Herbig Ae/Be Multiplicity Study

www.ctio.noao.edu/~haebe

Nicole van der Bliek, NOAO CTIO

Bernadette Rodgers, Gemini Observatory

Sandrine Thomas, UCO Lick Observatory

Greg Doppmann, NOAO Tucson

Jerôme Bouvier, University of Grenoble

Special Thanks to our summer students

- Claudia Araya (PIA, 2007)
- Maria José Cordero (PIA, 2006)
- Anne Sweet (REU, 2006)
- Ben Brandvig (REU, 2005)
- Lara Pierpoint (REU, 2003)

Why study Herbig Ae/Be stars?

- Herbig Ae/Be stars (HAEBEs) are intermediate-mass (2-8 solar masses) pre-main sequence stars
- Bridge the gap between low-mass T Tauri's and high-mass YSOs
  $\Rightarrow$ star formation as a function of mass
- Studies to date scattered, incomplete
  - Much less than studies of T Tauri stars
- Why not? heterogeneous sample, large distance range for significant sample

Why study their multiplicity?

- Stars do not form in isolation, nor in homogeneous mass environments
  - HAEBE binary frequency comparable to, or greater than, T Tauri frequency
- Constrain star formation models as a function of mass
  - Do high mass stars form like low mass stars?
  - IF there is a break, it occurs in HAEBE class
  - T Tauri binary studies support fragmentation
- Effect of HAEBE stars on their companions
  - "zone of influence" as function of primary mass

Note: difficult because of large delta-magnitude

Our project

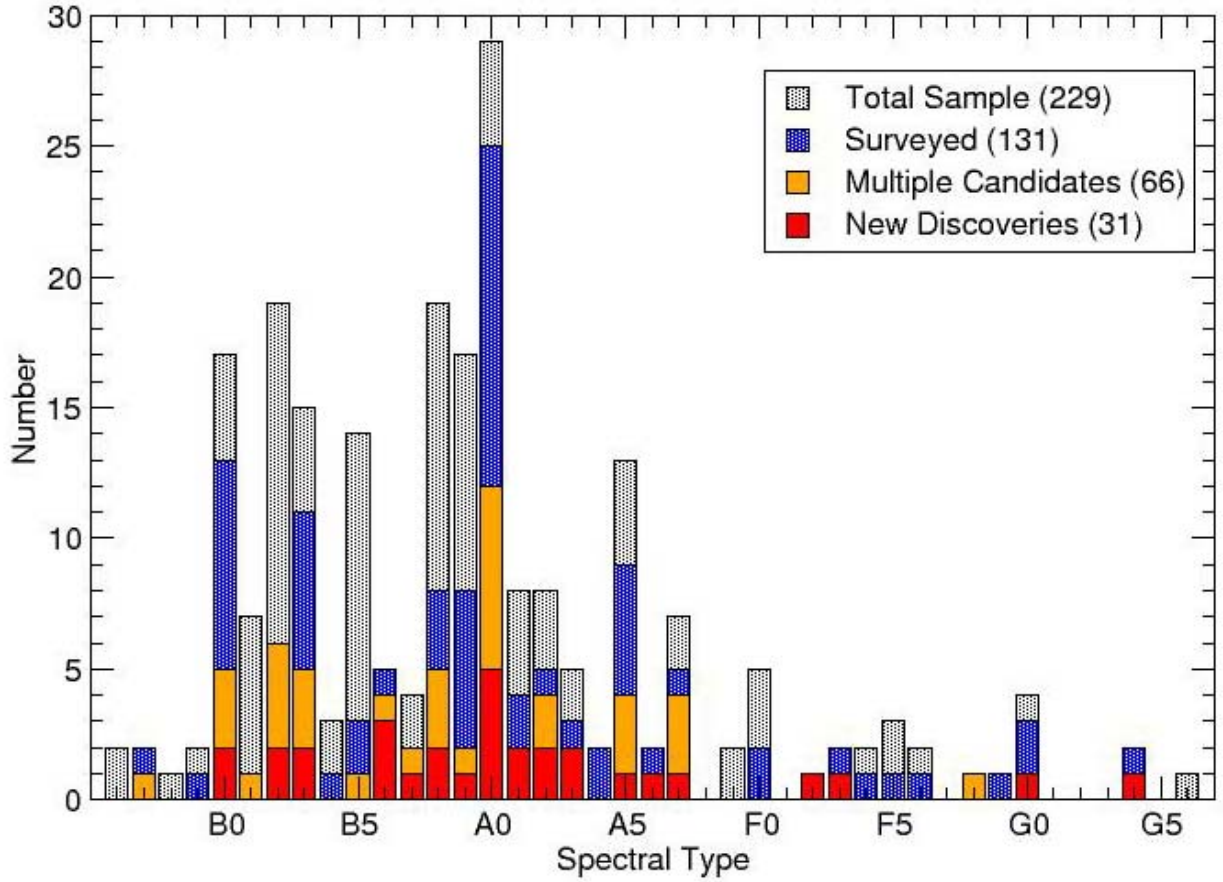
Broaden the sample of multiple HAEBE systems, and investigate their characteristics

- Known Sample: Previous Surveys
- Broaden Sample: AO Imaging
- Verify companionship
- Investigate Companions: NIR Photometry & Spectroscopy, and Mid-IR Imaging

HAEBE Sample

- About 280 stars from Thé et al. 1994, Tables 1-4
- Supplemented with HAEBE stars from literature, e.g. ISO papers
- Spectral types ranging from early B to late F

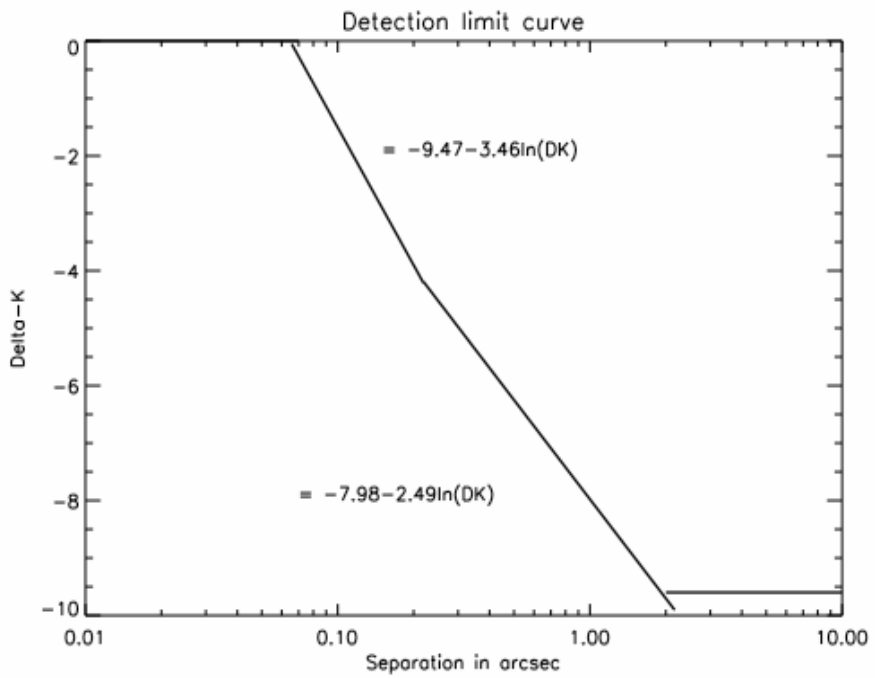
HAEBE Sample



229 HAEBEs with spectral type assigned

AO Imaging

- GN+NIRI/Altair & VLT+NACO
- Deeper and Closer
  - dK=2 @0.1"
  - dK=8 @ 1"
- Larger Sample
- Nearly doubled candidate multiples 35->66
  - ≈50% are multiples (>2)



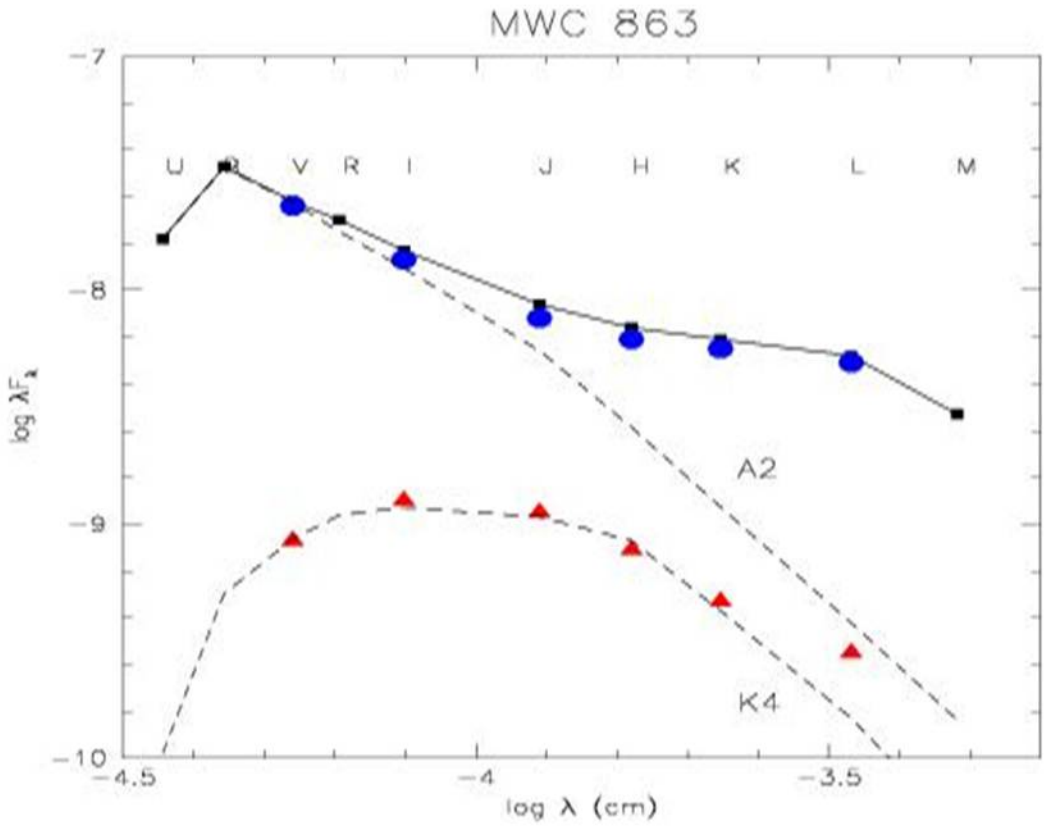
Note: dK(B0-K0) ≈7, while dK(A0-K0) ≈ 3

HAEBE Multiplicity surveys - previous & ours -

Survey	N_{tot}	N_{found}	*Res.*	*Sens.*	*Notes*
Leinert et al 1997	**26**	**11**	**~0.1”**		**Speckle interferometry**
Pirzkal et al 1997	**39**	**9**	**0.4”**	**K=10.5**	**Includes 1/2 of Leinert sample; wide FOV**
Bouvier & Corporon 2001	**63**	**29**	**~0.1”**	**dK=6.5**	**35 in addition to previous; 20 new multiples; small FOV**
This Work	**>80**	**46**	**0.06”**	**K~22, dK≤9**	**Northern sample so far; at least 25 new**

Physically bound?

- Spectral energy distribution



Photometry only
SED unconstraint
Uncertain IR excess

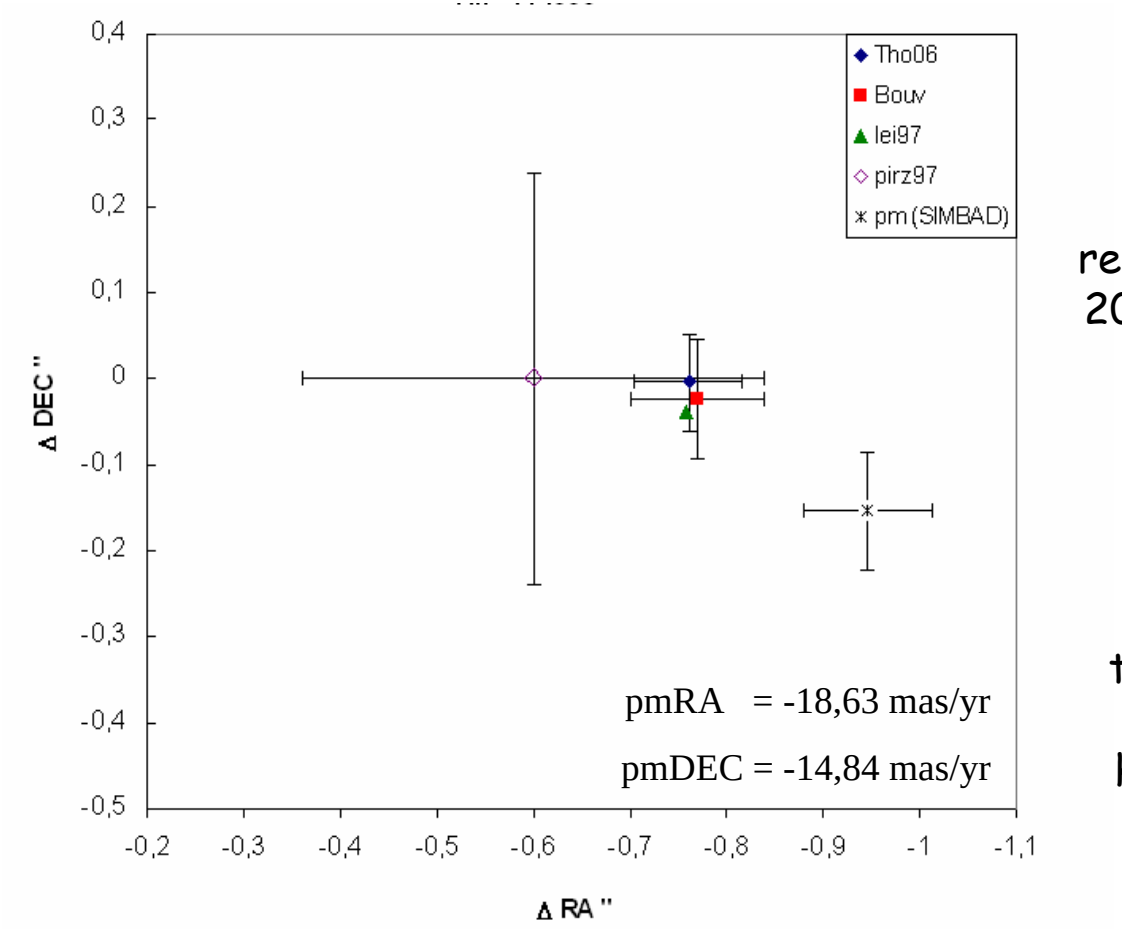
Physically bound?

- Spectral energy distribution
- Proper motion
  - PM available for 72 stars
  - Altair-NIRI images: 0,056"

    => 5,6 mas/yr for a 10 yr baseline
  - 17 objects with enough pm
  - 6 have ang.sep. and PA in literature

3 companion candidates are moving together with primary;
2 are located within error bars;
1 companion is definitely not moving with HAEBE star

HIP 114995



Position of secondary relative to primary in 1997 & 2006, with the 2006 position as a baseline

* *pm (SIMBAD)* indicates the position with respect to the primary if they did not have common proper motion

Physically bound?

- Spectral energy distribution
- Proper motion
- Statistical analysis
  - Probability of finding at least one unrelated source at an angular separation θ:
  - Depends on

    angular separation θ

    surface density Σ (30')

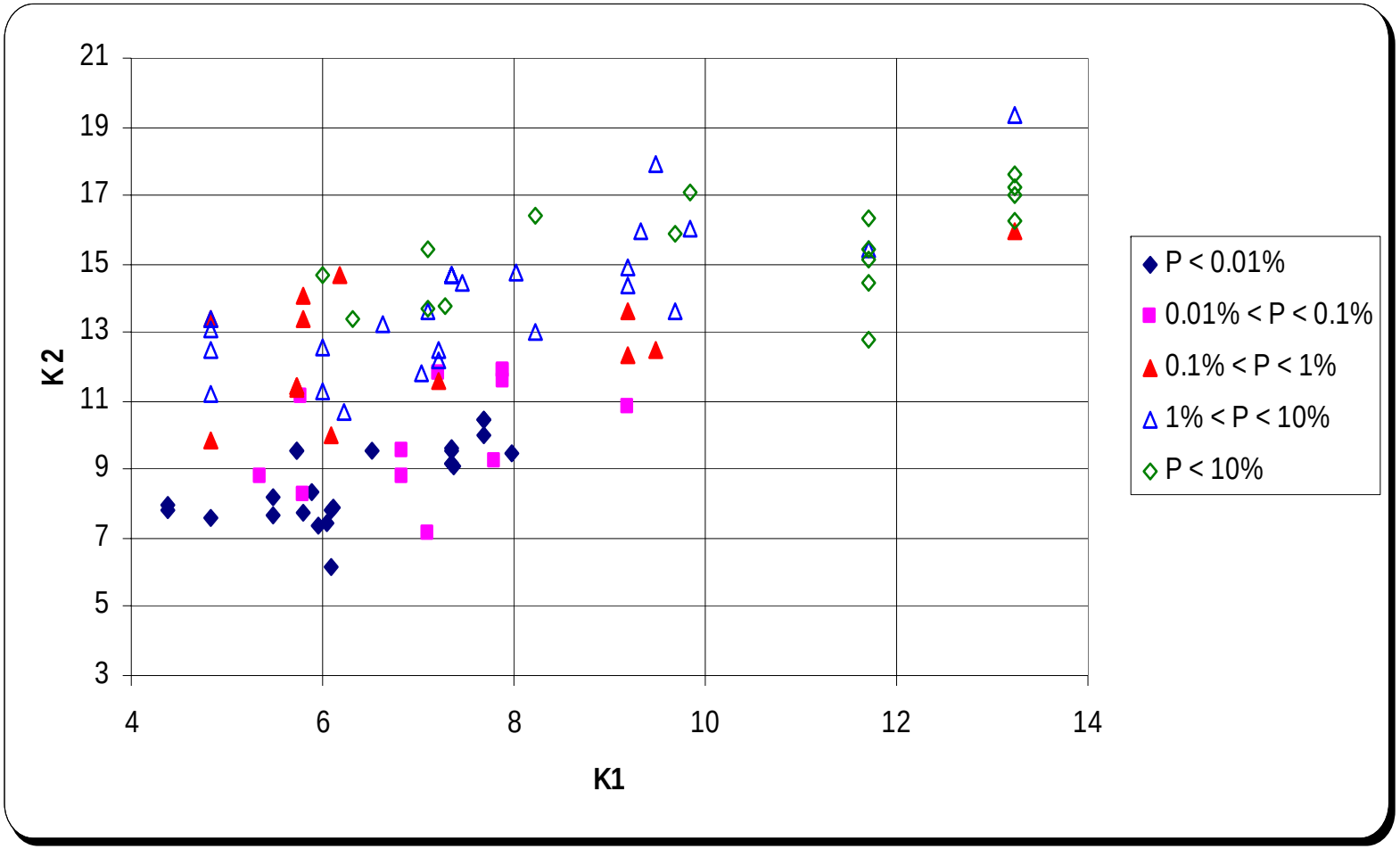
    (secondary magnitude)

$$P(\Sigma, \Theta) = 1 - e^{-\pi \Sigma \Theta^2}.$$

80 pairs of stars (45 primaries)

2/3 of companions have a certainty of 95% of being related

P is probability to find at least one unrelated source within θ



P depends on K2, K-magnitude of secondary star
Open symbols: probability is > 1%

Physically bound?

- Spectral energy distribution
  - Uncertain circumstellar extinction
- Proper motion
  - Multiple observations are needed
  - Only works for stars with fairly large proper motion
  - Not definitive in clusters
- Probability based on surface density
  - Applicable to large sample
  - Depends mainly on K magnitude of secondary
  - Not definitive in clusters
  - Fold in surface density, as function of spectral type

Summary of results
AO Imaging

- Combining those results with previous ones, the total number of HAEBE multiple candidates is 66. We nearly doubled the previously known sample. Survey continues...
- About 50% have more than one possible companion, suggesting a binary fraction potentially greater than 1.
- Proper motion study for 6 stars shows that 3 out of 6 stars move together, 1 does not.
- Statistical analysis based on surface density shows that 2/3 of candidates are likely to be companions, with 95% certainty.
- For stars in clusters it is more difficult to say something conclusive, both based on proper motion and on the statistics.

References

- Ours (so far)
  - Thomas et al. (2006, IAUS 240, 124)
  - AAS 2004 (2), 2006 (4), 2007 (3)
  - Bouvier & Corporon (2001, IAUS 200, 155)
- Others
  - Leinert et al, 1997, A&A 318, 472
  - Pirzkal et al, 1997, ApJ 481, 392
  - Thé et al. 1994, A&AS 104, 315
  - Ducourant et al. 2006, A&A 448, 1235
- This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France