The 25 Orionis cluster: hunting ground for young exoplanets

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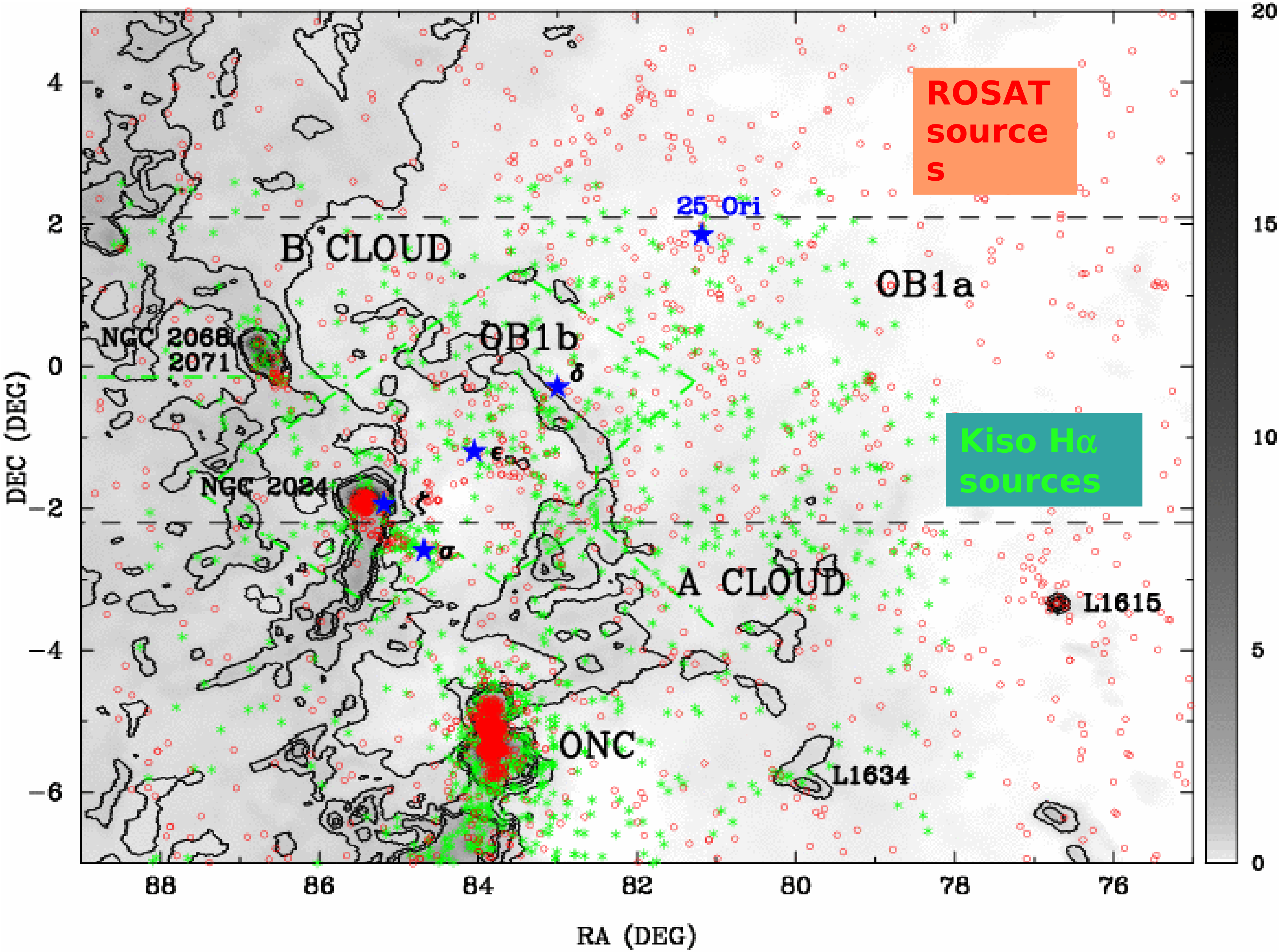
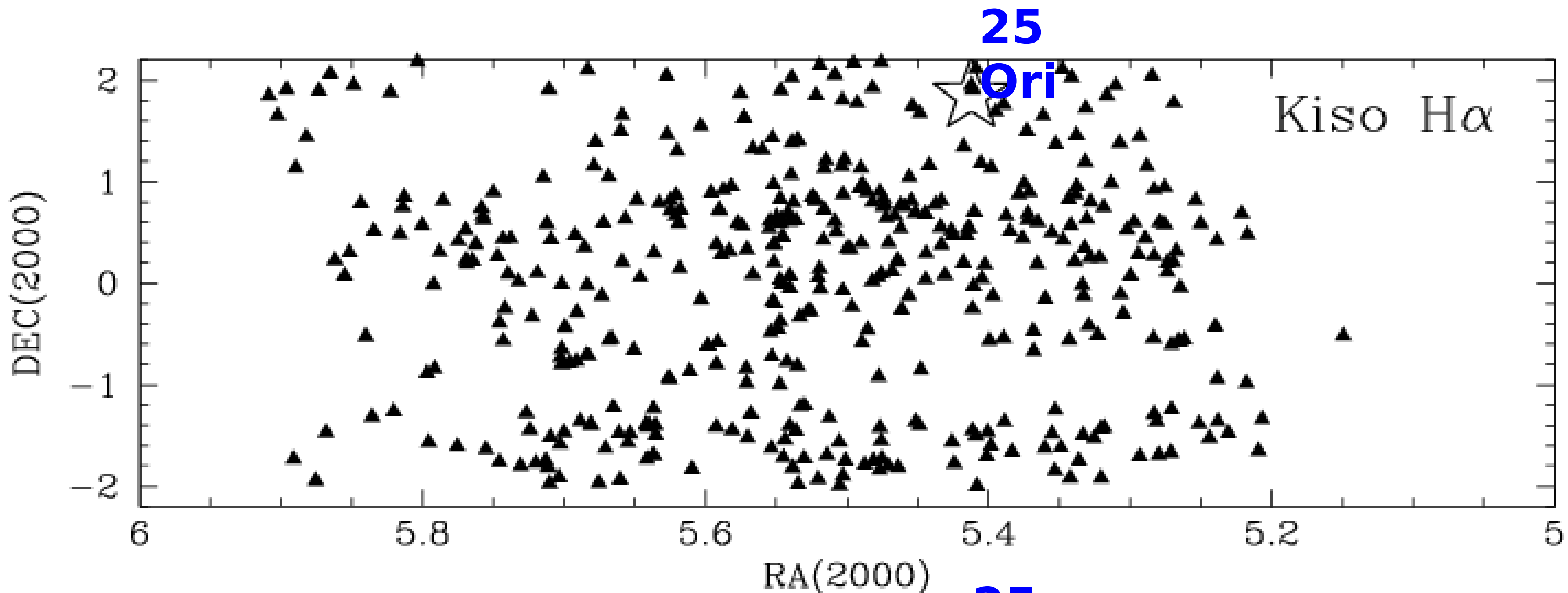
The quest for 10 Myr old stars

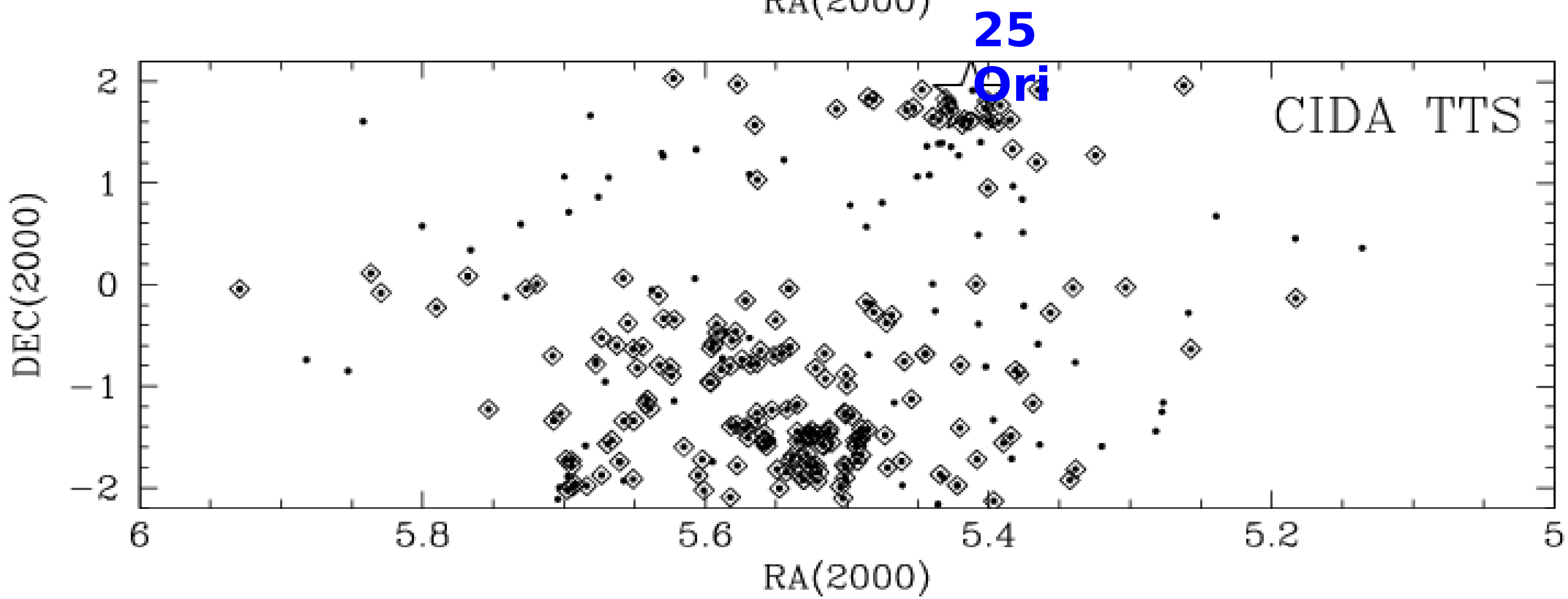
Searches for planetary transits around young stars have the best odds in a 10 Myr old cluster:

1) Numerous ensemble of stars with common properties (e.g. age, [Fe/H]) improves probability of detecting a transit
2) 10 Myr stars are old enough that stellar activity (optical/near-IR variability) has diminished greatly compared to 1 Myr objects like the ONC
3) Most 10 Myr old stars have lost their inner disks *(Briceño et al. 2001; Calvet et al. 2005; Hernández et al. 2007)*, which could otherwise complicate eventual detections → planet formation phase is largely over.

However, obtaining numerous samples of young stars at this critical stage has been an observational challenge, because after a few Myr, stars are no longer associated with their natal gas → difficult to isolate them from field stars


ROSAT source s
Kiso Hα sources
25 Ori
B CLOUD
OB1a
OB1b
NGC 2068 2071
NGC 2024
A CLOUD
L1615
ONC
L1634
DEC (DEG)
RA (DEG)


25
Ori
Kiso Hα
DEC(2000)
RA(2000)


25
Ori
CIDA TTS
DEC(2000)
RA(2000)

Existing 10 Myr old samples: sparse or far away

TW Hya: *(Webb et al. 1999)* **nearby, d~ 60 pc, but only about 20 members => small number statistics. Its sparse nature (spans ~20 deg^{2}) complicates membership determination** *(Mamajek 2005)*.

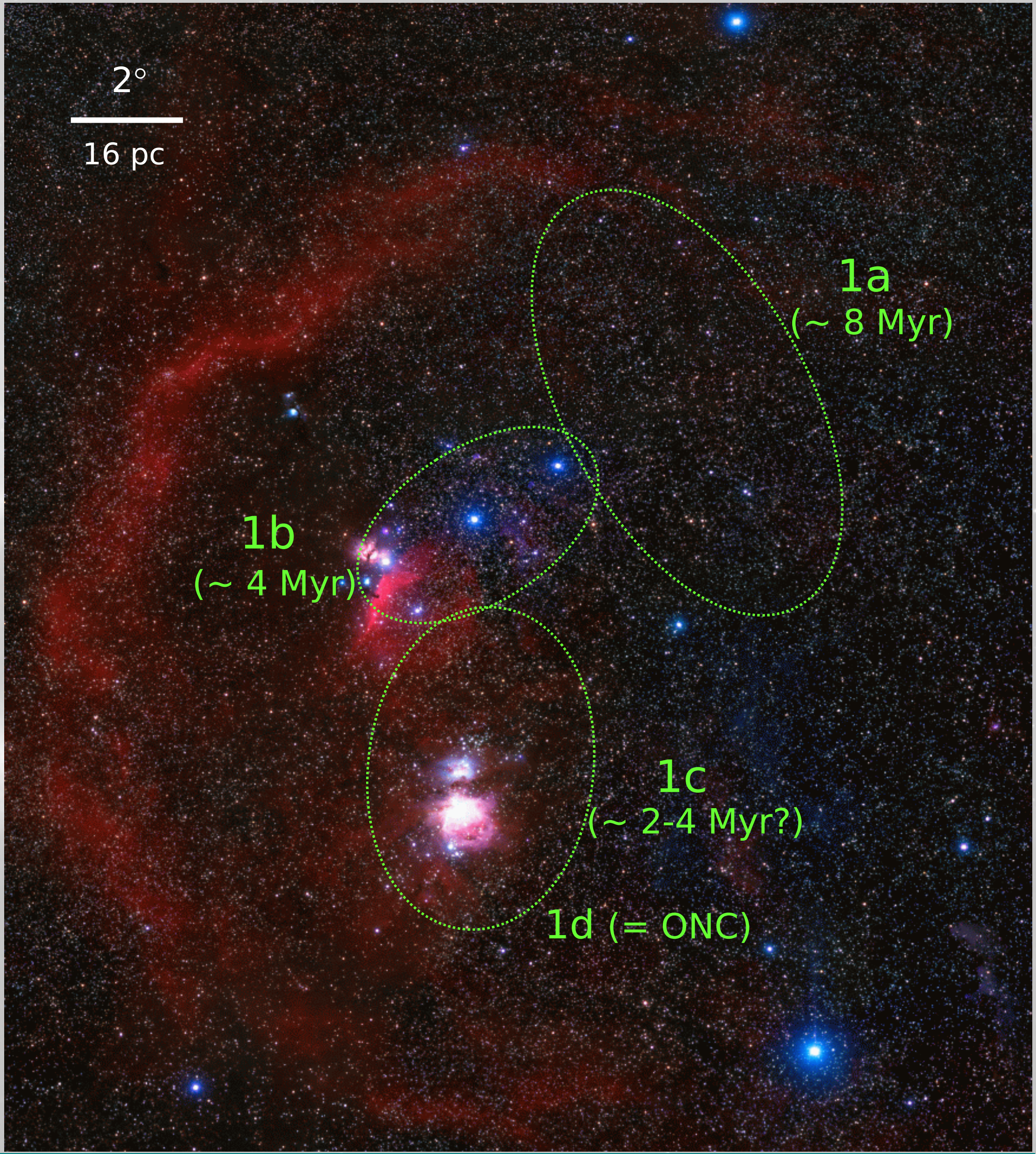
η Cha: d~ 90 pc *(Mamajek et al. 1999)*. **More compact, but as TW Hya, has only ~20 members.**

NGC 7160 in Cepheus *(Sicilia-Aguilar et al. 2005)*: **more numerous than TW Hya and η Cha, but much more distant (d ~800 pc).**

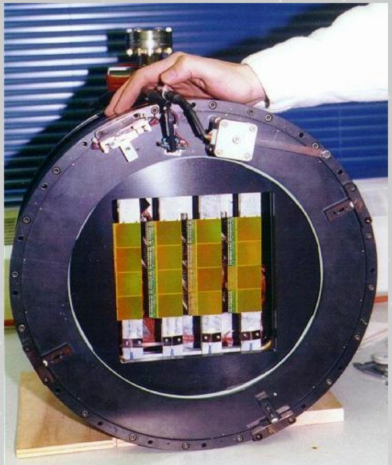
Why look for 10 Myr old stars in Orion OB1

Orion OB1 *(Blaauw 1964)* is nearby (d ~400 pc).
In this complex we witness all the stages of the star and planet formation process, as well as the various modes of star formation: clustered, in dense concentrations of young stars, and dispersed, in widely spread, low surface density young stellar population.

Problem: Orion OB1 spans ~180 deg^2, which has made difficult to conduct systematic, wide areas surveys to build a reasonably complete stellar census



The CIDA Variability Survey of Orion (CVSO)

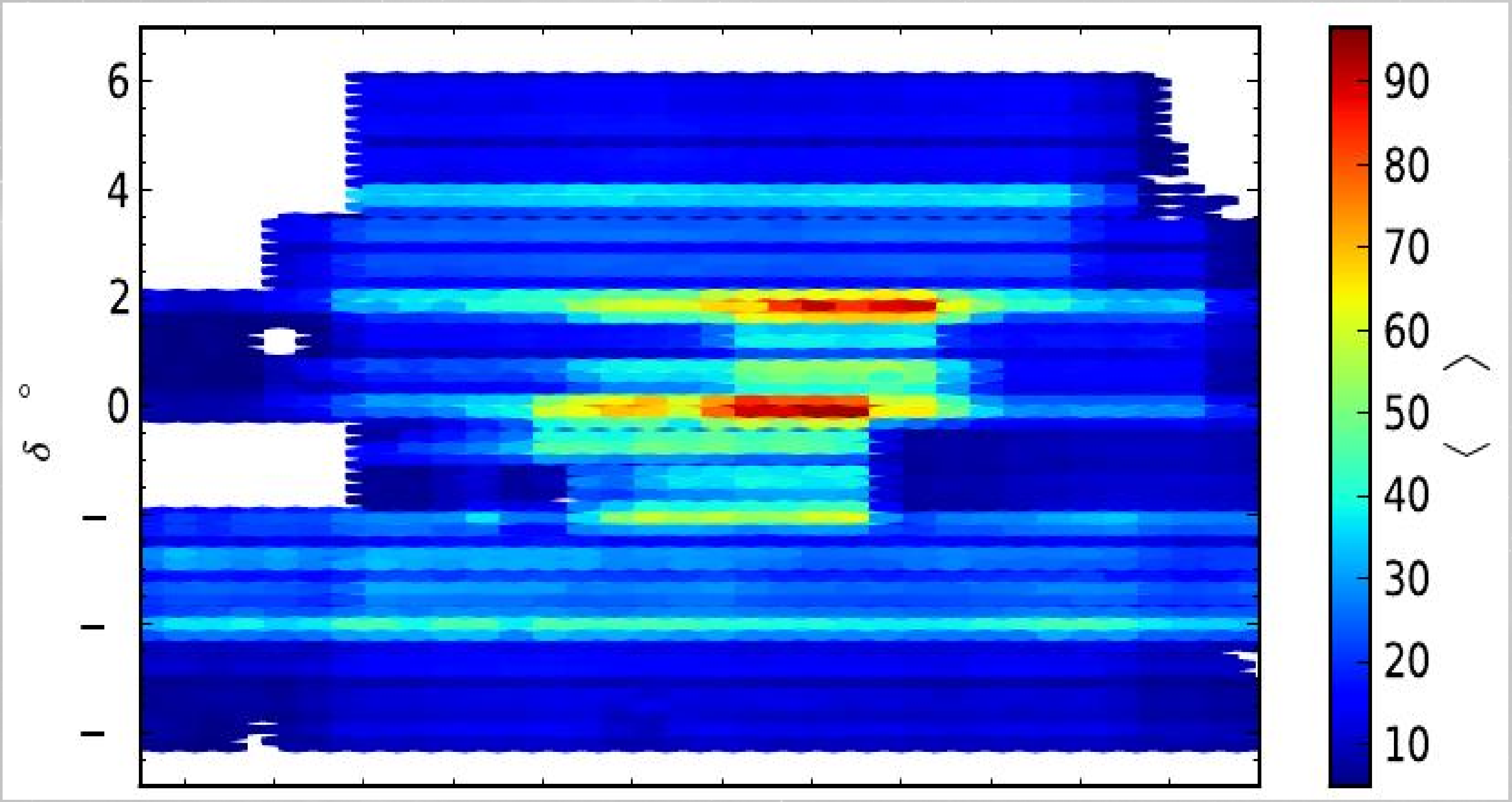


Since 1998 we have used an 8k x 8k CCD Mosaic Camera on the 1m Stock (Schmidt-type) telescope at the OAN-Venezuela, to conduct the most extensive and complete survey of the young stellar population in Orion OB1

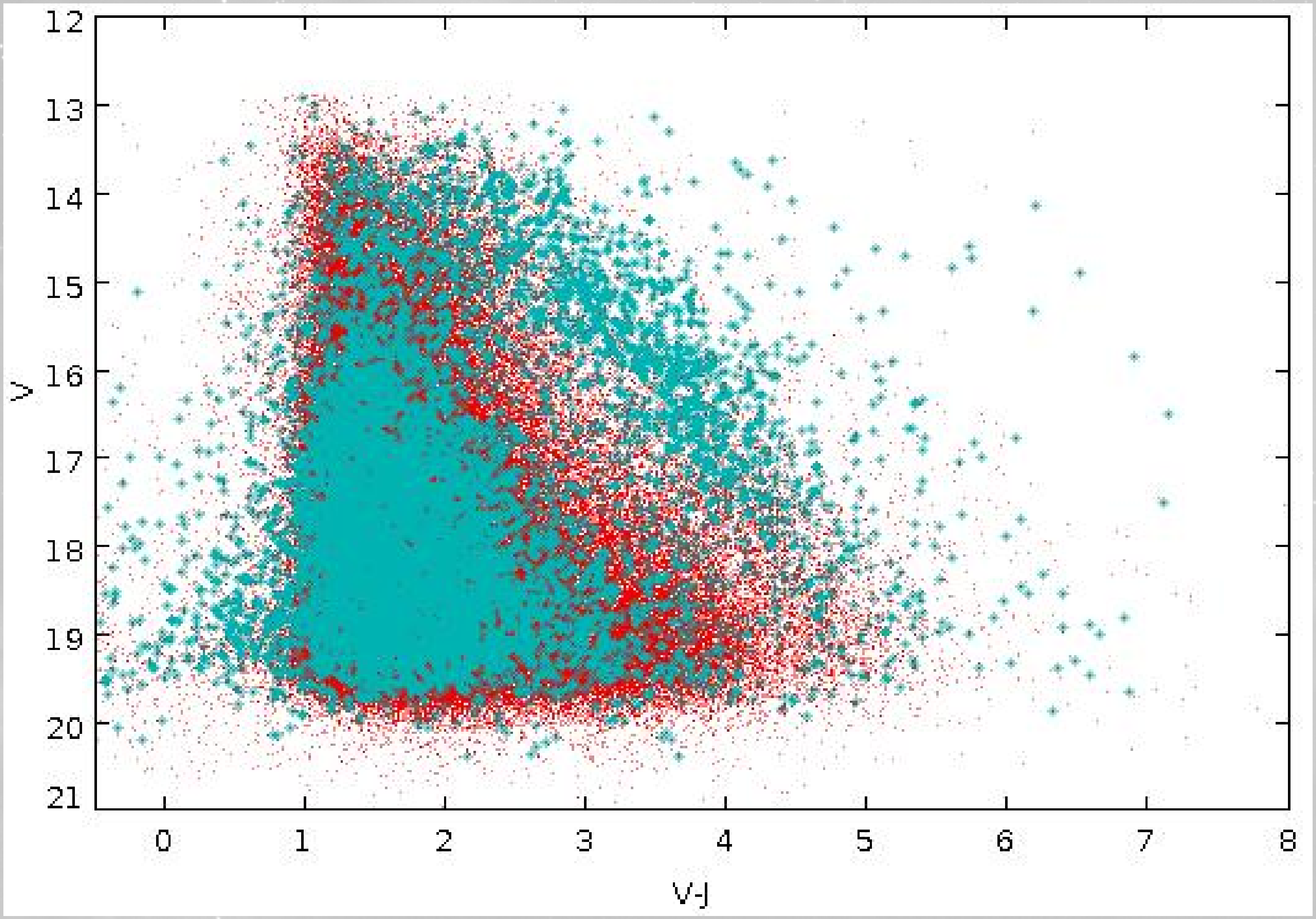
Observations:

- Drift-scan mode: 34 deg^2/filter/hr → ~290 deg^2/filter/night
- VRI–multi-epoch
- ~ 5.5 deg^2 FOV (1´´/pixel)
- **T_{exp}~140s → V_{lim}~19.7**

CVSO: time series of ~180 deg^2



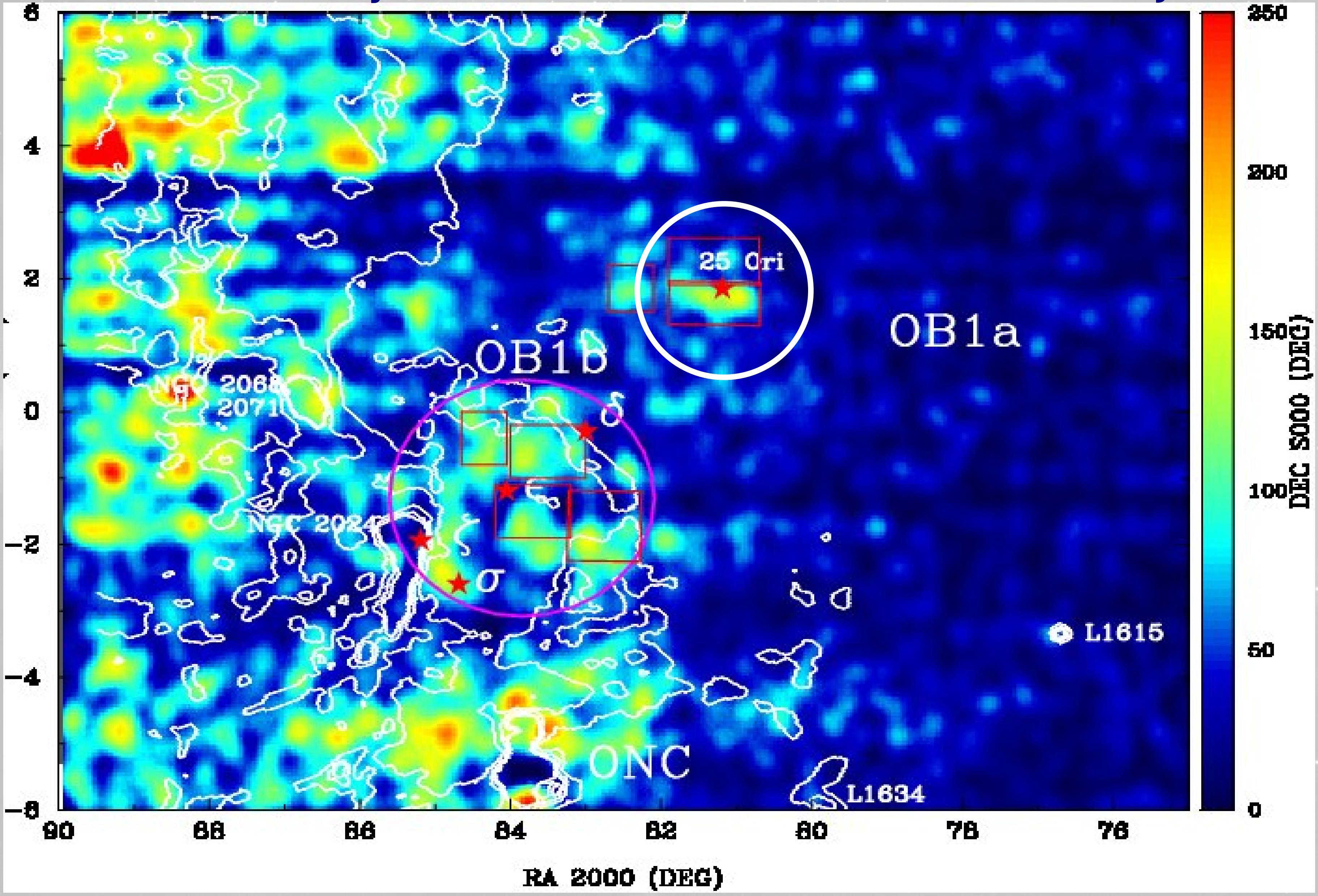
VARIABILITY: sorting out the young stars



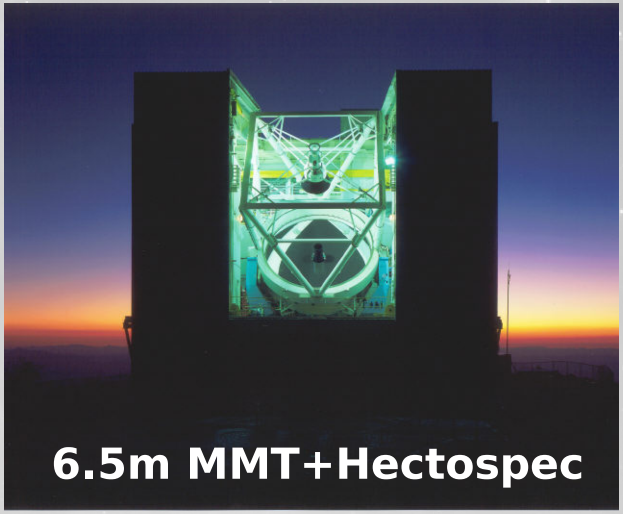
STETSON L_{VI} index *(Stetson 1996, PASP, 108, 851)*

DISTRIBUTION OF PMS STARS TRACES STRUCTURE

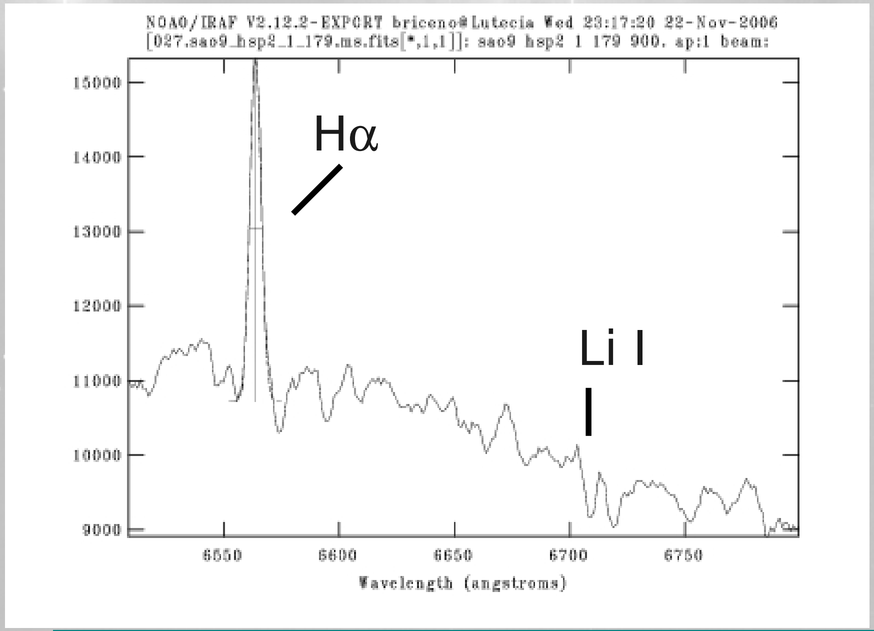
Surface Density of variables in PMS locus of V vs V-J CMD

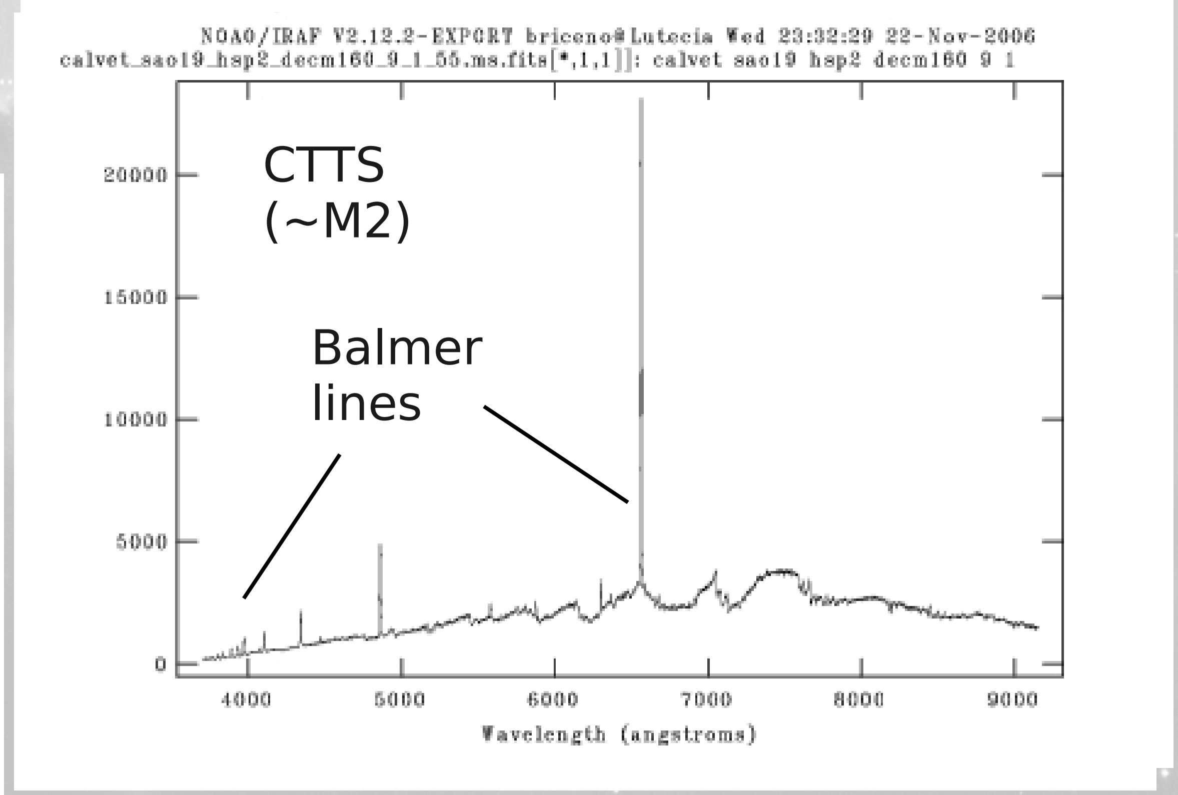


The CVSO: Spectroscopic follow-up



Membership confirmation:
spectra (Hα 6563, Li I 6707 & Na I 8195) → SpT → Teff



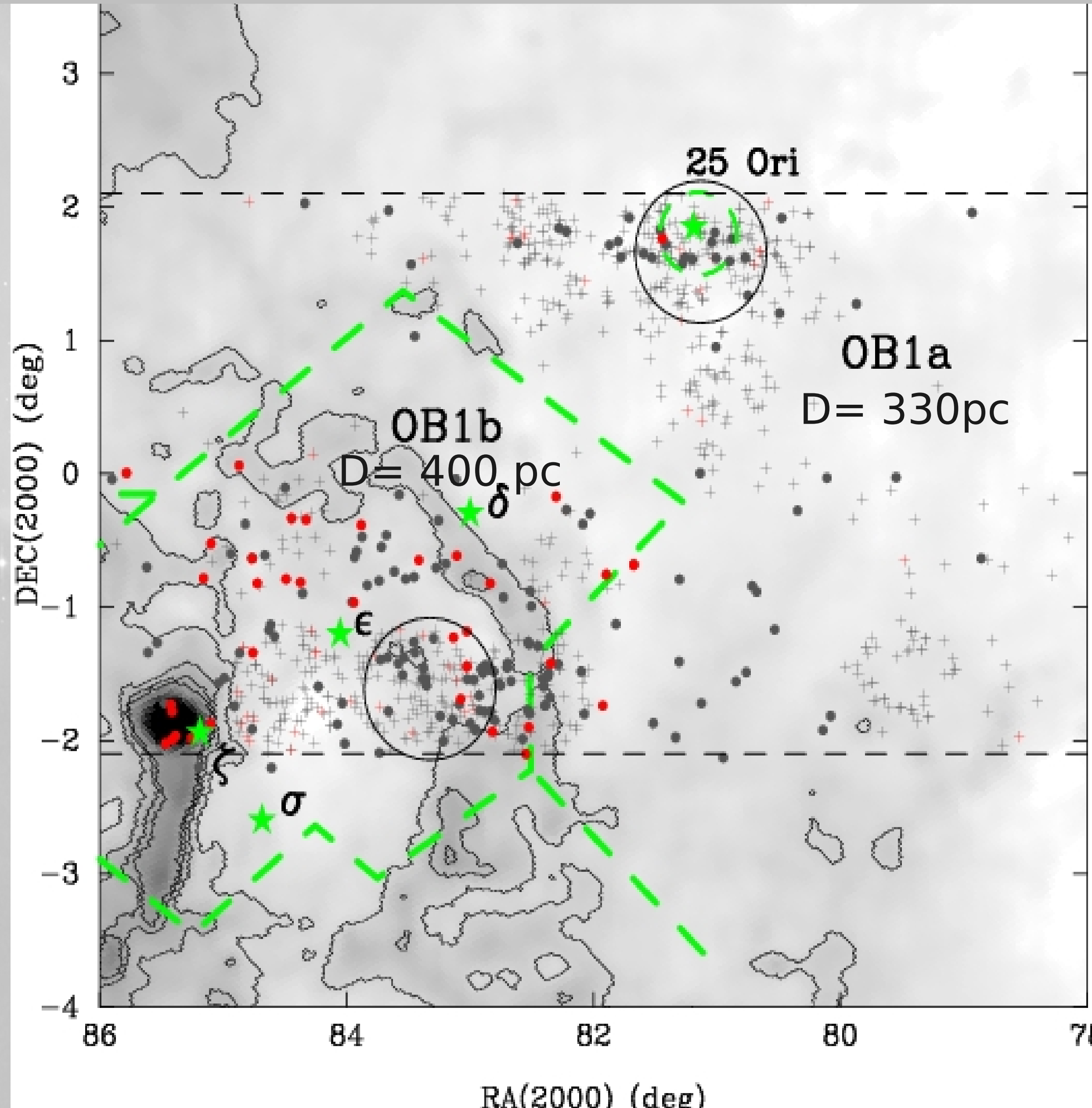


25 Orionis: a populous stellar group at 330pc

- ***Briceño et al. (2005, AJ, 129, 905)*:**
- find overdensity of TTS within r<1º of 25 Ori (B1Vpe) → spectra for ~20 TTS. Group includes 1 HaeBe (A2)
- ~450 photometric candidate members

- **Further follow-up work confirms cluster: spectra for ~200 TTS + Rvs *(Briceño et al. 2007, ApJ, 661, 1119)***

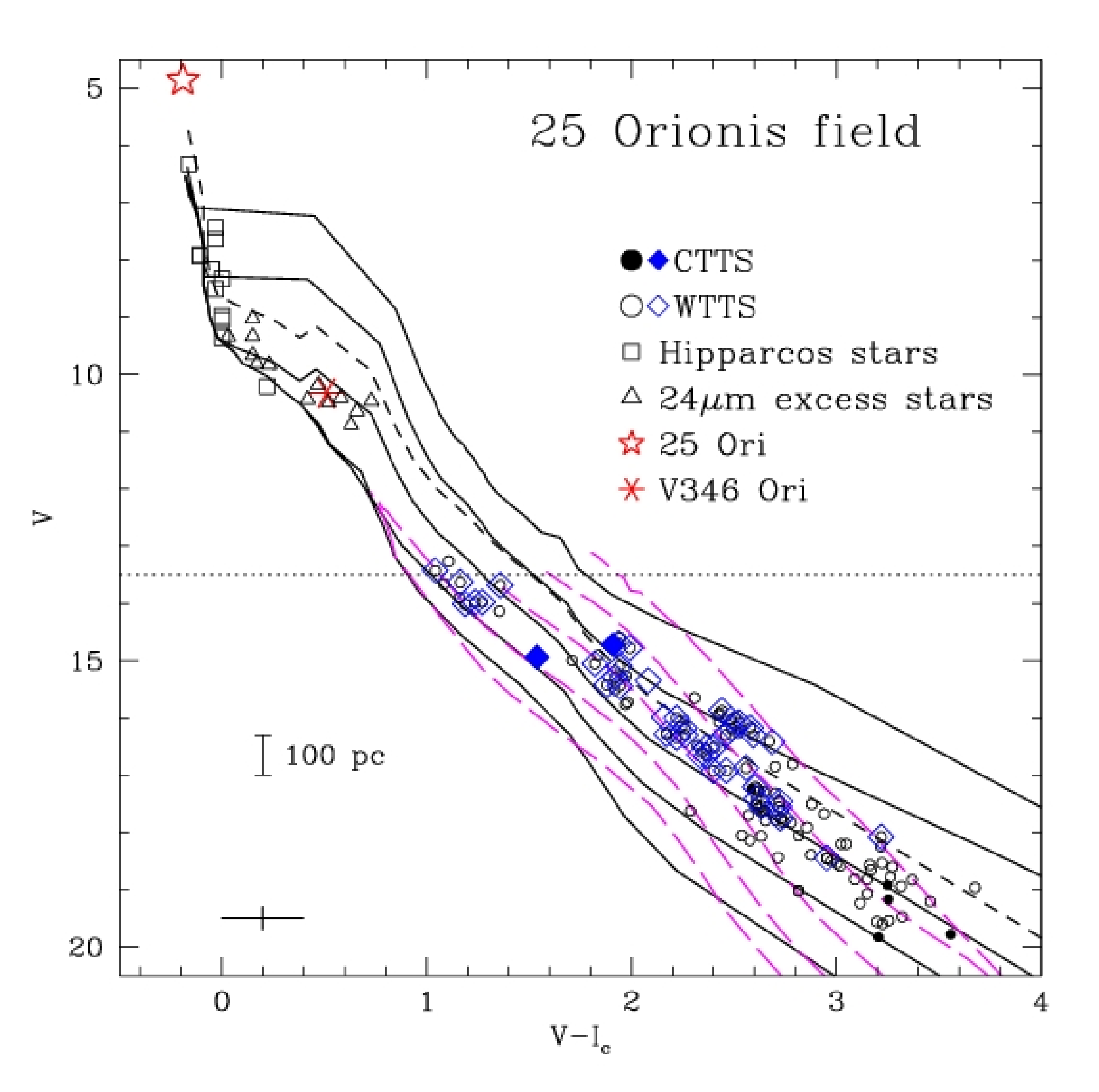
- *Kharchenko et al. (2005)* catalogue it as a cluster (ASCC 16, r=0.62º)



25 Orionis: age

The TTS in the cluster follow a well defined sequence that goes all the way up to the massive stars

We derive an isochronal age 7-10 Myr, consistent with determinations for O and B stars *(e.g. Blaauw 1964, 1991; Brown et al. 1994; Briceño et al. 2005, Briceño et al. 2007)*



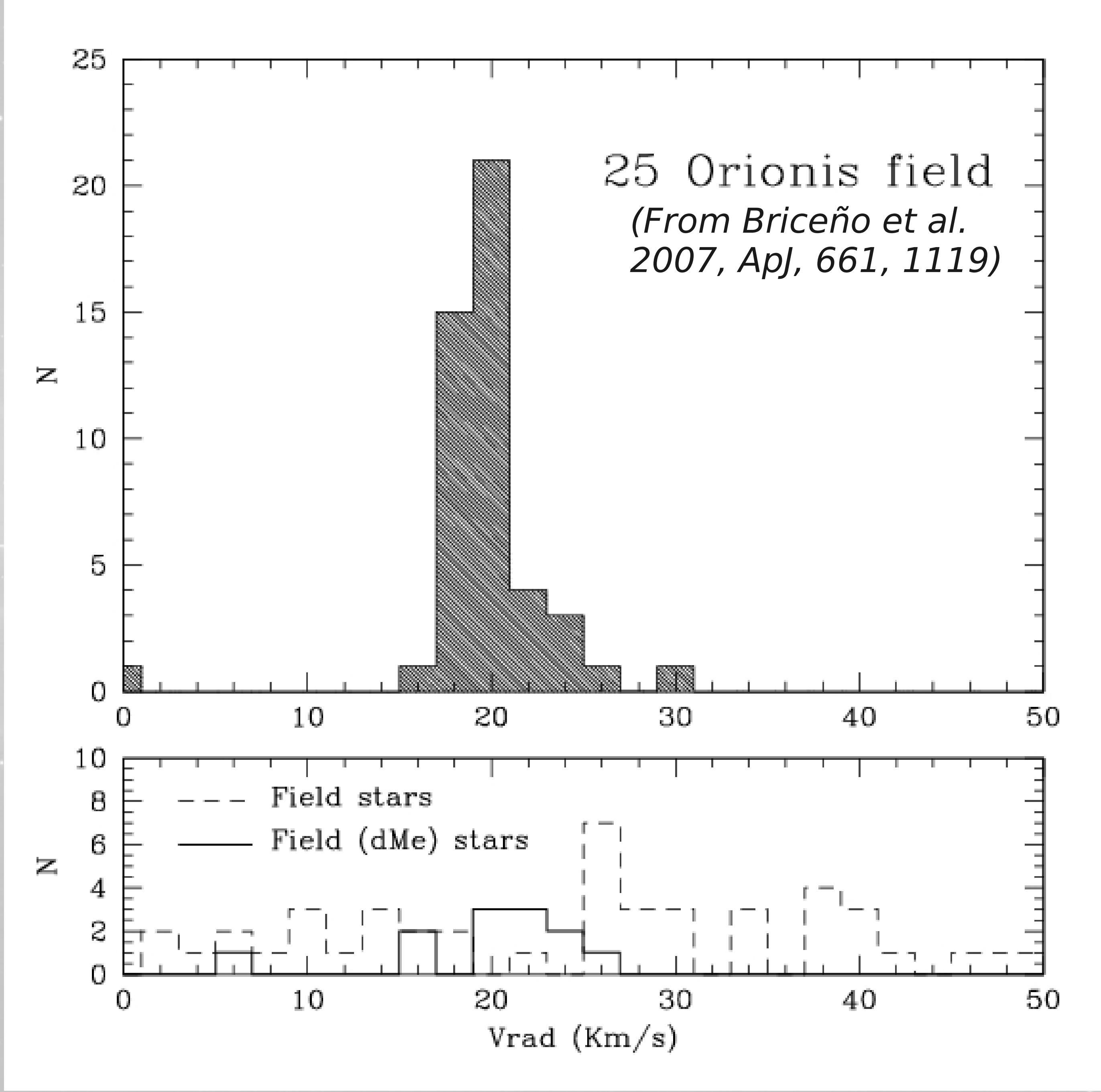
25 Orionis: kinematics

- **MMT+Hectochelle**
- R~34000, λ(0)=6563Å, Δλ=185Å.
- σ(Vr)= 0.88 km/s

Low-mass members:
RV = 19.7±1.7 km/s

- **RV(25 Ori)~ 20 km/s => physical link**
- **ΔV= -10 km/s respect to OB1b**

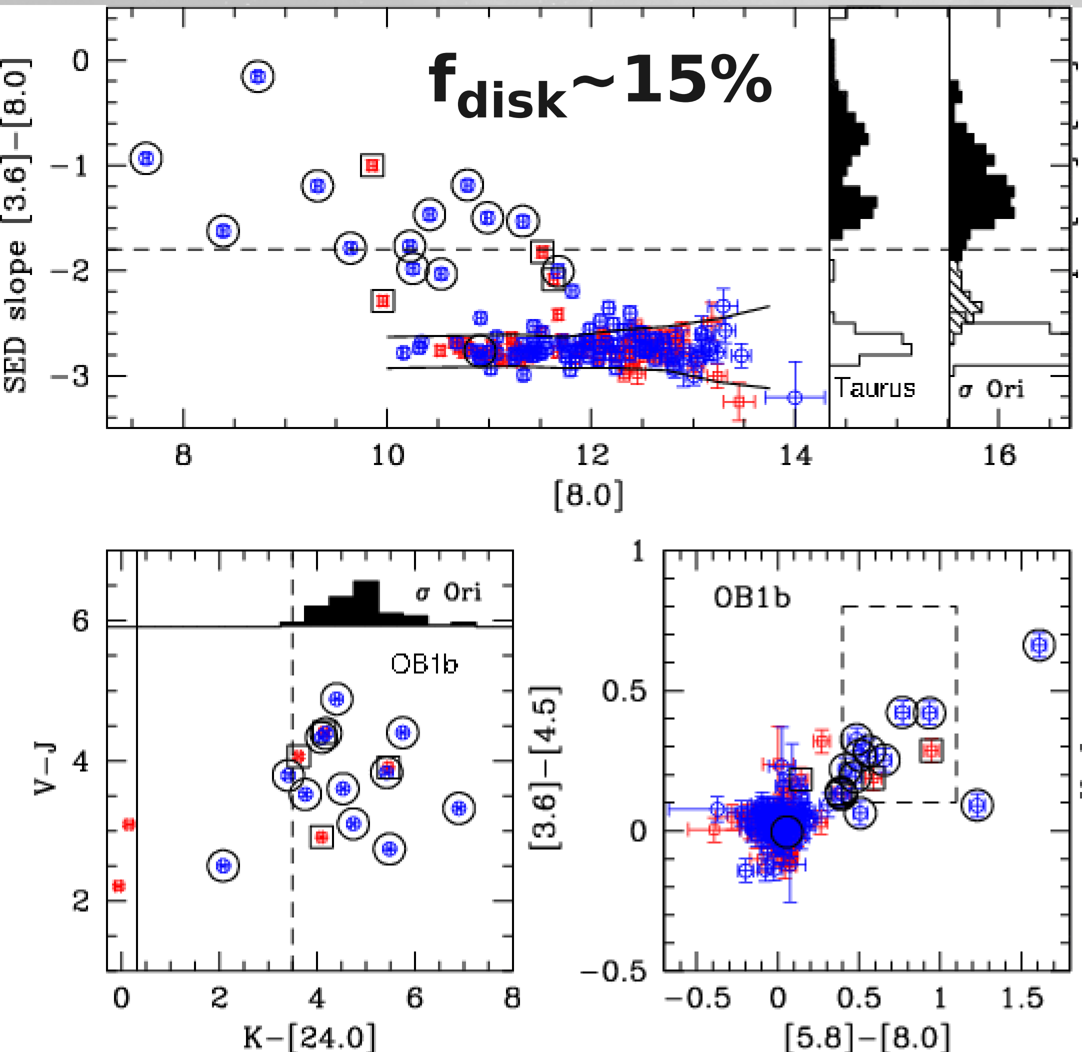
But...
RV (OB1a) ~ 24 km/s



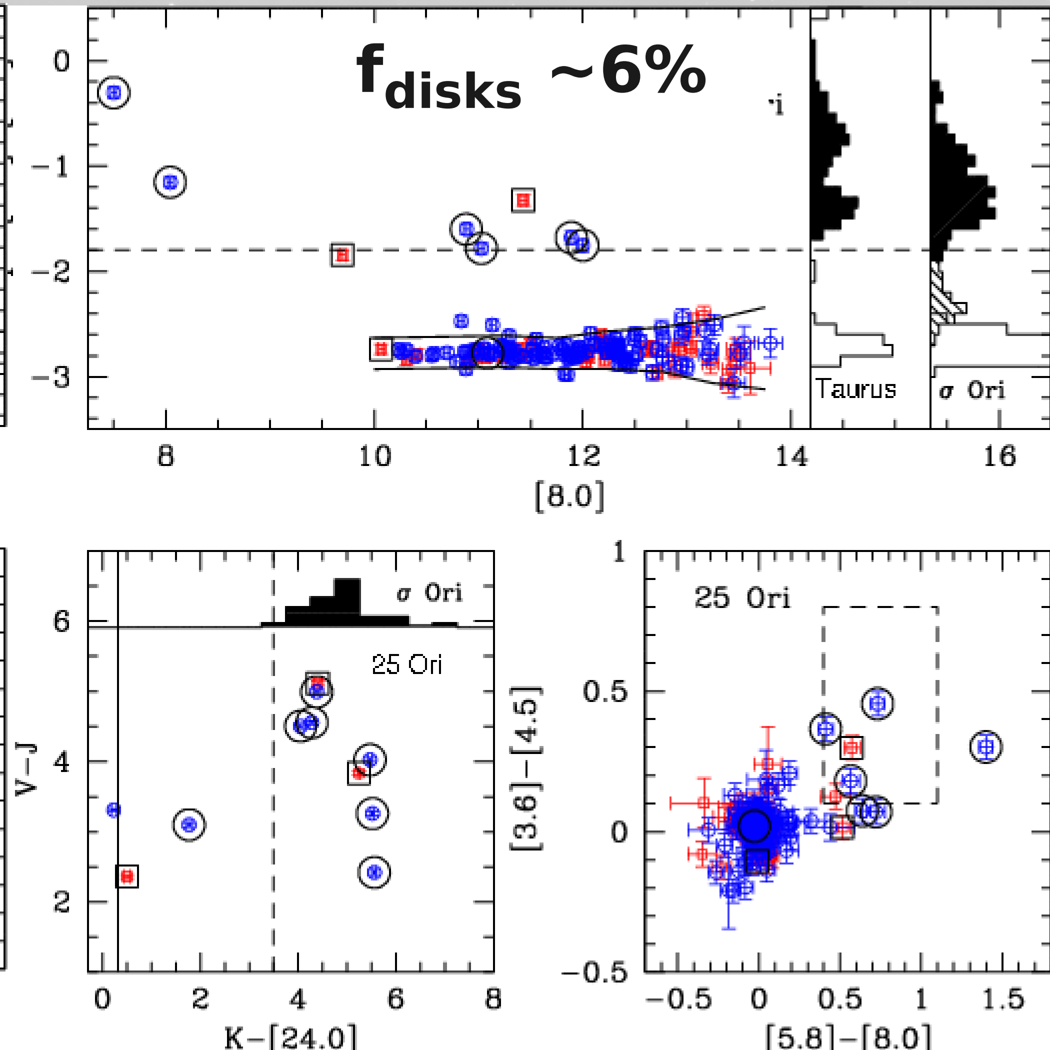
Inner disk evolution in Orion OB1

Spitzer IRAC/MIPS *(Hernández et al. 2007, ApJ, 671, 1748)*

OB1b (~4 Myr)

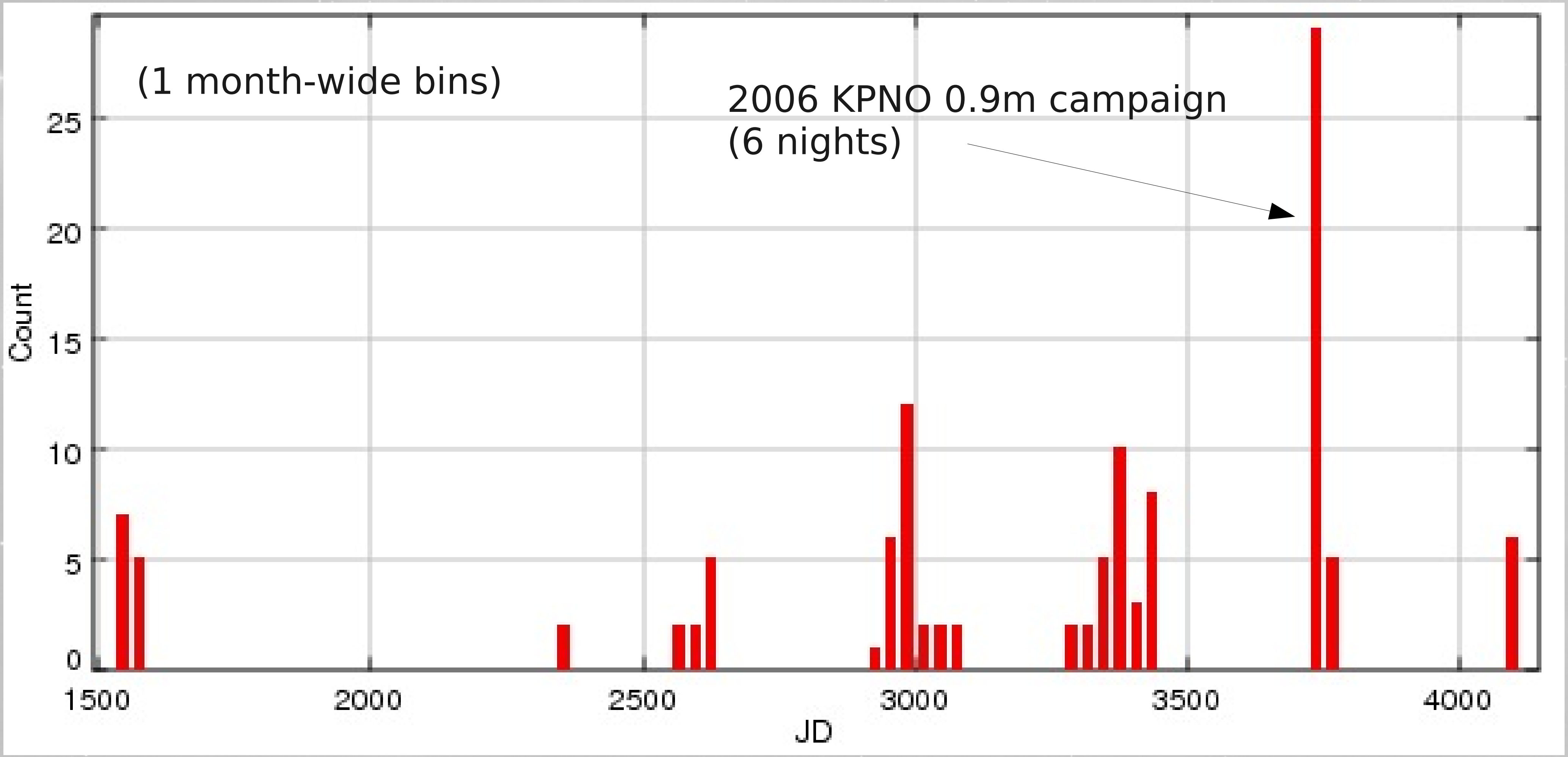


25 Ori (~8 Myr)

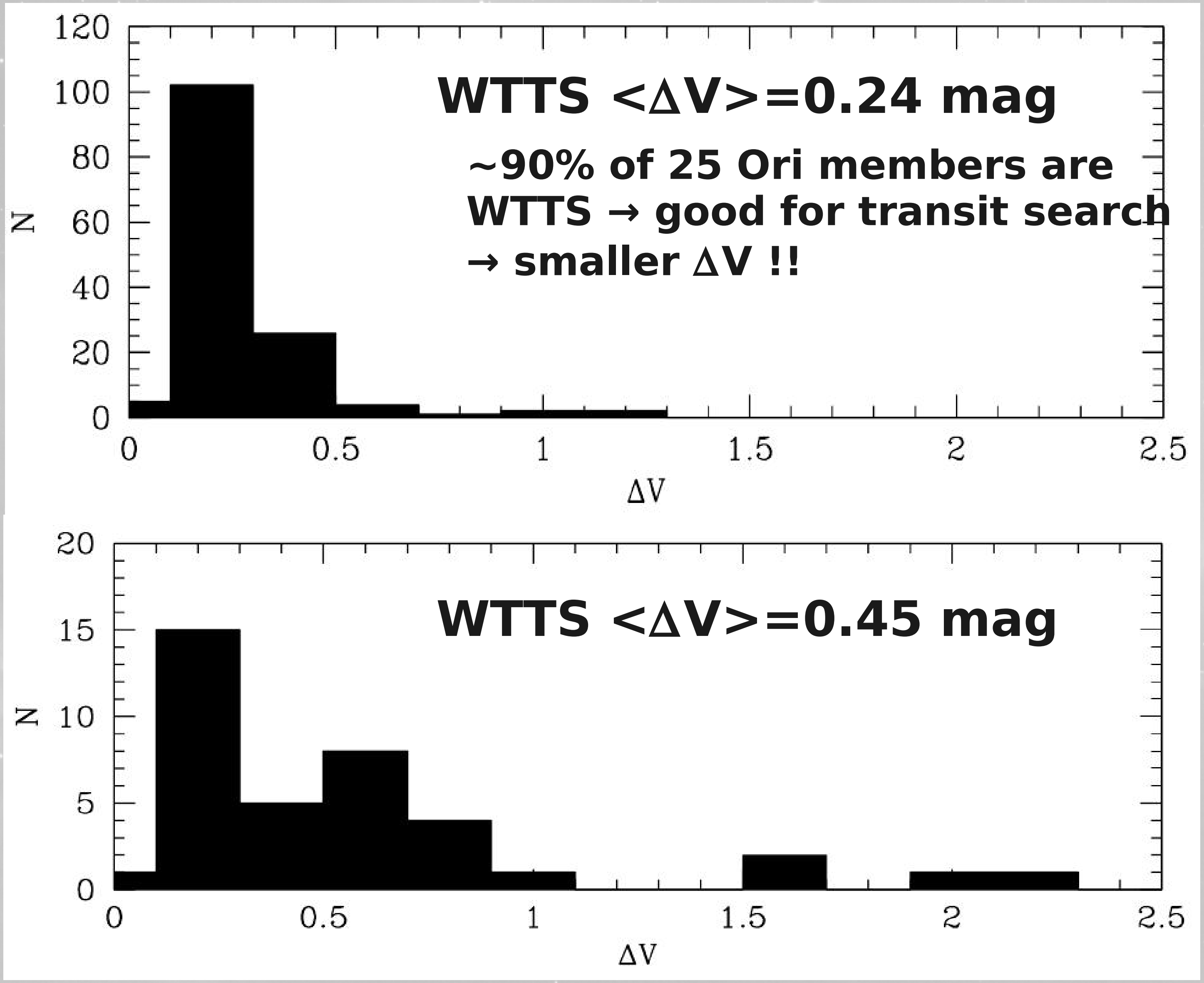


The CVSO variability data

Originally conceived as a tool to detect TTS → still, can be used to characterize TTS variability, and with enough data points, to derive rotational periods.
Also provides information on which stars are most stable over long time scales

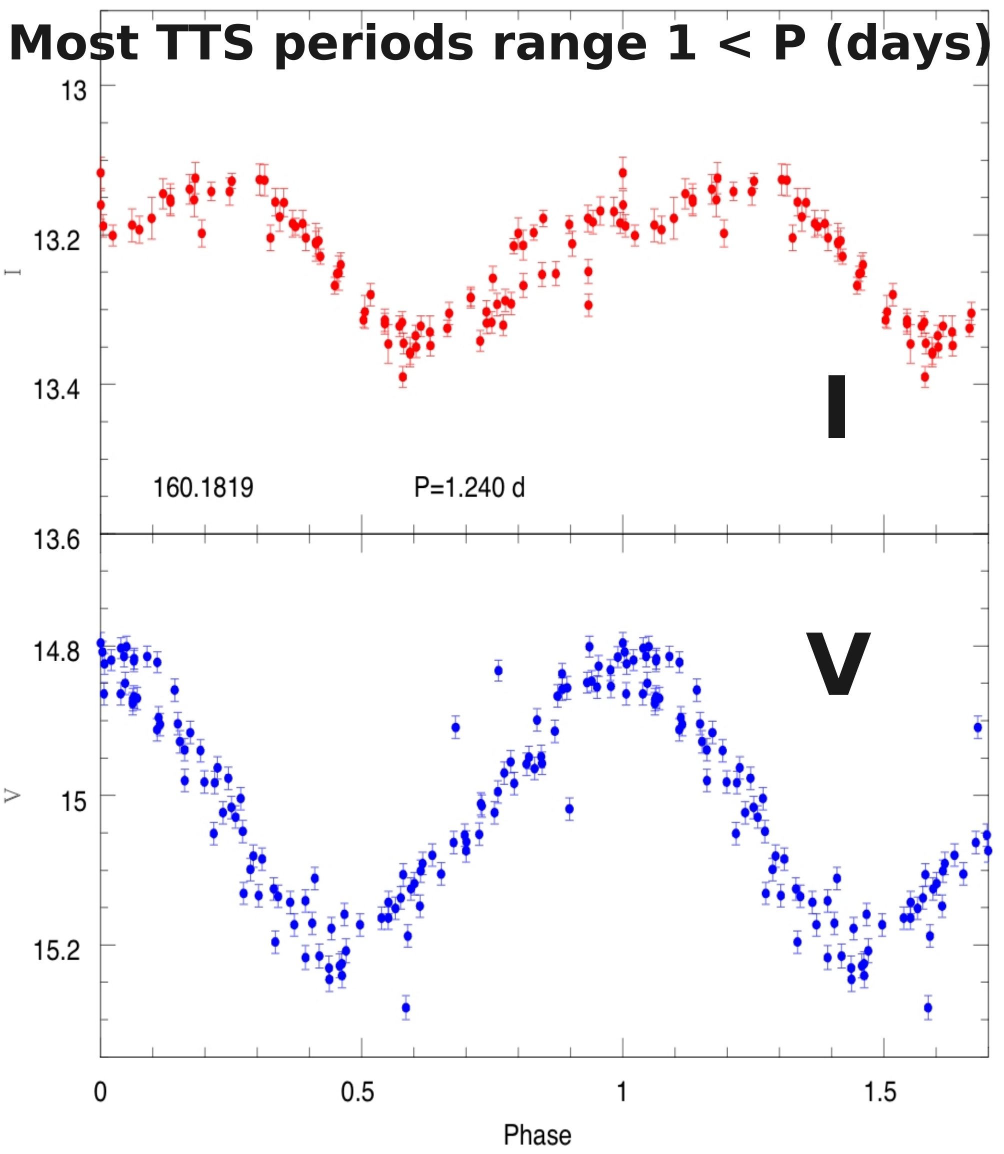


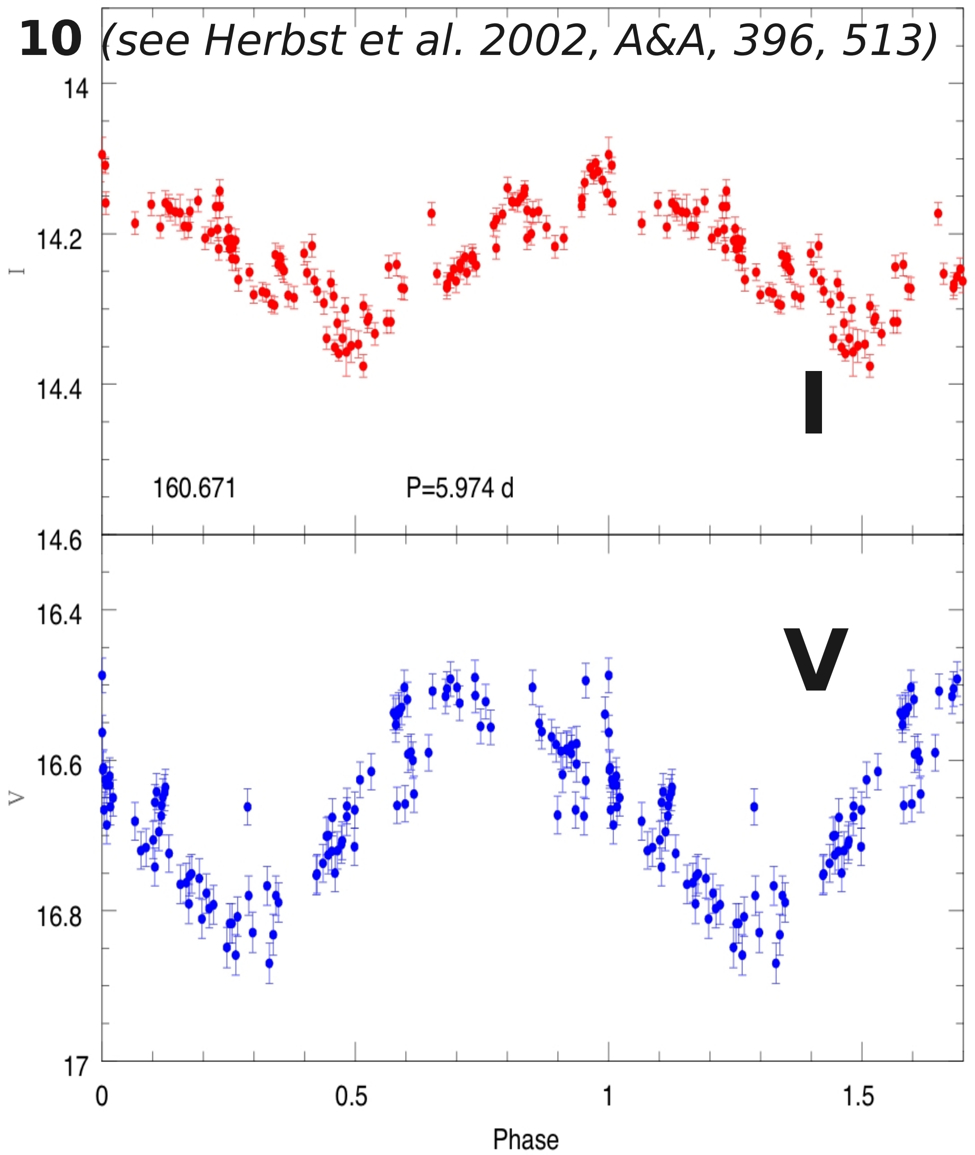
What does T Tauri variability look like?



25 Orionis: preliminary periods

Most TTS periods range 1 < P (days) < 10 *(see Herbst et al. 2002, A&A, 396, 513)*





Summary/Conclusions

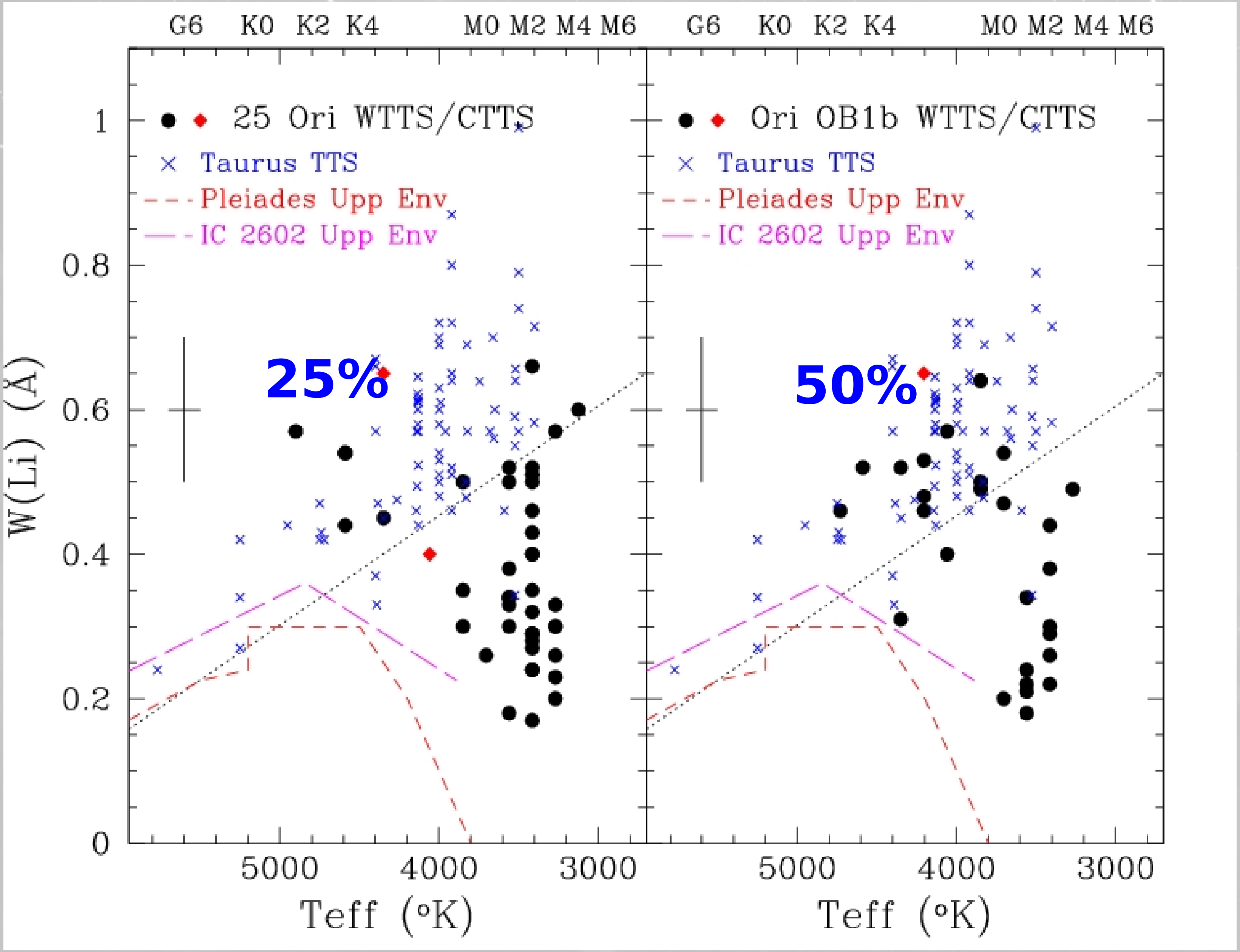
• The 25 Orionis stellar is the nearest and more densily populated ~10 Myr old cluster, with ~200 confirmed members and ~450 photometric candidates.

• It has been extensively studied and well characterized, with available membership lists that have spectral types, optical and near-IR colors, and multi-epoch photometry, which provides rotation periods for many objects, but most importantly, information on long term (several years) variability for both cluster members and field stars.

• Spitzer IR observations combined with Hα data from optical spectra show that 25 Ori has a low (~6%) disk and accretor fractions, consistent with its age, and indicative that most inner disks have dissipated

• **These many reasons make 25 Ori probably the best target for searching for transits from planets around young stars**

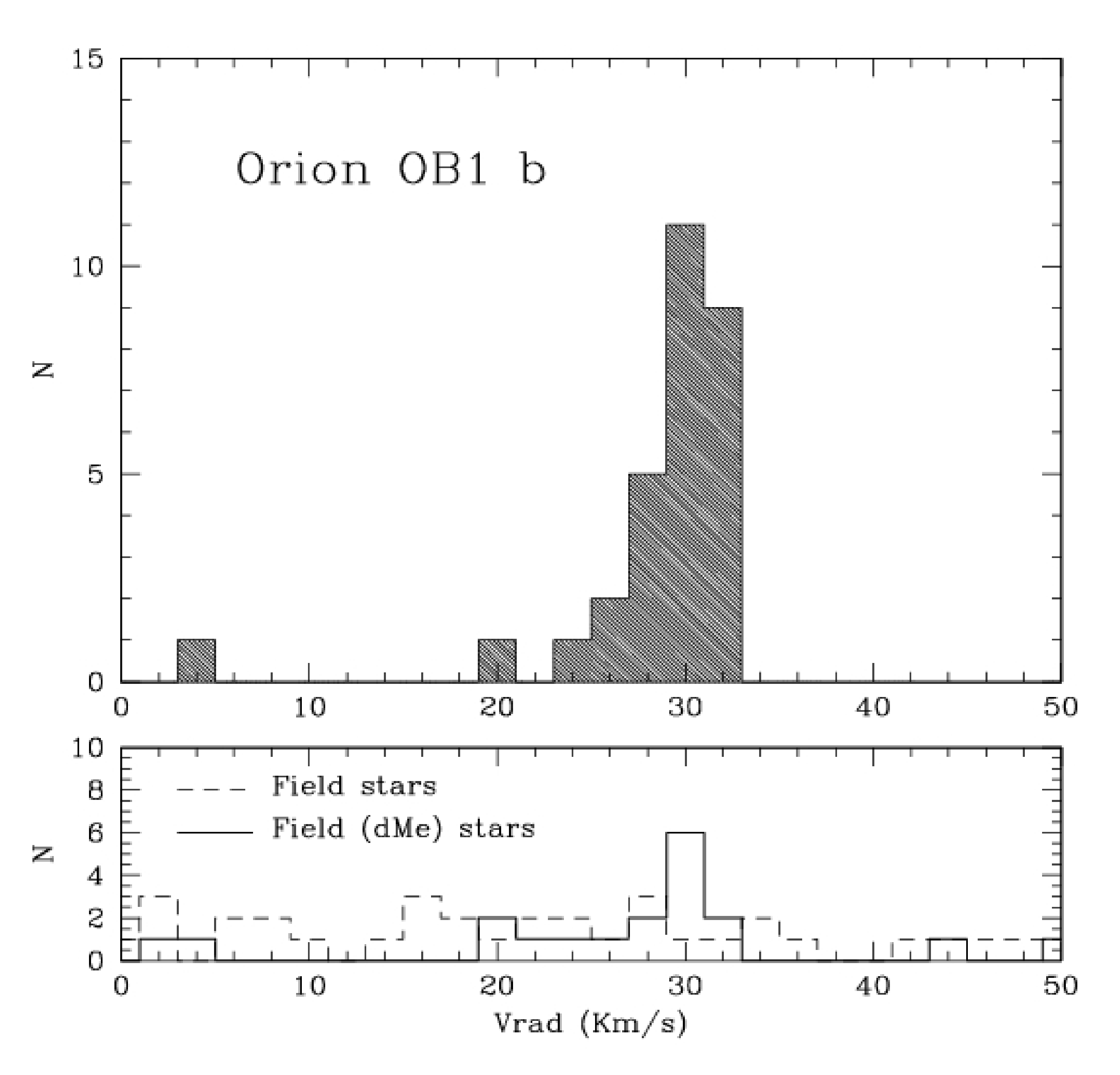
Evolution of Li I in Orion OB1

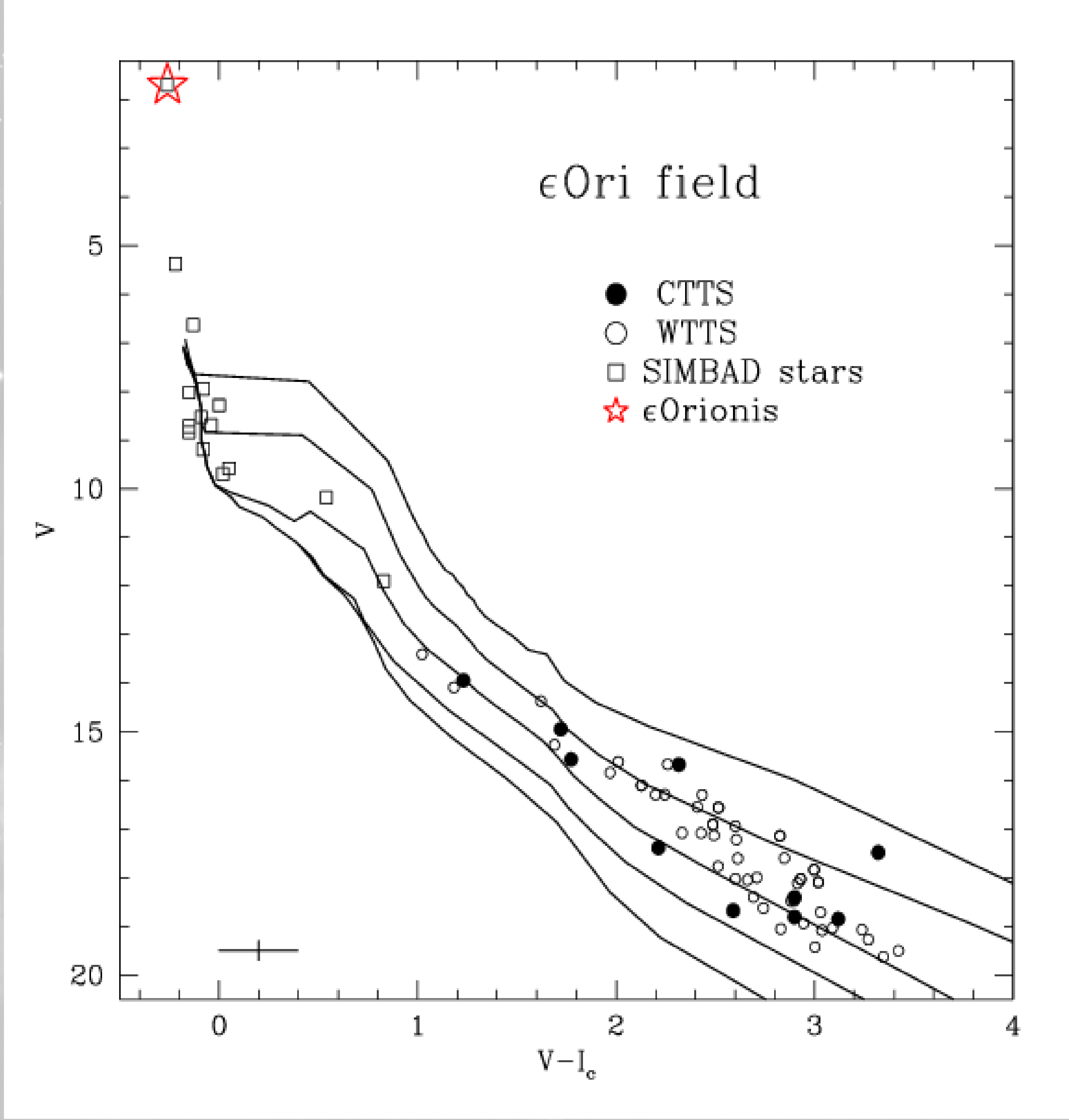


Orion OB1b:
a different kinematic population

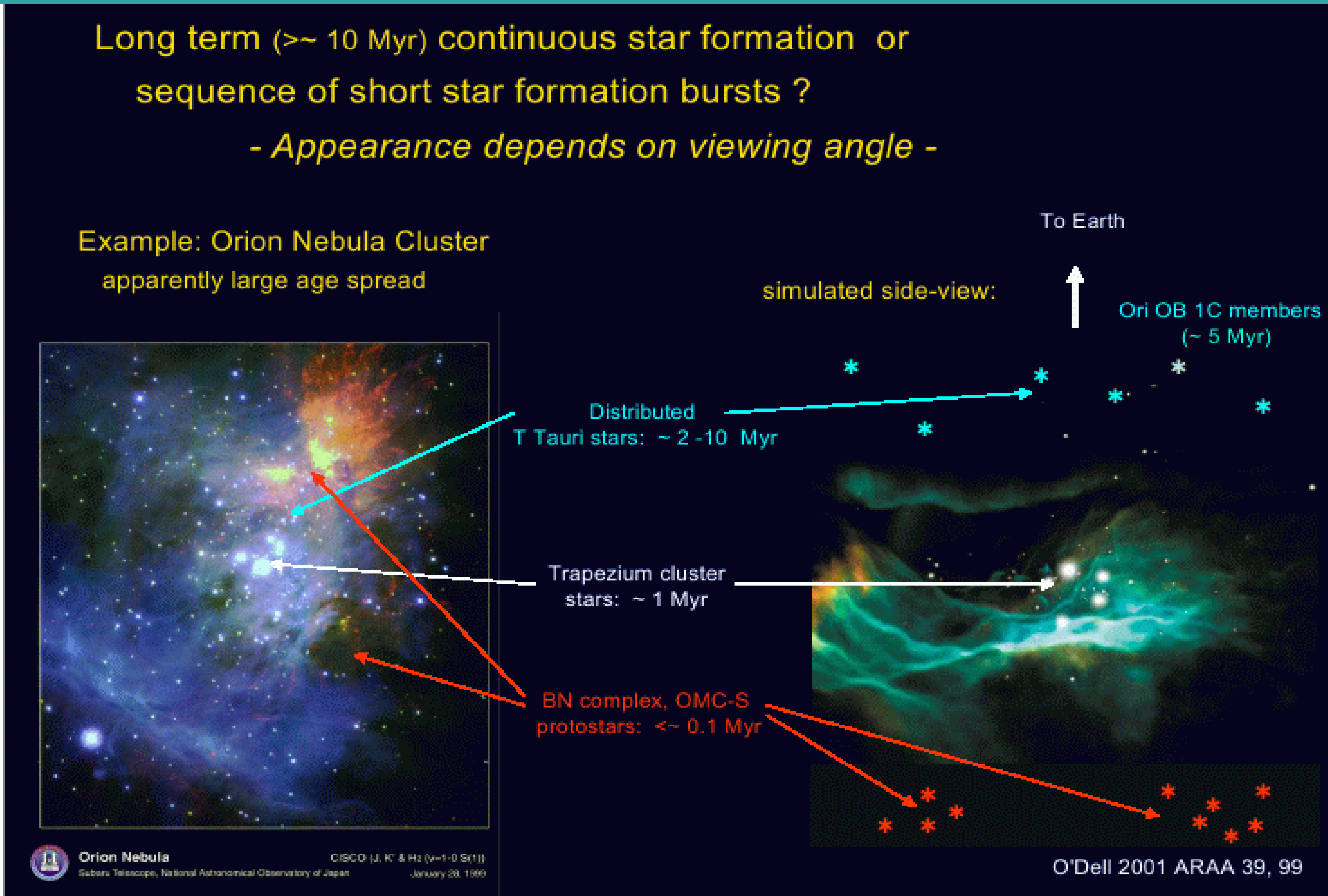
Vrad = 30.1 ± 1.9 km/s
Vgas= ~29 km/s,
Vrad(ε Ori)~ 27 ± 3 km/s

σ Ori cluster: Vrad ~ 31 km/s => common kinematics with Ori OB1b.




ϵOri field
CTTS
WTTS
SIMBAD stars
ϵOrionis
V
V−I_c
5
10
15
20
0
1
2
3
4

Long or short SF?



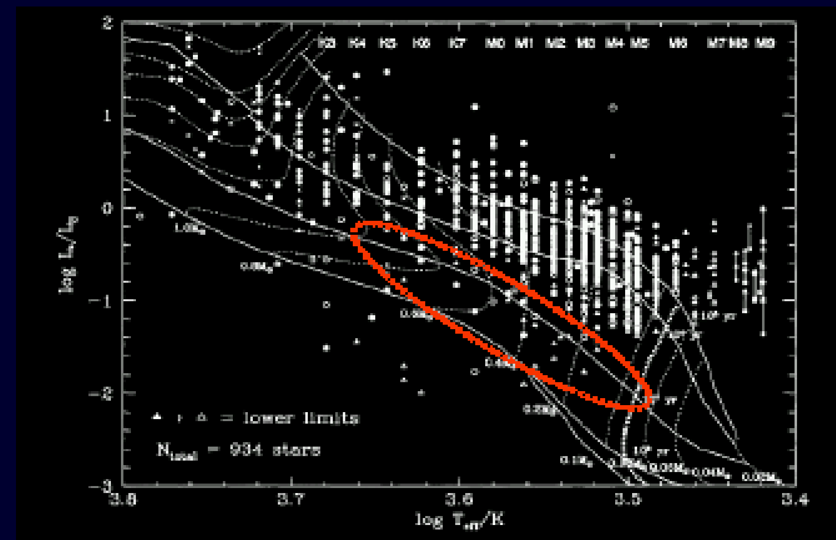
Age spread: Orion

HR Diagram of the Orion Nebula Cluster:

- most stars have ages <~ 1 Myr

- a few much older stars with ~ 10 – 20 Myr

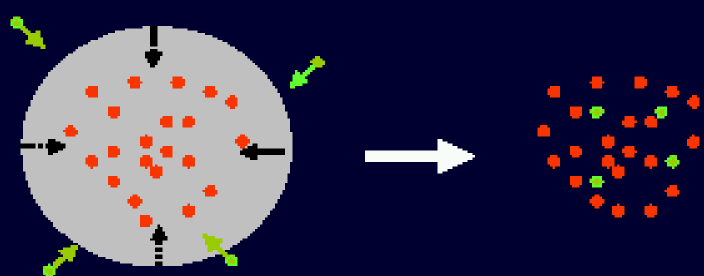
Is this evidence for extended periods of star formation activity ?



Hillenbrand 1997 (AJ 113, 1733)

Pflamm-Altenburg & Kroupa, et al. (in prep.):

A collapsing cloud can capture stars from surrounding (i.e. older) populations



The captured stars will become *kinematic members* of the cluster/association

Population of older ONC members can be explained by this model

→ no evidence for extended periods of star formation