Large-Area Continuum Surveys with ATCA+BIGCAT

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ATCA and Large Continuum Surveys

- ATCA has proud history of large surveys
  - Mosaicing is relatively simple
    - Point and shoot
    - Drive times may dominate for low freq observations (→ do on-the-fly?)
  - E-W Array
    - Co-planer baselines
    - No need for faceting or w-projection in imaging

ATCA and Large Continuum Surveys

Frequency	Area	Depth (rms/beam)	Name/Who
1.4 GHz	26 sq deg	80 microJy	ATESP, Prandoni et al. 2000
1.4/1.7 GHz	2 x ~3 sq deg	15 microJy	ATLAS, Norris et al. 2006/Franzen et al. 2015
2.1 GHz	25 sq deg	40 microJy	XXL-S, Butler et al, 2018
2.1 GHz	86 sq deg	100 microJy	SPT, O'Brien et al. 2018
5.5, 9.0 GHz	0.34, 0.28 sq deg	9, 20 microJy	ATLAS eCDFS, Huynh et al. 2012,2015,2020
5.5, 9.5 GHz	50 sq deg	30, 50 microJy	GLASS
5, 8, 20 GHz	20,000 sq deg	12 mJy at 20 GHz	AT20G, Murphy et al. 2010

BIGCAT Science Case for Surveys

- Active galactic nuclei
- Star formation in galaxies

The Role of AGN in Galaxy Evolution

AGN feedback is an essential ingredient of galaxy formation and evolution

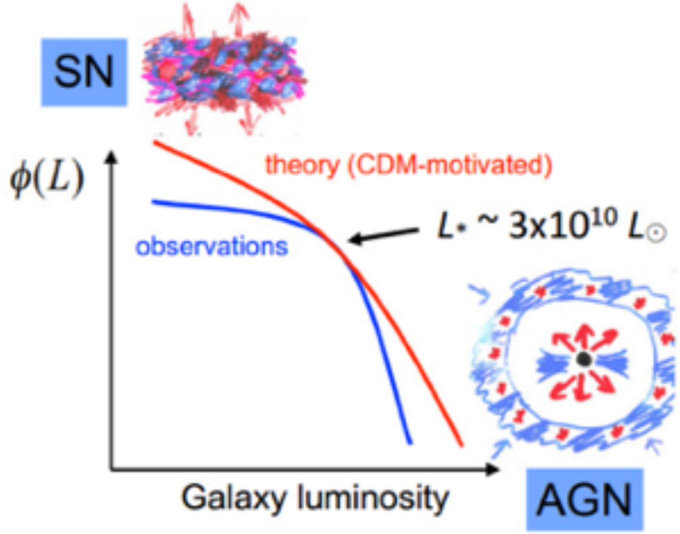
Radio/Hot Mode (Low Excitation Radio Galaxies)

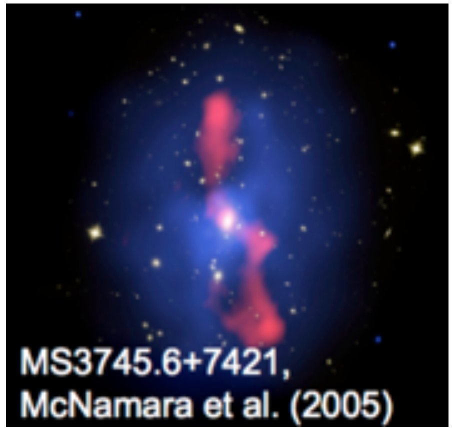
- Central BH fed by hot gas
- Low accretion rates (< 0.01 Eddington)
- Host galaxies have high stellar mass, redder colours
- Jet-driven mechanical feedback

QSO/Cold Mode (High Excitation Radio Galaxies)

- Central BH fed by cold gas
- High accretion rates (1 – 10% Eddington)
- Bluer hosts with associated ongoing SF
- Radiation-driven feedback (quasar winds)

e.g. Best et al. 2005, 2012; Hardcastle et al. 2007

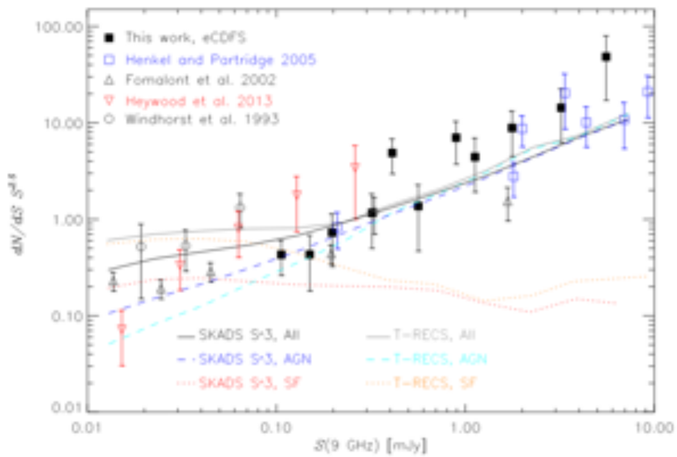




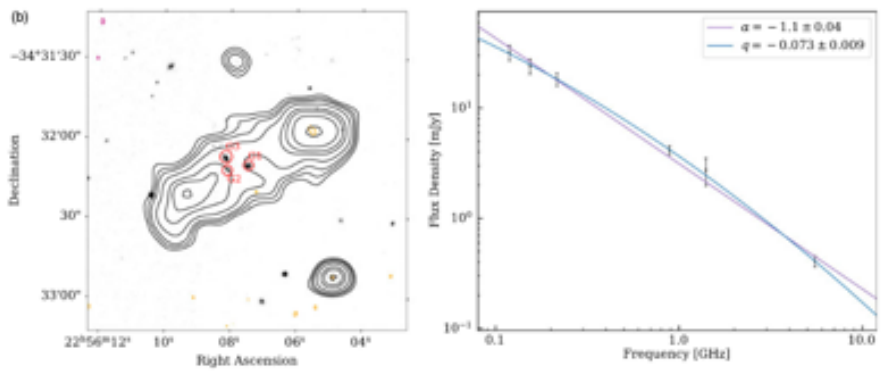
The Role of AGN in Galaxy Evolution

Surveys with BIGCAT can help:

- Complete census of AGN and their evolution
  - Source counts and luminosity functions
- Study physics and life-cycle of radio-loud AGN
  - Remnant radio galaxies
  - Ultra-steep spectrum sources (AGN at high z)
- Help us understand radio-quiet AGN
  - Is radio emission from AGN or SF?
    - – Morphology (jets), spectral information
  - Inverted sources, even at faint flux densities, low luminosity AGN



9.0 GHz, Huynh et al. 2020



Remnant candidate in GLASS, Quici et al. 2021

Star Formation in Galaxies

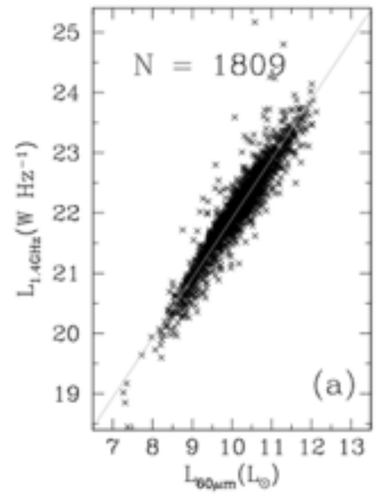
SN-accelerated electrons emit steep spectrum non-thermal (synchrotron) radio emission, ν ~ 1 GHz

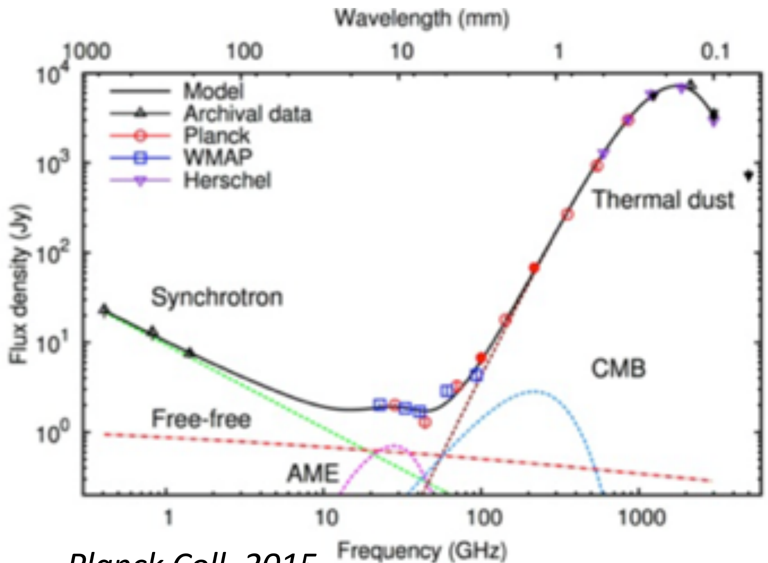
Tight IR-radio correlation –> radio can trace SF

Unaffected by dust, but physics not fully understood physics

Flat spectrum thermal (free-free) emission from electrons in HII regions, ν > 10 GHz

FIR-radio correlation *Yun et al. 2001*





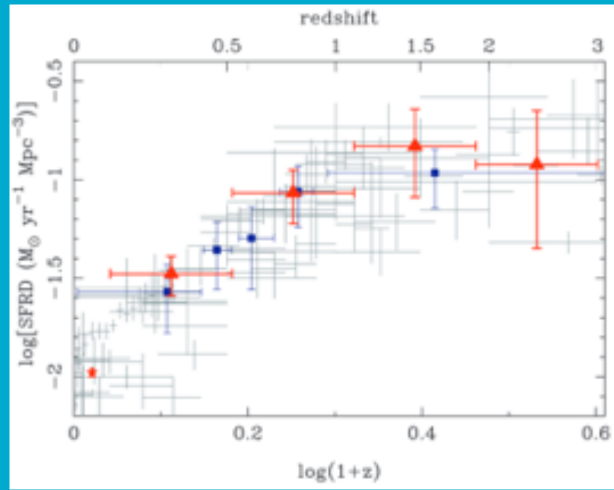
Planck Coll. 2015

Star Formation Science

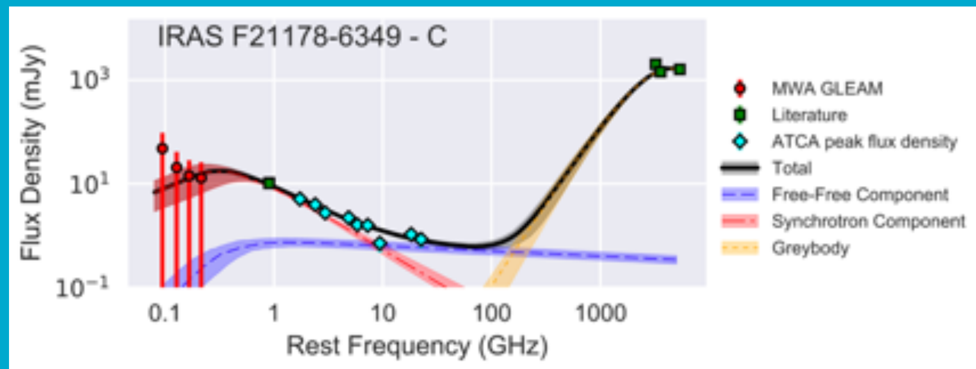
BIGCAT can probe spectral parameter space to help:

- Understand the radio thermal vs non-thermal components of radio emission in galaxies
- Better calibrate radio measures of SF

Seymour et al. 2008



SF History of the Univrse is a top SKA1 Priority Science Objective™



Galvin et al. 2018

BIGCAT Continuum Survey Requirements

- Continuum surveys don't drive requirements as much as other use cases:
  - 1 MHz channels is sufficient
  - Integrations times of a few to 10 sec, already met
    - < 10 sec may be required for fast mosaicking (first integration of a scan is usually poor due to antenna(s) not quite on source / settling).

- Requirements are more around high dynamic range imaging:
  - Need to handle **very-wide-band wide-field** imaging, MIRIAD is not great at this:
    - CASA, MWA uses WSCLEAN, ASKAPsoft/Yandasoft
    - Calibrate with MIRIAD, image with CASA/WSCLEAN/Yandasoft?

Possible BIGCAT Surveys

- Wide+deep at 5.5/9 GHz parameter space already filled by GLASS
  - Only possible as it was a Legacy survey

- 'Ultra-Deep' Simultaneous 5.5/9.0 (4cm) GHz survey
  - 0.3/0.25 sq deg
    - 220 hour integration = ~7/14 muJy rms
    - Expect about 400, 100 sources* at 5.5 GHz, 9.0 GHz
    - Get even deeper (>20%) if eCDFS (existing data)

* T-Recs sims, Bonaldi et al. 2018

Possible BIGCAT Surveys

- Deep or Wide 20 GHz blank survey
  - Blank Nyquist-sampled survey would require 2000 pointings per sq deg
  - Approx. minimum for imaging – 6 x 40 sec cuts = ~0.1 mJy/beam rms
  - 40 sources per degree*, assuming S20GHz > 0.7 mJy
  - Most pointings will be of blank sky.

  - If we require 1 source per pointing, need about 2 muJy/beam rms!
    – More than 10 x 12 hour integration per pointing, even with BIGCAT

* T-Recs sims, Bonaldi et al. 2018

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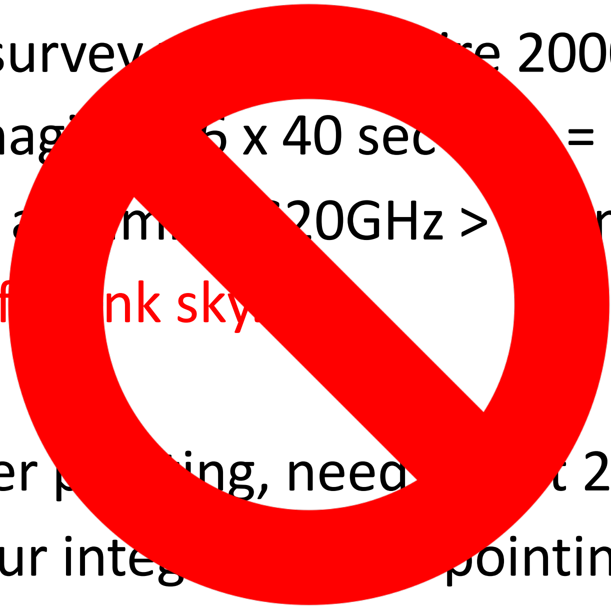

* T-Recs sims, Bonaldi et al. 2018

Possible BIGCAT Surveys

- Targeted ‘Deep’ 20 GHz survey (e.g. in GLASS/G23, 50 sq deg)
  - All EMU/RACS sources > 10 mJy, 30 per sq deg
  - Minimum for imaging – 6 x 40 sec cuts = ~0.1 mJy/beam rms
    - Would detect sources flatter than about alpha = -1.0, (S20 > 0.5 mJy)
  - Need 4 mins per source, have 1500 (30 x 50 sq deg) sources
    - ~100 hours on source, or ~125 hour program inc. overheads

  - So could do all bright ASKAP sources in G23/GLASS, in few hundred hours
    - Could target more EMU sources (S_EMU > 5 mJy?), or
    - Could go deeper on steeper spectrum sources

Possible BIGCAT Surveys

- Targeted 'Shallow' 20 GHz survey over say 1000 sq deg
  - Say 3000 sources and 6 x 40 sec cuts per source is reasonable for imaging
  - Source density of ~3 / sq deg
    - Implies S_EMU/S_RACS > 100 mJy
  - Would detect ultra-steep spectrum sources (alpha >~ -1.7)
    - S20GHz limit ~0.5 mJy
  - ~200 hours on source, or ~250 hour program inc. overheads

  - Target region with multiwavelength coverage
    - KiDS? Some other fields(?)

Summary

- Main science drivers for large BIGCAT surveys:
  - AGN populations and physics
  - Tracing star formation

- Possible high impact surveys:
  - ‘Ultra-Deep’ field at 4cm
    - (Deep-wide parameter space done by GLASS)
  - 7mm (20 GHz) targeted survey of RACS/EMU sources