The Importance of Spectroscopic Redshifts for Next-Generation Radio Surveys

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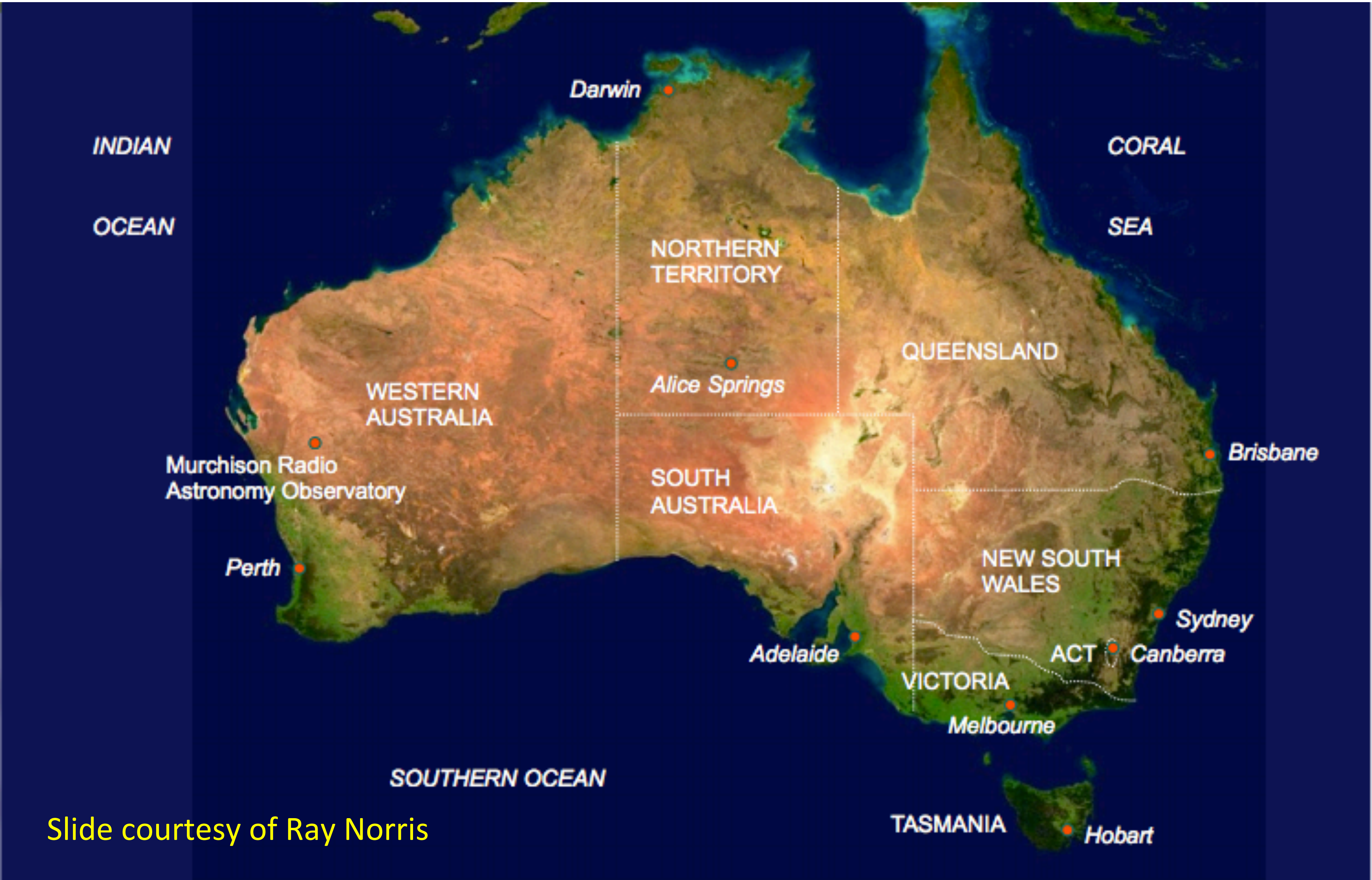
Andrew Hopkins (AAO)

Once upon a time in a land down under…



Slide courtesy of Ray Norris

ASKAP was built in the Shire of Murchison…

Slide courtesy of Ray Norris

Murchison is bigger than the Netherlands

Slide courtesy of Ray Norris

ASKAP: Australia SKA Pathfinder

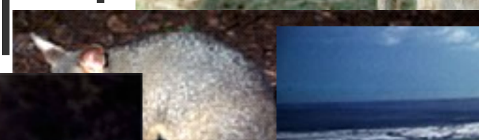
- A$170M
- 36 * 12m dishes
- 6km max baseline
- 192-pixel phased array feed (PAF)
- Location:

  middle of nowhere!

Image: Alex Cherney ©2012

ASKAP surve

- EMU - radio contin
- WALLABY - HI “al
- POSSUM - pol



- DING
  GAM

- VAST
- FLASH - HI ab

Slide courtesy of Andrew Hopkins

EMU:
Evolutionary Map of the Universe

- How have galaxies formed and evolved with cosmic time? (Norris et al. 2011)
- PI:
  - Ray Norris (CSIRO-ATNF)
- Project Scientists:
  - Andrew Hopkins (AAO)
  - Nick Seymour (CSIRO-ATNF)

EMU: Quick Look

- Frequency Range: 1130 – 1430 MHz
- Sensitivity: 10 uJy/beam
- Resolution: 10 arcsec FWHM
- Area: Entire sky south of +30 dec
- Instantaneous FOV: 30 sq deg

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- Instantaneous FOV: **30 sq deg** (yes you read that right!)

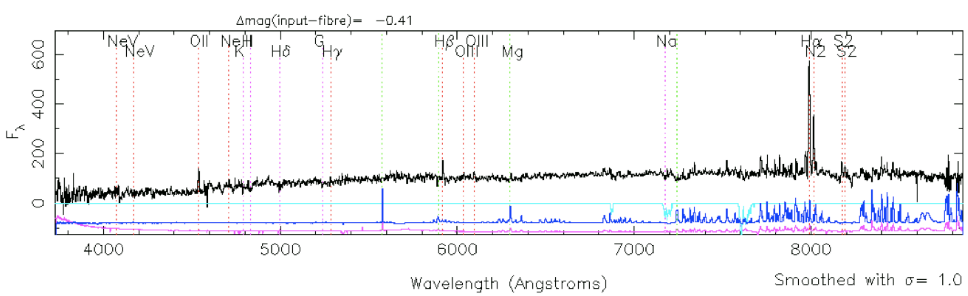
EMU: Quick Look

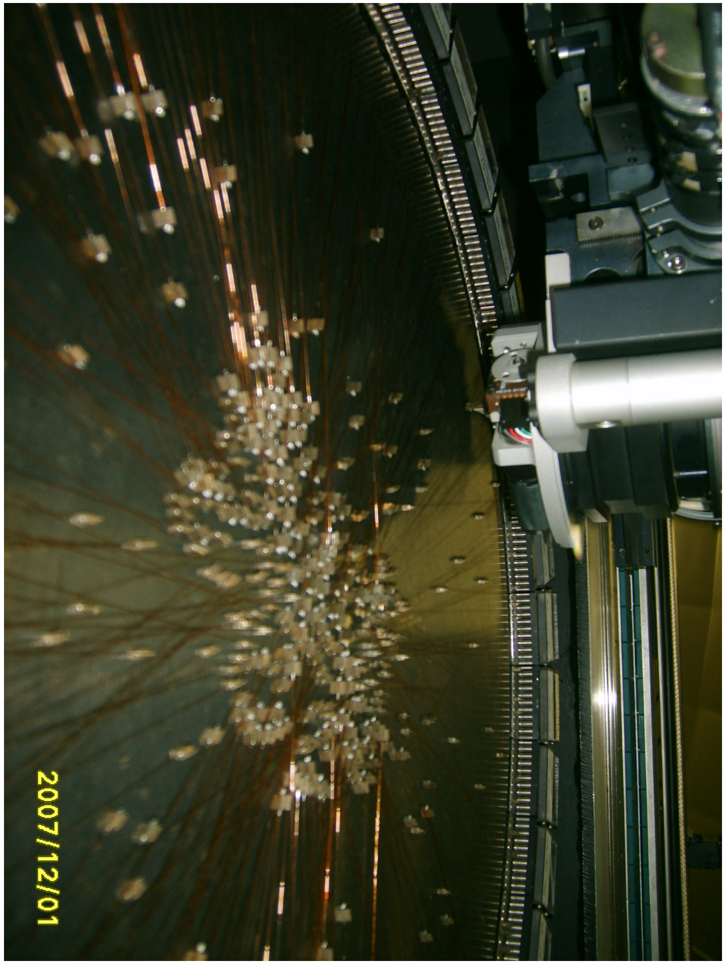
- Total integration time: ~1.5 years
- Number of Sources: ~70 million

- We need redshift information to study the evolution of these 70 million radio sources!

Spectroscopic redshifts

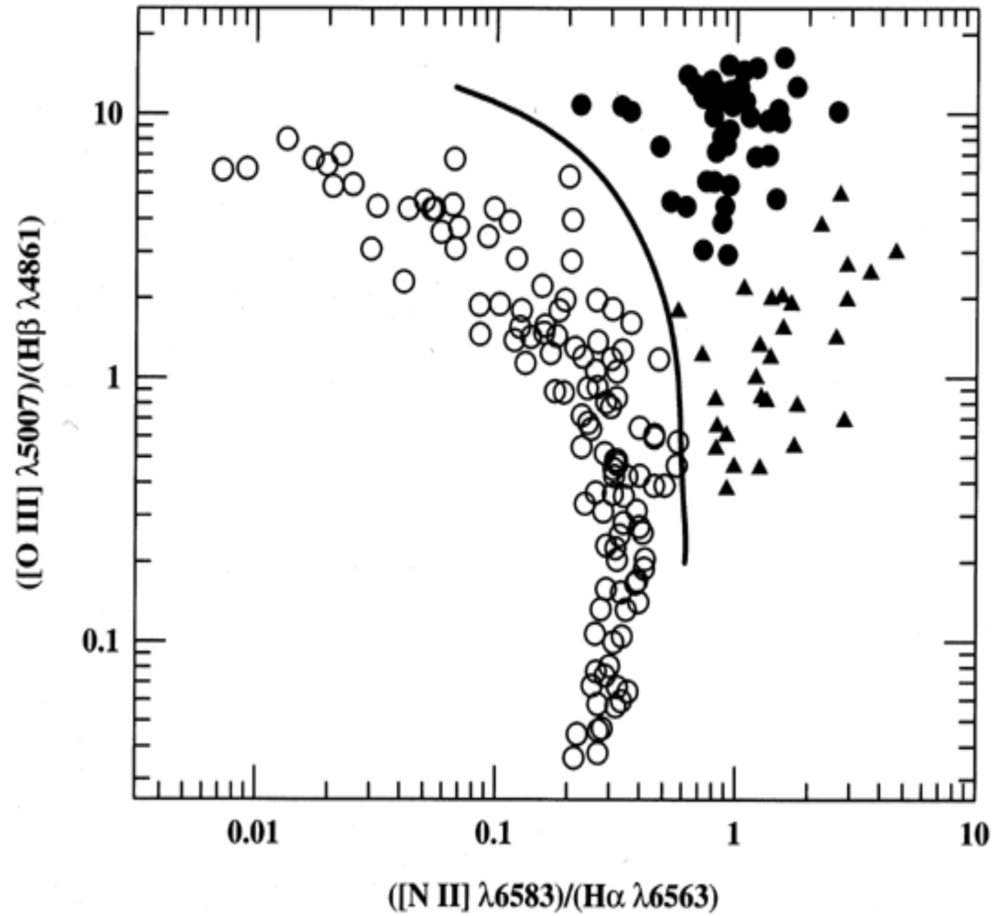
- Spectrographs can measure the redshift of a galaxy
- note: marked slower than photometric plates.





A wealth of data from galaxy spectra

- Accurate redshift determination
- High-resolution galaxy spectra allow unambiguous classification of star-forming galaxies and AGN
- Chemical composition of galaxy



BPT diagram (Baldwin et al. 1981) from Peterson book on AGN.

Let’s get 70 million spectroscopic redshifts!

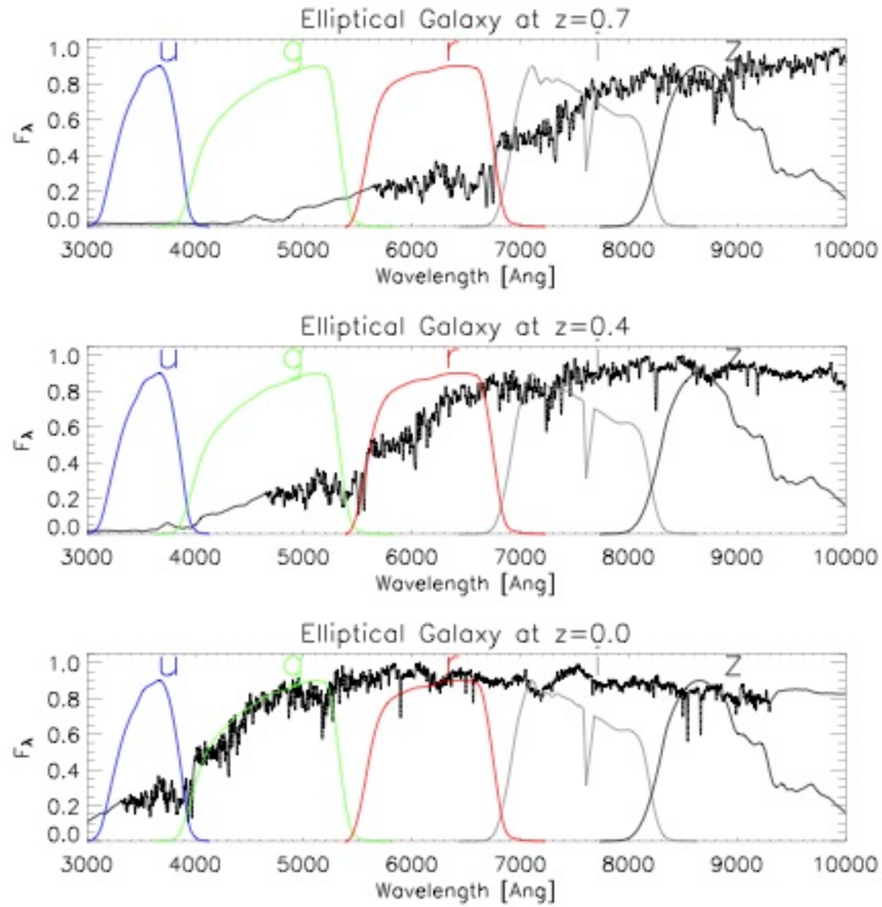
Let's get 70 million spectroscopic redshifts!

- **NO.** Sorry

- But there are workarounds
  - Photometric redshifts
  - Statistical redshifts

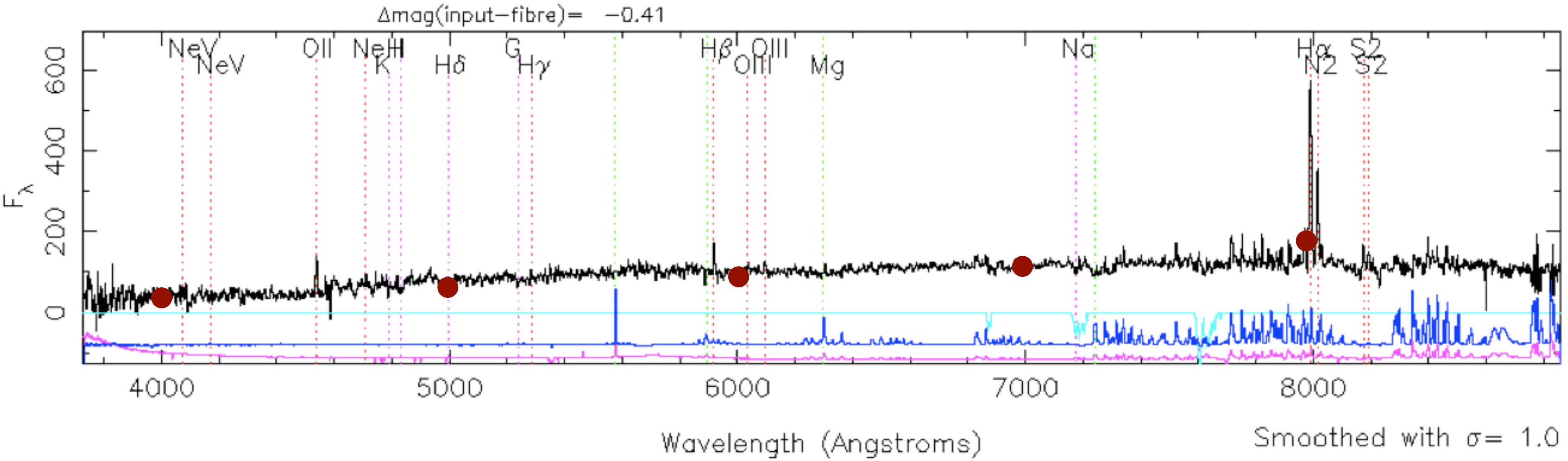
Photometric redshifts

- Fit the photometry to a set of template spectra
  - population synthesis models
  - observed SEDs of low-redshift galaxies
- ~Really low-resolution spectra



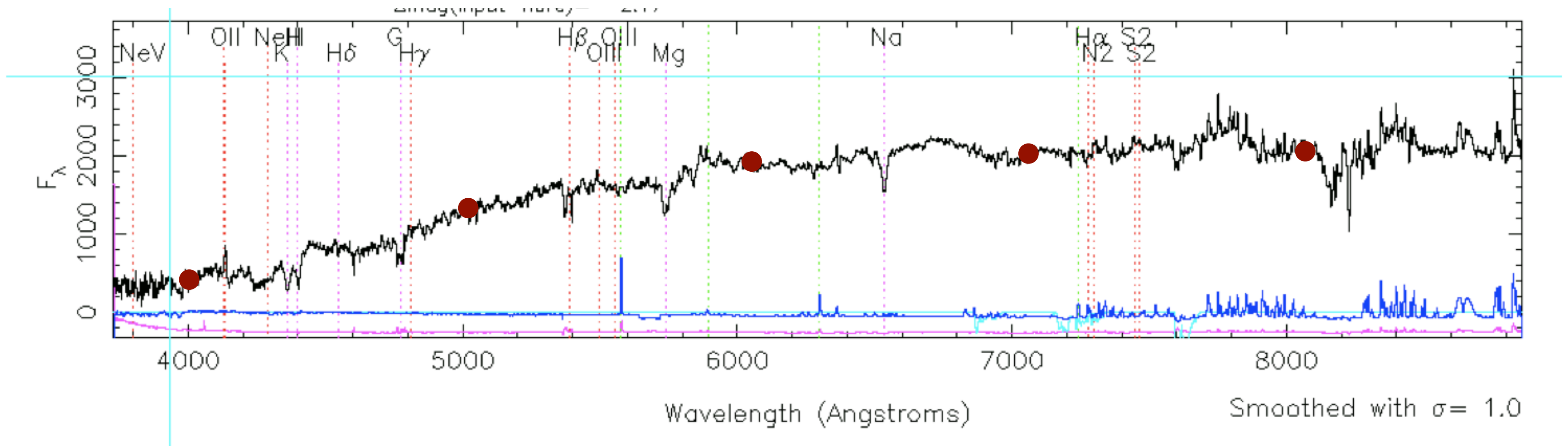
Padmanabhan (2007), this figure shows the way the spectrum of an elliptical galaxy moves through various photometric bands as it increases in redshift.

Star-forming galaxies



- Strong Balmer lines
- Forbidden lines including [OII], [OIII] and [NII]

Elliptical galaxies

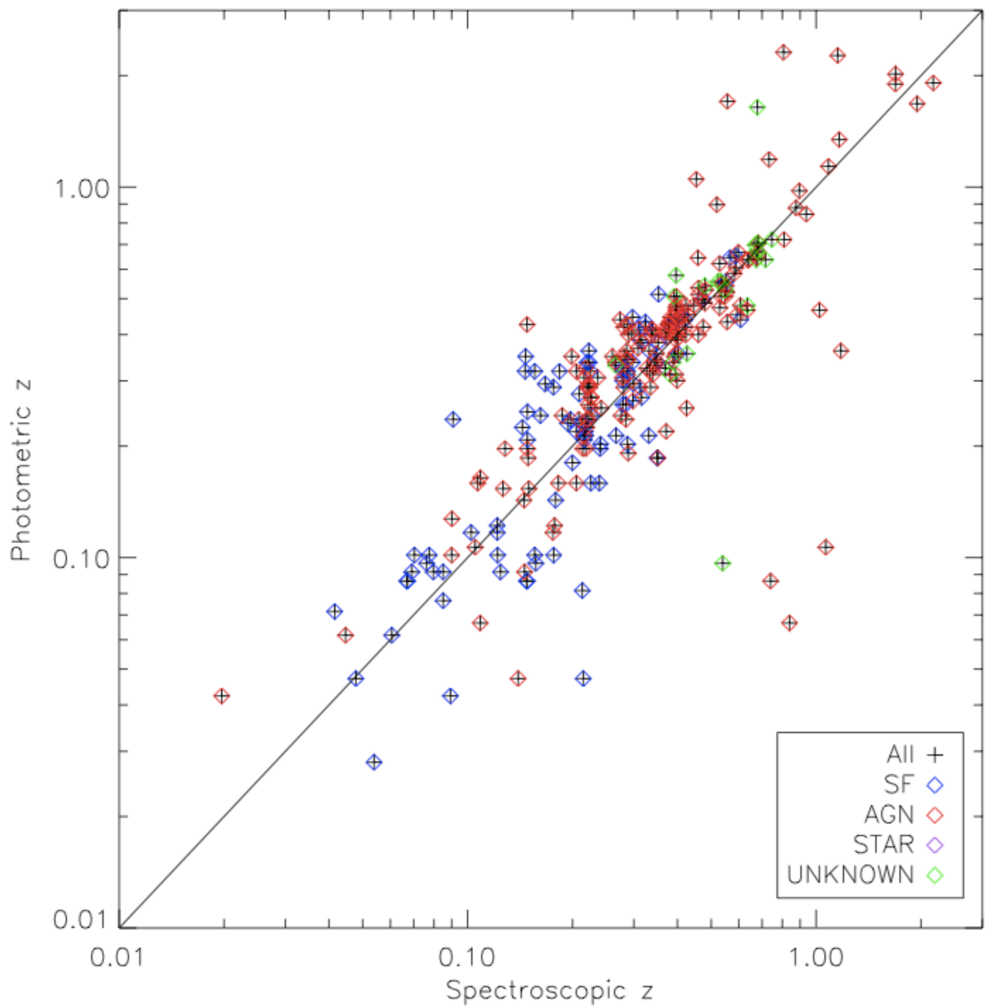


- Emission dominated by G & K stars
- The strong break at 4000Å is used to determine photometric redshifts

Problems with photo-z

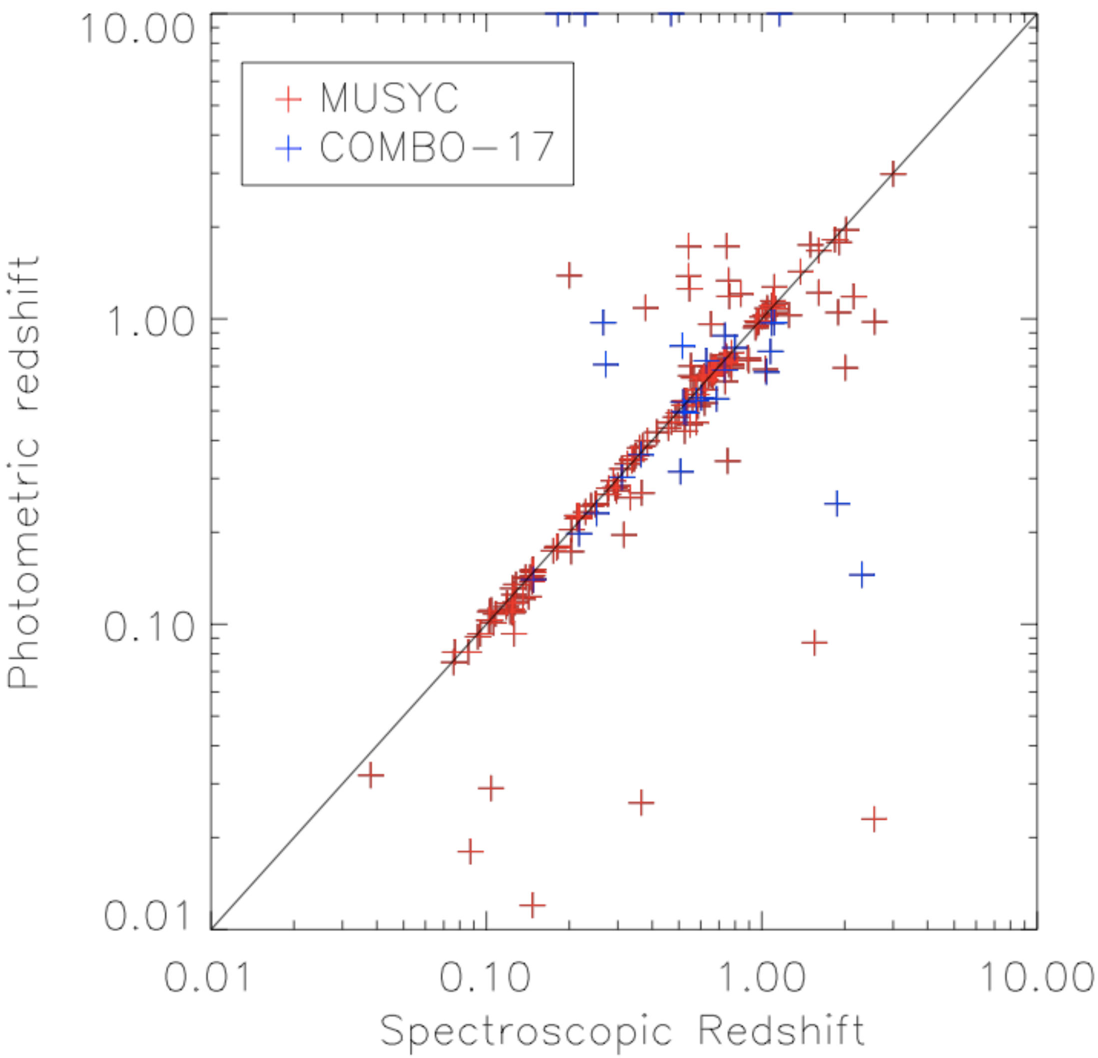
- Choice of template?
  - Galaxies evolve so templates constructed from low-z galaxies do not necessarily match very well at high-z
  - Using models makes it difficult to determine whether the models are good representations of real galaxies and the application of corrections (such as for dust) is difficult
- **Best results are obtained if large training sets derived from real galaxy spectra are used**
  - E.g. Salvato et al. (2009,2010) for the COSMOS survey
  - The training set must be analogous to the full dataset!
- Bell et al. (2009) note that using “state-of-the-art techniques”, typical errors on photometric redshifts using spectroscopic training sets quite small for red galaxies with strong 4000A breaks, but are larger for blue galaxies, which have featureless spectra dominated by emission lines that vary strongly from object to object
- Furthermore, EMU is a *radio* survey comprising a larger fraction of “odd” objects

ATLAS: Spec z vs. Phot z

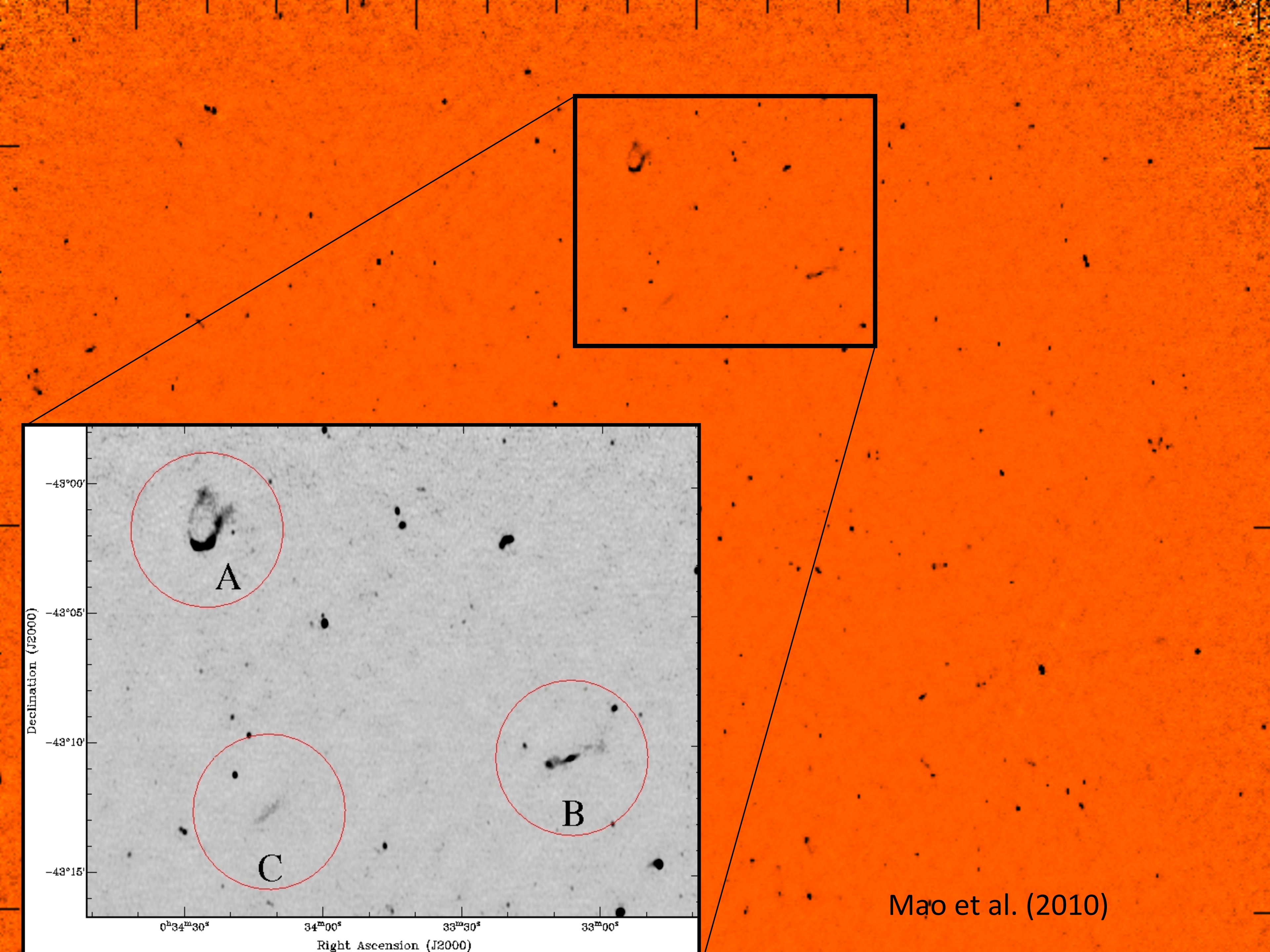


- ATLAS: Australia Telescope Large Area Survey (Norris et al. 2006, Middelberg et al. 2008)
- Photo-z from Rowan-Robinson et al. (2008)
- 5 optical bands and 2 IR bands
- Broad agreement but basically a scatter plot at z>1

ECDFS: Spec z vs. Phot z

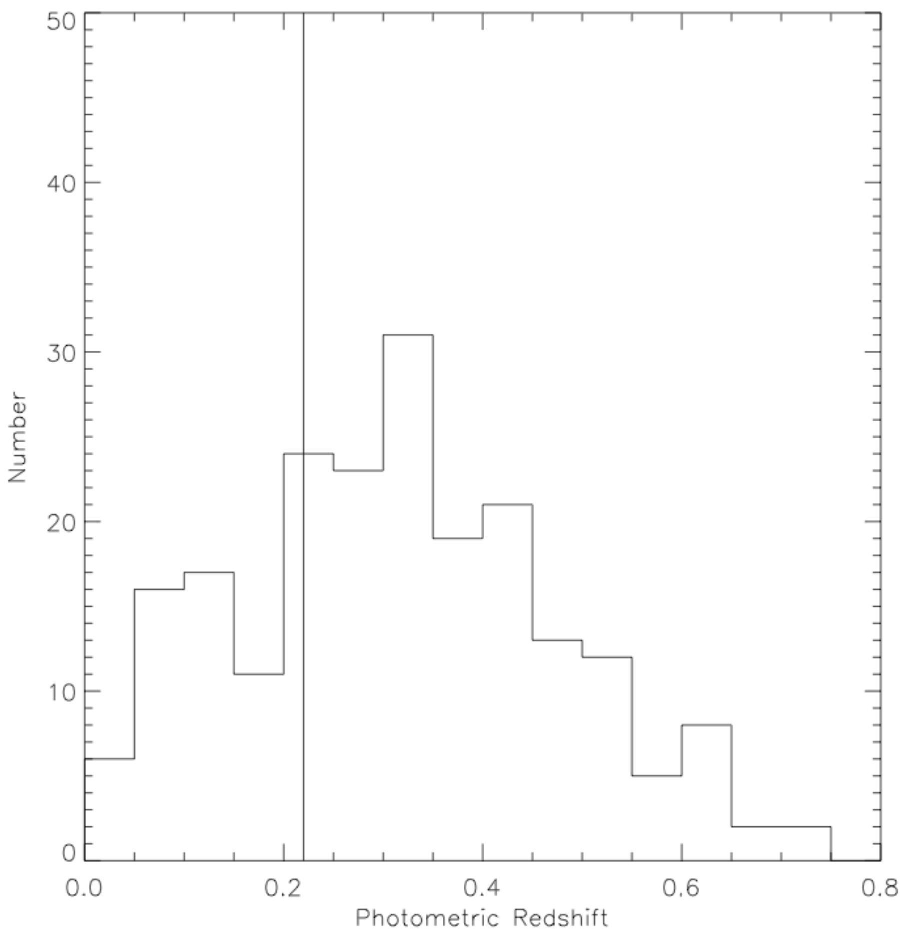


- Phot-z from MUSYC survey (Cardomone et al. 2010) and COMBO-17 (Wolf et al. 2004)
- COMBO-17 uses 17 bands to derive phot-zs
- MUSYC uses 32 bands to derive photo-zs
- These are among the best photometric surveys conducted to date!
- Good agreement but still basically a scatter plot at z>1
- (The mean z of EMU sources will be z ~ 1 for SF sources and z~1.9 for AGNs)



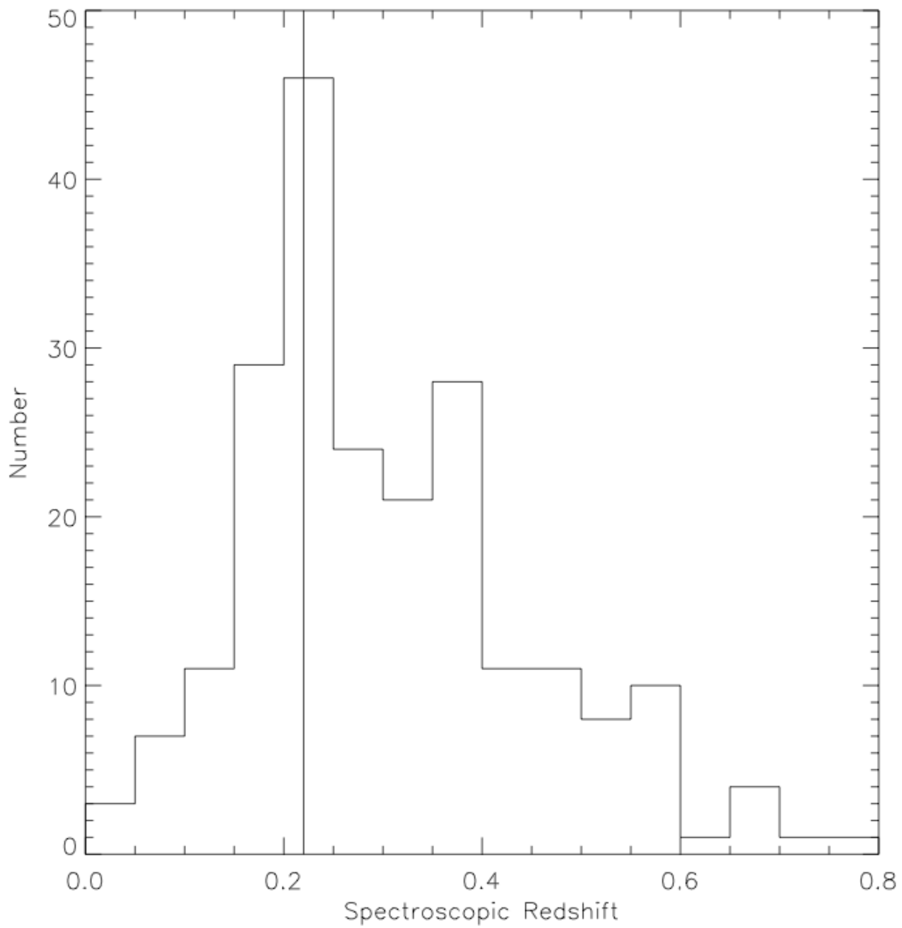
-43°00'
-43°05'
-43°10'
-43°15'
Declination (J2000)
0h34m30s
34m00s
33m30s
33m00s
Right Ascension (J2000)
A
B
C
Mao et al. (2010)

Spectroscopic vs. Photometric



- Binsize z=0.05
- Photometric redshifts from Rowan-Robinson (2008)
- Spectroscopic redshifts from our AAOmega observations

Spectroscopic vs. Photometric



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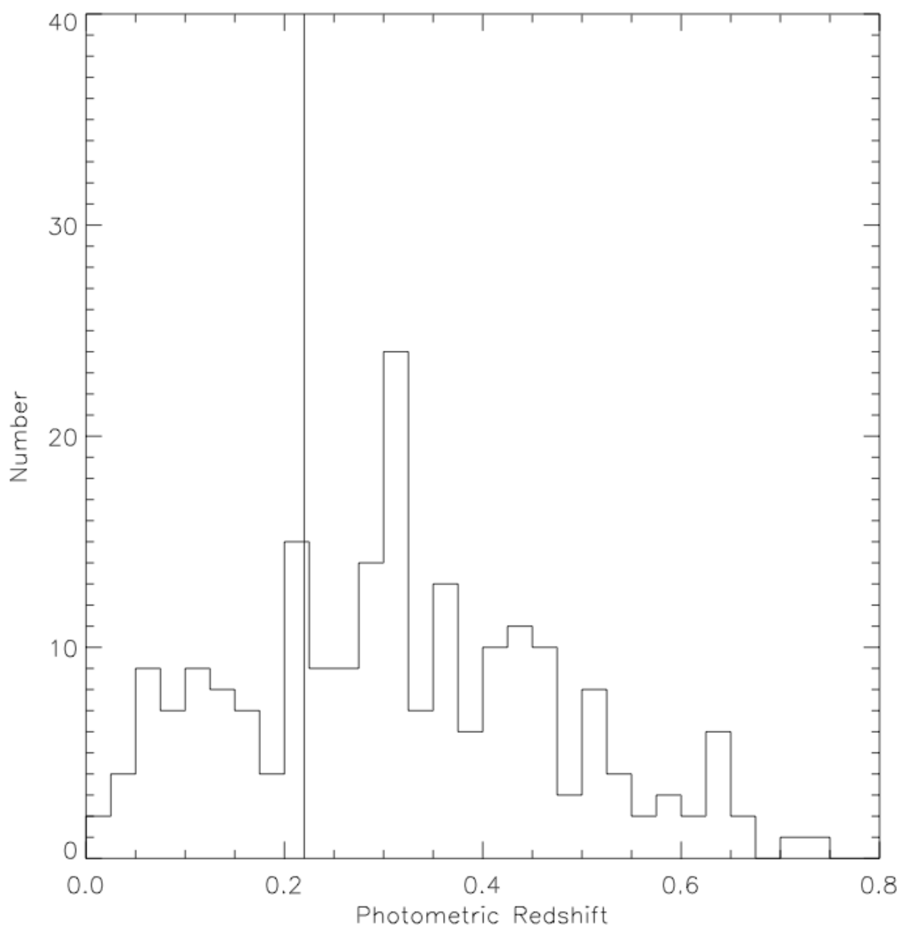
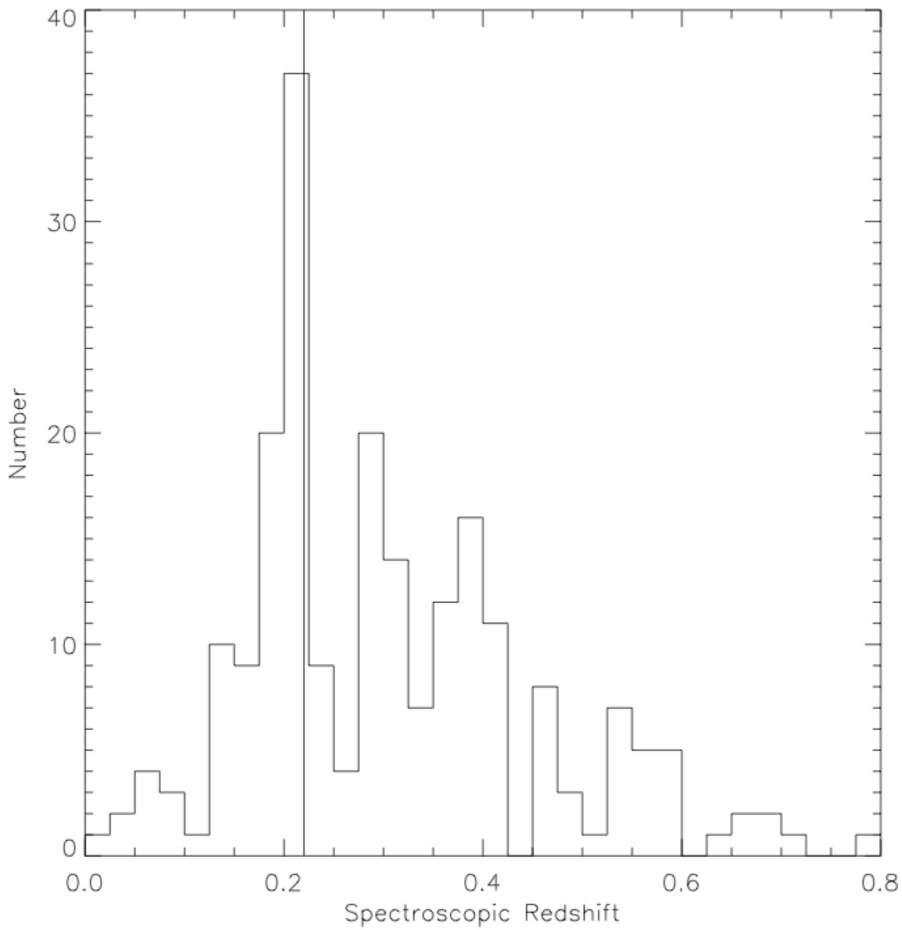
Spectroscopic vs. Photometric



- Binsize z=0.025
- Photometric redshifts from Rowan-Robinson (2008)
- Spectroscopic redshifts from our AAOmega observations

Spectroscopic vs. Photometric



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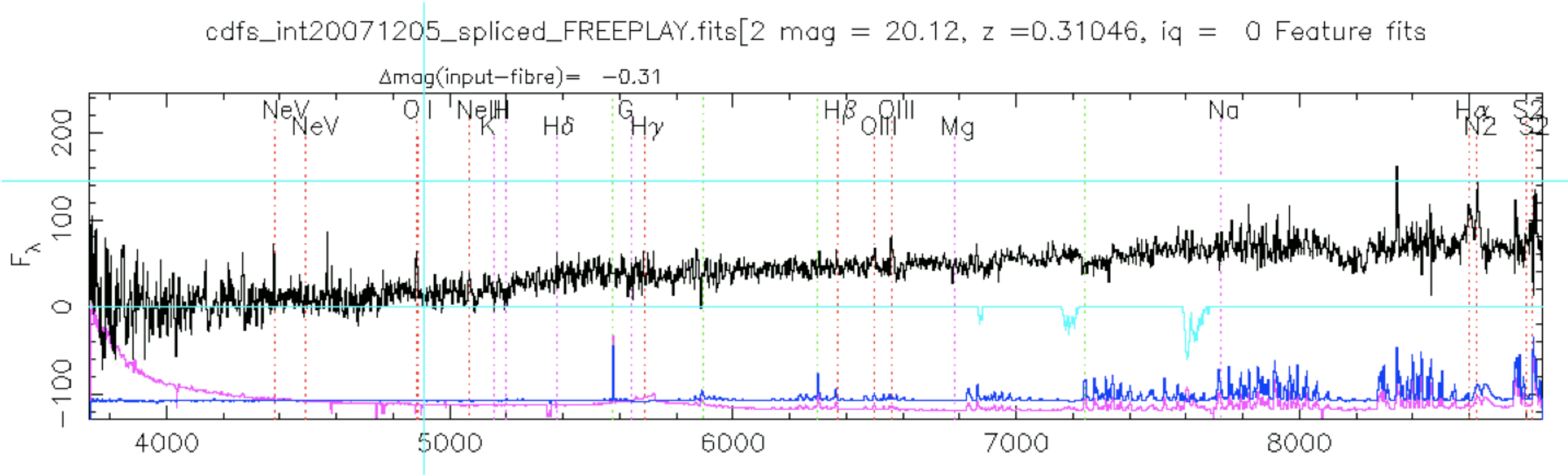
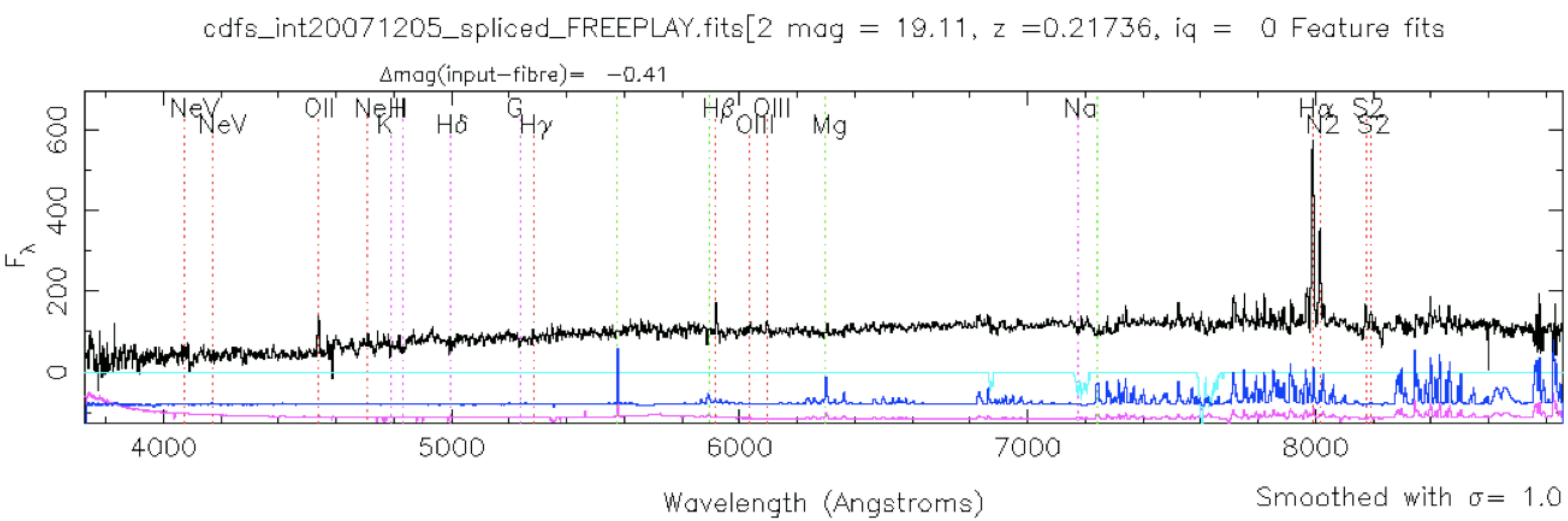
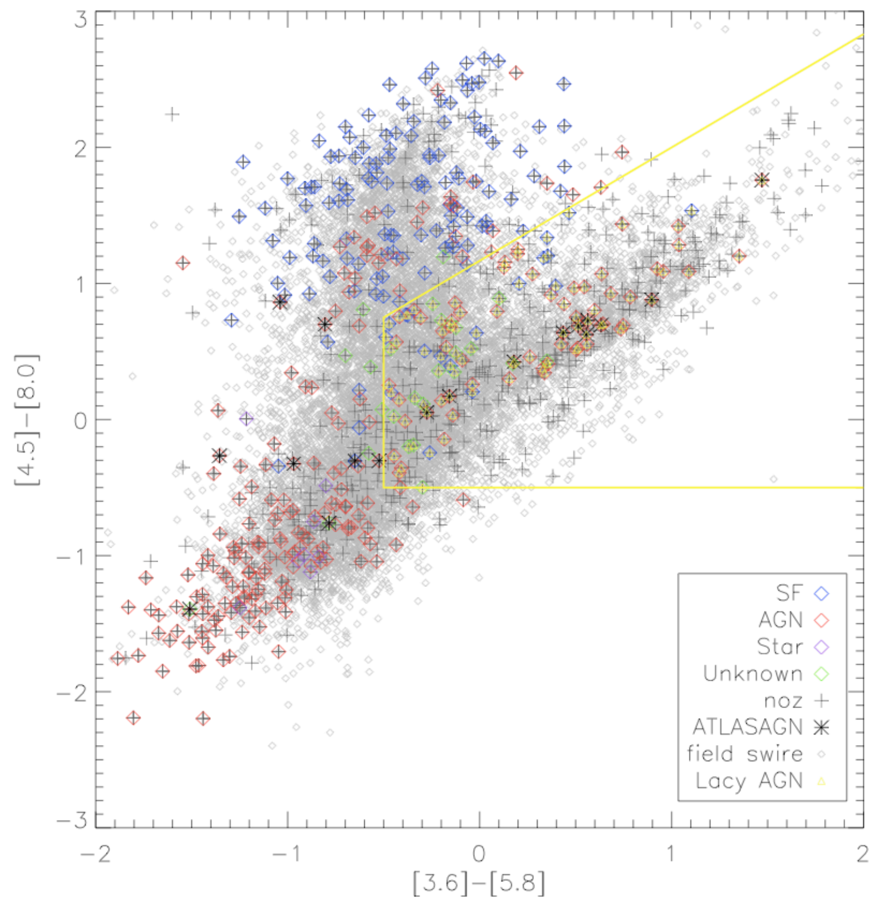
A quick look at statistical redshifts





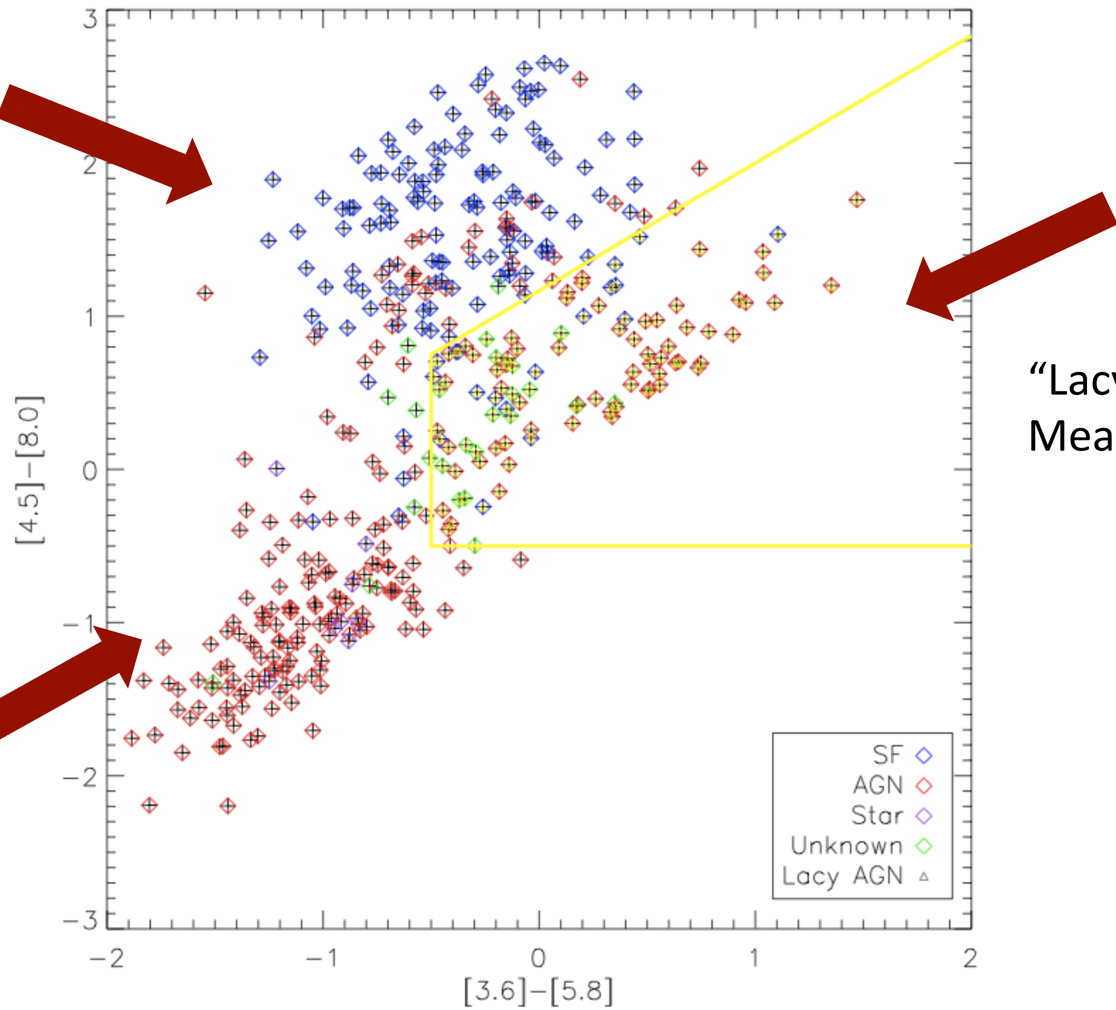
A quick look at statistical redshifts

- We compared our spectral classifications with mid-infrared colour-colour diagrams similar to using the SWIRE data from Spitzer (e.g. Lacy et al. 2004, Richards et al. 2006).



A quick look at statistical redshifts

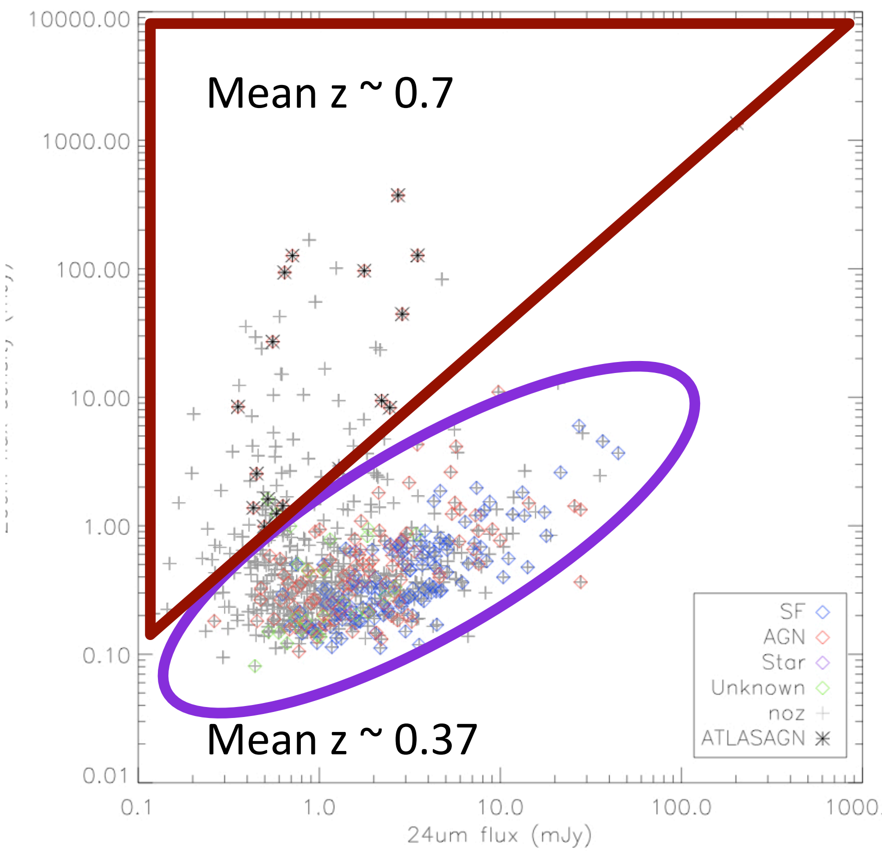
Mean z ~ 0.2

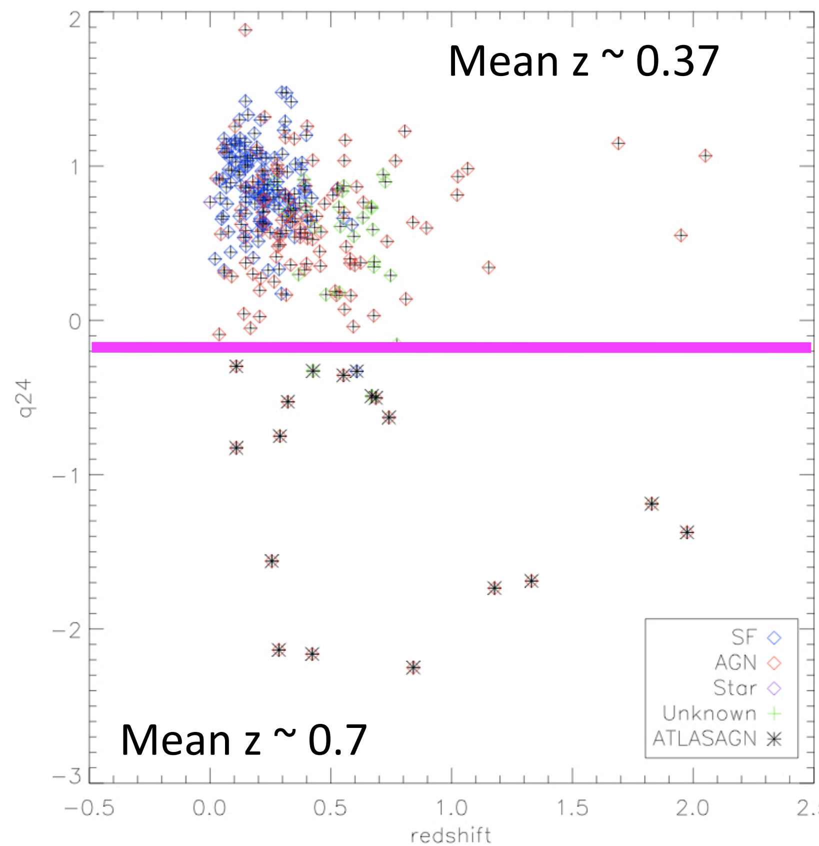


Mean z ~ 0.4

“Lacy Wedge”
Mean z ~ 0.6

Far-infrared Radio Correlation





Spectroscopic redshifts are necessary!

- While spectroscopy provides a wealth of data about an individual source – it is nigh impossible to obtain spectroscopic redshifts for all 70 million EMU sources – but **a good training set of spectroscopic redshifts is necessary to train both photometric redshifts and statistical redshifts.**
- EMU will have photometric redshifts for ~30% of its sources by 2013, increasing to 70% by 2020

Surveys that EMU with cross-match with (Norris et al. 2011)

Table 1: Key Multi-Wavelength surveys with which EMU data will be cross-identified (restricted to surveys 1000 sq. deg.). All magnitudes in AB. The EMU detected column is the fraction of EMU sources that are detectable to the sensitivity of the multi-wavelength survey. The survey matched column is the fraction of EMU sources in the previous column which are in the area of sky covered by the multi-wavelength survey. The sensitivity shown for the WISE survey is for the 3.5μm band.

Survey Name	Area (sq. deg)	Wavelength Bands	Mag. Limit[a]	EMU Detected (%)	Survey Matched (%)	Data Release Date
WISE[1]	40000	3.4, 4.6, 12, 22 μm	80 μJy	23	100	2012
Pan-Starrs[2]	30000	g, r, i, z, y	$r < 24.0$	54	50	2020
Wallaby[3,b]	30000	20 – 26cm	1.6mJy[c]	1	100	2013
LSST[4]	20000	u, g, r, i, z, y	$r < 27.5$	96	67	2020
Skymapper[5]	20000	u, v, g, r, i, z	$r < 22.6$	31	66	2015
VHS[6]	20000	Y, J, H, K	K< 20.5	49	66	2012
SDSS[7]	12000	u, g, r, i, z	$r < 22.2$	28	22	DR8 2011
DES[8]	5000	g, r, i, z, y	$r < 25$	71	17	2017
VST-ATLAS[9]	4500	u, g, r, i, z	$r < 22.3$	30	15	2012?
Viking[10]	1500	Y, J, H, K	K< 21.5	68	5	2012
Pan-Starrs Deep[2]	1200	$0.5 - 0.8, g, r, i, z, y$	$g < 27.0$	57	4	2020

TAIPAN

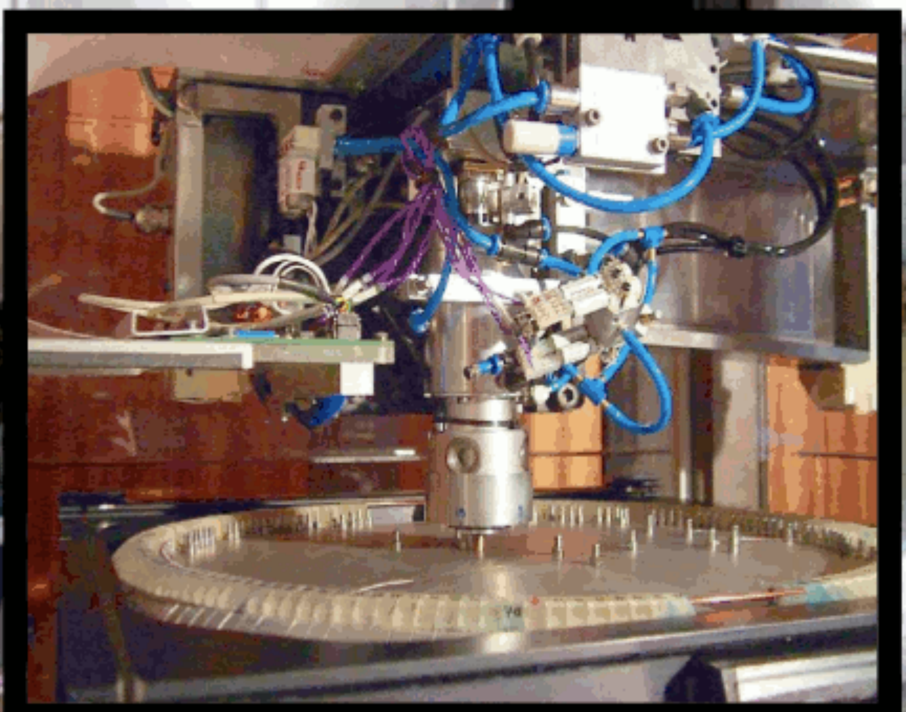
- Transforming Astronomical Imaging-surveys through Polychromatic Analysis of Nebulae
- Survey with the UK Schmidt Telescope at Siding Spring, following in the footsteps of the 6dF Galaxy Survey (Jones et al., 2004, 2009)
- All southern sky multi-object spectroscopic survey, ~0.5 million galaxies, r<~17 (but NIR selected, as with 6dFGS), 3-5 yr survey starting in ~2015.
- 10-12 December, workshop in Sydney: http://physics.mq.edu.au/astronomy/workshop_2012

Slide courtesy of Andrew Hopkins

The 6-Degree Field instrument (6dF)

- The 6-Degree Field is a floor-mounted spectrograph for the AAO's UK Schmidt Telescope:
  - commissioned in 2001
  - 5.7º field (25.5 deg^2)
  - up to 150 objects at a time

- 6dF has *by far* the largest F.O.V. of any multi-object spectrograph in the southern hemisphere…
  - 6dFGS: 110,256 new galaxy redshifts (2001 – 2005)
  - RAVE: >500,000 stellar radial velocities (2005 – present)



Slide courtesy of Andrew Hopkins

MACQUARIE UNIVERSITY
ASTRONOMY, ASTROPHYSICS AND ASTROPHOTONICS RESEARCH CENTRE

The next generation of hemispheric redshift surveys and the prospects for TAIPAN

10-12 Dec 2012, Sydney, Australia

SOC

Prof. Quentin Parker (Chair, MQ/AAO)
Prof. Andrew Hopkins (Co-Chair, AAO)
Prof. Lisa Kewley (ANU)
Prof. John Peacock (Univ. Edinburgo)
Dr. Heath Jones (Monash)
Prof. Bryan Gaensler (Univ. Sydney)

LOC

Prof. Quentin Parker (MQ/AAO)
Dr. Lee Spitler (MQ/AAO)
Dr. Michelle Cluver (AAO)
Dr. Maritza A. Lara-Lopez (AAO)
Dr. Borja Anguiano (MQ)
Travis Stenborg (MQ)
Amanda Manypeny (MQ)

Invited Speakers

Joss Bland-Hawthorn
Simon Driver
Lister Stavely-Smith
Baerbel Koribalski
Matthew Colless
Tom Jarrett
Jon Lawrence
Fred Watson
Florian Beutler
Ray Norris

Major topics: Synergies with ASKAP galaxy surveys, precision cosmology, galaxy evolution, the connection between gas and stars, the impact of environment and mergers, large scale structure, stellar and halo mass functions, star formation and AGN, and the intergalactic magnetic field.

http://physics.mq.edu.au/astronomy/workshop_2012

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