Searching for Close Binary Systems II

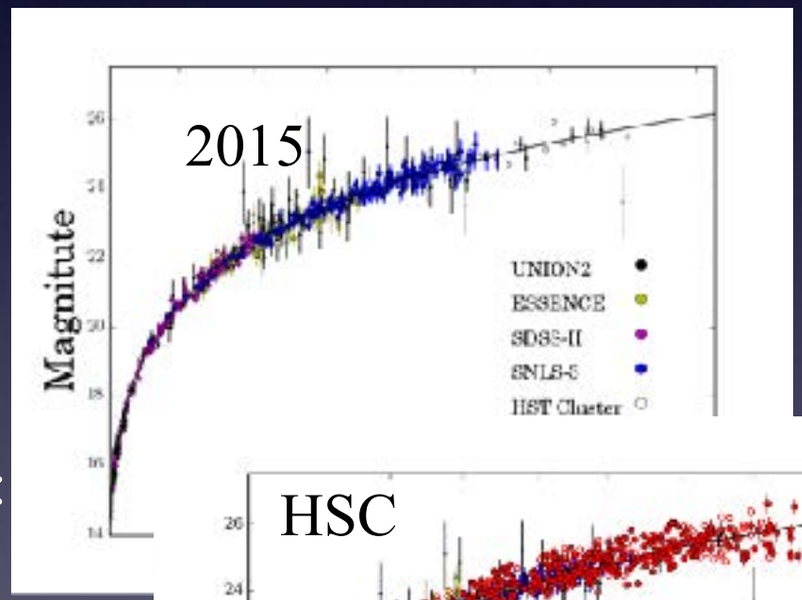
Nao Suzuki (Lawrence Berkeley National Lab)

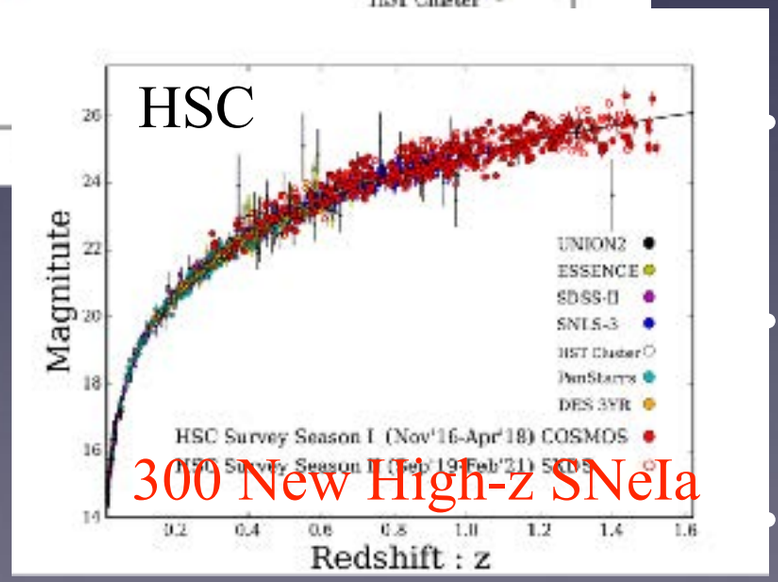
Close Binary Systems :

1. Gravitational Wave Source
2. Progenitor of Type Ia Supernova

White Dwarf-White Dwarf:
Double Degenerate System

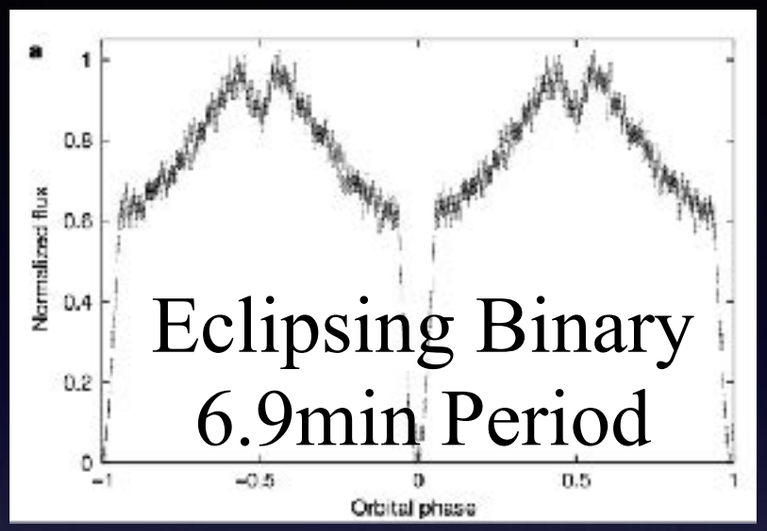
White Dwarf-Main Sequence Star:
Single Degenerate System





- §1: Recap : Close Binaries
- §2: Spectroscopic Binaries
- §3: New LTCV fitter
- §4: Future Prospects
- + Euclid / Roman
- +DESI-II, LS4, ZTF-III

§1 : Close Binaries

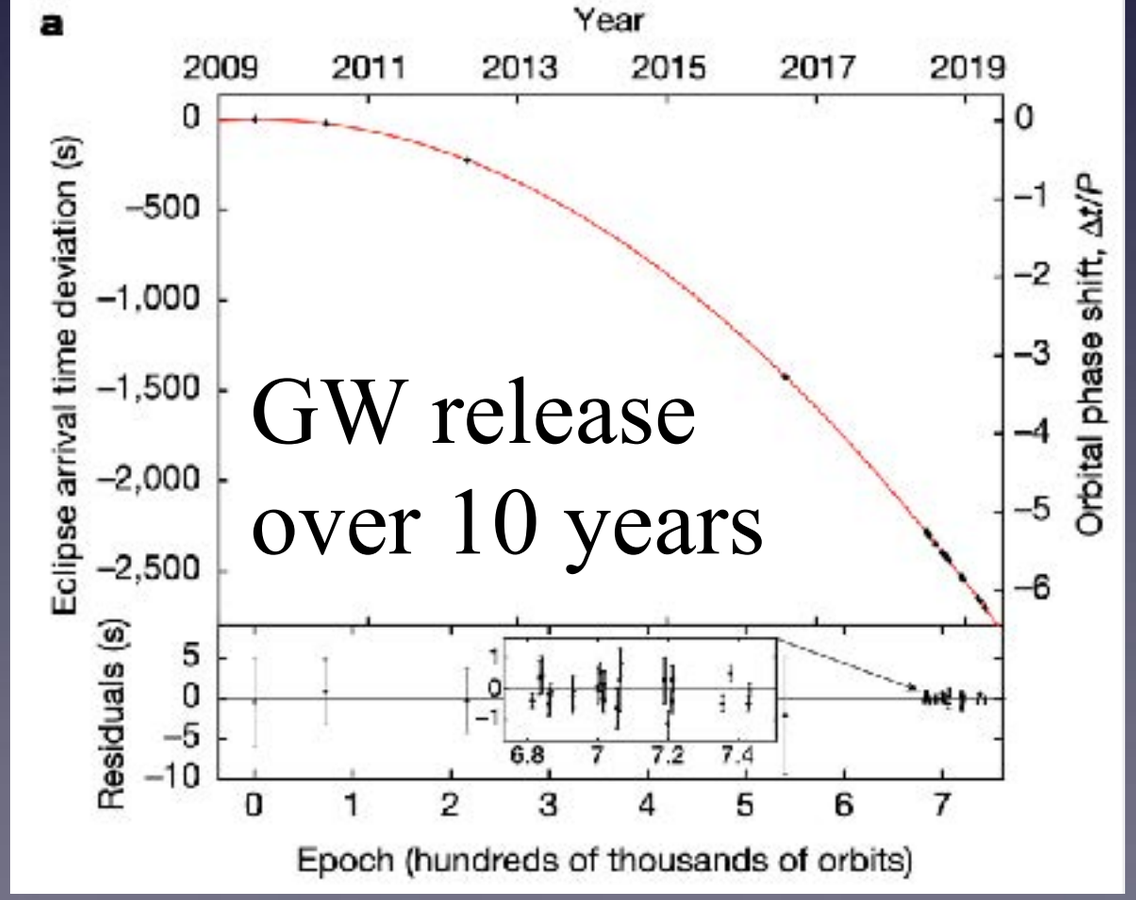


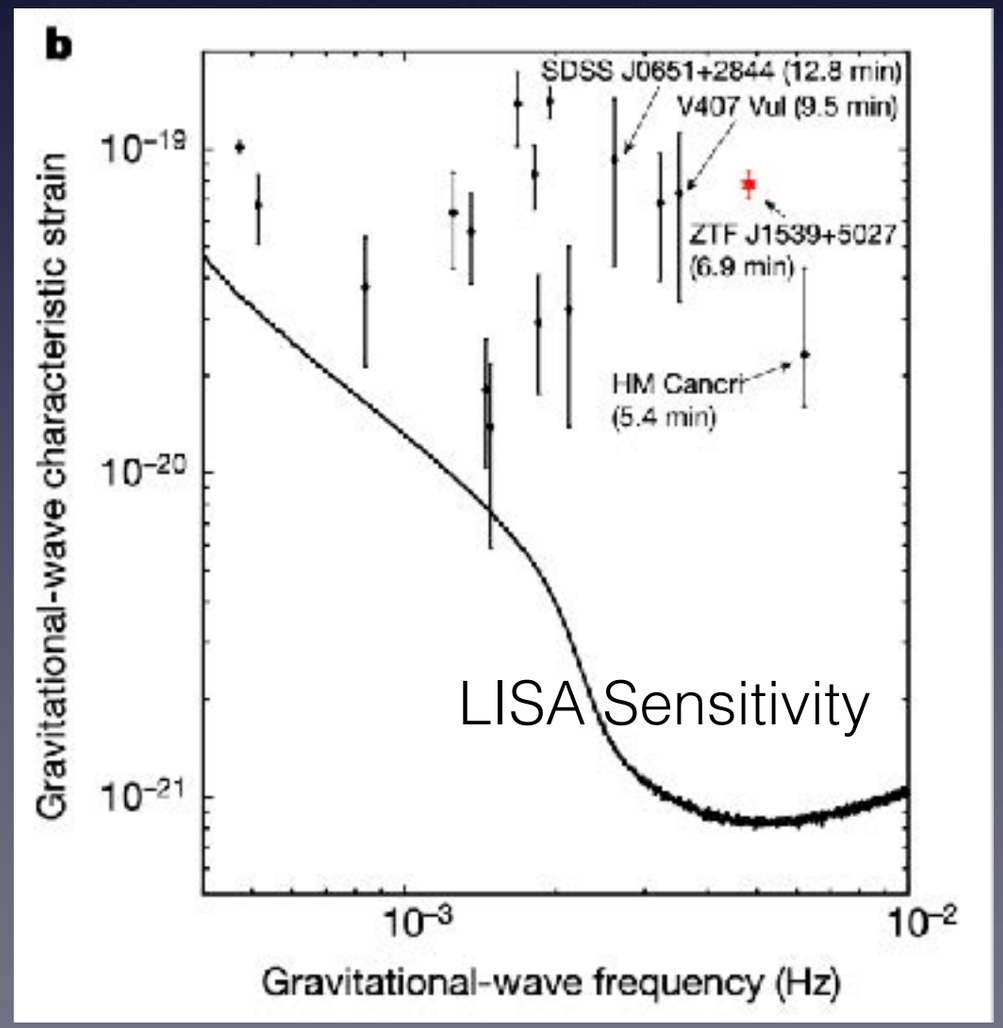
Zwicky Transient Facility (ZTF) :
Northern Hemisphere Sky Survey

M1: 0.61 $M_\odot$

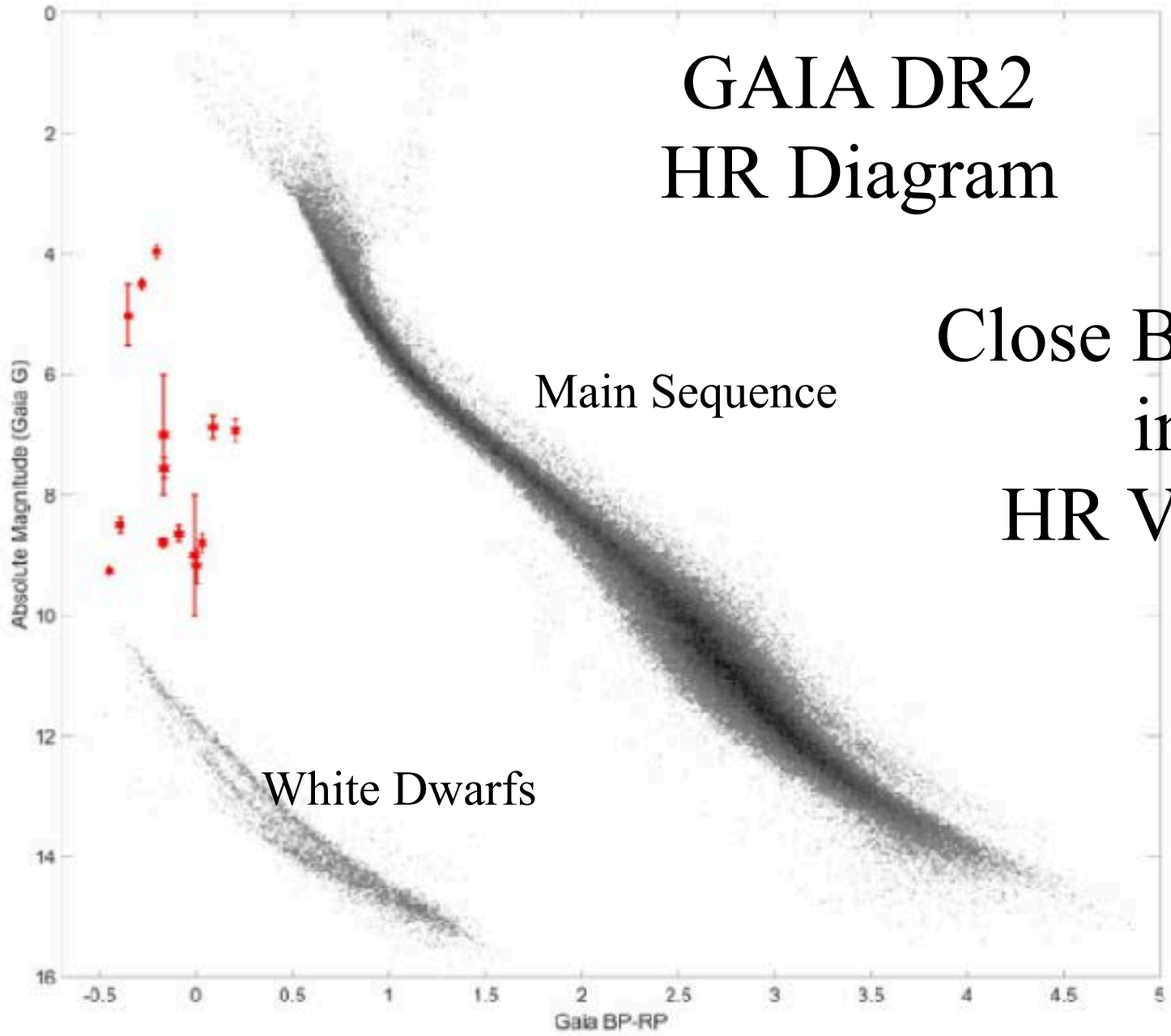
M2: 0.21 $M_\odot$

Burdge et al. 2019, Nature, 571, 528





GAIA DR2
HR Diagram

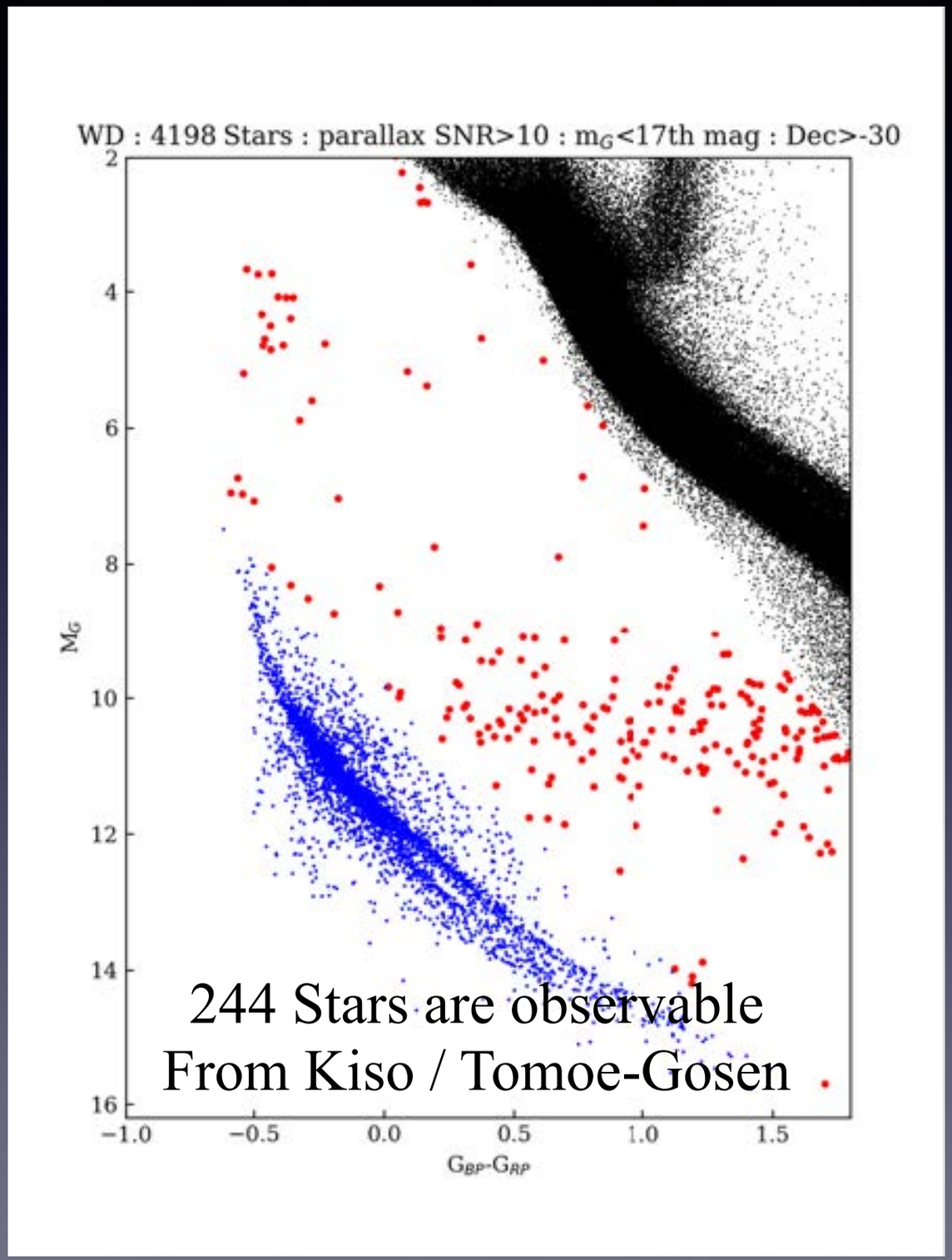


Close Binaries in HR Valley

Figure 8. Hertzsprung–Russell diagram illustrating the dereddened locations of 14 binaries in the sample with spectroscopic distances (ZTF J0643+0318 is omitted, as its modeling is ongoing). The red stars represent objects that are in our sample, with absolute luminosities calculated based on their spectroscopic distances. Most objects cluster between absolute magnitudes of 6.5 and 10.0, with the exception of the systems containing either He-burning stars or young and hot He WDs (which contribute significant additional luminosity, dwarfing both the luminosity of the companion WD and any accretion luminosity). The background color–magnitude diagram (CMD) is the sample of all stars in Gaia within 100 pc that have reliable astrometric solutions.

Burdge et al. 2020, ApJ, 905, 32

Tomoe-Gozen Proposal



- Monitor 244 HR Valley Stars
- 4198 White Dwarfs x eROSITA sources
- 244+4198=4442 Stars to be recorded!
- Spectroscopic Follow-up by Lick (KAST / APF)

Science Goals:

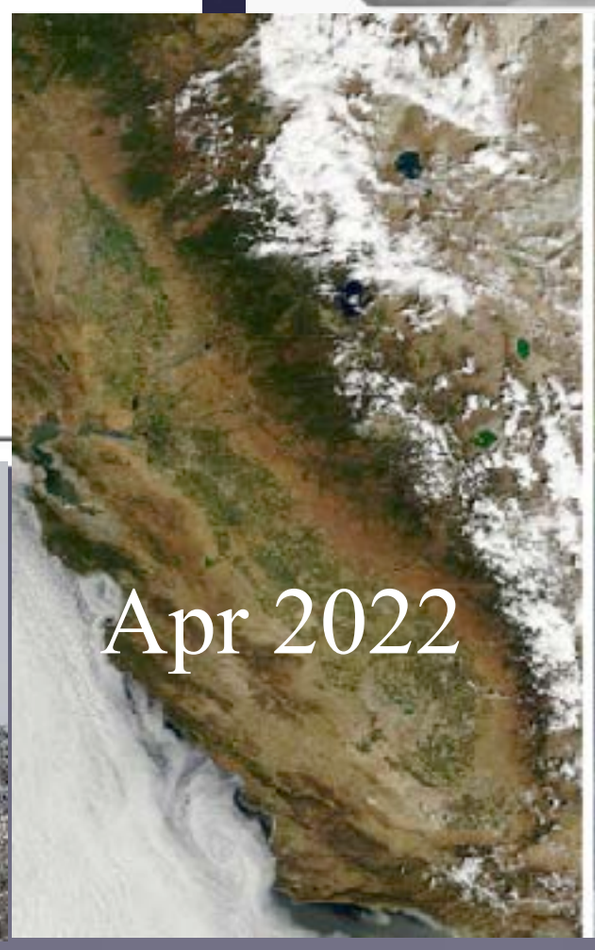
Binary Census = GW Background = SNIa Progenitor

Discover Closest Blackhole through Binary Motion

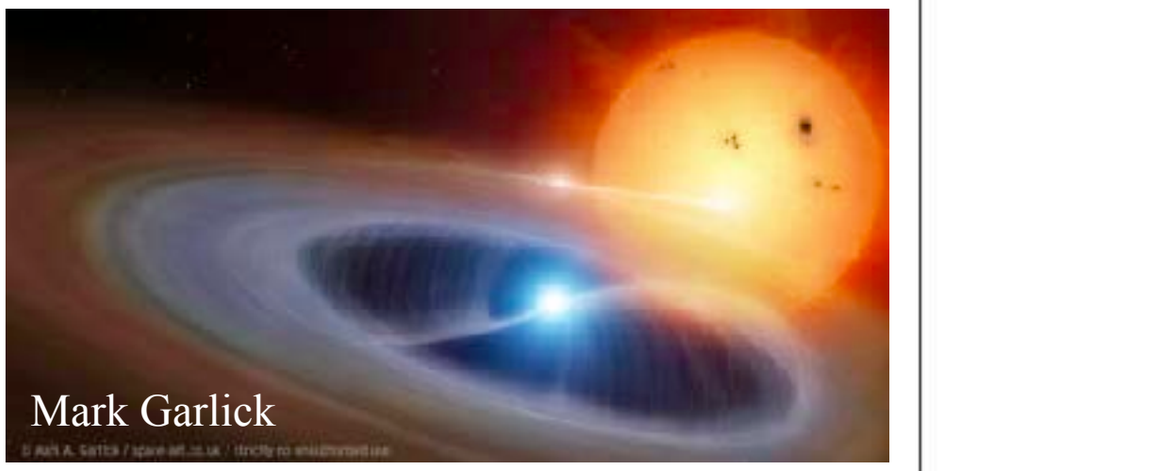
16 nights of Lick (3m) Observing Log : DESI SV Data Release (summer)

Table 2. 2023A (PI Suzuki) : Log by Run (Internal Memo)

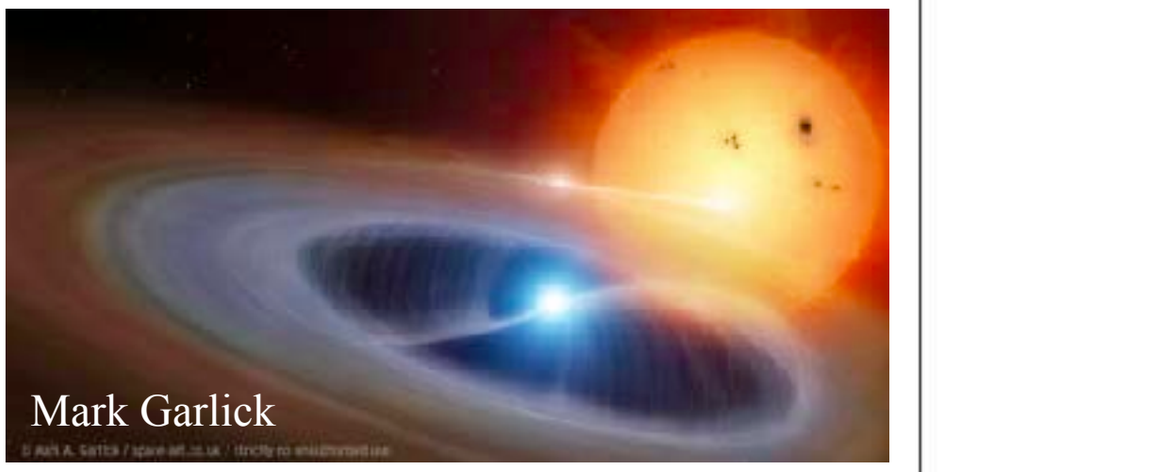
Date	INST	Open Time / Rate	seeing	PI	Note	Observers	Support
2023-02-24	KAST	0%	N/A	Suzuki	Heavy Snow	NS	
2023-02-25	KAST	0%	N/A	Suzuki	Heavy Snow	NS	
2023-03-26	KAST	80%	2.0"	Suzuki	Windy	NS@Mitaka IoA	
2023-03-27	KAST	0%	N/A	Suzuki	Storm	NS@Mitaka IoA	
2023-04-02	KAST	0%	N/A	Suzuki	Cloudy	NS	
2023-04-03	KAST	0%	N/A	Suzuki	Cloudy	NS	
2023-04-04	KAST	0%	N/A	Suzuki	Cloudy	NS	
2023-04-30	KAST	0%	N/A	Suzuki	Cloudy	NS	
2023-05-01	KAST	0%	N/A	Suzuki	Cloudy	NS	
2023-05-02	KAST	0%	N/A	Suzuki	High Humidity	NS	
2023-05-08	KAST	5%	2.0"	Suzuki	High Humidity	NS	
2023-05-09	KAST	0%	N/A	Suzuki	Clear / High Humidity	NS	
2023-06-22	KAST					NS	
2023-06-23	KAST					NS	
2023-07-10	KAST					NS	
2023-07-23	KAST					NS	



Cataclysmic Variables (CV)

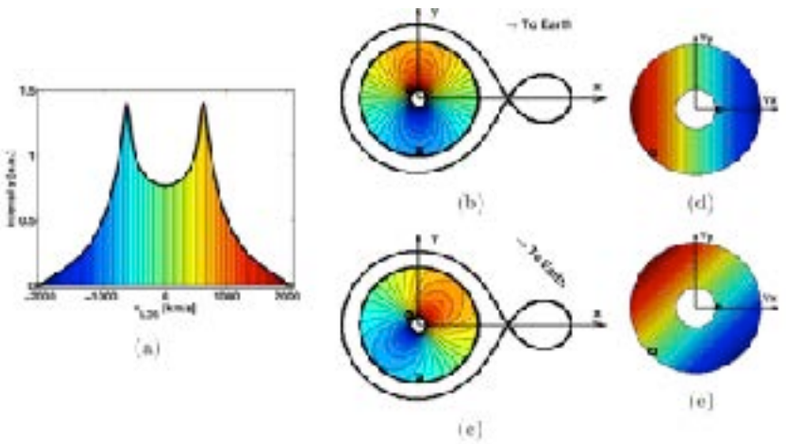


Cataclysmic Variables (CV)



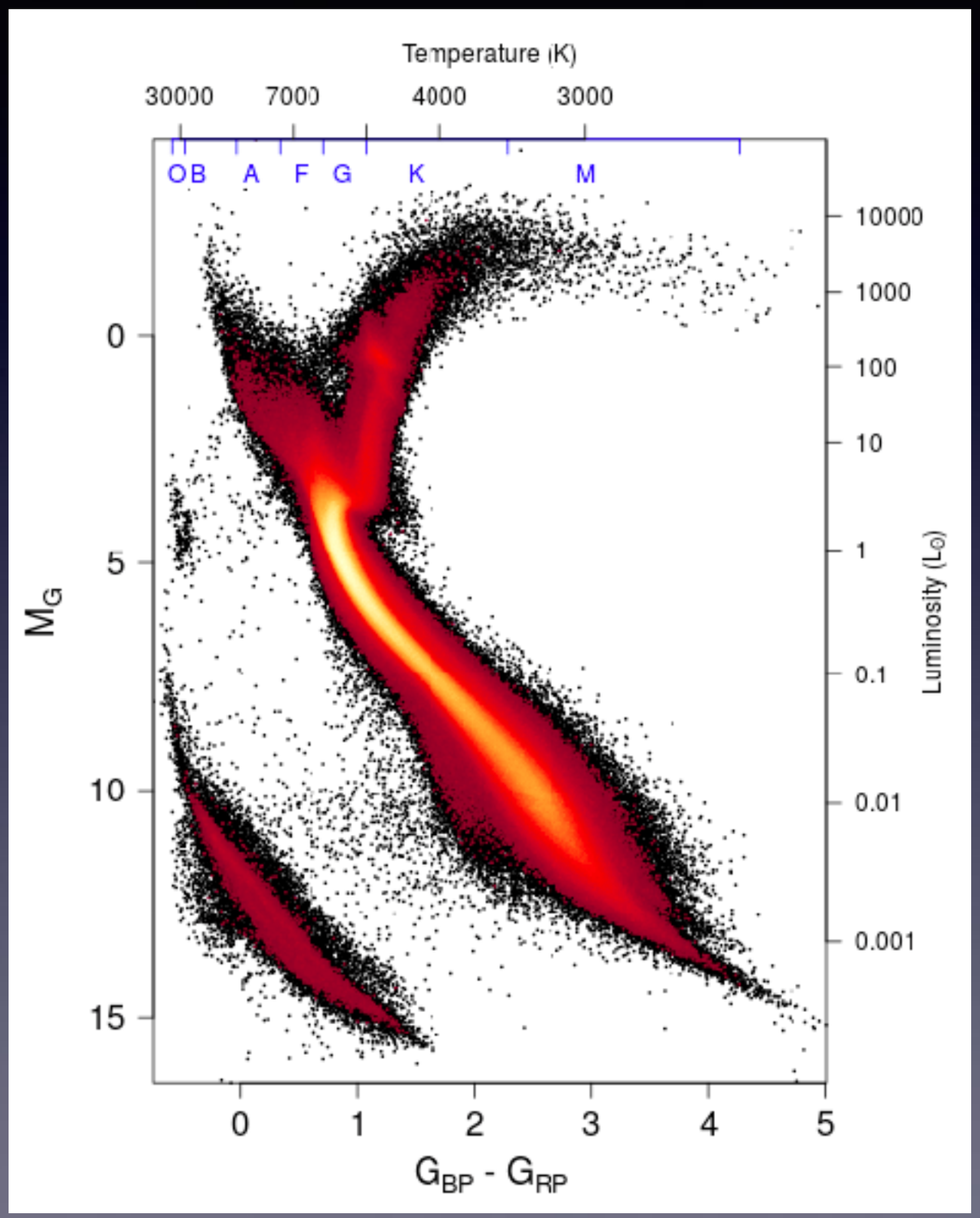
Cataclysmic Variables (CV)

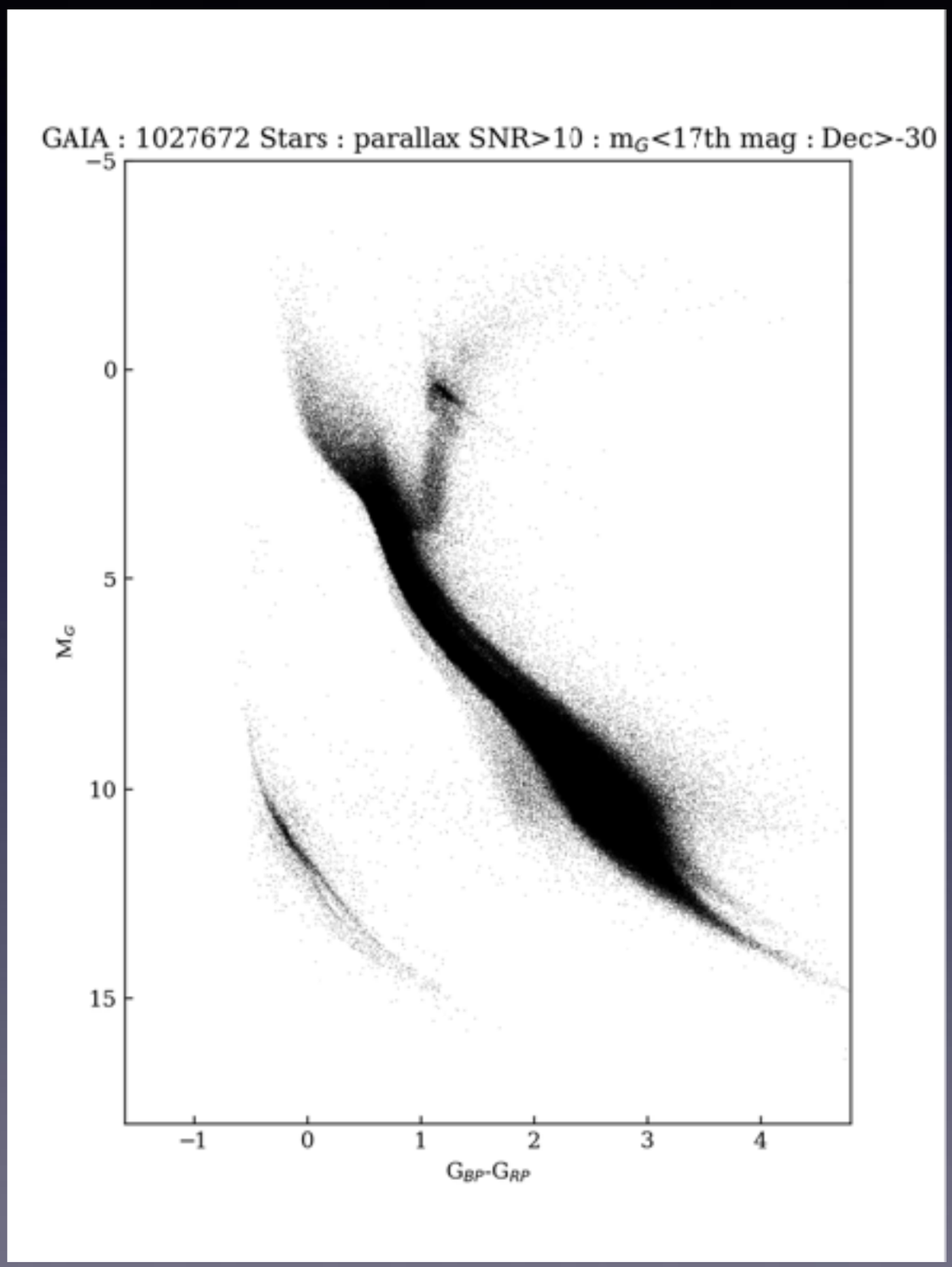
Mirko Salewski



1,027,672 Stars visible from Tomoe-Gosen

DEC > -30, m < 17th mag from GAIA DR3

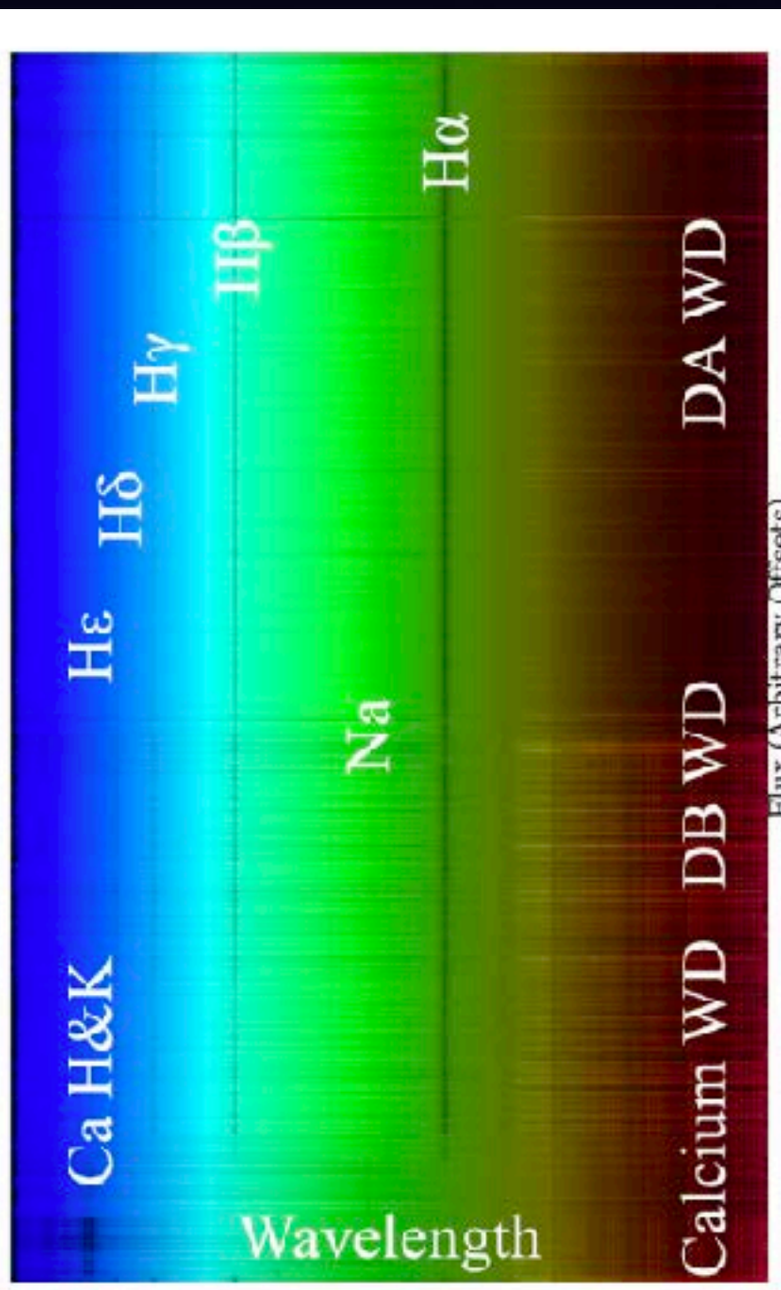


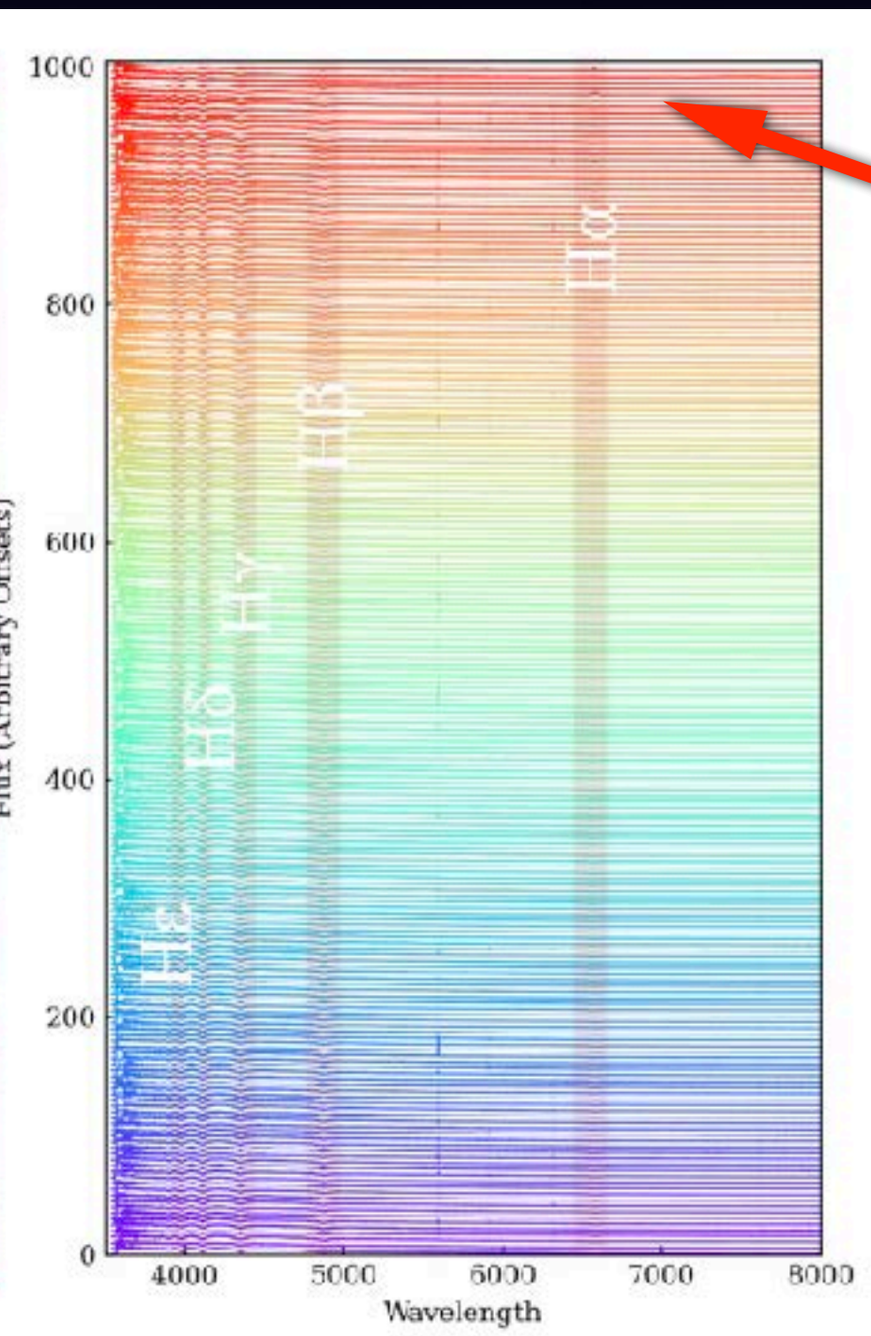


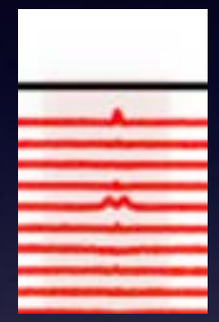
§3 : Spectroscopic Binaries

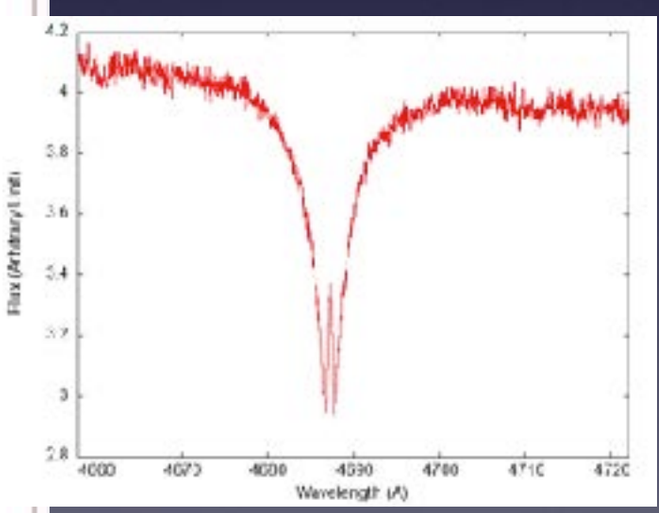
Finding Unresolved WD Binaries

SDSS 26,801 Spectra Entropy based Kullback-Leibler divergence









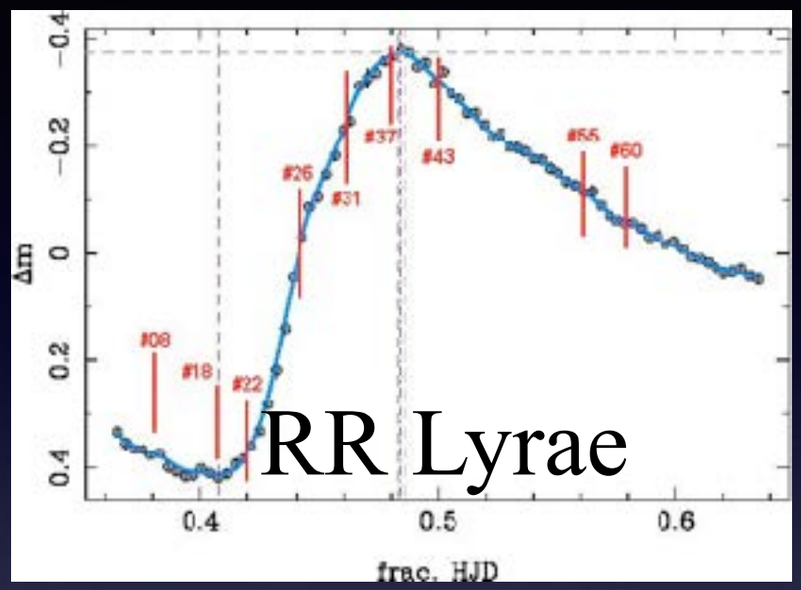
Roughly
5%
1000 WDs

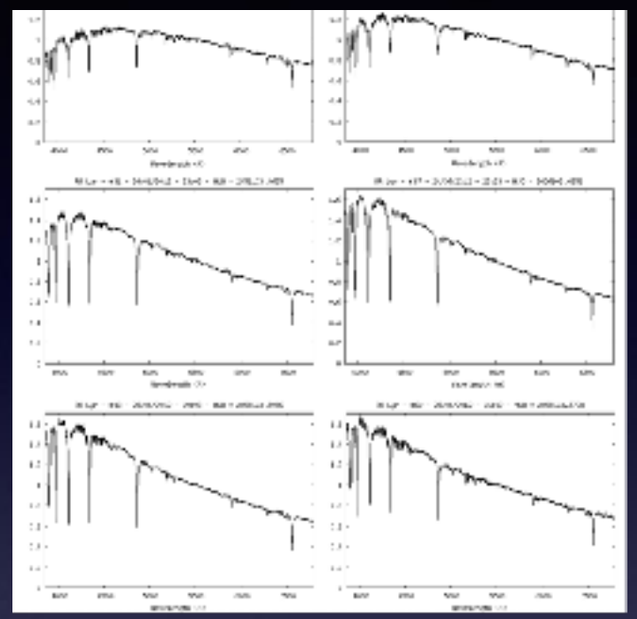
Back on the Envelope Estimate
0.7 Solar Mass Binary => 2.0 Roche Limit

Period (Min)	Time to Merge (Year)	Relative Fraction	In MW
120	1.63×10^8	1955.5	200,000
60	2.57×10^7	307.9	30,000
15	6.39×10^5	7.63	800
7	8.30×10^4	1.00	100
3	8.67×10^3	0.10	10

244 Targets x 5% (eclipsing fraction based on TESS)
=>12 Systems

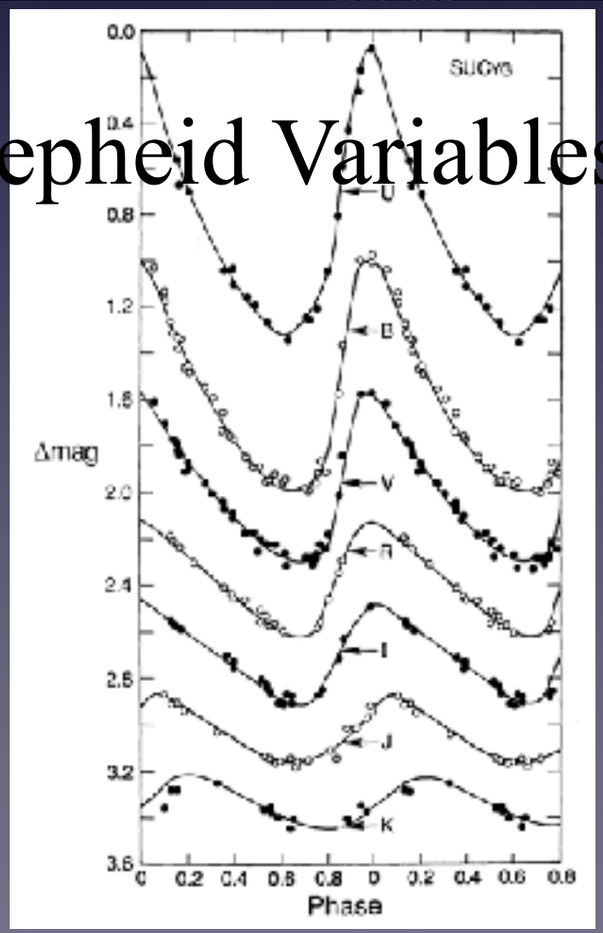
A Pilot Study for Time Domain Spectroscopy

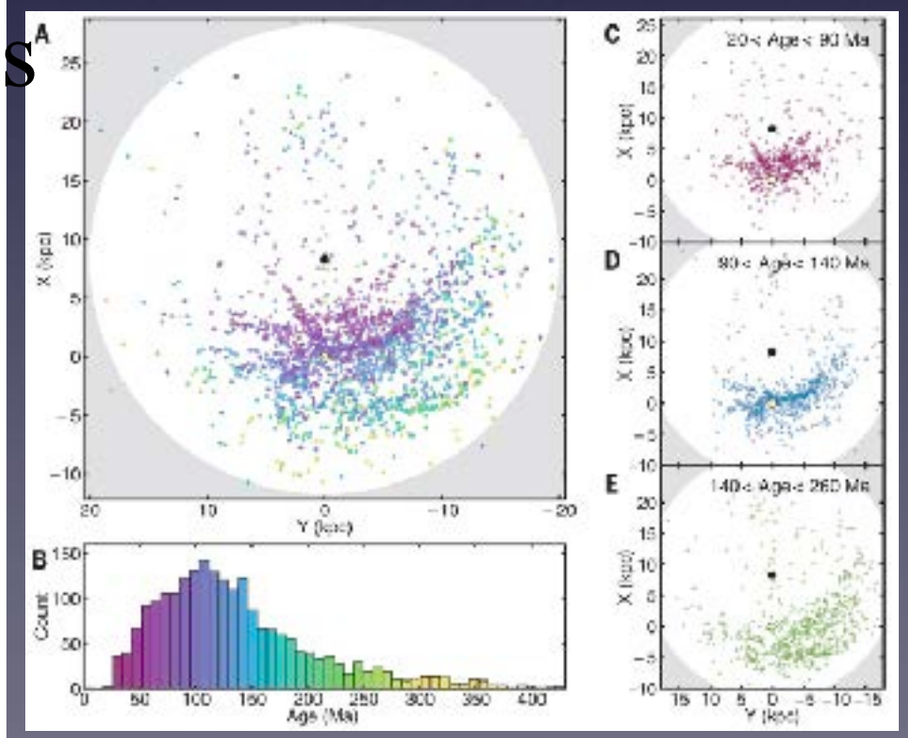




CV
WD-BH, NS-BH
RR Lyrae
Cepheid Variables
Supernovae

Age-Metallicity dependece
is addressed by photometry but not Spectroscopy





DESI-II Bright Time
2026?
+ZTF-III / Tomoe-Gosen

§3 New LTCV Fitter (SALT=>NaCl)

By Guy Augarde et al. (LPNHE team)

Astronomy & Astrophysics manuscript no. nacl
December 2, 2022

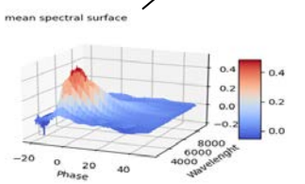
NaCl: Nouveaux algorithmes de Courbes de Lumière

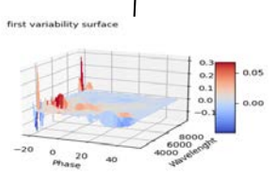
Guy Augarde[1], Nicolas Regnault[1], Marc Betoule[1], and Sébastien Bongard[1]

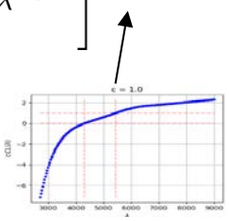
LPNHE, (CNRS/IN2P3, Sorbonne Univer
75005, Paris, France

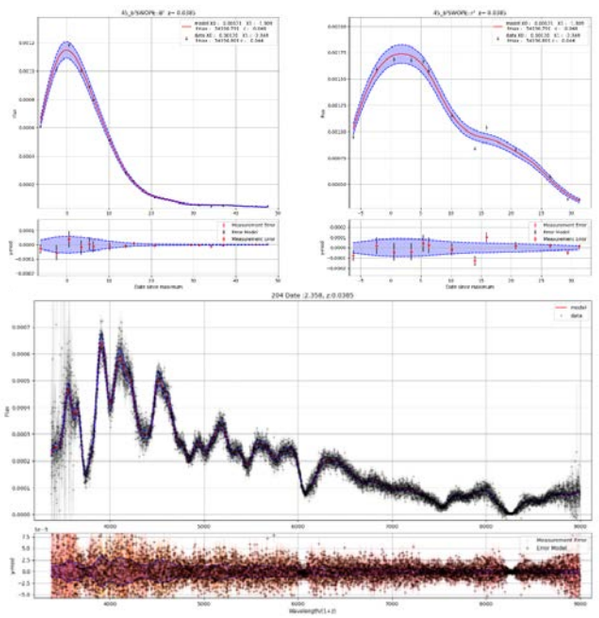
SALT4 (Augarde et al)

$$S_{obs}(\lambda,t) = \frac{1}{1+z} X_0 \left[M_0 \left(\frac{t-t_{max}}{1+z}, \frac{\lambda}{1+z} \right) + X_1 M_1 \left(\frac{t-t_{max}}{1+z}, \frac{\lambda}{1+z} \right) \right] e^{c\,CL(\frac{\lambda}{1+z})} \left[\sum_{i=0}^{N_s} s_i^{sp} \cdot \lambda^{N_s - i} \right]$$







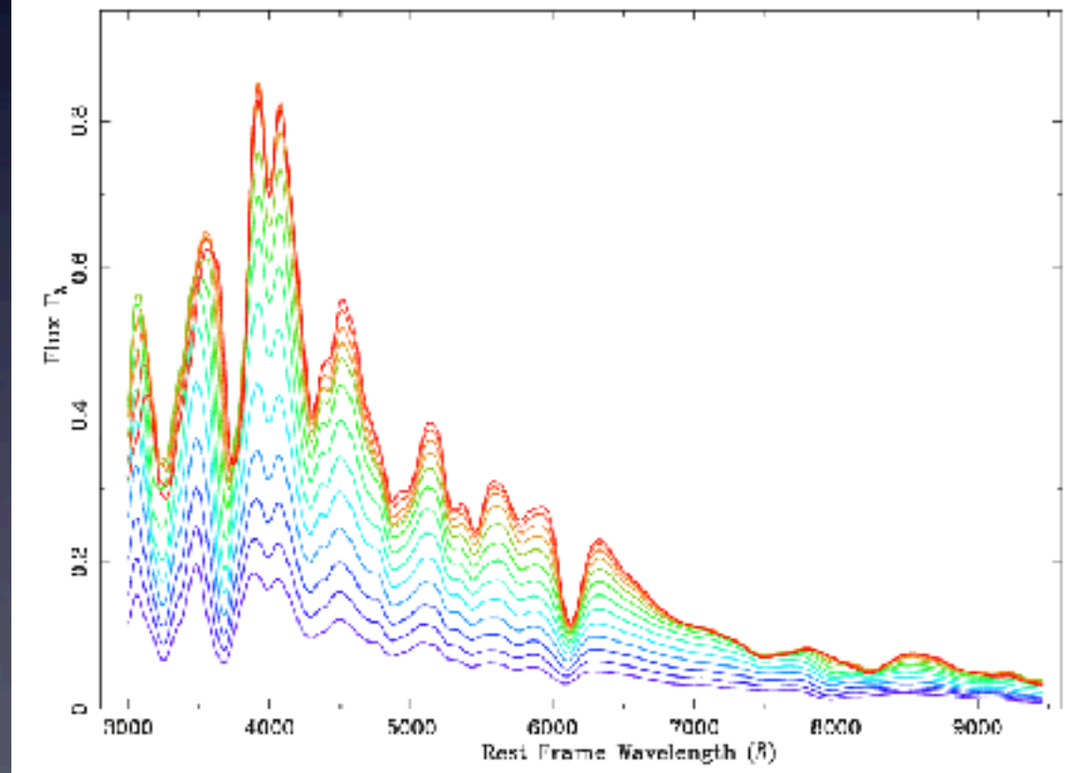


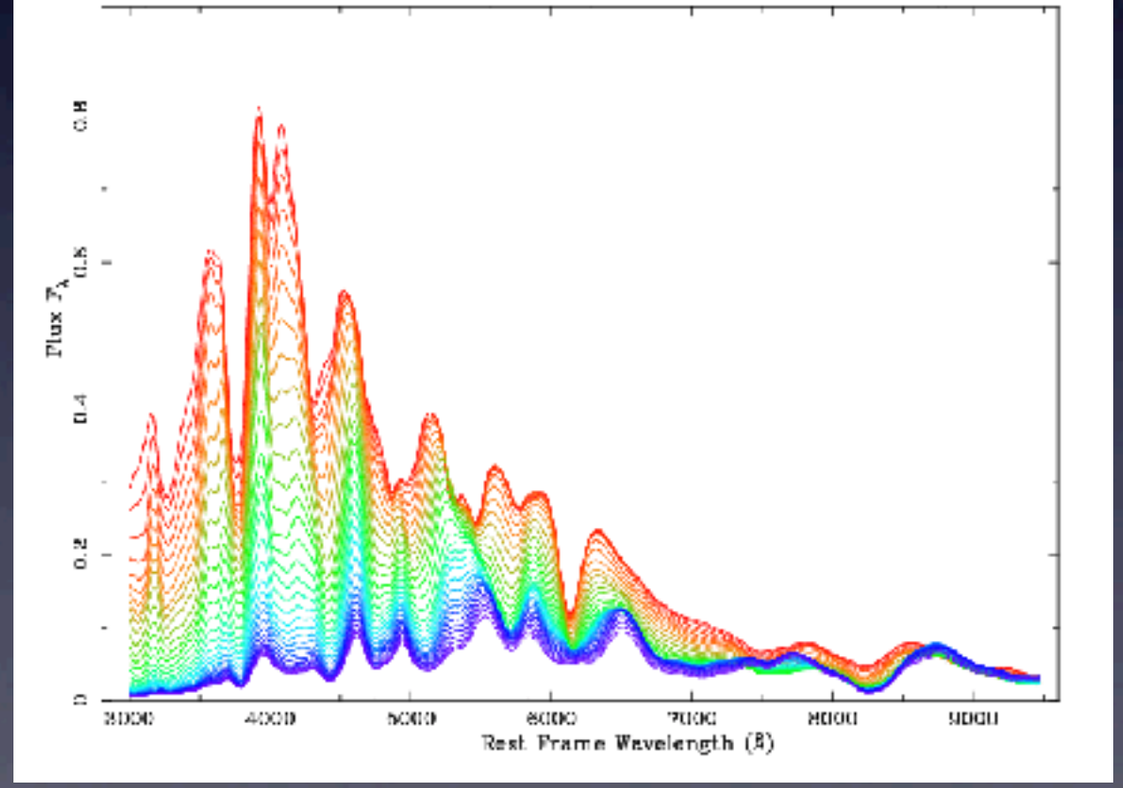
- These de G. Augarde
  - modélisation empirique de l'évolution spectrophotométrique des SNe Ia
  - update de “SALT2” (developpé au LPNHE)
  - ingrédient essentiel de la mesure des distances aux SNe
    - K-corrections
    - observables de standardisation
- Objectifs:
  - corriger limitations SALT2
  - (lot d’entrainement x 5 en 10 ans)
  - nouvelles observables de standardisation

Time Series (1st :94%, 2nd:4%, 3rd:1%)

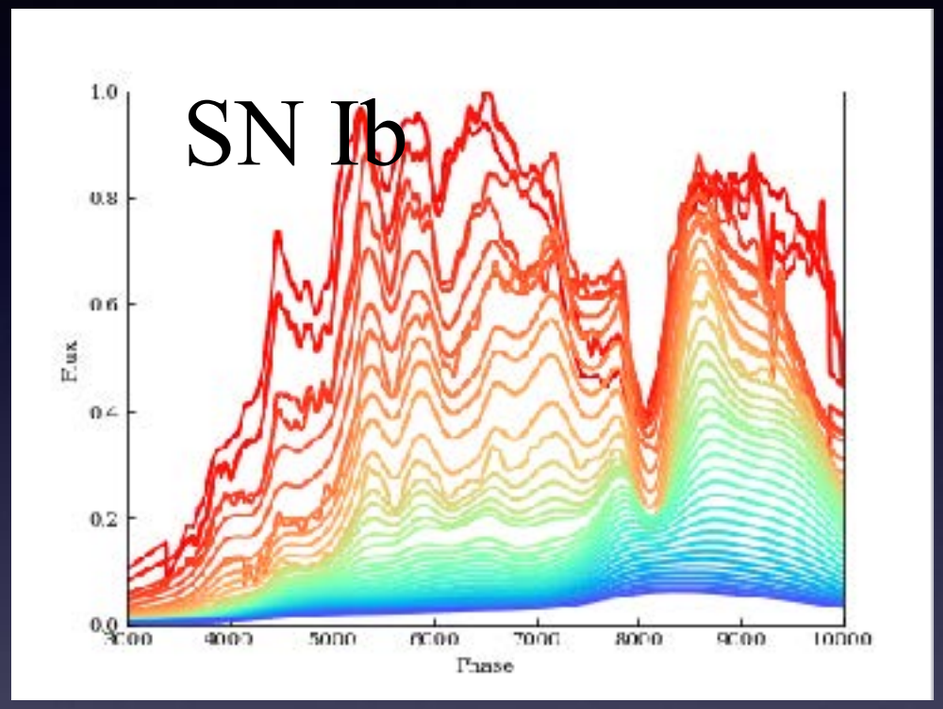
$$\vec{S} = \vec{\mu} + \sum_{j=1}^{n} c_j \vec{\xi_j}$$

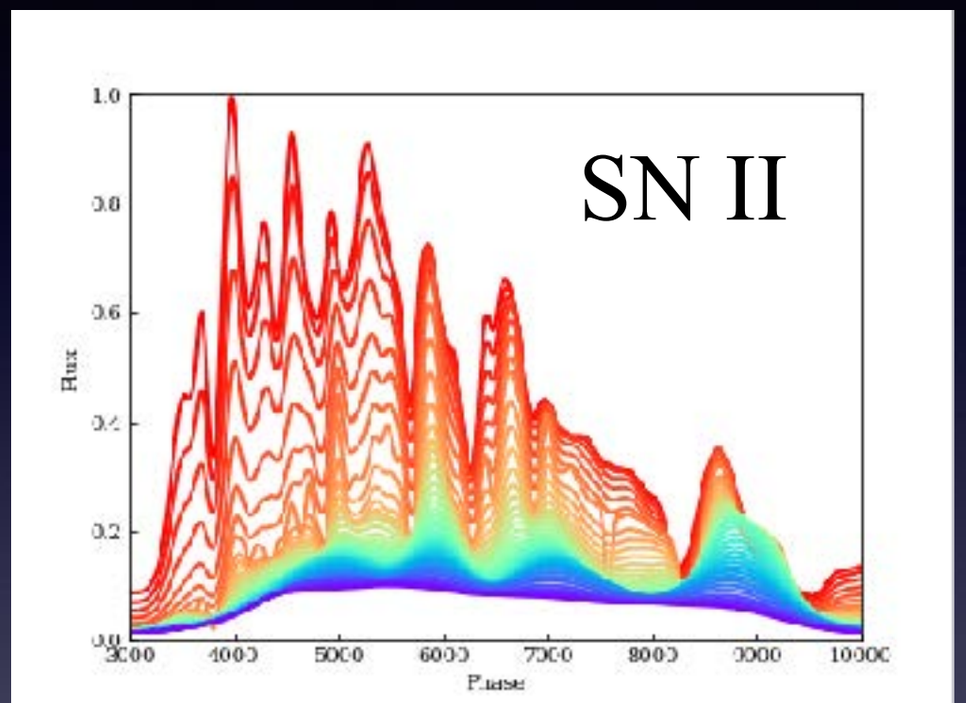
$$\vec{\xi_i} \cdot \vec{\xi_j} = \delta_{ij}$$

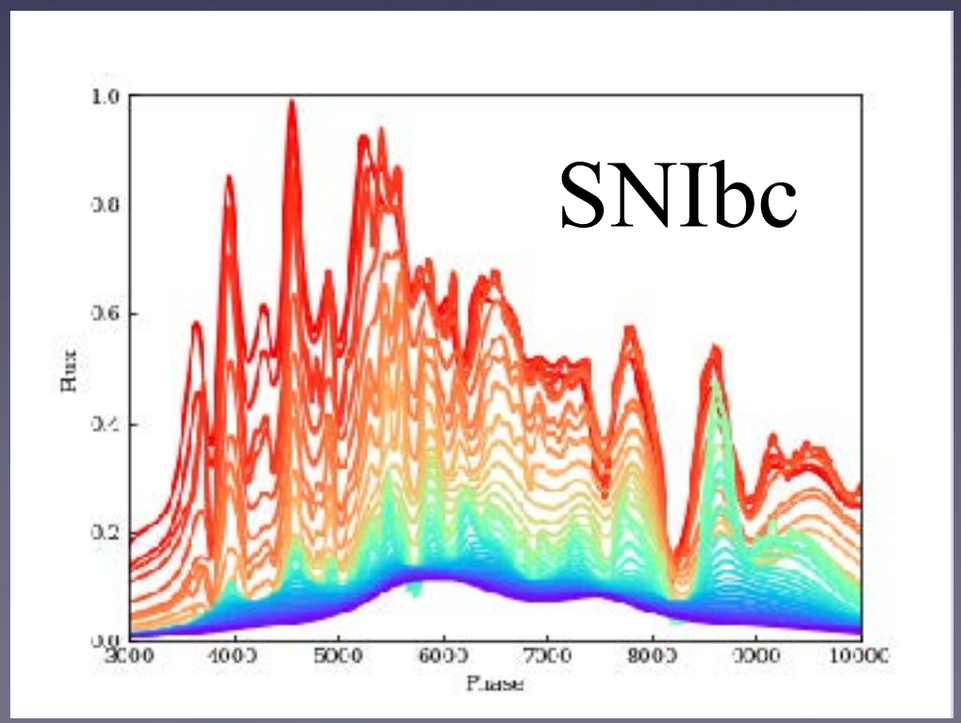


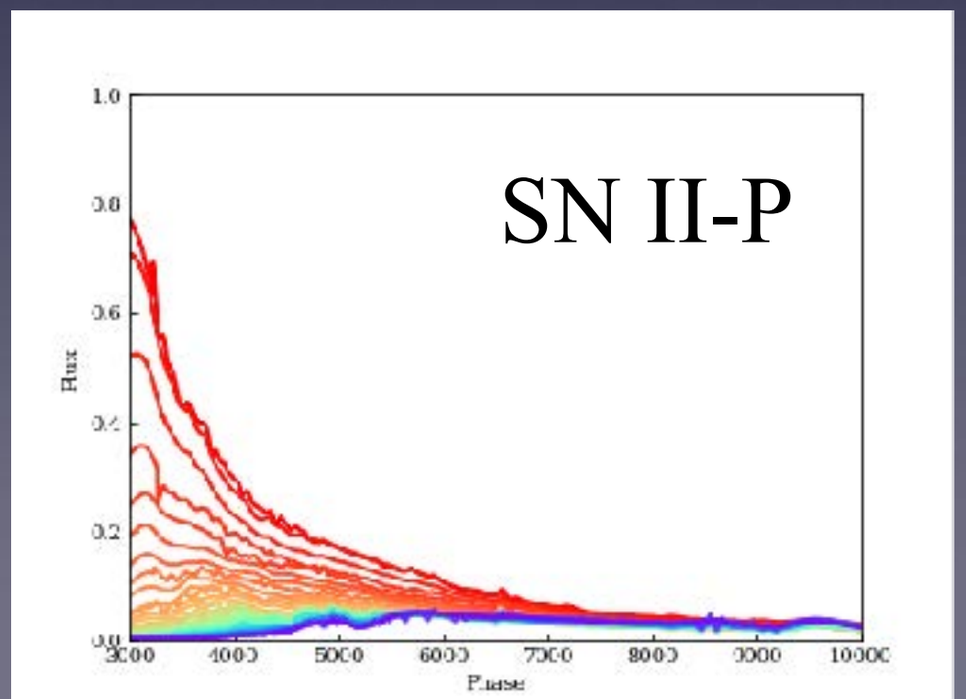


Towards ZTF-III, LS4, LSST
LTCV Fits to all types of SNe

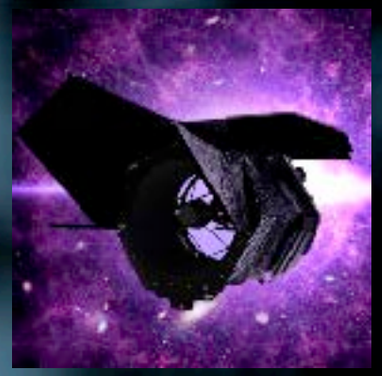








§4 Future Prospects towards 2025 : Summary

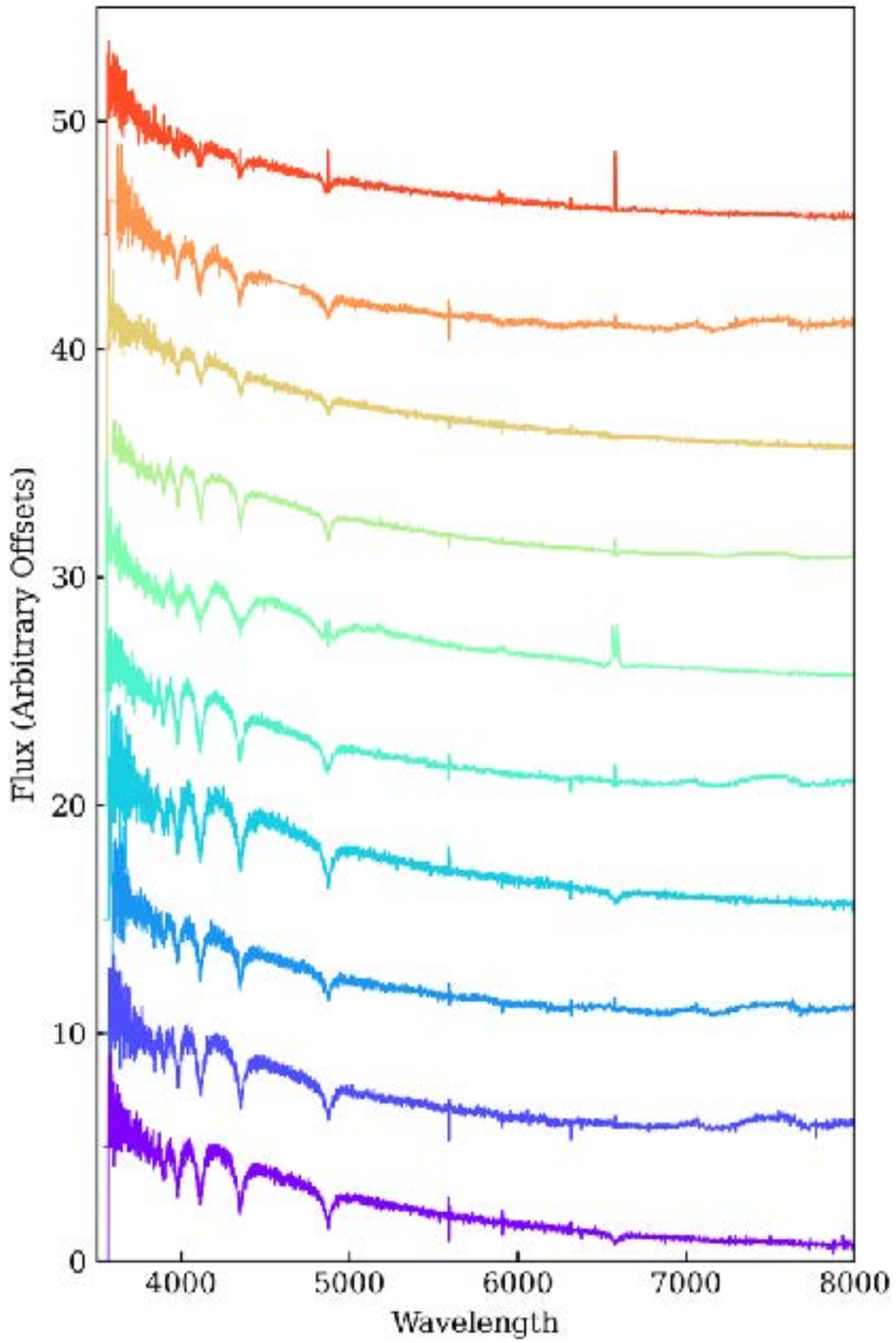


Simultaneous Observation with:
Euclid, YJH-band Observations
Roman, NIR Observations (Wide)
JWST footprints (See Roman Science Pitch)

Spectroscopic Follow-up : Time Series
Pilot Survey by Lick / KAST
DESI-II Bright Time Plan (2026-)

Period < 3 min : Tomoe + Spectral Time Series
CV (HR Valley : 244 Stars)
WD-WD, WD-BH, WD-NS Binaries (4198 WDs)

Back-up slides


50
40
30
20
10
0
Flux (Arbitrary Offsets)
4000
5000
6000
7000
8000
Wavelength