IMPERIAL

Extragalactic AME Detections

Mike Peel
Postdoc, Imperial College London

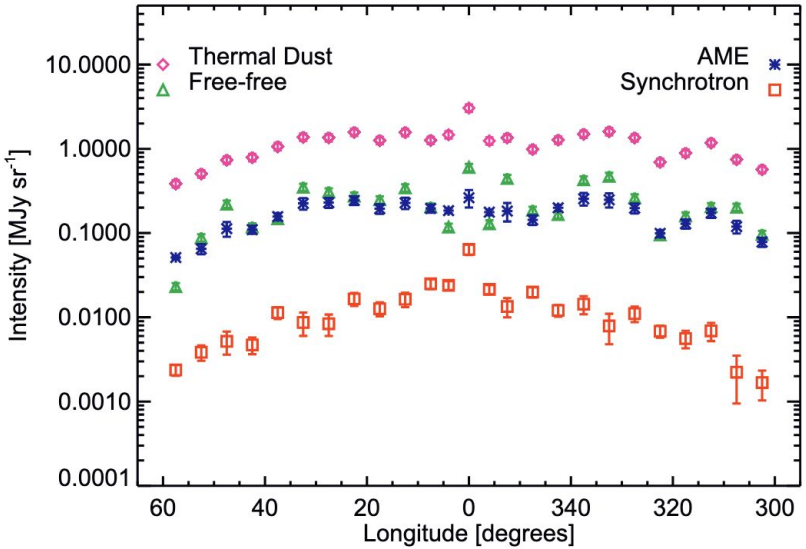
Villanova AME Workshop
17 June 2025

Overview

- Is AME a large or small scale emission feature?
- Resolving extragalactic regions
  - NGC 6946
  - NGC 4725
  - Free-free emission surveys
- Integrated SEDs
  - Early WMAP + Planck data
  - SMC
  - SRT observations
  - KVN observations
- Andromeda Galaxy
- Future prospects

Is AME a large or small scale emission feature?

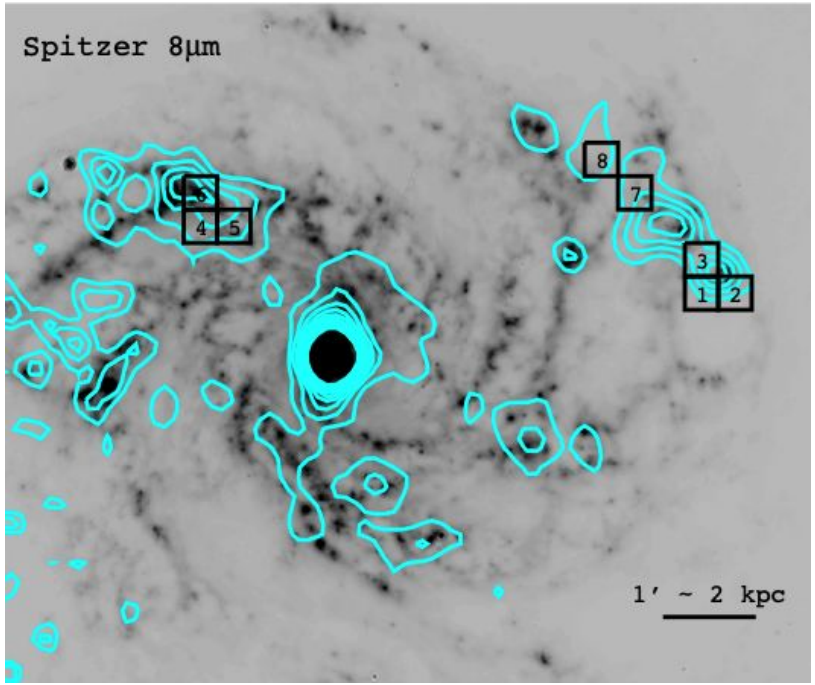
- Around 30% of Galactic emission
- Both compact (Perseus / Rho Oph / etc.) and diffuse (Galactic plane, high latitude)
- Seen on 1° scales more than higher resolution (e.g., Perseus)
- If you could look at our Galaxy from the outside, would you detect AME?
- (possibly) easier: do we see AME in other galaxies?



From Planck Collaboration XXIII (2015, A&A 580, A13, Davies corresponding author)
AME, free-free, sync at 28.4GHz

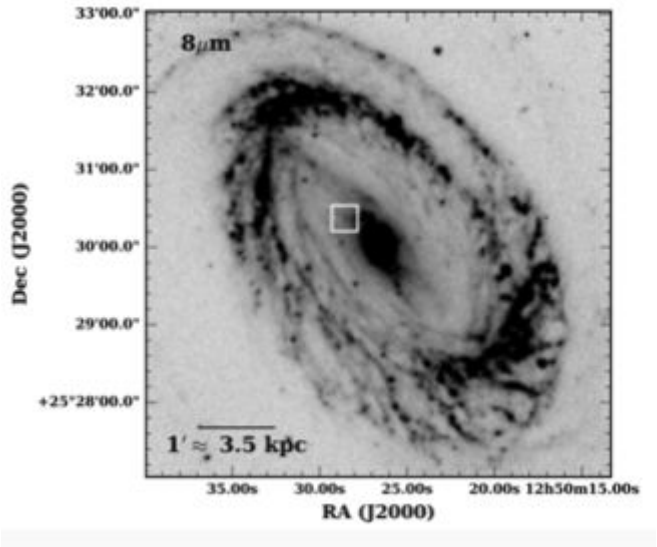
NGC 6946

- Murphy et al. (2010, ApJL, 709, L108) used GBT @ 33GHz to observe 10 star-forming regions in NGC 6946
- Found one region to be anomalously bright → extragalactic AME for the first time
- Confirmed with AMI at 15GHz (Scaife et al. 2010, MNRAS, 406, L45)
- Hensley et al. (2015, MNRAS, 449, 809) used CARMA at 30GHz to detect 8 regions with AME (see image)



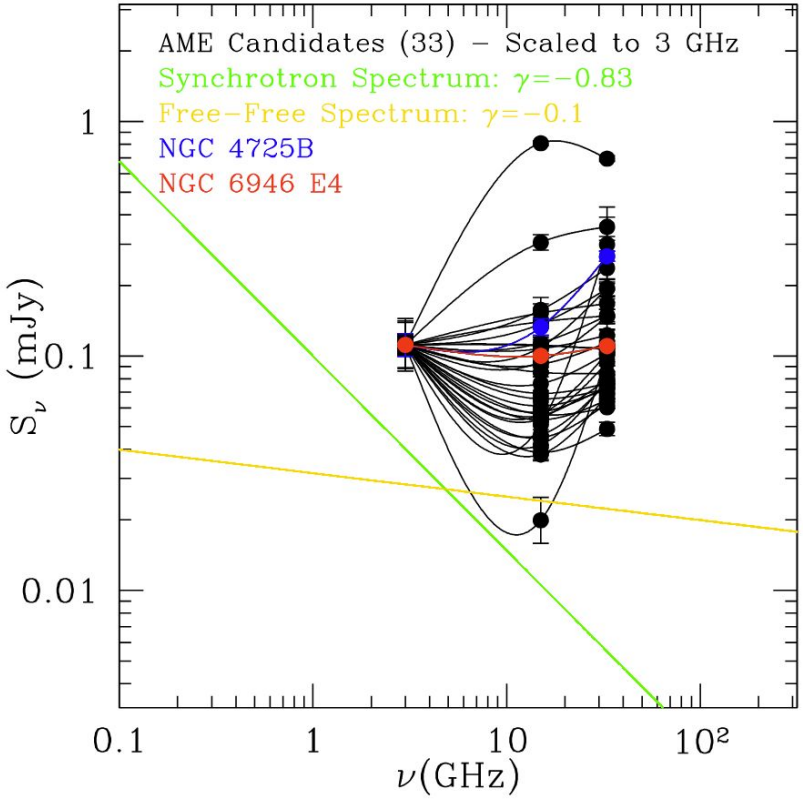
NGC 4725

- Murphy et al. (2018, ApJ, 862, 20)
- Detected a region in NGC 4725 with VLA at 33GHz that shows AME
- However, Murphy et al. (2020, ApJL, 905, L23) observed the region with ALMA - and didn't see thermal dust emission?



Free-free emission surveys

- VLA & GBT surveys at 33GHz to measure star formation rates through free-free
- AME could potentially bias these estimates
- GBT 33GHz survey: Murphy et al. (2012, ApJ, 761, 97) & VLA 33GHz survey: Murphy et al. (2018, ApJS, 234, 24)
- Linden et al. (2020, ApJS, 248, 25)
  3, 15, 33GHz - spectrum modelling, found 33 regions with increasing 15-33GHz emission, in 9 galaxies (2403, 3627, 4254, 4631, *4725*, 5194, 5457, *6946*, 7793)
- Dignan et al. (2025, arXiv:2506.1213)
  90GHz follow-up, 12 AME candidate regions in 4 galaxies (*4254*, *4725*, *5194*, *6946*)



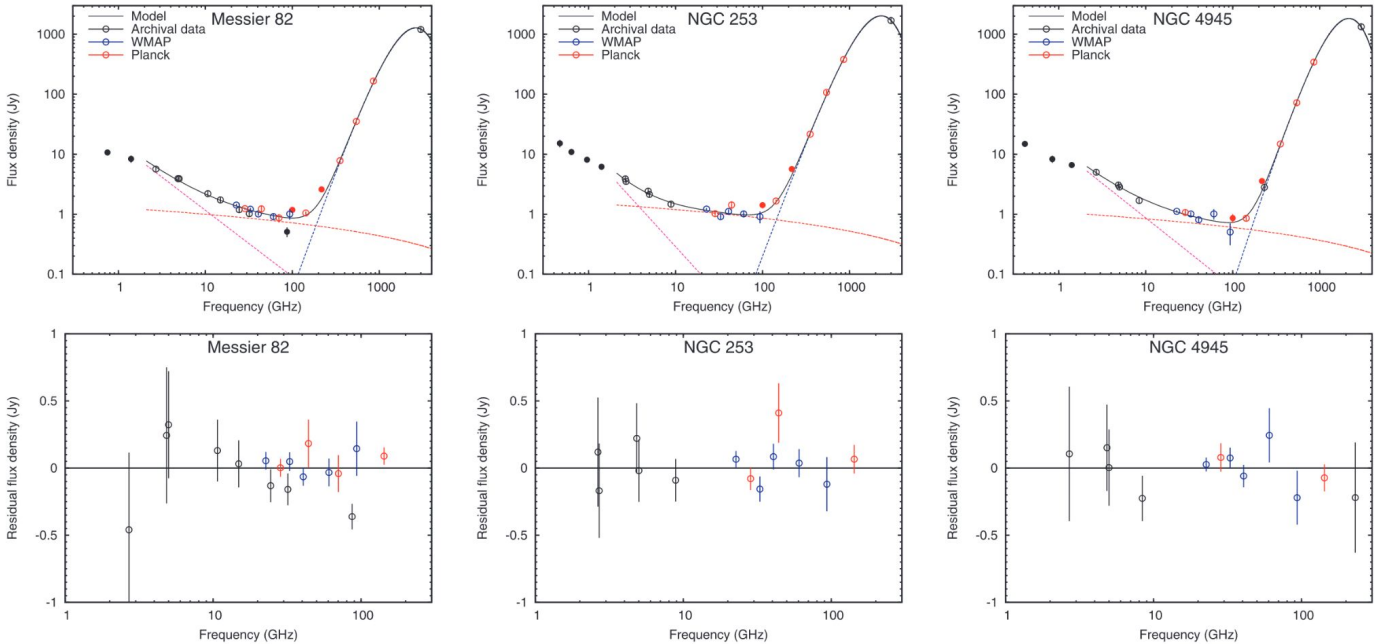
Linden et al. Fig. 8.

Integrated SEDs - WMAP and Planck

- Peel et al. (2011, MNRAS, 416, L99)
- M82, NGC 253, NGC 4945

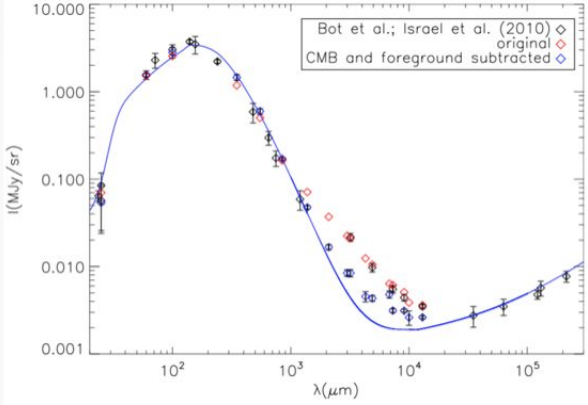
Able to use WMAP & Planck data for first time

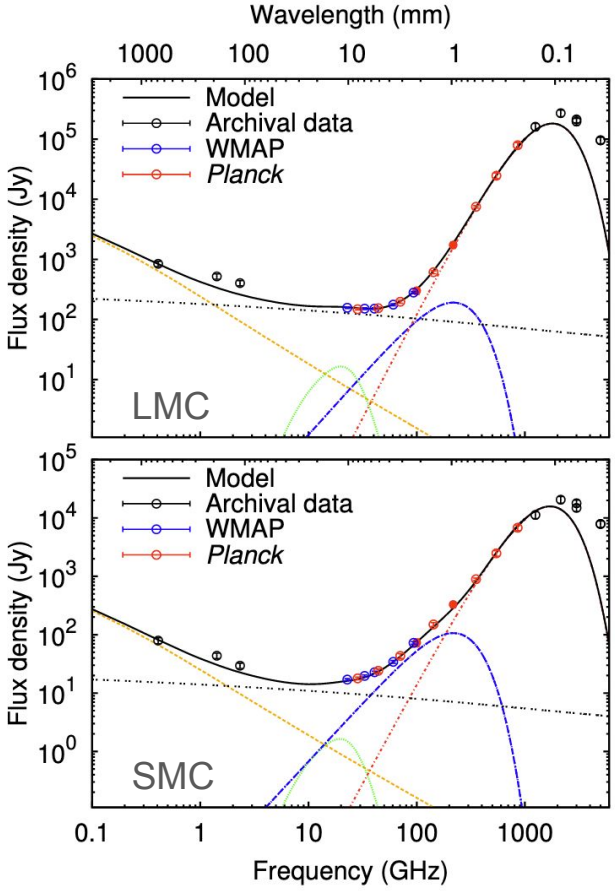
Upper limits set - lower fractions than our Galaxy



Magellanic Clouds?

- Bot et al. (2010) found submm excess in SMC, followed up with Planck Collaboration Early results XVII (2011)
- Commander sees small amount of AME, also in LMC (Planck Collaboration 2015, A31) - but also lots of CMB.
- Could submm excess be explained with magnetic dust? (Draine & Hensley 2016)

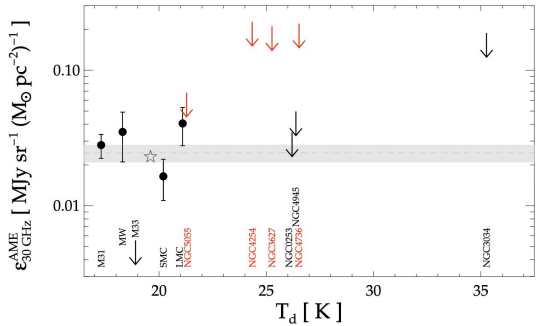




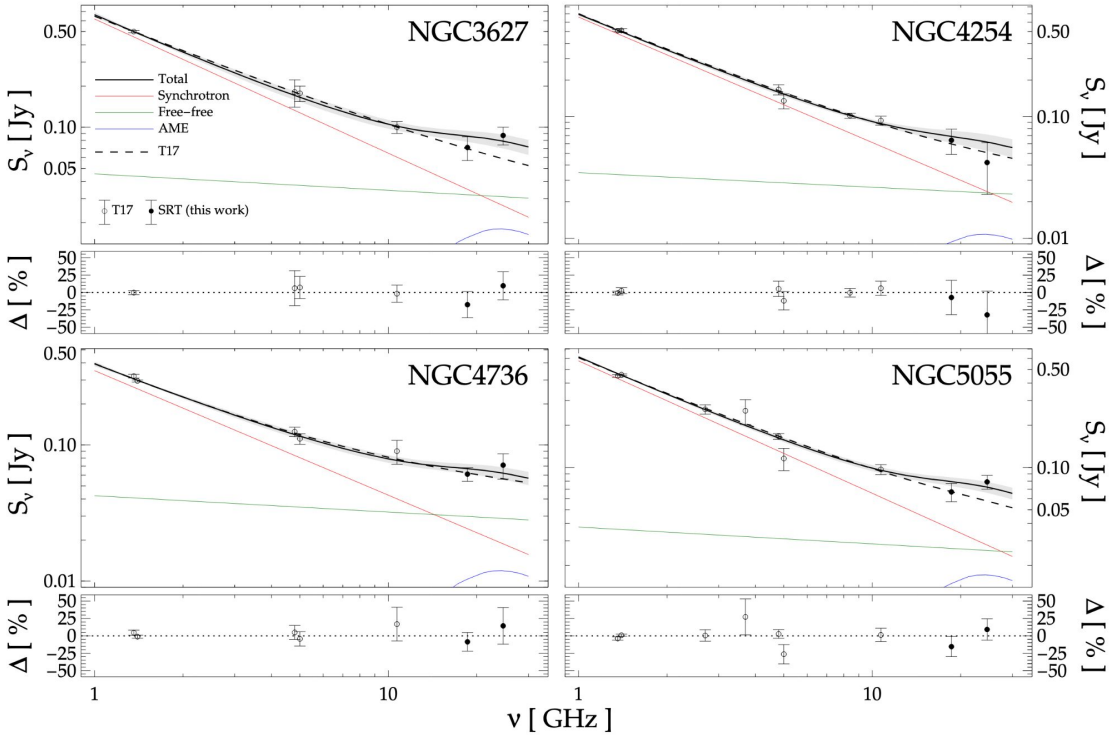
Sardinia Radio Telescope observations

Bianchi et al. (2022, A&A, 658, L8)

Upper limits in NGC 3627, 4254, 4736, 5055 - consistent with AME emissivities



(I have similar SRT data in hand for NGC6946, M51, NGC891, need to finish processing it... Recovering the largest angular scales can be tricky.)



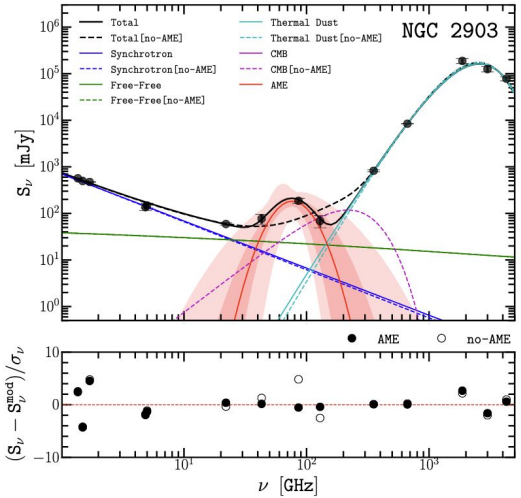
KVN observations

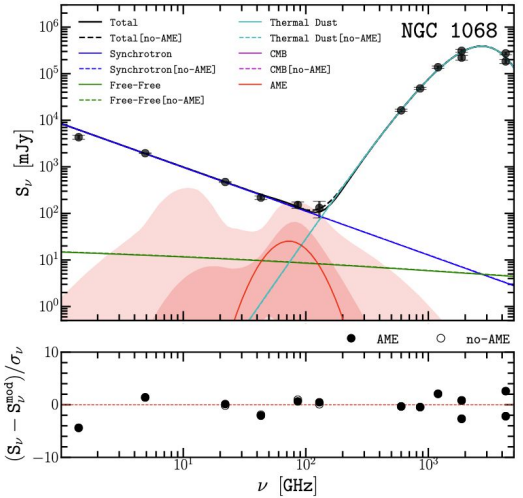
Poojon et al. (2024, ApJ, 963, 88)

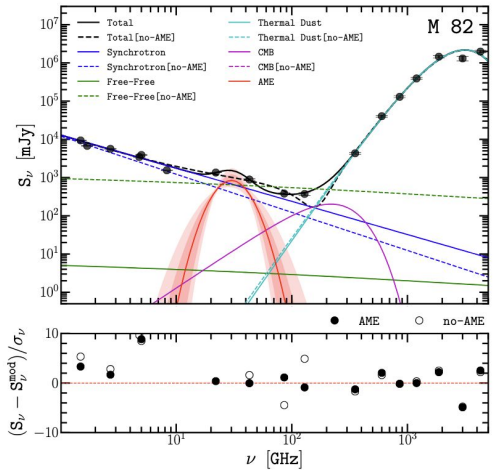
Clear detection in NGC 2903

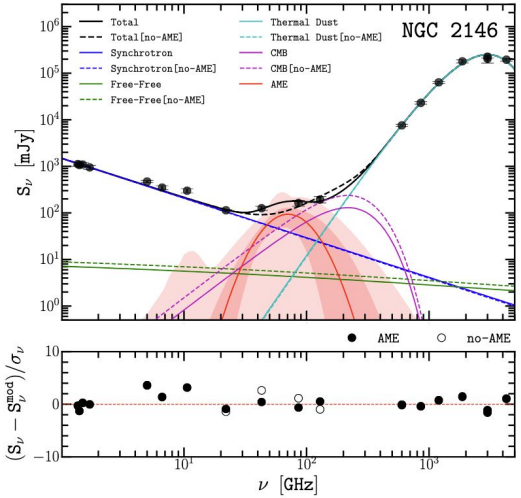
Marginal in NGC 2146, M82

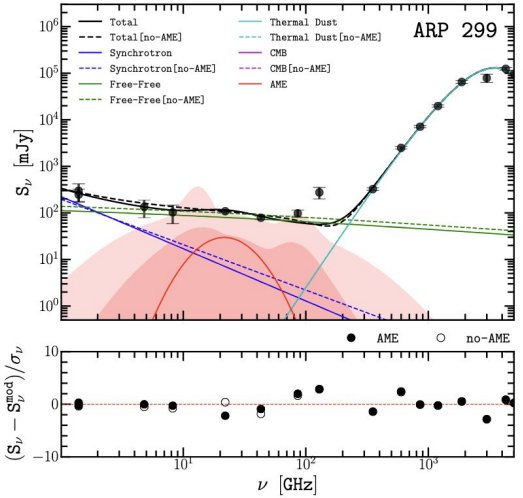
Upper limits in NGC 1068, ARP 299





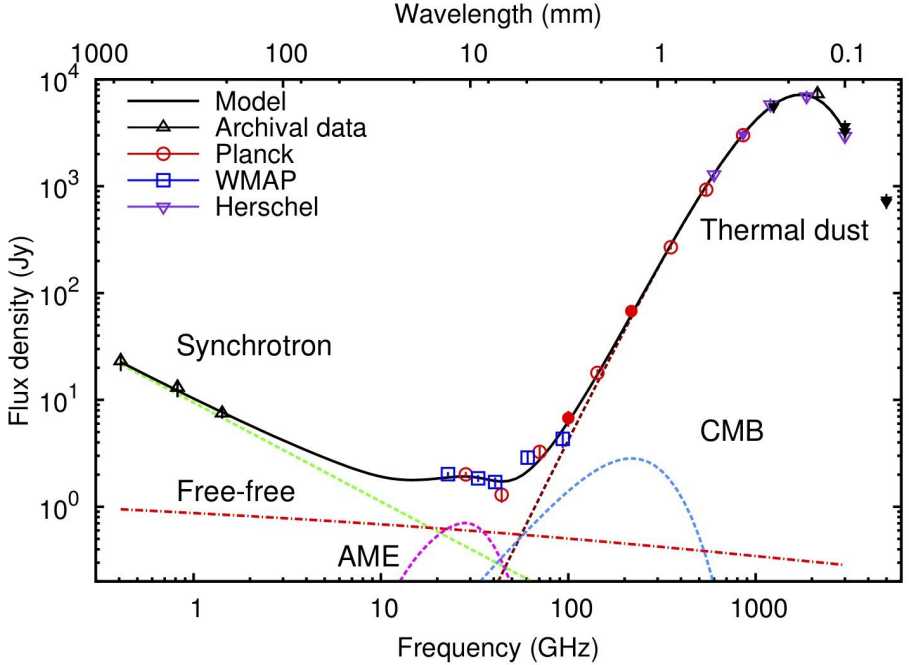


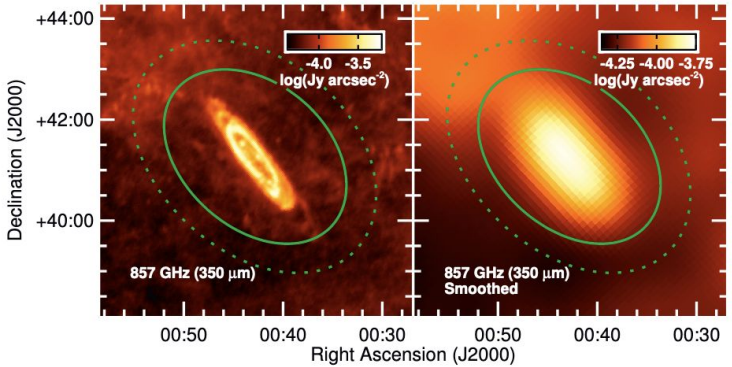




Andromeda Galaxy

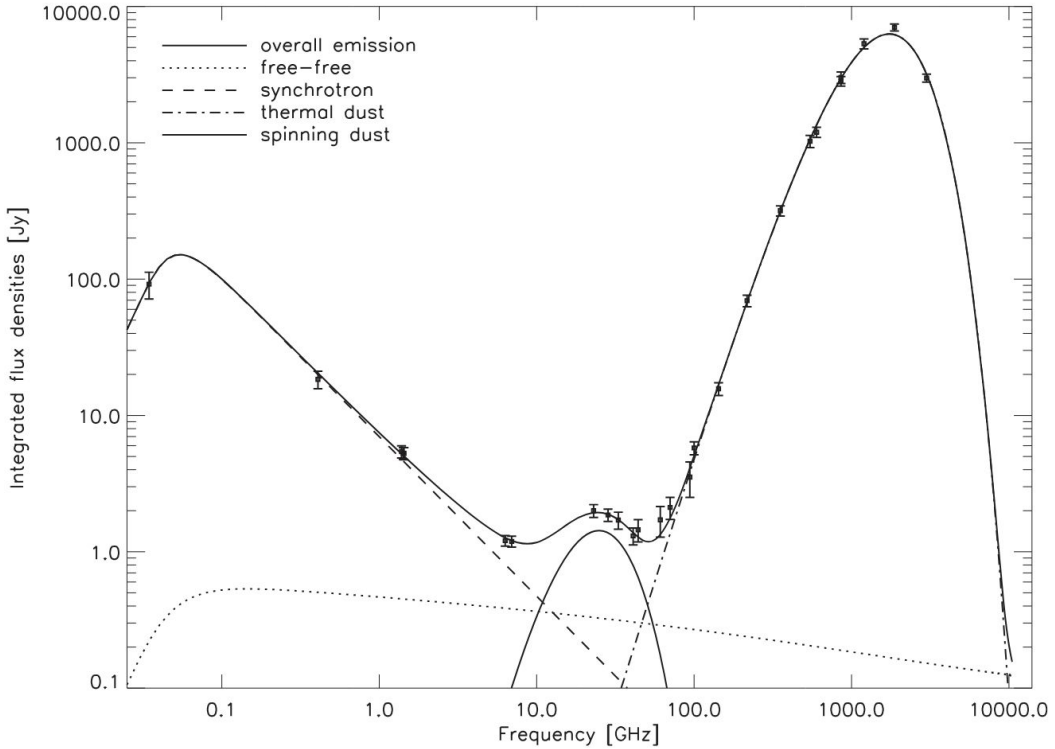
- M31 was an early detection at radio (Jodrell Bank: Brown & Hazard 1950) and infrared (e.g., IRAS)
- WMAP + Planck detected it at all frequencies
- Has a bright CMB anisotropy at southern end
- Variable radio point source nearby
- 1° emission much brighter than resolved emission (Effelsberg etc.)
- 2.3 sigma hint/upper limit on AME from Planck+WMAP
- Planck Collaboration XXV (2015, A&A, 582, A28, Peel corresponding author)





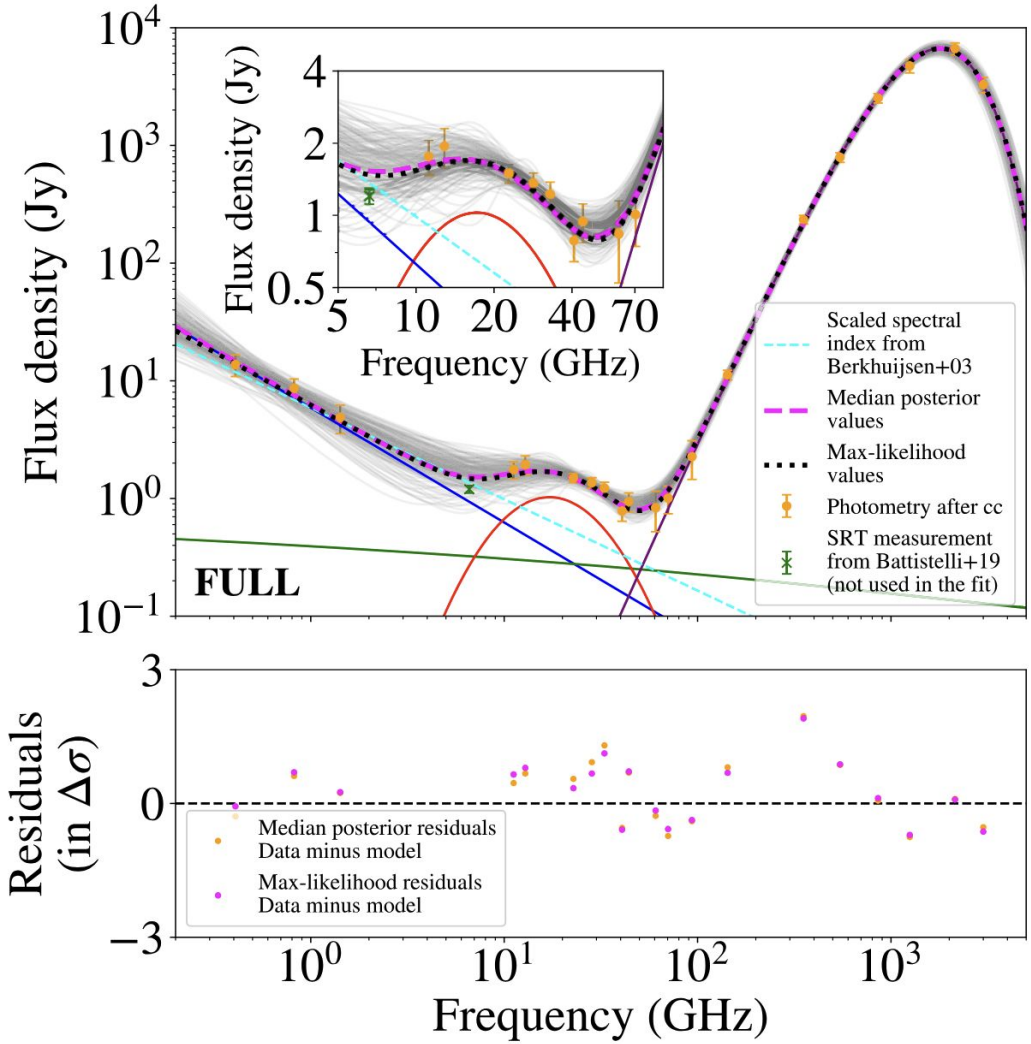
Andromeda Galaxy

- Battistelli et al. (2019, ApJL, 877, L31)
- New SRT observations at 6.7GHz
- WMAP + Planck data points filtered to match SRT scans
- Point sources subtracted at all frequencies
- 6.7GHz integrated flux density much low than Planck/WMAP
- → AME?



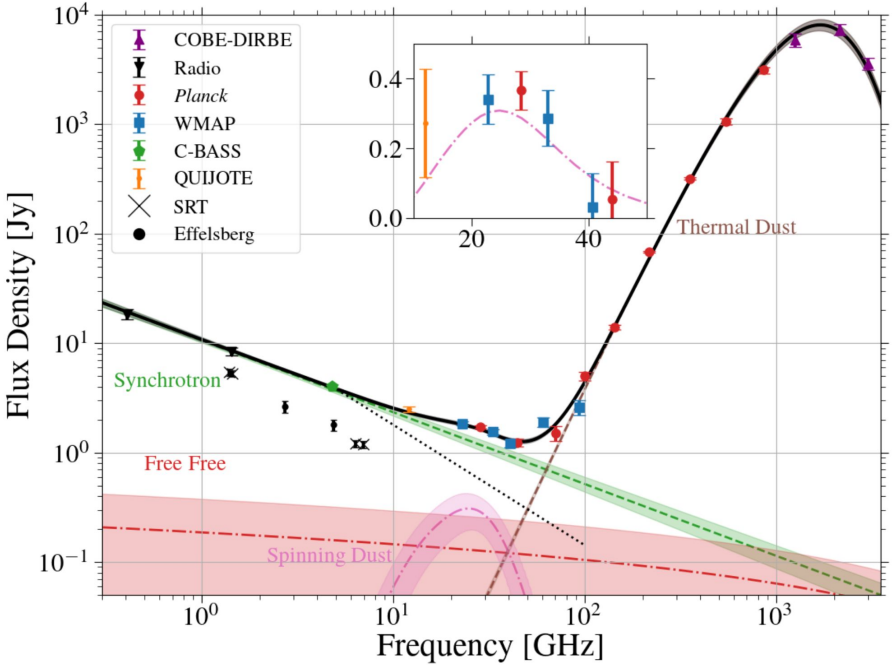
Andromeda Galaxy

- Fernández-Torreiro et al. (2024, MNRAS 527, 11945)
- New QUIJOTE observations
- All at 1° resolution
- Point sources inc. bright variable source subtracted
- 3.2 sigma detection of AME
- 1.06 ± 0.30Jy at 17 ± 3GHz
- SRT measurement a bit low but consistent (not included in fit)



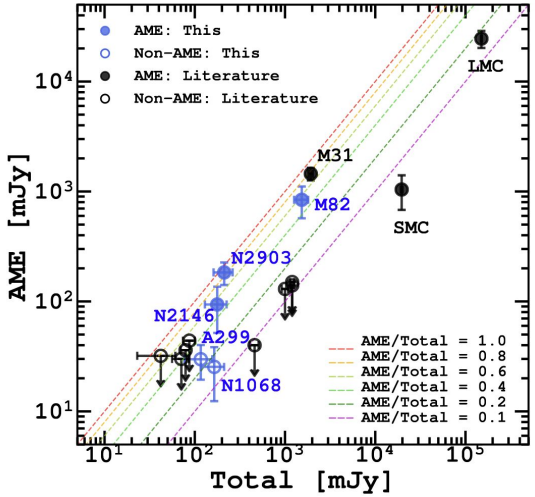
Andromeda Galaxy

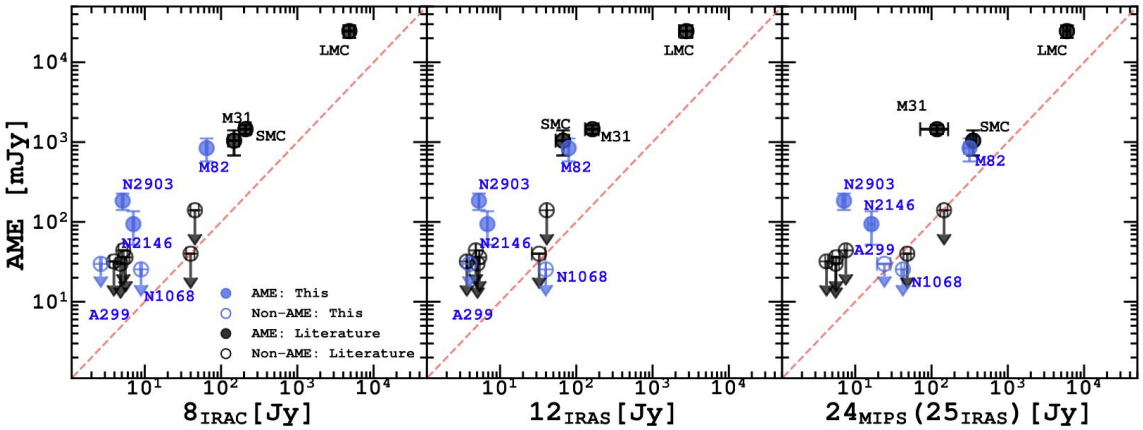
- Harper et al. (2024, MNRAS 523, 3471)
- New C-BASS observations
- All at 1° resolution
- Point sources inc. bright variable source subtracted
- 3.0 sigma detection of AME
- 0.27 ± 0.09Jy @ 30GHz
- C-BASS data point is significantly higher than SRT (and model above other ground-based observations)
- Synchrotron spectrum is critical
- What's going on? See Stuart's presentation tomorrow for possibilities

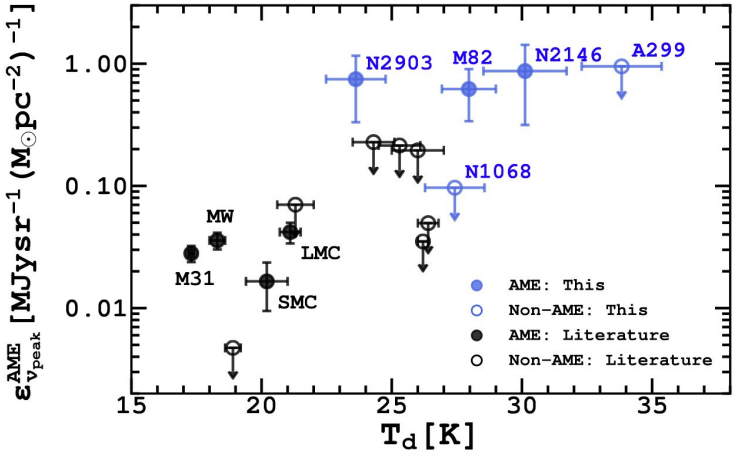


Searching for correlations?

- Difficult when there are few detections!
- Poojon et al. included some correlations with usual suspects from Galactic AME
- In Galactic AME research, every paper tends to find a different best correlation...







Future prospects

- Most detections so far in resolved regions (9 galaxies), but some in integrated SEDs
- Measuring resolved regions consistently is difficult - need to match interferometer resolutions
- Measuring complete spectrum consistently is difficult - need to capture all flux density / match resolutions
- Extragalactic AME detections are not easy!
- Knowing which galaxies to target is tricky

- QUIJOTE MFI2 @ 10-20GHz (see Rubino-Martin talk tomorrow!)
- SRT @ 18-26GHz
- COMAP @ 30GHz
- Simons Observatory @ 30-40GHz?
- VLA? (see Shroyer talk after the break!)
- ALMA, SKA, GBT, Others?
- Time for ground-based AME observations possibly running out due to satellite constellations (Starlink, OneWeb, Amazon Kuiper, Qianfan, etc.) at 12-20GHz+...