Brown dwarfs in the framework of the Virtual Observatory

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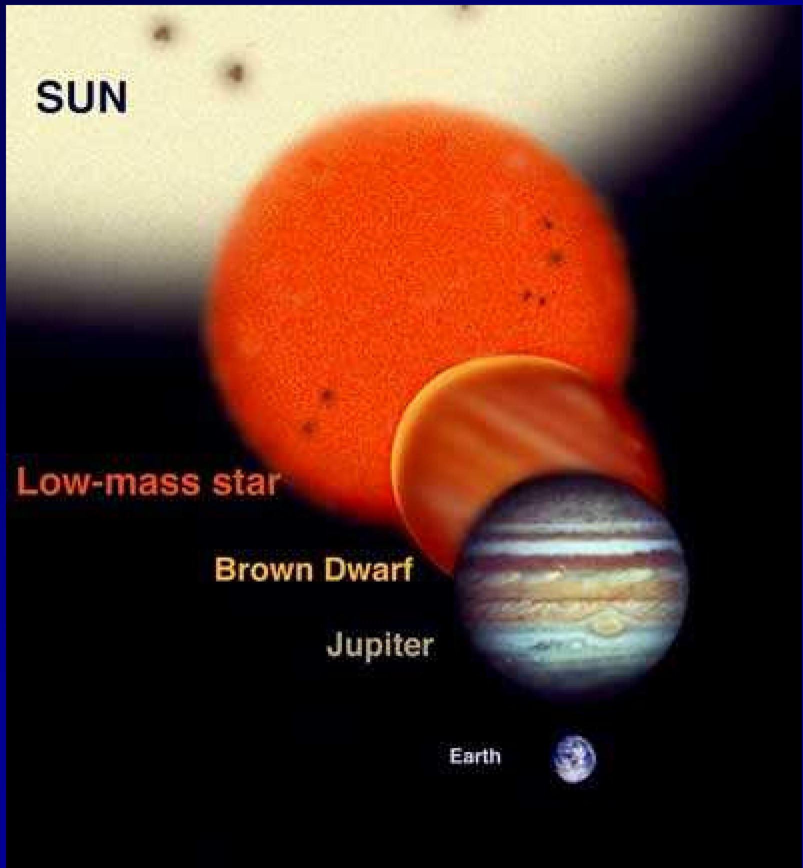
- Discovery of BDs
- Testing the BD formation theories

Brown dwarfs

➢ Represent a class of objects linking the properties of observable low-mass stars and BD with the properties of unobservable extrasolar-planets.



Discovery of brown dwarfs using 2MASS, DENIS & SDSS

What is the goal of the project?

- Is it to discover new objects?

NO (for the moment).

- Brown Dwarfs exist since more than 10 years ago.

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letters to nature

Nature **378**, 463 - 465 (30 November 1995); doi:10.1038/378463a0

Discovery of a cool brown dwarf

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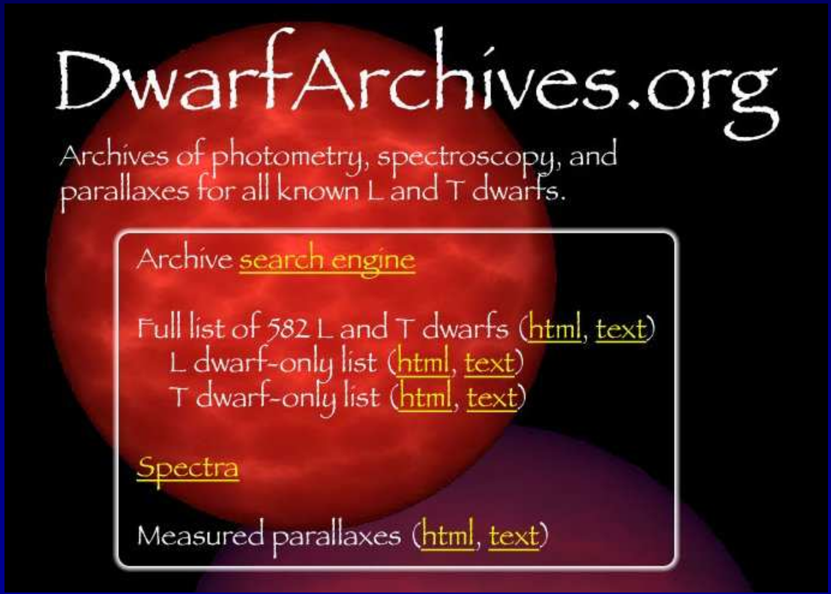
BROWN dwarfs are starlike objects with masses less than 0.08 times that of the Sun, which are unable to sustain hydrogen fusion in their interiors[1–4]. They are very hard to detect, as most of the energy of gravitational contraction is radiated away within ~10^8 yr, leaving only a very low residual luminosity. Accordingly, almost all searches for brown dwarfs have been directed towards clusters of young stars—a strategy that has recently proved successful[5,6]. But there are only modest observable differences between young brown dwarfs and very lowmass stars, making it difficult to identify the former without appealing to sophisticated models[7]. Older brown dwarfs should have a more distinctive appearance, and if they are companions to nearby stars, their luminosity can be determined unambiguously. Here we report the discovery of a probable companion to the nearby star G1229, with no more than onetenth the luminosity of the least luminous hydro-gen-burning star. We conclude that the companion, G1229B, is a brown dwarf with a temperature of less than 1,200 K, and a mass ~20–50 times that of Jupiter.

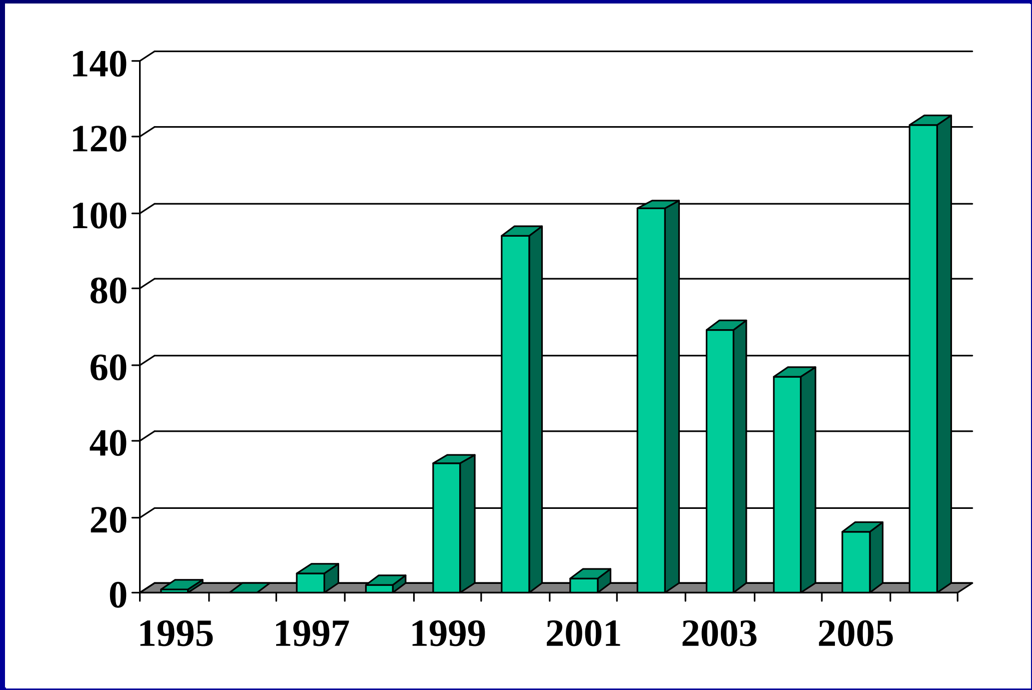
What is the goal of this project? (II)

- Are brown dwarfs very, very rare?

NO (I would simply say "rare").

- There are almost 600 already catalogued.

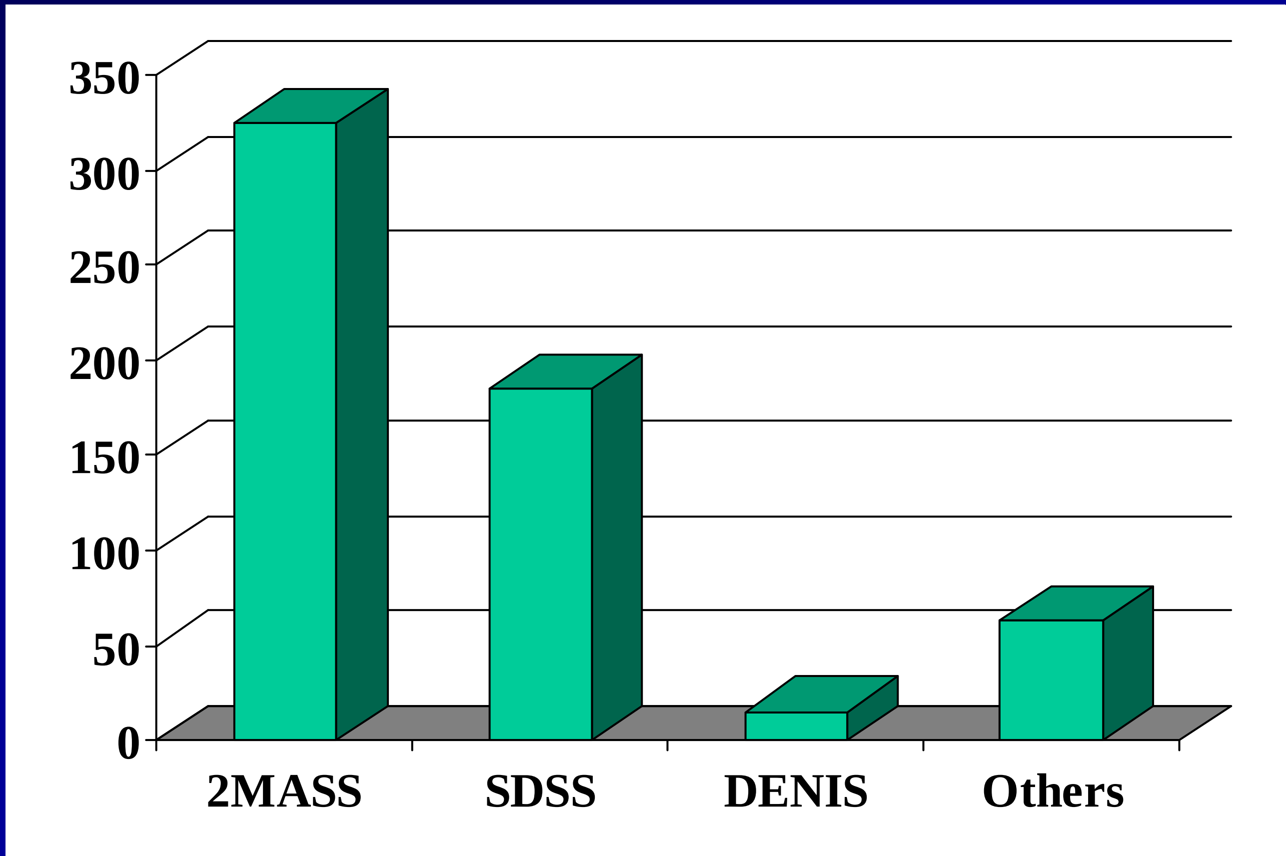




What is the goal of this project? (III)

- Are new datasets being used?

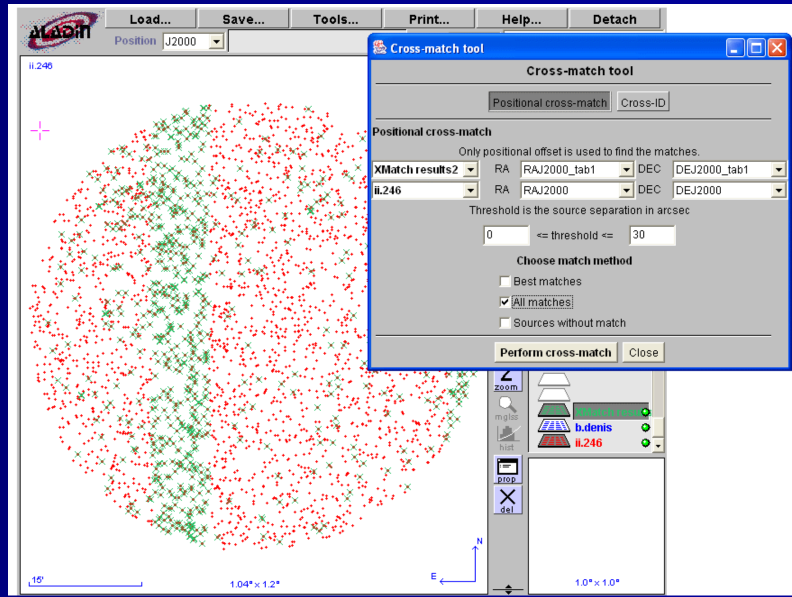
NO (for the moment).



What is the goal of this project? (IV)

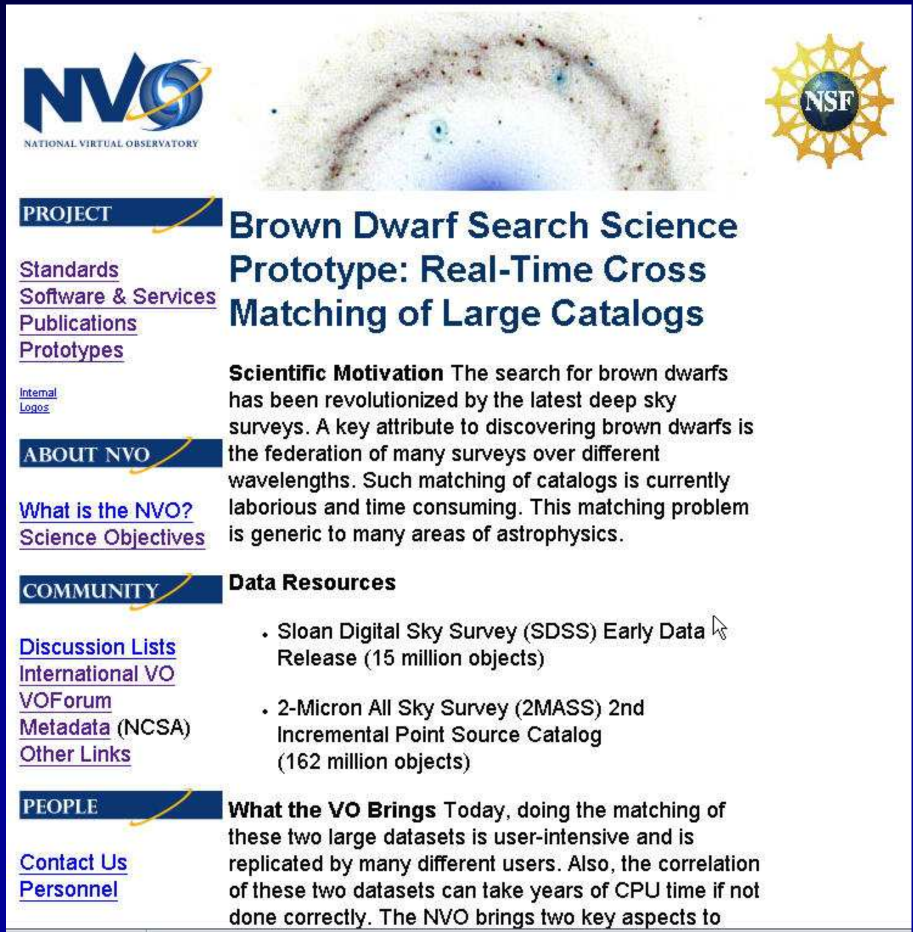
- So, what is new?

The VO!!! We plan to apply, for the first time a systematic mining using a Virtual Observatory methodology.



- The Virtual Observatory allows
  - ✓ Joining large data sets ("Interoperability").
  - ✓ Using tools to facilitate the efficient analysis of the contents ("Data Mining").

VO already successfully used to discover a L-type BD



PROJECT

Standards
Software & Services
Publications
Prototypes

Internal Logos

ABOUT NVO

What is the NVO?
Science Objectives

COMMUNITY

Discussion Lists
International VO
VOForum
Metadata (NCSA)
Other Links

PEOPLE

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Brown Dwarf Search Science Prototype: Real-Time Cross Matching of Large Catalogs

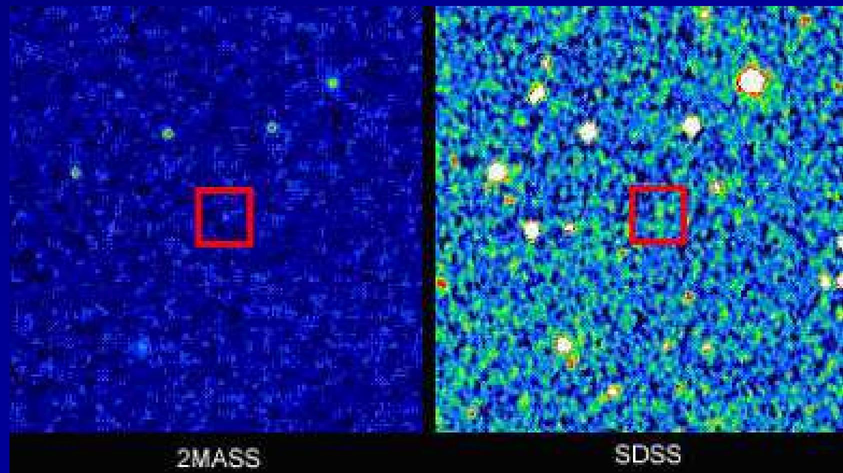
Scientific Motivation The search for brown dwarfs has been revolutionized by the latest deep sky surveys. A key attribute to discovering brown dwarfs is the federation of many surveys over different wavelengths. Such matching of catalogs is currently laborious and time consuming. This matching problem is generic to many areas of astrophysics.

Data Resources

- Sloan Digital Sky Survey (SDSS) Early Data Release (15 million objects)
- 2-Micron All Sky Survey (2MASS) 2nd Incremental Point Source Catalog (162 million objects)

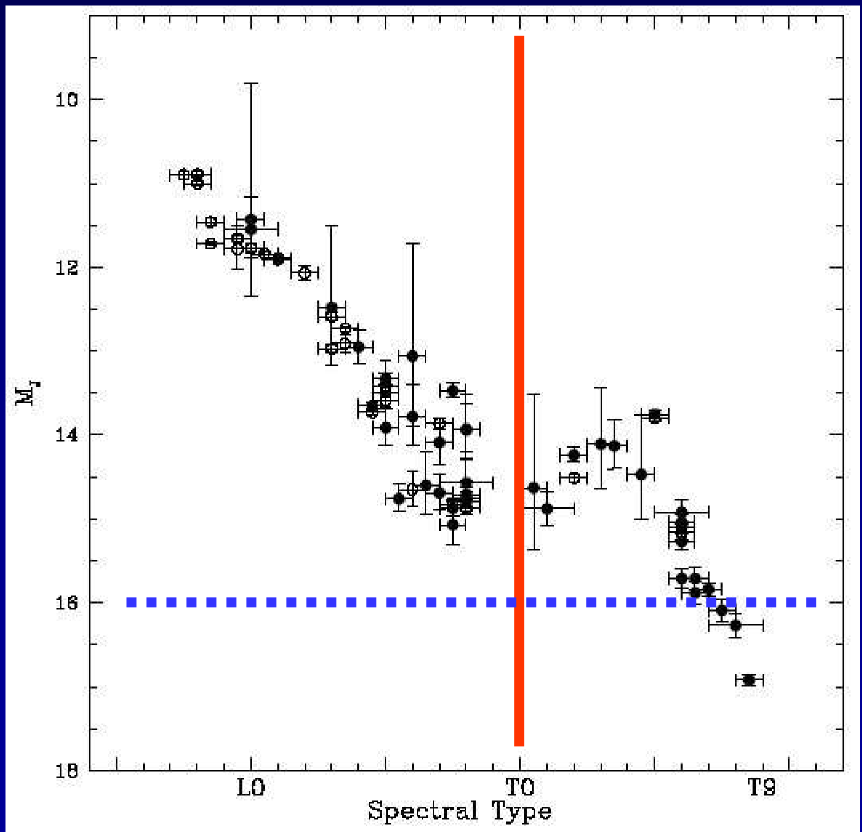
What the VO Brings Today, doing the matching of these two large datasets is user-intensive and is replicated by many different users. Also, the correlation of these two datasets can take years of CPU time if not done correctly. The NVO brings two key aspects to

- **Filtering criteria:** z & J-only detections with *z- J > 2.75*
- *SDSS: 15M obj.*
- *2MASS: 160M obj.*
- *300000 objects in common.*



One more time: What is the goal of this project?

- Final objective: Characterization of the nearby (< 10 pc) T dwarf population.



(Vrba,2004)

- ✓ 2MASS/J 10σ-limit: 15.8
- ✓ DENIS/J 3σ-limit: 16.5
- ✓ 2 < (z-J) < 4
- ✓ SDSS/z limit: 20.4

→ The nearby T dwarf population can be detected.

But …

➢ 2MASS has been intensively used to look for T dwarfs.

➢ WFTS: Wide-Field T Dwarf Search (Burgasser et al.2003, AJ):

THE 2MASS WIDE-FIELD T DWARF SEARCH. I. DISCOVERY OF A BRIGHT T DWARF WITHIN 10 PC OF THE SUN

Adam J. Burgasser[1,2], J. Davy Kirkpatrick[3], Michael W. McElwain[1], Roc M. Cutri[3], Albert J. Burgasser[4], & Michael F. Skrutskie[5]

Accepted by AJ for February 2003

✓ Searching T dwarfs since 1998 using 2MASS point source catalogue.

Then..., might it happen that there is nothing else in there?

- NO, this is not the case. There are, still, many T dwarfs to be discovered:
  - ✓ Models predict more T dwarfs than those so far identified (Burgasser, 2003)
  - ✓ New search strategies lead to new discoveries (e.g. Artigau et al. 2006)

But then, might it happen that there is nothing else in there?

DRAFT VERSION NOVEMBER 28, 2006
Preprint typeset using LaTeX style emulateapj v. 05/04/06

DISCOVERY OF THE BRIGHTEST T DWARF IN THE NORTHERN HEMISPHERE

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JASMIN ROBERT[1] AND LOÏC ALBERT[3]

Draft version November 28, 2006

ABSTRACT

We report the discovery of a bright ($H = 12.77$) brown dwarf designated SIMP J013656.5+093347. The discovery was made as part of a near-infrared proper motion survey, SIMP (Sondage Infrarouge de Mouvement Propre), which uses proper motion and near-infrared/optical photometry to identify brown dwarf candidates. A low resolution ($\lambda/\Delta\lambda \sim 40$) spectrum of this brown dwarf covering the 0.88-2.35 μm wavelength interval is presented. Analysis of the spectrum indicates a spectral type of T2.5 $\pm$ 0.5. A photometric distance of 6.4 ± 0.3 pc is estimated assuming it is a single object. Current observations rule out a binary of mass ratio $\sim$1 and separation $\gtrsim 5$ AU. SIMP 0136 is the brightest T dwarf in the northern hemisphere and is surpassed only by ε Indi Bab over the whole sky. It is thus an excellent candidate for detailed studies and should become a benchmark object for the early-T spectral class.

Subject headings: Stars: low-mass, brown dwarfs — stars: individual (SIMP J013656.5+093347)

Finding T-dwarfs: IR colors are not enough

- IR colors of early-T and M quite similar
- T dwarf candidates can be buried in an overwhelming number of background sources.

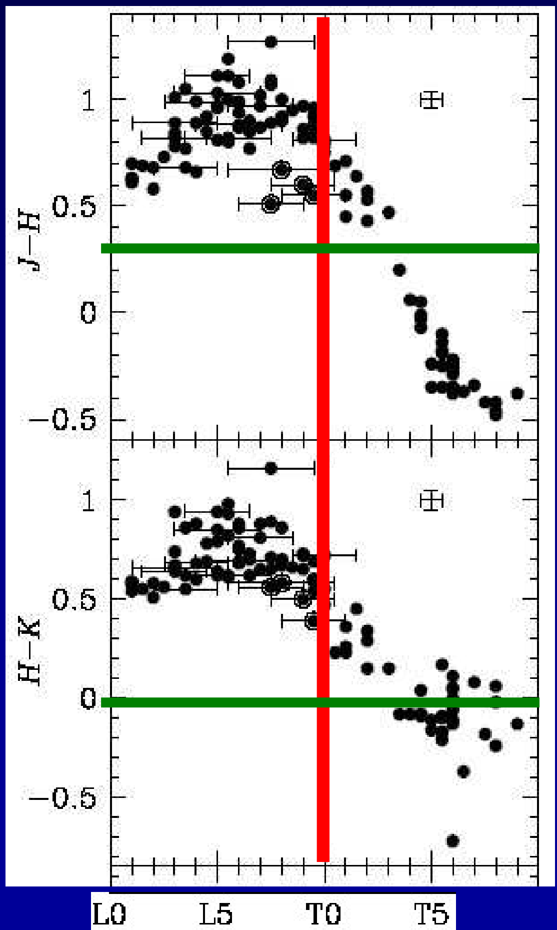


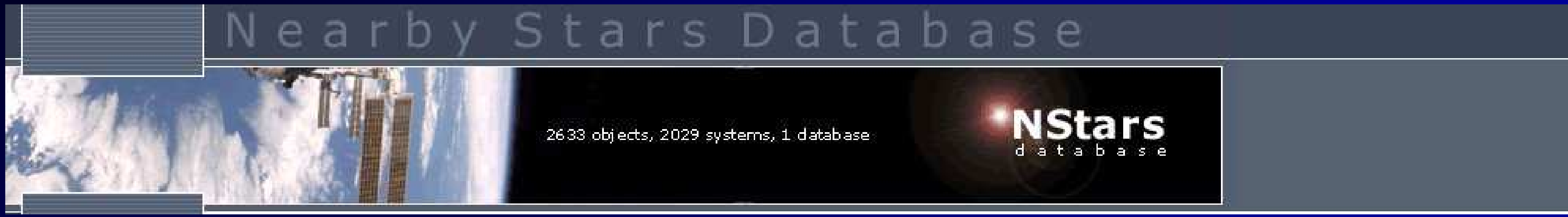
TABLE II

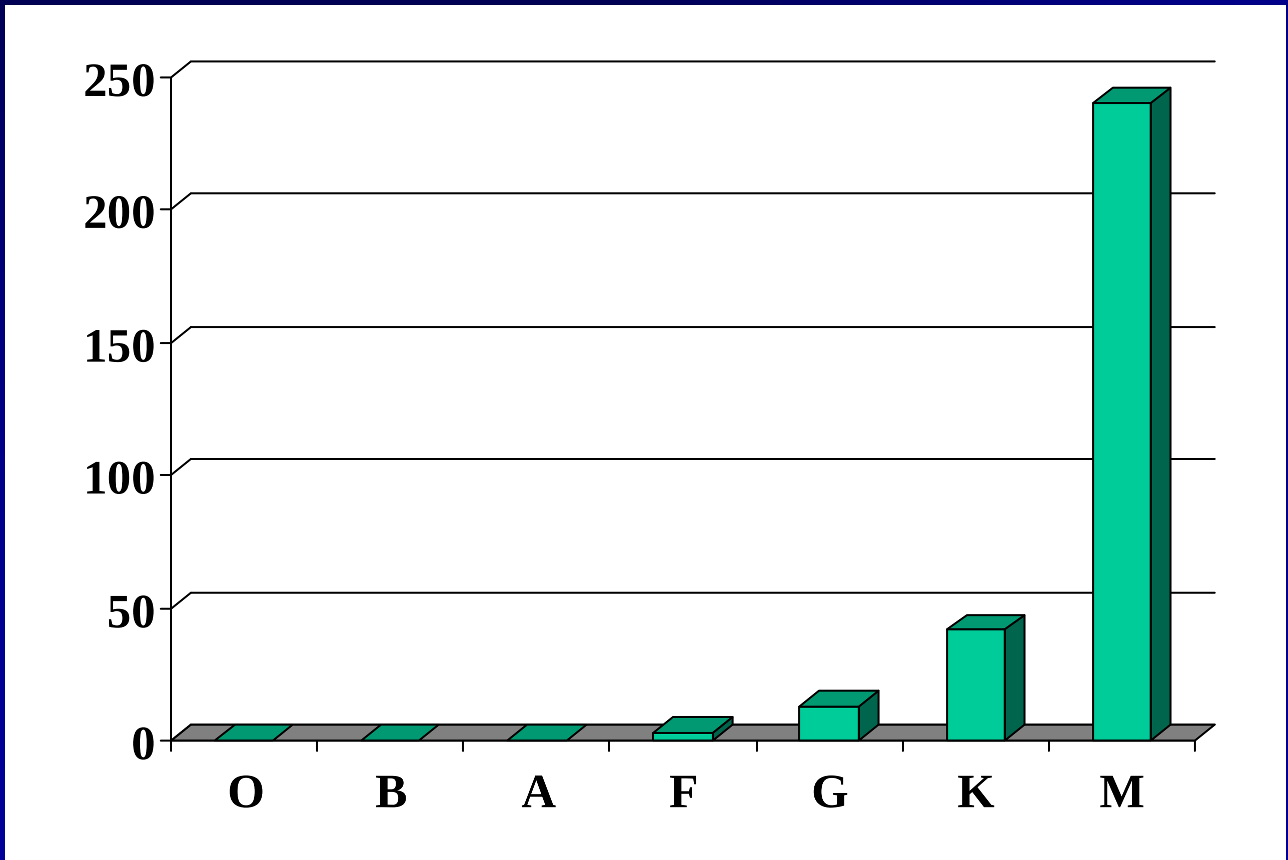
• (J-H)≤0.3 or (H-K) ≤ 0.0

(Burgasser et al. 2003, AJ).

								K-M
								-0.05
A0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A2	0.06	0.14	0.02	0.005	0.02	0.01	0.01	0.01
A5	0.27	0.38	0.06	0.015	0.08	0.02	0.02	0.03
A7	0.24	0.50	0.09	0.025	0.11	0.03	0.03	0.03
F0	0.33	0.70	0.13	0.03	0.16	0.03	0.03	0.03
F2	0.40	0.82	0.165	0.035	0.19	0.03	0.03	0.03
F5	0.53	1.10	0.23	0.04	0.27	0.04	0.04	0.02
F7	0.62	1.32	0.285	0.045	0.34	0.04	0.04	0.02
G0	0.66	1.41	0.305	0.05	0.36	0.05	0.05	0.01
G2	0.68	1.46	0.32	0.052	0.37	0.05	0.05	0.01
G4	0.71	1.53	0.33	0.055	0.385	0.05	0.05	0.01
G6	0.75	1.64	0.37	0.06	0.43	0.05	0.05	0.00
K0	0.88	1.96	0.45	0.075	0.53	0.06	0.06	-0.01
K2	0.98	2.22	0.50	0.09	0.59	0.07	0.07	-0.02
K4	1.15	2.63	0.58	0.105	0.68	0.09	0.10	-0.04
K5	1.22	2.85	0.61	0.11	0.72	0.10	0.11	
K7	1.45	3.16	0.66	0.13	0.79	0.11	0.13	
M0	1.80	3.65	0.695	0.165	0.86	0.14	0.17	
M1	1.96	3.87	0.68	0.20	0.87	0.15	0.21	
M2	2.14	4.11	0.665	0.21	0.87	0.16	0.23	
M3	2.47	4.65	0.62	0.25	0.87	0.20	0.32	
M4	2.86	5.26	0.60	0.275	0.88	0.23	0.37	
M5	3.39	6.12	0.62	0.32	0.94	0.29	0.42	
M6	4.18	7.30	0.66	0.37	1.03	0.36	(0.48)	

Finding T-dwarfs: IR colors are not enough





Stars with known spectral type at less than 10 pc

Motion could help…

- The Workflow:

- Proper motion:
- Photometry consistency:
- Look for optical counterparts

Pros and Cons of this methodology

➢ Pros:

• Both 2MASS and DENIS have an excellent photometric and astrometric accuracy.

➢ Cons:

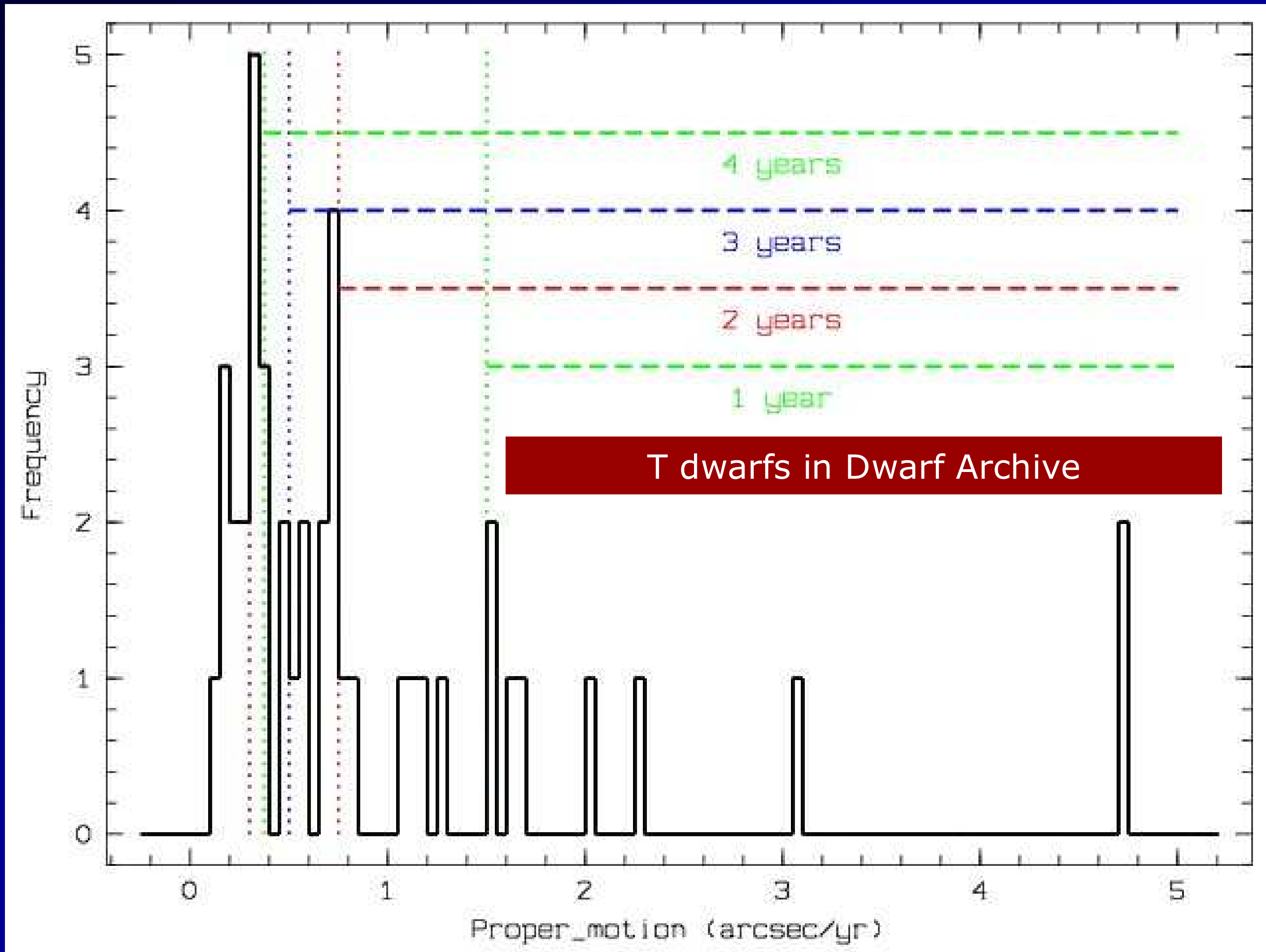
• Both surveys are almost simultaneous in time

➢ 2MASS / North: Jun 1997 – Feb 2001

➢ 2MASS / South: Mar 1998 – Feb 2001

➢ DENIS: Jan 1995 – Sep 2001

Pros and Cons of this methodology



Discovering field BDs with 2MASS/DENIS

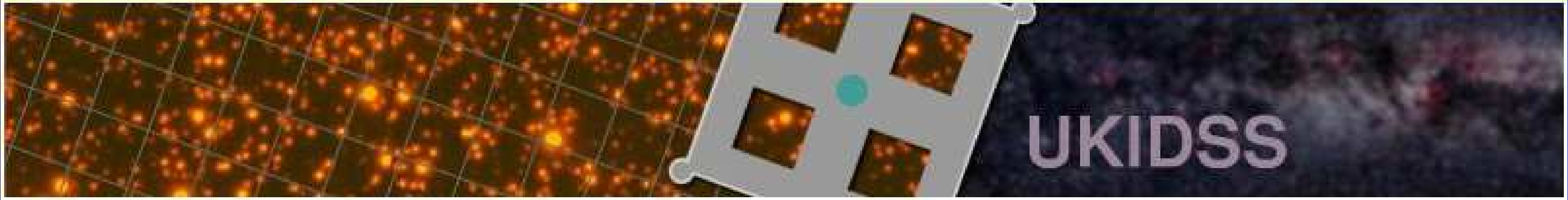
- Region surveyed:
  - ✓ RA: 300° – 360° / DEC: -10° / -34°
  - ✓ RA: 210° – 270° / DEC: -1° / -13°
- *10+8 potential candidates*
- Follow-up (IR imaging) already done. Analysis on-going.

Discovering field BDs with 2MASS/SDSS

- Region surveyed:
  - ✓ RA: 300° – 360° / DEC: 0° – 20°
- *Three potential candidates*, one of them already identified as BD (2004, AJ, 127, 3553)
- Follow-up (IR imaging) foreseen.

Future application of the VO methodology

What's next?



- Surveys
- Science Case
- Technical
- Consortium
- Archive
- Links

Queries, suggestions to:
Steve Warren,
UKIDSS Survey Scientist
+44(0)2075947554

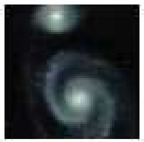
The UKIRT Infrared Deep Sky Survey

UKIDSS is the next generation near-infrared sky survey, the successor to 2MASS. UKIDSS began in May 2005 and will survey 7500 square degrees of the Northern sky, extending over both high and low Galactic latitudes, in JHK to K=18.5. This depth is three magnitudes deeper than 2MASS. UKIDSS will be the true near-infrared counterpart to the Sloan survey, and will produce as well a panoramic clear atlas of the Galactic plane. In fact UKIDSS is made up of five surveys and includes two deep extra-Galactic elements, one covering 35 square degrees to K=21, and the other reaching K=23 over 0.77 square degrees.

The survey instrument is WFCAM on the UK Infrared Telescope (UKIRT) in Hawaii. WFCAM has four 2048x2048 Rockwell devices, at 94% spacing, as illustrated at the top. The pixel scale of 0.4 arcsec gives an exposed solid angle of 0.21 sq. degs.

Four of the principal quarry of UKIDSS are: the coolest and nearest brown dwarfs, high-redshift dusty starburst galaxies, elliptical galaxies and galaxy clusters at redshifts 1<z<2, and the highest-redshift quasars, at z=7. UKIDSS aims to discover the nearest object to the Sun (outside the solar system) as well as some of the farthest known objects in the Universe.

The UKIDSS Consortium is a collection of some 100 astronomers who are responsible for the design and execution of the survey. The data become available to the entire ESO community immediately they are entered into the archive. Release to the world follows 18 months after each release to ESO.



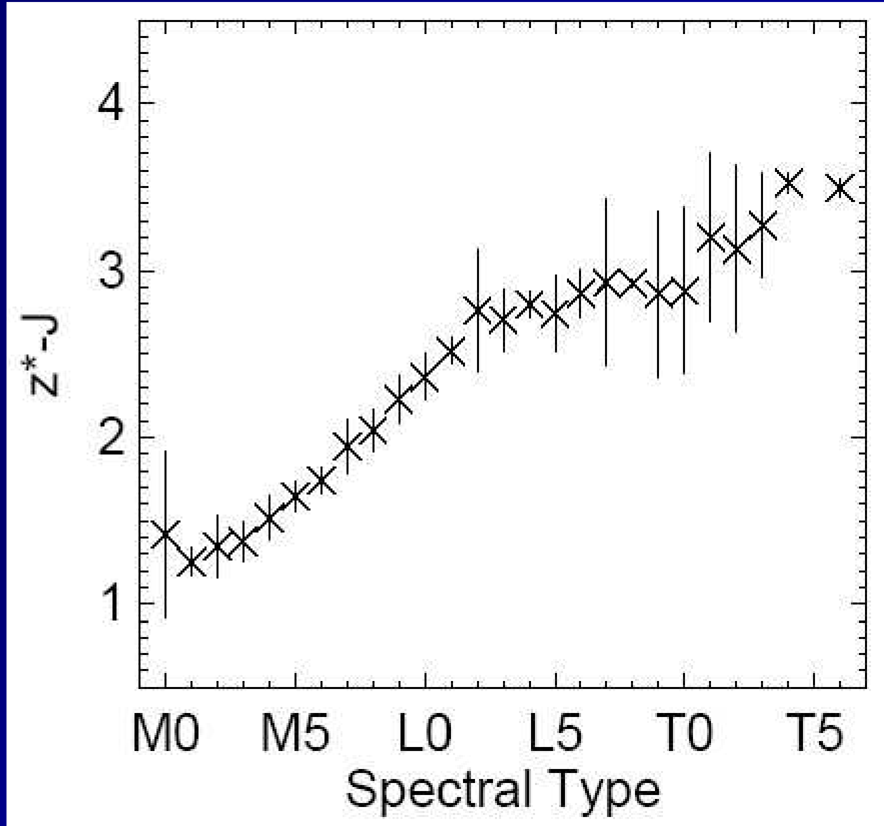
UKIDSS first pictures (June 2005)
Press release (24 June 2005)

Science verification pictures (Sept 2005)

UKIDSS (II)

- z (SDSS) limiting magnitude: 20.4
- J (2MASS) limiting magnitude: 15.8

→Faint SDSS sources do not have 2MASS counterparts.



- *The discovery of brown dwarfs cooler than T dwarfs (the "Y" dwarfs) is one of the key science drivers for UKIDSS.*

Testing the BD formation theories

Testing the BD formation theories

✓ The way how BDs are formed is still a matter of debate.

✓ Photoerosion of prestellar cores (Whitworth & Zinnecker, 2004):

✓ Turbulent fragmentation (Padoan & Nordlund, 2004)

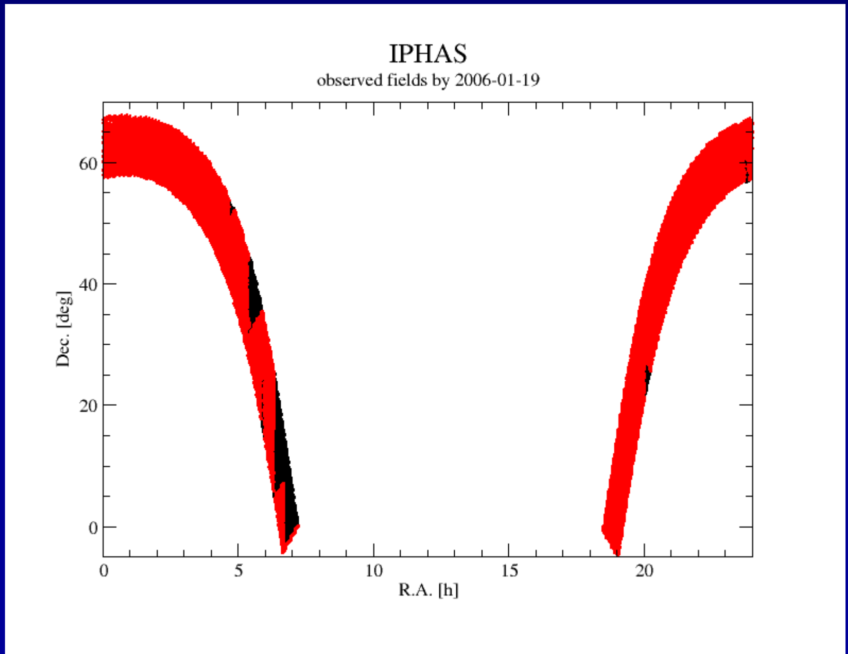
✓ Ejection (Reipurth & Clarke, 2001)

The ejection model

✓ So far, all the surveys for young BDs concentrate on the known star-formation regions.

✓ Depending on the ejection velocity BDs may have travelled far from their birth sites and not revealed by the previously mentioned surveys.

✓ Check the ejection model by cross-correlating IPHAS and 2MASS to search young BD by their Hα emission and IR colors.

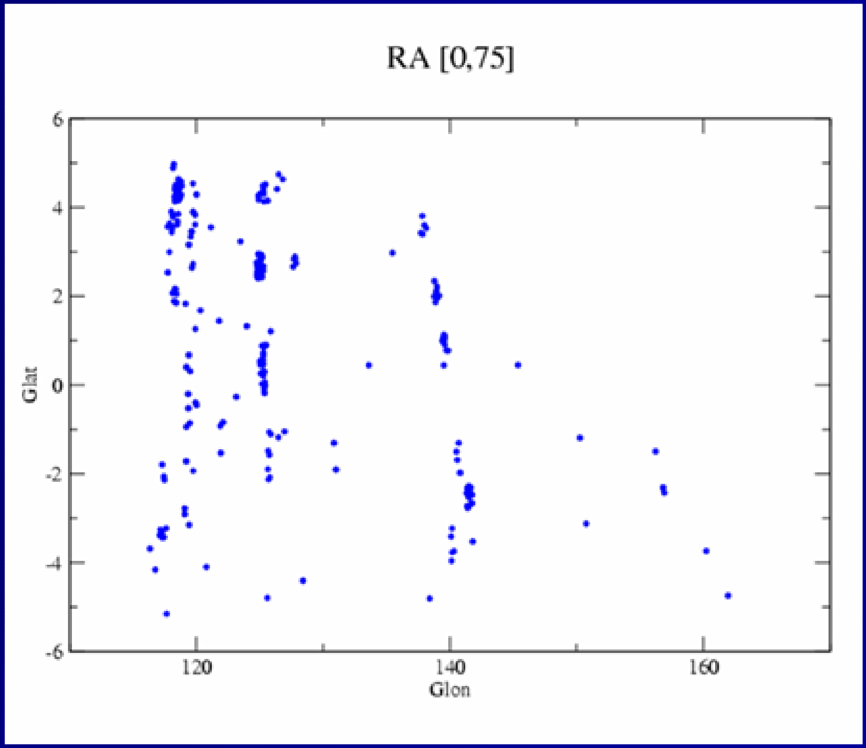


IPHAS

- INT Photometric Hα survey (Drew'05)
- 1800 deg²
- -5<b<+5
- r', i', Hα filters
- r'=20 (10 σ), i'~19
- 80M sources in the Final Catalogue.

The project: candidates and follow up

✓ Filtering using appropriate (r-Hα), (I-J), (J-H), (H-K) color criteria. (~ 300 candidates)



✓ Low resolution spectroscopic follow-up for a proper identification and determination of physical parameters.

- WHT: 2 nights (Aug 1st-2nd). 35 candidates observed.
- NOT/ALFOSC: 5 nights (Oct06).

Conclusions

• The scarcity in the number of known brown dwarfs has a considerable impact on different fields of Astrophysics, in particular on the area of star formation.

• This problem has been identified as a key VO-Science case both by AstroGrid (included in the "Top-Ten" cases) and EURO-VO (through its Science Reference Mission).

• Building a census of substellar objects implies the discovery of a statistically significant number of them through queries that combine attributes available from different archives.

• This is an approach out of the scope of the "classical" methodology but that perfectly fits into the Virtual Observatory.

• The goal of this presentation has been to demonstrate the potential of carrying out this type of analysis in the VO framework.