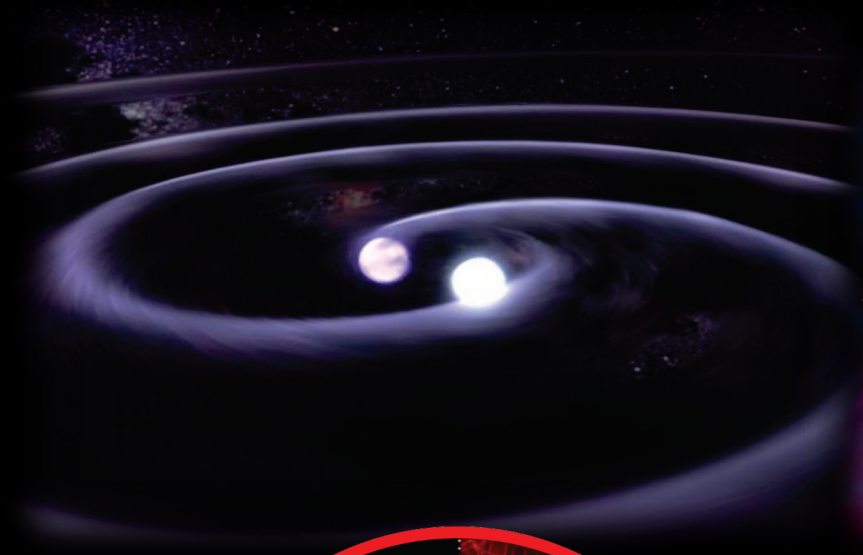
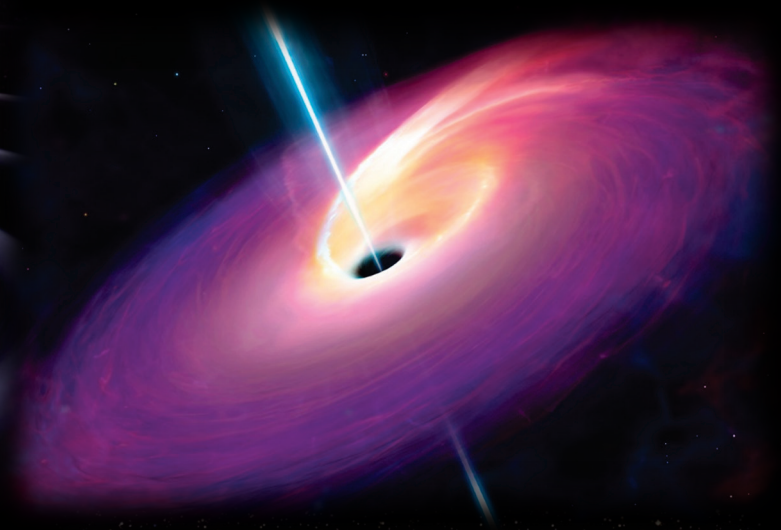
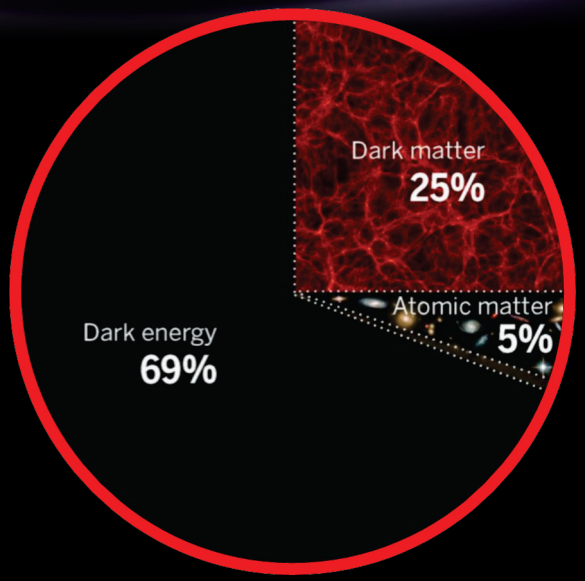
White dwarf binaries

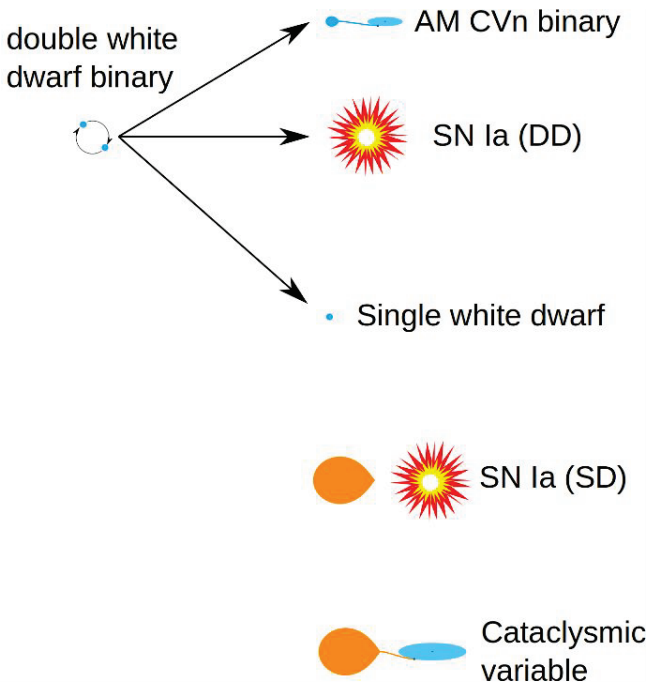
Boris Gänsicke – University of Warwick



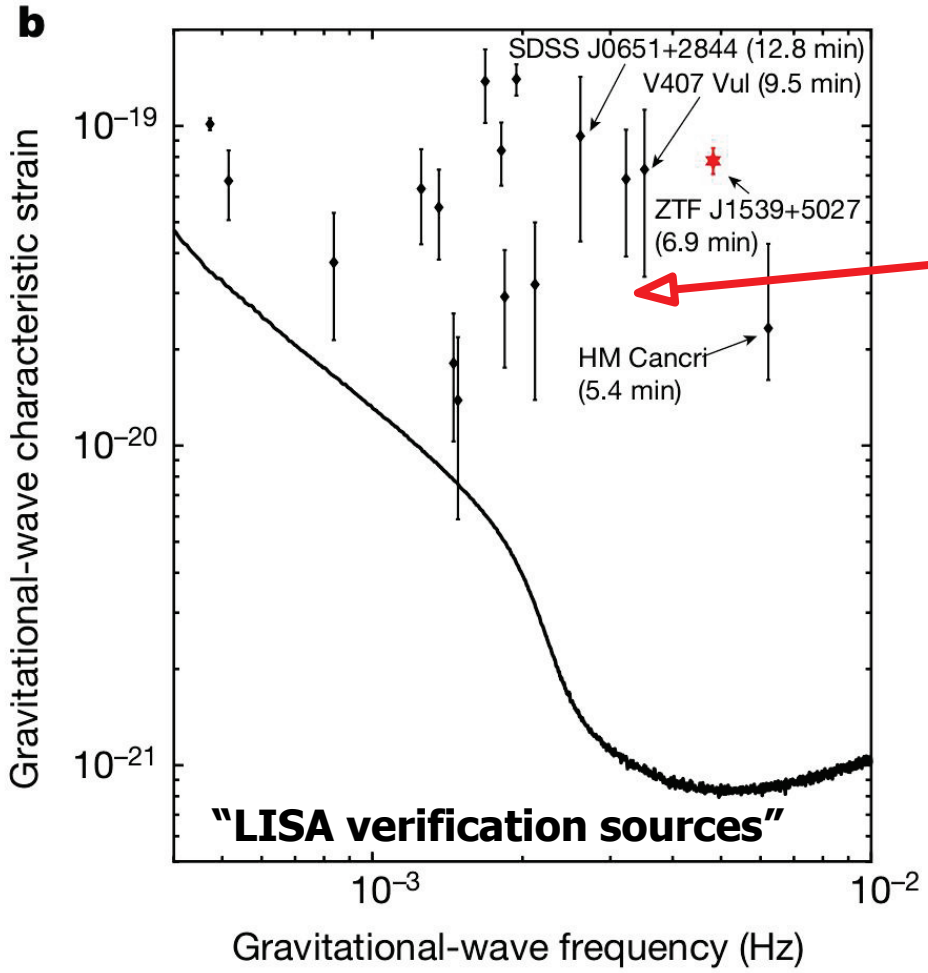


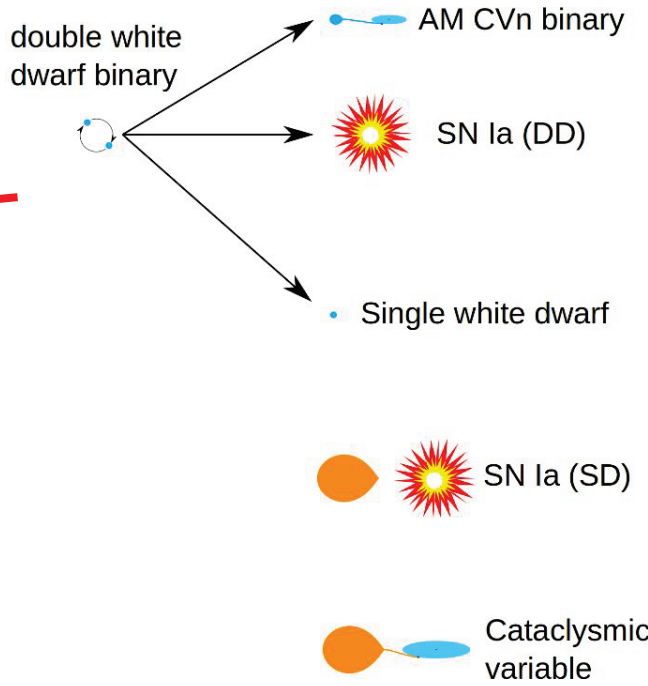


Things that people get excited about



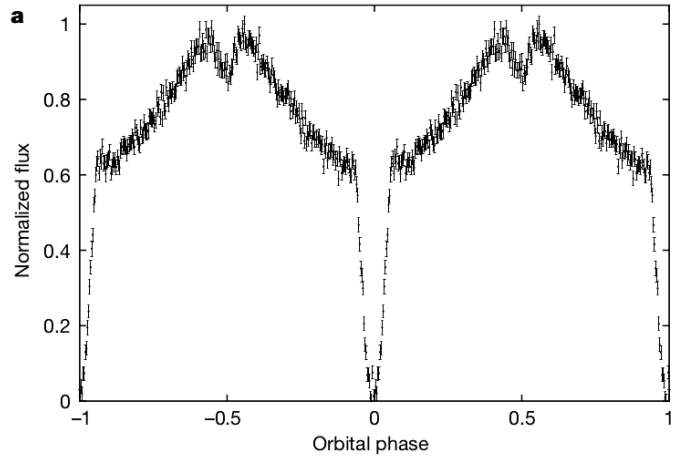
Low frequency gravitational wave sources…

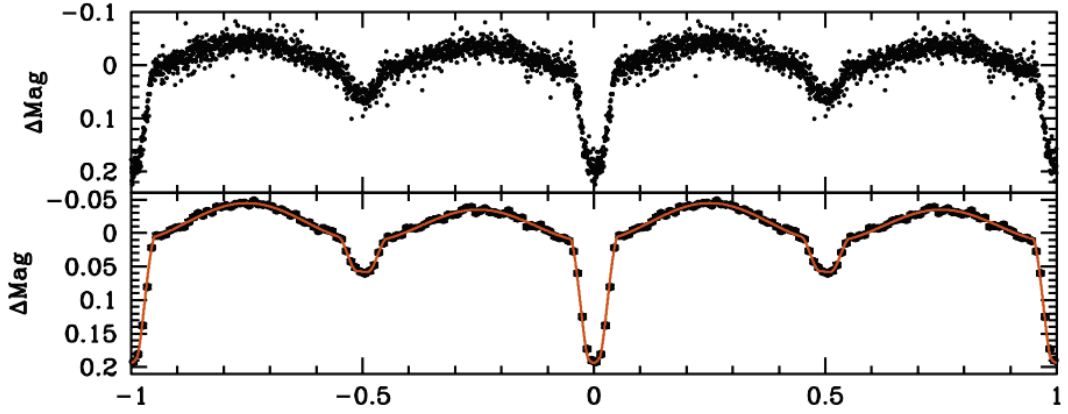


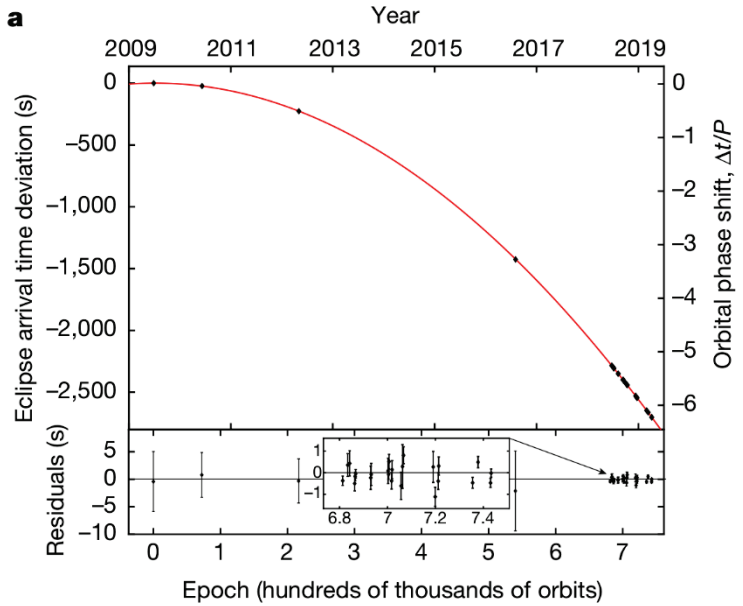


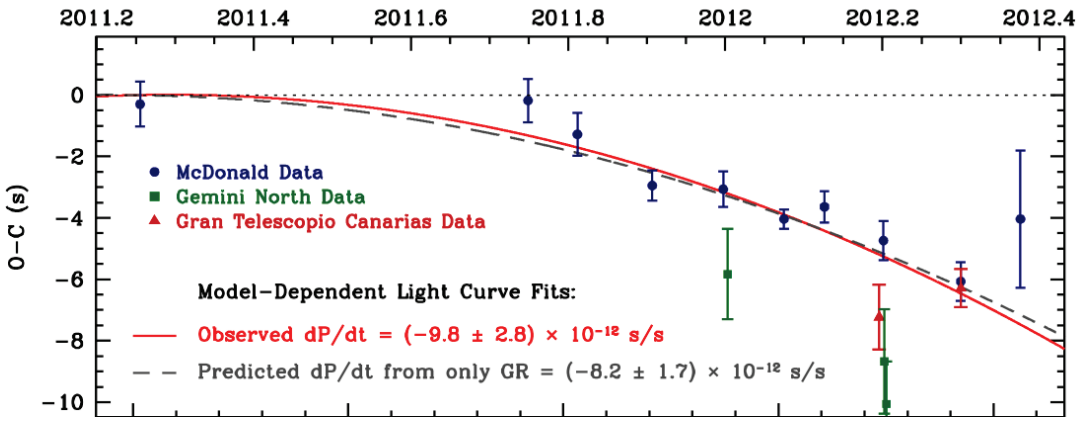
Burdge et al. [2019Natur.571..528B]

… short-period double-white dwarf binaries





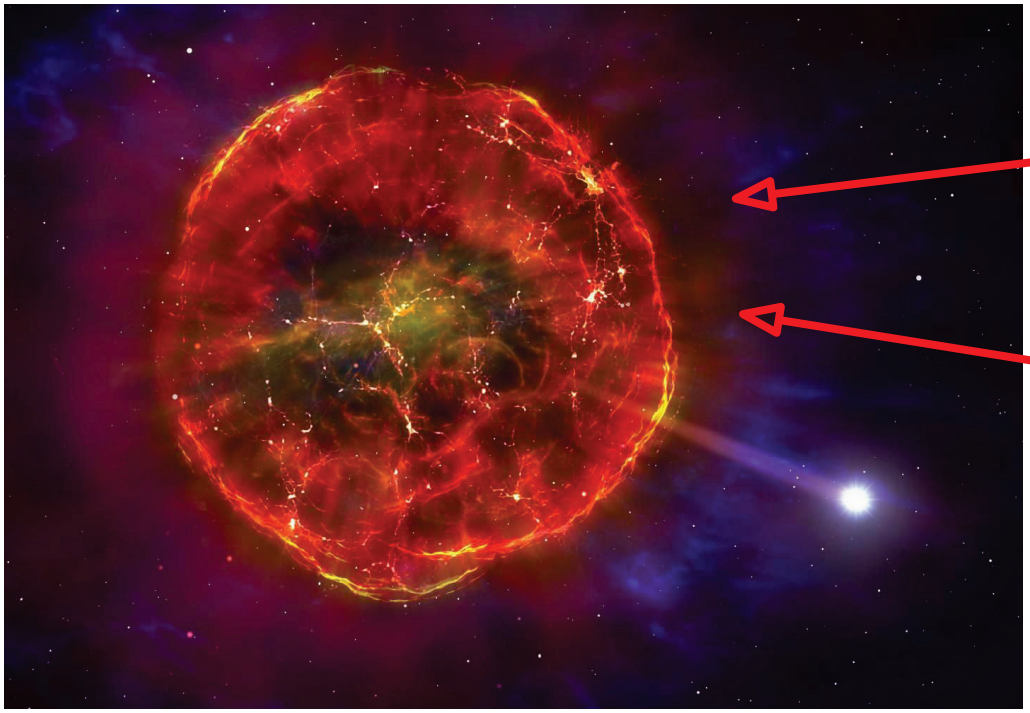


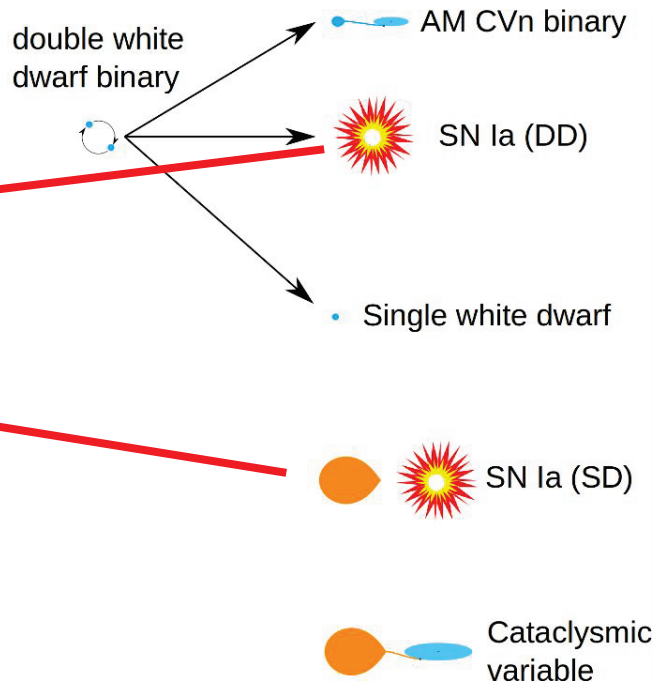


Hermes et al. [2012ApJ...757L..21H]

Burdge et al. [2019Natur.571..528B]

Cosmology, chemical evolution, stellar physics





Read "SNIa", think "thermonuclear supernova"

A new meaning to supernova "remnants"

Remnants of the partially burned primary and the charred donor

Shen et al. 2018ApJ...865...15S
Vennes et al. 2017Sci...357..680V
Kepler et al. 2016Sci...352...67K

STELLAR ASTROPHYSICS

An unusual white dwarf star may be a surviving remnant of a subluminous Type Ia supernova

S. Vennes,[1*] P. Nemeth,[2,3] A. Kawka,[1] J. R. Thorstensen,[4] V. Khalack,[5] L. Ferrario,[6] E. H. Alper[4]

REPORTS

STELLAR EVOLUTION

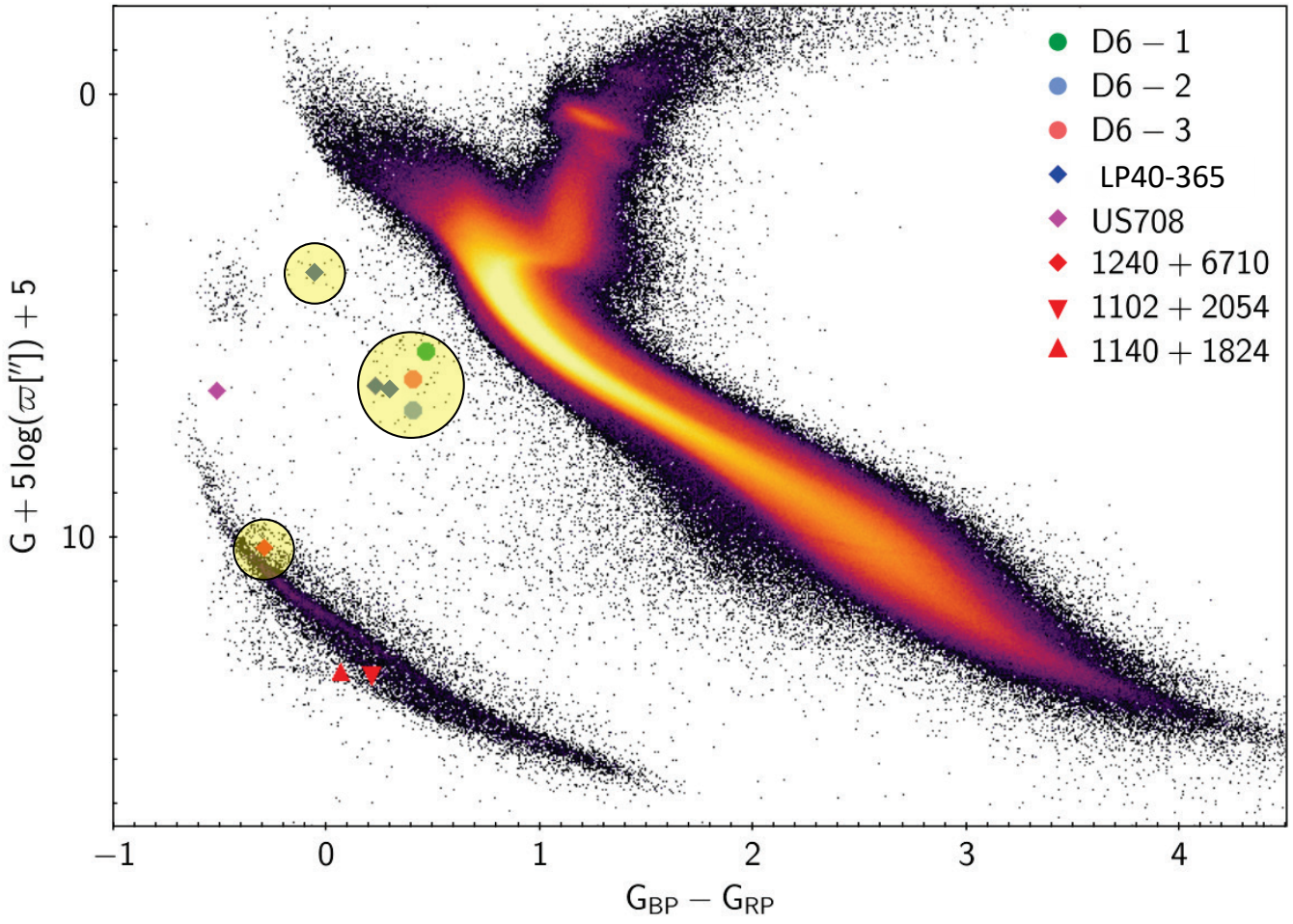
A white dwarf with an oxygen atmosphere

S. O. Kepler,[1*] Detlev Koester,[2] Gustavo Ourique[1]

Three Hypervelocity White Dwarfs in *Gaia* DR2: Evidence for Dynamically Driven Double-degenerate Double-detonation Type Ia Supernovae

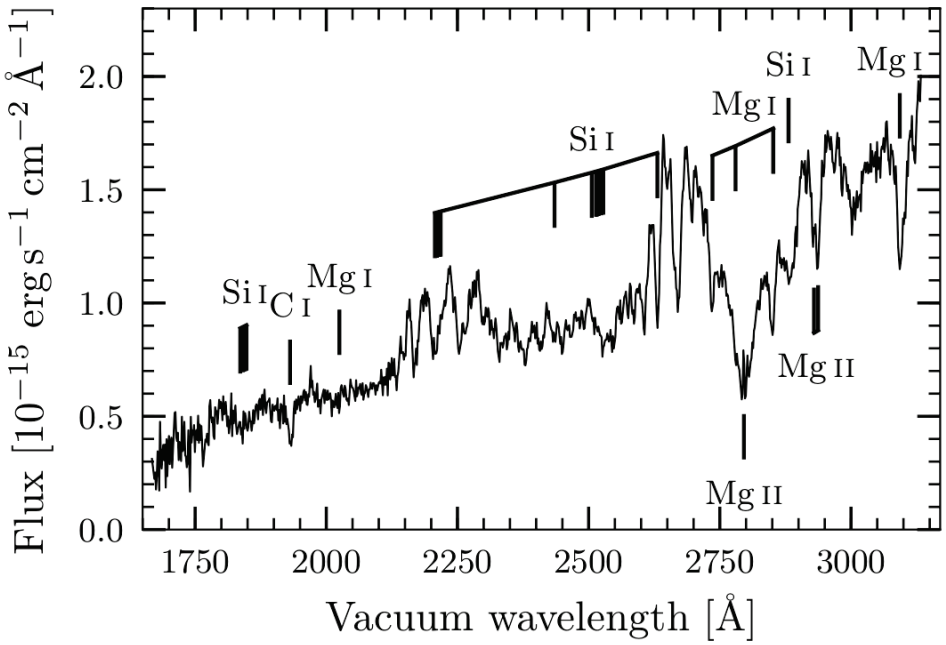
Ken J. Shen[1], Douglas Boubert[2], Boris T. Gänsicke[3], Saurabh W. Jha[4], Jennifer E. Andrews[5], Laura Chomiuk[6], Ryan J. Foley[7], Morgan Fraser[8], Mariusz Gromadzki[9], James Guillochon[10], Marissa M. Kotze[11,12], Kate Maguire[13], Matthew R. Siebert[7], Nathan Smith[5], Jay Strader[6], Carles Badenes[14,15], Wolfgang E. Kerzendorf[16], Detlev Koester[17], Markus Kromer[18,19], Broxton Miles[20], Rüdiger Pakmor[19], Josiah Schwab[7,24], Odette Toloza[3], Silvia Toonen[21], Dean M. Townsley[22], and Brian J. Williams[23]

A new meaning to supernova "remnants"



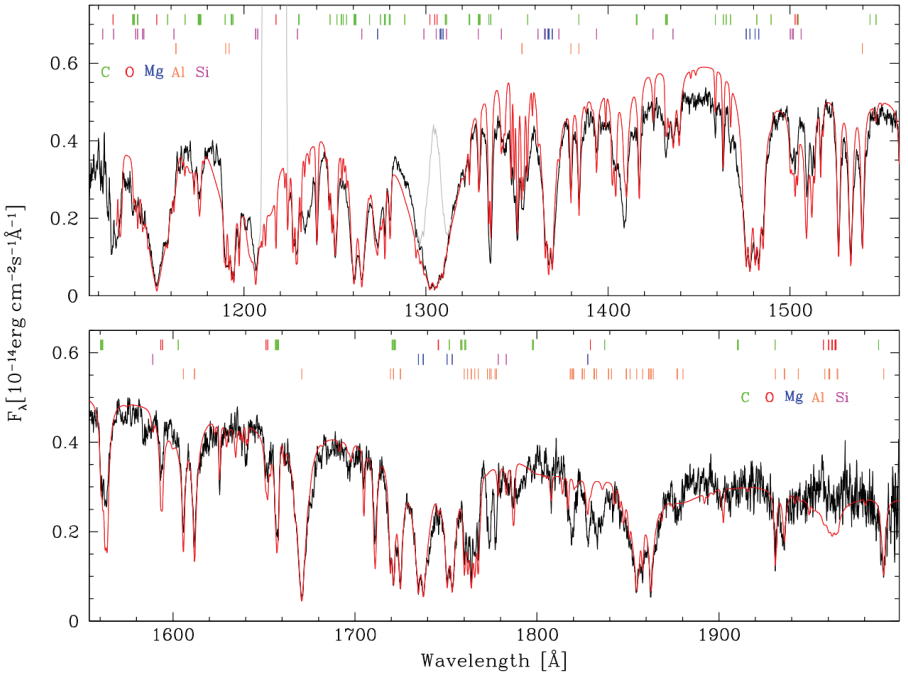
Measuring the abundances of these remnants …

HST/STIS G230L



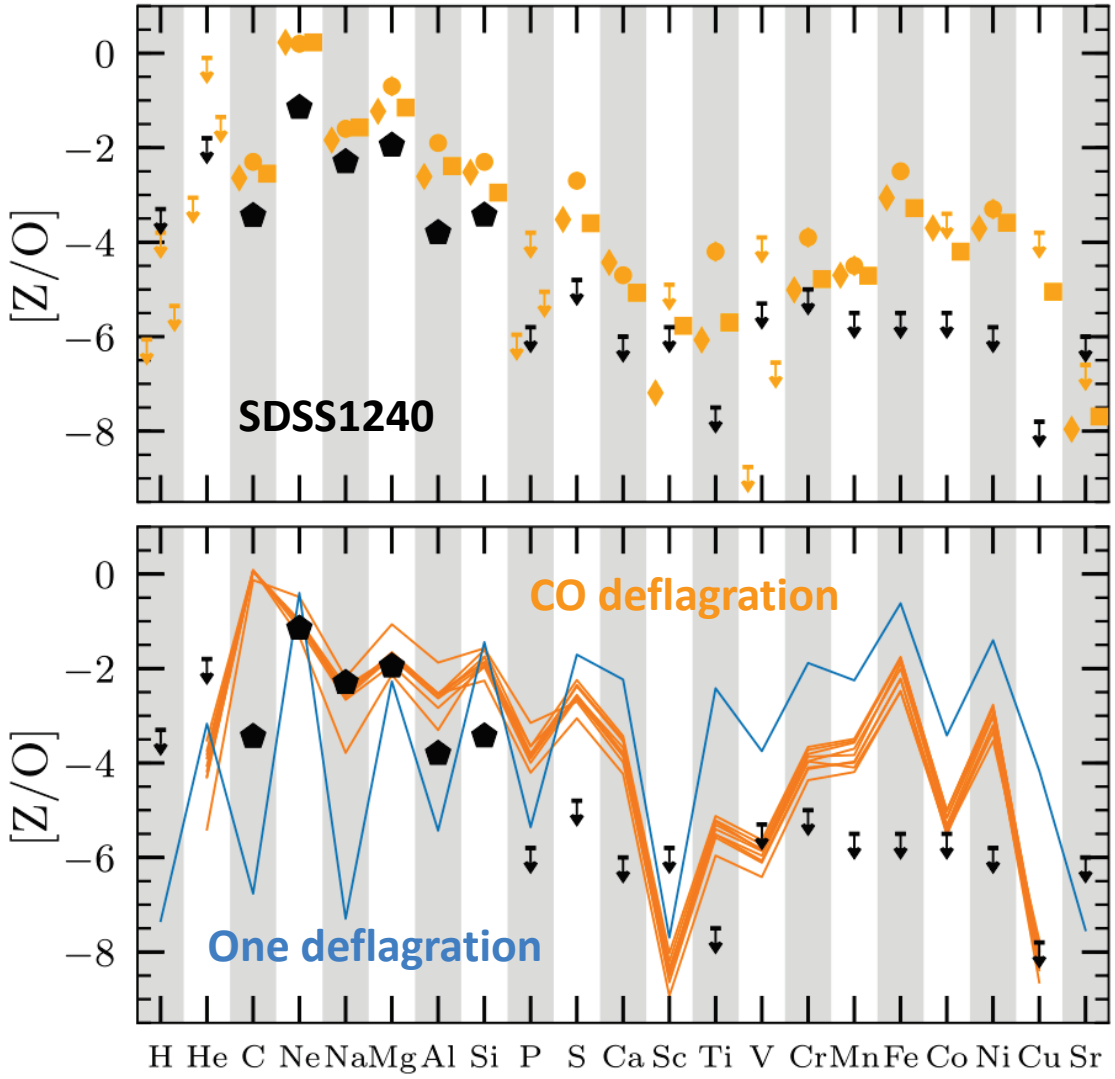
Raddi et al. [2019MNRAS.489.1489R]

HST/COS G140L



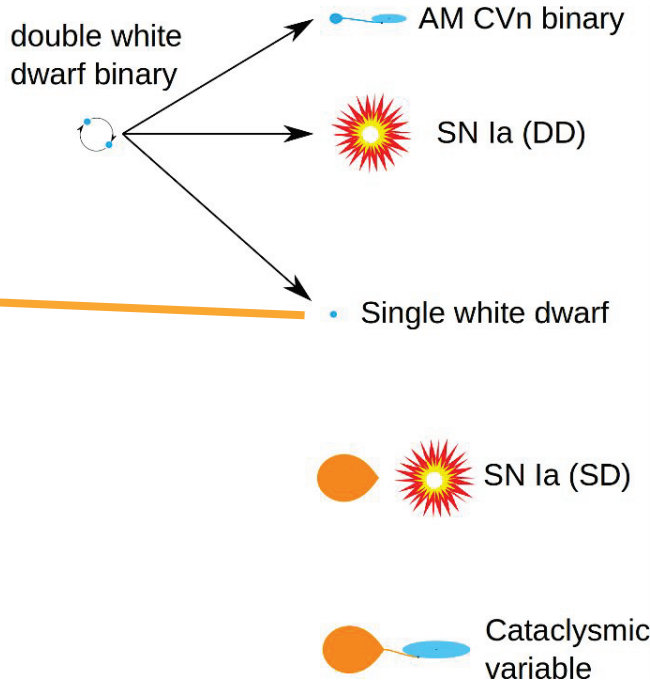
Gänsicke et al. [2020MNRAS.496.4079G]

… insight into thermonuclear processes in SN [Ia(x)]



Gänsicke et al. 2020MNRAS.496.4079G

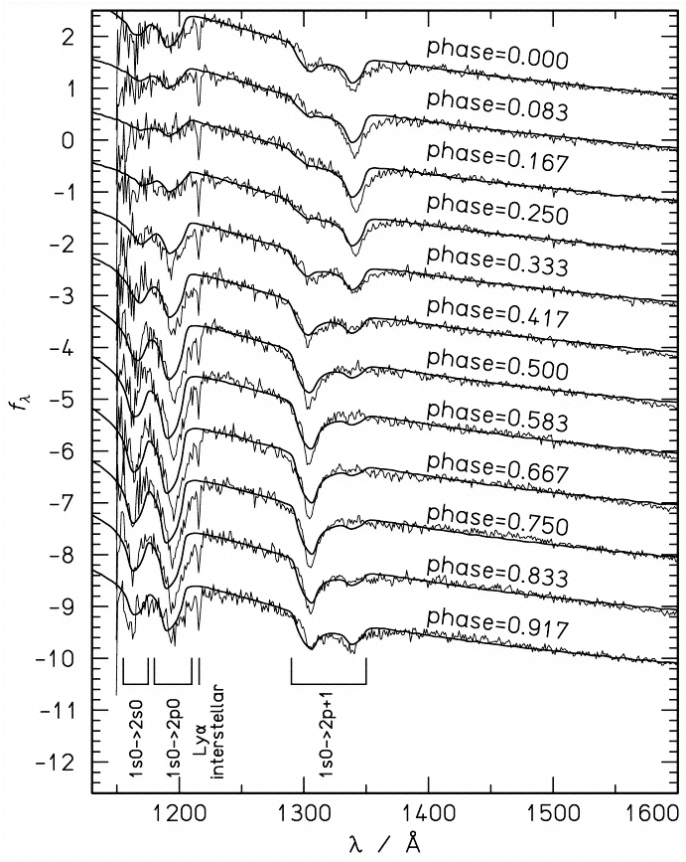
Mergers (can) lead to ultra-high magnetic fields

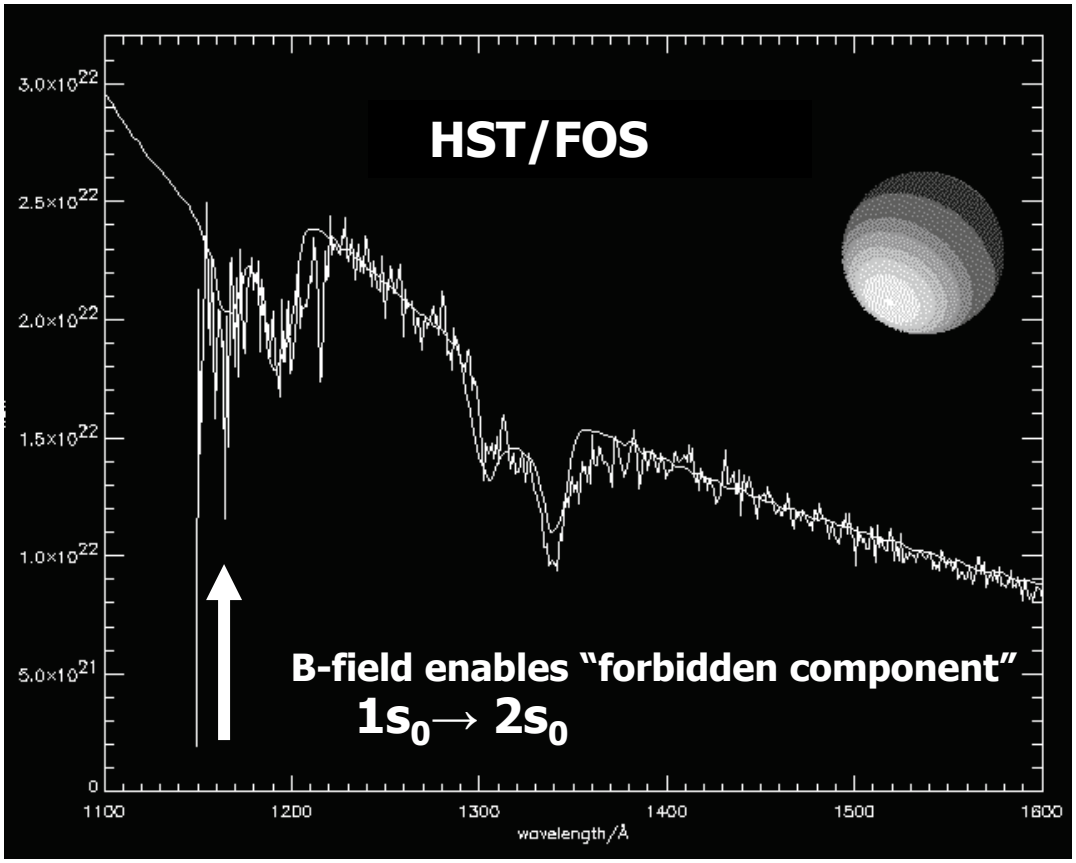


Caiazzo et al. 2021Natur.595...39C

Physics under extreme conditions

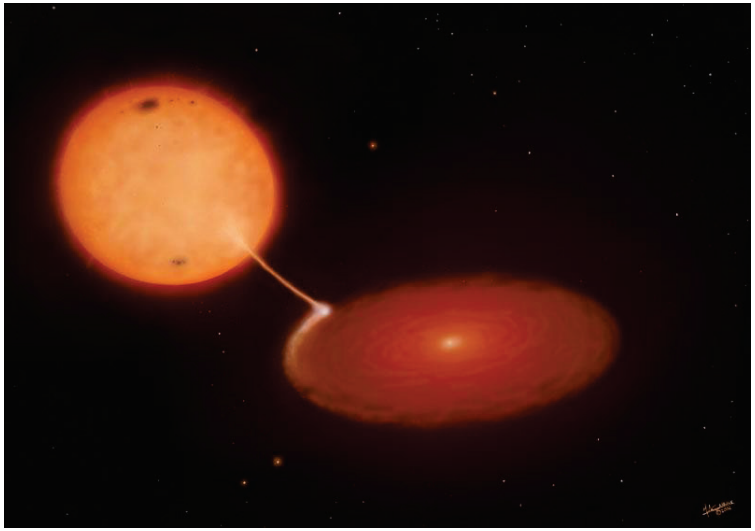
Field topology from phase-resolved far-UV spectroscopy

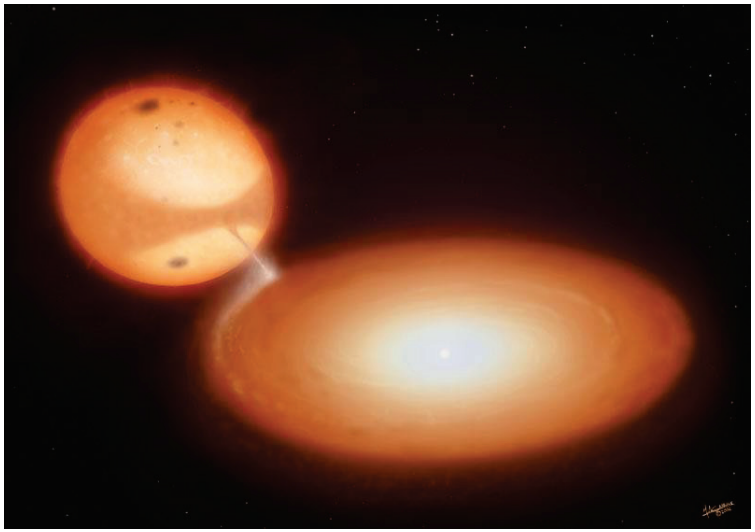


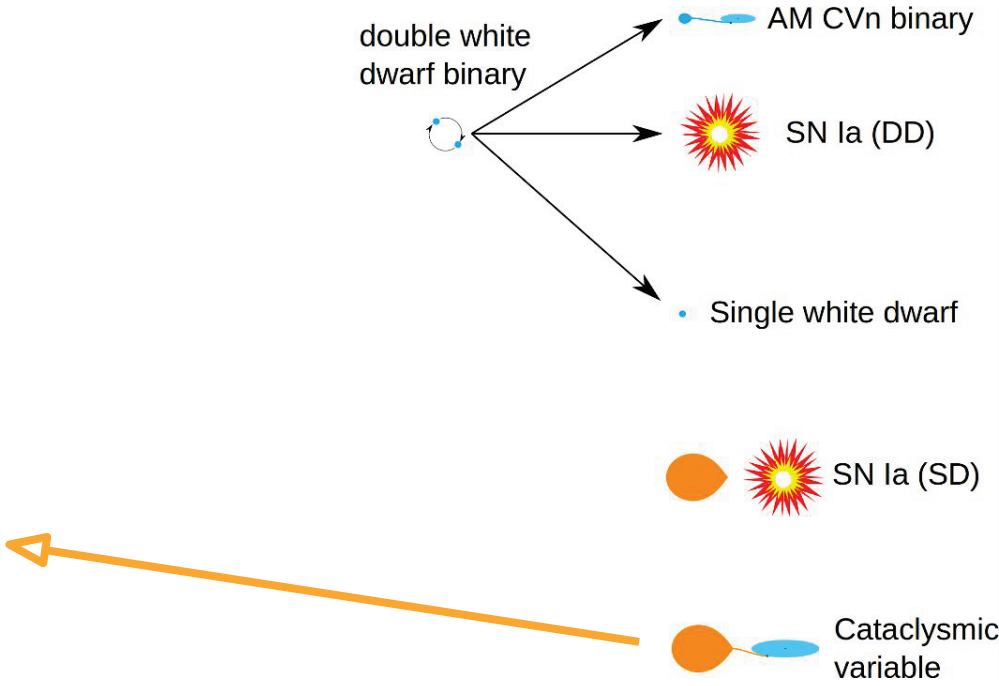


Burleigh et al. [1999ApJ...510L..37B]

Accretion physics laboratories

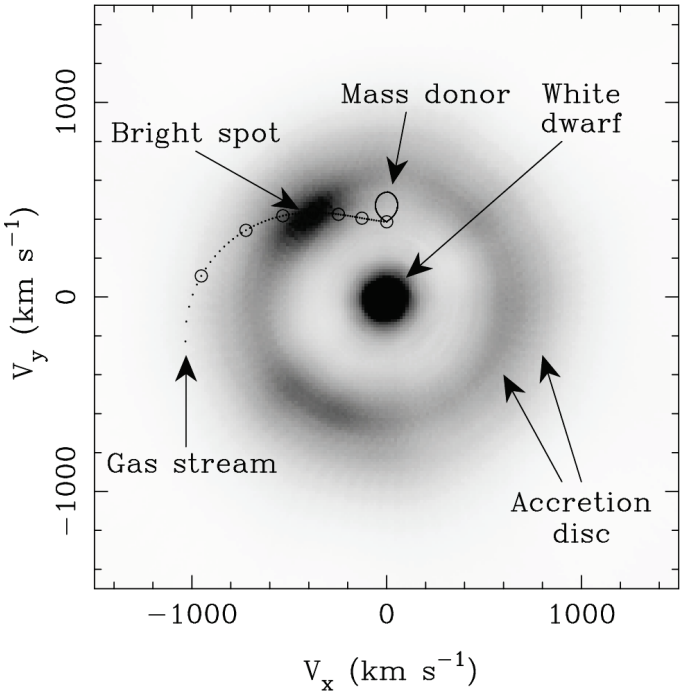


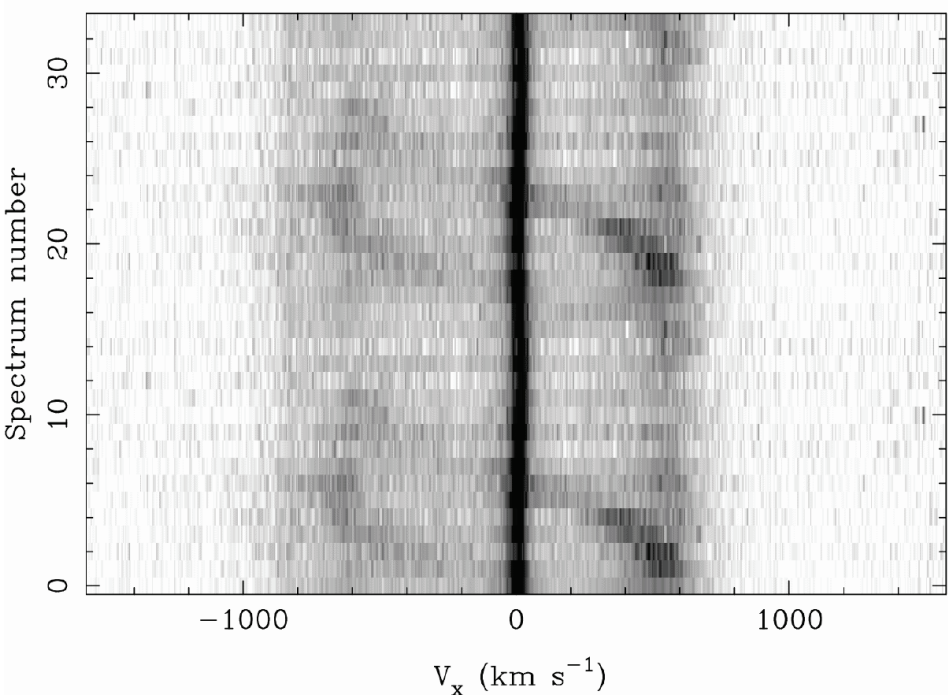




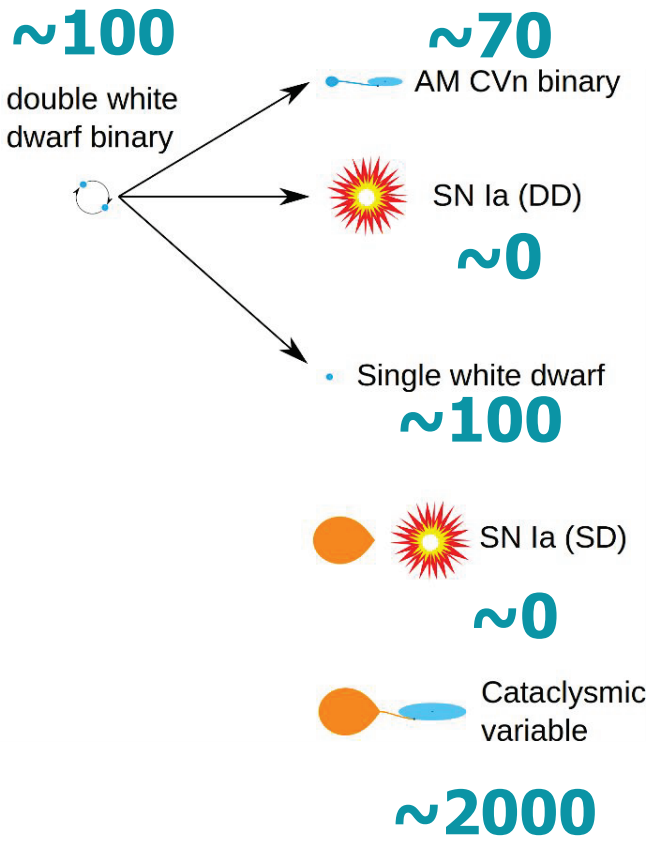
Accretion disc structure
Doppler tomography and eclipse mapping

- **Imaging of the disc: Marsh & Schwope 2016ASSL..439..195M**
- **Temperature distribution, $T(r) \propto r^{(-3/4)}$: Baptista 2016ASSL..439..155B**
- **Viscosity, $\alpha \approx 0.1$-0.4: King et al. 2007MNRAS.376.1740K**





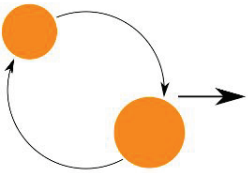
The known population is a small & mixed bag



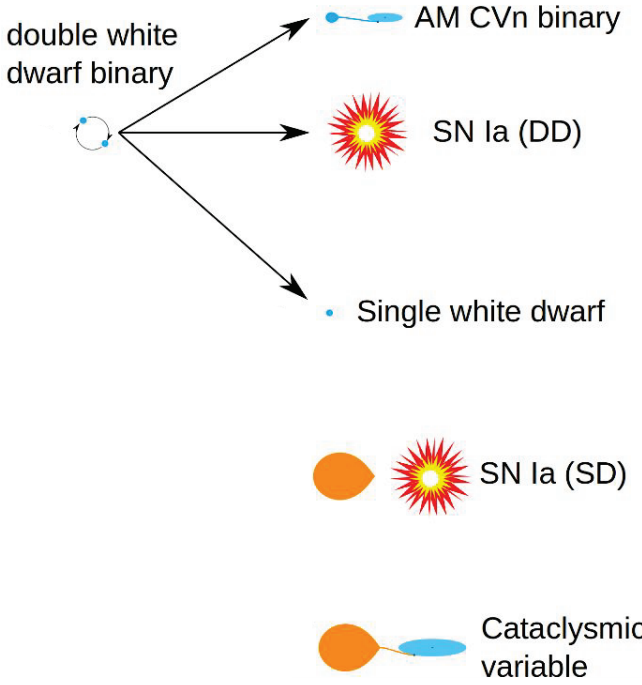
… and we don’t really understand how they formed!

How do they form?

2 x AFG-type



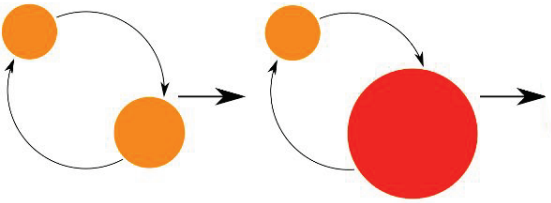
reasonably well known (RVs, Gaia, TESS…)



rare hard-to-characterise

How do they form?

2 x AFG-type



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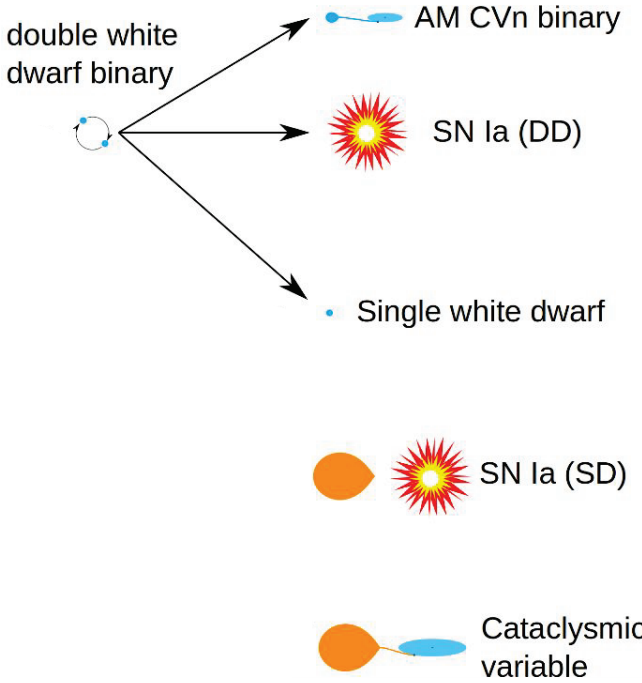

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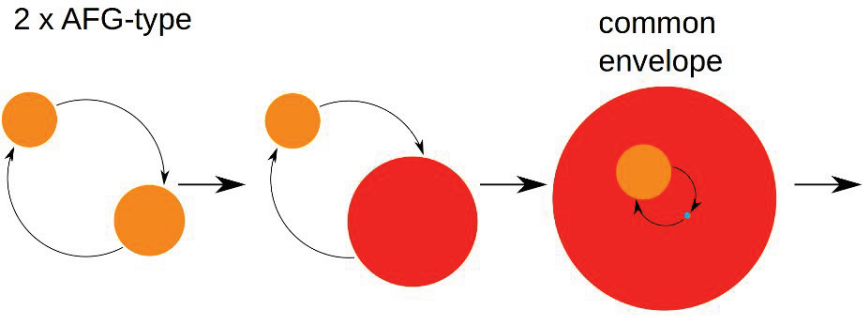

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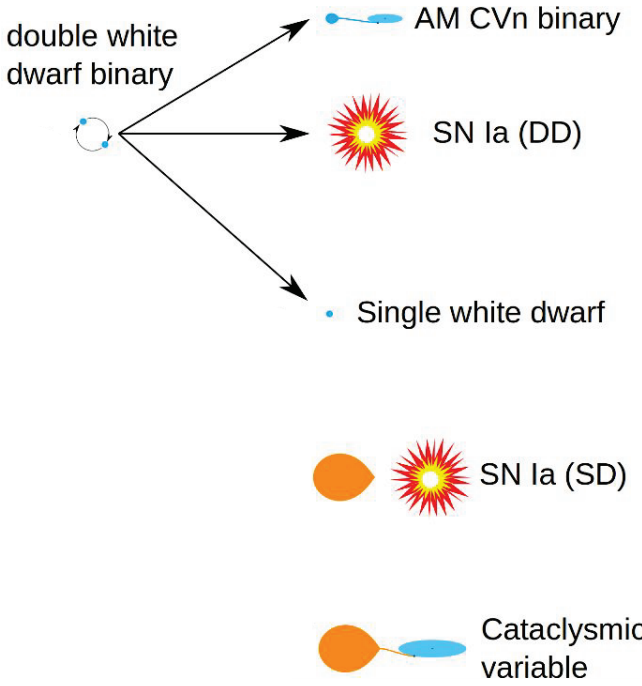
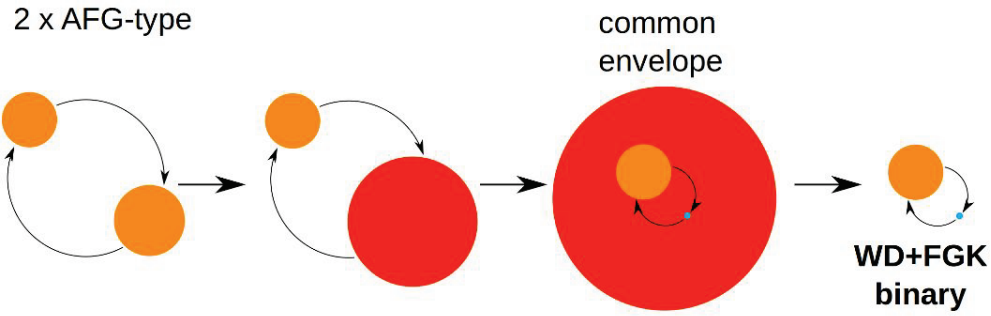
short-lived messy



rare hard-to-characterise

How do they form?



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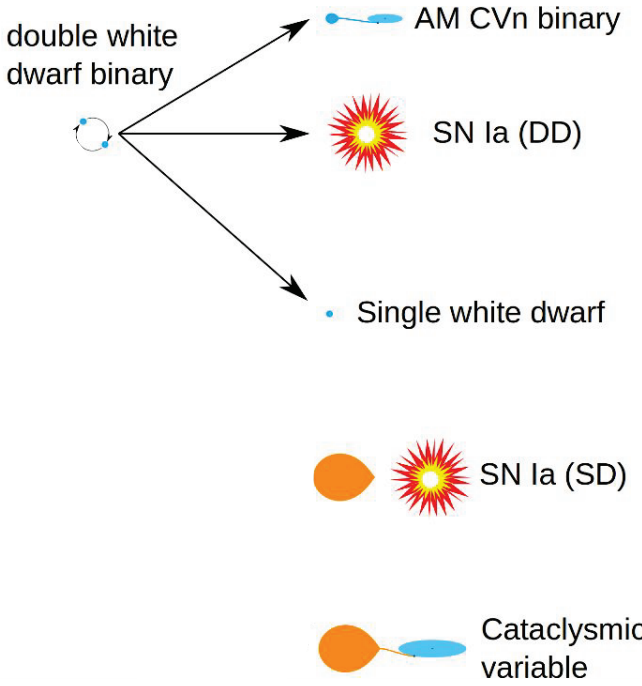
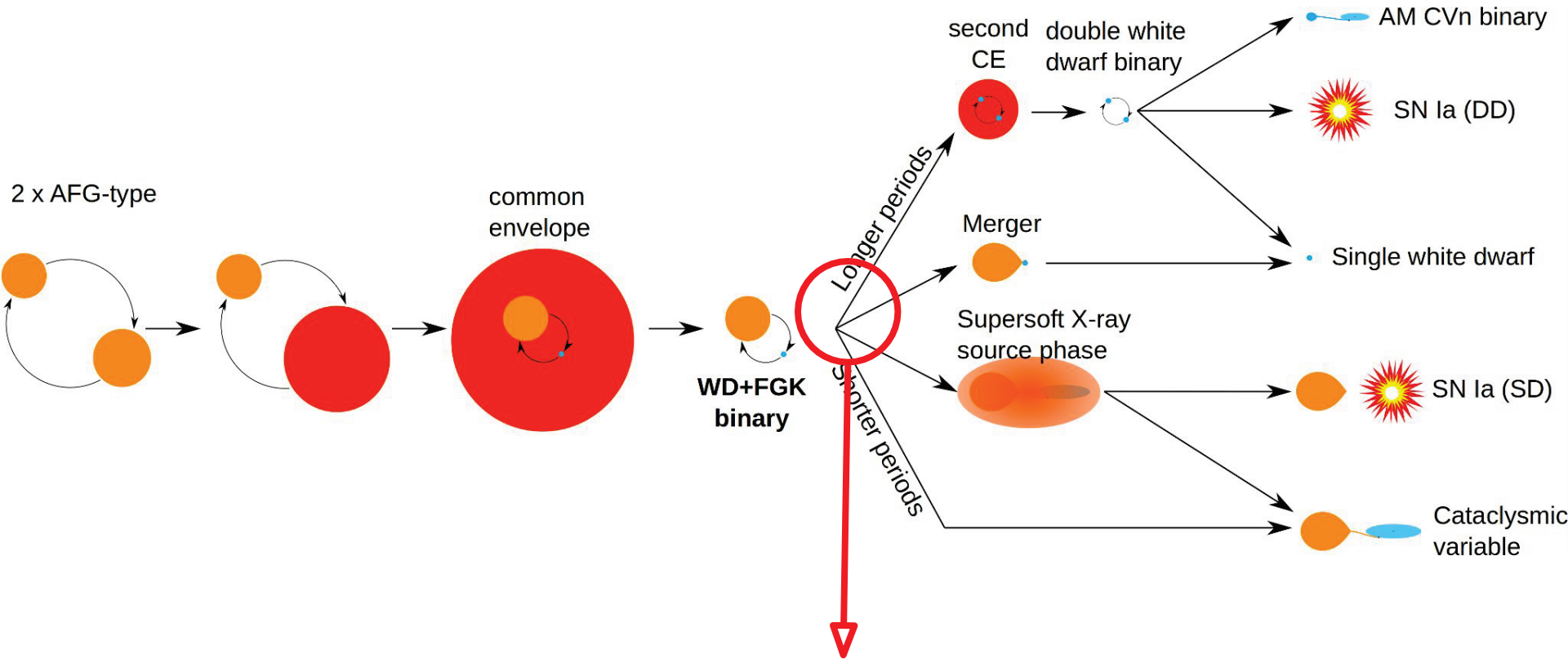


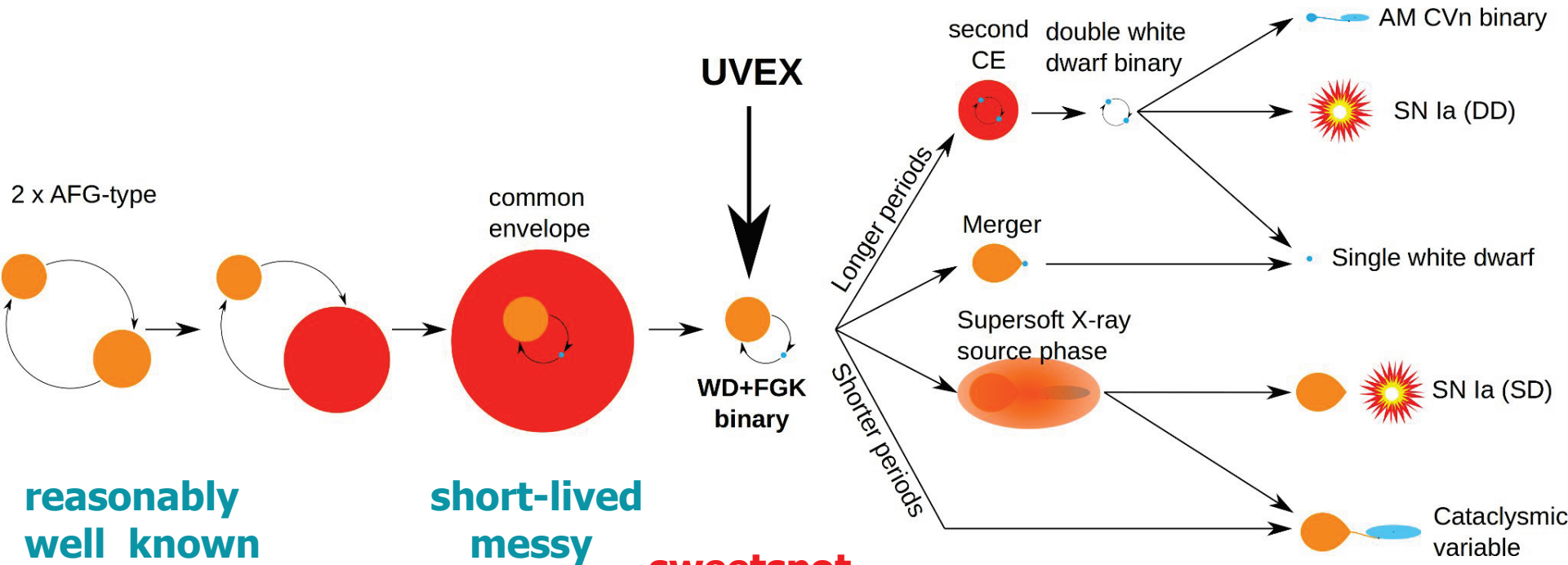
rare hard-to-characterise

How do they form?



branching depends on the masses of the two stars and their orbital period

UVEX to target WD + MS binaries



reasonably well known (RVs, Gaia, TESS…)

short-lived messy

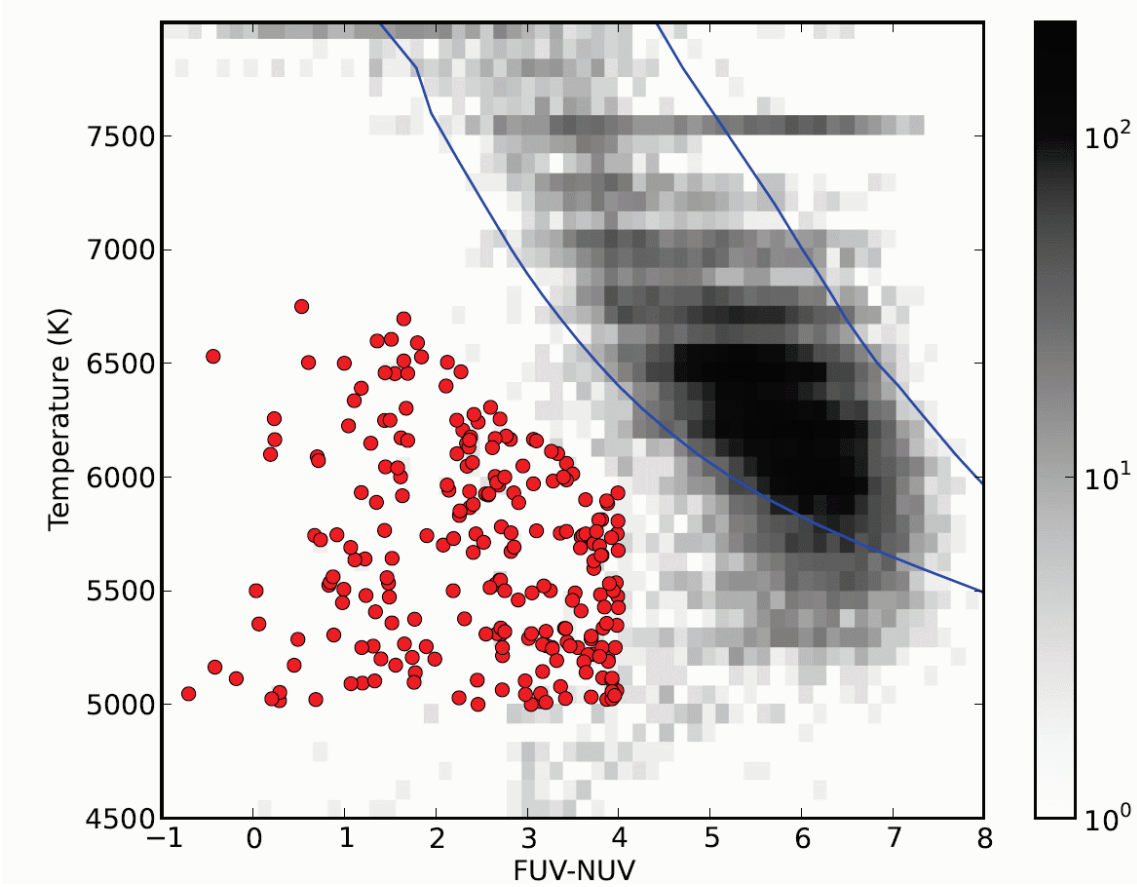
sweetspot

currently ~25 systems known

rare hard-to-characterise

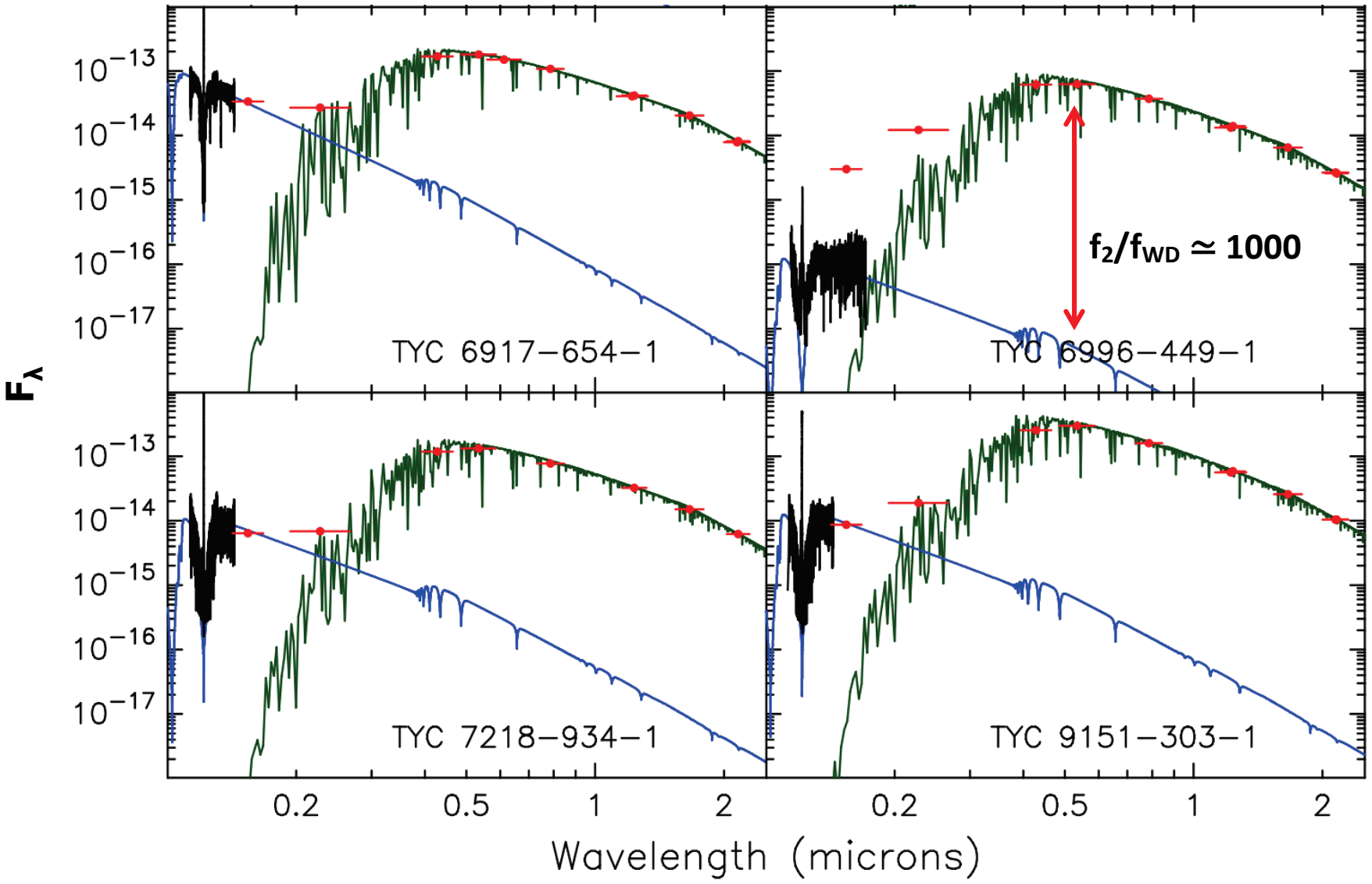
Early attempt: GALEX + RAVE selection

F,G,K stars from RAVE with GALEX ⇒ FUV excess



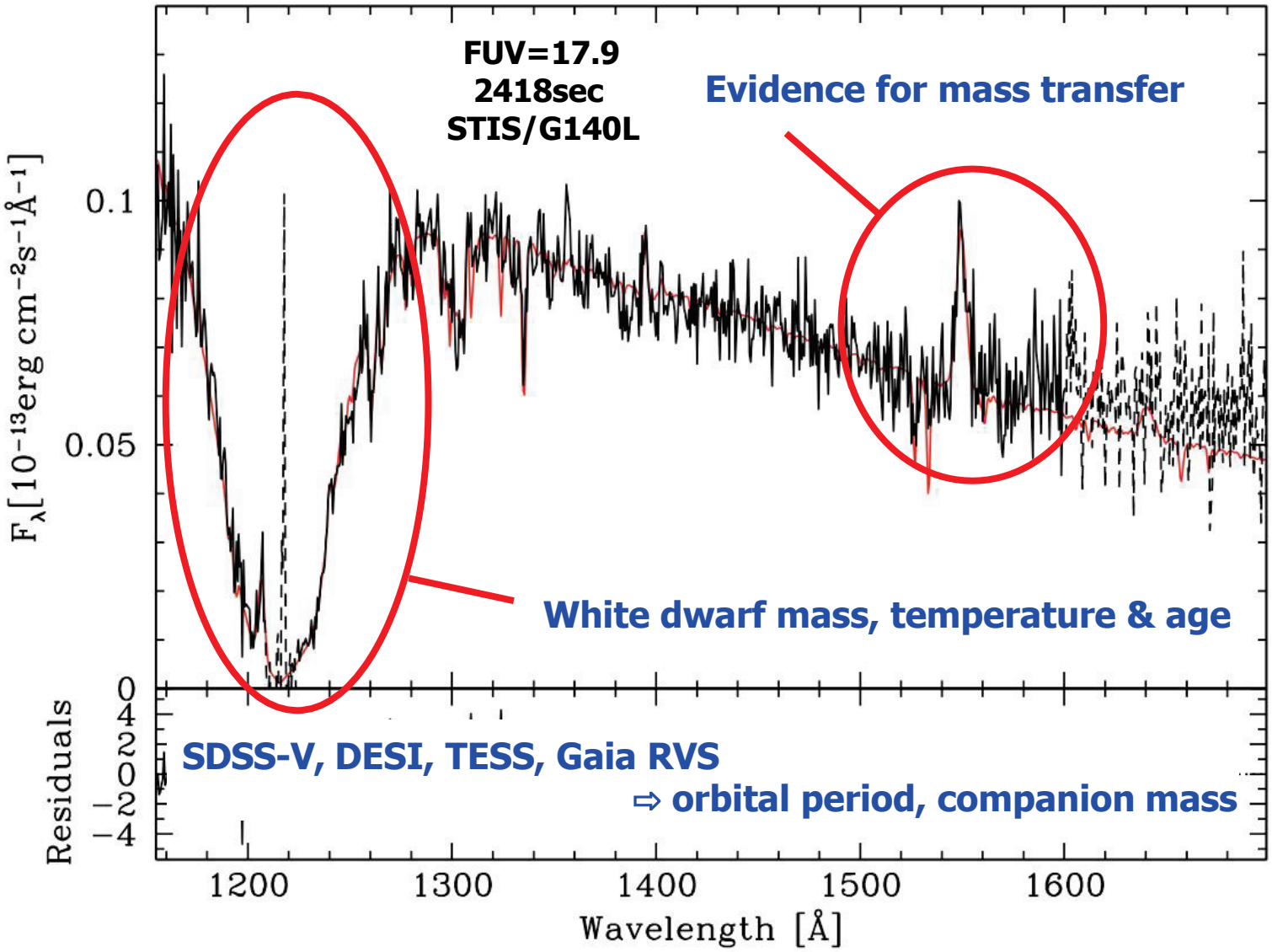
Parsons et al. [2016MNRAS.463.2125P]

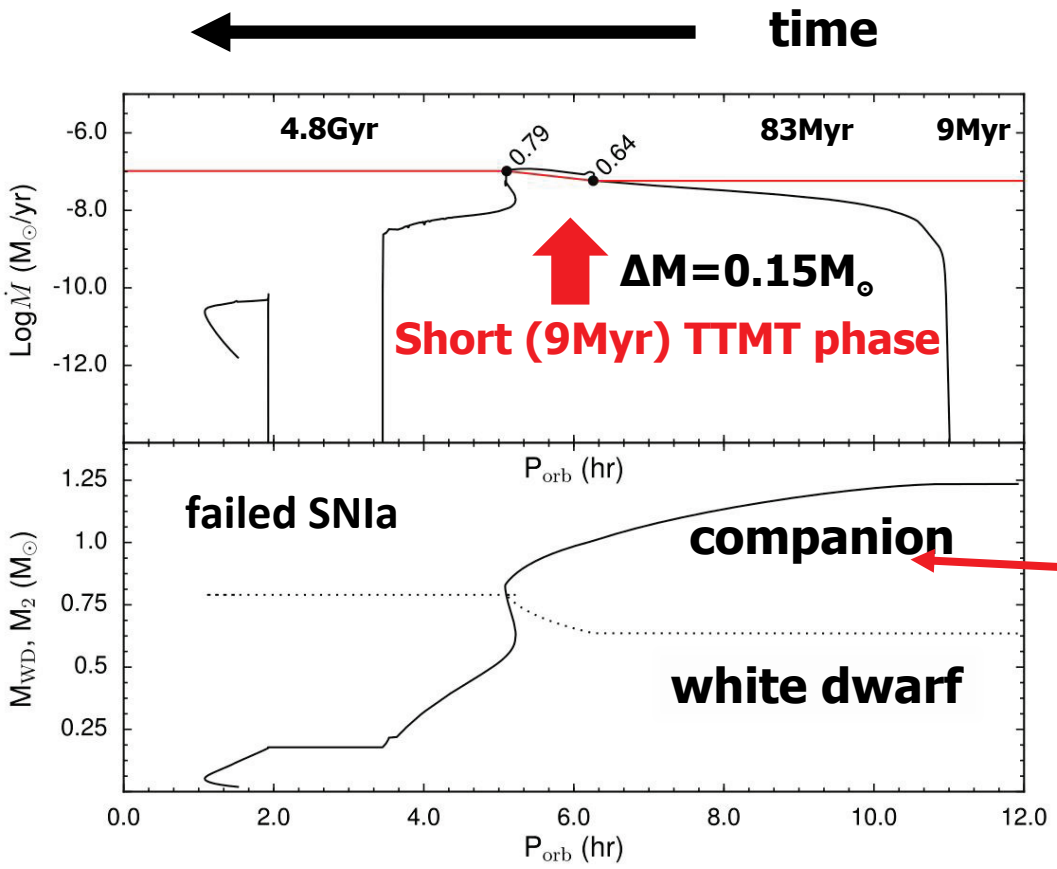
HST pilot study: 100% success



Parsons et al. [2016MNRAS.463.2125P]

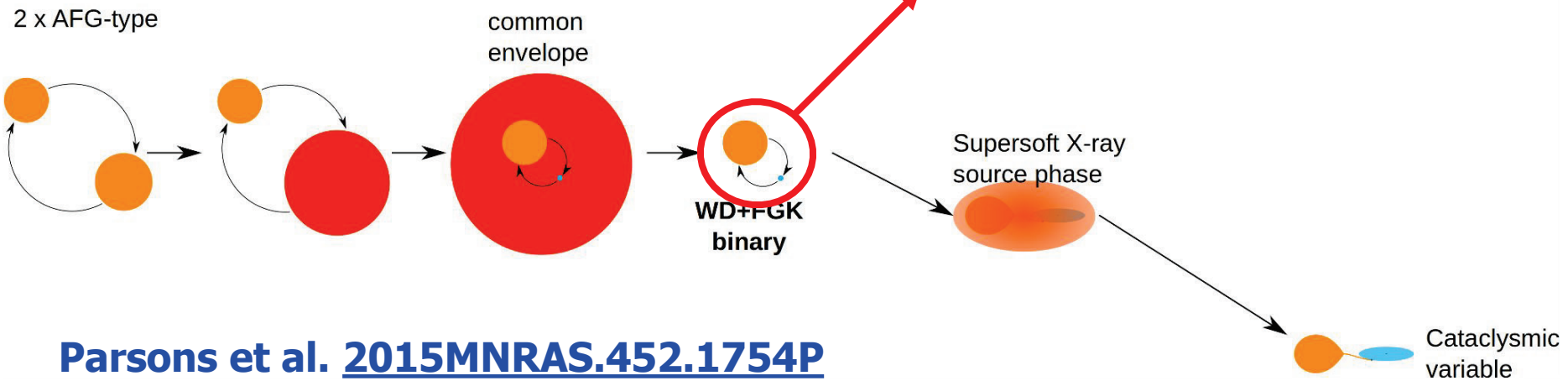
UVEX: all-sky survey: identification
far-ultraviolet spectroscopy: characterisation



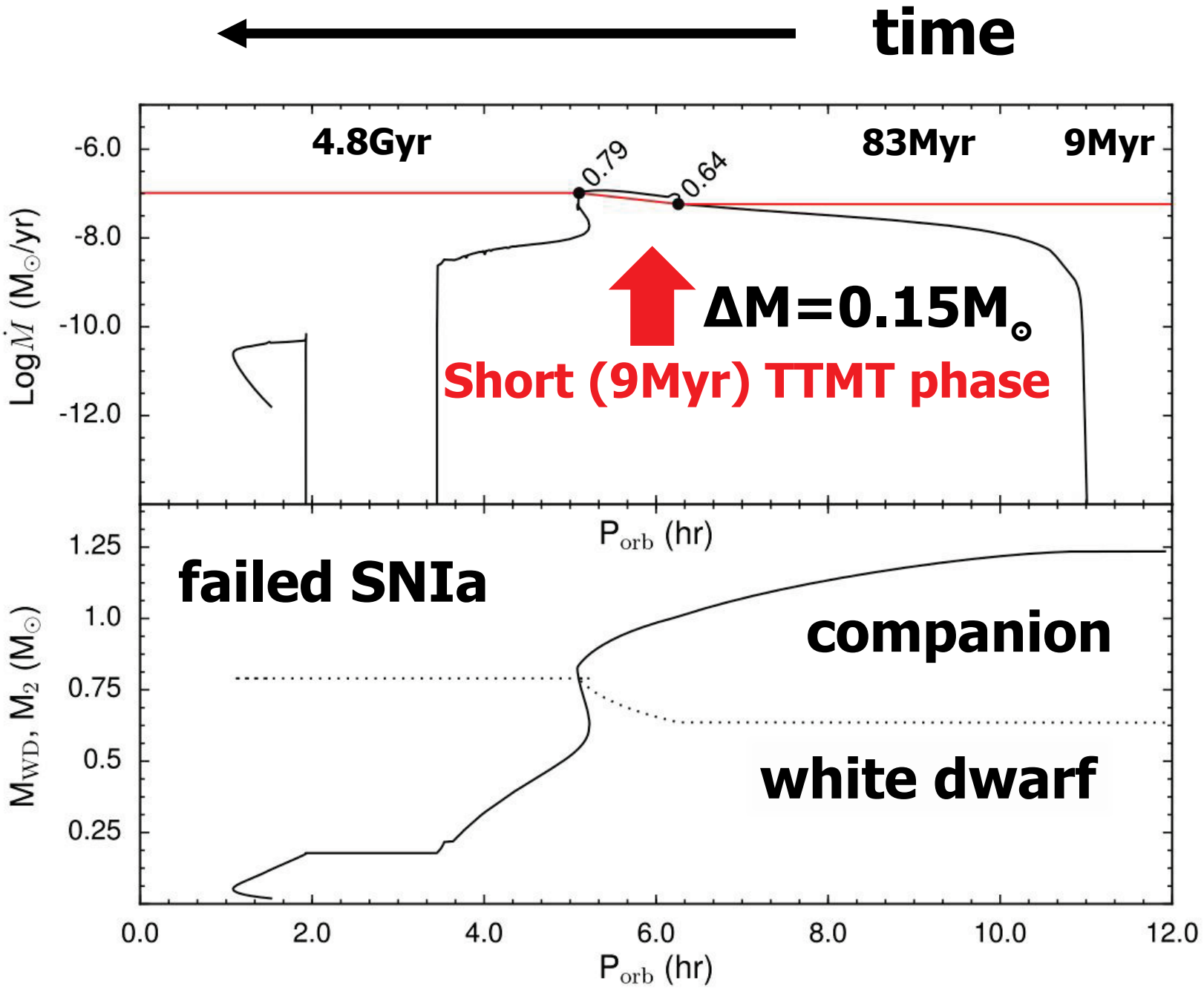


Stellar evolution models: predict the past and future evolution

Distance (pc)	250–320
Orbital period (d)	0.498 688(26)
K_{MS} (km s^{-1})	65.0 ± 0.3
$v_{rot} \sin i$ (km s^{-1})	75.0 ± 3.0
Inclination (°)	33–43
Separation ($R_\odot$)	3.20–3.28
White dwarf mass ($M_\odot$)	0.52–0.67
White dwarf temperature (K)	19 500–21 000
Main-sequence star spectral type	F8
Main-sequence star temperature (K)	6300–6500
Main-sequence star surface gravity	4.31–4.48
Main-sequence star mass ($M_\odot$)	1.22–1.25
Main-sequence star radius ($R_\odot$)	1.18–1.40

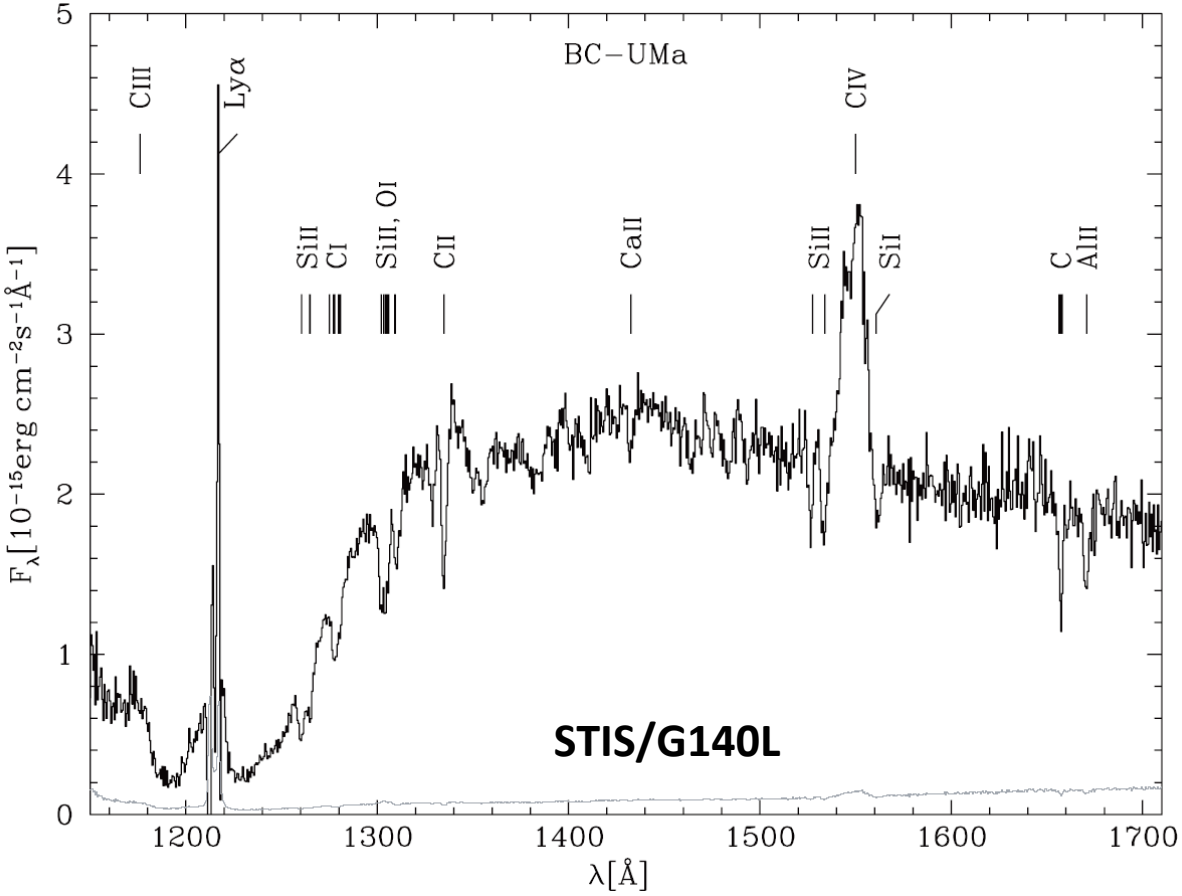


Parsons et al. 2015MNRAS.452.1754P

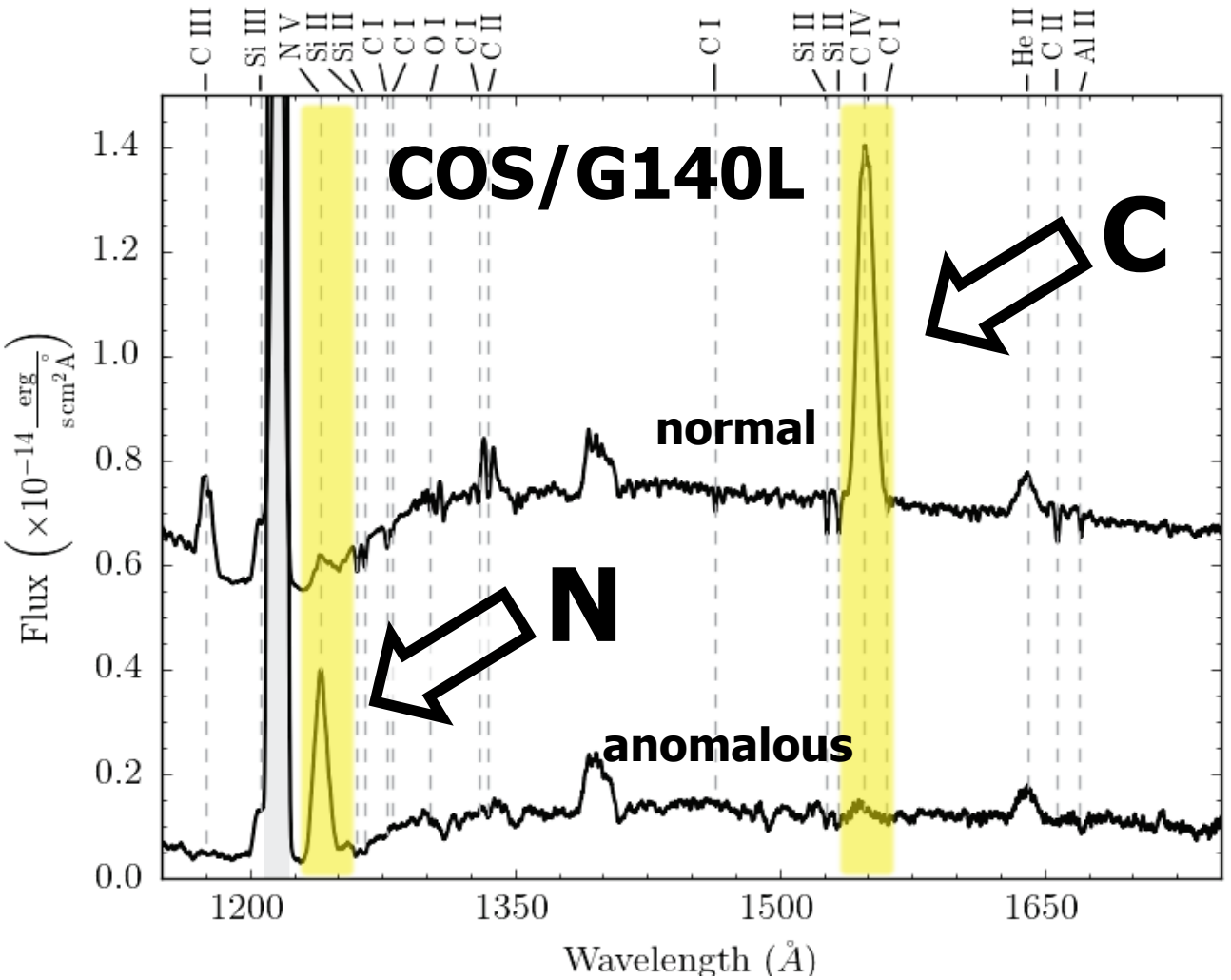

time
4.8Gyr
83Myr
9Myr
0.79
0.64
ΔM=0.15M⊙
Short (9Myr) TTMT phase
failed SNIa
companion
white dwarf
Log$\dot{M}$ (M$_\odot$/yr)
M$_{WD}$, M$_2$ (M$_\odot$)
P$_{orb}$ (hr)
P$_{orb}$ (hr)

WD abundances = donor star abundances

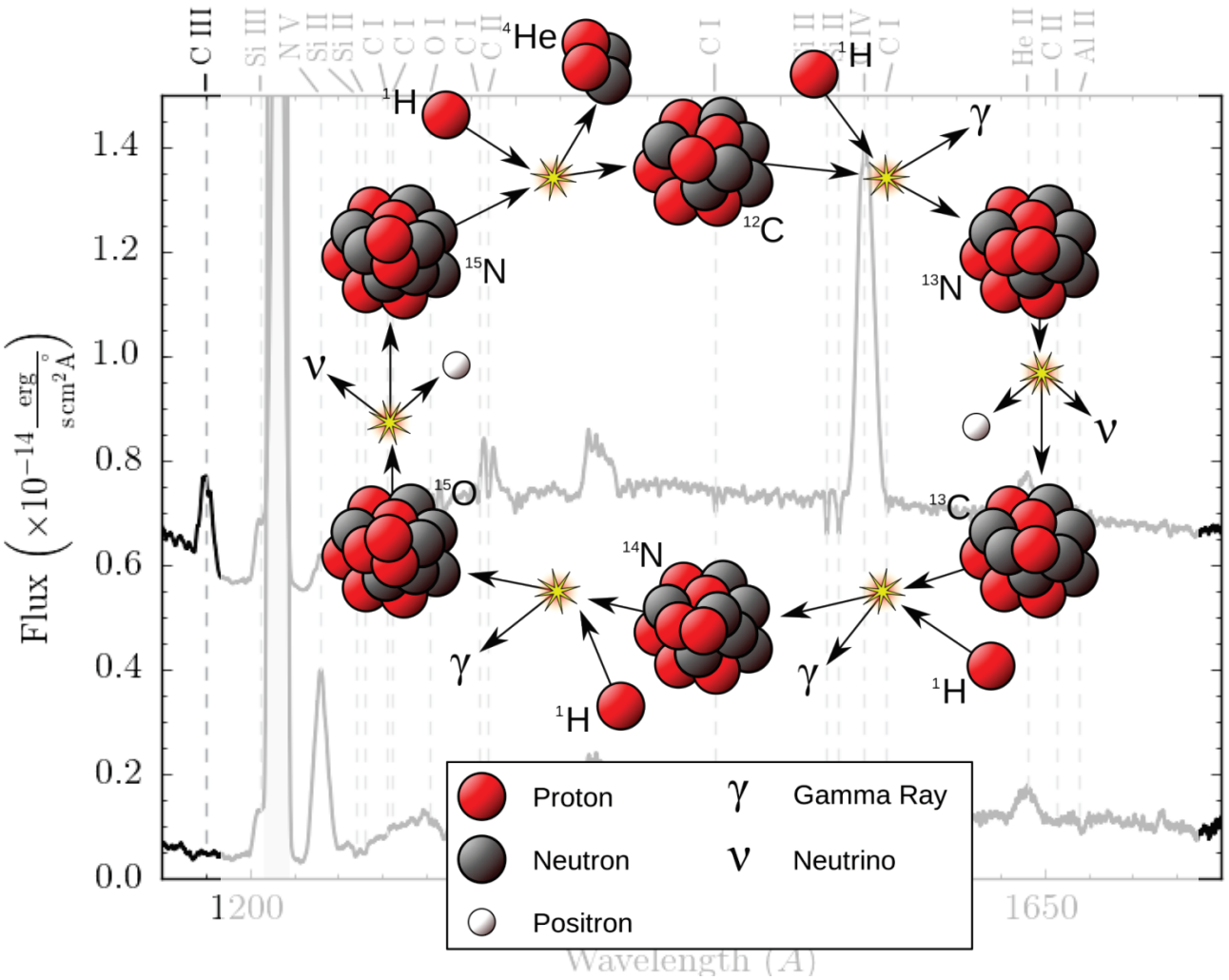
The white dwarf photosphere is continuously Replenished by material from the donor star



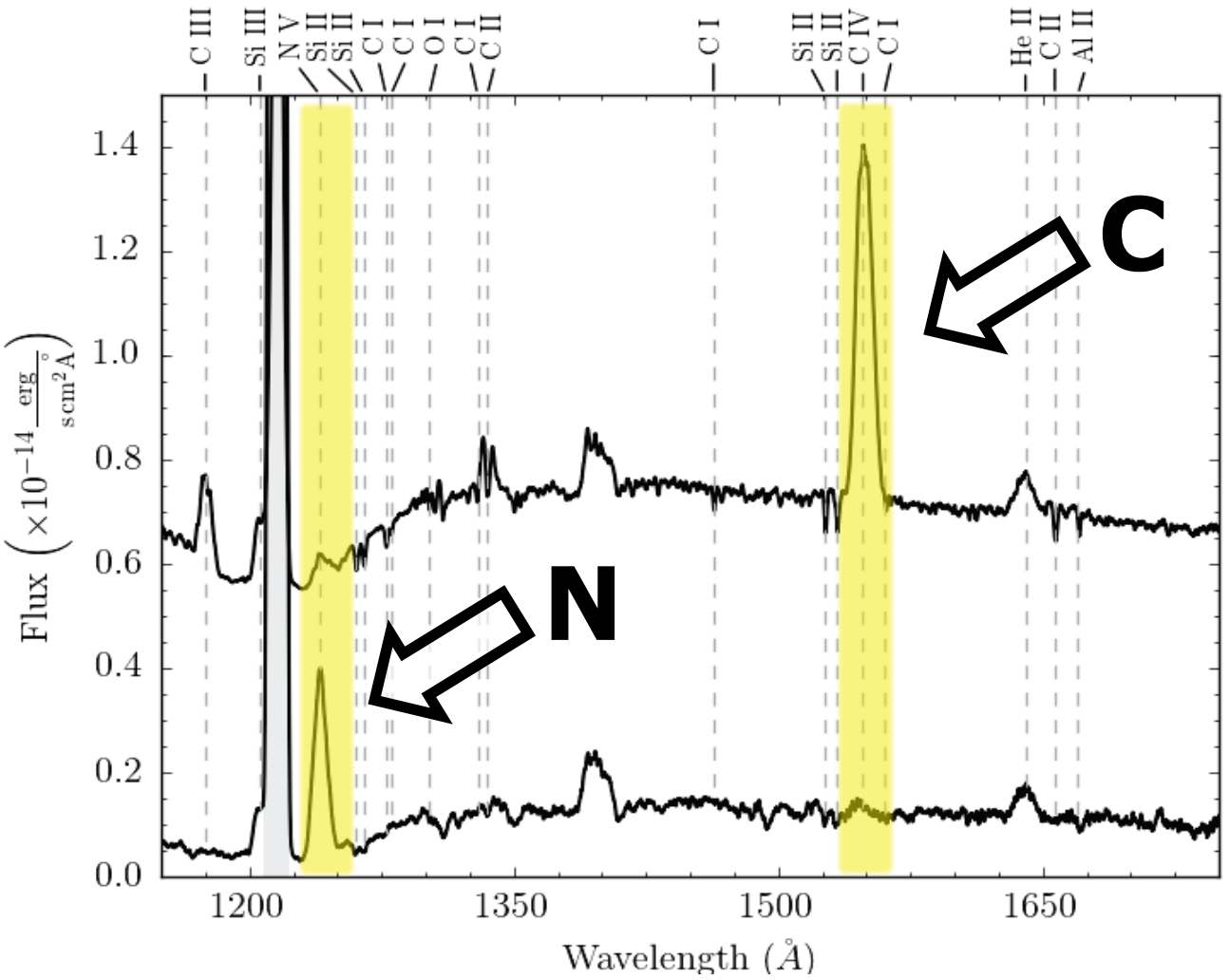
Carbon & nitrogen in accreting white dwarf binaries



Donor mass ≥1.2M⊙: CNO burning: C ⇓ & N ⇑

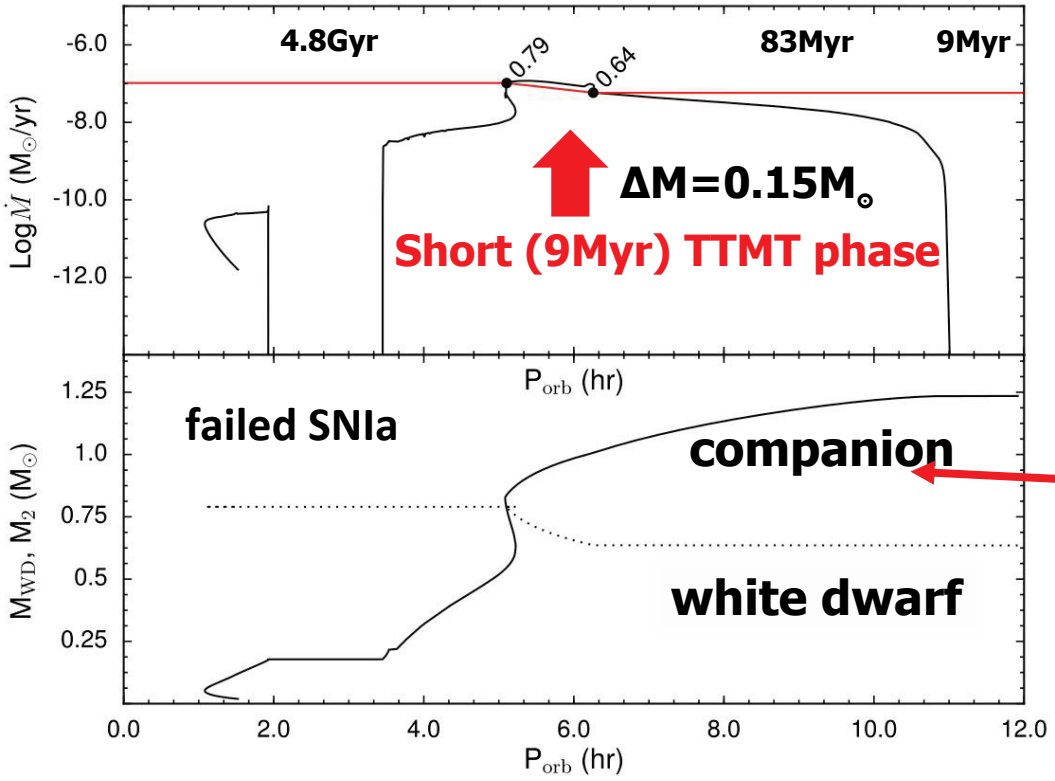


Far-ultraviolet spectroscopy identifies "failed SNIa" =evolved, hydrogen-depleted donors



Gänsicke et al. 2003ApJ...594..443G

time



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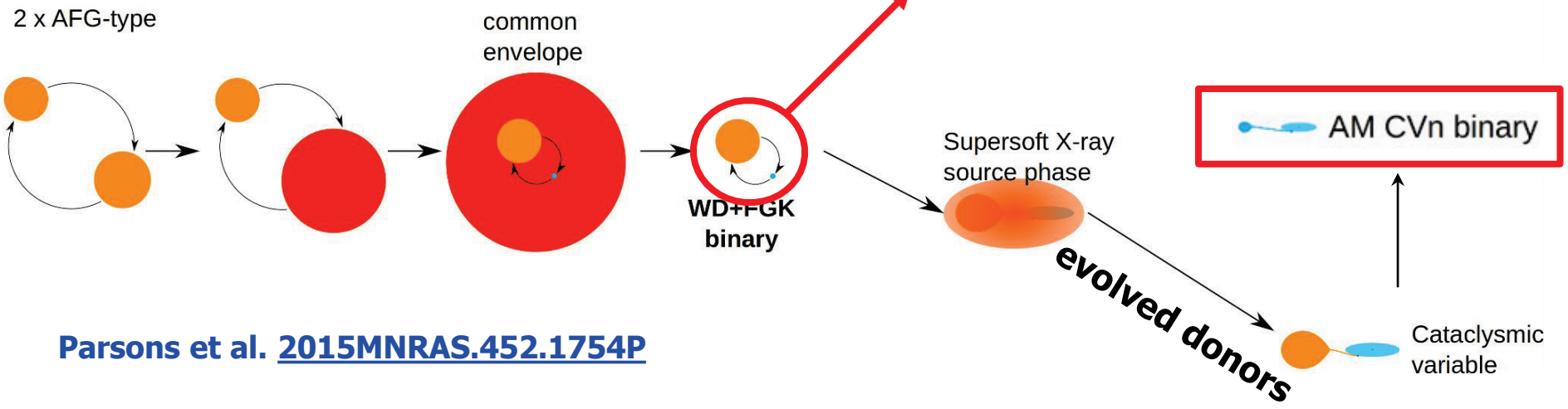

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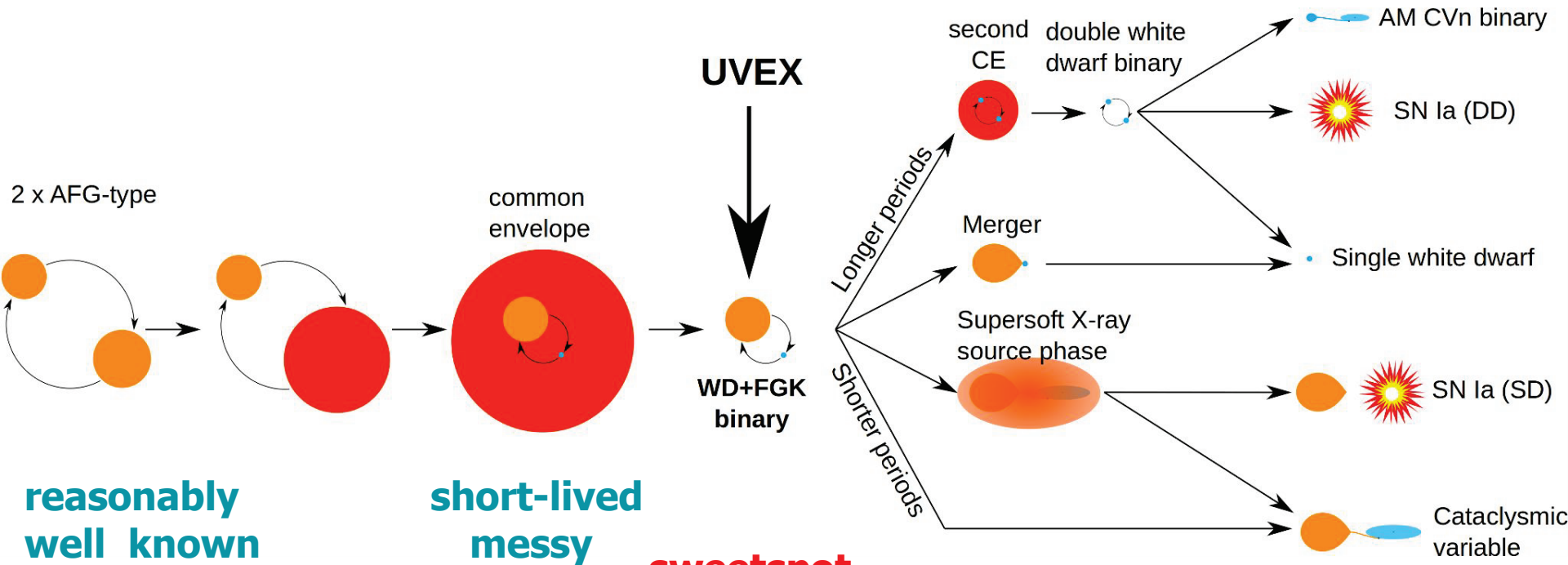


reasonably well known (RVs, Gaia, TESS…)

short-lived messy

sweetspot

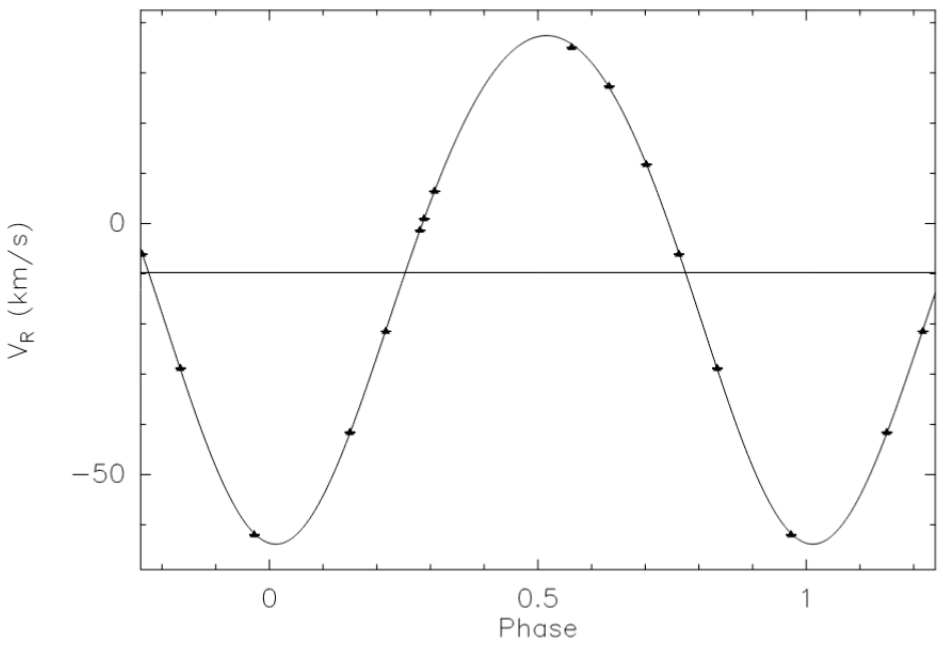
currently ~25 systems known

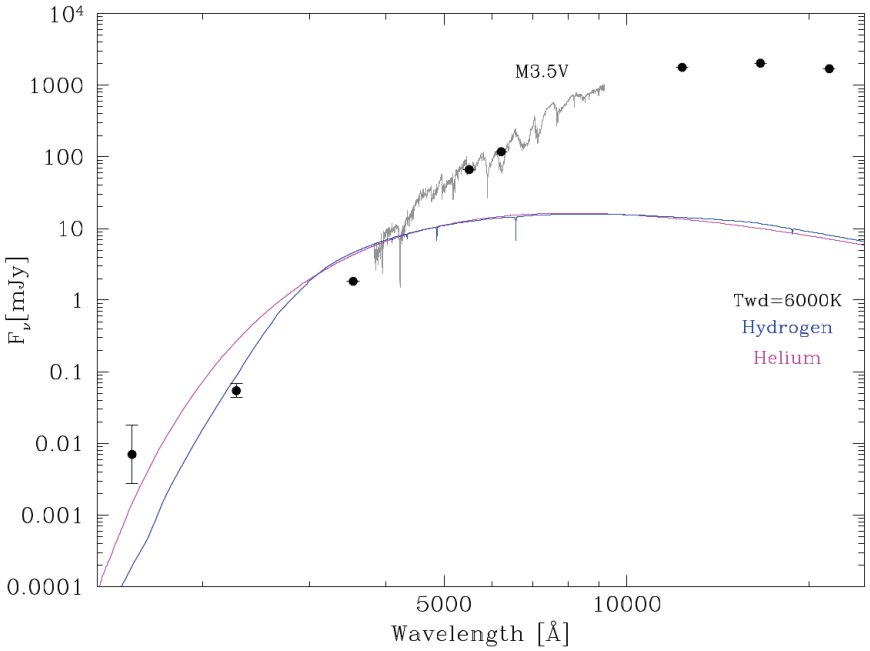
rare hard-to-characterise

Closer to home (d≈8pc!)

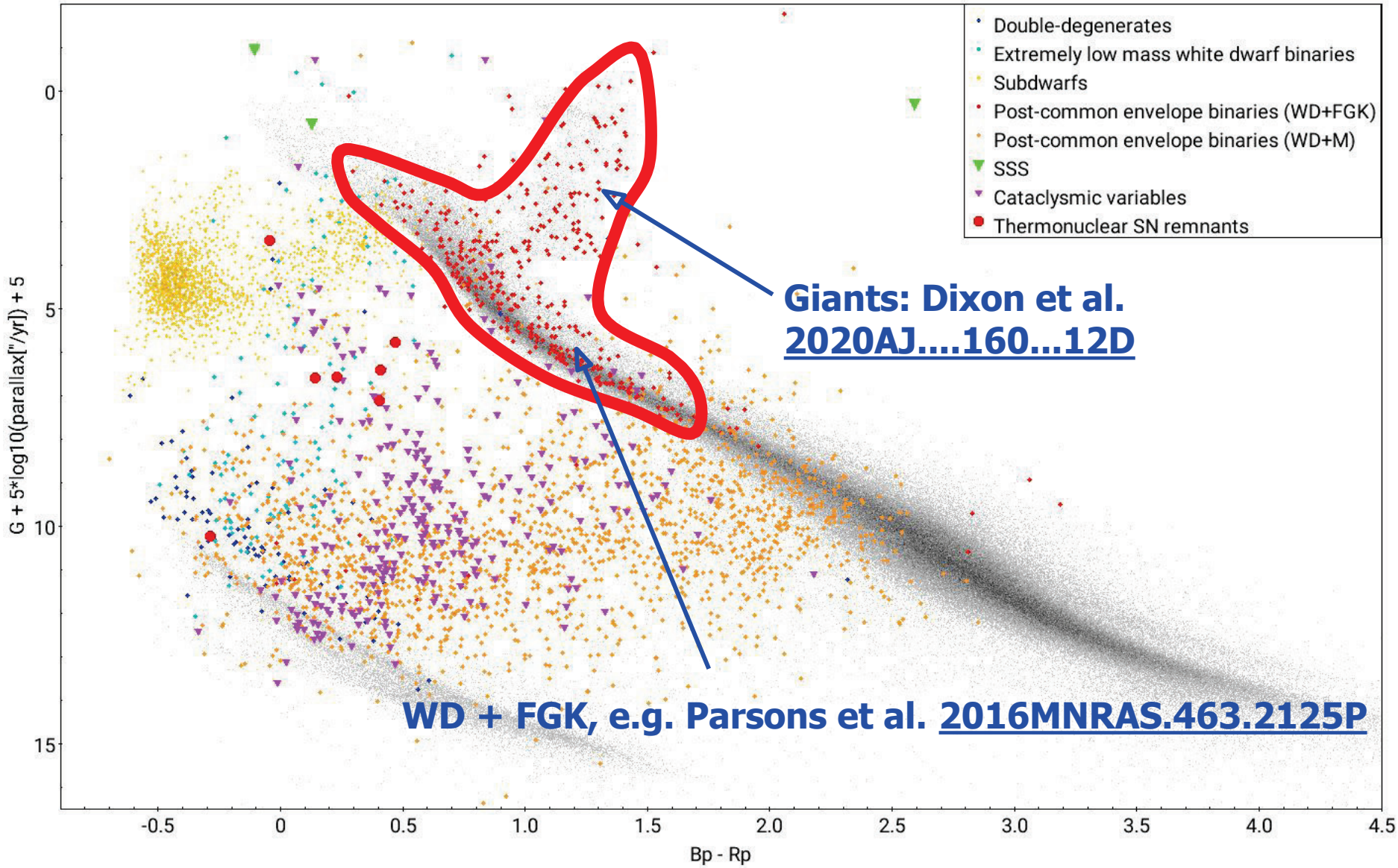
A single-lined dM+? binary with a mild UV excess: m(FUV)≈22

… most likely a white dwarf companion …
… but how common are such systems?

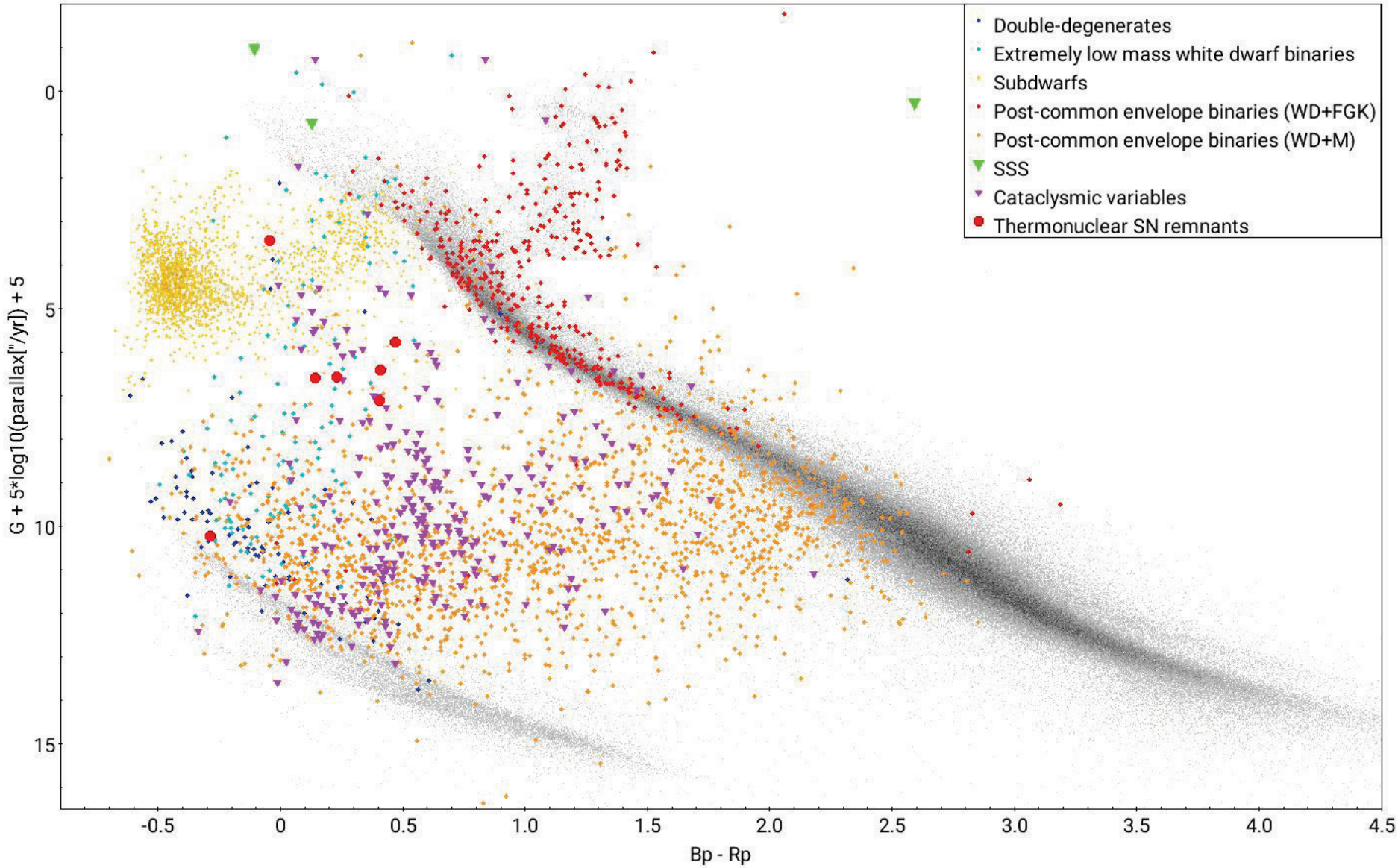




Identifying white dwarf binaries via their UV emission



Identifying white dwarf binaries via their UV emission



Summary

- **White dwarf binaries are important in the context of**
  - **Thermonuclear supernovae**
  - **Low-frequency gravitational wave radiation**
  - **Accretion physics**
  - **Matter under extreme conditions**

- **Ultraviolet excess is a key to their identification**

- **Low-resolution far-ultraviolet spectroscopy is an extremely powerful tool to establish their physical properties and evolutionary state**

- **The sensitivity and sky coverage of UVEX, hold an enormous potential for the study of all types of white dwarf binaries, in particular those with luminous companions**