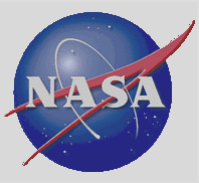


The Spitzer Experience – Giovanni Goes Wide and Deep with IRAC

Michael Werner

Spitzer Project Scientist

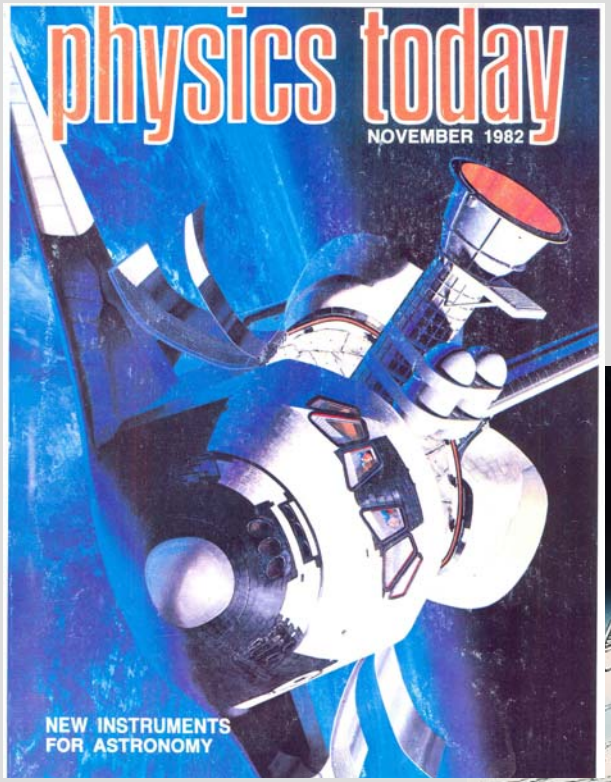
Jet Propulsion Laboratory, Caltech

JPL

Back in the Day….

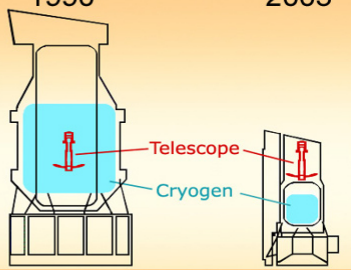
First meeting of Spitzer (SIRTF) SWG, July, 1984, at NASA Ames. At the time, the projected launch date for our first flight was January, 1993.

Not only the Scientists have Evolved



SPITZER SPACE TELESCOPE

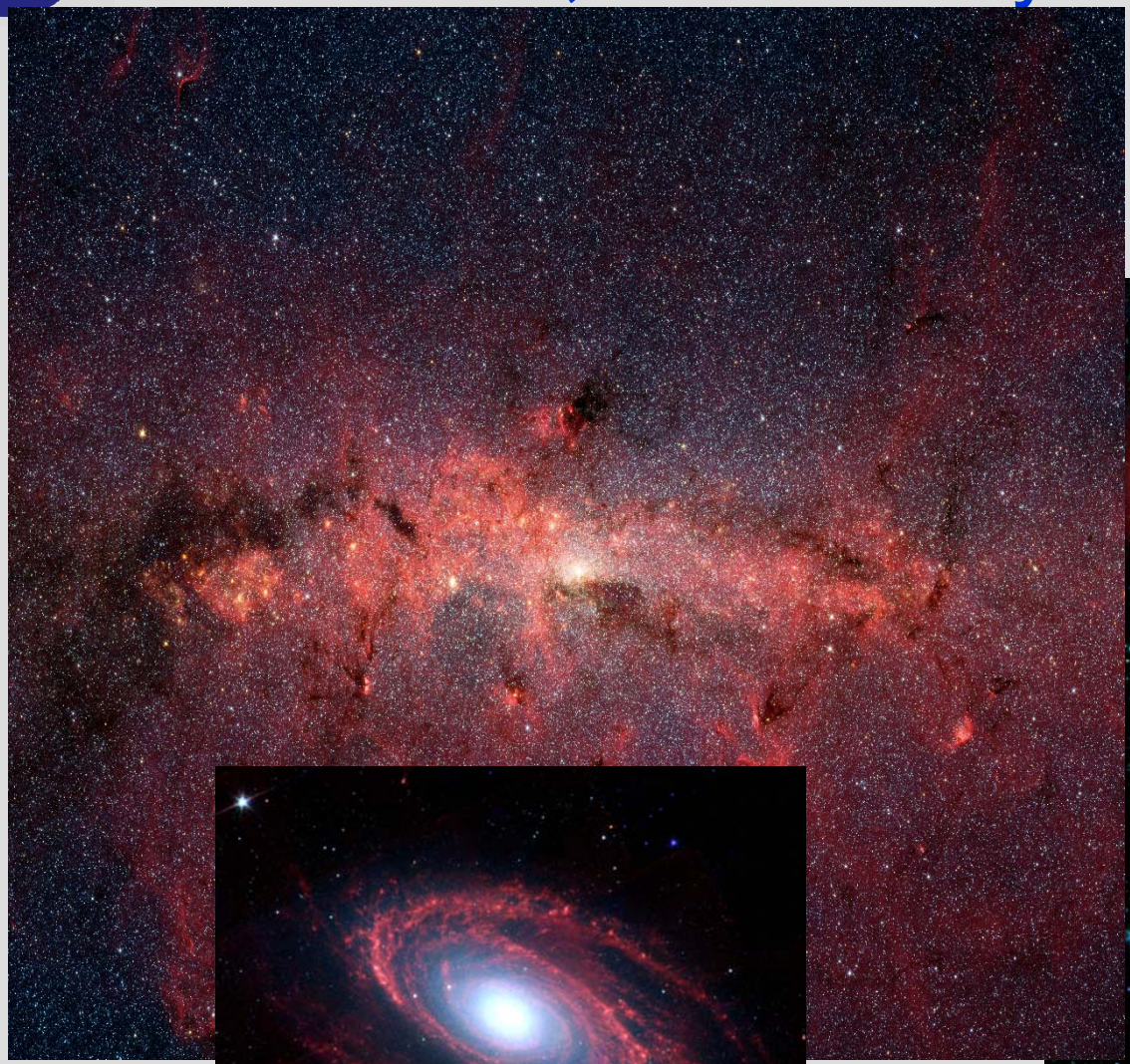
DESIGN CHANGES

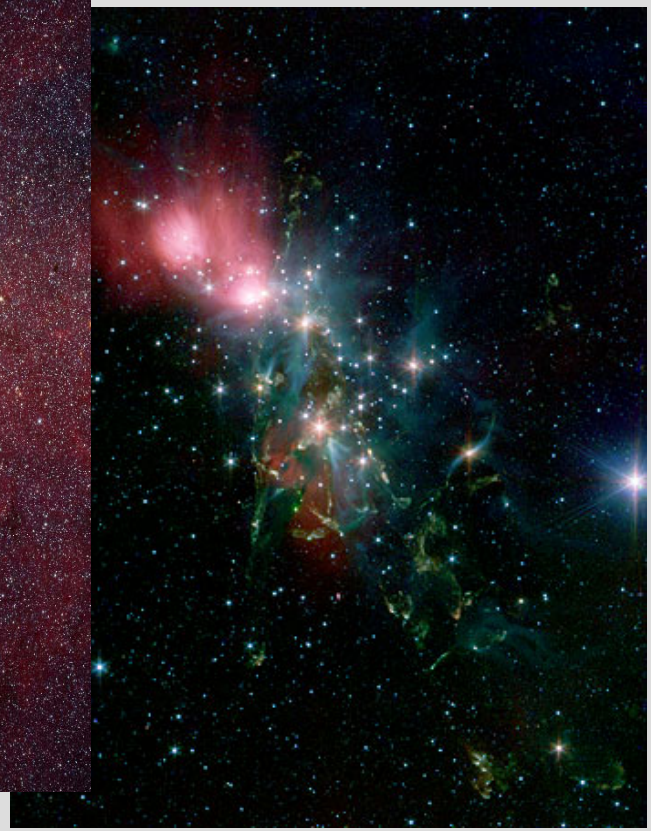


	COLD LAUNCH	WARM LAUNCH
Launch Mass	5700 kg	870 kg
Lifetime	5 years	5 years
Development Cost	~$2.2B	$0.67B
Launch Vehicle	Titan IV	Delta

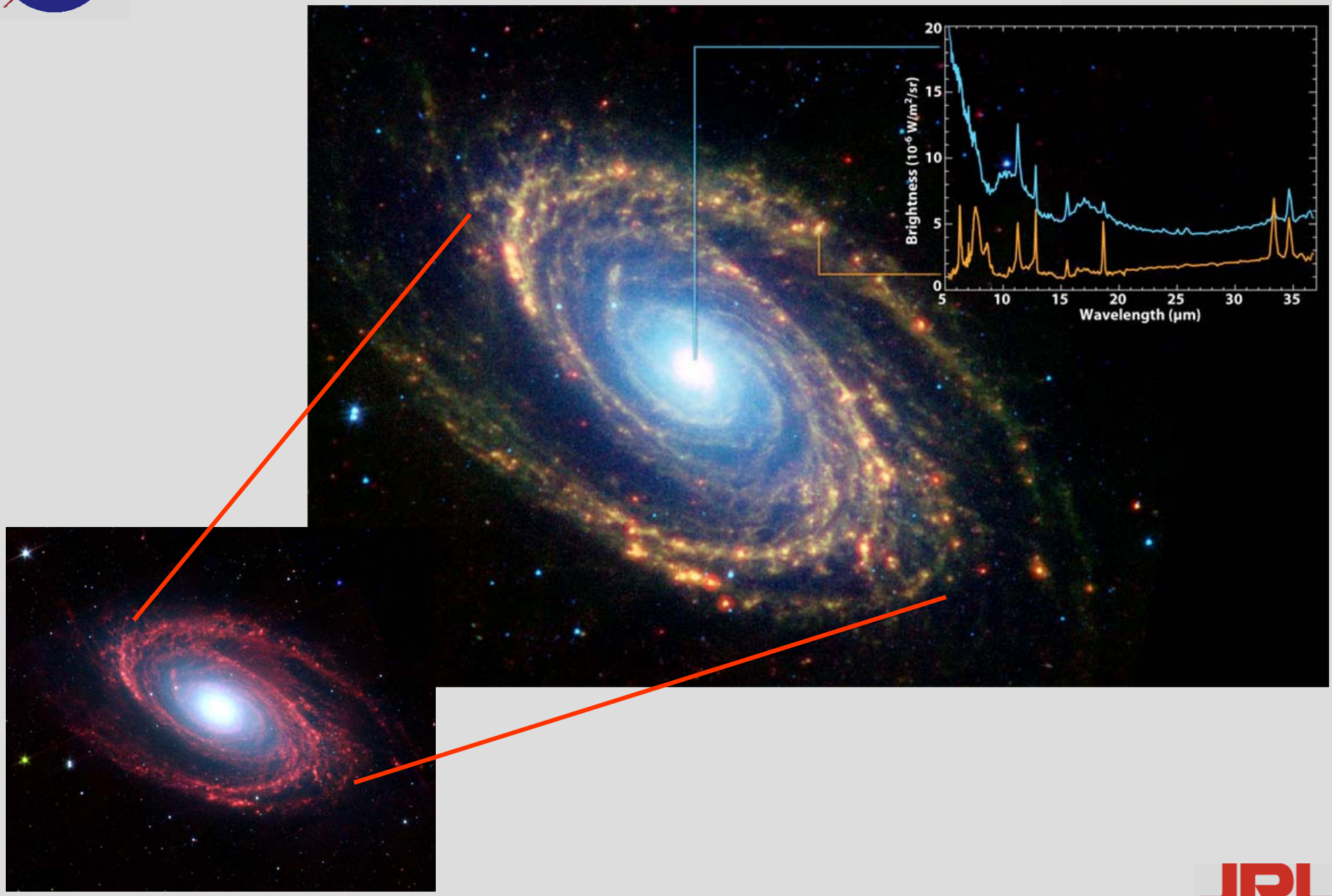
JPL

IRAC, IRAC Everywhere



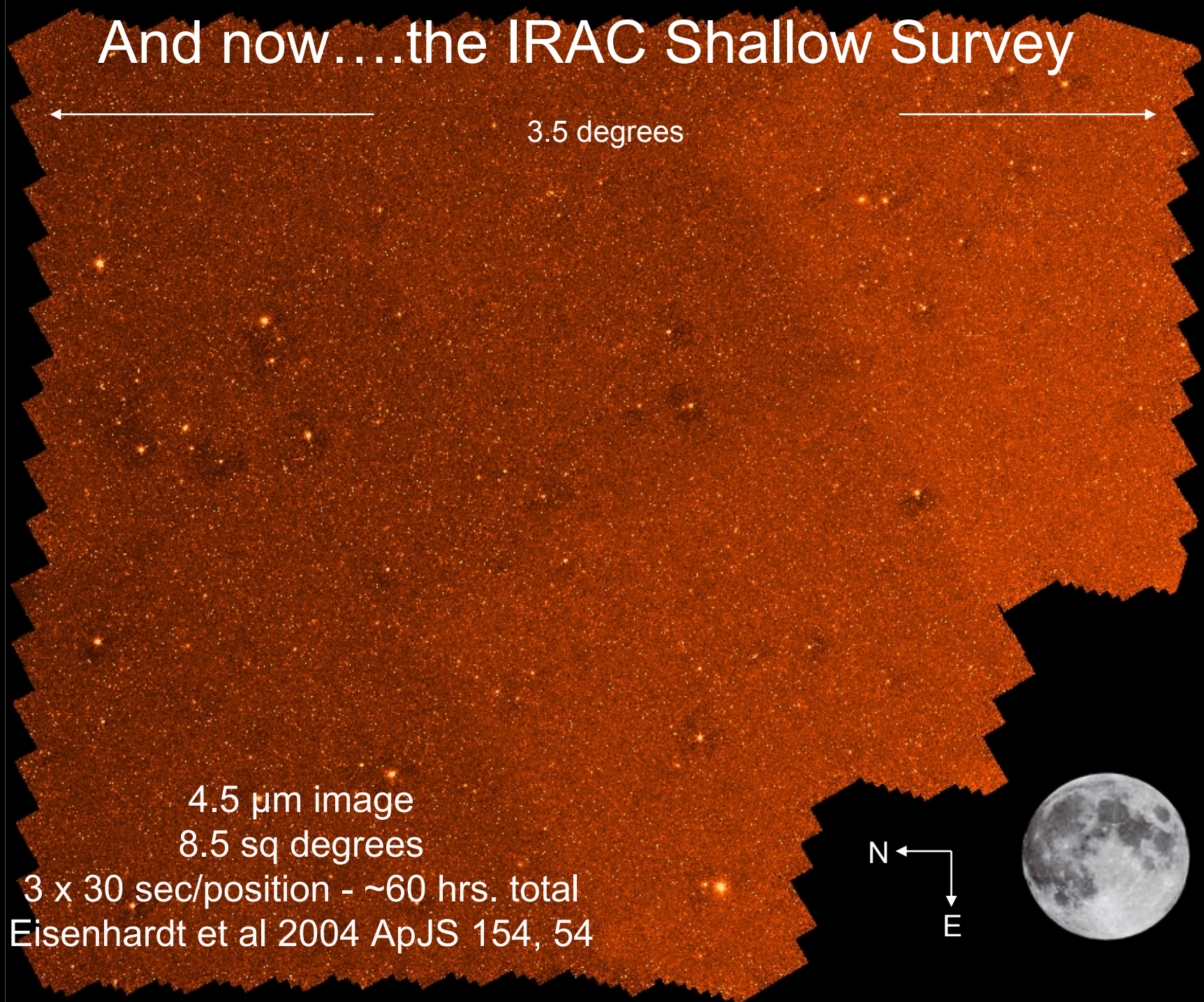


M81 Viewed by All Spitzer Instruments



Friends in High Places

And now….the IRAC Shallow Survey

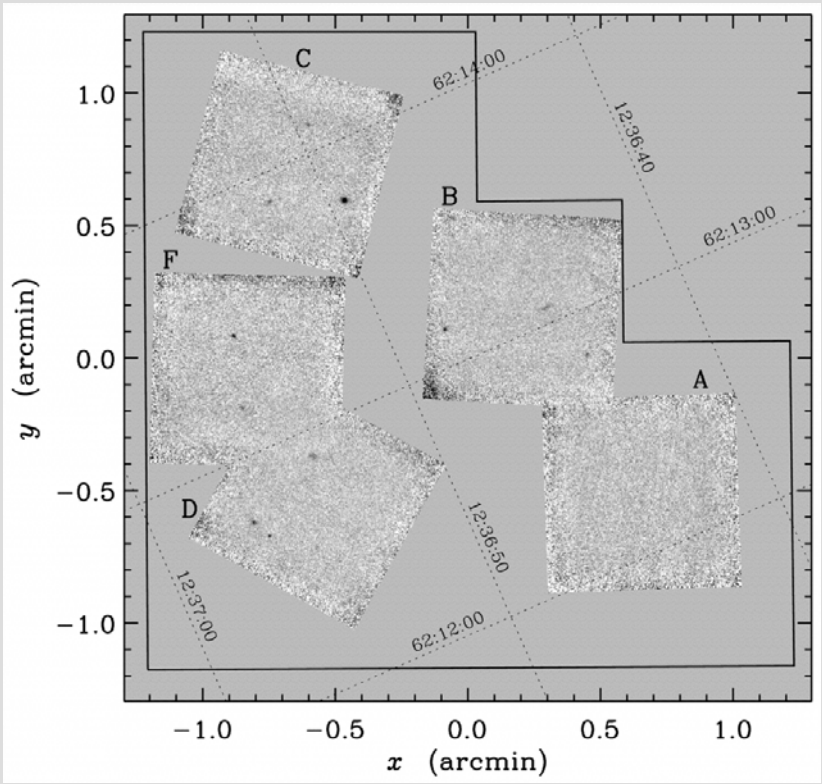


The IRAC Shallow Survey and the Spitzer Deep, Wide-Field Survey: ISS and SDWFS

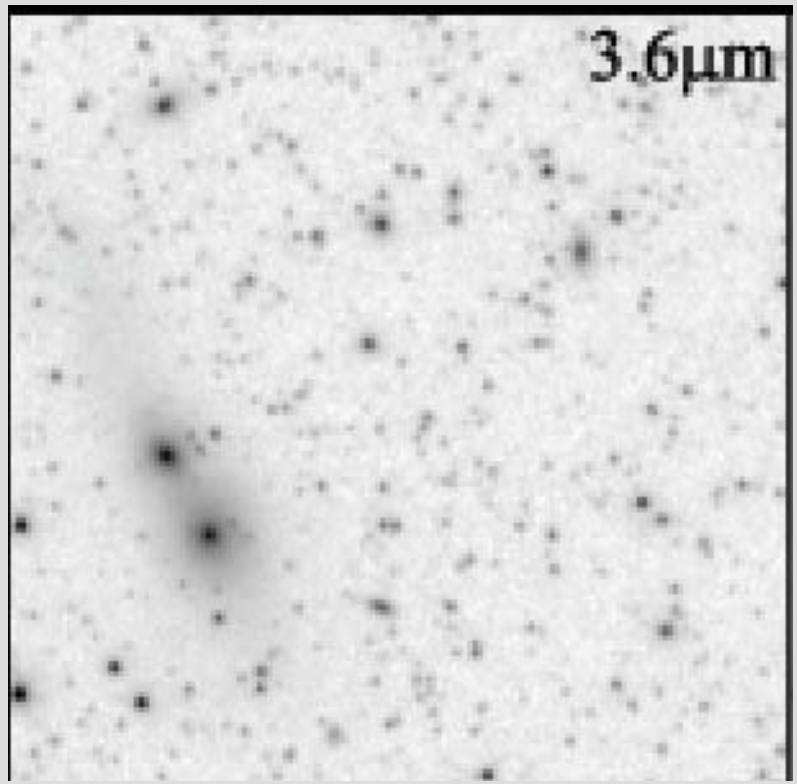
- Both ISS and SDWFS cover 8.5 sq degree in the NOAO DWFS field in Bootes
- Field selected because of low background, existing vis-NIR imaging, AGEs spectroscopy, etc. X-ray and Spitzer MIPS data also available
- ISS (2004) used 3x30s integrations in all four IRAC bands
- SDWFS (2007-8) re-imaged the field 3x between 8/2007 and 3/2008 – doubling [at least] the survey depth and facilitating searches for variability, proper motion, etc.

	Sensitivity (5-sigma), uJy				Number of Sources			
Band,um	3.6	4.5	5.8	8	3.6	4.5	5.8	8
ISS	**6.4**	**8.8**	**51**	**50**	**370K**	**280K**	**38K**	**34K**
SDWFS	**2.9**	**4.8**	**24**	**23**	**680K**	**525K**	**120K**	**100K**

A Giant Leap Forward….

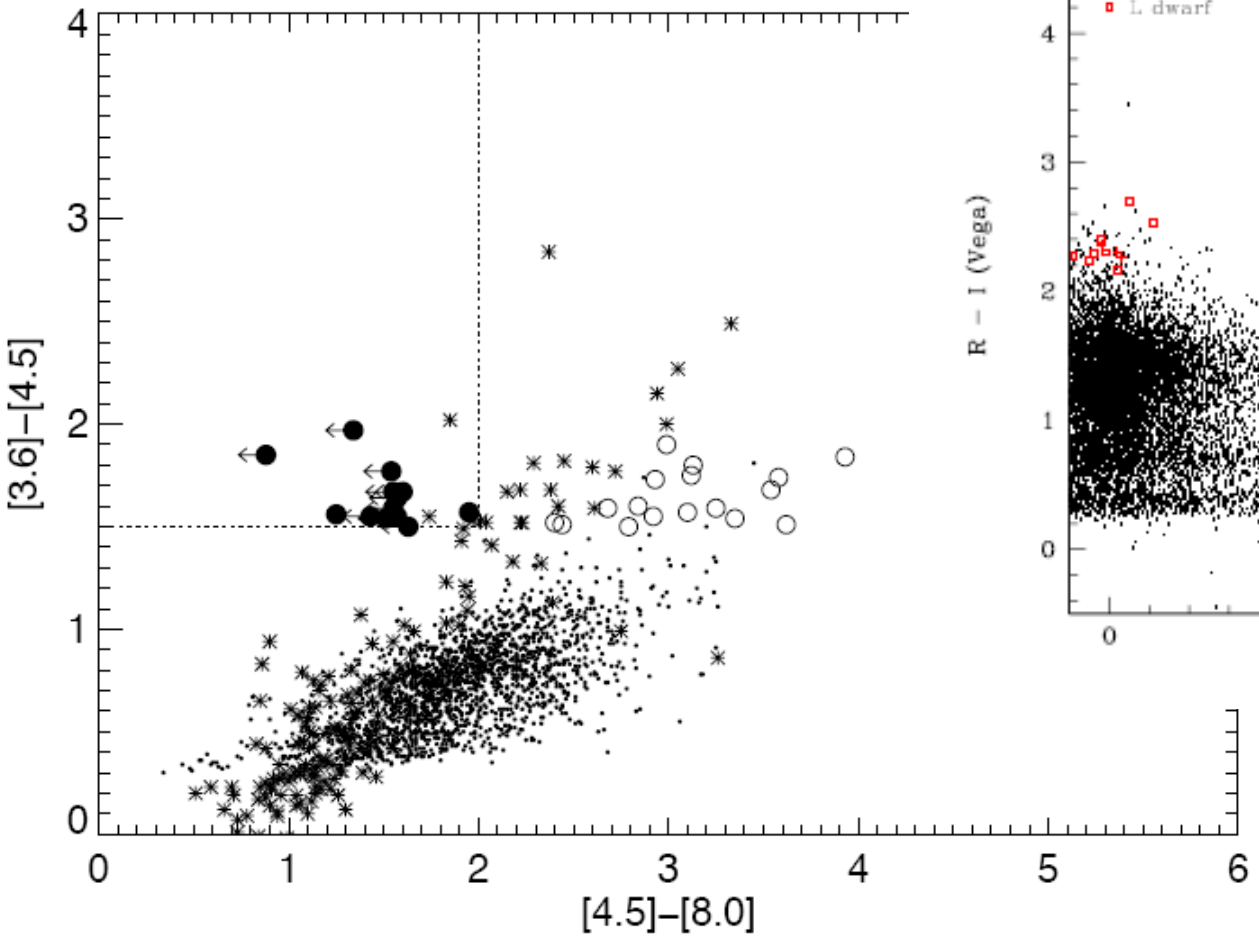


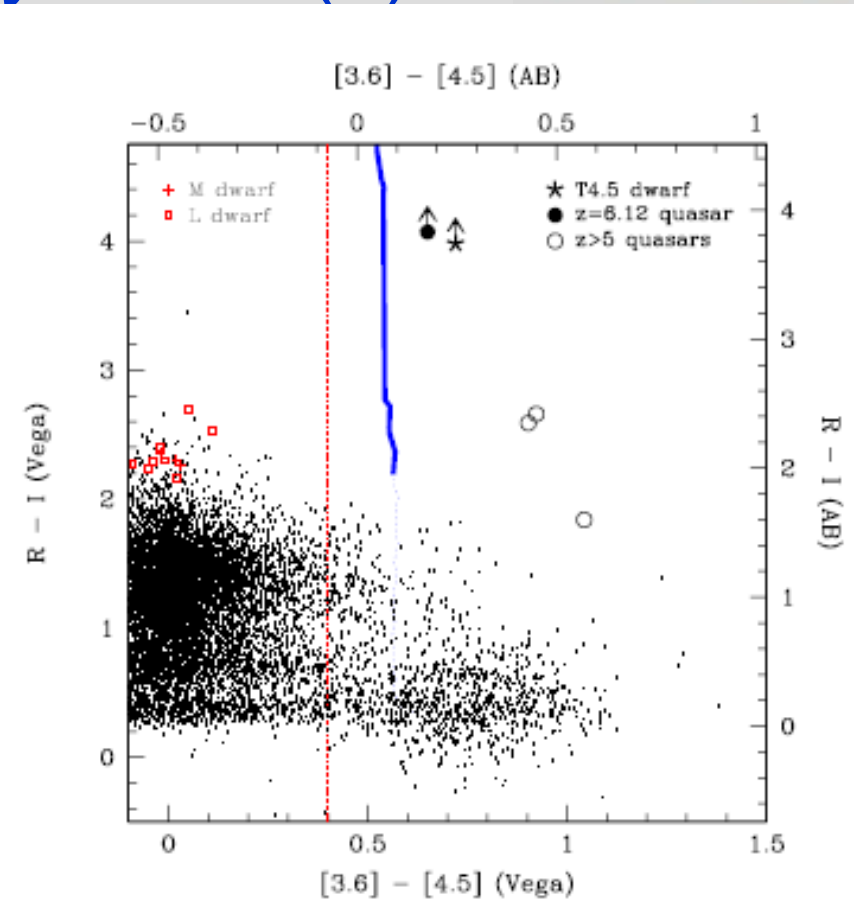
Hogg et al. (2000; AJ, 119, 1519) 3.2μm >2.5 hr exposure exposure / field – deepest published ground-based image at this wavelength - 5σ depth 2.7×10^{-5} Jy



Ashby et al [ApJ, in press]. 5x5 arcmin SDWFS thumbnail. 6 minutes integration – 5σ depth 3×10^{-6} Jy

Needles in Haystacks (1)

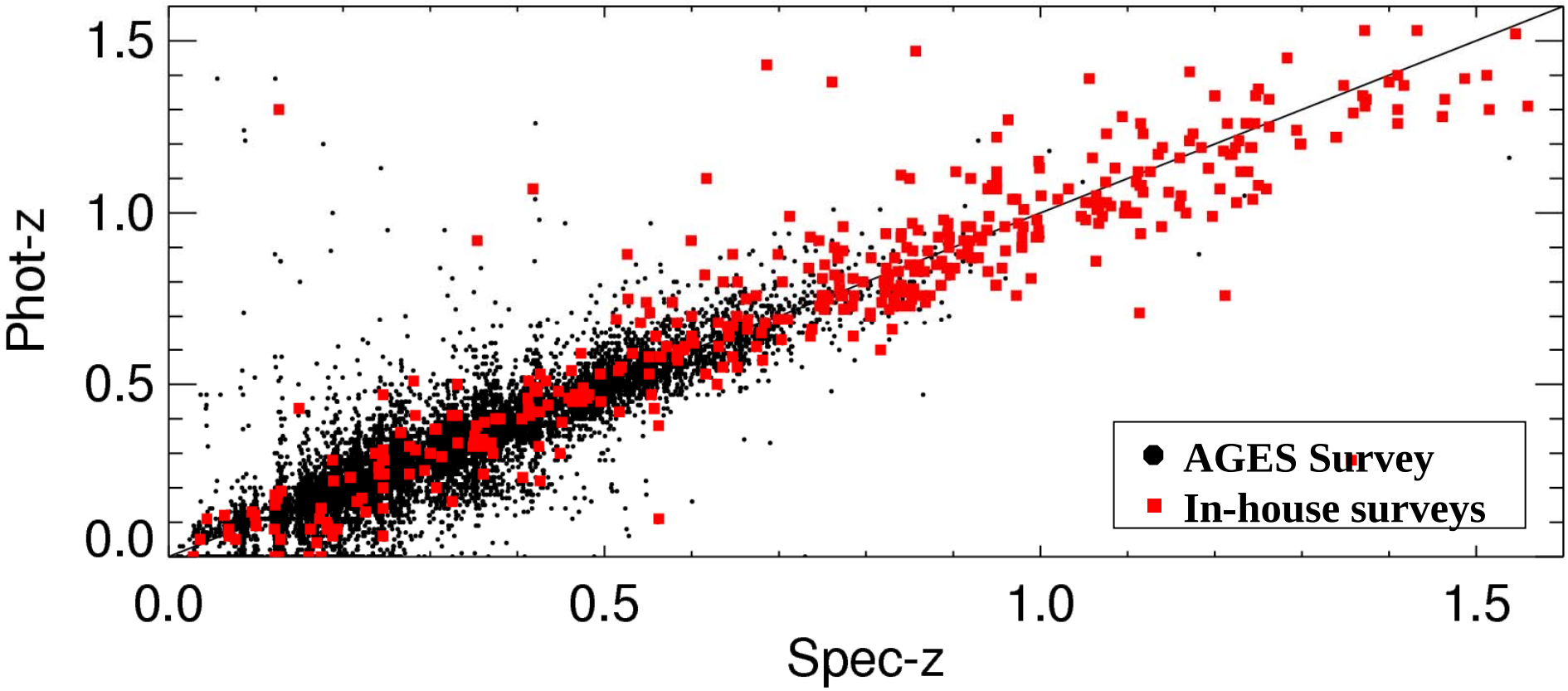




Color-color plots

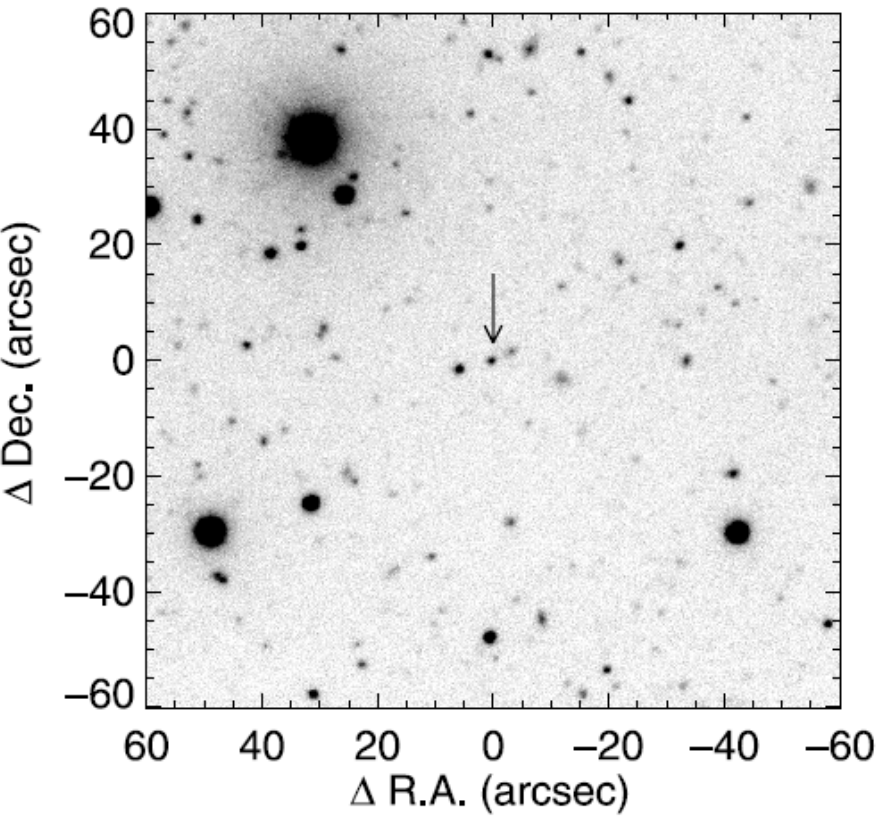
Needles in Haystacks (2)

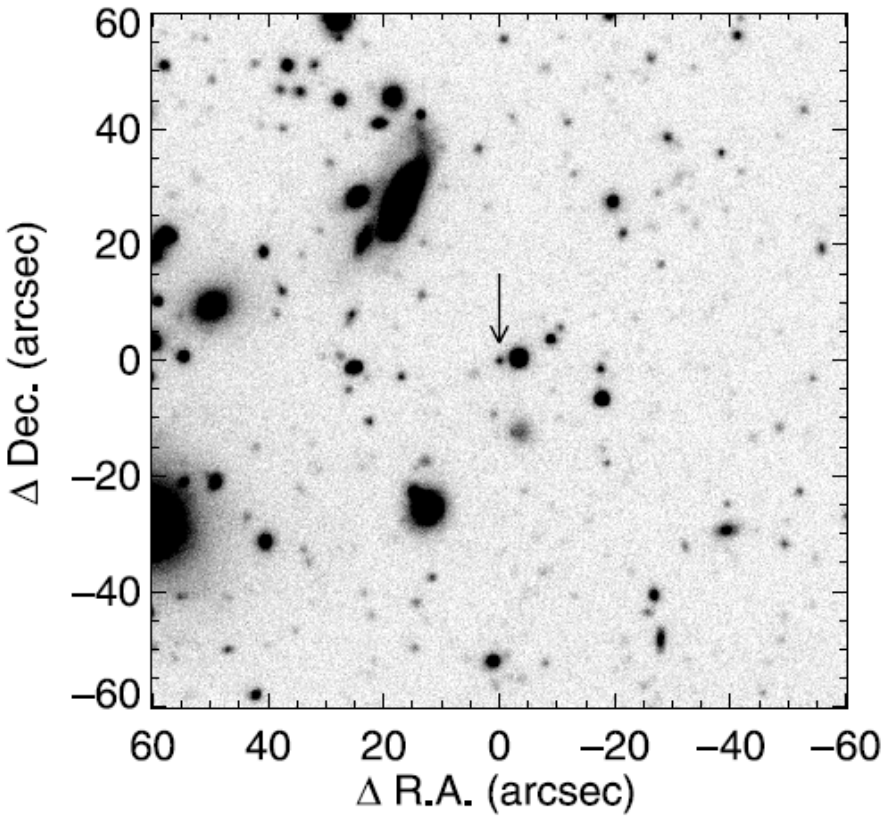
(σ = 0.101; σ /(1+z) = 0.059)



Photometric Redshifts (Brodwin et al)

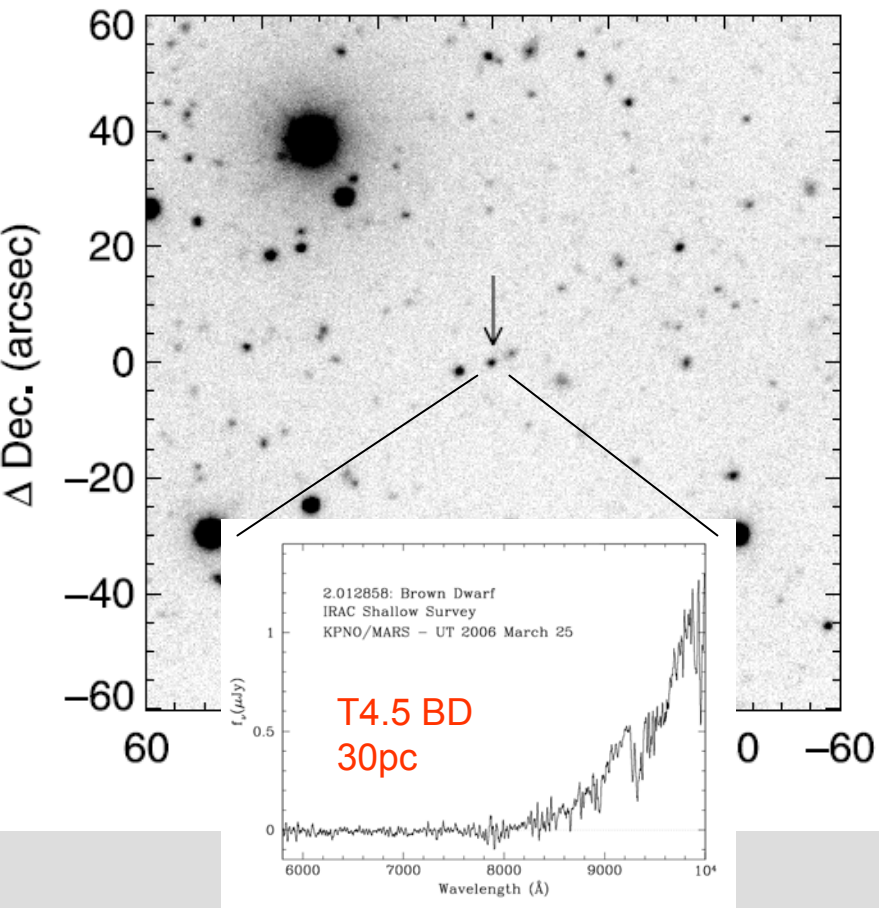
Needles in Haystacks (3)

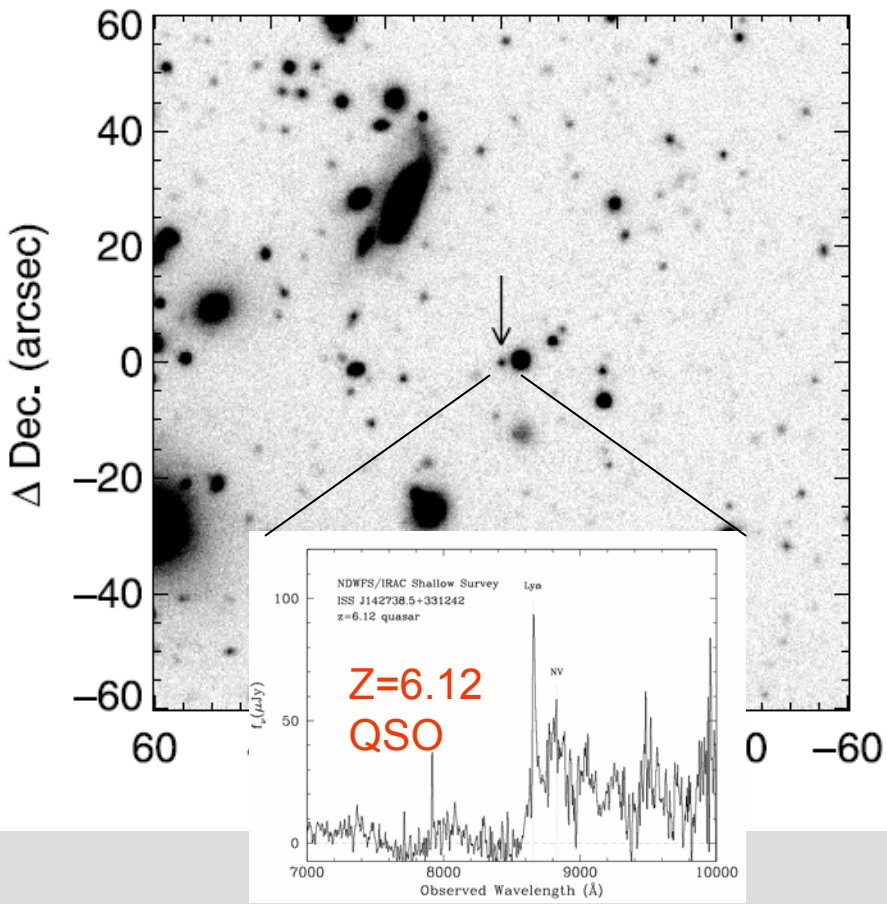




Spectra – Which Twin has the Toni? (Stern et al)

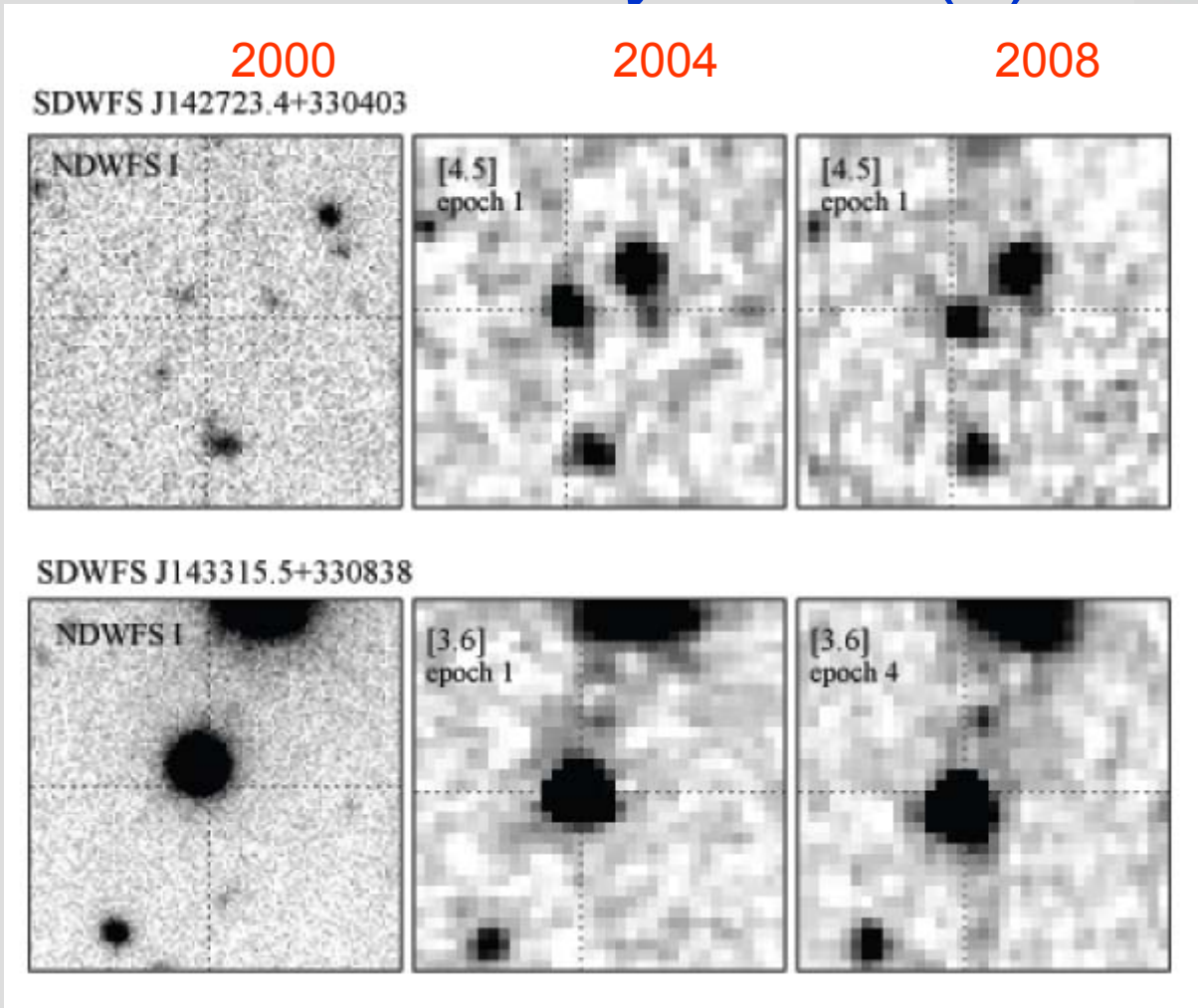
Needles in Haystacks (3)





Spectra – Which Twin has the Toni? (Stern et al)

Needles in Haystacks (4)



Proper Motions – Ashby et al (in press). These stars have proper motions of about 0.35 arcsec/yr. The upper is identified as a T7 brown dwarf; the lower as an M5 star.

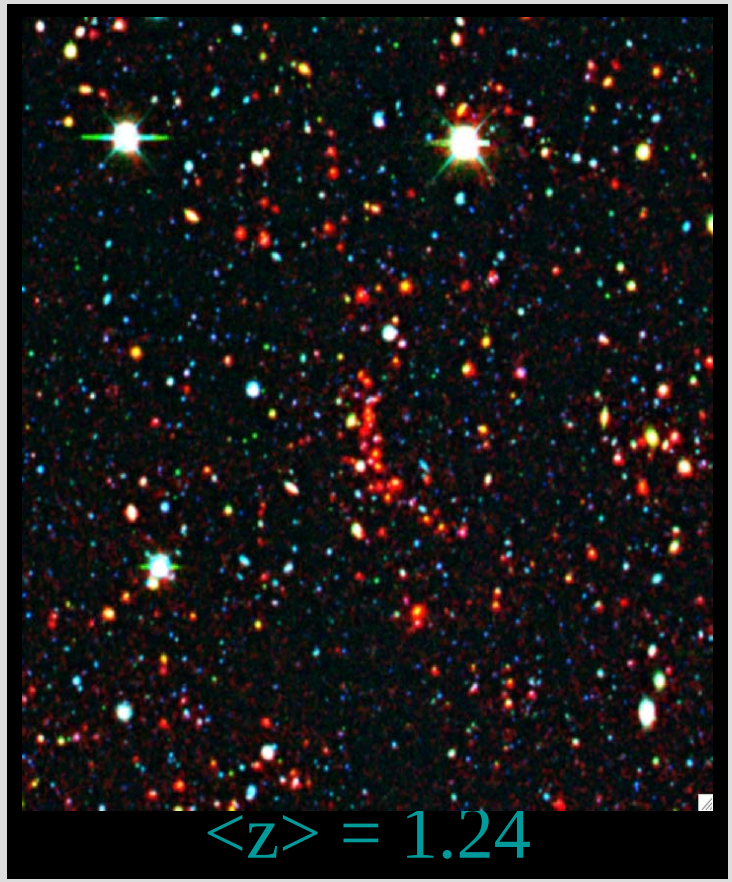
ISS Cluster Survey – Eisenhardt et al (ApJ, 2008)

- Summary of main results
  - Identified 335 galaxy cluster and group candidates from 4.5um selected sample
    - 106 have z>1 (12 confirmed spectroscopically)
      - Two have masses > 10^14 solar masses
    - 61 of 73 @ z<0.5 confirmed spectroscopically
    - For clusters with z<1, colors well fit by passive evolution from “spike” of star formation at z~3 or earlir
    - Higher redshift clusters suggest higher redshift of formation
  - Addition of SDWFS data will increase sample size and known members/cluster and push to higher z [most distant now is z=1.413]

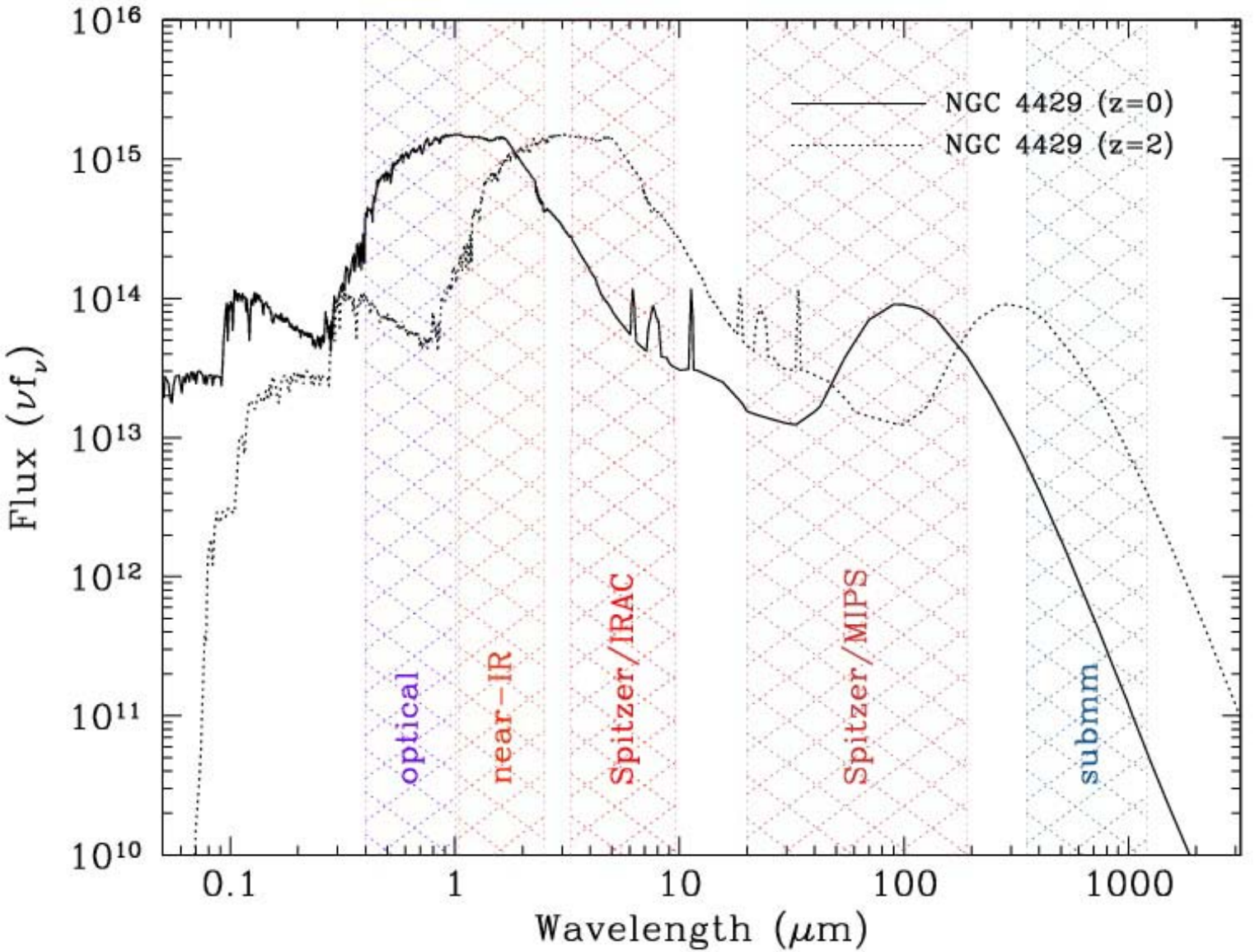
Searching for Distant Clusters of Galaxies

Observations shortward of 1um

With Spitzer 4.5um band added

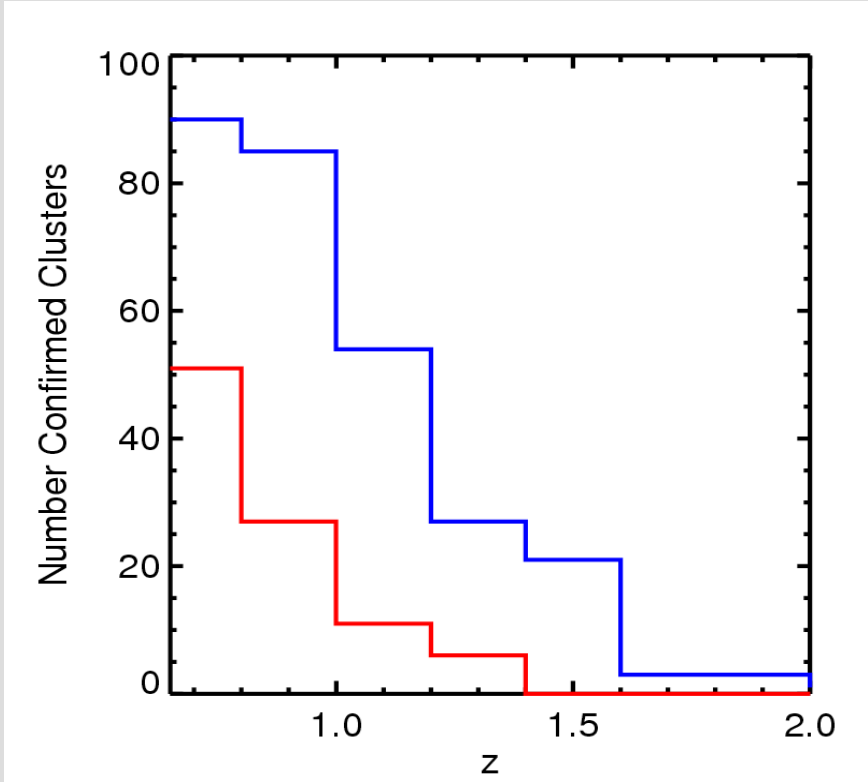


The Redshift at Work



ISS Clusters – A Revolution

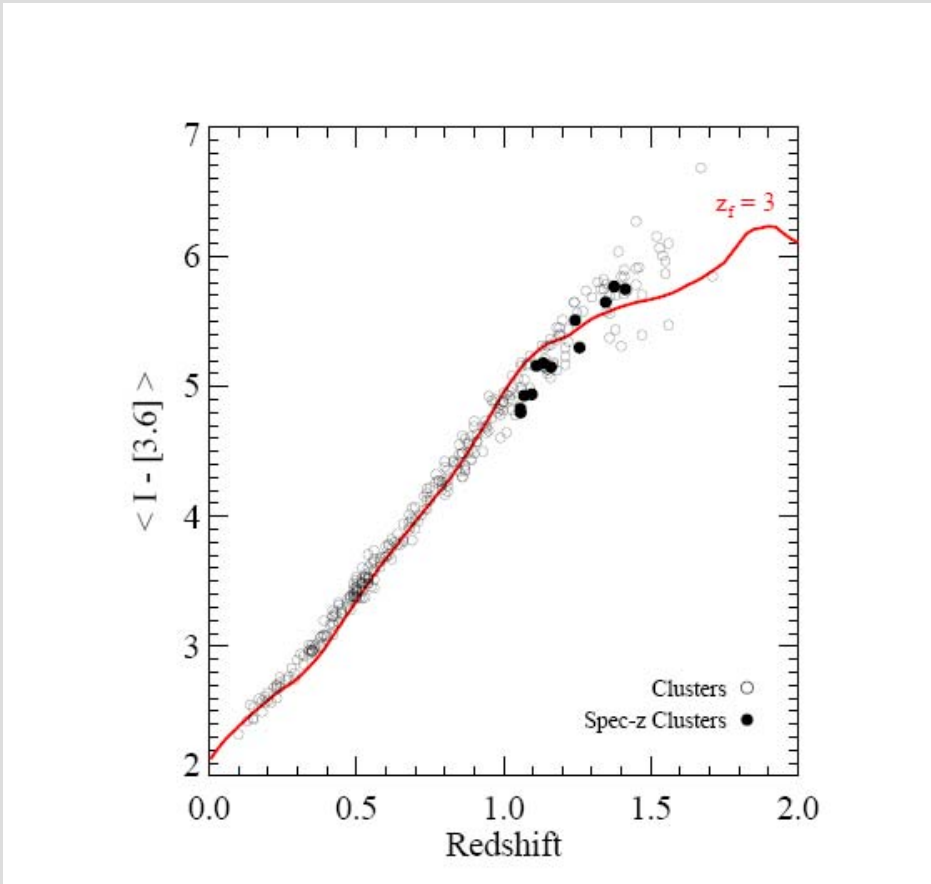
Clusters discovered in Bootes field greatly increase the number of known high redshift clusters [from red to blue].

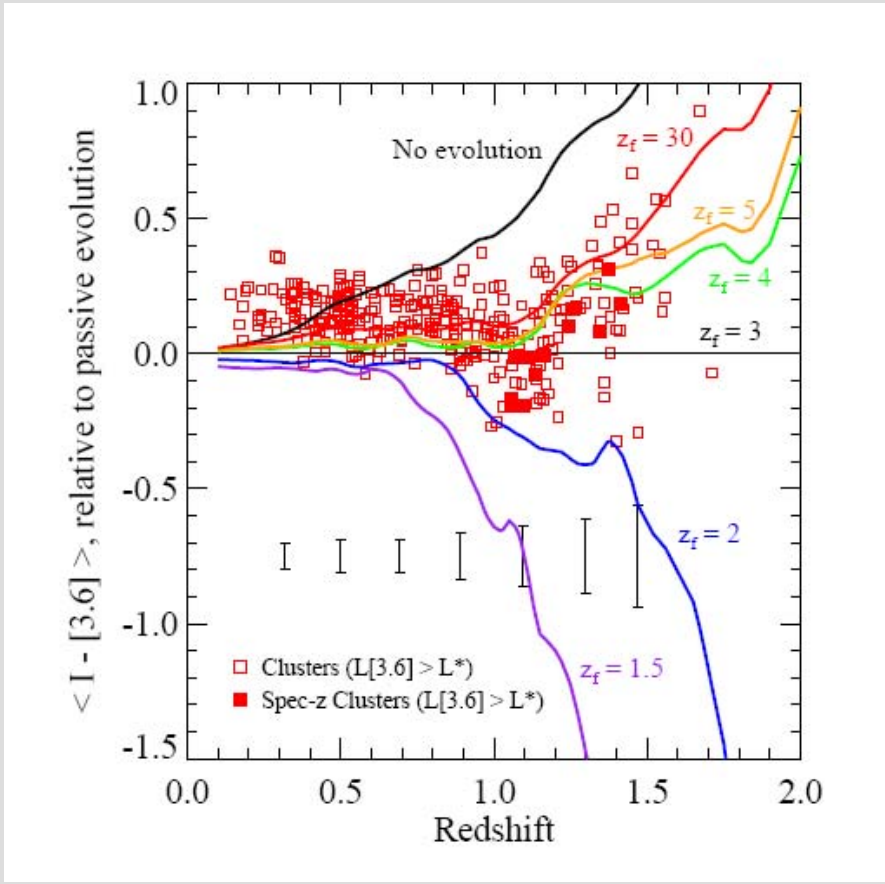


Potential Applications Include:

- Comparison of Galaxy Cluster Correlation Function with Predictions of Cosmological Models (Brodwin et al)
- Studies of Evolution of Cluster Galaxies
- Identification of z>1 Supernovae in Dust-Poor Galaxies

"Red Spike" Model Describes Star Formation History of the Clusters

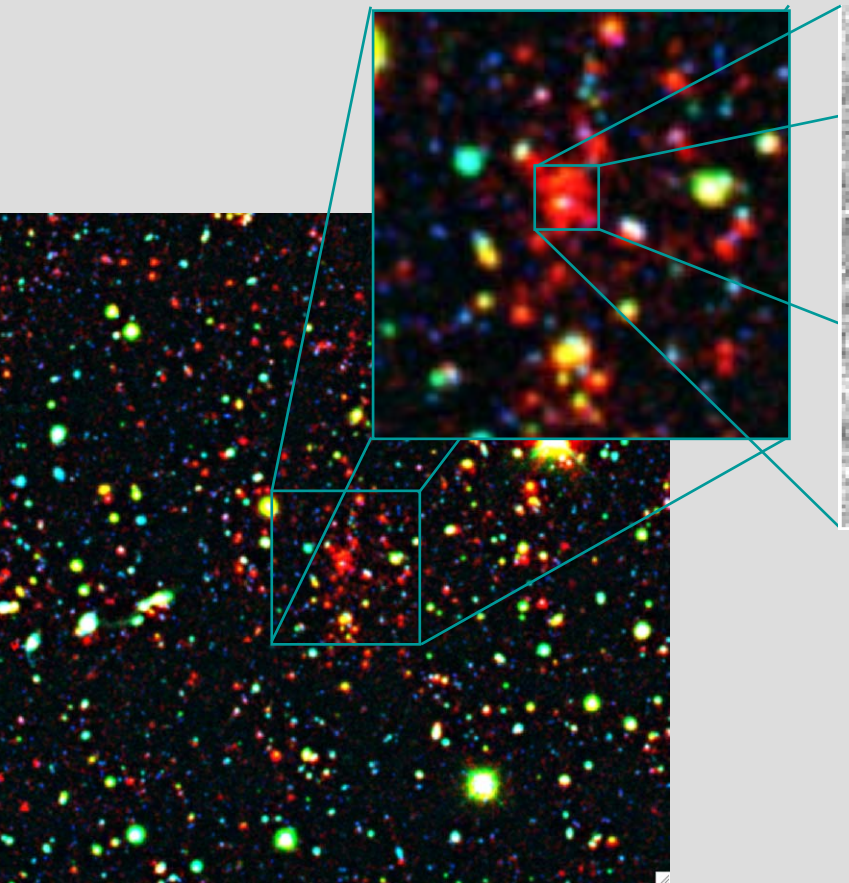


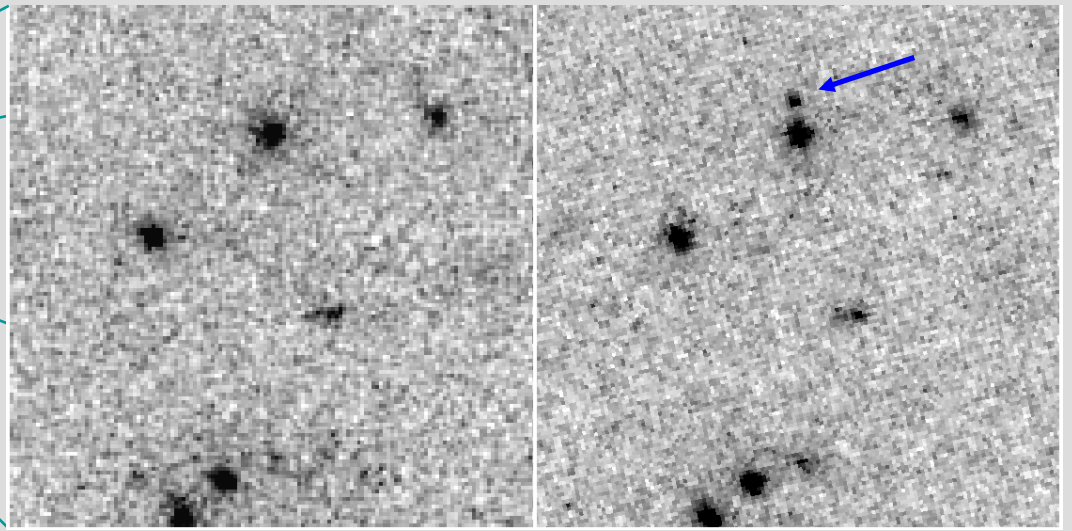


Mean Galaxy Color vs. Cluster Redshift is shown on the left. On the right, the same data are plotted relative to colors of z=3 red spike model

Hubble Searches for Supernovae in the Clusters Found by Spitzer

Studies of supernovae within galaxies in distant clusters should increase our understanding of the Dark Energy which is accelerating the expansion of the Universe

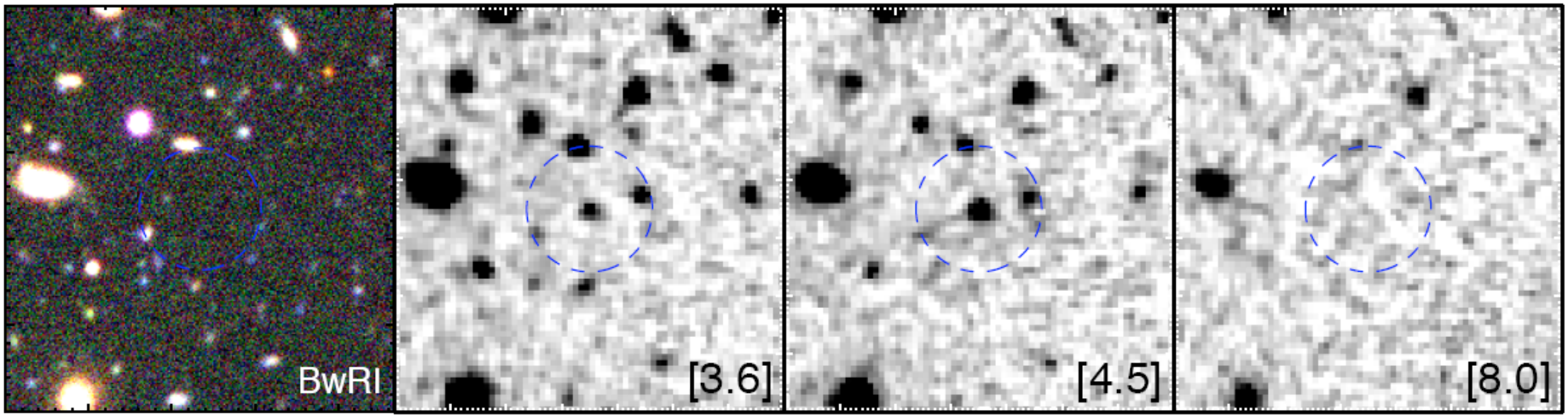




Reference Image **Discovery Image**

Discovery by Hubble [above] of a supernova in a distant cluster identified by Spitzer [left]

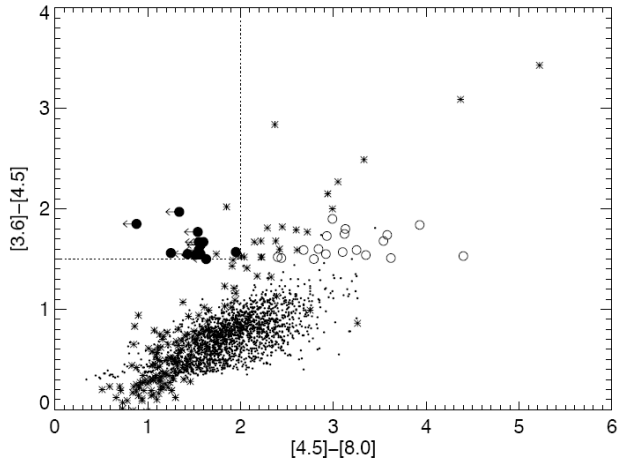
Late-T Brown Dwarfs in SDWFS – Early Returns (Eisenhardt et al, in press)



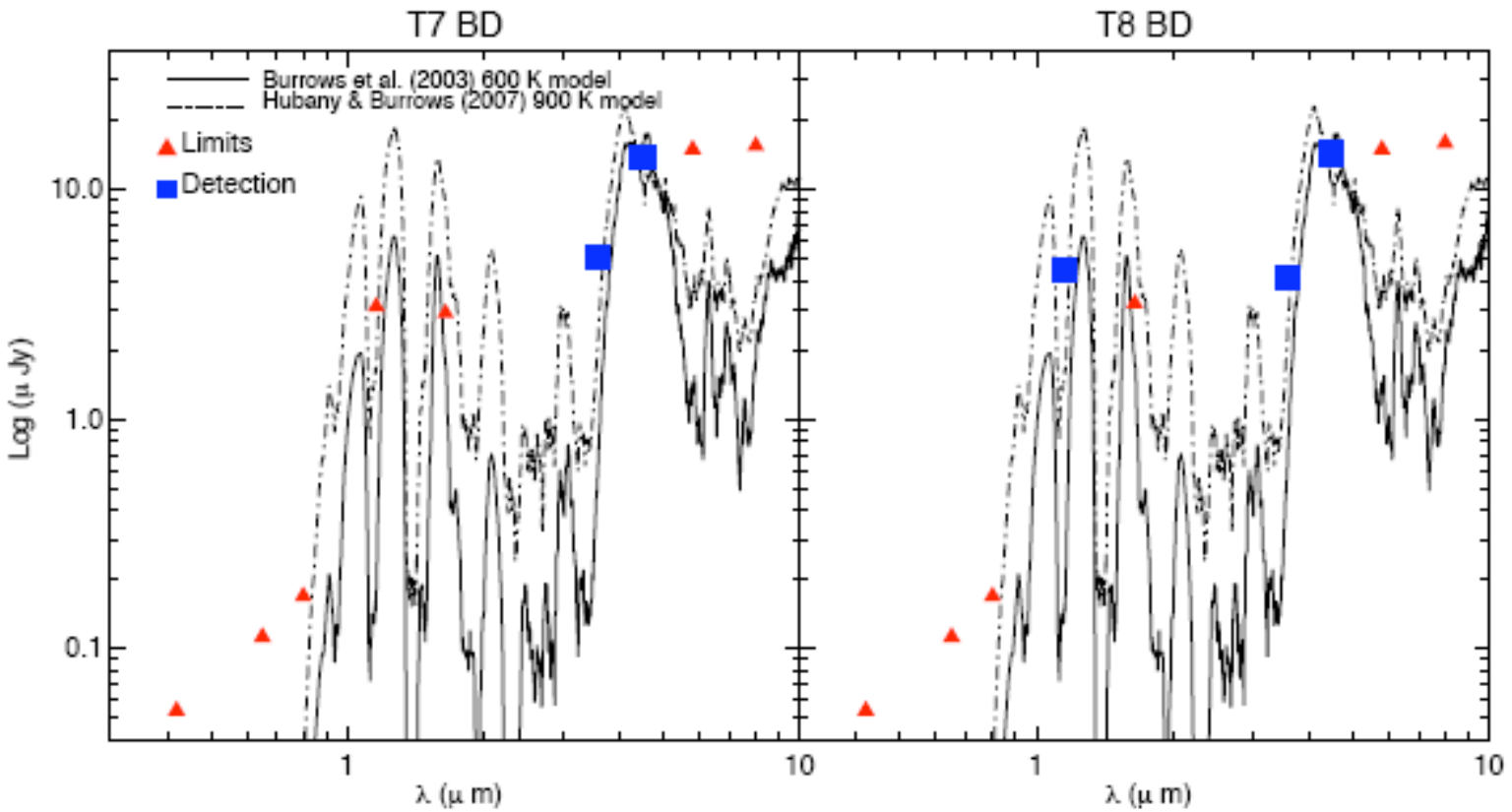
Color Selection [right] identifies candidate objects which are red between 3.6 and 4.5um, and faint in the optical and at 8um [above].

13 such objects are identified in the SDWFS data base

Implications for WISE to be discussed by Eisenhardt



Spectral classification adds Near IR to SDWFS data
Eisenhardt et al, in press



Success!

(George Rieke received medal, missed lunch)

Future Attractions

- Spitzer Warm Mission – Features IRAC Bands 1 & 2
  - Spitzer helium exhausted Friday 15 May
  - Check out and characterization of warm IRAC underway
  - Expect to start science observations in July
    - Approved for two years – then another senior review
    - Large programs and one year of small programs selected
    - Large programs to be presented at June AAS meeting in Pasadena
    - Next call will be Feb.-Mar. 2010
- Spitzer Science Symposium #6:
  - "Reionization to Exoplanets: Spitzer's Growing Legacy" October 26-28 2009, Hilton Hotel, Pasadena CA
    - http://ssc.spitzer.caltech.edu/mtgs/spitzer2009
    - Registration now open