Search and study of companions around Herbig Ae/Be stars

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Abstract

One of the most interesting constraints on star formation models comes from the study of multiplicity of young stars as a function of mass. While multiplicity studies of low mass T Tauri stars have been quite exhaustive, an unbiased and systematic investigation of multiplicity among Herbig Ae/Be stars is still lacking. We are therefore conducting a photometric and spectroscopic study of multiple systems among Herbig Ae/Be (HAEBE) stars, in order to first detect companions and then investigate their properties. The frequency and degree of multiplicity of HAEBE systems will provide new constraints on their formation mechanism.

A critical question in binary studies is whether the apparent companions are physically associated. Spectral information, combined with photometrically-calibrated SEDs, allow us to estimate distance and extinction of the secondary stars to address this question, and in addition investigate their pre-main sequence nature by looking at accretion diagnostics and critical velocity indicators (e.g. NIR excess, emission line profiles, vsini rotation, radial velocity).

Herbig Ae/Be Stars and Their Companions

Herbig Ae/Be:

- Intermediate-mass analog to T Tauri stars
- Pre-main sequence stars of 2-9 solar masses with emission lines
- Usually have a circumstellar disk, and NIR excess
- Tend to form with a high binary frequency (Leinert (1997) and Testi (1997))

Companions:

- Assumed to be T Tauri stars
- Expected to be 3 - 5 magnitudes fainter
- May lack of the expected NIR excess that is associated with T Tauris (Bouvier & Corporon, 2001)
- Spectral types are generally unknown.

Project Overview

The broad goal is to better understand intermediate-mass star formation, to be able to link low-mass and high-mass star formation theories and to study the pre-main sequence evolution of low-mass companions in the vicinity of more massive stars.

How:

- Determine potential companions with an adaptive optics system (for close/faint ones) and with an imager (for wide/bright ones)
- Determine spectral type of the companion (and confirm spectral type of primary)
- Establish binarity of the system (with spectral type and photometric colors)
- Observe emission lines and NIR excess (or lack thereof) to assess pre-main sequence nature
- Study temperature and gravity of true late-type companions to measure NIR excess through continuum veiling. We will measure the vsini rotation from the resolved line widths, and get accurate radial velocity information of the secondary's orbit (from high resolution spectra, R=18000) (Doppmann et al.).

Observations

Need of large telescopes equipped with an AO system like ALTAIR on Gemini north or NACO on the VLT (South).

This poster presents in detail only results obtained with ALTAIR, which allows to resolve companions of similar magnitude down to the theoretical diffraction limit.

The ALTAIR data were taken from Sept 05 until March 06:

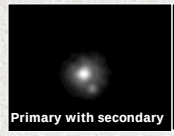
- Magnitude of the targets: 6 to 10 (=> primary as the guide star)
- Filters: K and Br γ
- FoV : 11 arcsec
- Expected resolution : diffraction limited (54mas)
- Pixel size : 21.9 mas.

14 stars have also been observed with the VLT (no included in the following):
4 confirmed binaries: HBC552, HD97300, HBC220, HD95881
2 new potential binaries: ZCMa, CU Cha

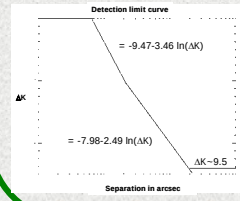
Reductions

Classical reduction (Dark, flat, sky) with the IRAF Gemini package Niri.
Photometry using an IDL version of DAOPHOT (Tokovinin et al):

- fitting of the image of the main star to all sources
- PSF reconstruction:



V350 Ori
ρ=0.29"
θ=207°
ΔK=3.2



Mean detection limit at 5σ

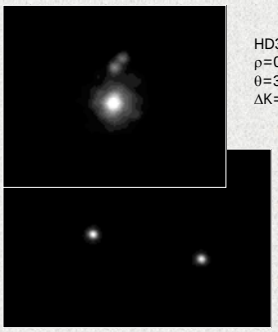
Calculated from targets without companions over the 6 months of observation => average performance.

- ΔK~9.5 for ρ>2"
- ΔK=4 detected for ρ>0.2"

Detection limits from each nights of observation are similar.

Results

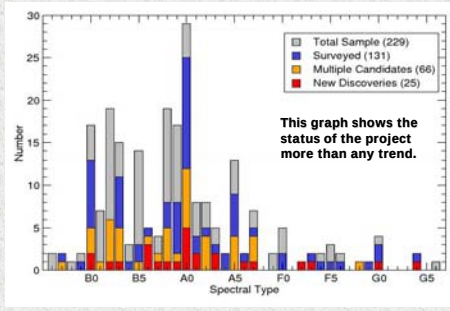
So far we found 41 targets with potential companions.



HD37411
ρ=0.46"
θ=358°
ΔK=3.3

XYPer
ρ=1.33"
θ=257°
ΔK=0.1

Multiplicity as a function of spectral type



List of stars with potential binaries

	Number	rho1 in arcsec	theta1	Dm1
PSCep	2	6.66	310.1	7.9
V628Cas	7	0.76	269.6	2.8
V633Cas	1	5.78	4.4	5.5
V1429Aql	2	1.19	319.3	7.4
V1685Cyg	1	0.72	175.1	5.4
V1977Cyg	1	4.75	54.5	6.6
LkHA147	2	1.63	340.7	3.0
V1493Cyg	3	0.58	294.8	3.2
LkHA168	2	0.31	208.9	2.6
V751Cyg	A lot	0.67	295.0	2.7
V1982Cyg	2	2.01	302.14	7.7
HD235495	4	2.08	297.0	4.6
V390Cep	1	0.30	248.8	5.2
V1578Cyg	4	1.31	309.6	4.6
WWVul	1	7.29	239.7	6.5
ILCep	4	7.80	329.2	0.1
AssCepOB3-71	1	6.17	29.2	8.3
HD245906	1	0.13	77.1	1.5
VVSer	1	7.47	249.6	7.1
HD179218	3	2.54	140.5	6.6
MWC1021	??	0.09	294.1	3.1
LkHA201	2	2.34	325.8	6.2
V700Mon	2	0.15	55.6	3.8
XYPer	1	1.33	256.7	0.1
VYMon	1	2.05	240.7	8.1
V699Mon	1	8.50	226.6	4.8
V1271Ori	1	8.38	294.7	6.7
HBC535	3	3.67	221.3	7.1
V892Tau	1	3.91	23.0	7.6
HKOri	2	0.35	40.8	1.8
CQTau	1	2.09	55.5	8.5
HBC334	> 5	0.44	347	4
RMon	1	0.71	293.6	4.9
HBC531	3	6.61	163.0	5.7
V590Mon	1	5.07	97.1	6.6
HBC324	2	8.01	354.0	3.9
HD36112	1	2.28	311.3	8.3
HD37258	1	0.99	30.3	2.8
BD-061259	1	2.04	46.7	4.0
HD37357	1	0.14	226.3	1.7
HD37411	2	0.46	357.5	3.3
V350Ori	1	0.29	206.8	3.2
BD-061253	1	0.12	232.8	1.4
V385Cep	2	2.84	229.9	7.9
VXCas	2	5.34	165.3	4.8

Known
New
New, debated

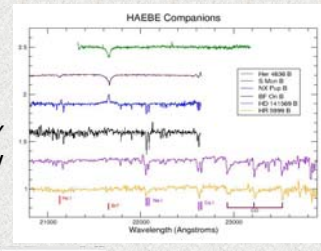
Comparison with other previous studies

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"	ΔK =6.5	20 new (unpublished) candidates; small FOV
This study	72	46	0.06"	ΔK~9.5	Northern sample so far; 31new candidates

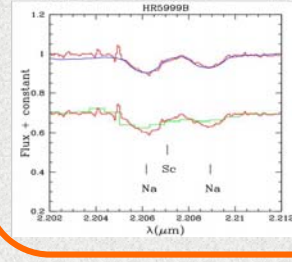
- 46 possible companions: 20 new ; 10 confirm previous studies; 11 no confirmed by other studies (maybe background stars), 5 are ambiguous (very close) and would need to be confirmed.
- 26 without companions up to DK=9 (>2").

Spectroscopic studies

Examples of result of the spectroscopic study obtained with GNIRS



The top two stars are early type while the bottom 4 are late type, as evidenced by Na and CO absorption. Only one star (NX Pup) shows prominent Brγ emission.



R=18,000 GNIRS spectrum of HR5999B (in red), fit to a synthetic model (in blue) of Teff=3700 K, log(g)=4.0, vsini=116 km/s, veiling of 1.0. Green plot = same source observed at R=1700 GNIRS. Structures in the Na and Sc lines only visible at high resolution => better characterization of the physical state of these late-type secondaries.

Conclusions and next steps

1. Combining those results with previous ones, the total number of HAEBE binary candidates is 66. We nearly doubled the previously known sample.
2. About 50% have more than one possible companion, suggesting a binary fraction potentially greater than 1.

Next steps:

- Determine physical association with near-infrared photometry and spectroscopy.
- Spectroscopic data for true companions:
  - study of their circumstellar disks (infrared-excess),
  - pre-main sequence activity (emission lines)
  - rotational and radial velocity (line widths)

Goal = understand the nature of the companion stars and the effect of the nearby primary on their formation.

References

- Doppmann et al. 2003, AJ 126, 3043
- Bouvier&Corporon, 2001, IAU 200, 155
- Leinert et al. 1997, A&A 318, 472
- Tokovinin et al, A&A, 450, p681, 2006
- Testi et al. 1997, A&A, 320, 159
- Pirzkal et al., 1997, ApJ, 481, 392
- Thé et al. 1994, A&AS, 104, 315