Francesco Palla
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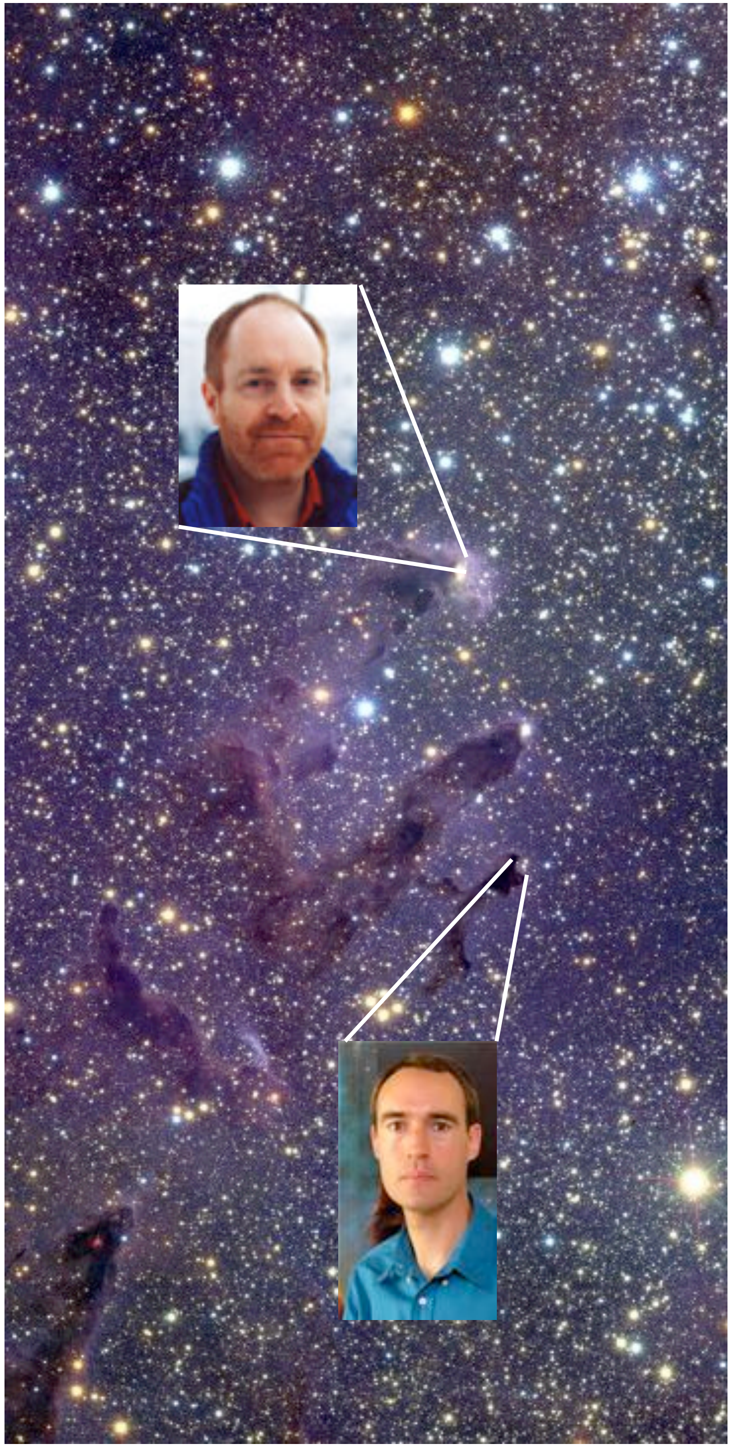


CONSTELLATION Dec 2006-Nov 2010
13 Institutes – 7 Countries

WP1
From Clouds to Cores to Protostars

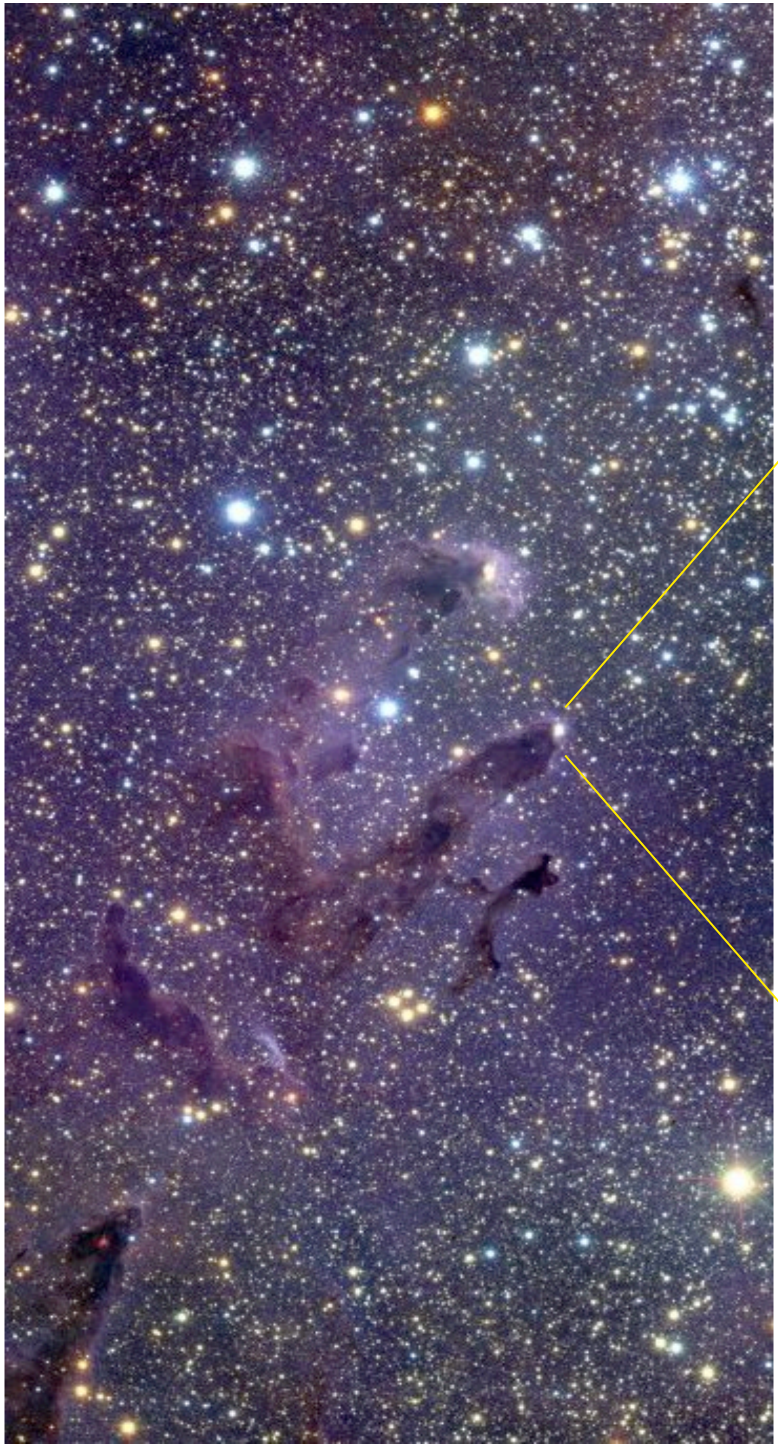
WP2
The Birth and Influence of Massive Stars

WP3
The Physics of the Low-Mass End of IMF

21 Young Researchers: 12 PhD – 9 Postdocs

22 collaborative papers in Yr1
58 collaborative papers in Yr 2
48 collaborative papers in Yr 3

….many thanks to



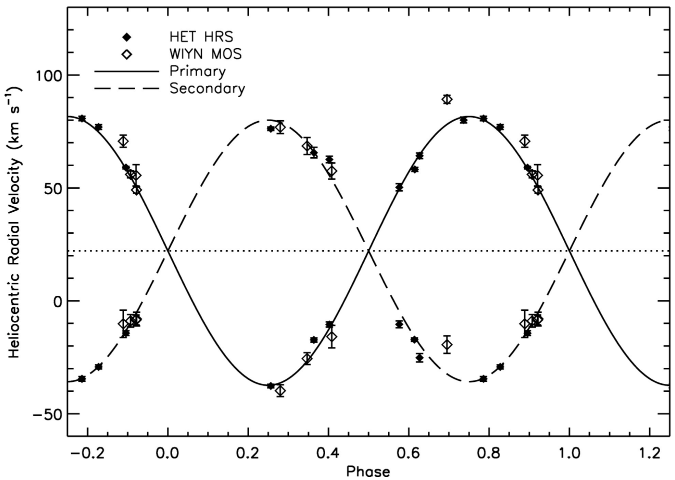
Exeter, July 2007 kickoff

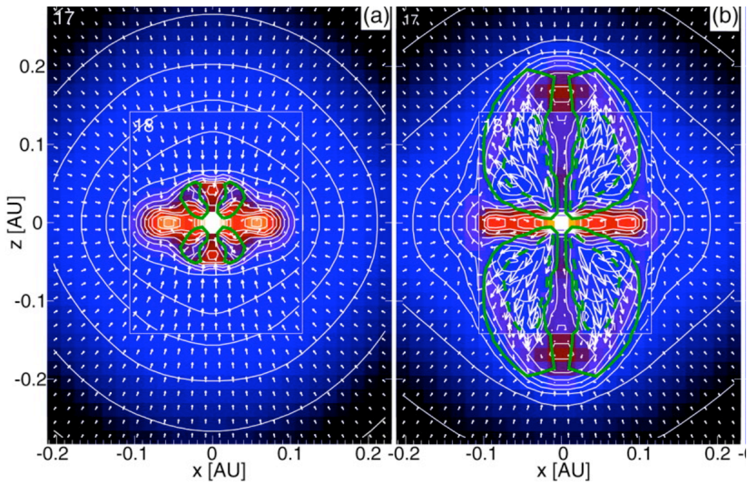
- ***Stellar mass, and to a lesser extent chemical composition, determines the entire stellar evolution.***
- ***Direct and unbiased mass estimates are of fundamental importance.***

From low- to high-mass stars:

- *Low-mass eclipsing binaries*

Initial conditions: Class 0-I





Dynamical mass measurements of PMS stars

- *One of the most precise (<2%) and accurate method for measurement of fundamental stellar parameters*

- *Most known PMS EBS are in the Orion sub-associations:*

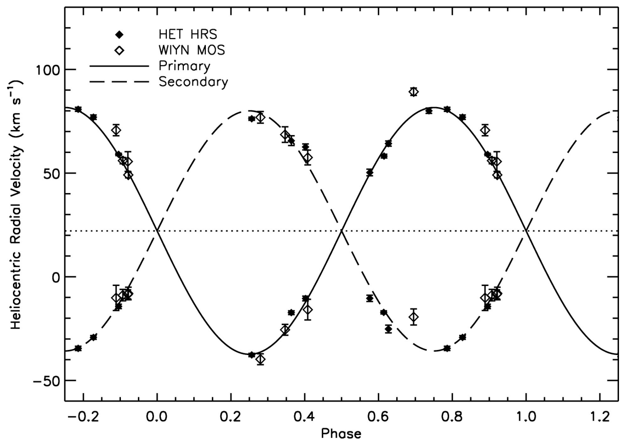
ASAS J05	*1.38 –1.33* M_0	*in Ori Ia*
RXJ 0529	*1.27 – 0.93* M_0	*in Ori Ia*
V1174 Ori	*1.0 – 0.7* M_0	*in Ori Ic*
Par 1802	*0.41 – 0.41* M_0	*in Ori Id*
JW380	*0.26 – 0.15* M_0	*in Ori Id*
2MASS J05	*0.05 – 0.03* M_0	*in Ori Id*

- *A clock for the ages of the subgroups… yet TBD*

DISCOVERY OF PAR 1802 AS A LOW-MASS, PRE-MAIN-SEQUENCE ECLIPSING BINARY IN THE ORION STAR-FORMING REGION

P. A. Cargile,[1] K. G. Stassun,[1] and R. D. Mathieu[2]

Received 2007 June 2; accepted 2007 September 20



Located 8xRcluster – Memb=98% - P=4.67 d

V_{rad} =22±1 km/s (vs 25±2 km/s) – large Li_{EW}

$M_P = 0.40 \pm 0.03\ M_0$ - $M_s = 0.39 \pm 0.03\ M_0$

$R_{P,S} = 1.75\ R_0$ → large radius … young (as ONC)

Youngest equal-mass eclipsing binary so far

Stassun etal 2008 Nature:

Improved solution: q=0.98 ± 0.01 → $M_{P,S} = 0.41 \pm 0.01\ M_0$

$R_P = 1.82 \pm 0.02\ R_0$ - $R_S = 1.69 \pm 0.05\ R_0$

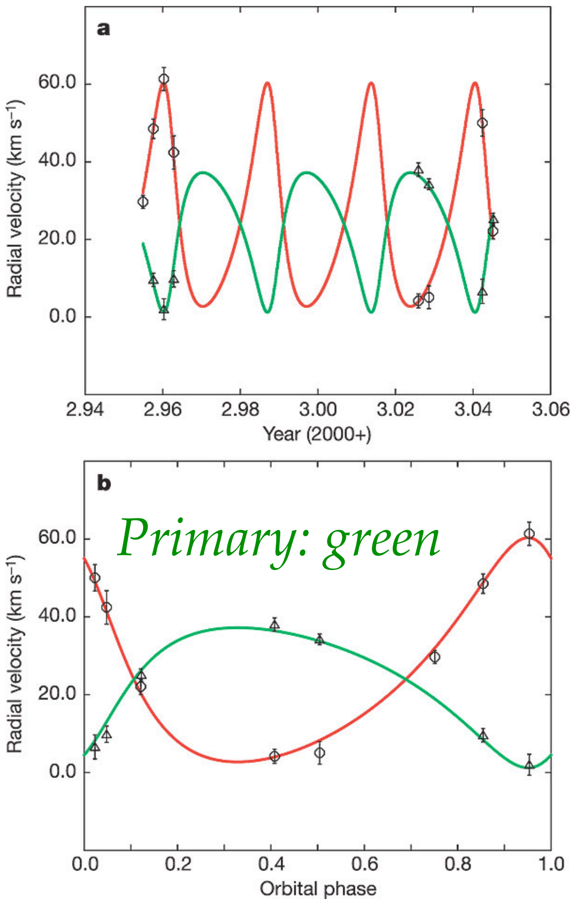
L and Teff → comparison in the HRD…TBD

Discovery of two young brown dwarfs in an eclipsing binary system …in the Orion nebula

2 MASS J0535-0546

Keivan G. Stassun[1], Robert D. Mathieu[2] & Jeff A. Valenti[3]

***Nature* 2006..2008,2009**



Radial velocity & Orbit solution

$M_P = 0.0541 \pm 0.0046\ M_0$
$R_P = 0.669 \pm 0.034\ R_0$

$M_s = 0.0340 \pm 0.0027\ M_0$
$R_s = 0.511 \pm 0.026\ R_0$

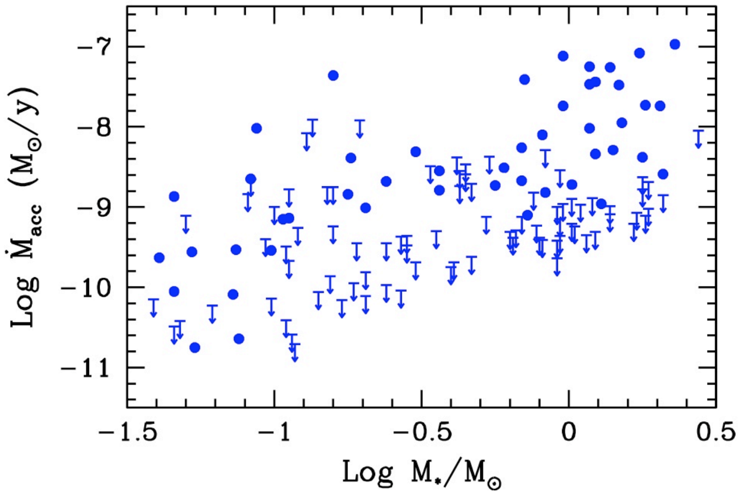
First time direct radii!

Relative depth of eclise: T_2/T_1=1.05 → Secondary is hotter … not expected!

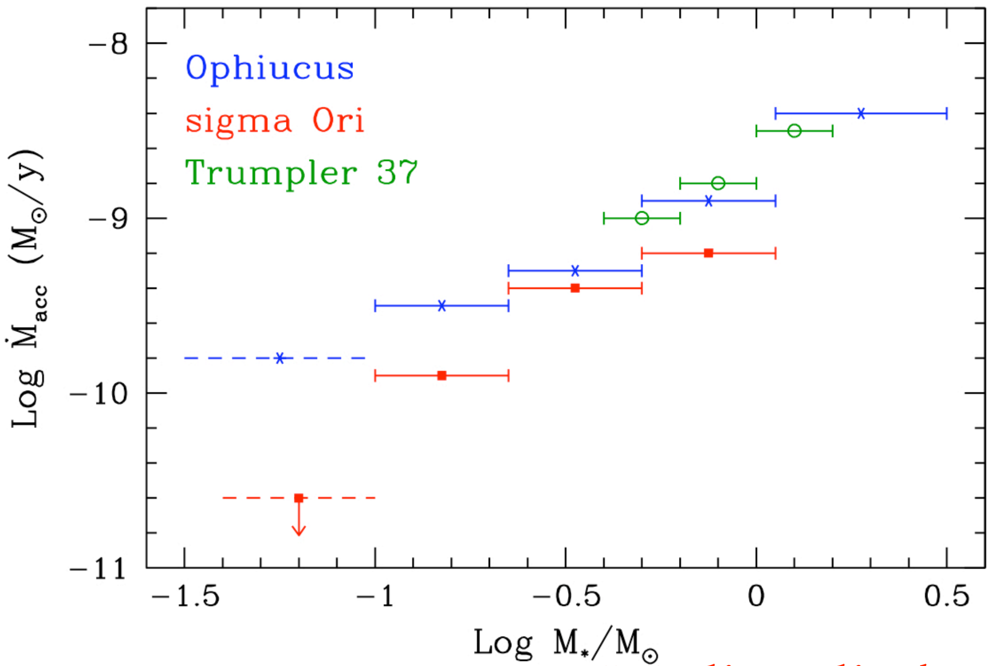
At t~1 Myr, BDs are 500% larger and ~1500 K warmer than older BDs

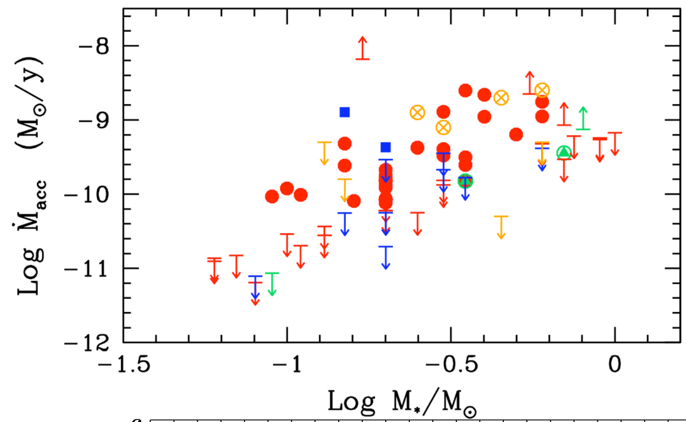
→ BD begin life in a star-like state…

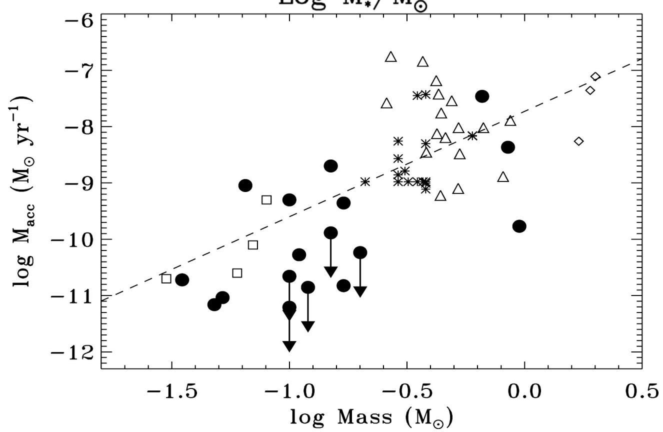
Mass accretion vs Stellar Mass



$M_{acc} \sim M_*^{\alpha}$, $\alpha \sim 2$







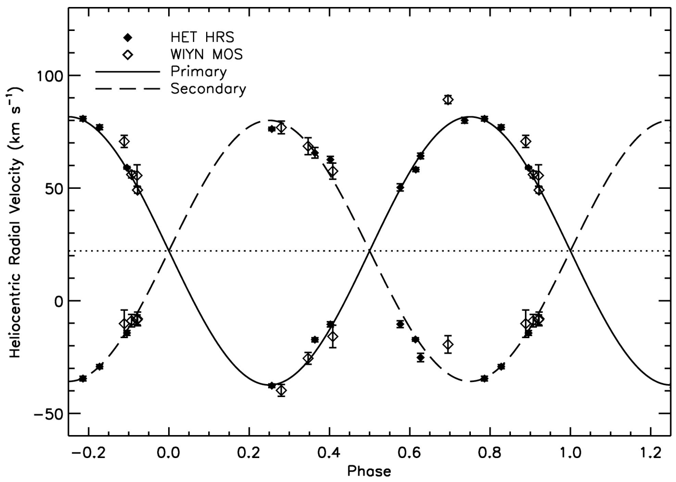
Median dist'n
H α 10% width

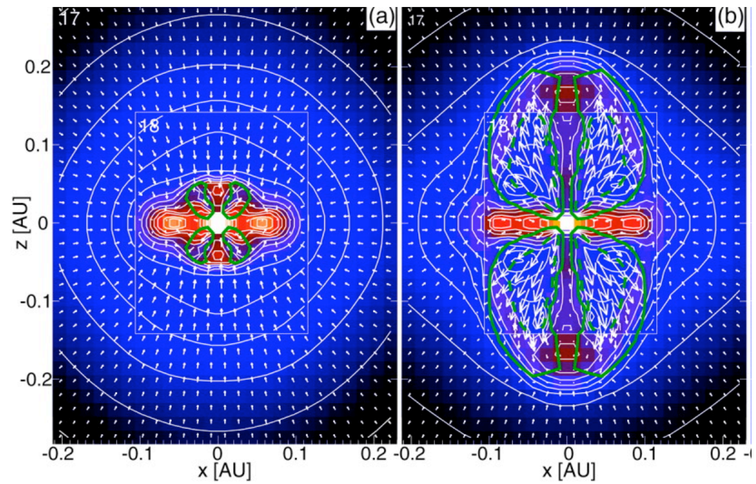
Rigliaco+ 2010

From low- to high-mass stars:

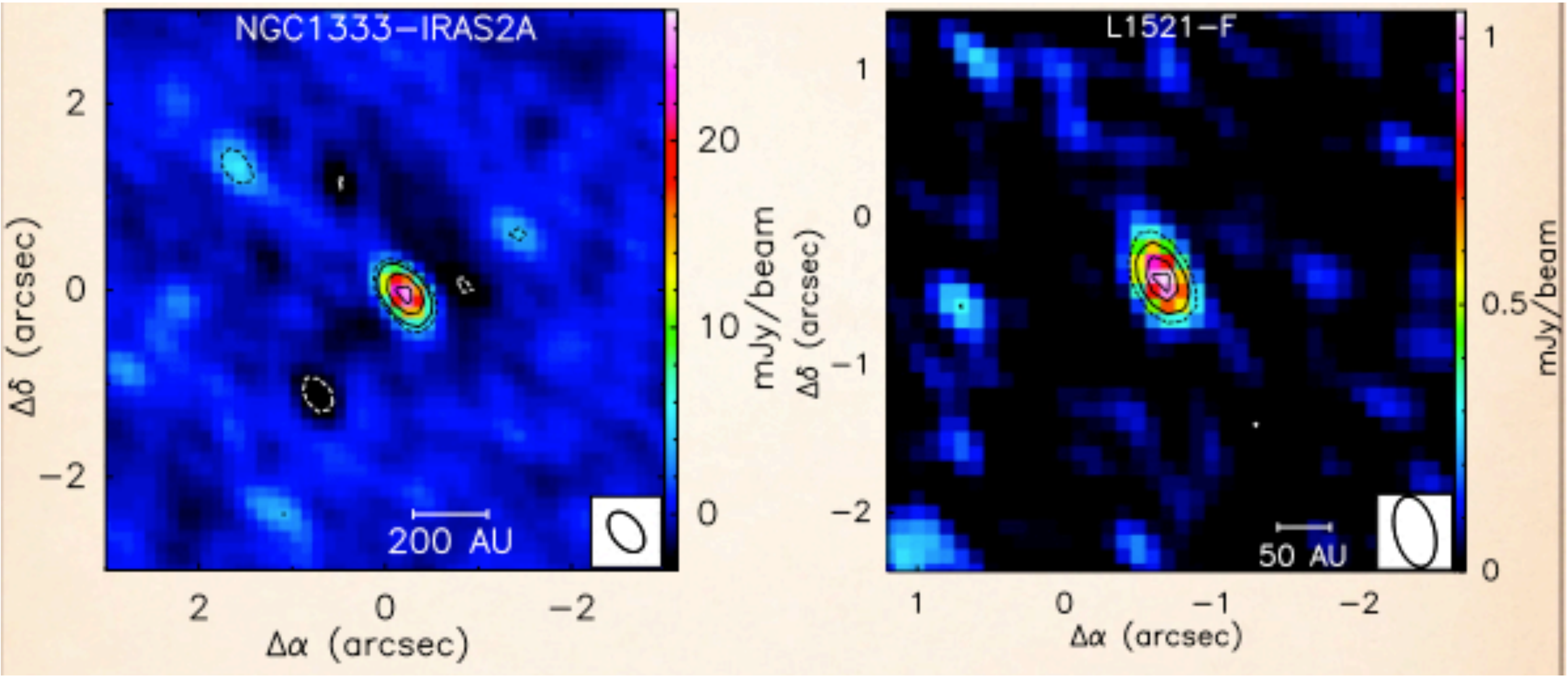
Low-mass eclipsing binaries

- *Initial conditions: Class 0-I*





High resolution 1.3 mm continuum maps: Class 0 sources are single & compact



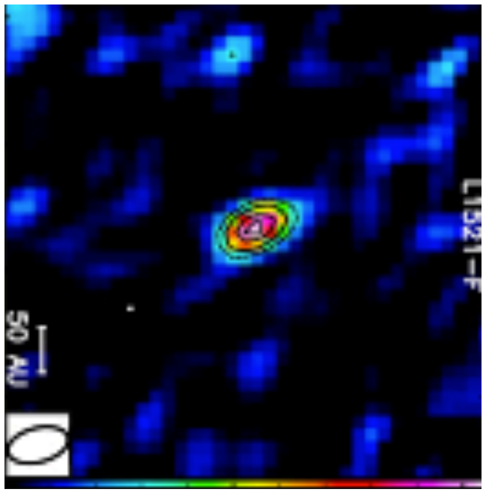
Maury+ 10

Predictions of magnetized protostellar collapse

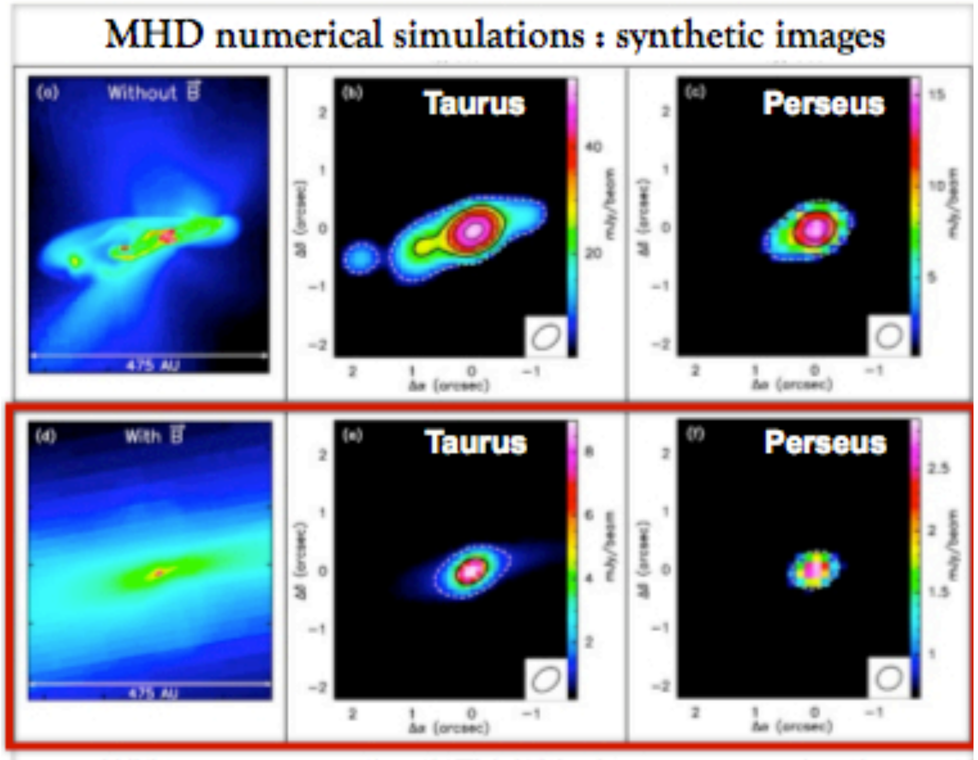
Suppression of

- *large scale rotating structures → mini-disks*
- *fragmentation at small scales (50-100 AU)*

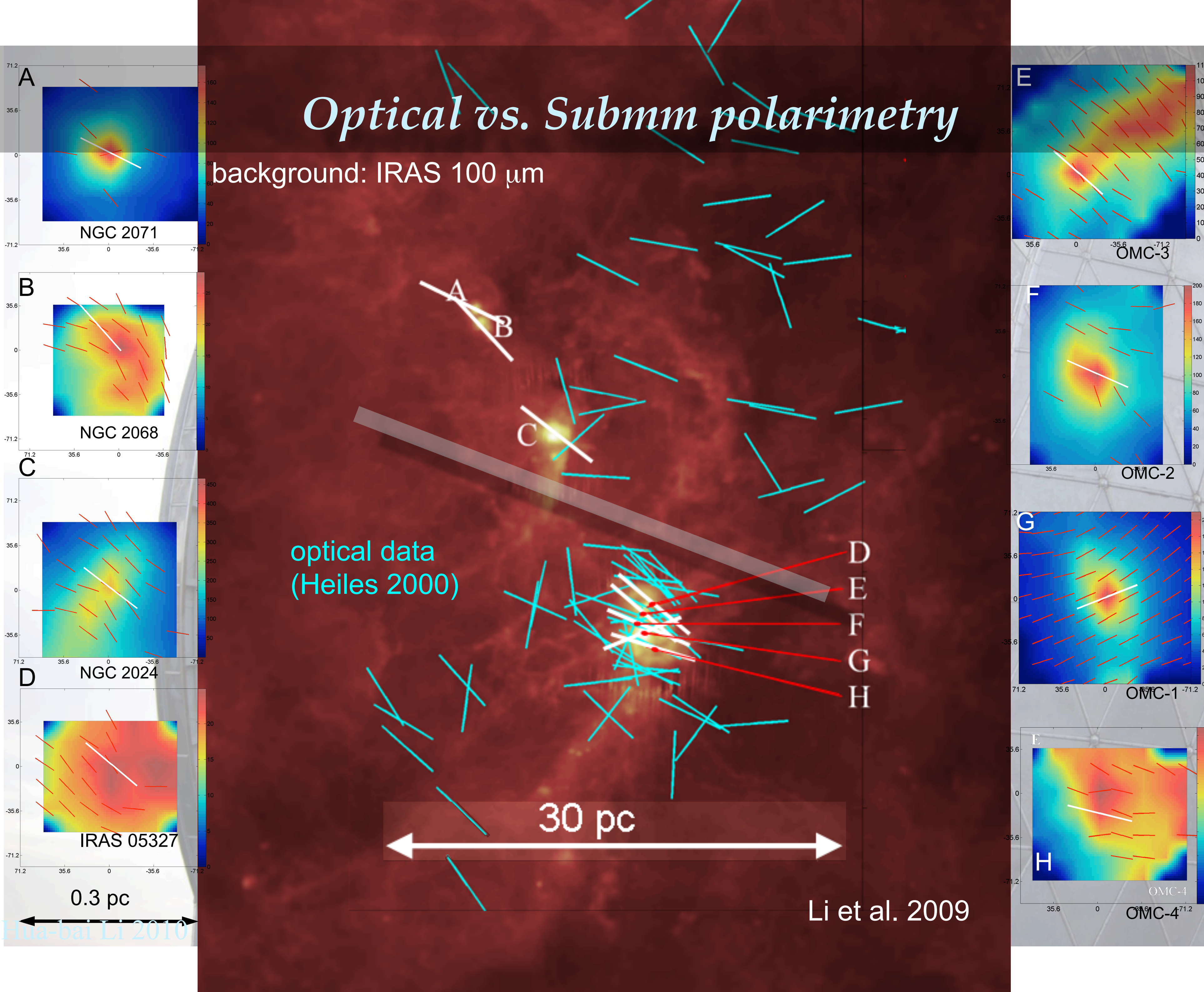
Comparison with MHD theory (Galli+) & models (Machida; Hennebelle+)
typical FWHM~0.2-0.6"



L1521-F – PdBA



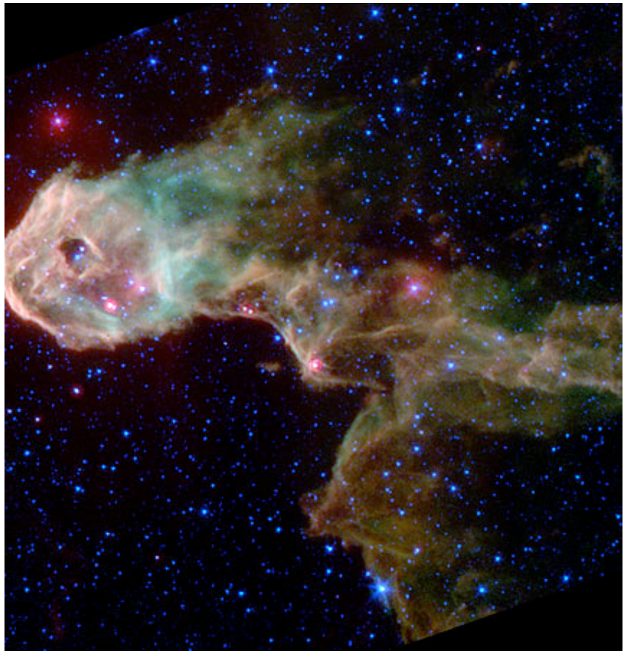
Optical vs. Submm polarimetry



From low- to high-mass stars:

Intermediate-mass Eclipsing Binaries

Pulsating Herbig Ae stars



• Inte lity
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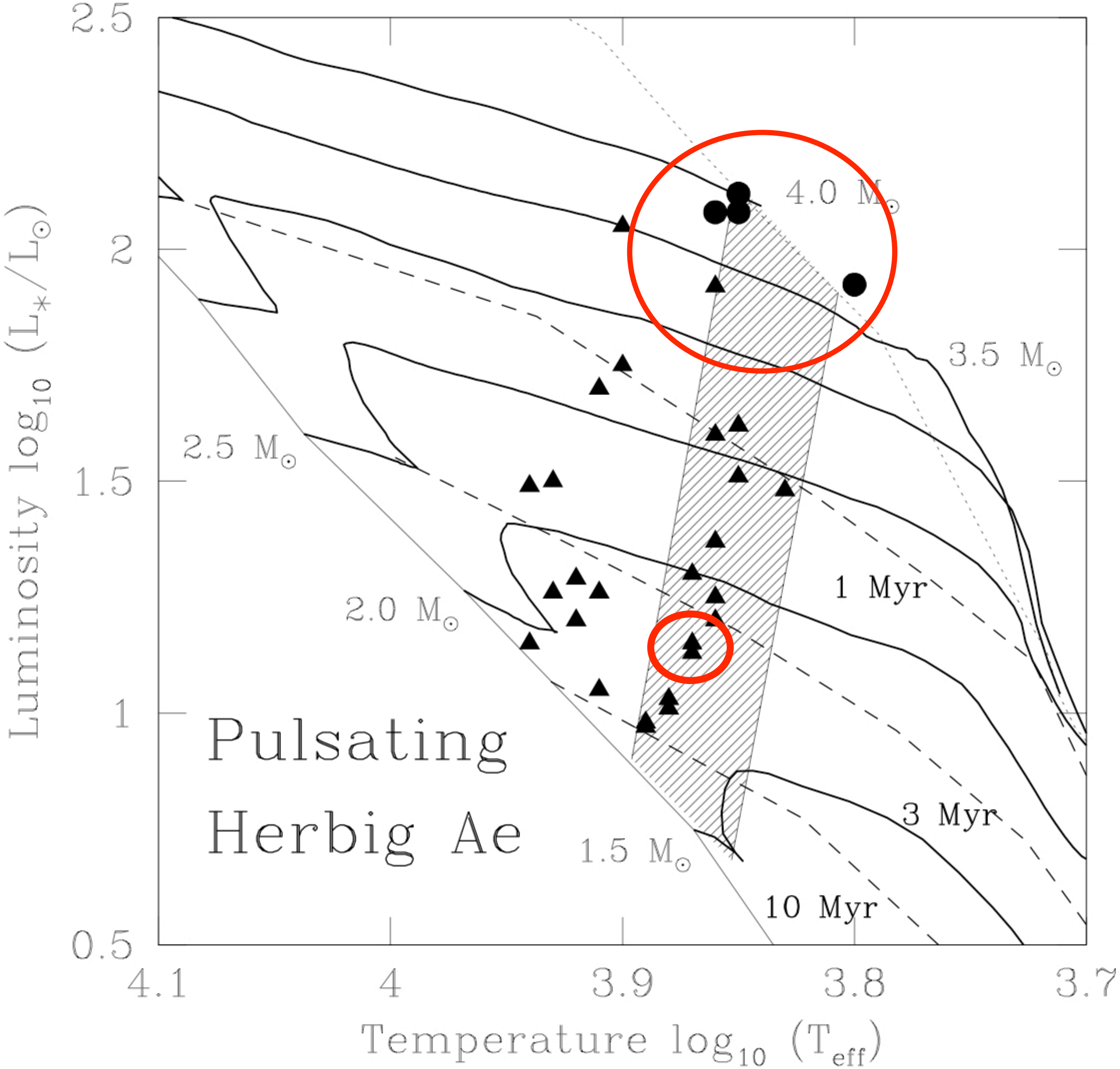
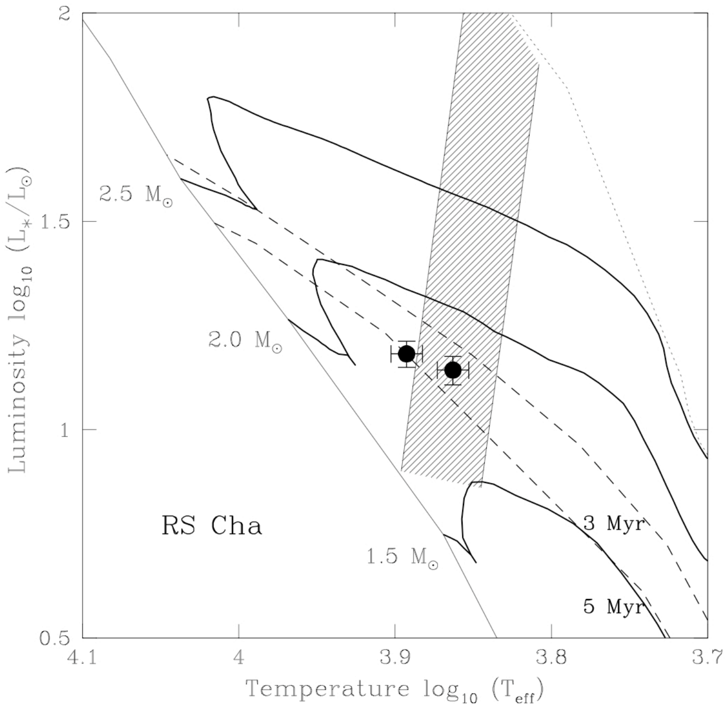
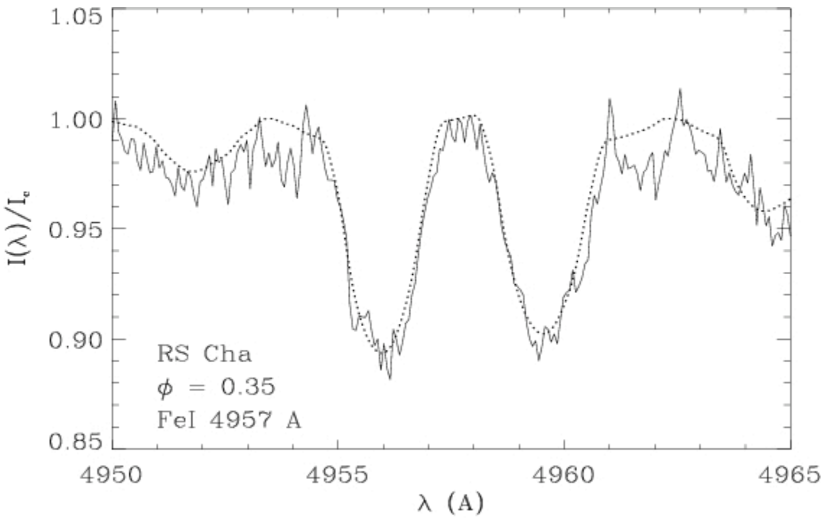


RS Cha: eclipsing, double-lined spectroscopic binary





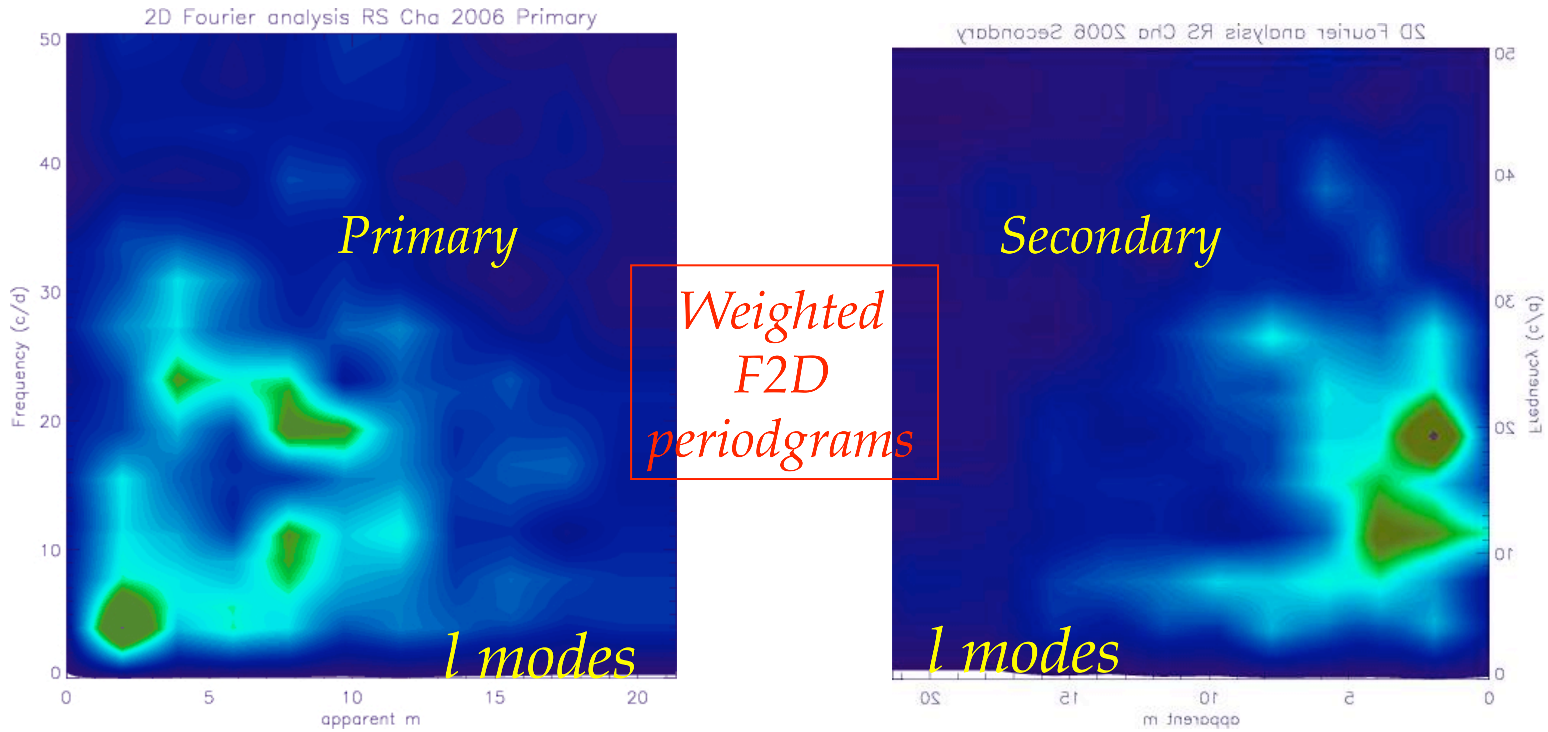
M_P=1.858±0.016 M_0
M_S=1.821±0.018 M_0 ; q=1.02

M(P,S)=1.88,1.80 M_0 ; q=1.04
t(P,S)=5.0,4.3 Myr

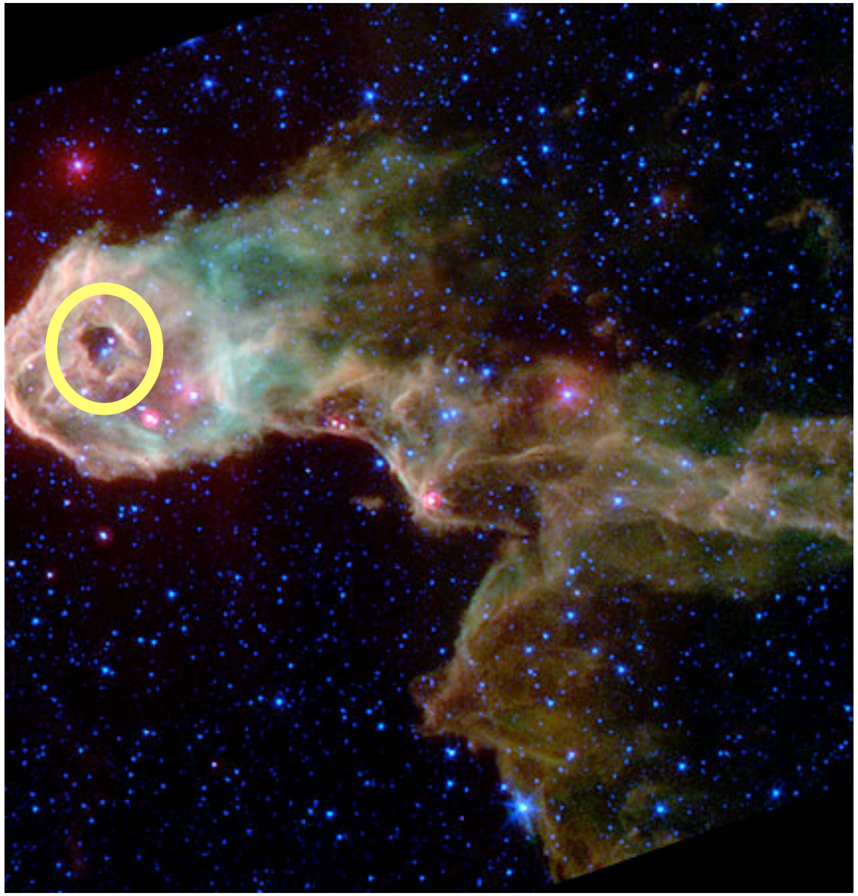
Spectrally resolved observations
Pulsation: ~1 hr → δ Sct-type
Alecian+ 05,07

Discovery of non-radial pulsations in both components of RS Cha (Boehm+ 2009)

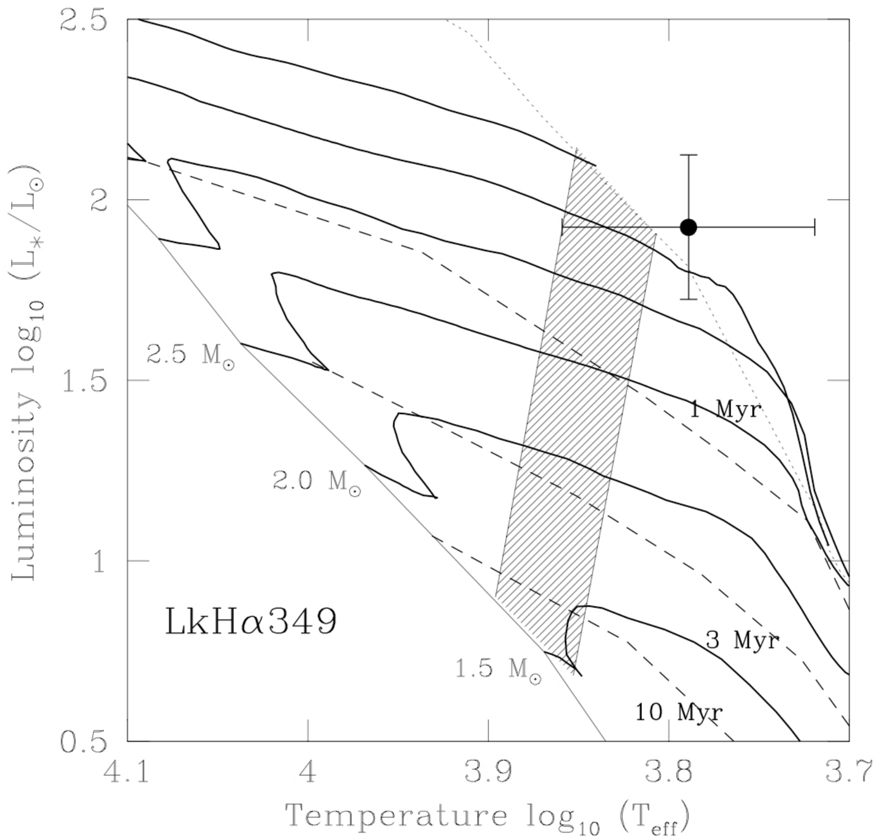
- *High resolution echelle spectroscopy – 14 nights*
- *Primary: f=21.1 d^{-1} - 2 puls. freq. → dominant mode: l=10 or 11*
- *Secondary: f=30.4 d^{-1} - 3 puls. freq. → dominant mode: l=0,1 or 2*
- *Future: numerical models to constrain internal structure…*

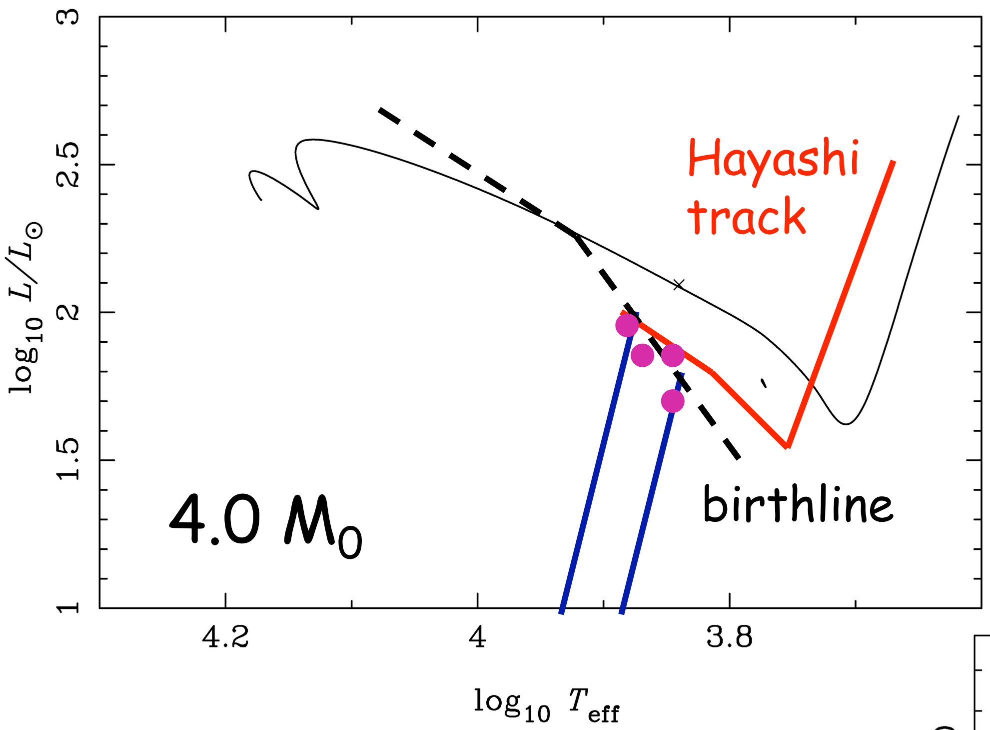


The youngest Herbig Ae: LkHa 349 in IC1396

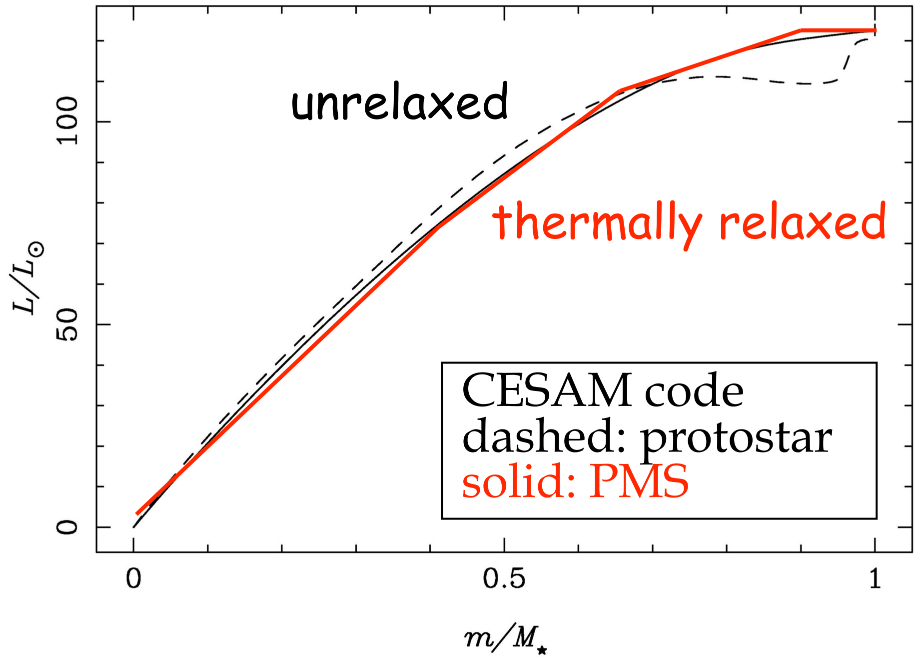


Spitzer: Reach et al. 2009





Initial Conditions: Hayashi vs birthline

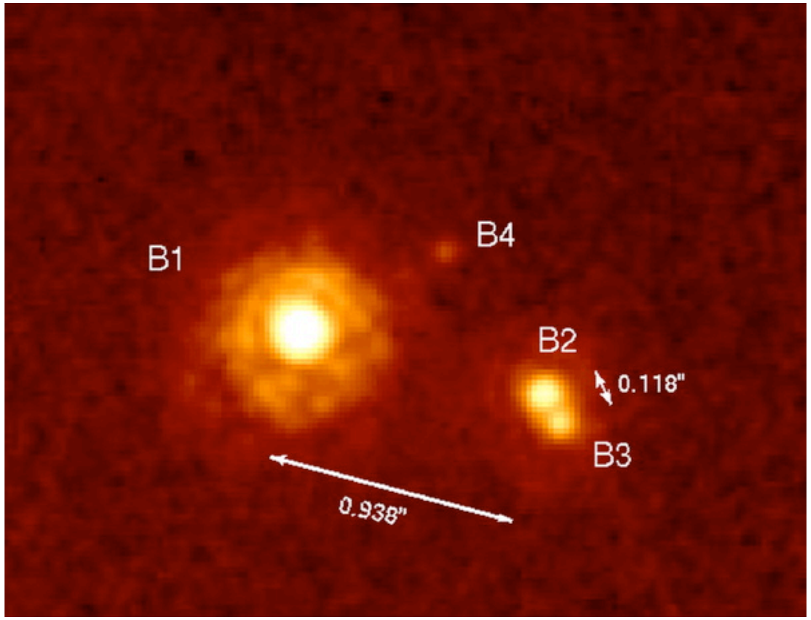


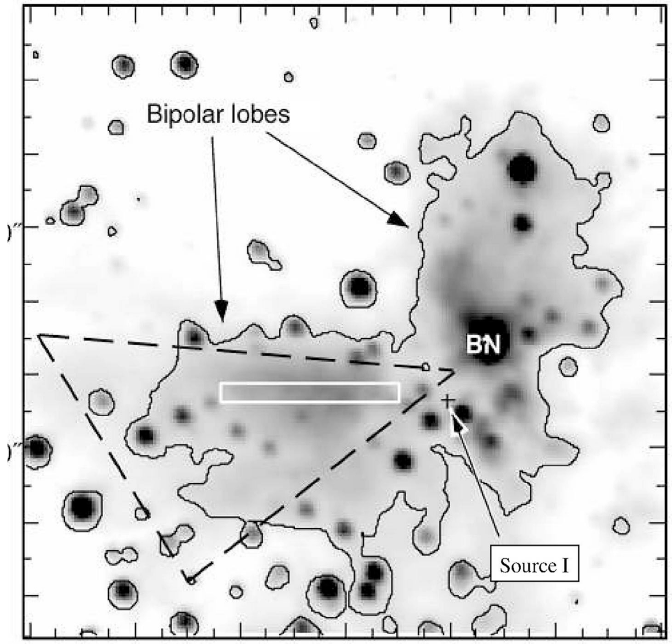
4 Herbig stars of ~4 M_0 inside the instability strip: differences in pulsation periods up to 2 hr for same mass

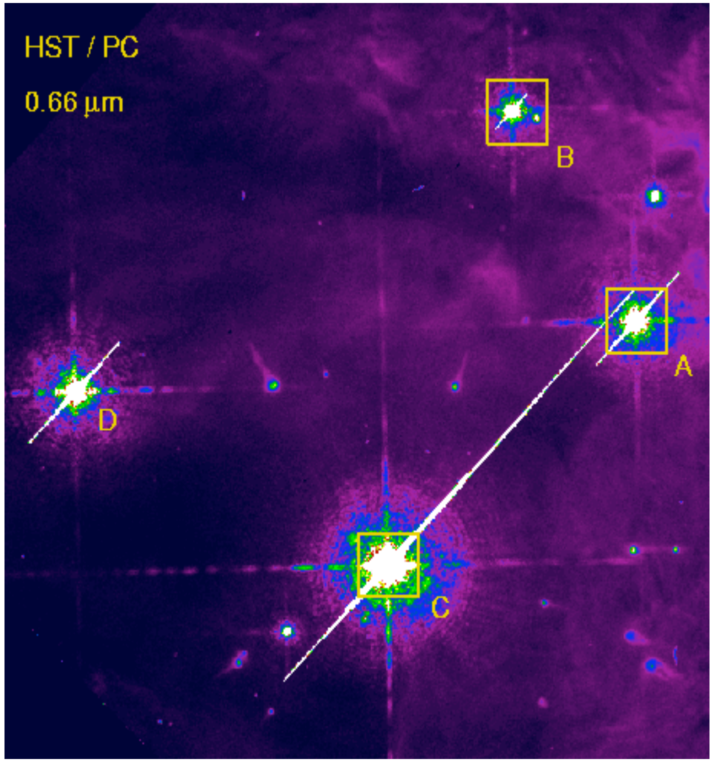
From low- to high-mass stars:

- *Massive (Eclipsing) Binaries*

Massive (proto)stars





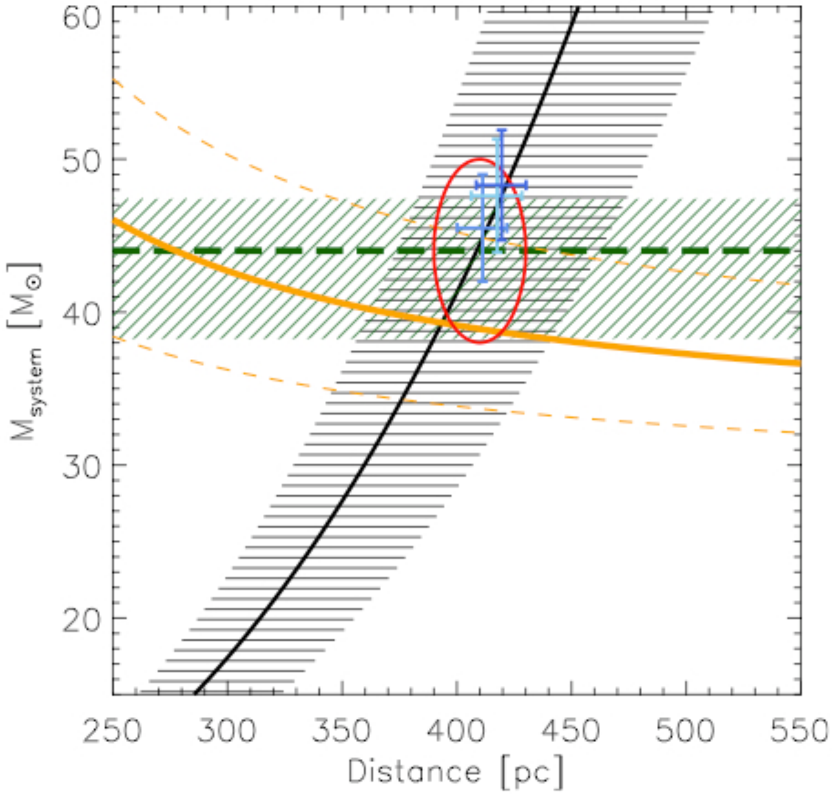


Θ^1 *Ori C* (Kraus+09)

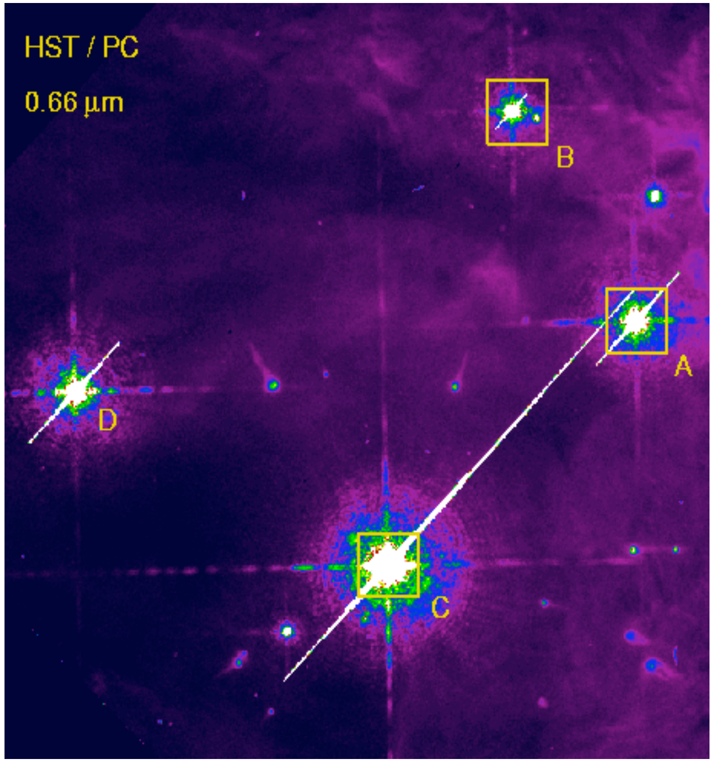
AMBER+speckle… 11 yr of data:
P=11.3yr – e=0.6; a=44 mas; sep~7 AU;

Total mass = 44 ± 7 Mo – q = 0.23

Dynamical distance = 410 ± 20 pc



System mass vs Distance: constraints from a^3/P^2



Θ¹ *Ori C* (Lehamnn+10)

3rd body companion to main star…

M1=32±3 Mo; M2=12±3 Mo →

q=0.41±0.12 (>0.23…)

M1=31±3 Mo; M1b=1.01±0.16 Mo;

M2=12±3 Mo

Properties of 3rd companion…? urgent

Θ¹ OriB: EBS, 3→4 components, M<10 Mo

Θ¹ OriA: EBS, M<10 Mo …

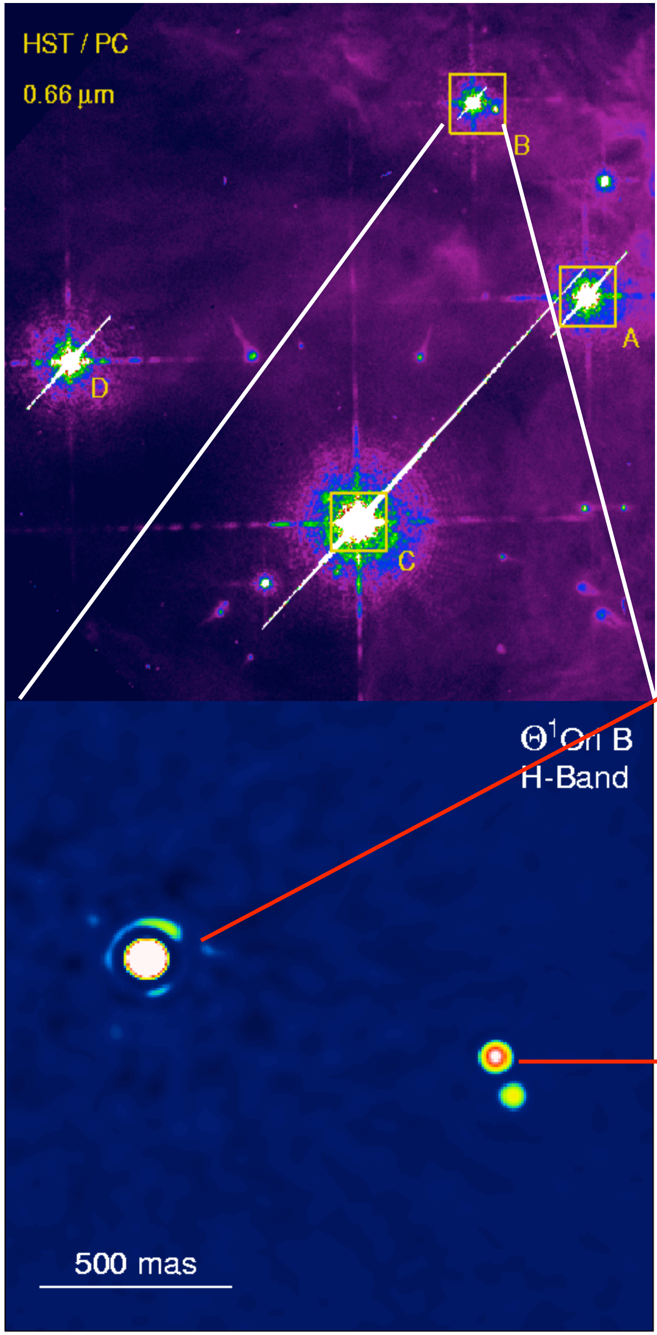
Θ^1 Ori B, P=6.5 d

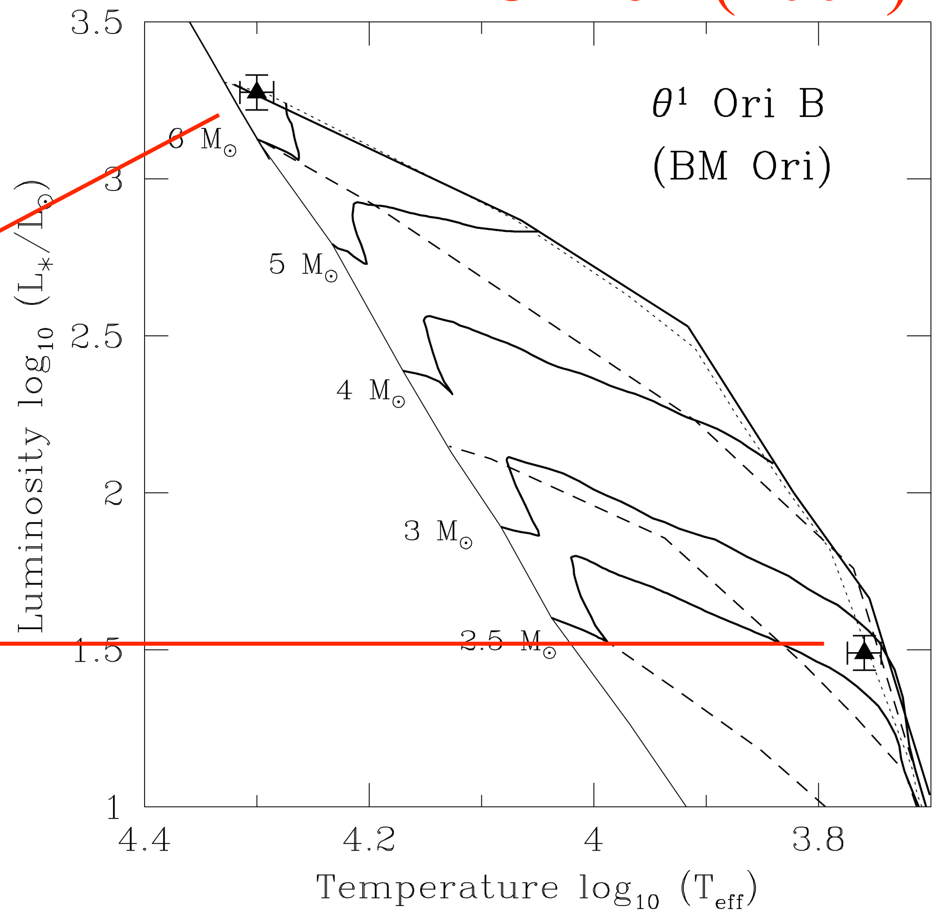
M(A)=6.3 M_0 - M(B)=2.5 M_0

t≈10^5 yr → very young, last to form

…solution to proplyd conundrum…

O'Dell (2002)





Westerlund 1

- *6 yellow HG, 4 RSG, 24 WR, 1 LBV,*
  50+ OB SG, 1 magnetar → burst…
- *EBS in Wd1: mass, radii as tests*
  independent distance
  dyn. mass magnetar progen.
- *4 systems found by Bonanos 07,08:*

Binary	P(days)	$M_1(M_\odot)$	$M_2(M_\odot)$	$R_1(R_\odot)$	$R_2(R_\odot)$
Wddeb	4.447	9.62	13.84	5.47	6.22
Wd36	3.182	10.75	12.51	9.45	10.15
WR77o	3.520	49.67	19.87	18.06	11.81
Wd13	9.267	29.91	23.86	26.88	24.08

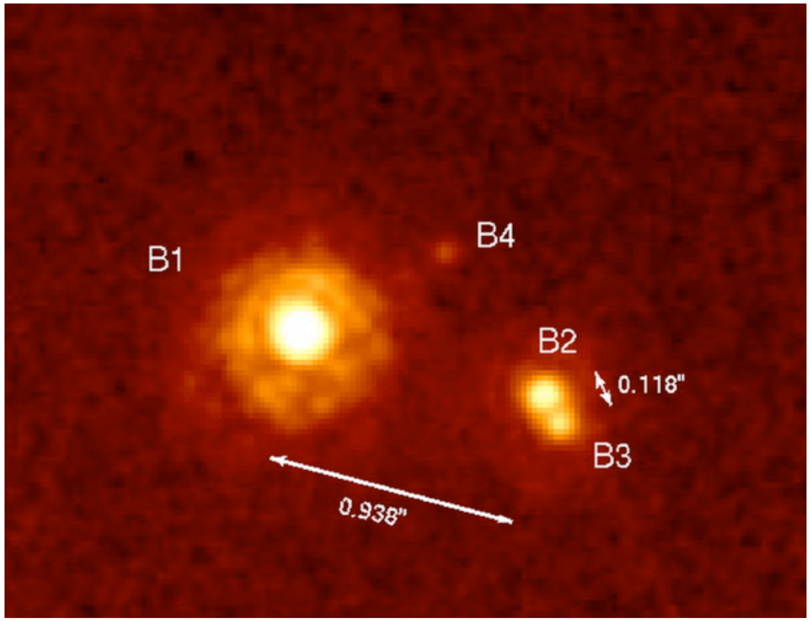
detached system
→ individ. mass

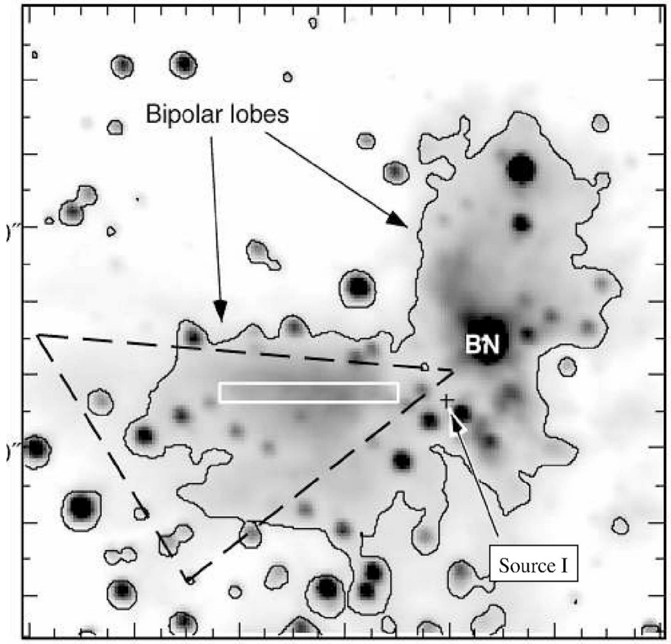
Search and new candidates in Arches cluster, LMC (Bonanos+10) …

From low- to high-mass stars:

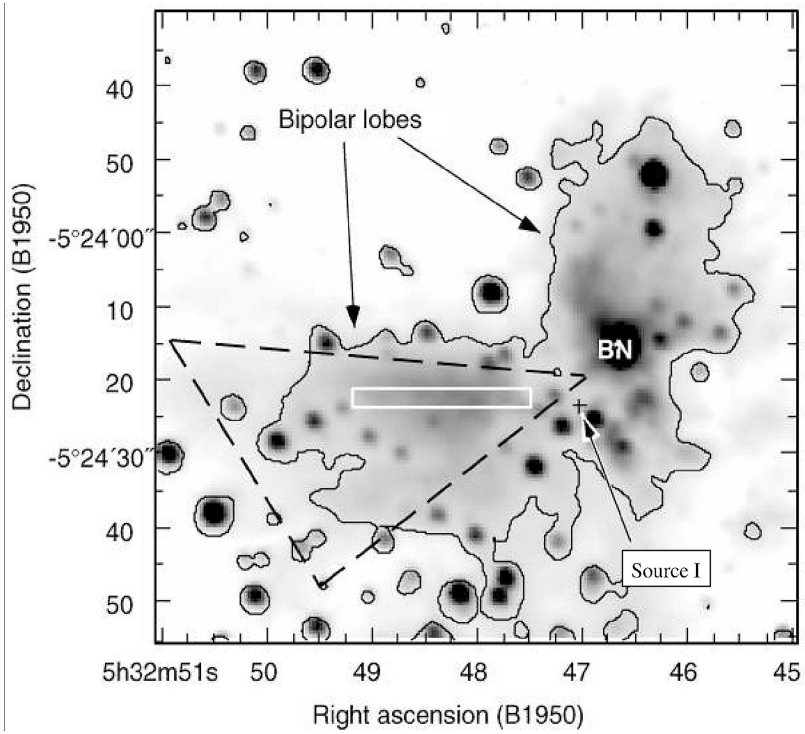
Massive (Eclipsing) Binaries

- *Massive (proto)stars*





Probing the nature of the nearest massive protostar: Orion KL/BN nebula



Scattered light @2 μm
Morino+ 1998 Nature

- *Radiation escaped along the major polar axis of disk/torus & reflected by dust within cavities excavated by CO outflow*

- *CO bandhead absorpt lines : different profiles when observed at spectral resolution >>1000:*

20 Mo protostar rotating @ 1/2breakup: ~50-100 km/s

accretion disk (double peaked): <50 km/s

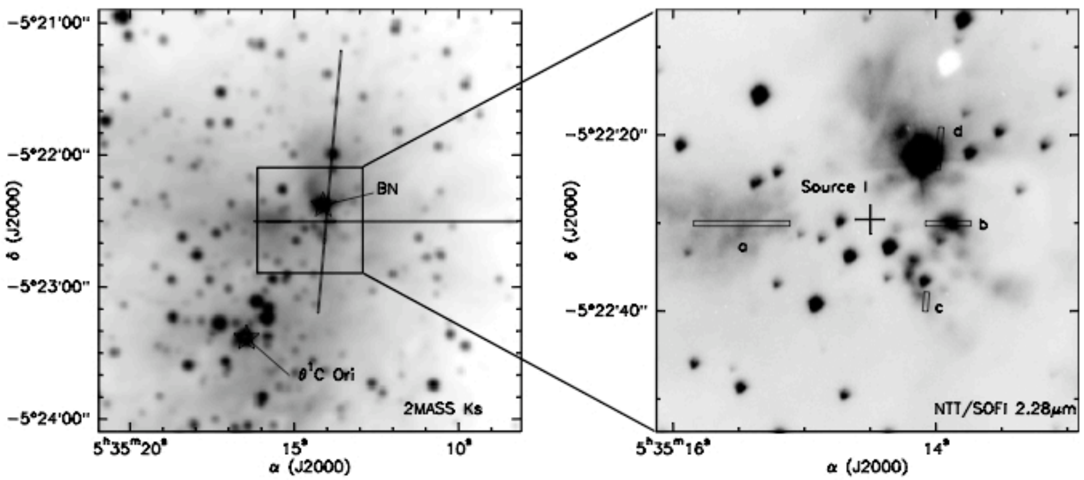
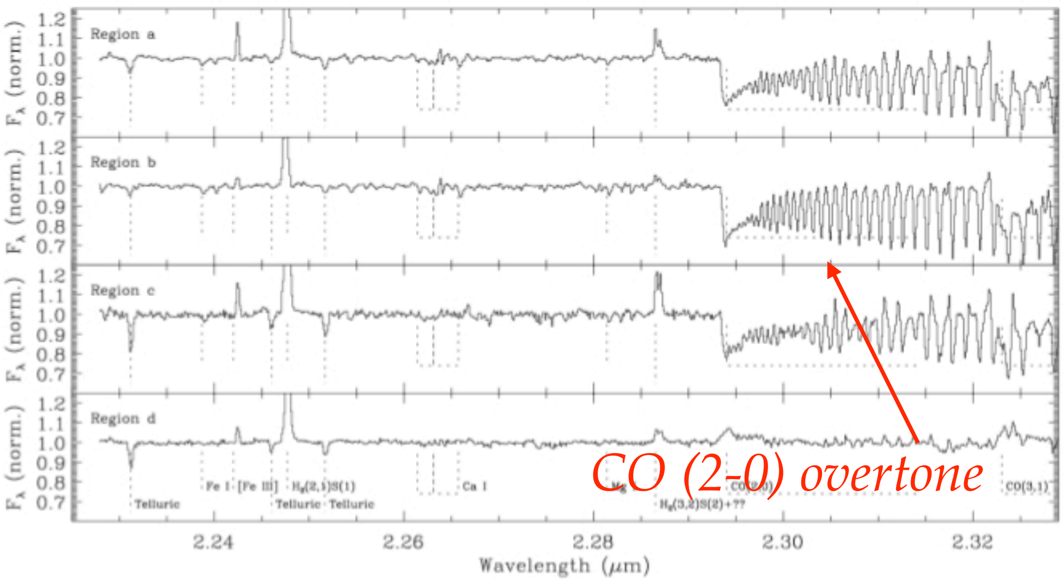
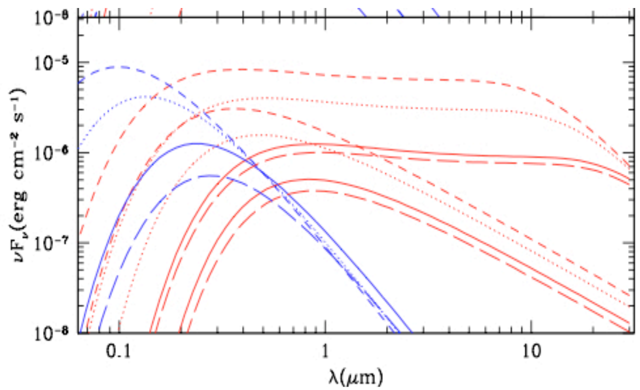


Fig. 1. Left panel: 2MASS Ks-band image of the Orion Trapezium and the Kleinmann-Low nebula region, θ^1 C and the Becklin-Neugebauer object are marked for reference. The positions of the two on-source slits are shown. Right panel: the region around Orion-KL source I (marked with a cross and labelled) at 2.28μm is reproduced from an ESO-Archive SOFI-NTT observation (originally acquired for the ESO programme 64.I-0493). The small slitlets marked from a to d show the regions we used to extract the spectra shown in Fig. 2



Testi, Tan, Palla 2010

- *Moderate high res NIR spectra (R=9000)*
- *Rich abs, line spectrum compared with cool stellar atmopshere & accretion disk*
- *σ_{1D} ~30 km/s → emission from disk around M~10 M_0 accreting at ~10^{-3} M/yr Turbulent core model…*



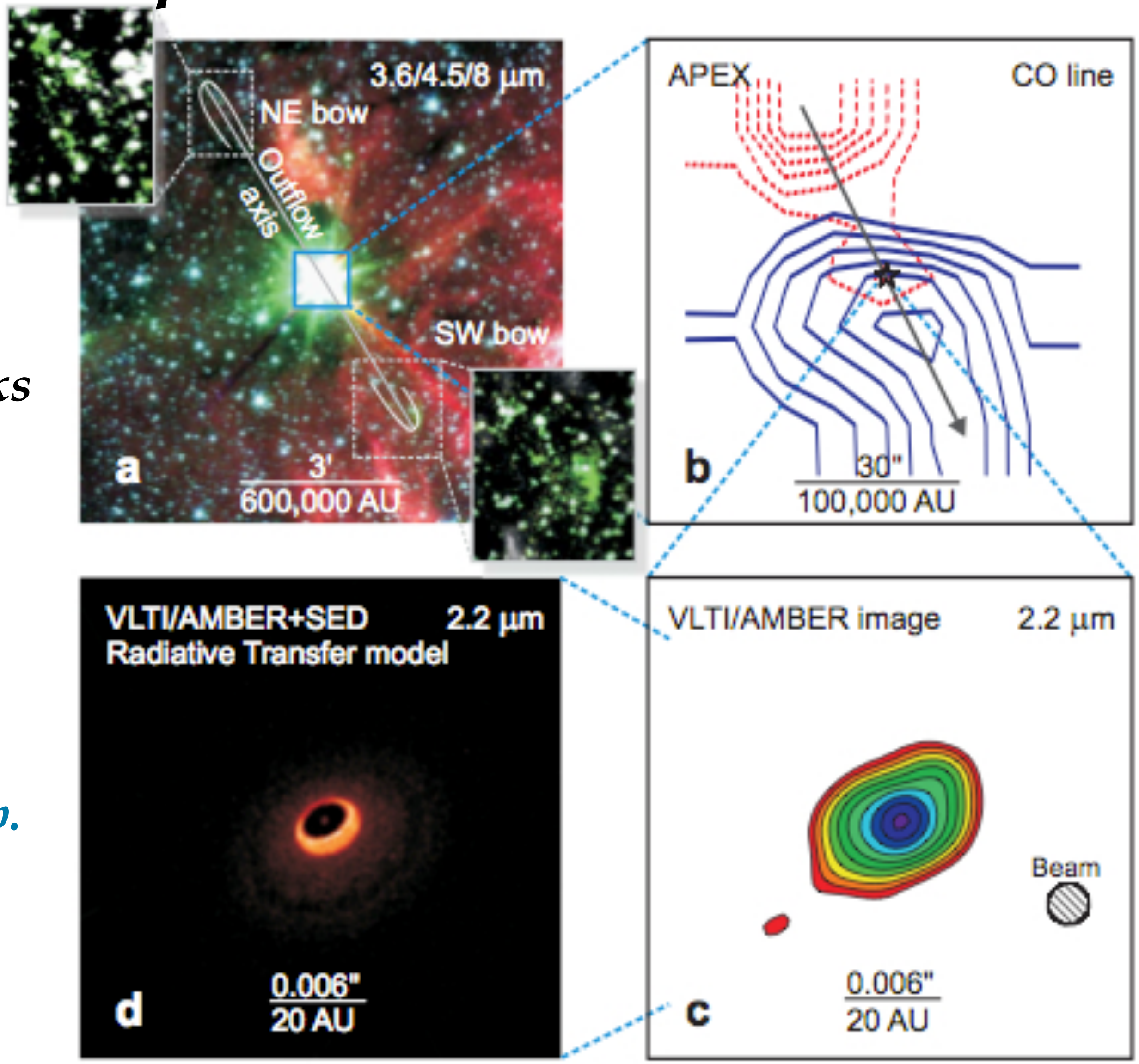
Compact disk around a ~20 Mo YSO (speckle + AMBER/VLTI)

- *Disk: low degree of asymmetry…*

problems for self-grav. disks

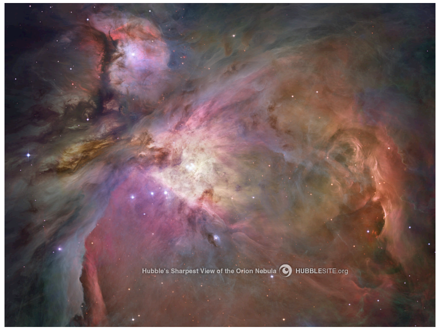
- *Absence of nearby companion (>10 mas)…*

problems for mergers, comp. accretion



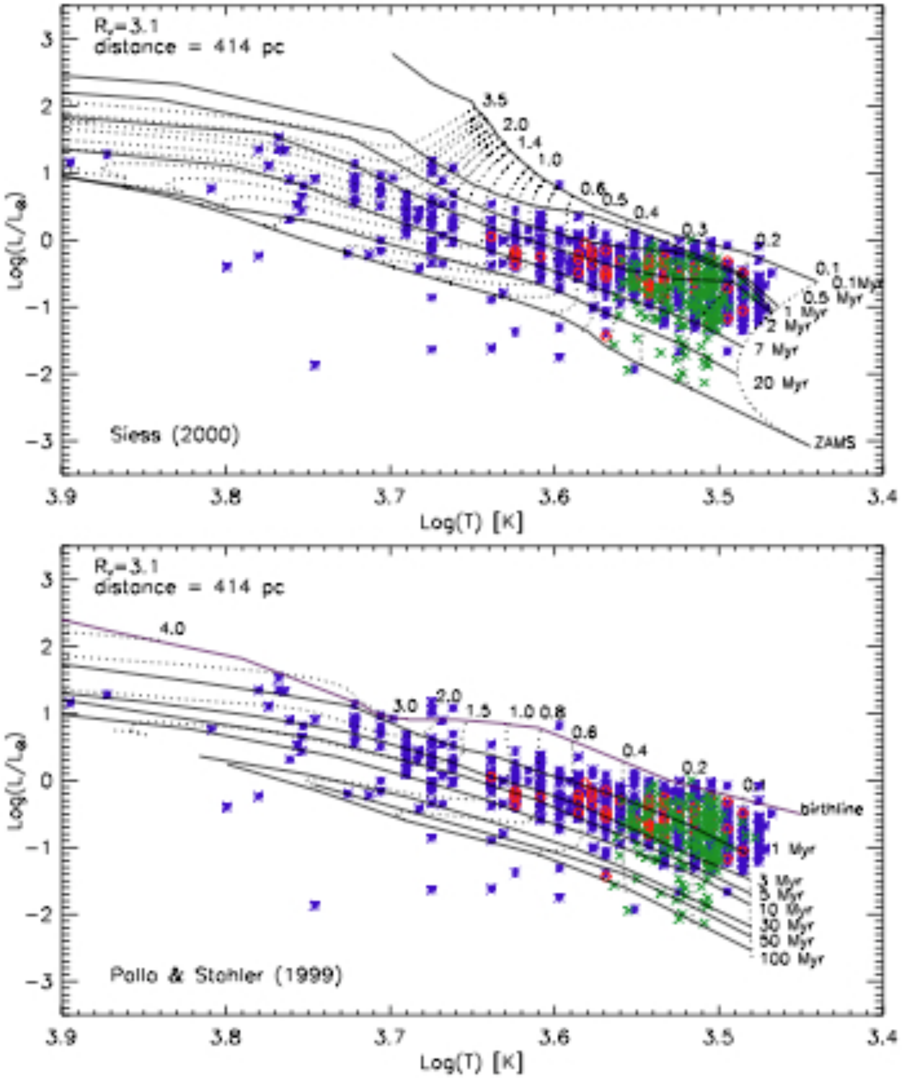
Kraus+ 10


Revisiting the ONC
(... and bigger)
Hubble's Sharpest View of the Orion Nebula
HUBBLESITE.org



Revisiting the ONC

HST Treasury Program – PI M. Robberto



blue: from H97, excluding stars with membership P<50%

red: stars with new spectral types

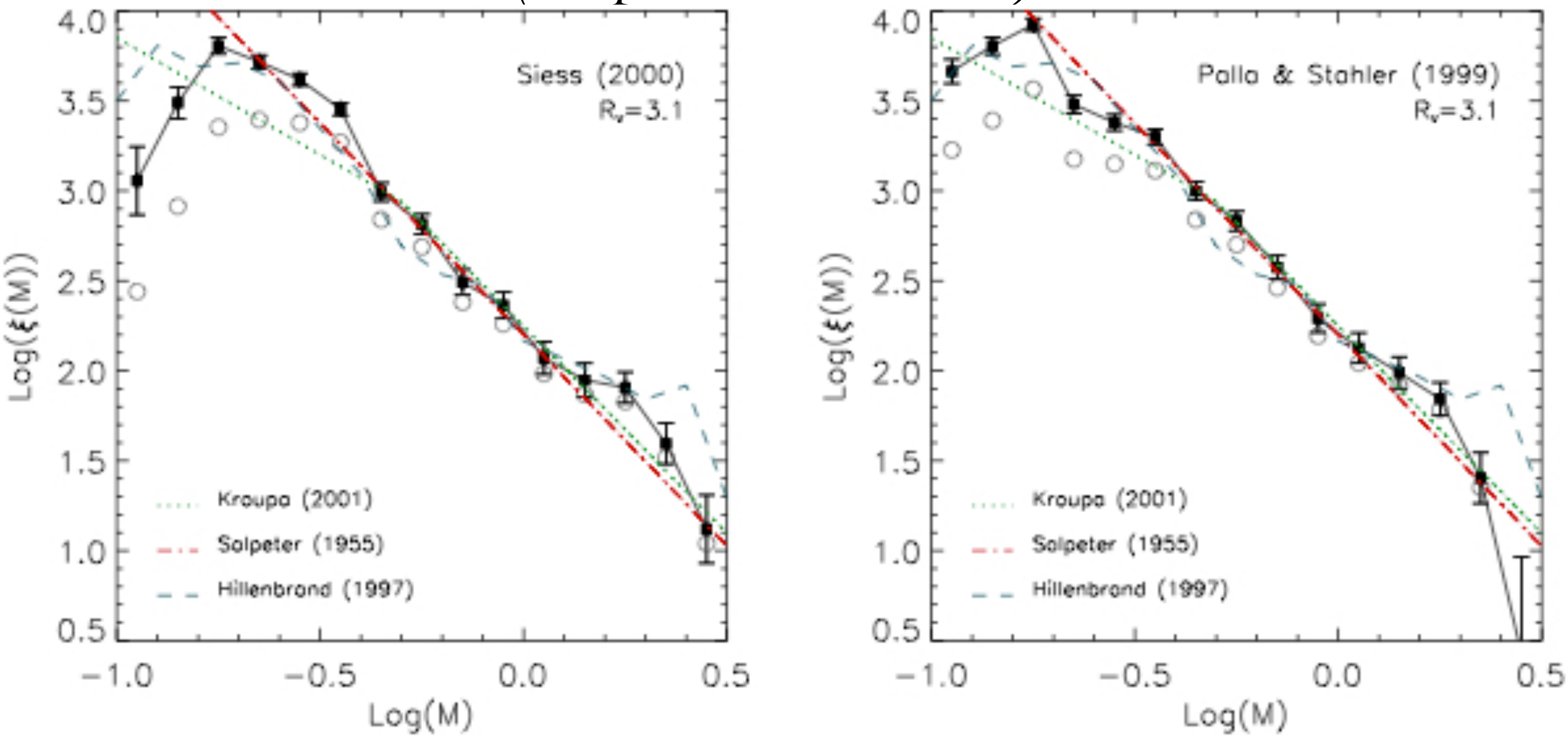
green: M-type with Teff from TiO index

Contamination by fore/background sources with unknown membership: 2-3%

Da Rio+ 10

The Initial Mass Function

(completeness corrected)



Significant differences for log M<~-0.3, both flatten:

Siess - clear turnover below 0.2 M_0, overabundance @0.2-0.3

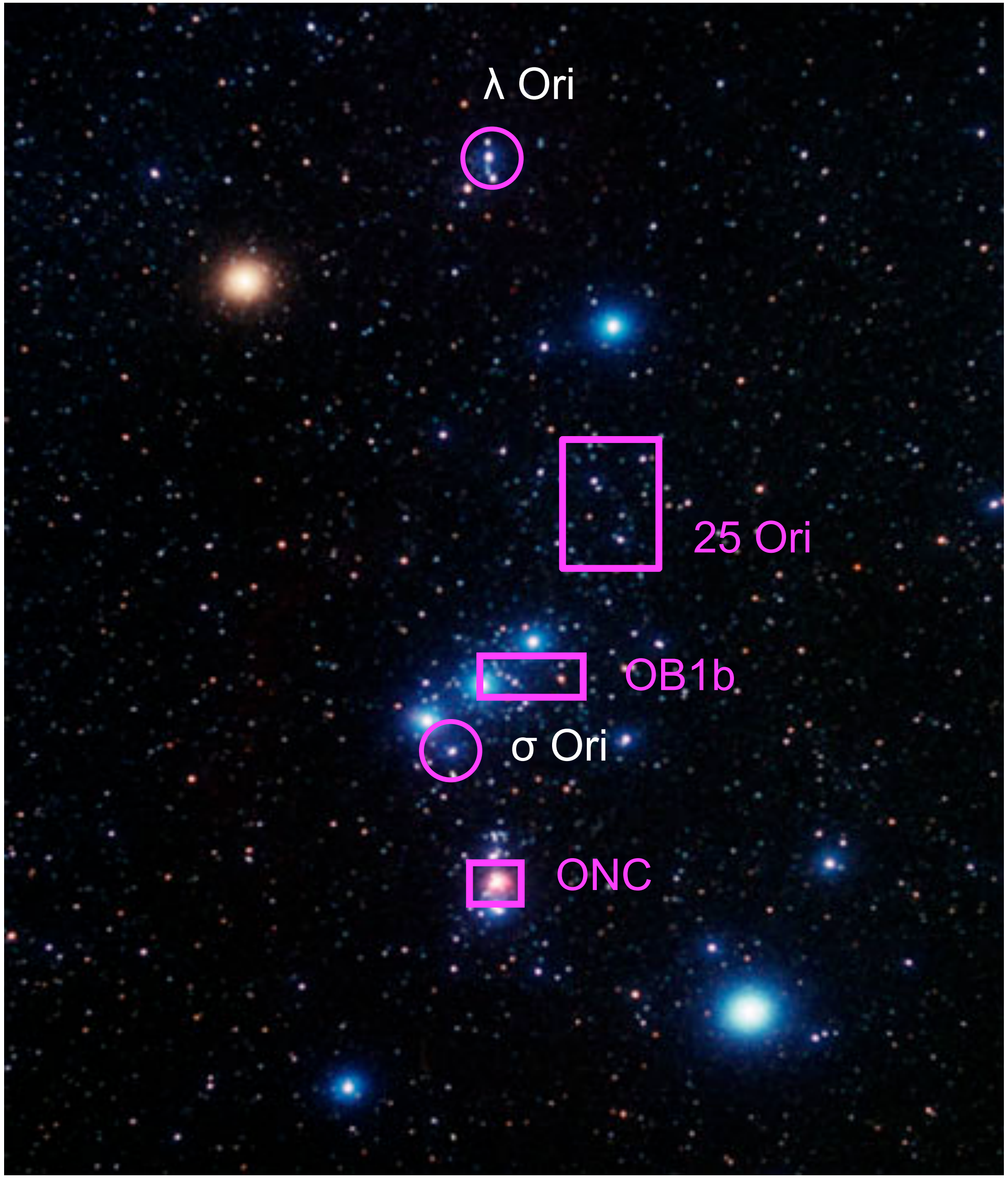
PS99 - modest change of slope, agreement with Kroupa IMF

Metallicity in the Orion associations

- *ONC (10 UVES): -0.14±0.03*
- *OB1b (10 UVES): -0.05±0.05*
- *25 Ori (8 UVES): -0.06±0.03*
- *Λ Ori (6 UVES): 0.0±0.02*

- *Homogeneous abundances (iron-peak elements, alpha-elements)*
- *No evidence for any star-to-star and group-to-group differences…*
- *All solar, but ONC…*

  (Taurus, Upp Sco: solar…)



Biazzo etal 2010

And now?

… next round of FP7 …

finding reliable industrial partners …