

Massive stars companionship in Trumpler 14

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&

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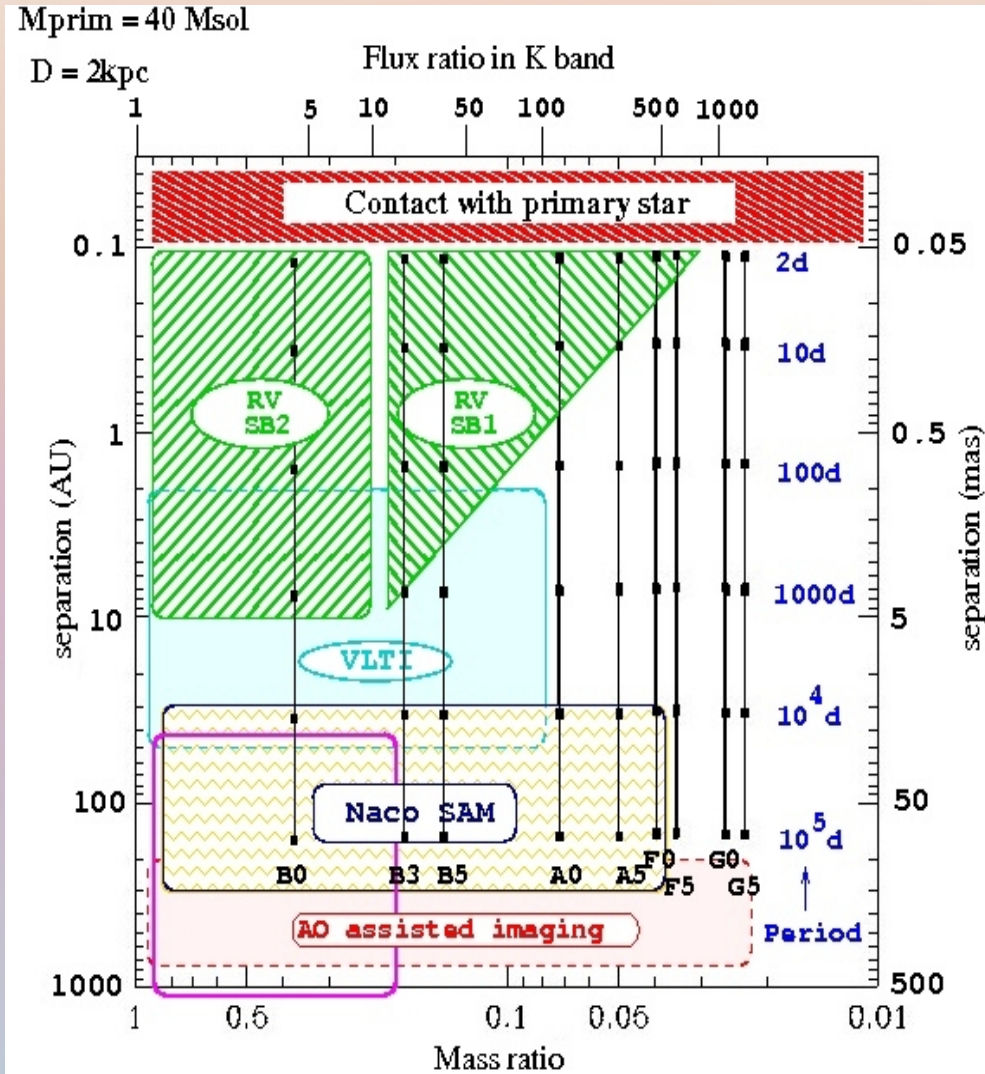
Science case

- Multiplicity of massive stars ?
- Comparison to low-mass stars ?
- How does the companions compare to the general cluster population ?
- Are they randomly drawn from classical IMF ?

Initial project

- 5 open clusters in Carina : 50 O and ~100 B0-5 stars
- but ... only Tr 14 : 9 O and ~15 early B stars

Parameter space



Recent works

I-band Adaptive optics

- Turner et al. 2008 • 116 O-stars in the GOC ($V < 8$) --> 31 companions (27%)
- $\Delta m_I < 6$ in $0.5''$ - $1.0''$
 - $\Delta m_I < 9.5$ in $1.0''$ - $5.0''$

Speckle interferometry

- Mason et al. 2009 • 385 O-stars (>95% in the GOC) --> 41 companions (11%)
(1998' update ...) • $\Delta m_V < 3$ in $0.03''$ - $5.0''$

Spectroscopy

Mason et al. review: 138 spectroscopic papers on > 300 objects --> 51% SB

- Tight binaries, Strong preference for O+OB (Sana et al. 2008, 2009)
--> formation process signature (angular momentum?)

Trumpler 14

- $d \sim 2.8 \text{ kpc}$
- $M \sim 10^4 M_{\text{sol}}$
- 9 O stars, ~ 15 B0-B3 stars
- One of the densest nearby open cluster
- The closest O2 I star ($\sim 80 M_{\text{sol}}$)
- The lowest high-mass SB fraction among nearby cluster
- Not included in recent AO campaign or HST fine guidance sensor observation

To keep in mind :

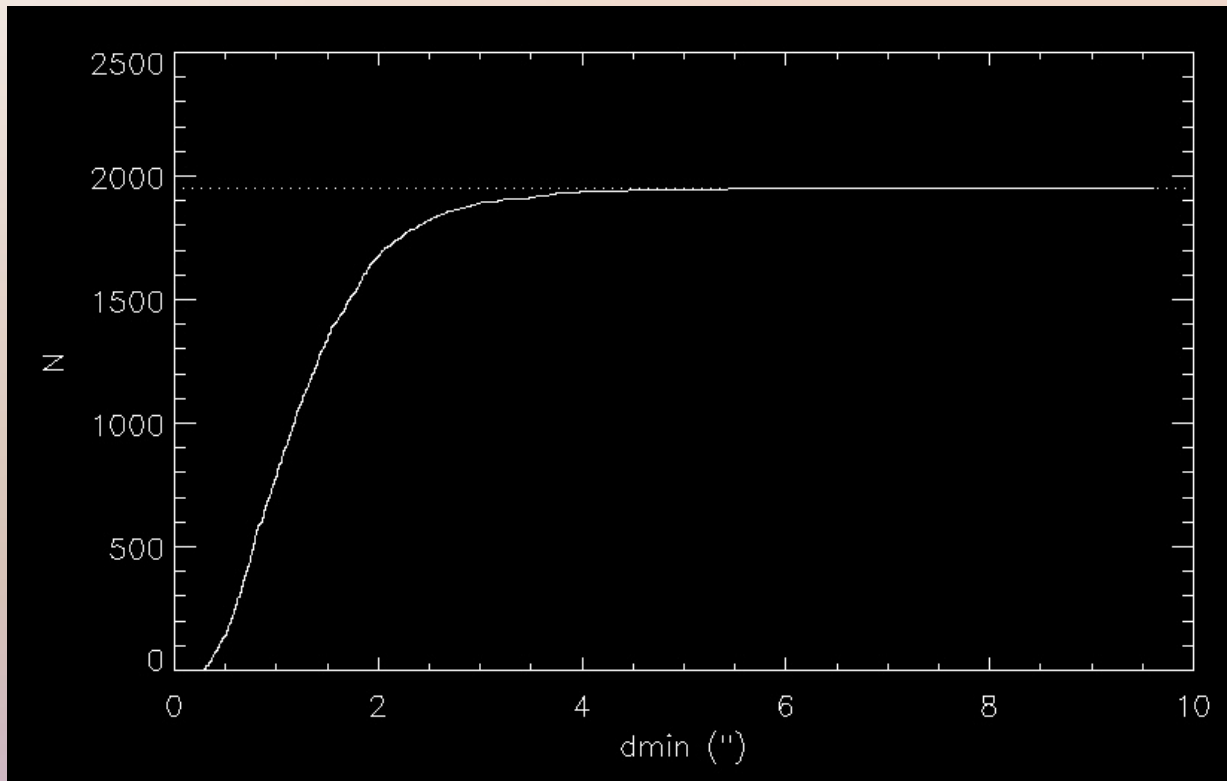
- @2.8pc : $1'' \iff 2500 \text{ AU}$

Data overview



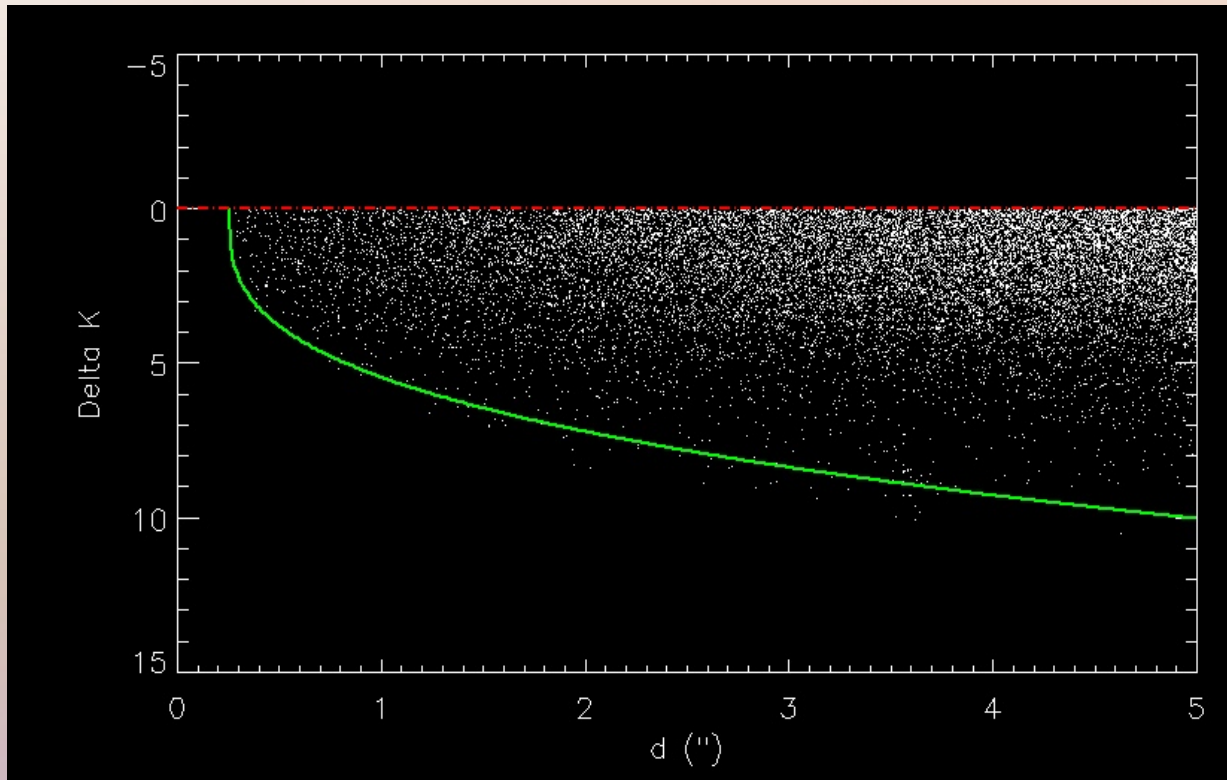
- 1948 sources detected
@ 6.3 sigma
- dynamic range ~ 10mag

Data overview



- 1948 sources detected @ 6.3 sigma
- dynamic range ~ 10 mag
- closest pair @ $d=0.25''$
- median(d_{\min})= $1.2''$
- $d < 0.5''$: 75 pairs
- $d < 1.0''$: 508 pairs
- $d < 5.0''$: 14 338 pairs

Data overview



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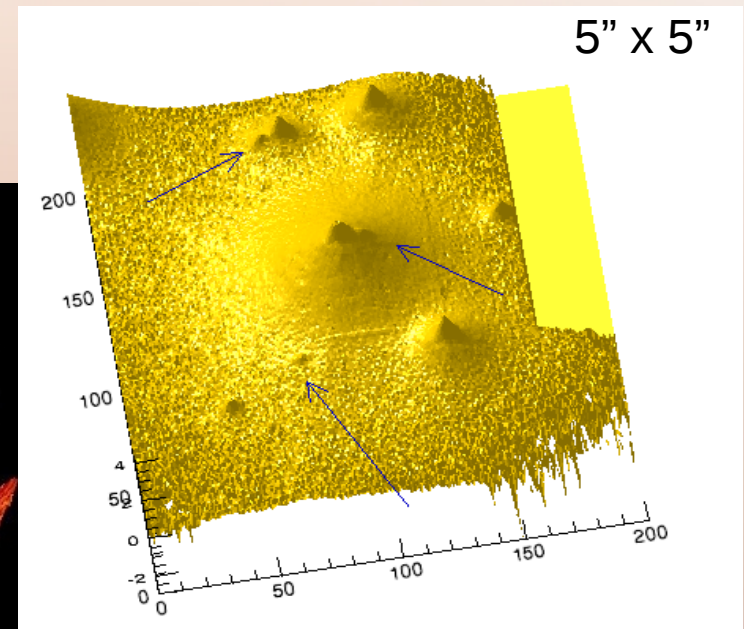
$$\Delta K_{\max} \propto (d-.25)^{1/3}$$

$$\Delta K_{\max} = 1 / 3 / 5 / 8$$

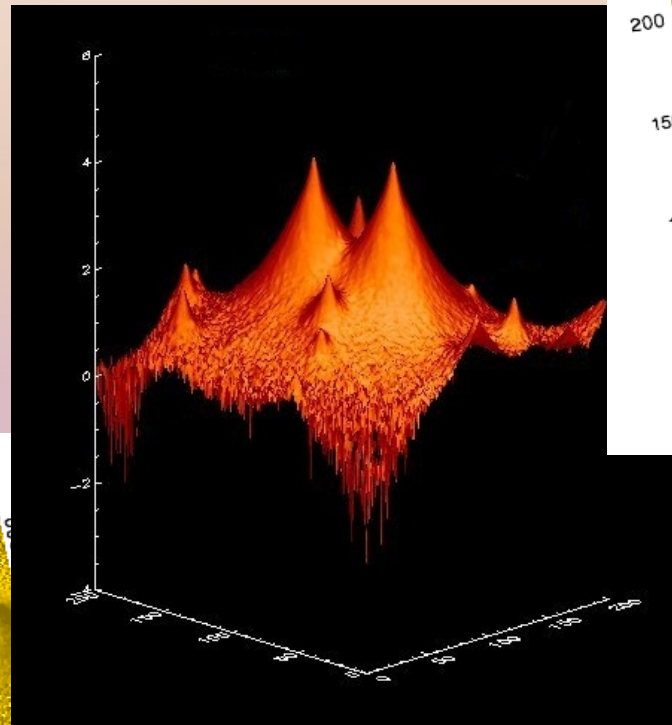
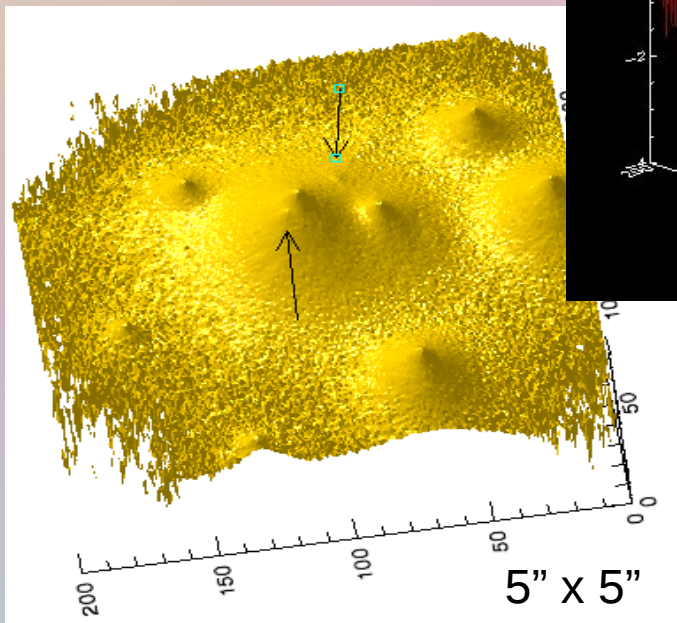
@ d = 0.3 / 0.5 / 1.0 / 2.

What we were looking for...

Tr 14-8 (O6.5V)

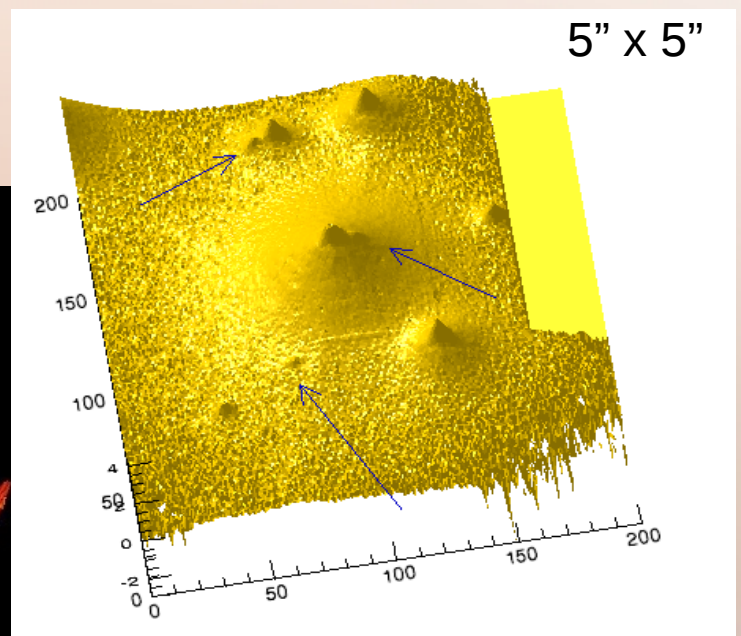


SAB 412 (O8V?)

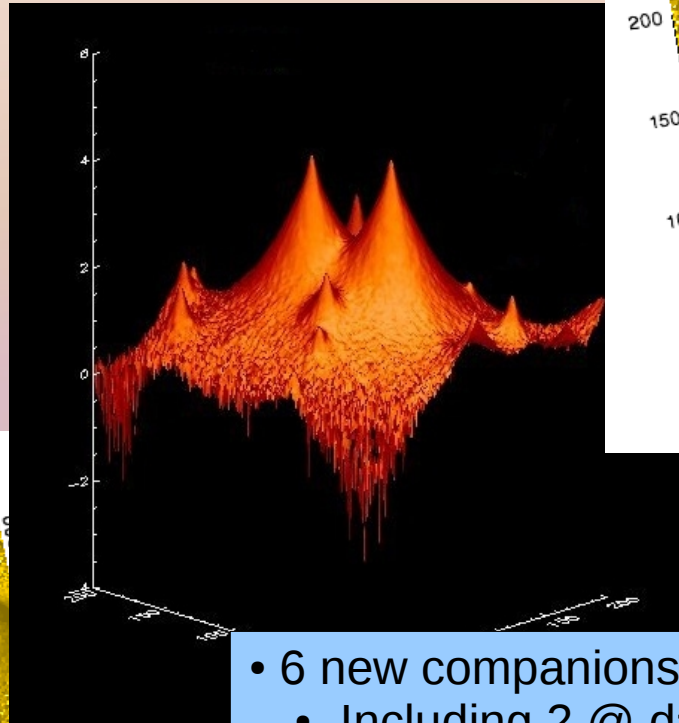
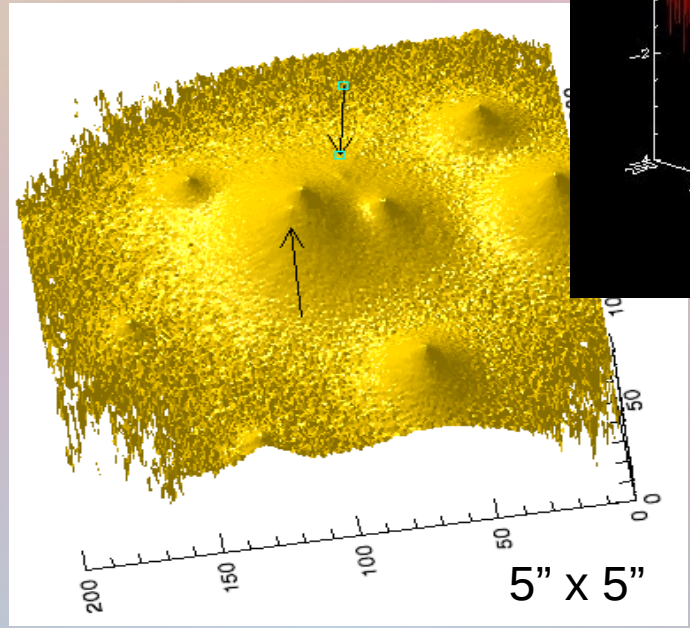


What we were looking for...

Tr 14-8 (O6.5V)



SAB 412 (O8V?)



- 6 new companions within $d < 1''$ (~2500AU)
 - Including 2 @ $d=0.20-0.25''$
- Visual pair fraction ~ 0.4 down to $K=18$

We found some ...

Random pairing or true companions ?

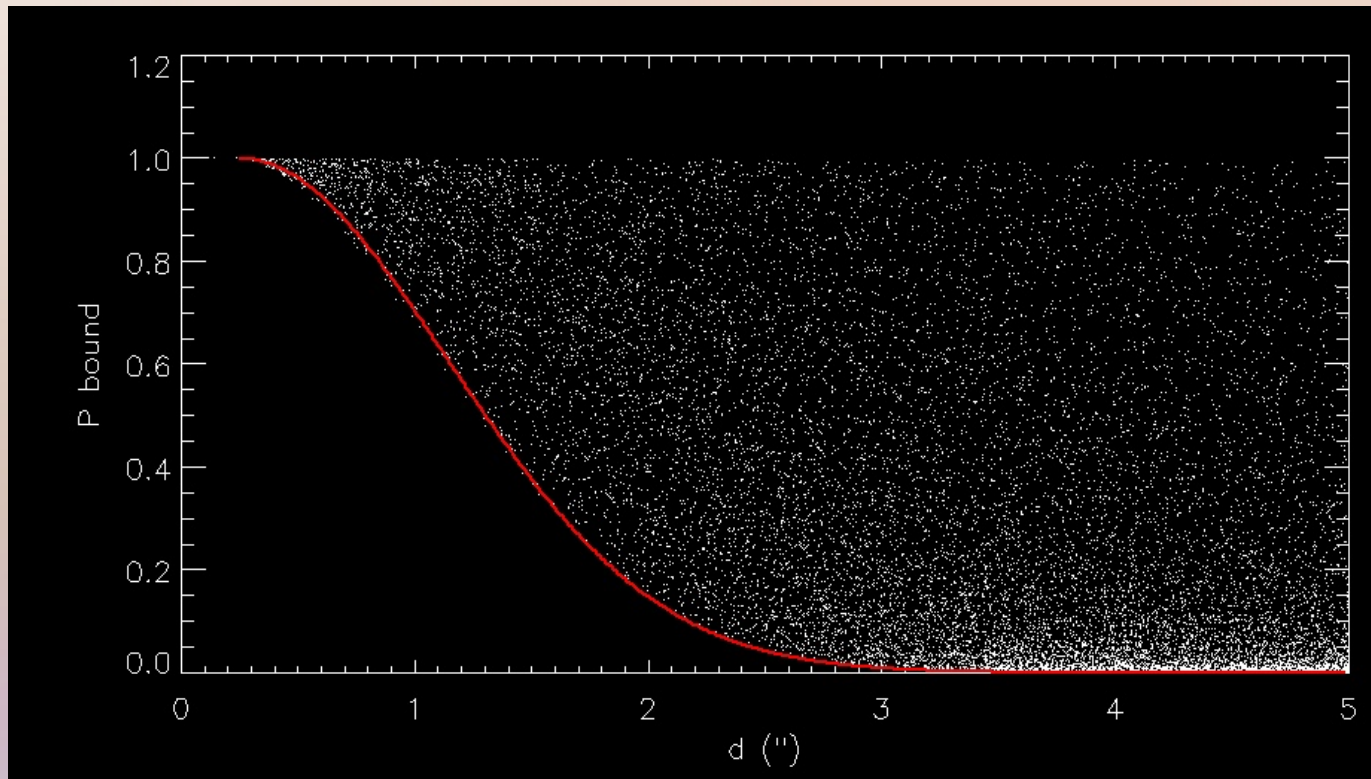
- $\sigma_{\text{moy}} \sim 700 \text{ src / arcmin}^2$
- $\sigma_{\text{max}} \sim 1500 \text{ src / arcmin}^2$ (Ascenso et al. 2007)

- $P_{\text{bound}} = \exp(- \sum_{K_p \rightarrow K_s} W_K)$

<---- Duchene et al. 2001

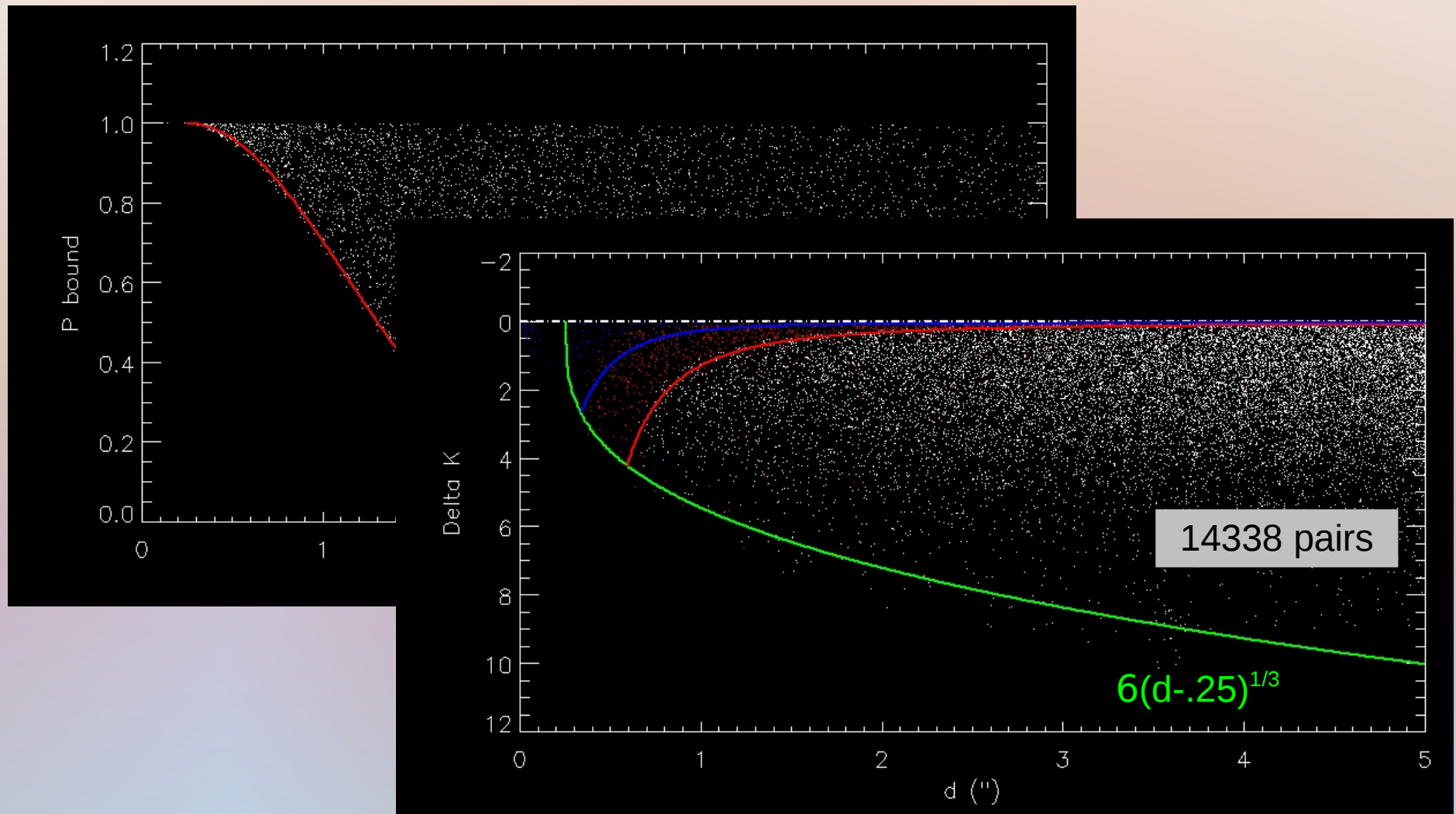
where $W_k = (d^2 - d_{\text{min}}^2)(K - K_p)$

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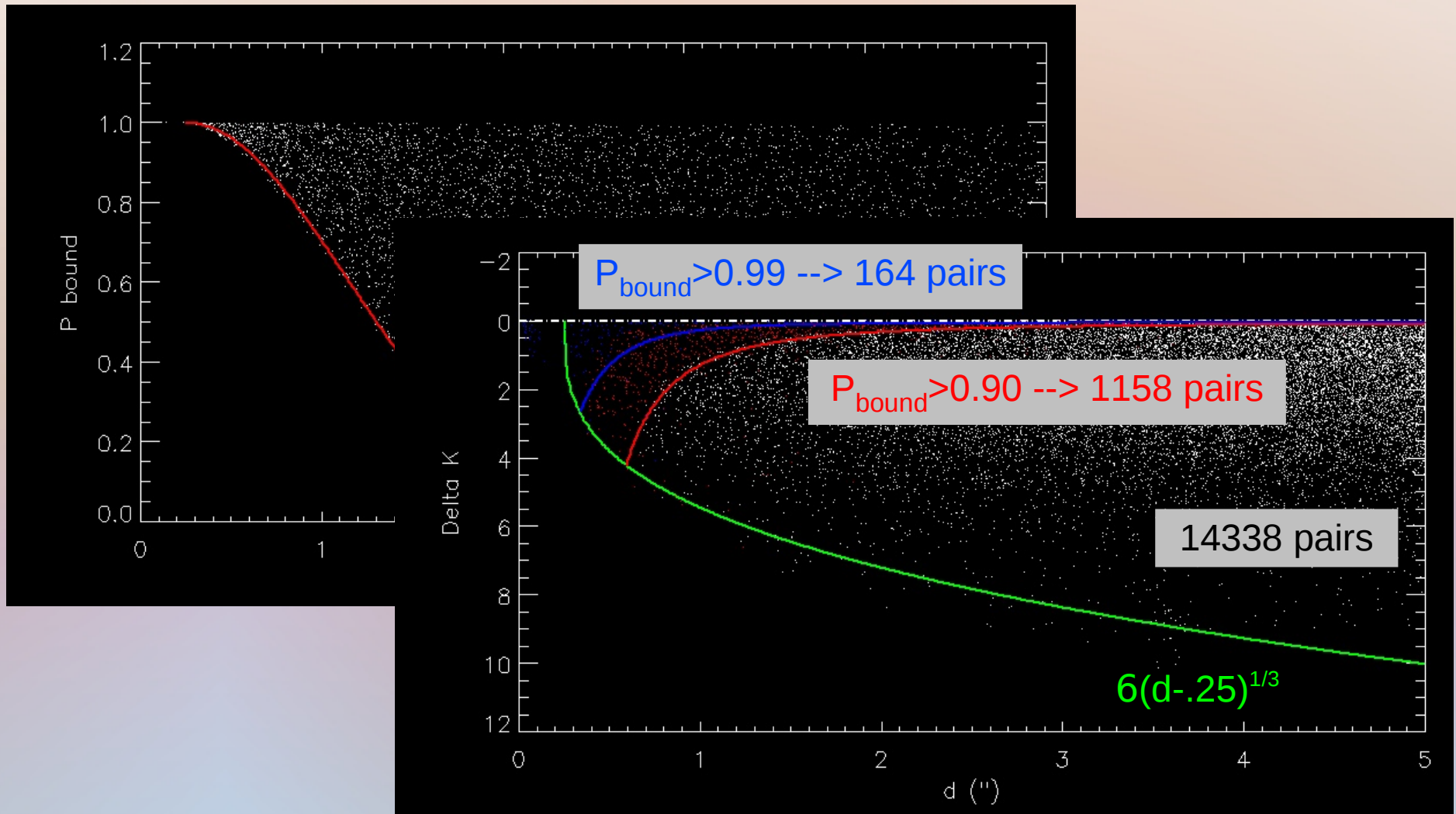


uchene et al. 2001

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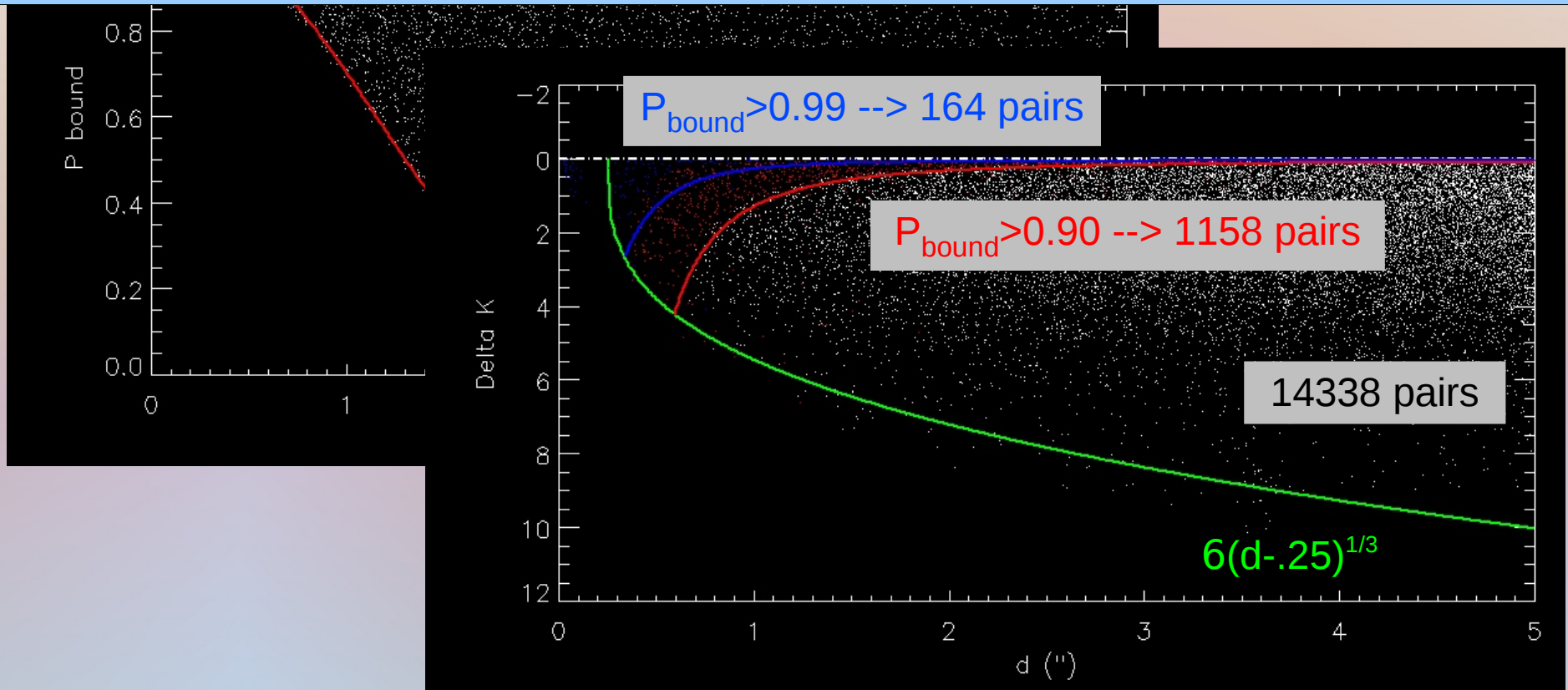


Random pairing or true companions ?



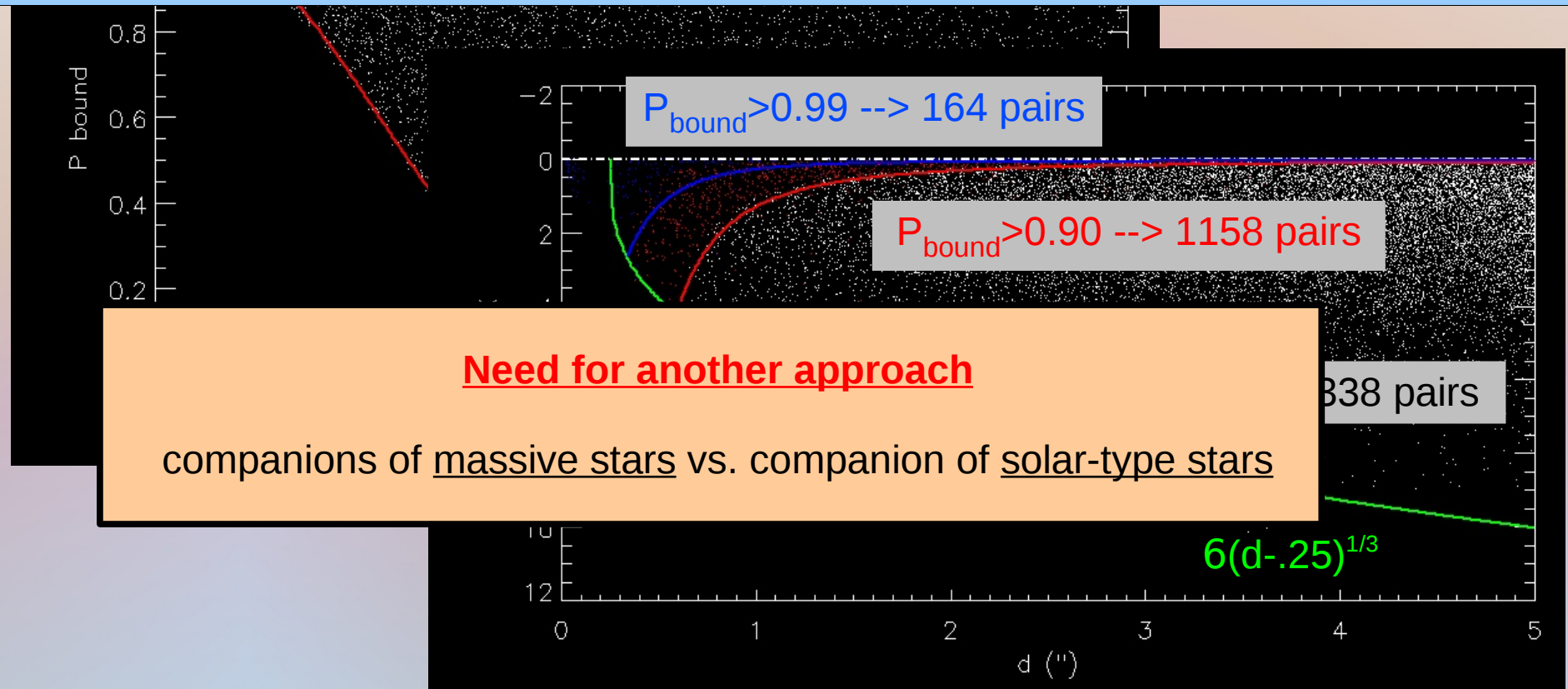
Random pairing or true companions ?

- only pairs with $\Delta K \sim 1$ or $d < 0.5''$ cannot be explained by projection effects
- It doesn't mean wider or larger contrast pair do not exist
- It means you cannot disentangle them :-)



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Need for another approach

companions of massive stars vs. companion of solar-type stars

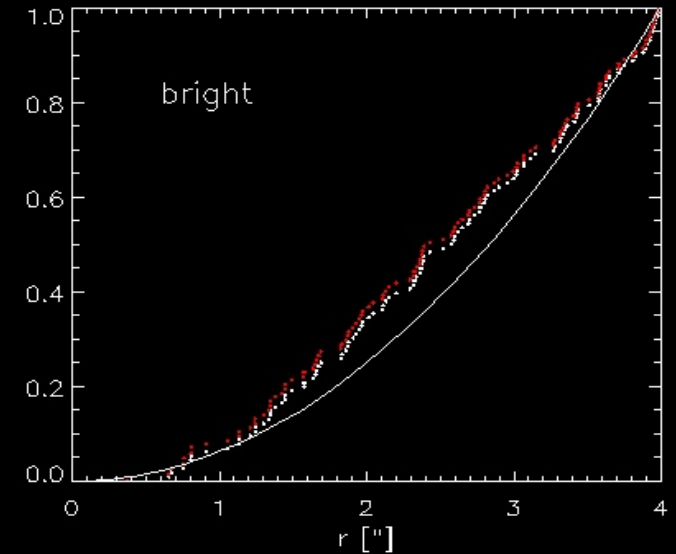
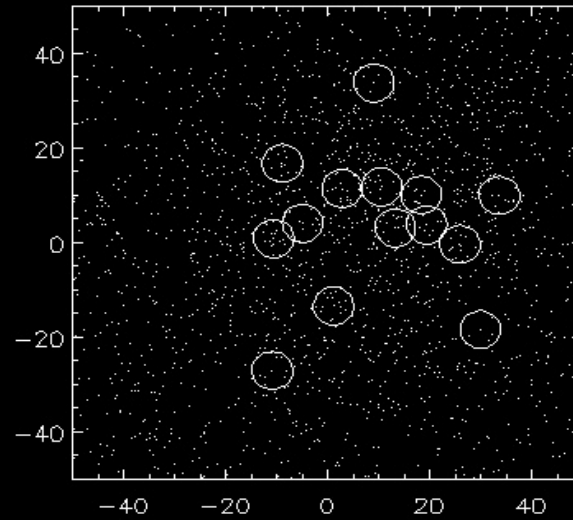
Growth curves

High Mass Stars

- $7.5 < K < 11$



- $M > 10 M_{\text{sol}}$

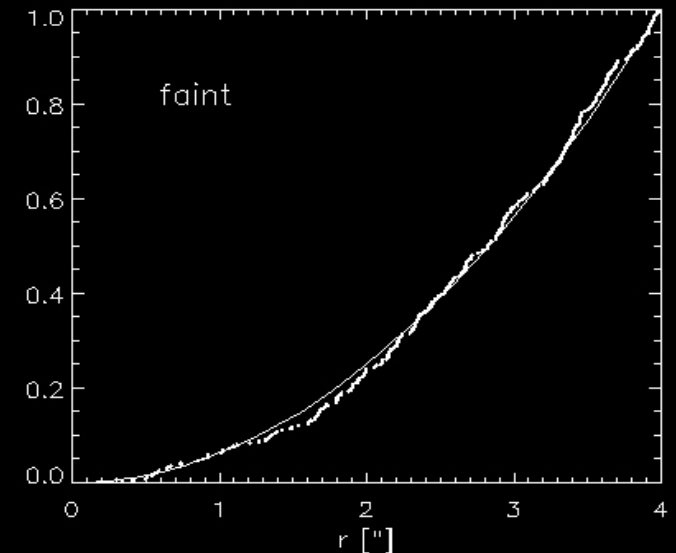
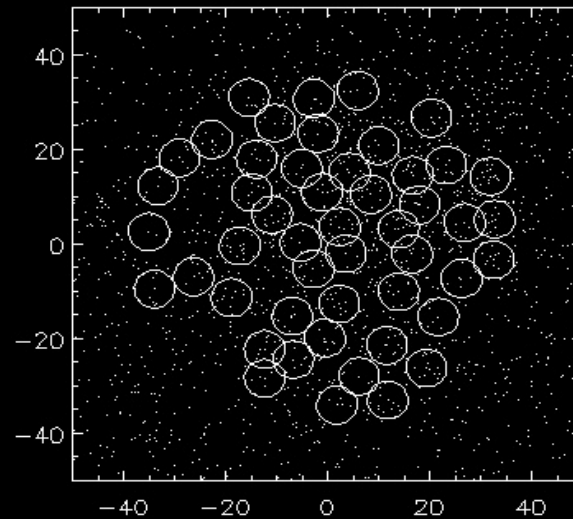


Solar-type Stars

- $12.5 < K < 14$



- $M \sim 1 M_{\text{sol}}$



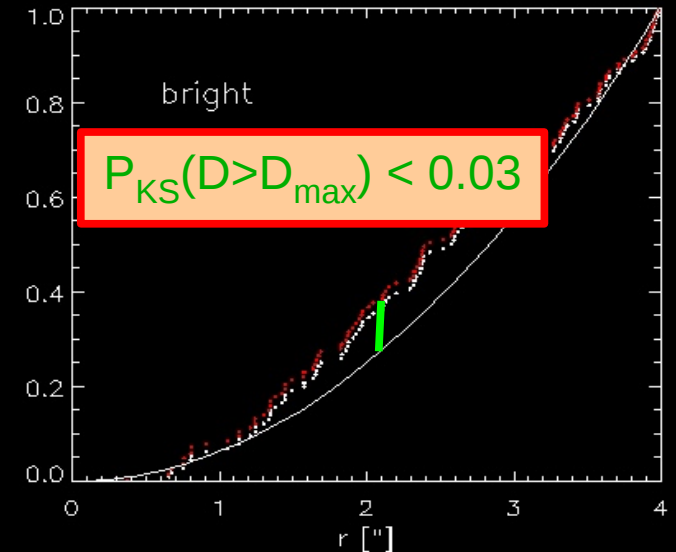
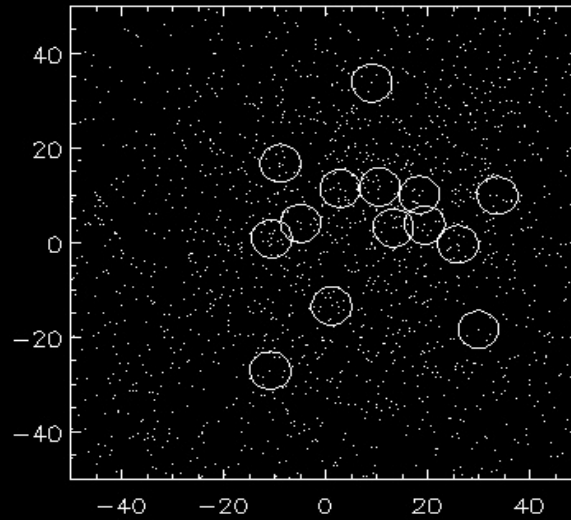
Growth curves (Ks<16)

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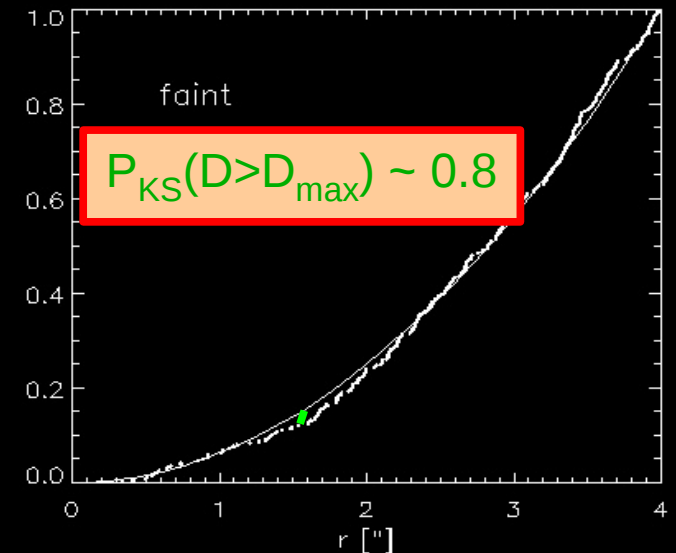
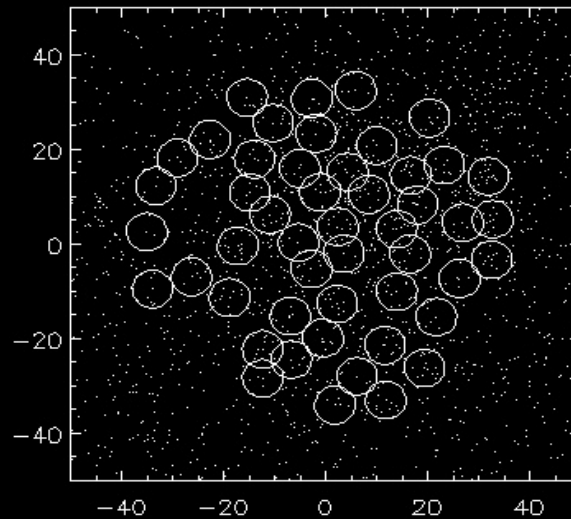


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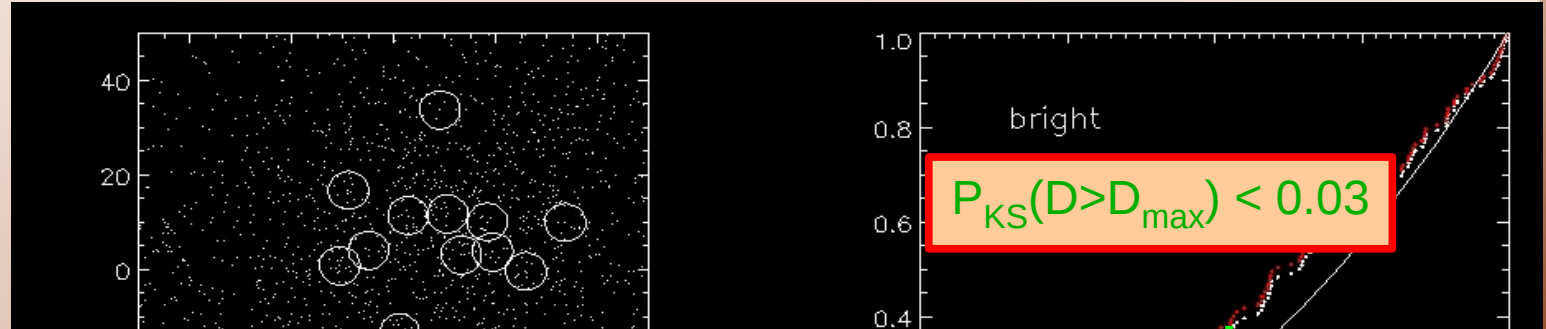
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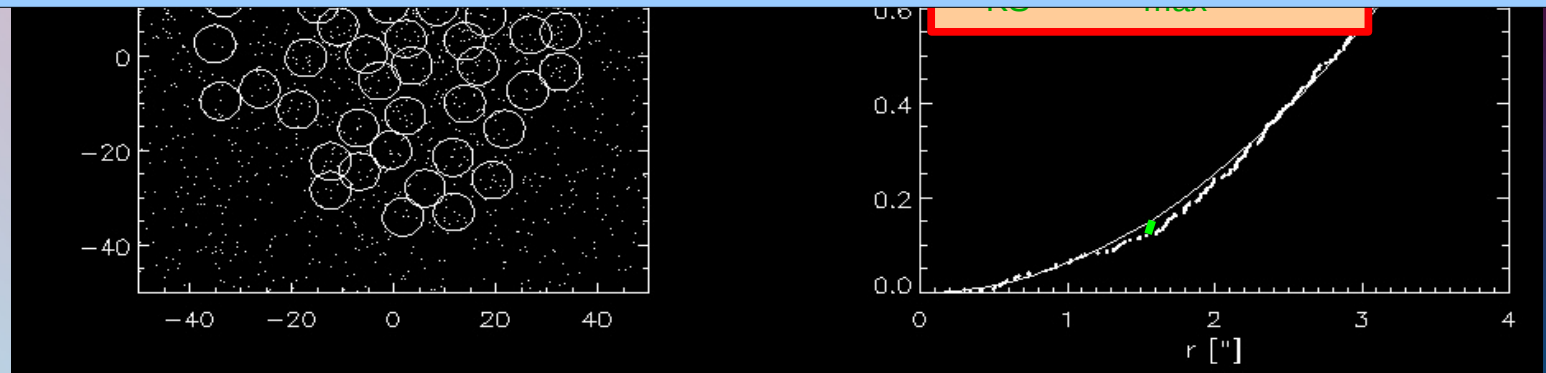


Within 10 000 AU

- Companions of LOW-MASS stars are compatible with uniform distribution in the fov
- Companions of HIGH-MASS stars are NOT (@ 0.02s.l.)
- Massive stars have statistically 2 more companions than solar-type stars



- $M \sim 1 M_{sol}$



Companion brightness

High Mass Stars

- $7.5 < K < 11$



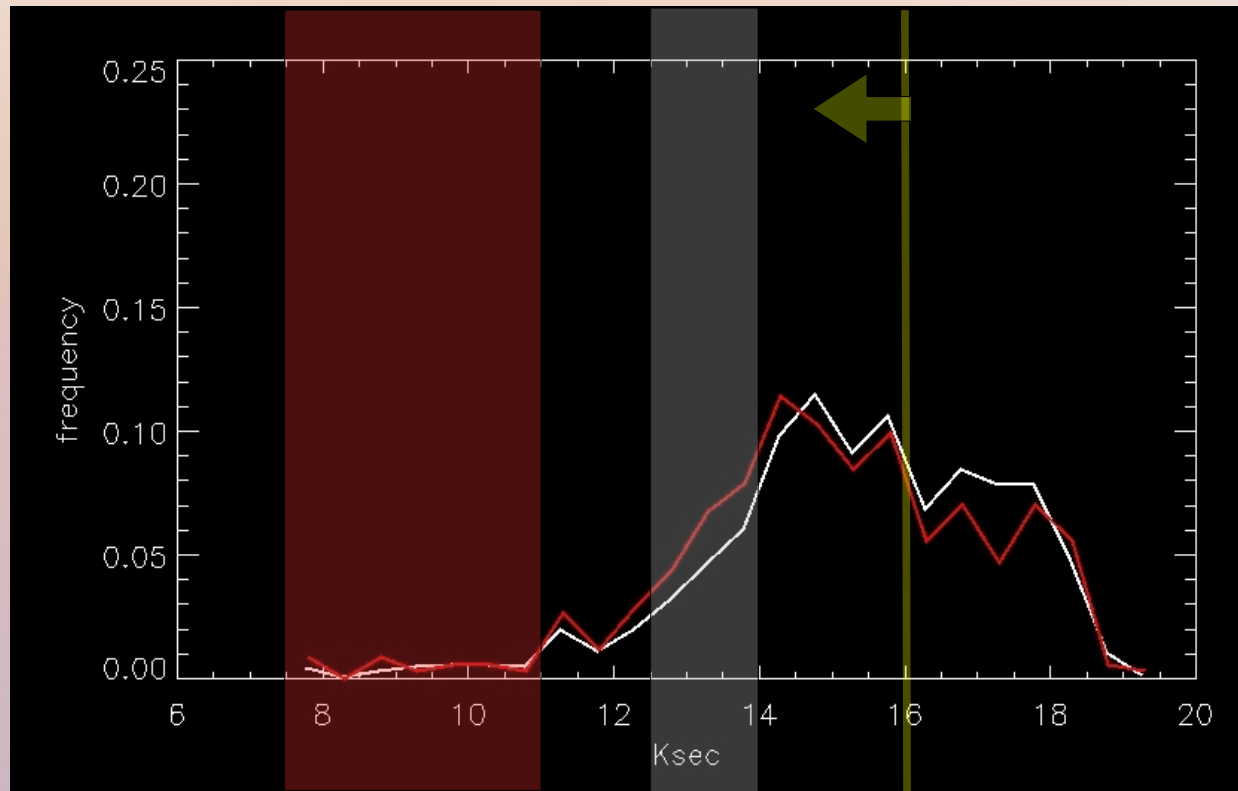
- $M > 10 M_{\text{sol}}$

Solar-type Stars

- $12.5 < K < 14$



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No significant differences

- range of brightness ratios
--> range a mass ratios

Conclusions

A MAD view of Trumpler 14

- AO corrected H & K-band imaging of Tr 14 in a 2' \emptyset FOV
- 1750 sources down to K \sim 18; image dynamics of 10 mag

Massive star environment in Trumpler 14

- 6 new companions with $d < 1''$ (~ 2500 AU), including 2 @ $d=0.20-0.25''$

Within 10 000 AU

- Massive stars have statistically more companions than solar type stars
--> massive star can sustain binary systems over large separation (Abt 1988)
- No obvious preference for high/low mass companion
--> possibly drawn from the cluster IMF
--> not a formation signature but a dynamical process

Conclusions

A MAD view of Trumpler 14

- AO corrected H & K-band imaging of Tr 14 in a 2' \emptyset FOV
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Deconvolution

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Dynamical model given M_{cluster} and R_{core}

The end ...



June 8-10 2009

... Or ...