

# Identifying Fermi AGN using high-frequency radio surveys

Elizabeth Mahony (USYD, ATNF), Elaine Sadler (USYD), Ron Ekers (ATNF), Phil Edwards (ATNF), Tara Murphy (USYD) and Marcella Massardi (INAF-OAPD)



THE UNIVERSITY OF  
SYDNEY



- › The AT20G Survey
- › Why it's an ideal catalogue for cross-matching with Fermi
- › Fermi-AT20G detections
- › 20 GHz flux vs gamma-ray flux density
- › Detection rate against Galactic latitude
- › Confusing sources

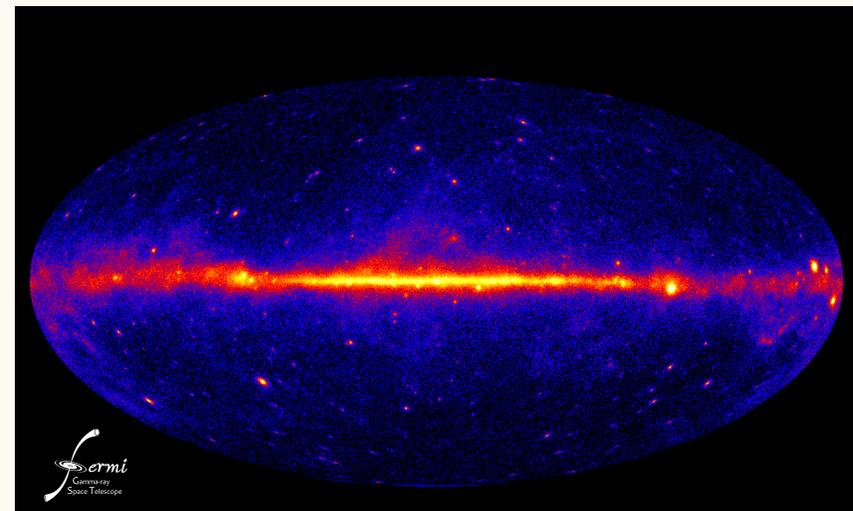


Image credit: NASA/DOE/Fermi LAT Collaboration

# The Australia Telescope 20 GHz (AT20G) survey

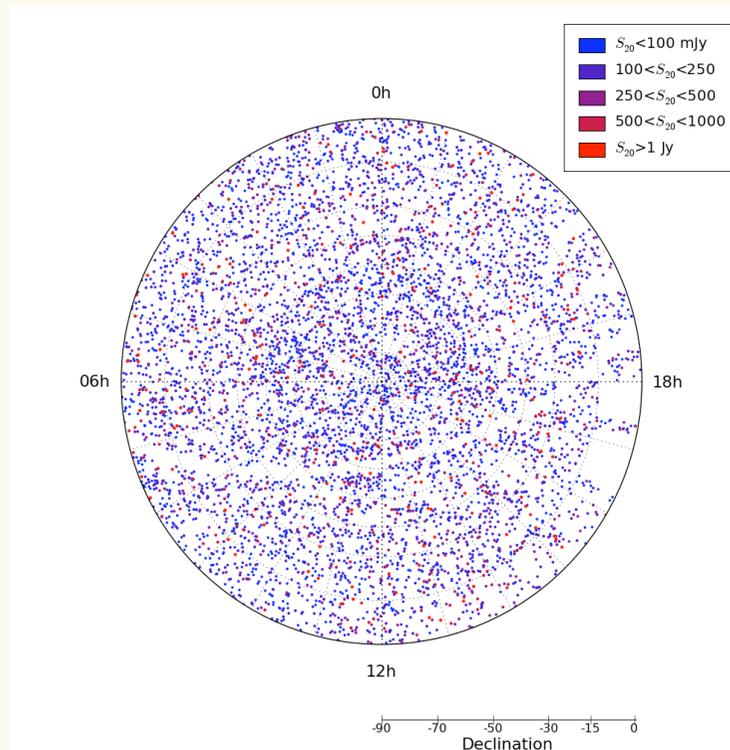
- › Blind survey of entire southern sky at 20 GHz
- › Using the Australia Telescope Compact Array
  - Located in Narrabri, northern N.S.W.
- › Observations carried out from 2004-2008
- › Catalogue of 5890 sources
  - Essentially all radio-loud AGN



The Australia Telescope Compact Array

Image credit: ATNF, CSIRO

# The Australia Telescope 20 GHz (AT20G) survey

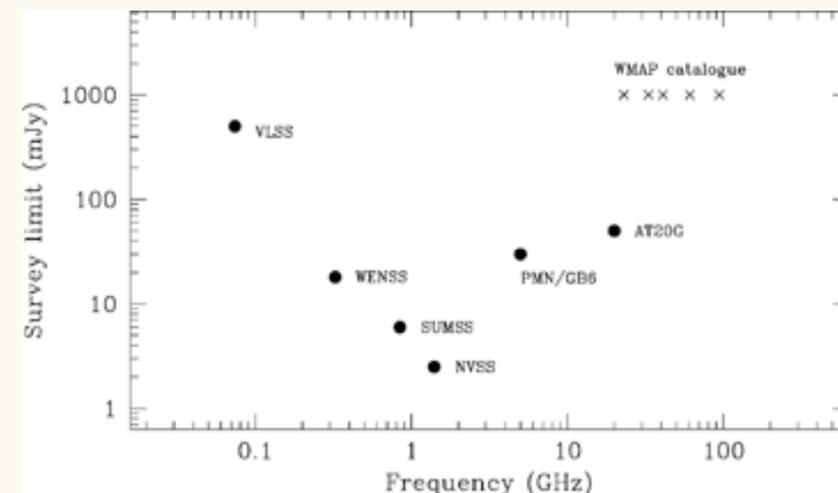


- › Flux limited at 40 mJy,
- › 93% completeness at 100 mJy
- › Near-simultaneous observations at 5, 8 and 20 GHz
  - provides spectral information
- › Most sensitive high-frequency, large area survey!

› Public data release (Murphy et al. 2010, MNRAS )

› AT20G Website:

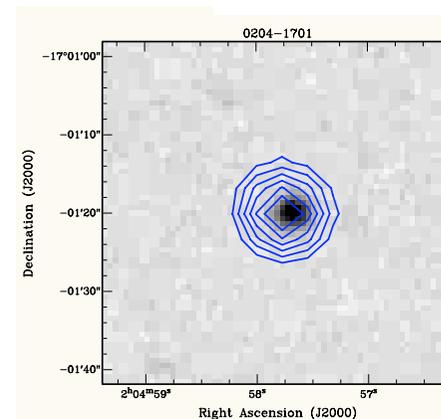
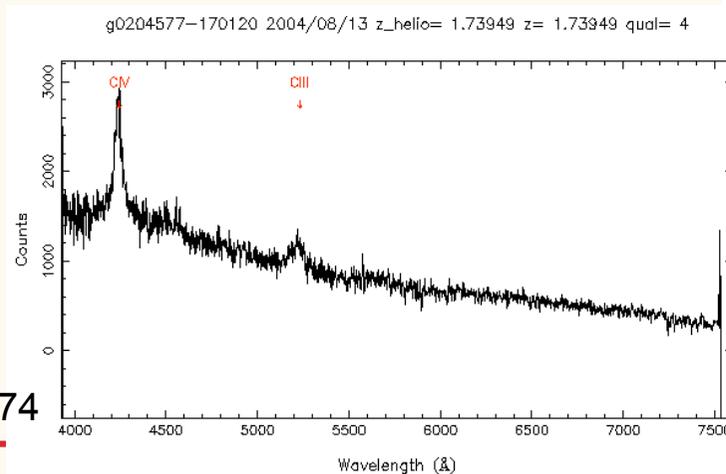
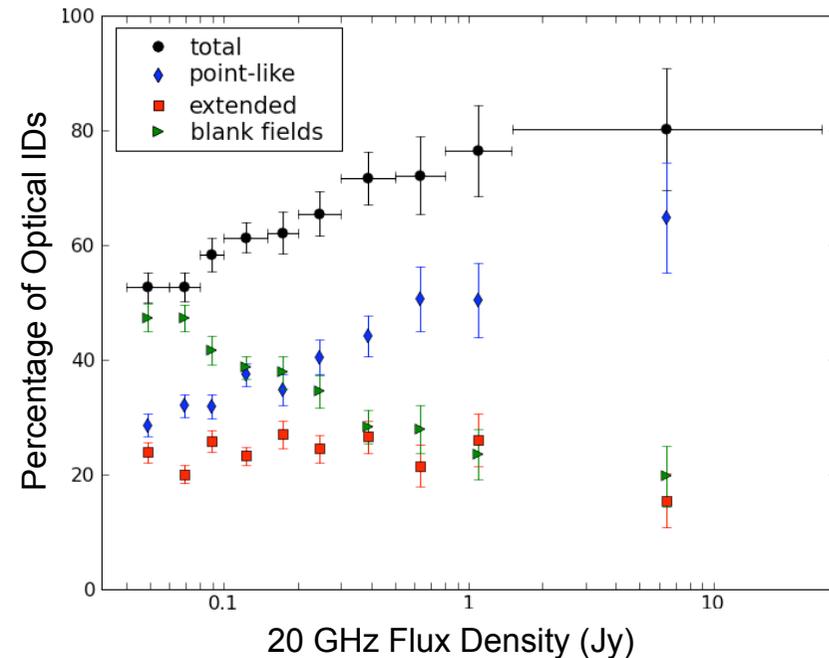
<http://www.atnf.csiro.au/research/AT20G/>



## Why AT20G is ideal for Fermi cross-matching

- › 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,  $b < 1.5$ )
- › Positional accuracy, better than 1 arcsec
  - Ideal for finding optical counterparts -> spectra, redshifts, intrinsic properties, spectral classification etc.
- › AT20G sky very similar to Fermi sky
  - Large number of FSRQ/blazars, particularly at brighter fluxes
- › 20 GHz emission is mainly from the cores of AGN
- › Ideal for finding AGN identifications
  - Don't see any of the Galactic Fermi sources in AT20G
  - Therefore all AT20G-Fermi detections are AGN

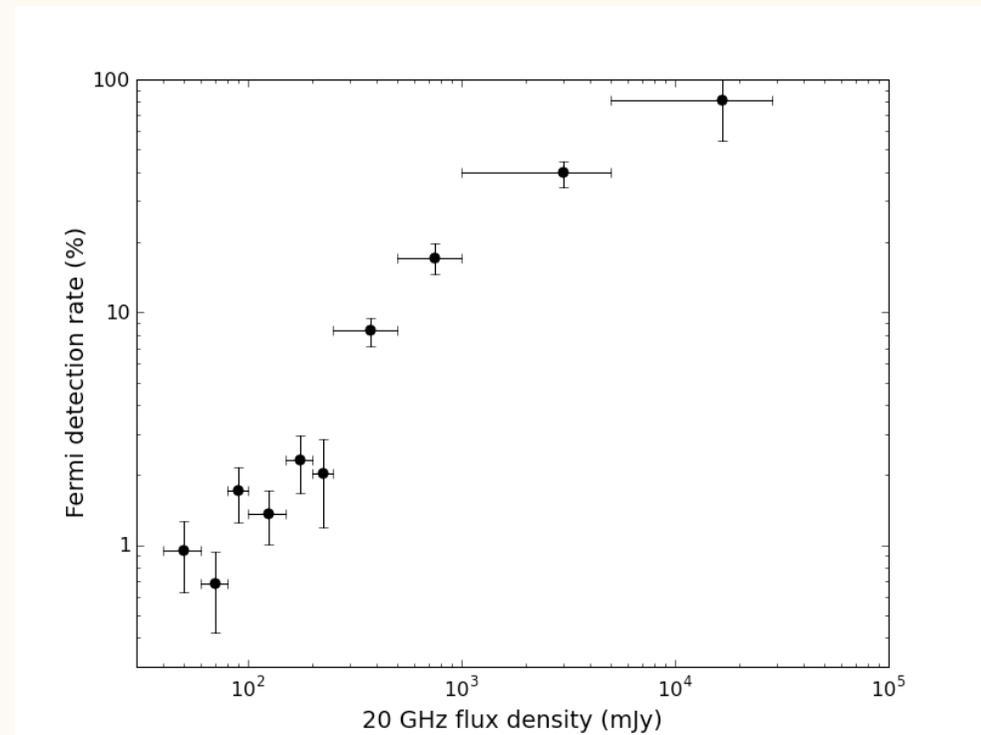
- › AT20G positions are accurate to 1 arcsec
  - Ideal for finding correct optical counterpart
- › Large numbers of FSRQ/Blazars
  - Number of radio galaxies increases with decreasing 20 GHz flux
- › 28% have redshifts
  - median redshift for QSOs:  $z=1.25$
  - median redshift for gal:  $z=0.25$



Mahony et al. 2010,  
in prep.

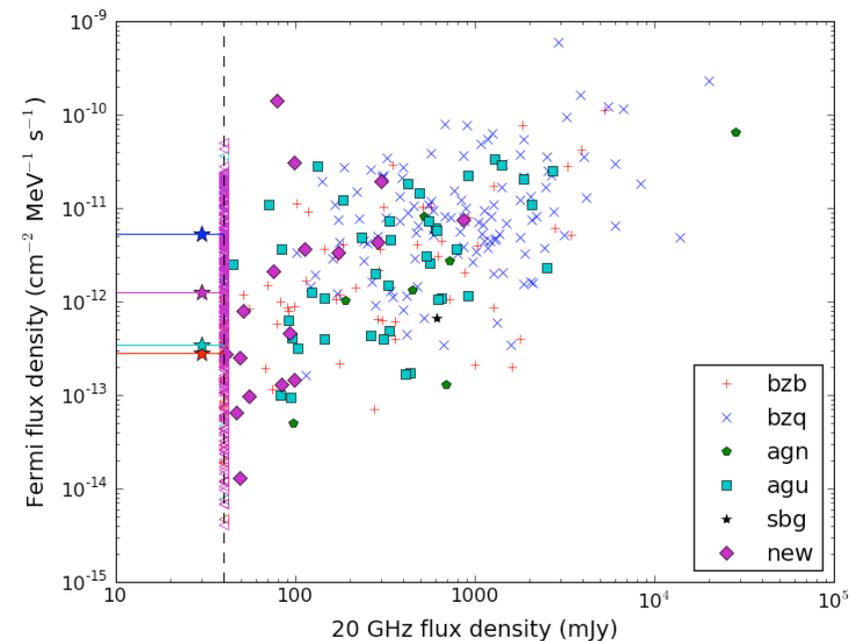
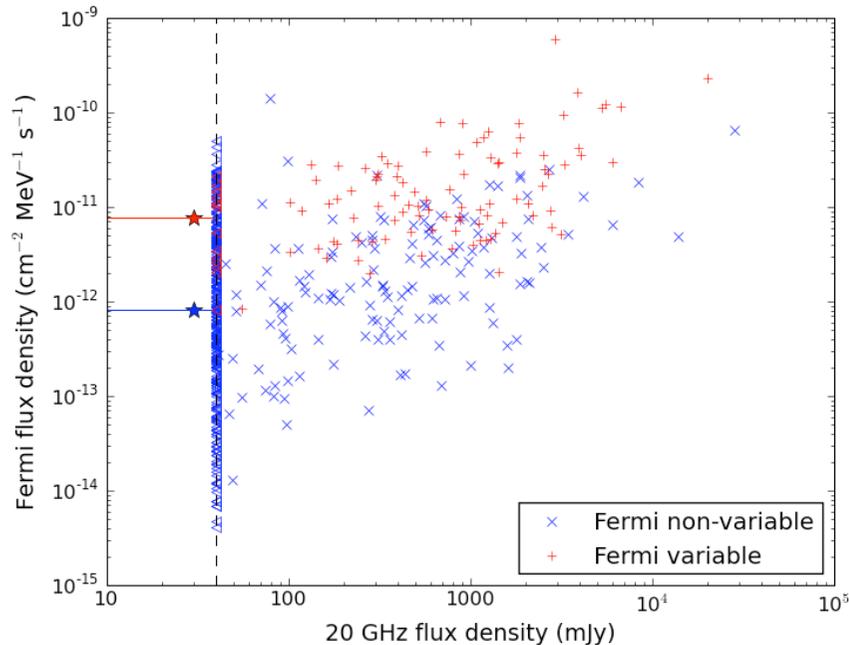
*Greyscale:*  
SuperCOSMOS  
B-Band image  
*Blue contours:*  
20 GHz flux

- › Total of 233 AT20G-Fermi matches (43% of southern Fermi sources detected in AT20G)
- › 95% completeness and 95% reliability
- › **In agreement with the 1LAC catalogue**
  - No missing high-freq population
- › 8 new identifications – all at low galactic latitudes where 1LAC is known to be incomplete
- › Detection rate increase with 20 GHz flux
  - A few % at 100 mJy
  - Close to 100% above 1 Jy



Mahony et al. 2010, ApJ in press

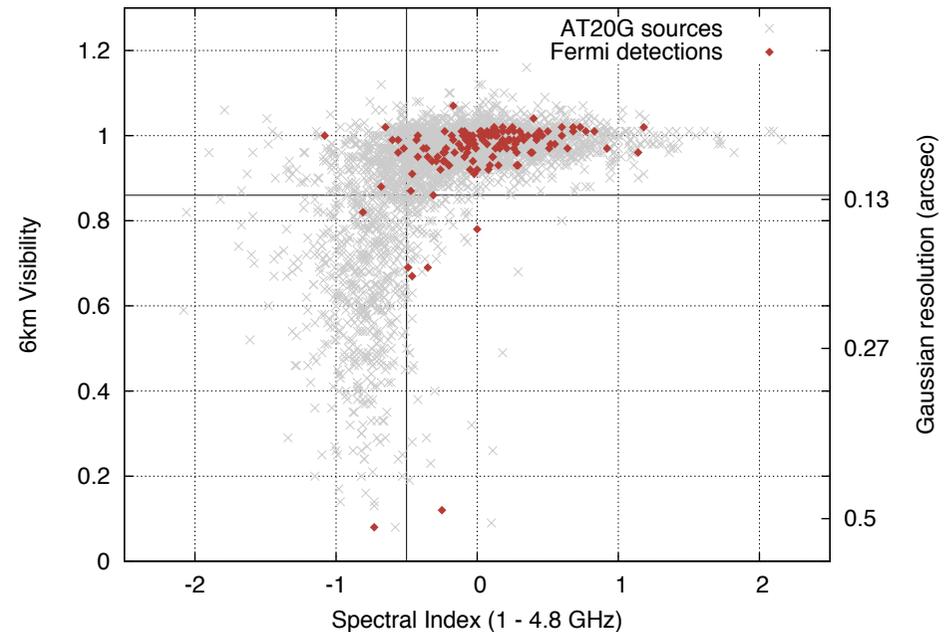
# 20 GHz flux density vs Fermi flux density



- › The AT20G detection rate for variable Fermi sources is 87%
- › For non-variables only 32%
  
- › Similar correlation noted by Ghirlanda et al., 2010
- › Non-simultaneous observations (separated by 2-5 years)
  - Is beaming making this correlation tighter?

- › We also have additional high resolution data available for most of the AT20G sources
- › Clearly shows two different AT20G populations:
  - Compact, flat-spectrum sources
  - Resolved, steep-spectrum sources
- › The Fermi detections are preferentially the compact, flat-spectrum sources
  - With the exception of a few nearby galaxies (e.g. NGC 253, NGC 4945)

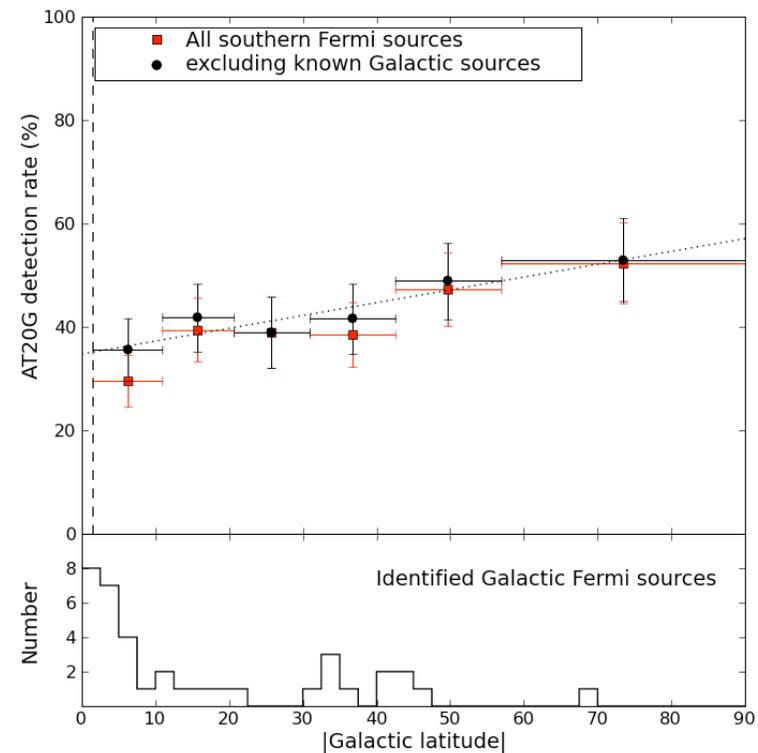
Spectral Index Distribution of AT20G - Fermi Crossmatched Sources



Chhetri et al., in prep

# Detection rate as a function of Galactic latitude

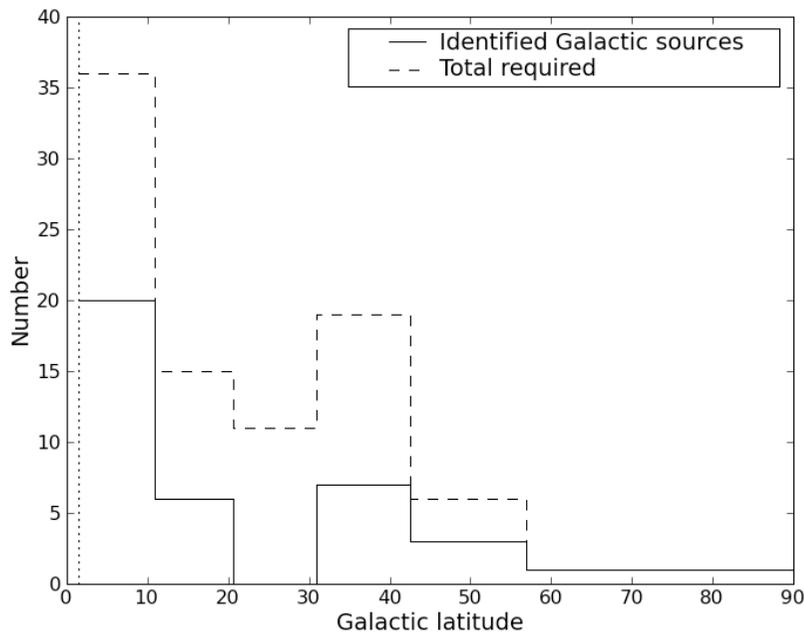
- › Expect AT20G detection rate to be constant with Galactic latitude
- › Binned in equal area bins
- › AT20G detection rate of Fermi sources is *lower* at low Galactic latitudes
- › Only partially accounted for by the known Fermi Galactic sources
- › Implies there is a unidentified Galactic population causing the AT20G detection rate to vary with  $|b|$



Mahony et al. 2010, ApJ in press

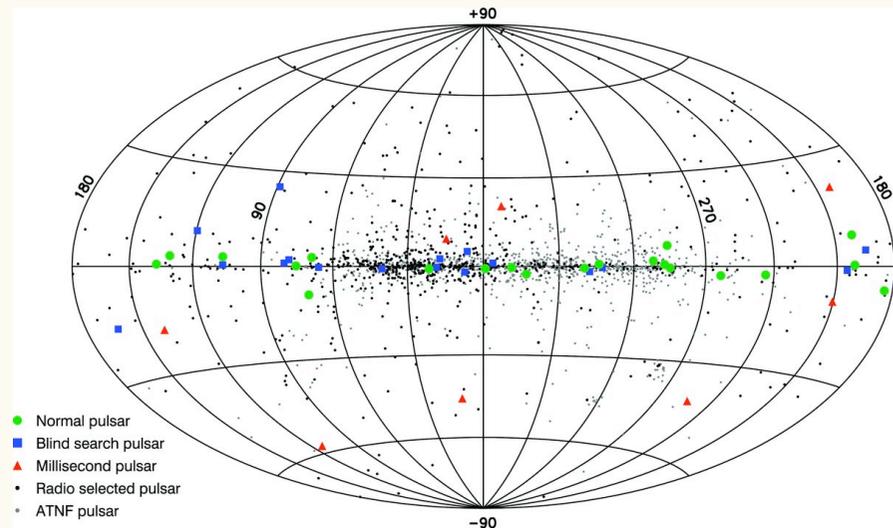


# Unidentified Galactic Fermi sources



Mahony et al., 2010, ApJ in press

- › 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 msp



Abdo et al., 2010, ApJS 187, 460

- › Due to the large error ellipse on the Fermi positions, confusion is increasingly becoming an issue.
- › For example:
  - PKS 1101-536
  - AT20G cross-matching identifies an AGN counterpart
  - Also appeared in the pulsar follow-up catalogue
  - Confirmed milli-second pulsar
  - **Which one is the gamma-ray source??**
- › This will only become more of an issue as Fermi goes deeper!

- › AT20G is a blind survey of the southern sky at 20 GHz
- › An ideal catalogue for identifying Fermi AGN
  - Clean sample – no spectral pre-selection
  - Large sample of FSRQ and blazars, similar to Fermi population
- › There are 233 Fermi sources with AT20G counterparts
  - The Fermi detection rate increases with 20 GHz flux
- › Gamma-ray flux density is correlated with 20 GHz flux
- › Detection rate of AT20G sources changes with Galactic latitude, suggesting that there are many Galactic Fermi sources that remain unidentified
  - At least 50 in the southern sky
  - Most probably pulsars

## › The AT20G team:

- Ron Ekers (ATNF, PI)
- Elaine Sadler (USyd)
- Sarah Burke-Spolaor (Swinburne/ATNF)
- Mark Calabretta (ATNF)
- Rajan Chhetri (UNSW/ATNF)
- Gianfranco De Zotti (INAF-OAPd)
- Phillip Edwards (ATNF)
- Paul Hancock (USyd)
- Carole Jackson (ATNF)
- Michael Kesteven (ATNF)
- Elizabeth Mahony (USyd)
- Marcella Massardi (INAF-OAPd)
- Tara Murphy (USyd)
- Katherine Newton-McGee (ATNF)
- Chris Phillips (ATNF)
- Roberto Ricci (INAF-IRA)
- Paul Roberts (ATNF)
- Robert Sault (UMelb)
- Lister Staveley-Smith (UWA)
- Ravi Subrahmanyan (RRI)
- Mark Walker (MAW)

**AT20G web address: <http://www.atnf.csiro.au/research/AT20G/>**

- › Thanks to the Astronomical Society of Australia (ASA) for providing funding to attend this conference