

# Astrometric Study of the Stellar and Substellar Populations of the Orion star Forming Region

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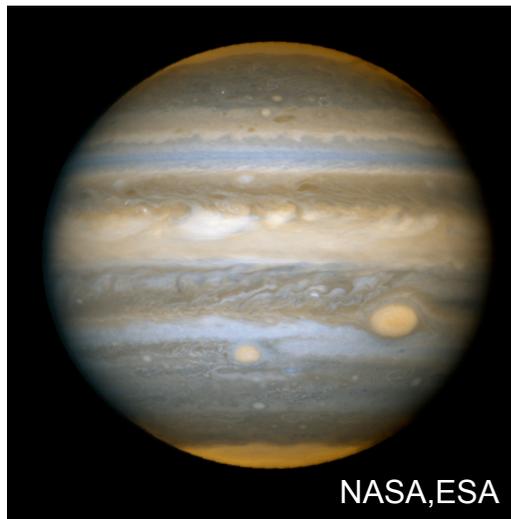
Jesus Hernandez, Nuria Calvet & Lee Hartmann  
University of Michigan, USA

Cecilia Mateu  
Centro de Investigaciones de Astronomía, Venezuela

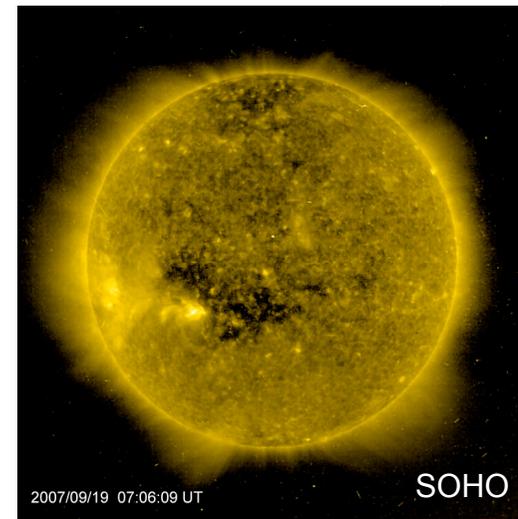
# GOALS

- Study the continuity across the substellar limit of observables associated with star formation and the early stellar evolution.
- Find and characterize the very low mass stars ( $M < 0.3 M_{\odot}$ ) and brown dwarf ( $0.072 < M/M_{\odot} < 0.02$ ) populations of subregions in the Orion SFR with ages spanning the first  $\sim 10$  Myr.

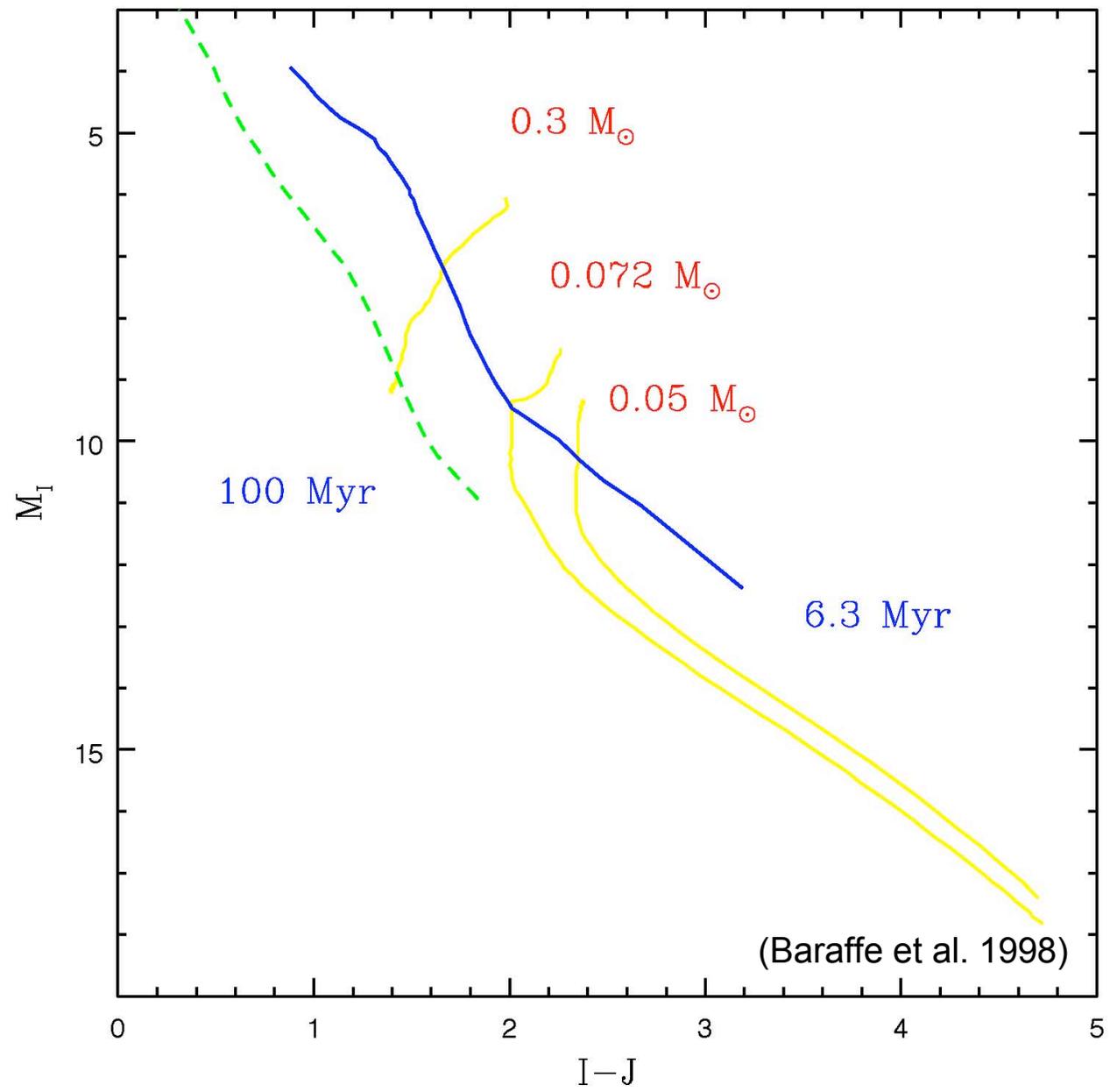
# The definition of Brown Dwarf



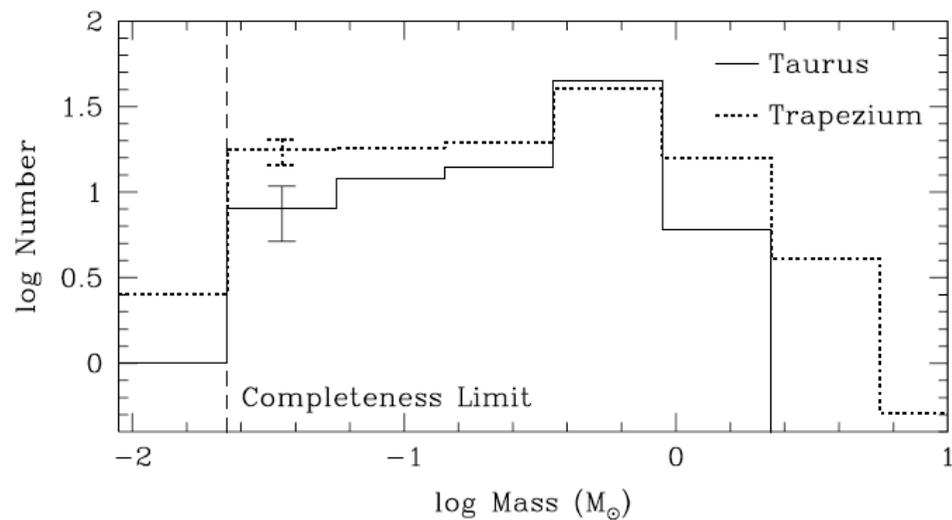
$\leq 0.001 M_{\odot}$   
(Oppenheimer et al. 2003)



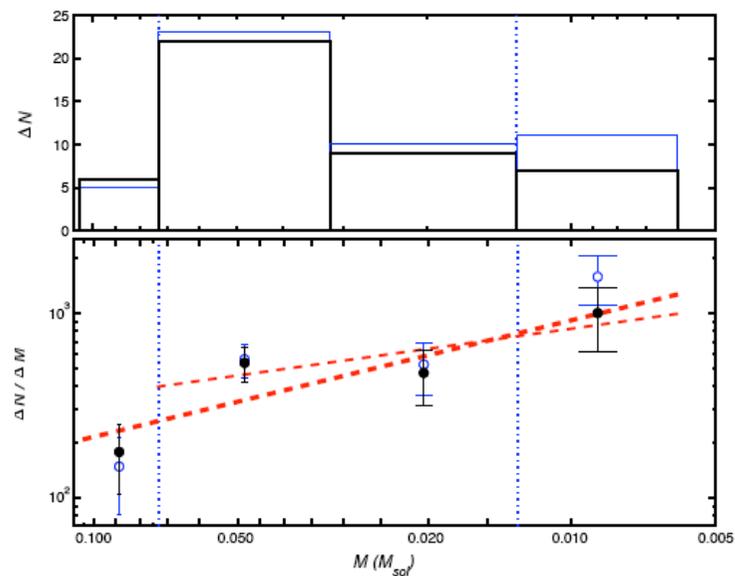
$> 0.072 M_{\odot}$   
(Baraffe et al. 1998)



# The relevance of brown dwarfs



(Briceño et al. 2002)



(Caballero et al. 2007)

# The CIDA Orion Survey

(Briceño et al. 2007b)

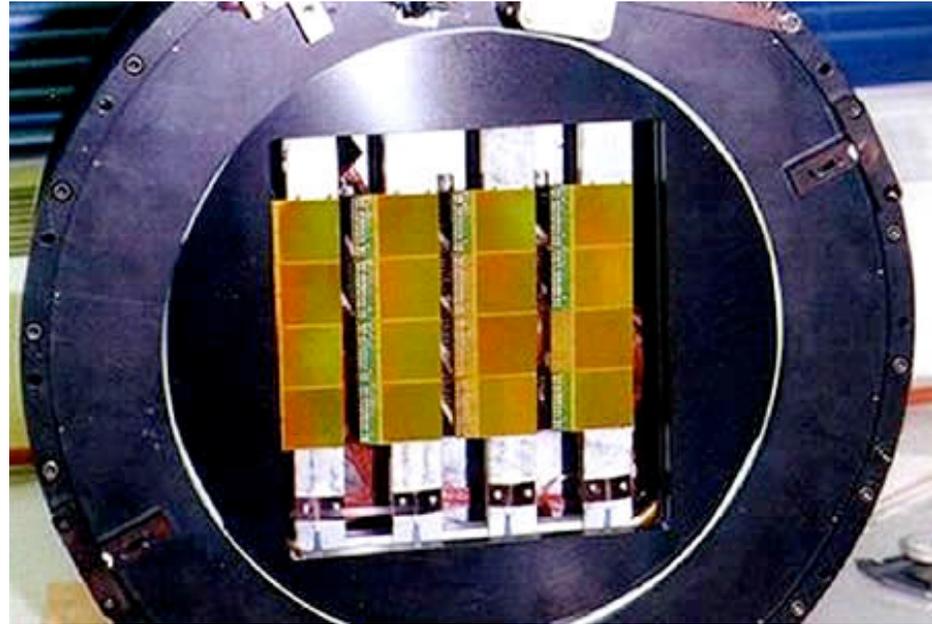
- 1/1.2 m Jürgen Stock Schmidt telescope + Quest-I camera
- Limiting magnitude I ~ 19
- ~ 180 squares degrees divided in 6 declination strips
- Multi-band observations (H $\alpha$ , B, V, R and I)
- Observations made since 1998
- ~ 40 to ~ 110 observations in each strip in B, V, R and I during the last 10 years



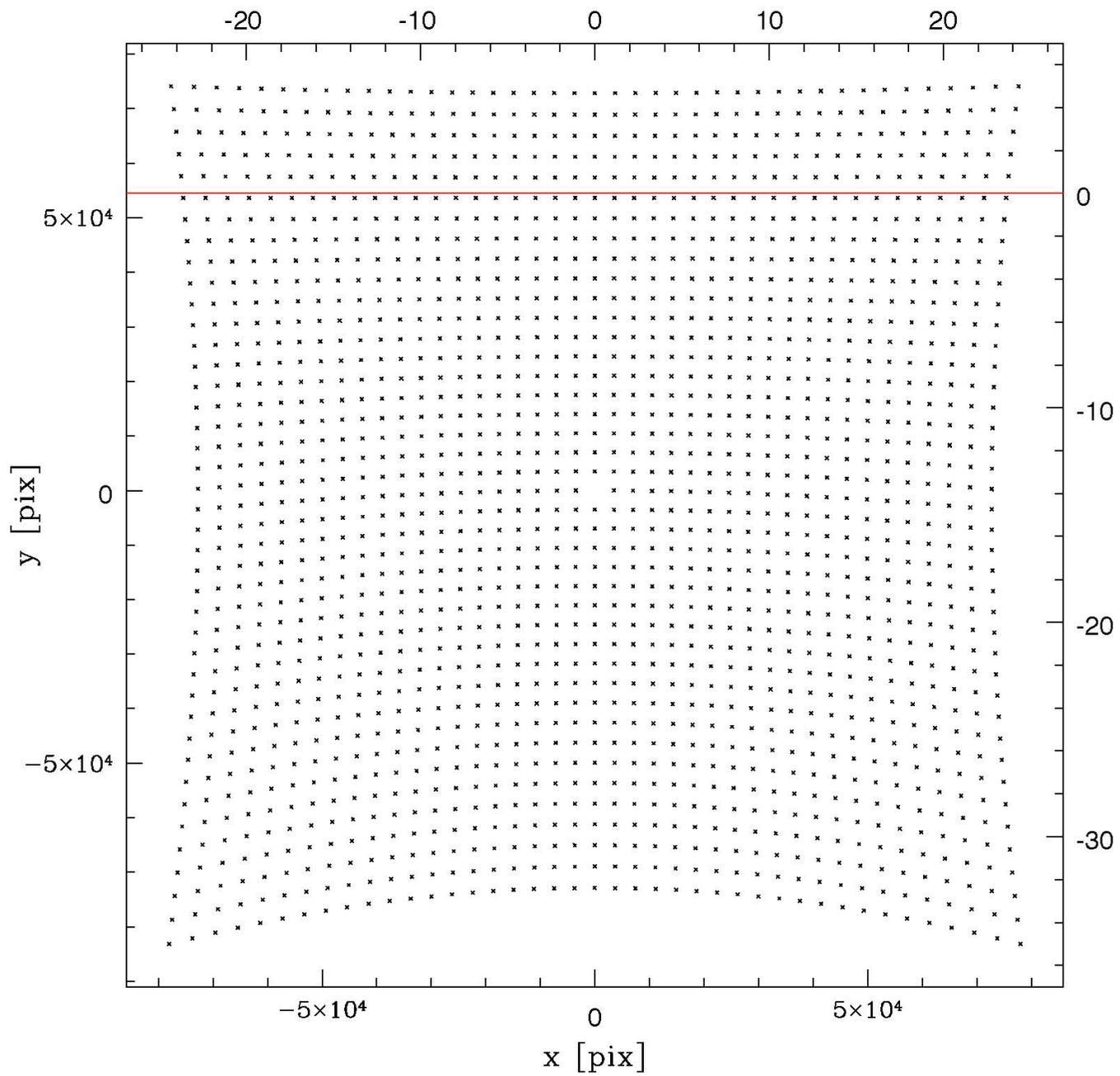
Adela 2008

# The Quest-I Camera

- Drift-Scan observations
- 16 ccd mosaic
- Scale 1.03 "/pixel
- Field of view  $\sim 4$  sq.deg
- Quasi-Simultaneous observations in 4 filters

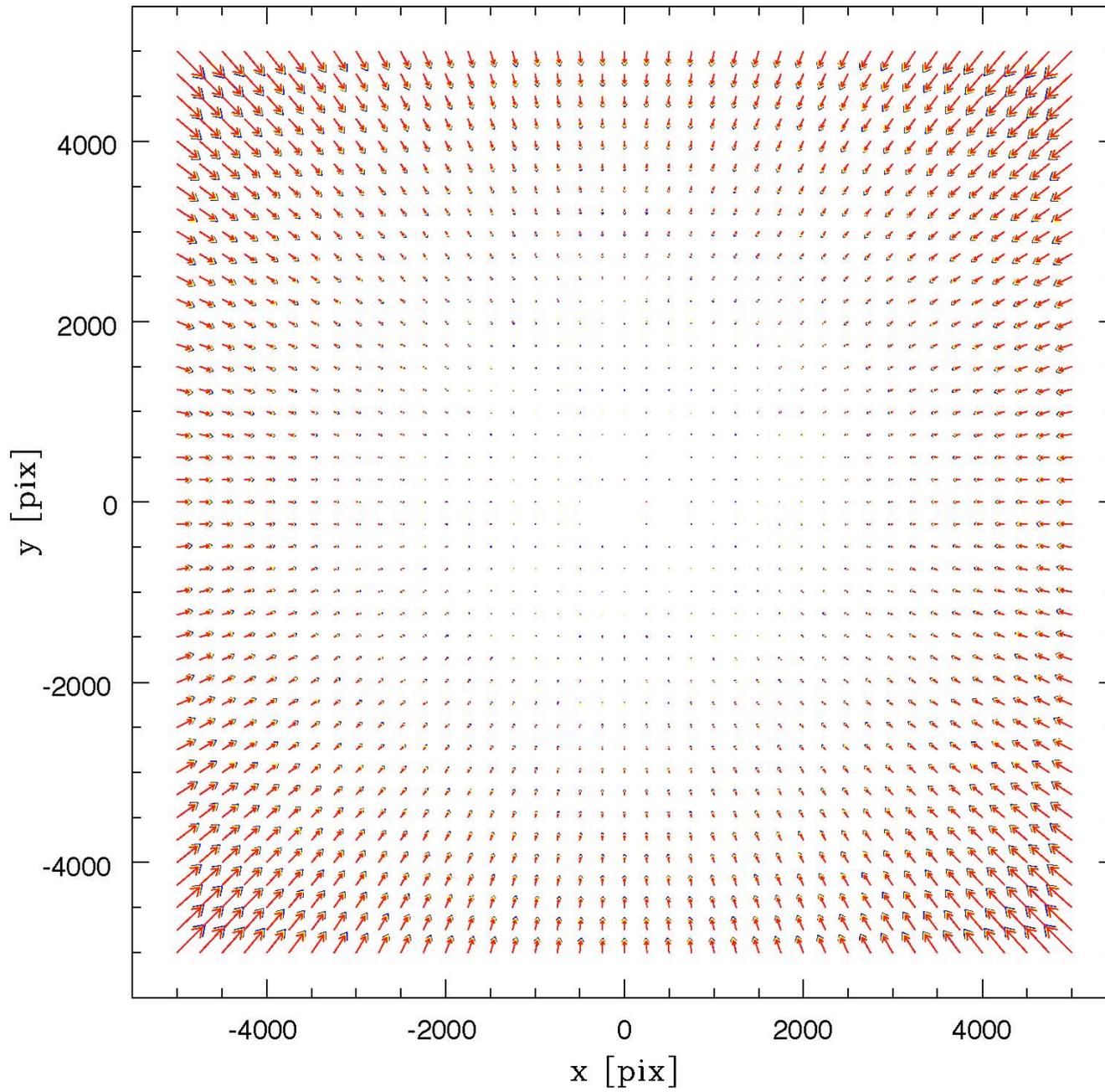


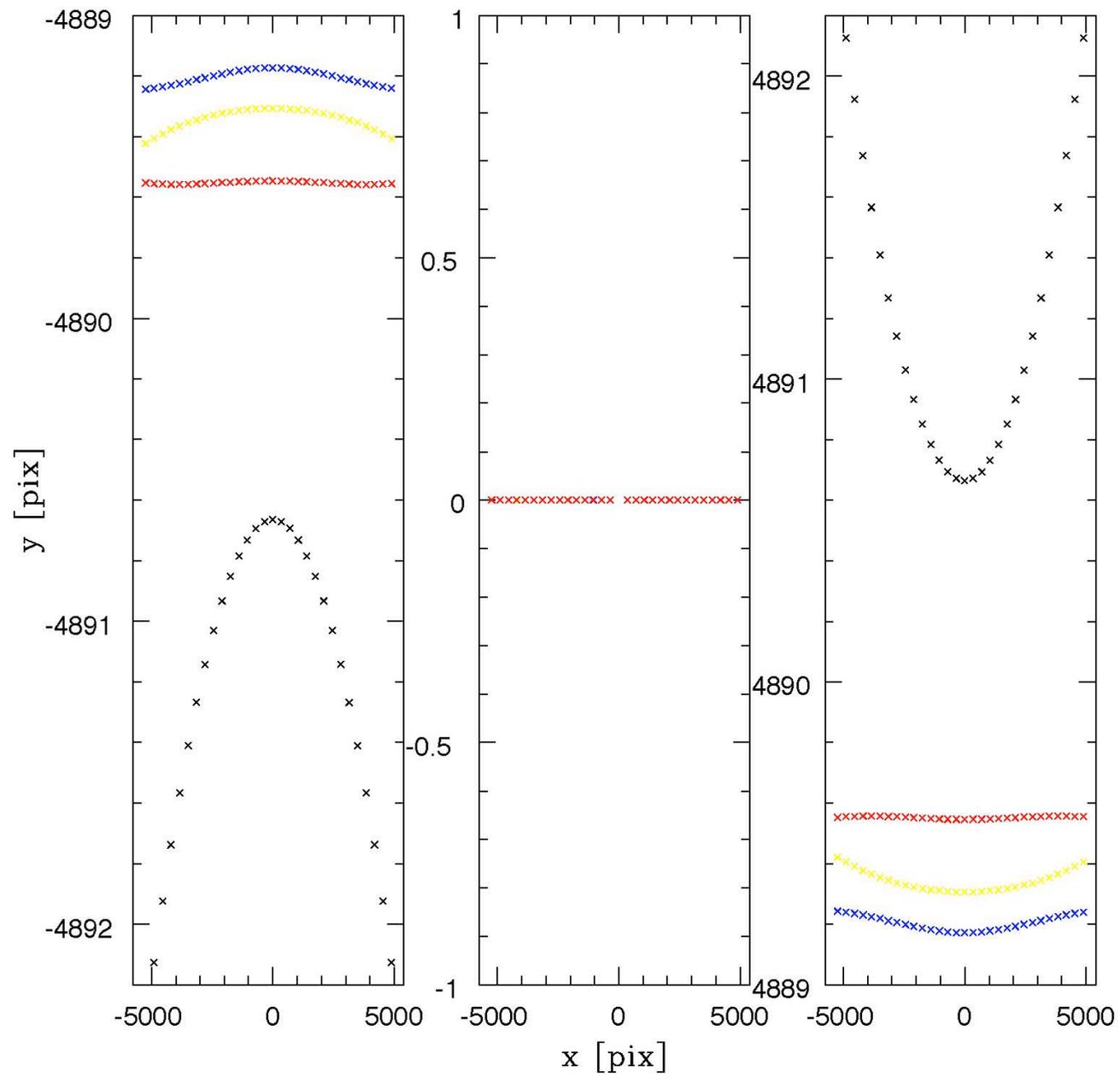
- The positions in  $\alpha$  depend on the read-out rate of the ccds
- The positions in  $\delta$  are affected by the camera's optical system
- The integration time is fixed for a given declination



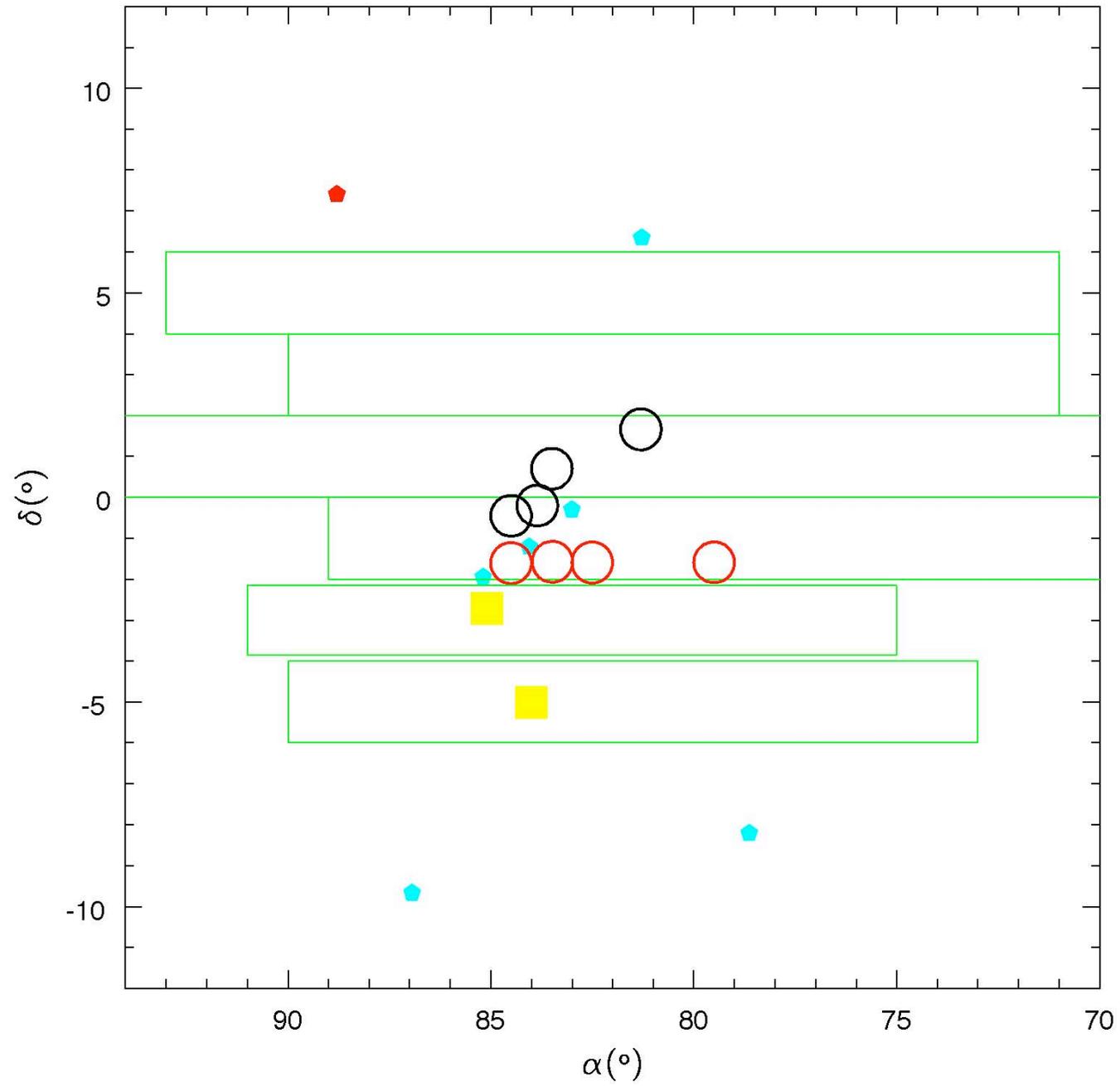
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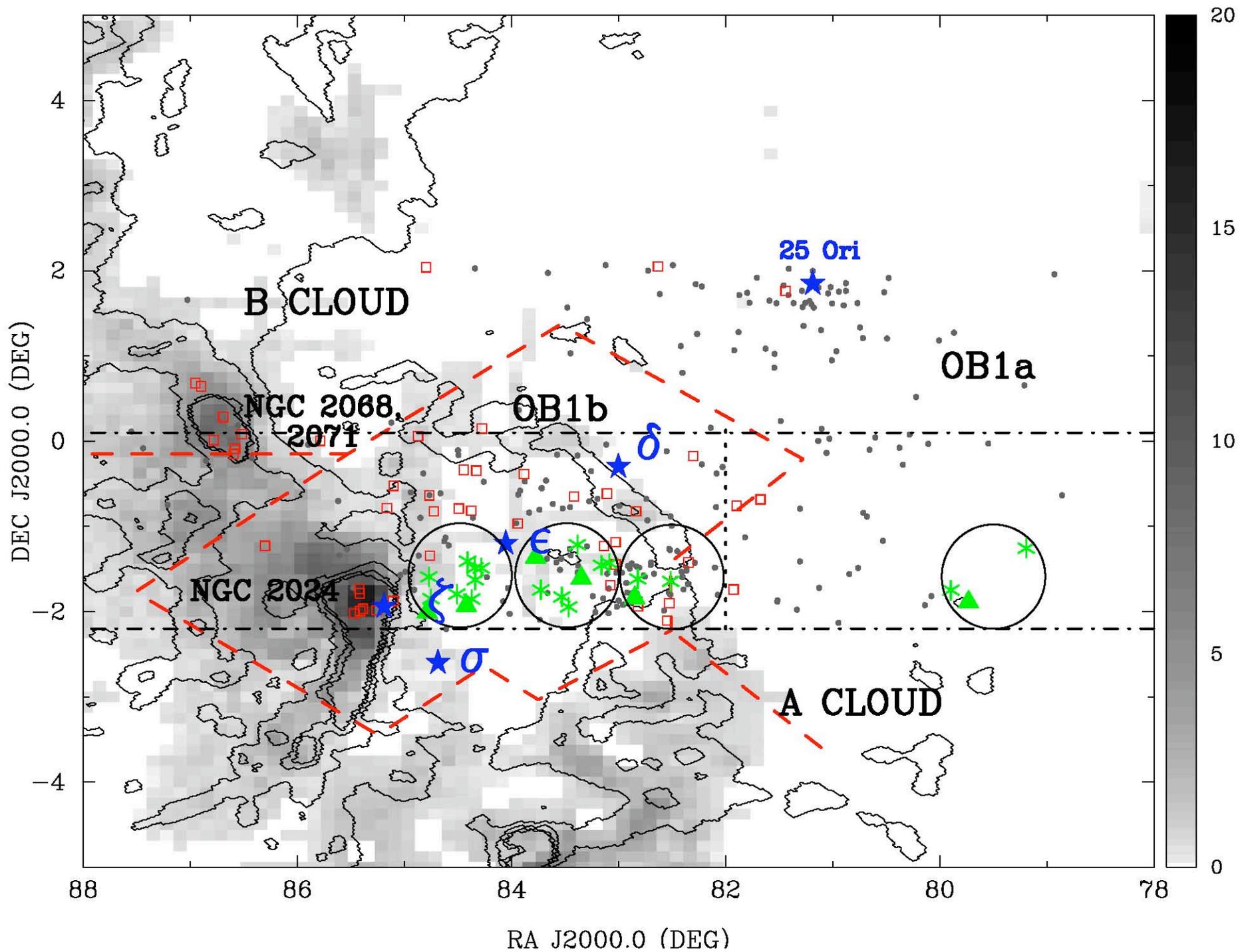
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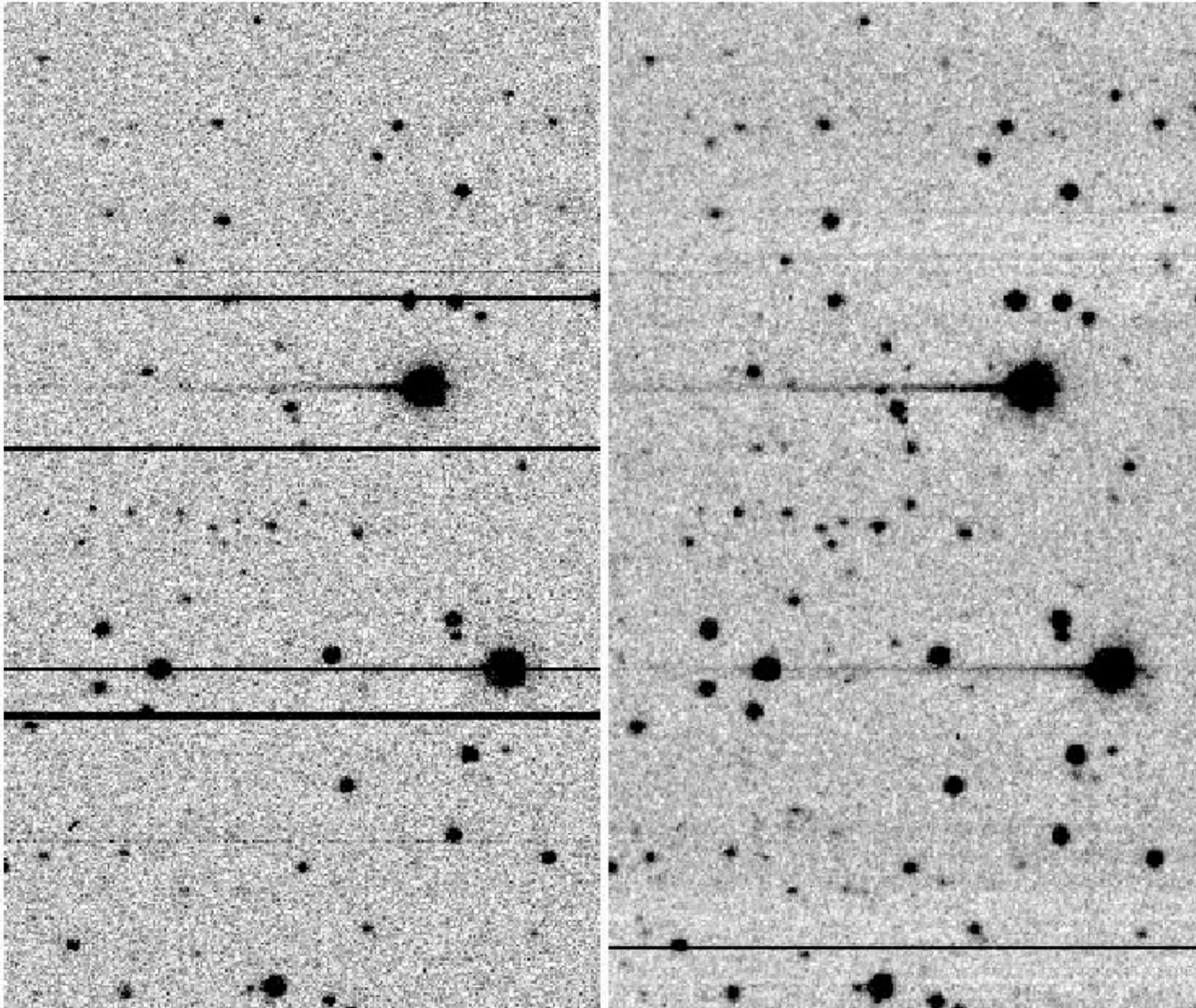




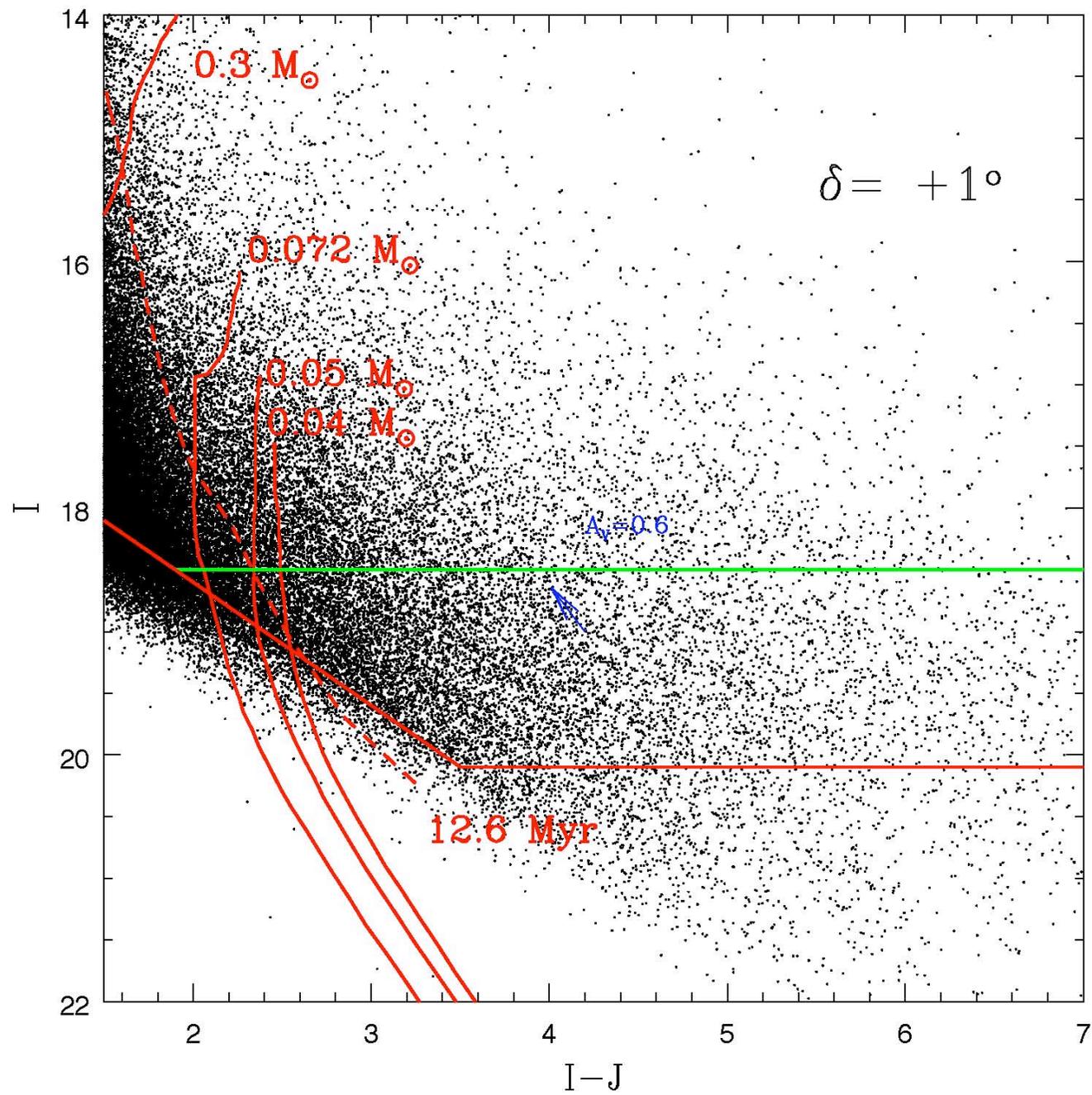
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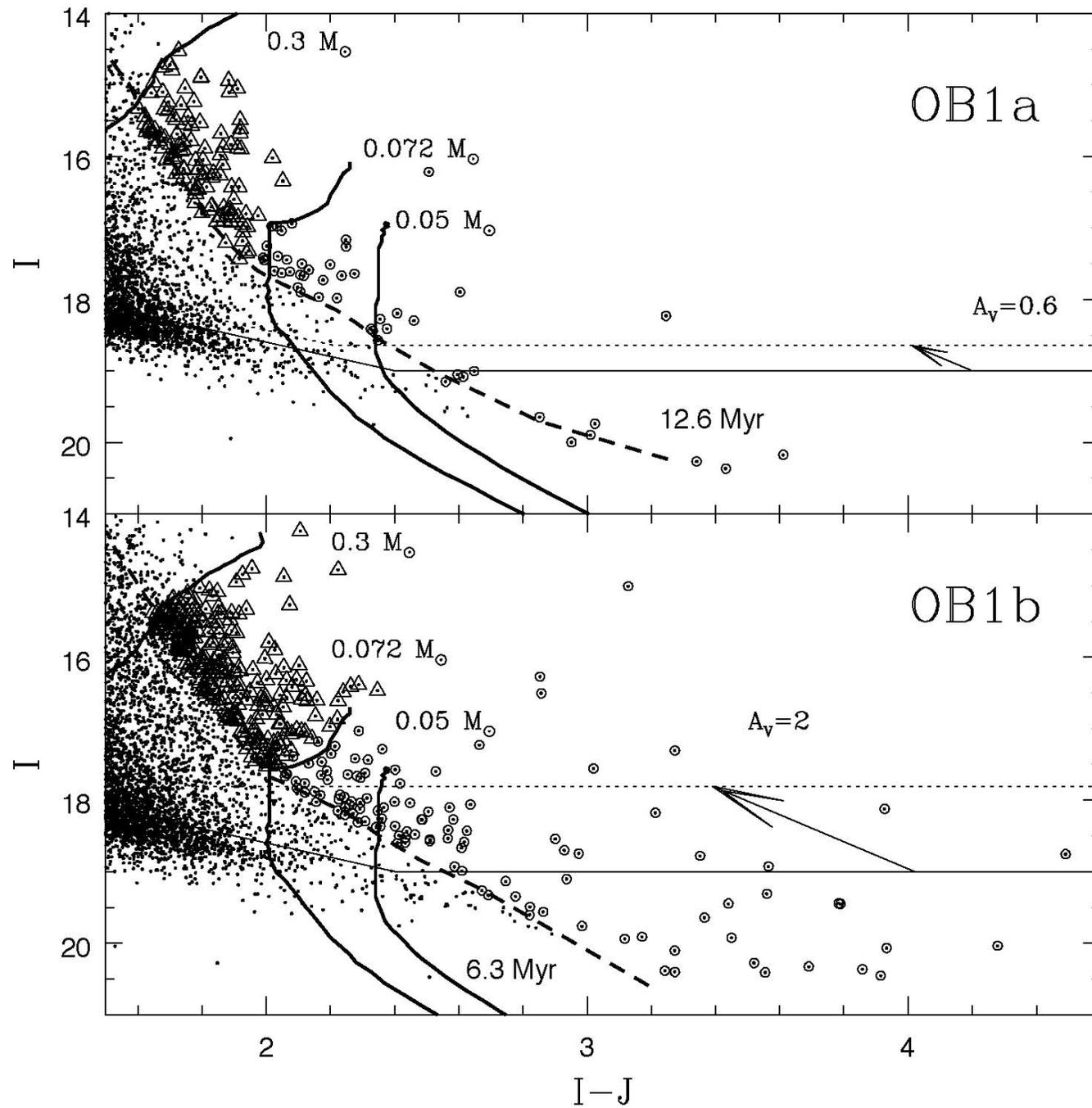


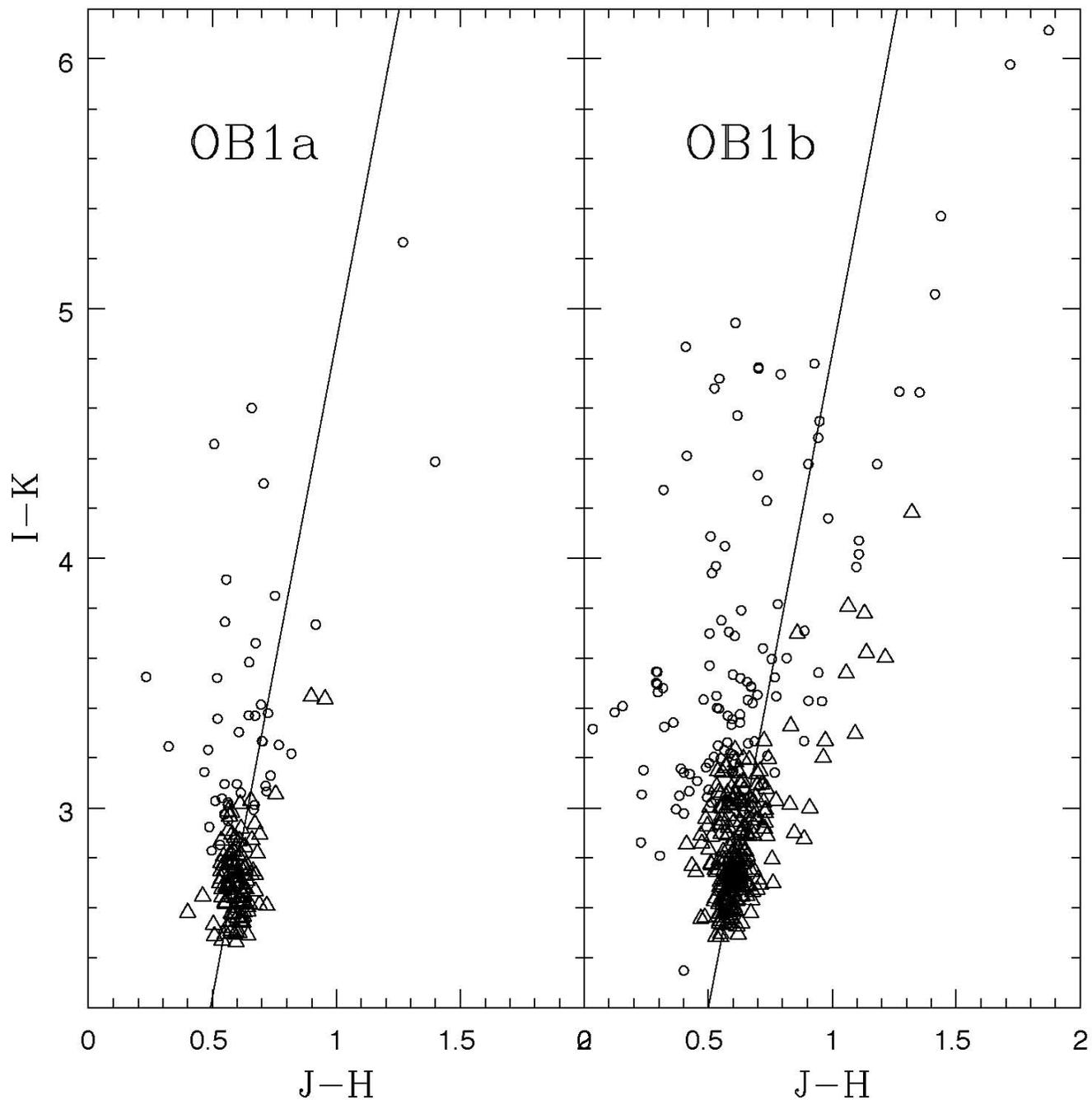
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# FIRST RESULTS

(Downes et al. 2008 submitted AJ)





# THE MEMBERSHIP CONFIRMATION AND SUBSTELLAR STATUS

Spectral features such as  $H\alpha$  and  $N_{II}$  can be used as youth indicators allowing the membership confirmation of photometric candidates.

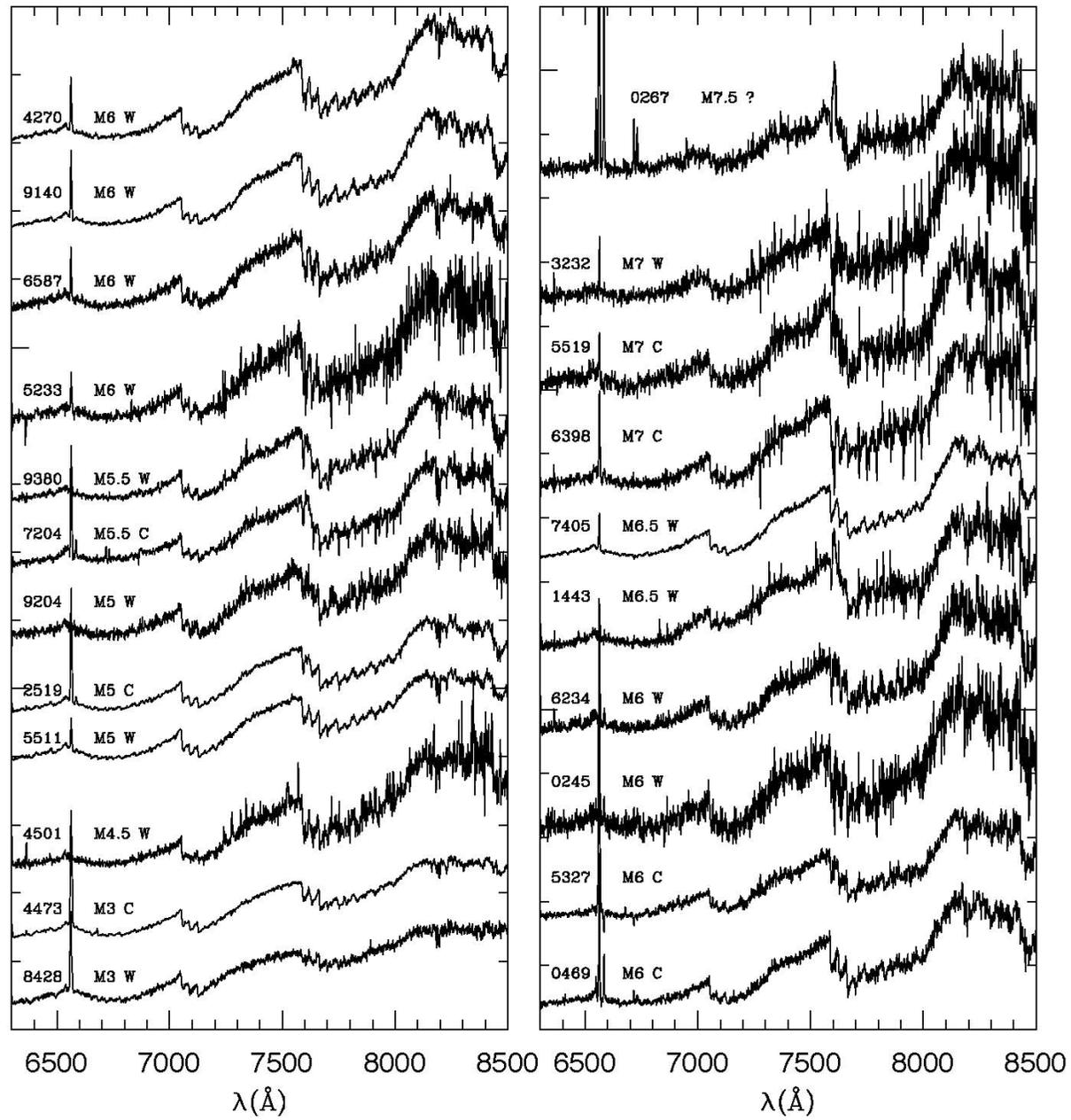
Spectral classification allows the confirmation of substellar status. At  $\sim 10$  Myr objects later than M6 are bona fide brown dwarfs.

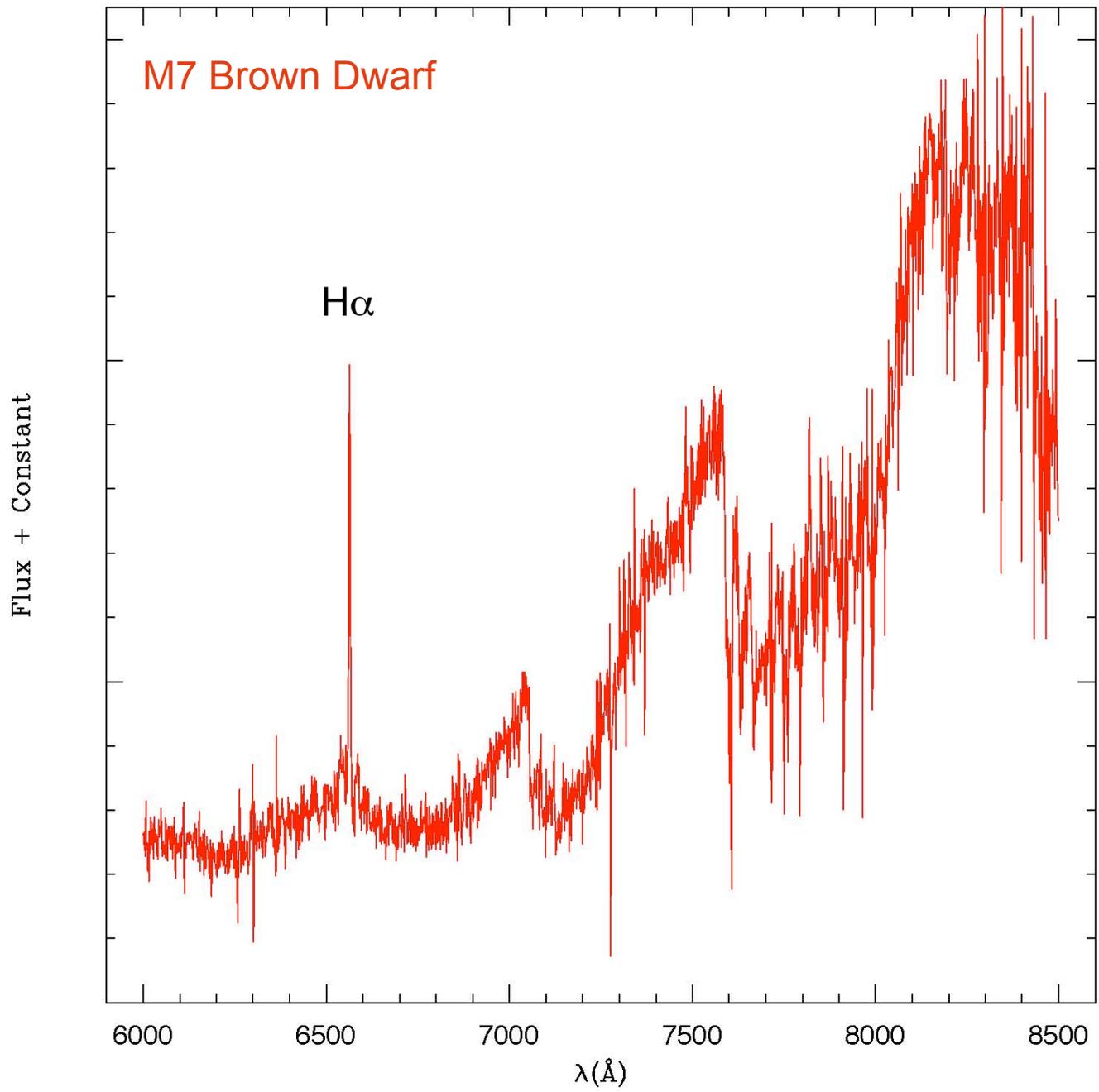


MMT (6m class telescope) + Hectospec (low resolution spectrograph ~300 fiber in 1 sq.deg)

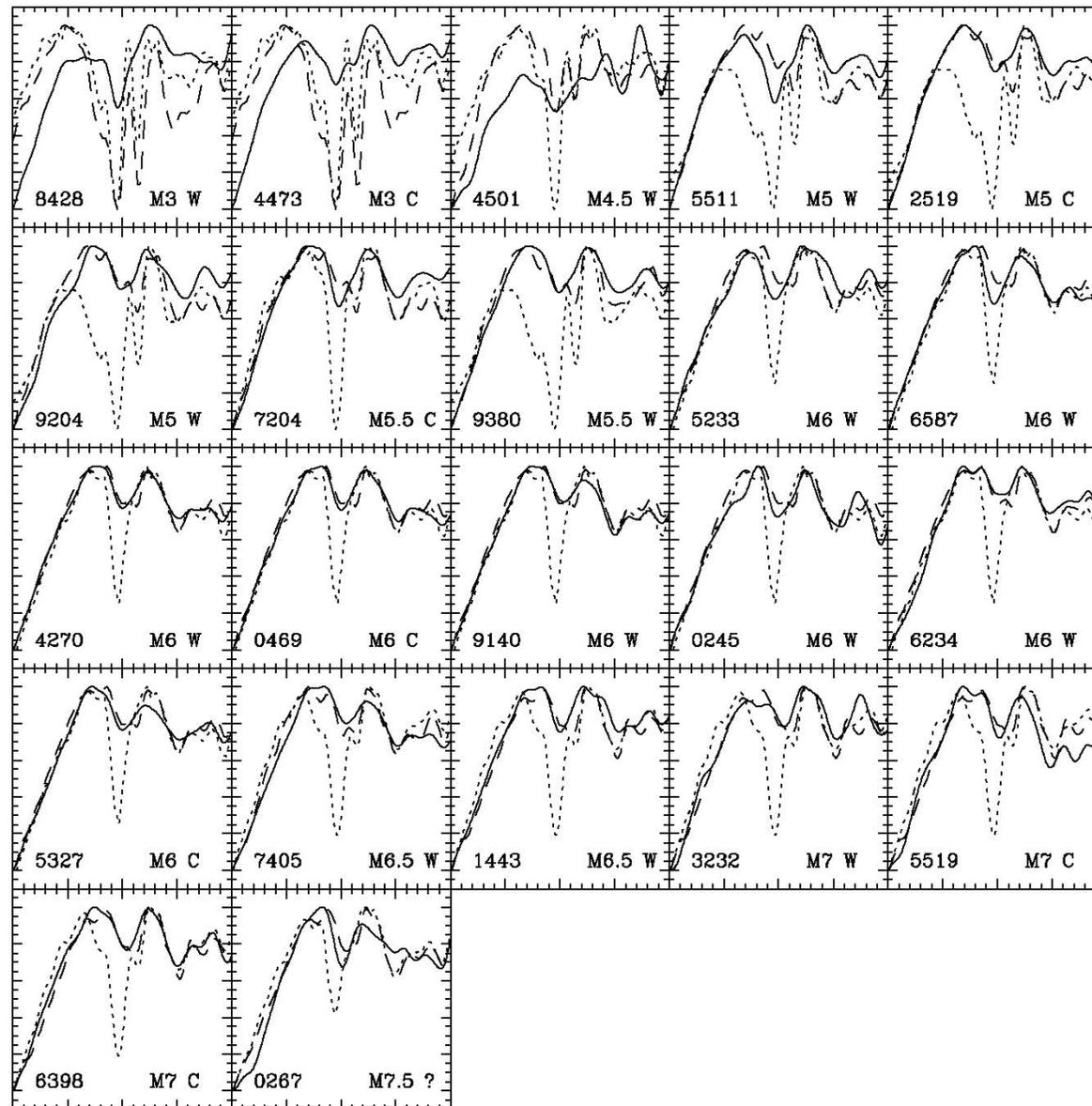
Integration time = 45 m (substellar limit) to 150 m (BD domain)

Flux + Constant



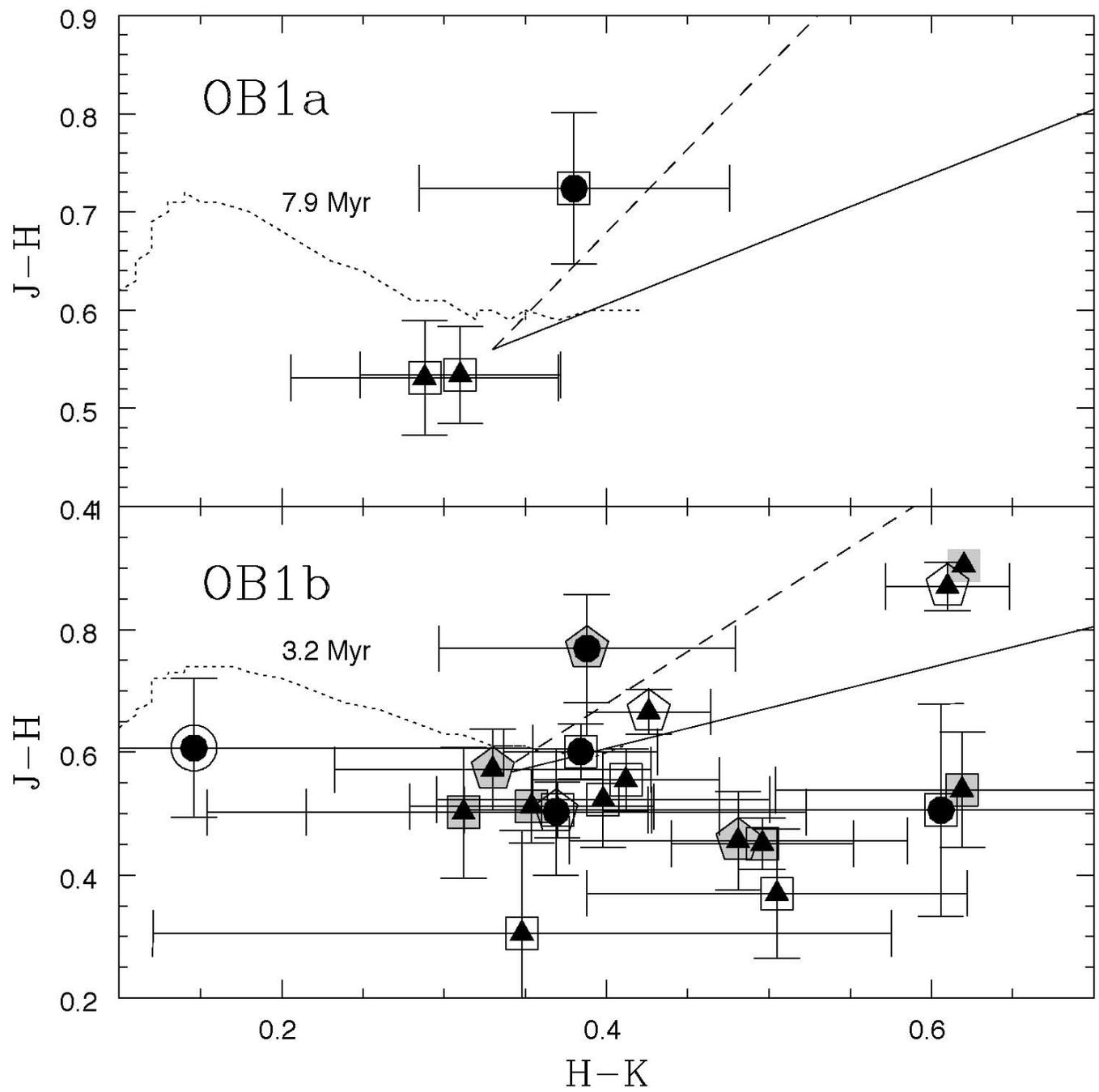


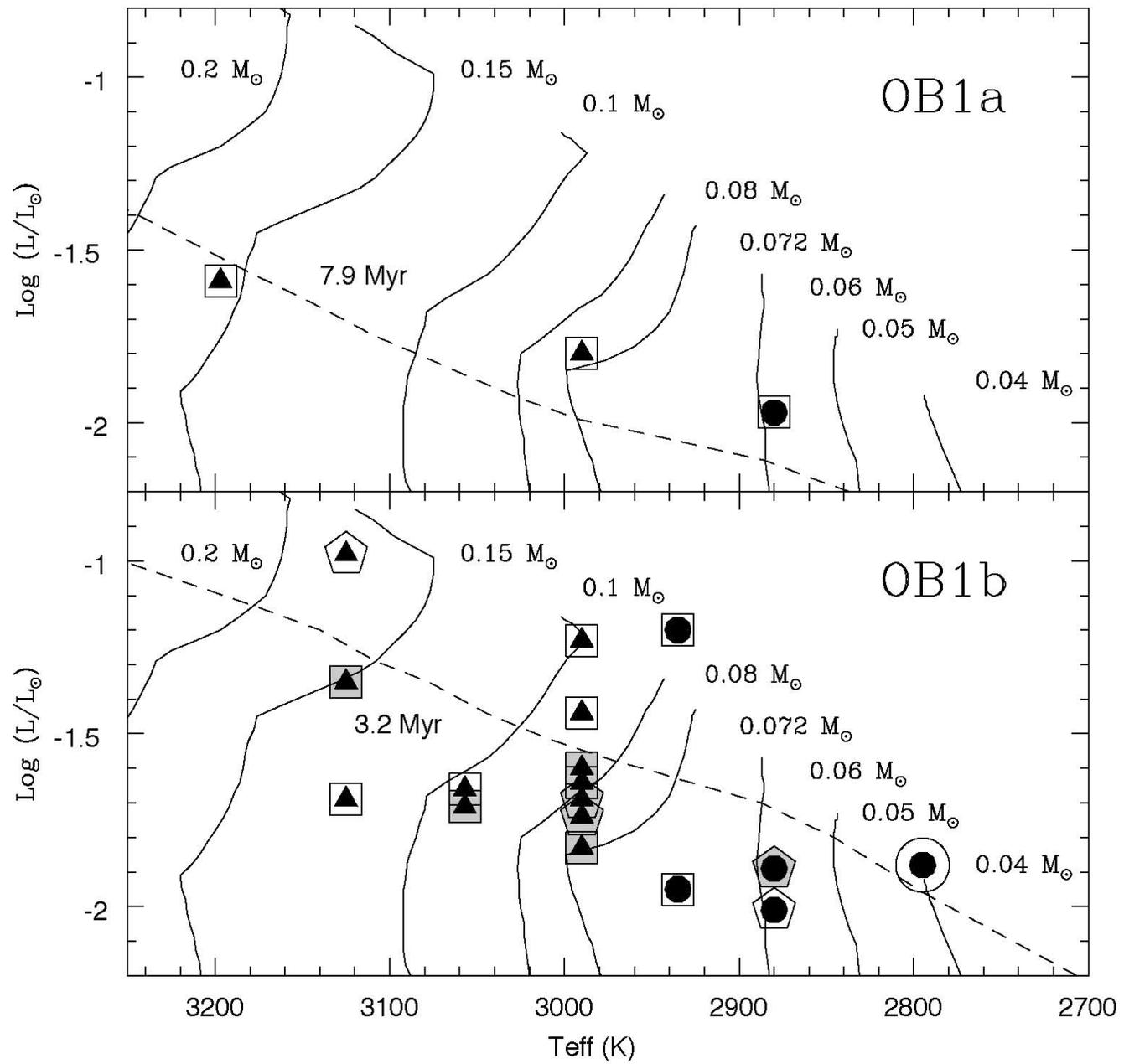
Normalized Flux



$\lambda(8000 - 8400 \text{ \AA})$







# INITIAL RESULTS IN THE DISPERSED POPULATIONS OF ORION SFR

Completeness	OB1a 0.05 Mo with ( $A_v < 0.6$ ) OB1b 0.072 Mo with ( $A_v < 2$ )
Optical spectra	OB1a 4 candidates ( $\sim 0.8$ deg) OB1b 26 candidates ( $\sim 2.5$ deg)
New members	OB1a 3 (1 M7 BD) OB1b 19 (5 M6-M7.5 BD)
TTS	OB1a All new members are WTTS OB1b 50 $\pm$ 35 BD are CTTS 36 $\pm$ 16 VLMS are CTTS
IR excess	OB1a All new members have photospheric colors OB1b 2 of 6 CTTS show infrared excess $> 0.2$

# INITIAL RESULTS IN THE DISPERSED POPULATIONS OF ORION SFR

Given the large uncertainties, these results are consistent with the corresponding WTTS/CTTS fractions in the same regions at the stellar regime reported by Briceño et al 2007b (6-11%, OB1a ; 13-23%, OB1b).

The difference in the number of substellar objects with indications of ongoing accretion between the two subregions suggests that disk fractions fall off in very much the same way for stars and brown dwarfs. This has been seen in other clustered environments of Orion such as Trapezium (Muench et al. 2001) suggesting that in the wide spread low stellar density regions the situation is the same.

Only 2 of 6 CTTS show IR excess. A possible explanation is that the settling of the dust in the disks of some objects with masses near the substellar limit may occur while there is ongoing gas accretion during the first  $\sim 4$  Myr.

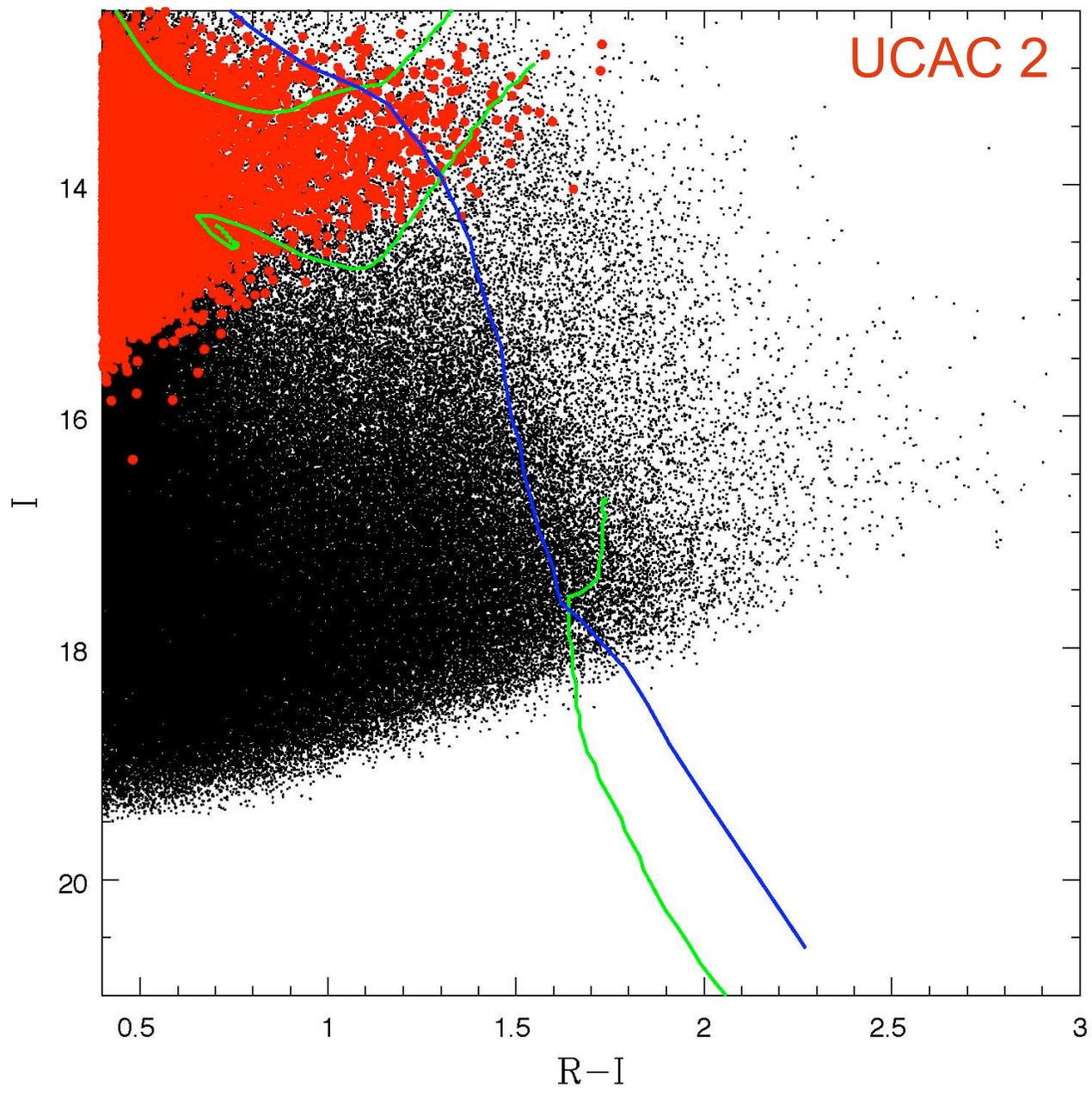
However, existing samples are still too small to establish the reality of any variation in disk properties across the substellar limit.

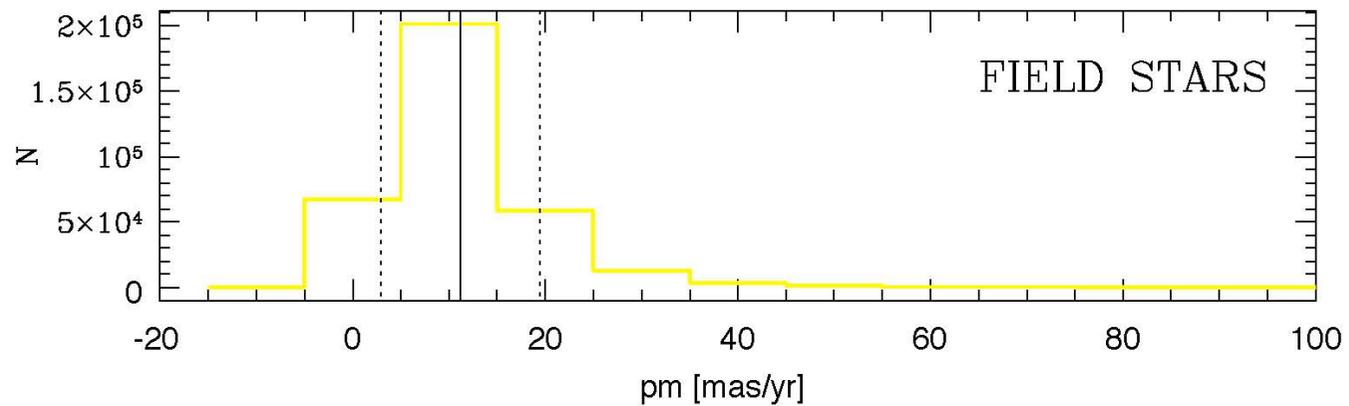
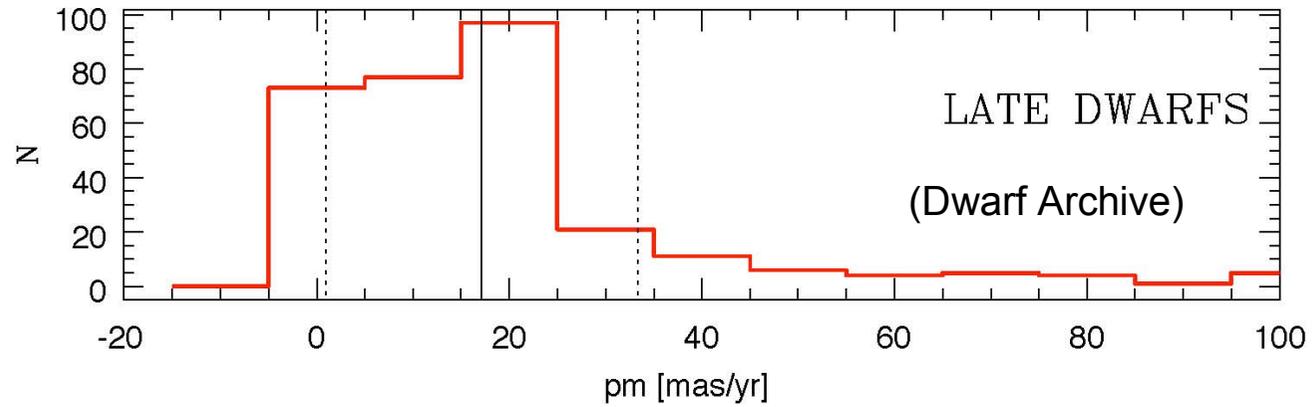
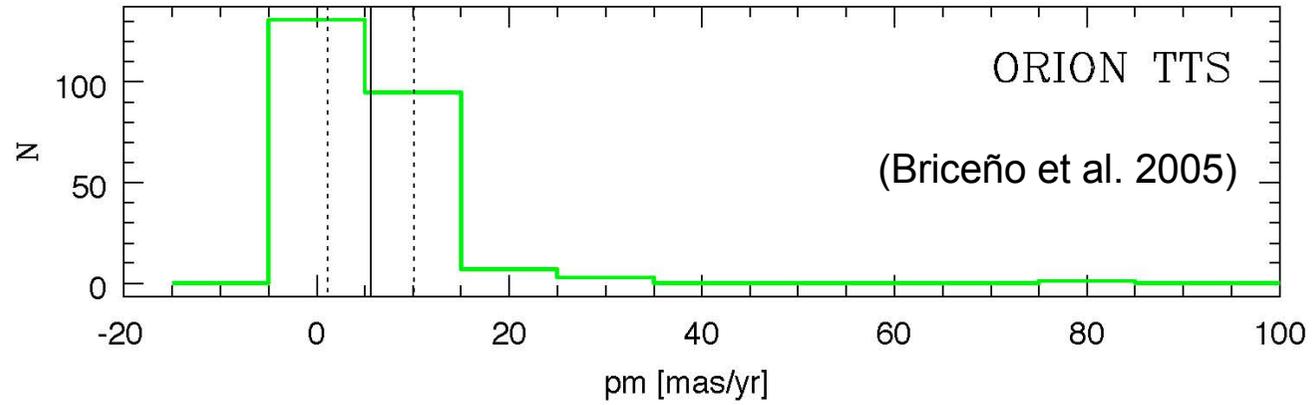
# THE MEMBERSHIP CONFIRMATION OF THE ENTIRE CANDIDATE SAMPLE

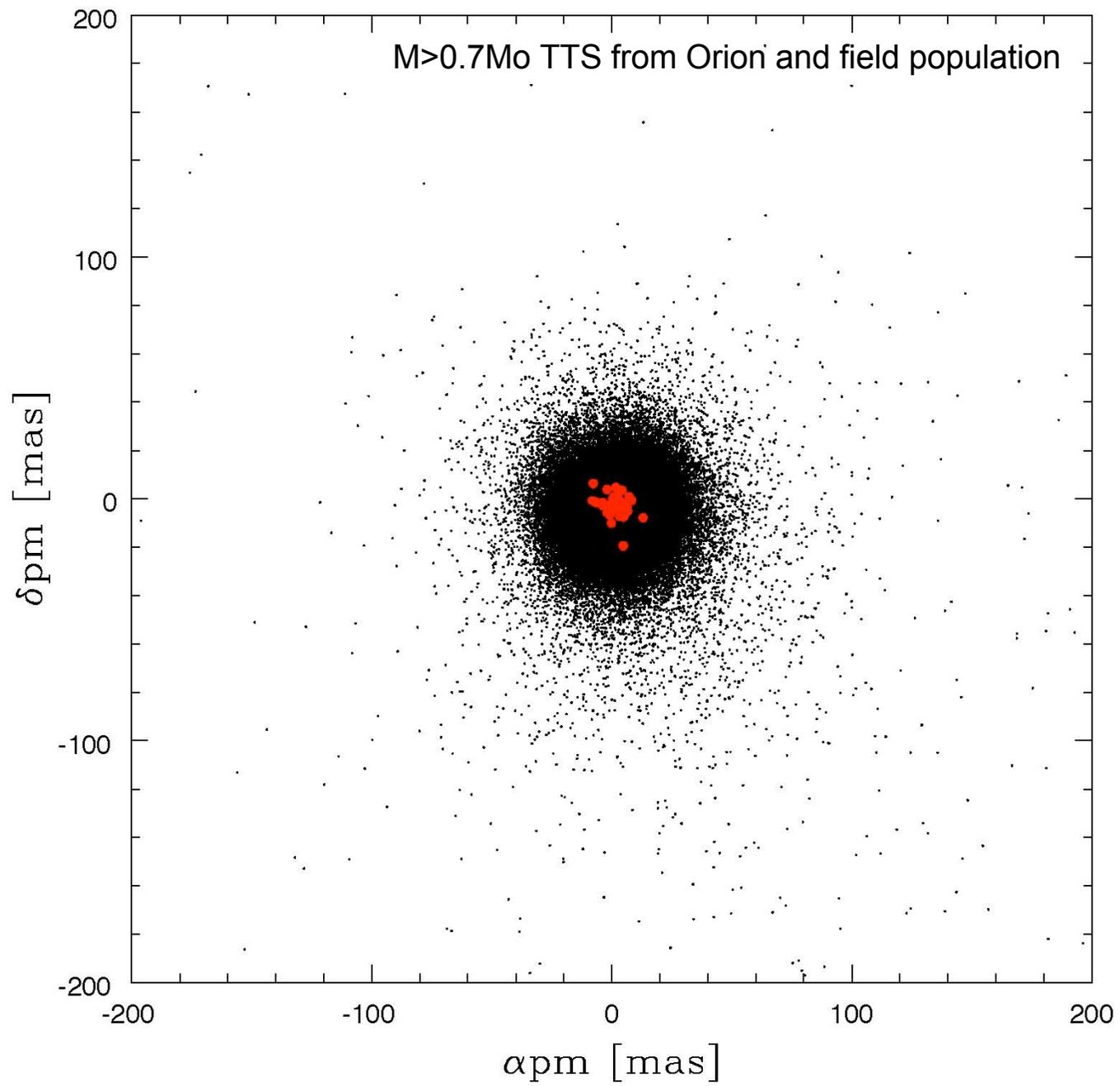
- High number of candidates (  $\sim 7000$  )
- Low spatial density (  $\sim 40$  in OB1b and  $\sim 10$  in OB1a )
- Faint magnitudes (  $17 < I < 22$  )  $\Rightarrow$  Long integration times
- = Is not possible to obtain spectra for each candidate.

# THE FRACTION OF NON MEMBERS

- ~ 20 % of the spectroscopically observed candidates result to be reddened early M stars from Orion and late dwarfs ( $>M3$ ) from the foreground.
- Our goal is to explore whether proper motions and photometry could produce a better selection of candidates detecting the foreground population.



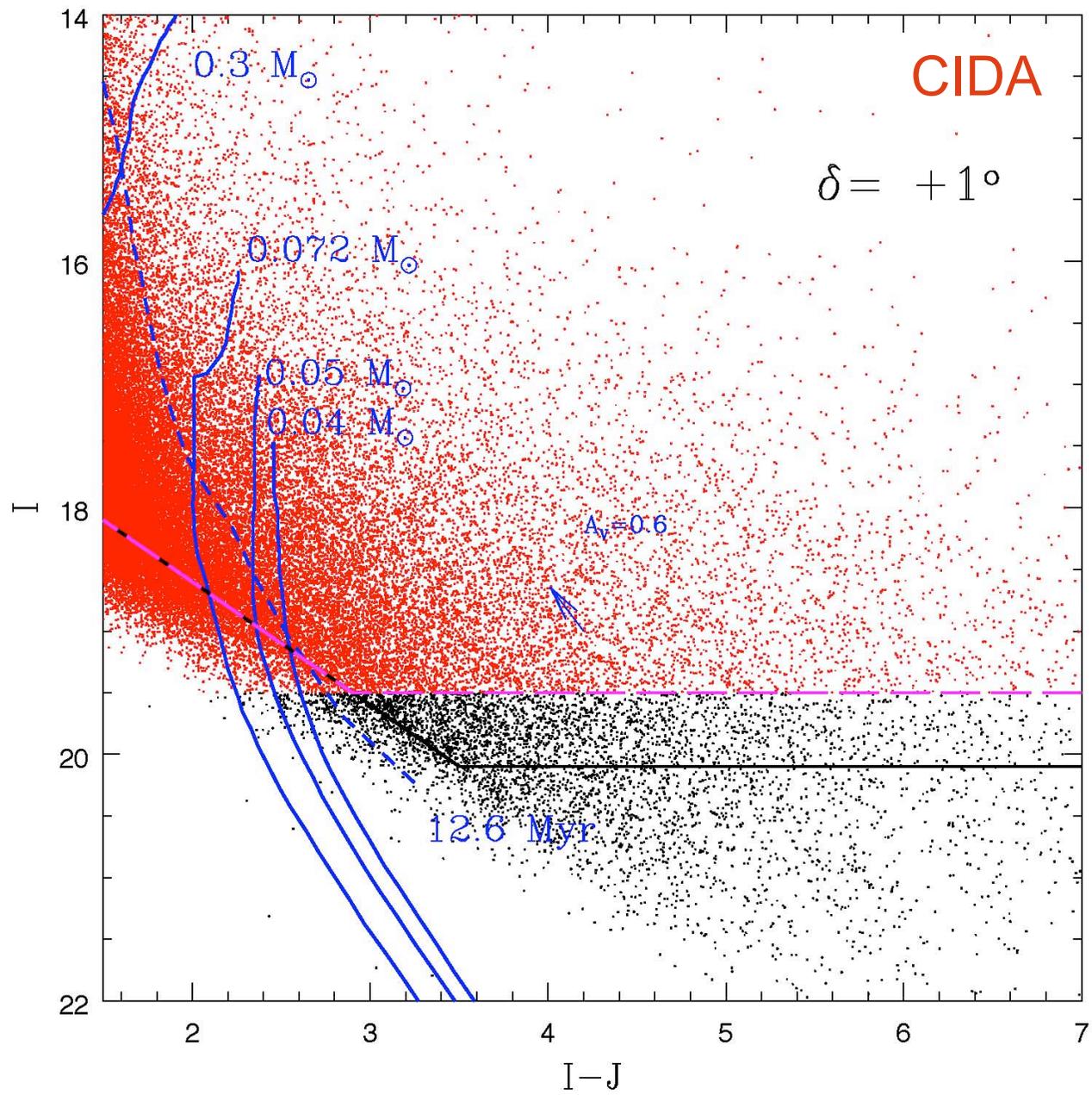


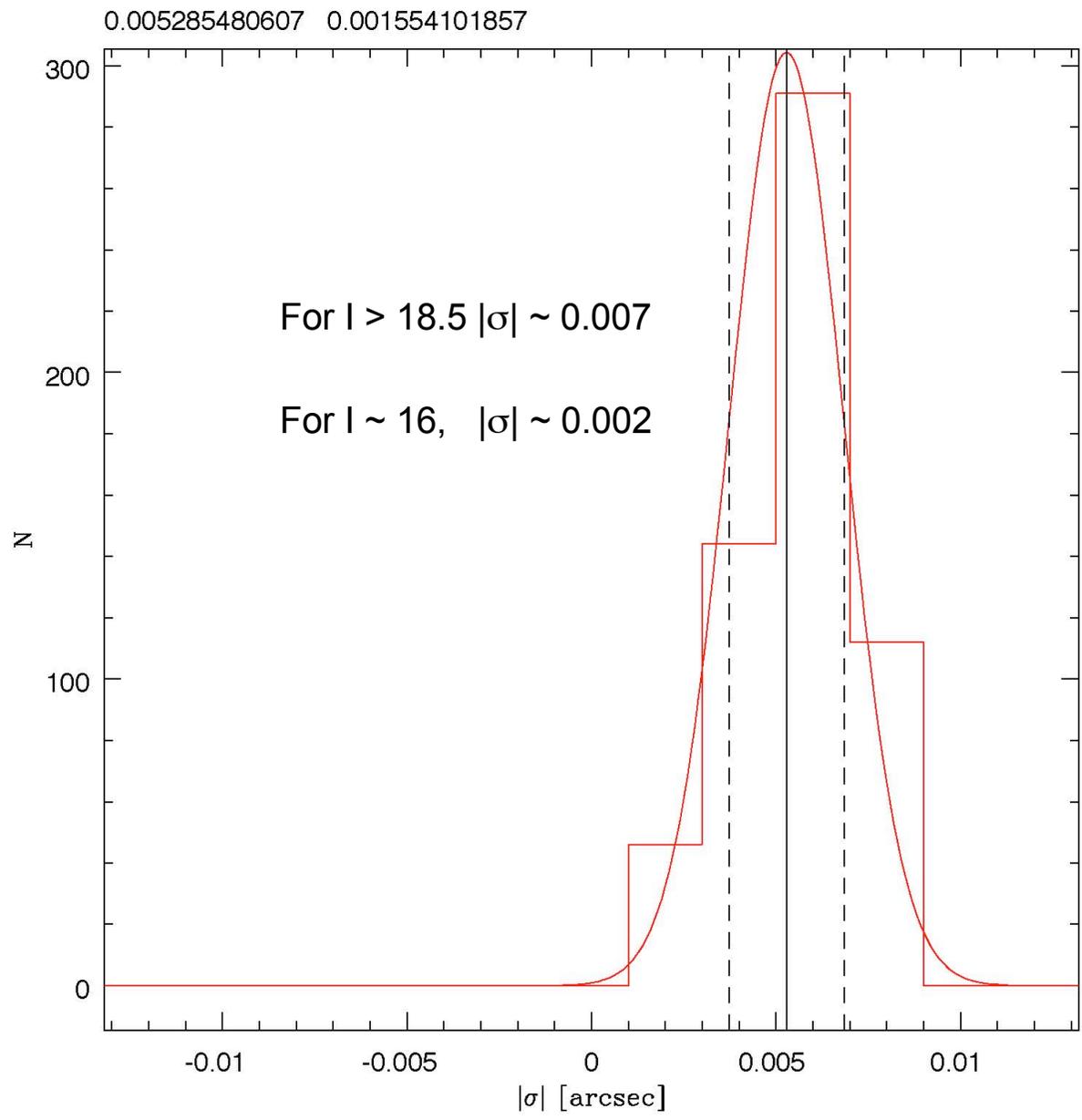


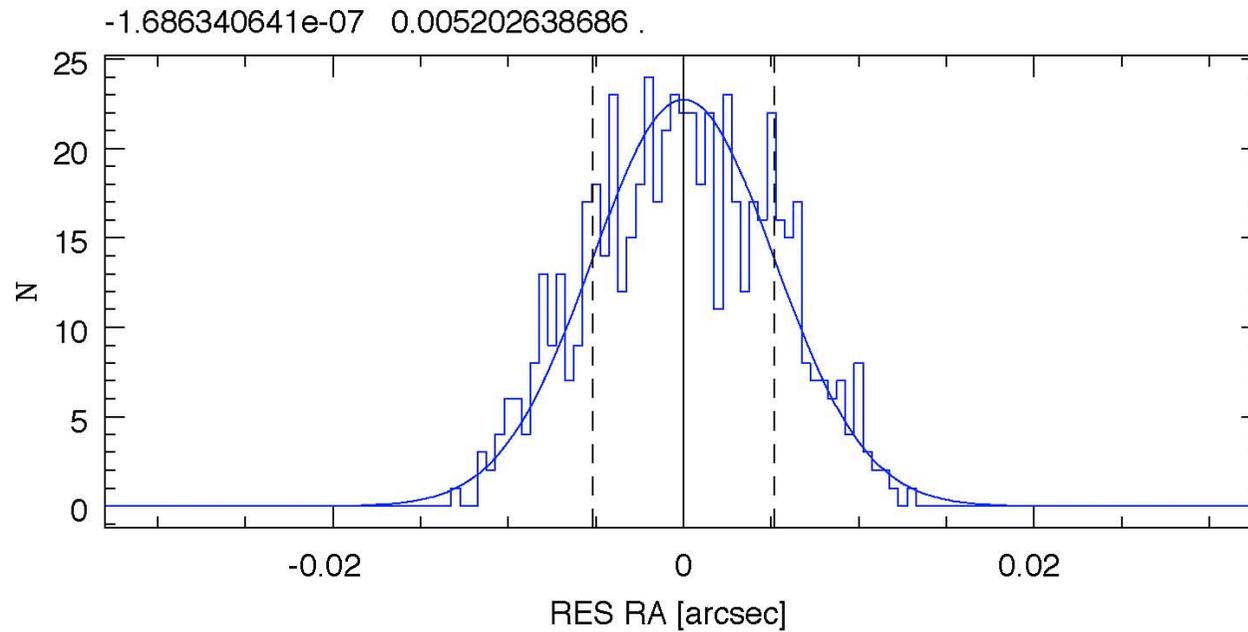
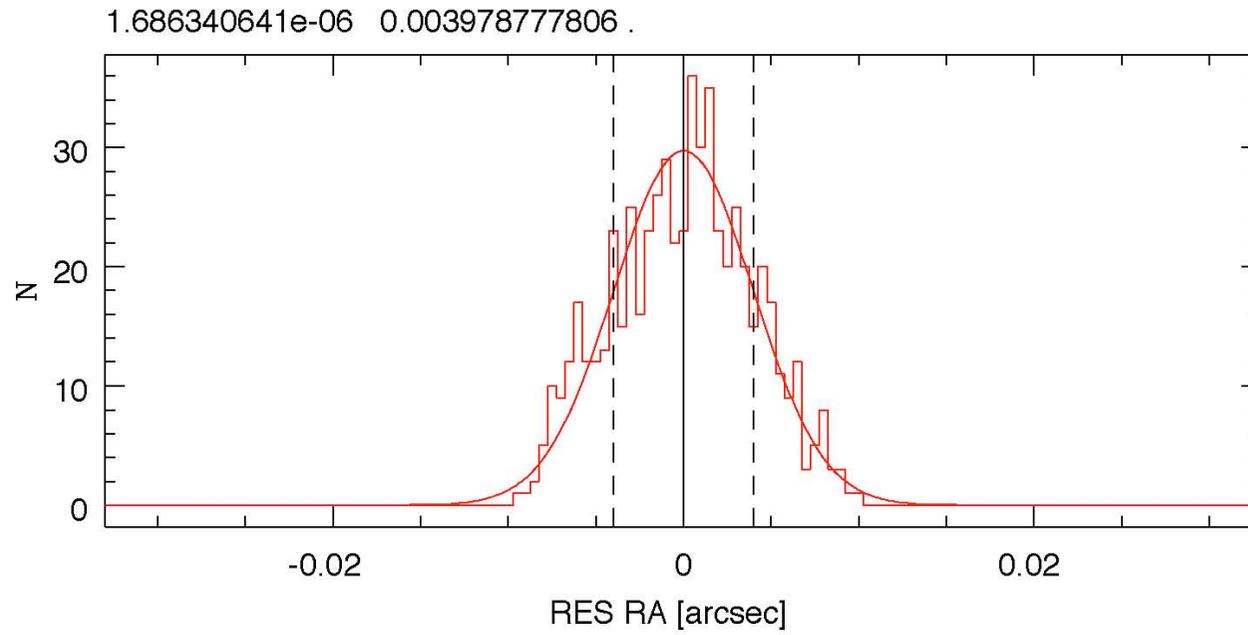
# Preliminar astrometric analysis of the CIDA Orion survey

Ongoing work: The automatization of the plates  
reduction procedure (320.000 ccd images)

- First (rough) astrometric reduction
- Detection of point sources using phot (iraf)
- Identification of point sources in UCAC2 catalogue
- $(x,y) \rightarrow (\alpha,\delta)$  using Stock (1982) procedures







# Available Accuracy

- $\alpha \sim 0.007$  arcsec
- $\delta \sim 0.008$  arcsec
- In a period of 10 years we can measure proper motions of about  $\sim 2$  mas/yr
- This accuracy allows the differentiation, at least, between the young Orion population and dwarf population from the foreground
- This accuracy allows to test some observables associated to the “ejected embryos” scenario (Reipurth & Clark, 2001), proposed as a possible brown dwarf formation process.

# Summary

By re-processing data from the CIDA Orion survey we found new very low mass stellar and substellar members in the dispersed and older Orion subregions OB1a and OBb.

Our initial results suggest the fraction WTTS/CTTS falls in the same way at both sides of the substellar limit during  $\sim 4$  y  $\sim 10$  Myr and that the settling of the dust in disks in some objects may occur while there is ongoing gas accretion during the first  $\sim 4$  Myr.

The photometric selection of candidates (IJHK) results in  $\sim 20\%$  of non Orion members that belong to the foreground population, and  $\sim 5\%$  of other contaminating objects.

Our first astrometric test of observations of the CIDA Orion Survey shows accuracies of  $\alpha \sim 0.007$  and  $\delta \sim 0.008$  [arcsec] at  $l \sim 19$ .

This accuracy places the limit of detectable proper motions at  $\sim 2$  [mas/yr] that will allow the distinction between Orion population and foreground population.

Finally, this accuracy will allow to test some observables associated to some proposed brown dwarf formation process.