Massive Binaries

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Why do we study massive binaries?

Double lined eclipsing systems provide the only way to empirically measure stellar fundamental parameters such as masses and radii throgh the simultaneous analysis of radial velocity and light variations.

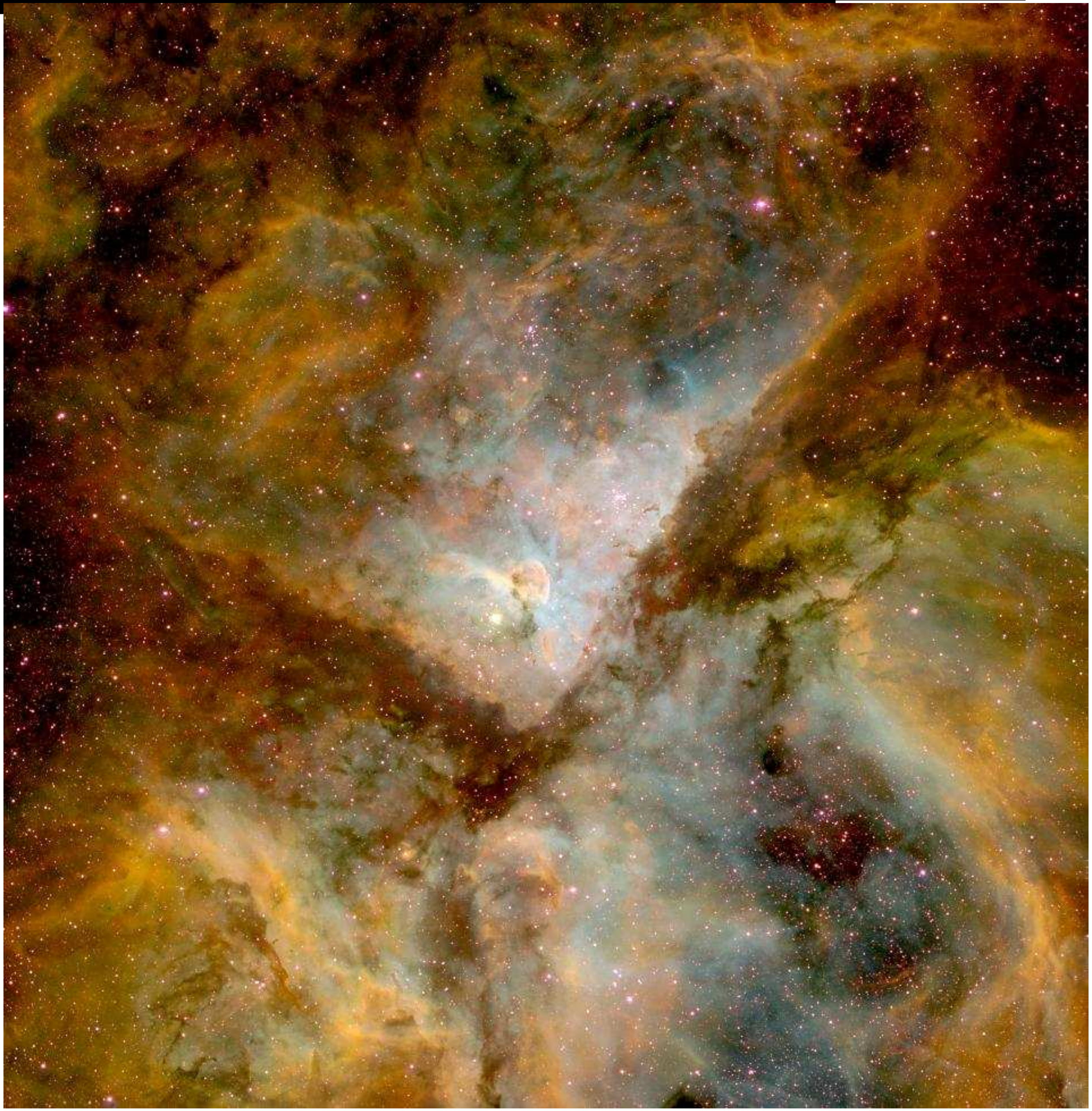
Massive binaries are special objects for the analysis of pair interactions, wind-wind collisions, etc.

Massive binaries have been succesfully used as extragalactic distance idicators: Guinan et al. 1998, Fitzpatrick et al. 2002, Ribas et al. 2002, Harries et al. 2003, Hilditch et al. 2005, Ribas et al. 2005, Bonanos 2008

Some questions need to be addressed

- How massive a star can be? (Oey & Clarke 2005, Figer 2005)
- Are massive stars always part of multiple systems? (Mason et al. 1998, Turner et al. 2008). Analysis of multiplicity provides clues to the understanding of massive star formation (Zinnecker & Yorke 2007).
  On the other hand, non detected multiplicity will affect the derivation of stellar parameters and can produce biases in the estimated IMF (Maíz Apellániz & Úbeda 2005)
- Why do masses derived from evolutionary models often desagree with those calculated via comparison of the spectrum with model atmospheres? Keplearian masses should help to find the origin of the “mass discrepancy” (Herrero et al 1992, Massey et al. 2005)

Found in massive star forming regions



HD 93205

THE ASTROPHYSICAL JOURNAL, 207:502–505, 1976 July 15

SPECTROSCOPIC STUDIES OF O-TYPE BINARIES. II. HD 93205, O3 V, IN THE CARINA NEBULA

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ABSTRACT

An orbit is derived for the recently discovered double-line binary HD 93205. The system, composed of an O3 V and an (approximately) O8 V star, has minimum masses of 39 $M_\odot$ and 15 $M_\odot$. The stars are unevolved main-sequence objects well within their limiting Roche radii. Although eclipses are not expected, photometry of the system could prove interesting.
Subject headings: stars: binaries — stars: early-type — stars: individual

I. INTRODUCTION

HD 93205 is one of several stars in the Carina Nebula (NGC 3372) classified O3 due to the absence of He I λ4471 at dispersion 62 Å mm^{-1} (Walborn 1971); it was also discovered to be a double-lined binary (Walborn 1971, 1973*a*). The possibility of determining an orbit and estimating the mass of a very early O-type star has prompted this investigation. The star is located in the cluster Trumpler 16 and has a V magnitude of 7.75 mag with a $B-V$ of 0.05 mag (Feinstein 1969). Walborn (1973*a*), using a luminosity calibration of O-type stars, determined a distance of 2600 pc for Tr 16, consistent with $M_V = -5.5$ mag for HD 93205. Feinstein, Marraco, and Muzzio (1973), using photometric main-sequence fitting, determined a somewhat greater distance of 3400 pc for Tr 16 and found M_V to be -6.0 mag for HD 93205. This star and the other O3 stars in the Carina Nebula appear at the upper end of the zero-age main sequence (ZAMS) and, according to Conti and Burnichon (1975), should have masses near 100 $M_\odot$.

II. OBSERVATIONS

The spectrograms of HD 93205 were all taken at the Cerro Tololo Inter-American Observatory. Half of the plates were taken at the coudé focus of the 60 inch (1.5 m) telescope, with a dispersion of 18 Å mm^{-1} (except for two at 9 Å mm^{-1}) and a widening of 0.6 mm. The other plates were taken at the Cassegrain focus of the 36 inch (0.9 m) telescope, with a dispersion of 42 Å mm^{-1} and a widening of 0.6 mm. All spectrograms were obtained with IIa-O emulsion (nitrogen-baked at the coudé) and developed in D-76. The journal of observations is contained in Table 1.

The coudé spectrograms, aside from the first one listed, were taken by P. S. C. These were measured on a Grant measuring machine at Kitt Peak National Observatory. Usually between 5 and 12 lines of H and He II in the primary were measured on each spectrogram. The internal probable errors were in the range 4–8 km s^{-1} but with a larger error in one instance (JD 529.52) where the comparison spectrum was inadvertently exposed over the stellar lines. The coudé plates were weighted unity, with the exception of this poor one which was weighted one-half.

The Cassegrain spectrograms and the first coudé plate were taken by N. R. W. They were measured with the CTIO Grant machine. Typically, 5–6 lines of H and He II in the primary were measured on each spectrogram. The internal *mean* errors were typically 6–10 km s^{-1}. The Cassegrain plates were weighted one-half, and one plate (JD 148.67) was given one-quarter weight because of an underexposed comparison spectrum.

The lines of the secondary could be recognized on a number of our spectrograms, but measurement was difficult because they were considerably weaker than those of the primary (§ IV). The measured lines (three at most per plate) were from He I and occasionally H, but the profiles of the latter were distorted by the presence of the narrow emission from the Carina Nebula (Walborn and Hesser 1975).

Most of the coudé spectrograms were traced on the microphotometer at the High Altitude Observatory by Mr. Stewart Frost. Filtered line profiles were provided by him using the routine outlined by Conti and Frost (1974). These spectra will be discussed in more detail elsewhere (Conti and Frost 1976). In several

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† Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

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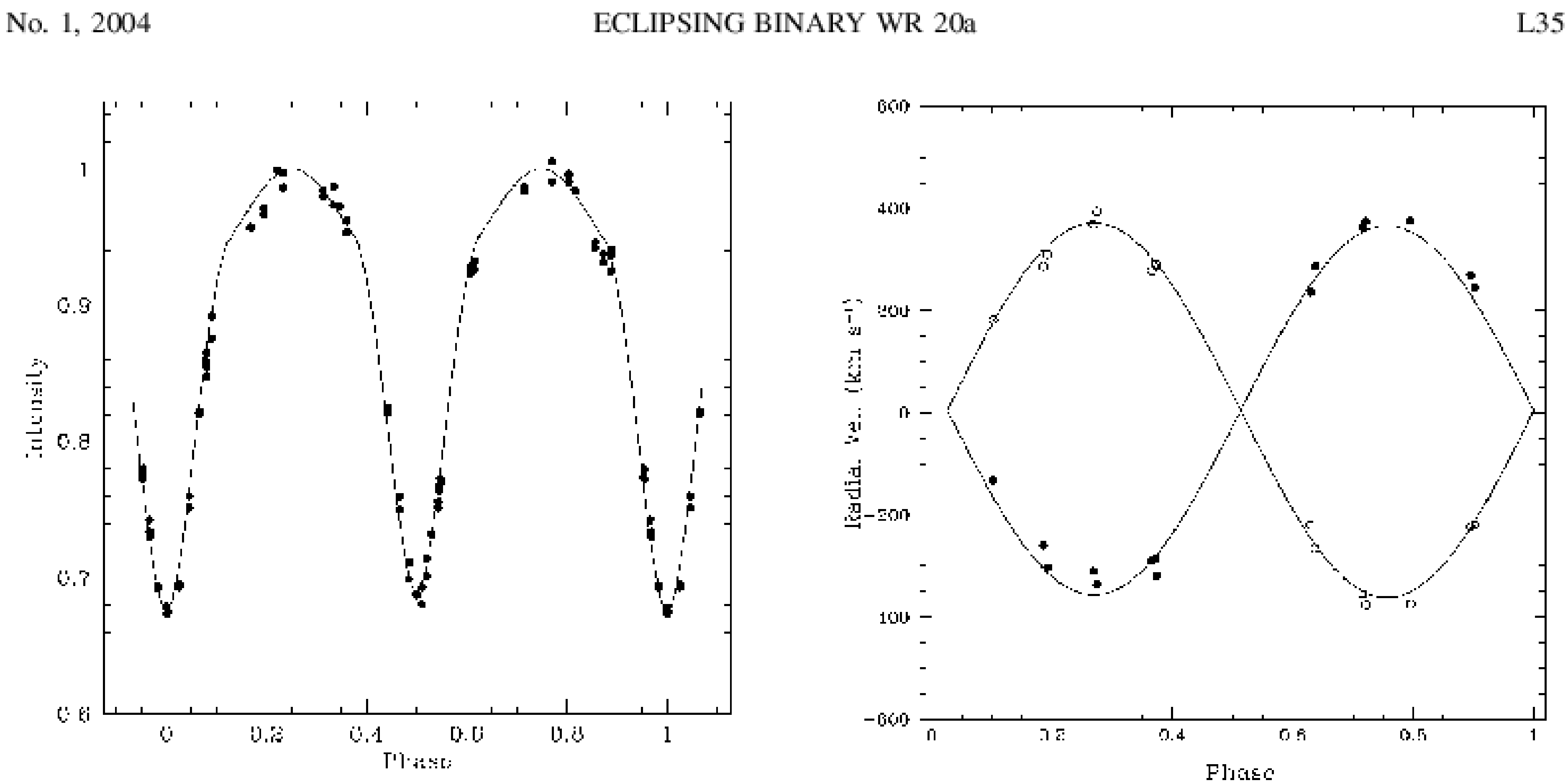
The most massive binaries

- NGC3603-A1 (WN6ha) 116 $\pm$ 31 + 89 $\pm$ 16 $M_\odot$ (Schnurr et al. 2008)
- WR21a (Of/WNLha) 87 $\pm$ 6 + 53 $\pm$ 4 $M_\odot$ minimum masses (Niemela et al. 2008)
- WR20a (WN6ha - O3If*/WN6ha) $\sim$ 83.0 $\pm$ 5.0 + 82.0 $\pm$ 5.0 $M_\odot$ Bonanos et al. 2004, Rauw et al. 2004, 2005
- HD93205 (O3.5V + O8V) $\sim$ 60- 40 + 25 - 17 $M_\odot$ (Benvenuto et al. 2002) indirect, via investigation of apsidal motion
- R136-MH38 (O3V + O6V) 56.9 $\pm$ 0.6 + 23.4 $\pm$ 0.2 $M_\odot$ (Massey et al 2002)
- WR22 (WN7+abs+O) 55.3 $\pm$ 7.3 + 20.6 $\pm$ 1.7 $M_\odot$ (Rauw et al. 1996; Schweickhardt et al. 1999)

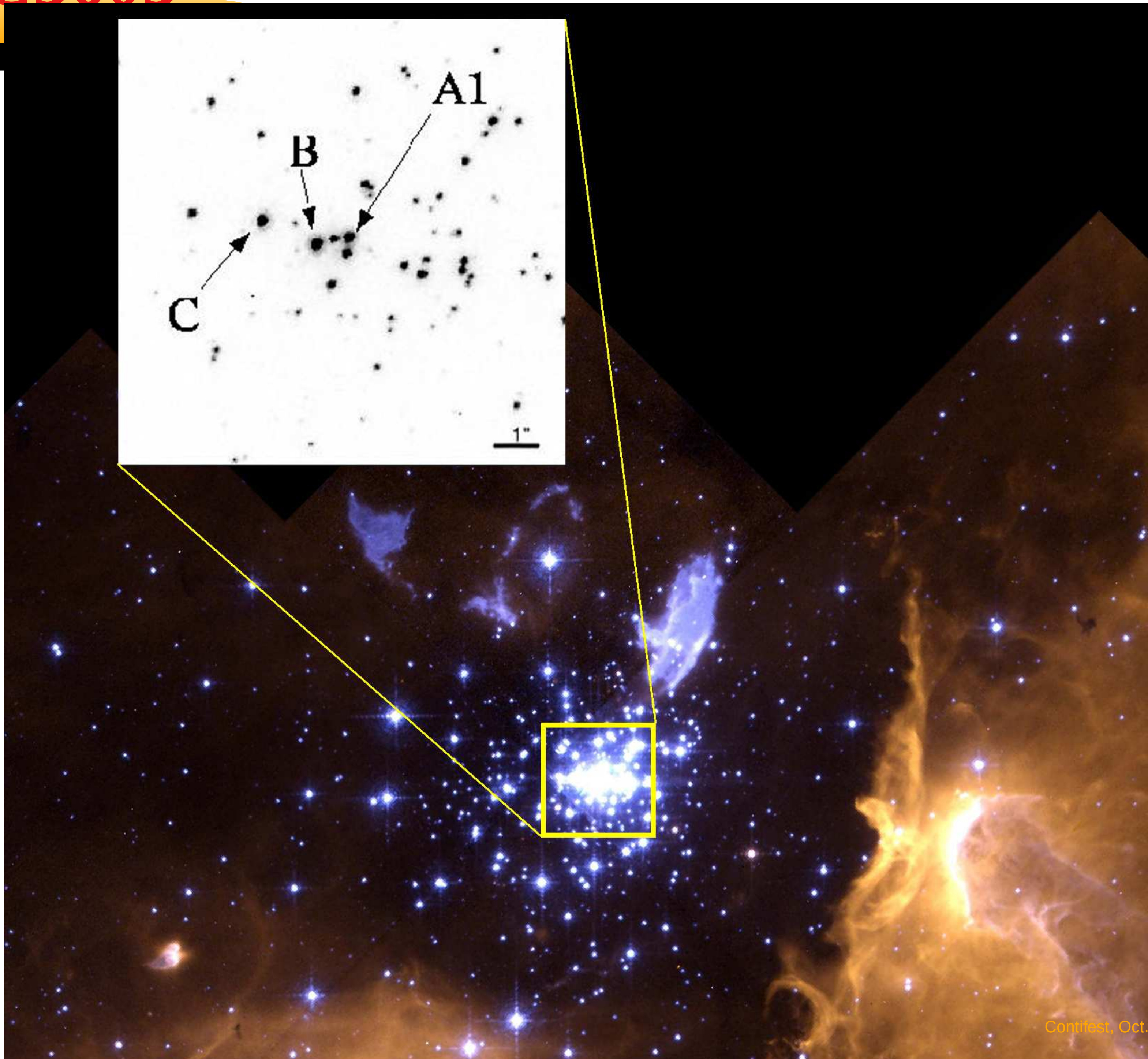
WR20a



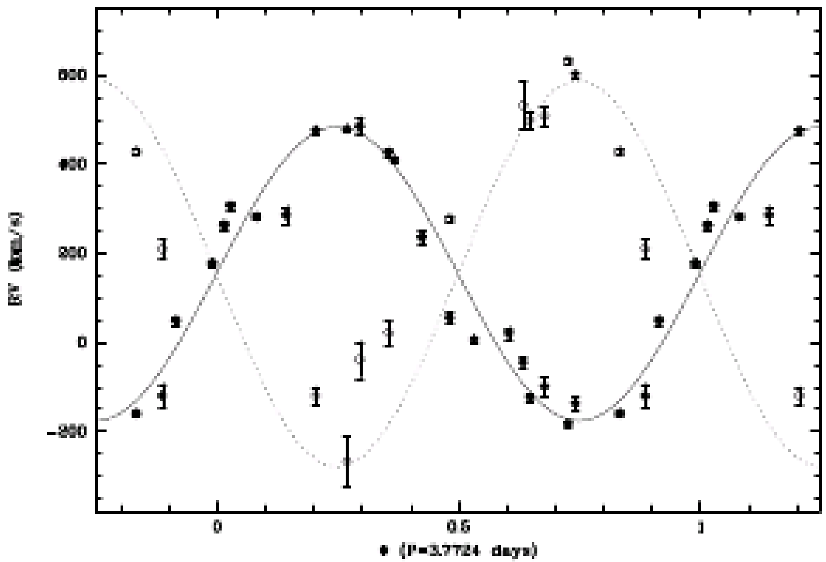
P = 3.386 d; K1 = 362.2 km s^{-1}; K2 = 366.4 km s^{-1}; i = 74.5°

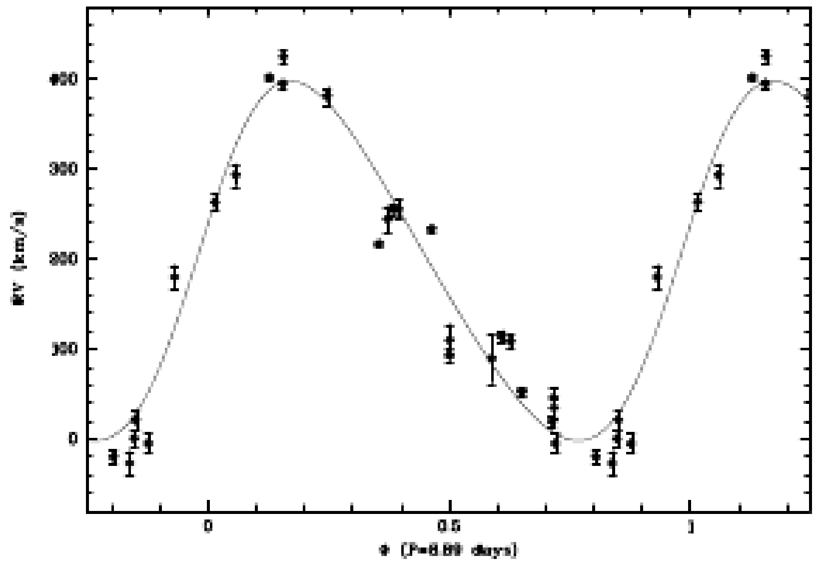
Bonanos et al. 2004

NGC3603



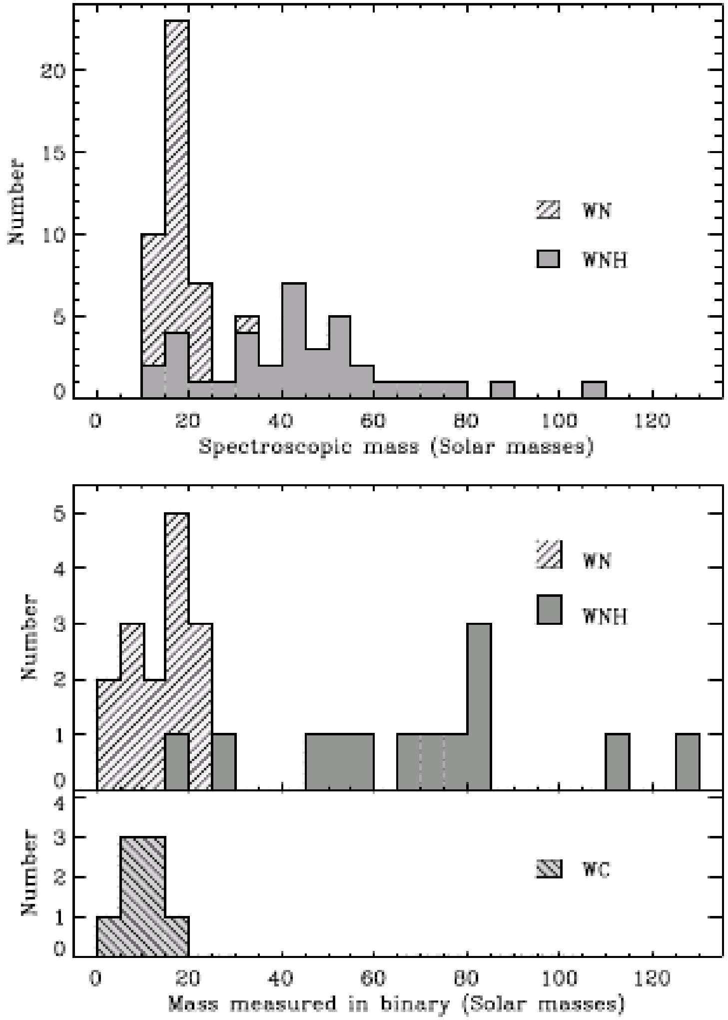
RV orbits for NGC3603 A1 and C





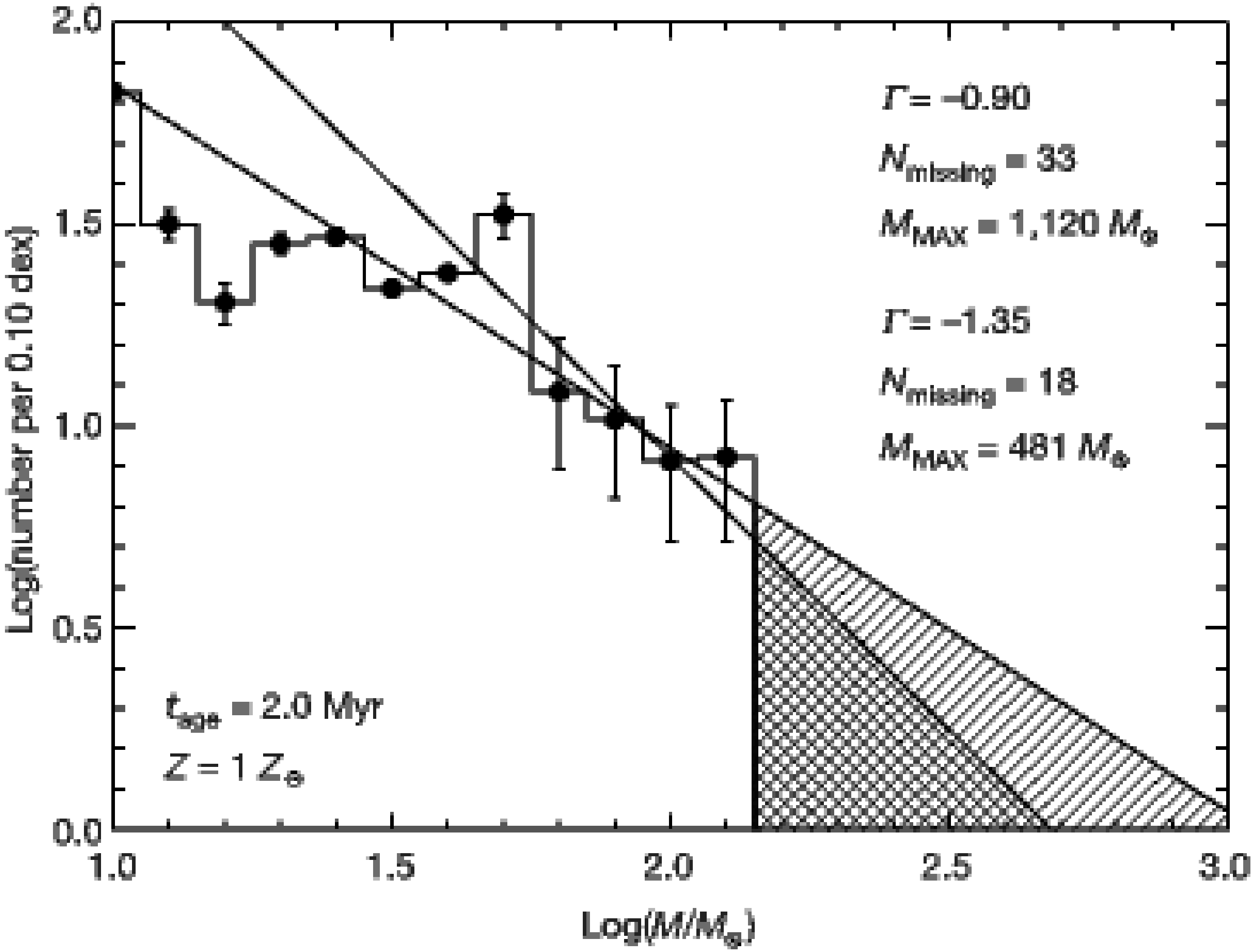
Schnurr et al.'08

The WNH class: Smith & Conti 2008



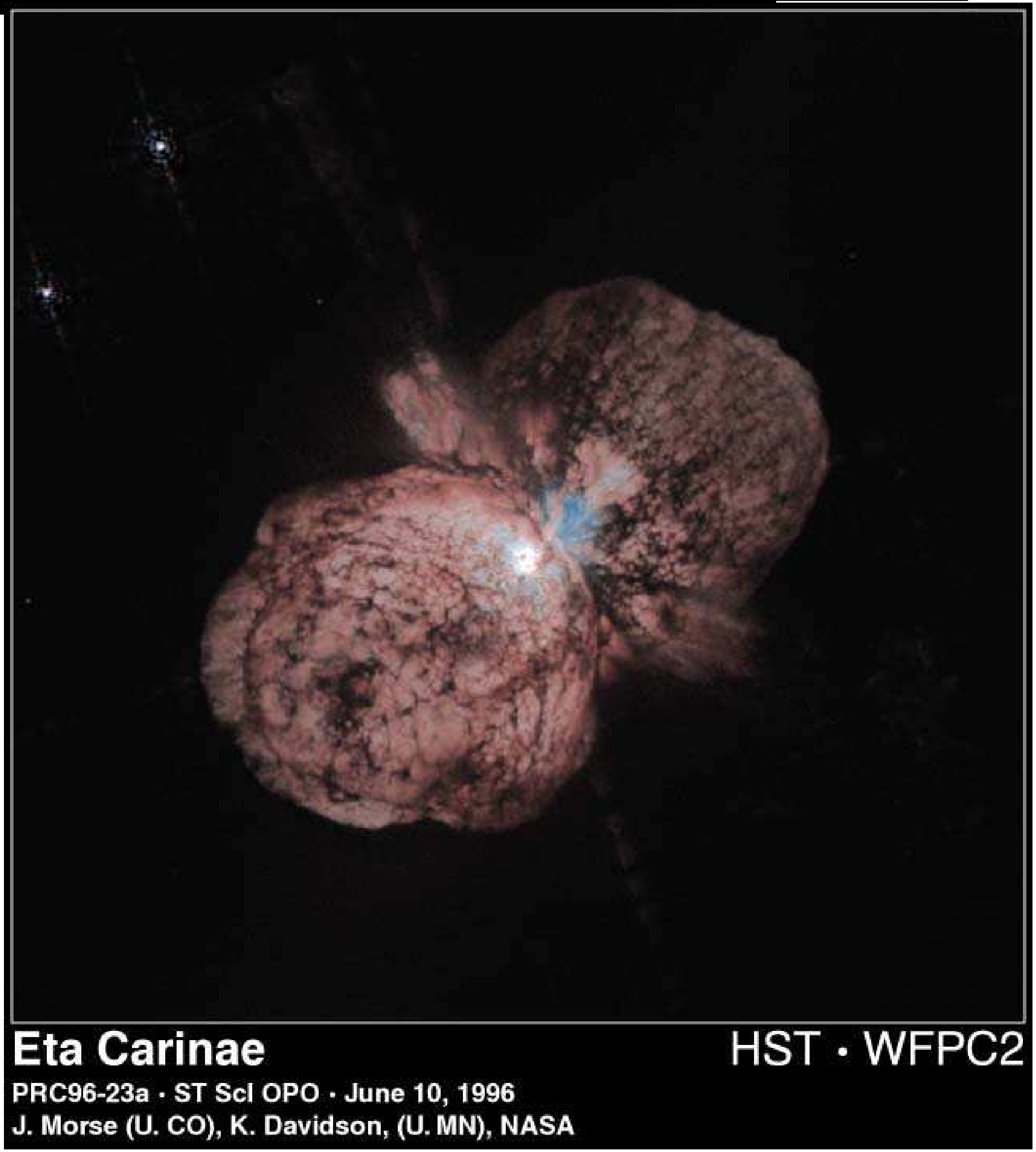
Includes the most massive among the previous list with the addition of R145 in 30 Dor $\sim$ 120 $M_\odot$ (Moffat 2006).

Getting close to the predicted mass limit

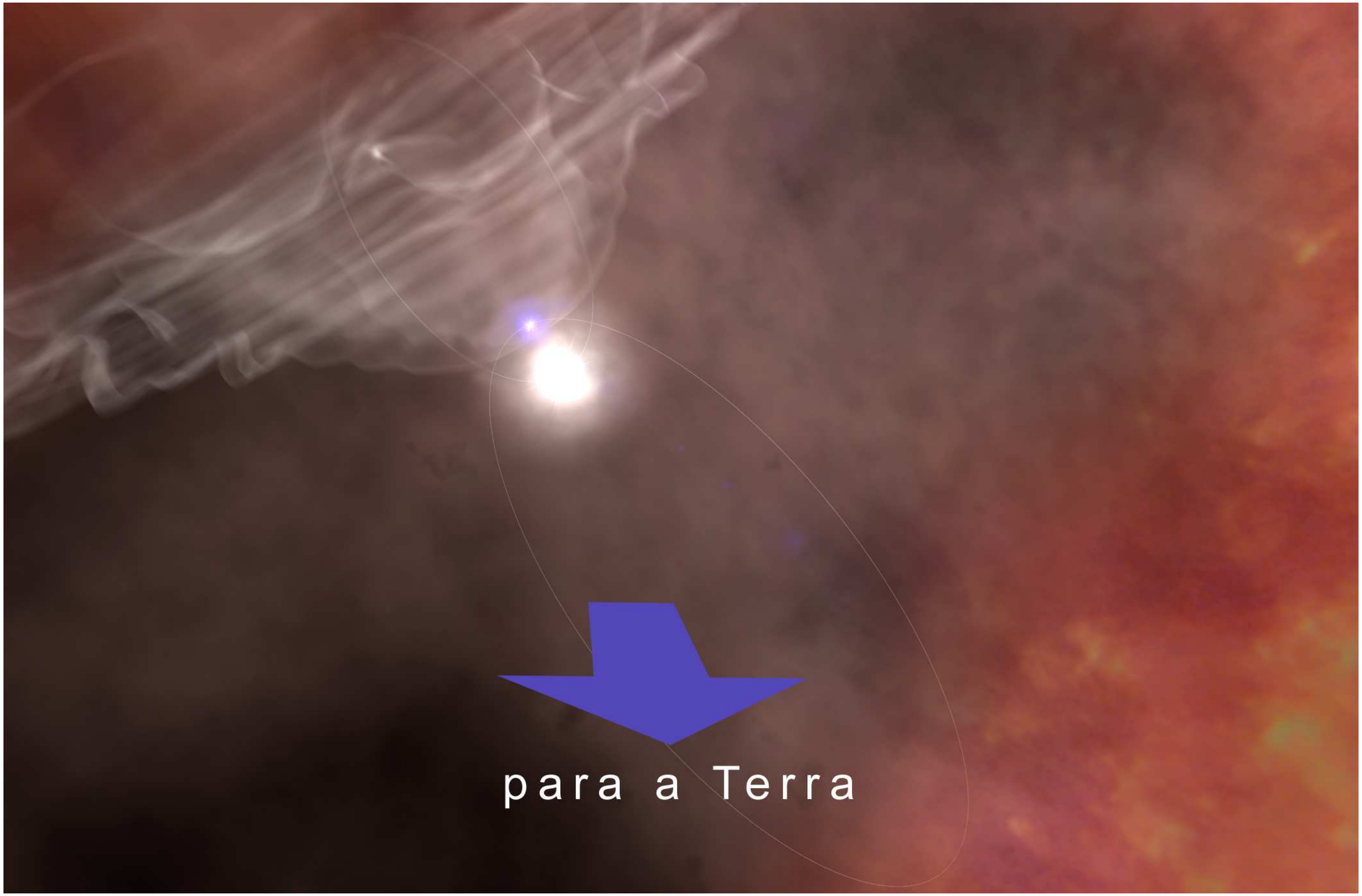


Arches cluster; Figer 2005

Favourite massive star in our neighborhood



Eta Carinae binary



Period: 5.5 years, periastron passage: January 2009!
Augusto Damineli, www.etacarinae.iag.usp.br

Mass discrepancy

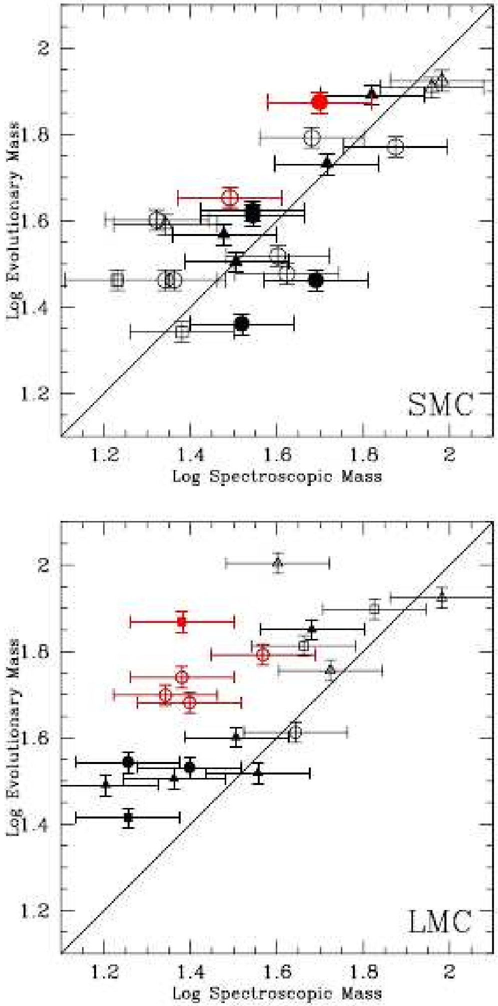


Fig. 29.— The mass discrepancy for our sample. Filled symbols denote the data new to this paper. Circles represent dwarfs, squares represent giants, and triangles represent supergiants. We have indicated in red the stars for which $T_{\rm eff}$ is greater than 45,000 K.

Massey et al. 2008, ApJ submitted

(FASTWIND vs Geneva models)

What is needed: accurate radial velocity and light curves for massive eclipsing systems. A good example: LH 54-425 (O3 V + O5 V) 47 $\pm$2 + 28 $\pm$ 1 $M_\odot$ (Williams et al. 2008)

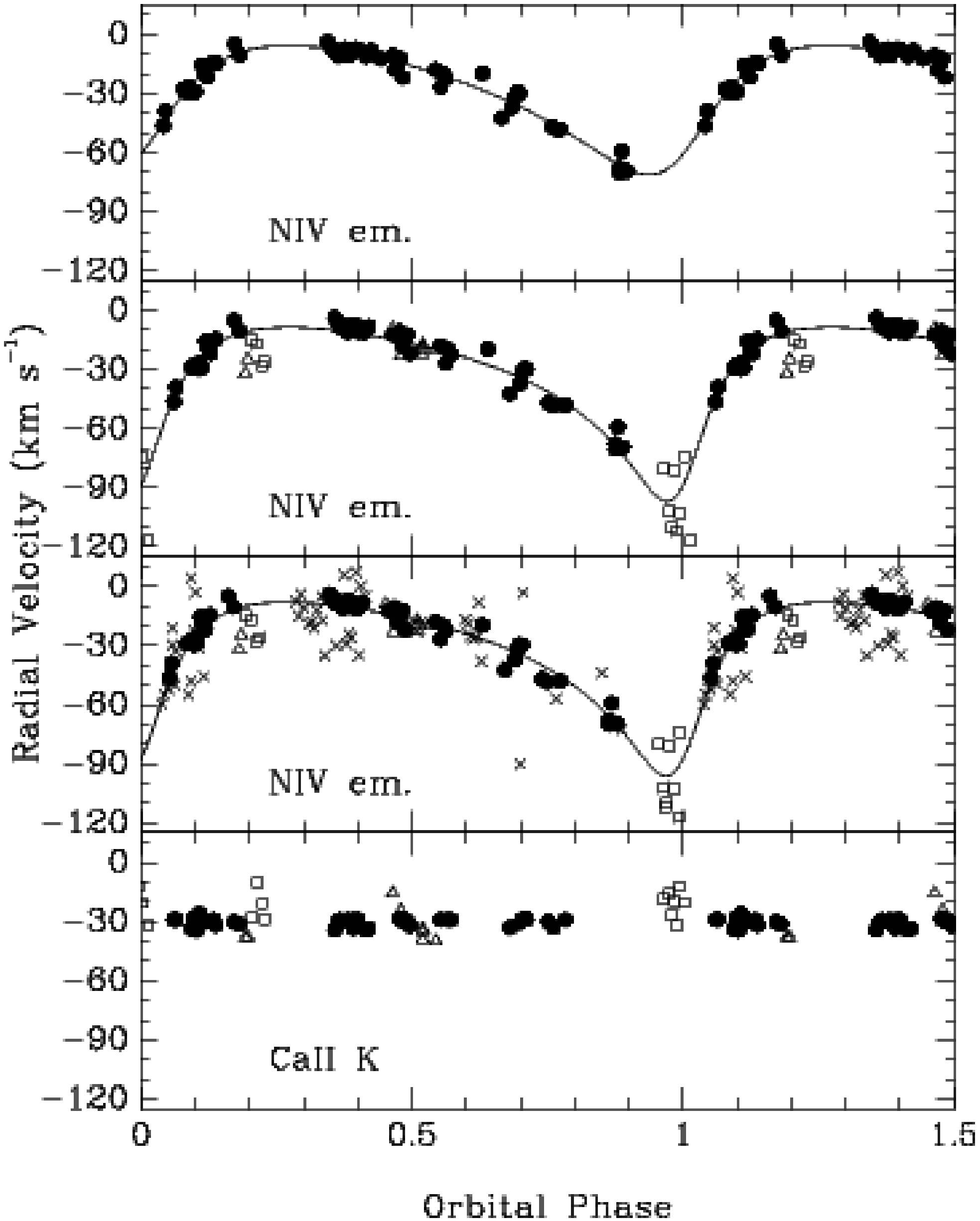
Going-on investigations by Bonanos et al. (OGLE eclipsing binaries) and Massey et al. (Magellanic Clouds clusters) should help in clarifying this issue.

The more and more we are running into systems where more than 2 stellar components are identified.

More than binaries

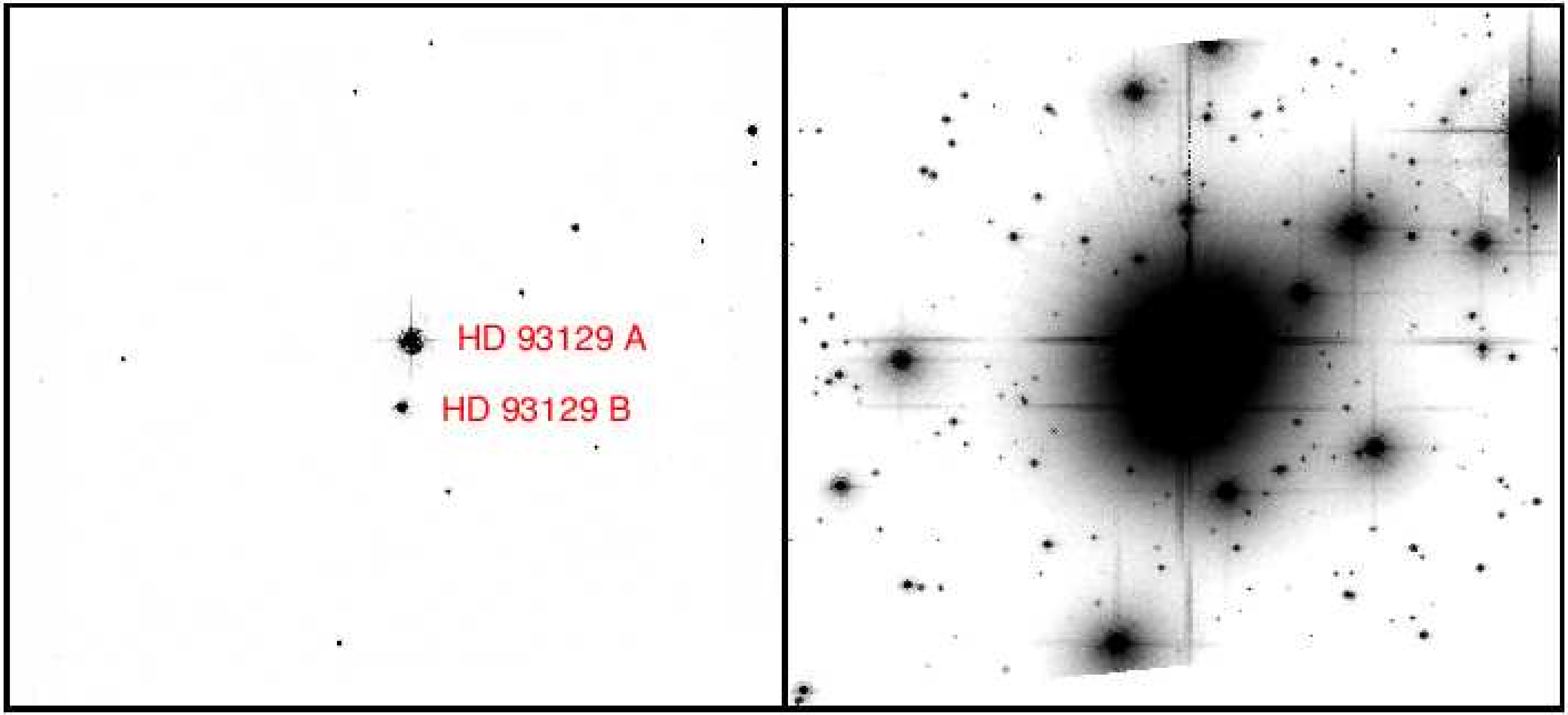
- Mason et al. 1998, at least 1/3 of the galactic O stars have close companions
- Turner et al. 2008, 40 new discovered companions in 31 systems
- Nelan et al. 2004, HD 93129A, HDE 303308, HD 93206
- Maíz Apellániz et al. HST-GO-10602 and HST-GO-10898
- XMega collaboration: selected targets in the Carina Nebula Region
- Gamen et al. http://ostars.dfuls.cl/ownsurvey
  RV survey of O and WN stars for which there is no multiplicity indication in the "Galactic O Star Catalog"; Maíz Apellániz et al. 2004

WR25 radial velocity orbit; P = 208d



Gamen et al. 2006

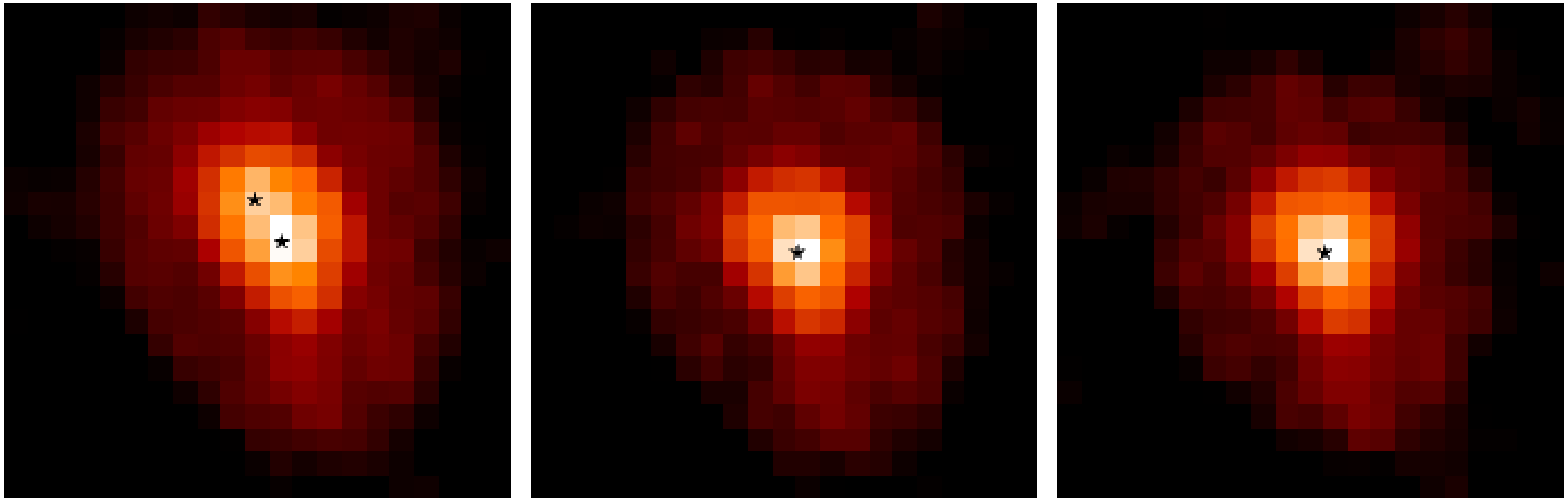
HD93129 ACS/HRC F435W, F850LP



$31.''0 \times 28.''6$

Maíz Apellániz et al., HST-GO-10898

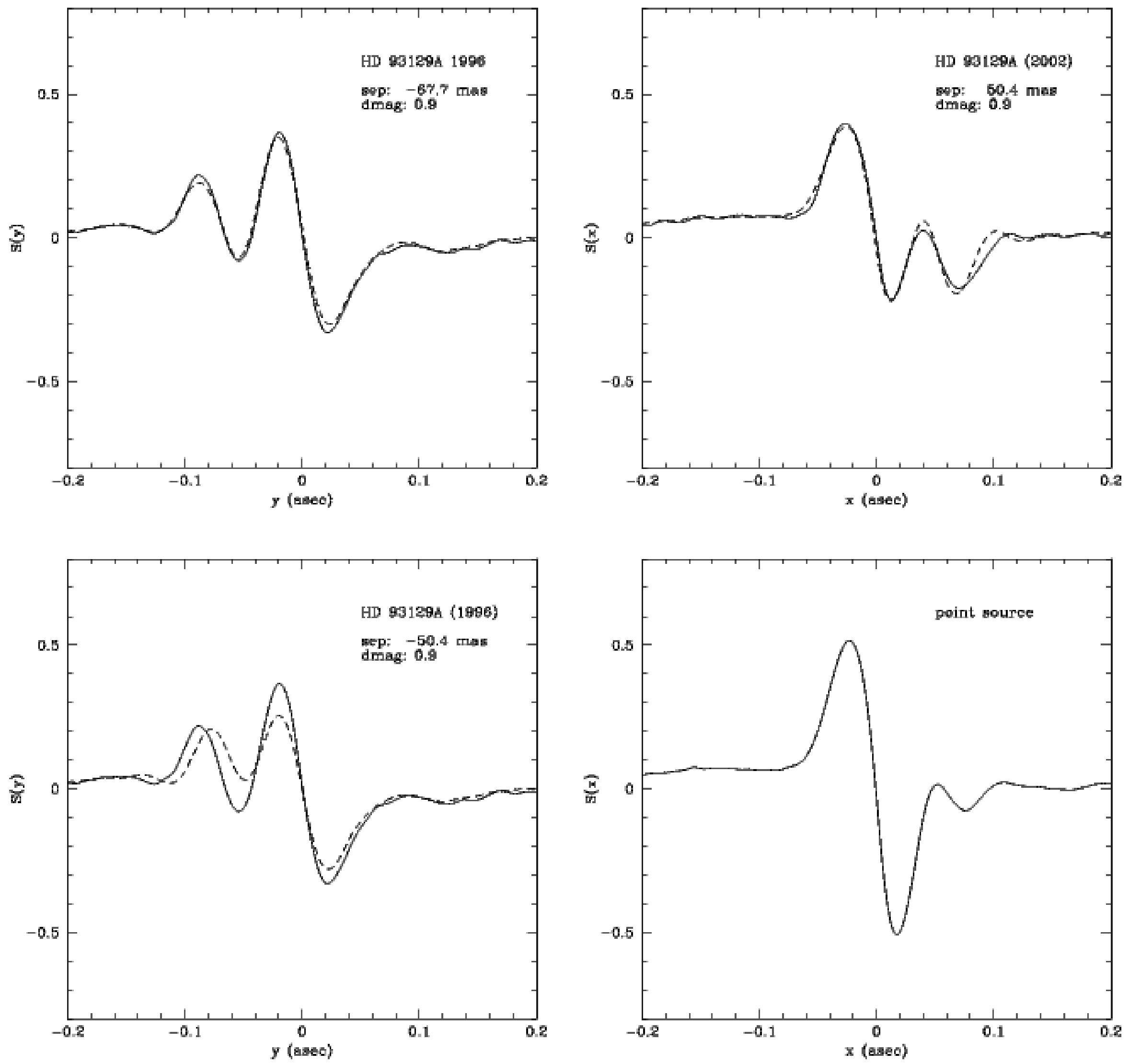
HD93129 ACS/HRC F435W



A, B and a single star PSF; $0.''53 \times 0.''53$

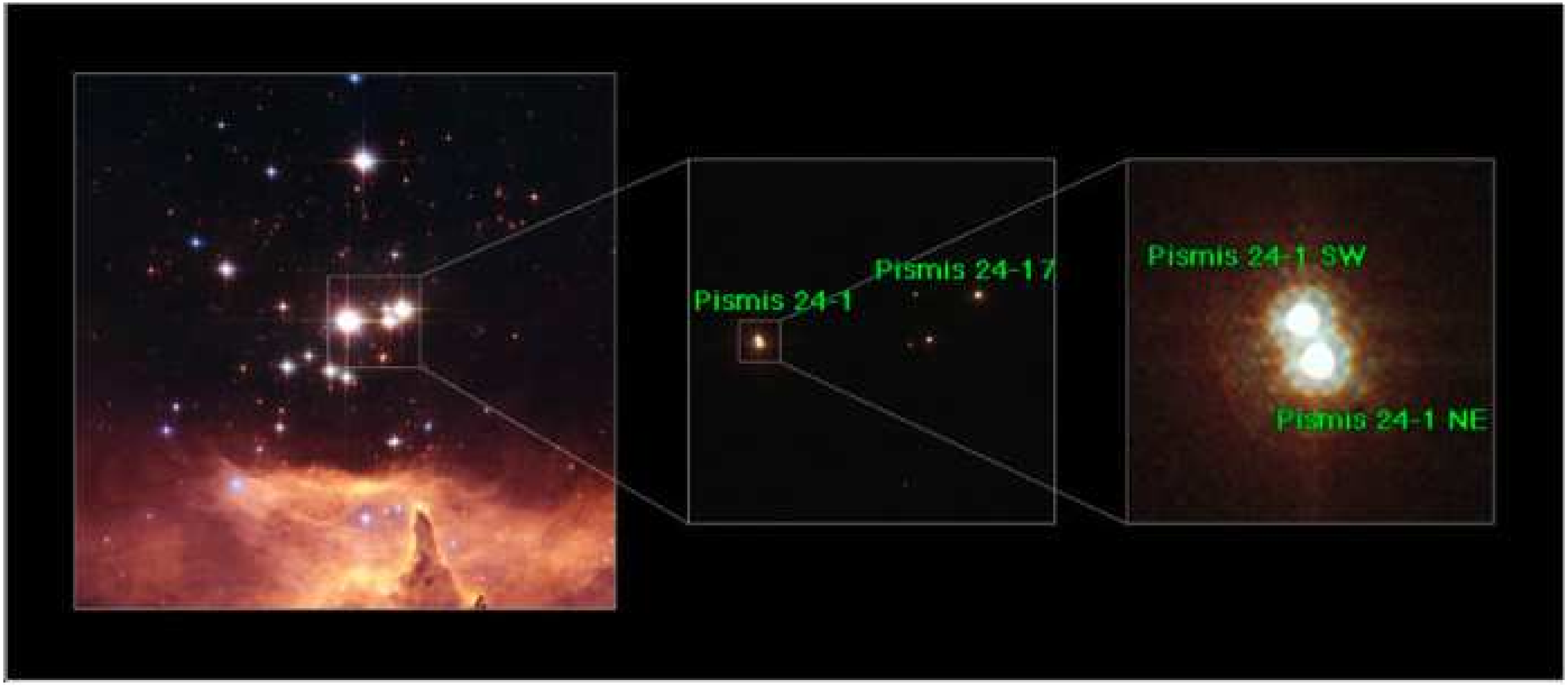
Maíz Apellániz et al., HST-GO-10898

HD93129A FGS

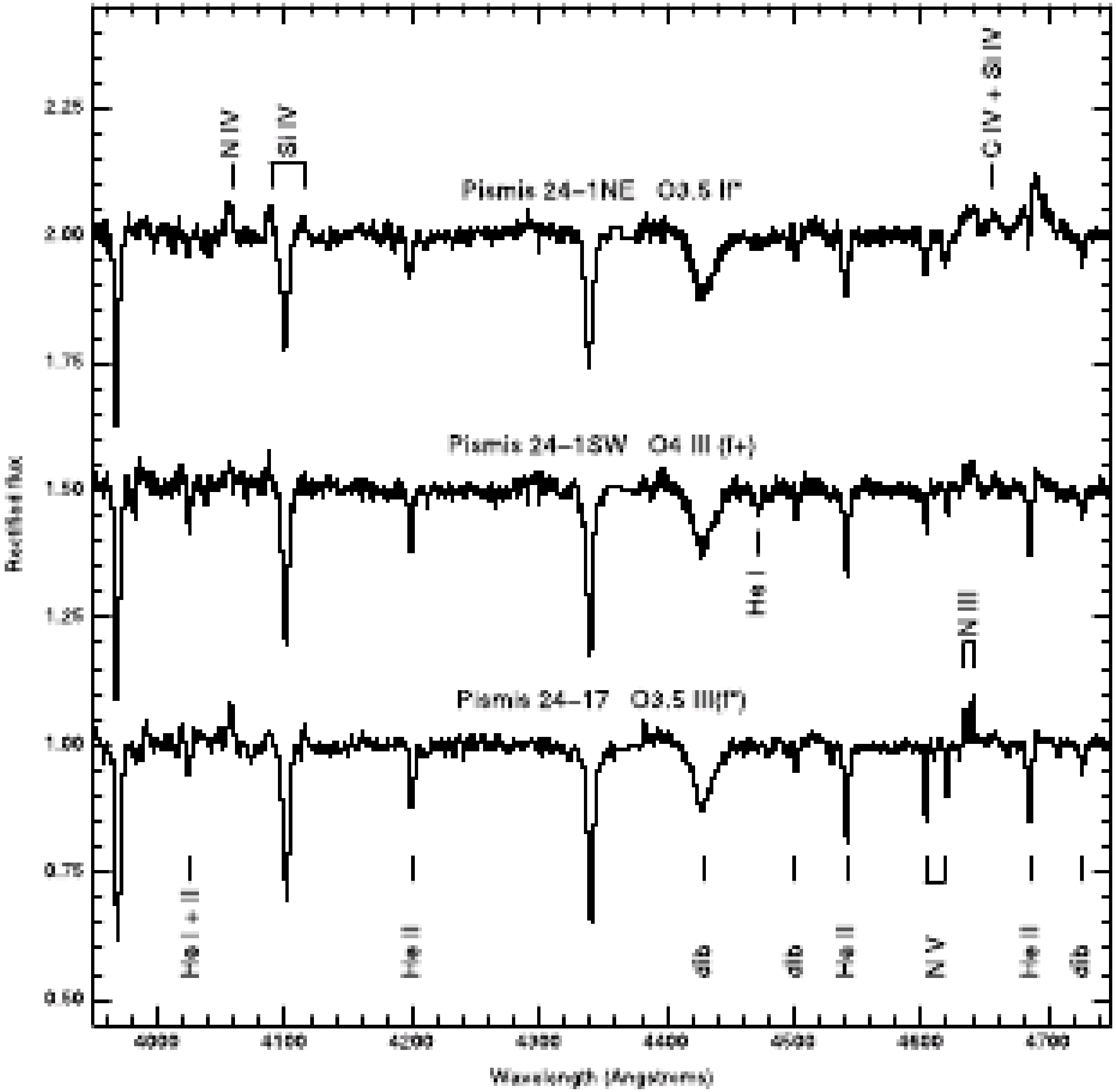


Maíz Apellániz et al., HST-GO-10898

Pismis 24-1: visual binary

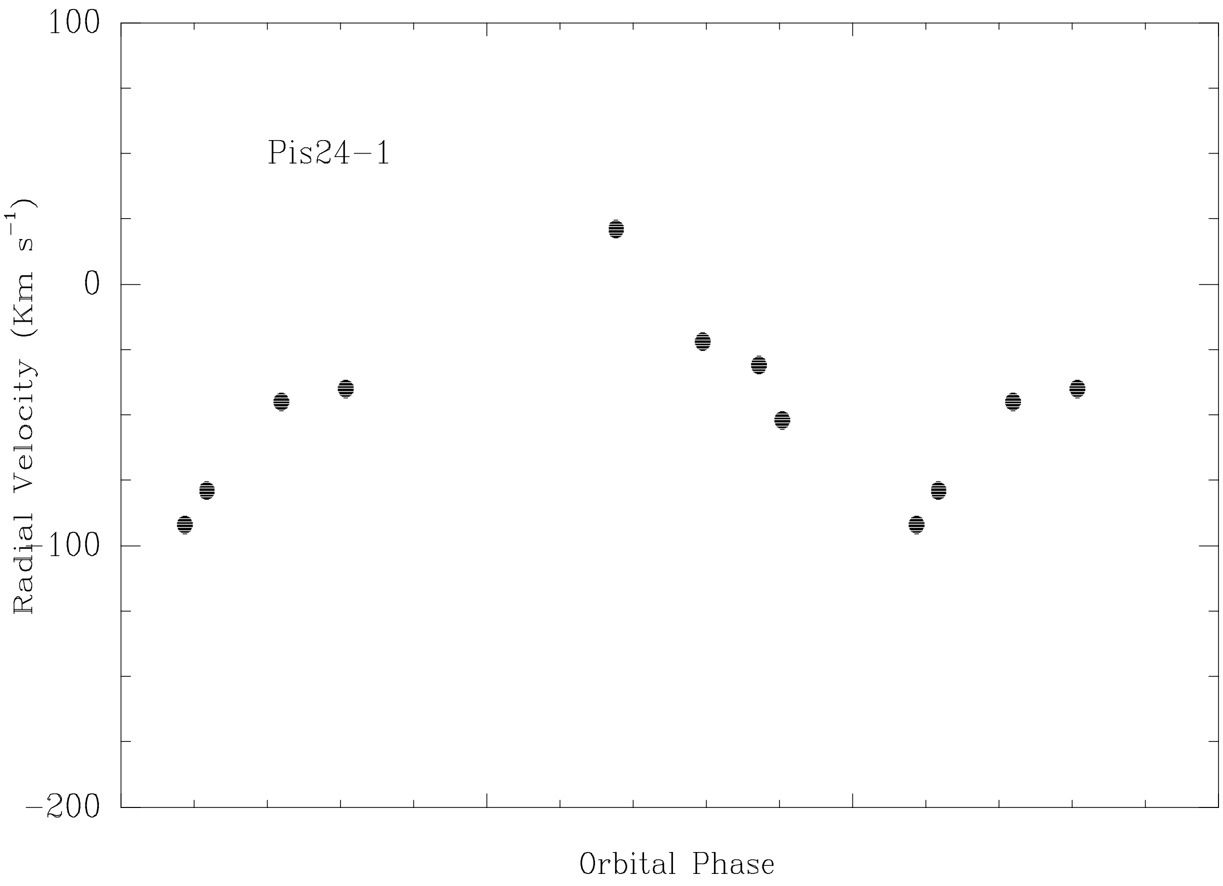


Pismis 24-1: individual spectra



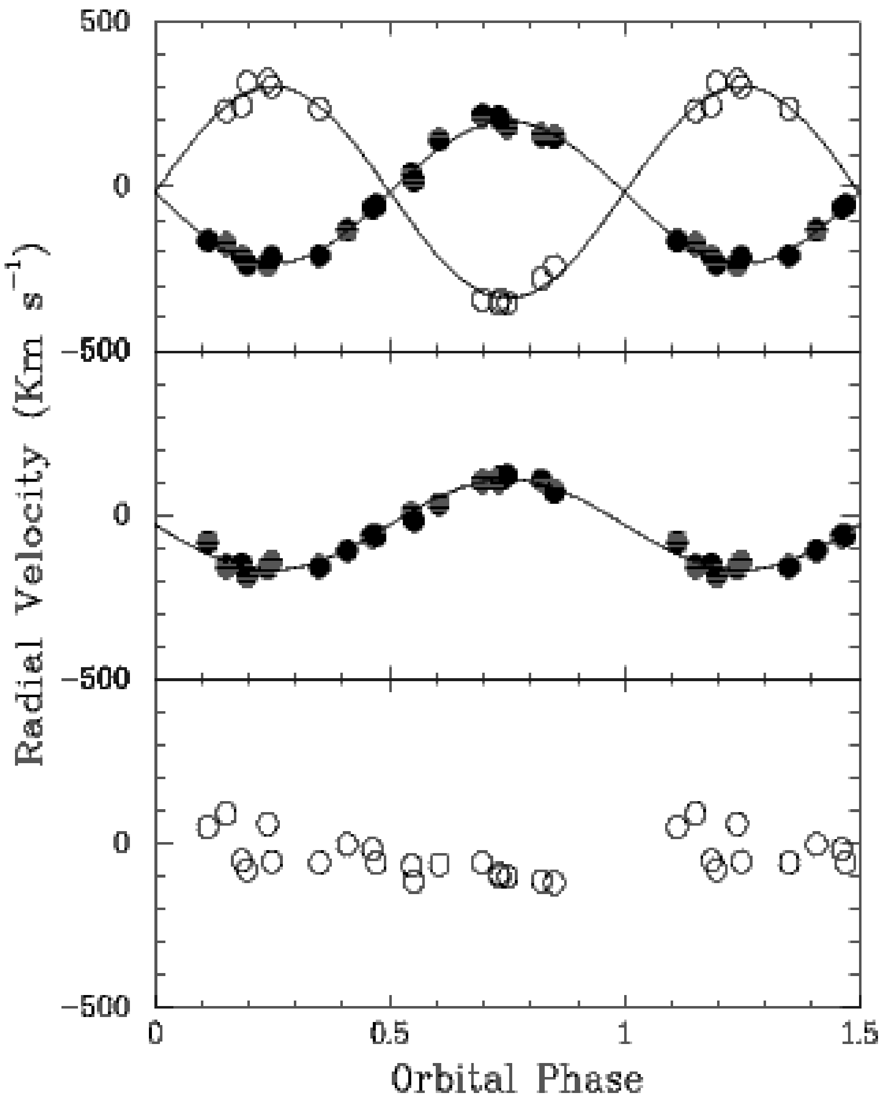
Maíz Apellániz et al, 2007

Pismis 24-1



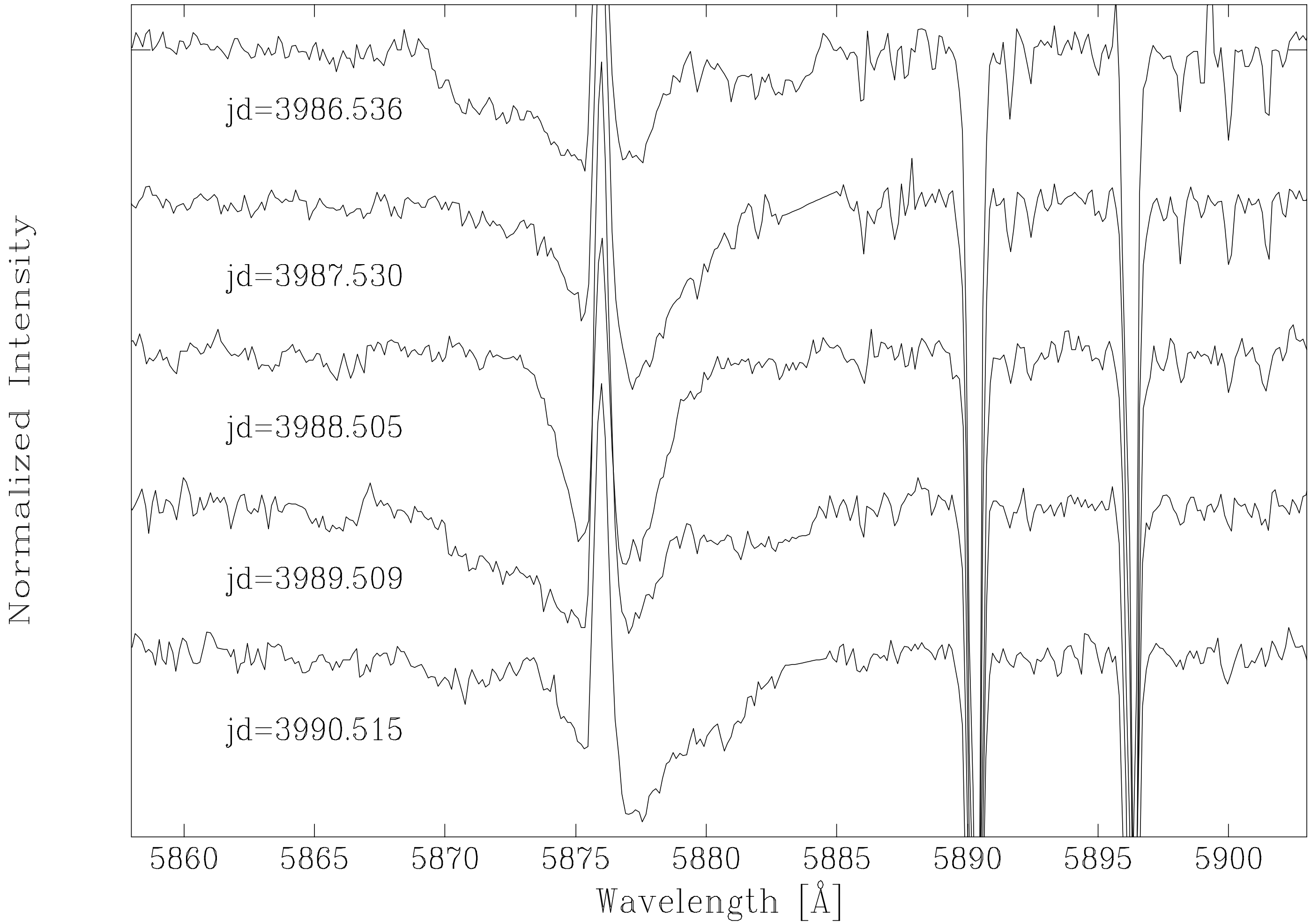
CASLEO radial velocities of NIV 4058 folded with the photometric period of 2.36088 days from Massey et al

HD150136: multiple system



Niemela & Gamen, 2005, MNRAS, 356, 974

Herschel36: multiple system



Arias et al, in preparation

You can only confirm that a massive star *is* a binary, but never that it is not.

Virpi Niemela

Many thanks to:
Julia Arias, Rodolfo Barbá, Kathy Eastwood, Roberto Gamen, Doug Gies, Laura Penny, Jesús Maíz Apellániz, Phil Massey, Alfredo Sota, Nolan Walborn, Amanda Zangari