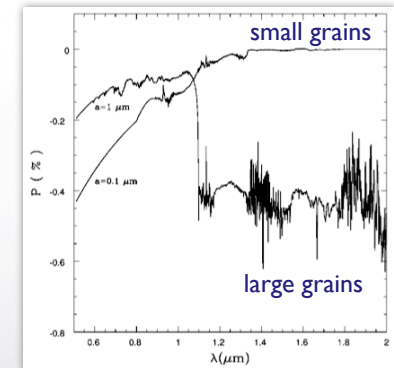


Observational properties of brown dwarfs (end)

Navigation icons: Home, Back, Forward

Polarimetry—expectations

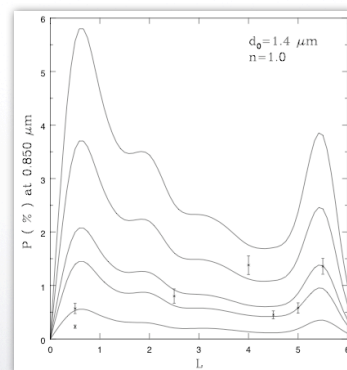
- Dust in the photosphere
 - produces scattering
- Non-spherical:
 - Relation eccentricity e —angular velocity ω :
 - uniform density ρ
 - uniform rotation
 - Chandrasekhar (1933)



Sengupta & Krishan (2001)

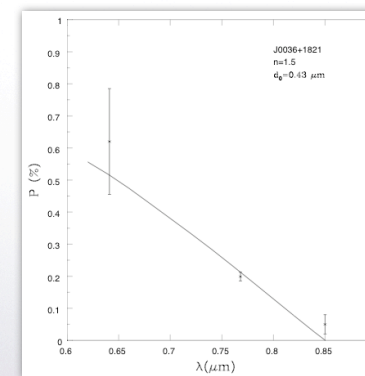
Polarimetry—expectations

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



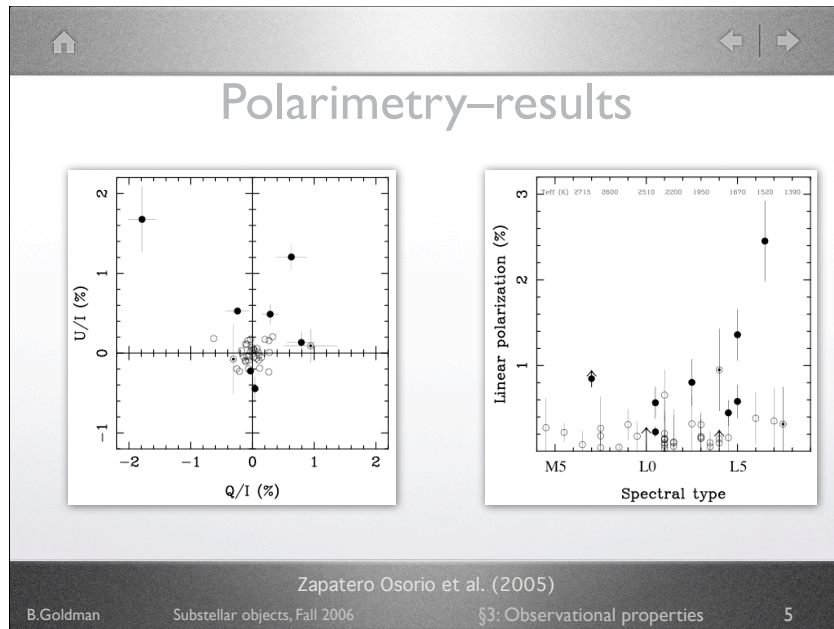
Sengupta et al. (2005)

Polarimetry—example



2MASS J0036+1821 (L3.5)

Sengupta et al. (2005)



How to search for brown dwarfs

- ## Methods
- **Wide-field surveys:**
 - colour selection
 - proper motion selection
 - **Brown dwarfs as companions to nearby stars (and brown dwarfs)**
 - Imaging
 - Doppler shift and astrometric wobbling
 - **Microlensing (gravitational effects)**
- B.Goldman Substellar objects, Fall 2006 §5: Search for brown dwarfs 7

Colour searches for nearby BDs

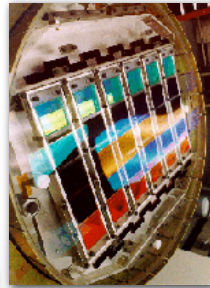
- **Near IR:**
 - 2MASS
 - DENIS
- **Optical:**
 - SDSS
 - POSS

The Infrared Milky Way: This map of the infrared sky includes the light of a half billion stars.
© 2MASS/Showcase
This picture is the property of the Massachusetts Institute of Technology. All rights reserved. Image courtesy of the 2MASS team.

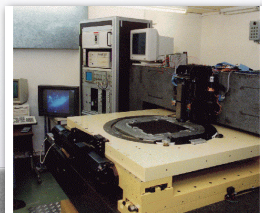
B.Goldman Substellar objects, Fall 2006 §5: Search for brown dwarfs 8

Technical advances

- Larger detectors
 - SDSS: 142 Mpixel CCD mosaic
 - larger IR arrays
- Simultaneous observations through dichroic beam splitter
 - 2MASS, DENIS
- Schmidt plate scanners



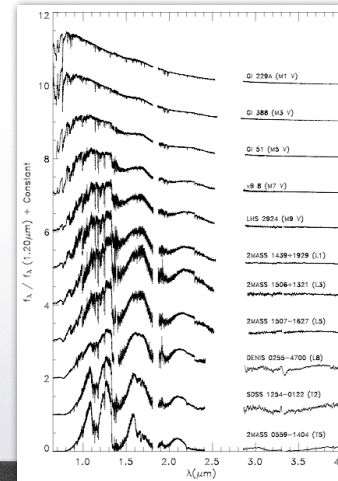
SDSS camera



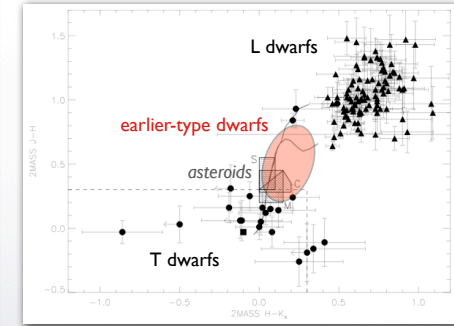
MAMA, Paris

Colour searches

Near infrared (2MASS)



Cushing et al. (2005)

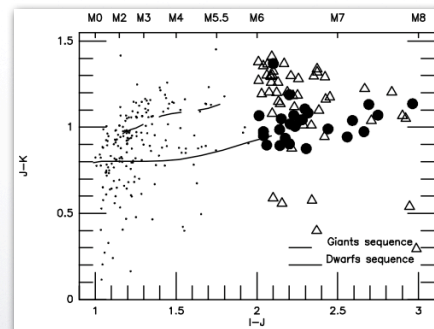


Burgasser et al. (2002)

Colour searches

Optical/near infrared (DENIS)

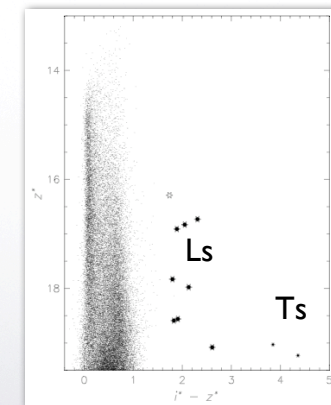
- Very red colours
- Needs to identify giants



Phan-Bao et al. (2002)

Colour searches

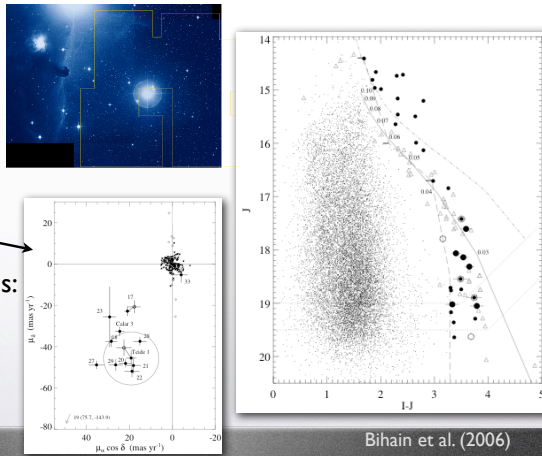
Optical (SDSS)



Fan et al. (2000)

The case of young clusters

- Example: Pleiades
- Search for young M, L dwarfs
- [Proper motion confirmation]
- Deeper observations:
 - ➔ more extragal. contamination



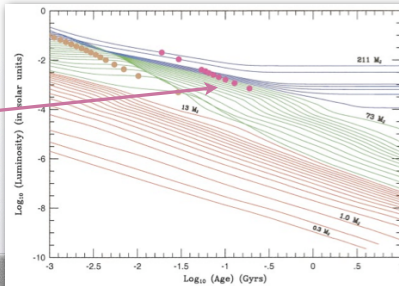
Bihain et al. (2006)

Issues: contamination

- Survey dependent:
 - simultaneous vs. multi-epoch observations
 - single-band detections
- Astrophysical contaminants:
 - very red extragalactic objects (EROs, QSOs)
 - cool giant stars
 - asteroids
- Artefacts:
 - bright star illumination
 - detector (bad pixels, memory effects,...)
 - cosmic rays

Confirmation

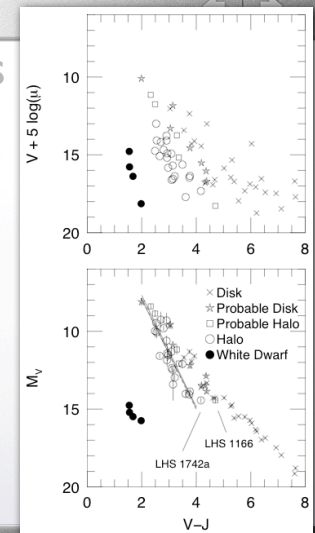
- Photometry:
 - second epoch observations
 - methane band imaging for T dwarfs
- Spectroscopy (low resolution):
 - spectral classification
 - effective temperature (through atmospheric models)
 - Lithium test (for old objects)



Burrows et al. (2001)

Proper motion surveys

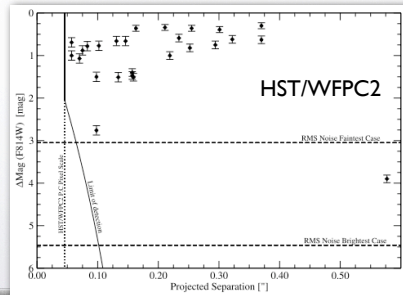
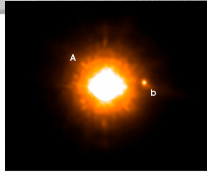
- Identify high angular velocity objects:
 - nearby, and/or
 - have high transverse velocity (thick disk, halo)
- Requires 2+ epochs
 - additional contamination: mismatches, galaxies (faint end)
 - second life of photographic plate surveys



Gould (2003)

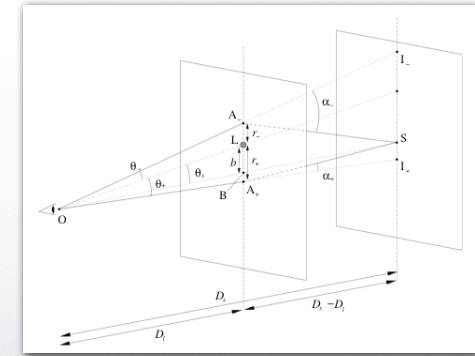
Companions

- Observe nearby stars at high angular resolution
- HST/Adaptive optics
- distance and age known from primary
- Also: radial velocity search for close binaries; astrometric monitoring; spectroscopic binaries; infrared excess

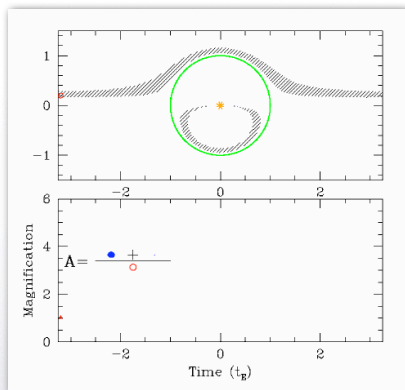


Bouy et al. (2003)

Microlensing



Microlensing



Gaudi: <http://cfa-www.harvard.edu/~sgaudi/movies.html>

Announcements:

Astronomisches Kolloquium

Gilles Chabrier (CRA Lyon)

Birth and Evolution of Protostars, Brown Dwarfs and Giant (Exo-)Planets

Tomorrow, 17:15 Uhr, im Grossen Physik-Hoersaal
Physikalisches Institut, Philosophenweg 12

The Hebrew University of Jerusalem
The Institute for Advanced Studies

The Victor Rothschild Memorial Symposium

The 24th Jerusalem Winter School in Theoretical Physics
General Director: David Gross

**The Lives of Low-Mass Stars
and Their Planetary Systems**

Directors: Lars Bildsten & Tsvi Piran
December 27, 2006- January 5, 2007

Lars Bildsten > KITP
Basics of Stellar Structure, Fully Convective Stars and Contraction to the Main Sequence

Adam Burgasser > MIT
Properties and Magnetic Activity of Low-Mass Stars and Brown Dwarfs

Adam Burrows > University of Arizona
Giant Planet Formation and the Atmospheres and Spectra of Extra-Solar Giant Planets

Eugene Chiang > UC-Berkeley
Observation and Theory of Proto-Planetary and Debris Disks Including the Kuiper Belt

Ralf Klessen > Heidelberg
Turbulence and Fragmentation during Low-Mass Star Formation

Ralph Pudritz > McMaster University
Hydromagnetic Outflows and Jets from Low-Mass Stars and Stellar Spin Evolution

Re'em Sari > Caltech
Terrestrial Planet Formation in Disks around Young Stars

Dimitar Sasselov > Harvard
Extra-Solar Planet Observations, Solar Nucleosynthesis and New Searches

Within the last decade, more than 100 planets have been found around nearby stars, revealing worlds quite different than our own and challenging our notions about planet formation. Simultaneous breakthroughs in our knowledge of distant bodies in our own Solar System, the Kuiper belt Objects, and distant studies of the lowest mass stars and brown dwarfs provide probes of the environments conducive to star and planet formation. This diversity arises during the formation of a star and the subsequent accumulation of matter in a protoplanetary disk around it. This school brings together lecturers across the breadth of this scientific endeavor, from the properties of the host stars where planets are formed to the studies of the planets themselves.

Participants: The school is intended for advanced graduate students and postdoctoral researchers from all over the world. Cost: Registration fee \$500. Hotel accommodation fees \$400. Financial support will be granted based on requests made during application. Applications should be made to the web site: www.is.huji.ac.il by November 15, 2006.

B.Goldman Substellar objects, Fall 2006 21

Next lecture

- ARI, Monday, November 20th, 15:15
- Initial mass function(s?) of brown dwarfs (observations):
 - in the field
 - in young clusters
 - in the Dark Halo: brown dwarfs and dark matter
- Readings:
 - *New light on dark stars: §9*
 - Chabrier, 2003 *PASP* **115** 763 (link on the web)

B.Goldman Substellar objects, Fall 2006 §5: Search for brown dwarfs 22