Linear polarization of ultracool dwarfs

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General Overview

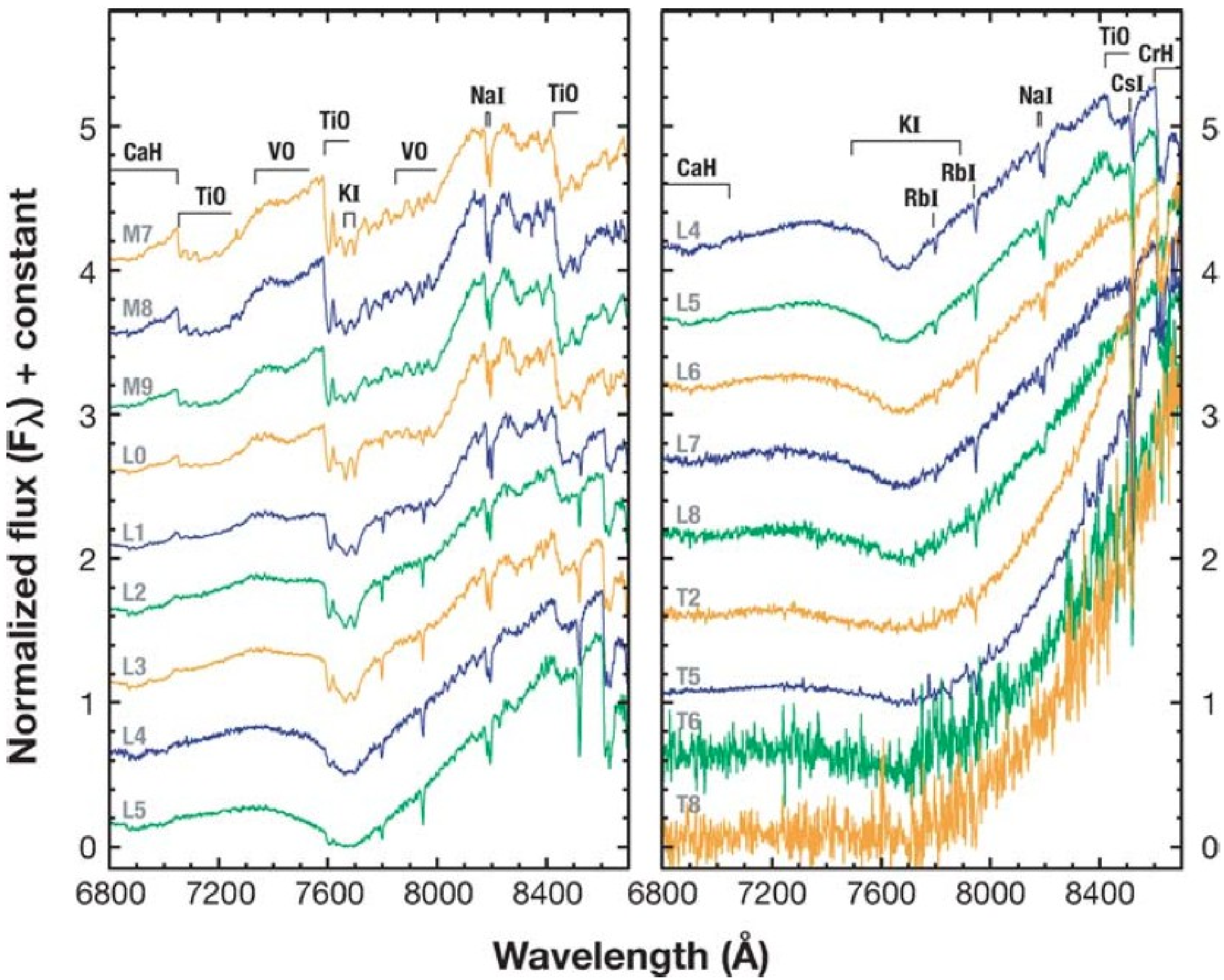
-Introduction
- -Ultracool dwarfs
- -What do models say about linear polarization in ultracool dwarfs?

-The samples
- -Rapidly rotating ultracool dwarfs
- -Young ultracool dwarfs

-Results

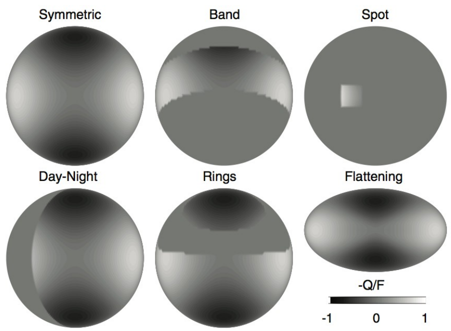
Ultracool Dwarfs

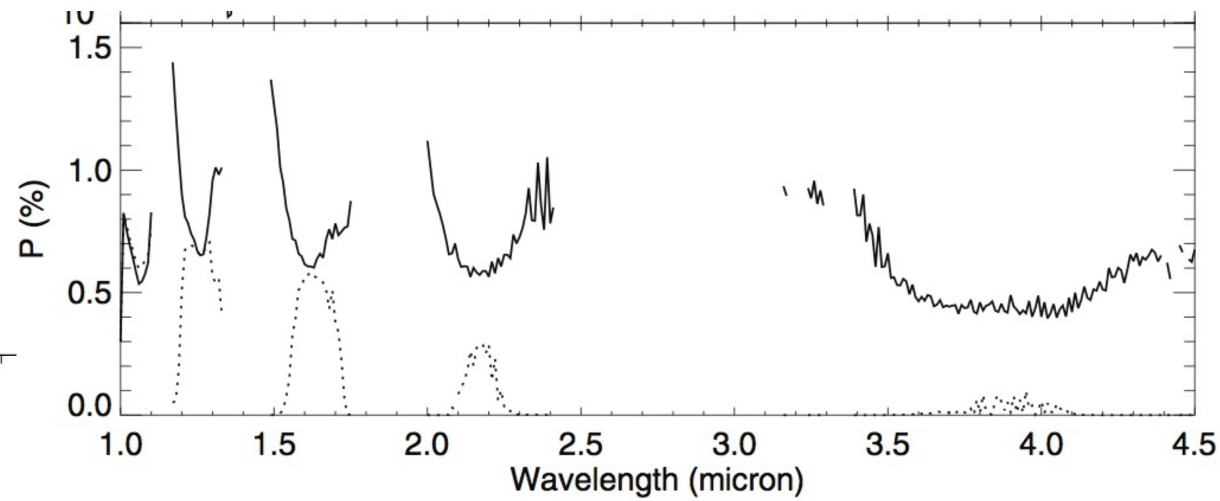
Low Teff's (≤2700 K), high atmospheric pressures, and large rotational velocities favor the formation of condensates through collisions of refractory atoms (e.g., Ti, V, Fe, Cr, Ca, Mg, ...).



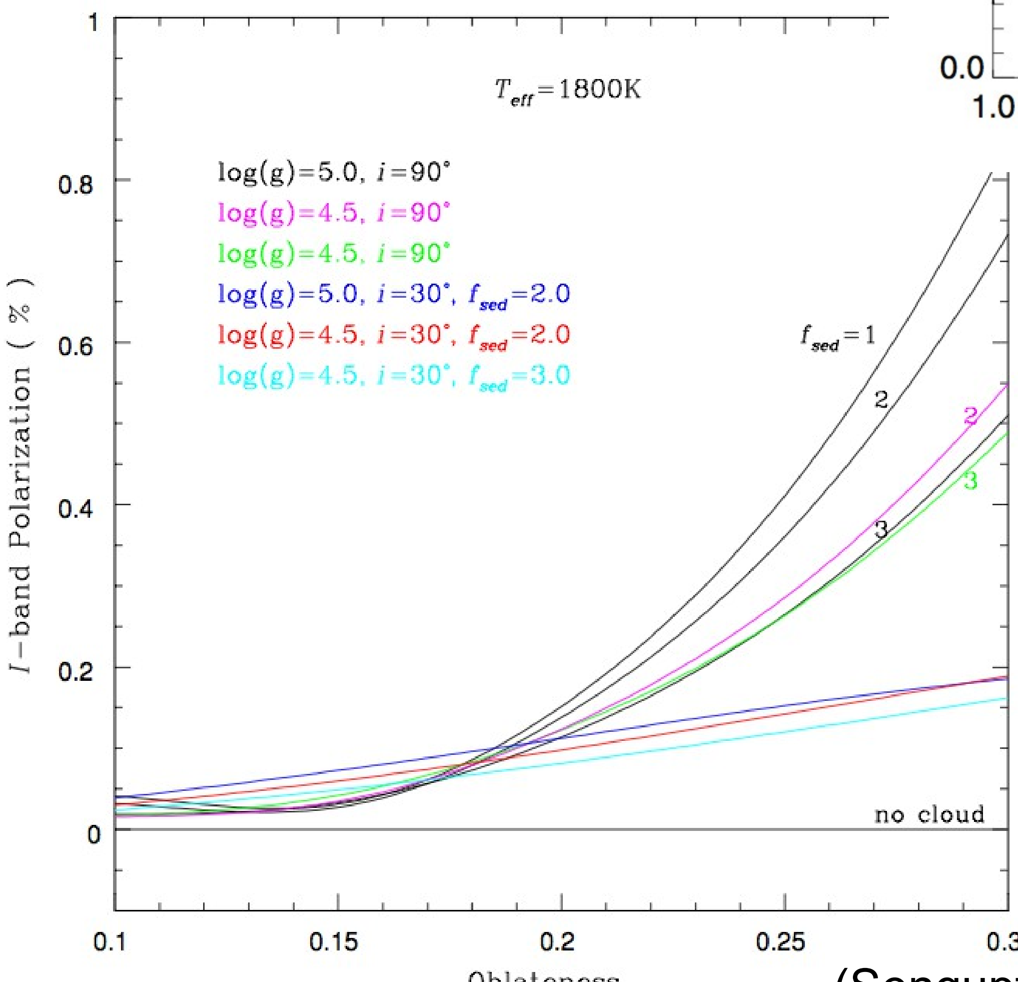
(Kirkpatrick 2005)

Linear polarization





(de Kok et al. 2011)



(Sengupta & Marley 2010)

Photospheric dust polarizes emergent flux.

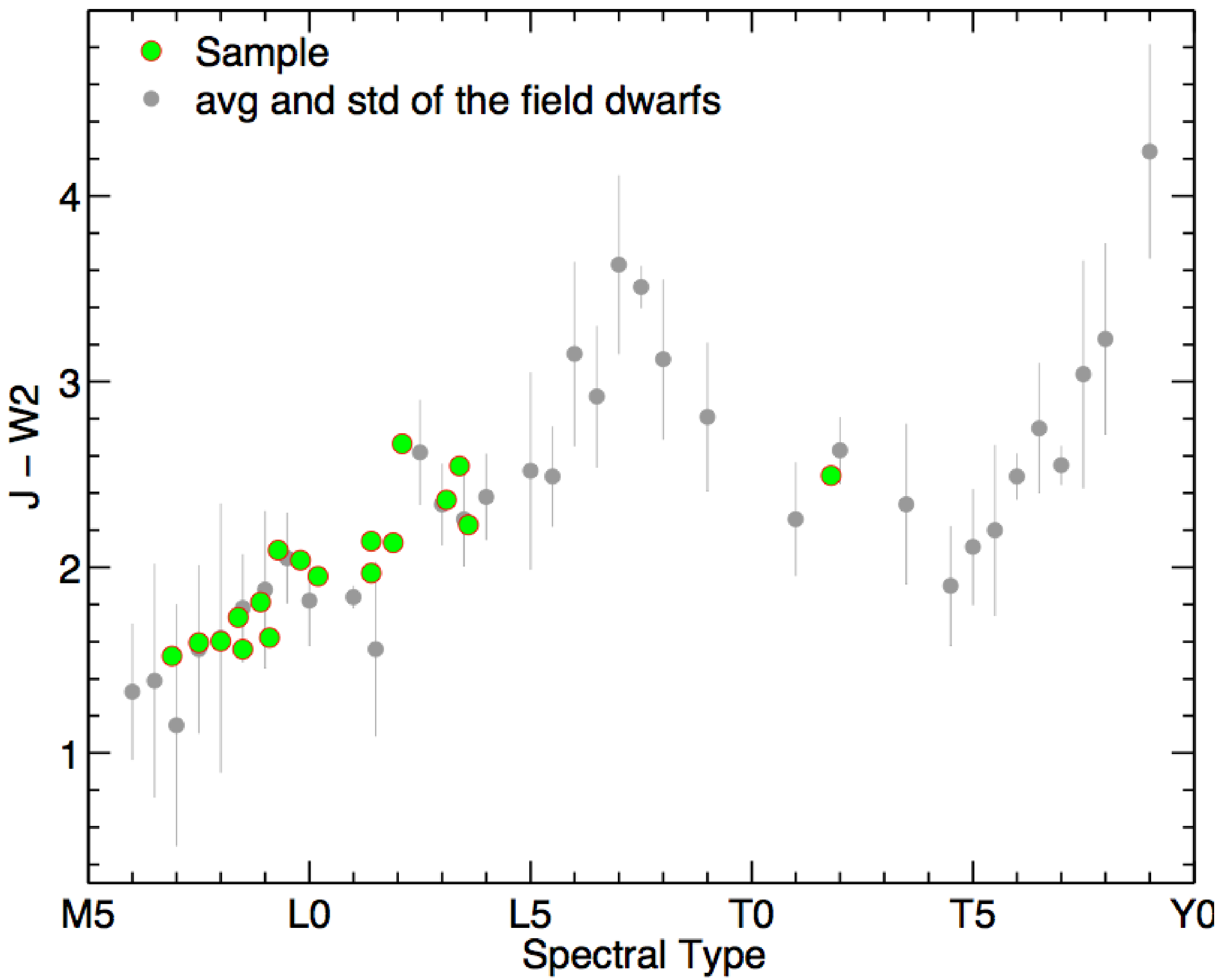
Asymmetries (e.g., oblateness, inhomogeneities in the atmospheres) prevent the total cancellation of linear polarization and yield non-zero polarization degrees.

The samples

Two samples to understand the impact of high rotation and low-gravity in linear polarization measurements.

Field rapidly rotating ultracool dwarfs:

18 M7-T2 field dwarfs
$10.2 < J < 14.9$ mag
$v \sin i \geq 30$ km s^{-1}



(Miles-Páez et al. 2013)

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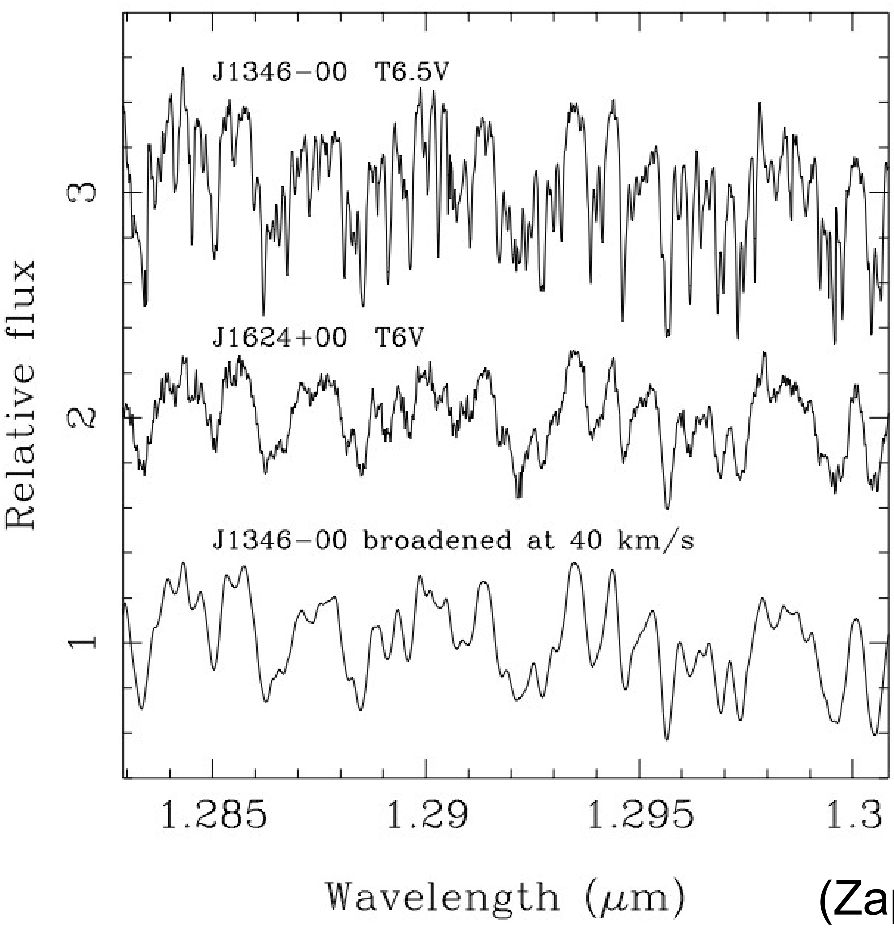
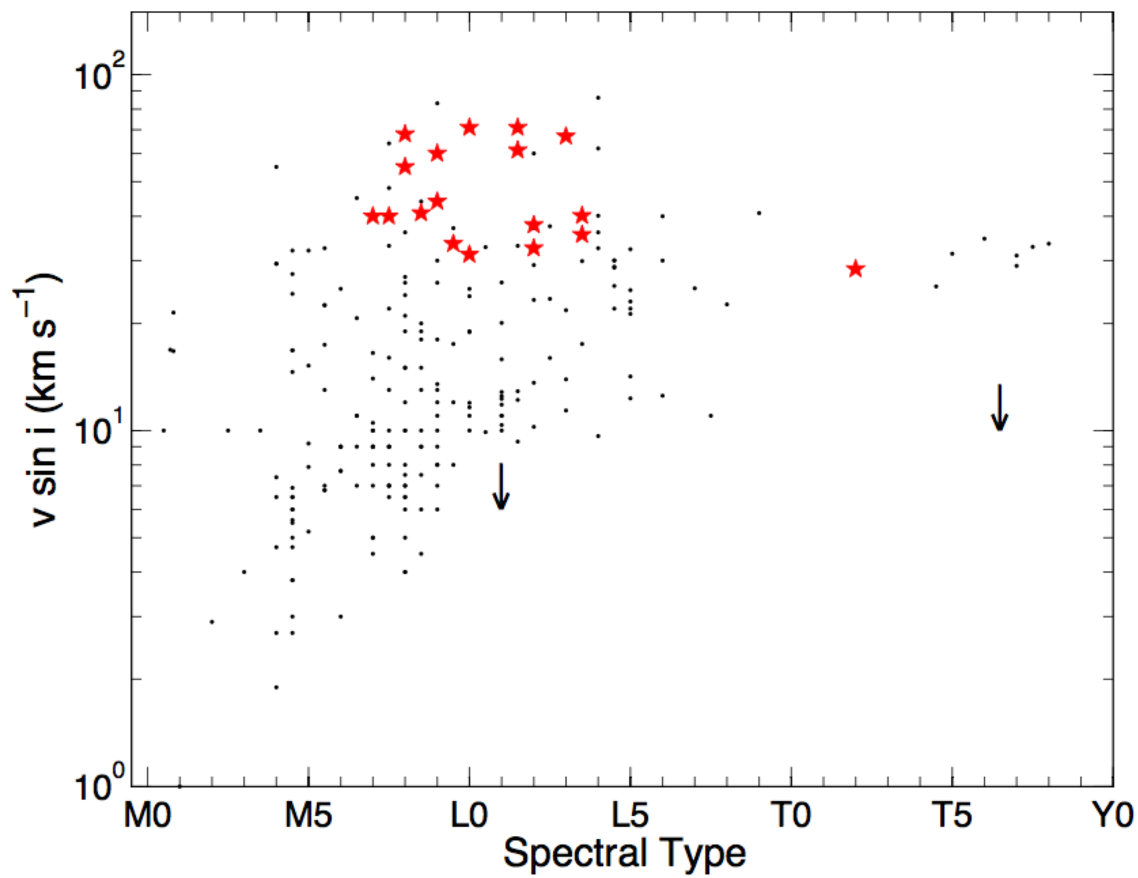


(Zapatero Osorio et al. 2006)



(Miles-Páez et al. 2013)

The samples

Young,low-gravity, ultracool dwarfs:

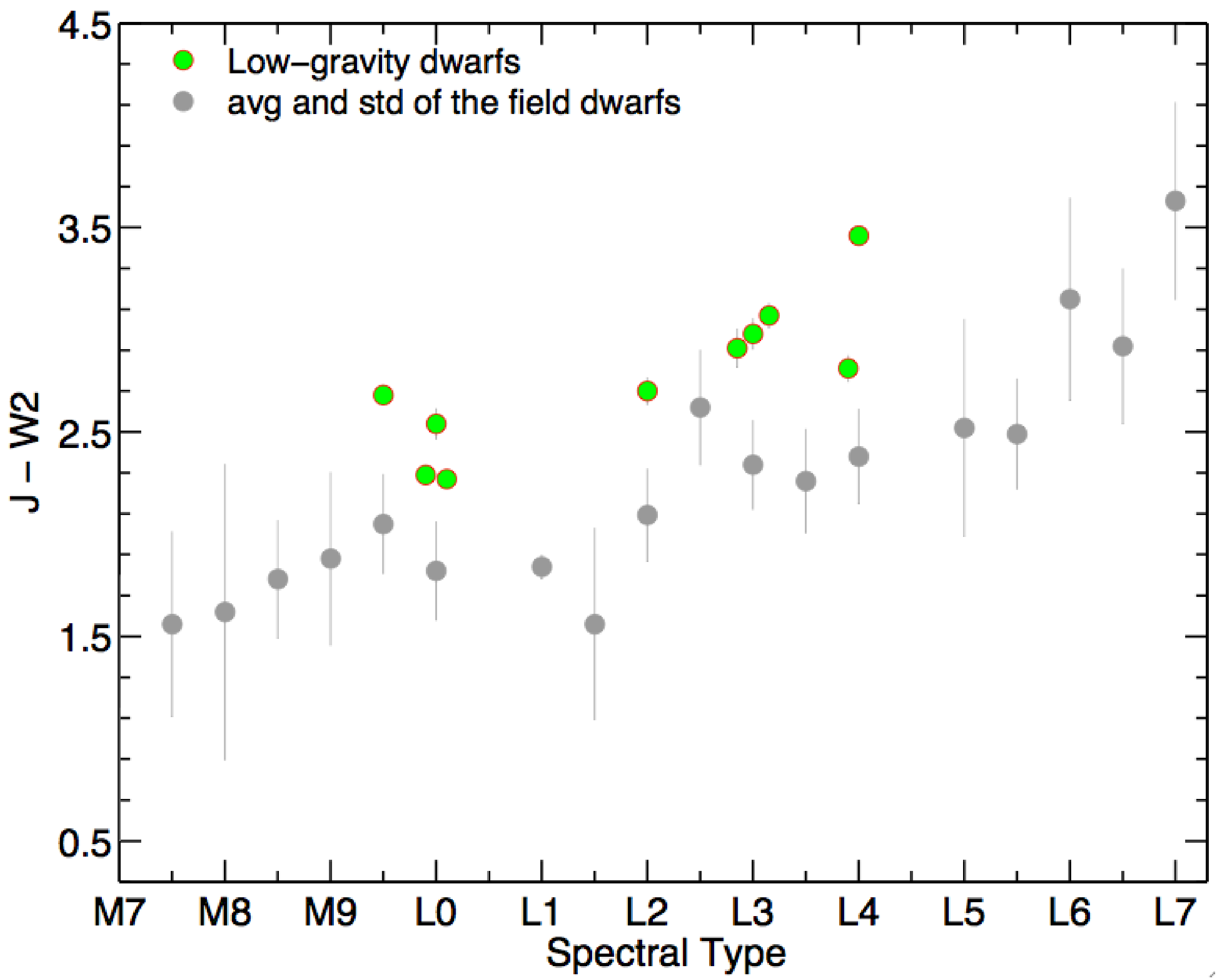
10 M9.5-L4 ultracool dwarfs:

13.5 < J < 15.8 mag

Redder than the field

Low pressure (or low-g) prevents the precipitation of dust grains below the photosphere, leading to thicker clouds, more condensate opacity, and redder NIR-colors.

Isolated in the field



(Miles-Páez et al. 2013, in prep.)

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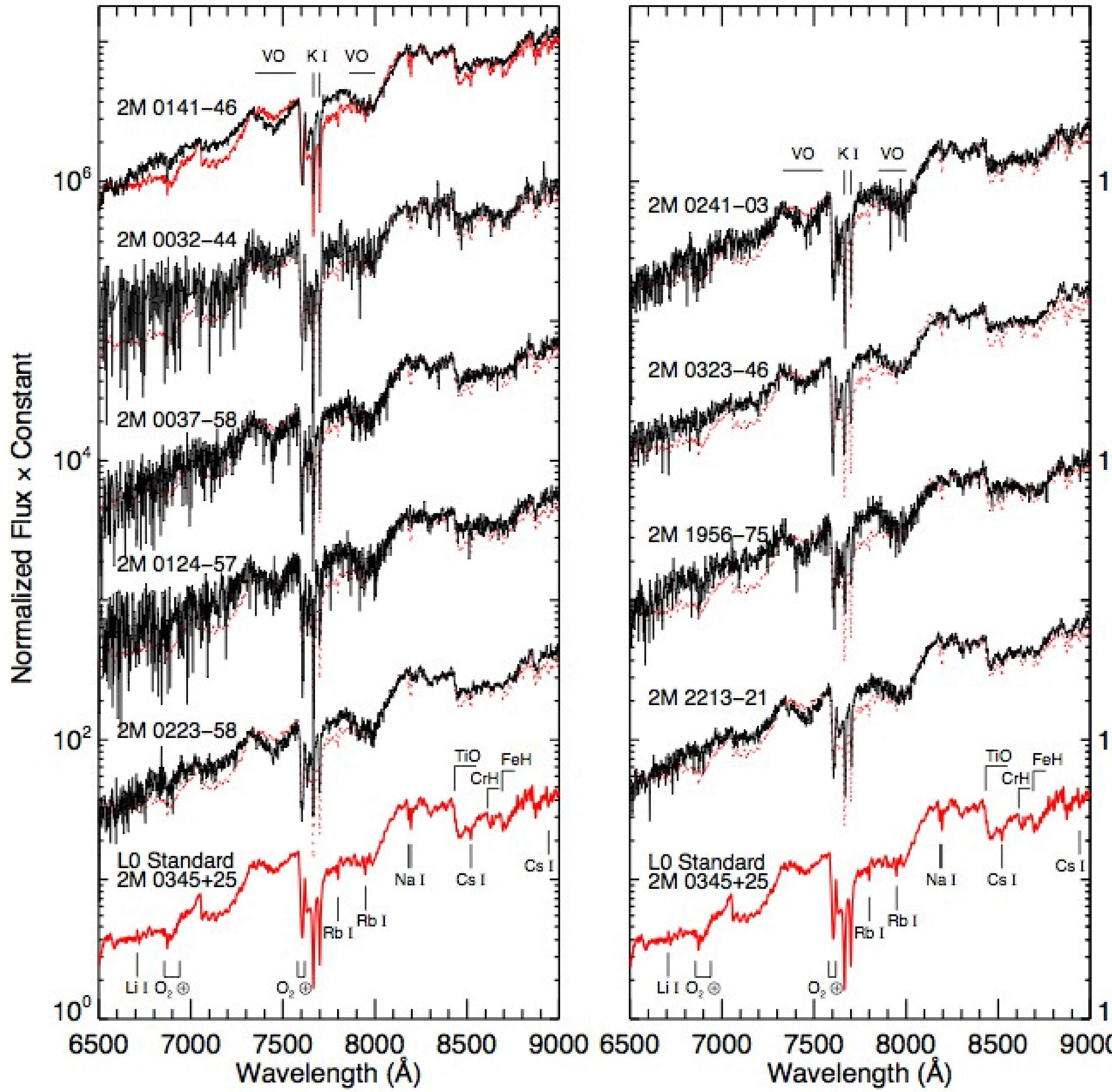


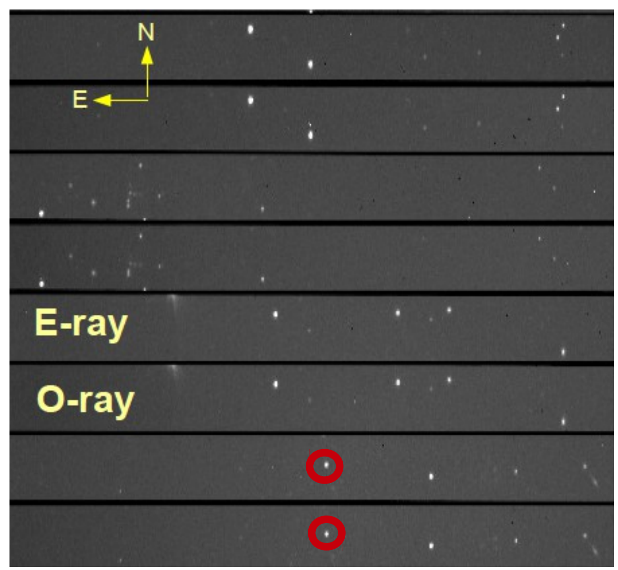
(Cruz et al. 2009)

Optical & near-infrared imaging polarimetry

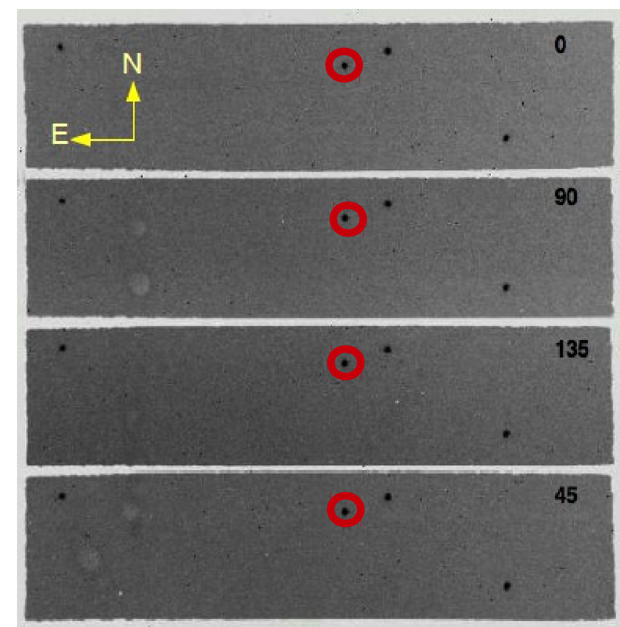
1- Rapidly rotating ultracool dwarfs:
Z & *J*-band LIRIS @ 4.2-m William Herschel telescope (Spain)

2- Low-gravity ultracool dwarfs:
I-band FORS2 @ VLT (Chile)
J-band LIRIS @ 4.2-m William Herschel telescope (Spain)

Objects always located on the same spot of the detector to avoid systematics.



FORS2 (3.4'x11")



LIRIS (4'x1')

Optical & near-infrared imaging polarimetry

Flux-ratio method

$$R_Q^2 = \frac{o(0^\circ)/e(0^\circ)}{o(45^\circ)/e(45^\circ)}; \quad Q/I = \frac{R_Q - 1}{R_Q + 1},$$

$$R_U^2 = \frac{o(22\overset{\circ}{.}5)/e(22\overset{\circ}{.}5)}{o(67\overset{\circ}{.}5)/e(67\overset{\circ}{.}5)}; \quad U/I = \frac{R_U - 1}{R_U + 1},$$

$$P = \sqrt{(Q/I)^2 + (U/I)^2},$$

$$\theta = 0.5 \tan^{-1}\left(\frac{U/I}{Q/I}\right),$$

$$\Downarrow$$

$$p^* = \sqrt{P^2 - \sigma_P^2}$$

(Wardle & Kronberg 1974)

Polarization criterion: $P/\sigma_p \geq 3$

3 sigma detection:
I-band: 0.45 % (low-g)
Z-band: 0.39 % (vsini)
J-band: 0.39 % (vsini), 0.60 % (low-g)

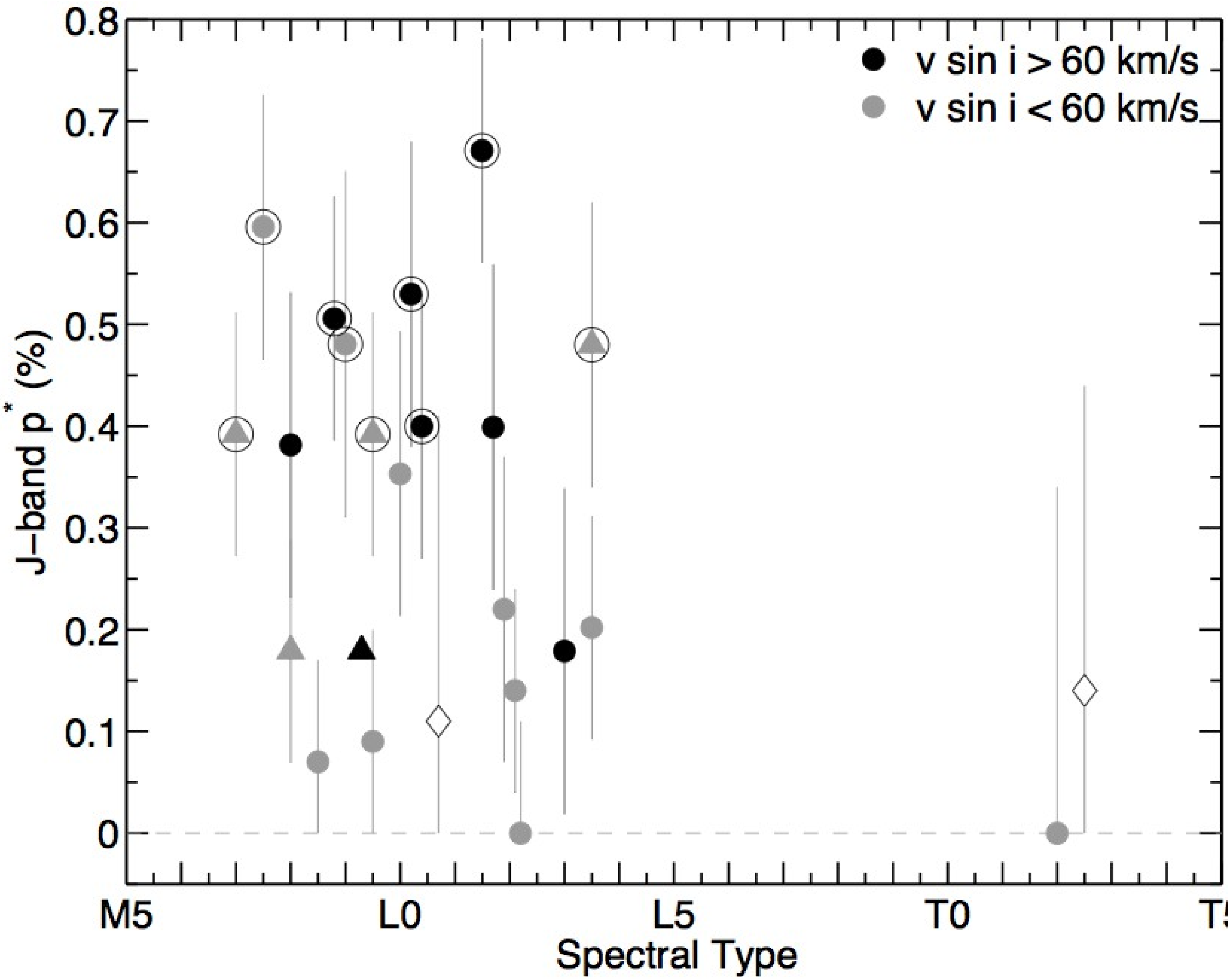
Instrumental polarization controlled by observing non-polarized standard stars (<0.1% in all the filters)

Offset in the polarization vibration angle:

Θ_0= +4.4 ± 1.3 deg (LIRIS)
Θ_0= -2.70 ± 0.3 deg (FORS2)

Rapidly rotating ultracool dwarfs

-The range of measured linear polarization degrees is similar for all explored vsini's (30-84 km/s) and spectral types (M7-L3.5).



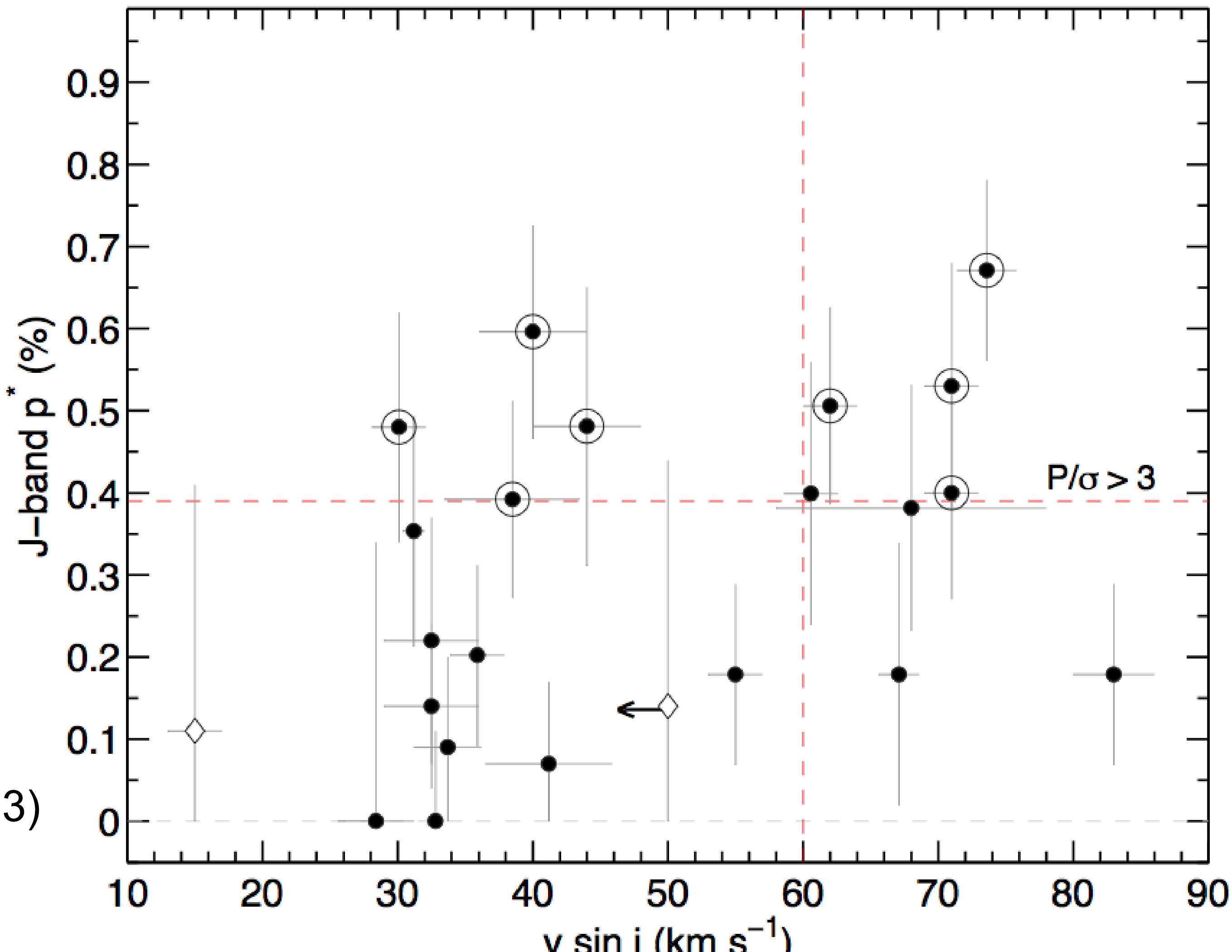
(Miles-Páez et al. 2013)

Rapidly rotating ultracool dwarfs

	vsini ≥ 60 km/s	vsini = 30-60 km/s
Fraction (%)	50 ± 29	18 ± 13
<p*> (%)	0.43 ± 0.16	0.18 ± 0.24

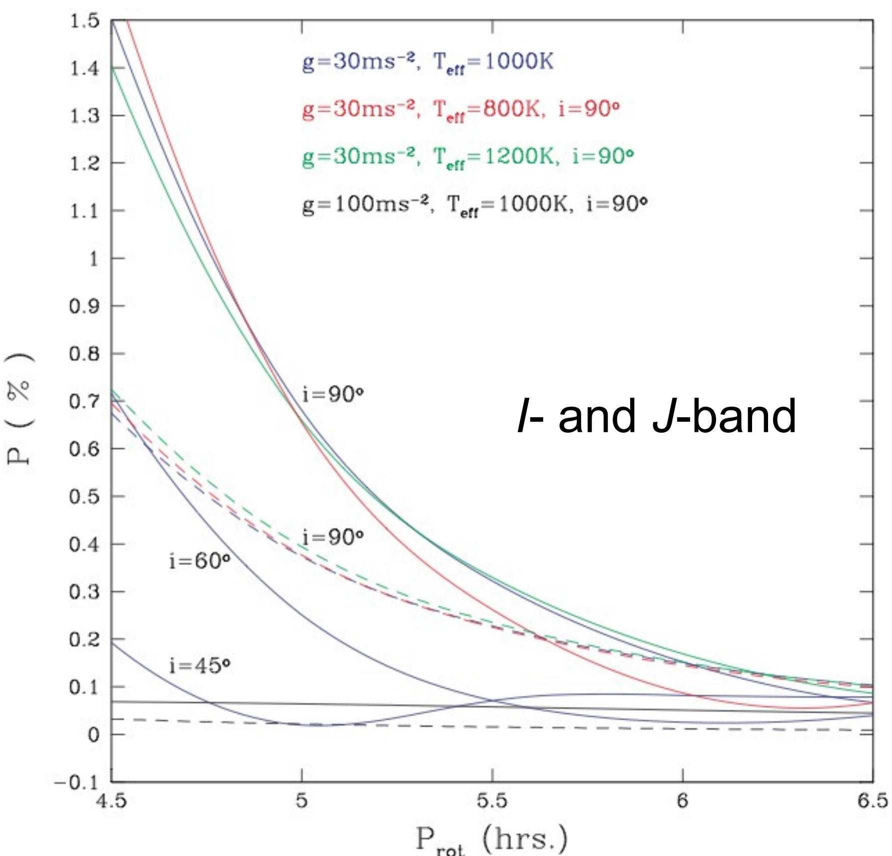
-Z-band data are consistent with the J-band at the 1-sigma level.

(Miles-Páez et al. 2013)

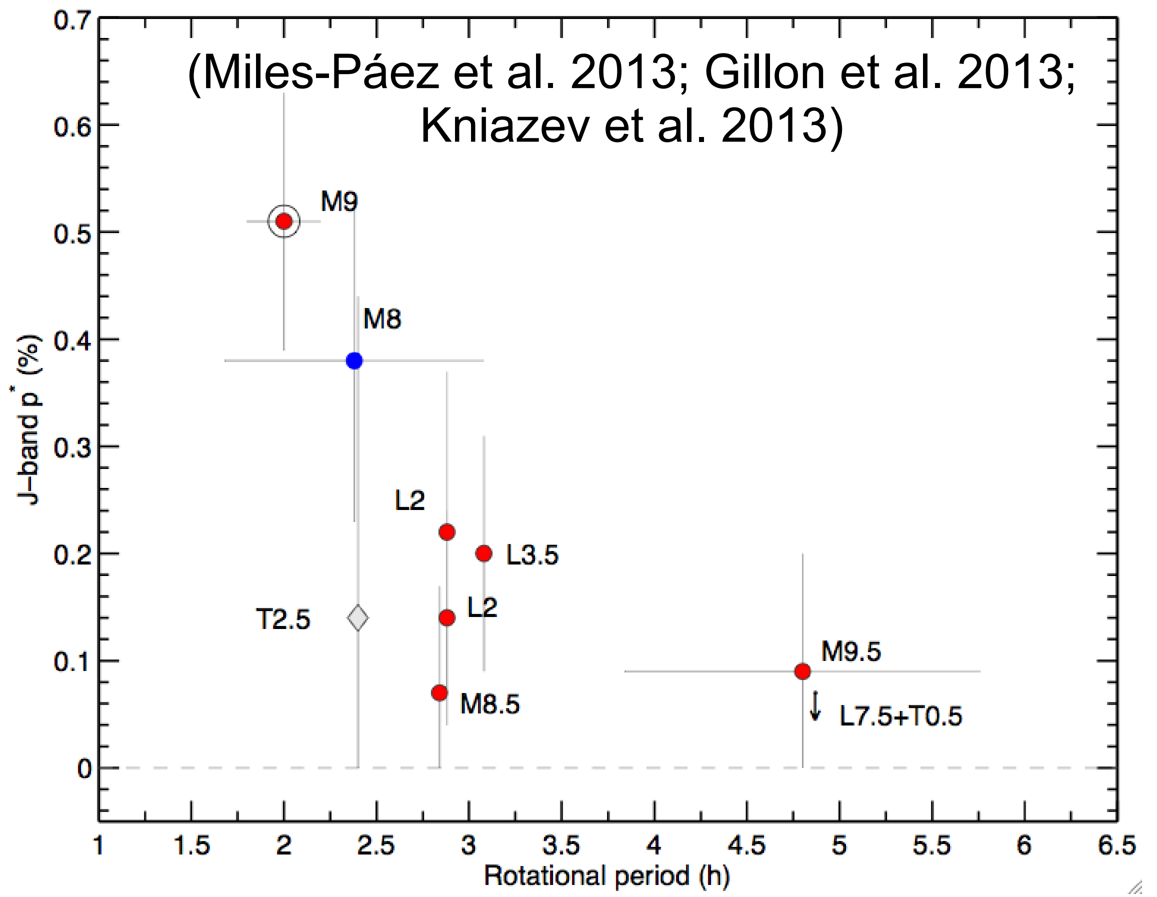


Rapidly rotating ultracool dwarfs

The inclination angle of the rotation axis introduces an ambiguity in our study. Solid results would be obtained by plotting p* as a function of true rotational velocity.



(Marley & Sengupta 2011)



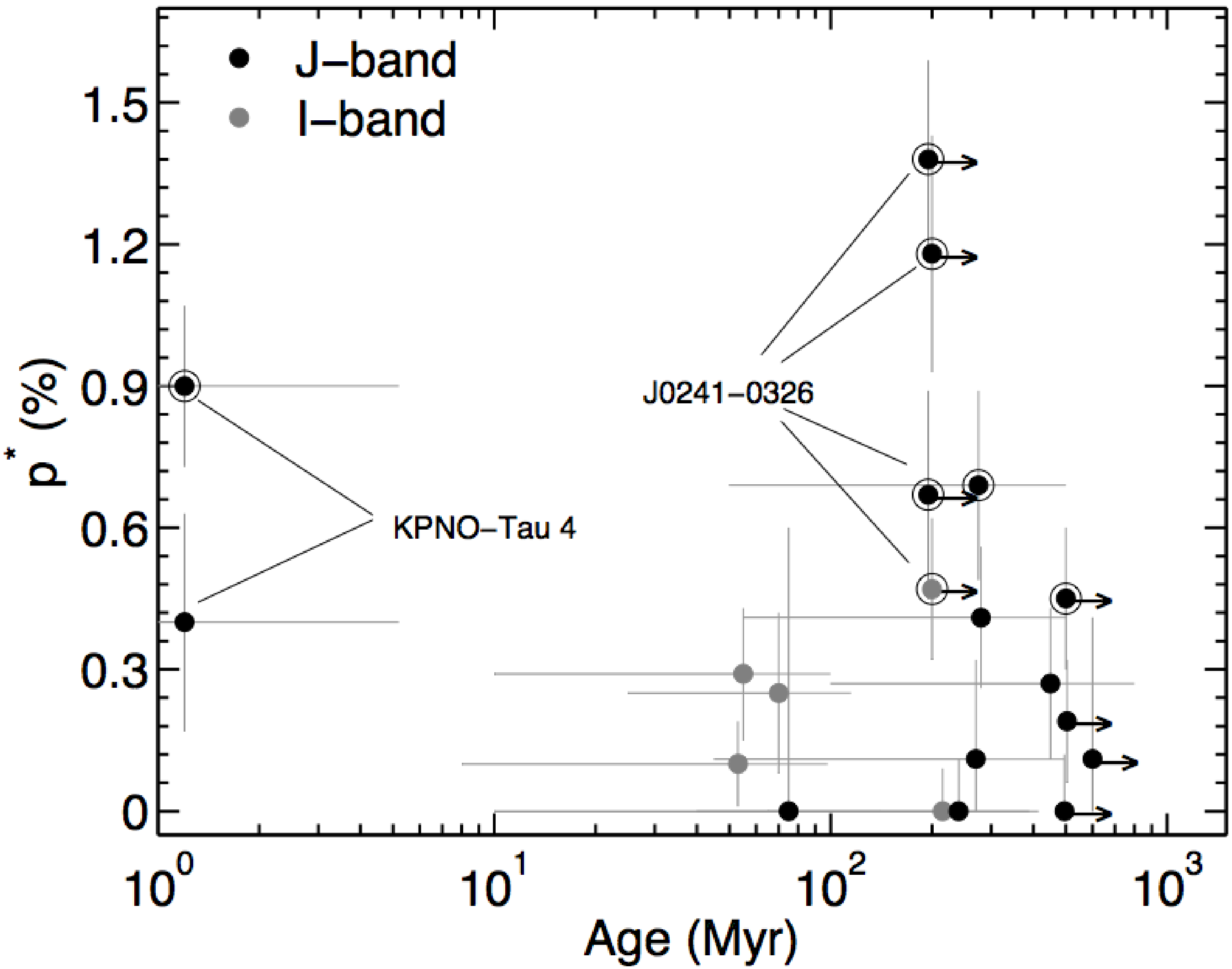
Observations qualitatively agree with models of dust scattering processes. Ultracool dwarfs with ages > 0.5 Gyr have a similar size around 1 R_{Jup}.

Young ultracool field dwarfs

I- and *J*-band values of p* are similar to the values found for older ultracool dwarfs.

Very young stars with (protoplanetary) disks typically have p* > 1-2%.

Our measurements indicate smaller degrees of polarization, thus statistically rejecting the hypothesis of protoplanetary disks.

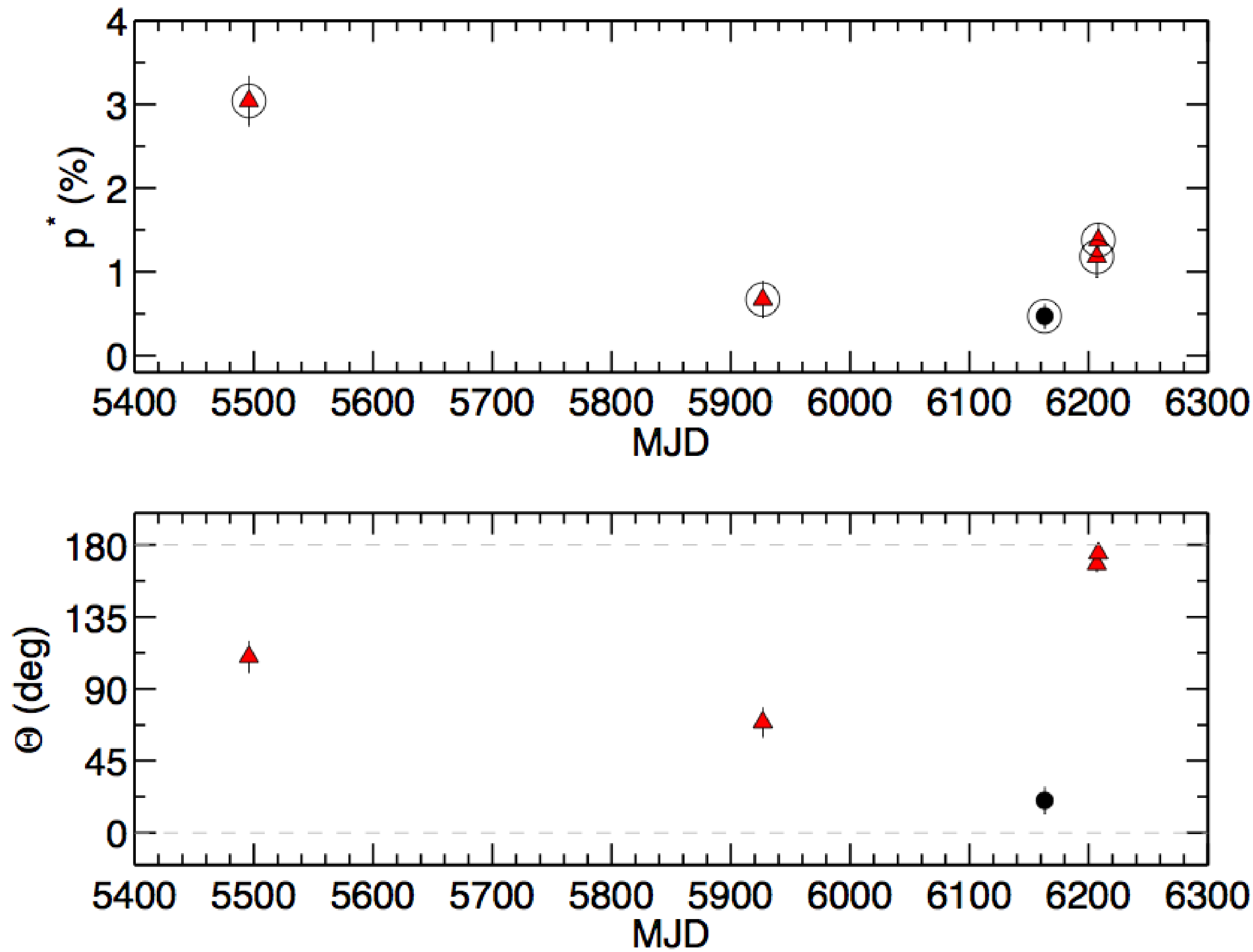


(Miles-Páez et al. 2013, in prep.)

Linear polarization can be used as a tool to monitor 'weather' in ultracool dwarfs

The existence of high rotation, convective motions and dust clouds can give rise to intrincated atmospheric dynamics

Linear polarization can be a tool to monitor the evolution of atmospheric dusty clouds.



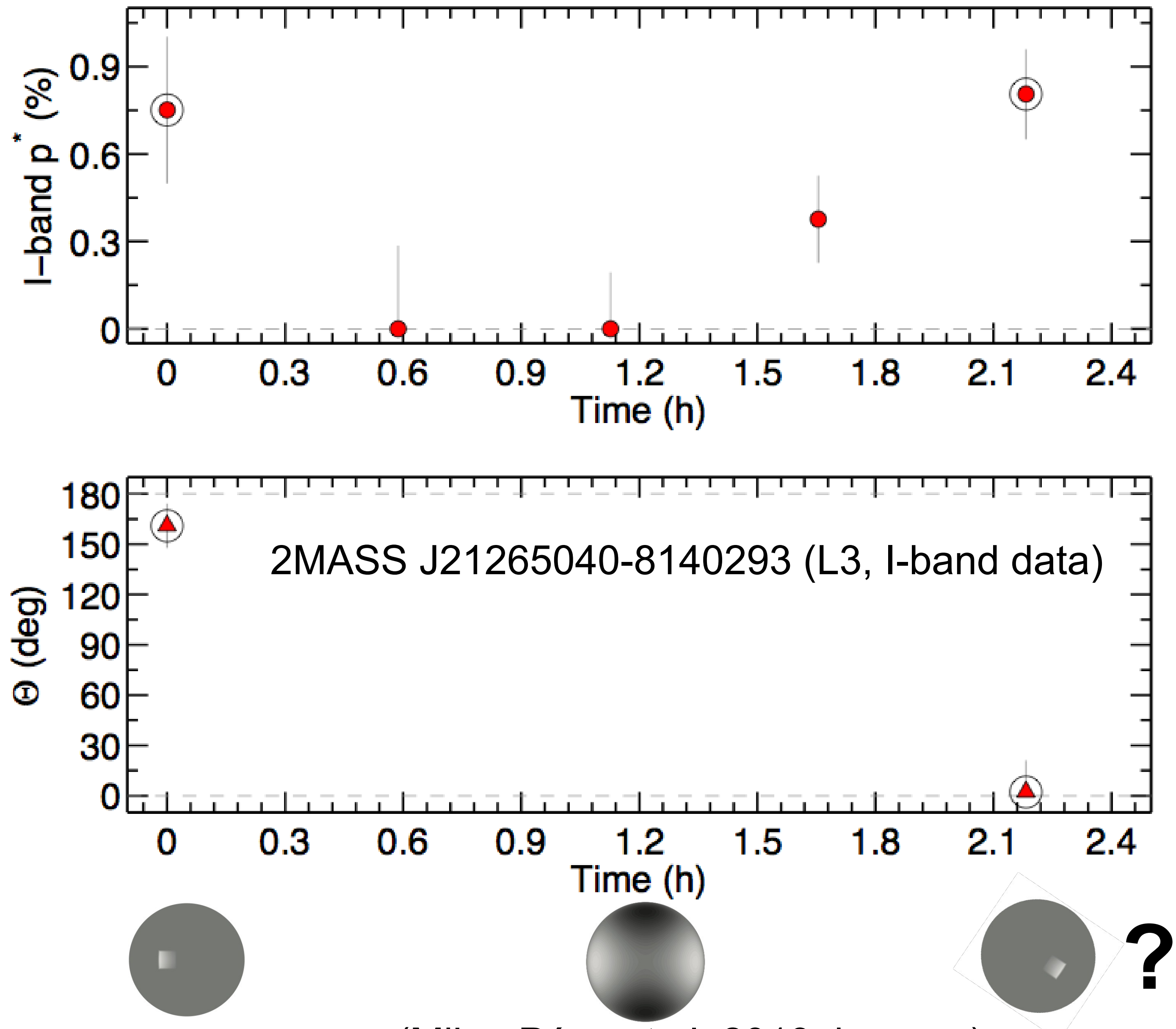
2MASS J02411151-0326587 (L0, J-band data)

(Miles-Páez et al. 2013, in prep.)

Linear polarization can be used as a tool to monitor 'weather' in ultracool dwarfs

Periodic and non-periodic photometric variability has been reported for M-, L- and T-dwarfs in the literature (Bailer-Jones & Mundt 2001, Martin et al. 2001, Koen 2004, Buenzli et al. 2012)

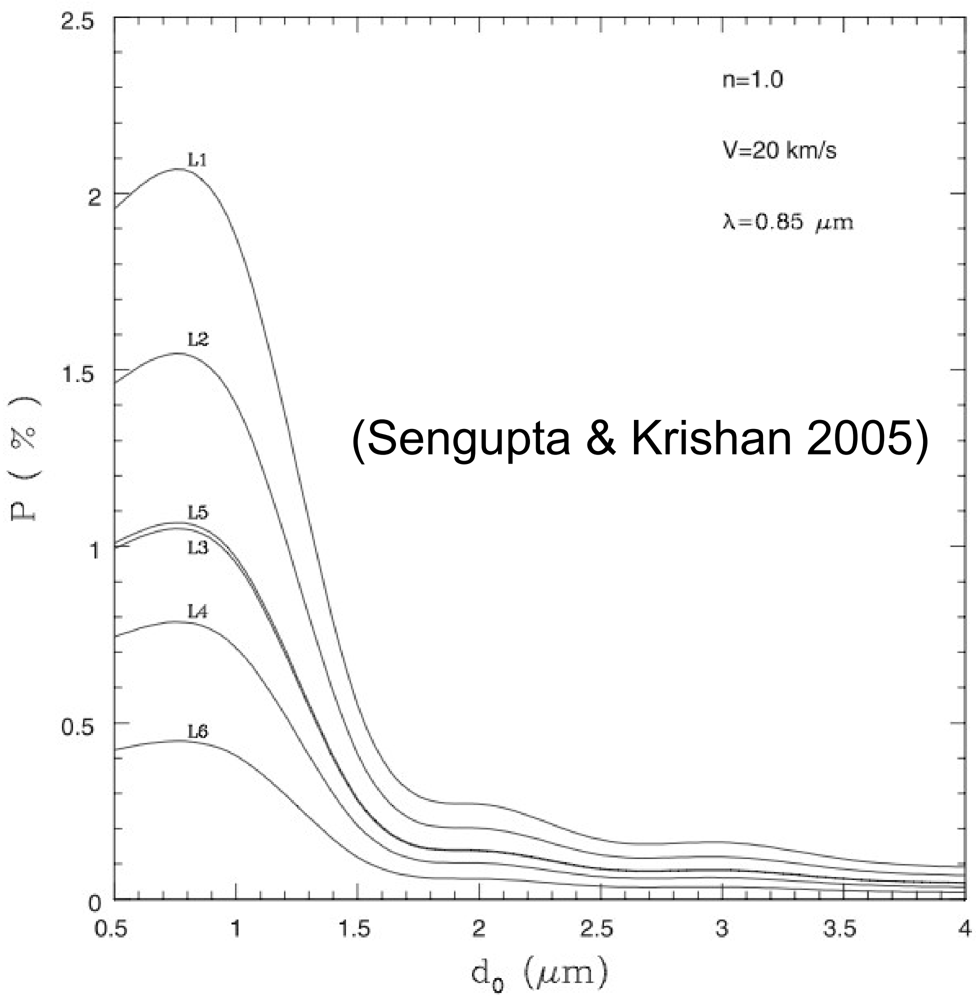
Given our polarimetric uncertainties, our data are sensitive to variations of >=0.3% in linear polarization.



(Miles-Páez et al. 2013, in prep.)

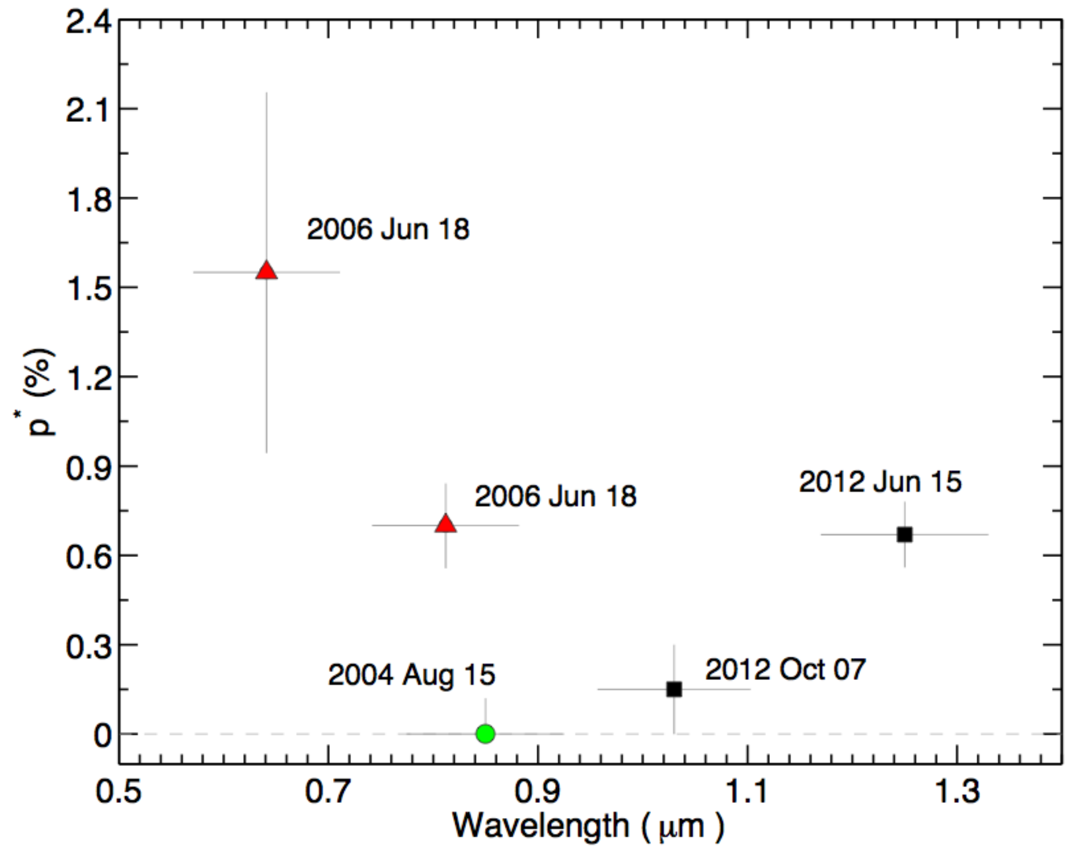
Linear polarization can be used as a tool to monitor 'weather' in ultracool dwarfs

Simultaneous multiwalength measurements can help to constrain grain size



(Sengupta & Krishan 2005)

2MASS J18071593+5015316 (L1.5)



(Zapatero Osorio et al. 2005; Tata et al. 2009; Miles-Páez et al. 2013.)

Summary

- For M7-L4 dwarfs we measure J-band linear polarization degrees between 0.4% and 1.5% with a confidence of ≥ 3σ.

- The fraction of linearly polarized dwarfs is larger among the fastest rotators than among moderate-rotating dwarfs.

- For the sample of moderately young field dwarfs, our polarization measurements are consistent with the presence of atmospheric dust, and statistically they do not confirm surrounding disks.

- We find short-scale time variability in linear polarization consistent with rotation. We also find large-scale time variability over hundreds of rotation cycles indicative of climatoloty.

Thanks!