

# Current status of the Sigma Orionis substellar mass function

Karla Peña Ramírez  
Postdoctoral Fellow  
IA-PUC, Chile

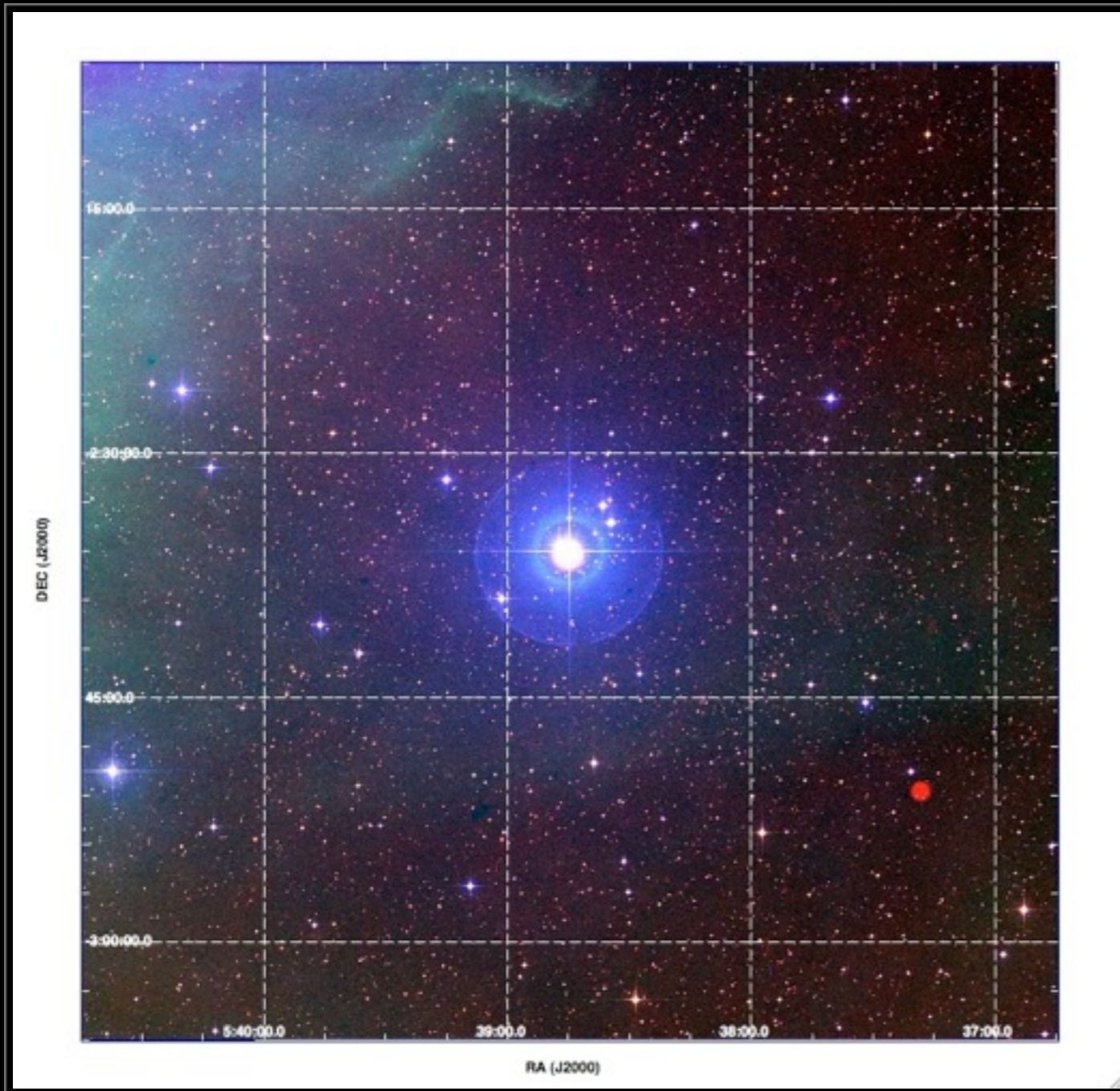
María Rosa Zapatero Osorio  
(CAB / CSIC - INTA)  
Víctor J.S. Béjar  
(IAC)



Charles Bell

31<sup>st</sup> International Colloquium of the Institut d'Astrophysique de Paris  
From Super-Earths to Brown Dwarfs: Who's Who?  
Paris - July 2 2015

# The $\sigma$ Orionis cluster



**Age:  $\sim 3$  Myr**

(Zapatero Osorio et al. 2002)

**Distance:  $\sim 352$  pc**

(Perryman et al. 1997)

**Extinction:  $A_v < 0.25$  mag**

(Lee 1968, Béjar et al. 2004)

**Metallicity:  $[Fe/H] = 0.02 \pm 0.09$  dex**

(González Hernández et al. 2008)

**Radial velocity:  $31.1 \pm 0.1$  km s $^{-1}$**

(Jeffries et al. 2006)

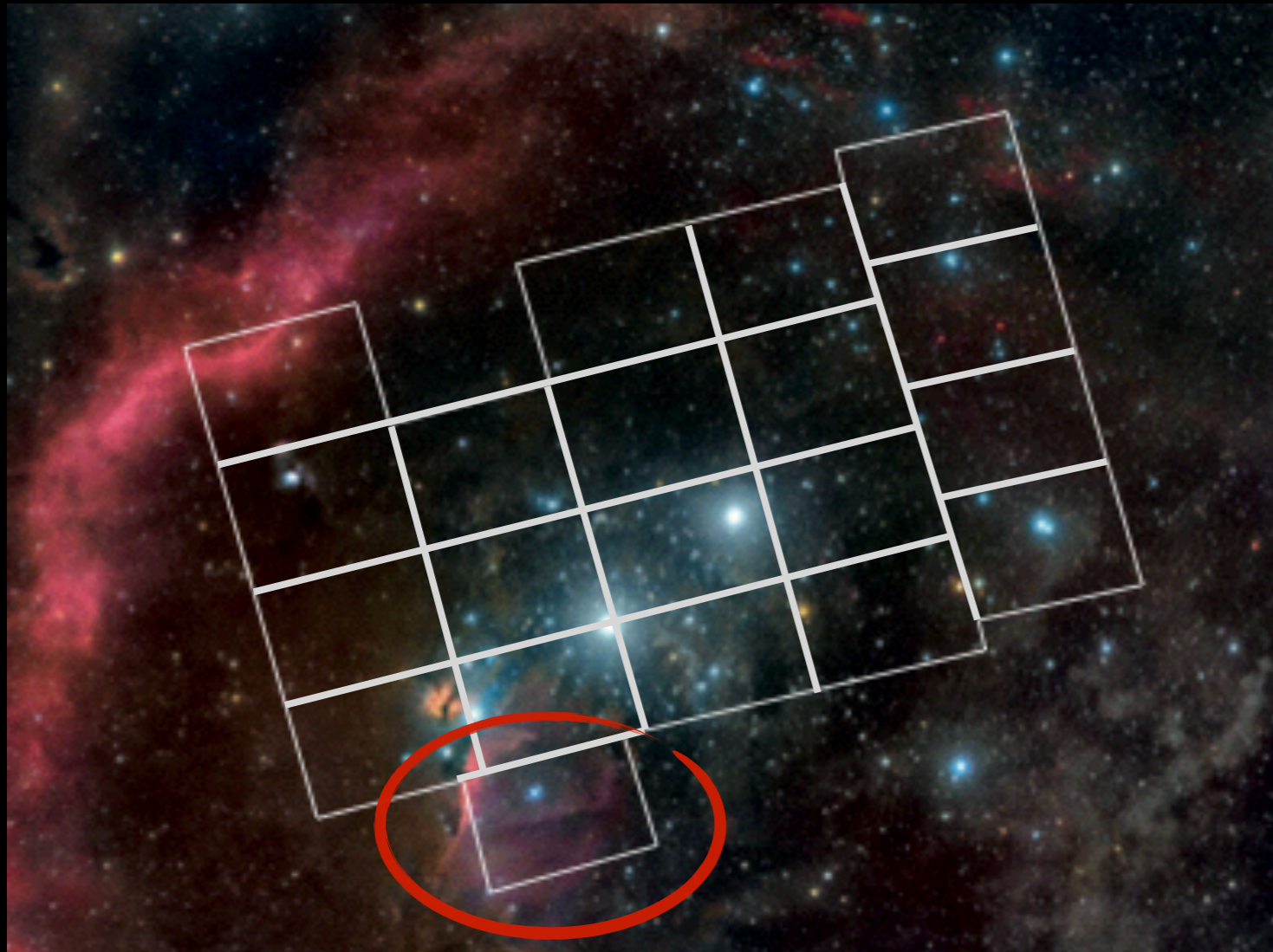
**Proper motion:  $4.7 \pm 1.0$  mas yr $^{-1}$**

(Perryman et al. 1997)

# VISTA Orion survey

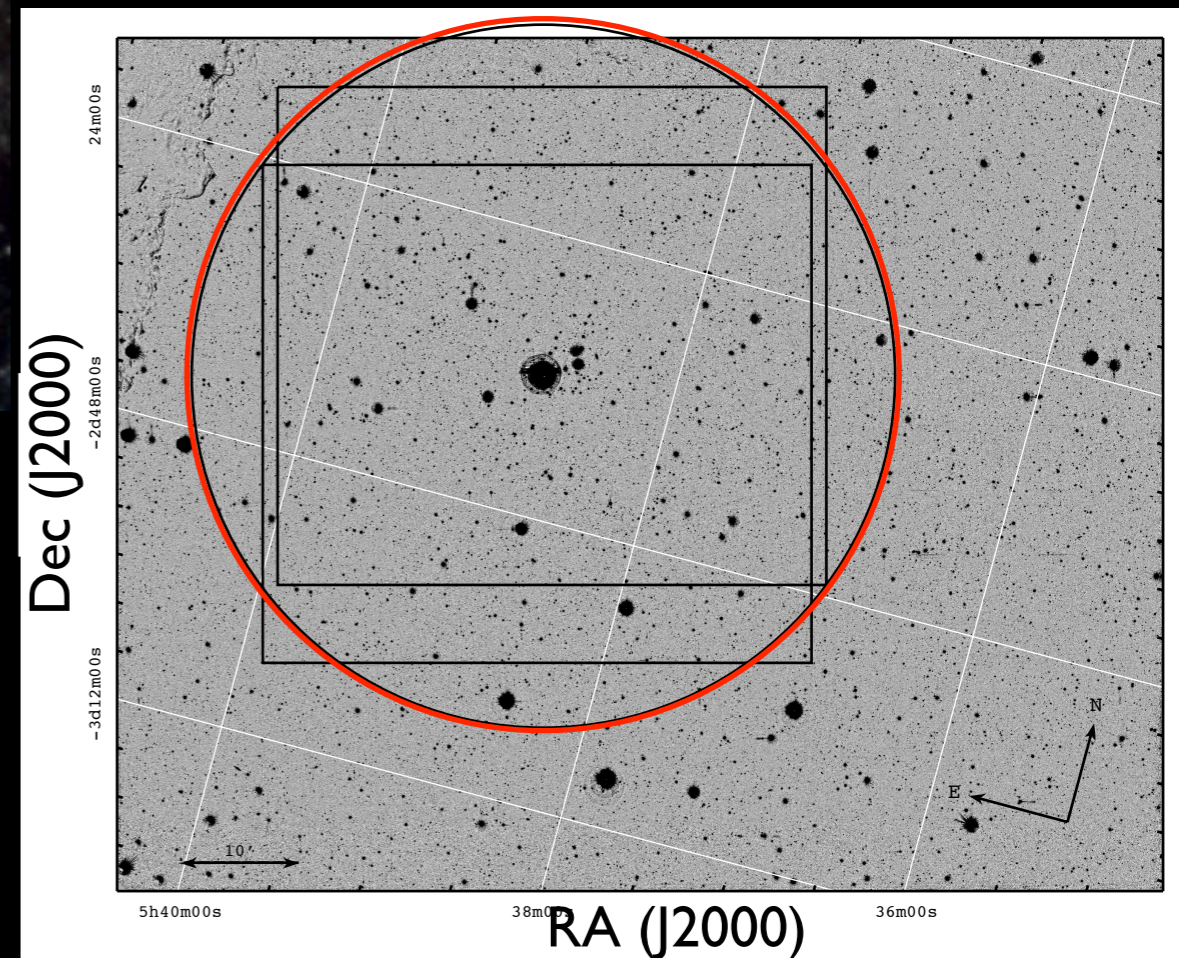
## VISTA/VIRCAM

Science Verification Data

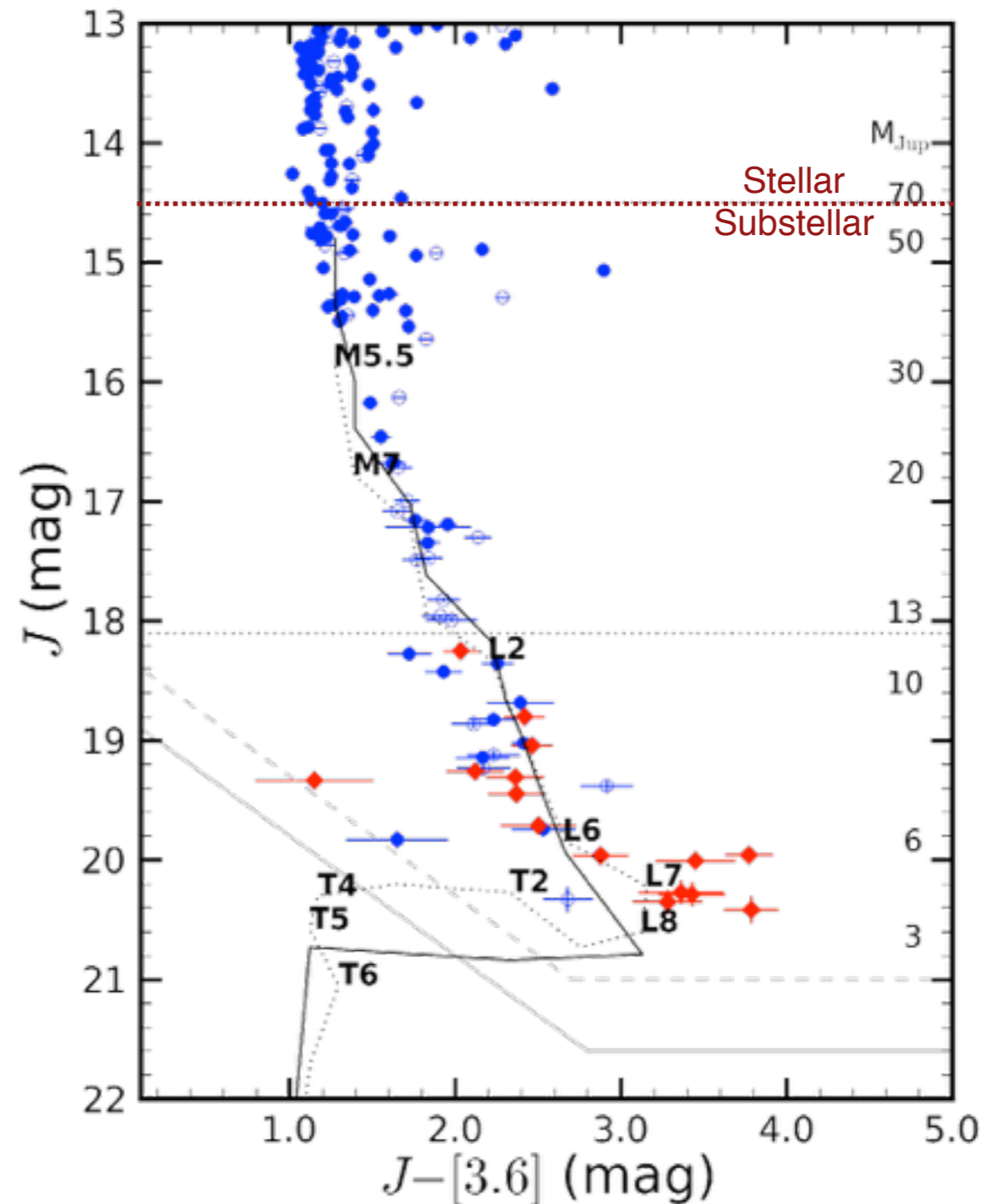
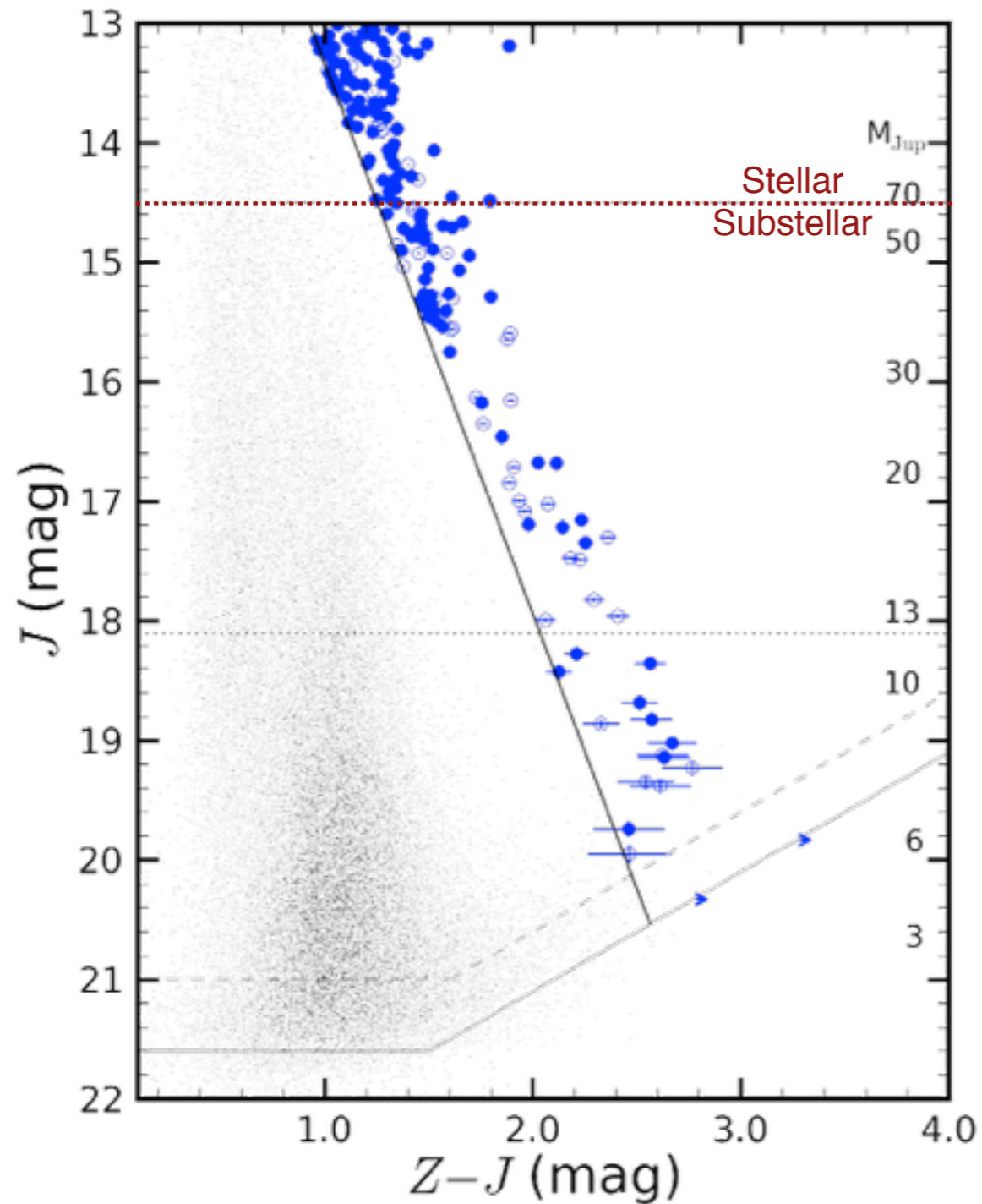


ZYJHKs filters  
+ Optical (IZ)  
+ Spitzer ([3.6], [4.5], [5.8], [8.0])  
+ WISE (W1-4)

Z comp  $\sim 22.6$  mag ( $\sim 6 M_{\text{Jup}}$ , 3Myr)  
J comp  $\sim 21.0$  mag ( $\sim 3 M_{\text{Jup}}$ , 3Myr)  
 $\sim 2800$  arcmin<sup>2</sup>



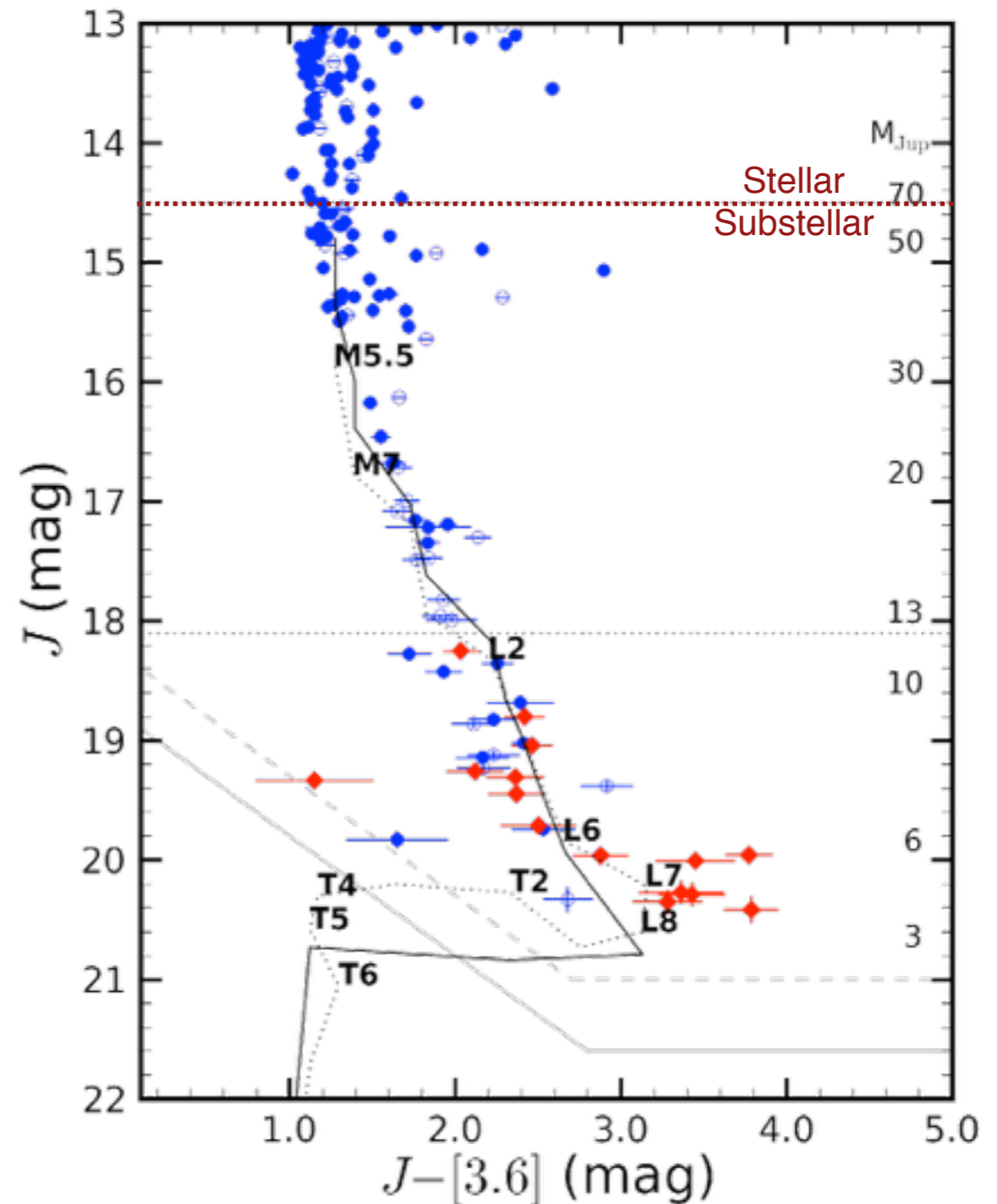
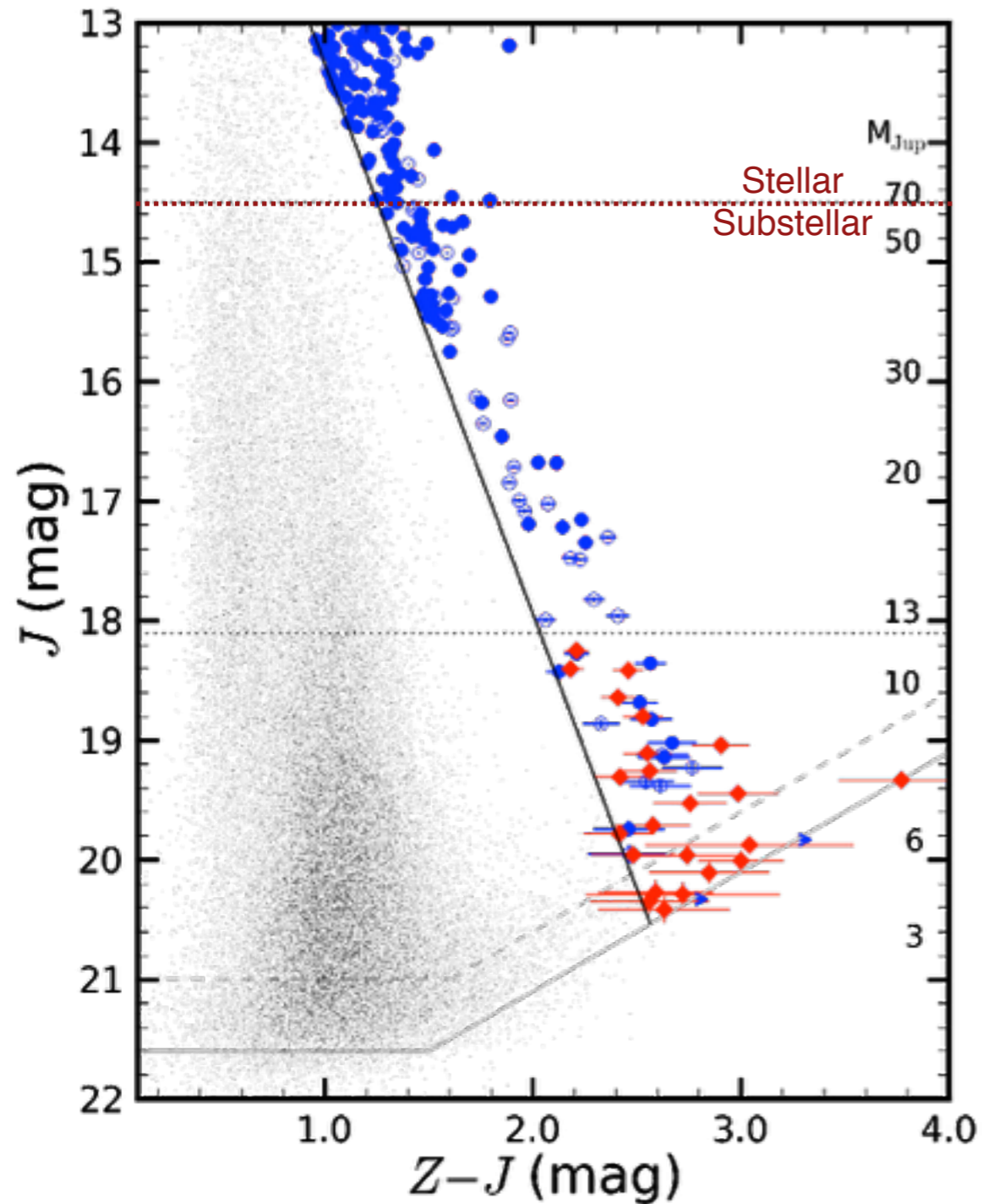
# VISTA photometric selection



$J = 13 - 20.5$  mag ( $0.25 - 0.004 M_{\odot}$ ),  $\sim 2800$  arcmin<sup>2</sup>

23 new photometric candidates + optical + *Spitzer* + *WISE* data

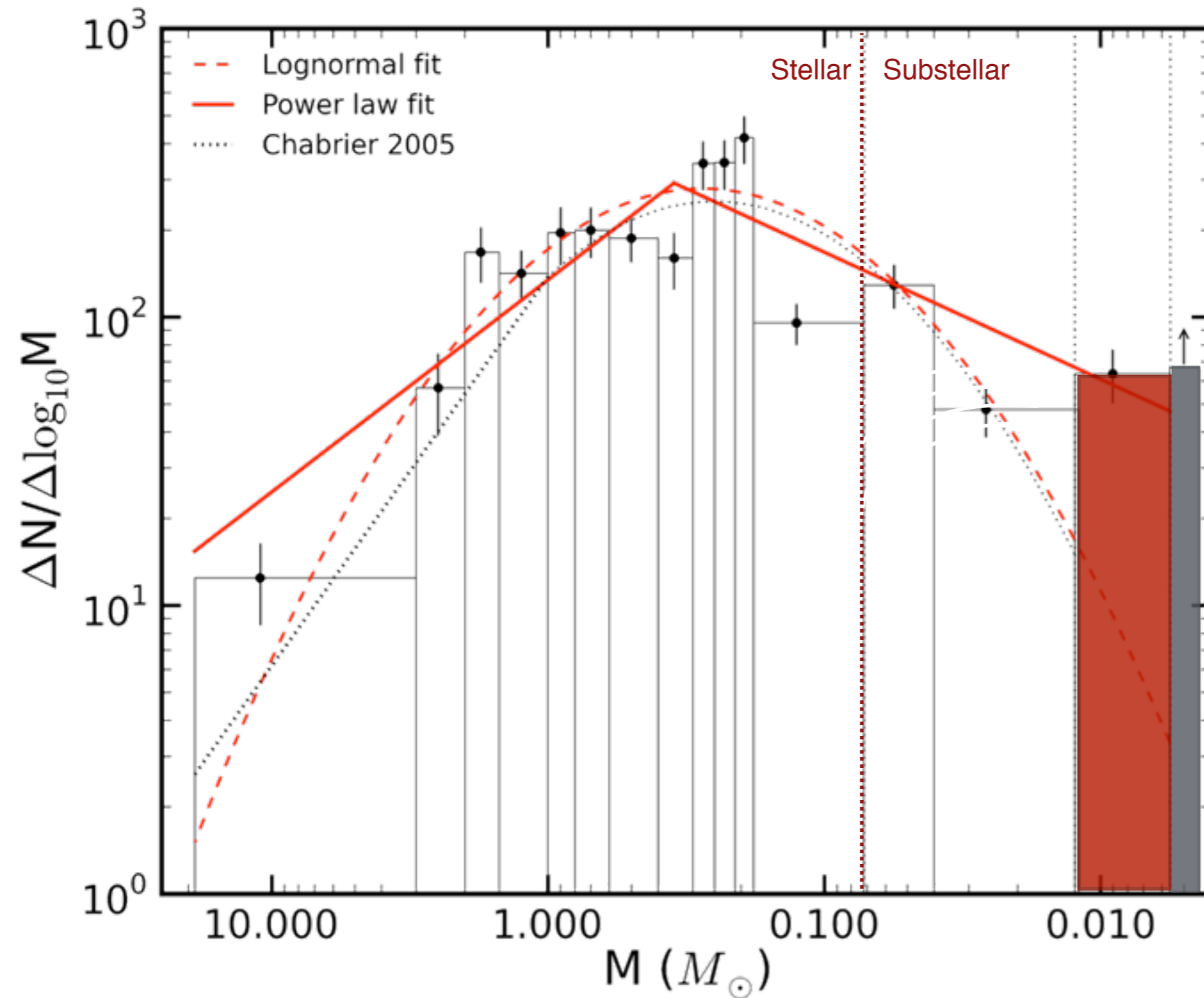
# VISTA photometric selection



$J = 13 - 20.5$  mag ( $0.25 - 0.004 M_{\odot}$ ),  $\sim 2800$  arcmin<sup>2</sup>

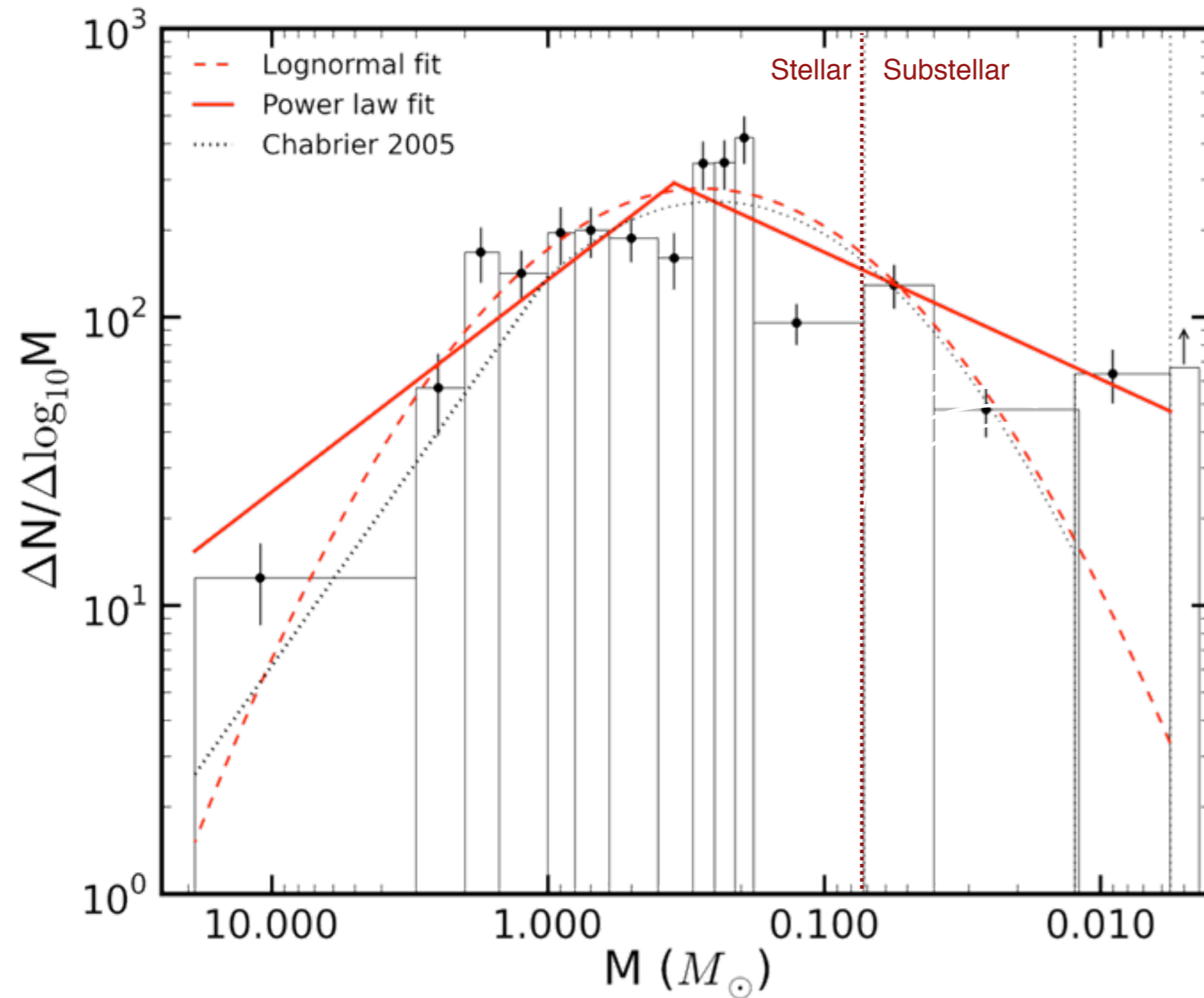
23 new photometric candidates + optical + *Spitzer* + *WISE* data

# $\sigma$ Orionis stellar and substellar mass function

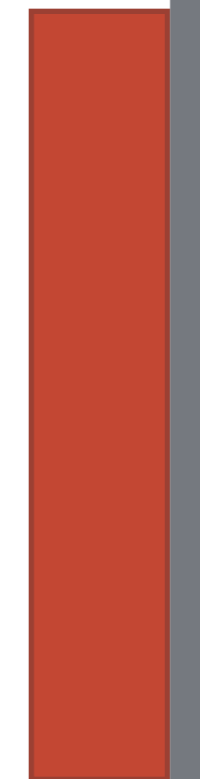


Entire mass function in 2012:  
71% of the sources are  
Sigma Orionis likely members

# $\sigma$ Orionis stellar and substellar mass function



Entire mass function in 2012:  
71% of the sources are  
Sigma Orionis likely members



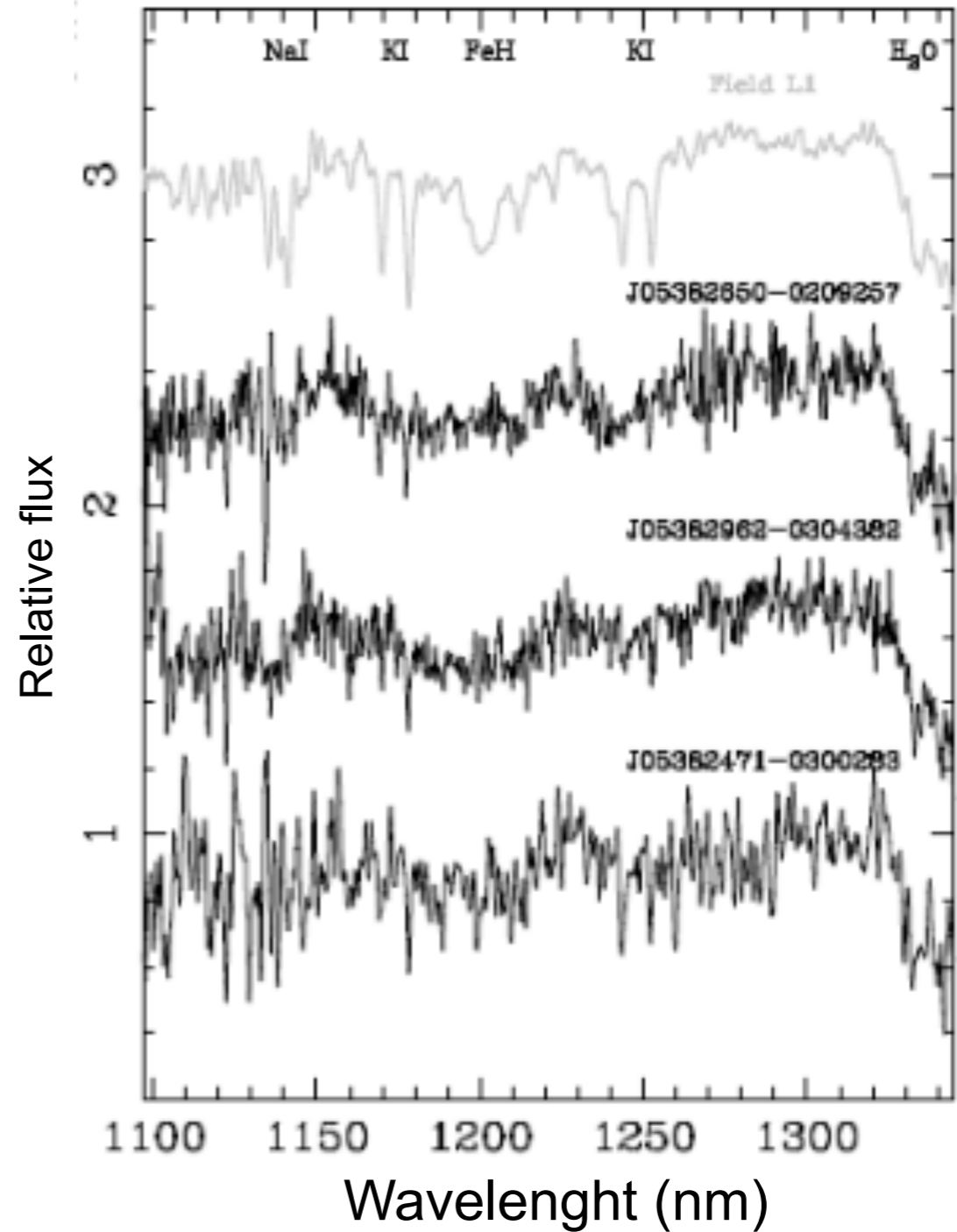
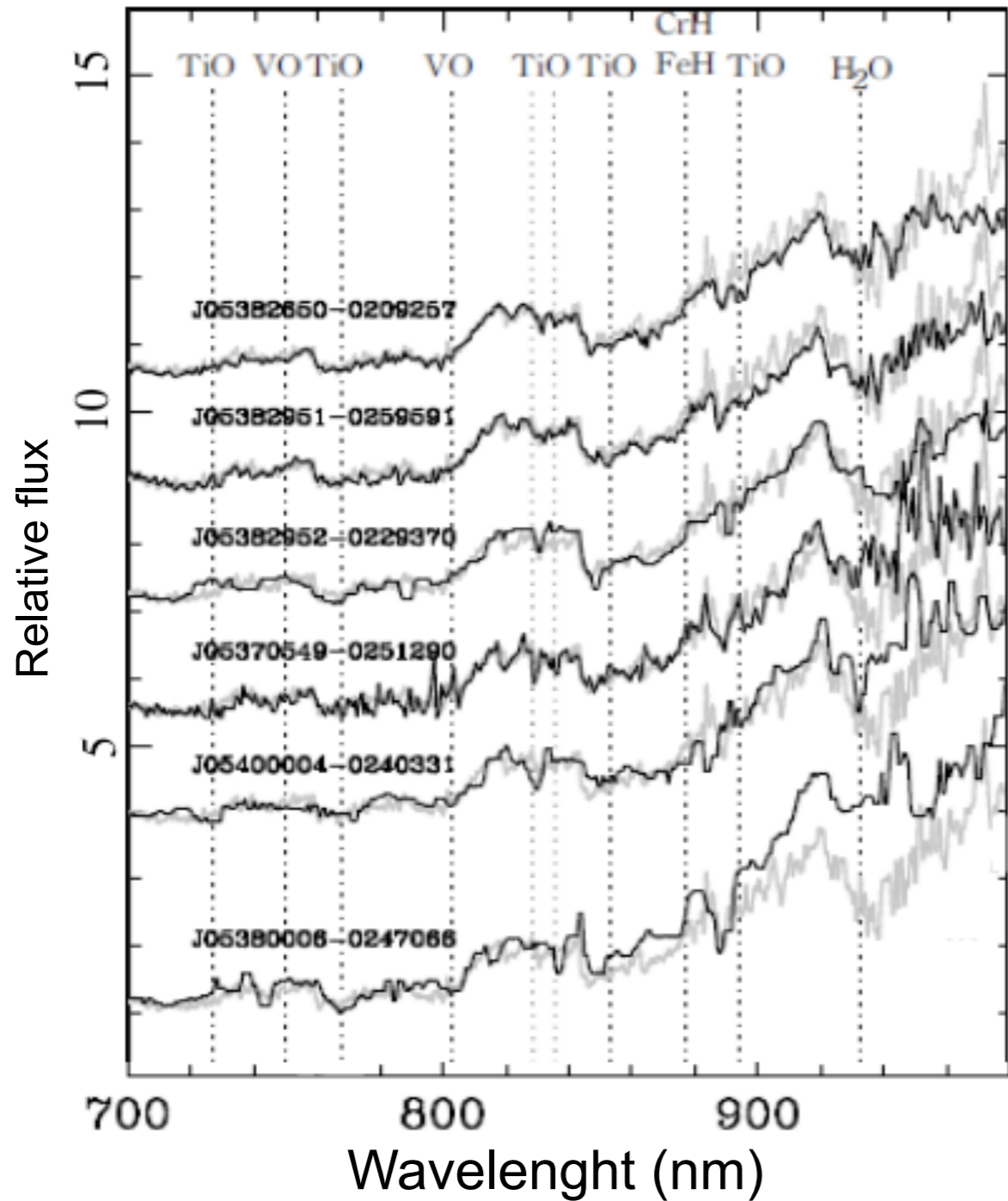
In 2013:  
Spectroscopic  
confirmation 27%

In 2015:  
Spectroscopic  
confirmation 86%

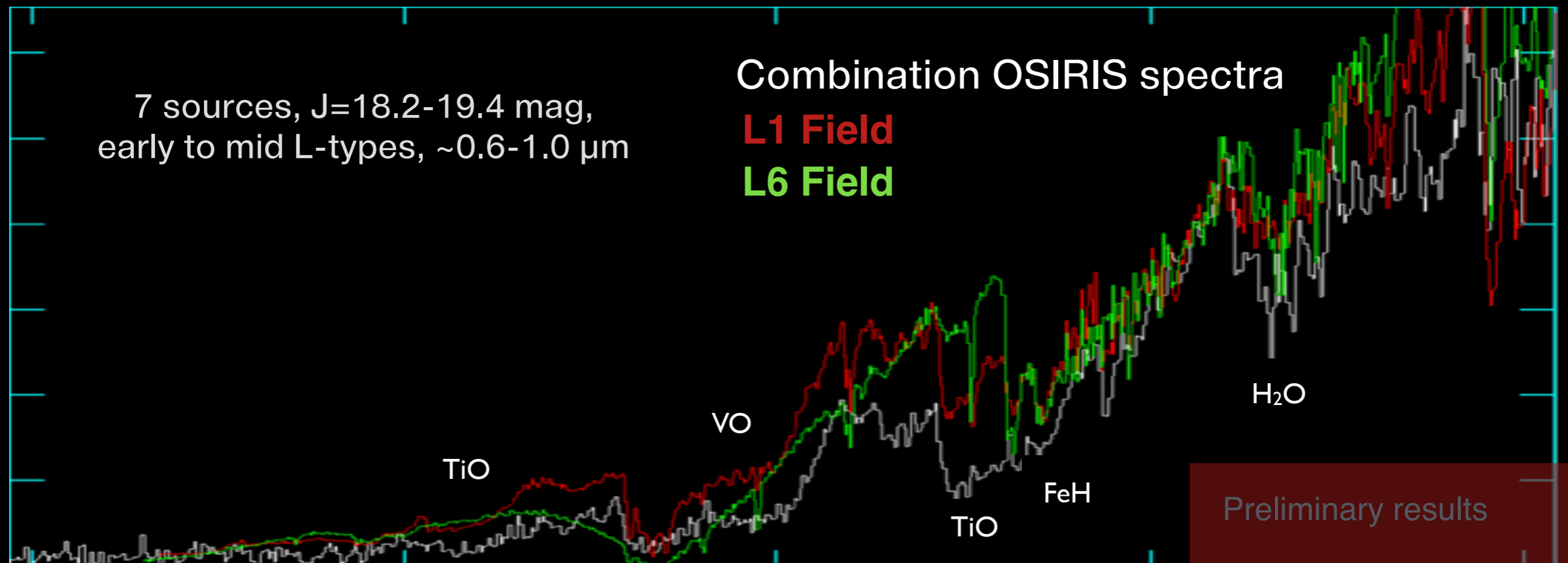
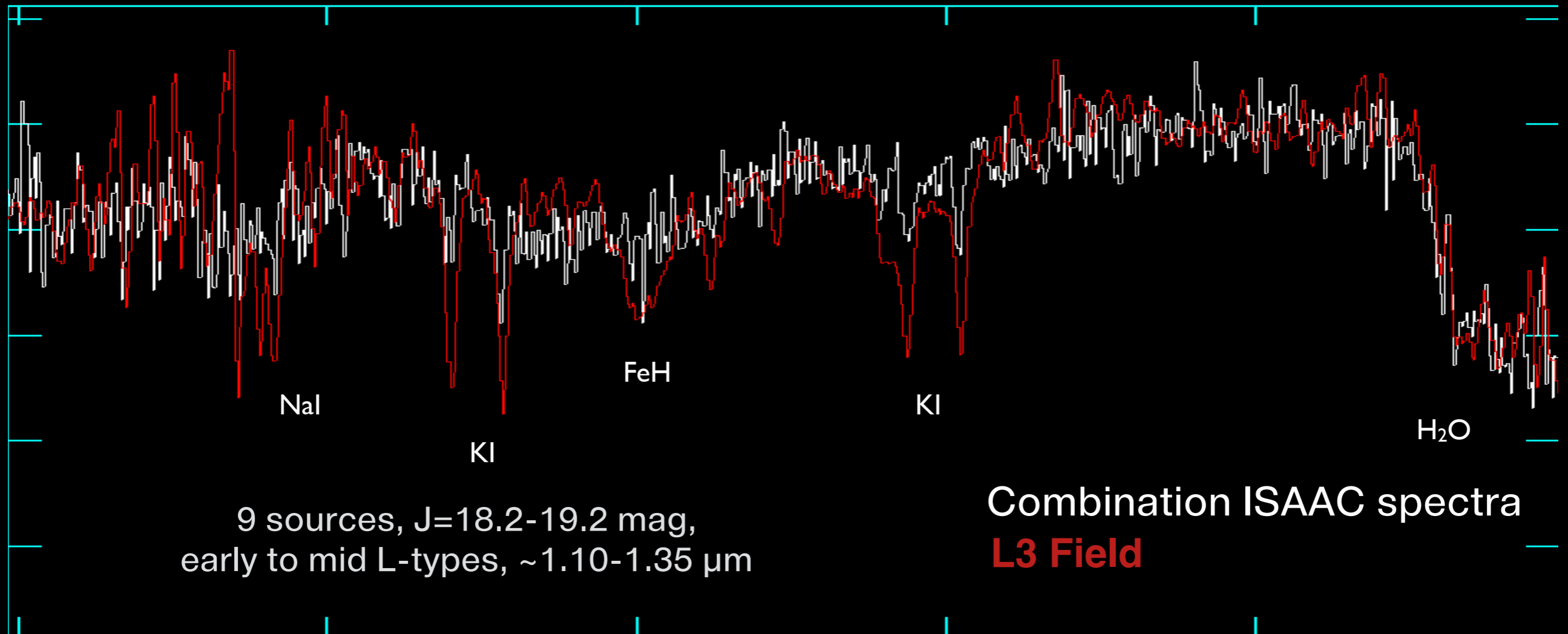
Success rate  
photometric  
selection > 80%

$N \sim 400, (19 - 0.004 M_{\odot}), \sim 2800 \text{ arcmin}^2$

# Optical and near-infrared spectroscopy OSIRIS/GTC + ISAAC/VLT







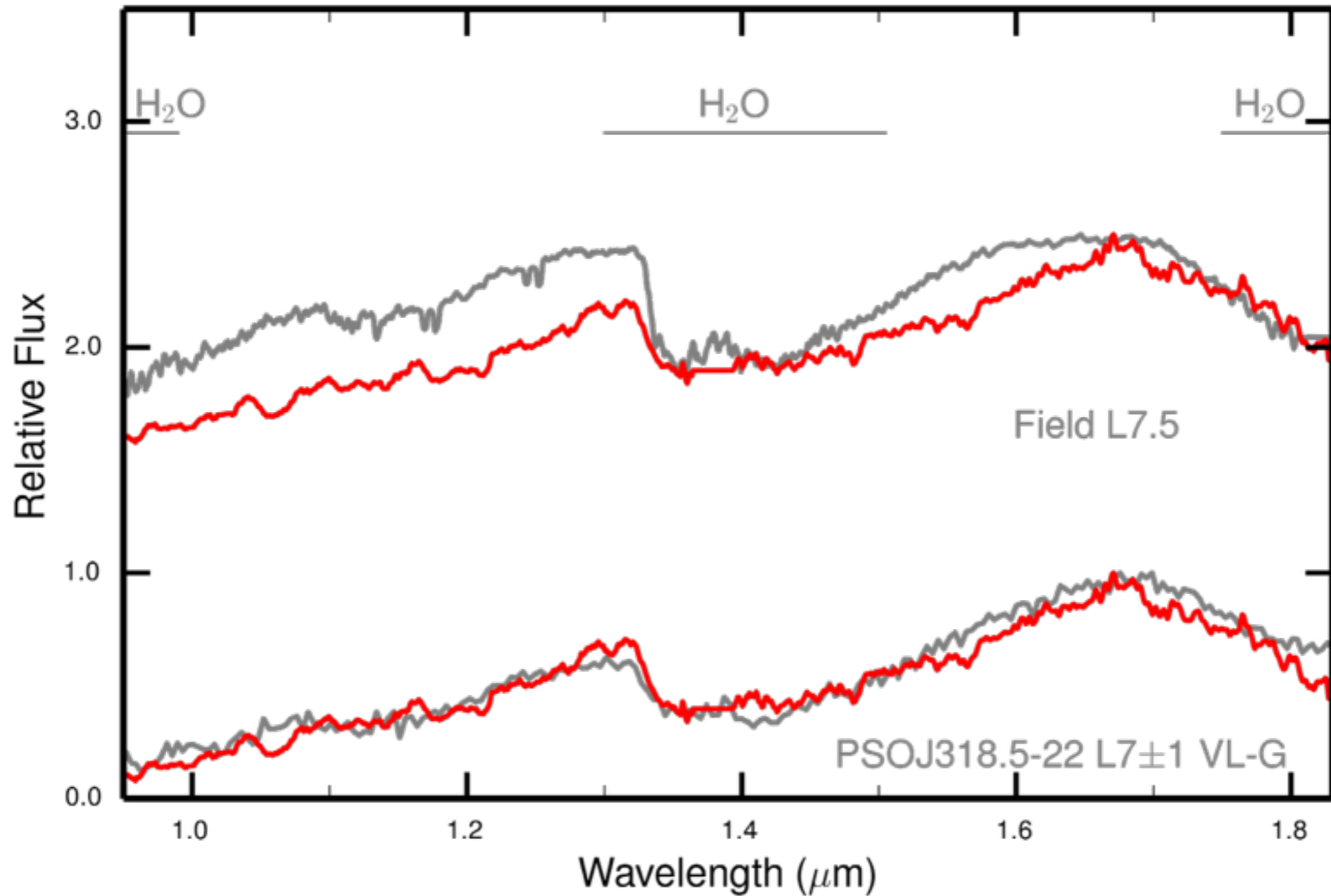
**Latest observed candidate:**

**SOriJ054037-024001**

**J=19.5 mag,  $\sim 7 M_{\text{Jup}}$**

**FIRE/LCO R $\sim 500$**

Preliminary results



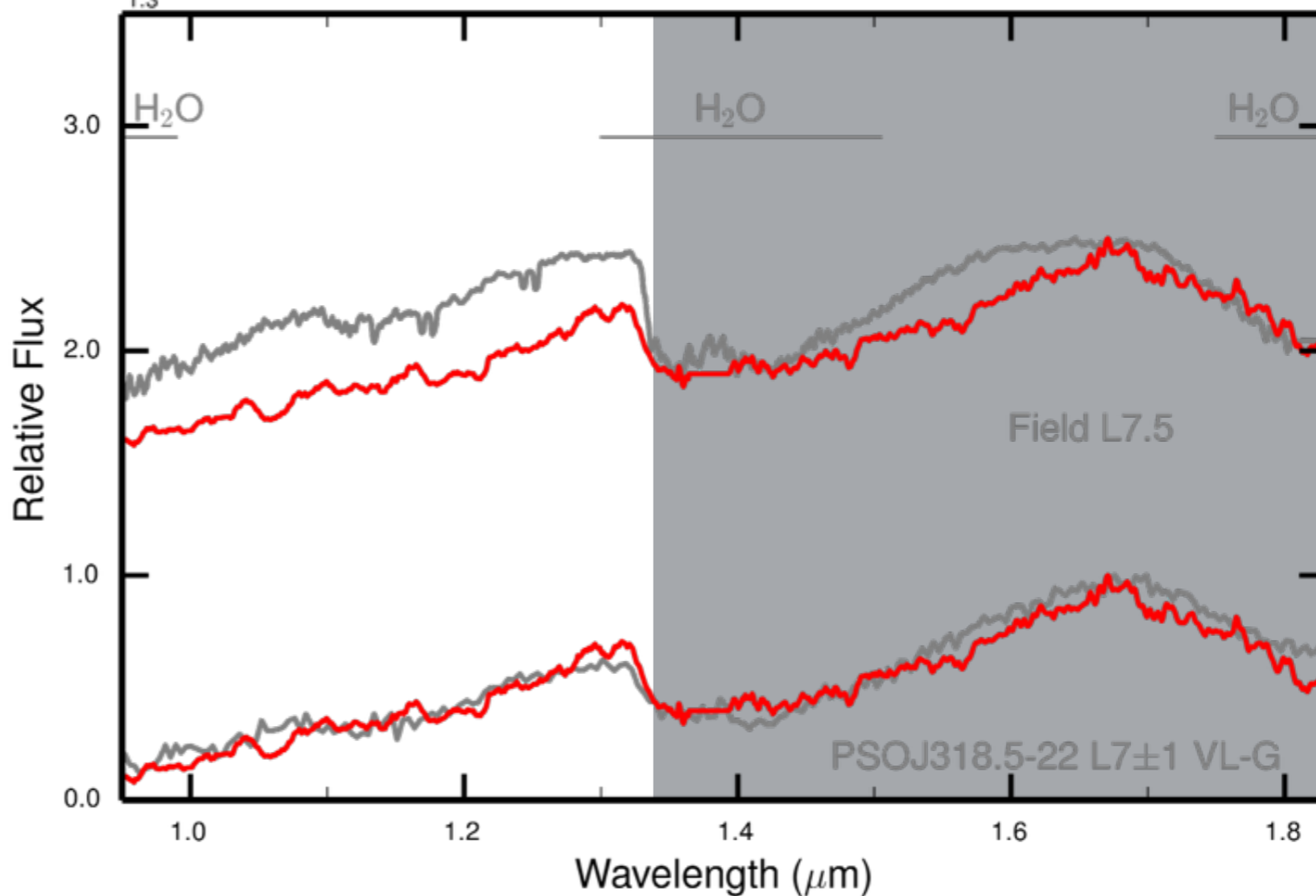
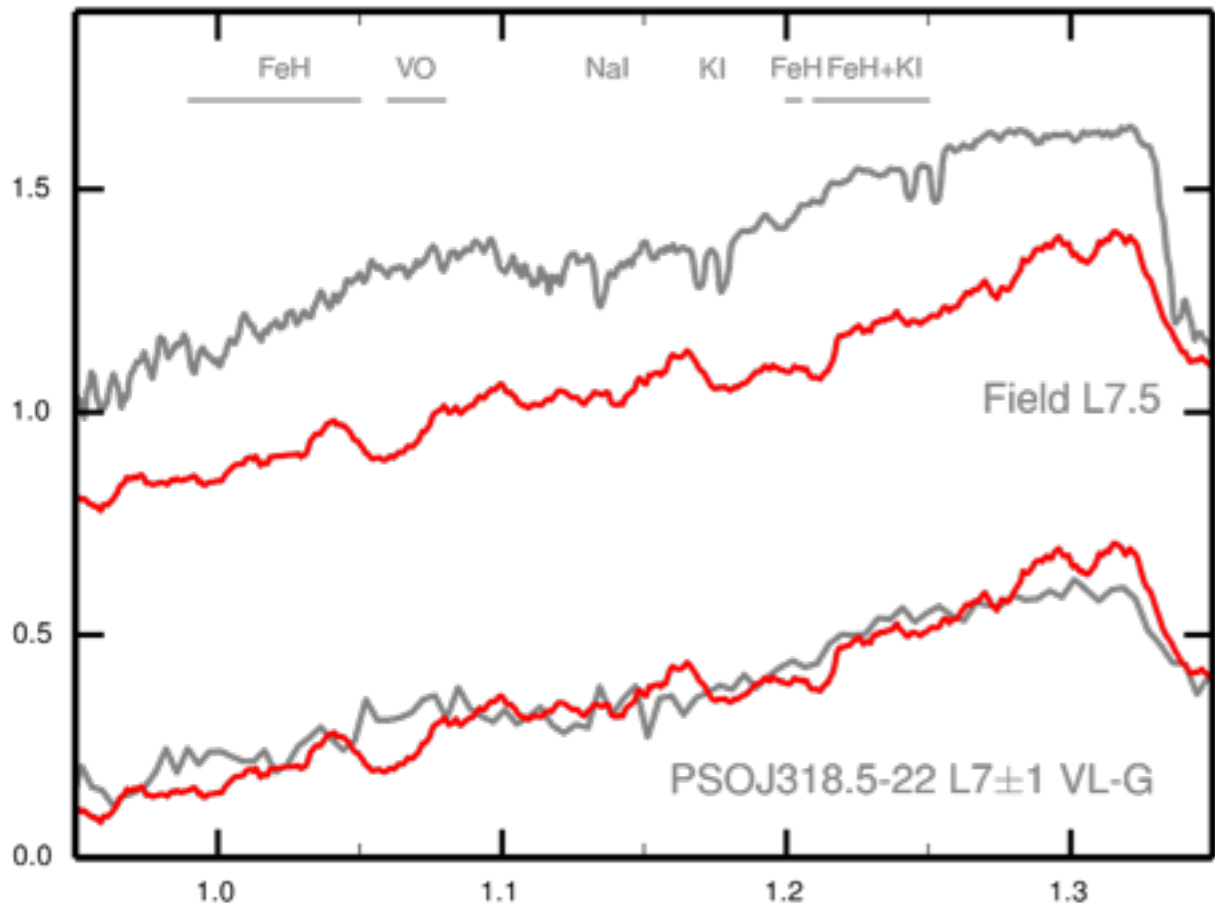
**Latest observed candidate:**

**SOriJ054037-024001**

**J=19.5 mag,  $\sim 7 M_{\text{Jup}}$**

**FIRE/LCO R $\sim 500$**

Preliminary results



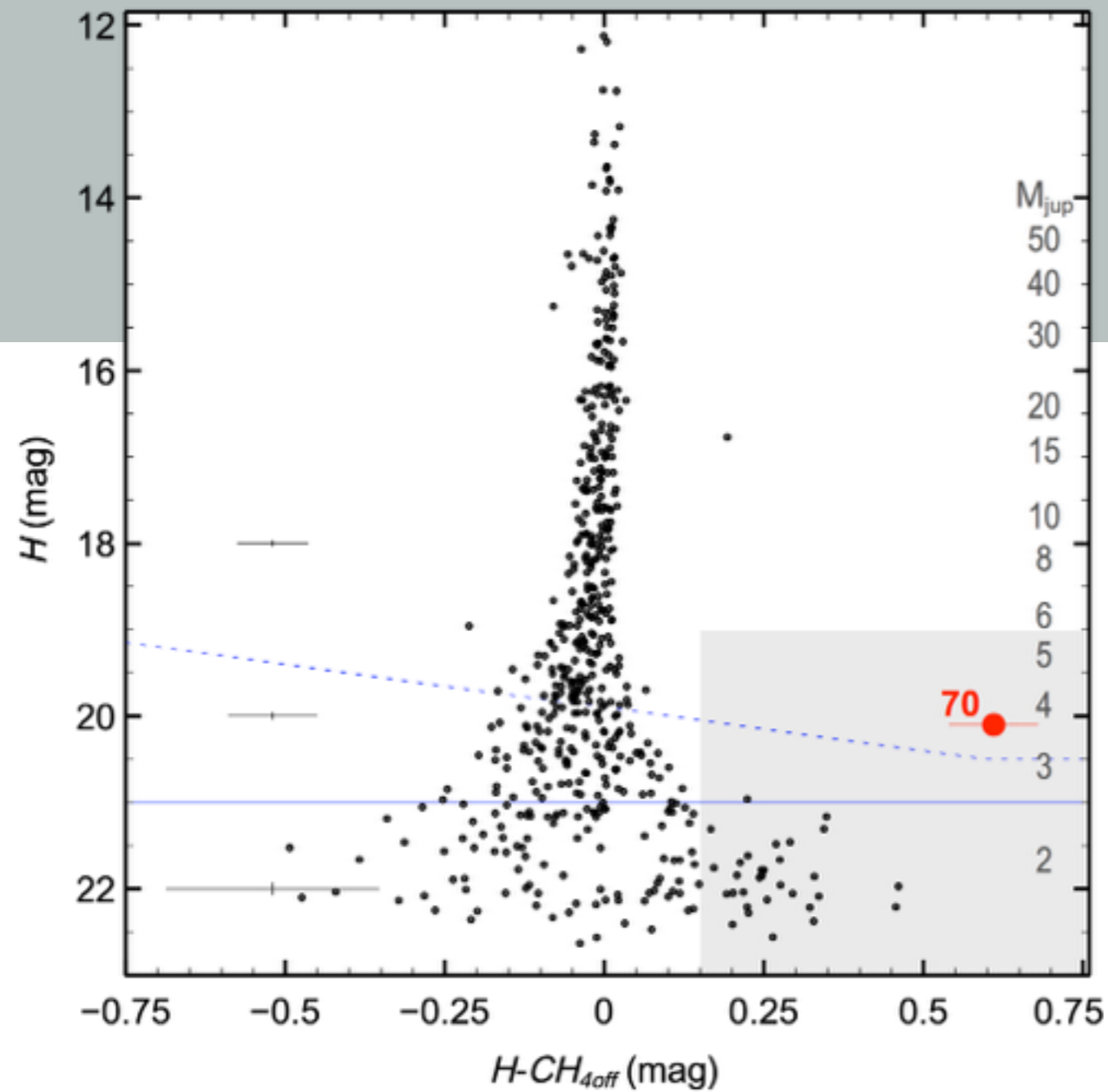
15 spectra

J=18.2-19.9 mag

M  $\sim 11-6 M_{\text{Jup}}$

Deep search for T type sources

$J_{\text{comp}} \sim 21.7$  mag  
in  $\sim 120$  arcmin<sup>2</sup>

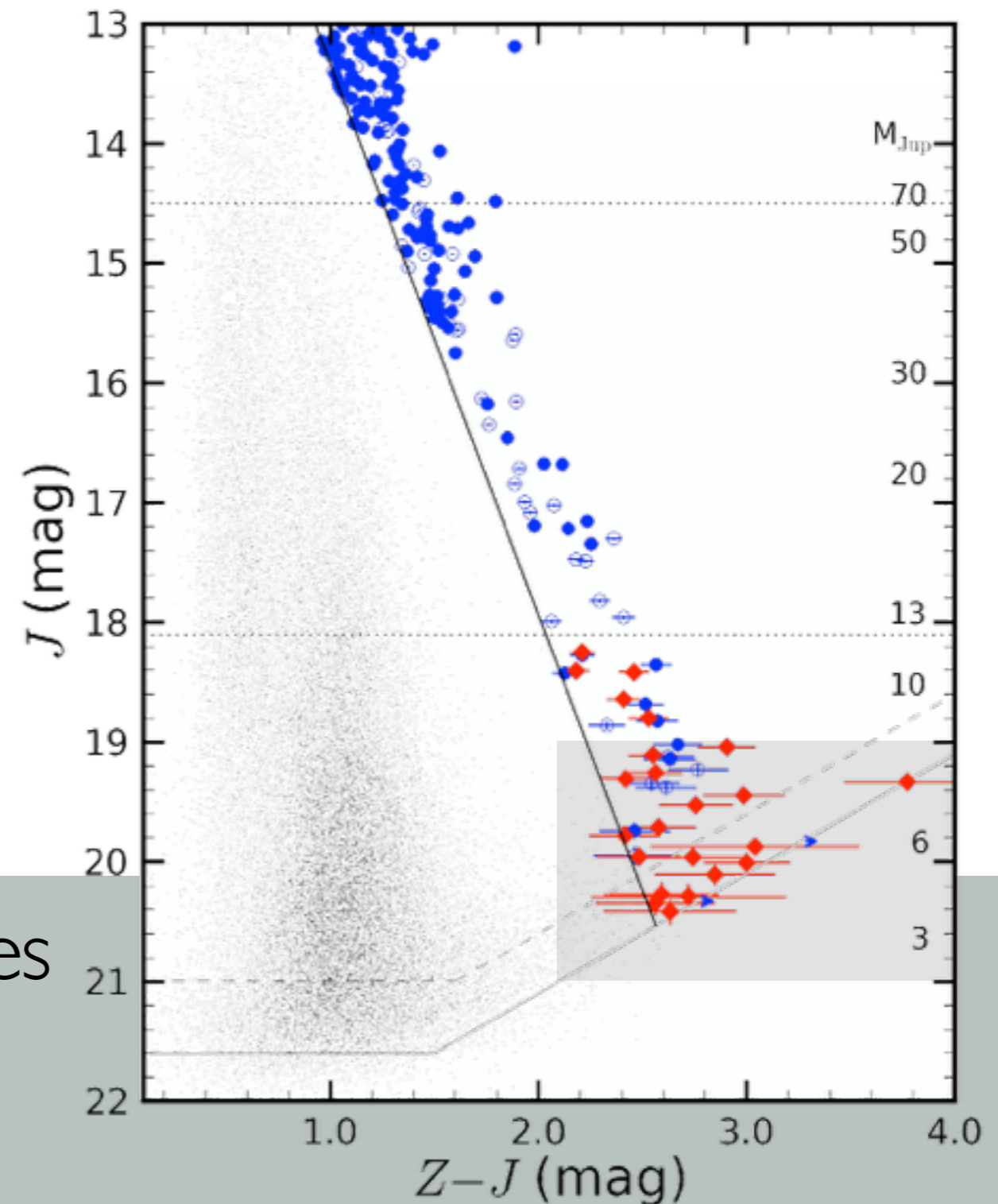


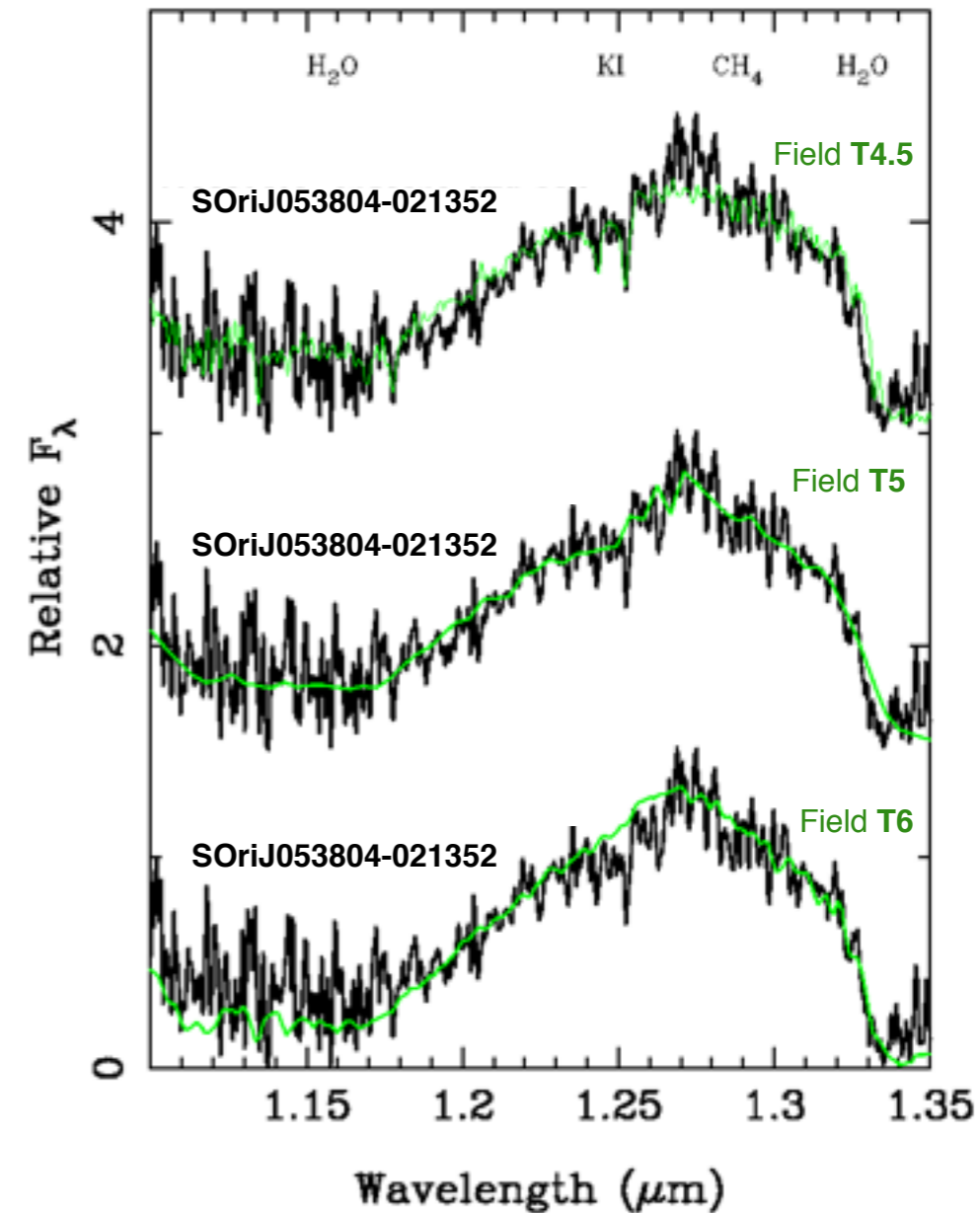
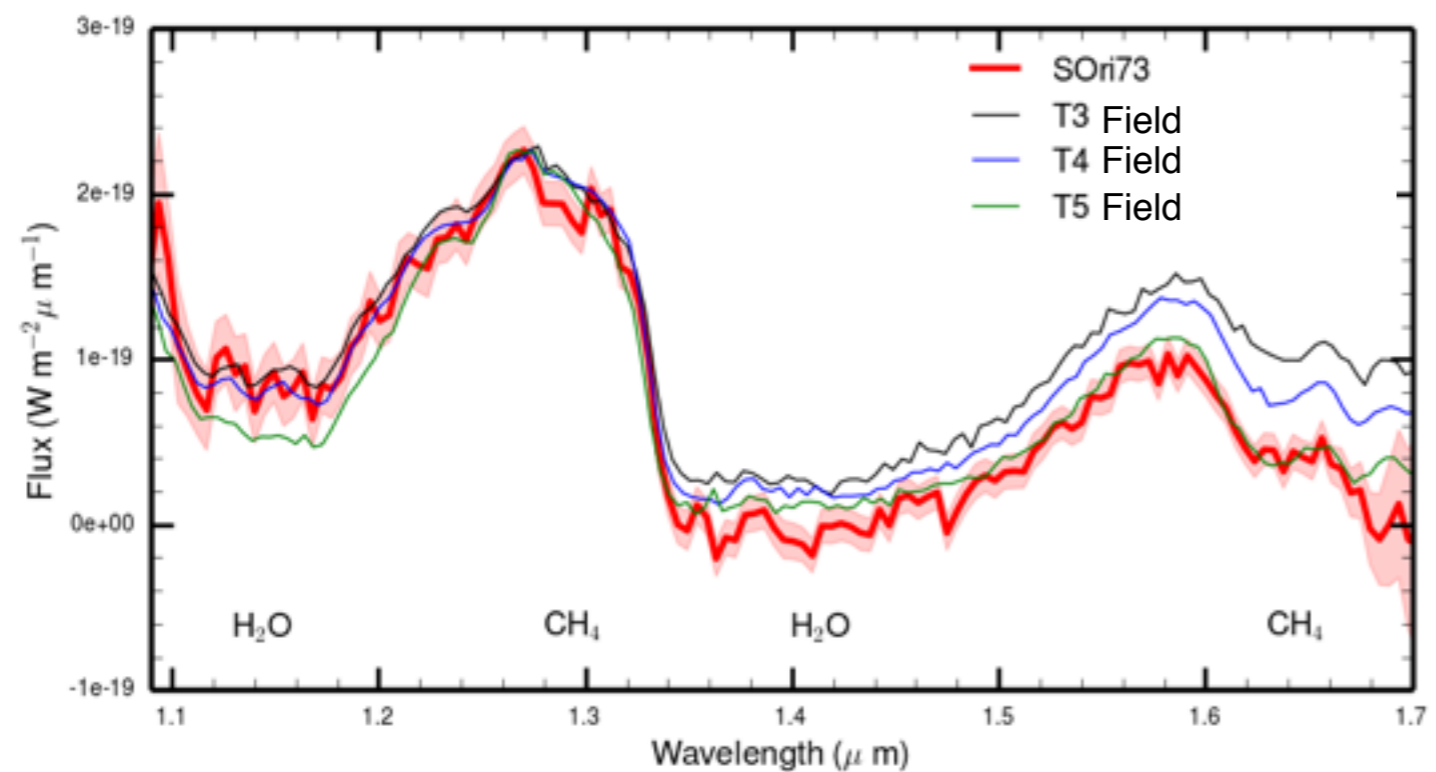
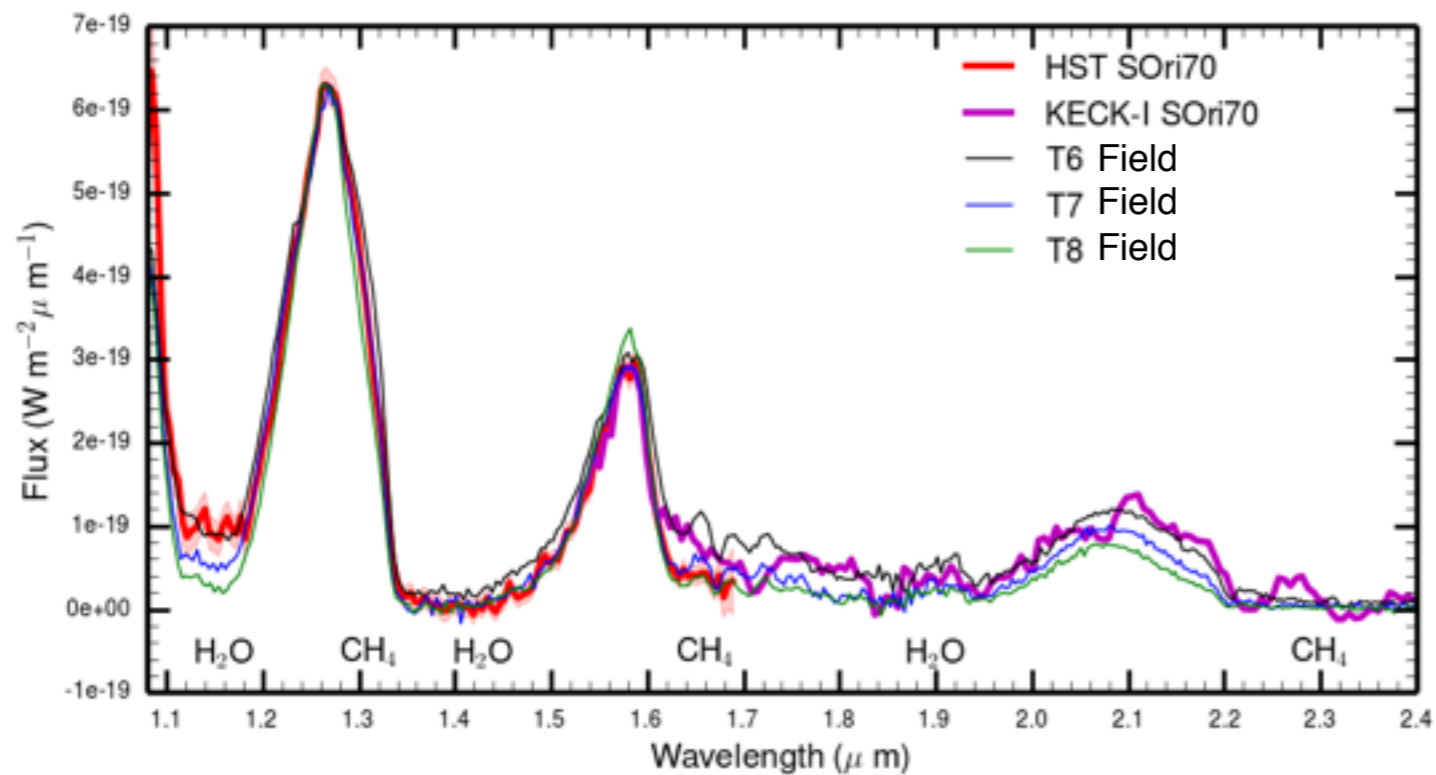
Methane imaging plus  
proper motion (>7 yr) analysis

Extended search for T type sources

$J_{\text{comp}} \sim 21.0$  mag

in  $\sim 2800$  arcmin<sup>2</sup>





ISAAC J band spectroscopy (J0538-0213)  
 HST public spectra (Program I2217, Pl. Lucas) for SOri70 and SOri73)

J = 19.3 - 20.6 mag

# Summary & Conclusions

There is a **spectroscopical confirmed population** of very low mass substellar sources in Sigma Orionis. This could be the **largest clustered substellar population** known to date.

Upcoming 20h at FIRE/LCO December 2015

There is an apparent lack of **T type sources** in Sigma Orionis:

- \* Not formed (opacity limit by fragmentation, **IMF mass cut off**)
- \* Not reached yet (even deeper imaging, fainter than predicted by theoretical models )
- \* **Different kinematics (ejection dynamical interactions)**

## Further research

Built the **spectroscopic sequence** of substellar sources in Sigma Orionis.  
An **astrometric study** in the entire low mass Sigma Orionis populations.  
Search for **companions** in the entire region...still a lot of work to do!!!

# Current status of the Sigma Orionis substellar mass function

kpena@astro.puc.cl



Charles Bell

31<sup>st</sup> International Colloquium of the Institut d'Astrophysique de Paris  
From Super-Earths to Brown Dwarfs: Who's Who?  
Paris - July 2 2015