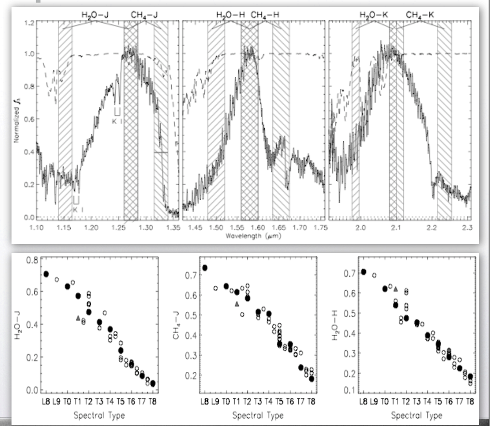
Observational properties of brown dwarfs

T dwarf sequence definition

- Based on IR spectroscopy
- Geballe et al. (2002) superseded by Burgasser et al. (2006)



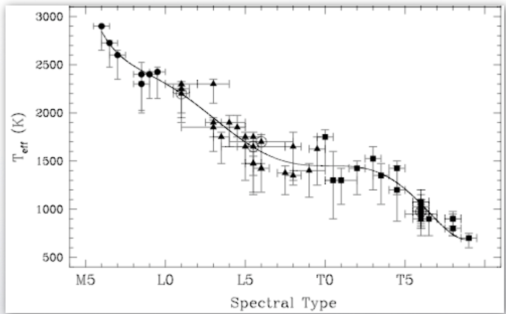
Burgasser et al. (2006)

The L/T transition puzzle

Remember Stefan's law:

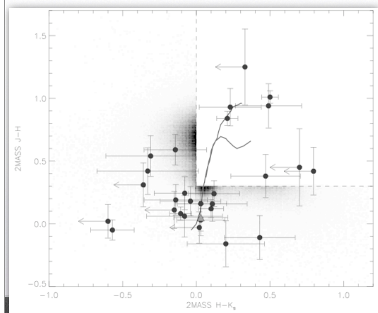
$$L = 4\pi R_{BD}^2 . \sigma . T_{eff}^4$$

- radius (model)
- L_{bol}:
  - larger λ coverage
  - distance (parallax)

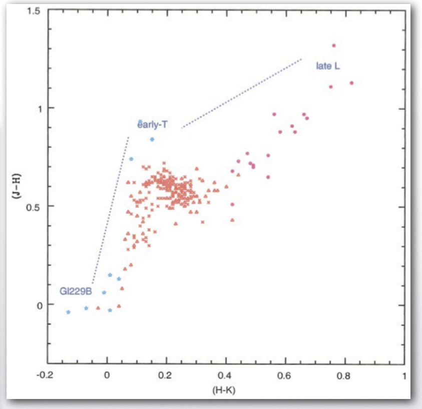


Golimowski et al. (2004)

The elusive early Ts



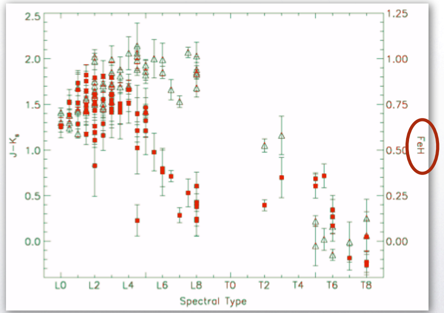
Burgasser et al. (2003)



Reid (2000)

The cloud breaking hypothesis

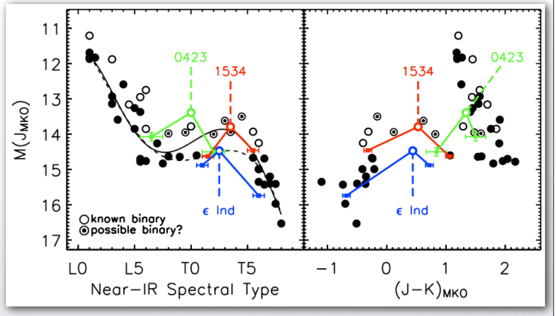
- Re-appearance of FeH for later spectral types, as BDs get bluer
  - ⇒ Indication that a deeper, warmer region is probed?



Burgasser et al. (2002)

The binary explanation

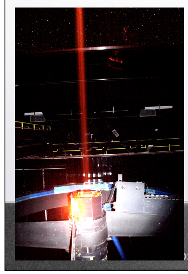
Are most transition objects binaries?
would solve the problem of the atmospheric metamorphosis at constant-temperature



Liu et al. (2006)

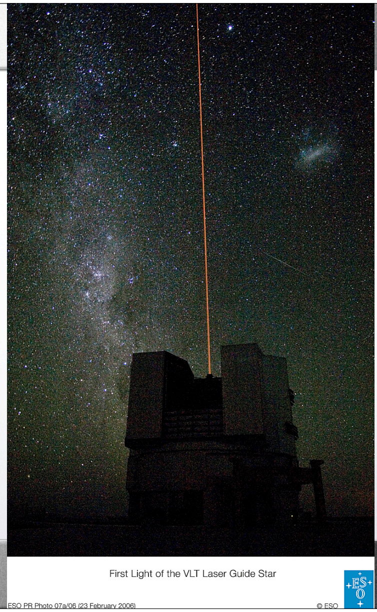
Technical mean: laser guide star

- New method to correct (in real time) atmospheric distortion with a laser guide "star"



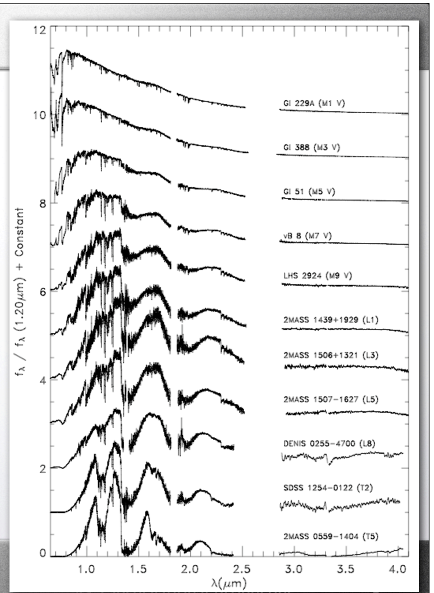
ESO–Paranal
Feb 2006

Subaru
Oct 2006

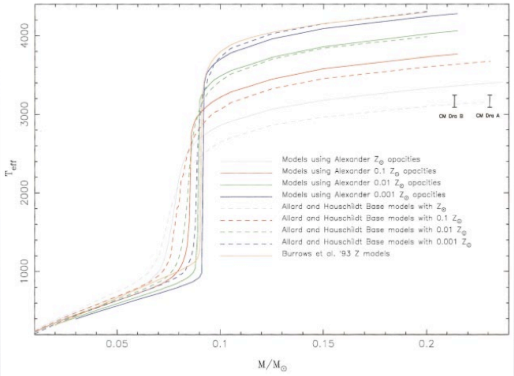


Summary

- Two new spectral classes
  - based on molecular absorption strength not seen in earlier (warmer) classes
  - well accepted schemes
- Problems remain
  - L/T transition
  - relation type–temperature
  - additional parameters:



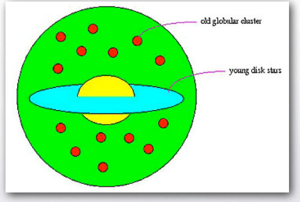
Metallicity



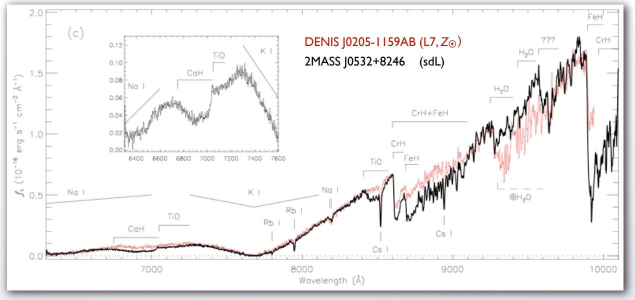
Burrows et al. (2001)

A few words on the Galaxy

- Thin disk:
  - continuous star formation over the past ~8 Gyr
- Thick disk:
  - sequel of a merging event?
  - low metallicity
- Bulge
- Stellar halo (*or* spheroid)
  - very low metallicity
- Dark halo (*or* halo)
  - unknown nature

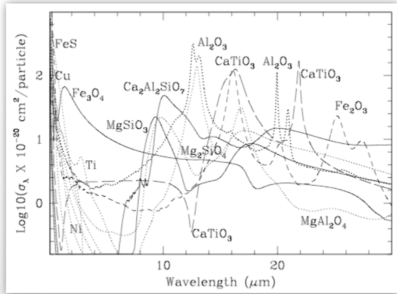


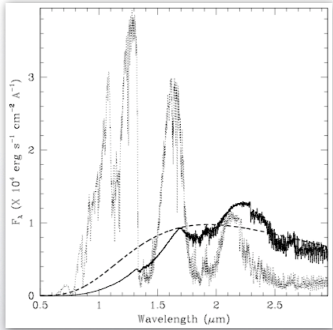
Metallicity spectral effects



Burgasser et al. (2003)

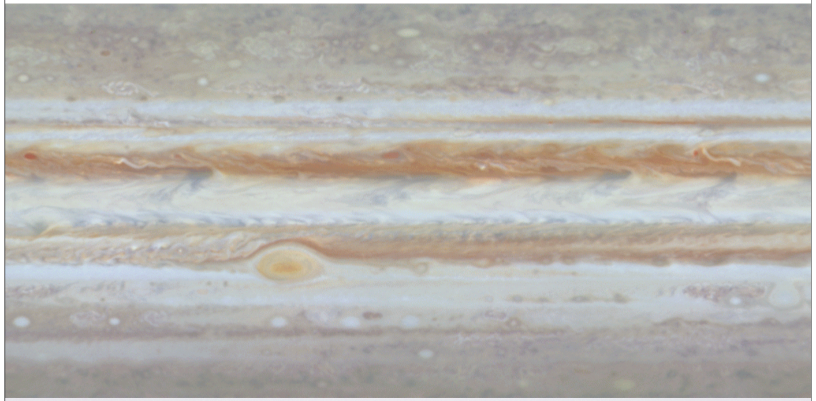
The role of dust



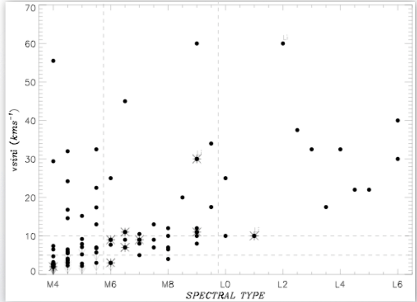


Allard et al. (2001)

Variability



Rotational velocity

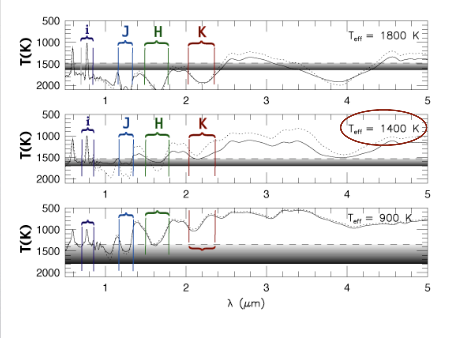


Mohanty & Basri (2003)

Atmospheric model predictions

- Models predict the temperature of where photons come from (temp. brightness profile)
- Multi-λ observations may constrain cloud location

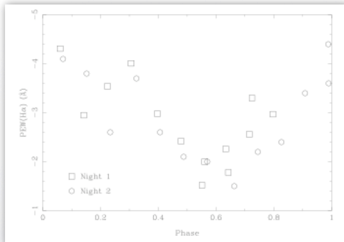
dotted lines: clear
solid lines: cloudy



Ackerman & Marley (2001)

Some results

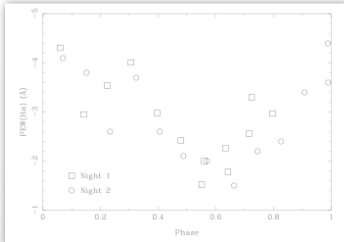
Kelu 1 (L3)



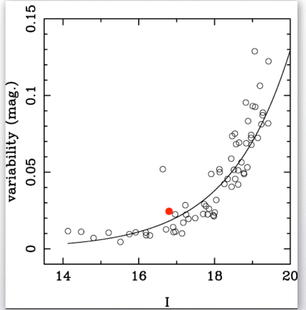
Clarke et al. (2003)

Some results

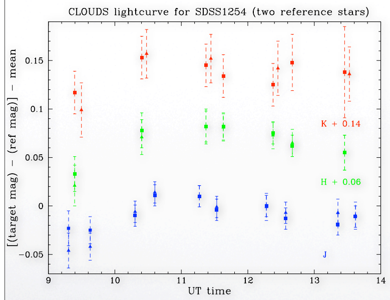
Kelu 1 (L3)



Clarke et al. (2003)



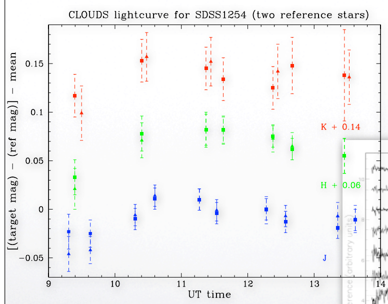
More results



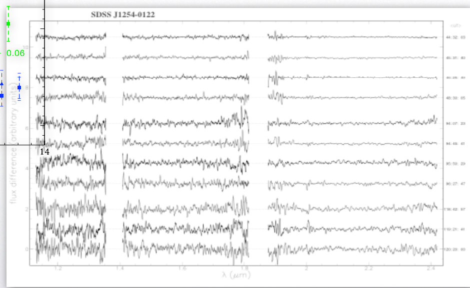
SDSS J1254–0122 (T2)

Goldman et al. (2003) Goldman et al. (submitted)

More results



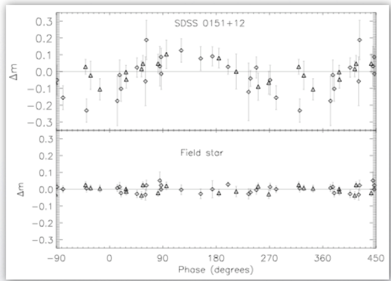
SDSS J1254–0122 (T2)



Goldman et al. (2003) Goldman et al. (submitted)

Some more results

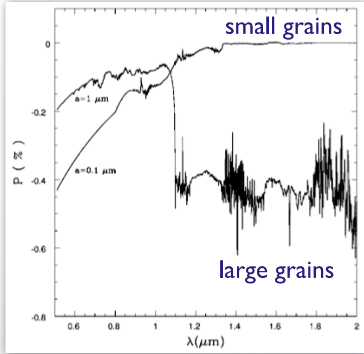
SDSS J0151+1244 (T1)



Enoch et al. (2003)

Polarimetry–expectations

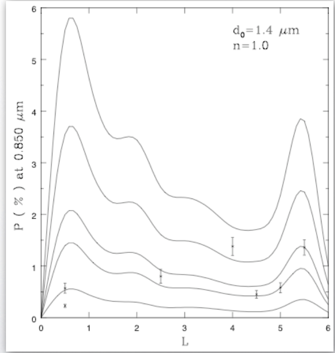
- Dust in the photosphere
  - produces scattering
- Non-spherical:
  Relation eccentricity e–angular velocity ω:
  - uniform density ρ
  - uniform rotation
  - Chandrasekhar (1933)



Sengupta & Krishan (2001)

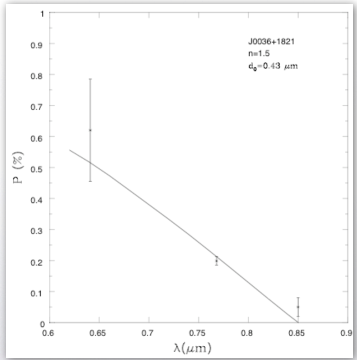
Polarimetry–expectations

- A lot of assumptions:
  - rotational velocities
  - density profile
  - cloud location
  - particle size distribution
  - single/multiple scattering



Sengupta et al. (2005)

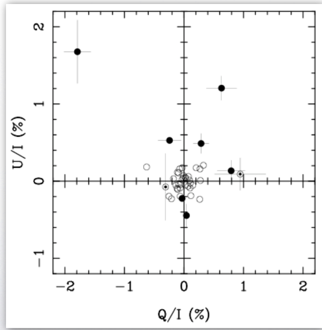
Polarimetry–example

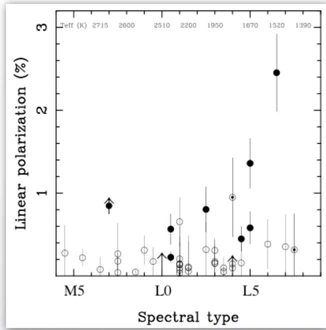


2MASS J0036+1821 (L3.5)

Sengupta et al. (2005)

Polarimetry–results





Zapatero Osorio et al. (2005)

Next lecture

- ARI, Monday, November 6th, 15:15 by Thomas Henning
- Internal structure:
  - core gas degeneracy
  - energy transport
  - evolution
- Readings:
  - *New light on dark stars:* §3
  - Chabrier & Baraffe, 2000, ARA&A, **38** 337
  - Burrows et al, 2001, Rev.Mod.Phys. **73** 719 (§§I–IV)