

# CFBDSIR2149-0403, a puzzling free-floating planet candidate: low-gravity or high-metallicity ?

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## Abstract

Discoveries of very massive planets, on one hand, and very low mass isolated brown dwarfs, on the other hand, show that the brown dwarf and the planetary mass ranges widely overlap. When these low mass brown dwarfs are close and bright enough to be observed in spectroscopy, their atmospheres are much easier to study than similar exoplanets that lie nearby their very bright host stars.

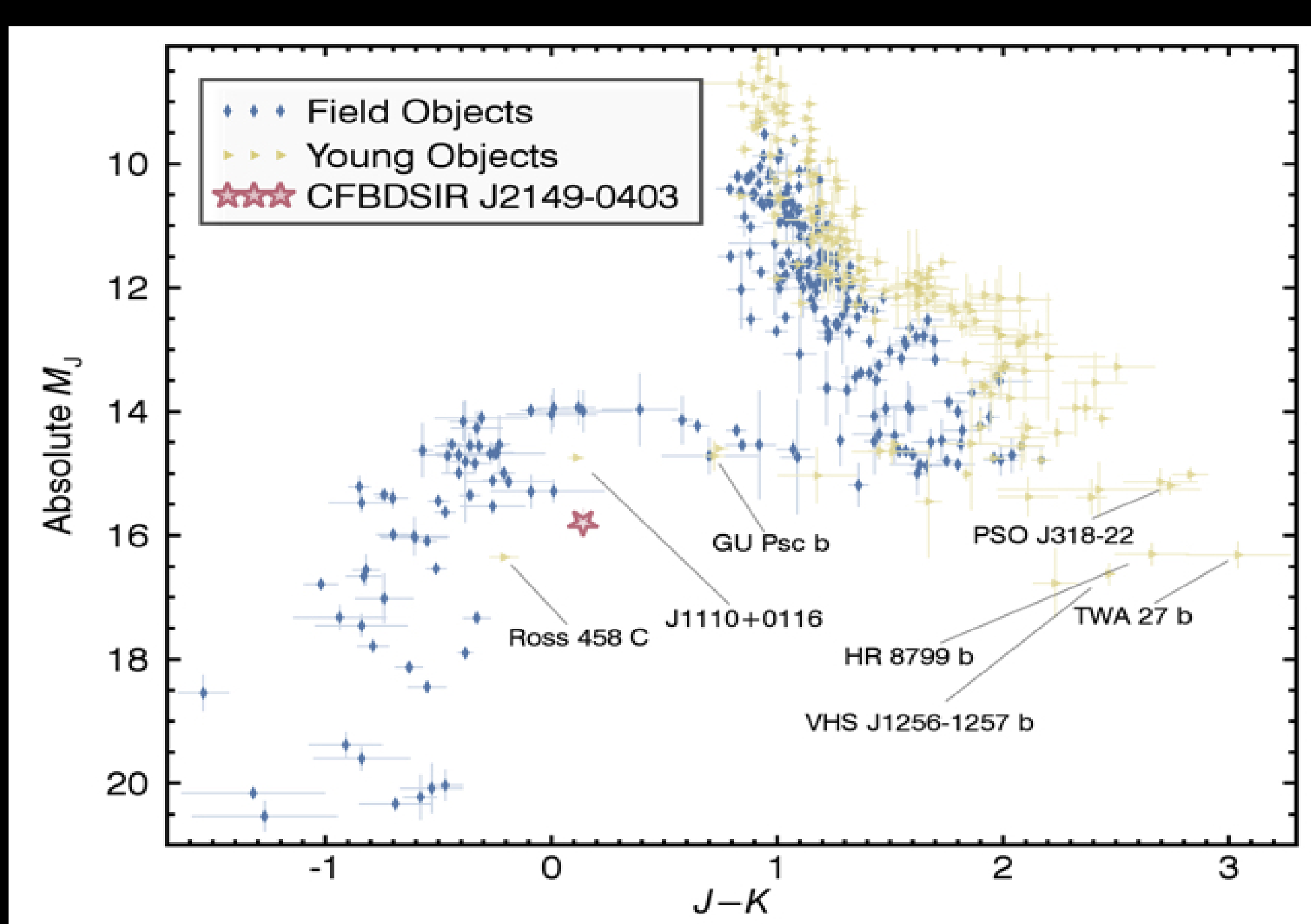
When we identified CFBDSIR214947.2-040308.9 (Delorme et al 2012), it appeared as a good candidate member of the AB-Doradus young moving group and together with the low gravity features in its spectrum made it a unique T type isolated planetary-mass object.

In order to ascertain its nature and determine its physical properties, we conducted additional observations: X-Shooter spectroscopy from 0.8 to 2.3  $\mu\text{m}$ , mid-IR photometry with the Spitzer Space Telescope, as well as a parallax follow-up over 2 years.

While the spectral information confirm the low gravity or high metallicity of the atmosphere, the new kinematics safely rule out membership to any known young moving group. Therefore this object is a peculiar late T dwarf, perhaps a young free floating planet or an older, heavier brown dwarf with supersolar metallicity.

**Spectral indices:** We derived from the X-Shooter spectrum the spectral indices that trace the strength of several molecular absorption features typical of T dwarfs ( $\text{H}_2\text{O}$ ,  $\text{CH}_4$ ,  $\text{NH}_3$ ). The atmospheric features are typical of a **T7.5 dwarf**, with a significantly **enhanced K/J index**, telltale of a weak collision induced absorption, and therefore of **a low pressure photosphere**.

**Parallax and proper motion:** We monitored CFBDSIR 2149-0403 with the VLT near-infrared imager HAWK-I and derived  $\mu\alpha \cos \delta = 138.3 \pm 1.2 \text{ mas yr}^{-1}$ ;  $\mu\delta = -93.6 \pm 1.5 \text{ mas yr}^{-1}$ , and a trigonometric distance of  $55 \pm 5 \text{ pc}$ . Both the trigonometric distance and radial velocity obtained from the X-Shooter spectrum ( $10 \pm 8 \text{ km s}^{-1}$ ) **reject a possible membership to all moving groups** considered by the Bayesian Analysis for Nearby Young AssociationSII tool (BANYANII, Gagn  et al 2014).

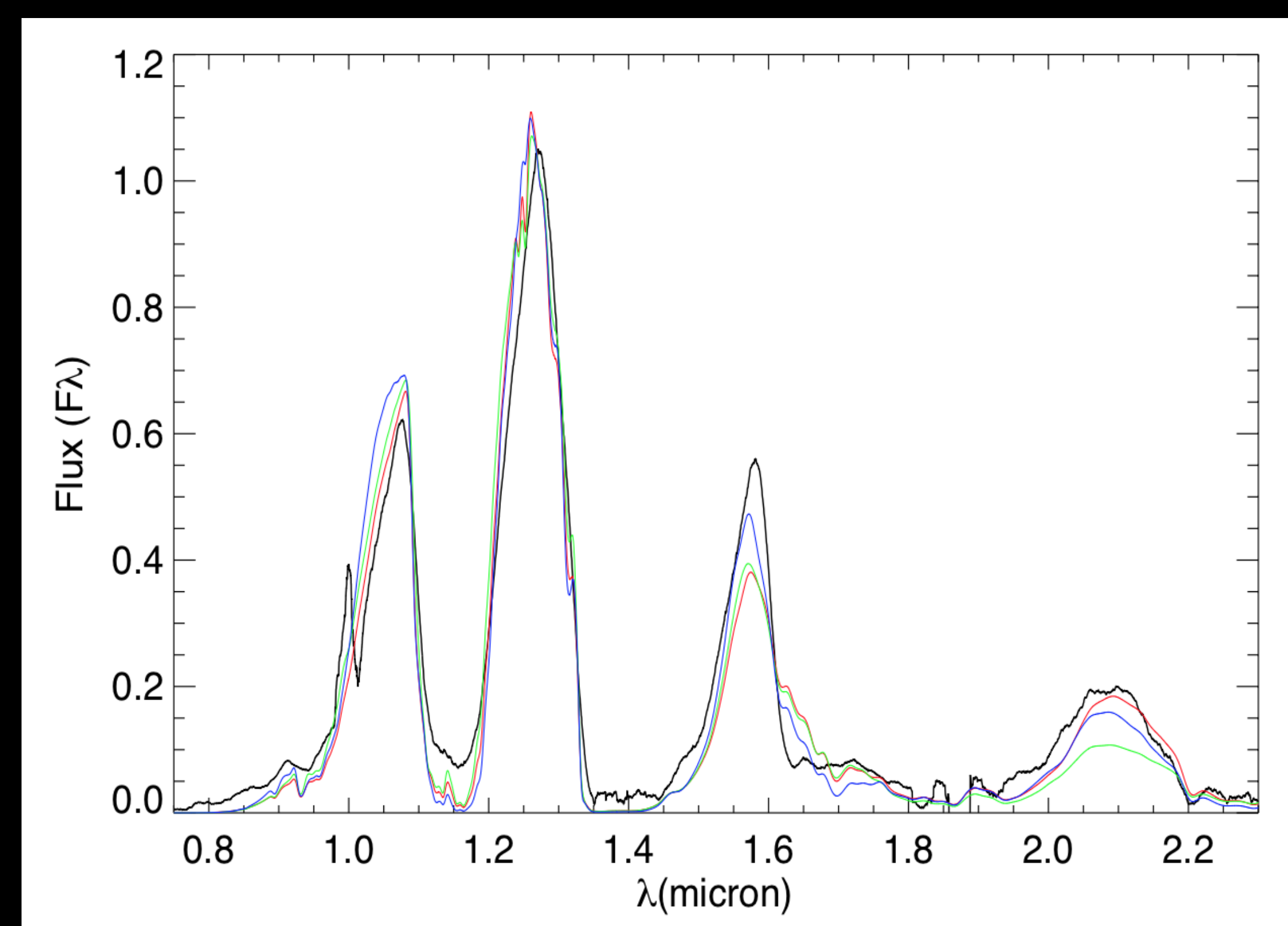


Colour and absolute magnitude of CFBDSIR2149-0403 (red star) compared to known field and young L and T dwarfs.

**Atmospheric properties:** We performed a fit of our full X-Shooter spectrum against a grid of BT-Settl atmospheric models (Allard et al 2013). The best fitting model corresponds to a cool (**700 K**), low gravity ( **$\log g=3.5$** ) atmosphere at **solar metallicity**. We also tried to force high metallicity ( $[\text{M}/\text{H}]=+0.3$ ) and field gravity ( $\log g \geq 5.0$ ) fits.

The field gravity solution shows significant discrepancies with respect to the observations in all bands.

The high-metallicity solution provides a much better fit than the low-gravity one in the Y band and a slightly better one in the K band. However it also favors moderate gravity ( $\log g=4.5$ ) and leads to a relatively high effective temperature (850K) for a T7.5 object, resulting in a poor fit of the  $\text{H}_2\text{O}$  and  $\text{CH}_4$  lines in all the H-band range.



Black: X-Shooter spectrum, binned to  $R \sim 100$ .  
Blue: Best fitting overall model (700K,  $\log g=3.5$ ,  $[\text{M}/\text{H}]=0$ )  
Red: Best fitting model when high metallicity is forced (850K,  $\log g=4.5$ ,  $[\text{M}/\text{H}]=0.3$ )  
Green: Best fitting model when field gravity and solar metallicity is forced (900K,  $\log g=5.0$ ,  $[\text{M}/\text{H}]=0.0$ )

We also derived the equivalent width of the potassium lines around 1.25 $\mu\text{m}$  using the prescriptions detailed in Faherty et al (2014); McLean et al (2003). The best fitting model, with very low gravity ( $\log g=3.5$ ) also leads, by far, to the best agreement in KI equivalent width.

**On the nature of CFBDSIR2149-0403:** The overall fit of the spectrum, as well as the KI lines, favors a low gravity object. Effective temperature derived from the absolute luminosity using evolutionary tracks (Baraffe et al 2003) shows that younger ages hypothesis (**20 to 100 Myr**) derive effective temperature and radius that are in close agreement with those derived from the comparison with atmosphere models. This makes most probable CFBDSIR2149-0403 to be a **very young 2-3  $M_{\text{Jup}}$  free floating planet**. However the hypothesis of being a **relatively young super-solar metallicity** higher mass object remains also plausible.

**References** Allard F. et al 2013 (Memorie della Societa Astronomica Italiana, v.84, No. 4, p.1053) • Baraffe I. et al 2003 (A&A, 402, 701) • Delorme P. et al 2012 (A&A, 548, A26) • Faherty et al 2014 (ApJ, 790, 90) • Gagn  J. et al 2014 (ApJ, 783, 121) • McLean et al 2003 (ApJ, 593, 561)