A revised orbital solution for HESS J0632+057 (=MWC 148)

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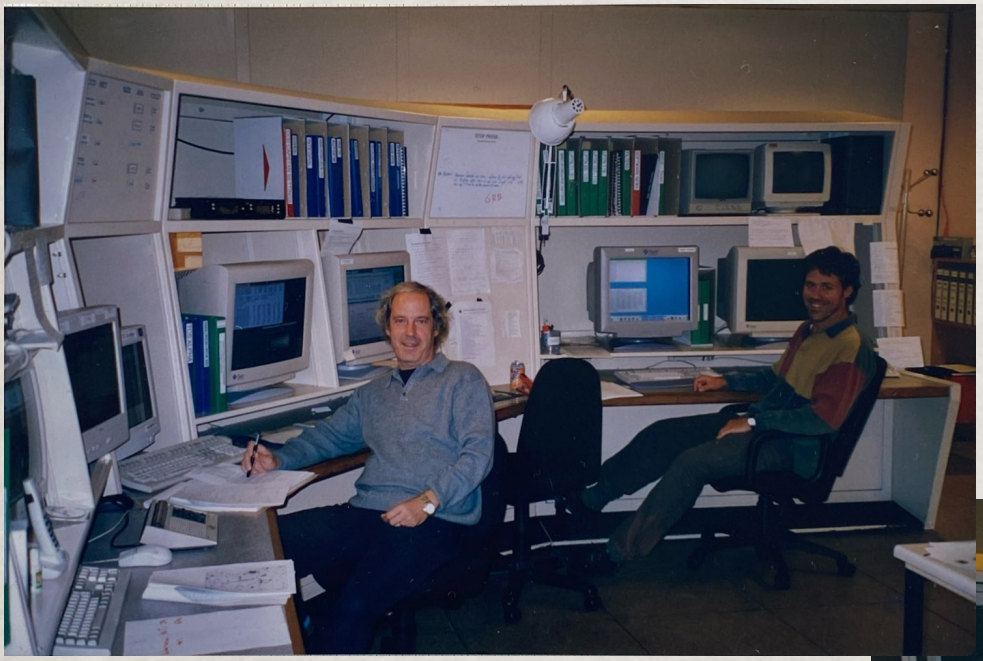
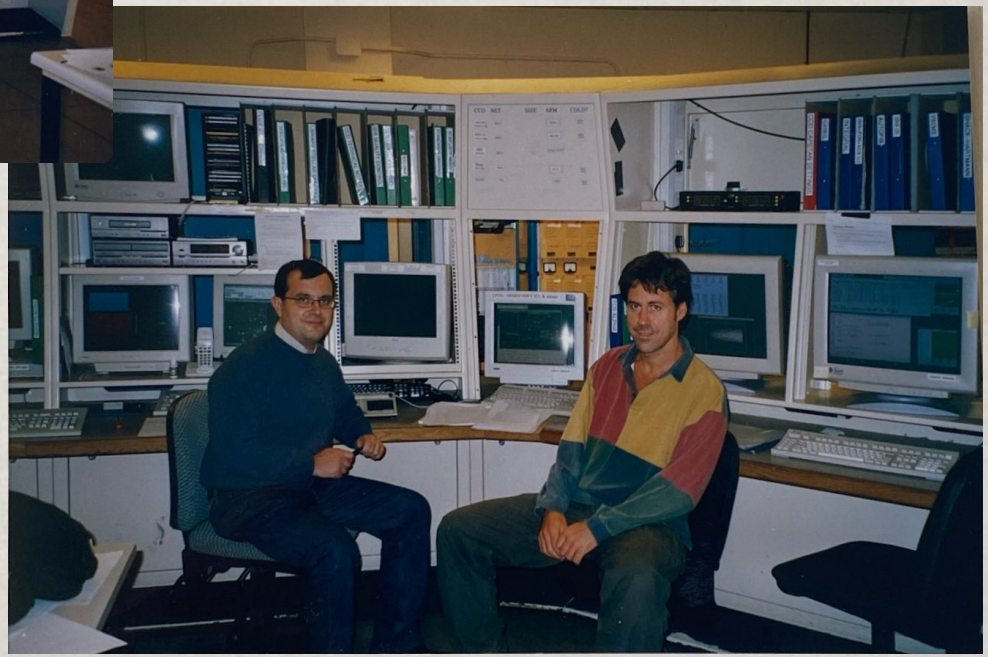
A fruitful collaboration on γ-ray Binaries



Josep Maria Paredes
Josep Martí
Marc Ribó
Ignacio Negueruela
….

LS 5039
LSI + 61 303
MWC 656



WHT control room, sometime around year ≈2000

2010: 3 γ-ray binaries known: PSR B1259-63, LS I +61 303, LS 5039.

Other HE/VHE sources proposed but required confirmation:
1FGL J1018.6–5856, AGL J2241+4454, **HESS J0632+057** …

Optical spectroscopic campaigns, mostly with robotic telescopes, to prove binarity and determine orbital parameters

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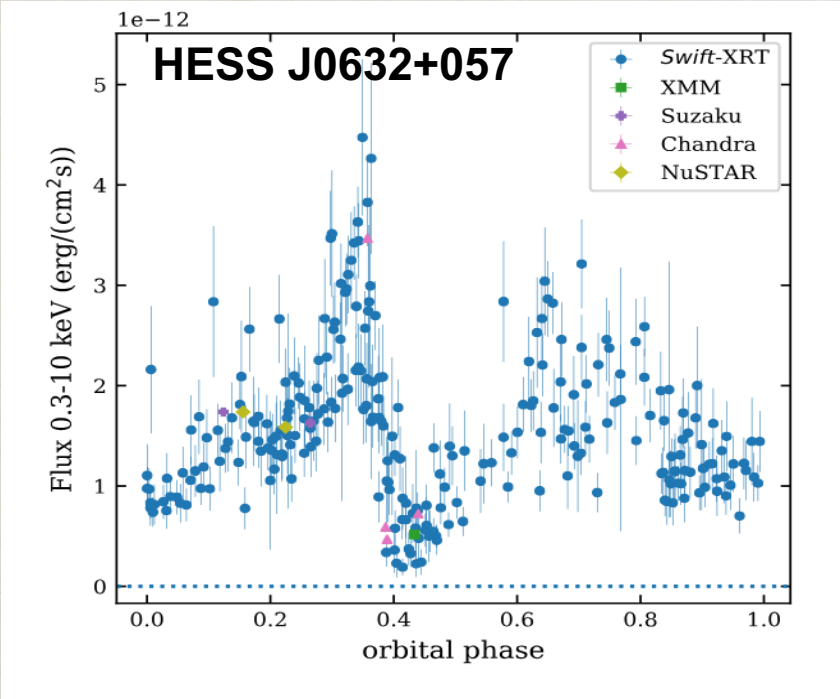
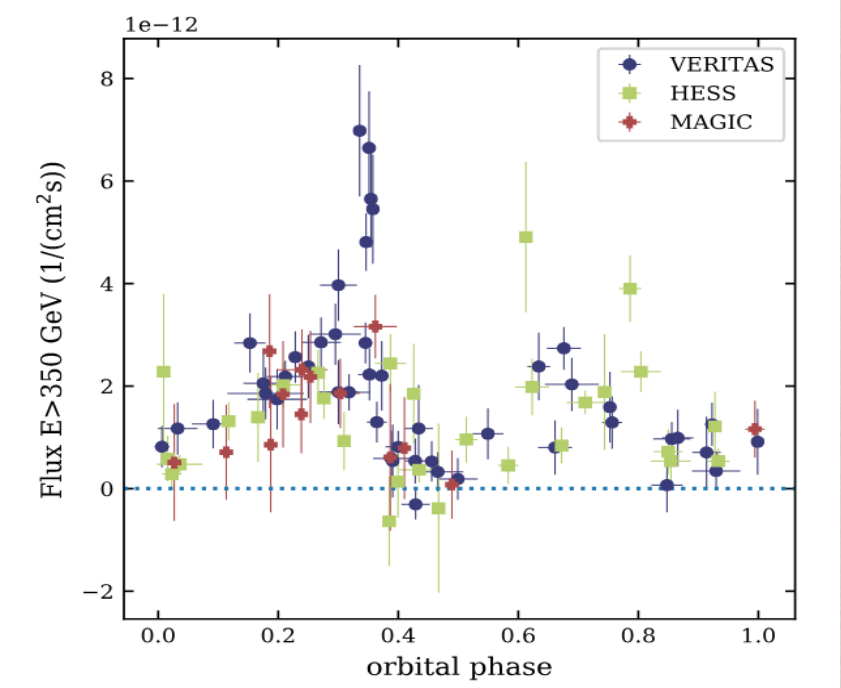




P=317.3 ± 0.7 d

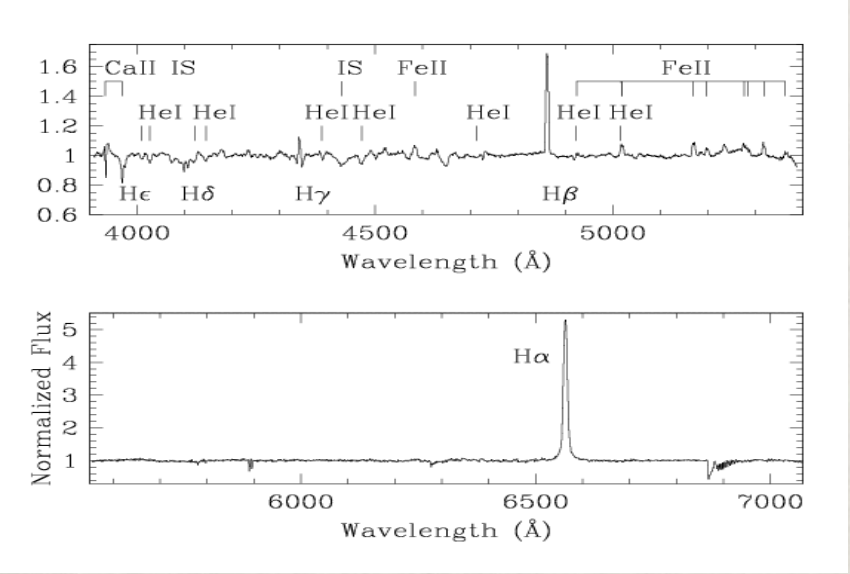
Bongiorno+ 2011; Aliu+ 2014; Malyshev+ 2019; Adam+ 2021

Mon. Not. R. Astron. Soc. **421,** 1103–1112 (2012) doi:10.1111/j.1365-2966.2011.20368.x

On the binary nature of the γ-ray sources AGL J2241+4454 (= MWC 656) and HESS J0632+057 (= MWC 148)

J. Casares,[1,2★] M. Ribó,[3★] I. Ribas,[4★] J. M. Paredes,[3★] F. Vilardell[5★] and I. Negueruela[5★]

(=C12)



1) INT/WHT: Oct/Dec 2008 at ~100 km/s res.

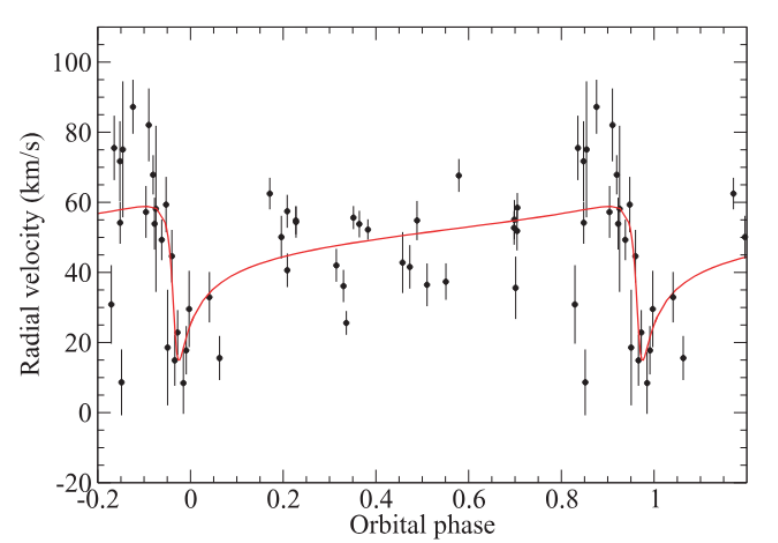
2) Mercator: Nov 2009 at 7 km/s res.

3) ST: Jan-Apr 2010 „ „

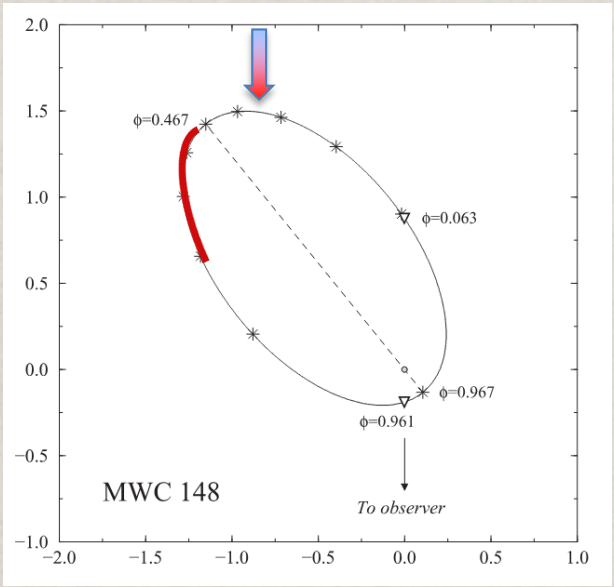
4) LT: Sept 2010-May 2011 at 55 km/s res.

B0pe star with broad HeI absorptions (V sin i=370 km/s)

X-correlation of HeI regions with average spectrum



Parameter	MWC 148
P_{orb} (d)	321 (fixed)
T_0 (HJD −2450 000)	4857.5 (fixed)
e	0.83 ± 0.08
ω (°)	129 ± 17
γ (km s^{-1})	48.3 ± 8.9
ϕ_{peri}	0.967 ± 0.008
K_{opt} (km s^{-1})	22.0 ± 5.7
$a_1 \sin i$ ($R_\odot$)	77.6 ± 25.9
$f(M)$ ($M_\odot$)	$0.06^{+0.15}_{-0.05}$
σ (km s^{-1})	12.8



X-ray & VHE emisión at phases ≃ 0.35 & ≈ 0.6-0.8

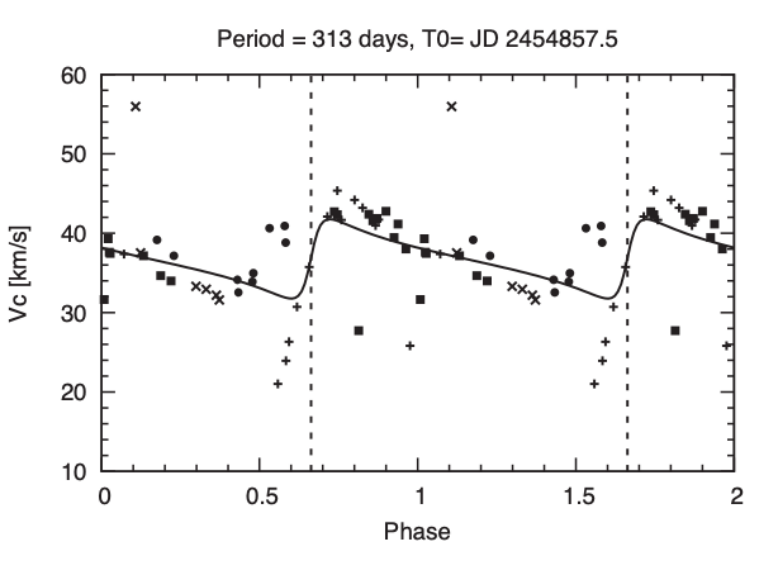
➡ close to apastron

We warned "data is limited and orbital solution requires confirmation"

1) Moritani et al. 2018 PASJ 70 61 (=M18)

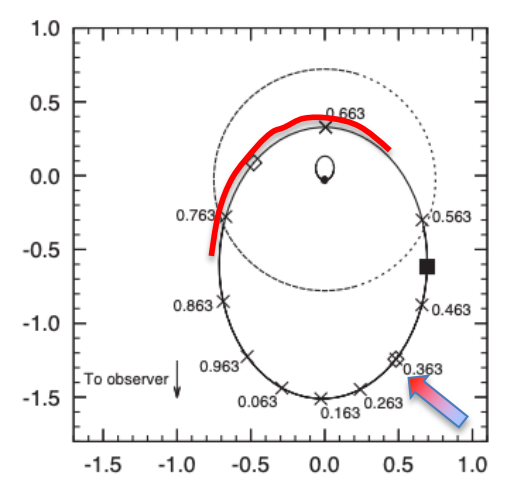
High-res spectra in **Oct 2013-Apr 2017**

Radial velocities from wings of Hα emission ⟹ trace the Be star



$e = 0.64 \pm 0.29$

$\phi_{\rm peri} = 0.66$



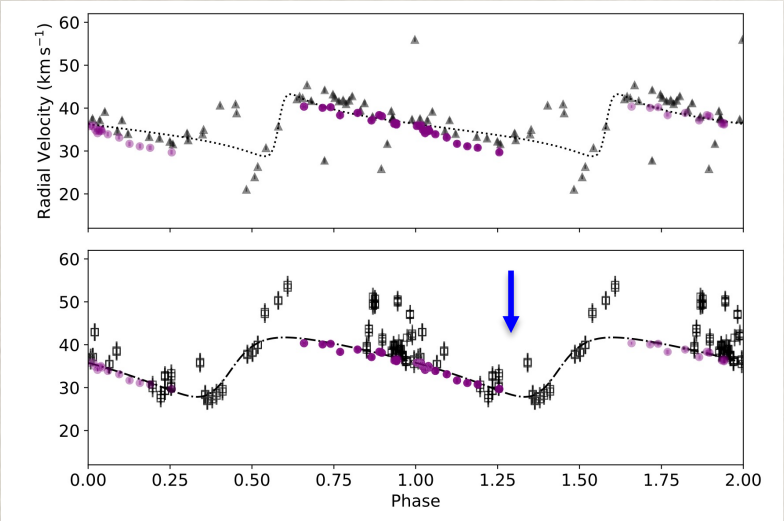
Sharp X-ray/VHE peak **after apastron**

Broad X-ray/VHE max. **after periastron**

2) Matchet & van Soelen 2025 MNRAS 536 168 (=M25)

High-res spectra in **Dec 2020-March 2023**

Radial velocities from wings of Hα emisión (Voigt profile fit)



(a) M25+**M18**

$e = 0.75 \pm 0.24$

$\phi_{\rm peri} = 0.58 \pm 0.01$

(b) M25+**C12**

$e = 0.40 \pm 0.08$

$\phi_{\rm peri} = 0.42 \pm 0.03$

Hα centroid, but blue-shifted

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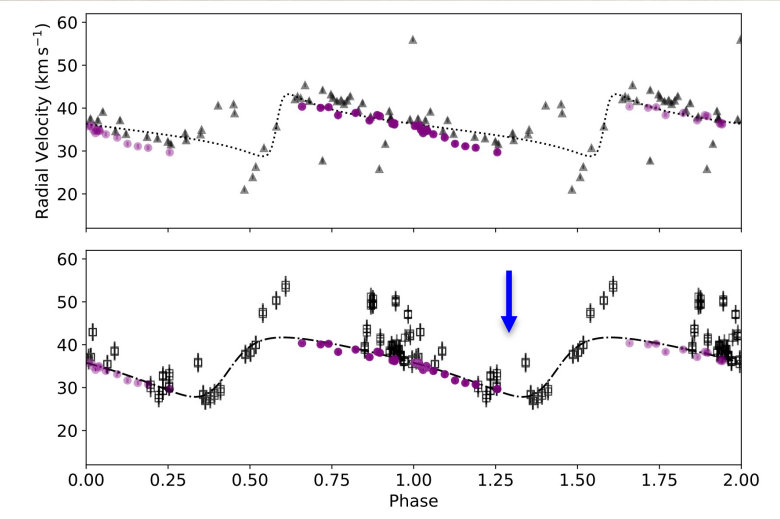

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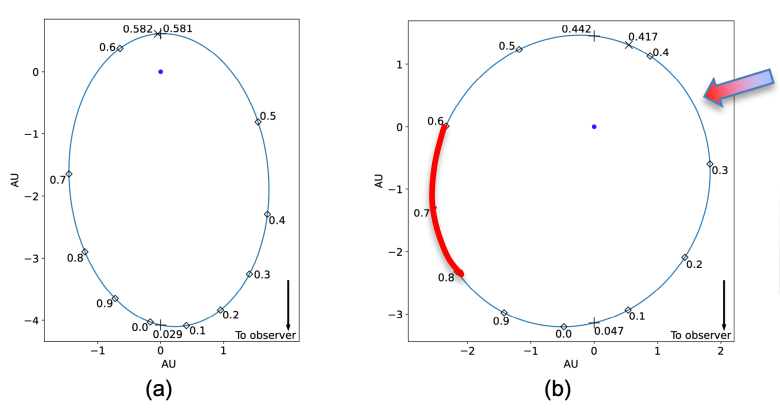


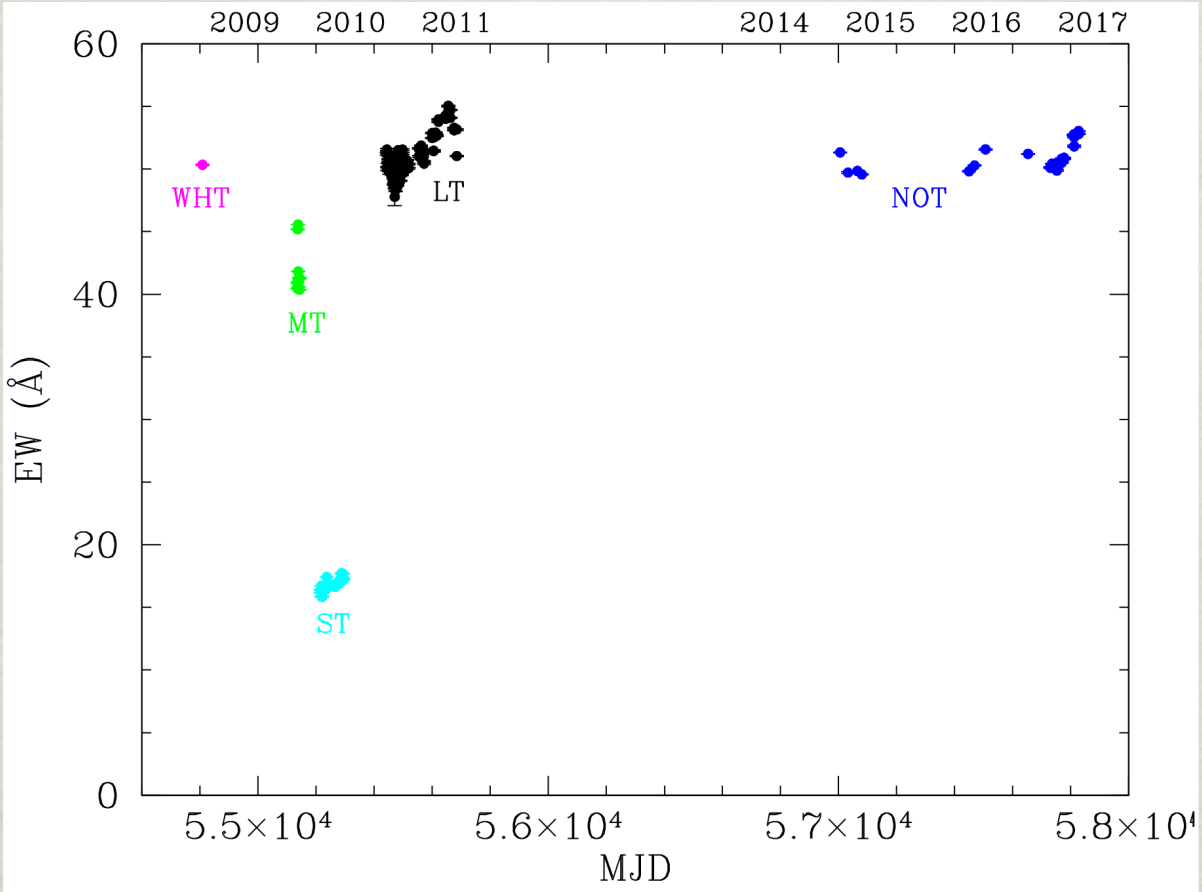
(b) M25+**C12**

Sharp X-ray/VHE peak at ≃ **periastron**

Broad X-ray/VHE max **before apastron**

NEW NOT+FIES DATA SET

35 high-res (R~25000) spectra in **Dec 2014-March 2017**



EW stable at ~52 Å , except for the MT & ST campaigns

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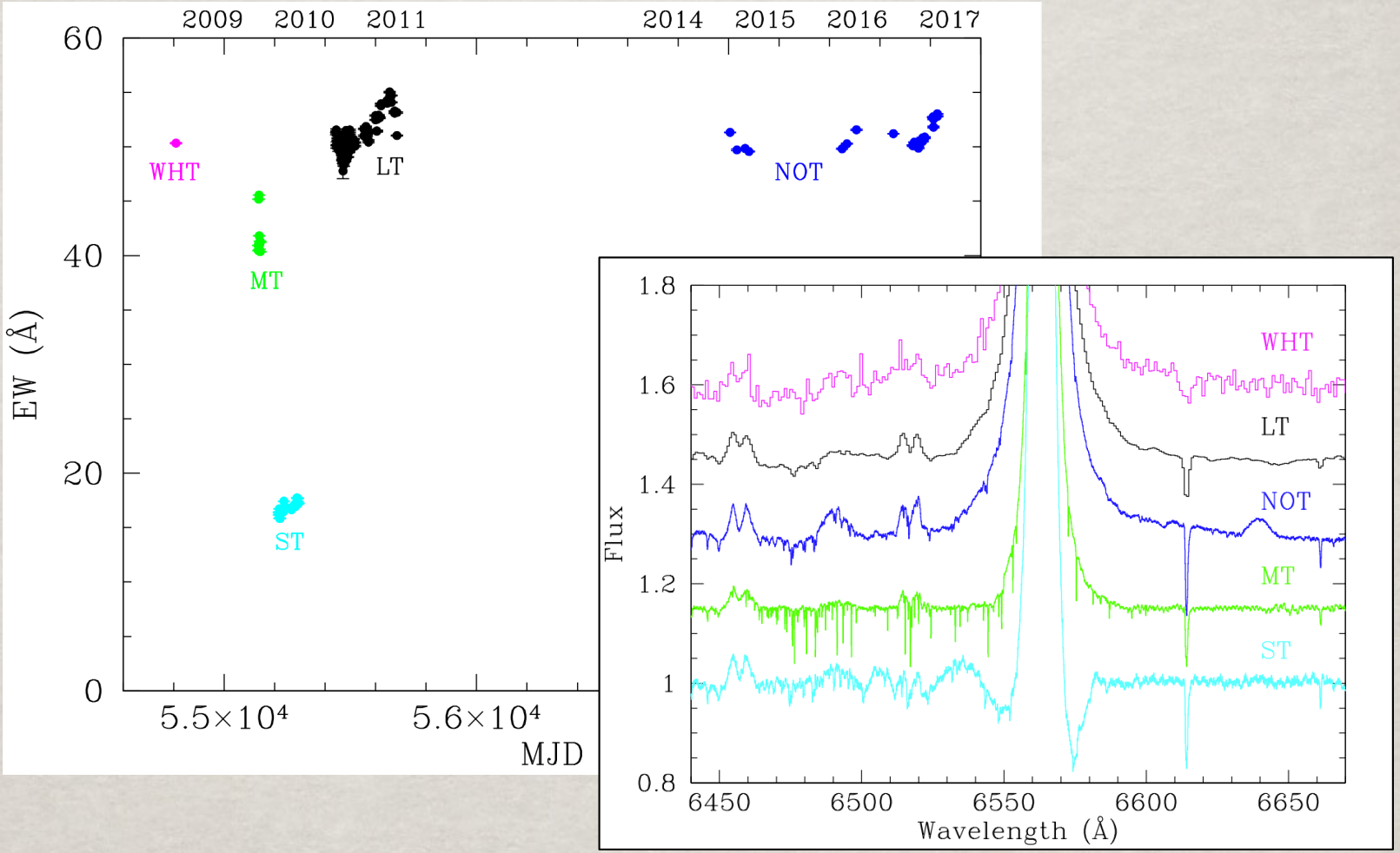
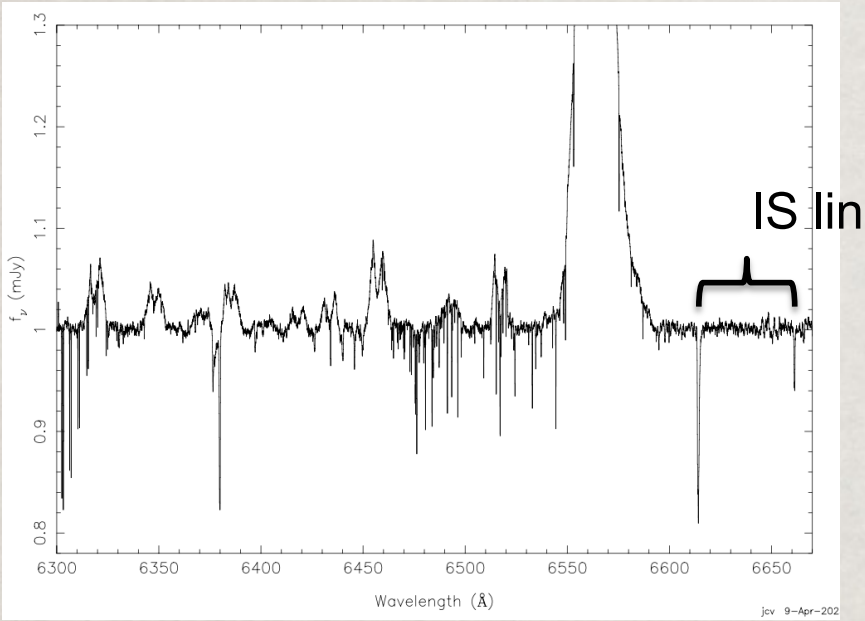
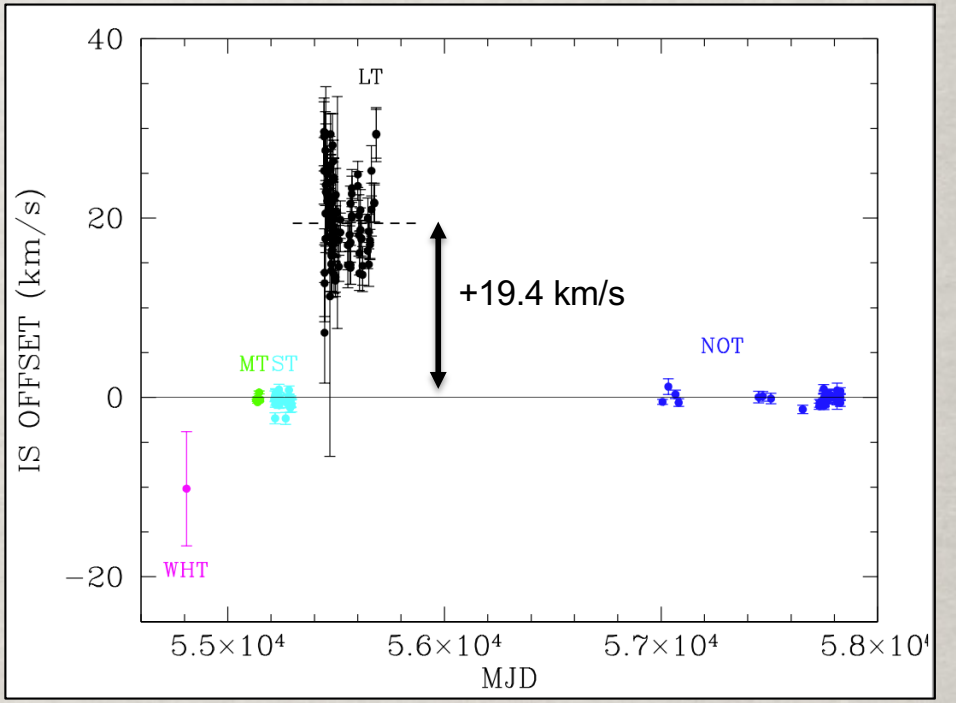


Hα narrower in MT & ST campaigns (≈ Nov-2009-Apr 2010)

→ **disruption of the inner Be disc ??**

REVISED WAV. CALIBRATION WITH IS LINES

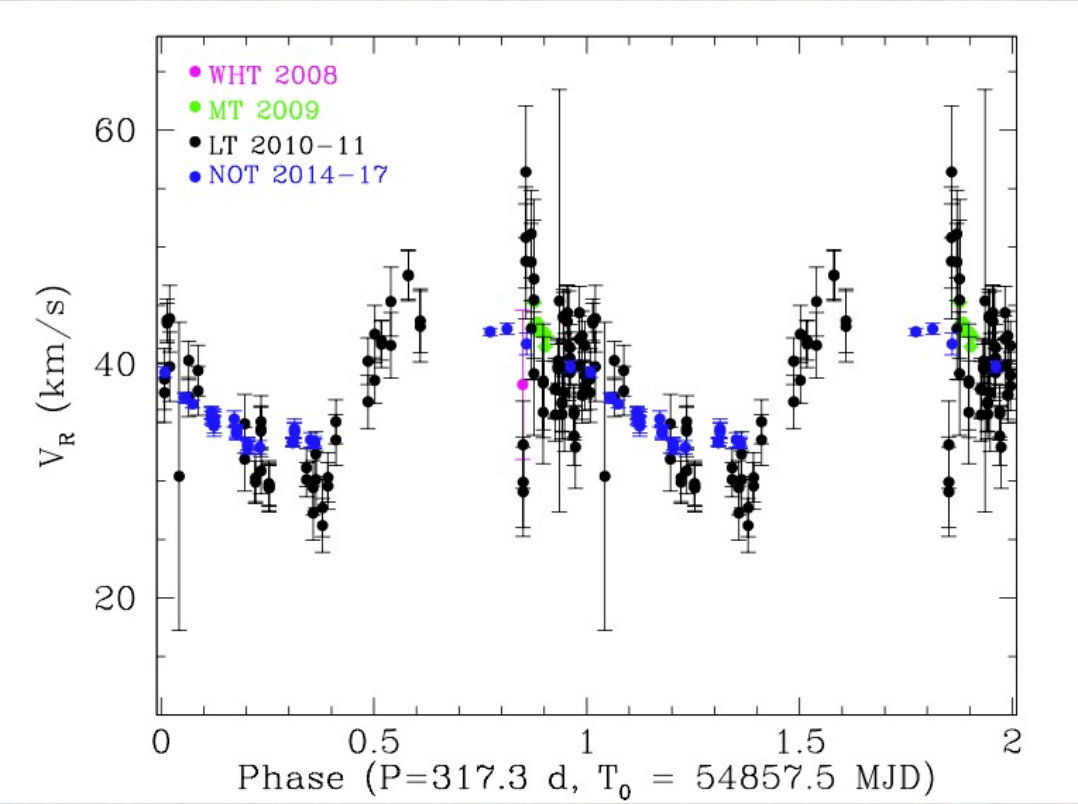




LT spectra systematically shifted by +19.4 km/s

REVISED Hα (CENTROID) VELOCITIES

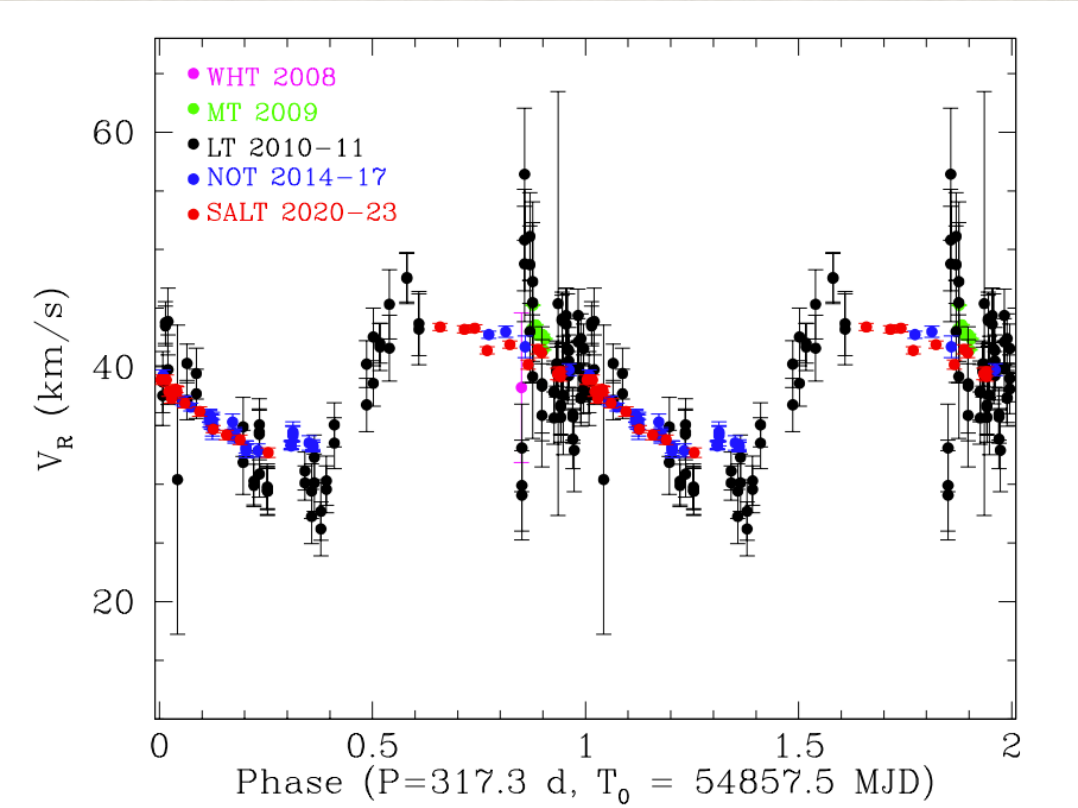
All spectra corrected for IS shifts



Hα velocities measured from single Gaussian fit to whole profile

LT velocities NOW show reduced dispersion compared to C12, particularly at phases ~0.3-0.6

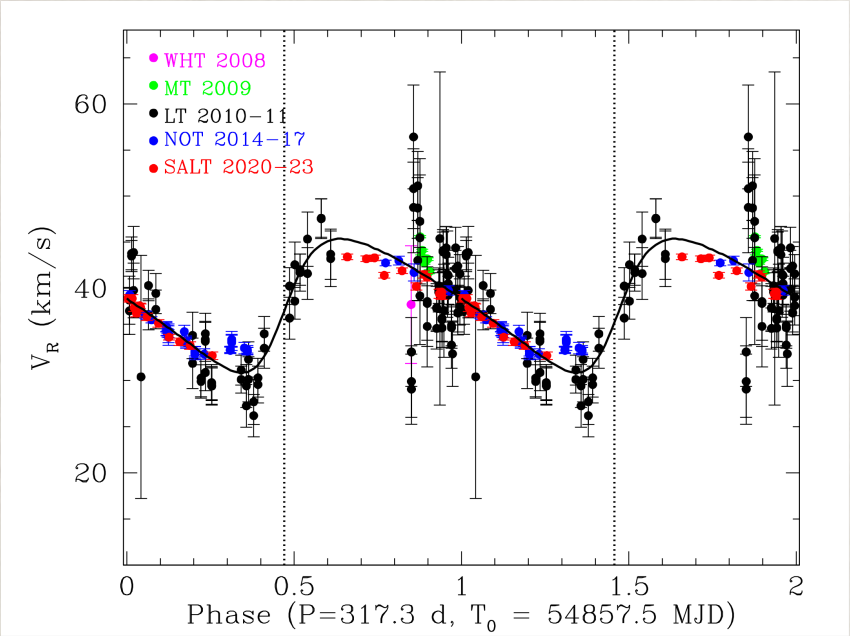
Hα CENTROID VELOCITIES



SALT (wing) velocities (+3.2 km/s) **overlap** with new NOT velocities

→ Hα centroid also traces the orbit of the Be star

ECCENTRIC ORBIT FIT (credit Marc Ribó)



$e = 0.34 \pm 0.06$

$\phi_{peri} = 0.46 \pm 0.03$

$\omega = 255.8 \pm 13.3$ deg

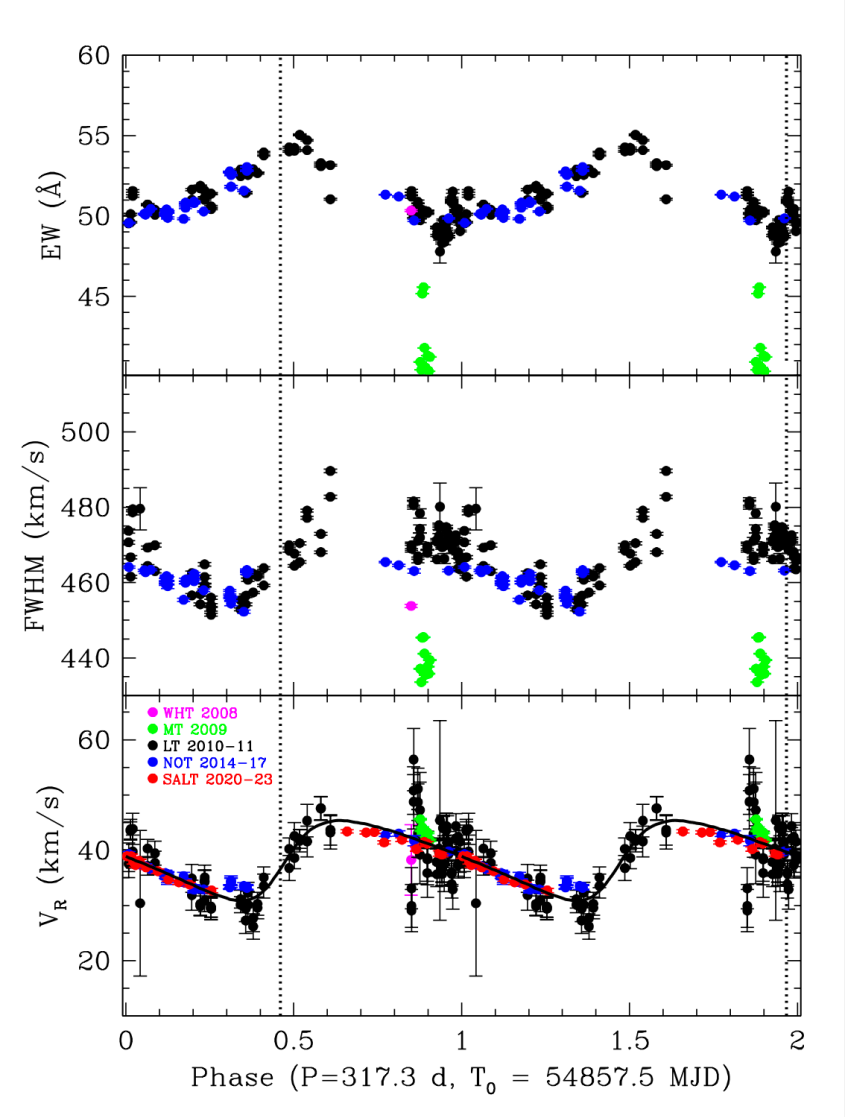
$K_1 = 7.3 \pm 0.6$ km/s

$\gamma = 38.7 \pm 0.3$ km/s

$a \sin i = 0.199 \pm 0.017$ au

$f(M) = 0.010 \pm 0.003\ M_\odot$

Consistent with M25+C12 within errors



EW peak at periastron → NS passage triggers disc enlargement?

FWHM mimics rad vel curve → disc ellongated and coupled to the orbit. A signature of tidal distorsion?

CONCLUSIONS

- Hα centroid traces the motion of the Be star as well as the line wings

- Revised rad vel (plus new data) provides updated orbital solution: e = 0.34$\pm$0.06 , ϕ_{peri} = 0.46 $\pm$0.03, consistent with M25+C12 solution

- X-ray/TeV peaks occur before & after periastron

- Consistent with NS crossing of an inclined disc, similar to PSR B1259-63