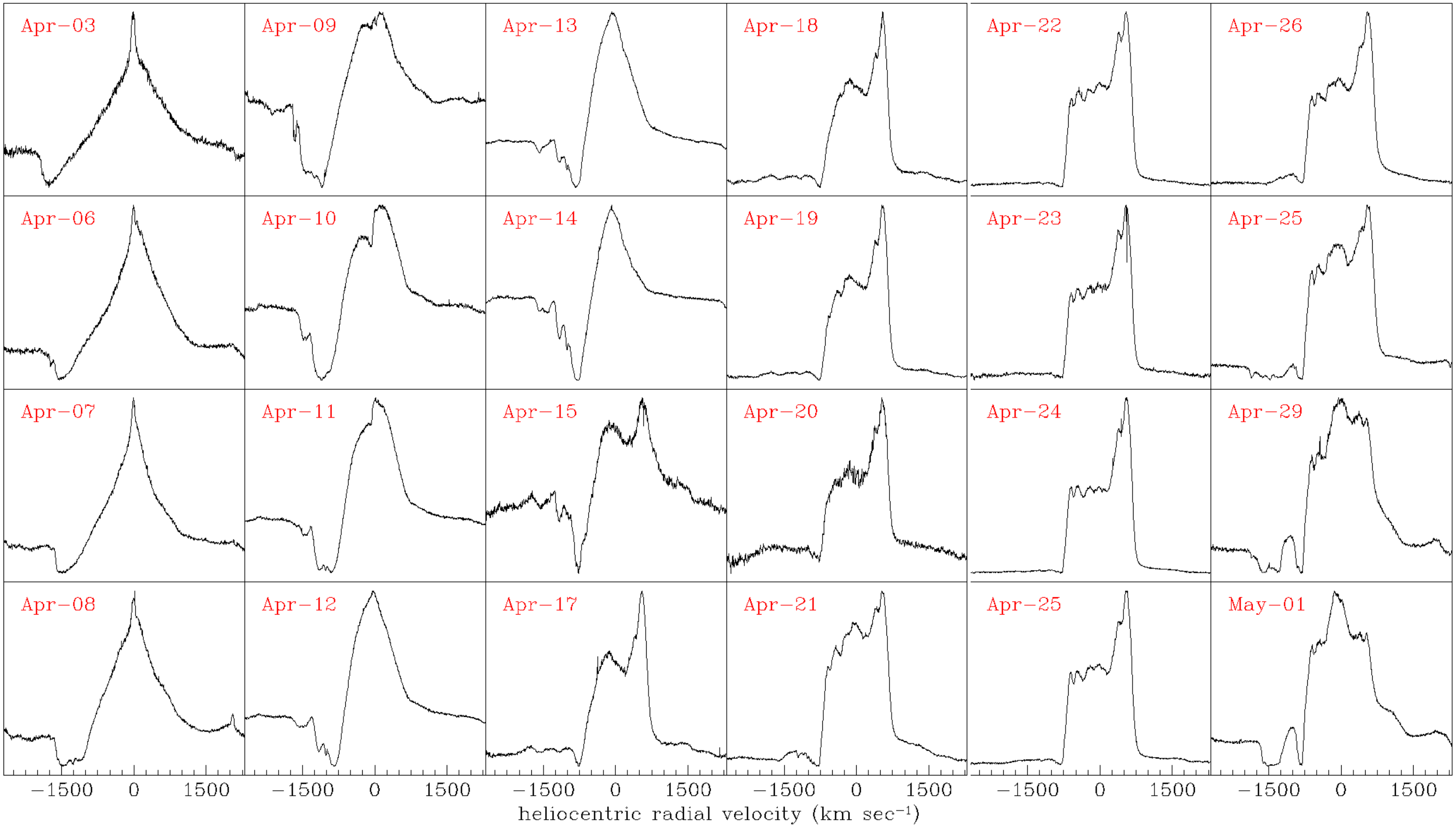
- to impact on the "**big picture**", optical/NIR people should
  - group into larger and coordinated entities
  - work on statistically large sets of novae
  - going "robotic" with their telescopes
  - invest on young/energetic PhD/post-docs
  - invest on theoretical modeling of unexplained phenomena exclusive of the optical/NIR range

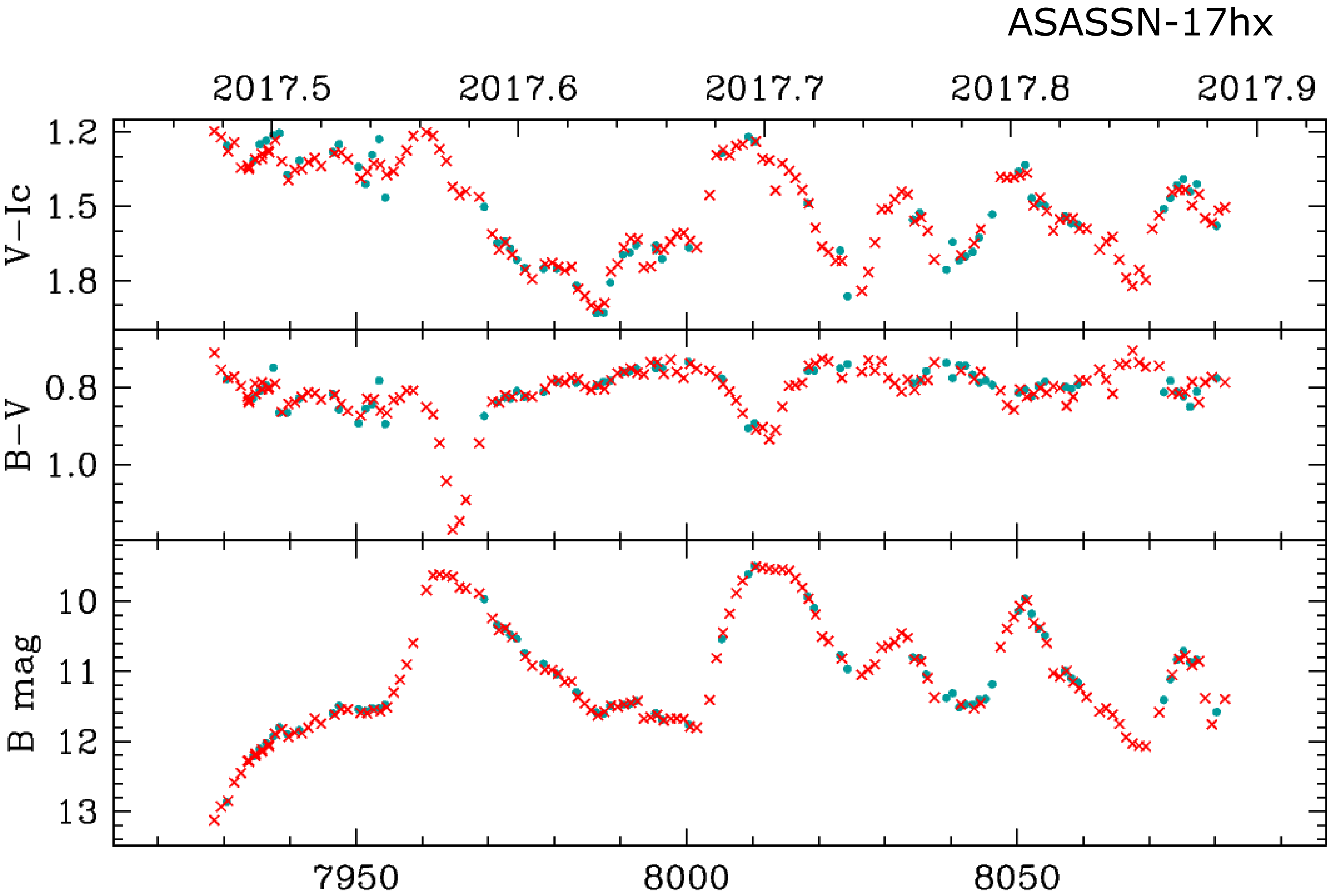
- achieving a "**critical mass**" is vital in placing succesfull proposals (expecially ToO) to large international facilities (e.g. VLT+UVES) or applying for E.U. grants to support young reserachers

- in optical observations, expecially long times series combining high resolution spectroscopy and very accurate UBVRI photometry, there is a lot more information that the little usually extracted

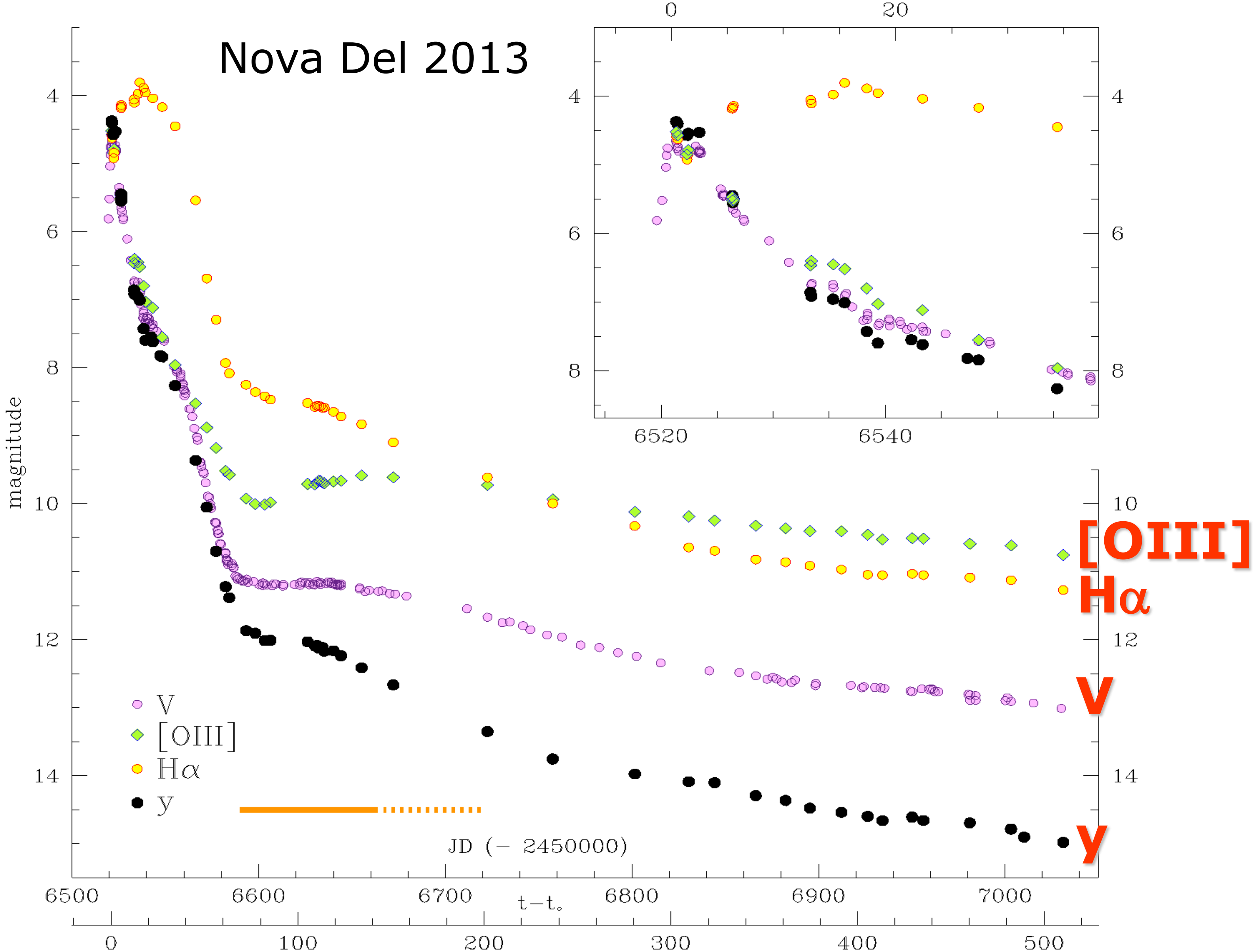
Nova Oph 2015

Hβ 4861




ASASSN-17hx
2017.5
2017.6
2017.7
2017.8
2017.9
V−Ic
1.2
1.5
1.8
B−V
0.8
1.0
B mag
10
11
12
13
7950
8000
8050

• a mix of medium+narrow bands allows to separate the photometric information stored in the continuum from that in the emission lines, irremediably mixed together by conventional broad-band data



- there are many uncharted areas where optical/NIR data still enjoy a *low* level of competition from observations at other wavelengths ranges

- this may not last for long tough, so let’s group together and face them full spead ahead

- as said earlier, no chance to solve them by looking isolately one nova at a time, apart from all others

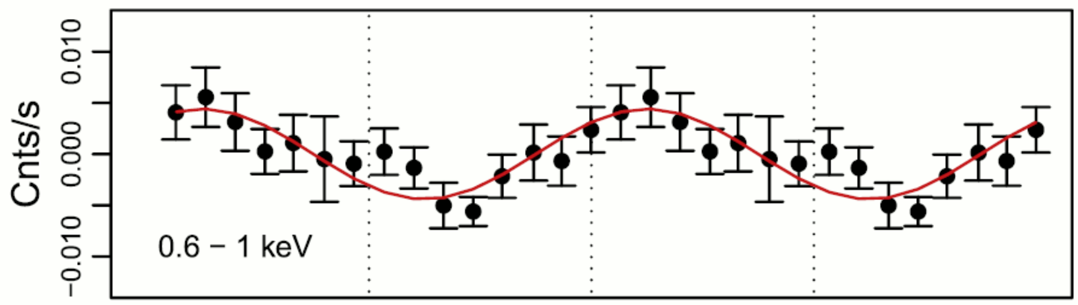
- need investing in ad hoc theoretical efforts

- a few example – among many more – for a rejuvenated optical/NIR all-out effort on novae: →

magnetic field signatures, I.P. novae

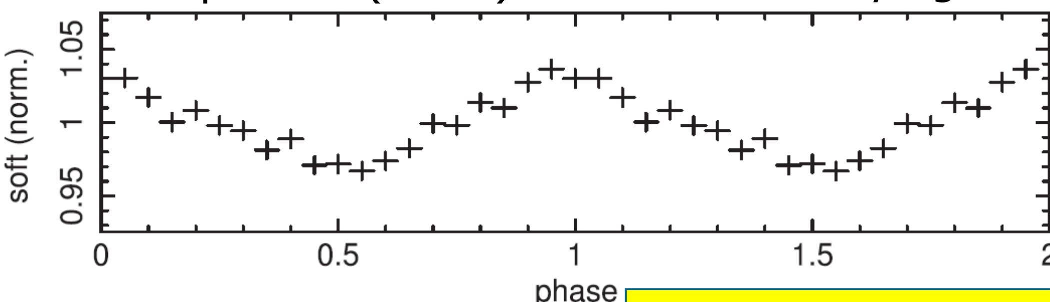
N Cyg 2008 N.2 (V2491) *Swift* X-ray lightcurve P=38 min

Zemko et al. 2015



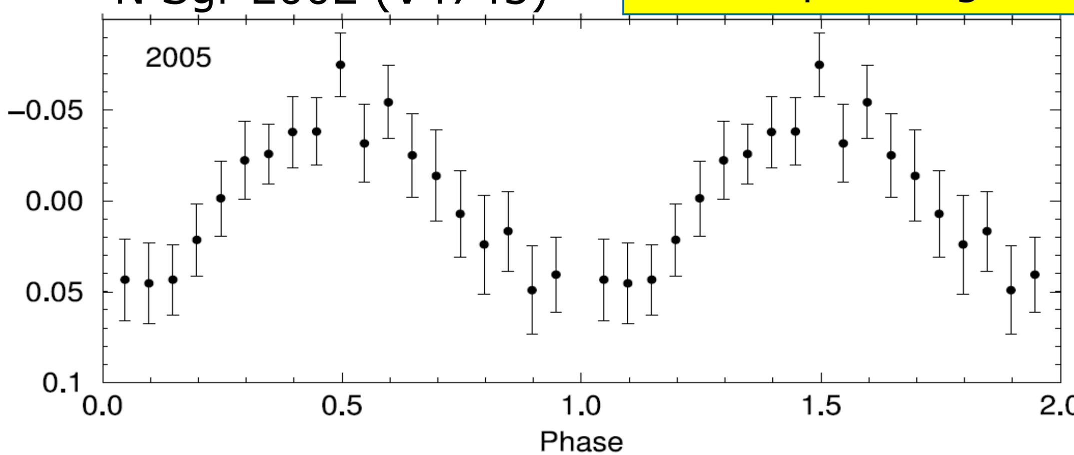
N Lup 2016 (V407) *XMM* X-ray lightcurve P=9 min

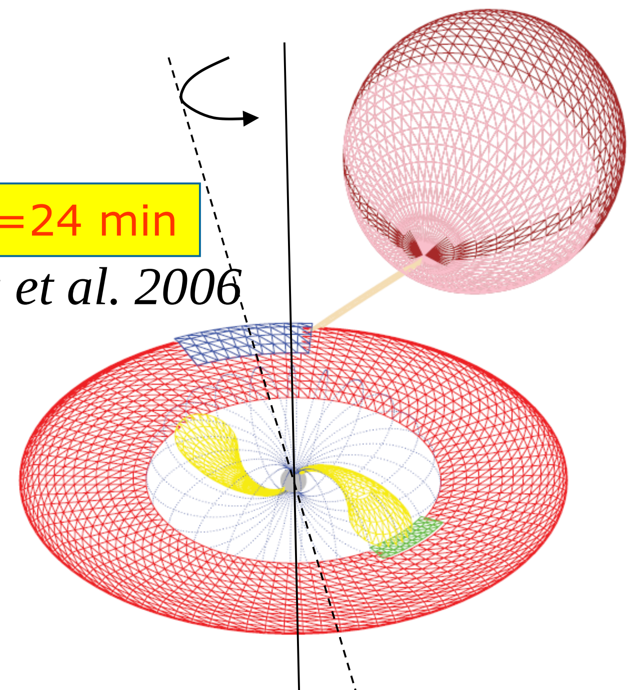
Aydi et al. 2018



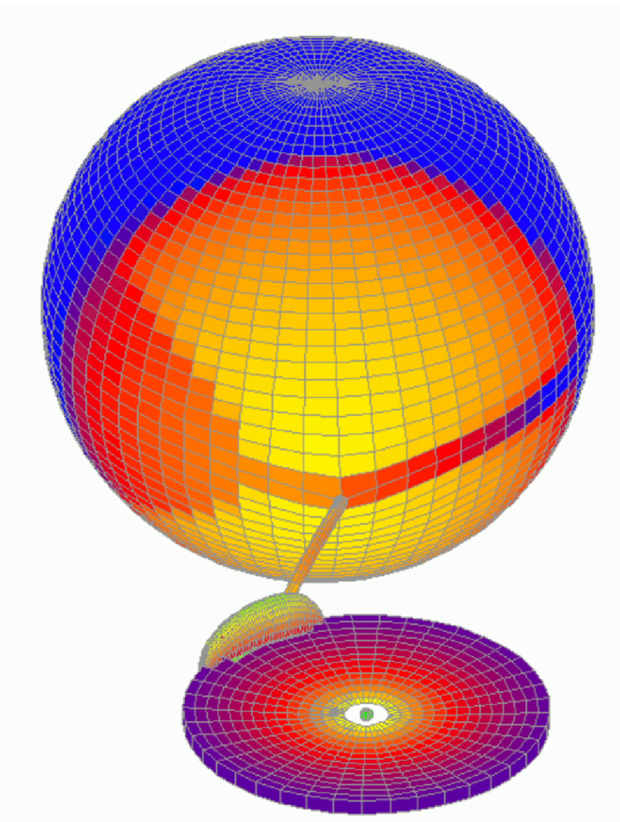
N Sgr 2002 (V4743) *30cm* optical lightcurve P=24 min

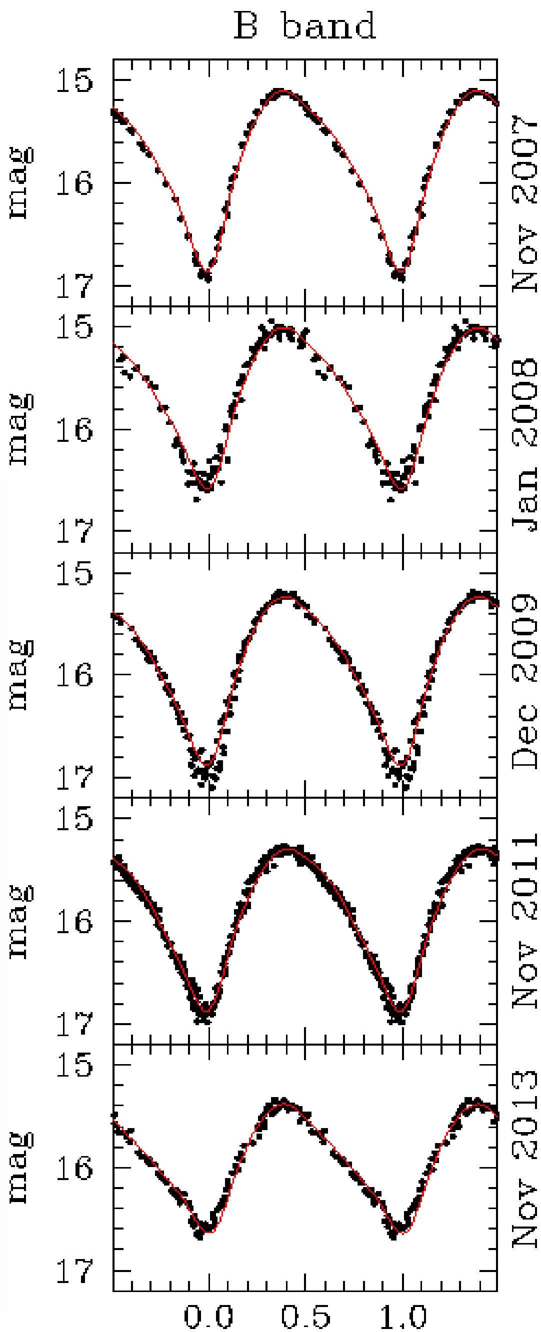
Kang et al. 2006





irradiated secondaries and amount of mass transfer in quiescence



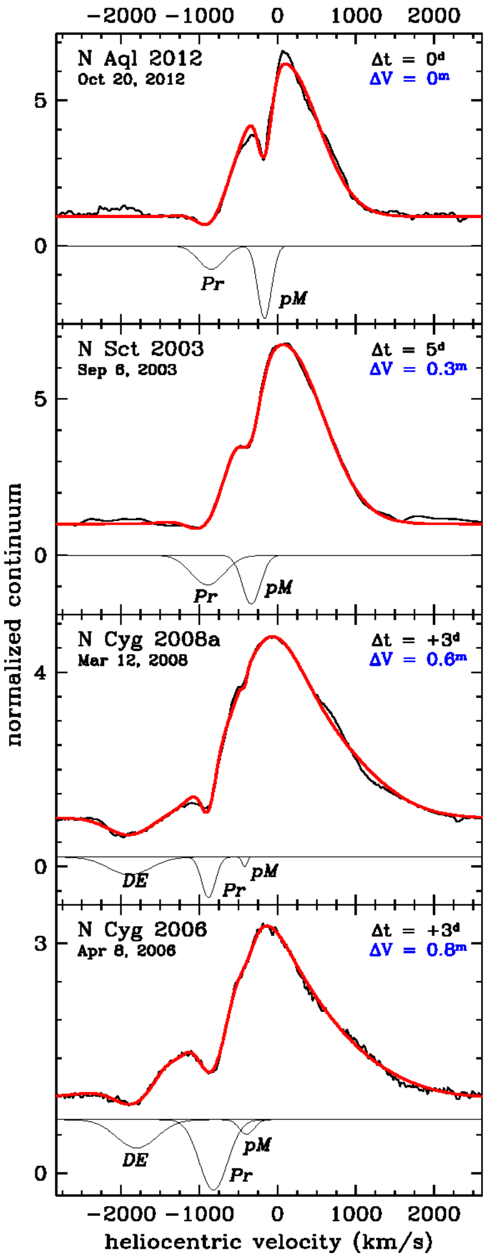


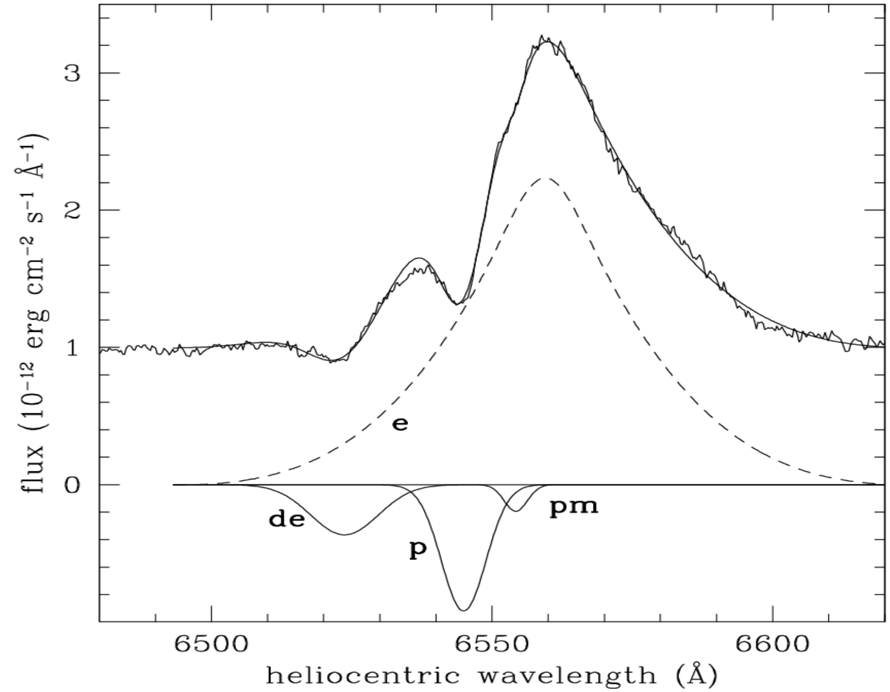
	2007 Nov	2008 Jan	2009 Dec	2011 Nov	2013 Nov
Period (days)	0.693266				
Distance (Kpc)	3				
Orb. incl. (°)	61				
E(B-V)	0.60				
WHITE DWARF					
Mass ($M_\odot$)	0.75				
Radius ($R_\odot$)	0.03				
Teff (kK)	315	325	290	275	255
COMPANION STAR					
Mass ($M_\odot$)	0.56				
Teff (K)	5500				
Limb dark.	0.3				
Re-thermalized	50%				
ACCRETION DISK					
Angular aper. (°)	5				
Ext. radius ($R_\odot$)	0.88	0.87	0.85	0.83	0.82
Teff outer rad. (K)	7500	7800	8000	8300	8700
Gamma	1.5				
Limb dark.	0.2				
Stream diameter(?)	0.06				
Overflow	no				
HOT SPOT					
Teff peak (kK)	60	61	61	62	63
Limb dark.	0.2				
Thickness ($R_\odot$)	0.15	0.17	0.17	0.20	0.22
Angular aper. (°)	27	28	27	26	25
Angle1 (°)	190	190	195	195	180
Angle2 (°)	205	210	210	210	215
Angle3 (°)	275	275	270	270	260
Temp1	0.1	0.9	0.1	0.1	0.7
Temp3	0.65	0.65	0.6	0.6	0.5

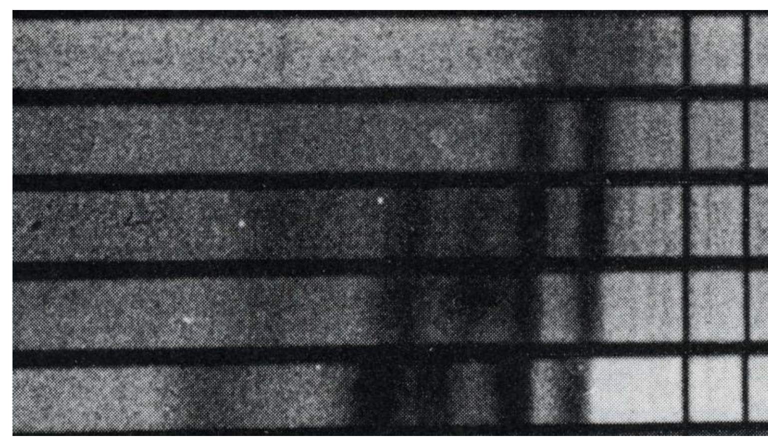
Frigo and Munari 2018

origin, location and physics of absorption systems in FeII novae

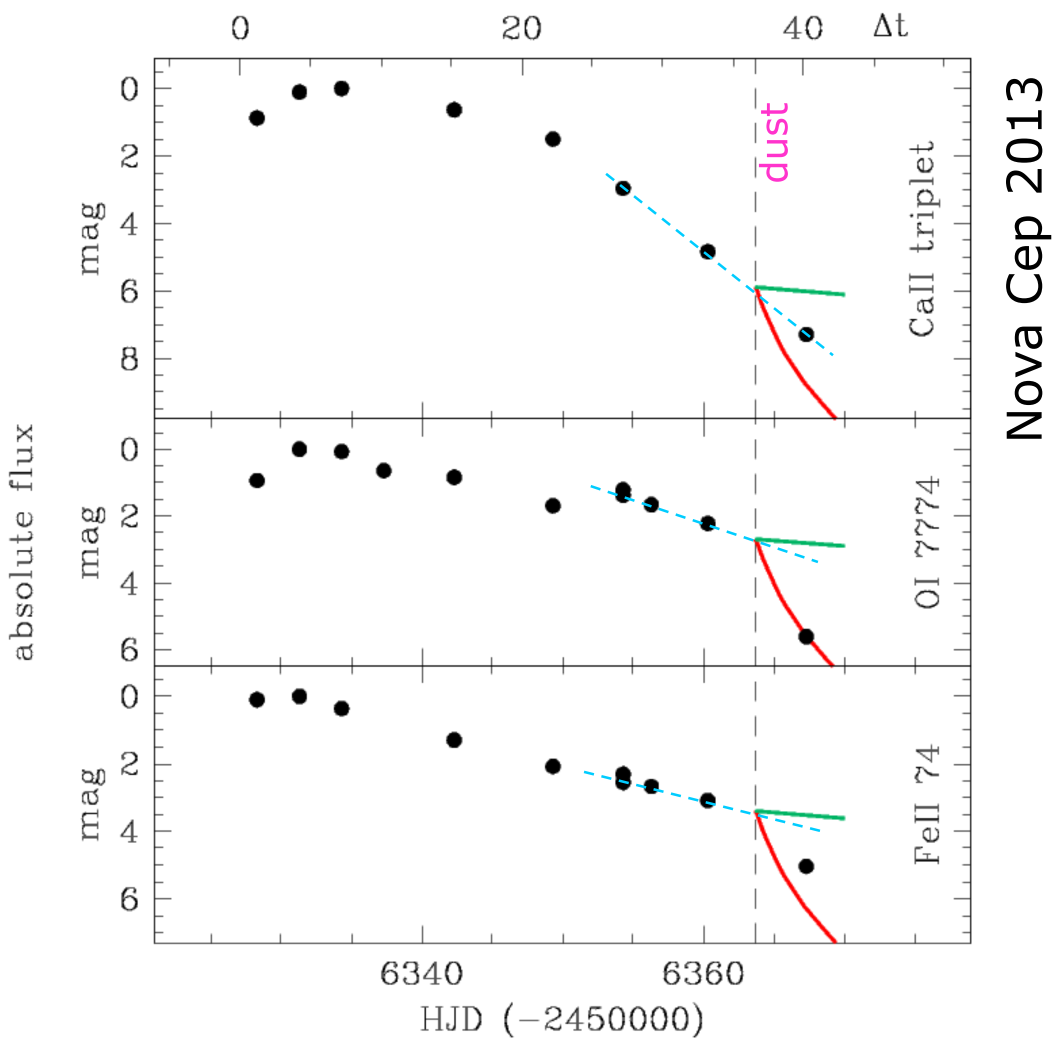
- pre-max
- principal
- diffuse enhanced
- Orion

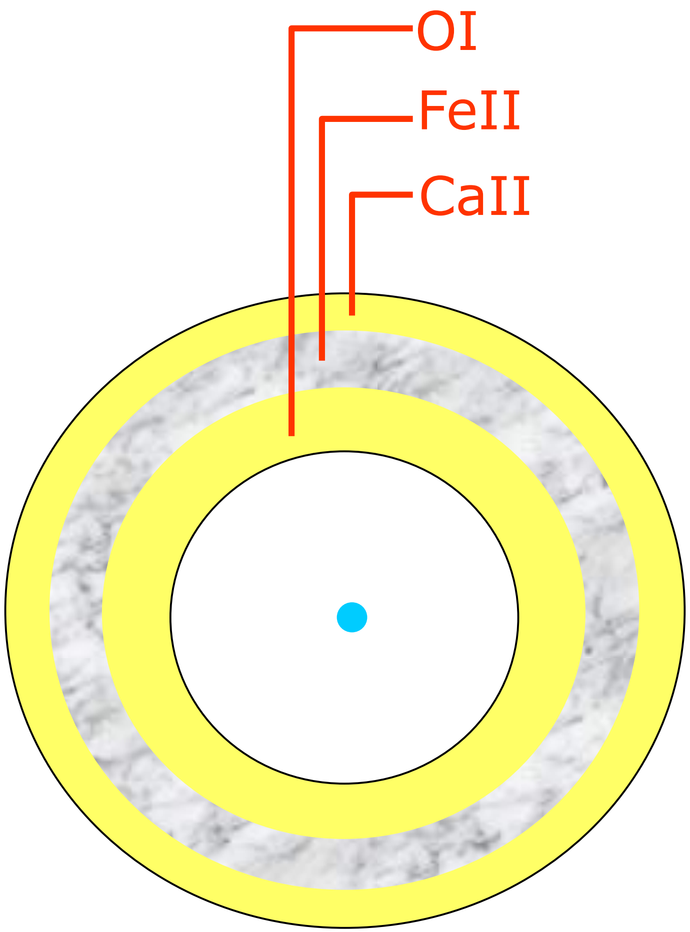






location of dust forming regions from changes in the integrated emission line profiles

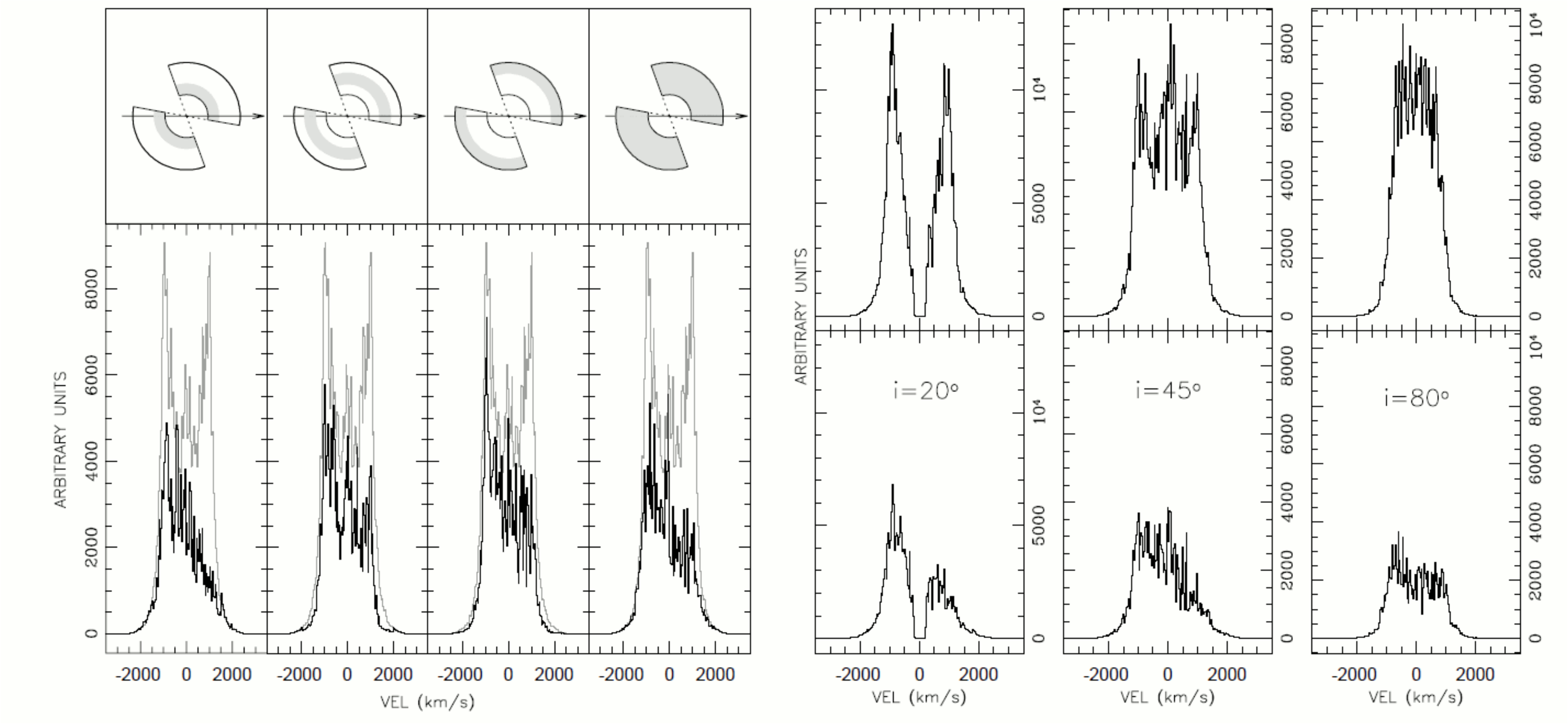




forthcoming dust formation predictable from presence of { MgI 1.504, 1.711 μm; NaI 2.206, 2.208 μm }

Munari et al. 2014

location/shape of dust forming regions from deformation of emission line profiles

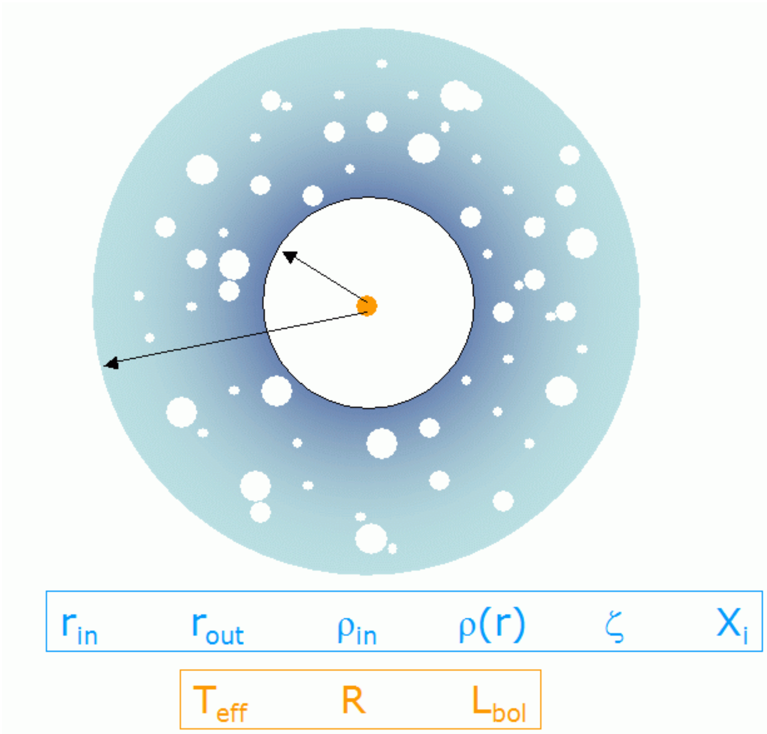


Shore et al. 2018

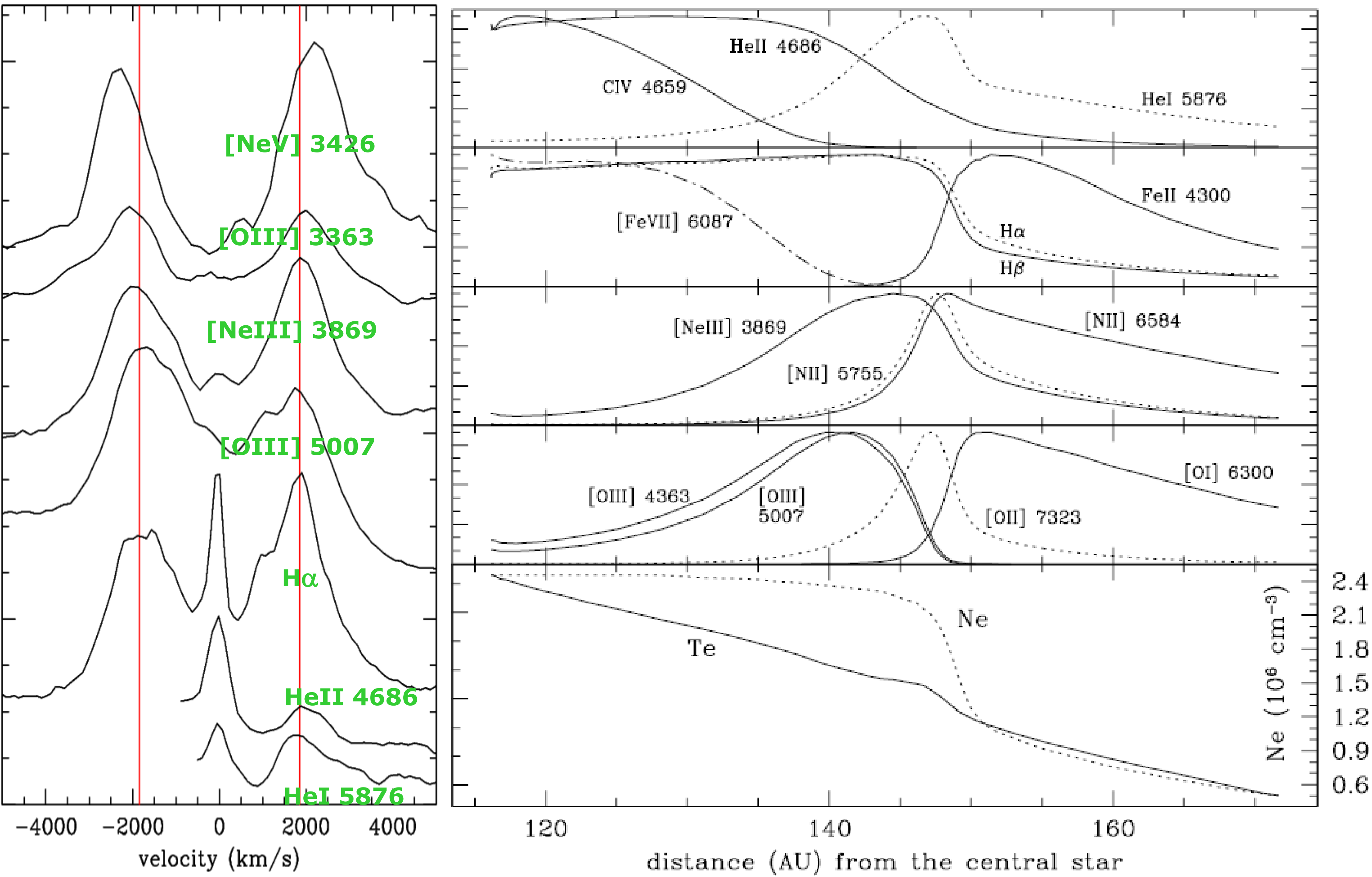
photo-ionization analysis + high resolution profiles
$\longrightarrow$ chemistry and 3D spatio-kinematics structure of ejecta

line	*obs*	*comp*
$H\alpha$ + [NII] 6548-84	4.50	3.40
$H\beta$	1.00	1.00
$H\gamma$ + [OIII] 4363	1.96	3.27
$H\delta$	0.36	0.29
$H\epsilon$		0.19
H8	0.20	0.13
5876 HeI	0.14	0.14
7065 HeI	0.06	0.08
4686 HeII	0.20	0.14
4679 NII	0.06	0.07
5755 [NII]	1.95	1.70
4640 NIII	0.38	
6300 [OI]		
7325 [OII]	0.70	0.57
4959 [OIII]	1.32	1.16
5007 [OIII]	4.30	3.40
3869 [NeIII]	0.10	0.12
4720 [NeIV]	0.005	0.0045
7135 [ArIII]	0.016	0.016
7236 [ArIV]	0.0013	0.0016
7006 [ArV]	0.0024	0.0023
6087 [FeVII]	0.007	0.007

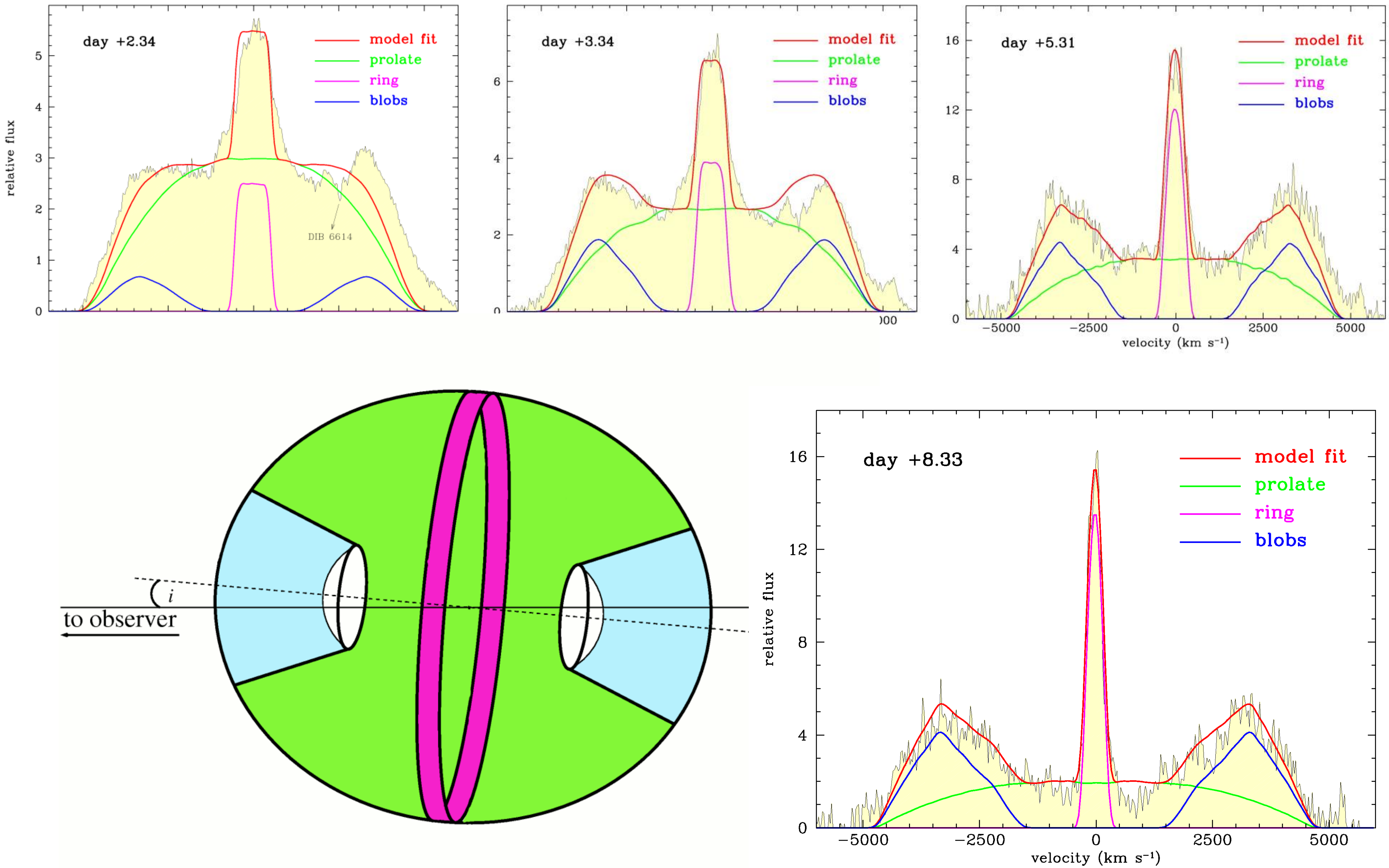
$\log T_{\rm BB}^{\rm eff}$ (K)	5.236
$\log R_{\rm BB}$ (cm)	10.14
$\log r_{\rm in}$ (cm)	15.35
$\log r_{\rm out}$ (cm)	15.40
$\log \rho_{\rm in}^{H}$ (cm^{-3})	7.781
$\log \rho_{\rm out}^{H}$ (cm^{-3})	7.874
$\log N_{\rm in}^{e}$ (cm^{-3})	8.00
$\log N_{\rm out}^{e}$ (cm^{-3})	5.00
ξ	0.12
$H/H_\odot$	0.80
$He/He_\odot$	0.87
$N/N_\odot$	316
$O/O_\odot$	26
$Fe/Fe_\odot$	1.0
$Ar/Ar_\odot$	1.0
$Ne/Ne_\odot$	1.0



Munari et al. 2008


[NeV] 3426
[OIII] 3363
[NeIII] 3869
[OIII] 5007
Hα
HeII 4686
HeI 5876
-4000
-2000
0
2000
4000
velocity (km/s)
HeII 4686
CIV 4659
HeI 5876
FeII 4300
[FeVII] 6087
Hα
Hβ
[NeIII] 3869
[NII] 6584
[NII] 5755
[OIII] 4363
[OIII] 5007
[OI] 6300
[OII] 7323
Ne
Te
2.4
2.1
1.8
1.5
1.2
0.9
0.6
Ne (10^6 cm^{-3})
120
140
160
distance (AU) from the central star

ejecta 3D structure from kinematical disentangling



Munari et al. 2015