CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

CSIRO

THE UNIVERSITY OF SYDNEY

Australian Government
Australian Research Council

Tracing the HI content in obscured AGN with ASKAP

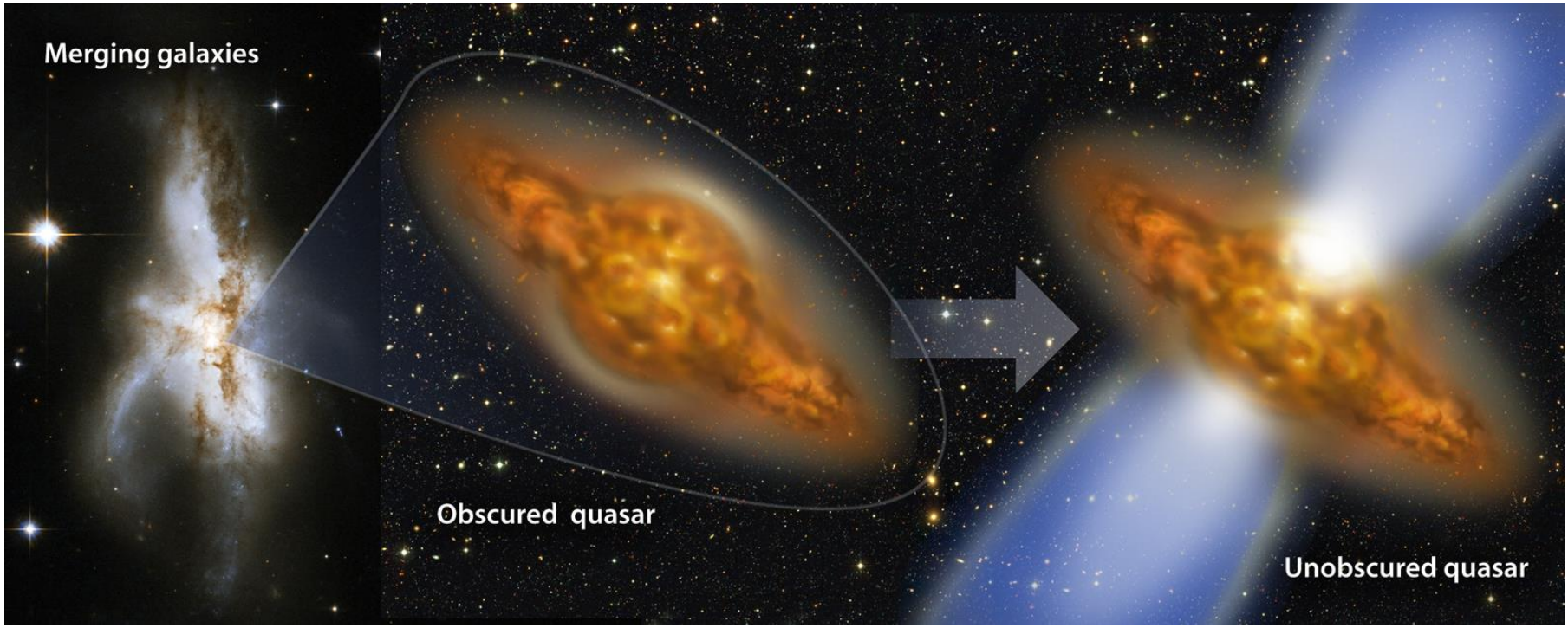
Marcin Glowacki

Supervisors: Elaine Sadler & James Allison

ASKAP-FLASH
First Large Absorption Survey in HI

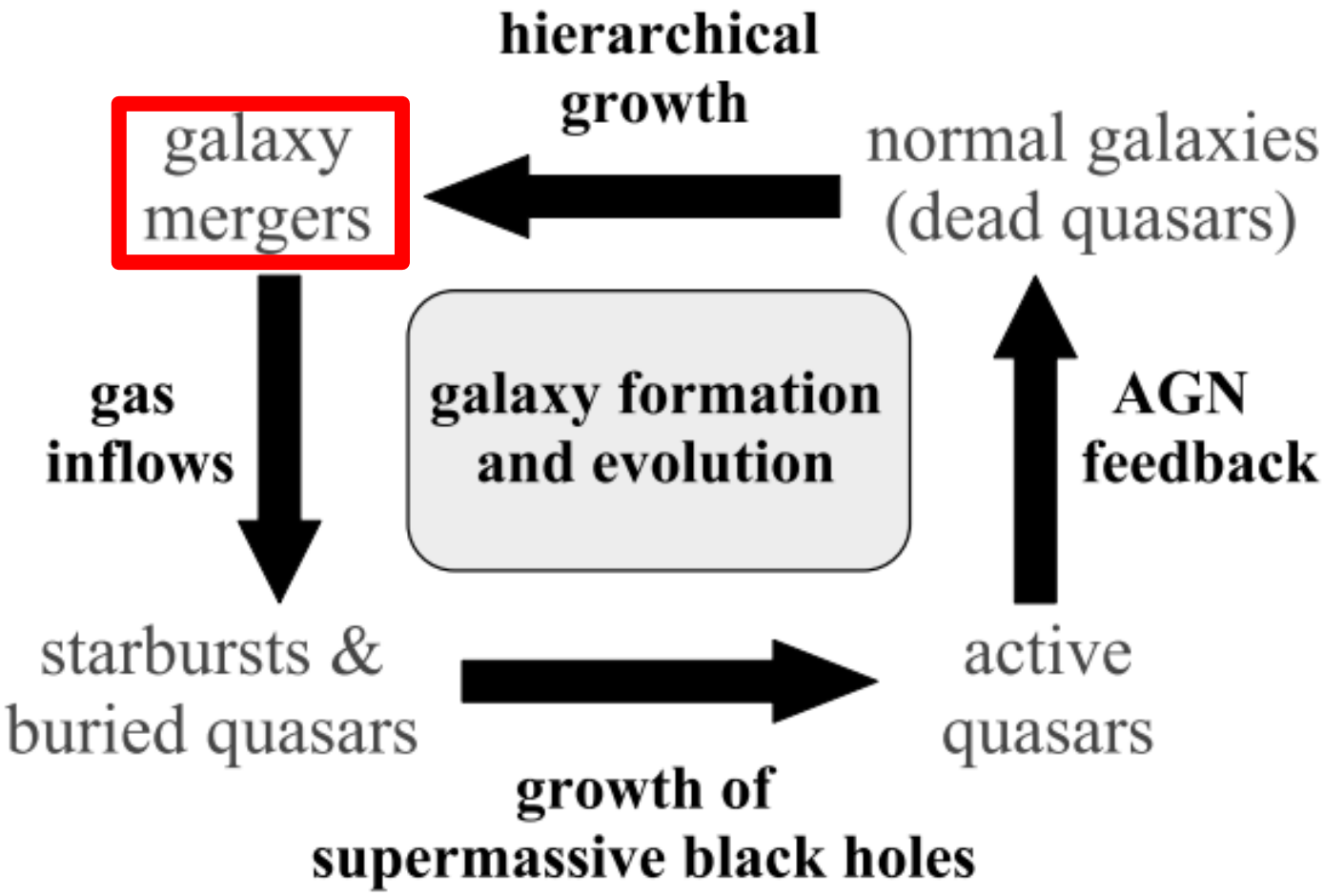
Obscured Quasars

- Optically obscured quasars represent a transitionary period between:
  - Merger event → gas + dust fuels the AGN
  - AGN switches on, feedback disperses material



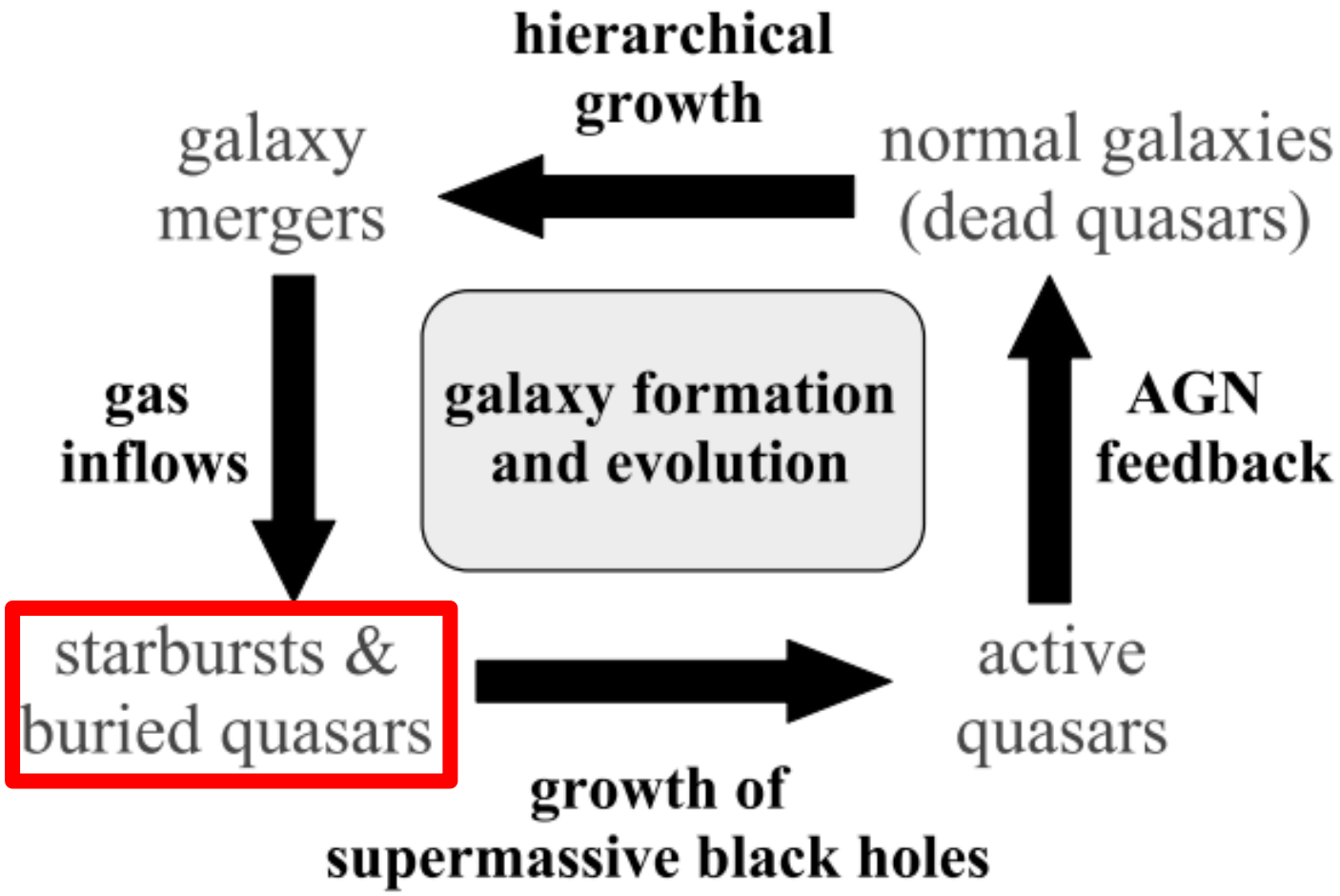
Artist's impression, by Karen Teramura

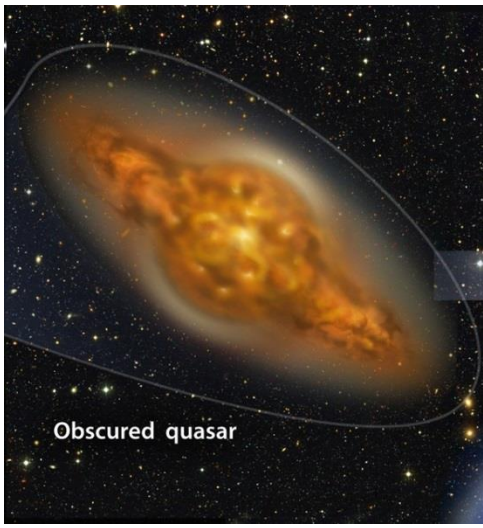
Obscured Quasars



Hopkins et al. (2006)

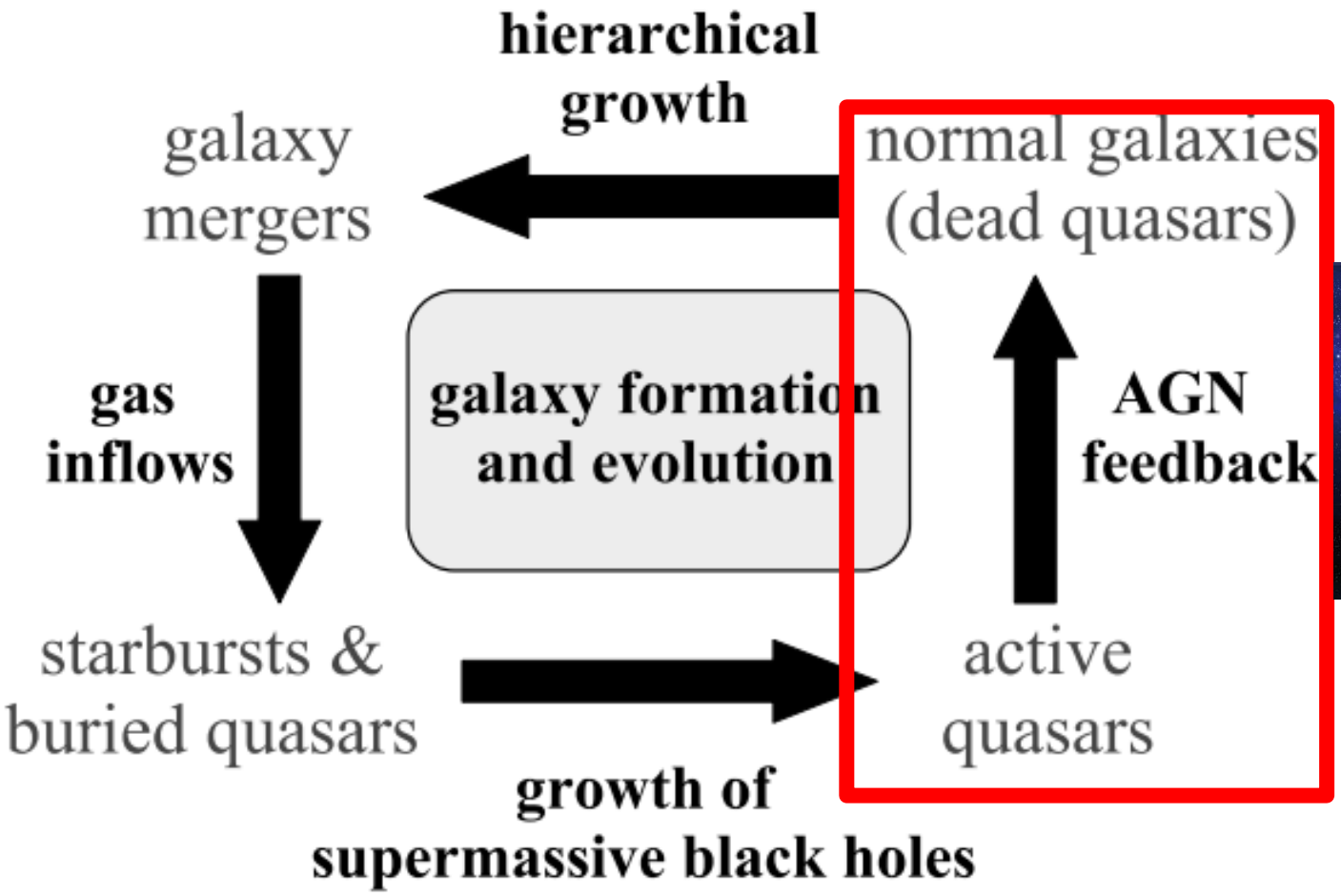
Obscured Quasars





Hopkins et al. (2006)

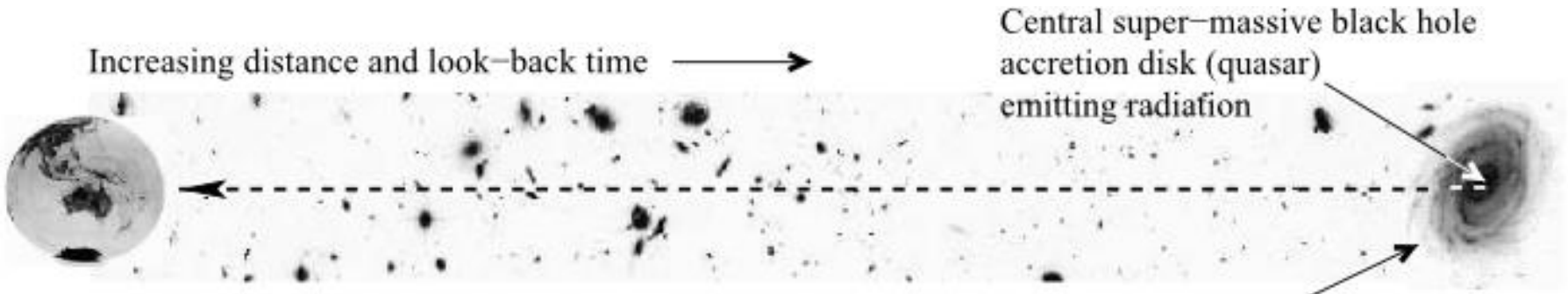
Obscured Quasars

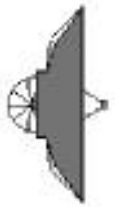


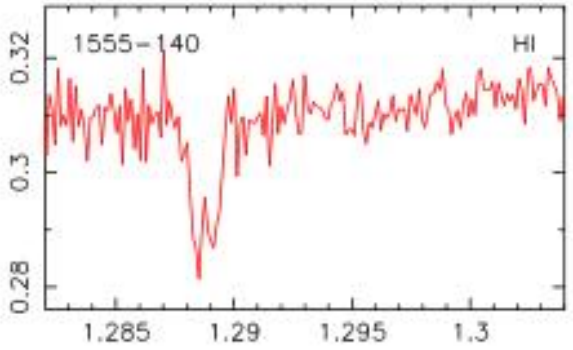
Hopkins et al. (2006)

HI 21 cm in Absorption

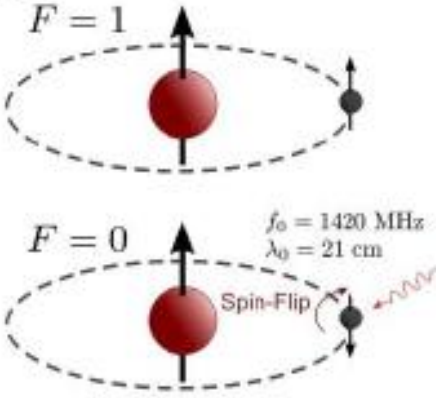
- Can trace gas within host galaxy or along line-of-sight of a radio-bright source (e.g. AGN)
- No redshift limit for transition in absorption





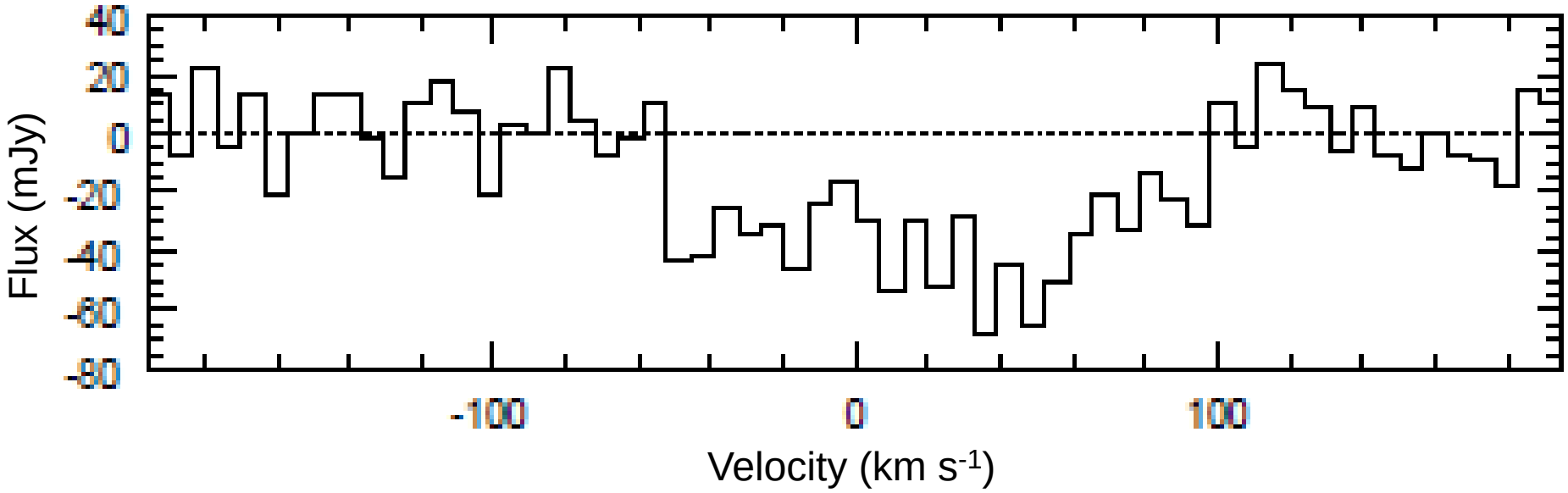


Cold neutral gas in quasar host galaxy absorbs the radiation through the 21−cm spin−flip transition of neutral hydrogen, giving an absorption line in the flux emitted from the quasar



How much HI content?

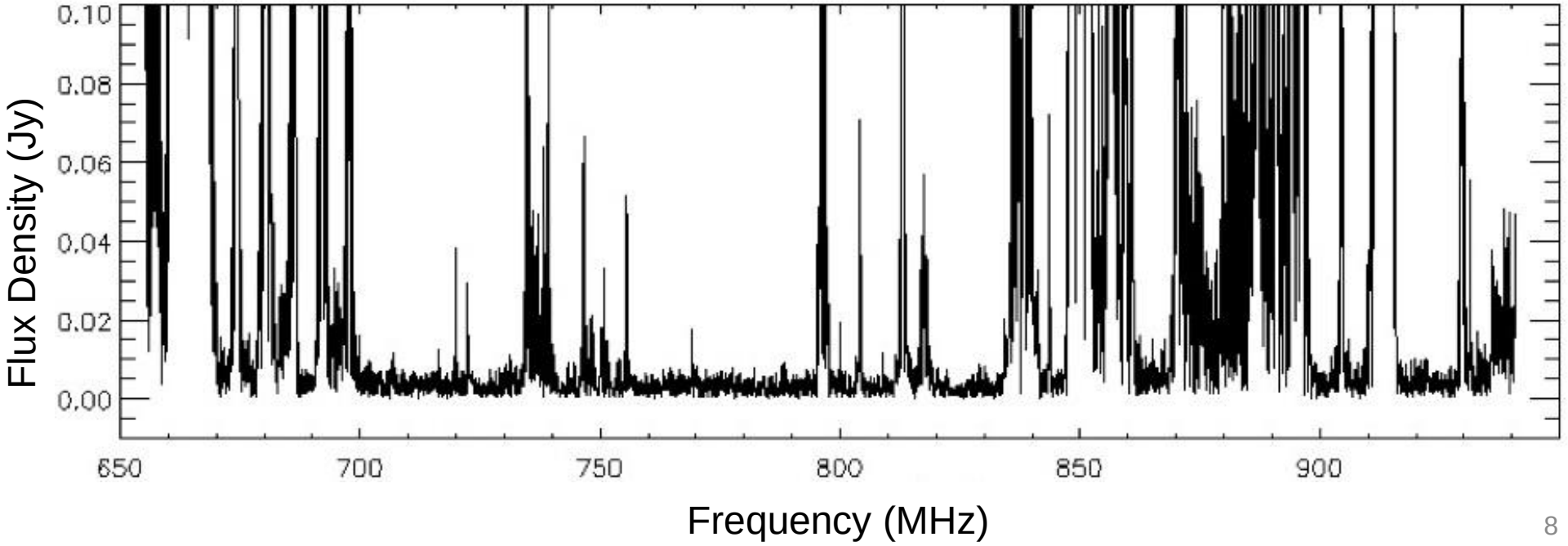
- Carilli et al. (1998) found an **80% HI absorption detection rate** (associated and intervening)
- **Only 5 objects** searched to low optical depths
- Need to study a larger sample to learn about gas kinematics near quasars in obscured phase



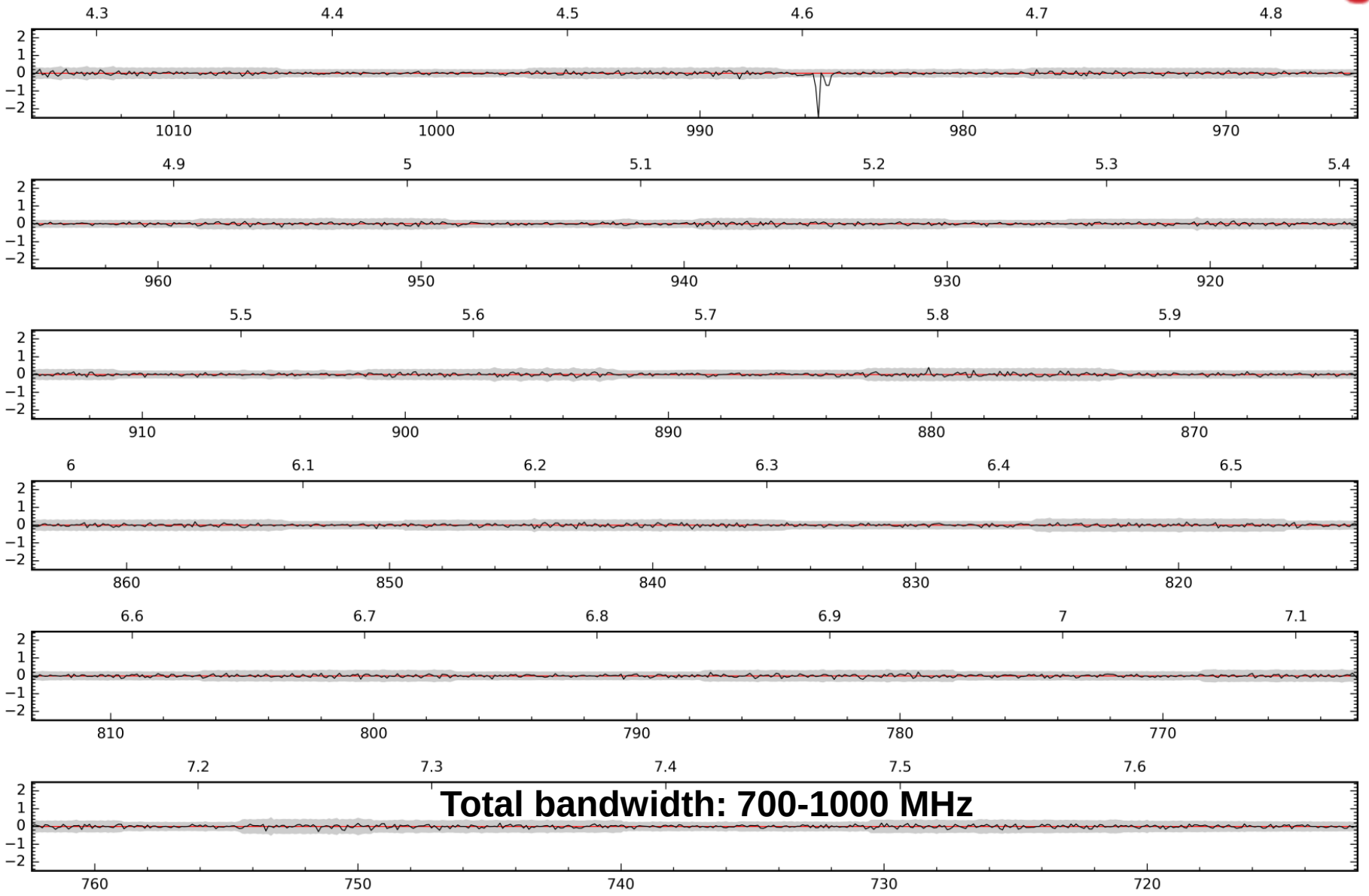
RFI

- Radio Frequency Interference (RFI) is problematic for radio surveys, particularly spectral line surveys
- Need HI absorption feature to fall in an uncorrupted location of the spectrum to be able to see it

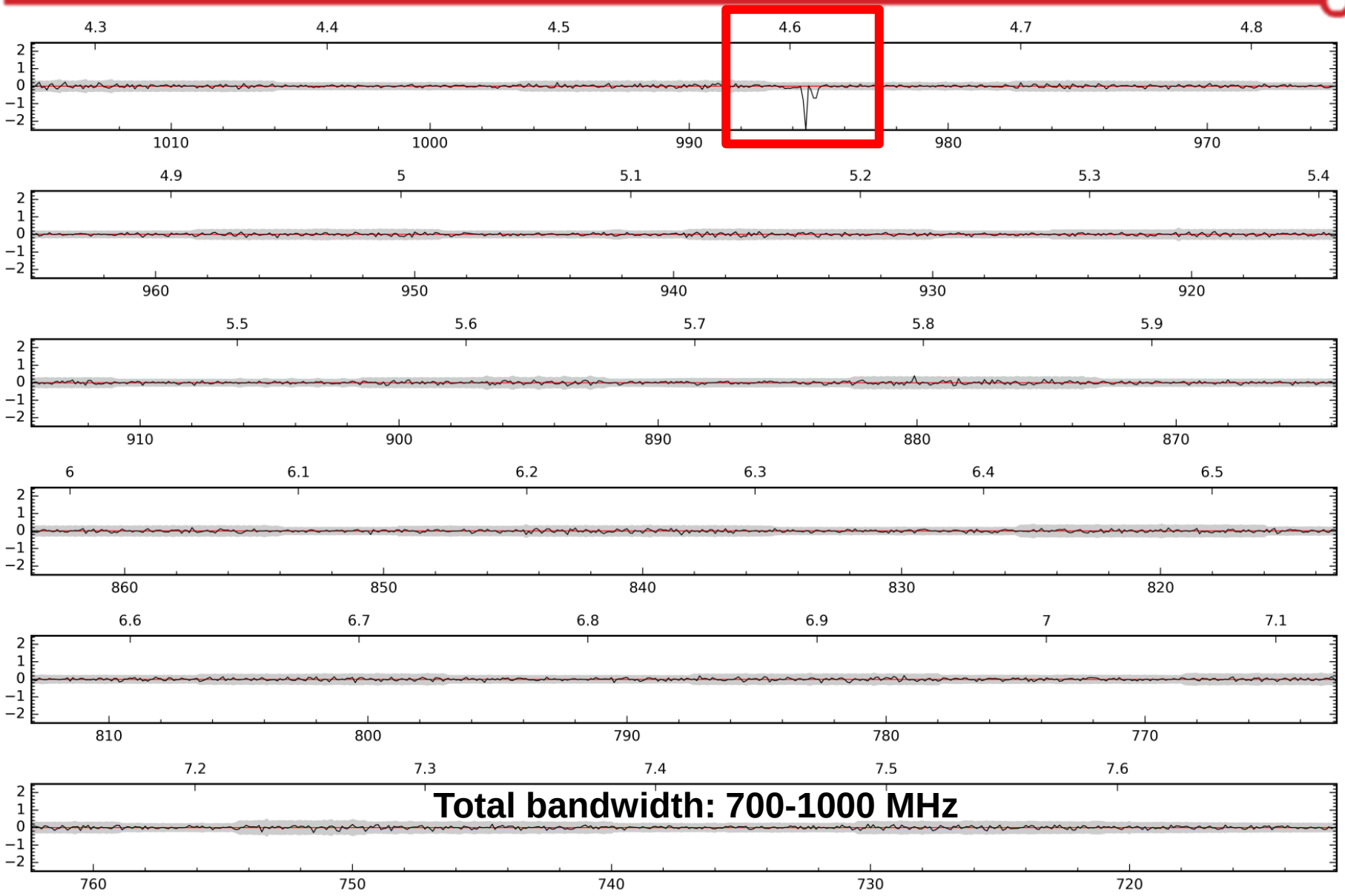
Green Bank Telescope spectrum, 650 – 950 MHz



“Bam, and the RFI is gone”



“Bam, and the RFI is gone”



ASKAP and FLASH

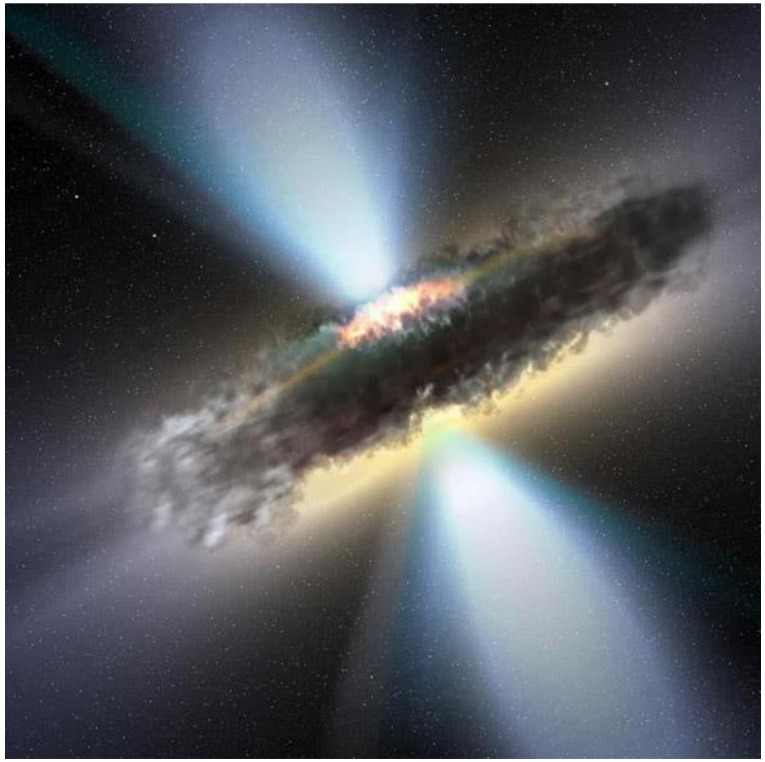
- Array of 36 antennas (currently has ~12)
- Uses PAFs (Phased Array Feeds)
- At **radio-quiet MRO site**

ASKAP-FLASH
First Large Absorption Survey in HI

- **FLASH: All-sky HI search at redshifts $0.4 < z < 1$**
- **Estimated ~1000 new detections against 150,000 sightlines**

HI survey of obscured AGN

- Aim – to further explore Carilli et al. (1998) work with current telescopes in radio-quiet site
- Used ASKAP-BETA (6 antennas) to search for HI absorption toward obscured quasars

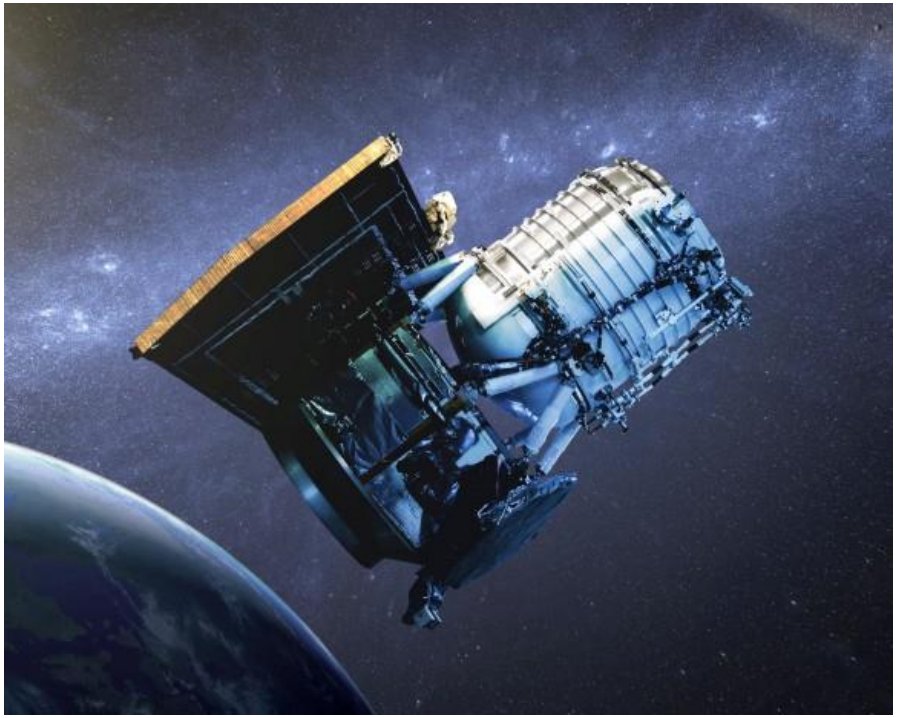


Credit: ESA / V. Beckmann (NASA)

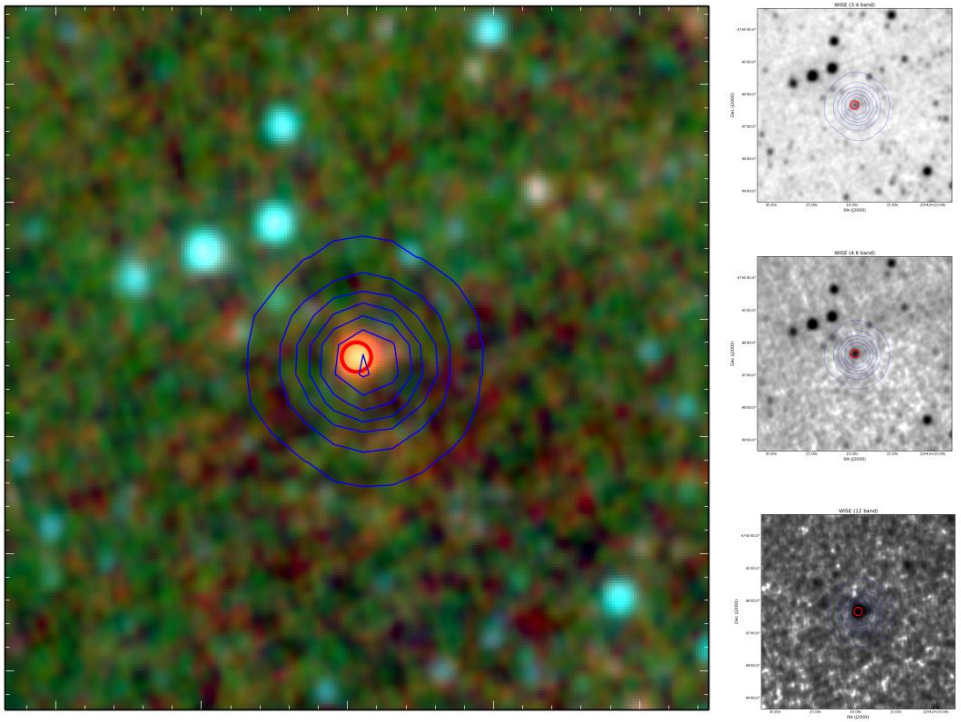
- Considerations:
  - ASKAP-BETA a prototype telescope; not as sensitive as other radio telescopes
    - Radio-loud sources selected
  - Replicate sample selection
  - Explore mid-infrared data now available

Sample Selection

- Starting point: **Kuhr et al. (1981)** radio catalogue
- Brightness, declination and redshift cuts
- **Two subgroups**: **Optically faint** (R-band magnitude > 20 mag) and **mid-infrared colour selected** (WISE)

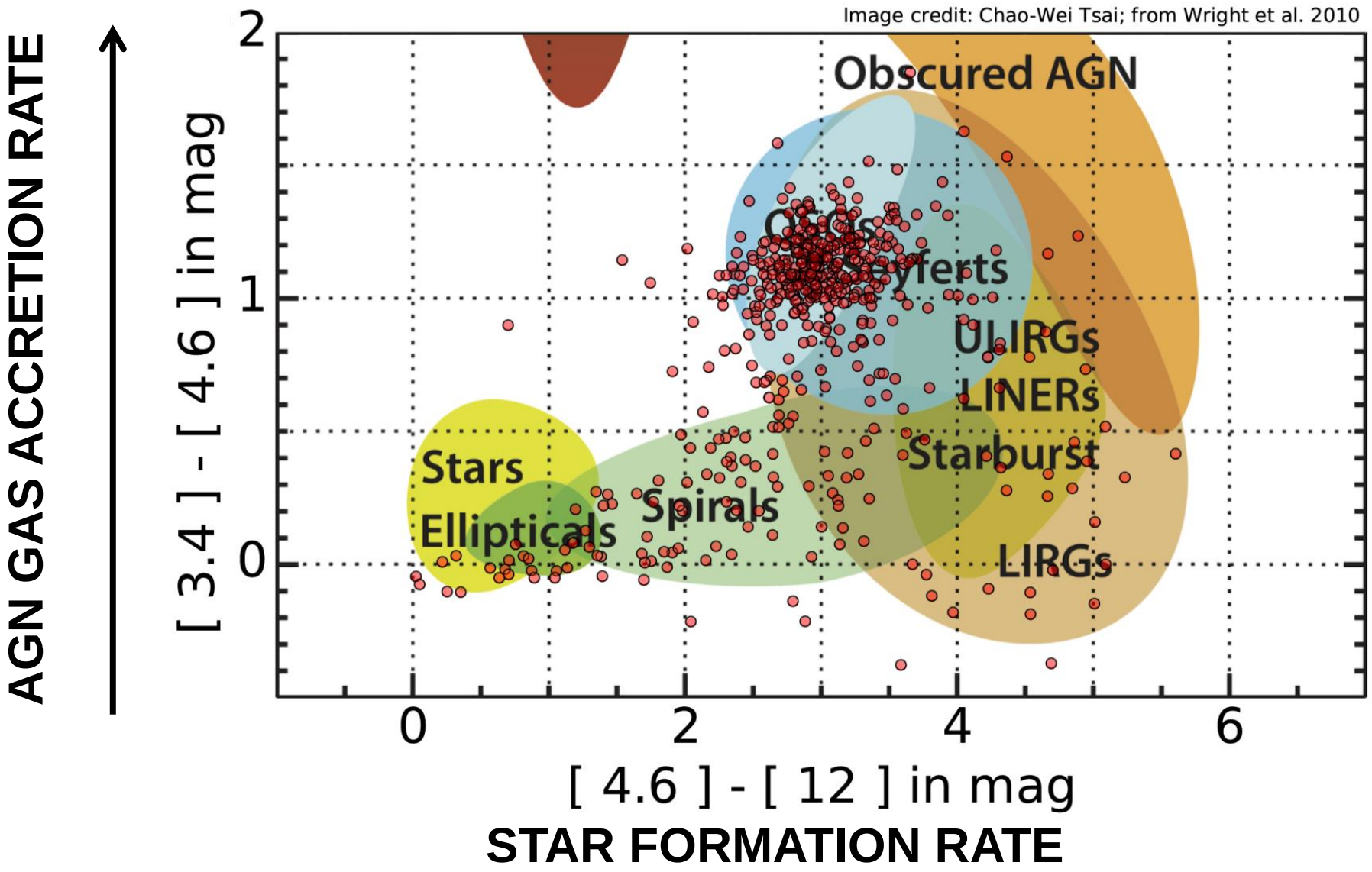


Wide-Field Infrared Survey Explorer

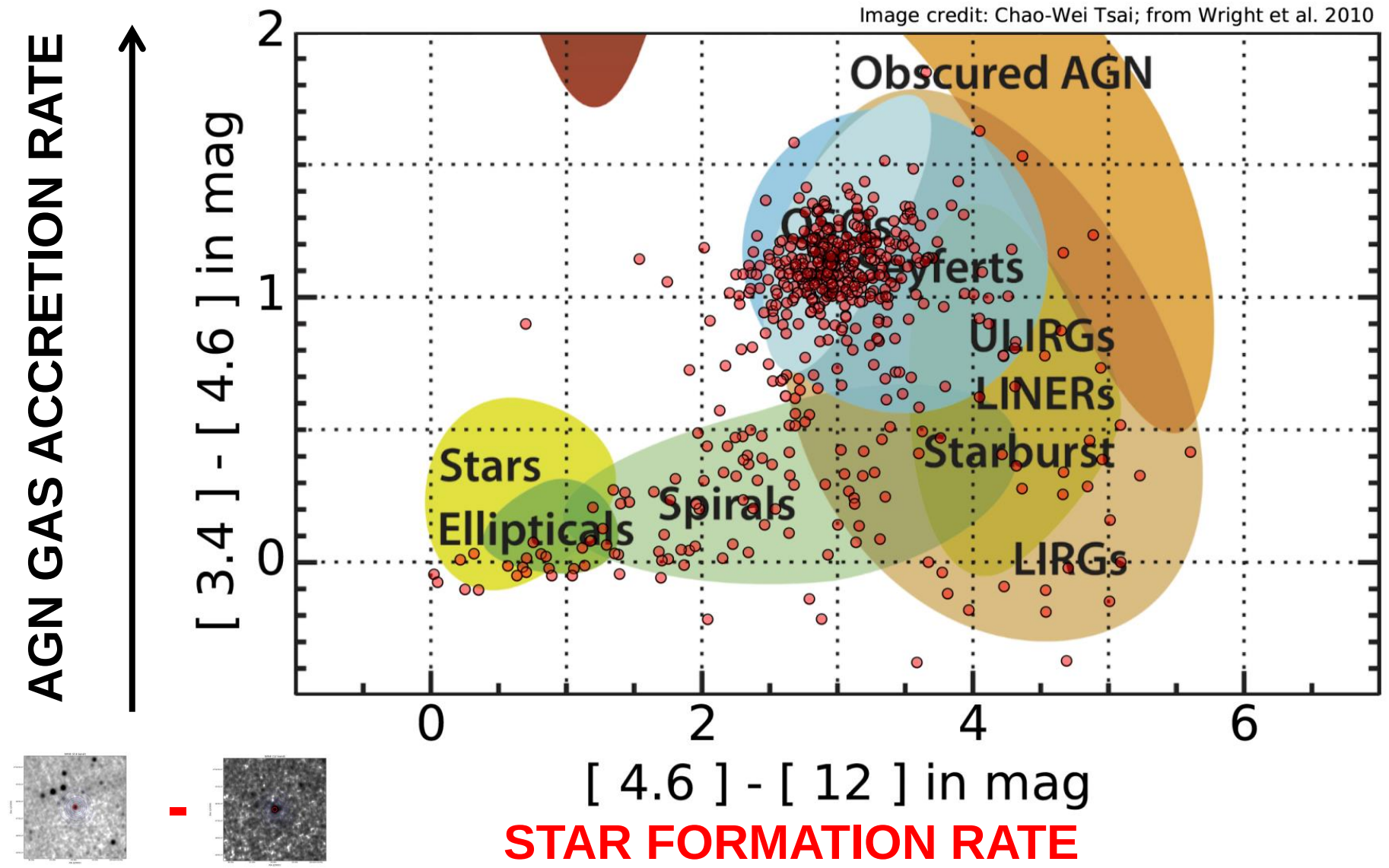


WISE 3-colour image of 3C275

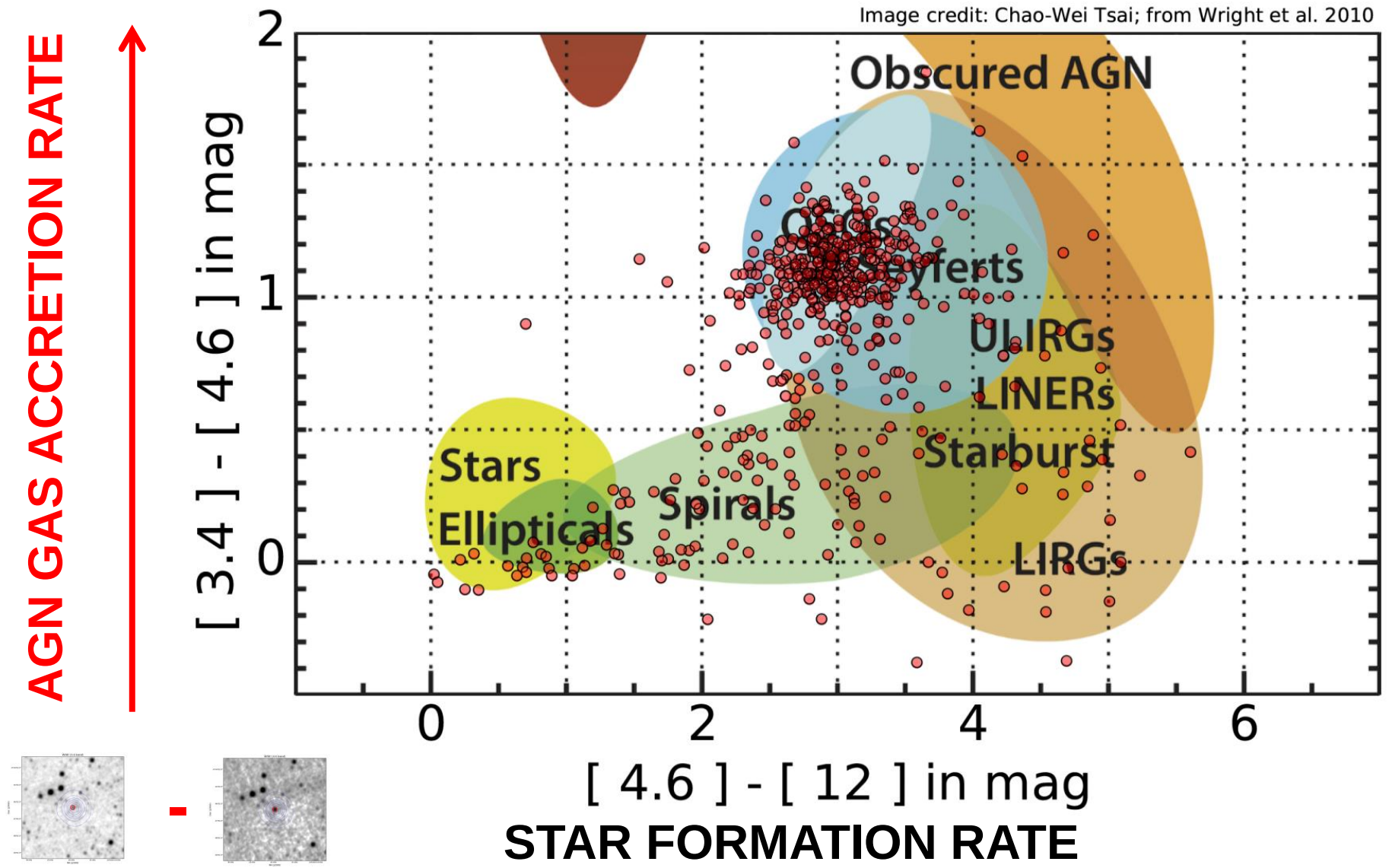
WISE Colour selection



WISE Colour selection



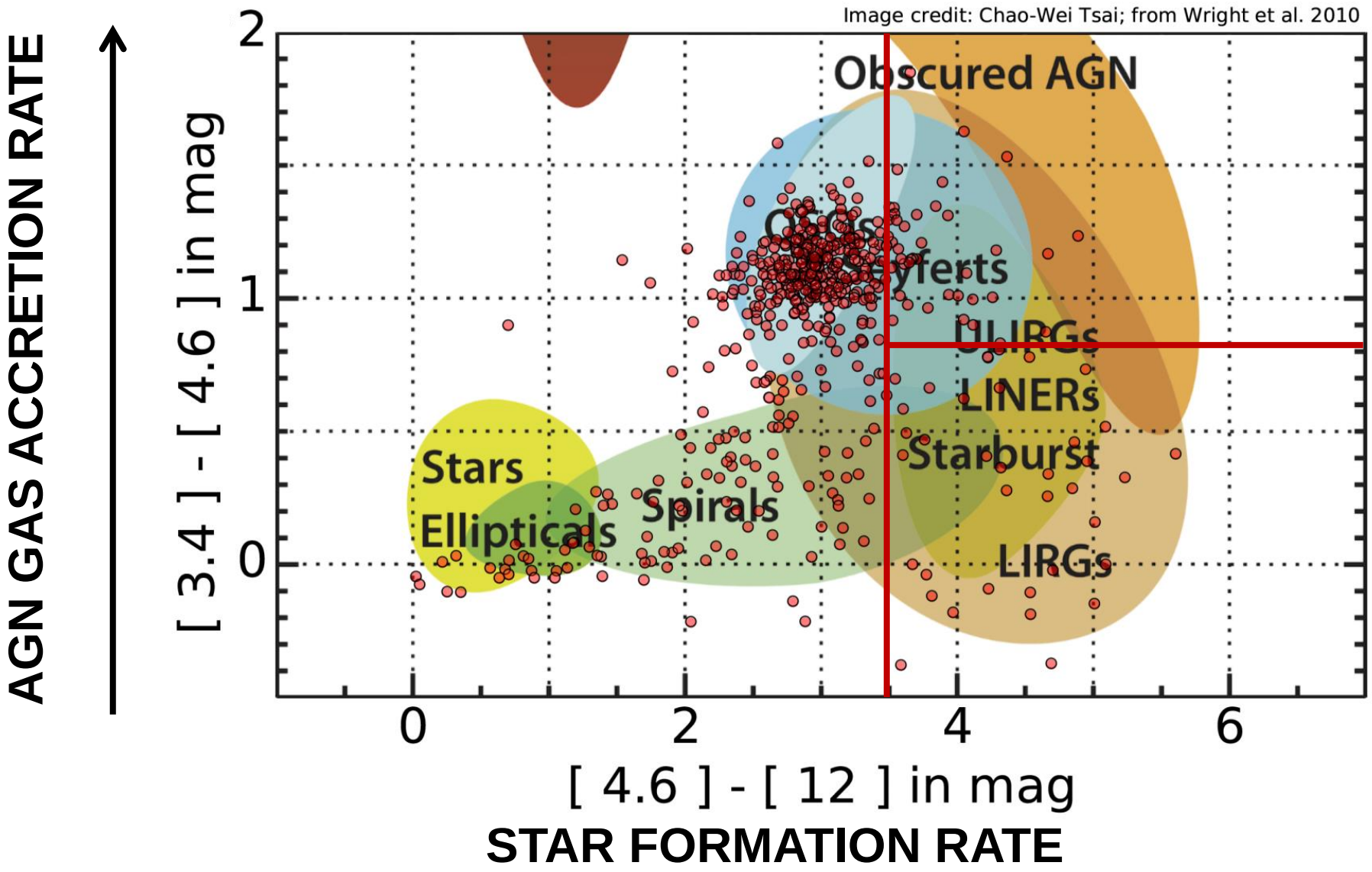
WISE Colour selection



AGN GAS ACCRETION RATE

STAR FORMATION RATE

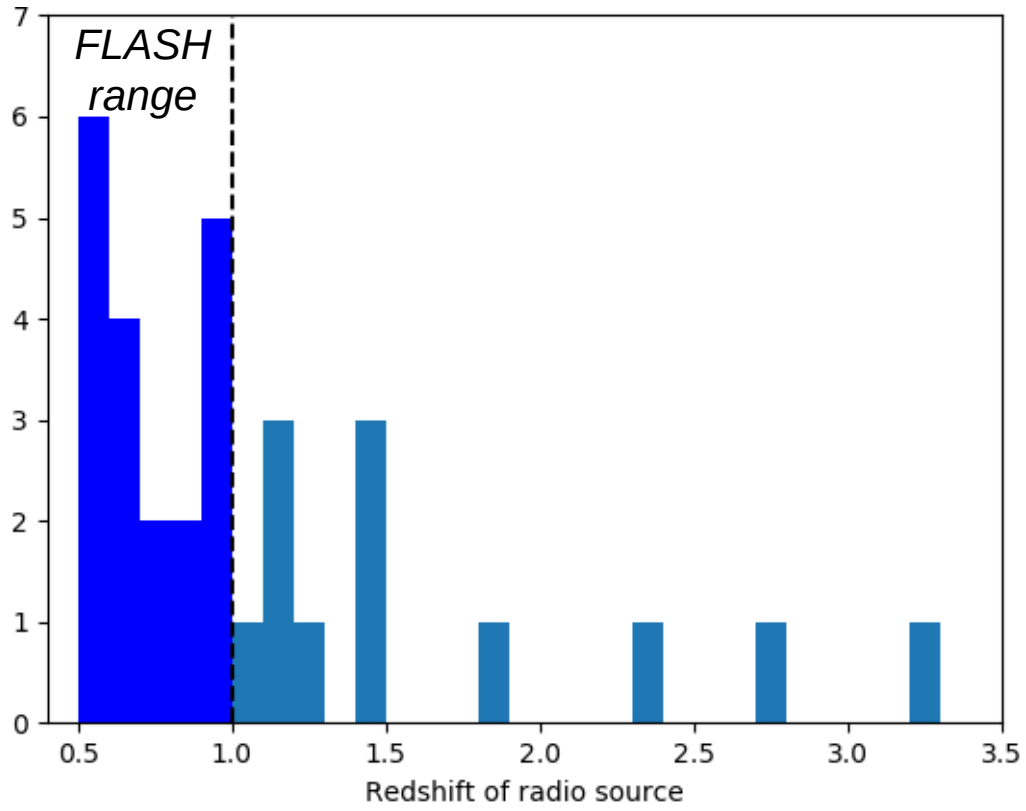
WISE Colour selection



Redshift distribution

- **Associated and intervening search for HI towards 39 radio-bright sources**
- Within 0.4 < z < 1.0 range: 19 sources
- Some redshifts unreliable – e.g. photometric estimates
- 7 radio sources with no known redshift

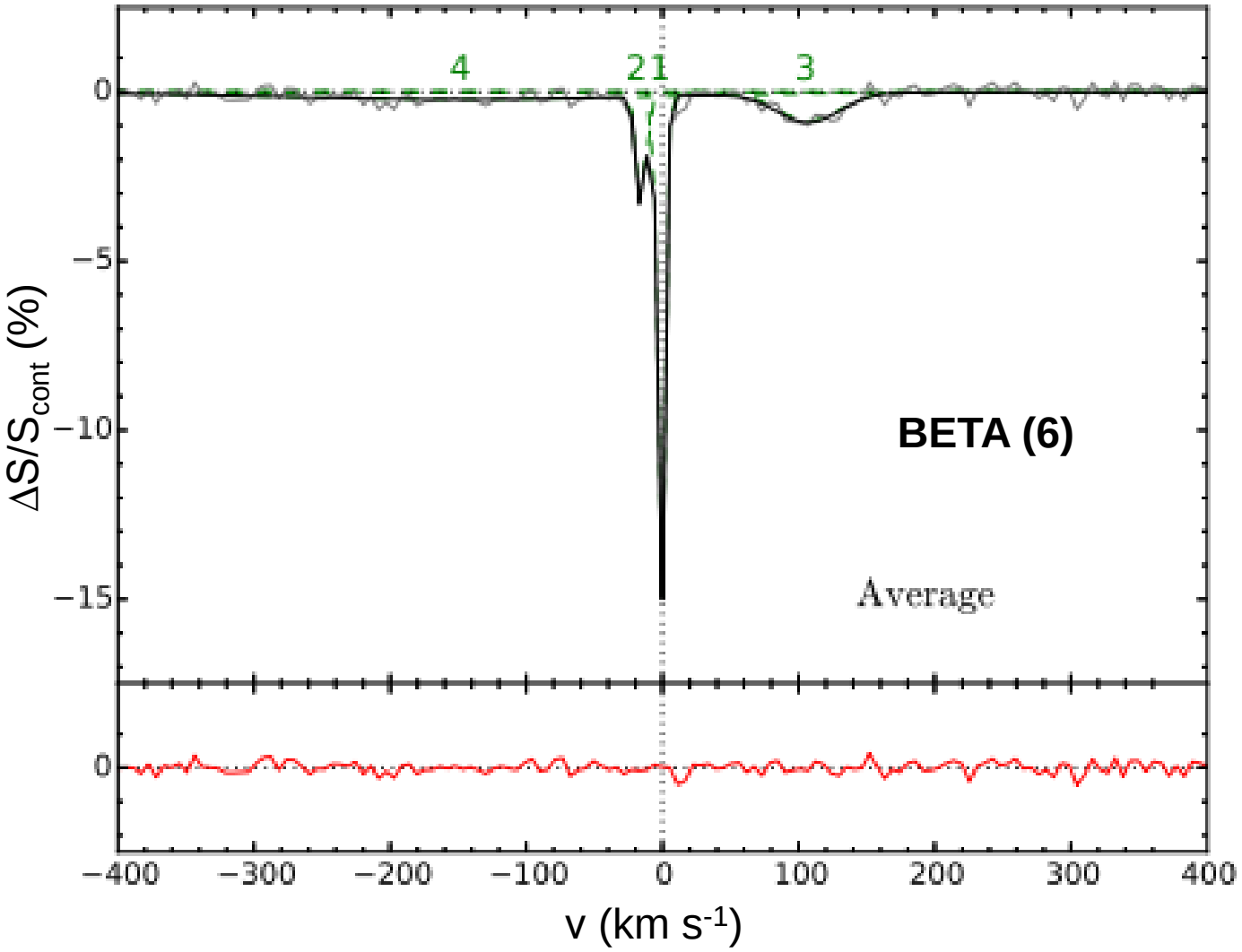
	Optically Faint	Mid-Infrared	
Number	31	15	*Overlap: 7*
0.4 < z < 1	15	11	*Overlap: 7*
Detections	3	0	



New Detections

PKS 1740-517: z = 0.44

Allison et al. 2015, MNRAS



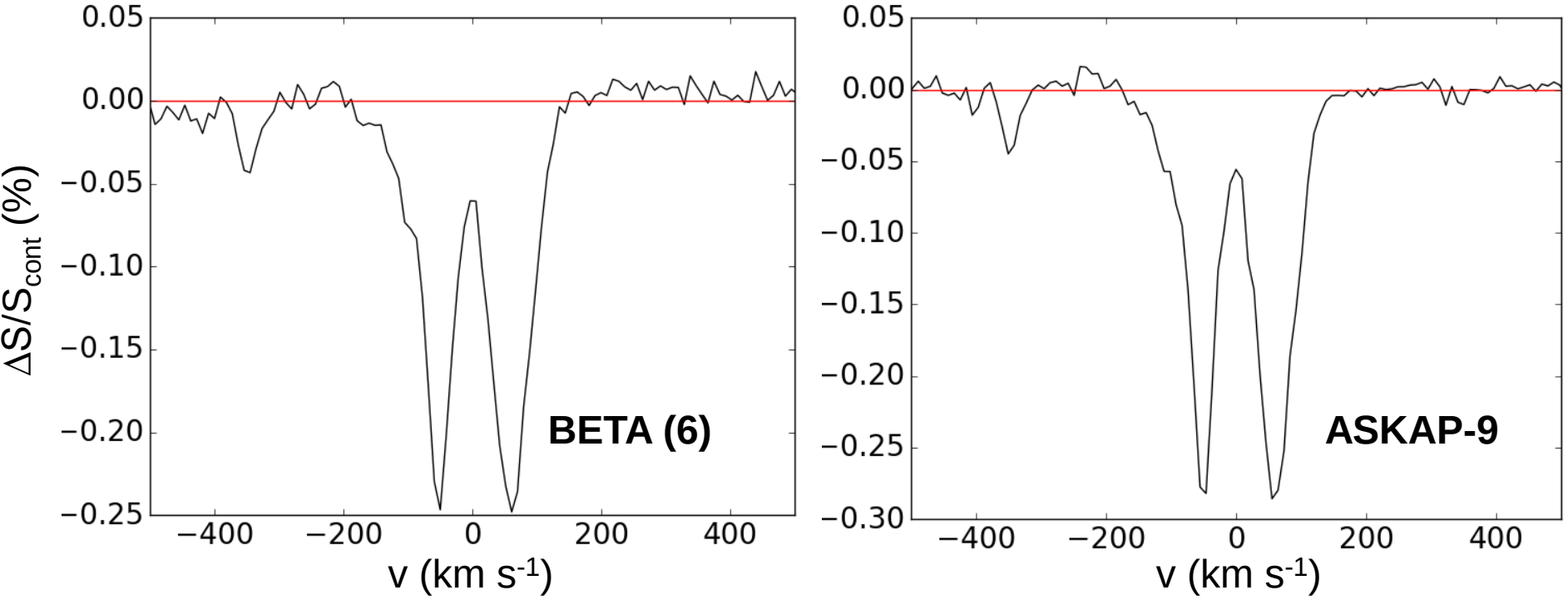
FLASH HI samples with ASKAP-BETA targeted for example:

- Giga-Hertz Peaked Spectrum (GPS) sources
- Soft X-ray absorbed sources (**Vanessa's talk!**)
- Optically faint sources

PKS 1740-517 falls into these three groups!

New Detections

PKS 1829-718: z = 0.54

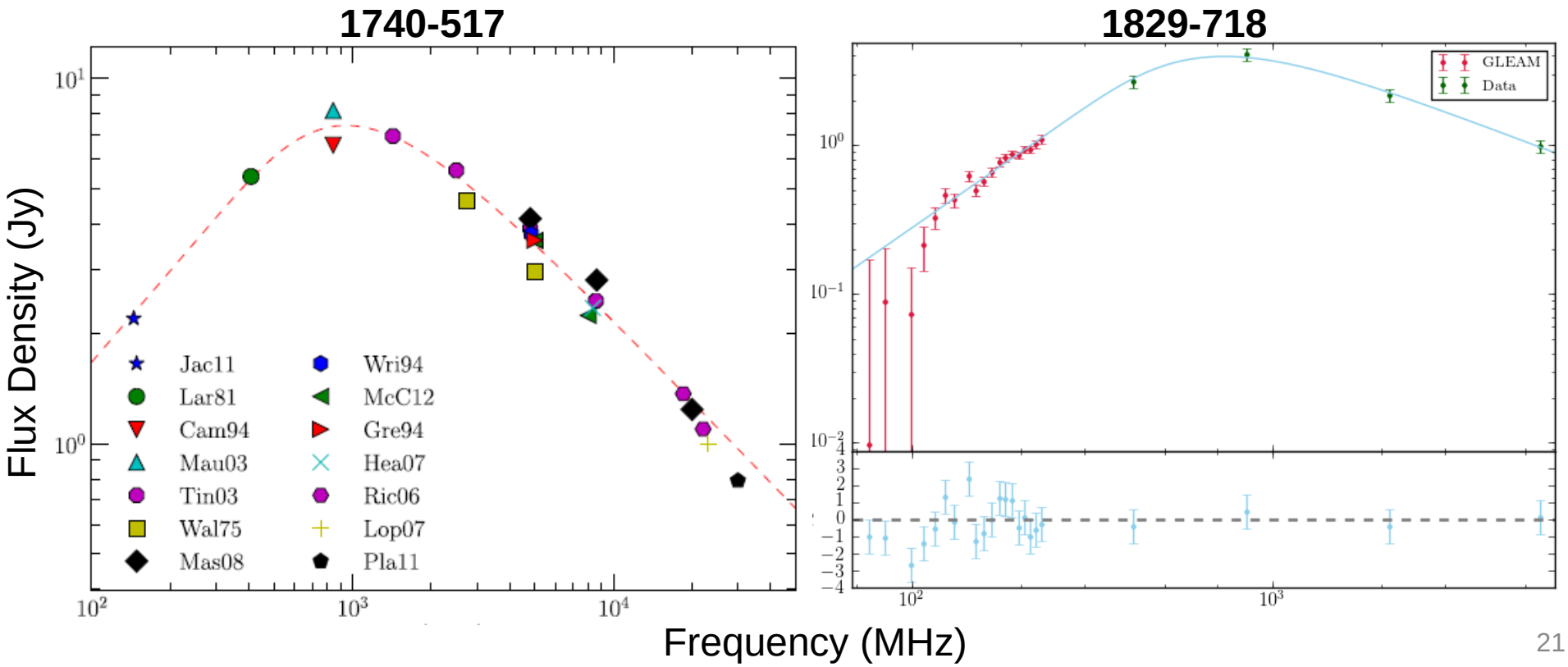


Searched to ~23 mag (Costa 2001) with only ‘possible identification’
Intervening or associated? If associated, the twin dips could be gas rotating around a disk with the third feature an outflow

Common links?

- PKS 1740-517 and PKS 1829-718 are associated with Giga-Hertz Peaked Spectrum (GPS) sources
- GPS sources thought to be young/recently retriggered AGN

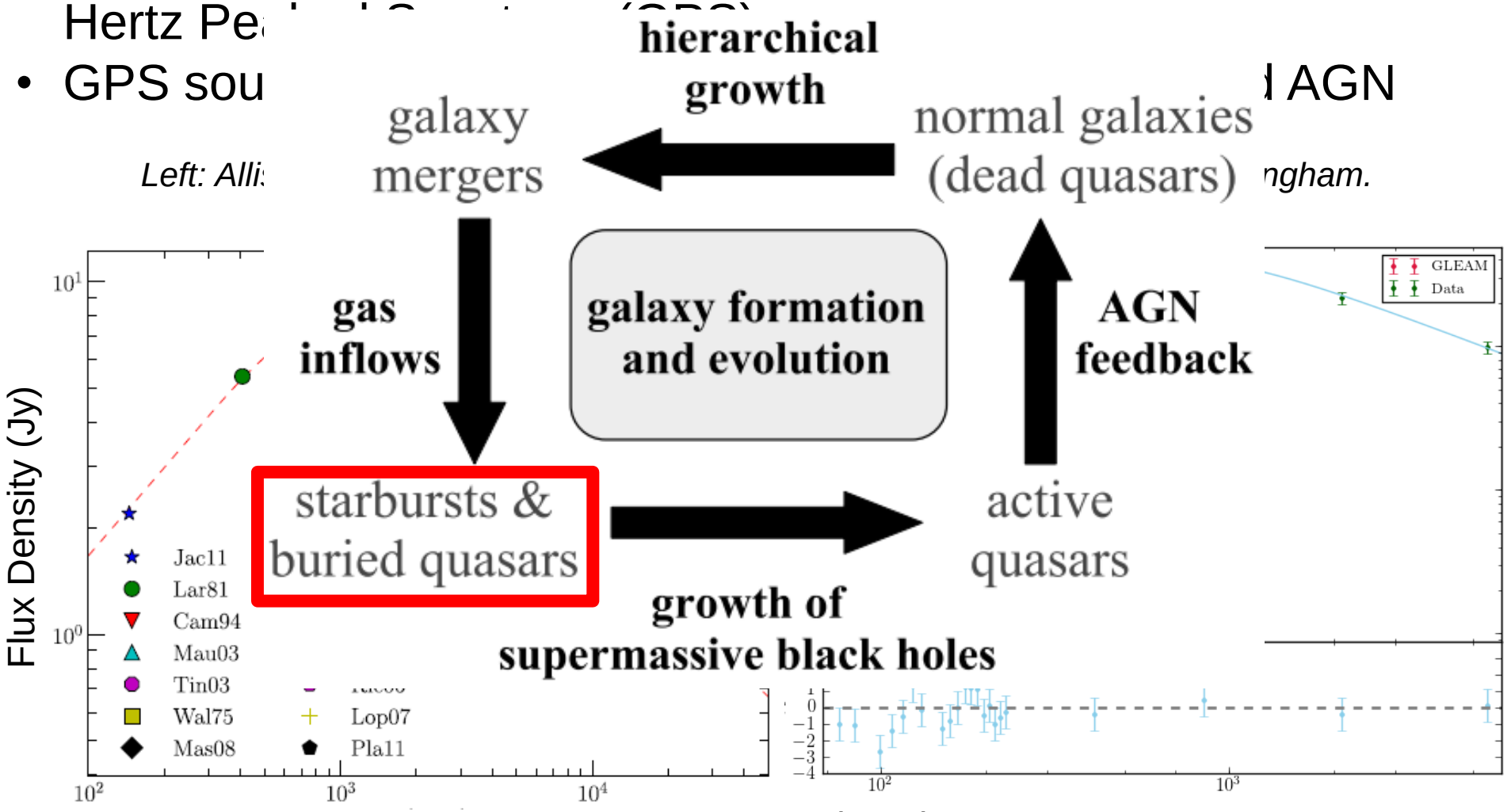
Left: Allison et al. 2015. Right: MWA GLEAM data, courtesy of Joseph Callingham.



Common links?

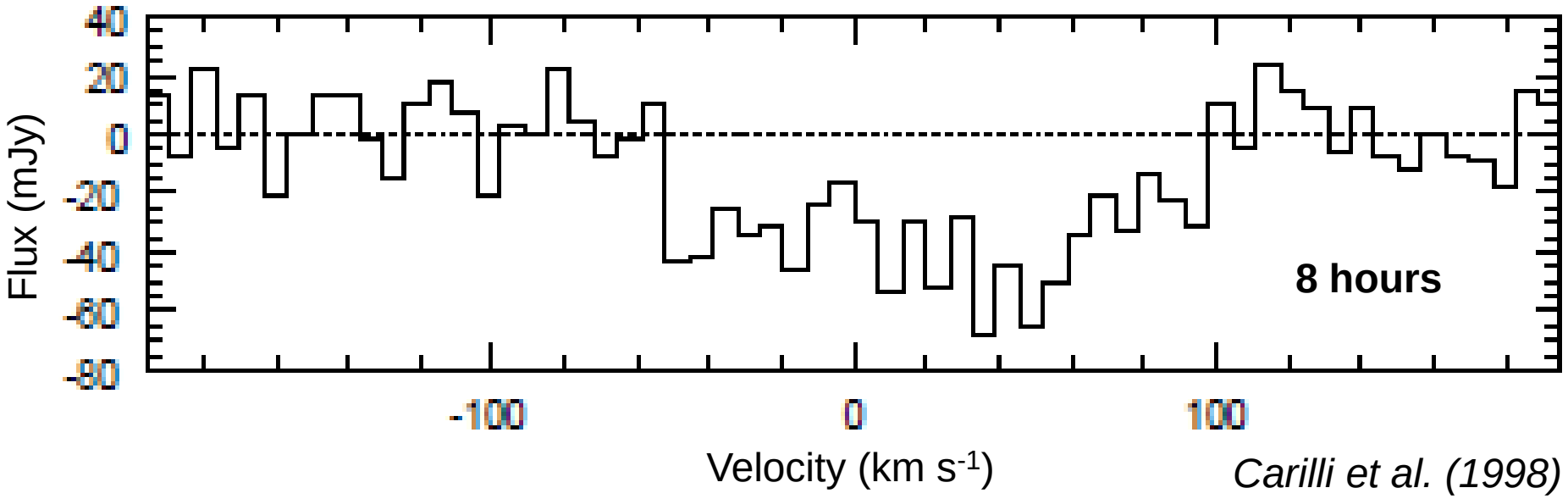
- PKS 1740-517 and PKS 1829-718 are associated with Giga-Hertz Pe[illegible]
- GPS sou[illegible] AGN

Left: Alli[illegible] ngham.



Known detection

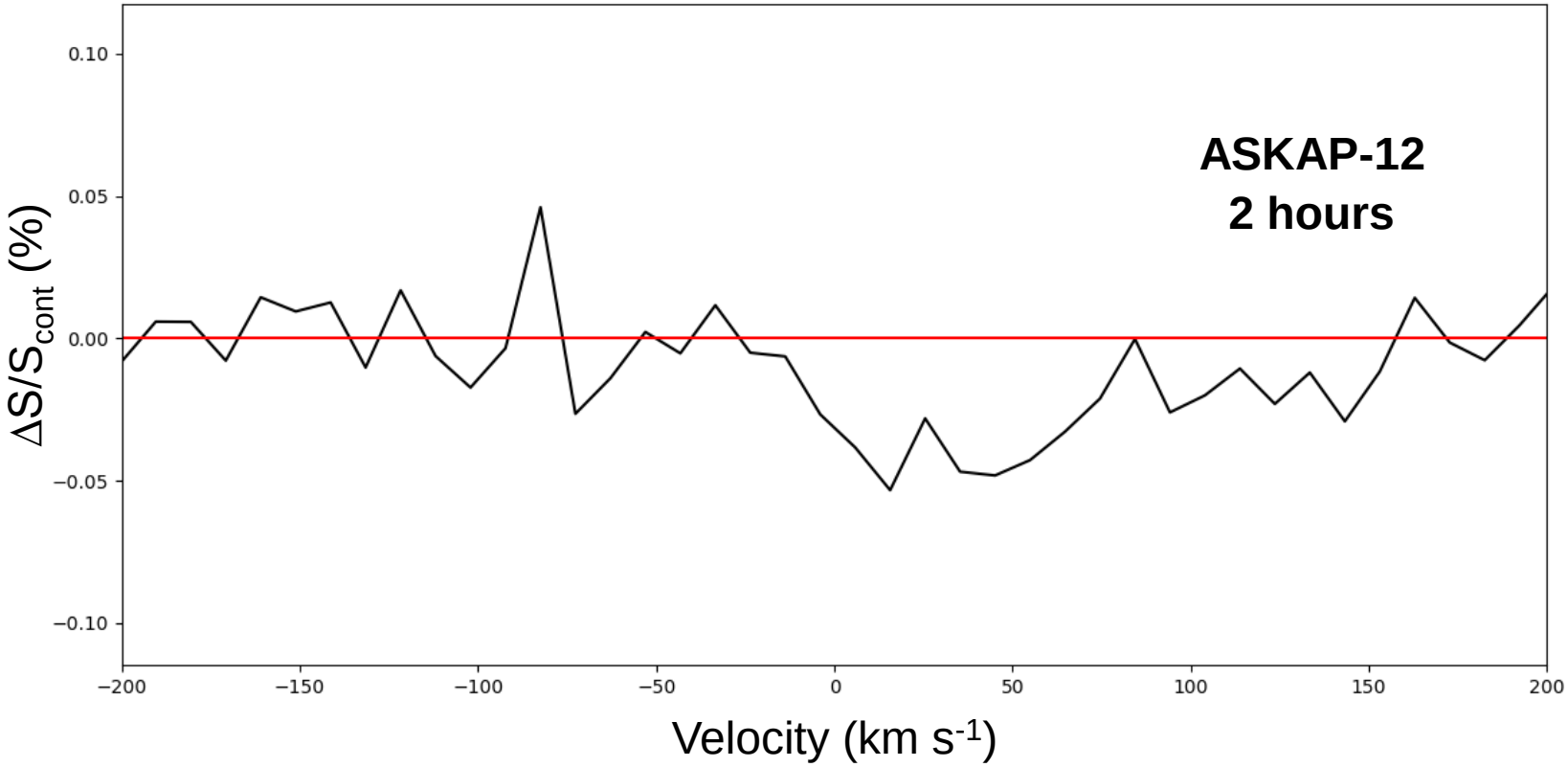
- **PKS 0500+019**
- Redshift of absorption feature is z = 0.585
- Optical depth ~ 4%
- Possibly within an intervening galaxy – background quasar?



Carilli et al. (1998)

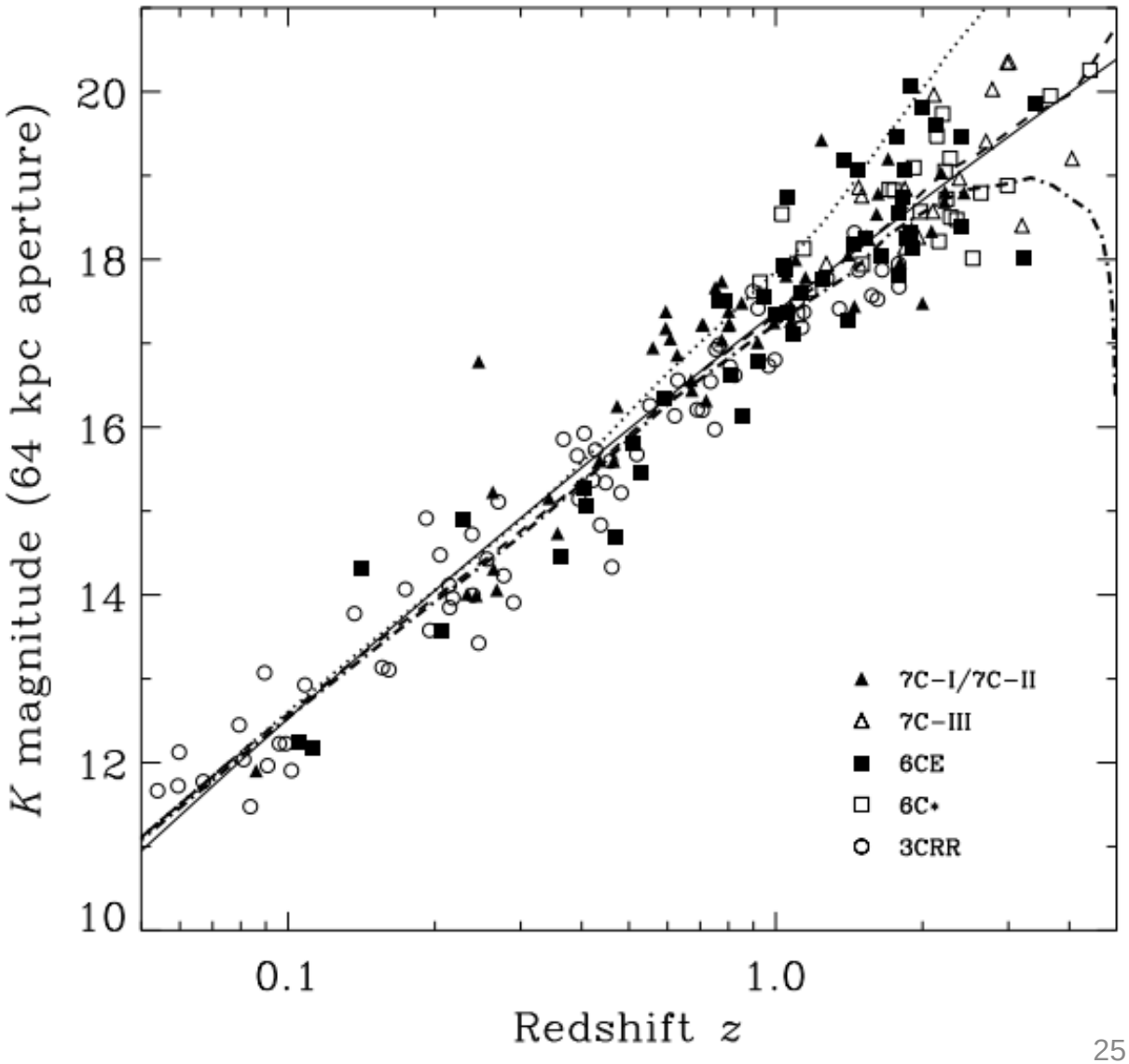
Known detection

- **PKS 0500+019**
- Redshift of absorption feature is z = 0.585
- Optical depth ~ 4%
- Possibly within an intervening galaxy – background quasar?



Redshift Estimate?

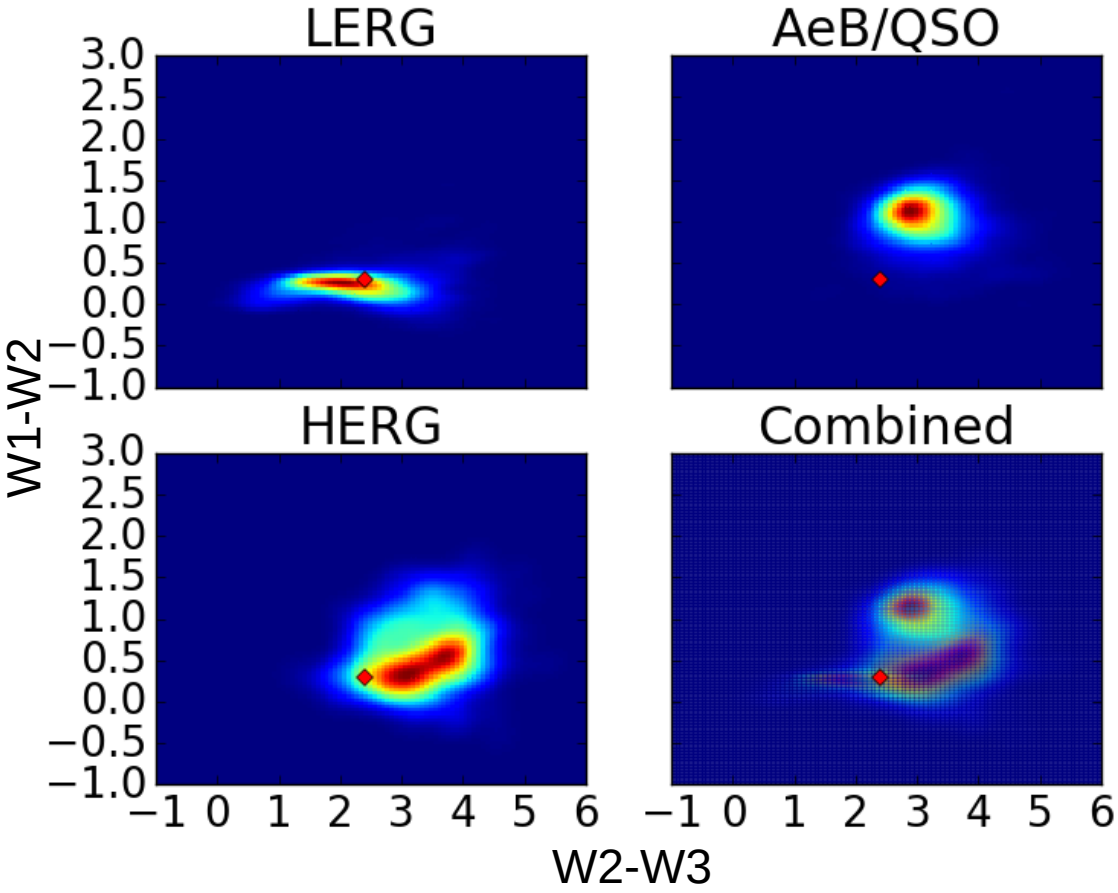
- Can we estimate the redshift of radio galaxies without optical spectroscopy?
- K-z relation exists for radio galaxies (Willott et al. 2003)
- Can explore similar wavelengths for relationship with redshift
- WISE: an all-sky survey that offers this!



Willott et al. (2003)

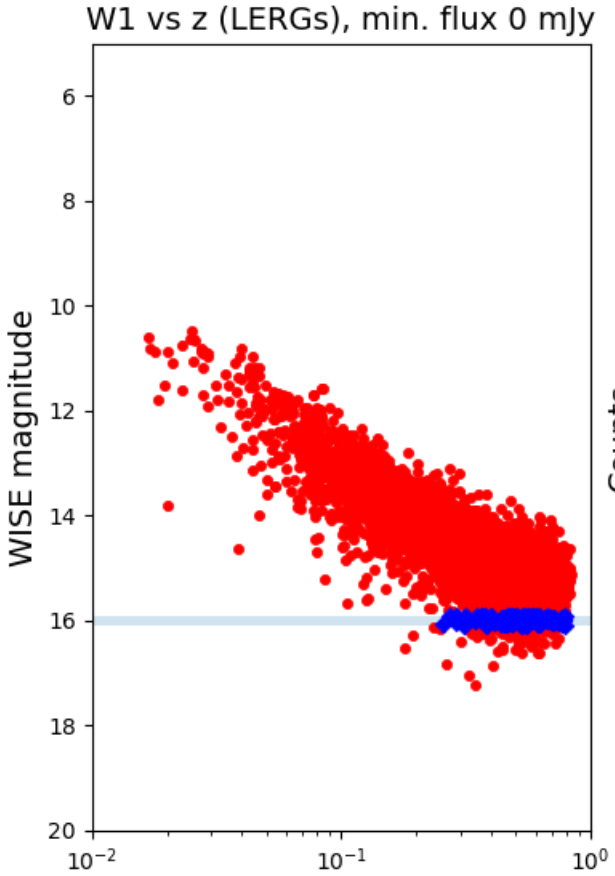
WISE class estimate

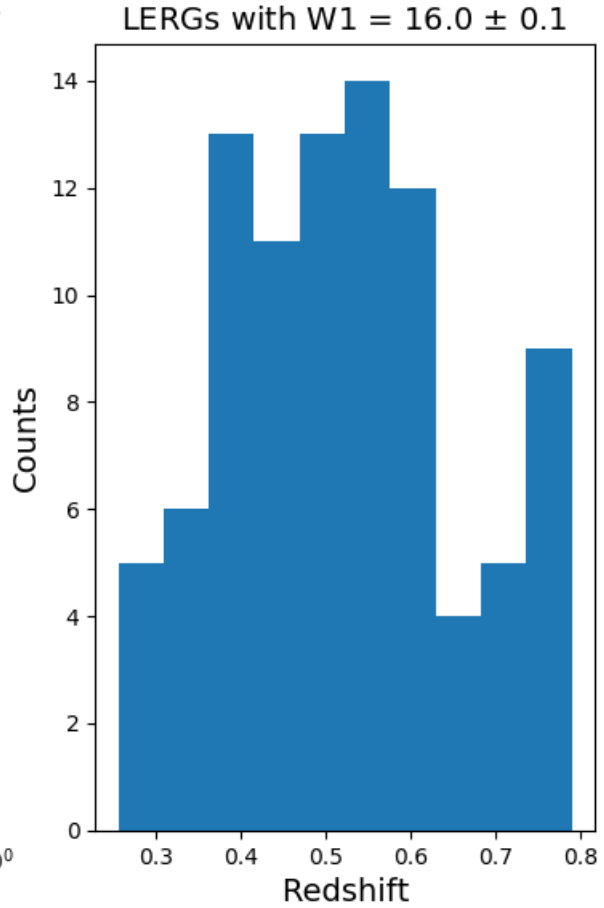
- Use LARGESS sample (Ching et al. 2017) as training set
- Spectroscopic redshifts and class identification:
  - Low-excitation radio galaxy (LERG)
  - High-excitation radio galaxy (HERG)
  - QSO
- Can estimate radio galaxy class based on WISE colour information

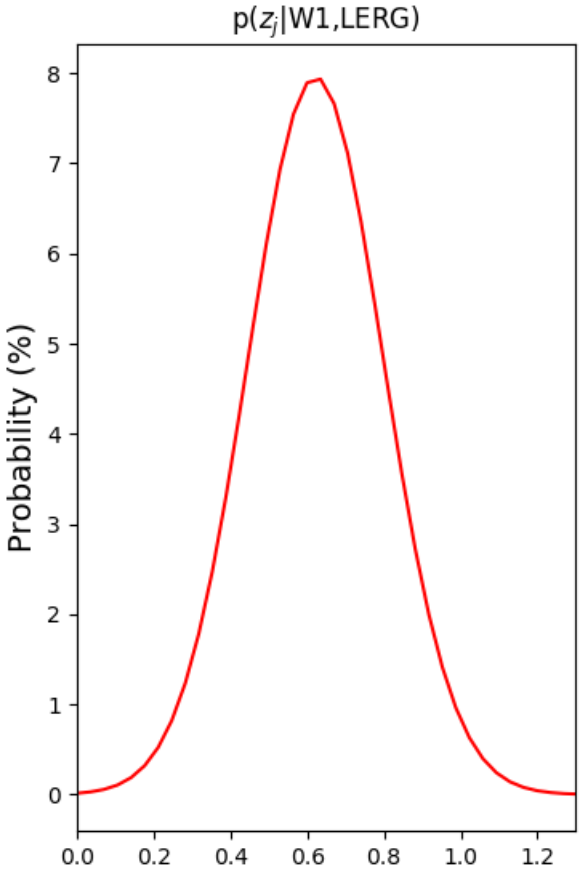


WISE redshift estimate

- From WISE magnitude, generate redshift distributions
- Repeat for all radio galaxy classes, then weight by likelihood of each class

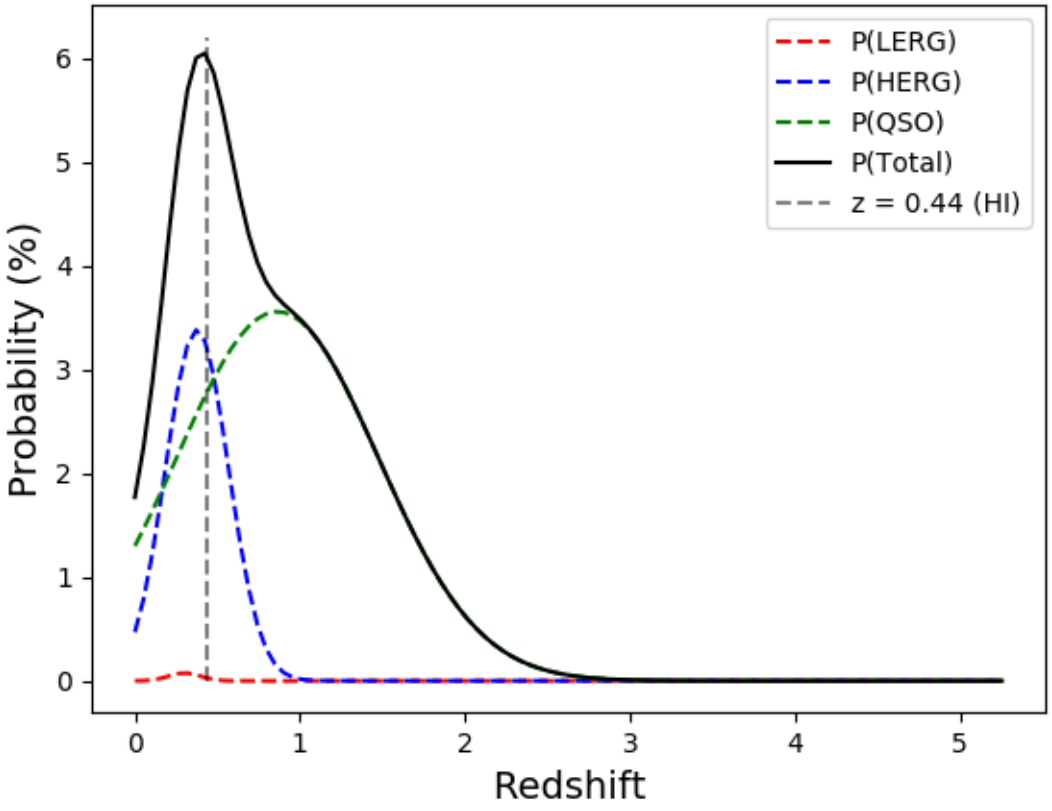




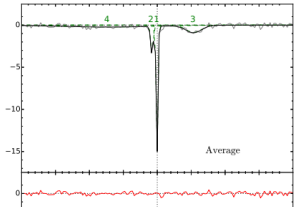


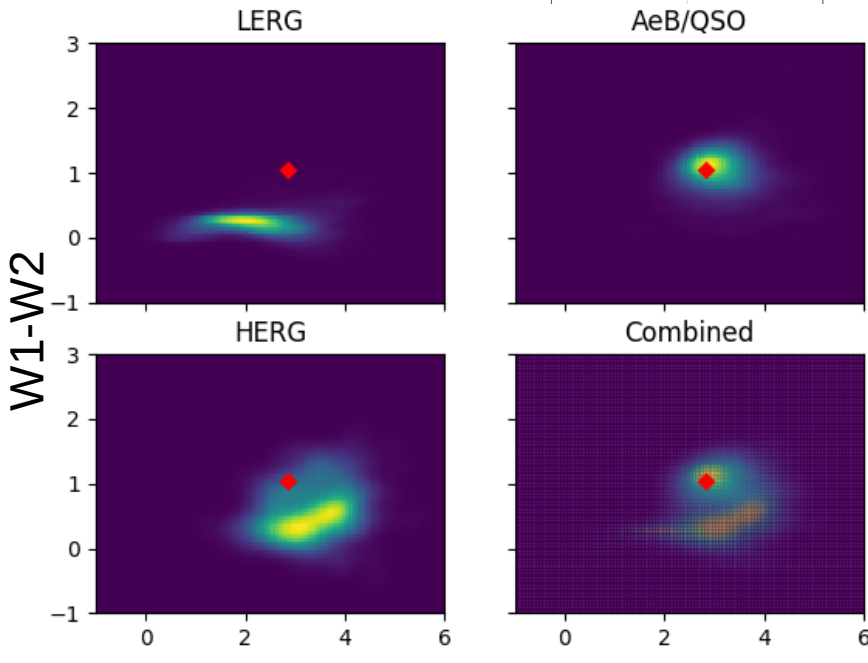
WISE redshift estimate

- **PKS 1740-517** redshift probability distribution
- Estimate from WISE magnitudes agrees well with redshift
- QSO or HERG classification from WISE colour information



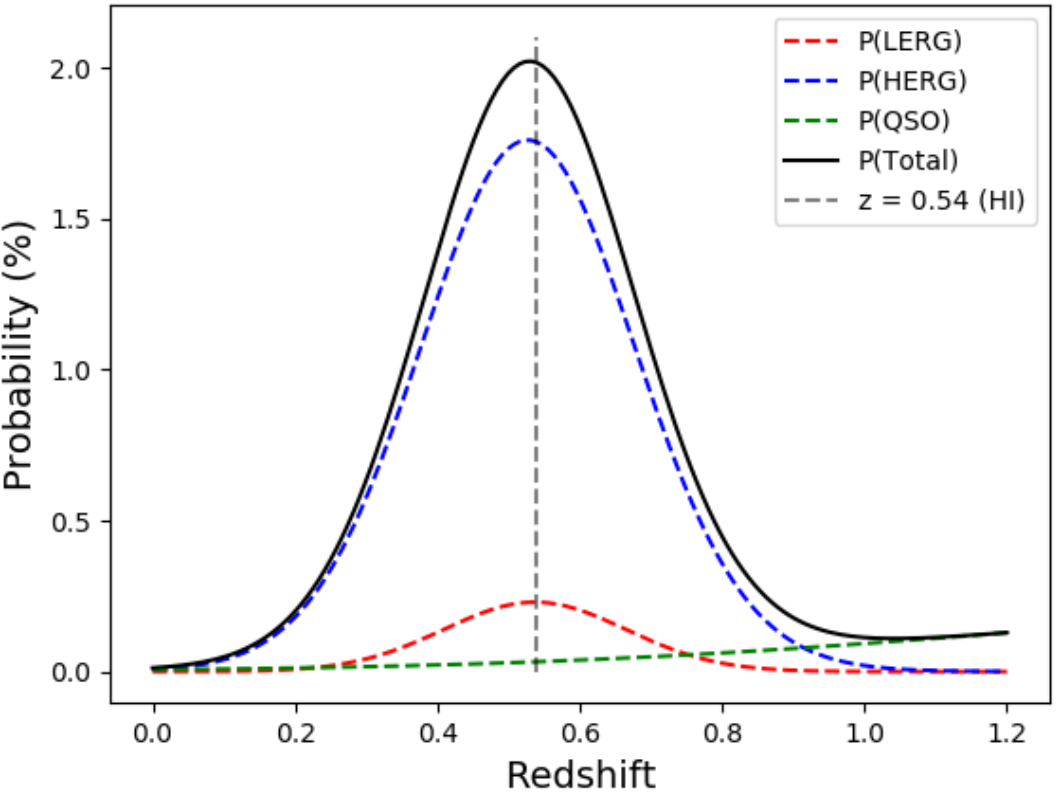
$z_{HI} = 0.44$



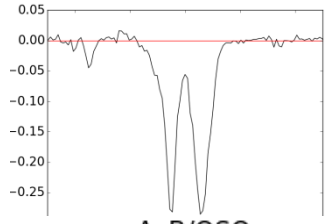


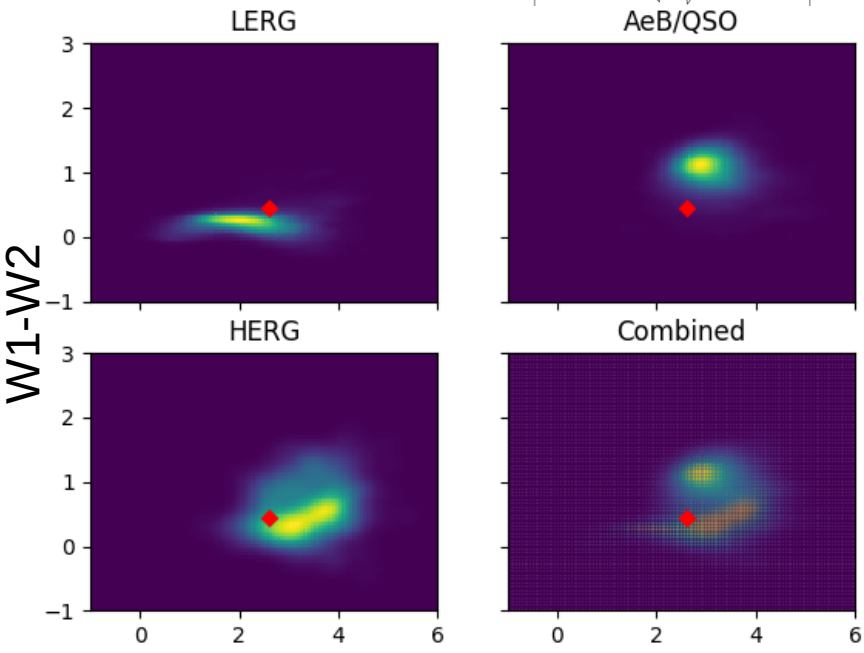
WISE redshift estimate

- **PKS 1829-718** redshift probability distribution
- Estimate from WISE magnitudes agrees well with $z_{HI} = 0.54$
- Most likely to be a HERG from WISE colour information



$z_{HI} = 0.54$



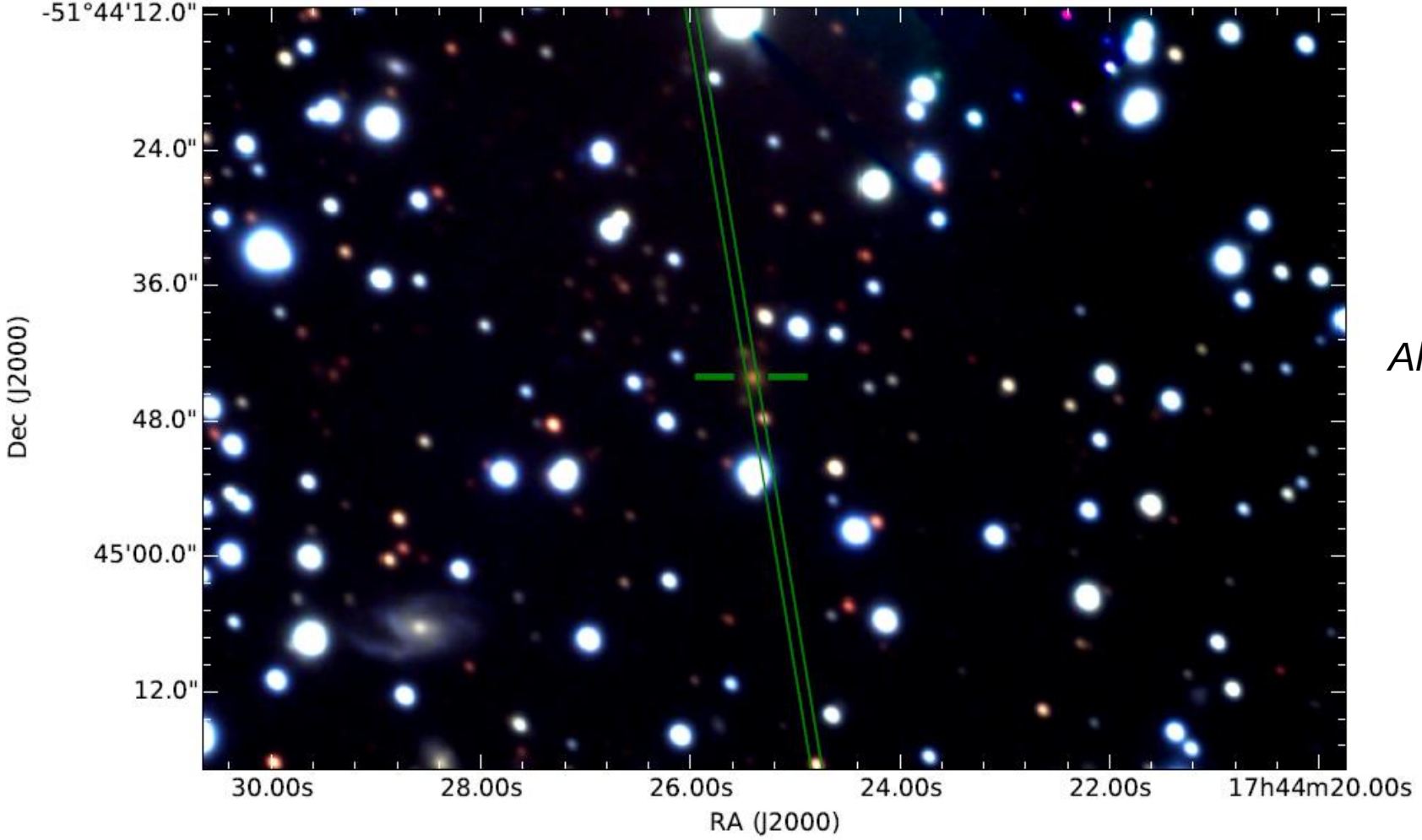


Summary

- **Optically obscured quasars represent a short transitionary stage in galaxy evolution**
- **Used the HI 21-cm transition in absorption** to trace gas kinematics in a commissioning sample with **ASKAP-BETA**.
- **Made three detections of HI (z = 0.44, 0.54, 0.58)**
- **Use mid-infrared WISE magnitudes to estimate redshift**
- **FLASH** will find HI in high-redshift galaxies across southern sky

Multi-wavelength follow-up

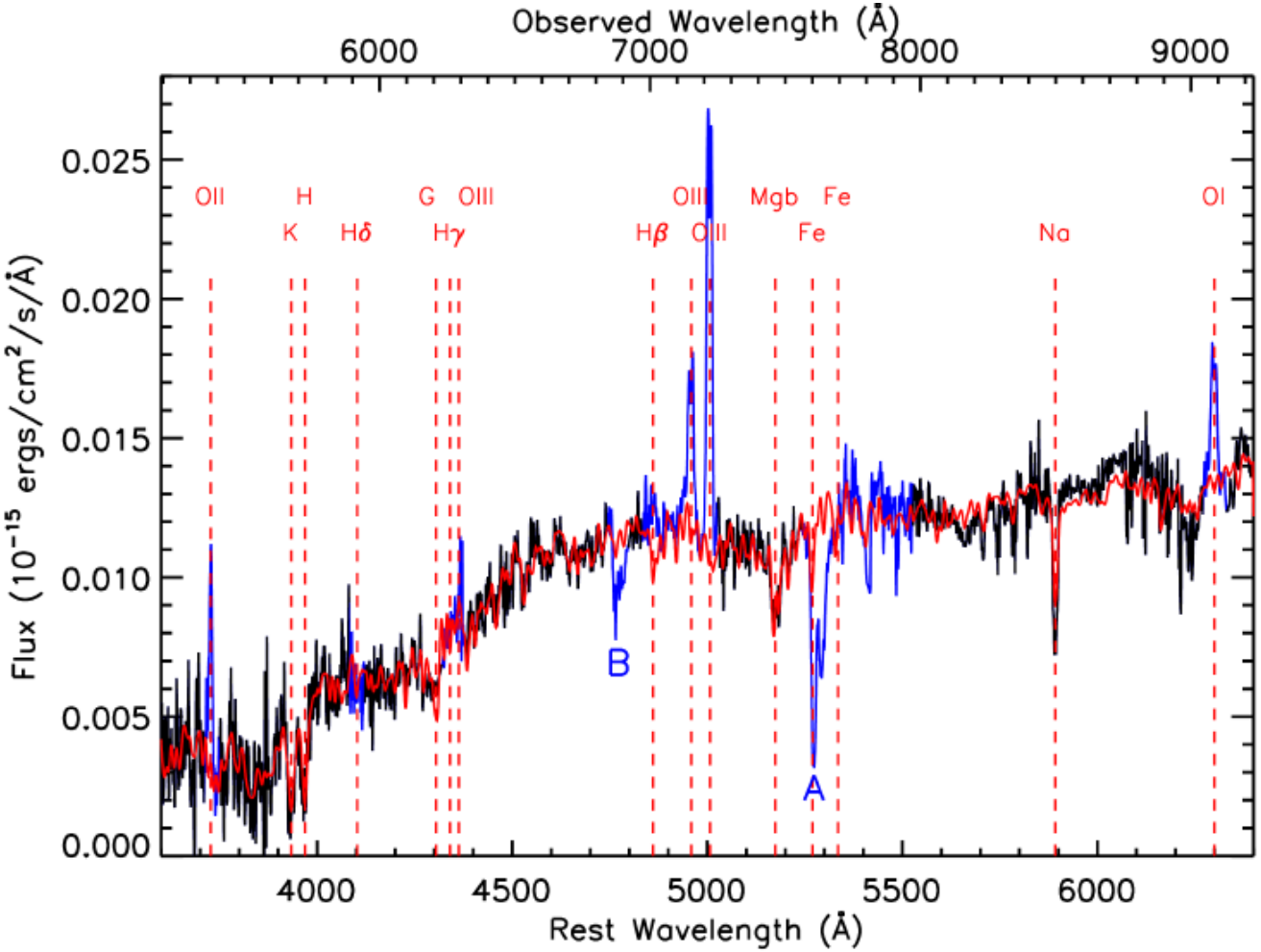
- PKS 1740-517 followed up with Gemini to verify redshift
- What about all the other radio galaxies in southern sky?



Allison et al. (2015)

Multi-wavelength follow-up

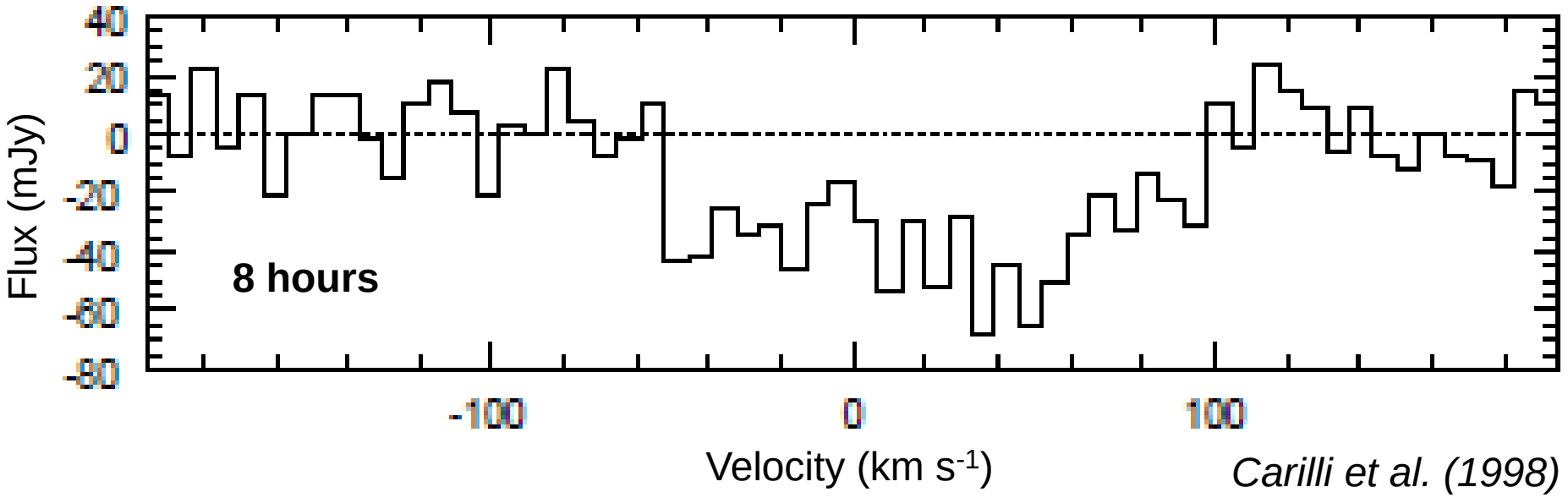
- PKS 1740-517 followed up with Gemini to verify redshift
- What about all the other radio galaxies in southern sky?



Allison et al. (2015)

Known detection

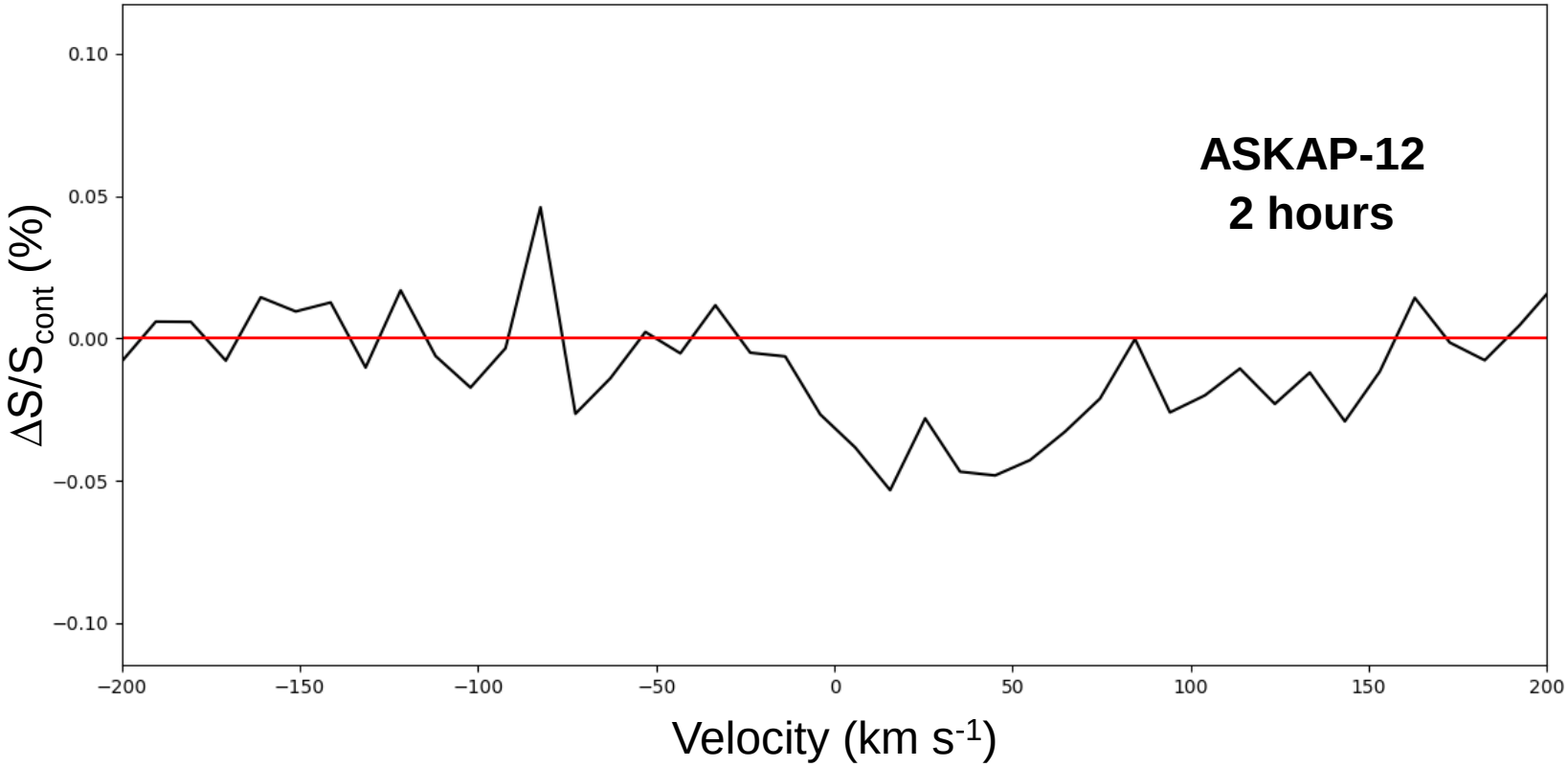
- **PKS 0500+019**
- Redshift of absorption feature is z = 0.585
- Optical depth ~ 4%
- Possibly within an intervening galaxy – background quasar?



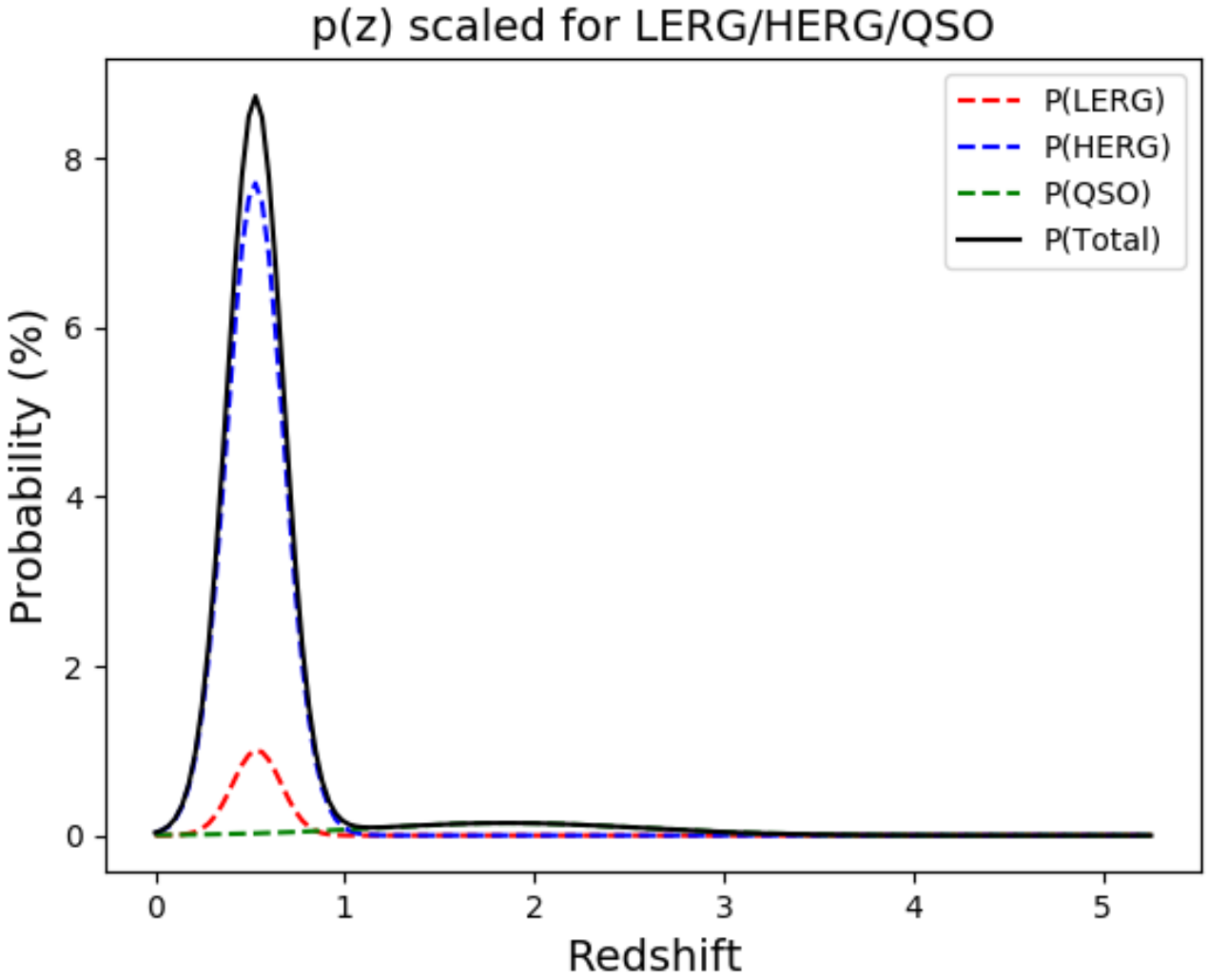
Carilli et al. (1998)

Known detection

- **PKS 0500+019**
- Redshift of absorption feature is z = 0.585
- Optical depth ~ 4%
- Possibly within an intervening galaxy – background quasar?



PKS 1829-718 Prob. Dist.



WISE Photometric Redshift

- PKS 0500+019 redshift probability distribution
- Lower redshift peak < HI redshift z = 0.585
- Speculated to be a background galaxy (Stickel et al. 1996)