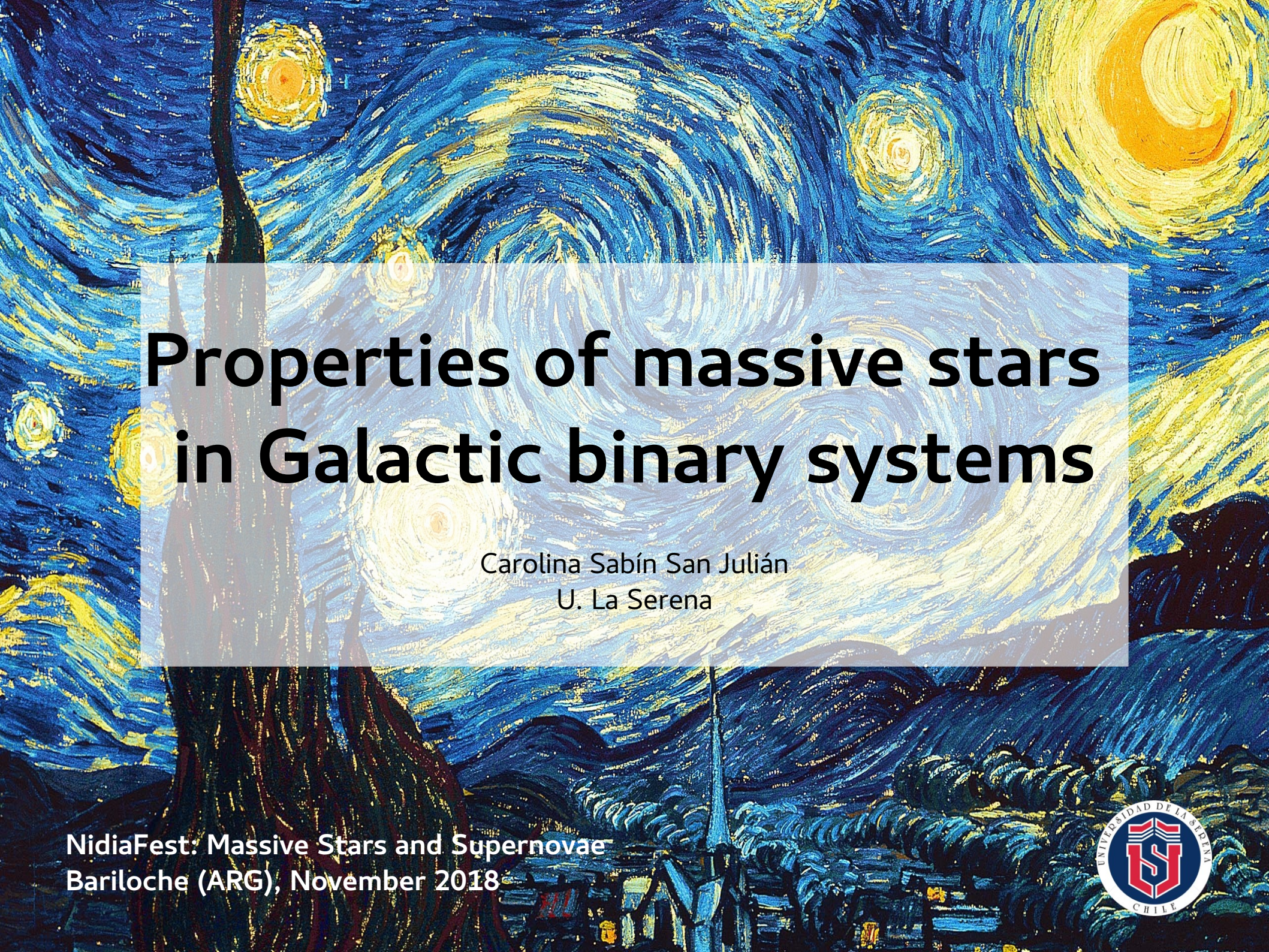


Properties of massive stars in Galactic binary systems

Carolina Sabín San Julián
U. La Serena

NidiaFest: Massive Stars and Supernovae
Bariloche (ARG), November 2018

OWN Survey: overview

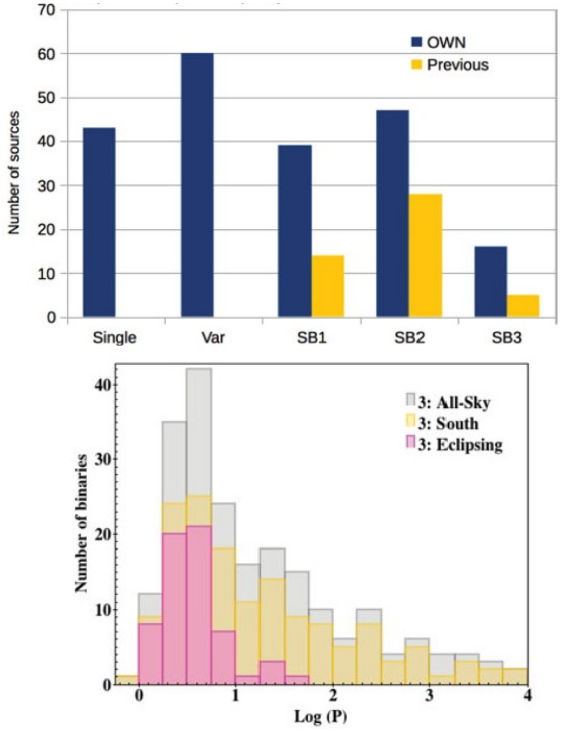
- Multiplicity status of Galactic O and WR stars (V < 11) in Southern hemisphere via spectroscopic and RV monitoring

- 7500+ optical spectra of **~300** stars
  with R = 15000 – 50000 using 2-m class telescopes
  at CASLEO, Las Campanas, La Silla, CTIO

  → More than 100 new binary/multiple systems
  → Orbital periods of 1.5 – 2200 days obtained

- Strong synergies with similar surveys:
  GOSSS, IACOB, CAFÉ-BEANS

Barbá+17, IAUS329



OWN Survey: massive binary systems

- Study the properties of non-evolved OB stars in Galactic binary systems
- Characterize stellar and orbital parameters → test state-of-the-art stellar atmosphere and single evolutionary models
- High resolution, high S/N and good phase coverage

OWN Survey: massive binary systems

- Study the properties of non-evolved OB stars in Galactic binary systems
- Characterize stellar and orbital parameters → test state-of-the-art stellar atmosphere and single evolutionary models
- High resolution, high S/N and good phase coverage

SB2 with wide orbits

- ✔ Binary interaction less probable
- ✖ Orbital inclination angle

Eclipsing SB2

- ✔ Absolute orbital elements
- ✖ Mass transfer more likely

OWN Survey: massive binary systems

Spectroscopic data
(OWN)
+
Photometric data
(Bochum, ASAS,...)

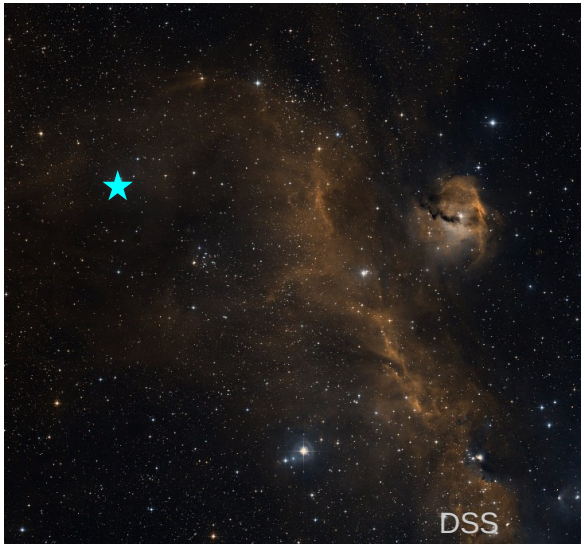
+

RVs, spectral disentangling, orbital solution
+
Stellar atmosphere / Evolutionary models

Mass discrepancy
Evolution
Binary interaction
....

HD 54662

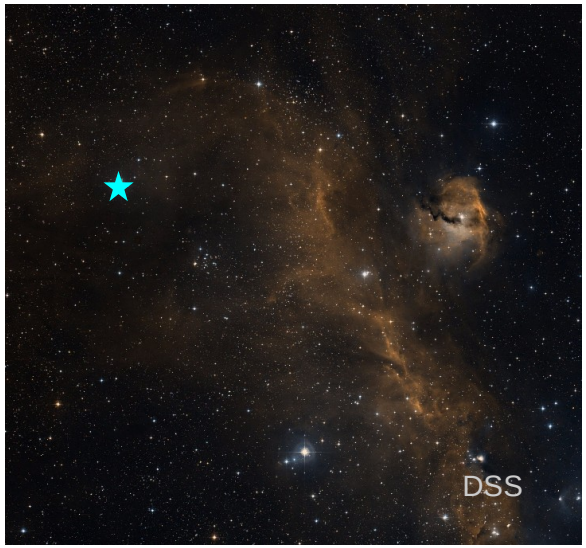
- Long period, earliest member of CMa OB1 association (Seagull Nebula complex)
- SB2 with main-sequence O-type components
  Binary nature first revealed by Boyajian+07 (spectroscopic data+literature)
- Le Bouquin+17
  VLTI data+RVs from Boyajian+07
  P=2100 d, e=0.06, M_A=316 M_{Sun}, M_B=58 M_{sun}, i = 75°
- Mossoux+18
  Spectroscopic data
- P=2100 d, e=0.11, M_A=9.7 M_{Sun}, M_B=8.2 M_{sun} (i from LB17)



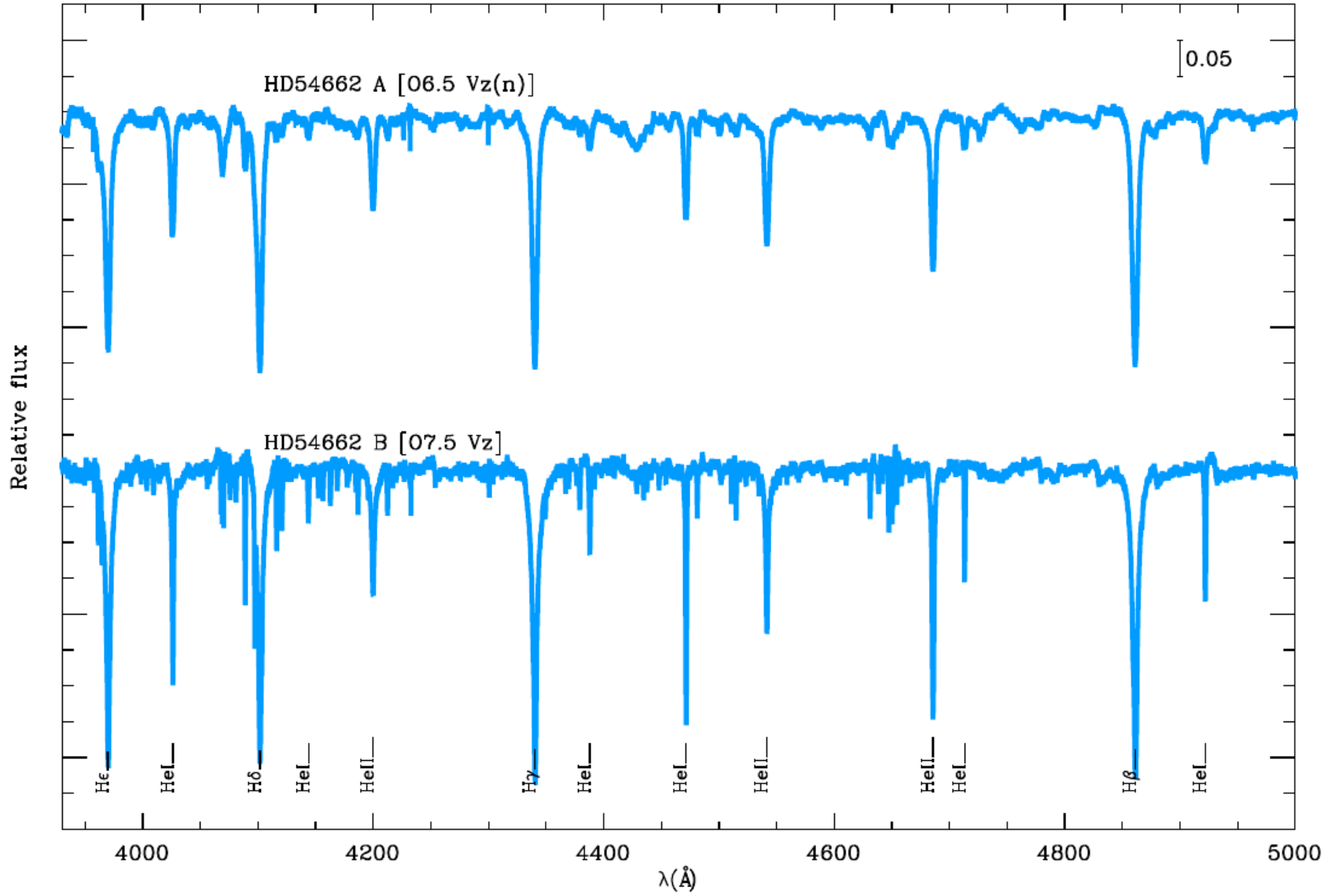
HD 54662

- OWN database: ~50 new optical spectra
- Spectral disentangling method by González & Levato 2006
  → individual spectra + RV measurements, using our highest quality spectra

- Spectral classification with MGB (Maíz Apellániz+12), using a library of O-type standards from GOSSS:
  A→ O6.5 Vz(n)
  B→ O7.5 Vz

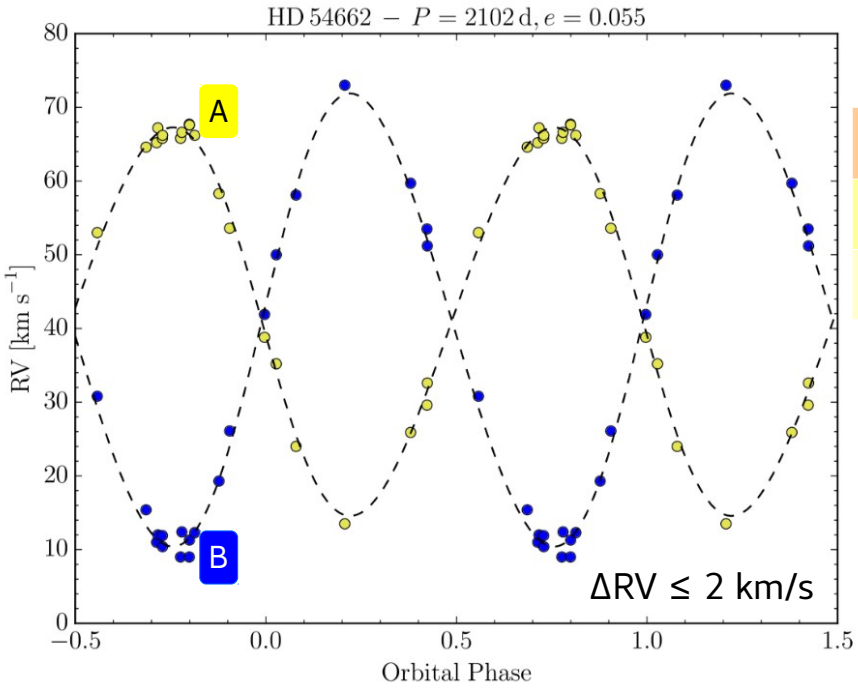


HD 54662: disentangled spectra



HD 54662: spectroscopic orbital solution

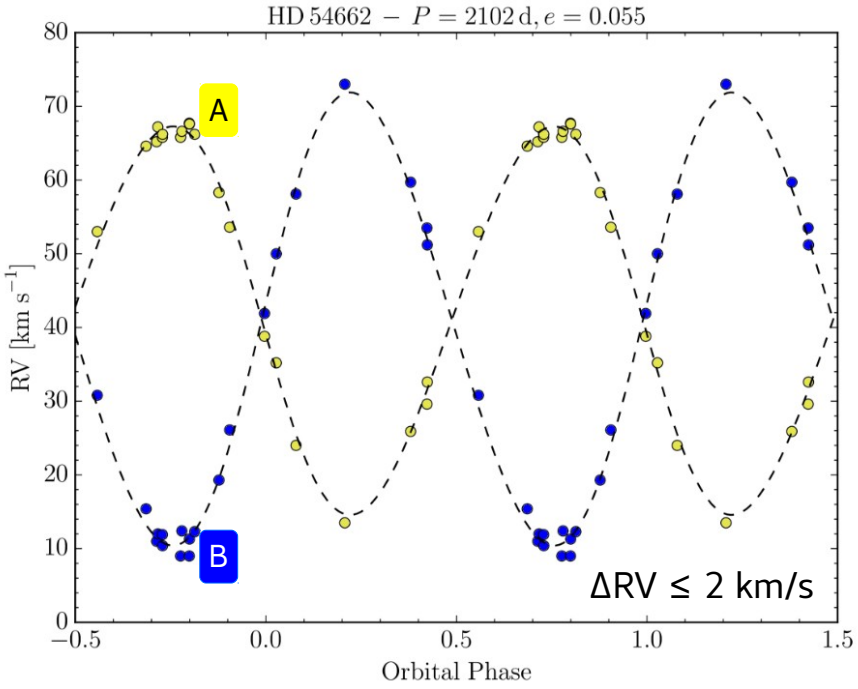
Orbital solution using GBART (Bertiau & Grobben 1969, updated by F. Bareilles)



	Boyajian+07	Le Bouquin+17	Mossoux+18	This work
P [d]	557.8±0.3	2103±4	2103±3	2102±9
e	0.28±0.04	0.06±0.01	0.11±0.02	0.055±0.009

HD 54662: spectroscopic orbital solution

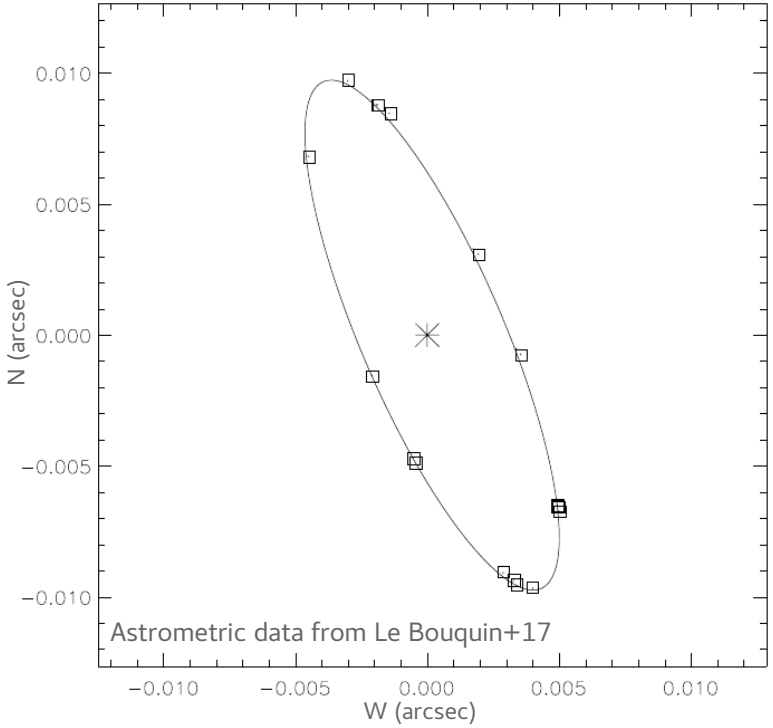
Orbital solution using GBART (Bertiau & Grobben 1969, updated by F. Bareilles)



	Le Bouquin+17	Mossoux+18	This work
K_A [km/s]	17.8±0.8	19.3±0.6	26.4±0.3
K_B [km/s]	98.0±18.0	22.9±0.7	30.7±0.3

HD 54662: 3D orbit

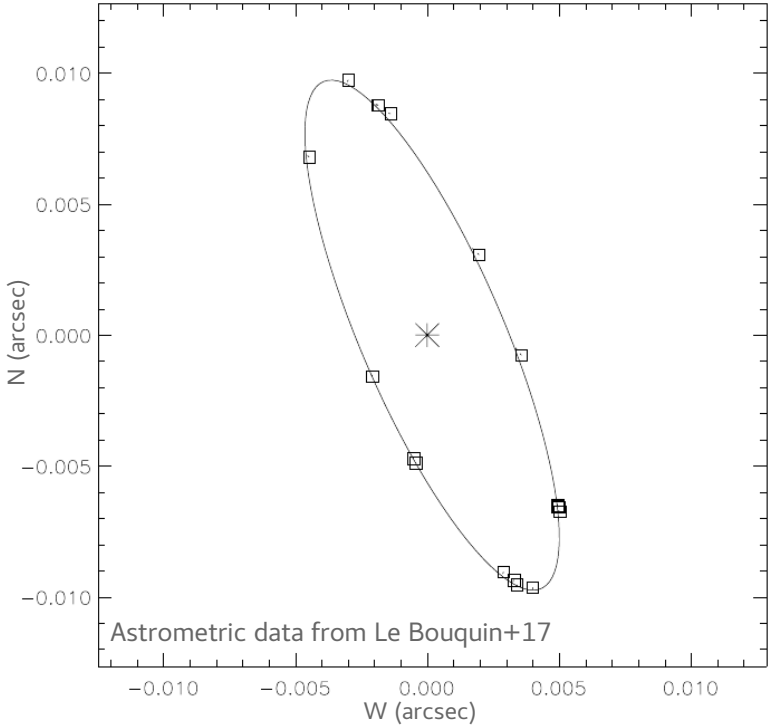
`orbit` (A. Tokovinin) + astrometric data from Le Bouquin+17 + our RV measurements



	Le Bouquin+17	Mossoux+18	OWN
M_A [M_{Sun}]	316 ± 168	9.7 ± 0.7	23.8 ± 1.1
M_B [M_{Sun}]	58 ± 19	8.2 ± 0.6	20.3 ± 1.1

HD 54662: 3D orbit

`orbit` (A. Tokovinin) + astrometric data from Le Bouquin+17 + our RV measurements



i=75.1°±0.5°
Le Bouquin+17: 74.87°±0.43°

d =1087±25 pc
Le Bouquin+17: 1100±100 pc
GAIA DR2: 1170±110 pc

HD 54662: quantitative spectroscopic analysis

- Quantitative analysis of the individual disentangled spectra

- Projected rotational velocities ($v \sin i$):
  `IACOB-broad` (Simón-Díaz & Herrero10): FT+GOF techniques, using OIIIλ5592

	A [O6.5 Vz(n)]	B [O7.5 Vz]
$v \sin i$ (km/s)	160	40

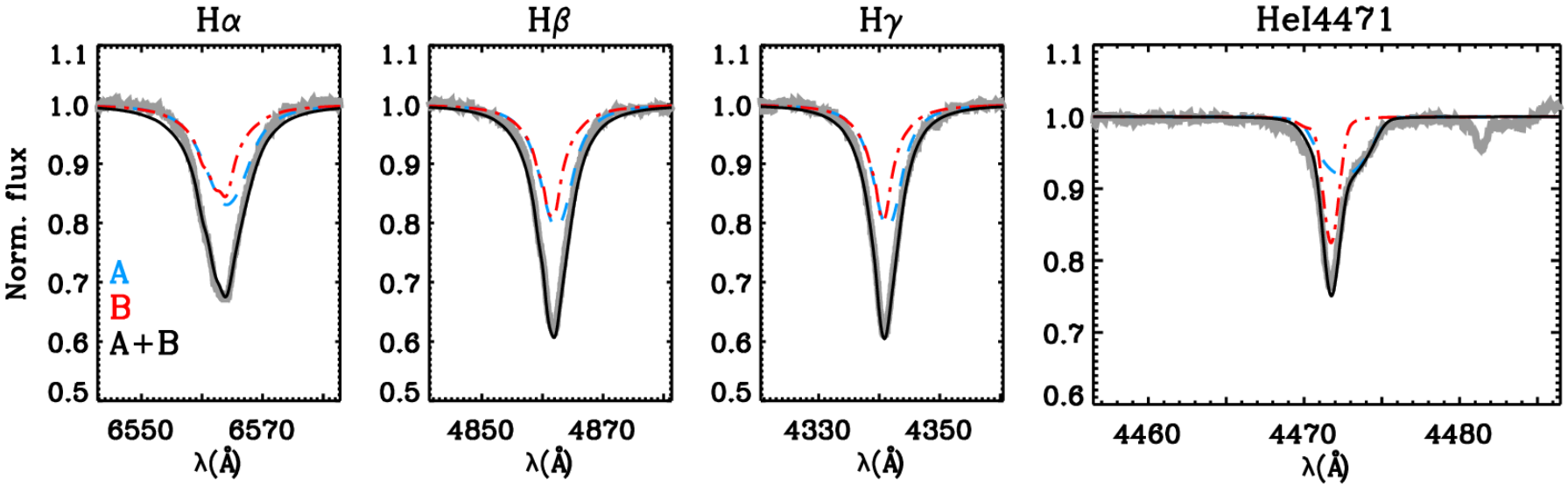
Asynchronous rotation / non-parallel rotation axes → formation

HD 54662: quantitative spectroscopic analysis

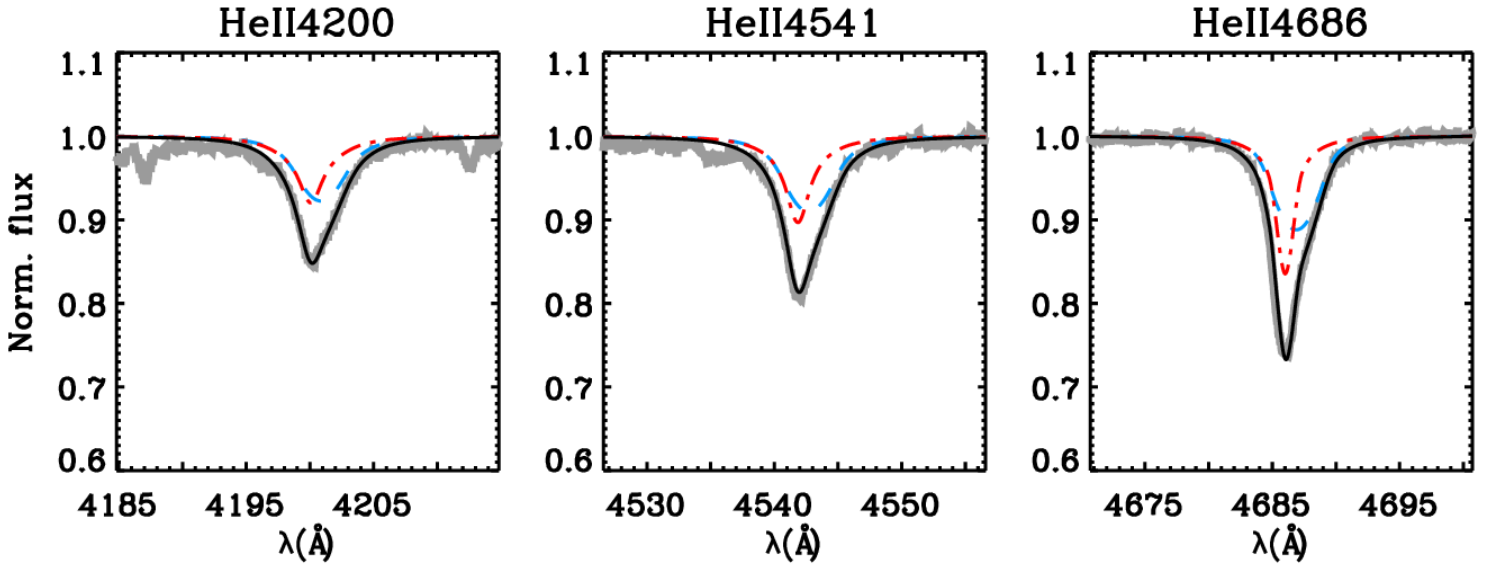
- Quantitative analysis of the individual disentangled spectra

- Spectroscopic and physical parameters
  `IACOB-GBAT` (Simón-Díaz+11,Sabín-Sanjulián+14,Holgado+18): FASTWIND stellar atmosphere models (Santolaya-Rey+97, Puls+05) + χ^2 automatic algorithm
  T_{eff}, log g, Y_{he}, wind parameters, R_*, L_*, M_{sp}

HD 54662: quantitative spectroscopic analysis



T_{eff}=39 kK
logg=3.9 dex
T_{eff}=39 kK
logg=4.0 dex

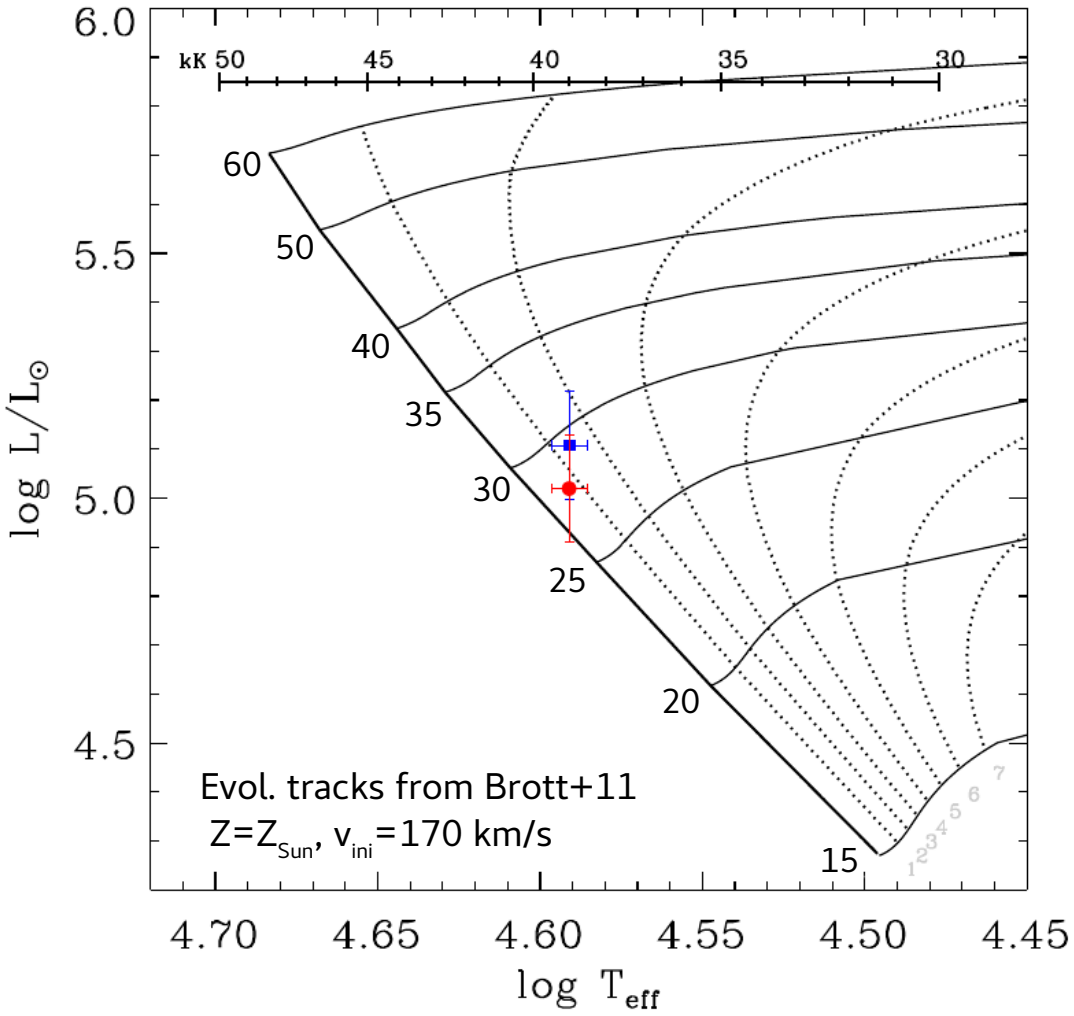


HD 54662: quantitative spectroscopic analysis

	Mossoux+18 (CMFGEN)		This work (FASTWIND)	
	T_{eff} [kK]	log g	T_{eff} [kK]	log g
A	37.5±1.0	3.81±0.10	39.1±1.0	3.90±0.10
B	37.7±1.0	3.96±0.10	39.0±0.6	4.00±0.10

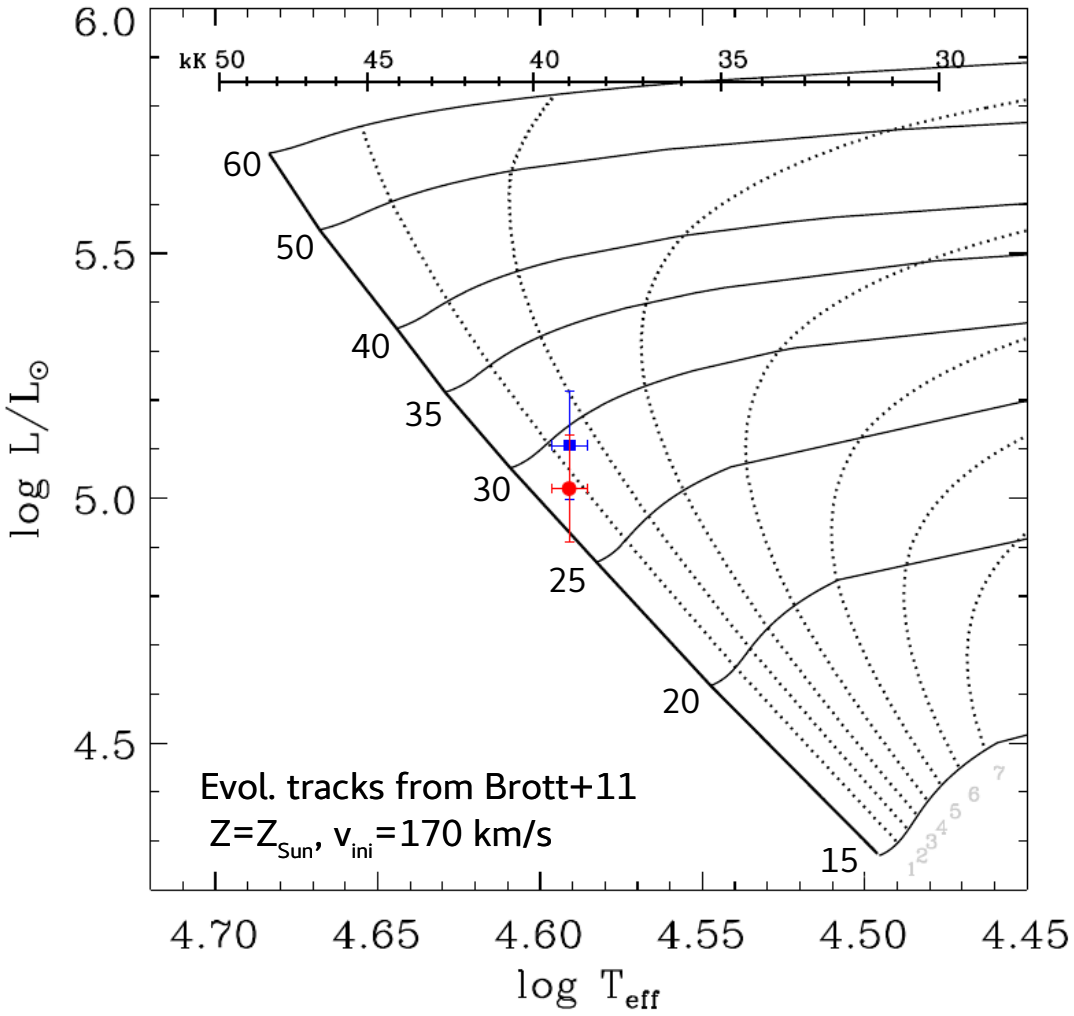
- Differences in the disentangled spectra
  Mossoux+18: O6.5 Vz for both, ΔM_V ~ 0.75 mag (EW He lines) // this work: ΔM_V ~ 0.2 mag

HD 54662: mass



	M_{dyn}	M_{sp}
A	23.8±1.1	23.9±4.5
B	20.3±1.1	18.4±4.8
TOT	44.1±1.5	42.3±6.5

HD 54662: mass



	M_{dyn}	M_{sp}	M_{ev}
A	23.8±1.1	23.9±4.5	29.6±2.0
B	20.3±1.1	18.4±4.8	28.6±1.8
TOT	44.1±1.5	42.3±6.5	58.2±2.7

Long-standing *mass discrepancy problem* (Herrero+92)

→ A statistically significant number of quantitatively analyzed massive binaries is crucial

HD 54662: summary

- High R and high S/N optical spectra with good phase coverage
- New accurate RV measurements, orbital solution and disentangling
- Detailed analysis with state-of-the-art stellar atmosphere and evolutionary models
- Asynchronous rotation
- Mass discrepancy

Thank you

NidiaFest: Massive Stars and Supernovae
Bariloche (ARG), November 2018