

SISTEMAS ESTELARES

**Material didáctico para las clases de
“*Estrellas Binarias*”**

**Clases teóricas dictadas por:
Dra. Lilia P. Bassino**

Curvas de velocidad radial:

“Double stars”, Heintz

THE ELEMENTS OF SPECTROSCOPIC ORBITS

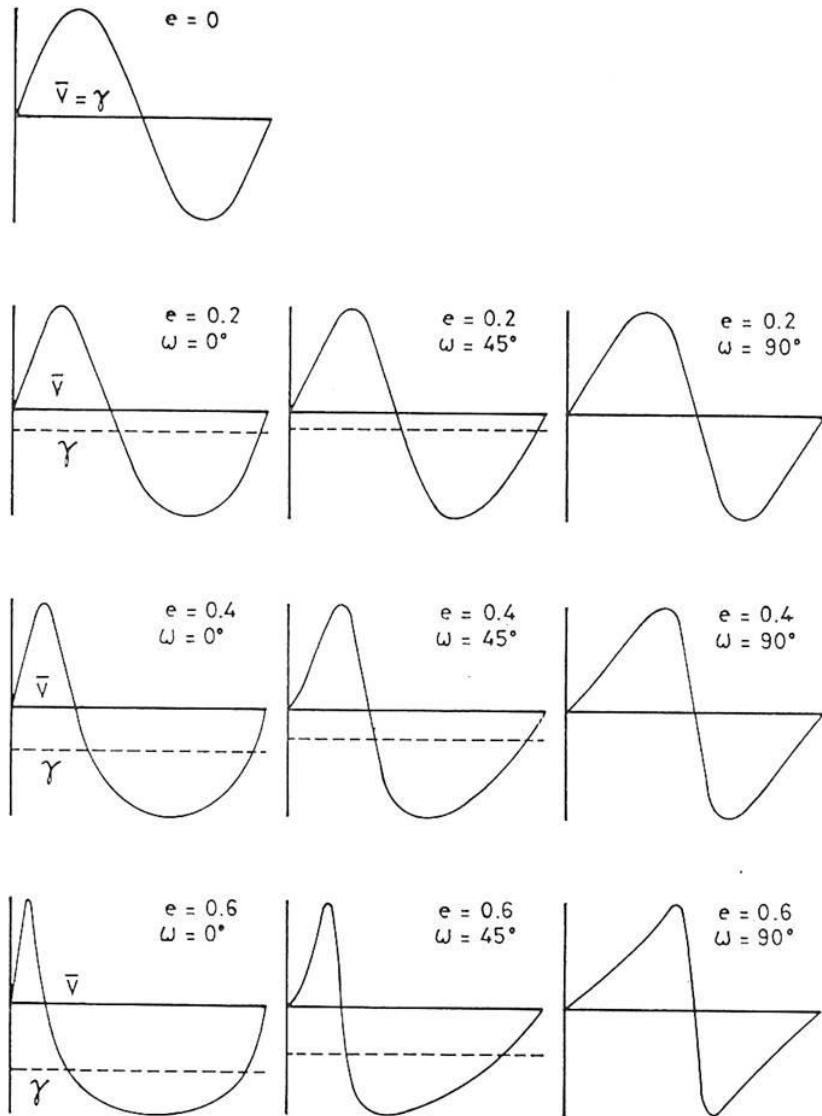
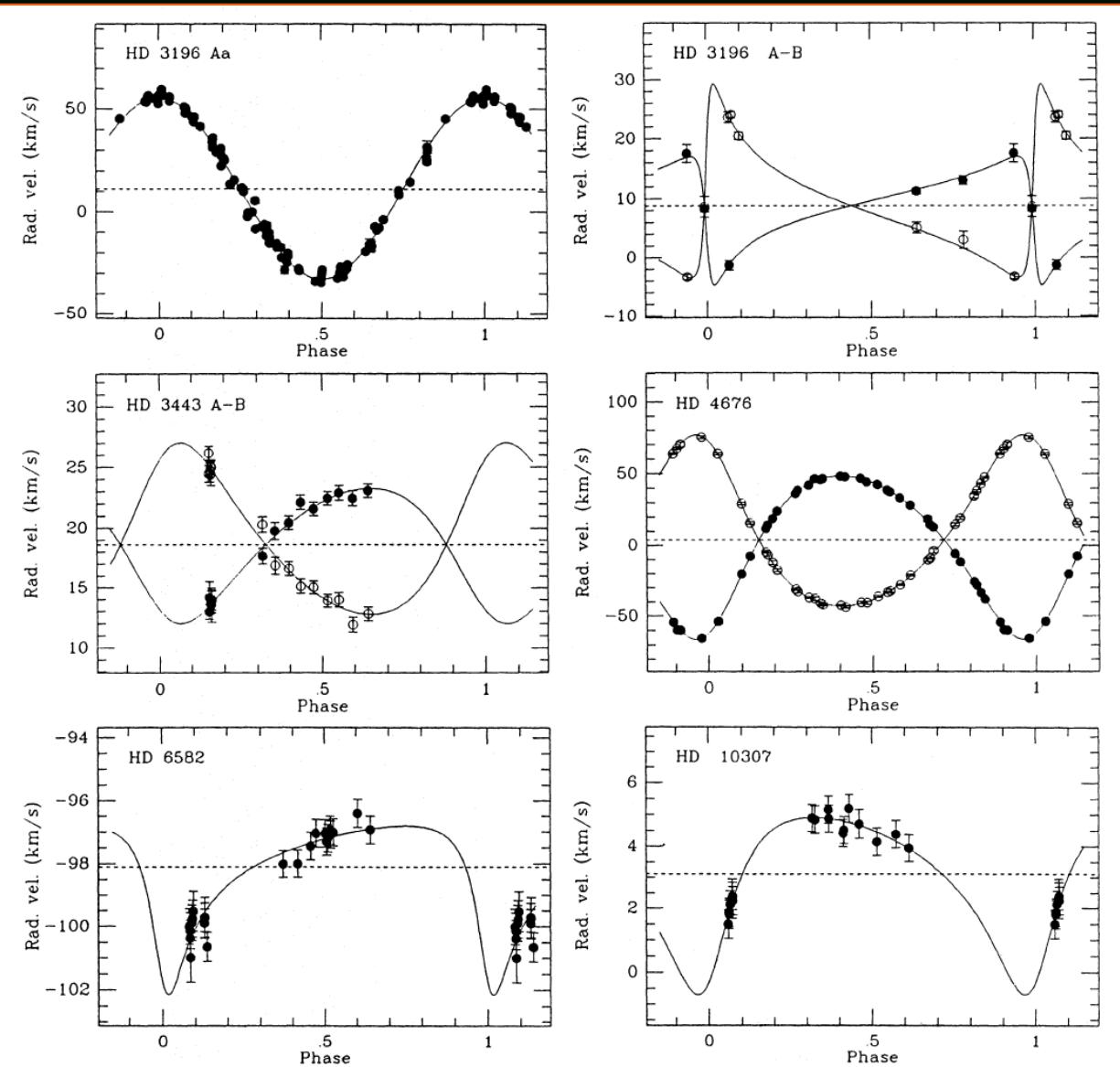


Fig. 20. The shapes of radial-velocity curves for different values of the elements e and ω .

Curvas de velocidad radial:



En catálogos:

SB1:

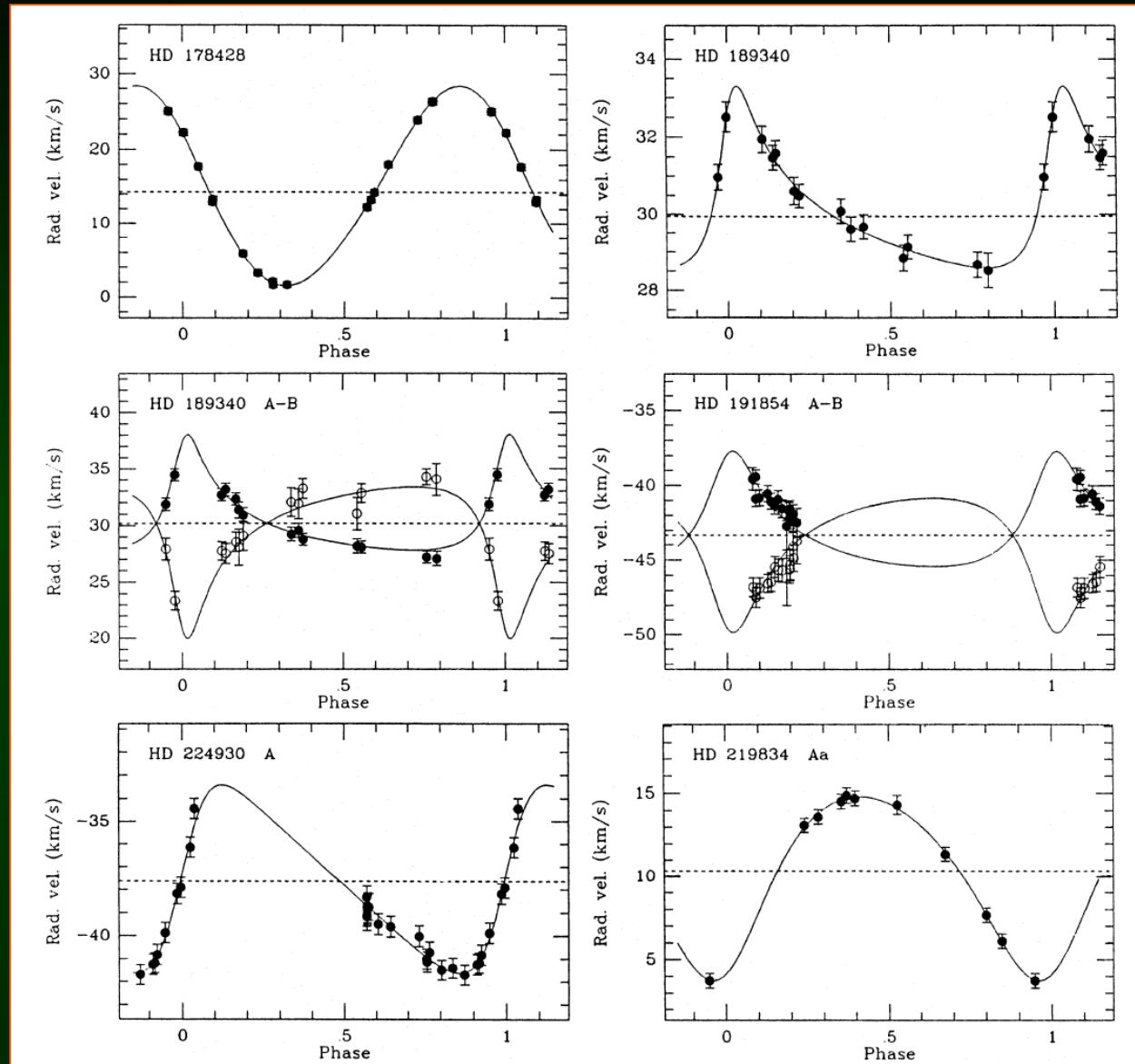
1 espectro visible
(single-lined binary)

SB2:

2 espectros visibles
(double-lined binary)

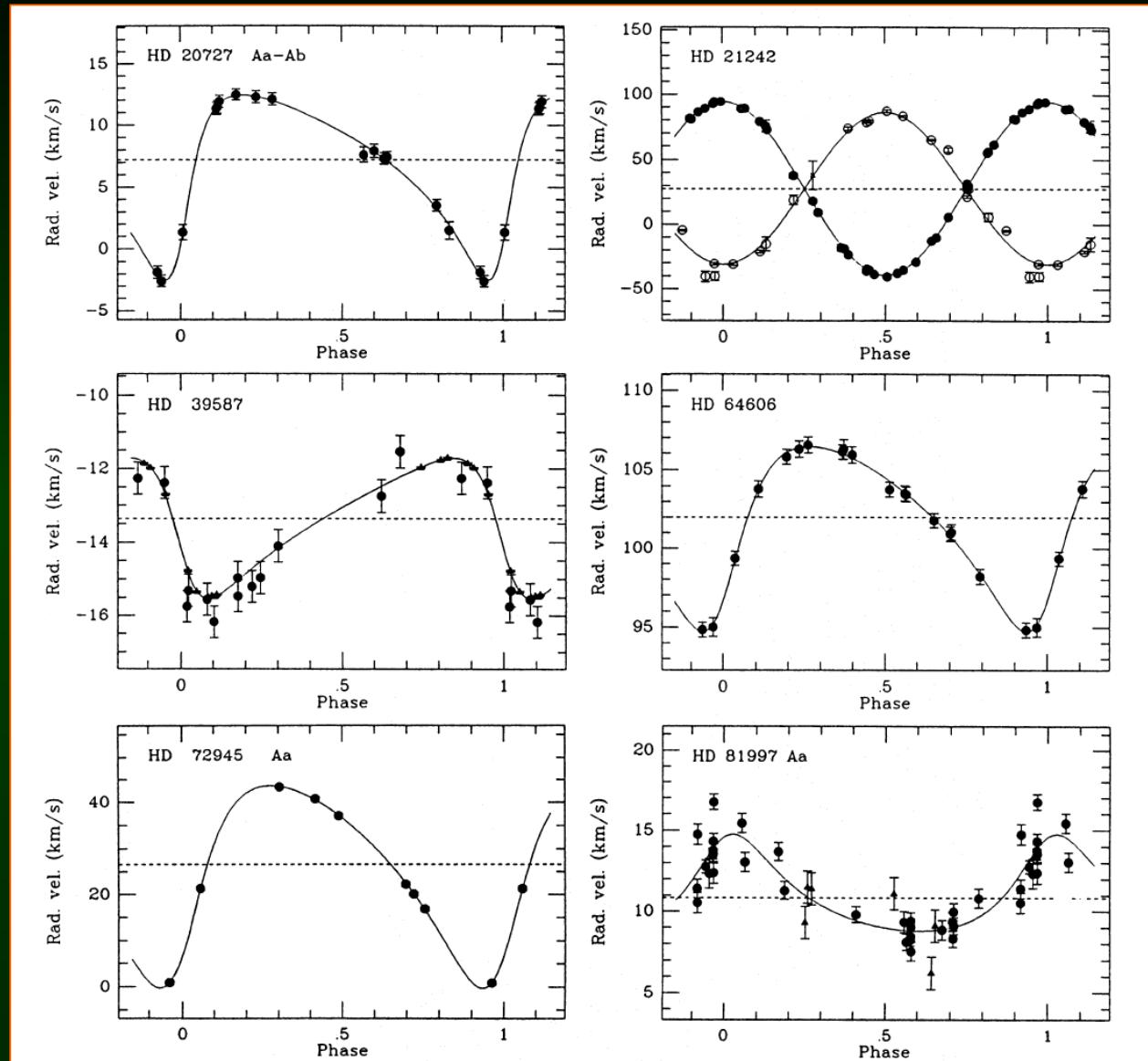
Duquennoy & Mayor
1991, A&A 248, 485

Curvas de velocidad radial:



Duquennoy & Mayor
1991, A&A 248, 485

Curvas de velocidad radial:



Duquennoy & Mayor
1991, A&A 248, 485

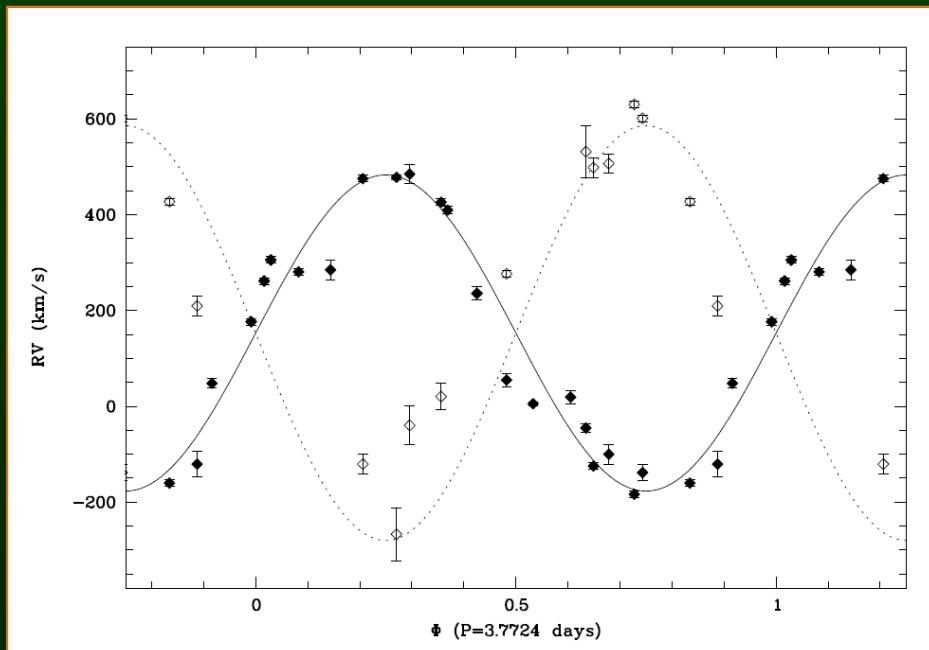
Ej. estrellas de gran masa: “VMS very massive stars” con masa > 100 masas solares

En el cúmulo abierto Galáctico NGC 3603, muy joven (10^6 yr), masivo y denso:

Binaria espect. y eclipsante A1,
ambas componentes son WR.

Table 3. Orbital parameters for both the primary and the secondary component of A1 from the combined, weighted fit, forcing a circular solution. The inclination angle and the period have been adopted from Moffat et al. (2004).

Parameter	Primary	Secondary
P [days]		3.7724
i [$^\circ$]		71
e		0
E_0 [2,450,000.5+]		3765.25 ± 0.03
γ [kms $^{-1}$]		153 ± 12
K [kms $^{-1}$]	330 ± 20	433 ± 53
σ_{o-c} [kms $^{-1}$]	42	82
M [M_\odot]	116 ± 31	89 ± 16



Ej. candidatas a VMS:

En la región de formación estelar 30 Dor (región HII) en la Nube Mayor de Magallanes (LMC).

➤ i desconocida \Rightarrow masas aprox.

Melnik 34: binaria espect. SB2, fuente intensa de rayos X, ambas componentes son WR.

Parameter	<i>Evolutionary modelling: BONNSAI</i>	
	Star A	Star B
$\log(L^*/[L_\odot])$	$6.41^{+0.09}_{-0.08}$	$6.35^{+0.08}_{-0.09}$
$X_{\text{He}} [\%]$	33^{+3}_{-8}	33^{+3}_{-8}
$v_{\text{rot}} [\text{km s}^{-1}]$	240^{+171}_{-20}	250^{+170}_{-29}
T [K]	54388^{+327}_{-822}	54355^{+339}_{-855}
$\log(\dot{M}^*/[M_\odot \text{yr}^{-1}])$	$-5.00^{+0.13}_{-0.11}$	$-5.06^{+0.11}_{-0.12}$
Age [Myrs]	0.5 ± 0.3	0.6 ± 0.3
$M_{\text{cur}} [M_\odot]$	139^{+21}_{-18}	127^{+17}_{-17}

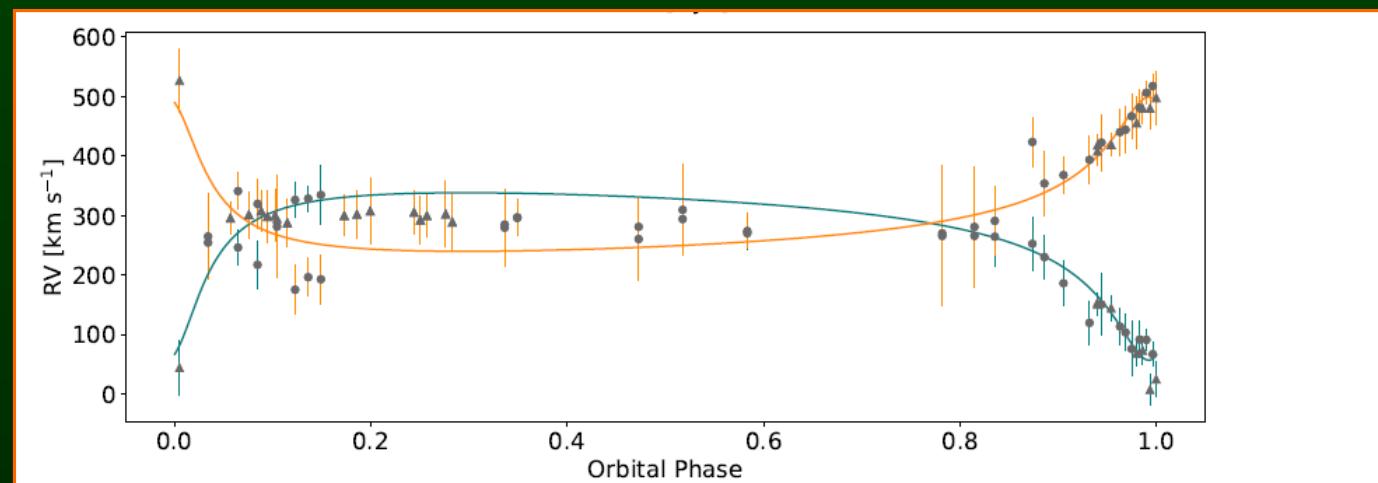


Figure 9. Best fitting radial-velocity curve for the VLT/UVES and Gemini/GMOS data providing the parameters for solution UG1.

Tehrani et al. 2019,
MNRAS 484, 2692

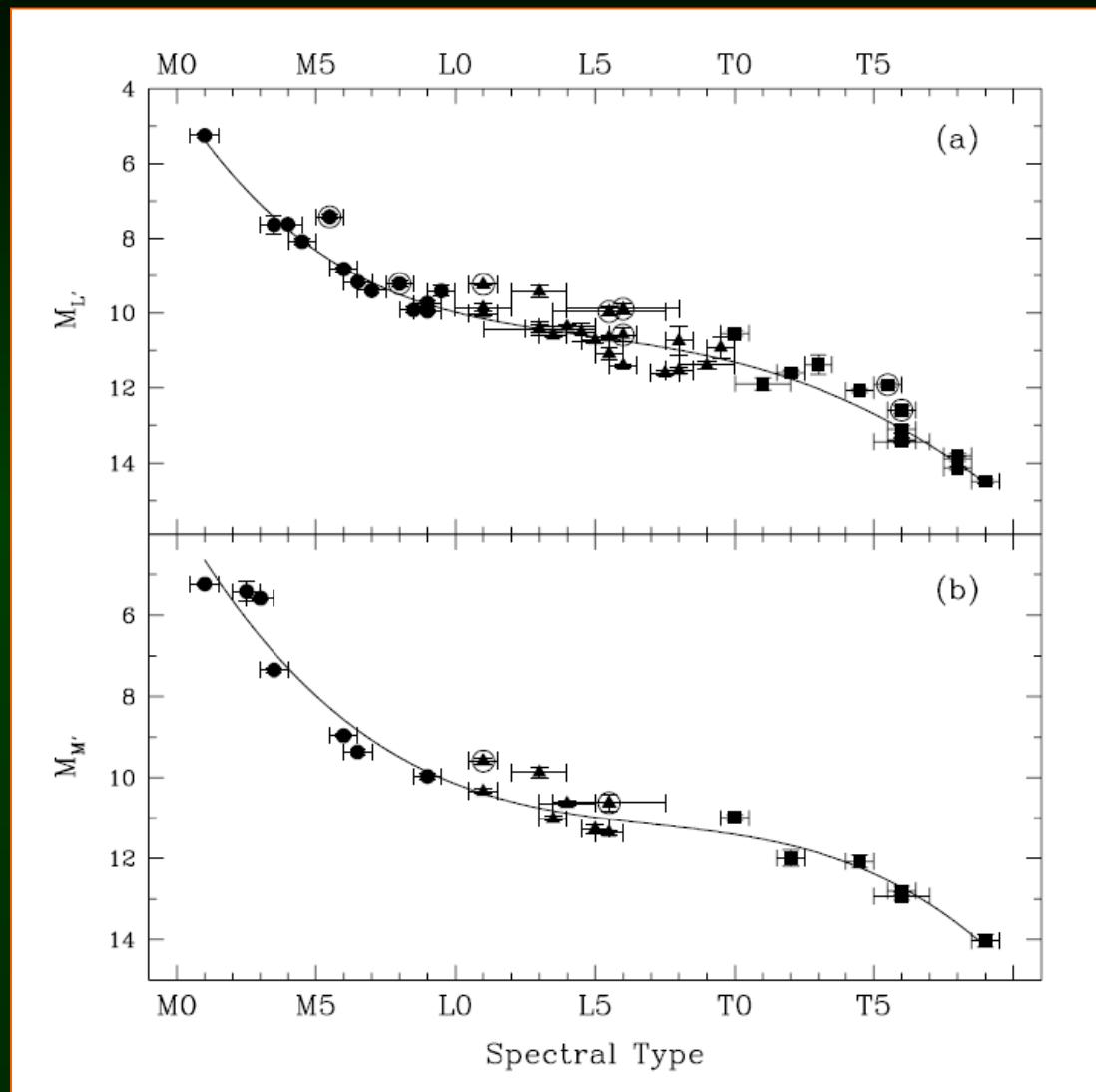
DCM de estrellas de menor masa: tipos M, L y T

L': 3.4 - 4.1 μm

M': 4.6 - 4.8 μm

(filtros del MKO Observatory)

Golimowski et al. 2004,
AJ 127, 3516



Espectros de estrellas O5 a M5:

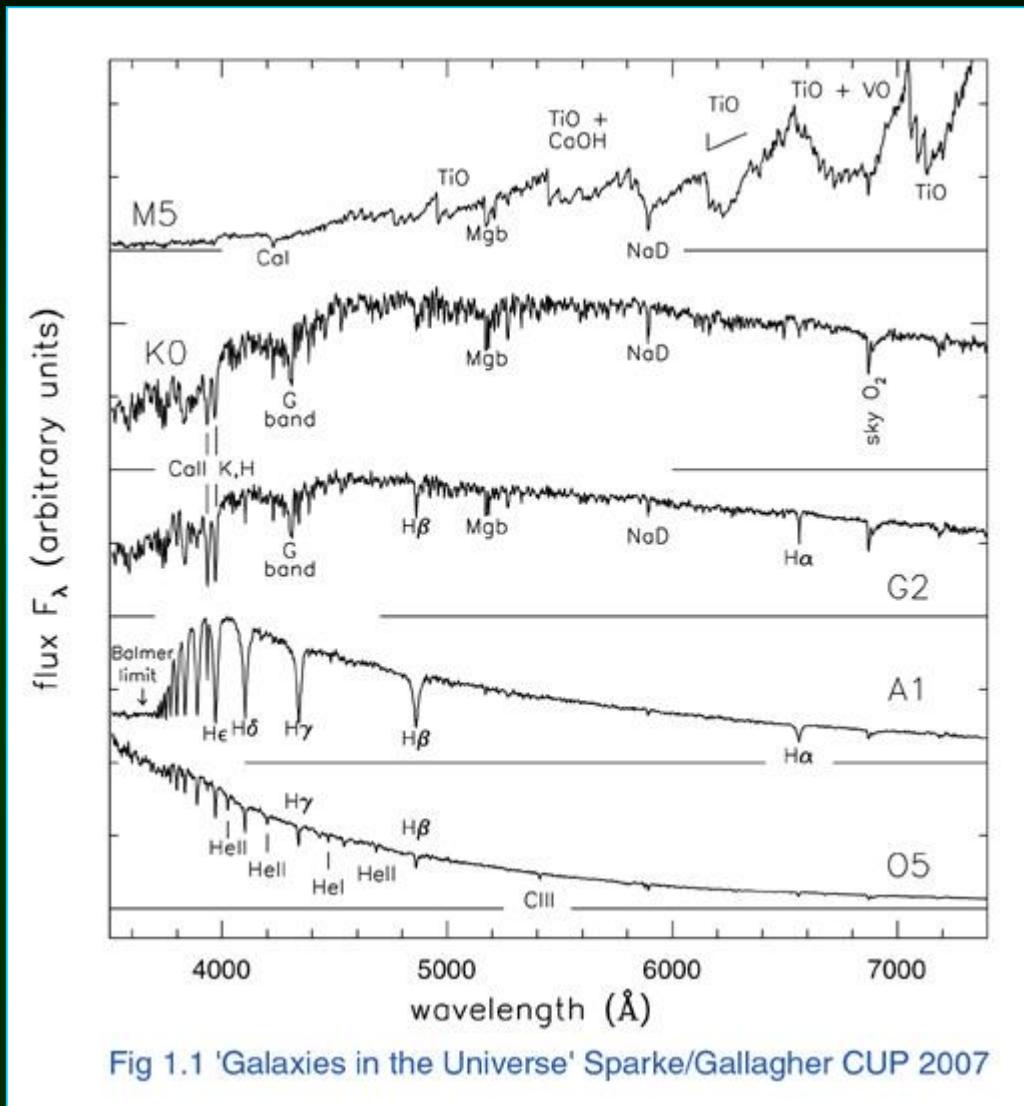


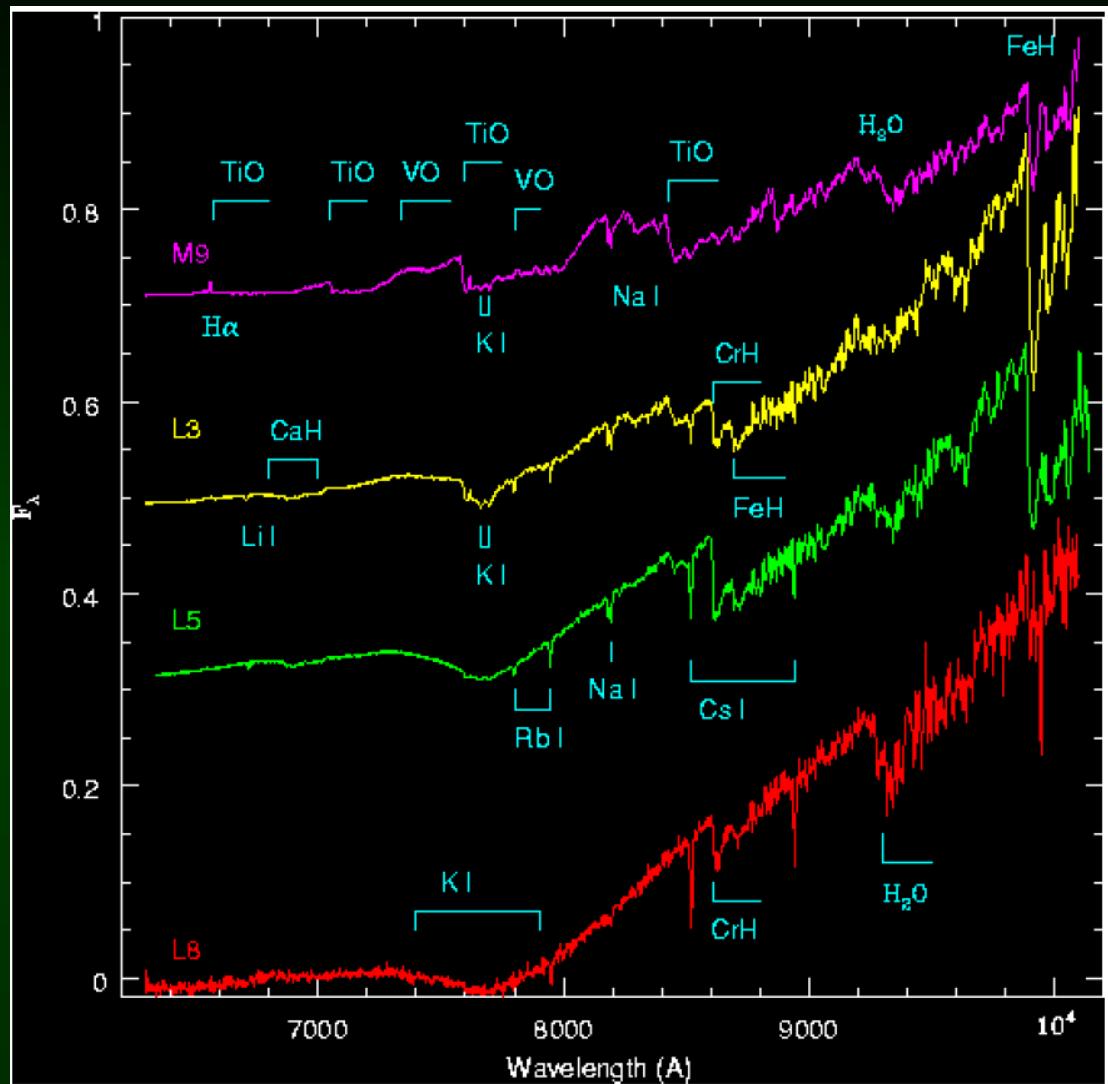
Fig 1.1 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

"Galaxies in the Universe"
Sparke & Gallagher

Estrellas de menor masa: tipo L

TiO, VO / CaH, FeH, H₂O

Li I, K I, Na I, Rb I, Cs I

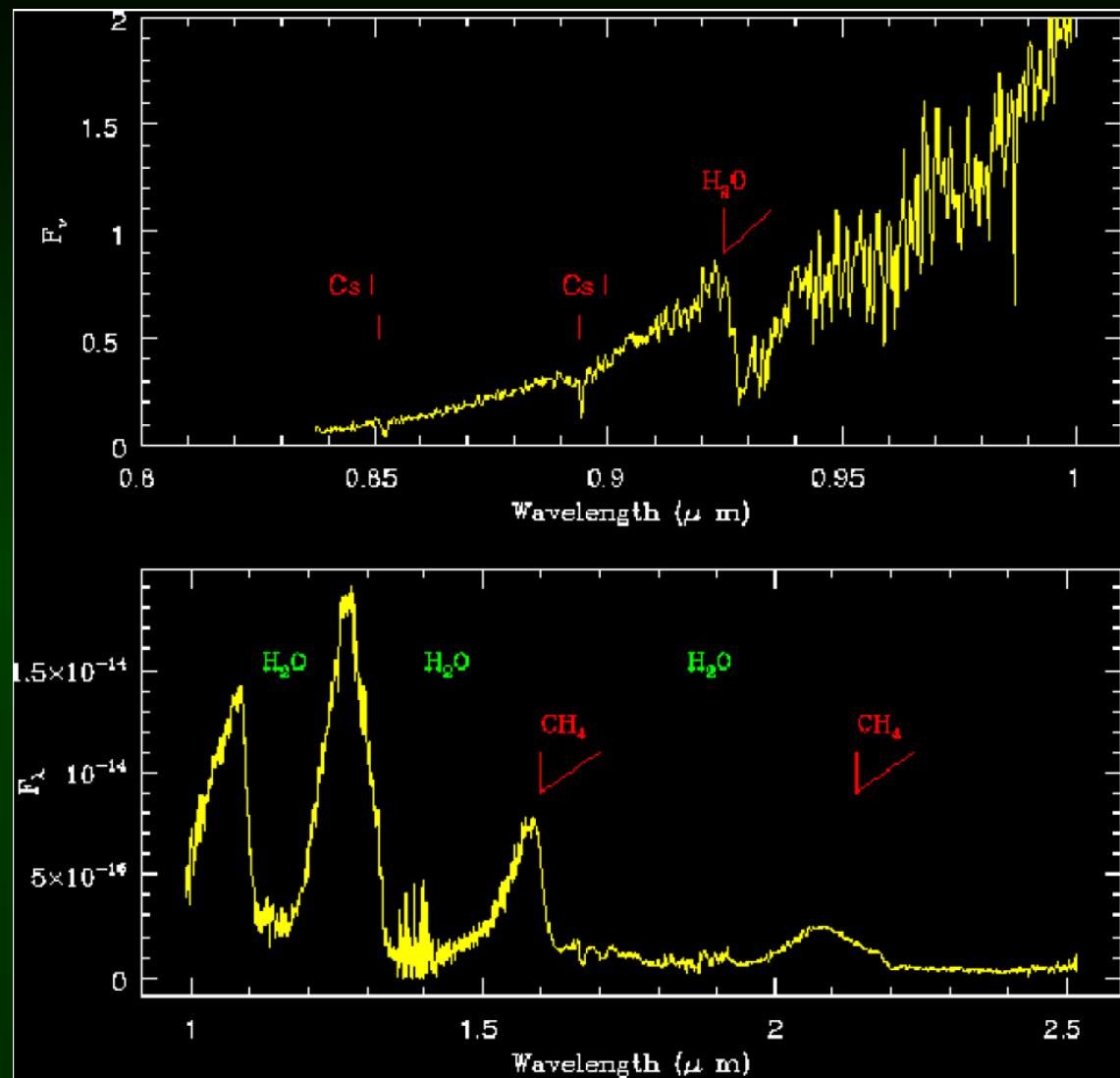


“L dwarf and T dwarf spectral classification”

<http://www.stsci.edu/~inr/lwdwarf1.html>

Estrellas de menor masa: tipo T

CH₄, H₂O



“L dwarf and T dwarf spectral classification”
<http://www.stsci.edu/~inr/lgdwarf1.html>

DCM de estrellas O hasta T , en IR:

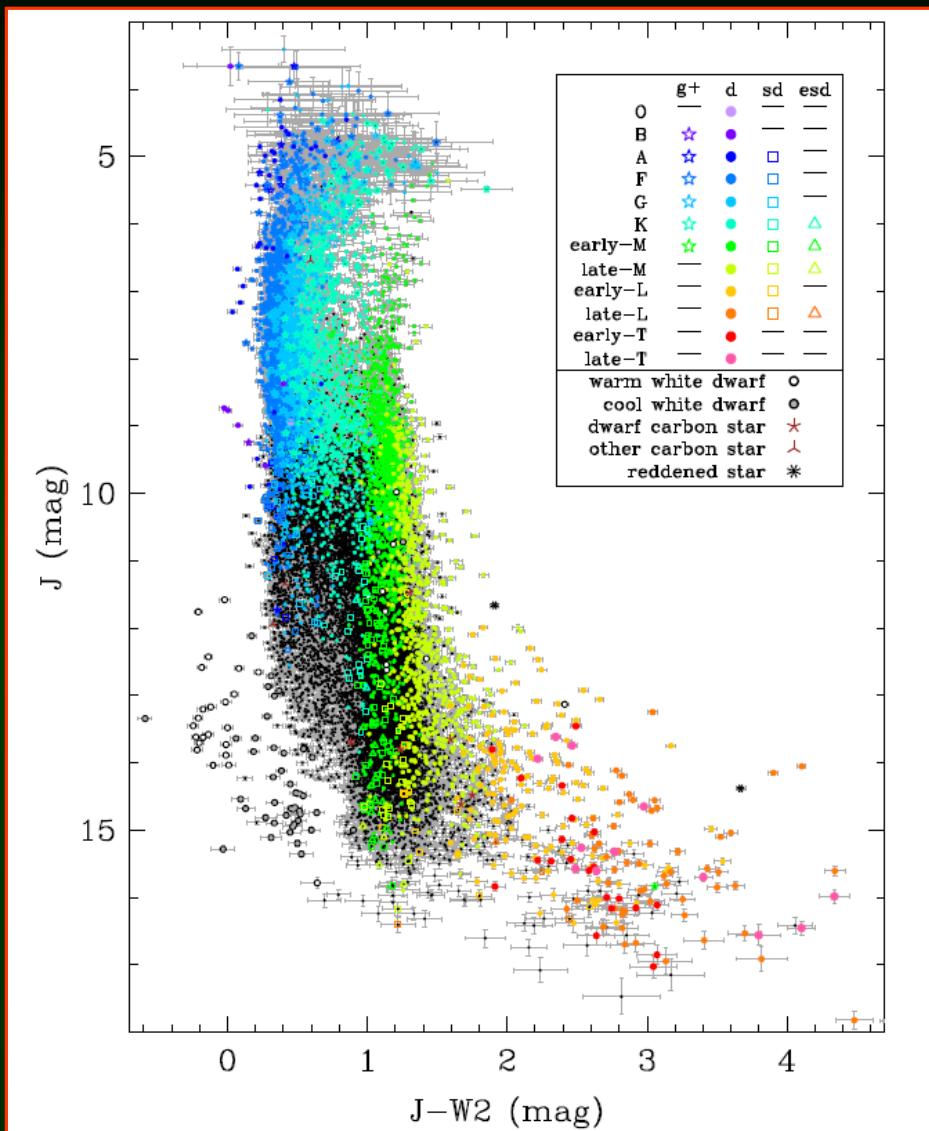
All WISE 2DR: Second Data Release
(coord., mag. W1 y W2, mov.)

+

2MASS J, H, K mag

banda W2 : 4.6 μm

Kirkpatrick et al. 2016,
ApJS 224, 36



Estrellas de menor masa: tipo Y

Y0, Y1, Y2

$d \leq 20$ pc

$T_{\text{eff}} < 500^{\circ}\text{K}$ (Leggett et al. 2016)

masas (por modelos)= 2 a 30 M_{JUP}

espectros: CH_4 , H_2O ; NH_3

Kirkpatrick et al. 2012,
ApJ 753, 156

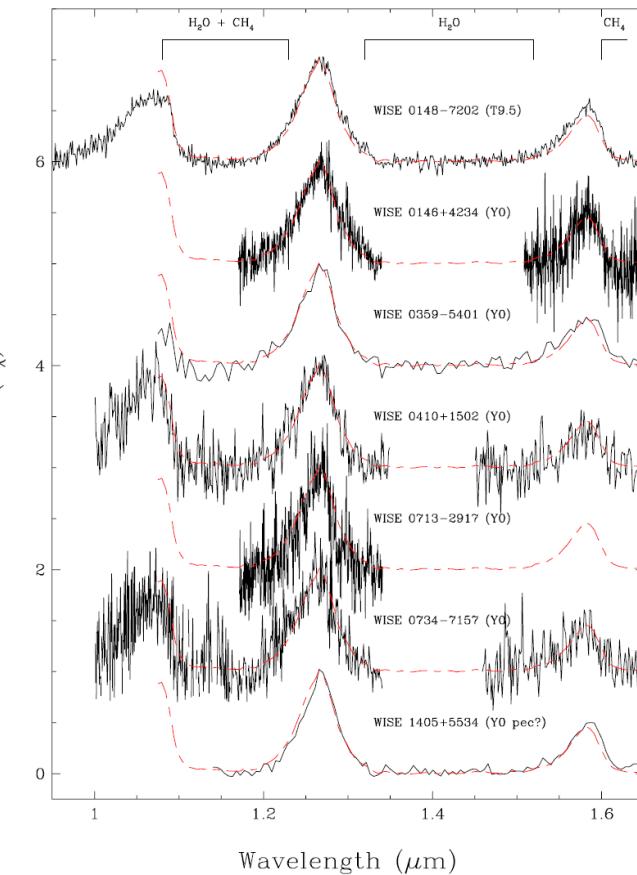


Fig. 3.— Along with Fig 4 and Fig 5, the spectra of all known Y dwarfs together with a comparison spectrum of the T9.5 dwarf WISE 1048-7202. Each spectrum is normalized to one at its peak in the *J*-band and integral offsets have been added to separate the spectra vertically. Overplotted on each spectrum is the Y0 dwarf spectral standard WISE 1738+2732 (dashed red curve). For NIRSPEC data taken in the N5 configuration (*H*-band), the normalization has been set so that the *H*-band peak of the Y dwarf matches the *H*-band peak of the spectral standard.

DCM incluyendo estrellas enanas tipo Y

filtro H: 1.6 μm

Kirkpatrick et al. 2012,
ApJ 753, 156

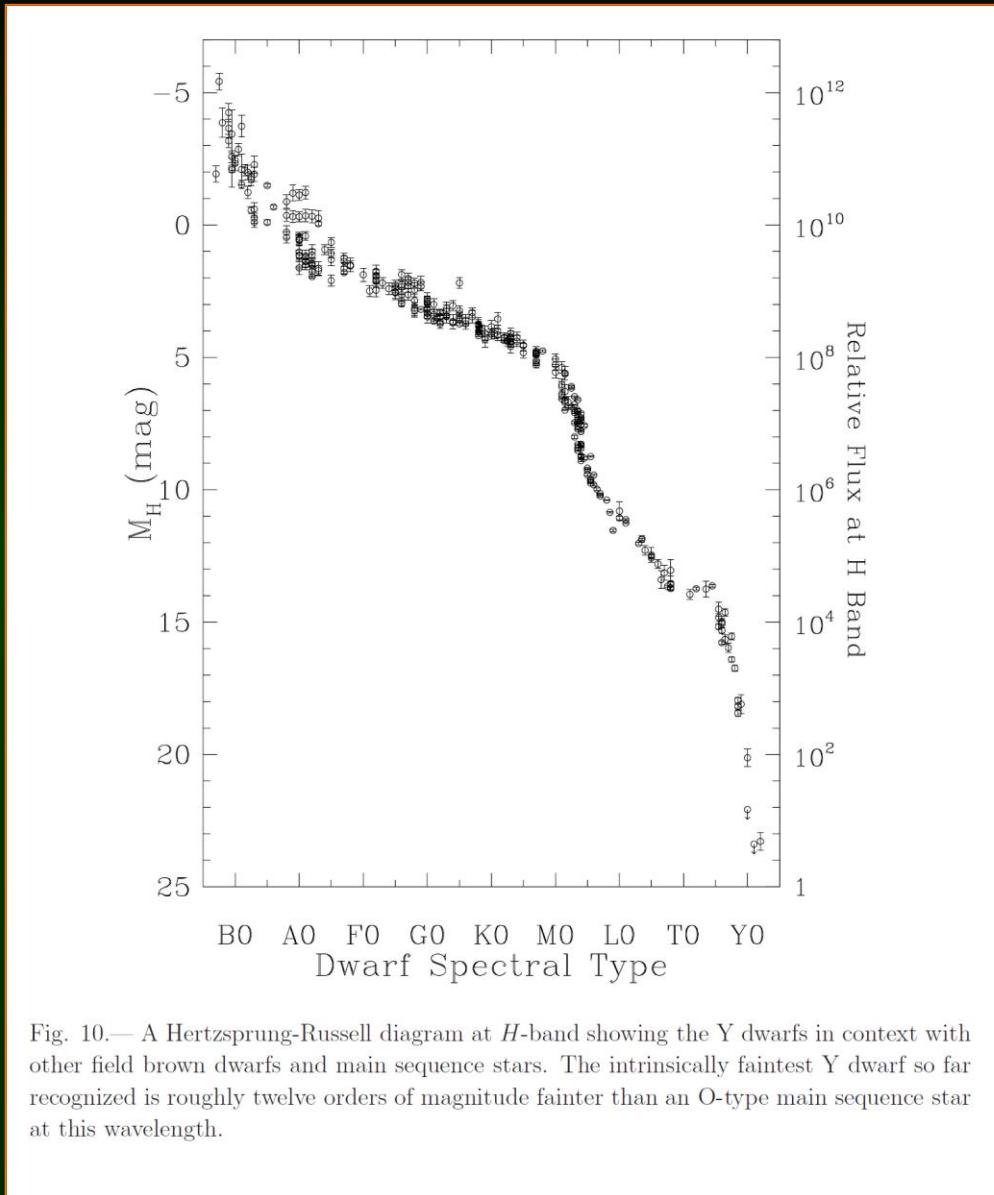


Fig. 10.— A Hertzsprung-Russell diagram at H -band showing the Y dwarfs in context with other field brown dwarfs and main sequence stars. The intrinsically faintest Y dwarf so far recognized is roughly twelve orders of magnitude fainter than an O-type main sequence star at this wavelength.

Multiplicity among solar-type stars

III. Statistical properties of the F7–K binaries with periods up to 10 years*

J. L. Halbwachs¹, M. Mayor², S. Udry², and F. Arenou³

A&A 397, 159–175 (2003)

Clase de lum. V, alrededores del Sol + 2 cúmulos abiertos

170

J. L. Halbwachs et al.: Statistical properties of F7–K binaries

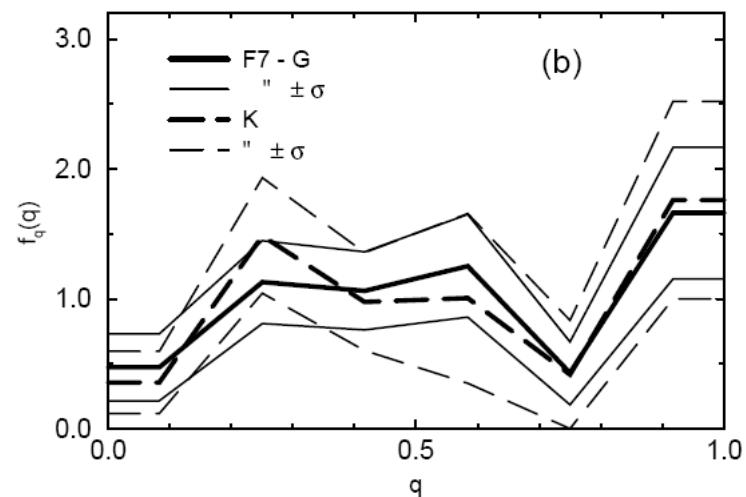
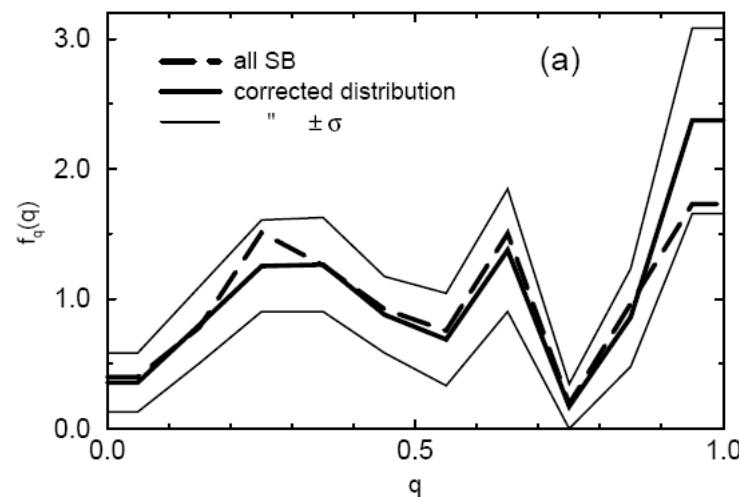
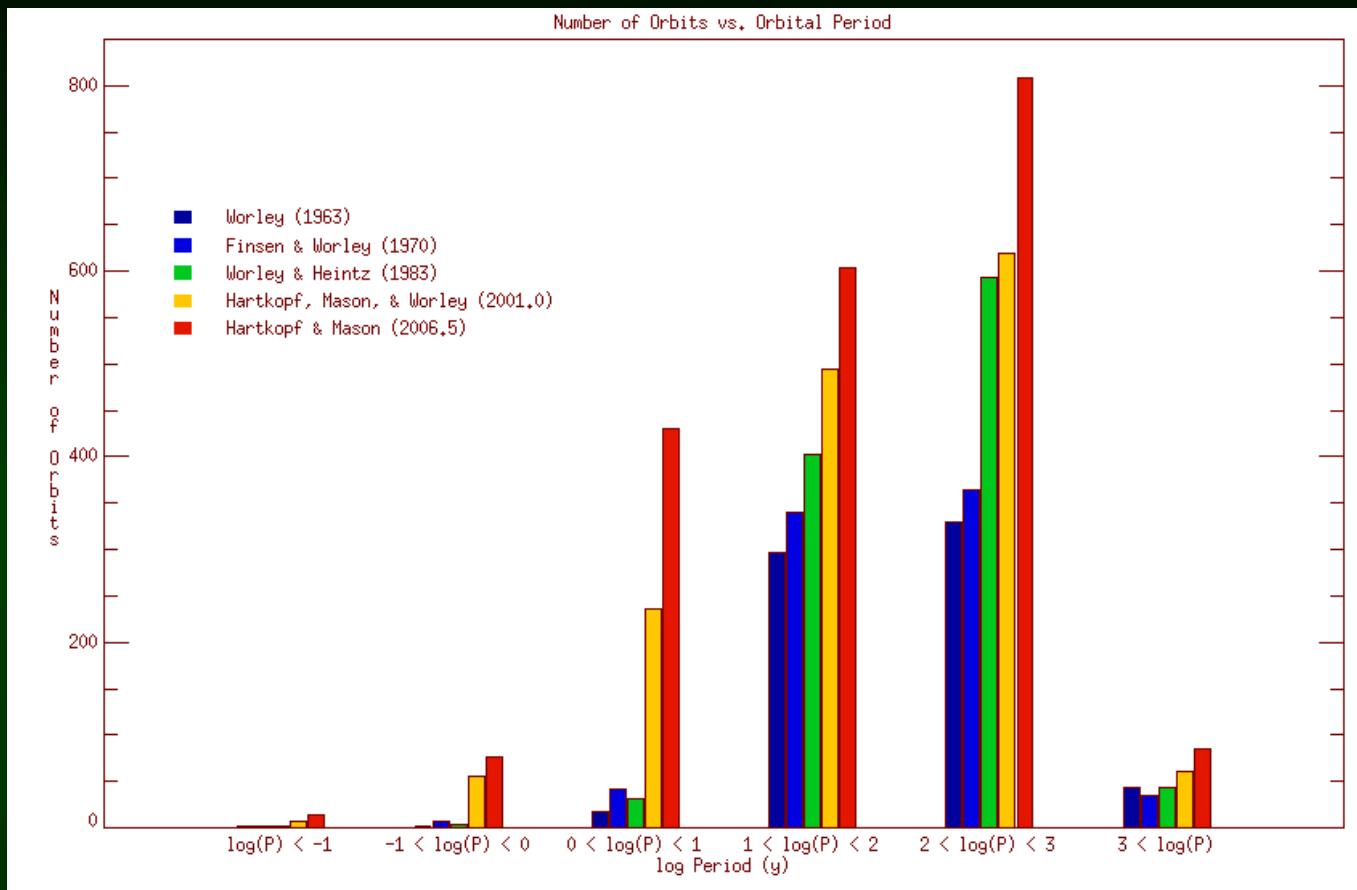


Fig. 7. Distribution of the mass ratios. As in the calculations, the distributions are drawn by joining the centers of the bins; the mass ratios range is divided in 10 equal bins in panel (a), and in 6 bins in the others. **a)** derived from the nearby SB and from the cluster SB with $P < 10$ years; the observed distribution refers to all the SB, without any restriction about the ability to derive their orbital elements with CORAVEL; **b)** the F7–G stars compared to the K-type stars

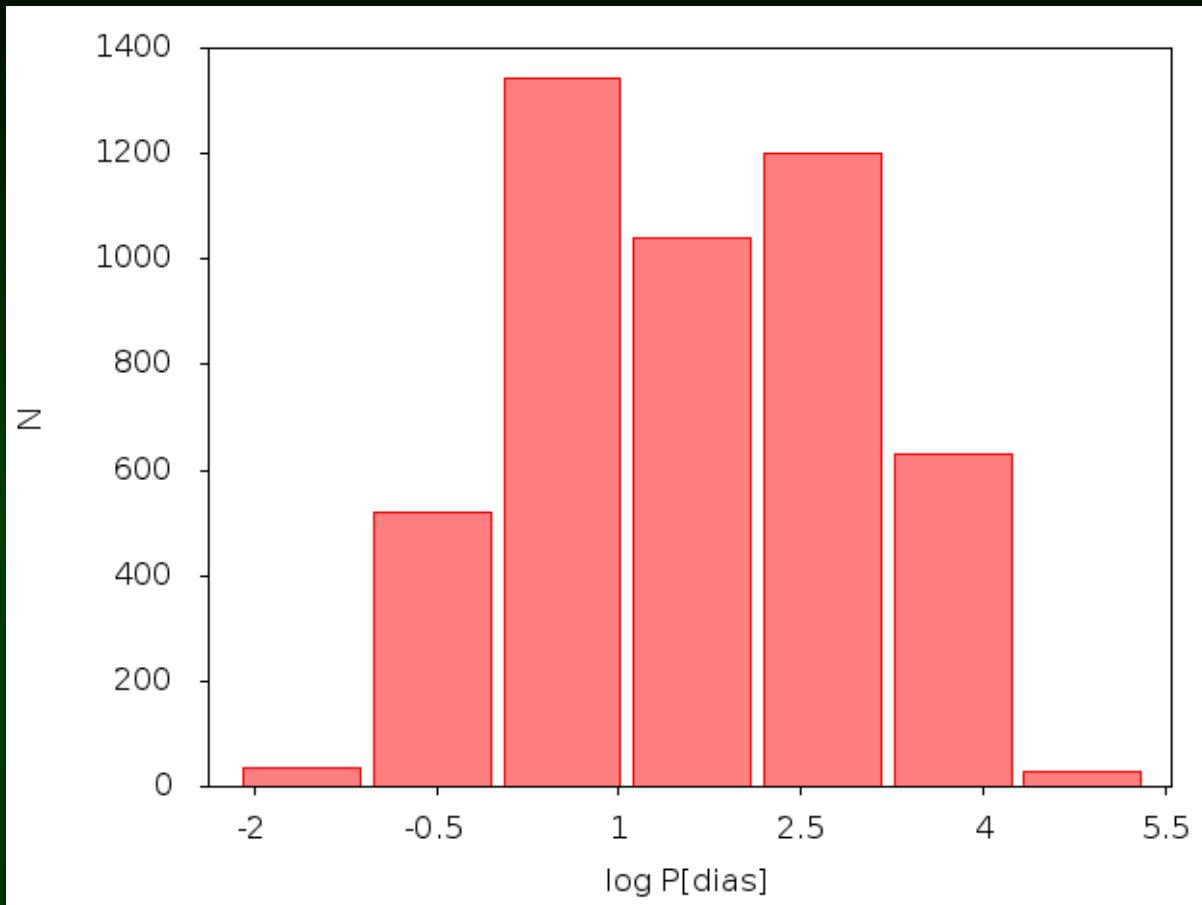
Análisis estadístico de distintos tipos de binarias: Binarias visuales



“Sixth Catalog of Orbits of Visual Binary Stars” / 2800 órbitas

Hartkopf et al. 2006, US Naval Observatory (actualizado constantemente)
<https://ad.usno.navy.mil/wds/orb6.html>

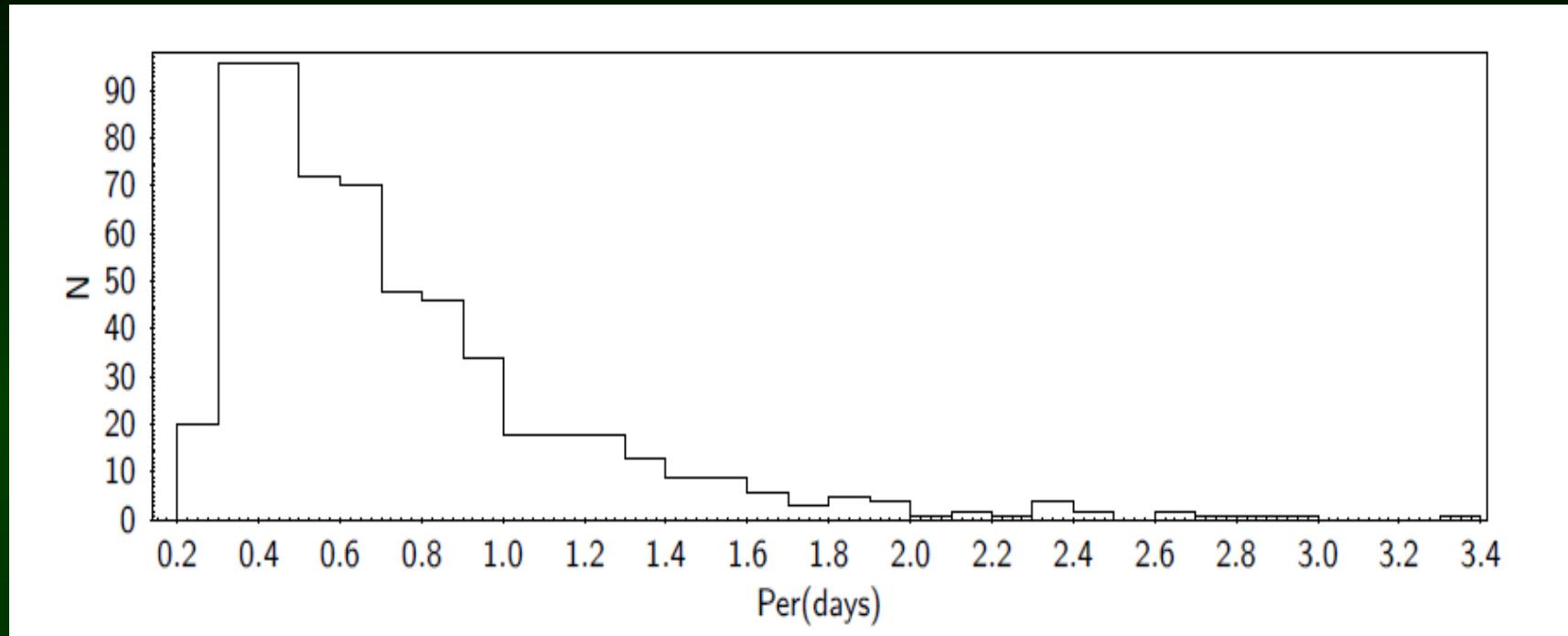
Análisis estadístico de distintos tipos de binarias: Binarias espectroscópicas



“SB9: Ninth catalog of spectroscopic binary orbits” / 4800 órbitas

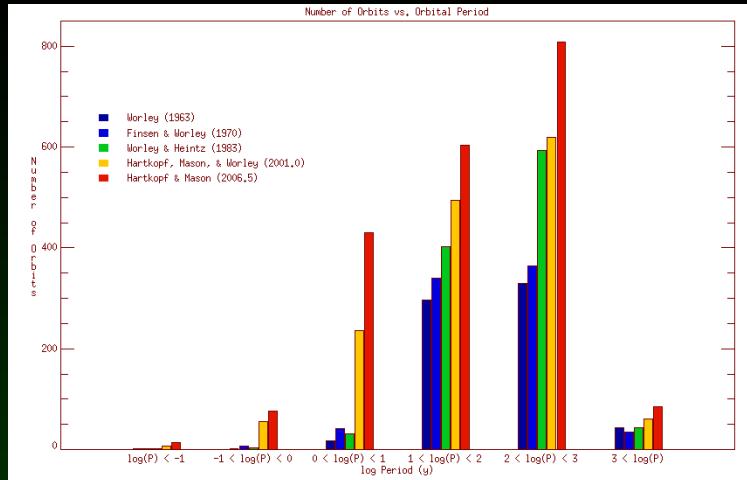
Pourbaix et al. 2004, A&A 424, 727 (actualizado constantemente)
<http://sb9.astro.ulb.ac.be/mainform.cgi>

Análisis estadístico de distintos tipos de binarias: Binarias eclipsantes tipo “Algol”

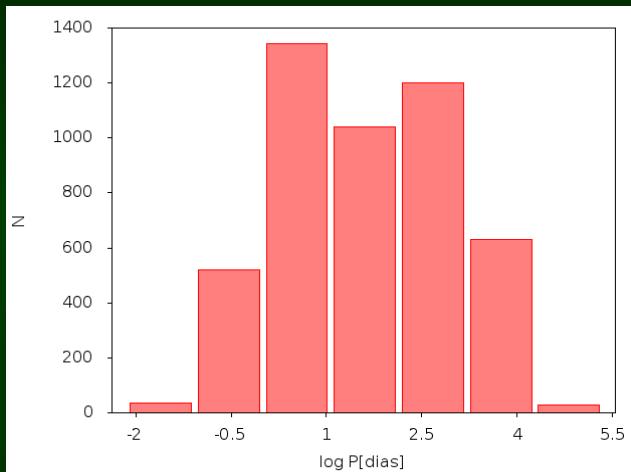


“Updated catalog of 4680 northern eclipsing binaries (EBs)
with Algol-type light-curve”

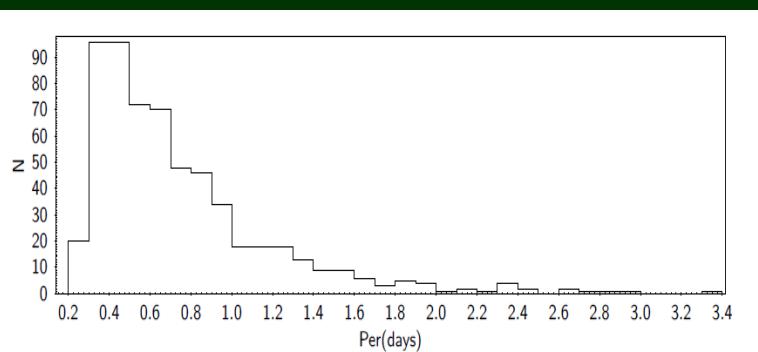
Papageorgiou et al. 2018, ApJS, 238, #4



$\log P$ [años] Binarias visuales

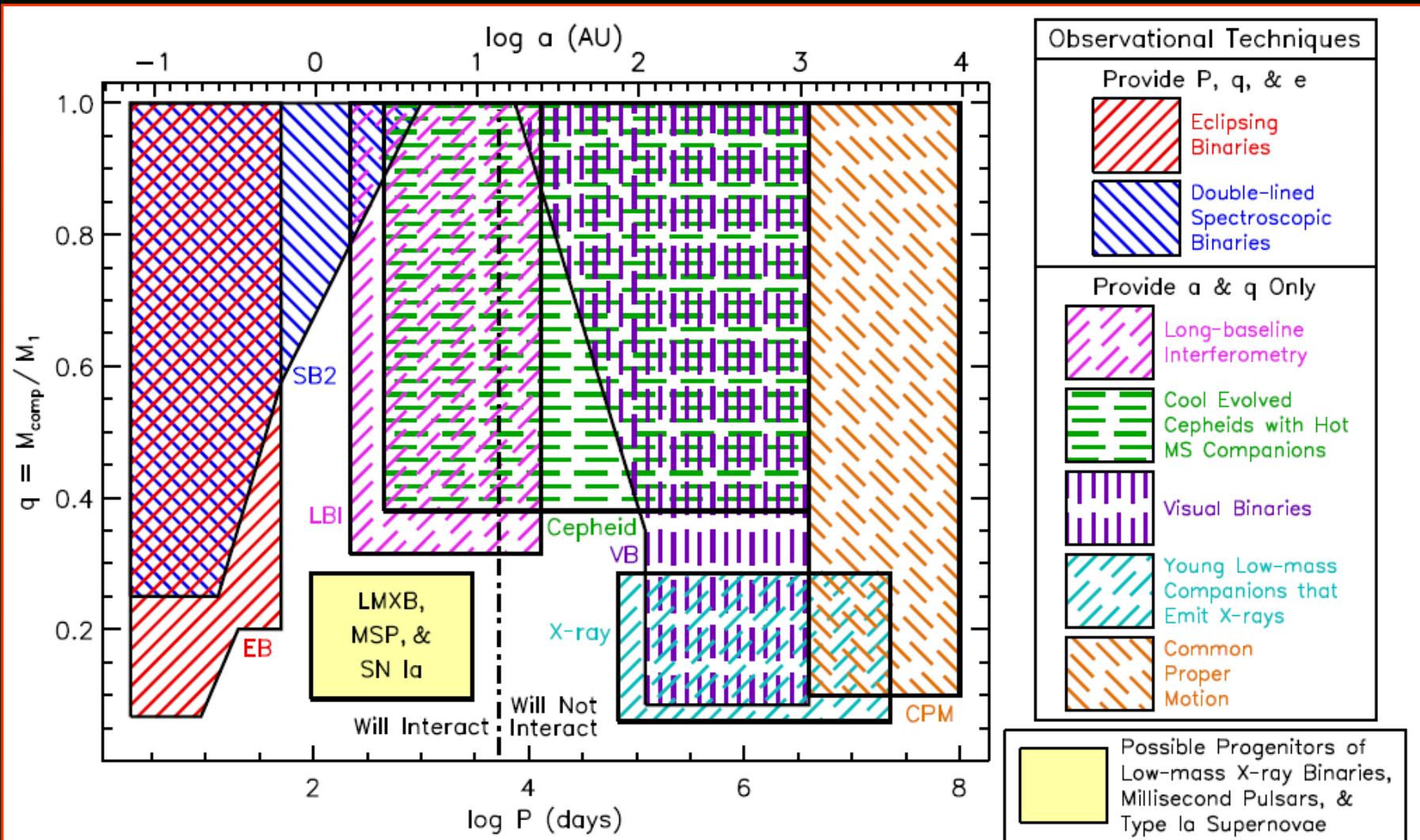


$\log P$ [días] Binarias espectroscópicas



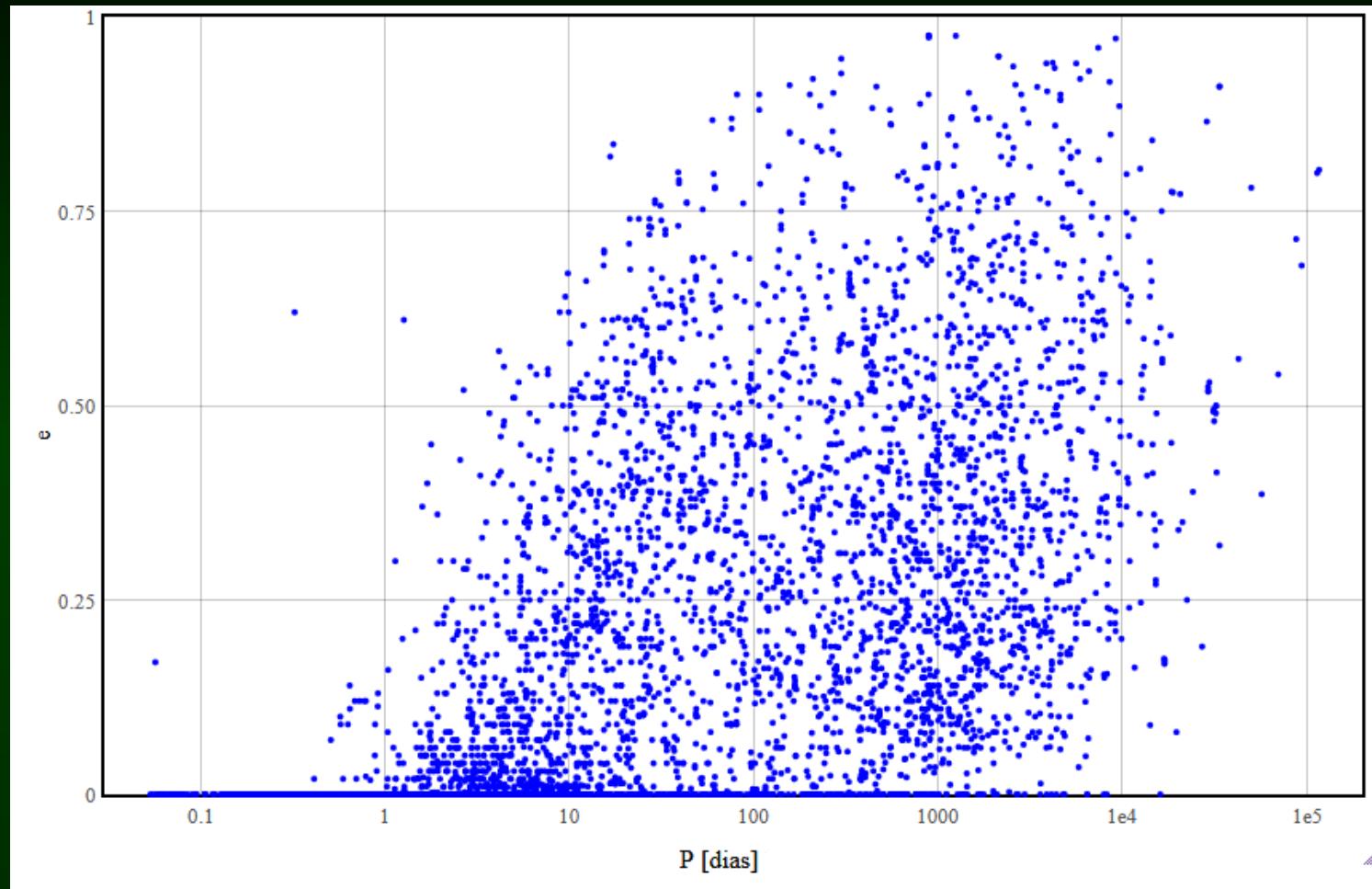
P [días] Binarias eclipsantes tipo “Algol”

Análisis estadístico de binarias con primaria tipo O,B V: log período P vs. cociente de masas q



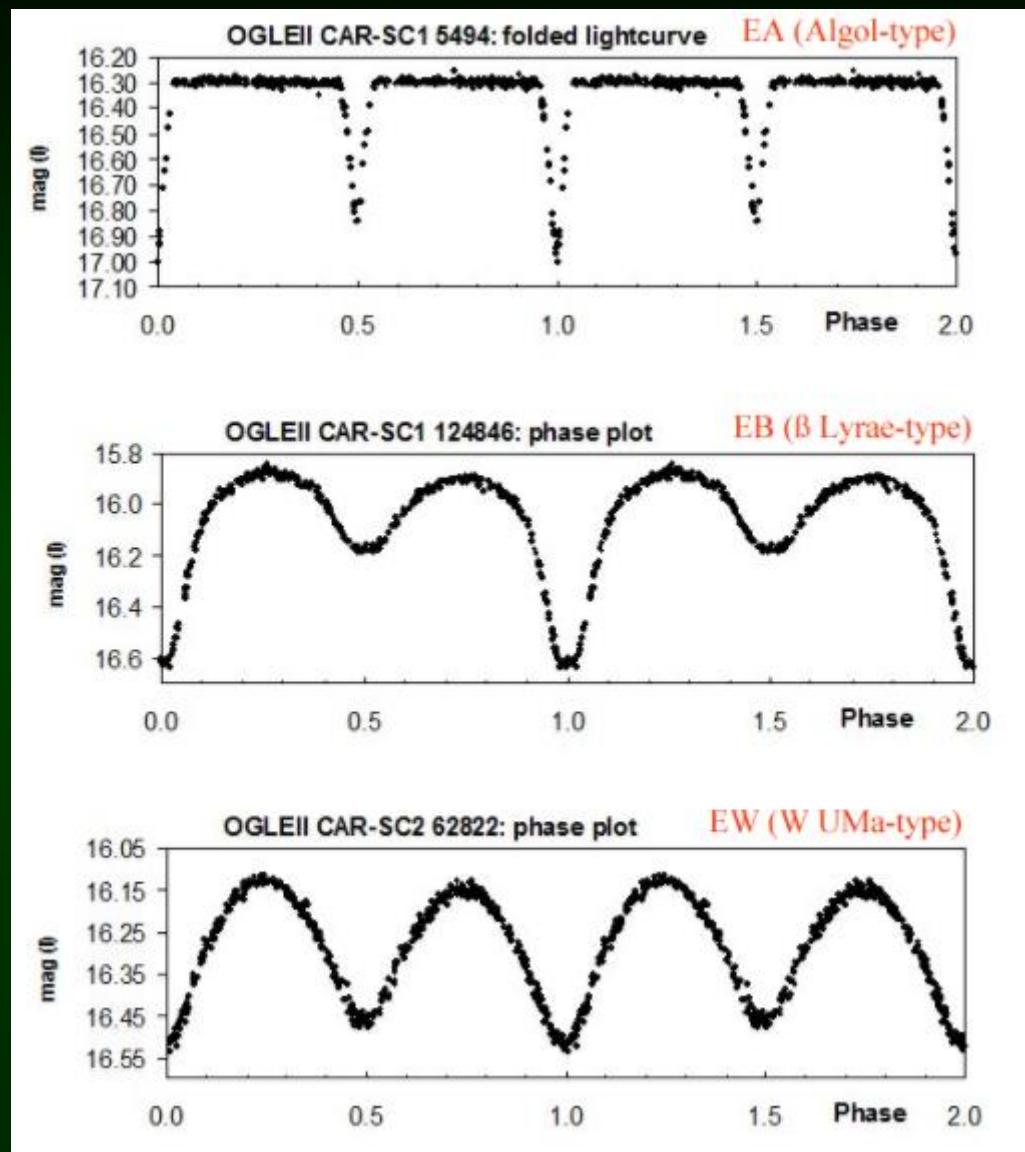
Moe & Di Stefano 2017,
ApJS 230, 15

Análisis estadístico de distintos tipos de binarias: Binarias espectroscópicas, 4800 observ.



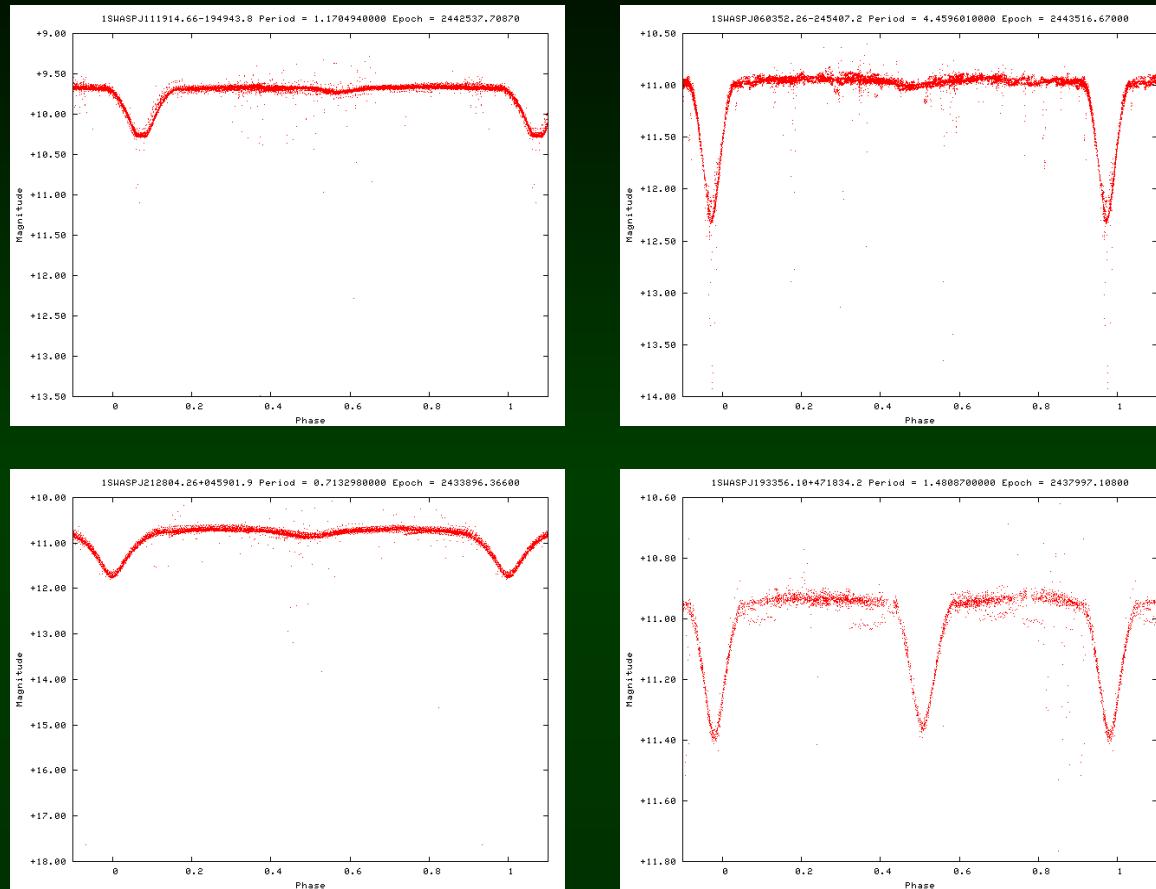
“SB9: The ninth catalogue of spectroscopic binary orbits”,
Pourbaix et al. 2004, A&A 424, 727 / actualizado constantemente

Clasificación de Binarias Eclipsantes según la forma de sus curvas de luz



Hümmerich et al. 2013
Variable Stars Observer Bulletin

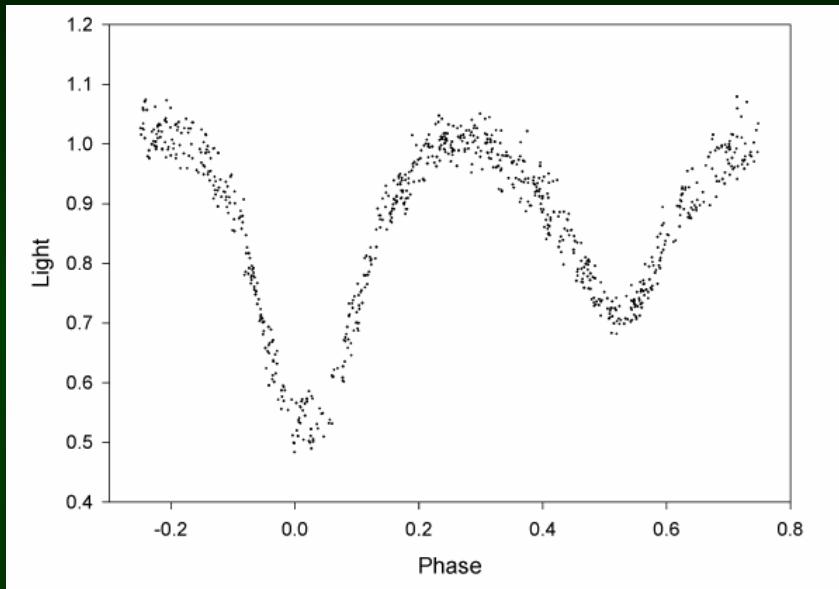
Curvas de luz tipo Algol (EA)



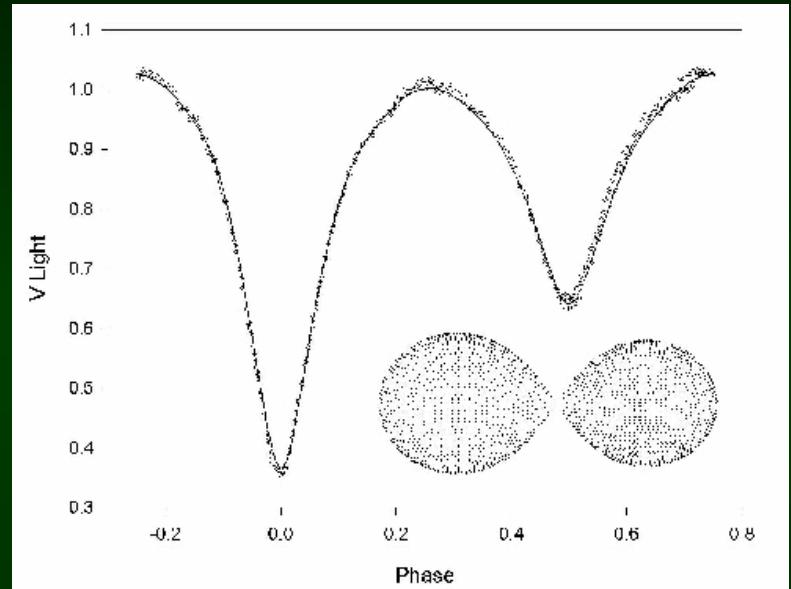
Super WASP Observations of Variable Stars
(WASP: Wide Angle Search for Planets)

Curvas de luz tipo β Lyrae (EB)

β Lyrae

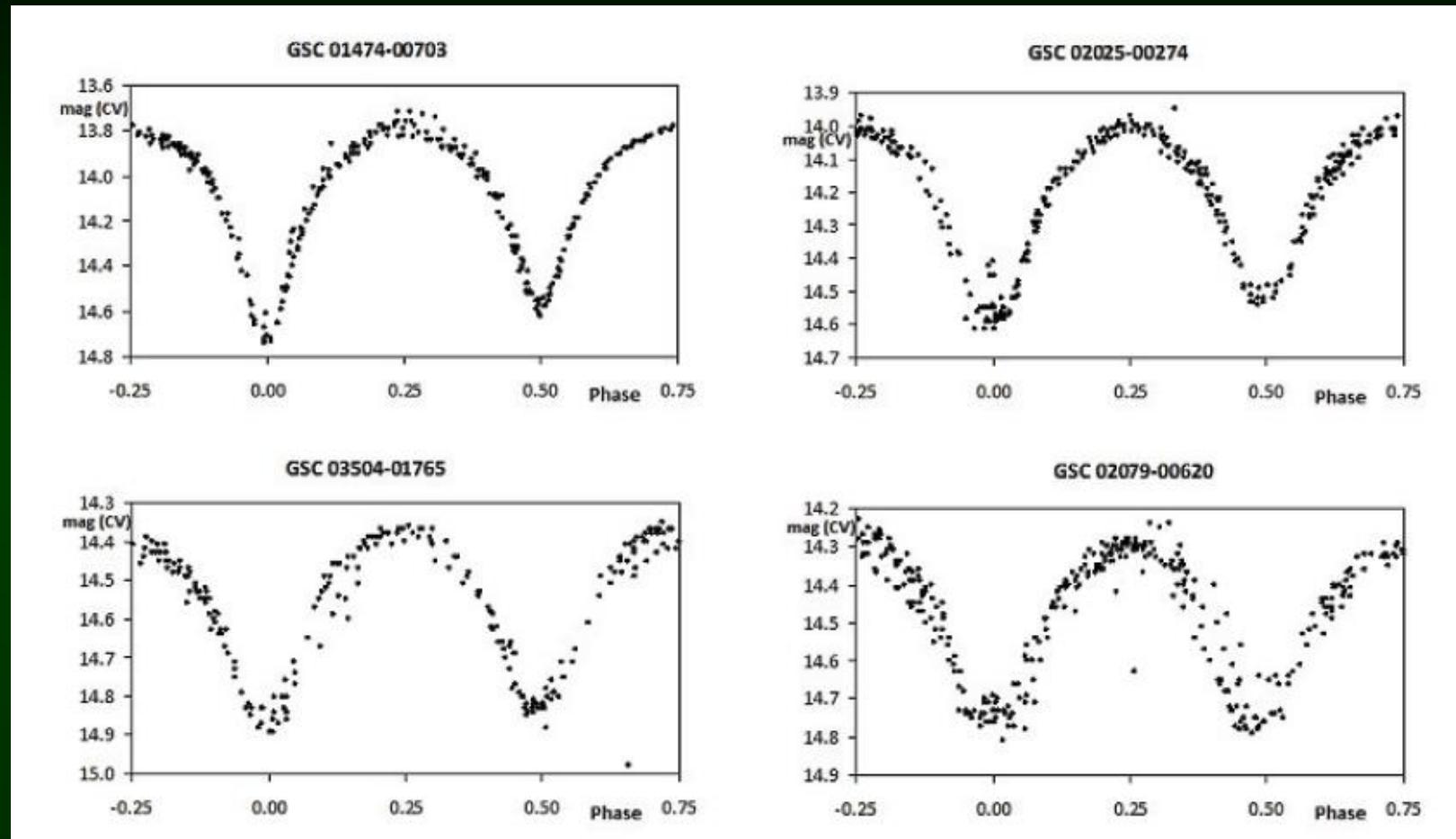


GSC 1534:0753



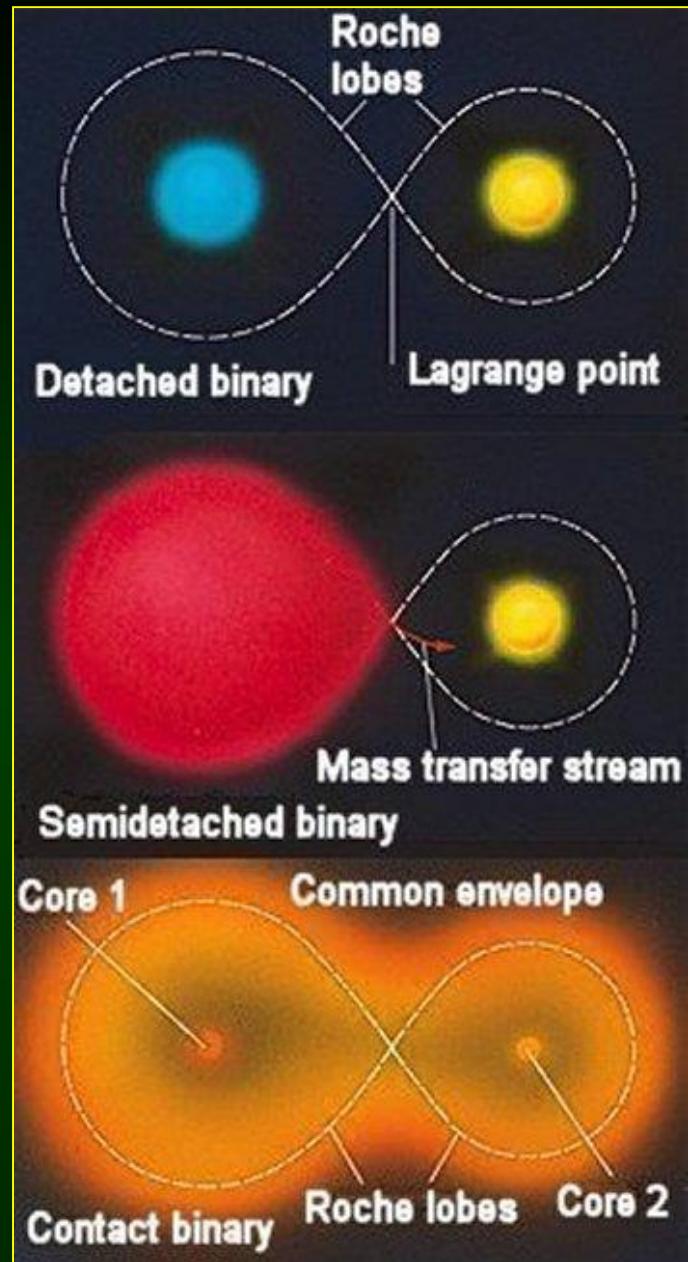
Dirk Terrell
Southwest Research Institute

Curvas de luz tipo W UMa (EW)



Hümmerich et al. 2013
Variable Stars Observer Bulletin

Clasificación de Binarias Cercanas



Ej. de evolución de un sistema binario con transferencia de masa

“Astrophysics I”, Bowers & Deeming

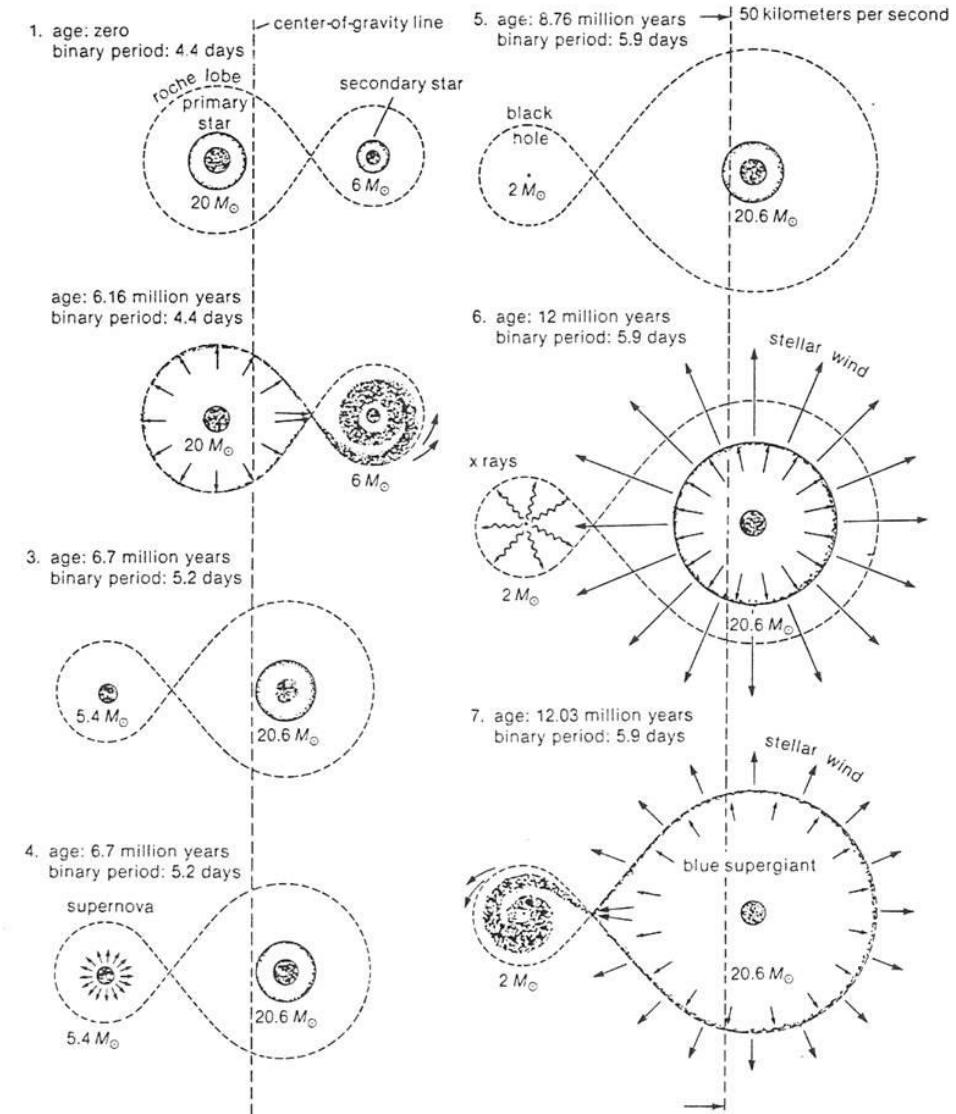


Figure 17.11. Evolution of a binary system containing a blue supergiant and a black hole.