Experience with the Subaru Telescope and Possible Future Involvements

--- *Perspective as an International User*

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Subaru Users Meeting
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Deacon Niall … Hertfordshire U (UK)
Loic Albert, Etienne Artigau, Rene Doyon … U Montreal (Canada)
Gregory Herczeg, Jessy Jose … NAOC (China)
Mickael Bonnefoy, Philippe Delorme … UJF (France)
Mike Liu … IfA (UH, USA)
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Conclusions

- Now … 4 m class to select (reliable) candidates;
  Rho Oph, Taurus (130 pc); IC 348 (320 pc)
  8-10 m to secure the discovery
  Rho Oph, Taurus OK; no Ts beyond

- Next … 8-10 m for candidacy
  TMT/GMT sp. confirmation AND characterization

→ Cool atmosphere physics and chemistry (cloud formation, isotopes …)

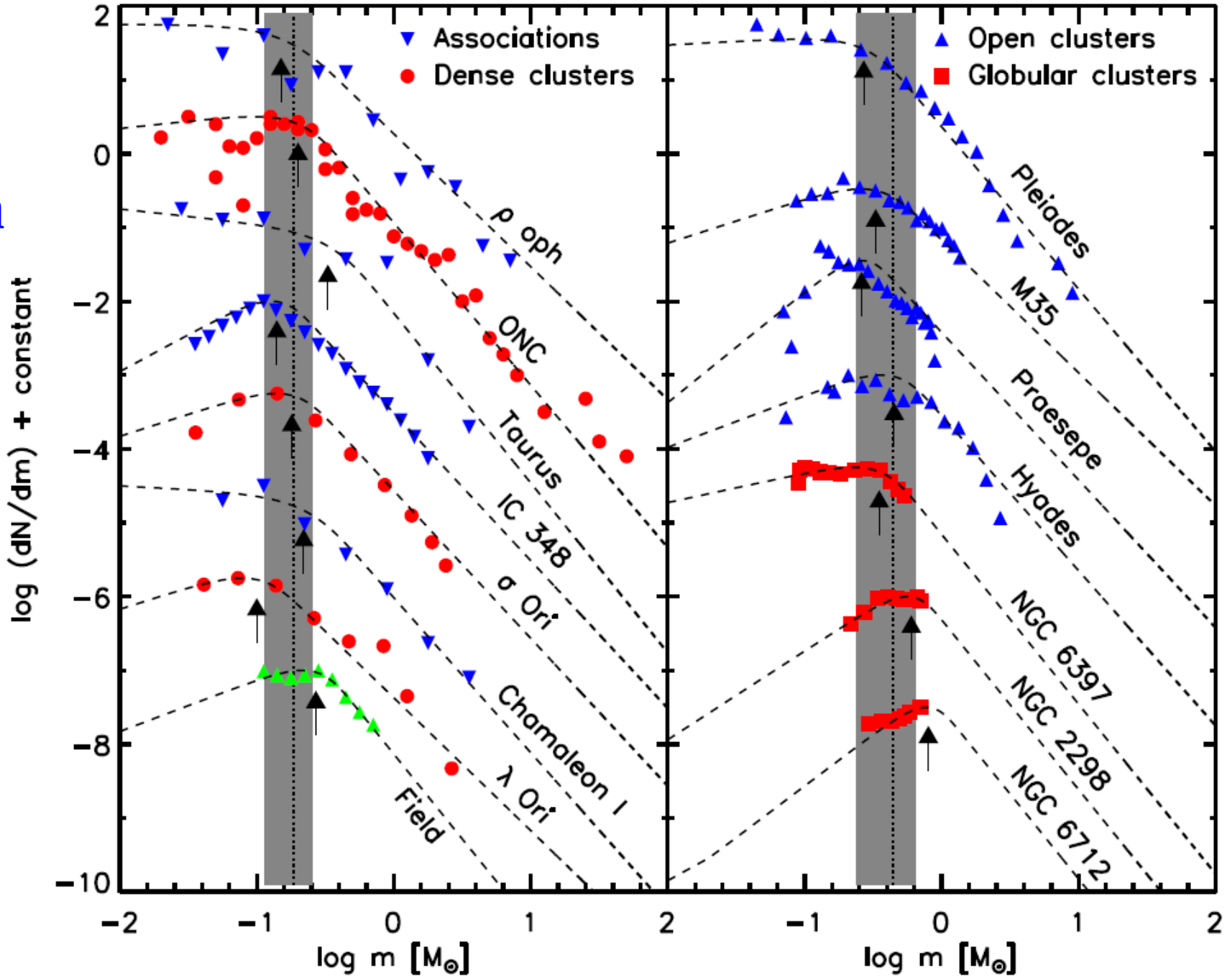
Substellar objects = Brown dwarfs or planet-mass objects

→ Census of young BDs and PMOs vs YSOs
spatial distribution, velocity dispersion, binary/disk/mass …

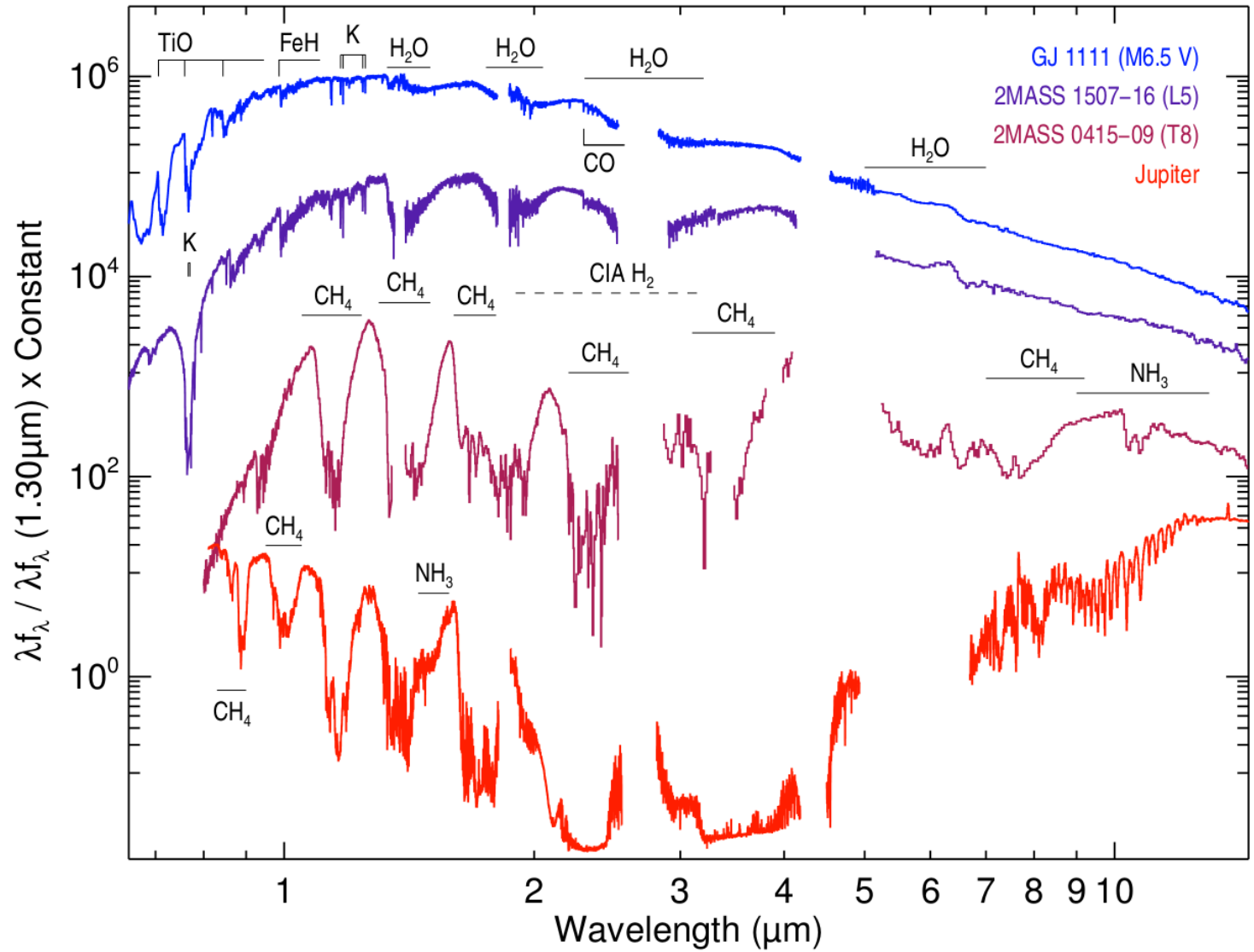
- Atmospheres 2200 to 750 K; cooling quickly (changing spTy) after birth; cooling faster for less massive ones
- SED peaking in NIR; rich atomic and molecular features; dust condensation
- So far most known substellar objects found in the field; aged
- To study their formation and early evolution → a young sample
- Brighter when younger. But even the nearest SFRs are a far cry. In an SFR, an M6 is a planet.

- Strategy
  - ◆CFHT imaging (methane or water on-off), cool atmospheres in CMDs for candidates
  - ◆Gemini/VLT/Subaru for spectroscopic confirmation

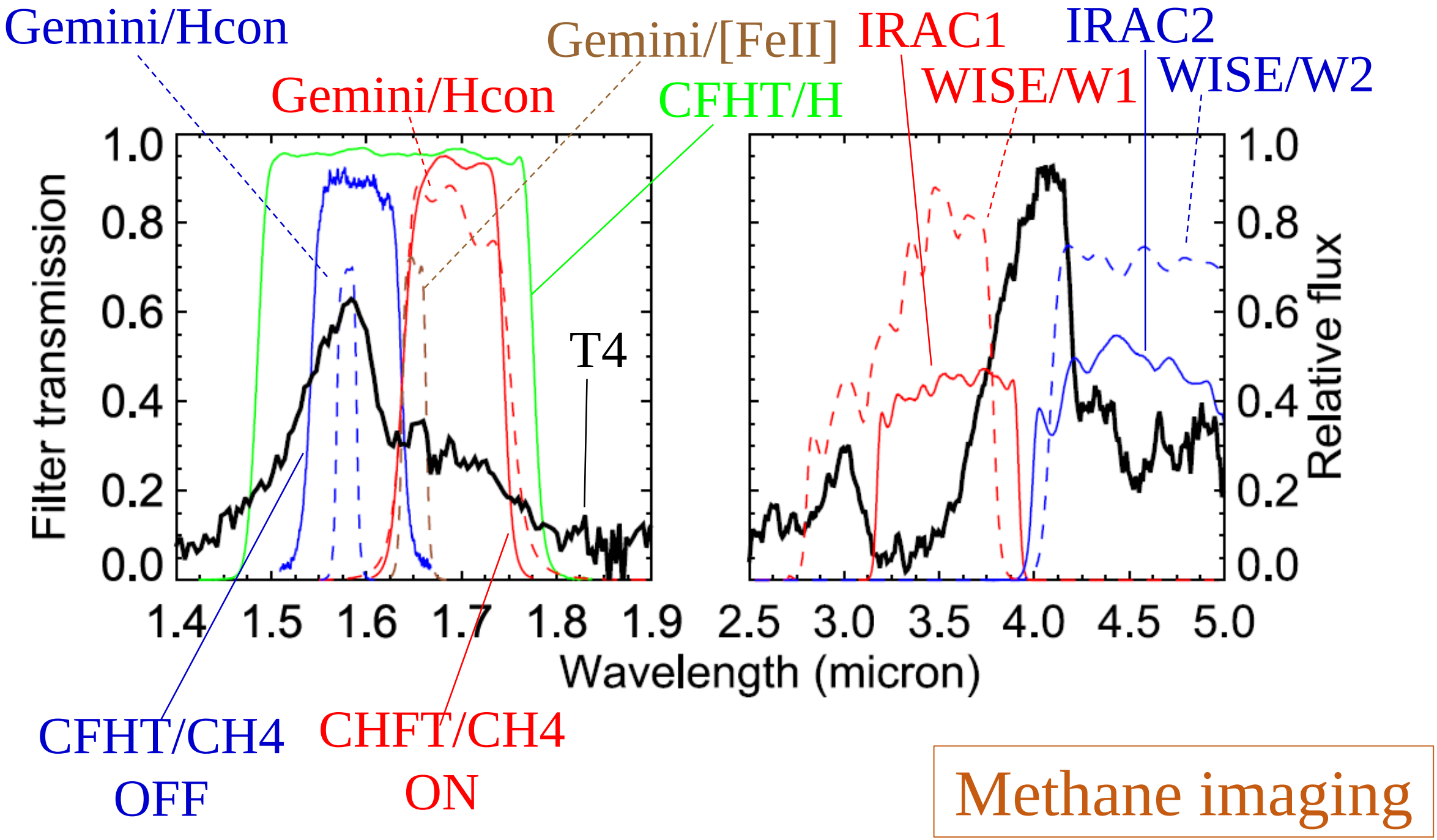
(Initial) Mass Function



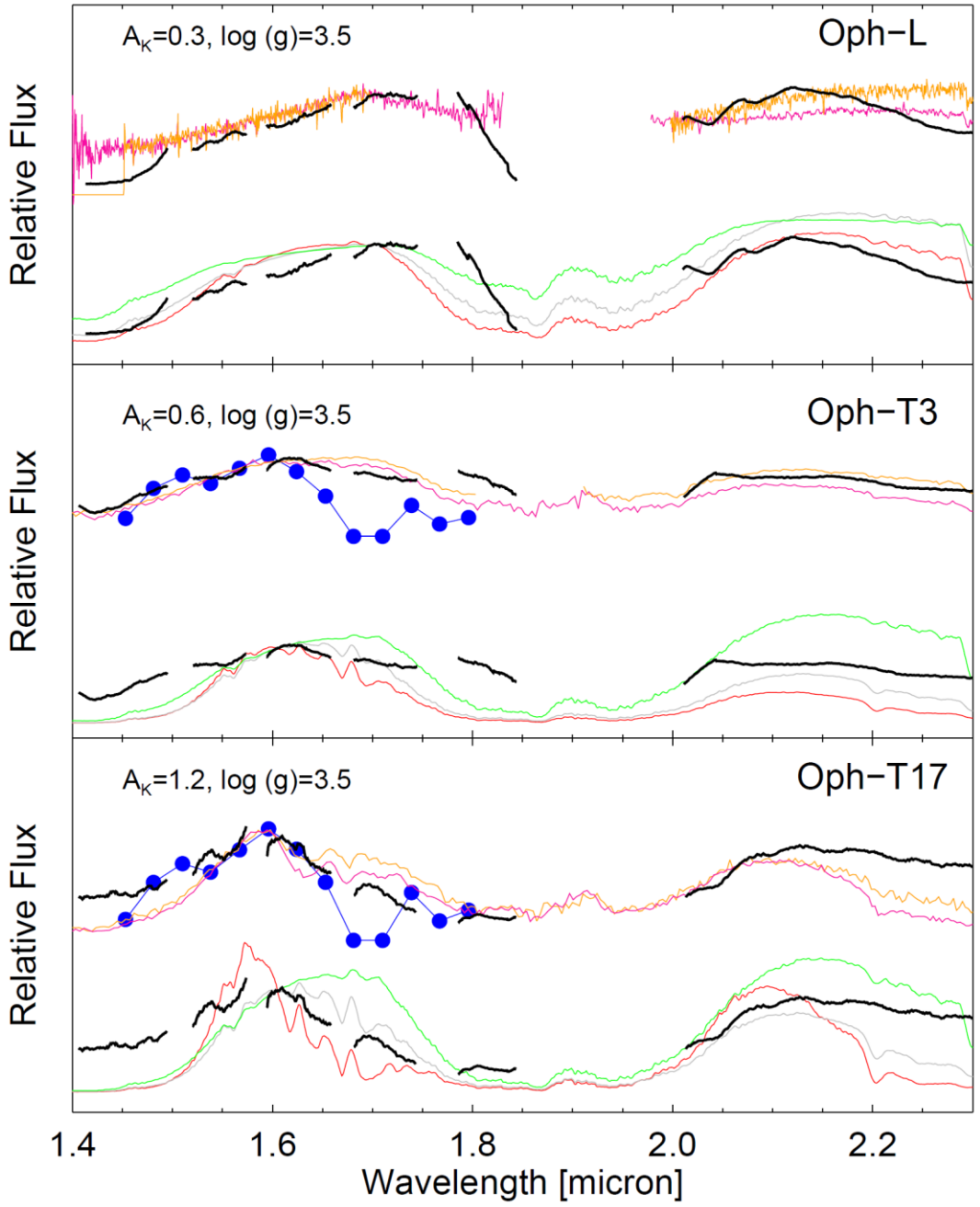
Bastian+10



http://www.exoclimes.com/paper-outlines/exoplanets-and-brown-dwarfs-ii/



Methane imaging



2 T dwarfs and 1 L dwarf confirmed

2M0437 (L0); 2M1207b (low-*g* exoplanet)

1100, 1200, 1300 K

L9, T1, HR8799e

H=18.38

900, 1000, 1100 K

T3, T4

H=19.16, 18.80

800, 900, 1050 K

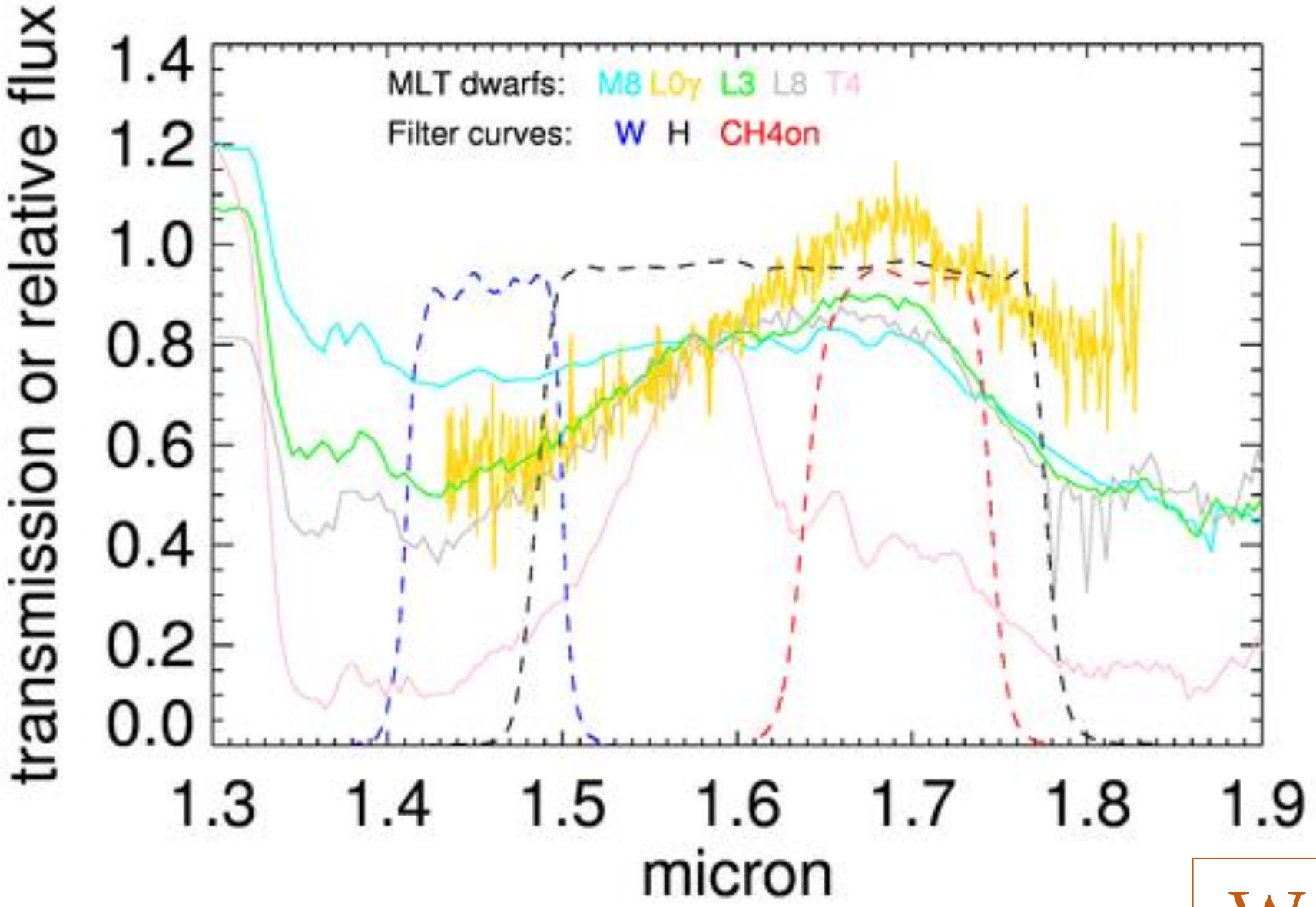
Gemini-S/Flamingo2

1800-2000 s

6 candidates observed in 2014, 1 emGalaxy, 1 bg star, 2 cool stars but no methane

In Rho Oph

Chiang & Chen (2015a, b)



A customized ("W") filter to diagnose water absorption near 1.4 μm

Water imaging

In Taurus

In L1495, 14 candidates;
1 known M6/7

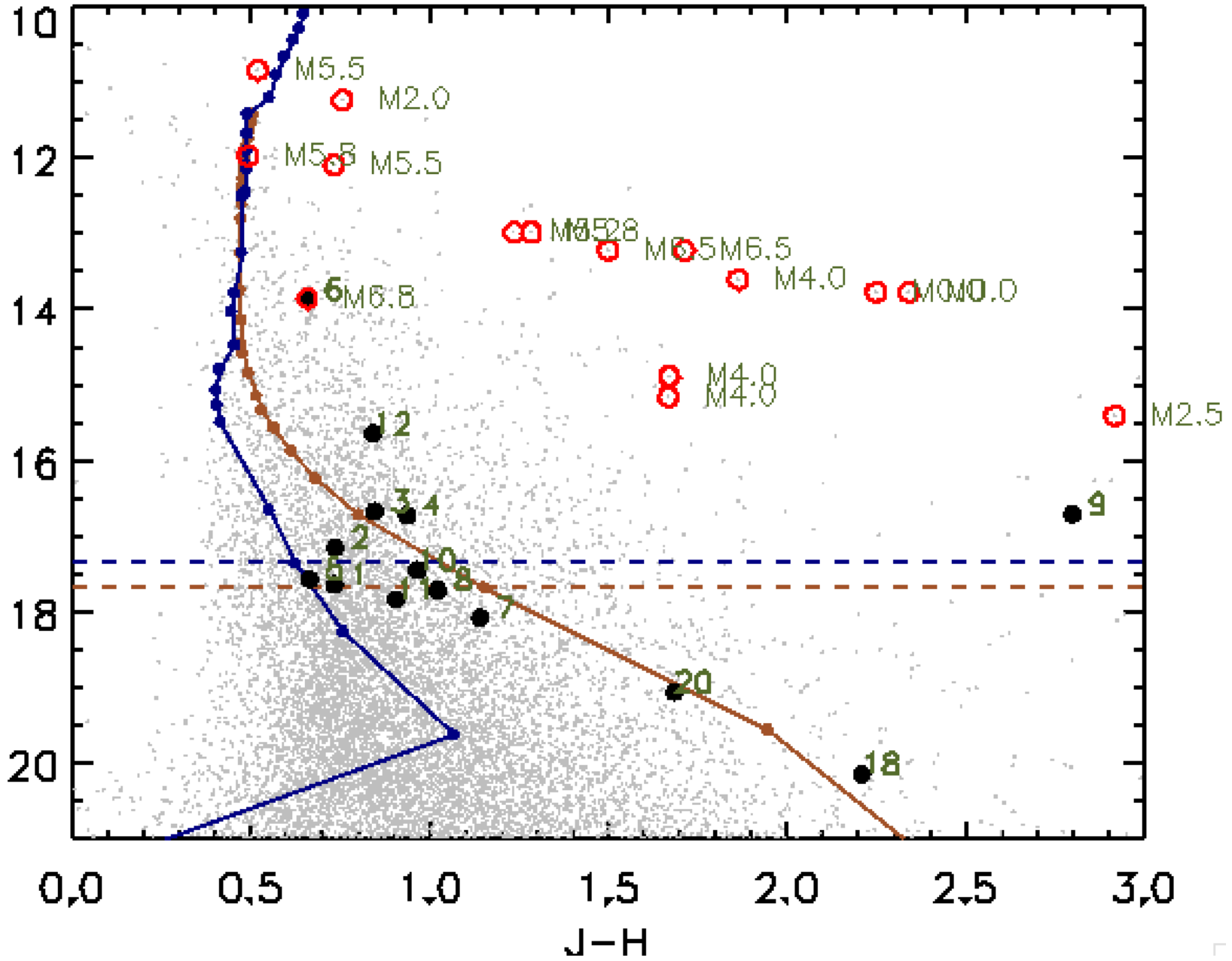
NIR spectroscopy

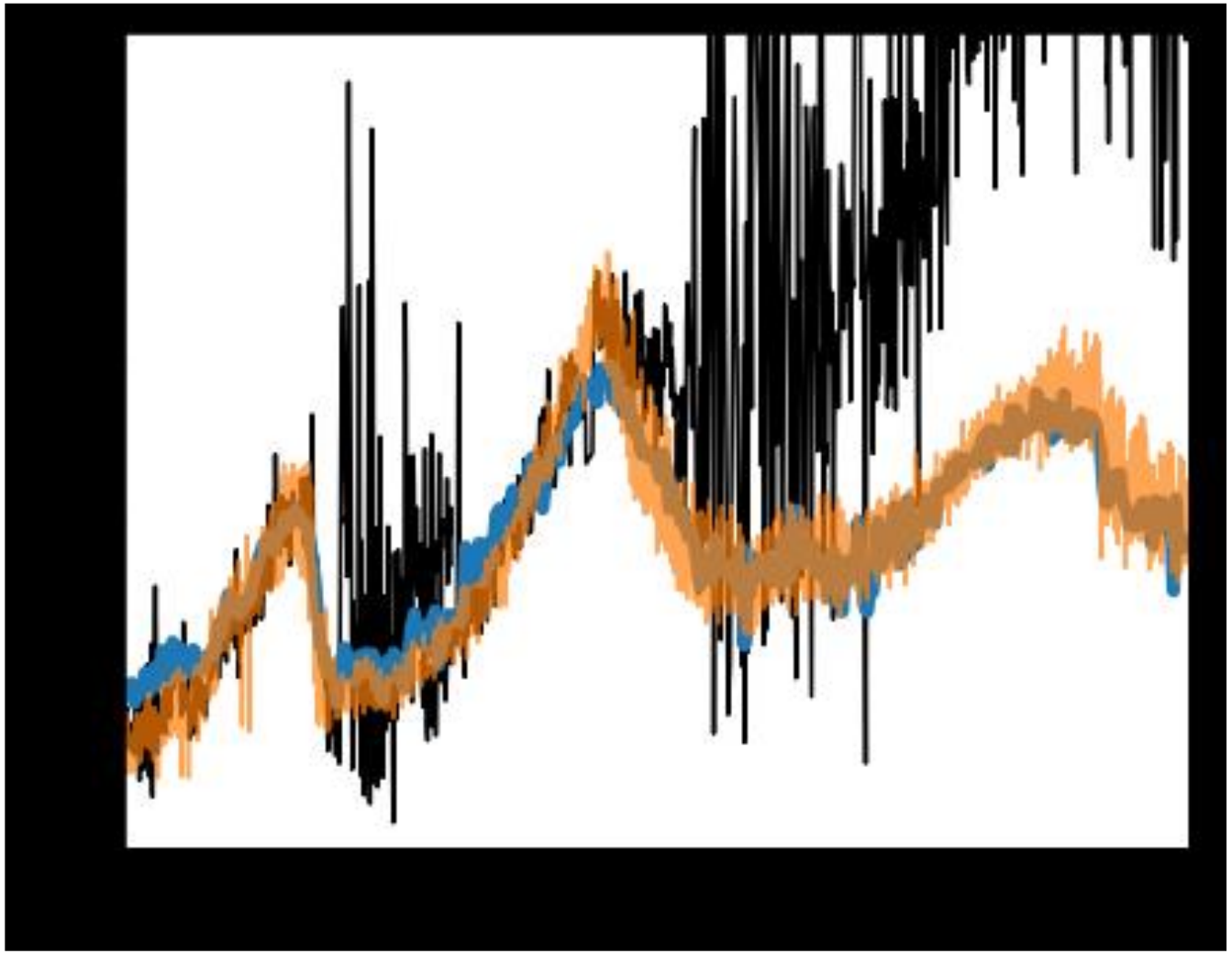
✓ Palomar TripleSpec (Dec 2016)

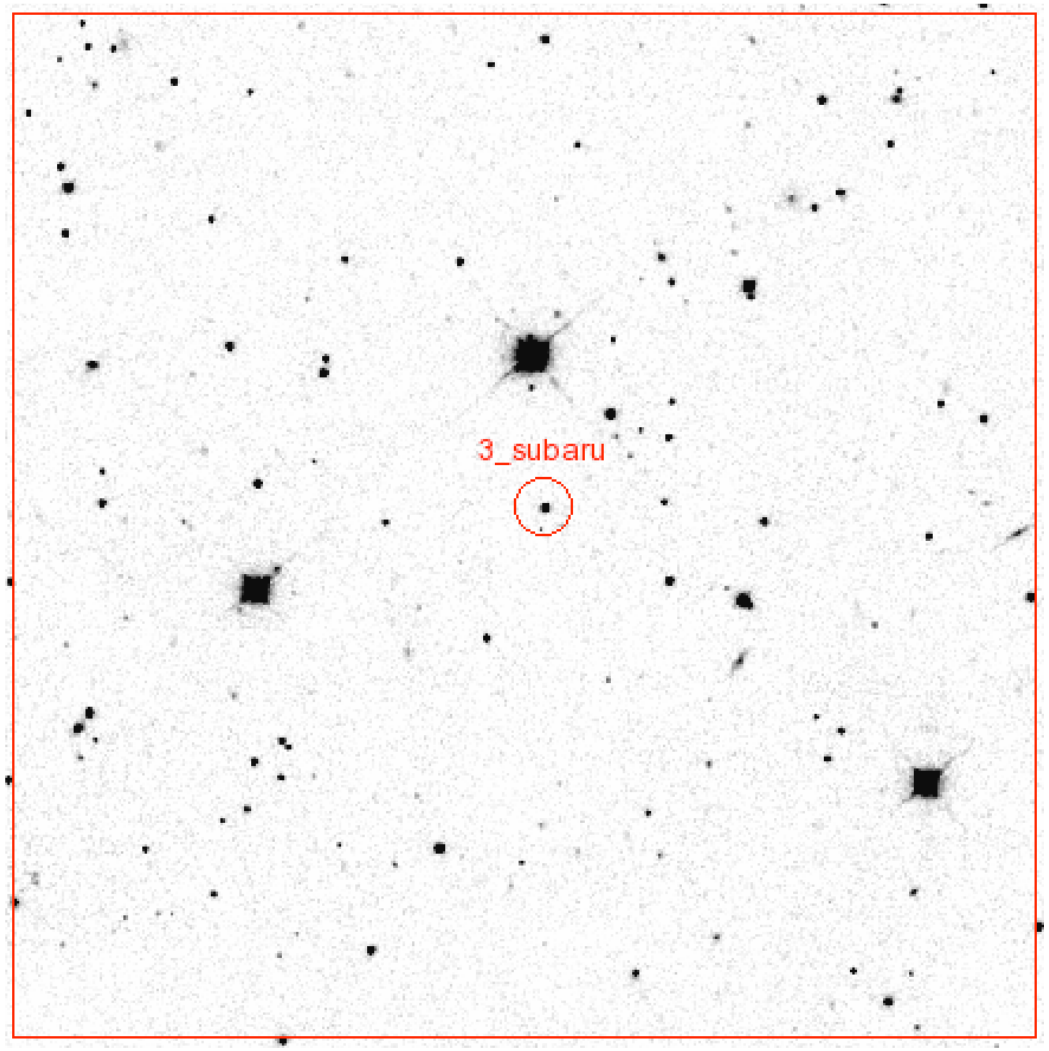
#9 embedded YSO
#12 background M

✓ Subaru IRCS (Feb 2017)

#3 confirmed

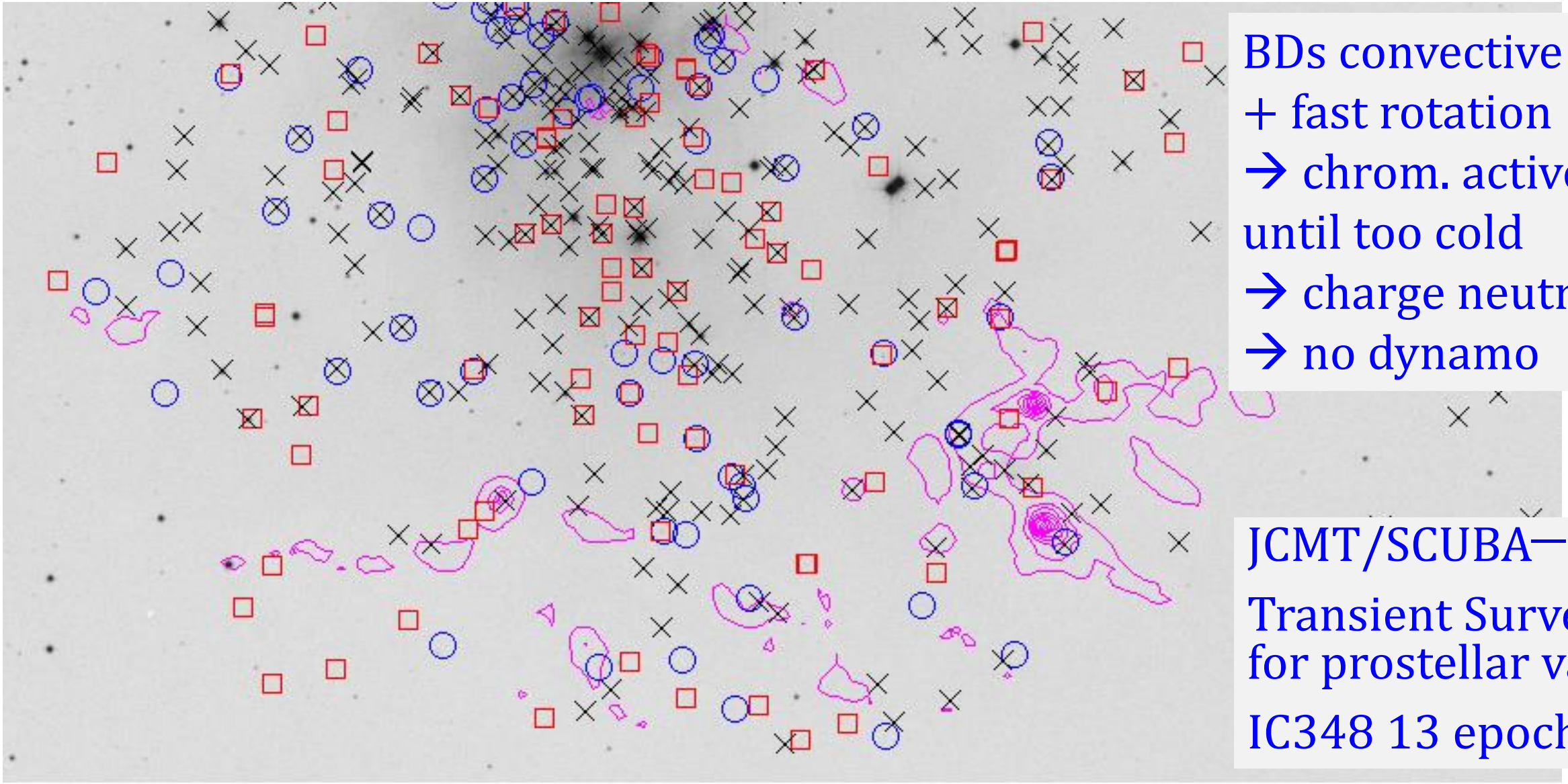






$A_V = 4.0$
low-gravity L4 (2M1551+0941)
BT grid $T_{\rm eff}$=1700 K, log(g)=3.5

PMO ~ 4 to 6 M_J



X-ray sources, confirmed and candidate BDs, and JCMT smm clouds in IC 348

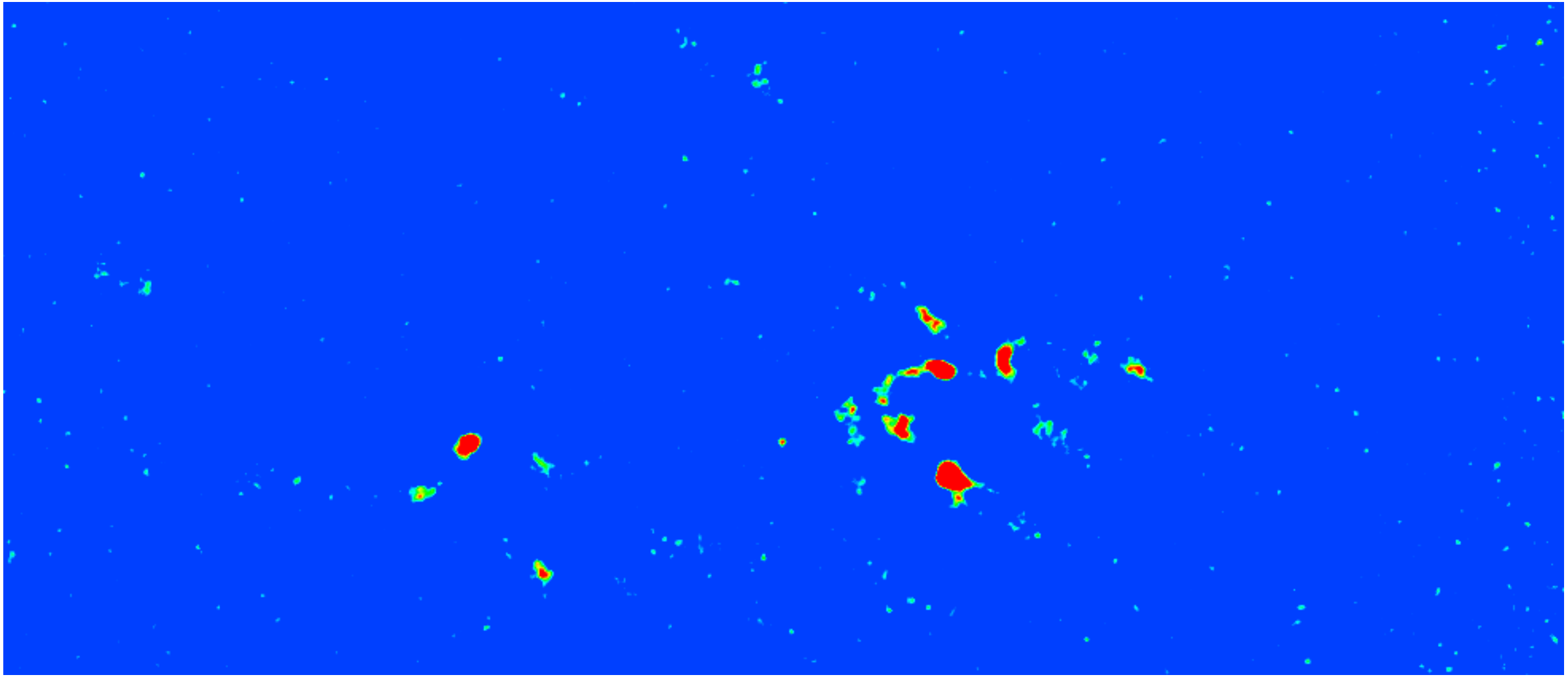
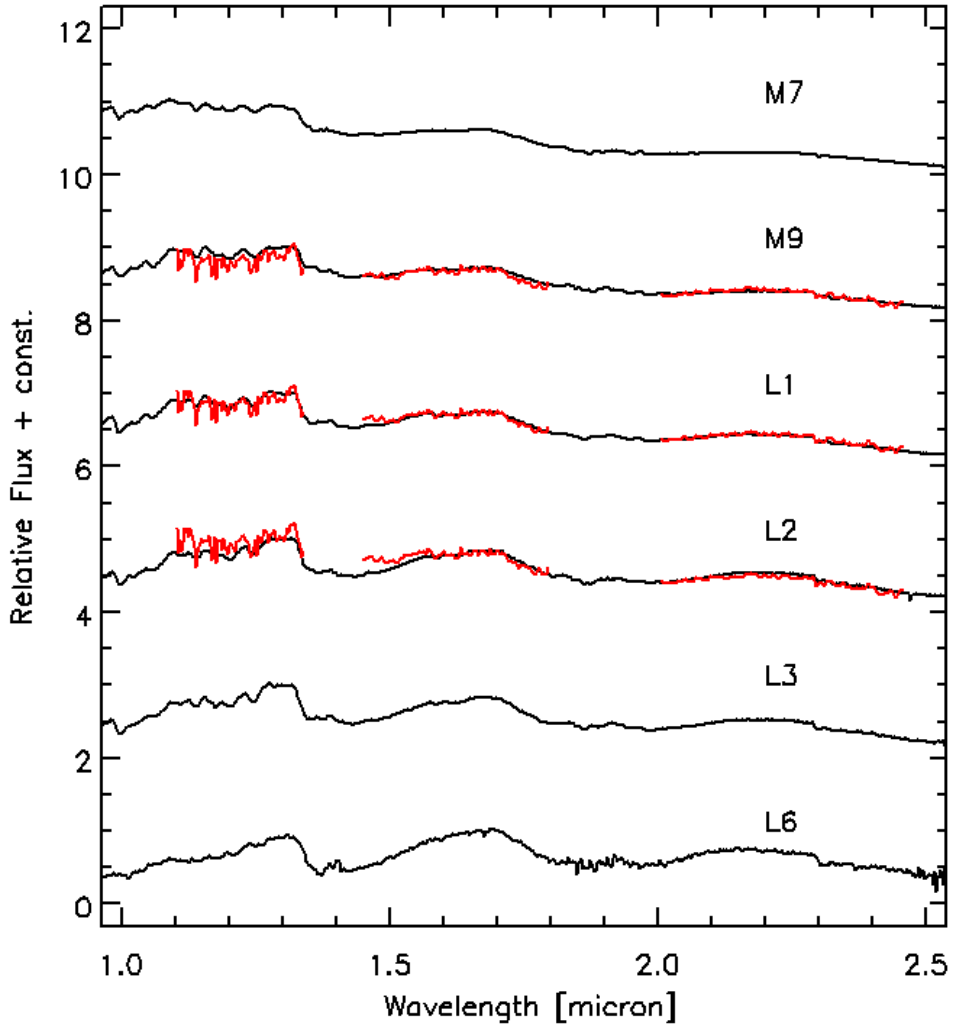


Fig 4: color image of the JCMT/SCUBA-2 450 micron data

A brown dwarf member in the Coma star cluster (800 Myr; 85 pc)



Previously known coolest member: M9

We identified and confirmed an L1, and an L4.

Palomar 200”
TripleSpec

Tang+18

Subaru & us …

Young PMOs in Taurus

- We were awarded 1 night in Feb 2017 for confirmation spectroscopy of our PMO candidates in L1495 Taurus.
- The weather was bad, so only one target was observed with an acceptable SNR. It was confirmed as an L4 young PMO.

Brown Dwarfs in HSC

- Skrzypek's photo-typing to identify brown dwarfs in the HSC survey
- Identified ~12 metal-poor brown dwarfs (sub-brown dwarfs). A Gemini proposal (in the 18A semester) will carry out the follow-up observations.

Our Subaru attempts …

- 18A — L1495 follow-up, service time, Rank A (waiting for observations)
- 17B — L1495 follow ups, service time, rejected; wrong proposal format
- 17A — L1495 follow-up, EAO time, awarded one night; weather unfavorable, one target observed and confirmed as an young L4
- 16B — L1495 follow-up, normal time, rejected
- 16A — L' imaging of Rho Oph T dwarfs, service time, not executed
- (We turned to Gemini time since 2013. In 2014, we were awarded Gemini time for Rho Oph, VLT too)
- 12B — Rho Oph follow-up, special call, rejected
- 12A — Rho Oph follow ups, normal time, rejected

Finding Field Brown Dwarfs in HSC Data

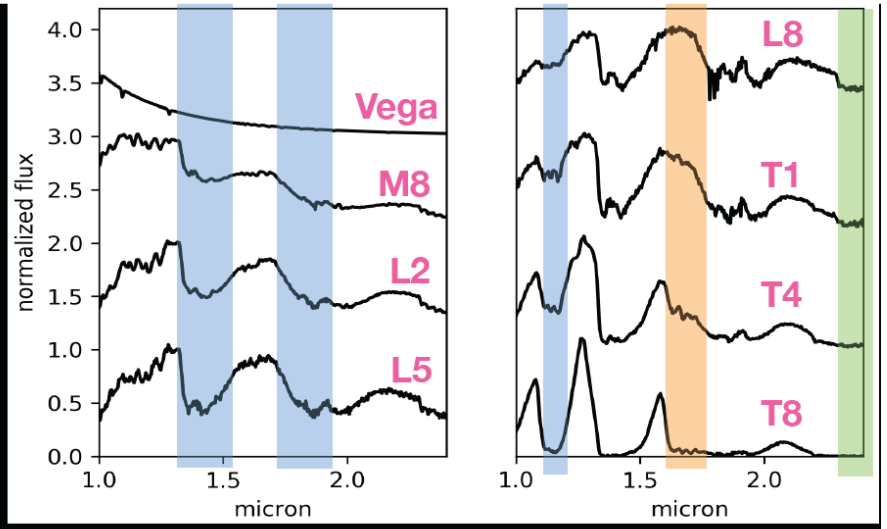
Halo population

Identification of ~12 sub-brown dwarfs (old, metal-poor)

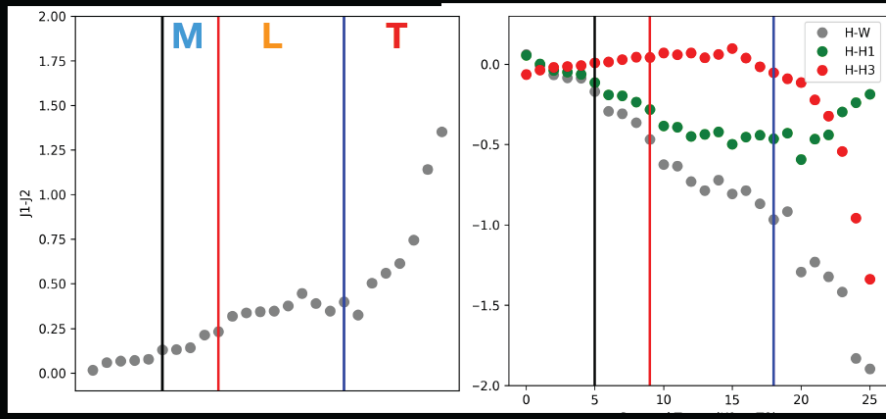
Pop III white dwarfs, too

Data readily available; no observing proposals

- HSC + ULTIMATE
- medium bands are sensitive to molecular bands (H2O: J1-J2, H-H1 CH4: H-W3)
- proper motions with 10-year baseline (HSC+ULTIMATE)
- Volume-limited sample up to 200 pc for coolest L (thick disk)
- ULTIMATE goal — discovering Pop III brown dwarfs



Infrared SEDs of brown dwarfs. Prominent molecular bands are marked in colors: H2O, CH4, and CO



Synthetic photometry of median-band filters
Top: J1 - J2 Low: H-H1, H-H3, H-W (CFHT)

Conclusions

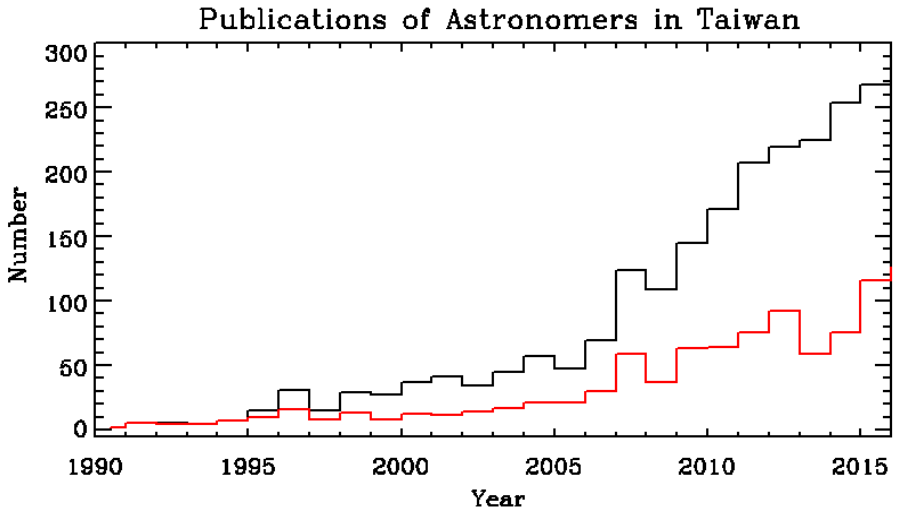
- Fortunate in Taiwan to have access to CFHT, Subaru, SMA, JCMT, ALMA …
- We are using CFHT for wide-field imaging to find BD candidates, and seek for spectroscopic time for confirmation.
- (BDs in young star clusters; associated with X rays)
- Whenever time of a large telescope was awarded, we produced good science.
- Remote and queue observing highly desirable; molecule line filters required (user supplying OK)

台灣聯大國際天文研究中心

UST International Center for Astronomical REsearch (iCARE)

Proposed end of 2017; results imminent

- A joint center between NCU and NTHU on multi-messenger time-domain cosmic phenomena **ZTF, LSST, PS2, CFHT, Subaru, 2mT, …**
- Adding 5-10 FTEs; international recruitments including a senior director
- Proposed annual budget 2 M$



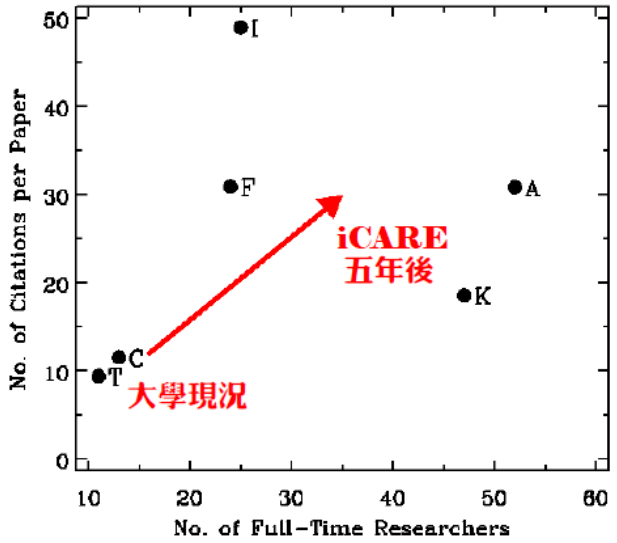


圖 6——表 2 中各機構平均論文引用數相對於全職科研人員的人數。自左起為 NTHU、NCU、U of Florida、U of Illinois—Ubana Champaign、Kavli Institute of Astronomy and Astrophysics，以及 Academia Sinica—Institute of Astronomy and Astrophysics. 紅色箭頭所示為 10 內預期達目前 3 倍的影響力。