


[Ten to the] Fifty-One Ergs (22 May 2019)

Confirmation of the D⁶ Type Ia supernova scenario with hypervelocity white dwarfs in *Gaia* DR2

Ken Shen (UC Berkeley)
+Andrews, Chomiuk, Badenes, Miles, Townsley, et al.



[Ten to the] Fifty-One Ergs (22 May 2019)

Do Dynamically Driven Double Degenerate Double Detonations Drive Dwarf Death? Definitely!

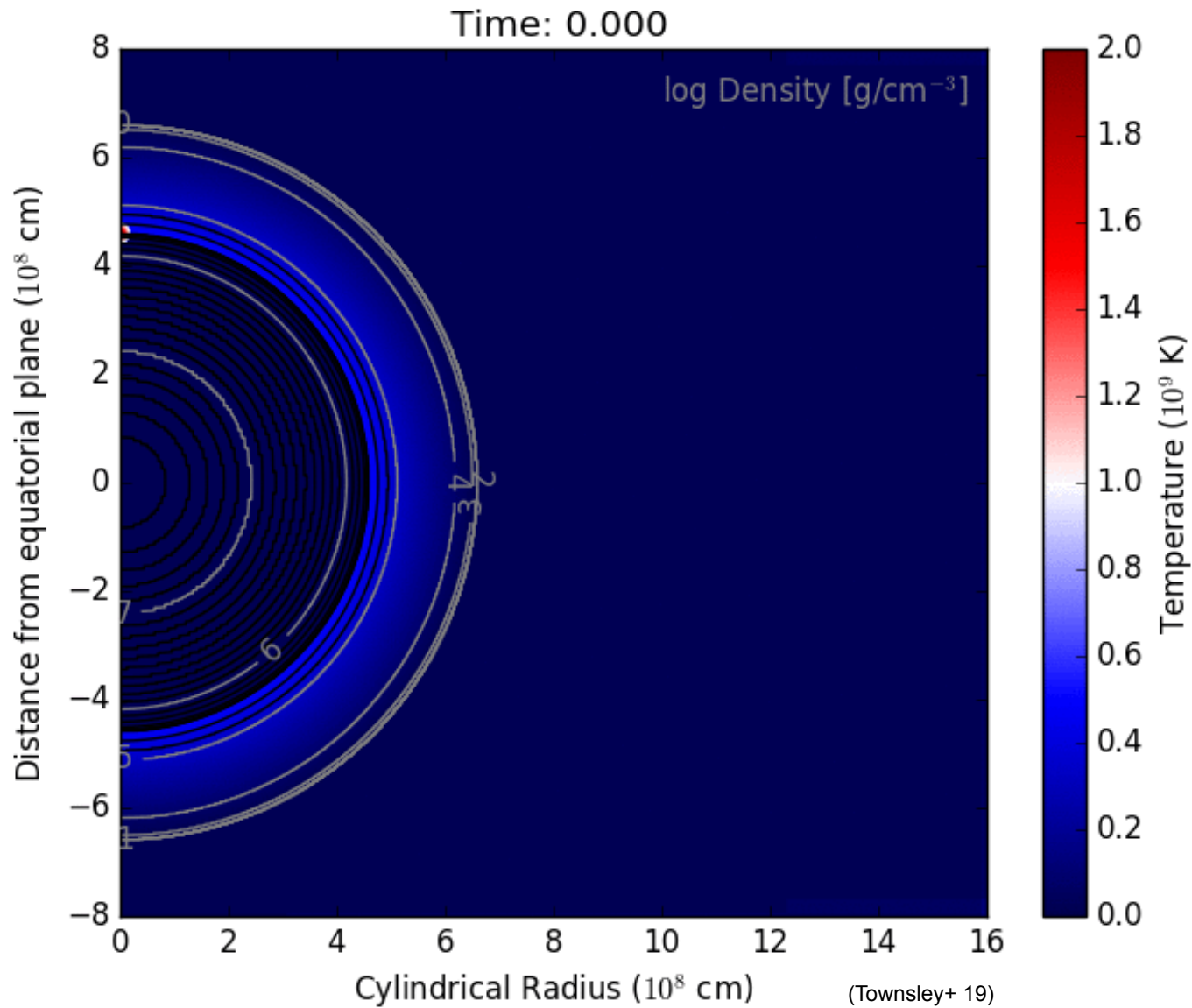
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The landscape of SN Ia progenitor scenarios

Explosion mechanism Companion, Mass transfer	M_{Chandra} , core convection, deflagration-detonation	Sub- M_{Chandra} , He detonation, then C detonation
H-rich Stable \dot{M}	“Single degenerate” (Whelan & Iben 73)	
He-burning star Stable \dot{M}	“Single degenerate” (Yoon & Langer 03)	“Double detonation” (Taam 80; Nomoto 82; Woosley+ 86)
He WD Stable \dot{M}		“Double detonation” (Bildsten+ 07; Fink+ 07)
He WD Unstable \dot{M}		“Double detonation; D ⁶ ” (Guillochon+ 10)
C/O WD Unstable \dot{M}	“Double degenerate” (Webbink 84; Iben & Tutukov 84)	“Double detonation; D ⁶ ” (Dan+ 11; Pakmor+ 13)

- And others: tidal disruptions by BHs (Rosswog+ 09), WD+WD collisions (Raskin+ 10, Katz+ 12), violent merger / spiral instability (Pakmor+ 10, Kashyap+ 15)

Sub- M_{Chandra} double detonations

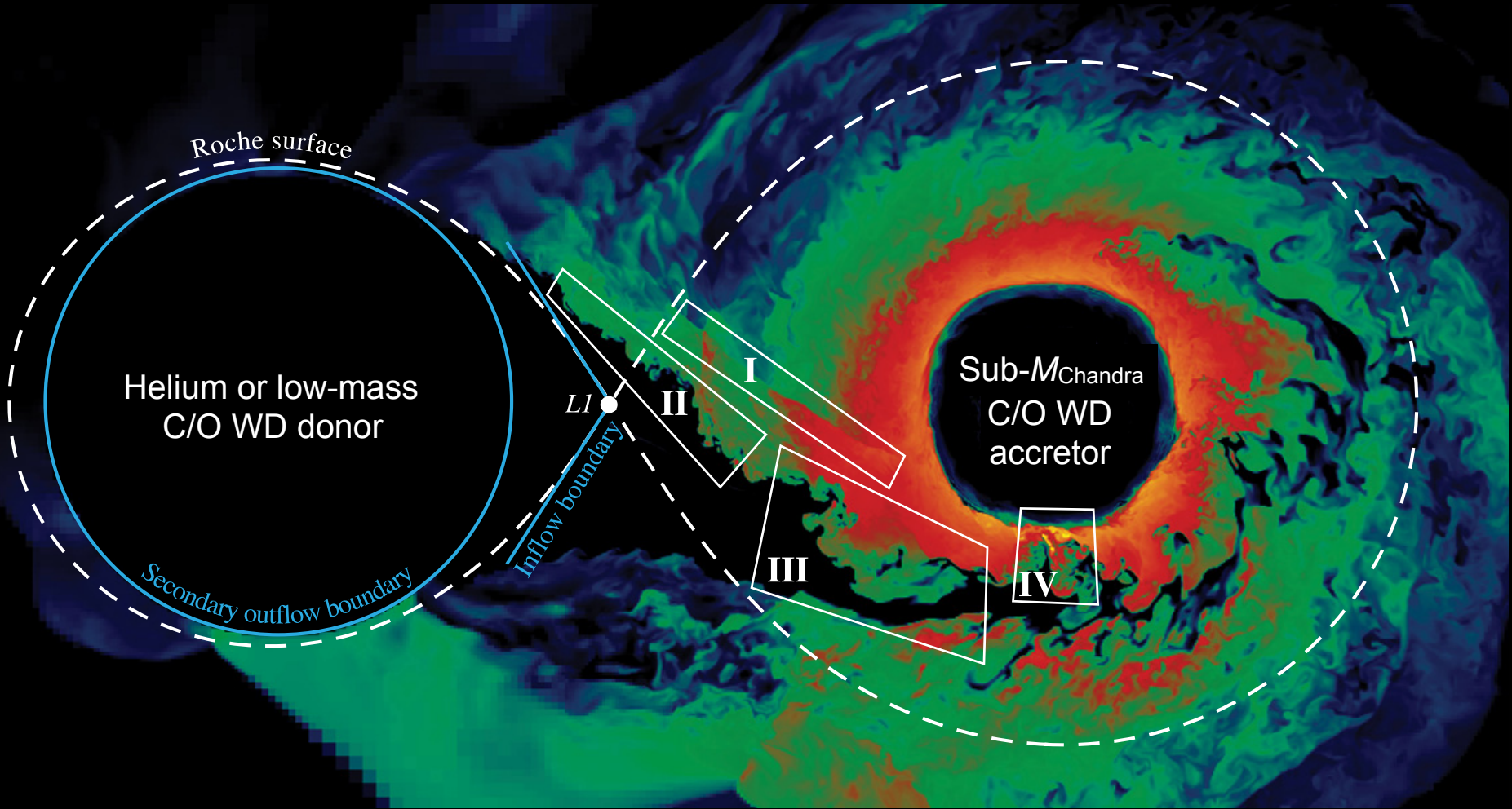


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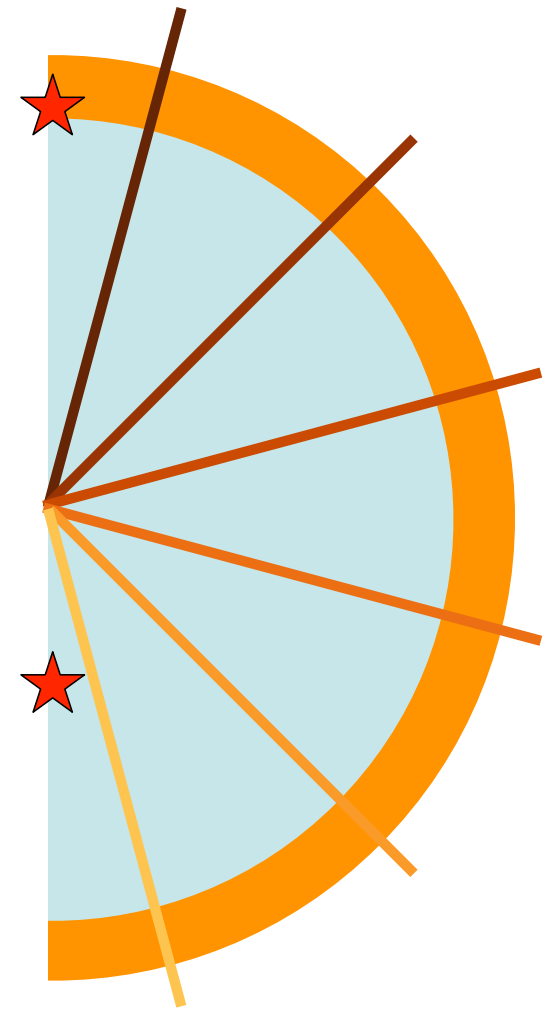
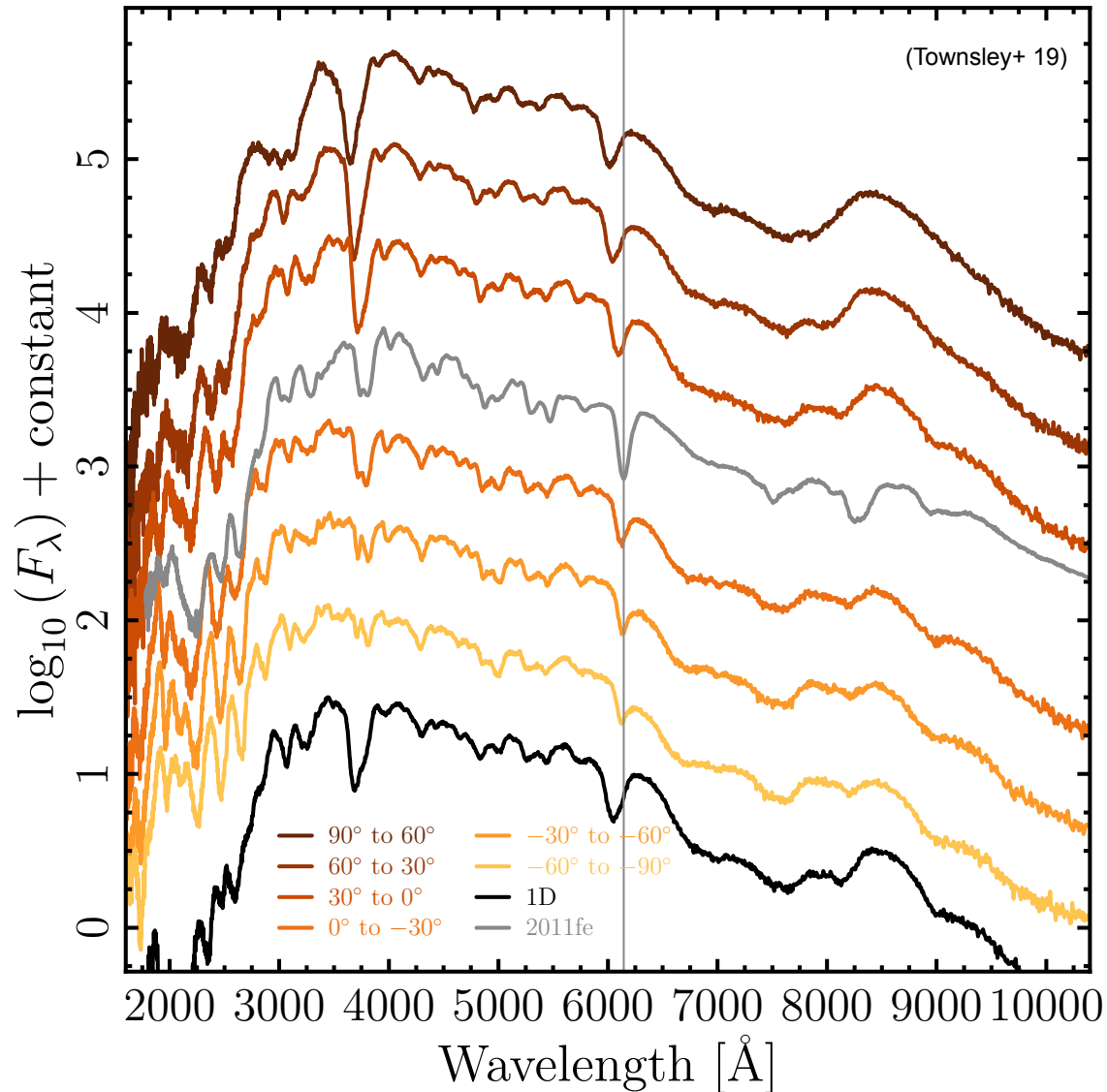
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Dynamically driven double degenerate double detonations (D^6)



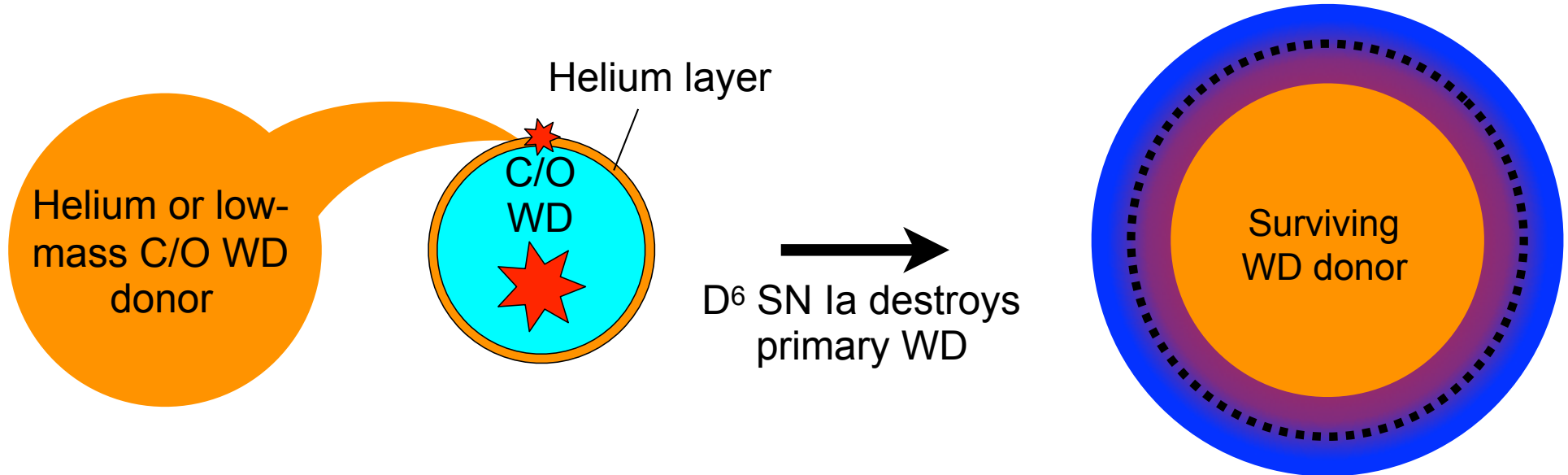
(Guillochon+ 10)

Multi-D + helium shell + large net in LTE (1.0 + 0.02 Msol)



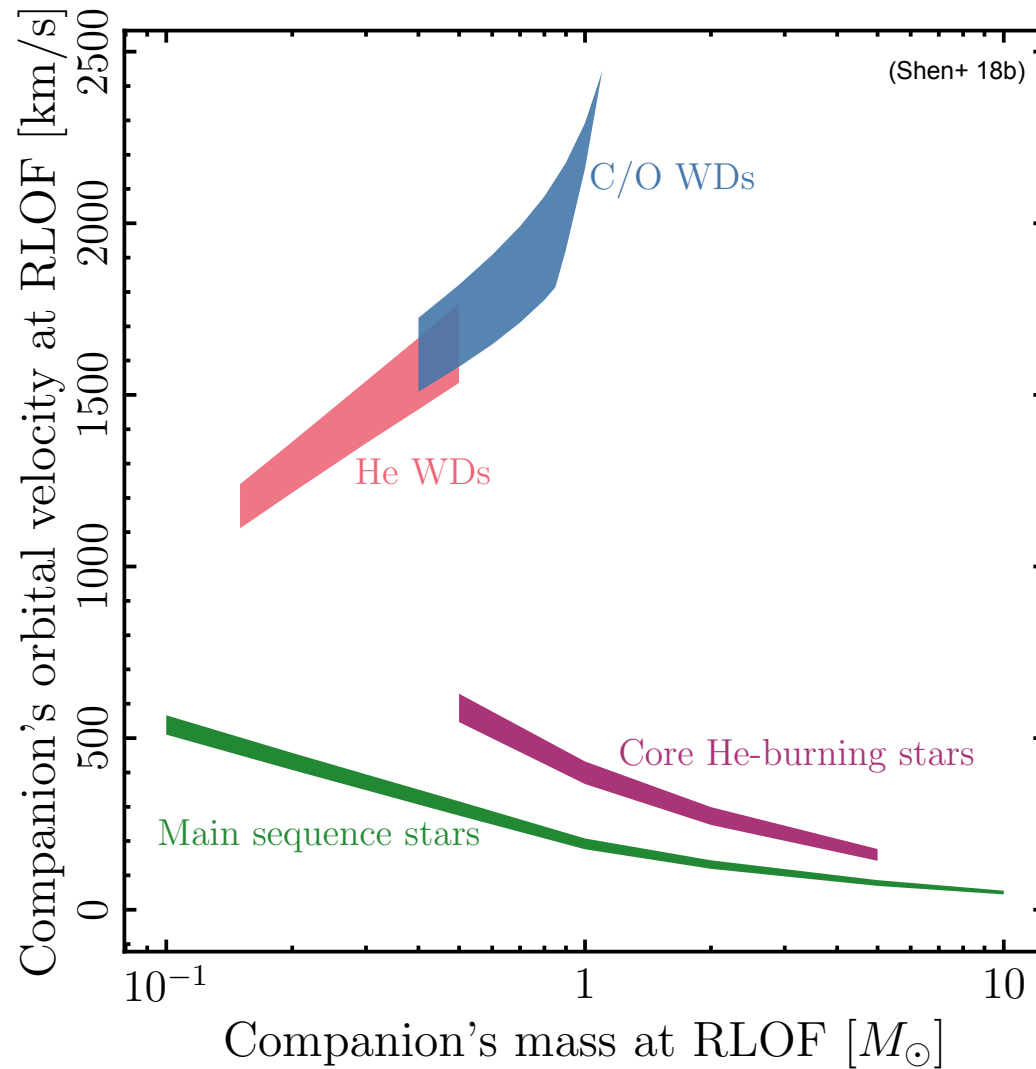
- Reasonable spectra, but light curves evolve too rapidly:
combination of multi-D + non-LTE + large network + helium shell?
- See Dean's poster (#24)! And Abi's and Fernando's posters (#18 and 14) for related work

Surviving WD donors from D⁶ SN Ia systems



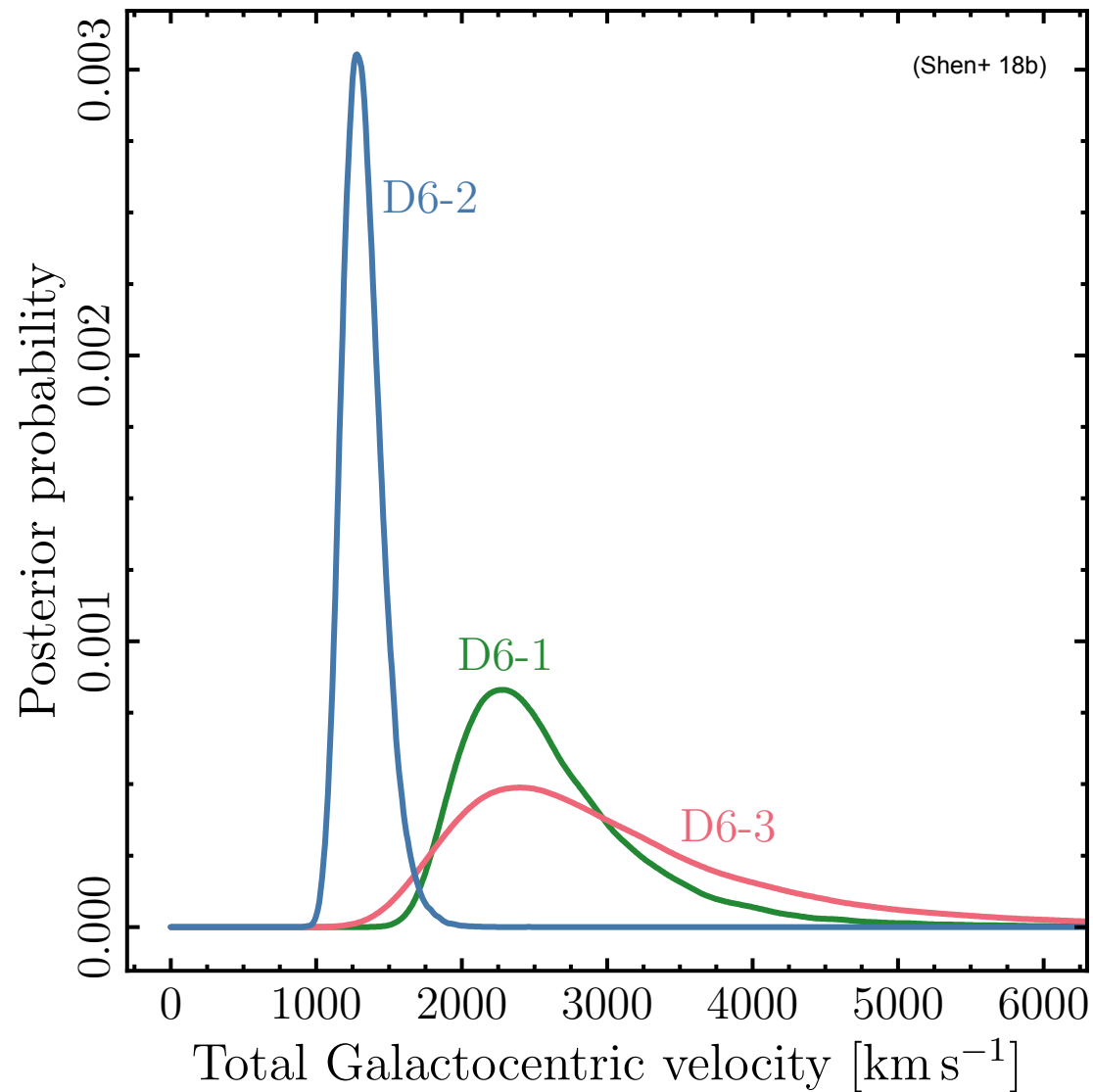
- Ignition can happen before companion fully disrupted
 - Avoids excess asymmetry, polarization of complete merger
 - **Companion WD might survive explosion**

Hypervelocity runaway D⁶ survivors



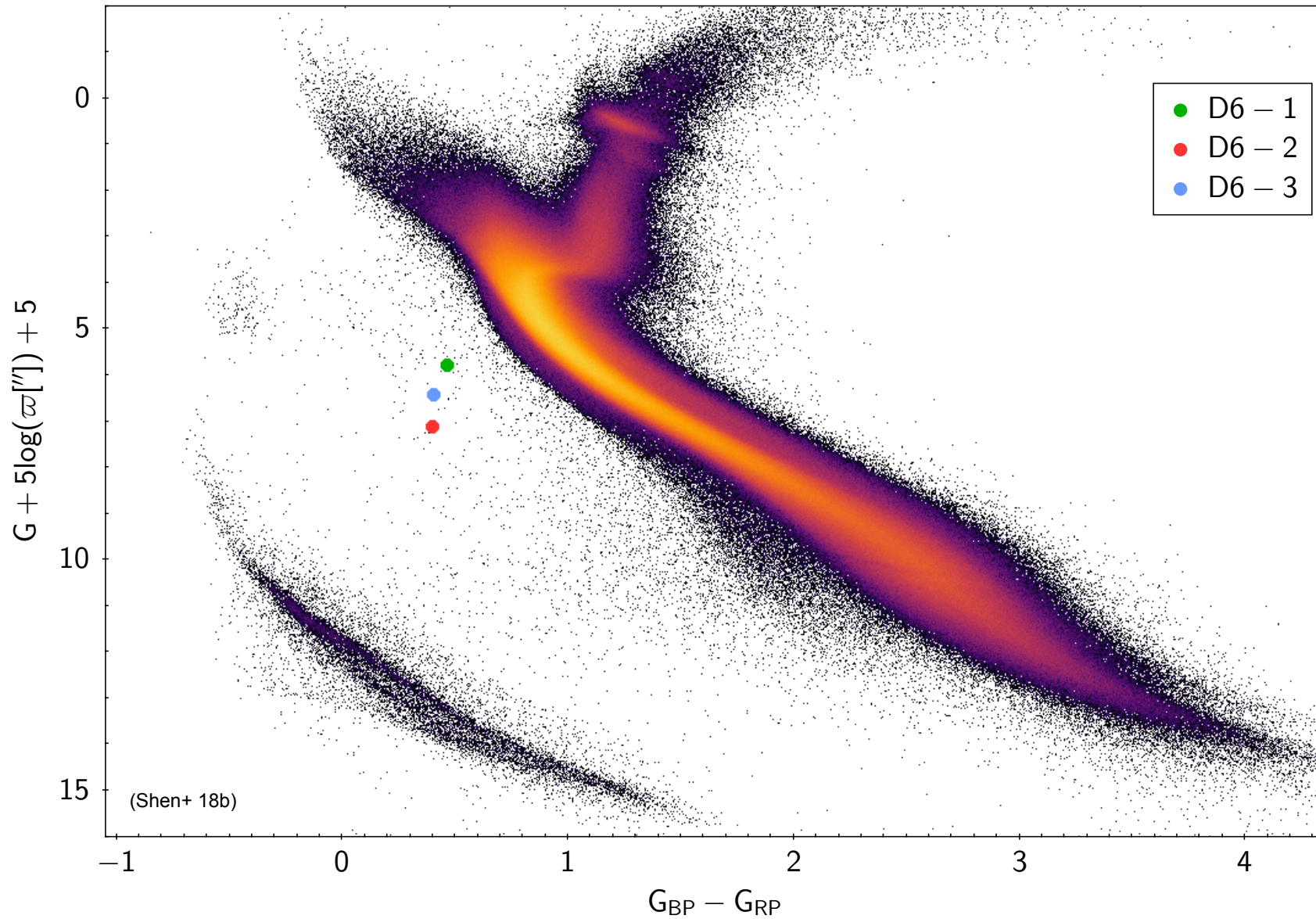
- ~25 within 1 kpc, 300-400 within 2.5 kpc
- *Gaia* DR2 search: Shen +Andrews, Chomiuk, Badenes, Miles, Townsley, et al. 18

The fastest unbound stars in the Milky Way



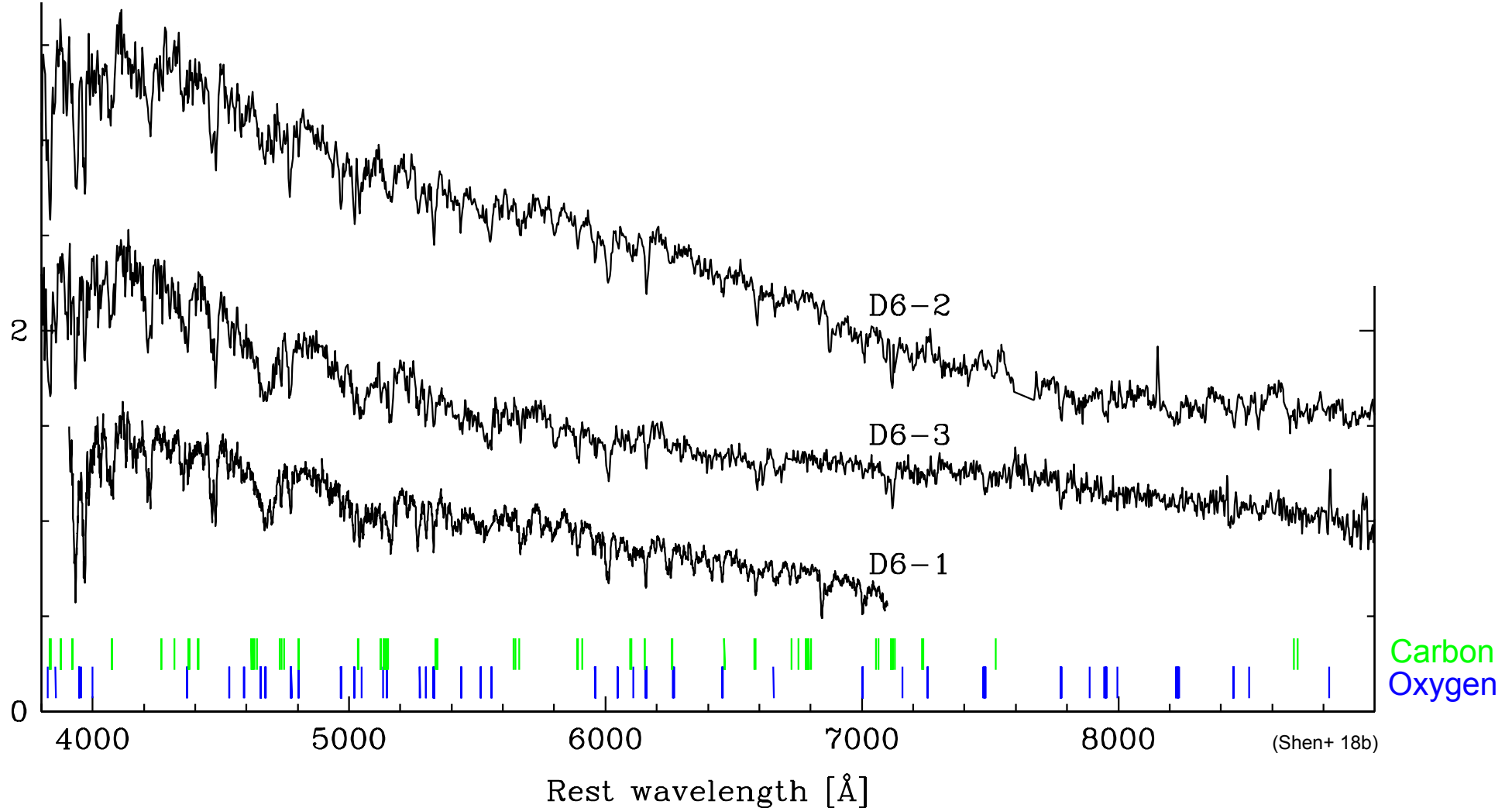
- 1000 - 2500 km/s ($\sim 0.02e^{51}$ erg!), consistent with WD companion in WD+WD system
- Not ejected from Galactic center

Similar and unique CMD positions



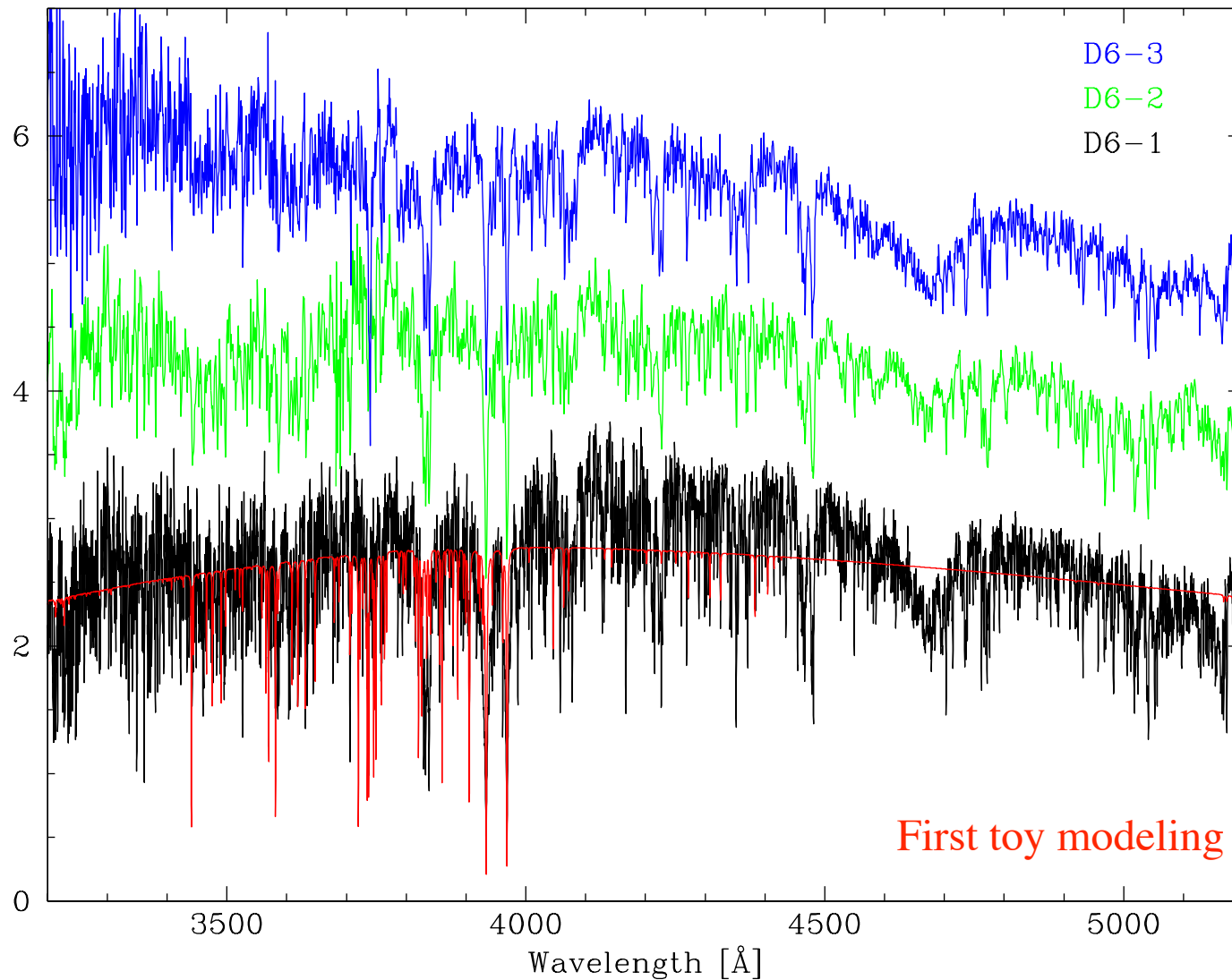
- Not on the WD cooling track ... energy injection during / after unstable mass transfer?

Similar and unique spectra



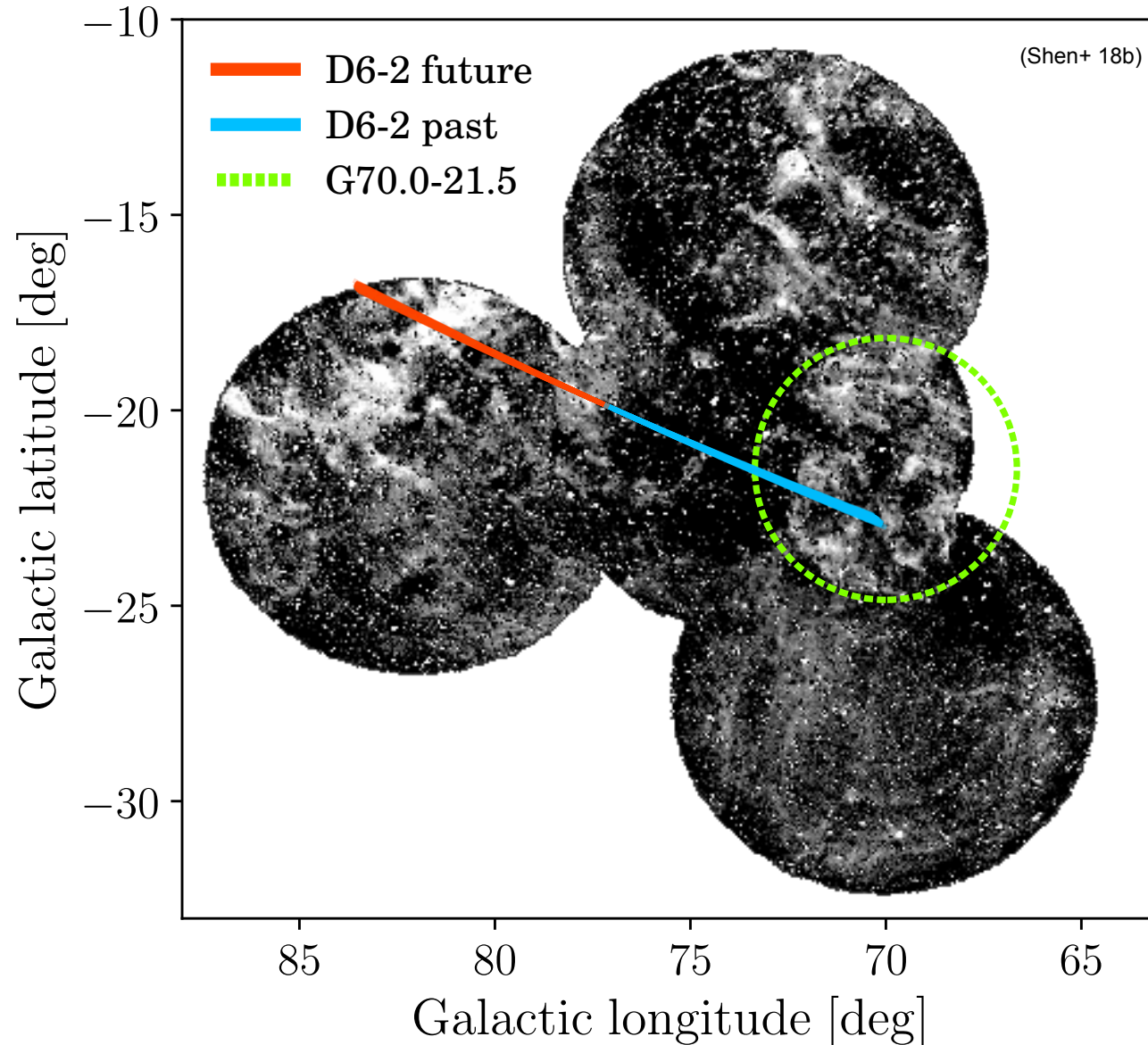
- As expected: no H; strong C, O, Mg, Ca, and Fe!
- Have high-res spectra, but $\log(g)$, T_{eff} , abundances, etc. need UV spectra to break degeneracies

Similar and unique spectra



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And one comes from a SN remnant!



- Fesen et al. (2015): farthest off the plane → SN Ia?
- Age matches travel time; distance also consistent
- The only D^6 star with high-resolution H-alpha

Summary

- Sub- M_{Chandra} double detonation simulations reproduce overall observations
 - But some deviations from observations
 - Non-LTE + multi-D work may solve these issues (hopefully!)
 - See posters #14, 18, and 24
- ***For the first time, we have detected SN Ia surviving companions!***
 - Three stars picked only for velocity: same part of CMD, very similar and unique spectra, with predicted compositions
 - And one comes from a likely SN Ia remnant with matching age and distance
 - ***Dynamically driven double degenerate double detonations do definitely drive dwarf death!***
- Future work & remaining mysteries:
 - UV spectroscopic follow-up for abundances, atmospheric parameters, M , R
 - Modeling of the high-resolution spectra: do abundances match sub-Chandra yields?
 - Do the others have associated SN remnants?
 - What is the current structure of the D^6 stars? Stellar evolution and explosion calculations, high-cadence photometry to look for pulsations
 - What is their future evolution? Where are the other 300-400? Are these just the three brightest ones? ***Do dynamically driven double degenerate double detonations dominate dwarf death?***