Unveiling the high-frequency radio source population with the AT20G survey

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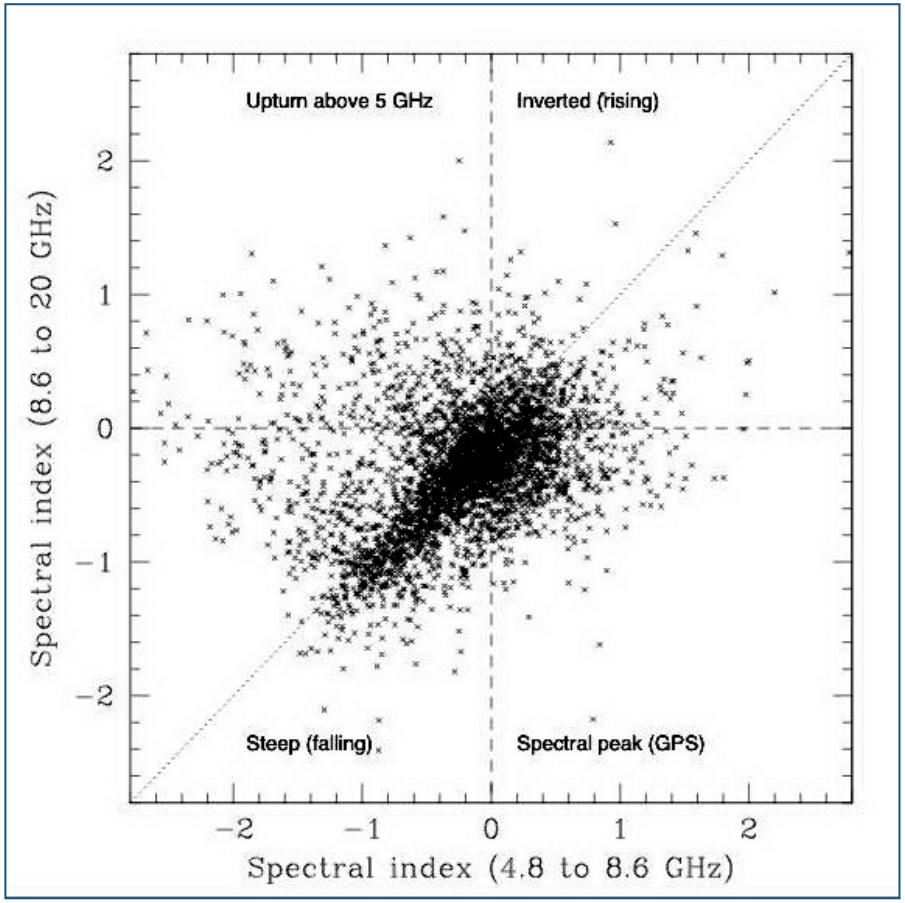
Radio properties of AT20G sources

- 20 GHz source population is very different to that selected from 1 GHz surveys
- Dominated by flat-spectrum cores
  - 87% of AT20G sources have α>-0.5
  - 37% of 1 GHz surveys have α>-0.5



Murphy et al. 2010

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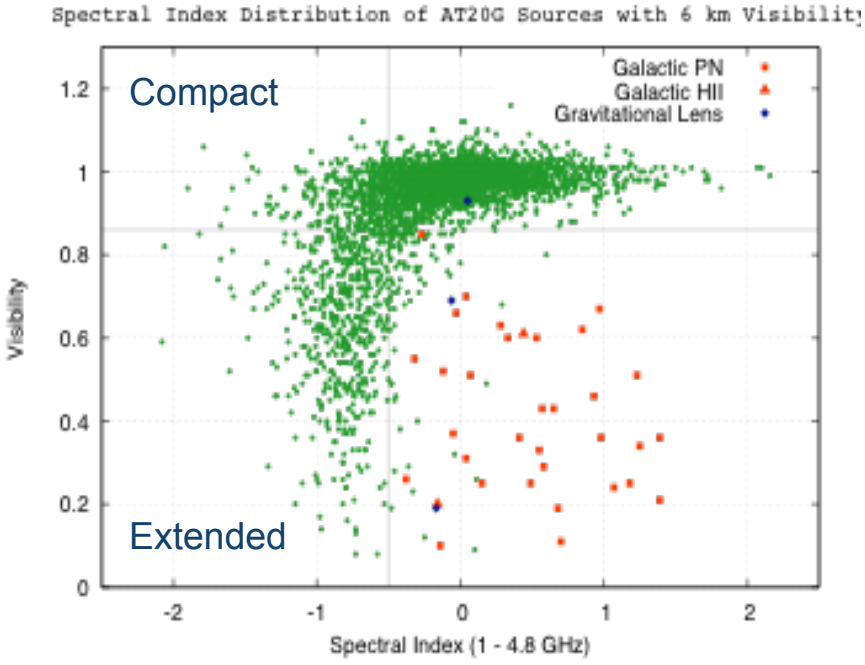
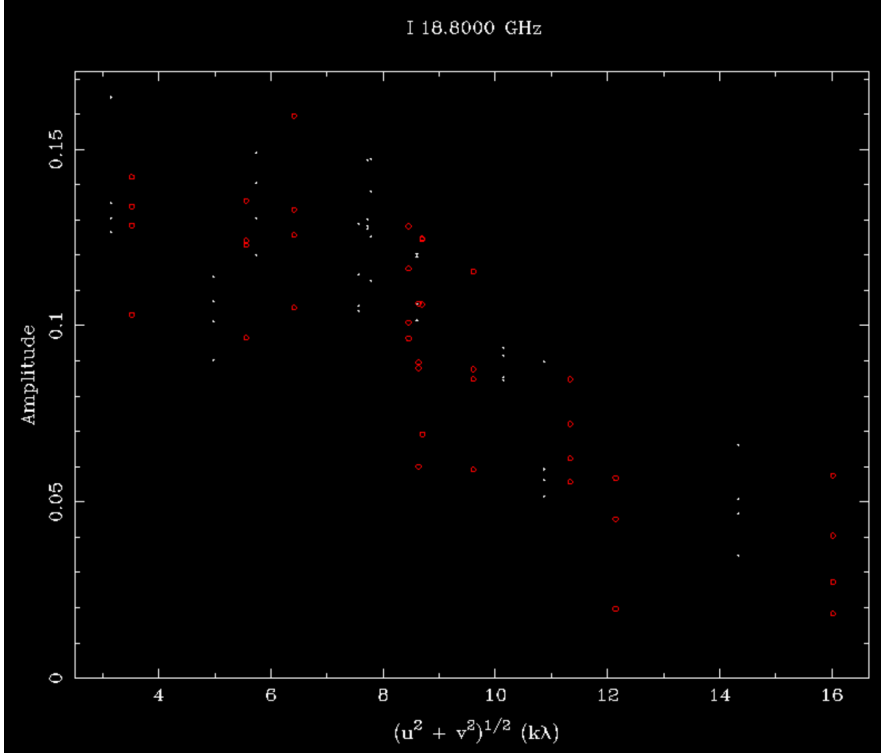
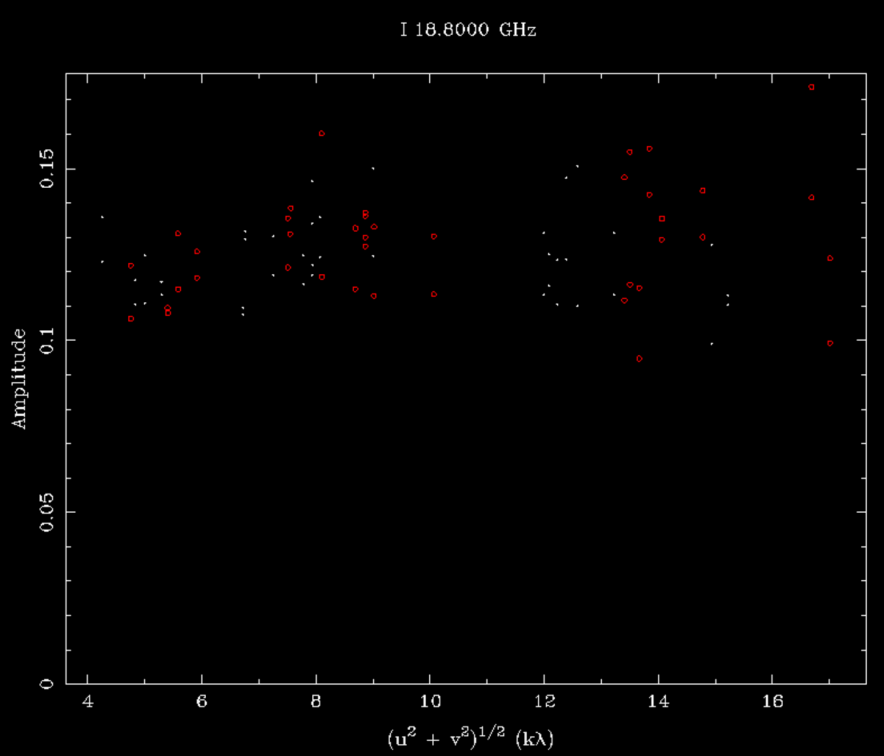
  - 87% of AT20G sources have α>-0.5
  - 37% of 1 GHz surveys have α>-0.5
- Dominated by compact sources:
  - 72% of AT20G sources are compact on the 6km baselines
  - Primary AT20G catalogue uses 5 ATCA dishes on short baselines (flagged 6km baselines)
    - 95% of AT20G sources are compact (on scales of ~15 arcsec)



Steep spectrum Flat spectrum

Chhetri et al. 2012


I 18.8000 GHz
Amplitude
0
0.05
0.1
0.15
4
6
8
10
12
14
16
(u2 + v2)1/2 (kλ)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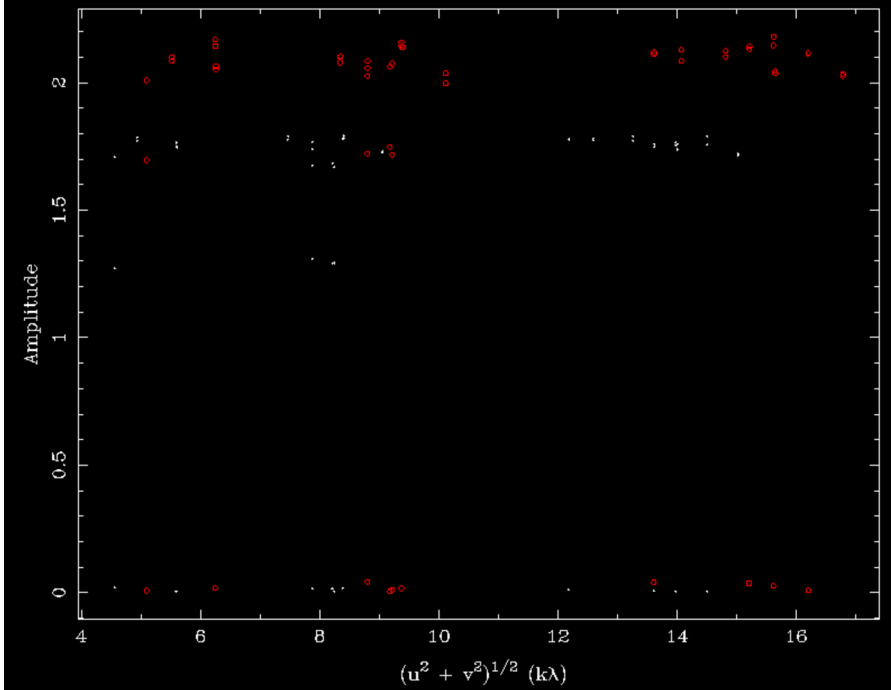
Amplitude
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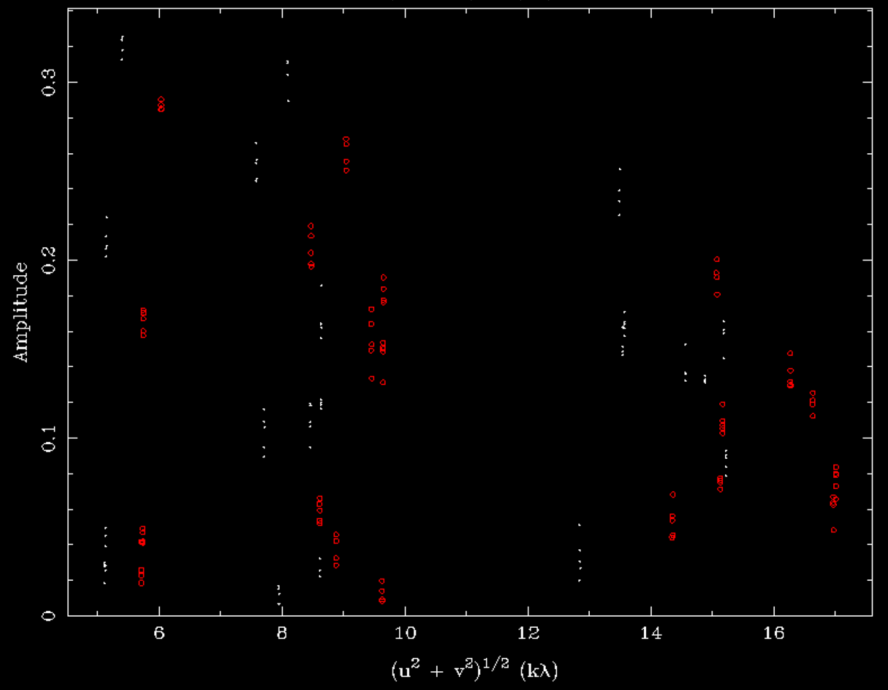
Amplitude
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(u2 + v2)1/2 (kλ)

Whilst the radio data provides a unique sample of objects, these data alone are insufficient to completely constrain models of radio source properties and the evolution of radio galaxies.

➡ Need multiwavelength information!

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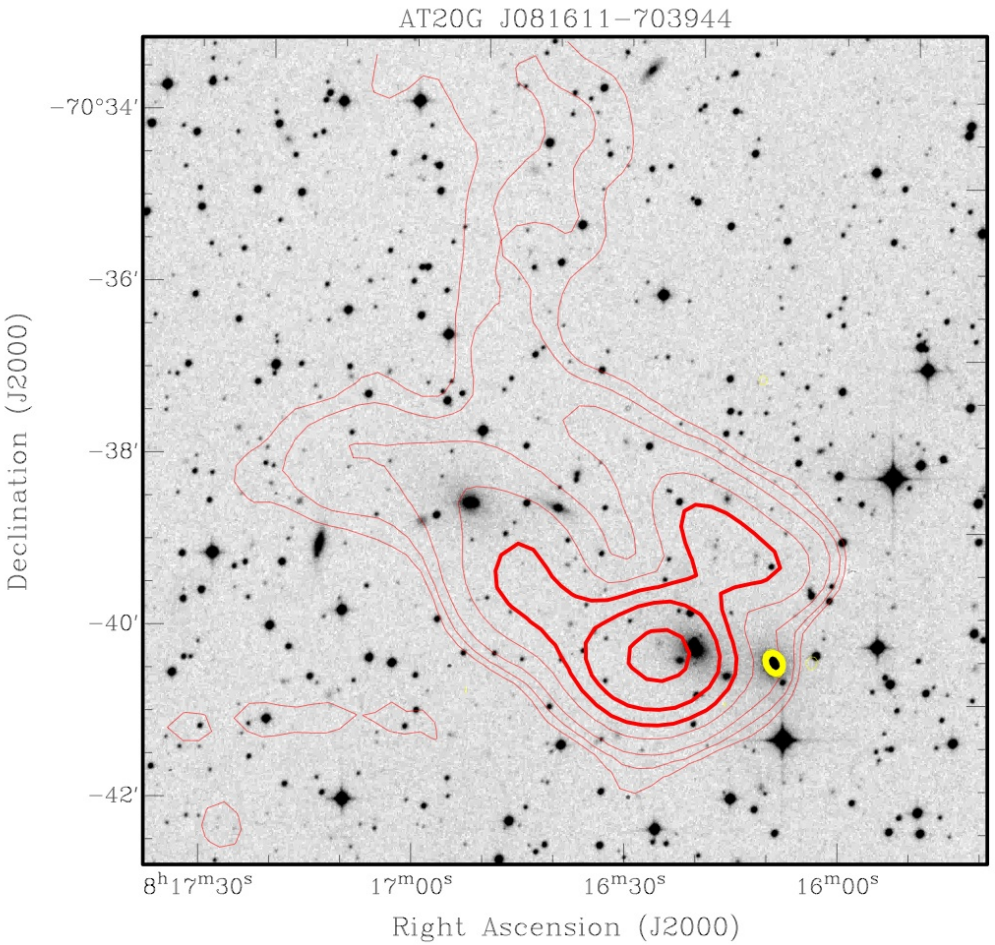
Optical properties of AT20G sources

Finding optical counterparts

- First step – finding the correct optical counterparts
  - Crossmatched AT20G with SuperCOSMOS database (B + R band photographic plates from UKST)
- 20 GHz emission probes the core of the AGN, not the large scale jets/lobes (unlike low frequencies)
  - Very useful in identifying the correct ID

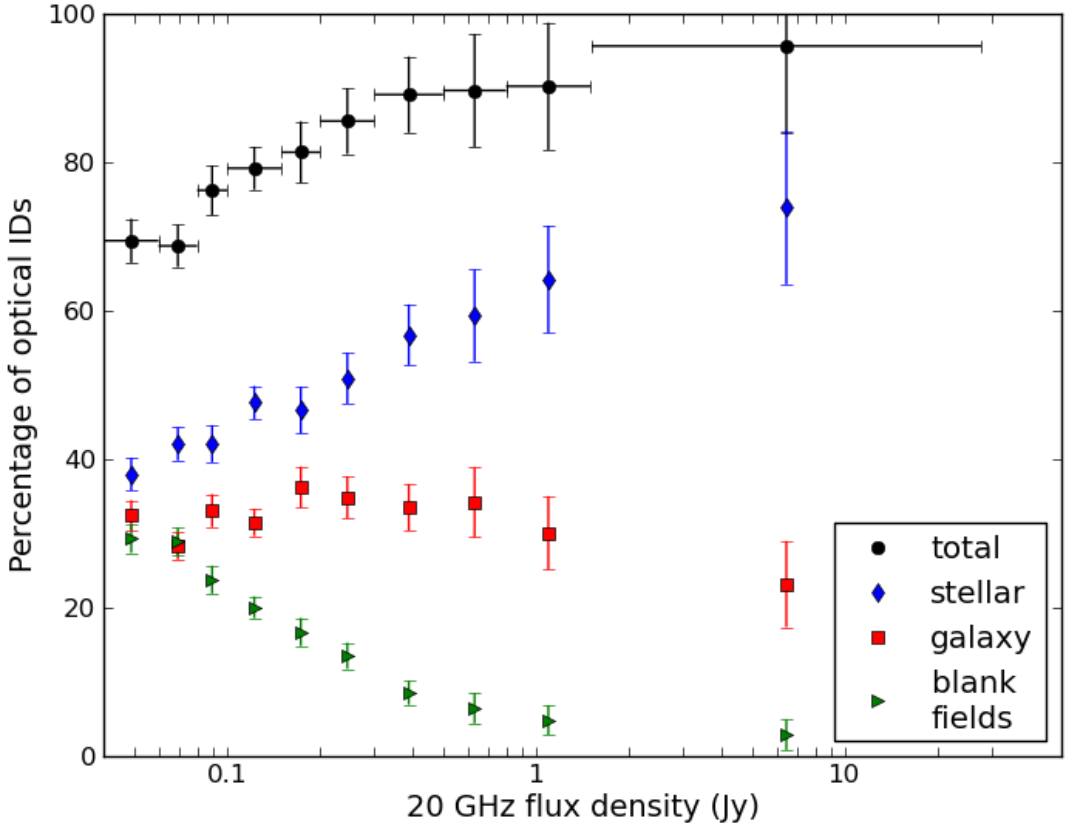


Yellow contours: 20 GHz
Red contours: 1.4 GHz
Background: Optical B-band image

Sadler et al. 2014

Optical source morphology

- 78.5 % of AT20G sources have optical IDs
  - Lower freq. surveys ~25-30%
- Optical ID rate increases with increasing 20 GHz flux density
  - Sample dominated by QSOs - particularly at high flux densities
  - Galaxies + blank fields (distant galaxies) start to dominate at lower fluxes
- Only a subset (~15%) have spectroscopic information
  - formed a complete sample with z<0.3 to study to spectroscopic properties



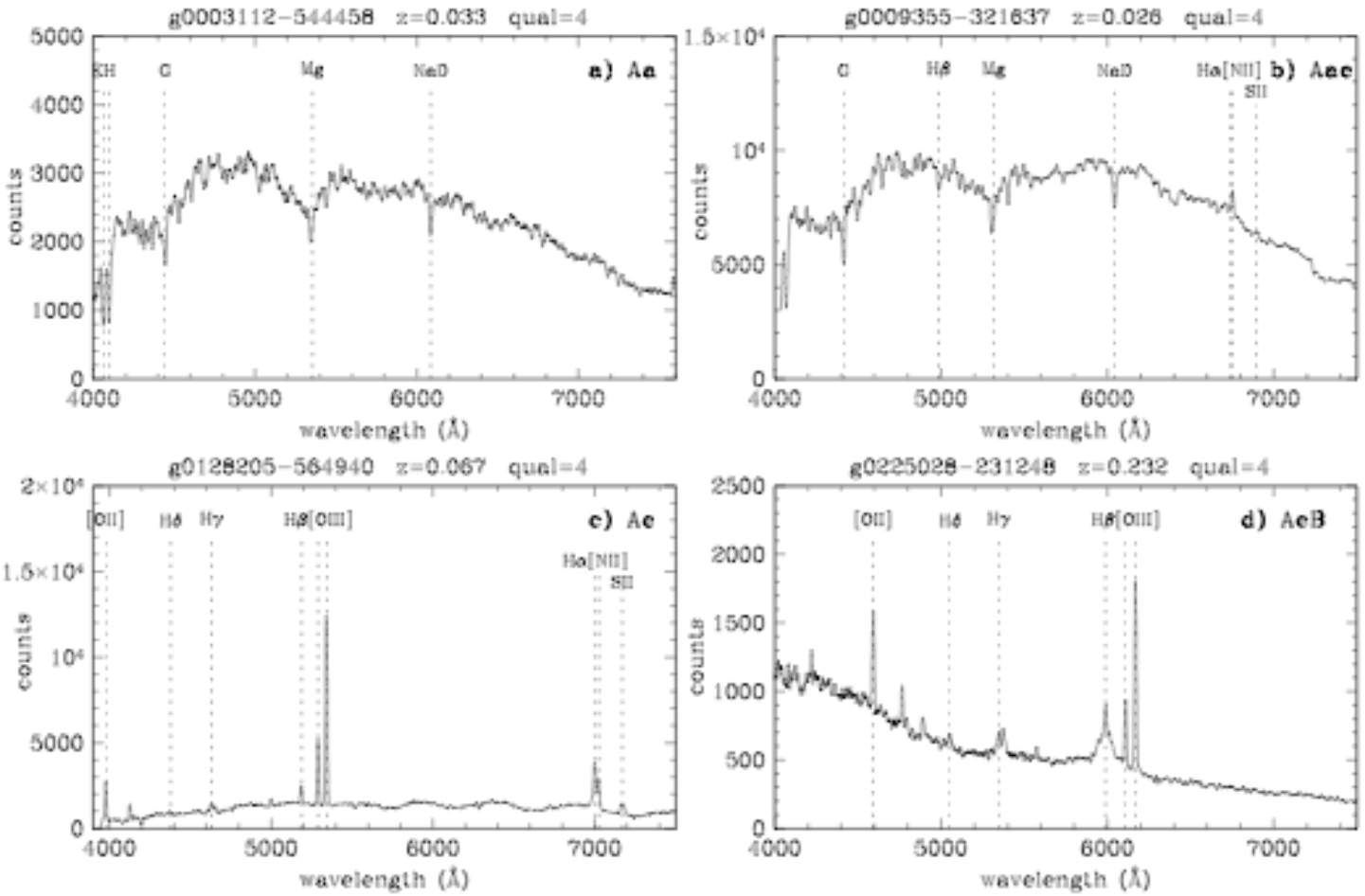
Mahony et al. 2011

High-excitation vs. low-excitation radio galaxies

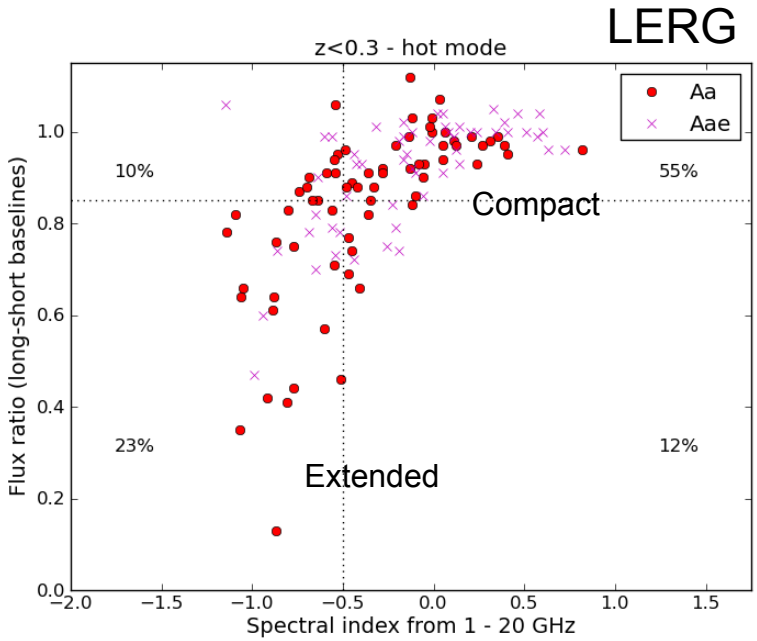
Do the different accretion mechanisms translate to differences in the observed radio properties?

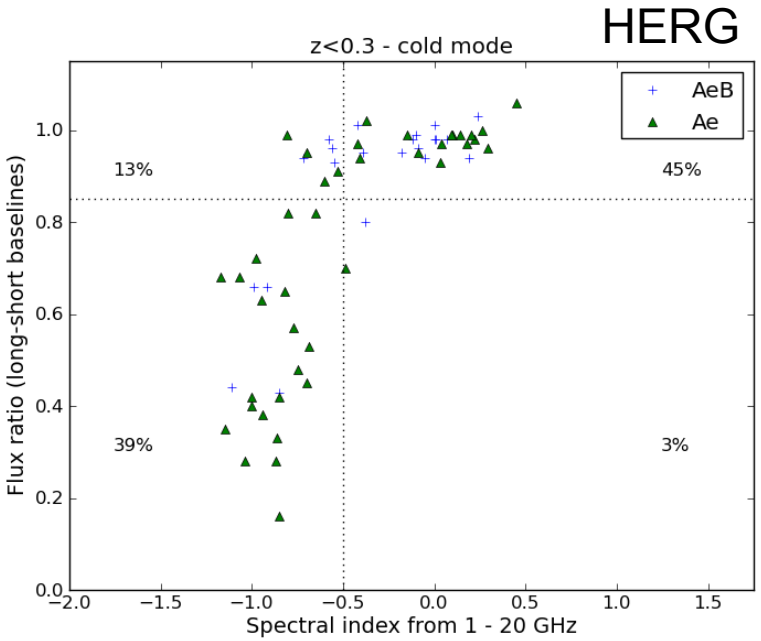
LERG:
Low accretion rate

HERG:
High accretion rate



High-excitation vs. low-excitation radio galaxies



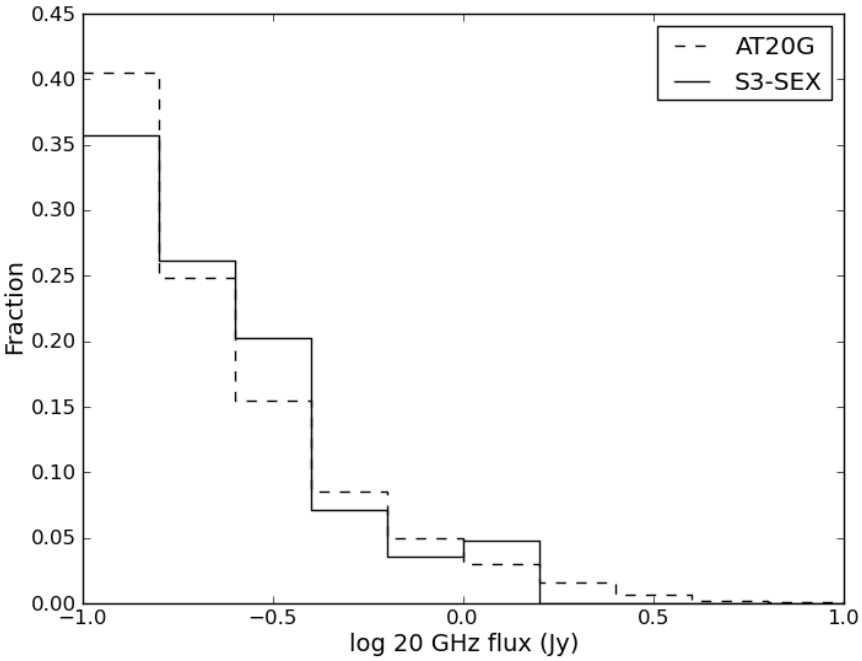


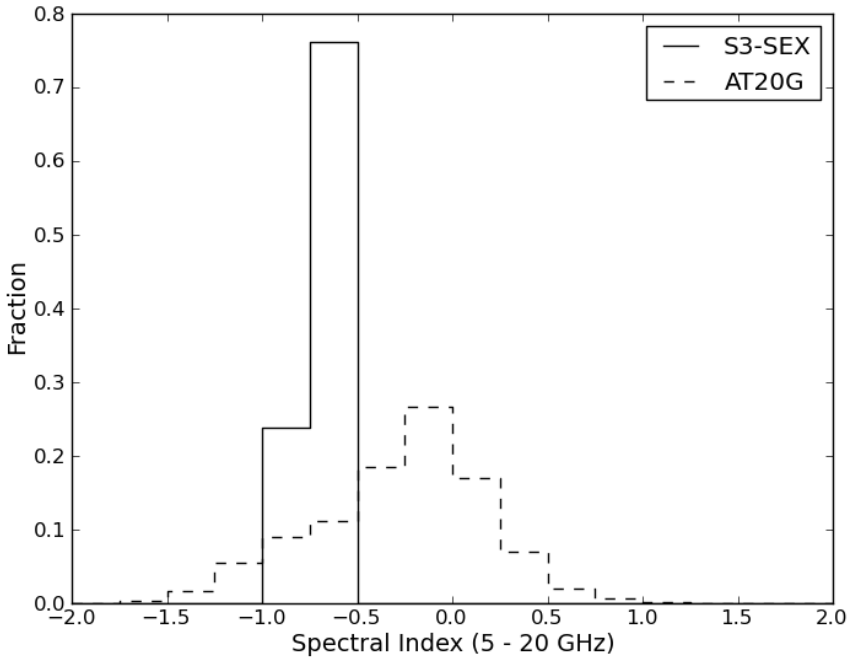
Mahony et al. 2011

- HERGs have a steeper median spectral index
  - α = -0.49 for HERGs, α = -0.18 for LERGs
- HERGs have a higher percentage of extended sources
- Sources which are accreting more efficiently have more powerful radio jets and lobes

AT20G vs. SKA Design Studies

- SKA simulated skies (S^3) Semi-empirical simulations:
- Selected S^3 sources at 18 GHz with S_{18}>100 mJy to compare with AT20G





Mahony et al. 2011

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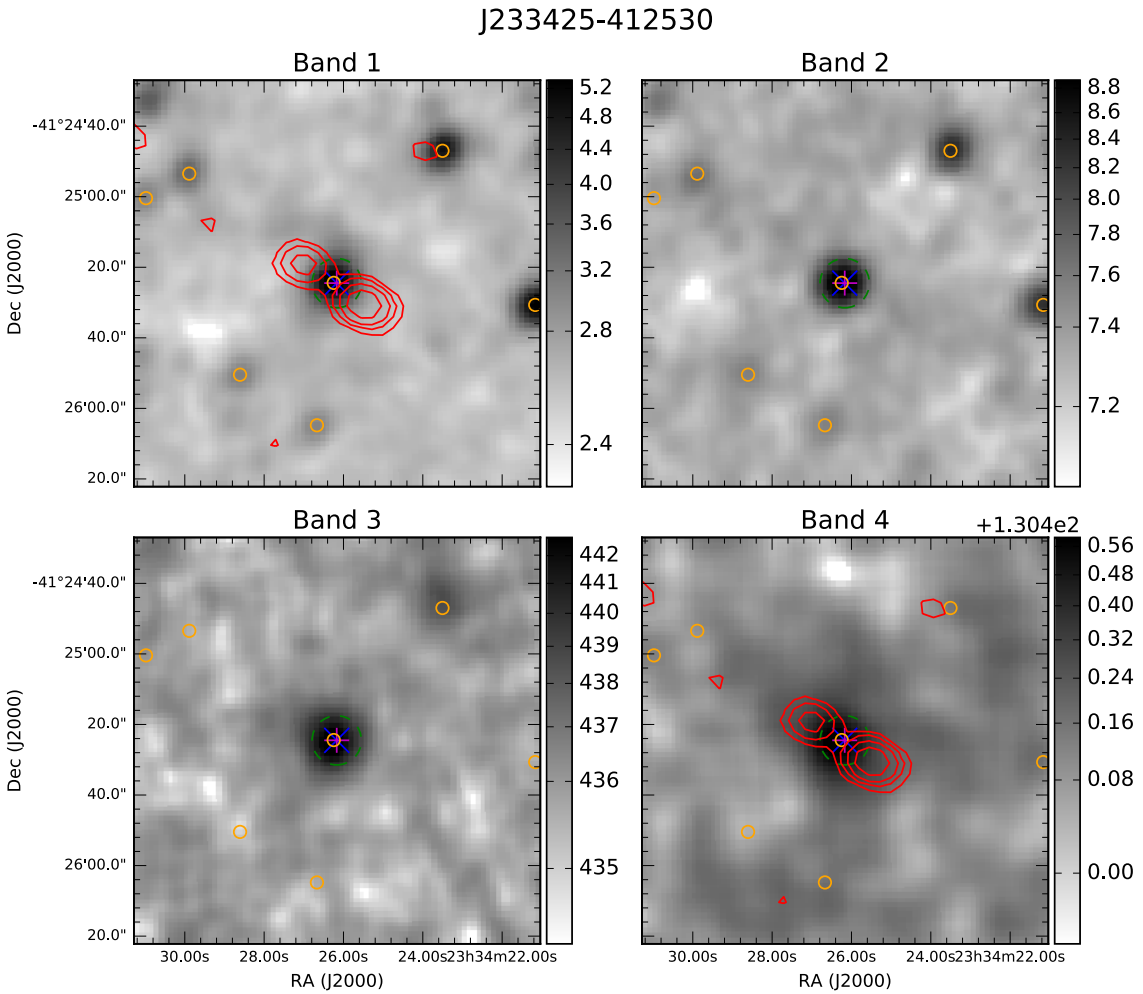
IR properties of AT20G sources

WISE crossmatching

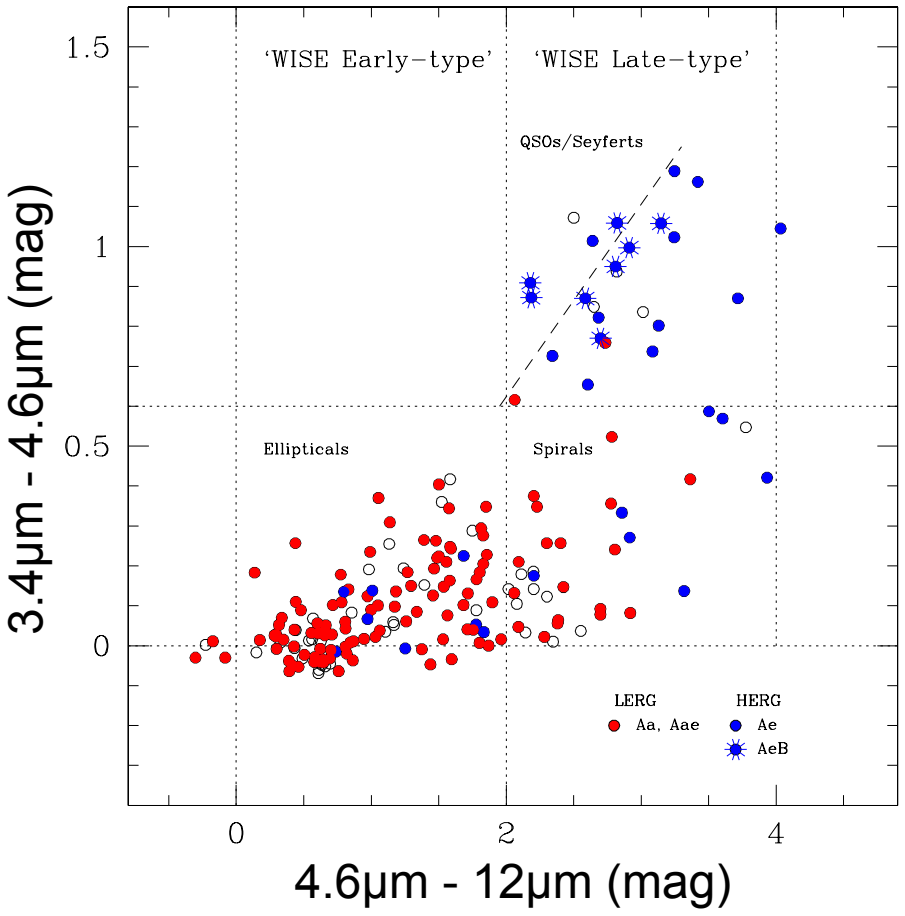


Red contours: 20 GHz
Background: WISE images
Yellow: WISE sources

- Crossmatched with WISE survey
  - 3.4, 4.6, 12, 22um images
  - Used optical position if available (otherwise AT20G position)
- ~90% have IR counterparts
- See Rajan's talk on Friday!

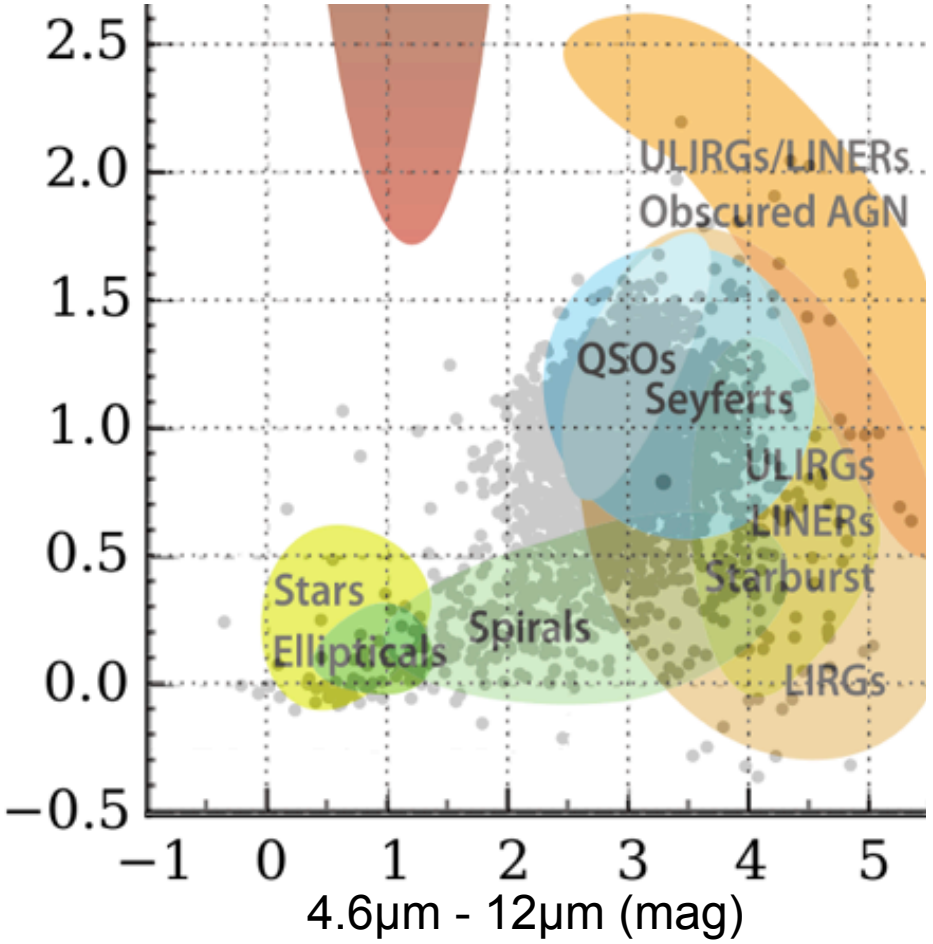
WISE colour-colour plots

Local 20-GHz population:



Sadler et al., 2014

Compact AT20G sources:



Chhetri et al., in prep.

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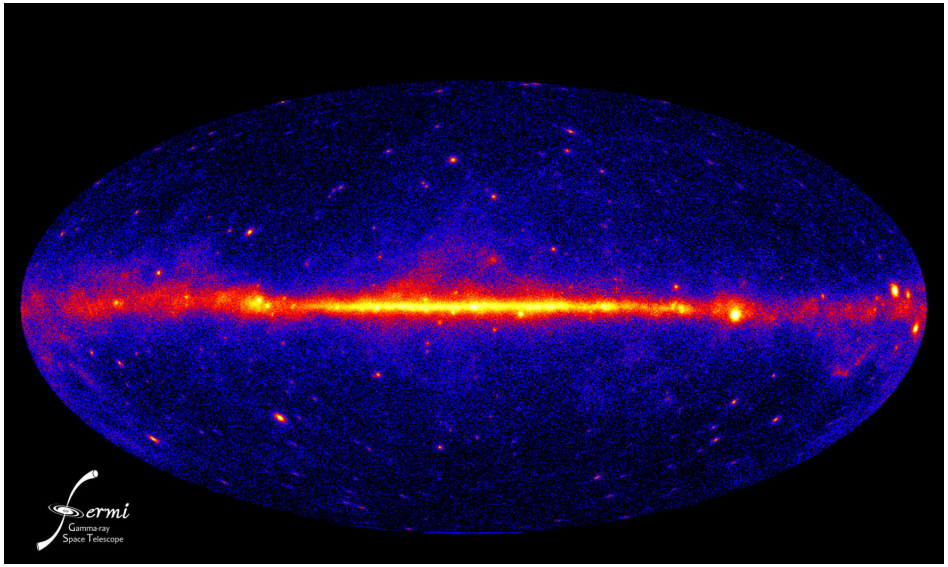
High-energy properties of AT20G sources

The Fermi-LAT 1-year Point Source Catalogue

- Crossmatched with the Fermi-LAT 1 year catalogue
- F.o.v. ~2 sr
- Scans the sky every 3 hrs
- Energy range 20 MeV – 300 GeV
- Average positional uncertainty ~9 arcmin
  - Multiwavelength essential!!!
- Released the 1-year Point Source Catalogue early 2010
  - 1451 sources, mixture of AGN and Galactic sources

Image credit: NASA

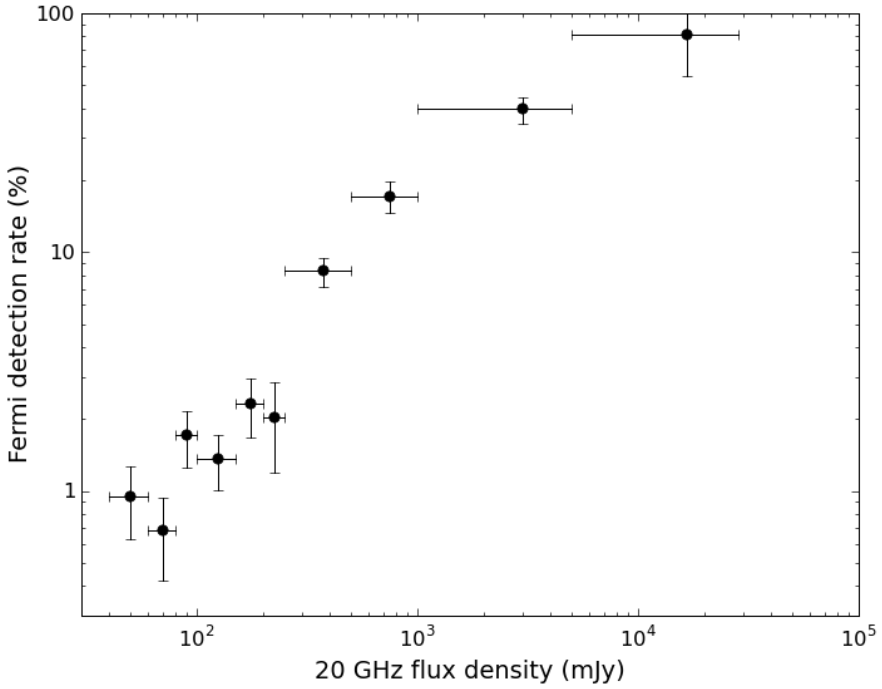


AT20G: the ideal catalogue for Fermi crossmatching

- Clean sample – completely blind survey at 20 GHz
  - No spectral pre-selection based on lower radio frequencies
  - Cleaner sample for doing statistical analysis
  - Uniform sky coverage (excluding Galactic plane, $|b|<1.5°$)
- AT20G sky very similar to Fermi sky
  - Large number of Flat Spectrum Radio QSOs (FSRQ)/blazars
- Ideal for finding AGN identifications
  - Don't see any of the Galactic Fermi sources (e.g. pulsars, x-ray binaries) in AT20G

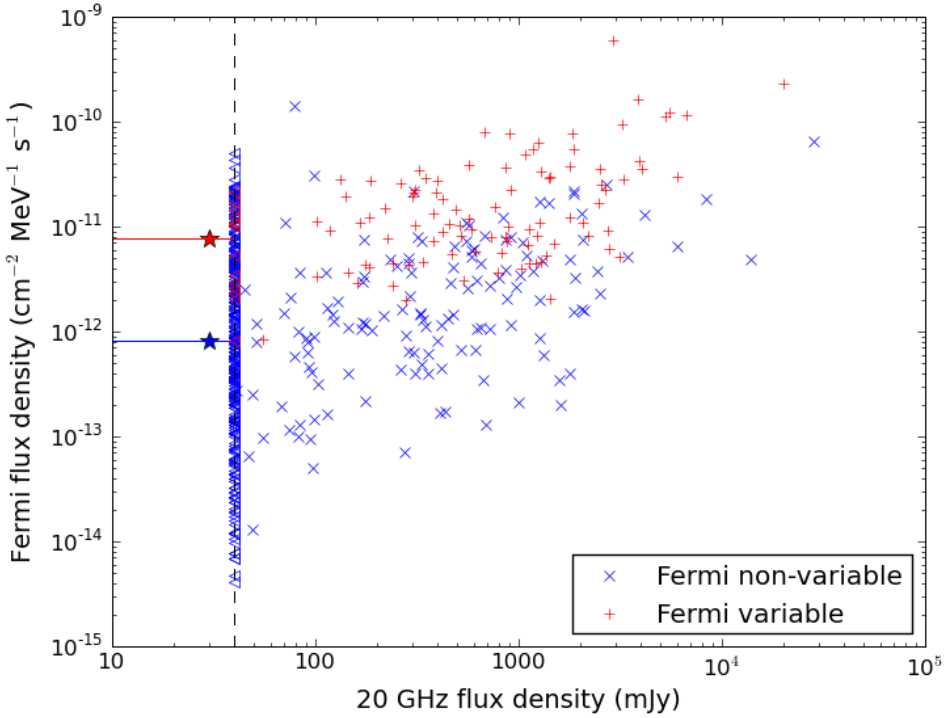
Gamma-ray properties of AT20G sources

- Total of 233 AT20G-Fermi matches (43% of southern Fermi sources detected in AT20G)
- In agreement with the 1LAC catalogue
  - No missing high-freq population
- **8 new identifications** – all at low galactic latitudes where 1LAC in known to be incomplete
- Detection rate increases with 20 GHz flux
  - A few % at 100 mJy
  - Close to 100% above 1 Jy



Mahony et al. 2010

Gamma-ray properties of AT20G sources



›We find a correlation between 20 GHz flux density and gamma-ray flux density

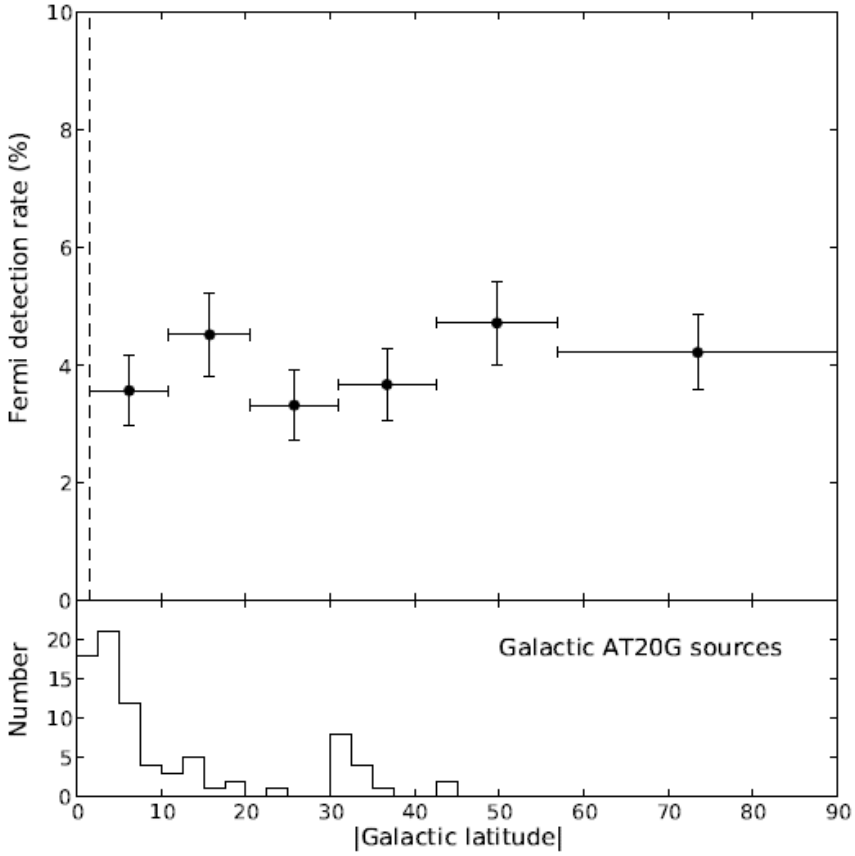
›The AT20G detection rate for variable Fermi sources is 87%
›For non-variables only 32%

Gamma-ray properties of AT20G sources

Chhetri et al. 2012

- The Fermi detections are preferentially the compact, flat-spectrum sources
  - With the exception of a few nearby galaxies (e.g. NGC 253, NGC 4945)
- The majority are associated with QSOs and BL-Lac objects

Detection rate as a function of Galactic latitude

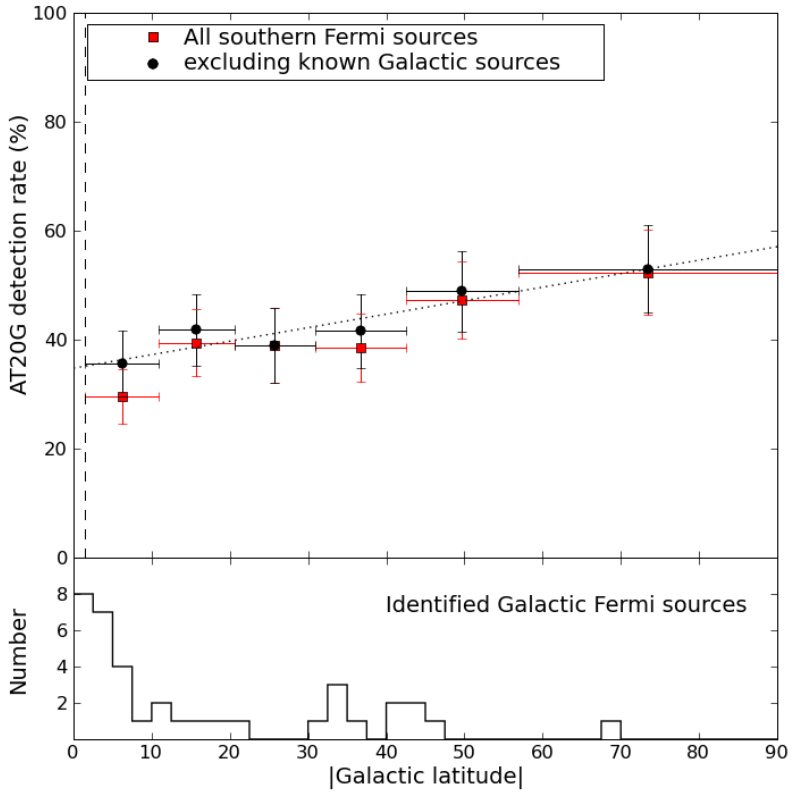


Mahony et al. 2010

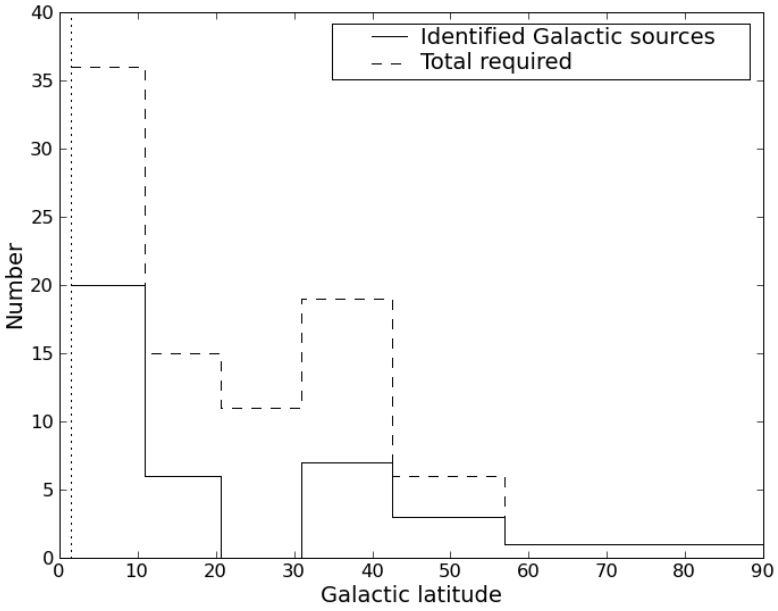
- 4% of AT20G have a gamma-ray counterpart
- Constant with Galactic latitude
  - Expected as AT20G all AGN

Detection rate as a function of Galactic latitude

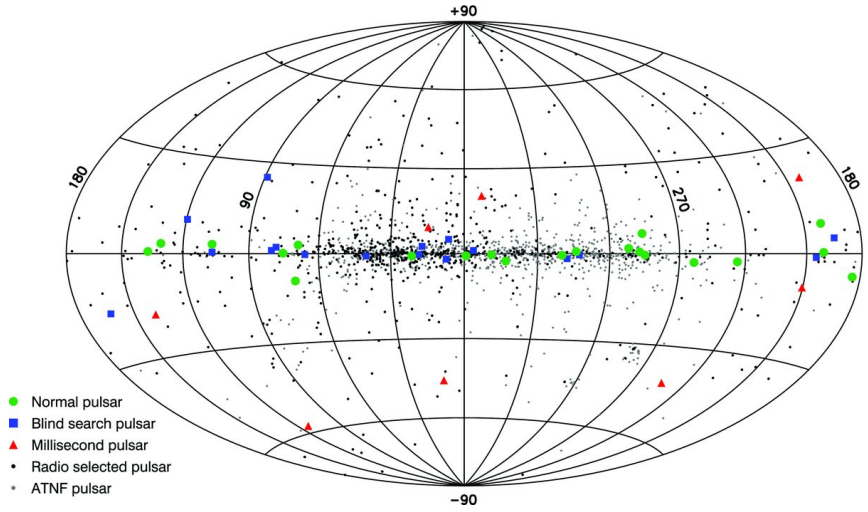
- Since AT20G only detects AGN Fermi sources, expect detection rate to be constant with Galactic latitude
- AT20G detection rate of Fermi sources is *lower* at low Galactic latitudes
- Only partially accounted for by the known Fermi Galactic sources
- Implies there is a unidentified Galactic population causing the AT20G detection rate to vary with |b|
  - Probably ms pulsars



Unidentified Galactic Fermi sources

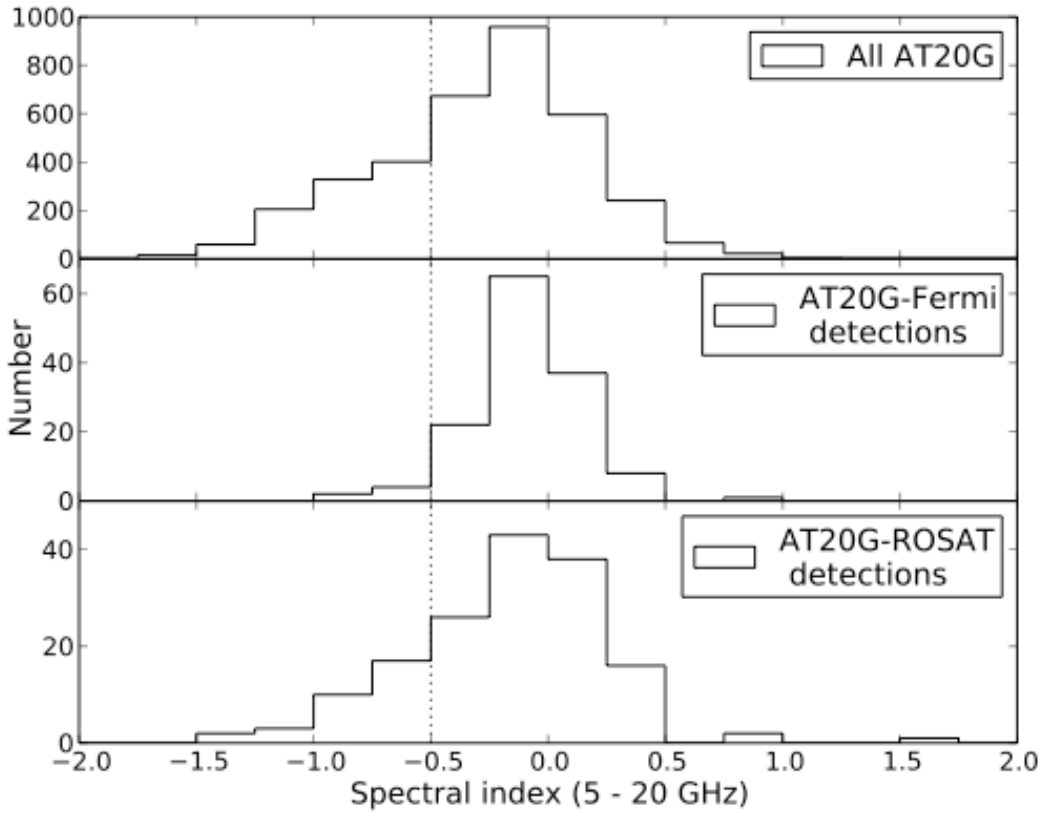


- At least 50 unidentified high-latitude Galactic sources in the south
- Large spread in Galactic latitude
- Many of these probably pulsars
  - Young pulsars: all at |b|<3.
  - Milli-second pulsars: quasi-isotropically distributed
- So far ~40 young pulsars discovered to be gamma-ray emitters
- ~18 confirmed msps



Abdo et al., 2010

AT20G – X-ray matches

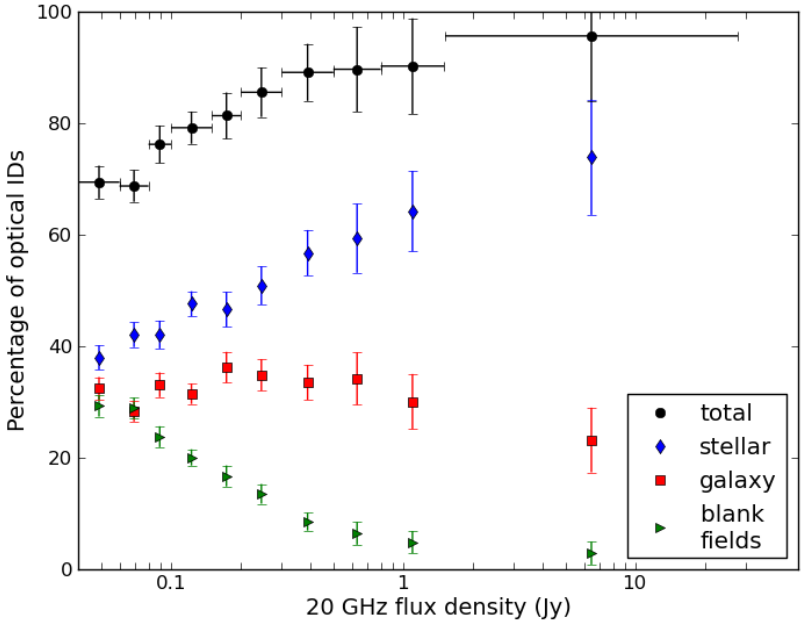


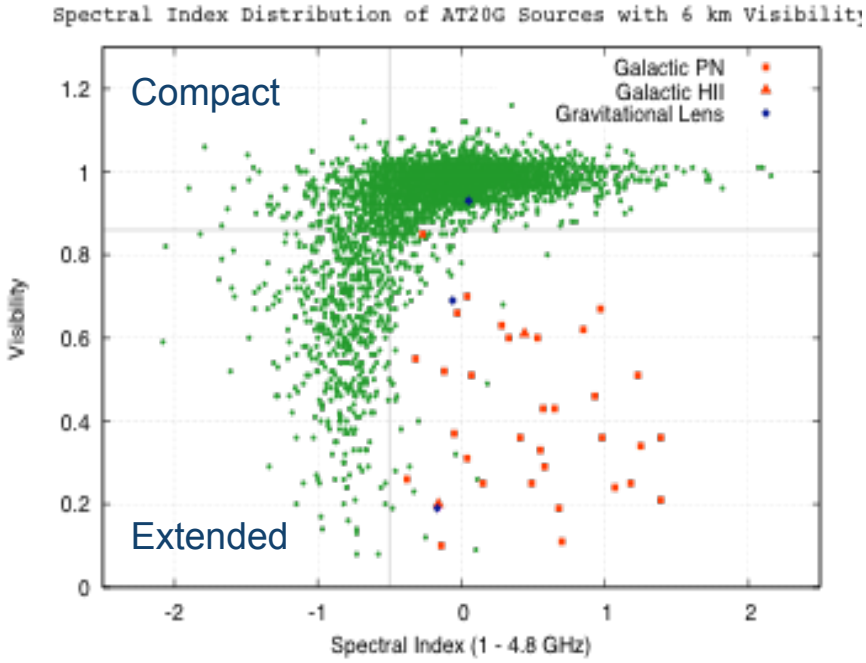
Massardi et al., 2011

- Crossmatched with the ROSAT all-sky survey
  - 280 matches
- Similar number to Fermi matches
  - But only small amount of overlap
  - Same amount as expected by chance
- K-S test show that the spectral index distributions (X-ray and gamma-ray) are drawn from different populations (99% significance)

Conclusions

› The 20 GHz source population is dominated by flat-spectrum cores

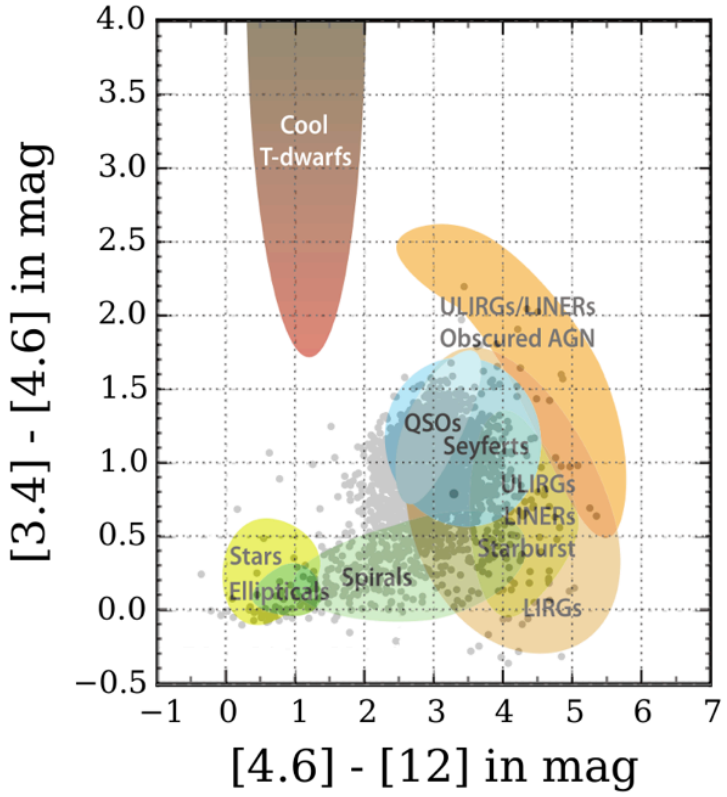




Steep spectrum Flat spectrum

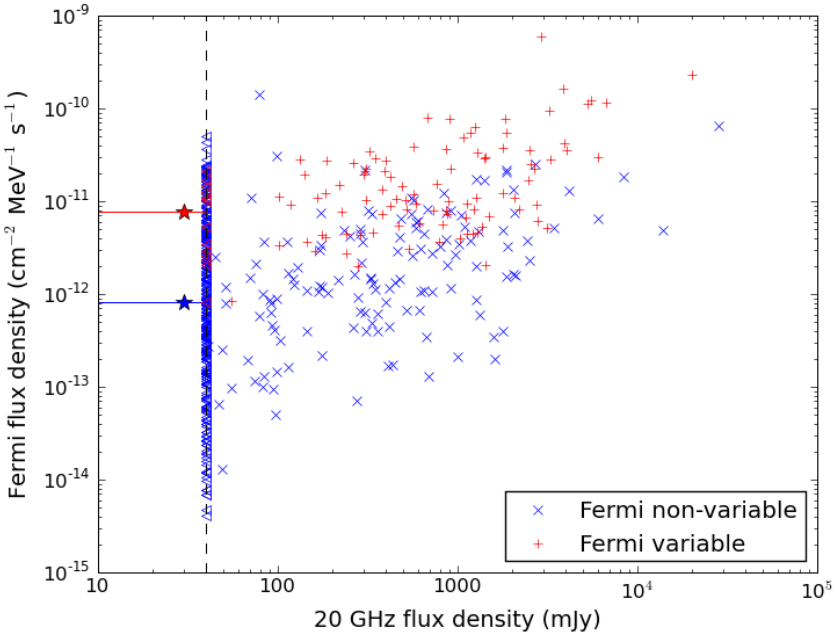
› Dominated by QSOs in the optical, with local radio galaxies coming in at fainter flux densities

Conclusions



› AT20G sources predominately classified as QSOs in the IR

- More ellipticals in the local 20 GHz population



› 20 GHz flux density is correlated with gamma-ray flux density

- AT20G excellent resource for identifying Fermi sources

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