Global maps and weather movies of exoplanets & brown dwarfs

Luhman 16B
(published last week in Nature)

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with:
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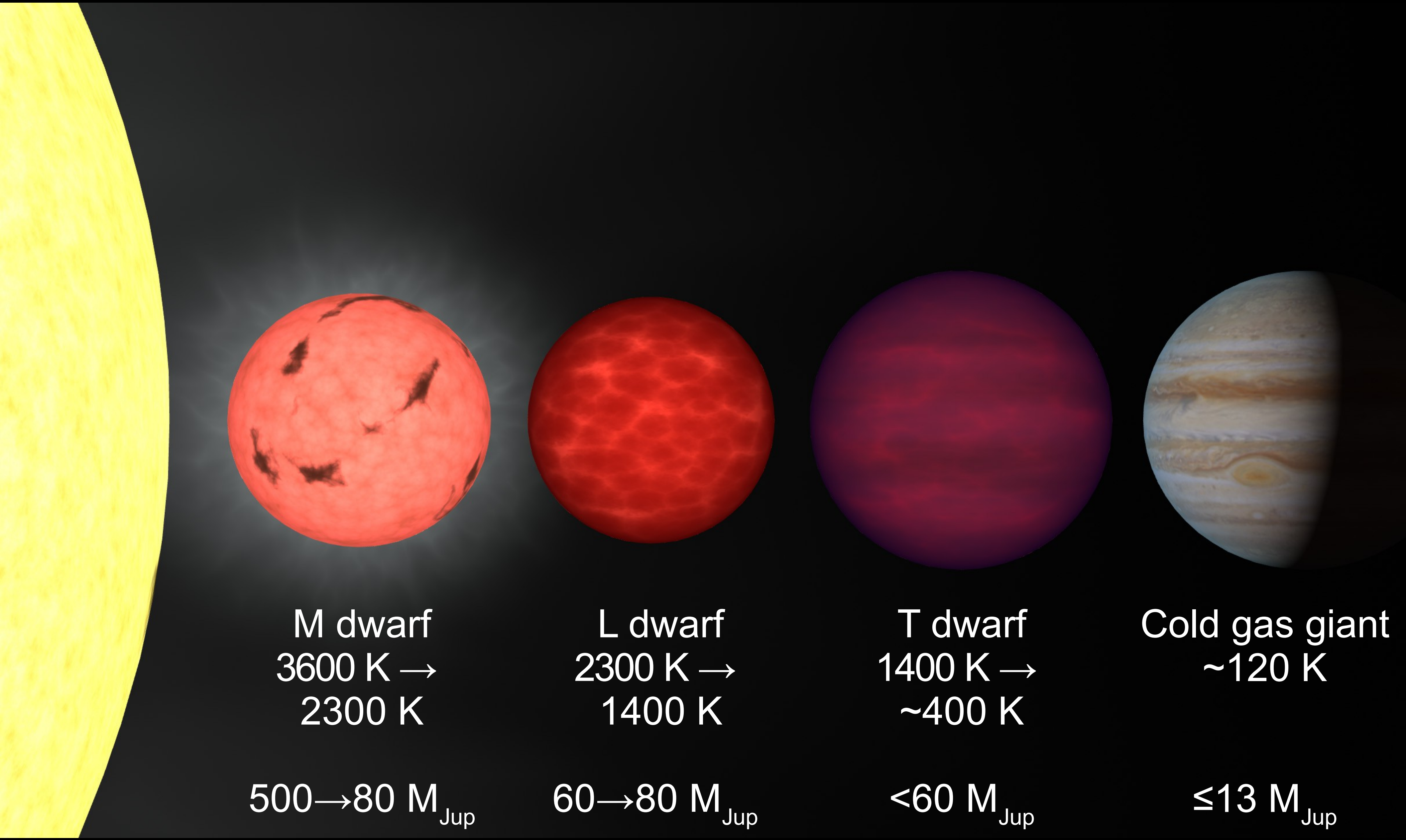
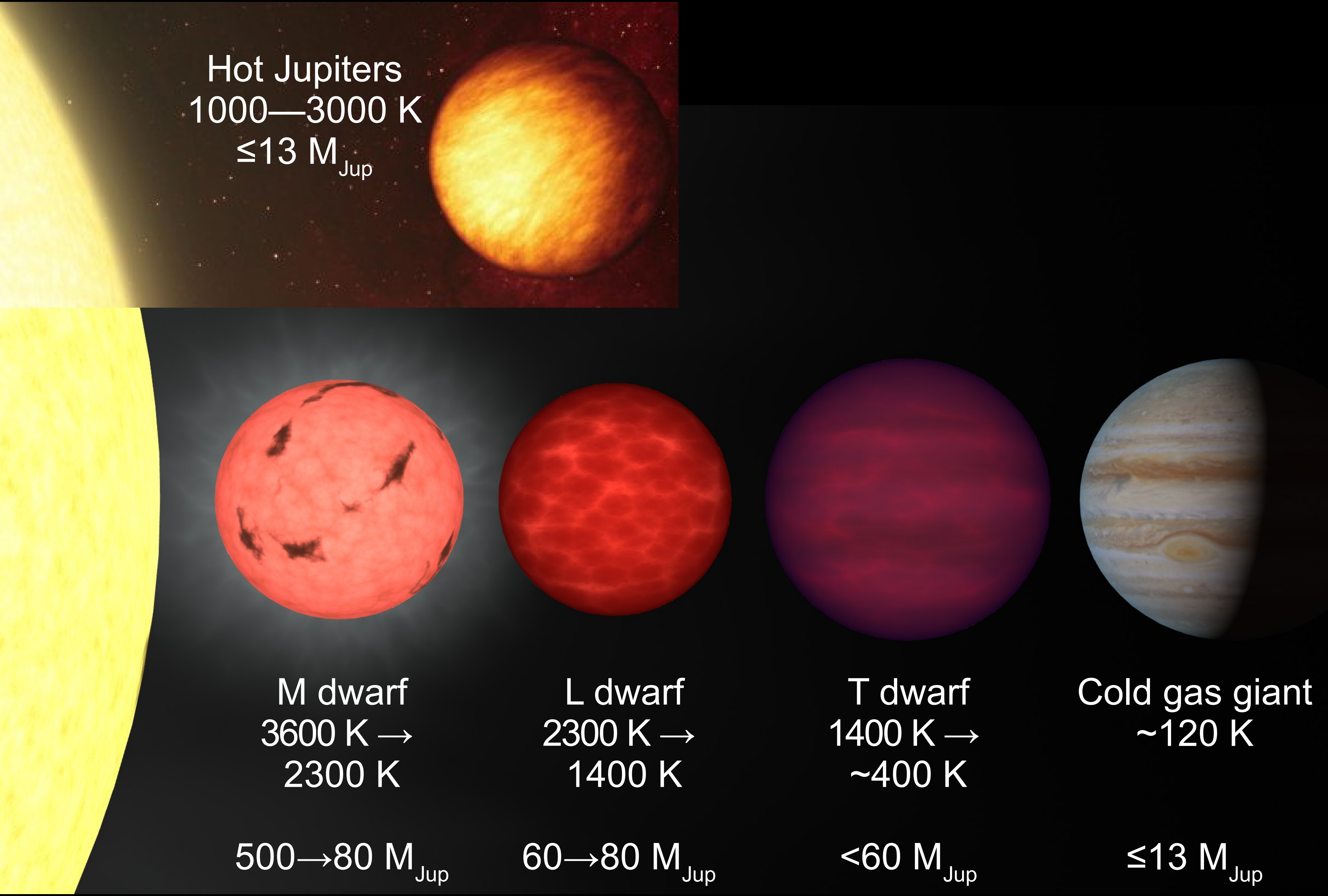

M dwarf
3600 K →
2300 K
500→80 M_{Jup}
L dwarf
2300 K →
1400 K
60→80 M_{Jup}
T dwarf
1400 K →
~400 K
<60 M_{Jup}
Cold gas giant
~120 K
≤13 M_{Jup}


Hot Jupiters
1000—3000 K
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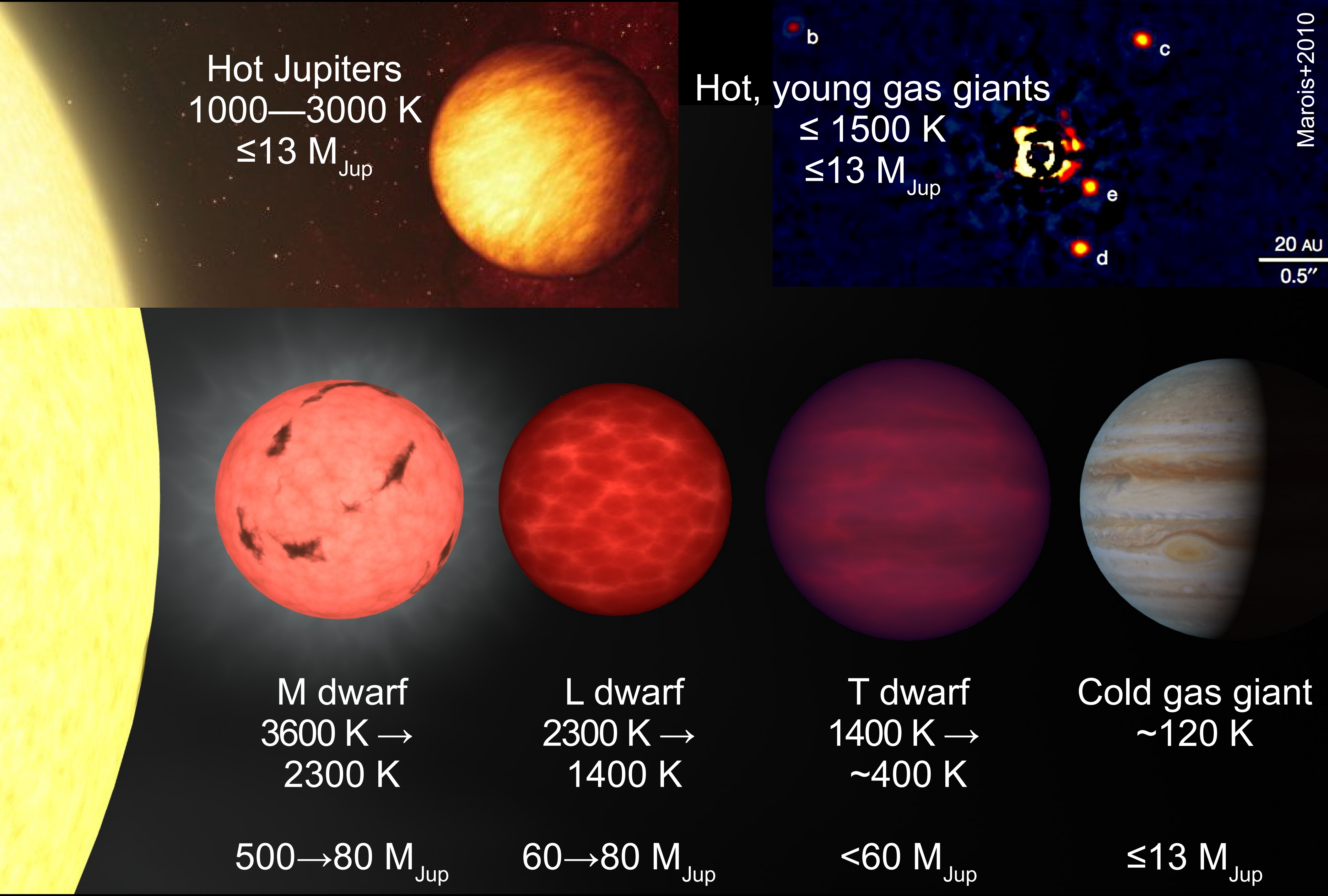

Hot Jupiters
1000—3000 K
≤13 M_{Jup}
Hot, young gas giants
≤ 1500 K
≤13 M_{Jup}
b
c
e
d
Marois+2010
20 AU
0.5″
M dwarf
3600 K → 2300 K
500→80 M_{Jup}
L dwarf
2300 K → 1400 K
60→80 M_{Jup}
T dwarf
1400 K → ~400 K
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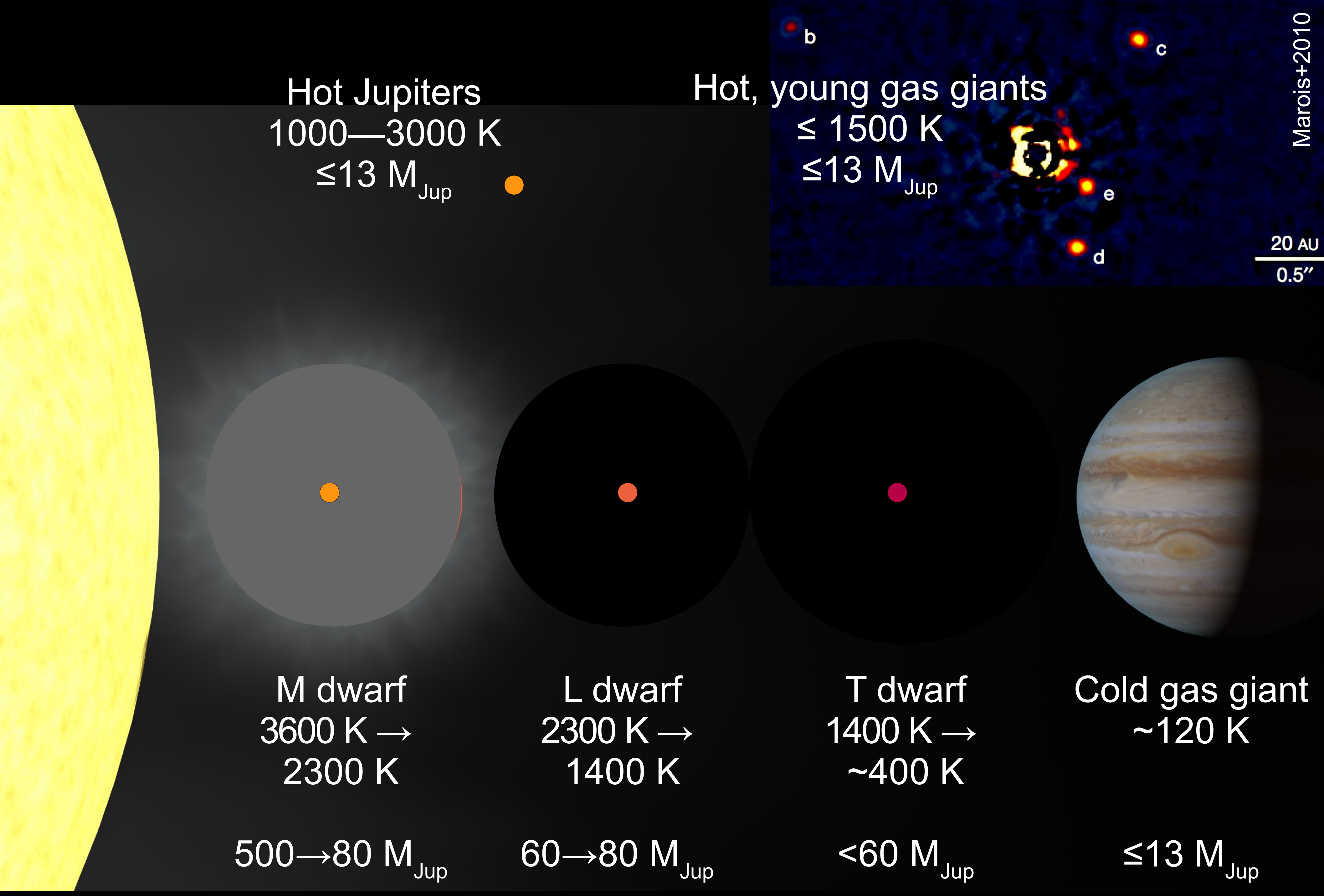

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DISCOVERY OF A BINARY BROWN DWARF AT 2 pc FROM THE SUN*

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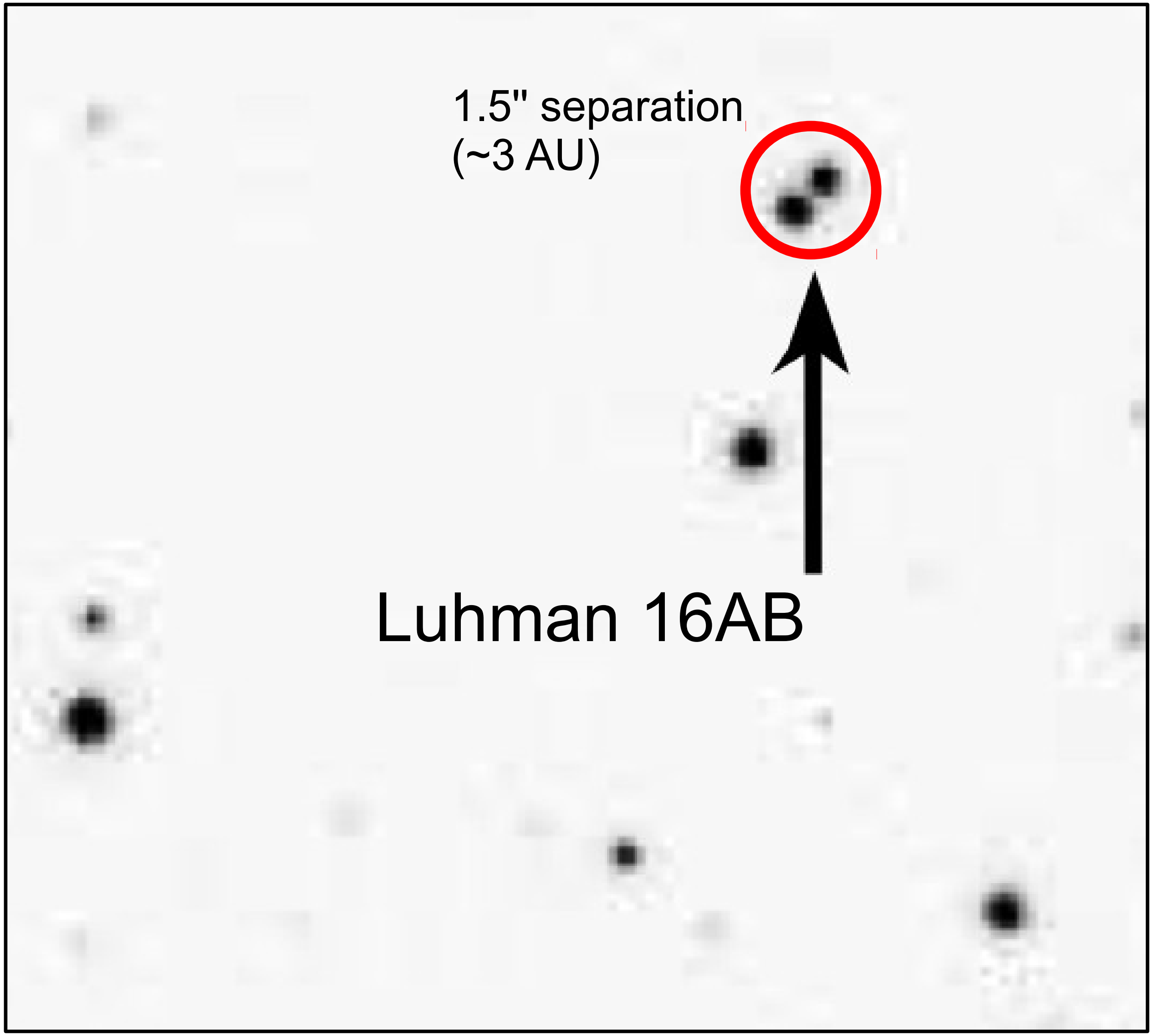
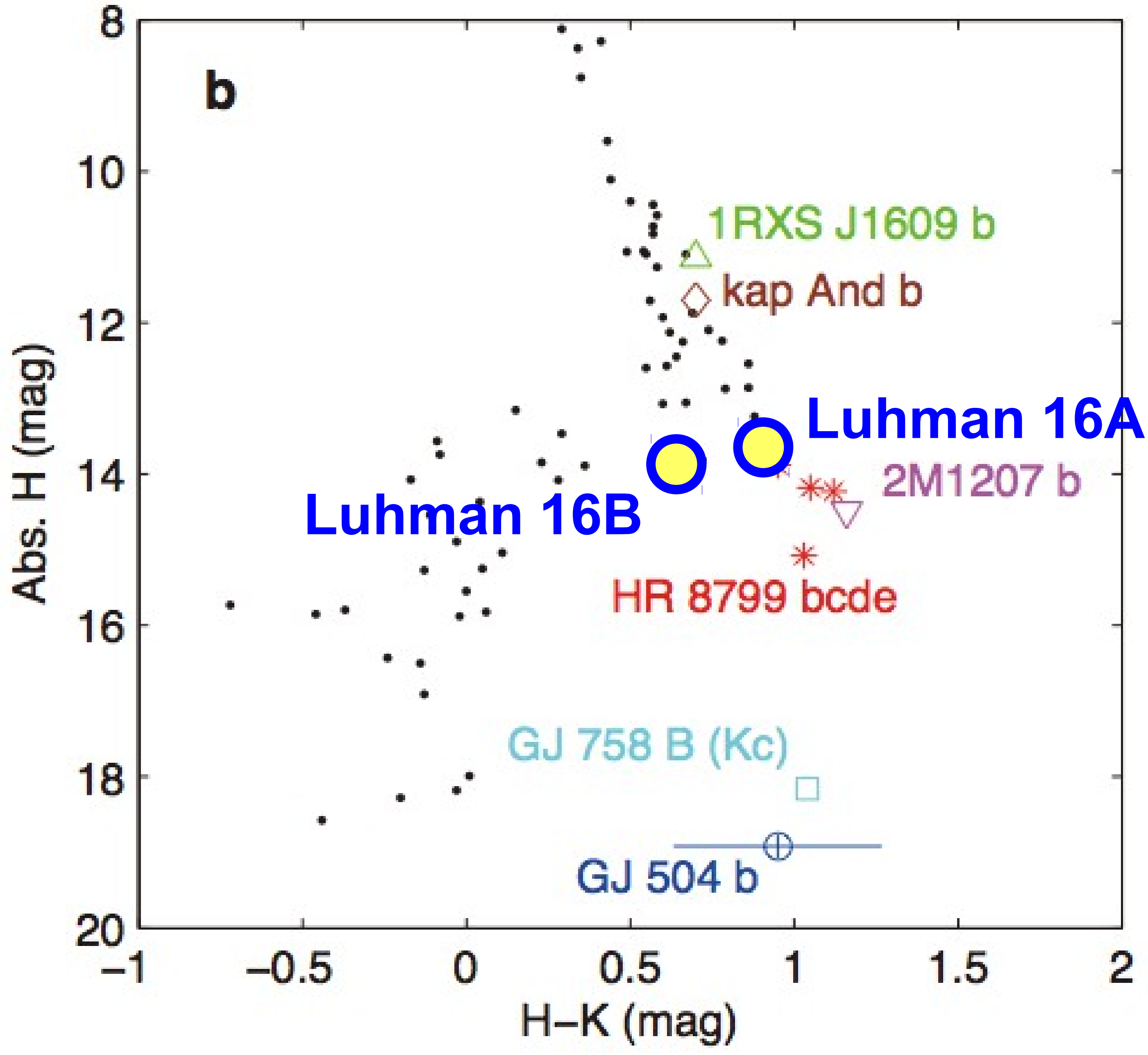
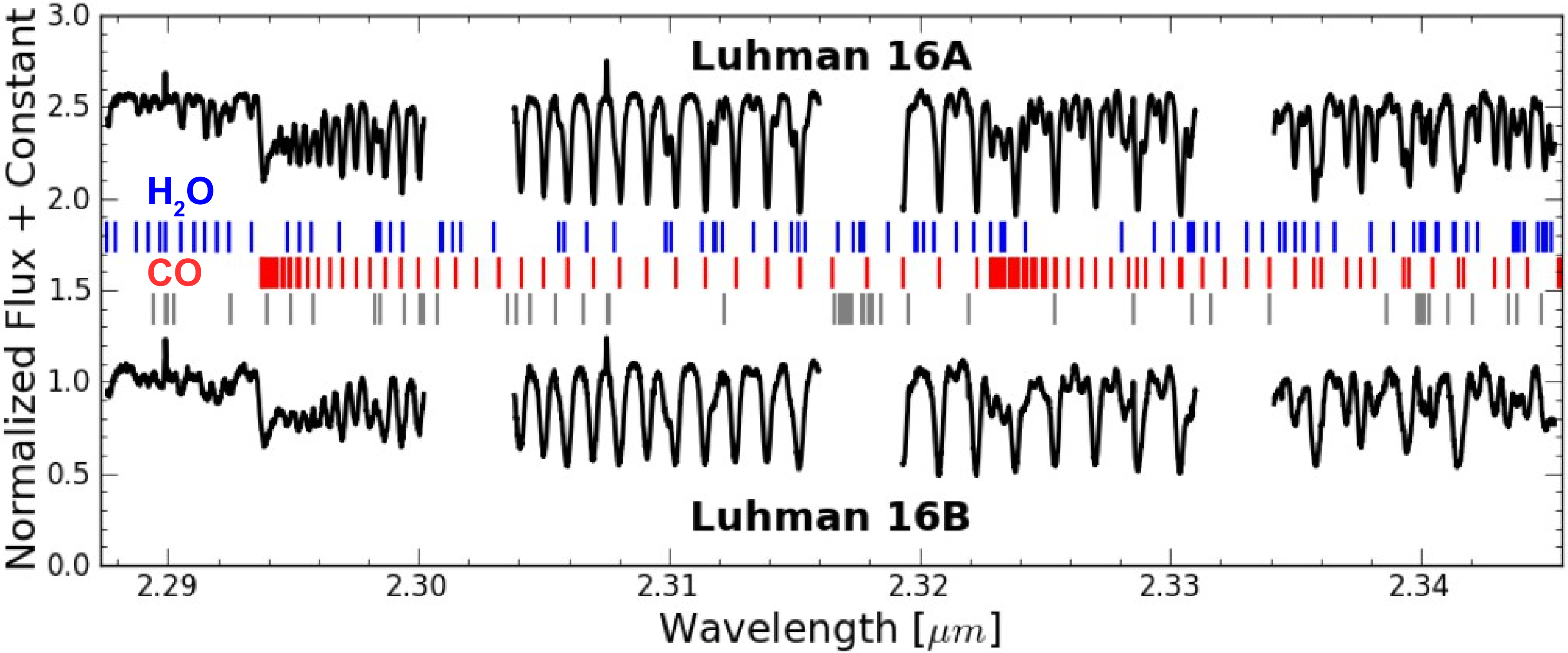


Both brown dwarfs are near the L/T transition:



Kuzuhara+2013
Kniatsev+2013
Burgasser+2013

We observed Luhman 16AB with CRIRES for 5 hr (one rotation of 'B'):



IC et al., *Nature* 2014

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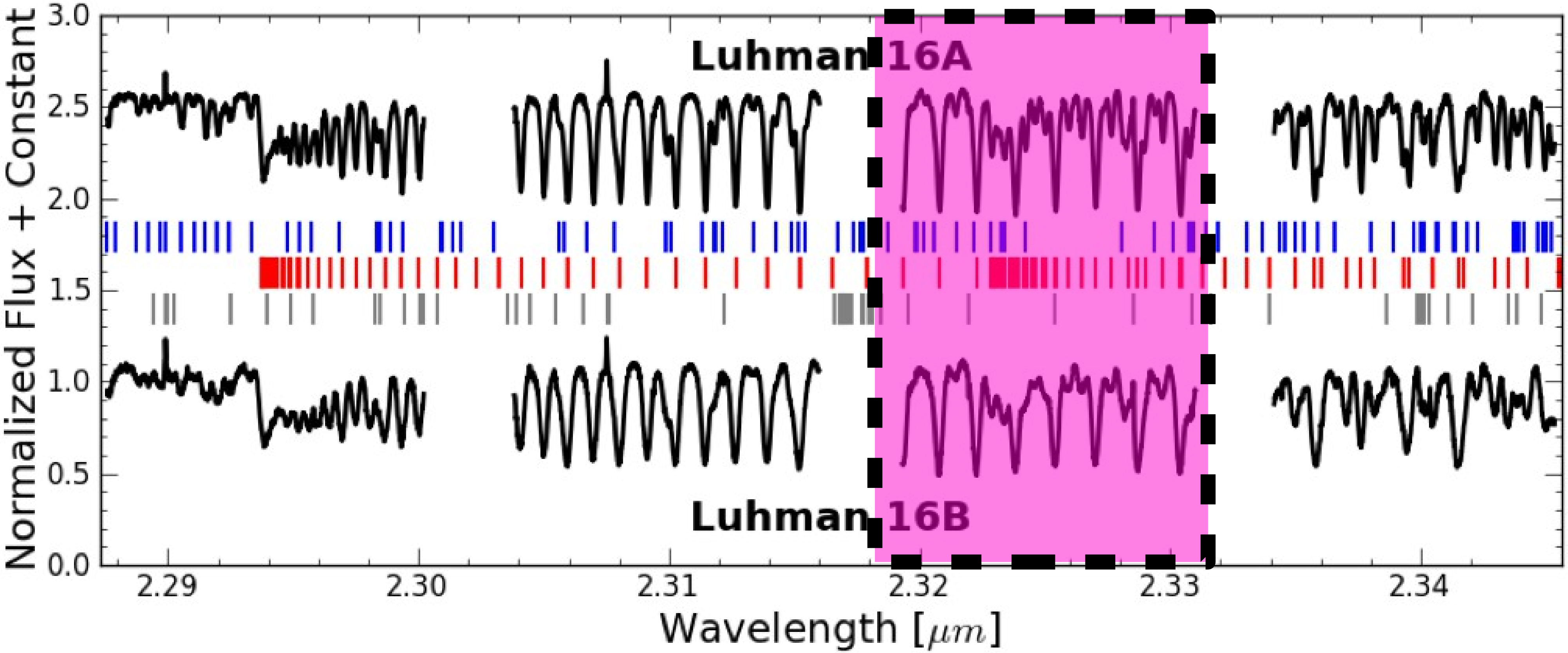
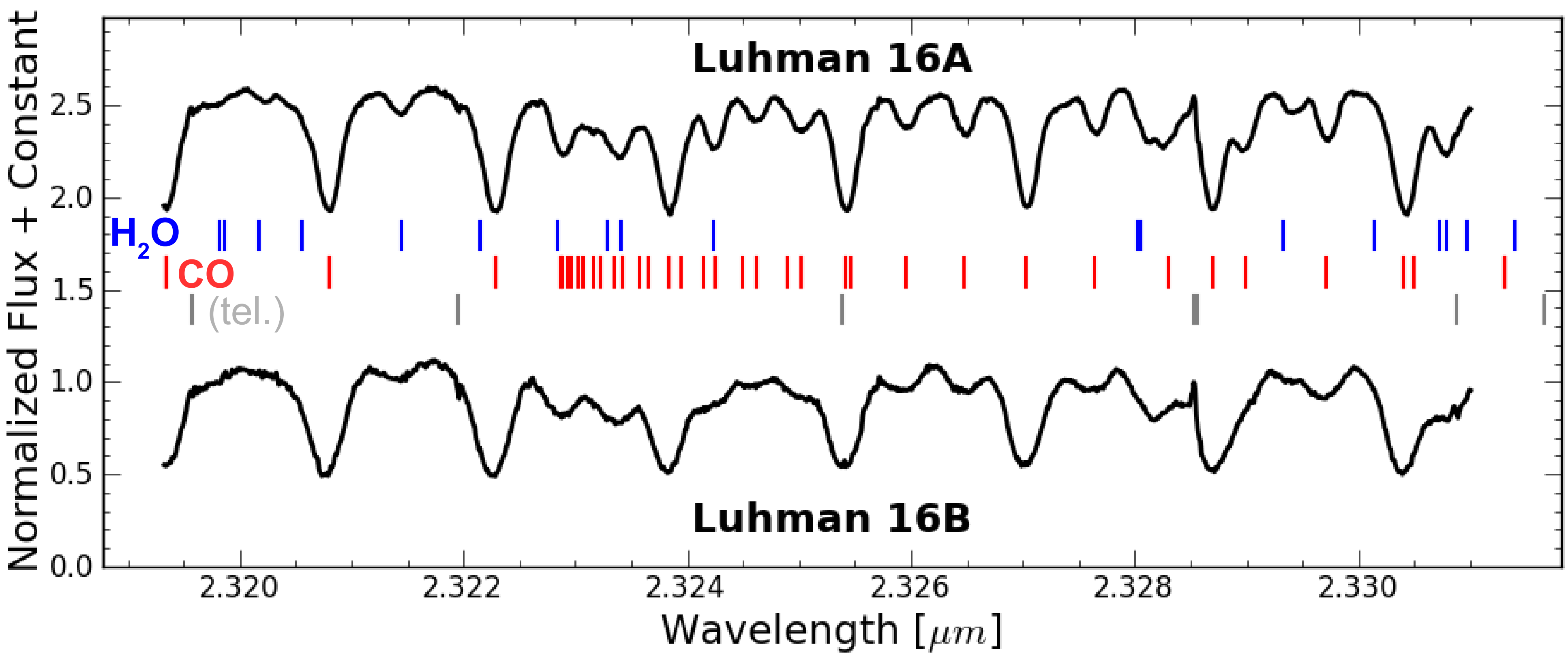


IC et al., *Nature* 2014

Spectra are similar, but Luhman 16B has broader lines ($v \sin i$ = 26 km/s):



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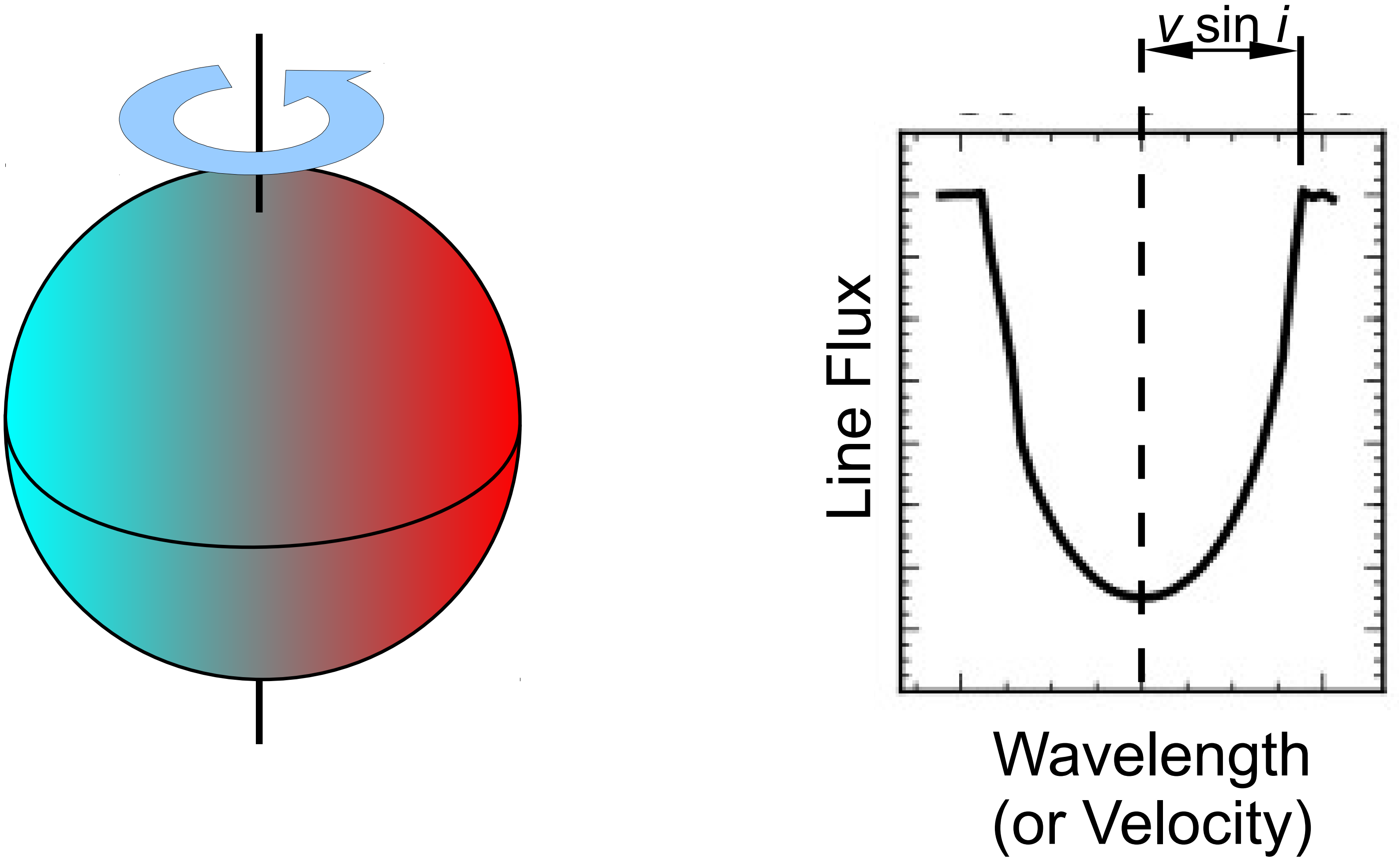
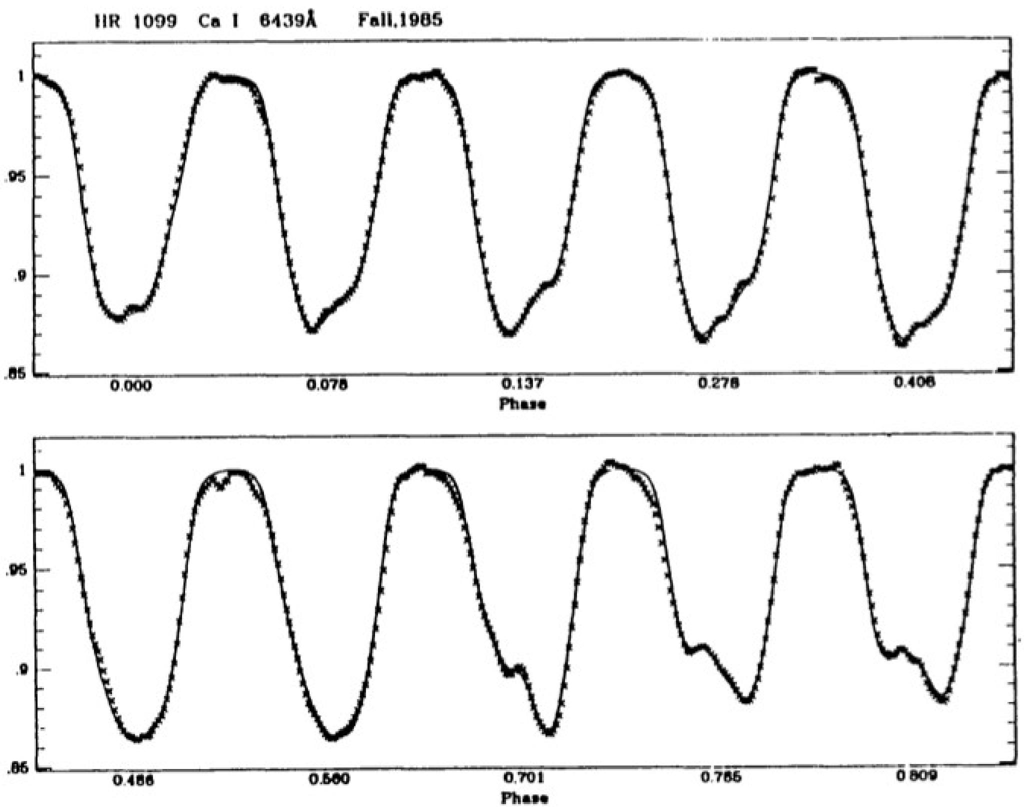
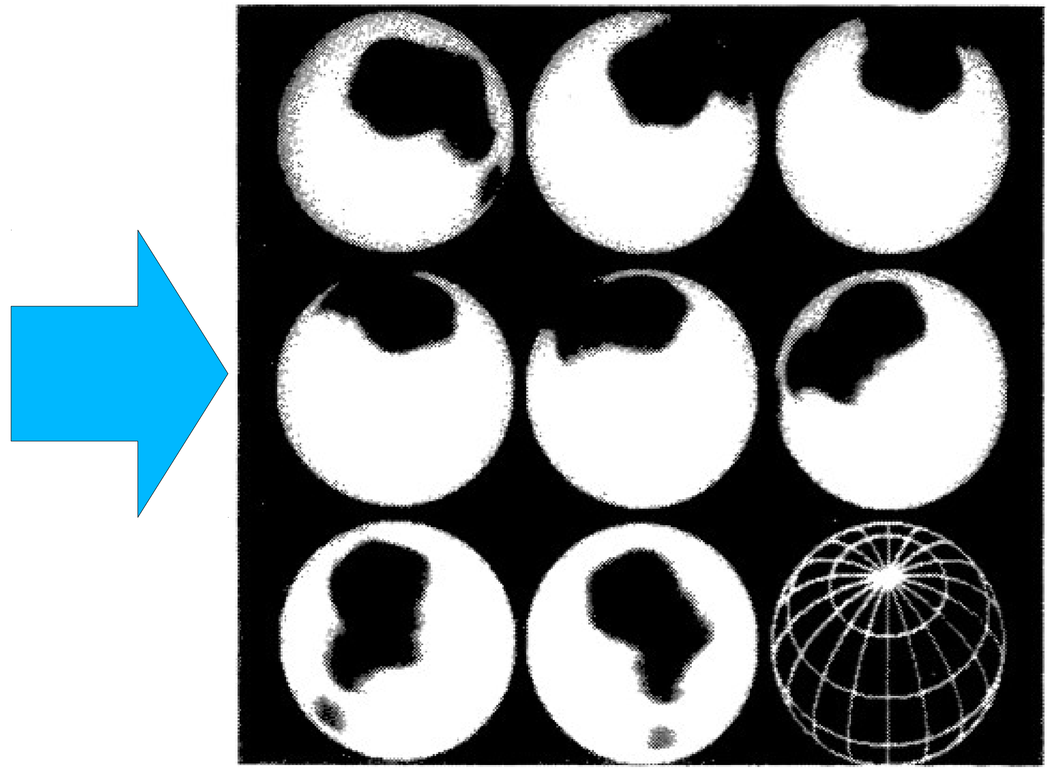
Spectral line profiles are dominated by rotational broadening:



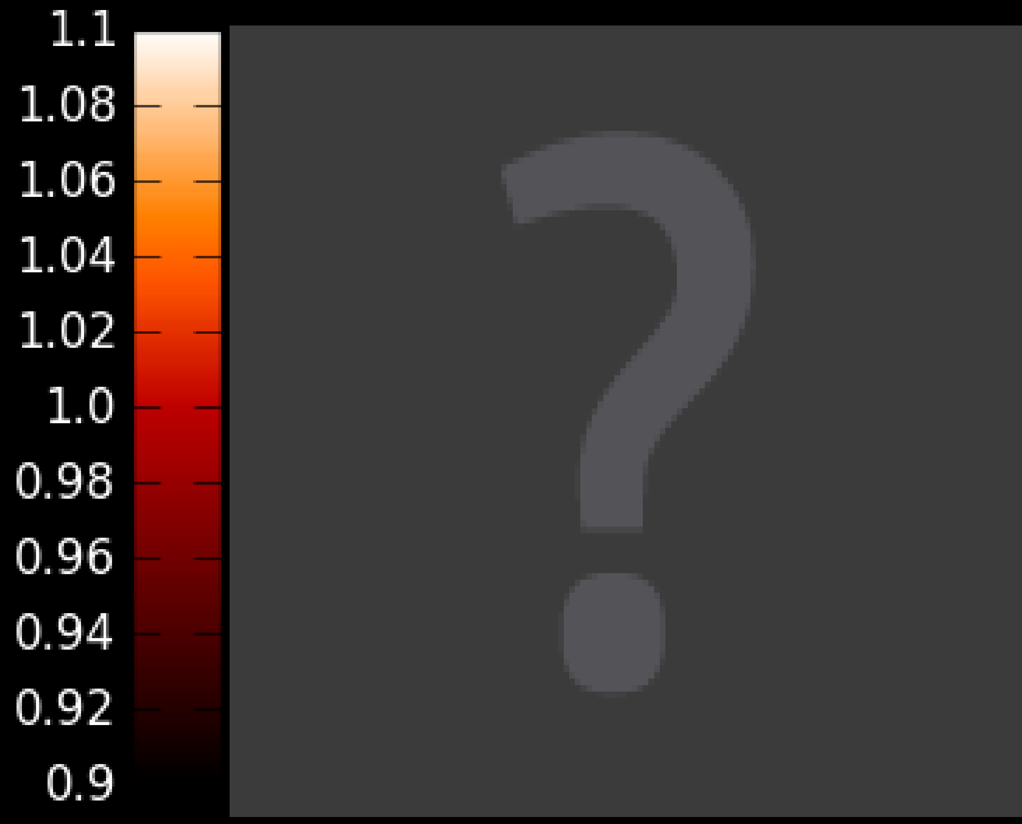
“Doppler Imaging” inverts varying line profiles into a global 2D map:



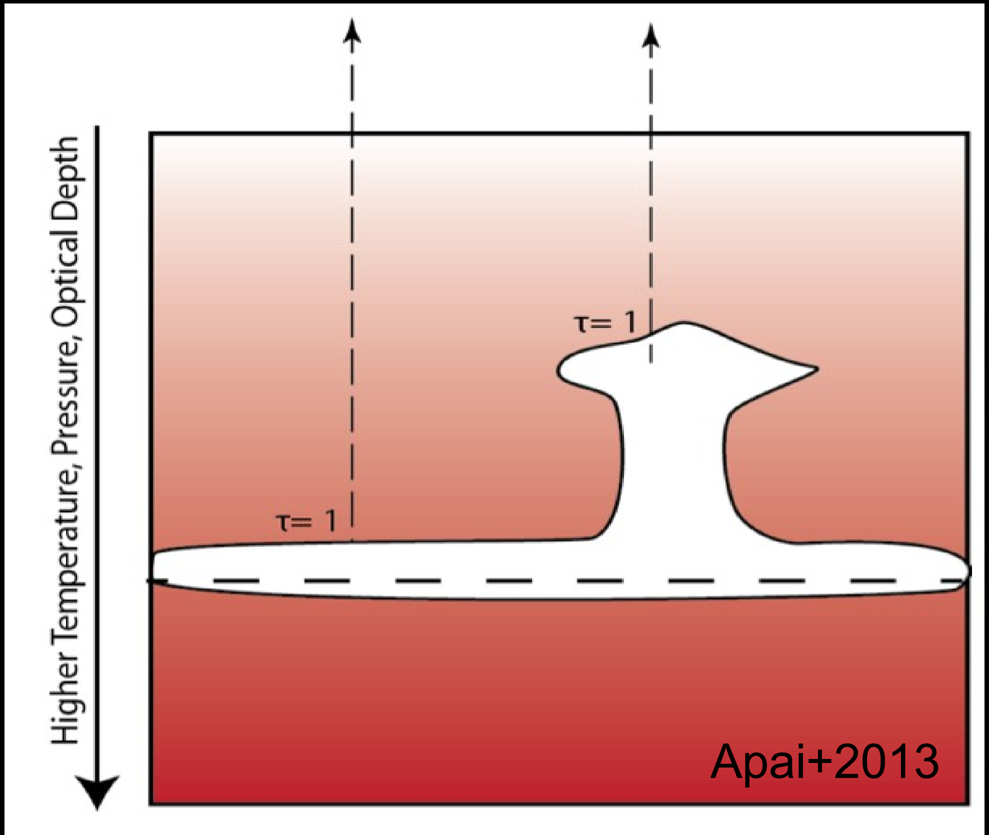


Vogt 1987

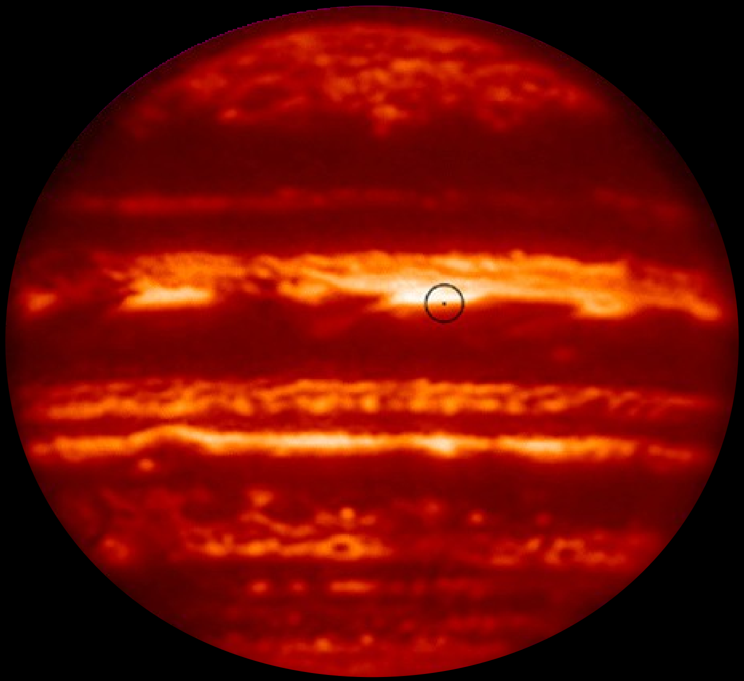
Global Doppler Map of Luhman 16B

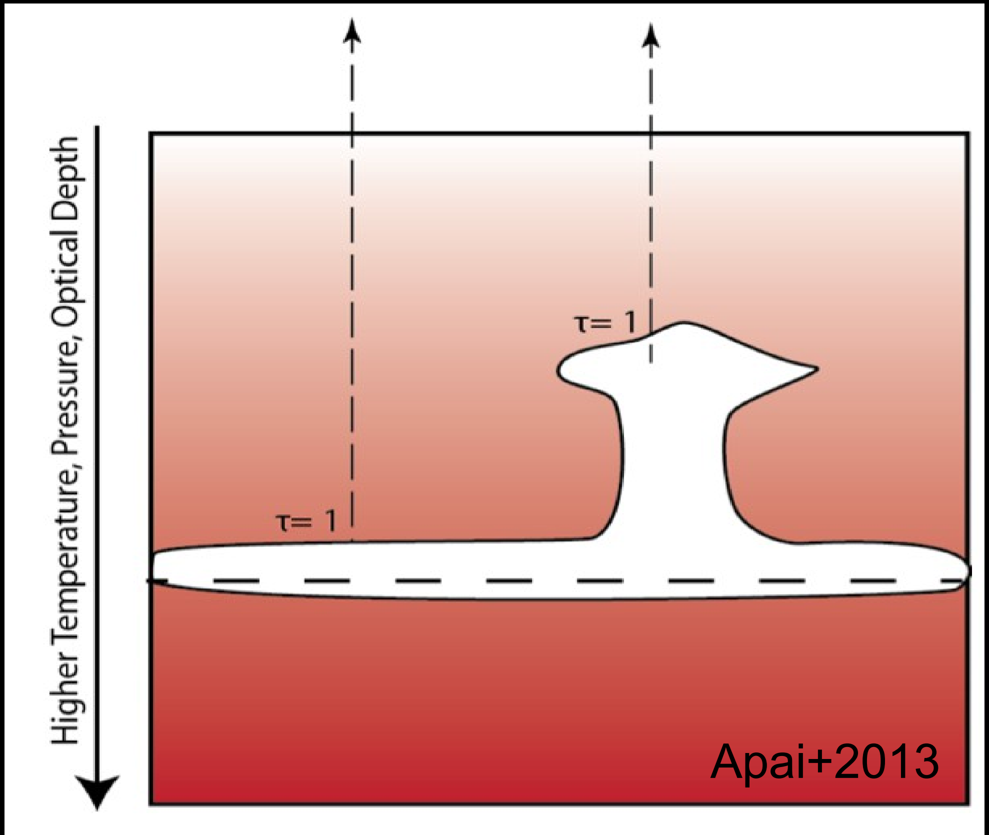


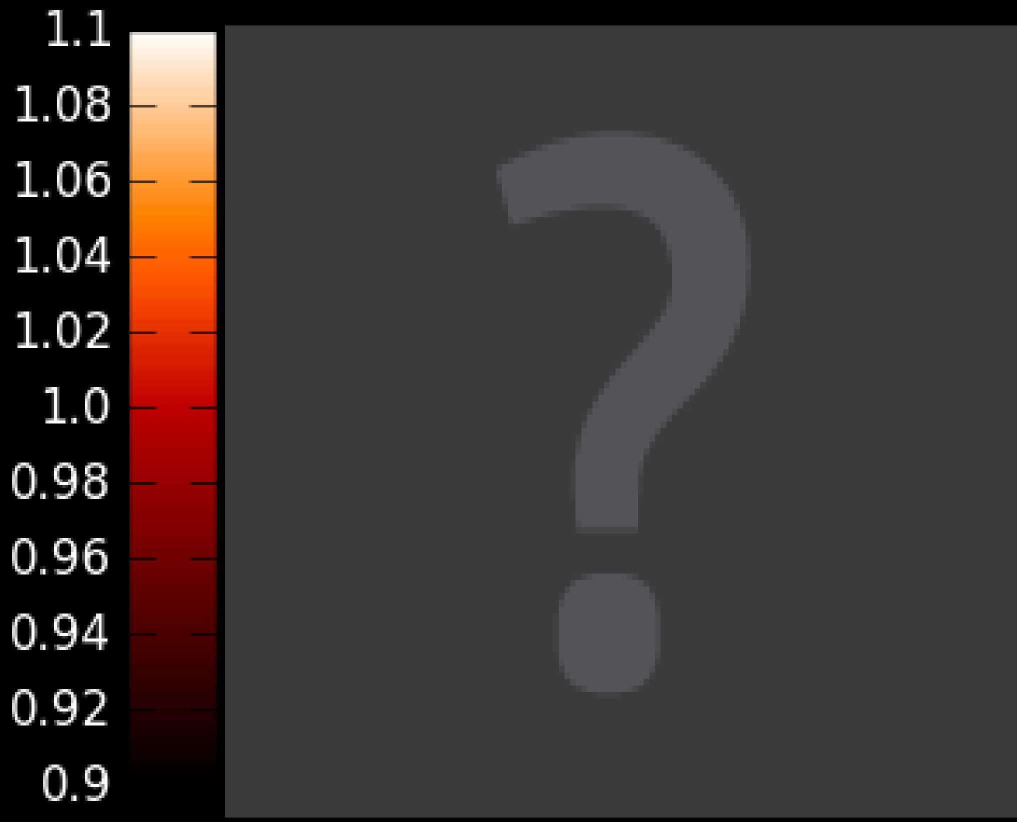
IC et al., *Nature* 2014



Global Doppler Map of Luhman 16B







IC et al., *Nature* 2014

Can we map other brown dwarfs?

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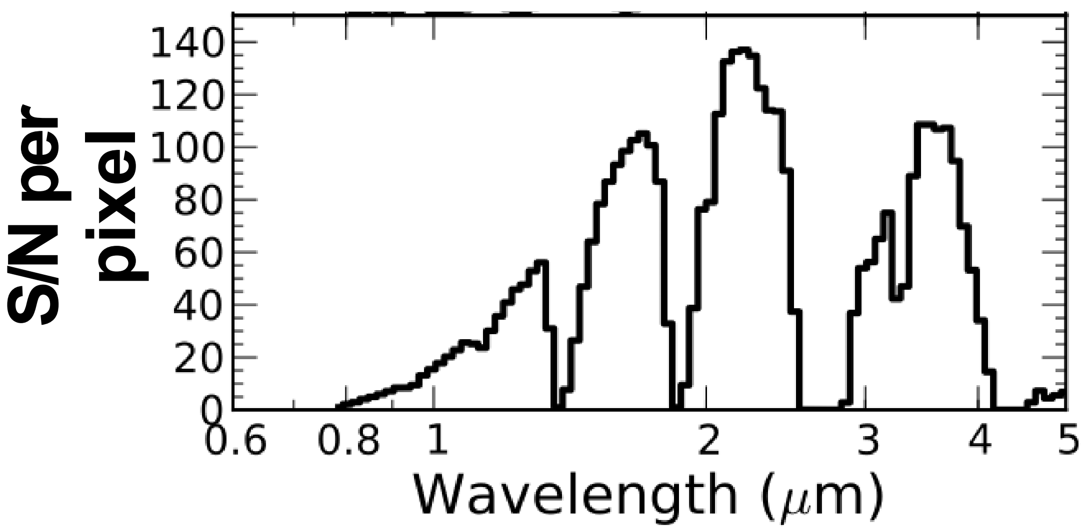
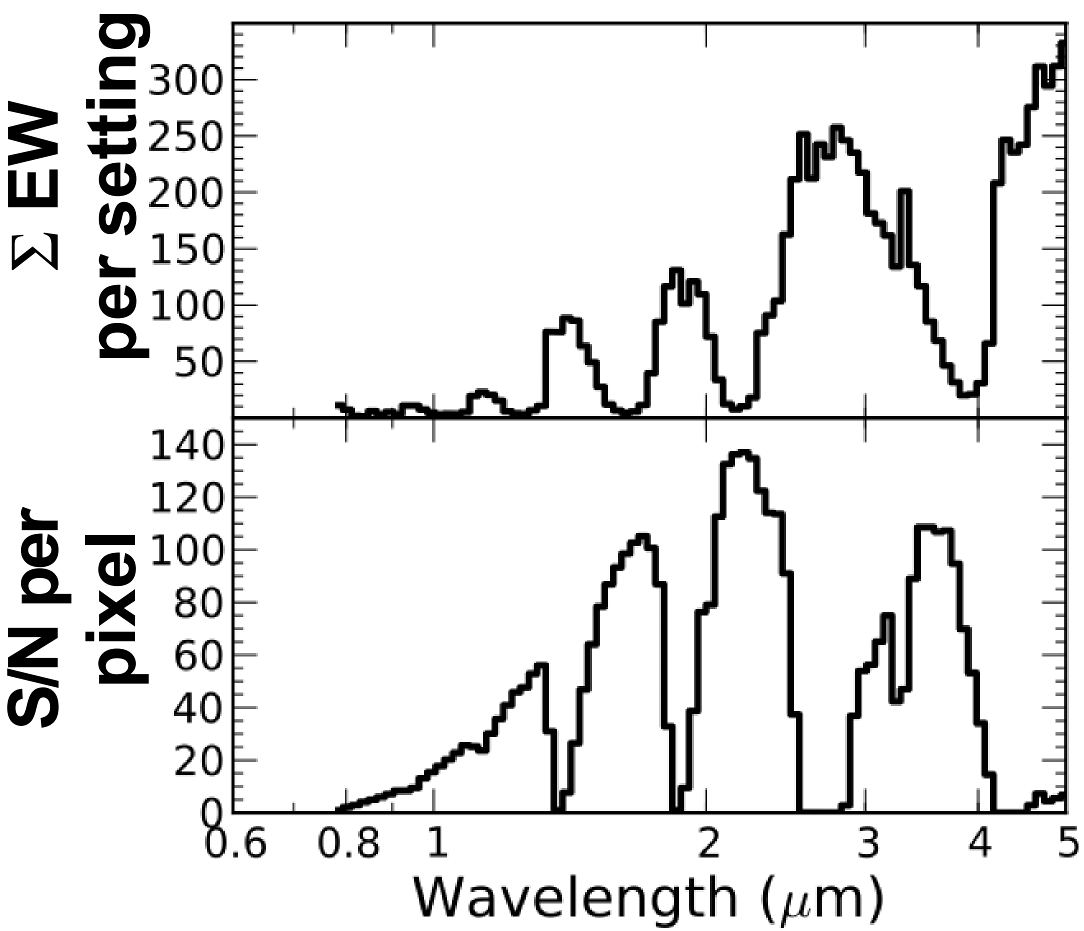
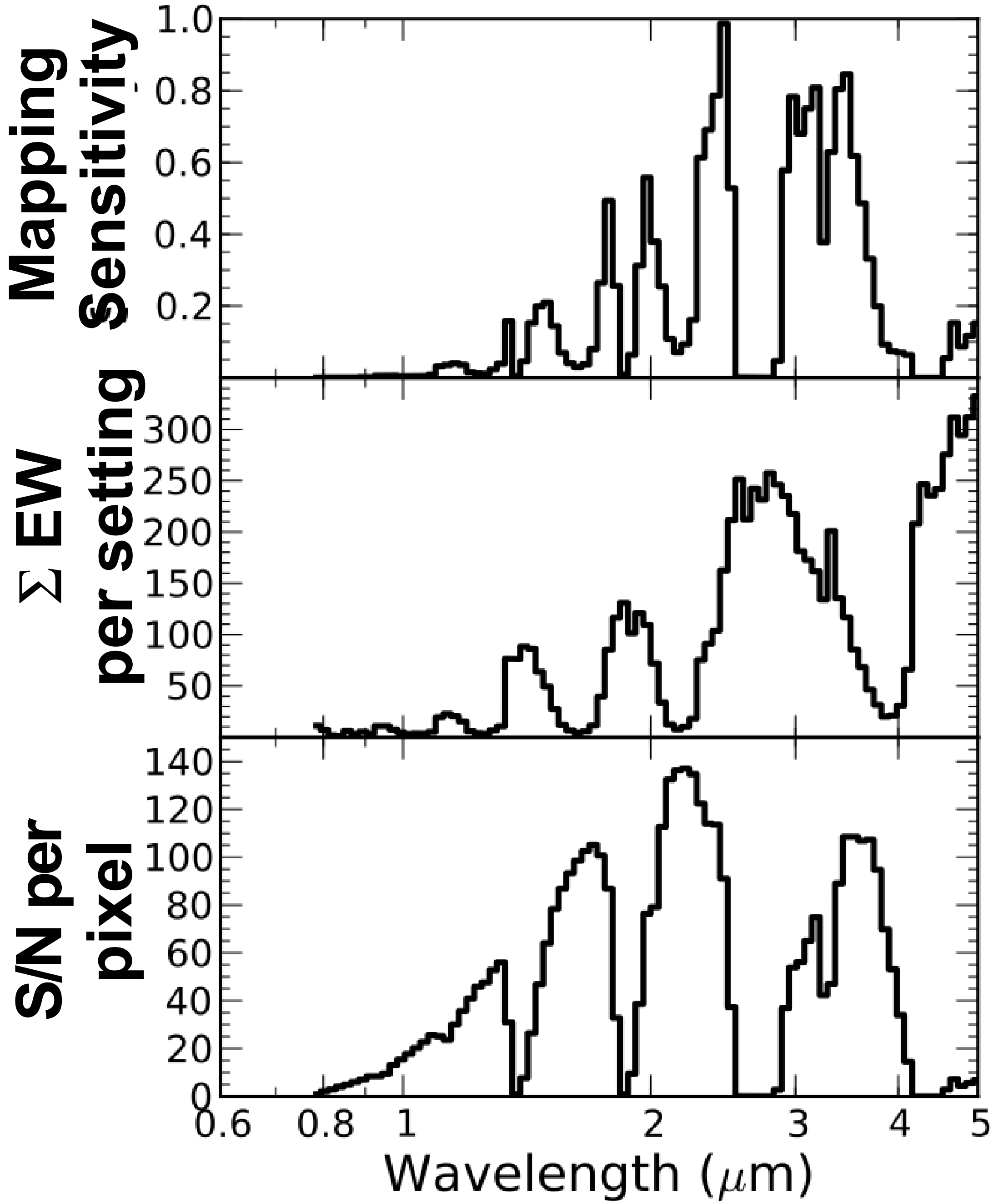
Sensitivity ~ (S/N) x (Σ EW) x (variability)

Estimated S/N for Luhman 16B with VLT/CRIRES:



Compute total equivalent width per 0.02λ:



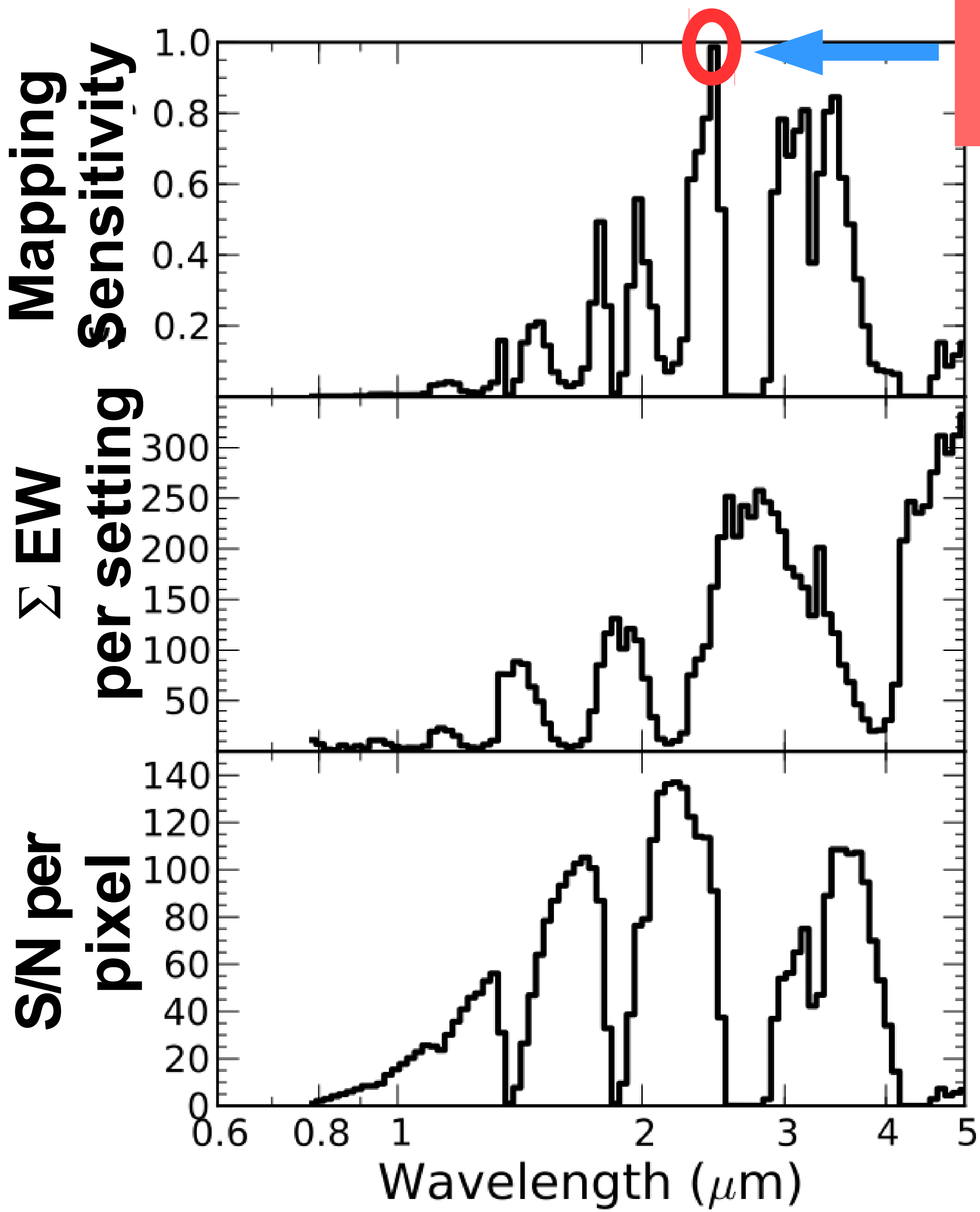


Sensitivity ~

(Σ EW) x

(S/N) x

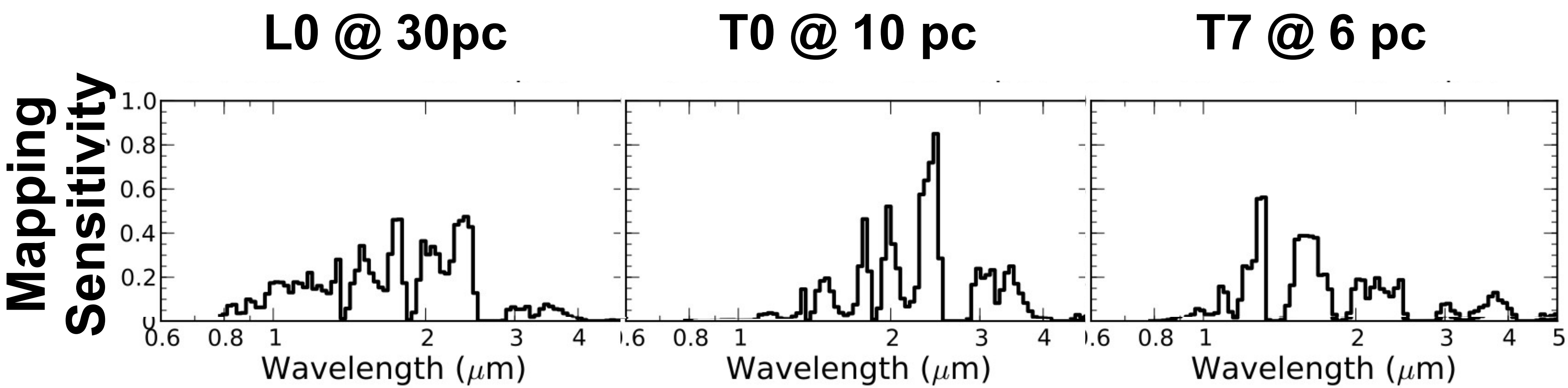
(variability)



Our CRIRES map comes from a single bin @ 2.3 μm.

Sensitivity ~
(Σ EW) x
(S/N) x
(variability)

With **E-ELT/HIRES**, dwarfs down to *H*~13 could be mapped using entire NIR spectrum:



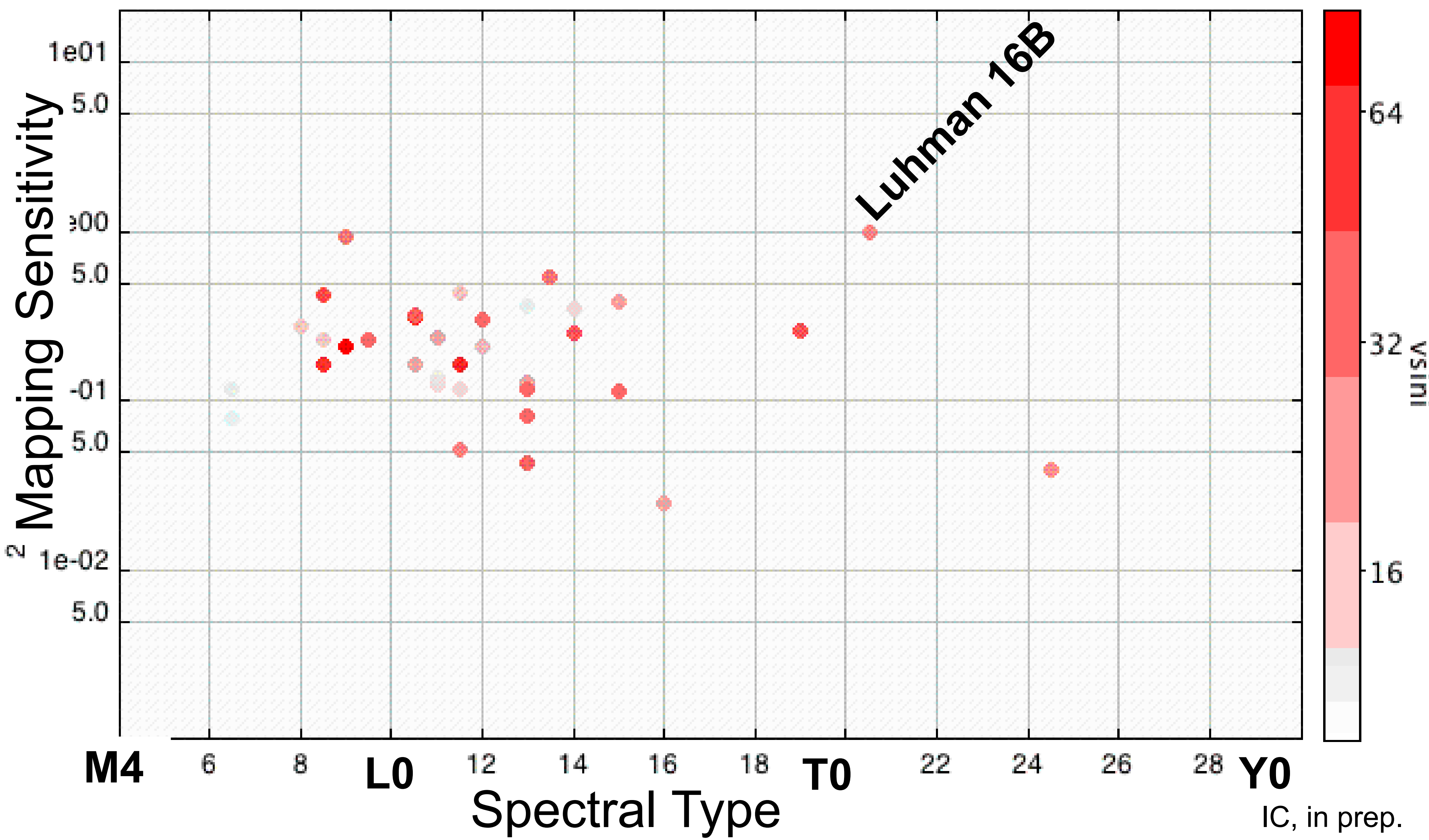
>150 brown dwarfs!

IC, in prep.

Can we map other brown dwarfs?

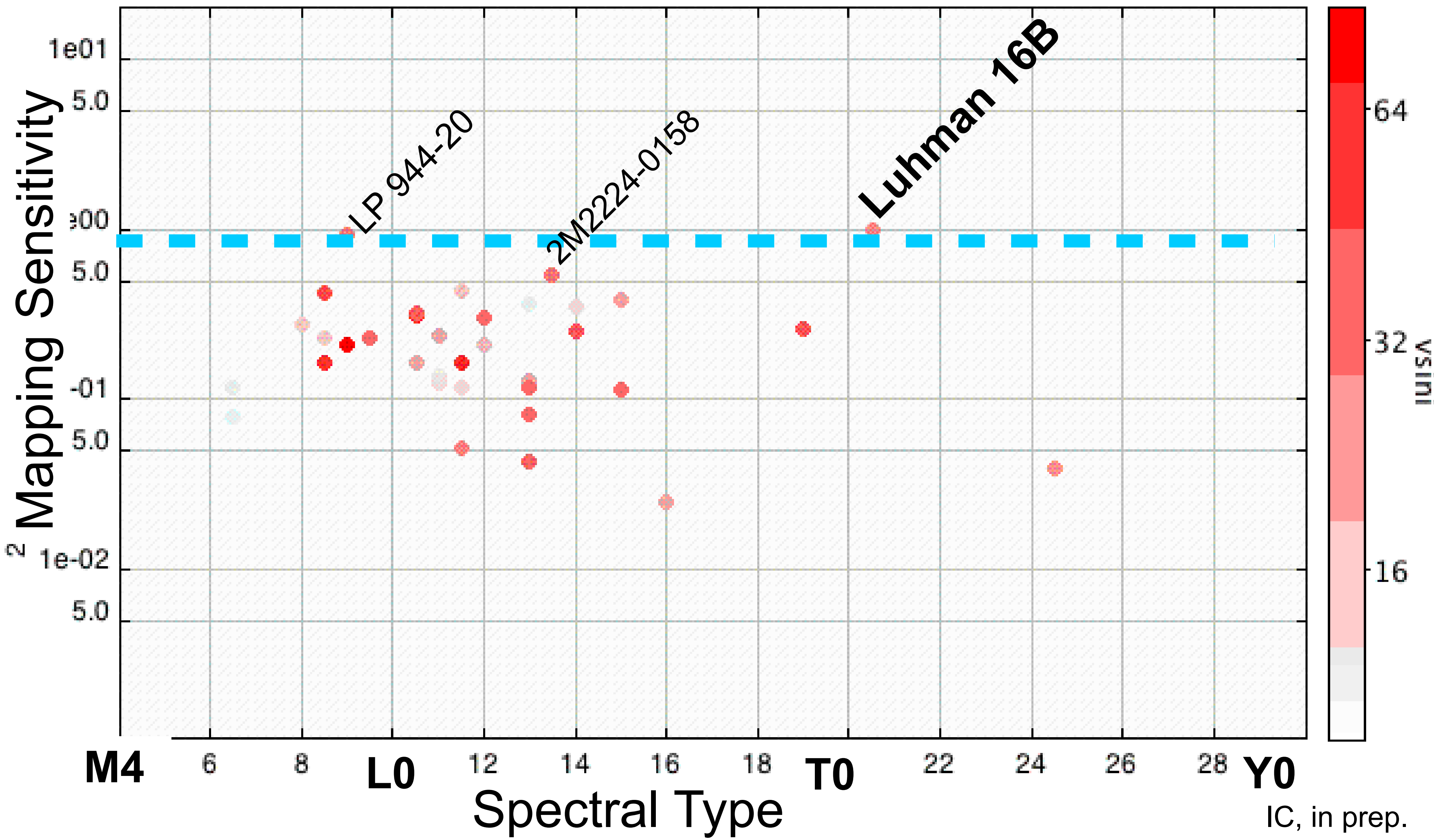
Yes!

Estimated "mapping sensitivity" for known variable brown dwarfs:



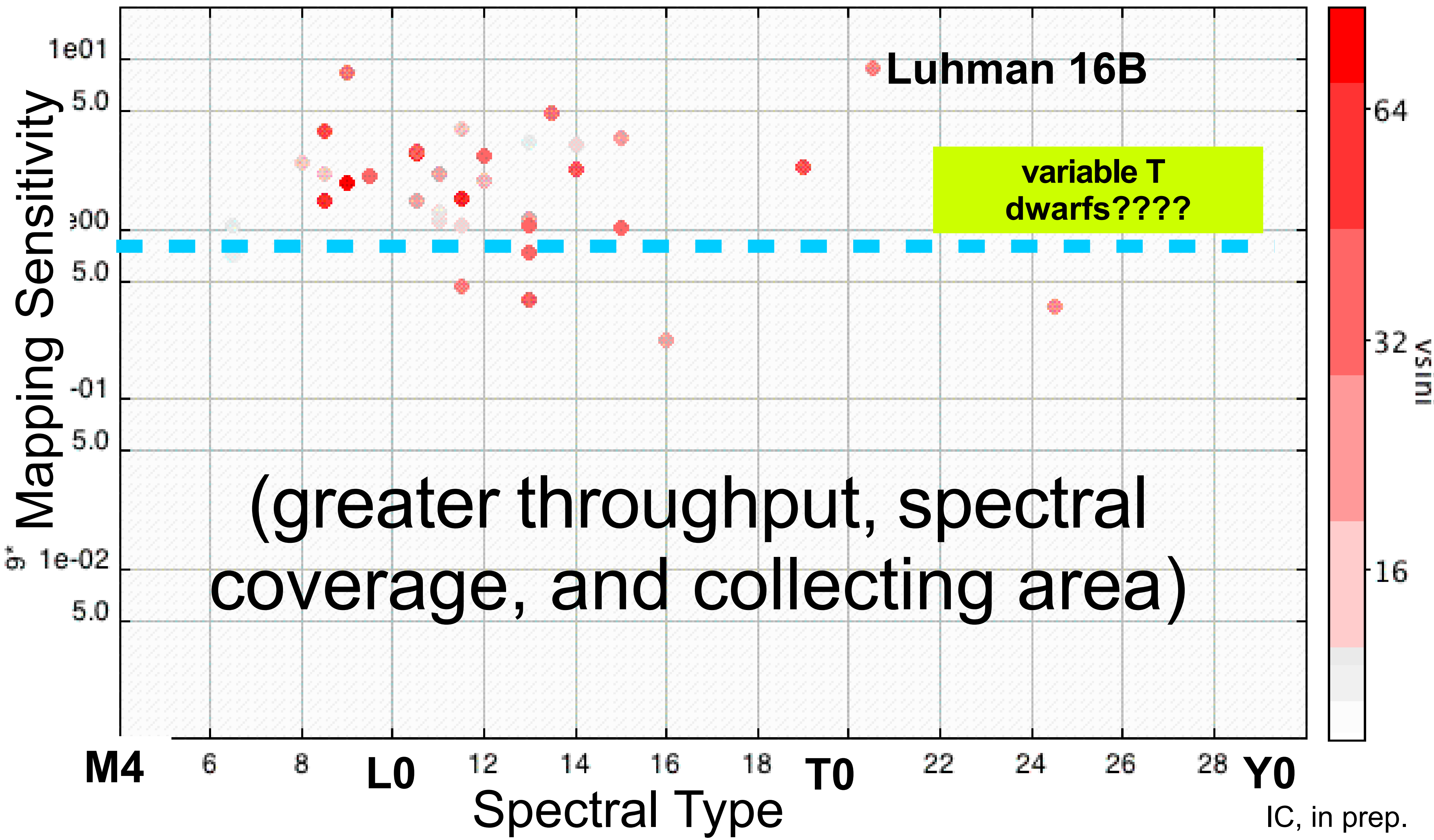
IC, in prep.

Current CRIRES can map ~a few brown dwarfs:



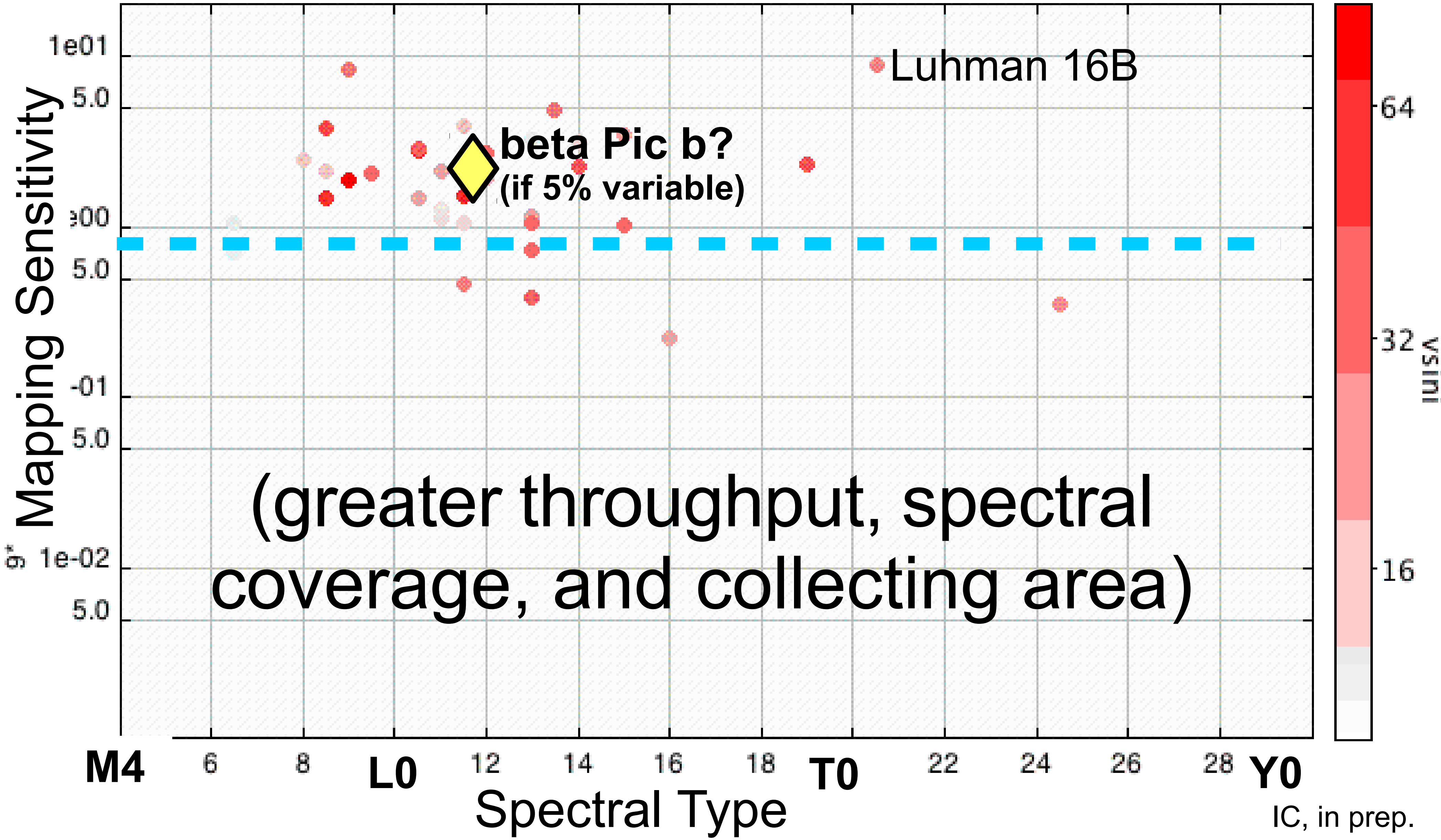
IC, in prep.

E-ELT/HIRES would allow Doppler Imaging of dozens of brown dwarfs:



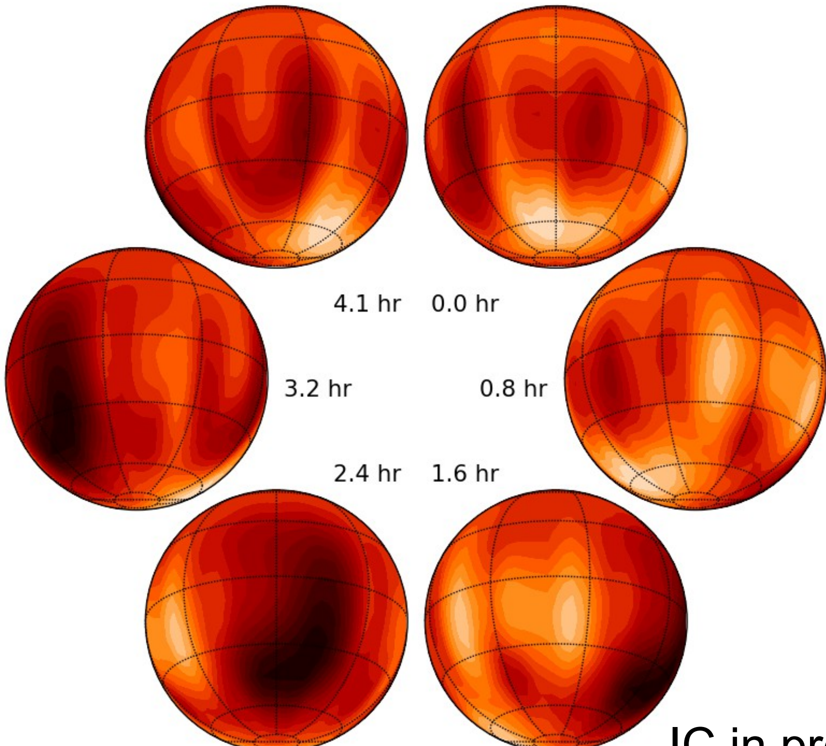
IC, in prep.

E-ELT/HIRES may even allow **global mapping of giant exoplanets**:

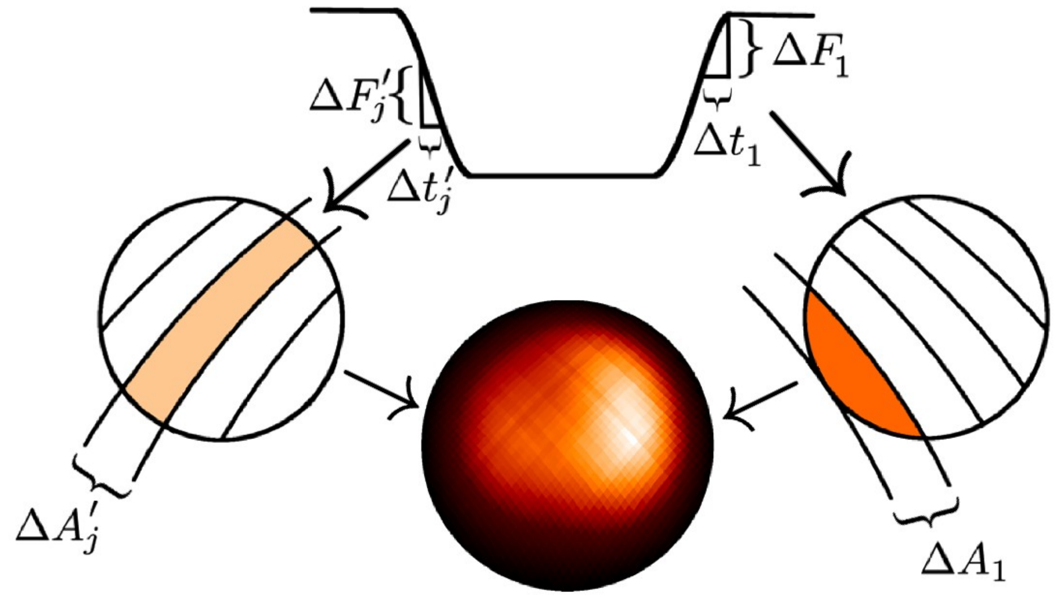


IC, in prep.

Doppler Imaging is complementary to JWST exoplanet science:



IC in press.



Majeau+2012,
de Wit+2012

Doppler Imaging of Planets & brown dwarfs with E-ELT

Eclipse mapping of giant, transiting exoplanets w/JWST

- E-ELT HIRES & METIS can map dozens of brown dwarfs, and a few bright exoplanets

- This work will produce global maps and weather movies of brown dwarf atmospheric chemistry, dynamics, and cloud properties

What do we need?

- High spectral resolution (R>50,000)

- Broad, *simultaneous* spectral coverage

- High efficiency (AO w/infrared WFS would help)

- More measurements (w/higher precision) of brown dwarf variability, rotation periods, and *v* sin *i*