Probabilistic identification of brown-dwarfs in IR surveys

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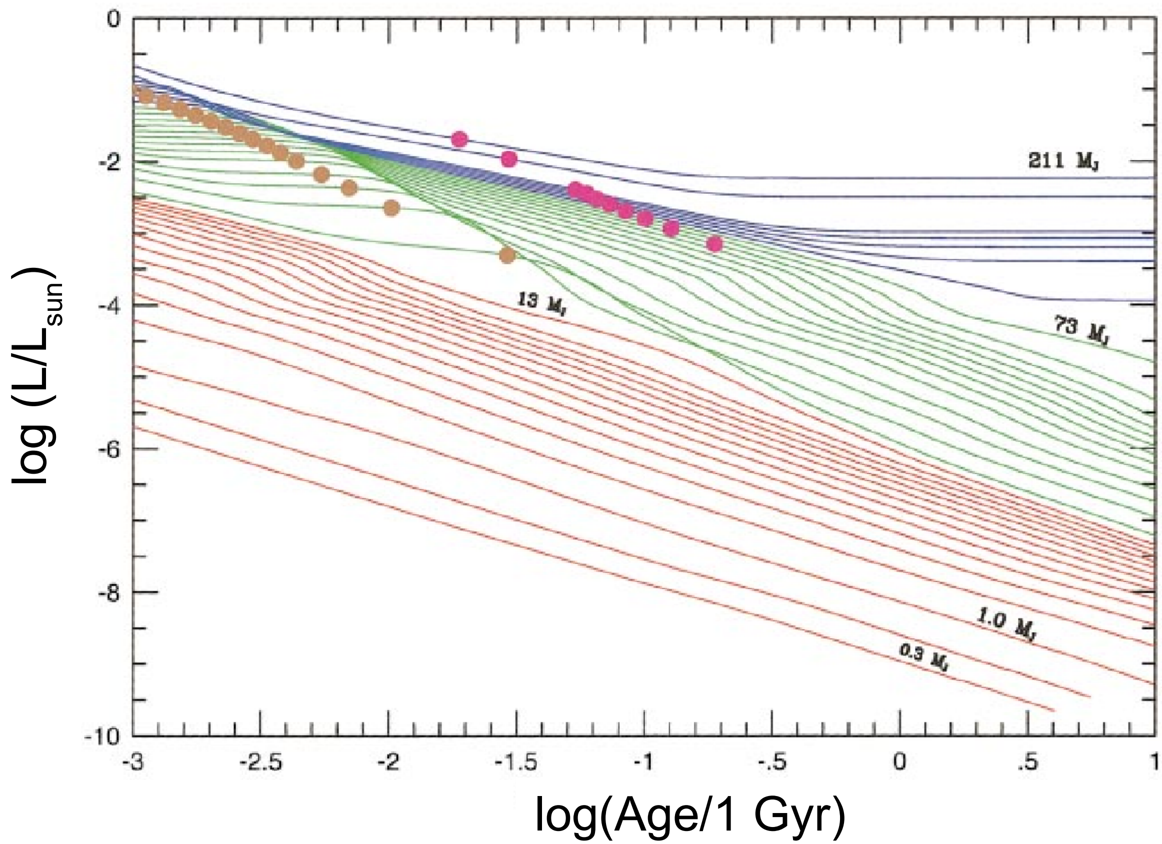
Brown dwarfs
Low Mass end of the MF

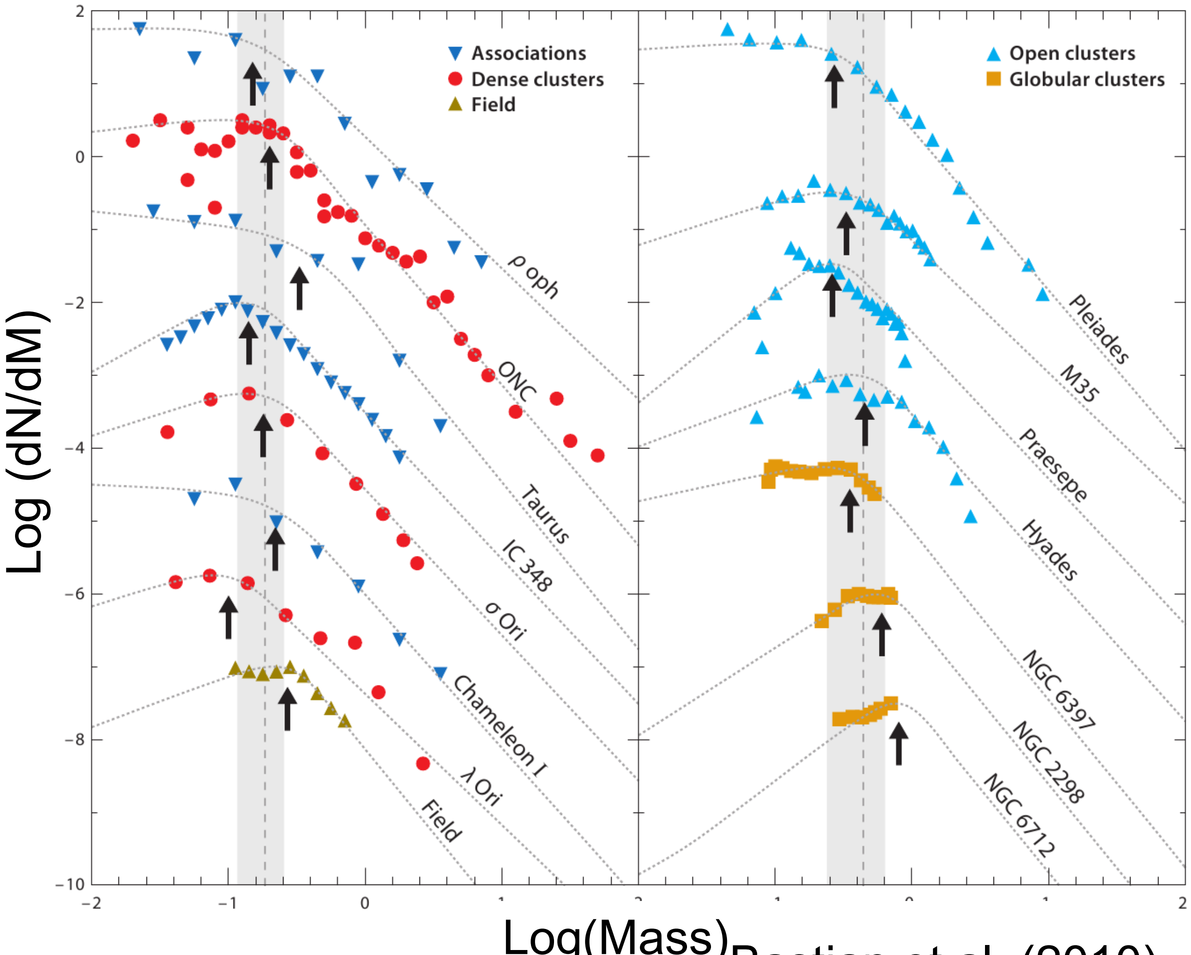
- Objects below hydrogen burning limit
- M< 0.08Msun (~80 M_{jup})
- Short period of deuterium burning for M>13 M_{jup}
- Low luminosities
- Low effective temperaturess T<2000K
- Atmospheres are molecular



Burrows (2001)

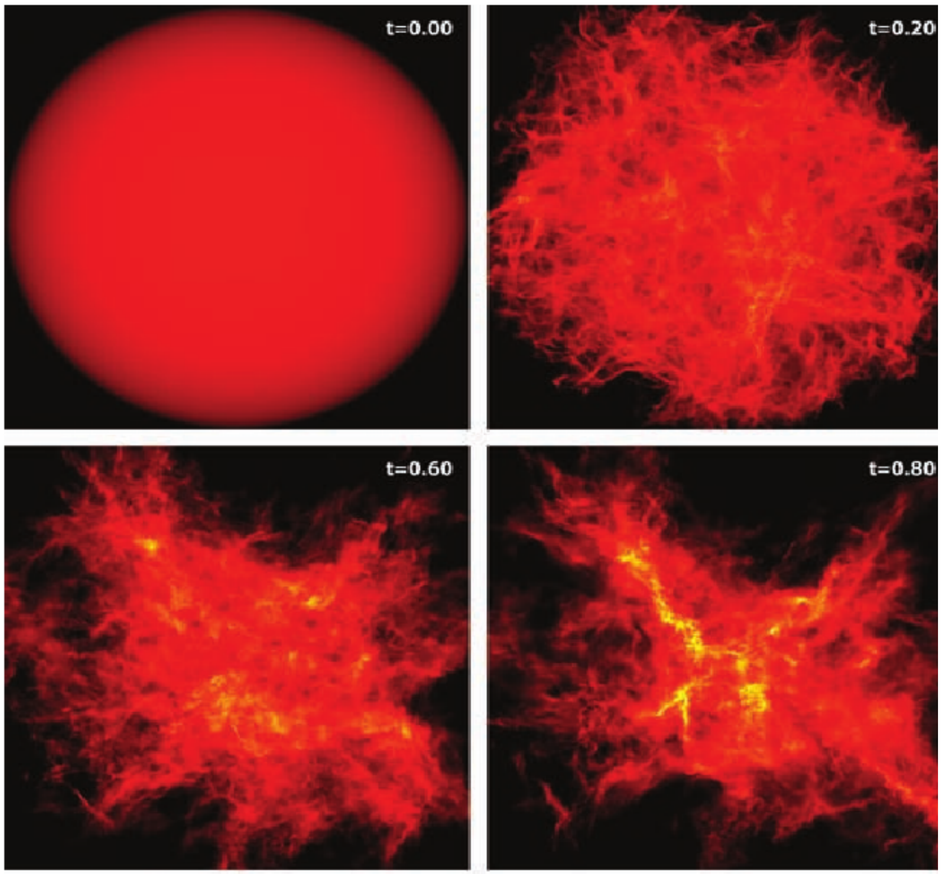
Initial Mass function

- Brown dwarfs are
  at the extreme end of MF
- «Universality» of the IMF
- Understanding IMF is crucial for stellar astronomy, galaxy physics, feedback, reionization.
- Sensitive to physics of star formation

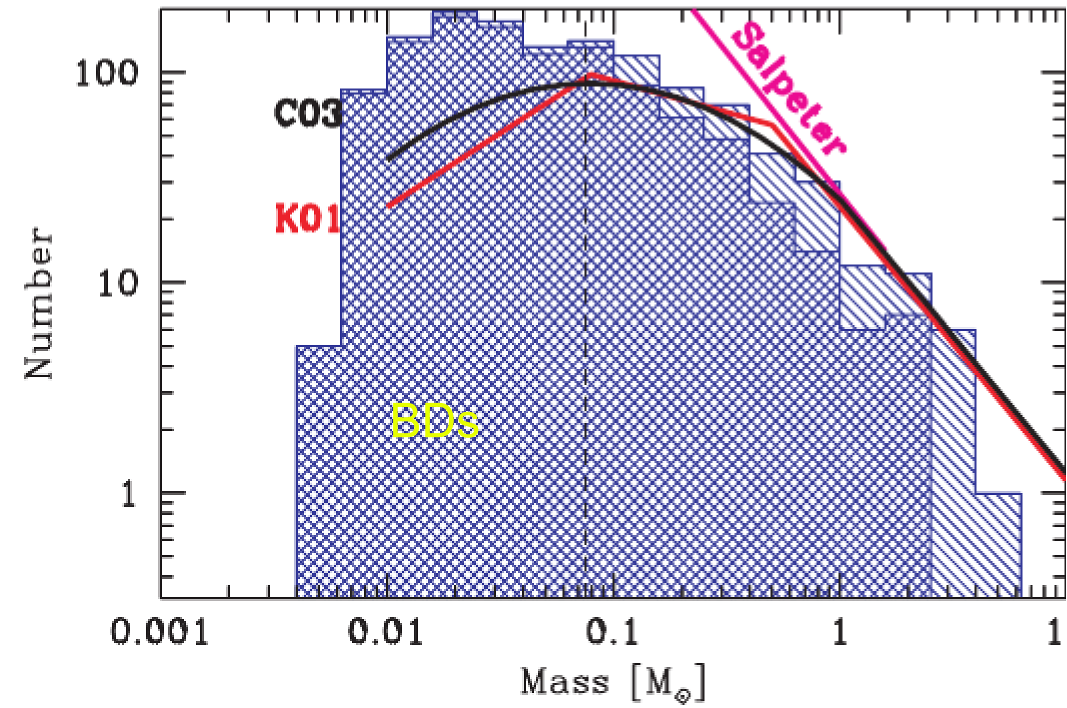


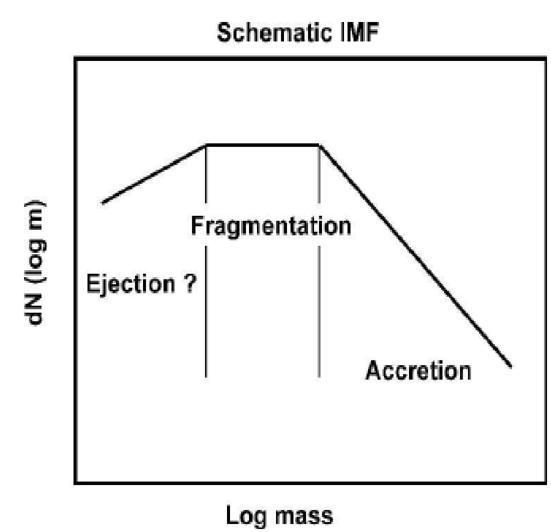
Bastian et al. (2010)

BDs in numerical simulations



Bate et al (2009)

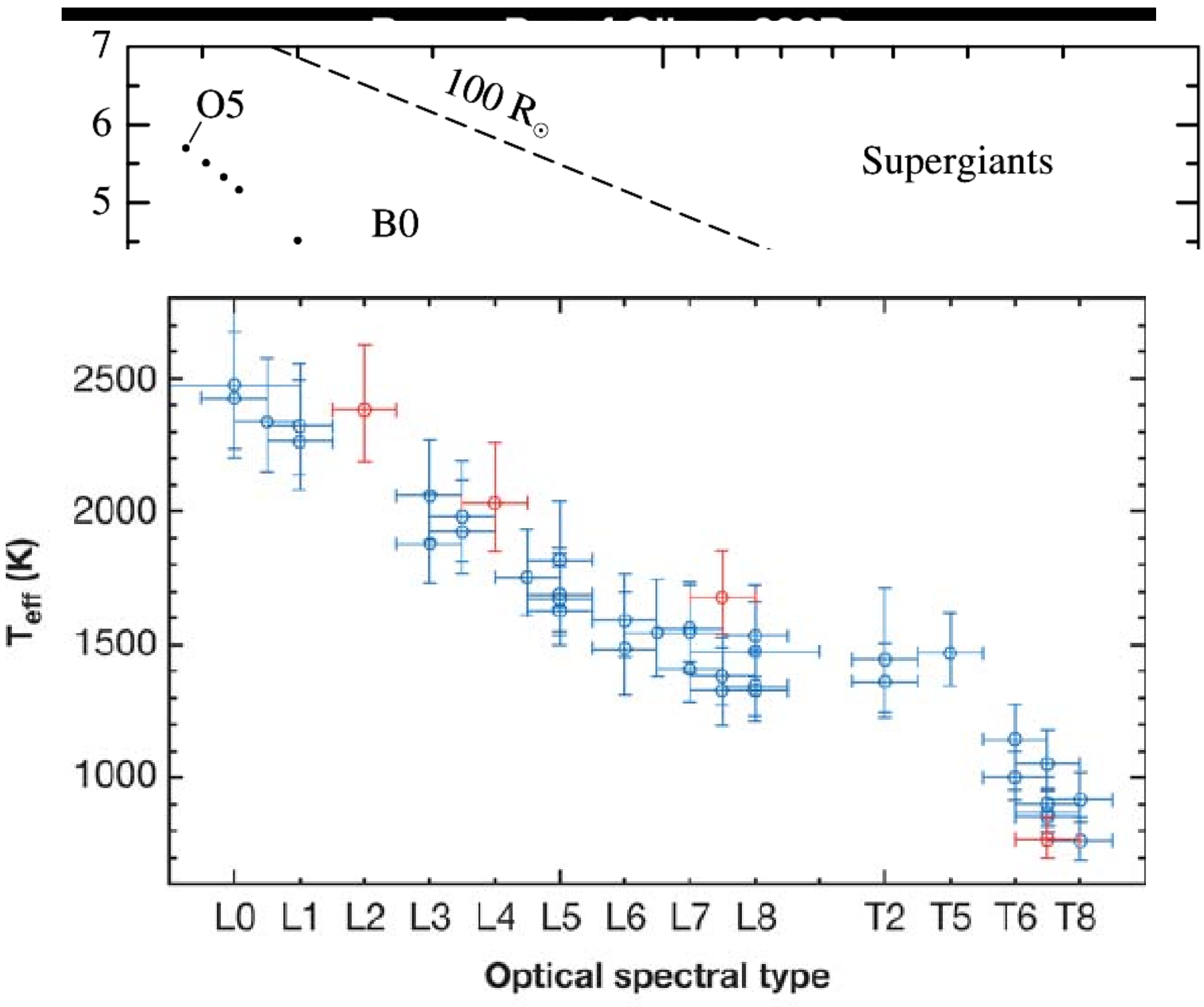




Possible explanation for low mass of BDs: lack of accretion after the formation due to ejection from dense areas

First BD discoveries

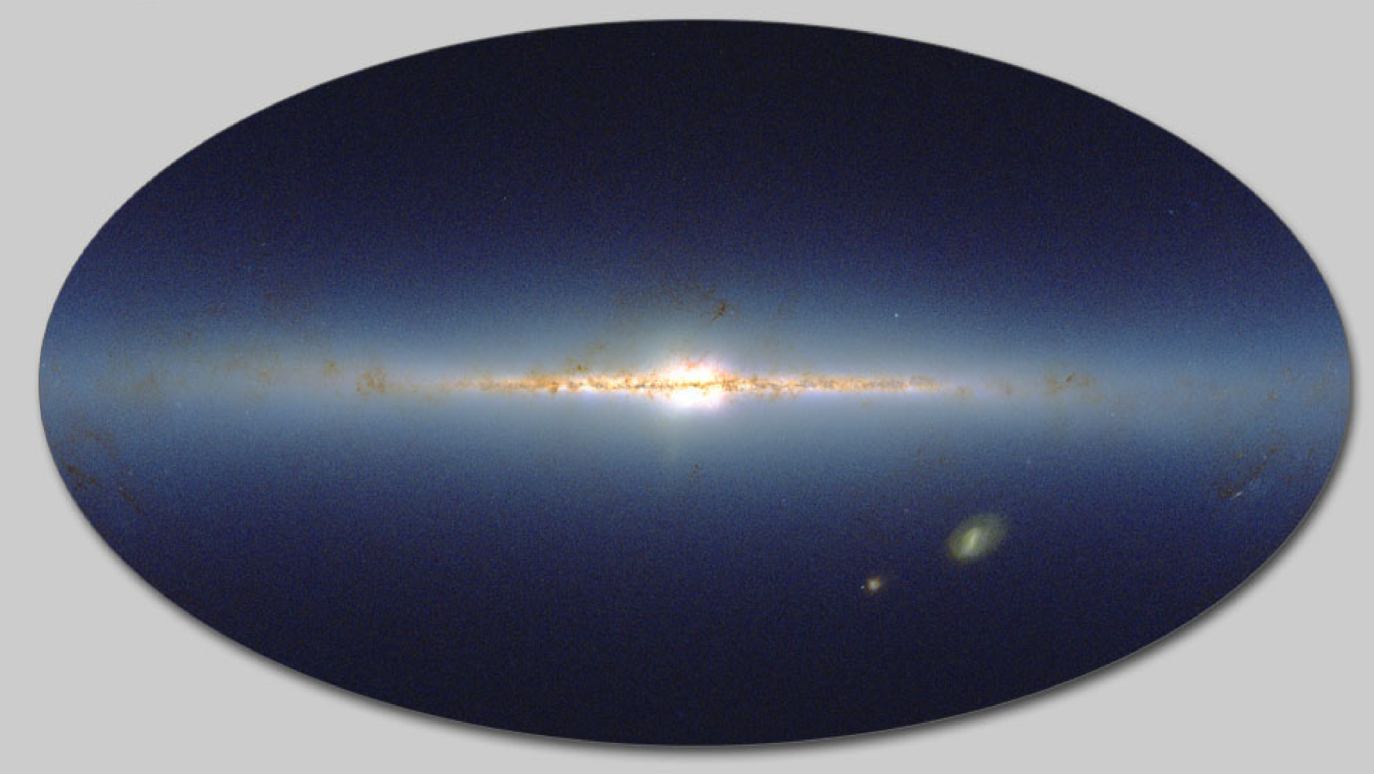
- GL229B discovered in 1994
- 2MASS, DENIS
- Spectral classification extended to LT types (Teff<3000K)



Kirkpatrick (2005)

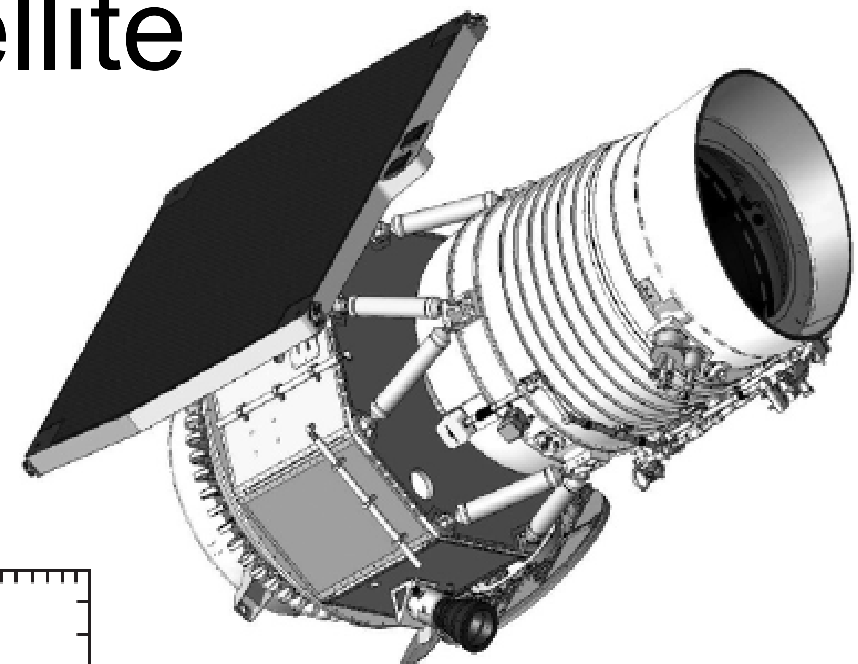
Large/allsky IR surveys

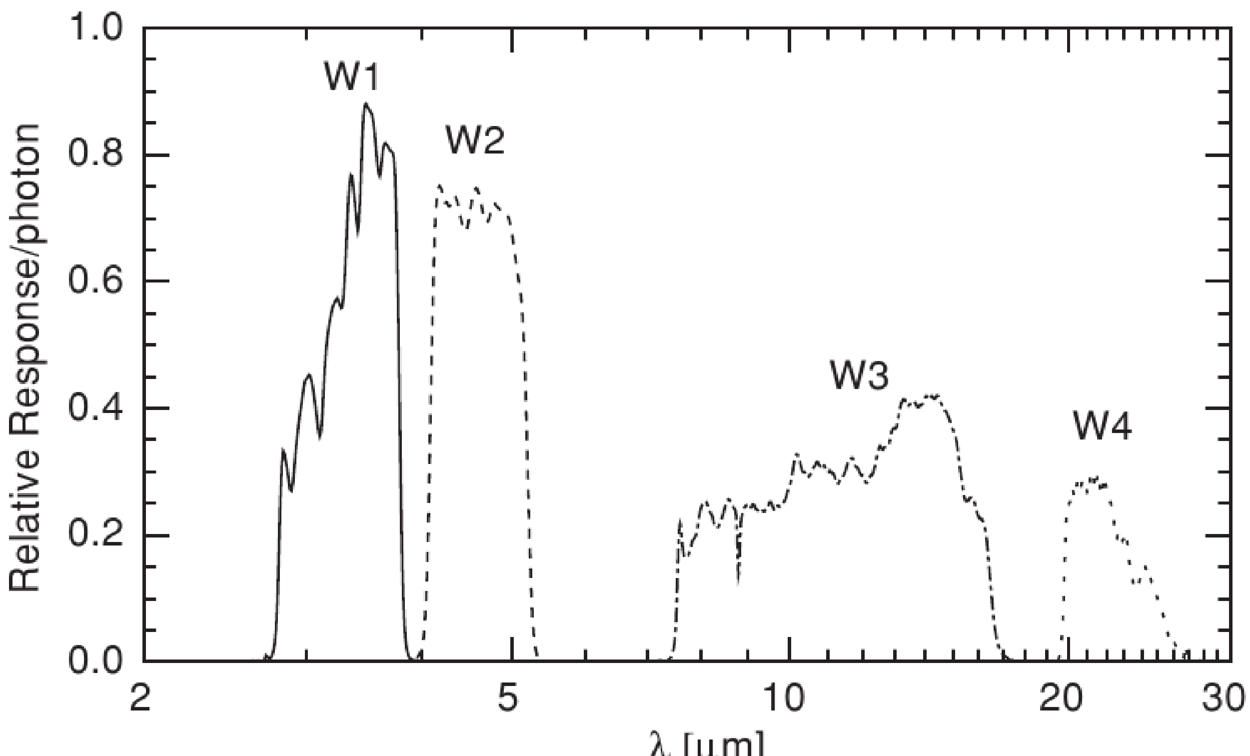
- 2MASS (allsky)
- DENIS
- UKIDSS
- WISE (allsky)
- VISTA surveys



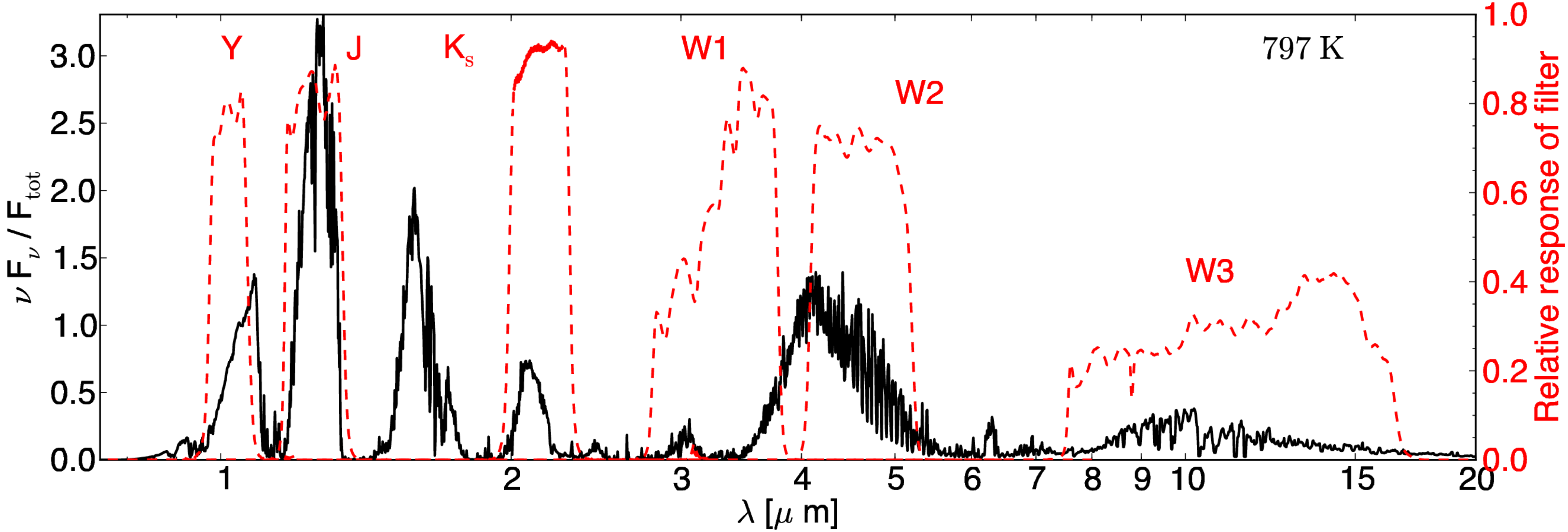
WISE satellite

- Launched in 2009
- 4 filters: W1, W2, W3, W4





Spectral features of BDs



BD spectrum at ~ 800K

- Absorption dominated spectrum
- Water, methane absorption

Previous searches for BDs in WISE

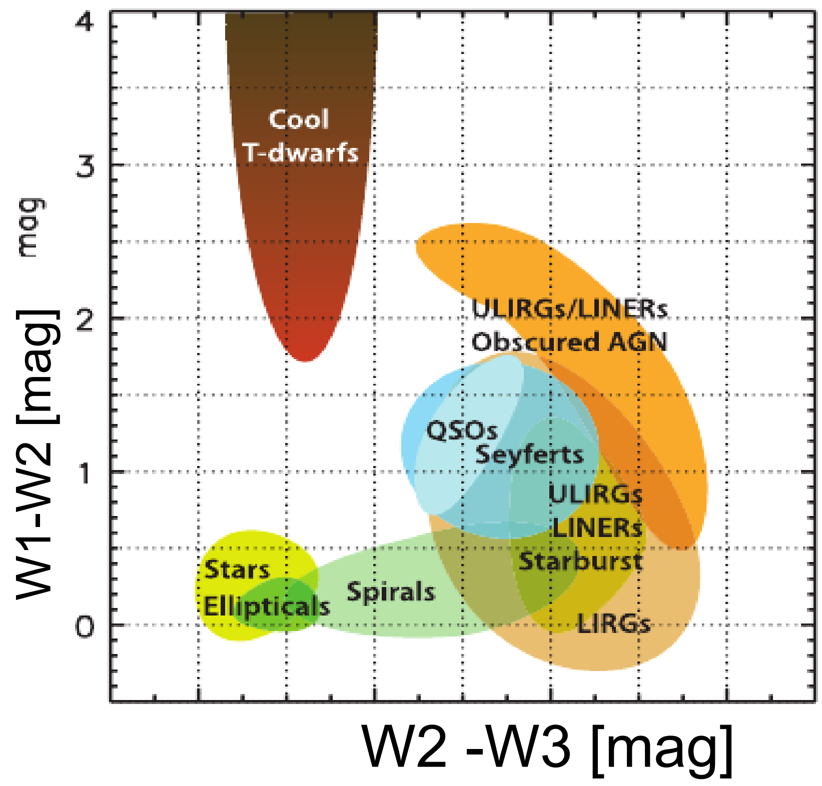
- Bright objects
- Simple criteria:

  Colour-cuts

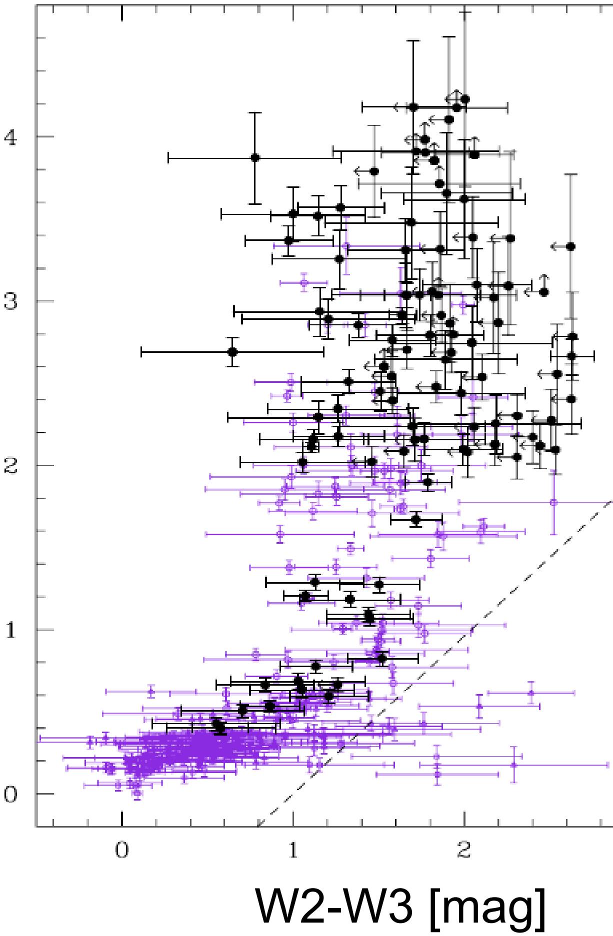
  Large colors
- Kirkpatrick et al (2011-2013)
- Expensive

  spectroscopic

  followup



Wright et al (2010)



Kirkpatrick (2012)

WISE satellite

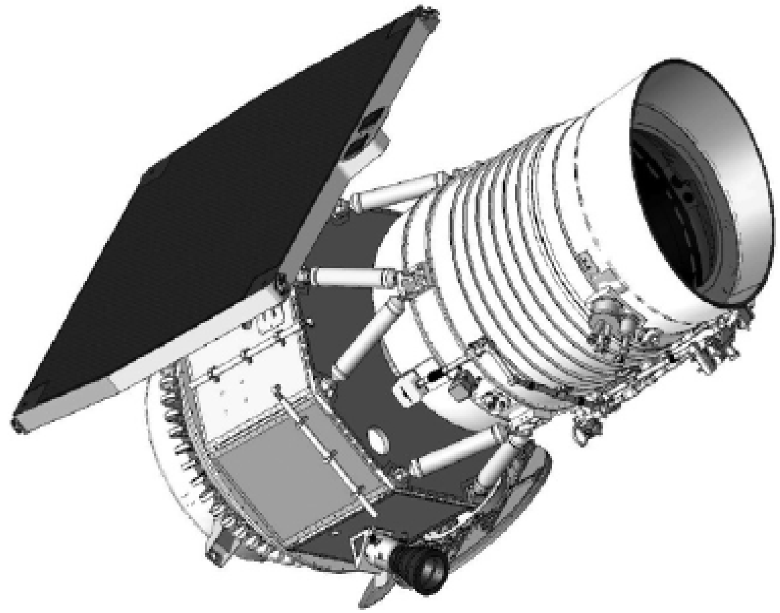
Depth in different filters:

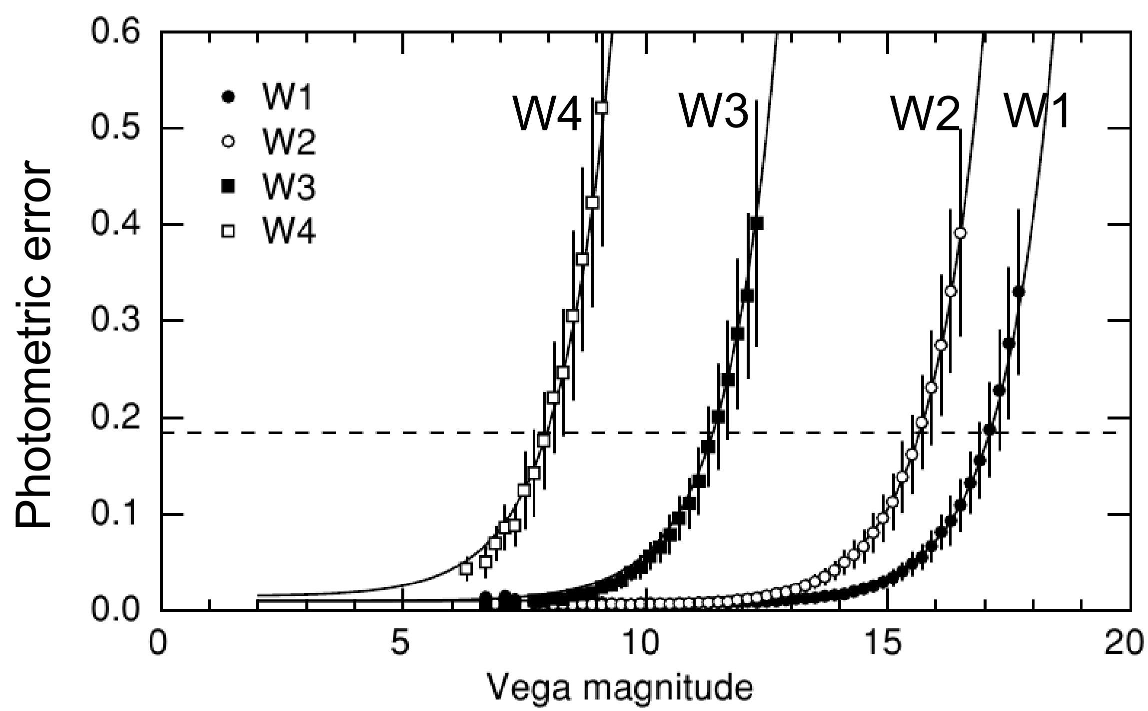
W1: 17 mag

W2: 16 mag

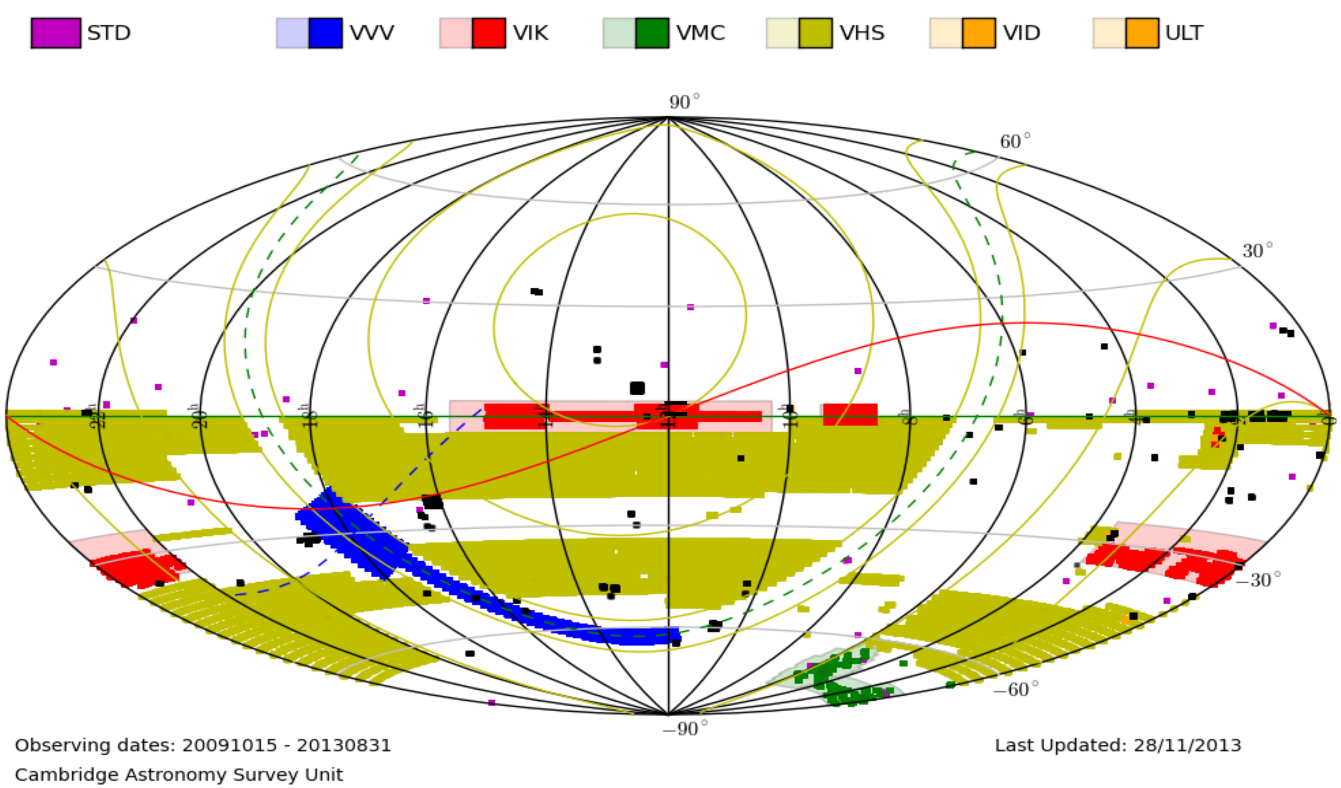
W3: 11 mag

W4: 7 mag





VISTA hemisphere survey (VHS)



PI: Richard McMahon

- VHS part of a set of VISTA surveys, done in the IR
- 3 surveys: VHS ATLAS, VHS GPS, VHS DES
- YJHK bands for VHS ATLAS area

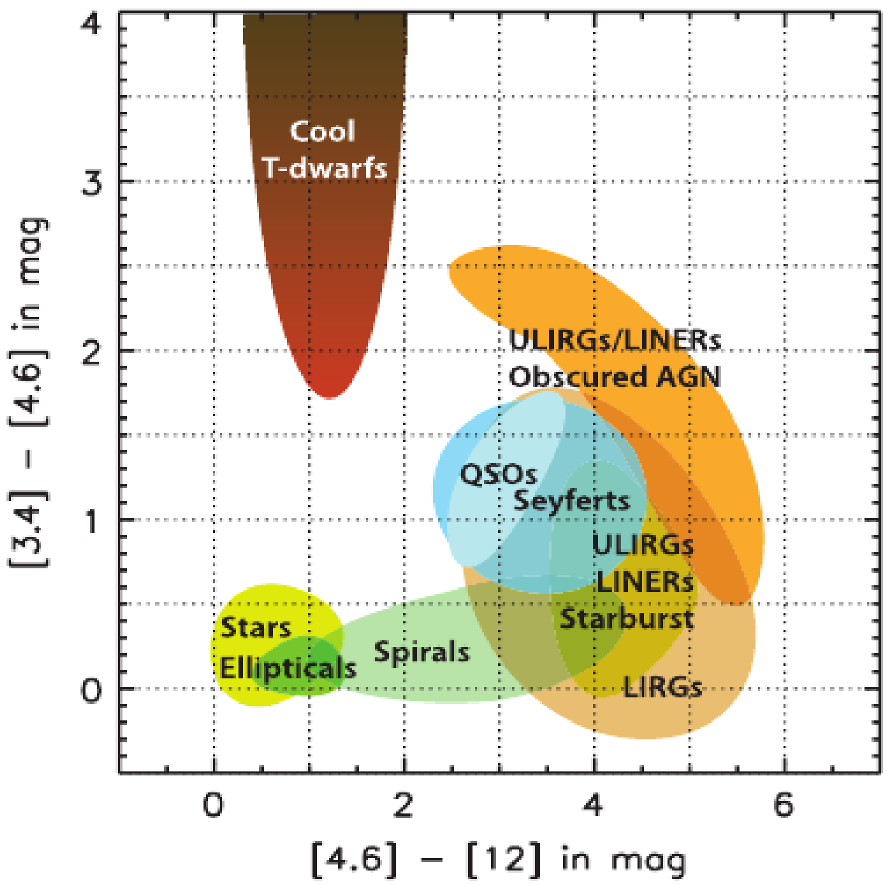
Combined dataset

- Cross-match between WISE & VHS ATLAS & USNO
- Filters I, Y, J ,K, W1, W2
- We model colors J-W2 W1-W2, J-K, Y-J, I-J
- In total, the dataset is 5-D:

  W2, J-W2, W1-W2, J-K, Y-J, I-J

The classical method breaks for faint sources

- W3 error is too high
- Scattering from the selection box (incompleteness)
- Scattering into the selection box (contamination)
- Detection limits



Wright et al (2010)

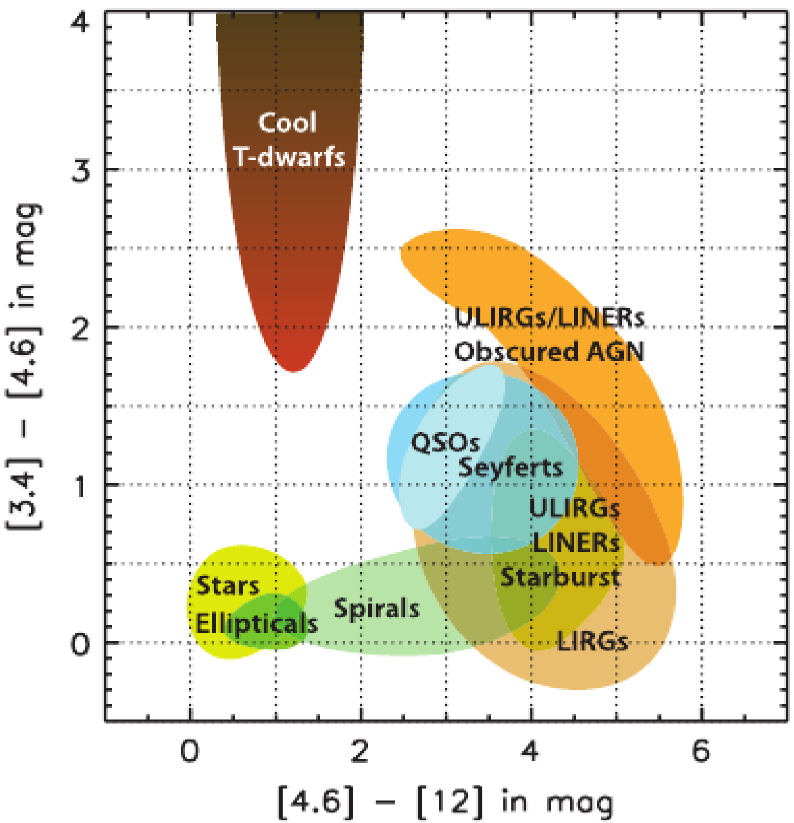
Bayesian classification method

$P_i(\mathbf{x})$ PDF in N-dimensional color space x
i – class of object

n_i Number density of the species i

$$P(i|\mathbf{x}) = \frac{n_i\, P_i(\mathbf{x})}{\sum_j n_j\, P_j(\mathbf{x})}$$

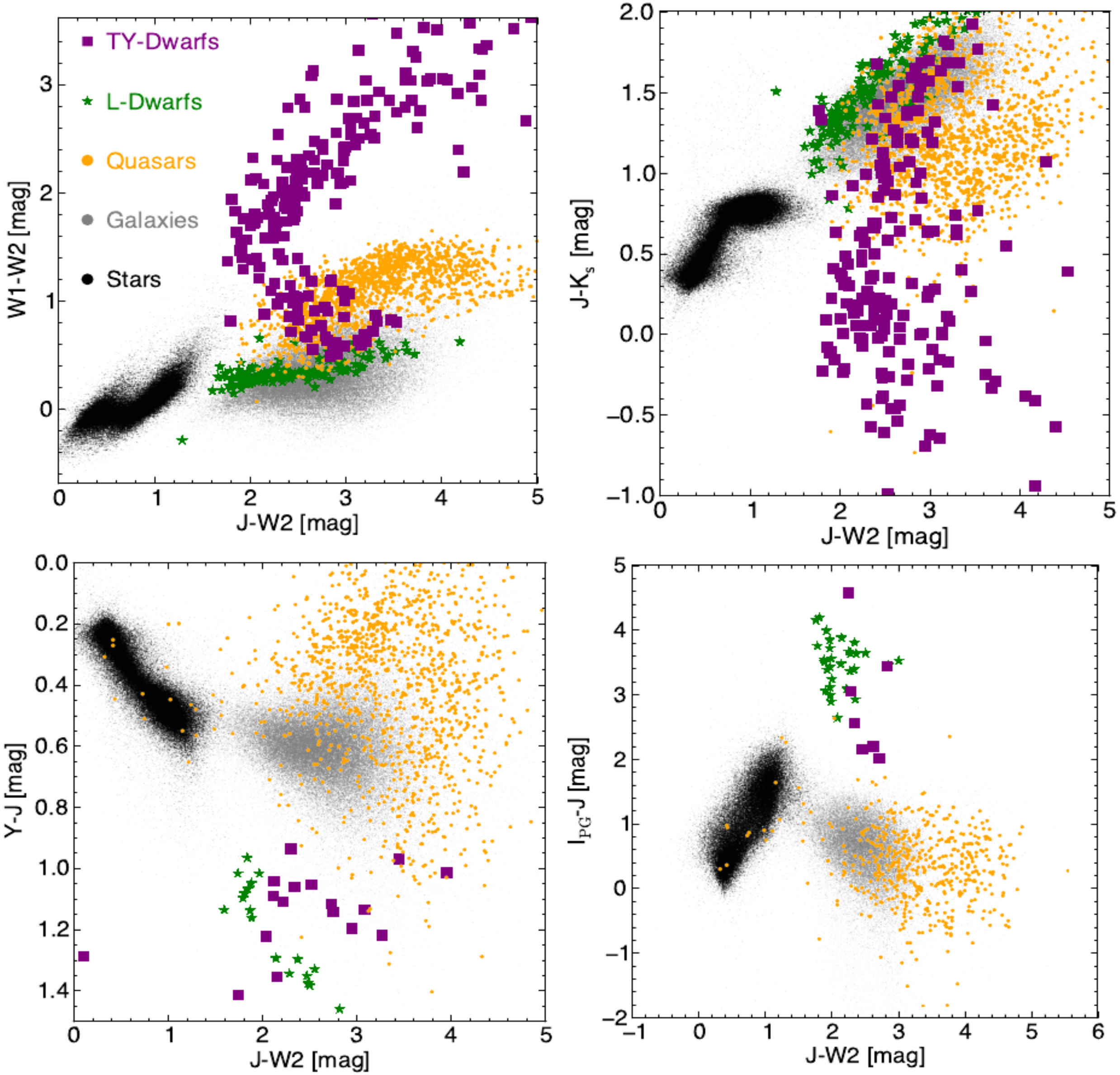
Posterior probability for the class i



The main contaminants

- Quasars
- «normal» stars
- L-dwarfs
- Galaxies

Brown dwarfs



4 slices through the color space

Gaussian Mixtures Models

$$P(\mathbf{x}) = \sum_j A_j \exp(-0.5(\mathbf{x} - V_j)\Sigma_j^{-1}(\mathbf{x} - v_j))$$

- Multi-dimensional, very flexible
- Garanteed convergence (via Expectation Maximization)
- Fast,Easy to sample from
- Applications: e.g.Bovy et al (2011,2012), Koposov et al (2013)
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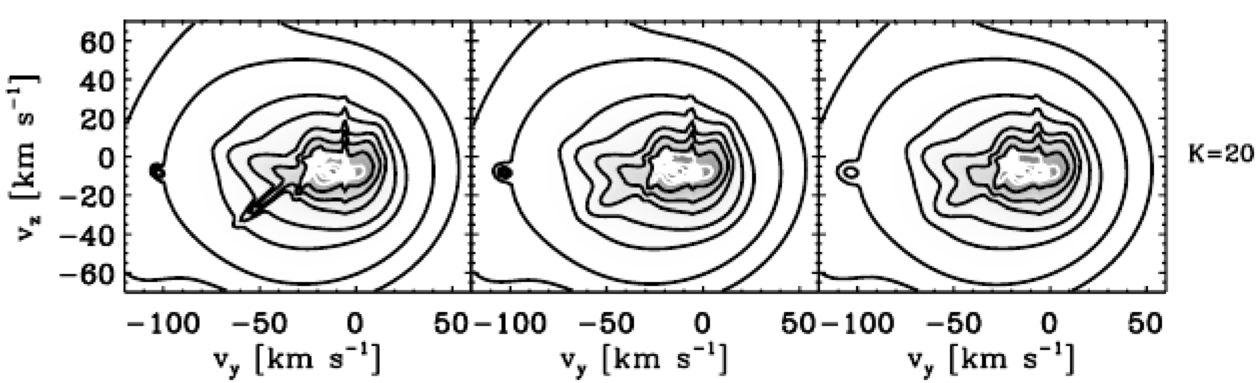
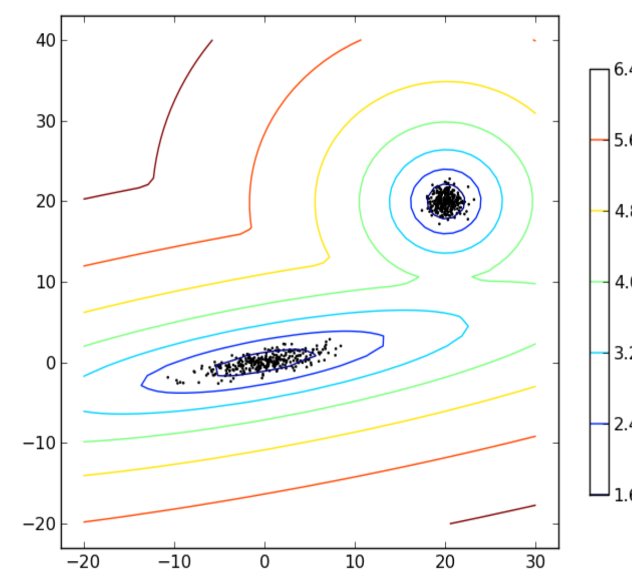
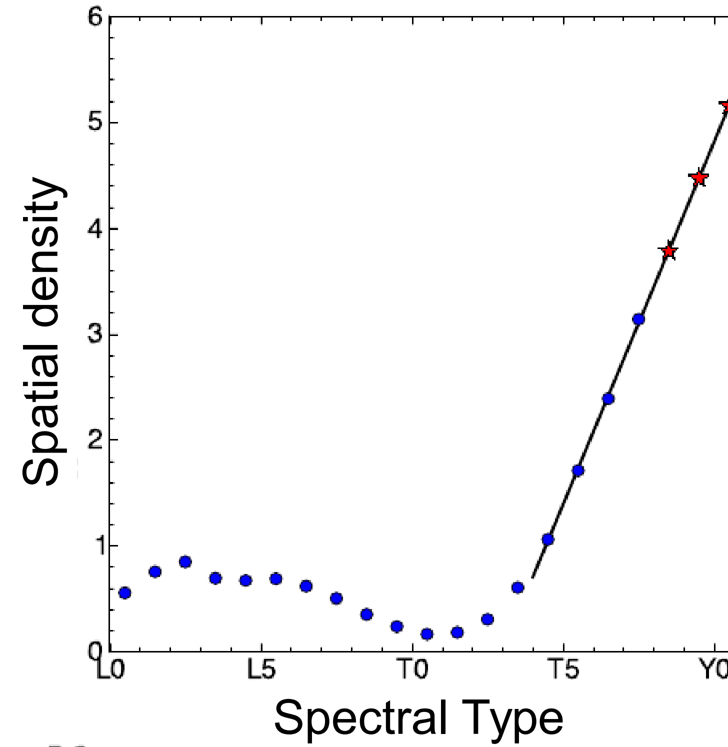
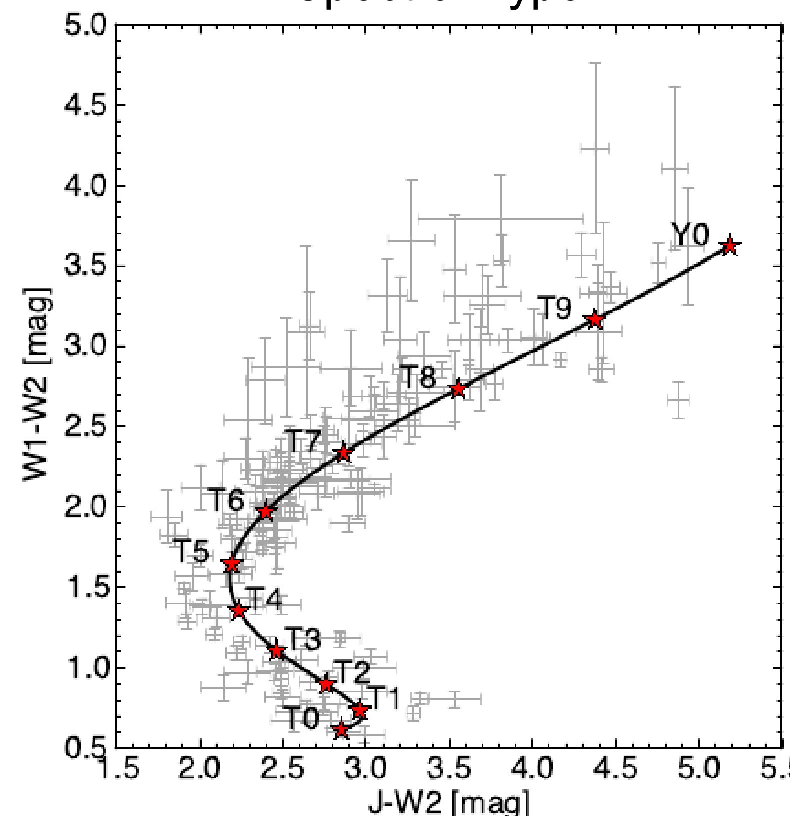




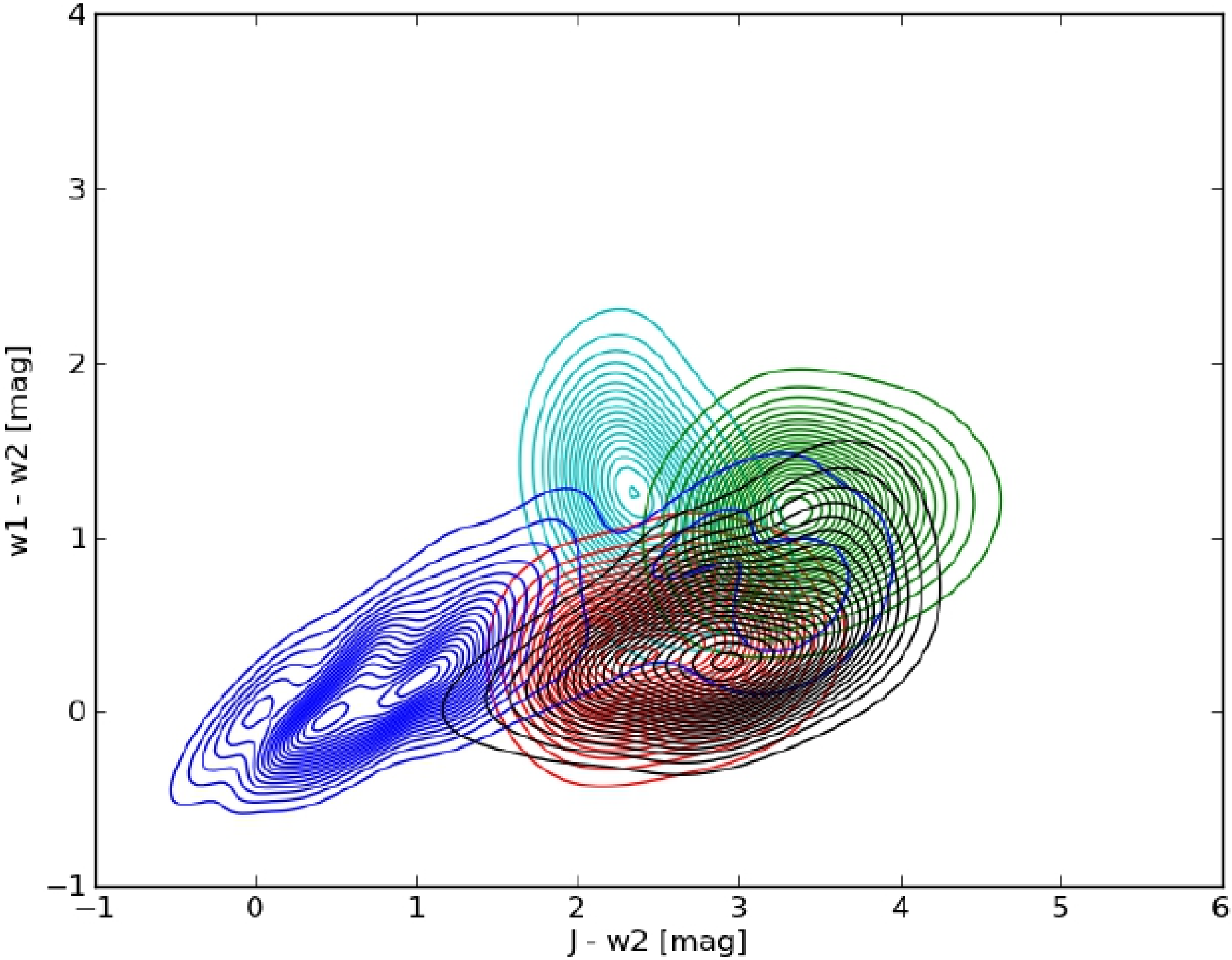
LTY dwarfs

- The LTY dwarfs:
- We adopt the color-type, color-magnitude relations
- Spectral type distribution from Burgasser (2007)
- Assume uniform distribution in the Galaxy: $P(r) \propto r^2$



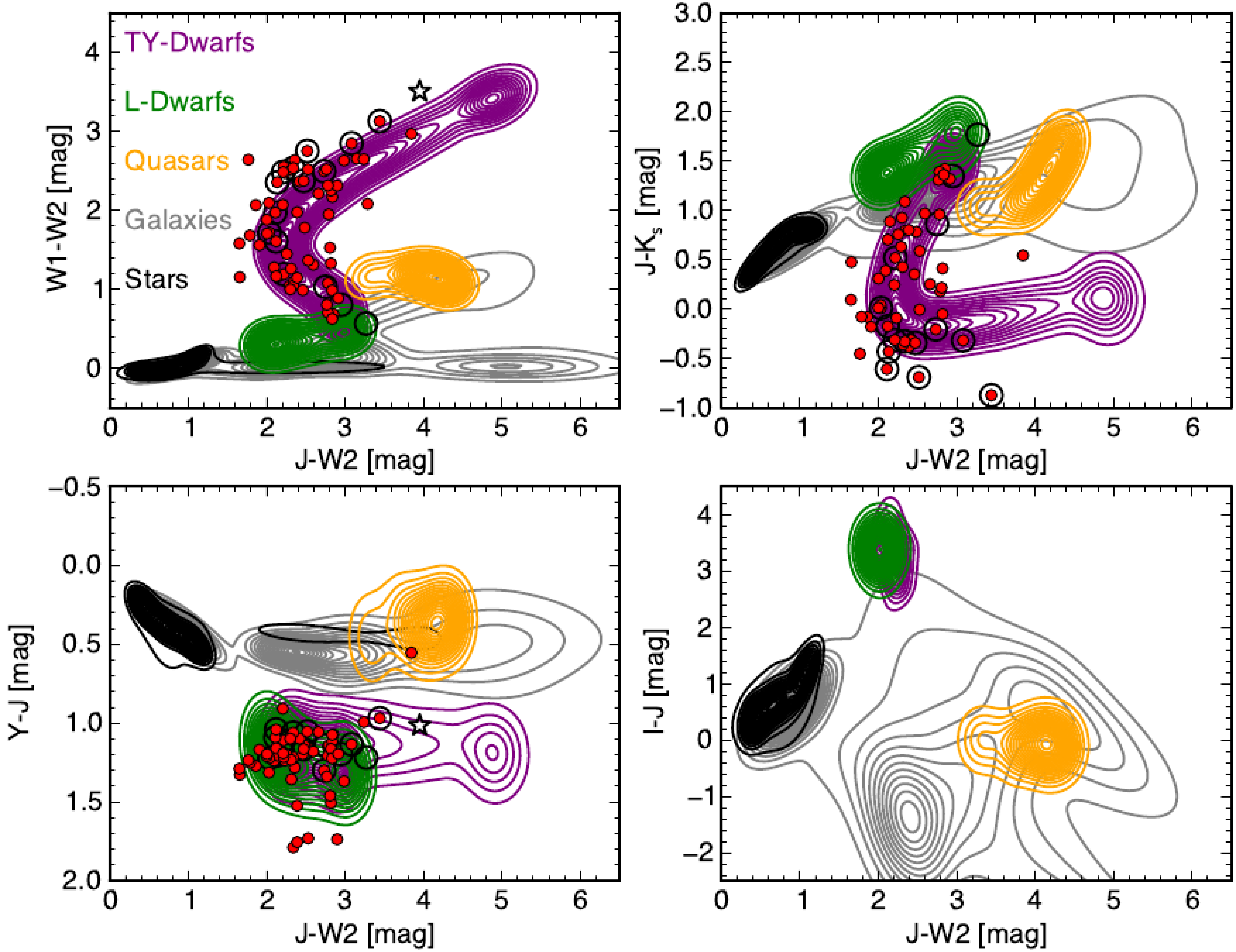


Model changes with magnitude



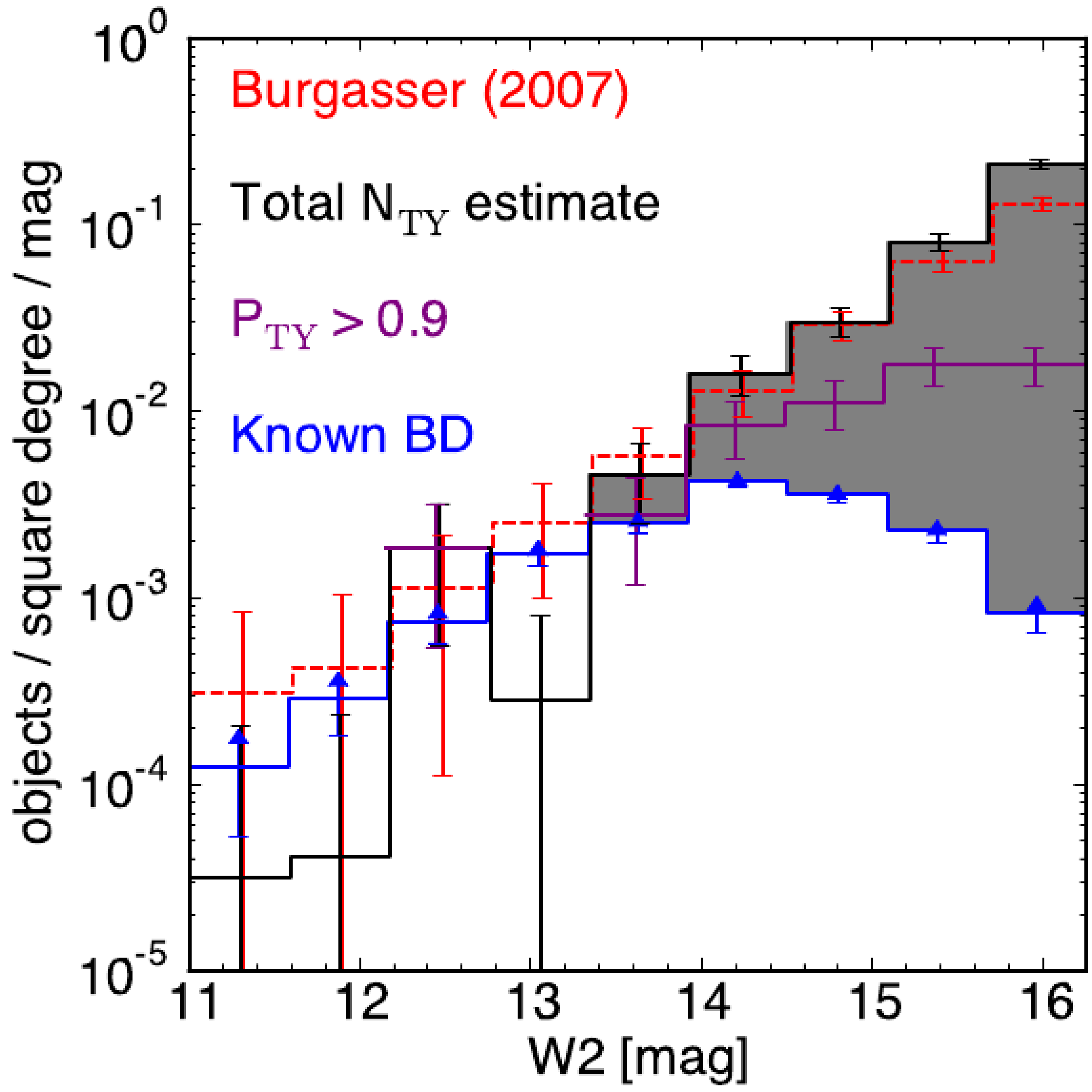
Brown dwarfs Stars QSOs L-dwarfs

Gaussian mixture models for W2~12mag
New BD discoveries



Estimation of the Luminosity function

- We can correct for incompleteness using our probabilistic approach
- We don't have to do spectroscopic followup of every object



Conclusions

- A new sofisticated, efficient method of identifying brown dwarfs was developed
- We properly use all the available data.upper limits
- We have found ~ 60 new brown dwarfs
- We have found most known brown dwarfs in the observerd area
- We have measured the LF of BDs corrected for incompleteness