ANOMALOUS MICROWAVE EMISSION AS SEEN BY SKA

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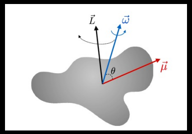
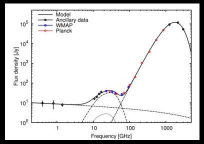
Valentina Vacca

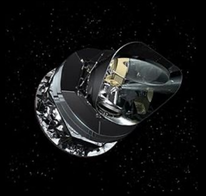
OVERVIEW



- AME: dust correlated (anomalous) microwave emission



- Planck did great but not enough angular resolution
- This calls for high angular resolution study of AME



- Arcmin level data are great for galactic and near-by extragalactic science (e.g. M31)

CSIRO's Parkes radio telescope. Credit: David McClenaghan, CSIRO

- Even higher angular resolution would be great especially for extragalactic AME search

- This requires SKA1–MID band 5 and 6
- Polarization would help to disentangle magnetic and electric emissions

SKAO

- z=0.5 red-shifted sources could match the SKA1-MID ever at 15GHz

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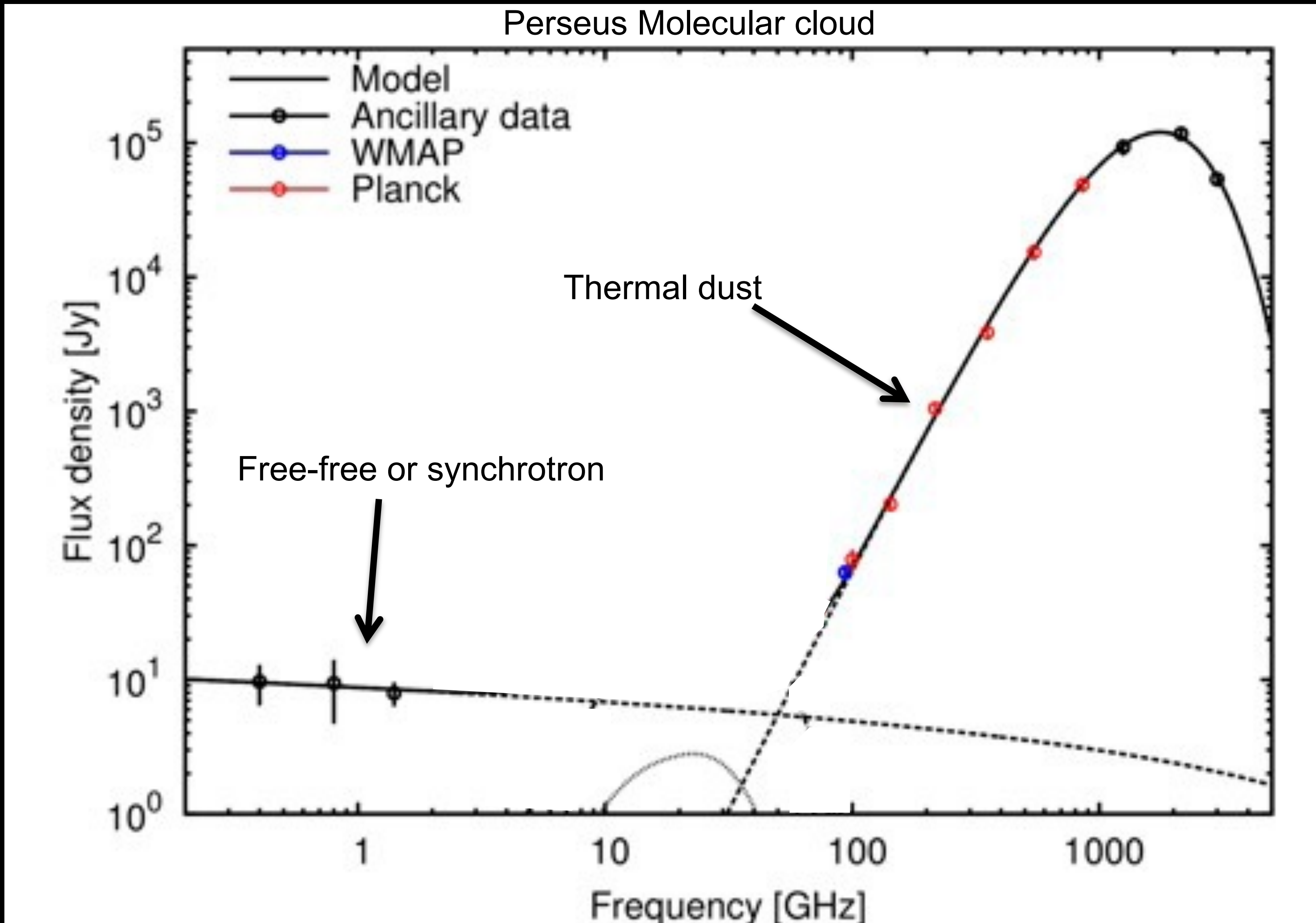

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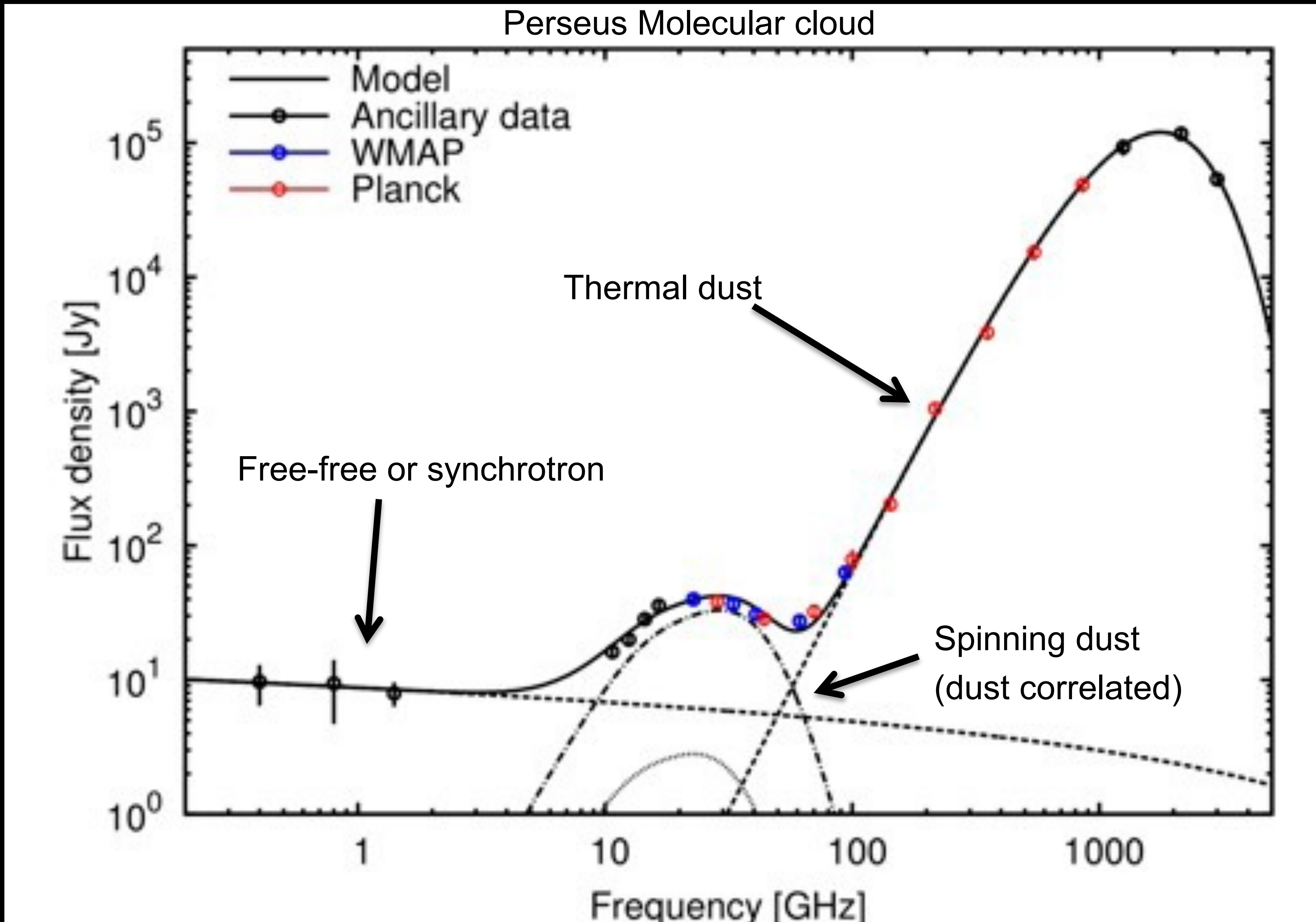
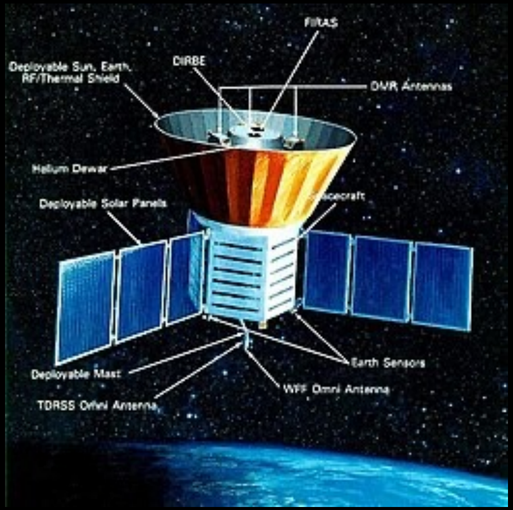


AME: FACTS



- First discovered by COBE correlating DMR (MW) with DIRBE (IR): AME is dust correlated

- It is characterized by a parabolic spectrum in the log(Flux)-log(Freq) plot with a peak at around 25GHz

- Detected in ~40 galactic regions and only in 4 extra-galactic sources

- Mainly detected so far by microwave CMB experiments: a concern as a foreground

- If polarized, it can lead to an incorrect determination of ***r*** in future high sensitivity CMB satellites (Remazeilles et al. 2016).

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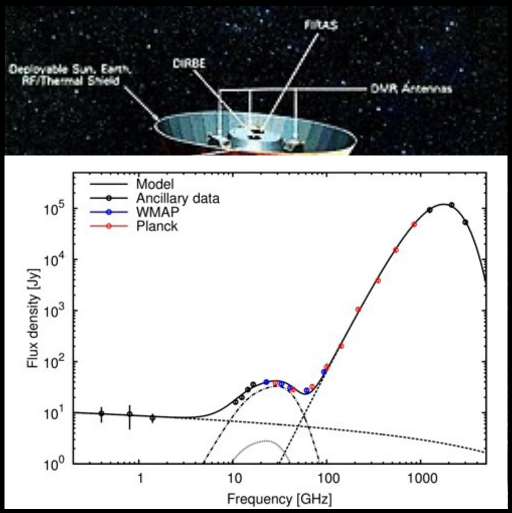

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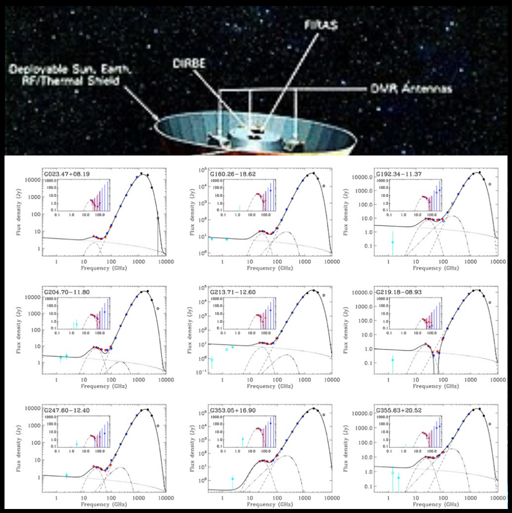

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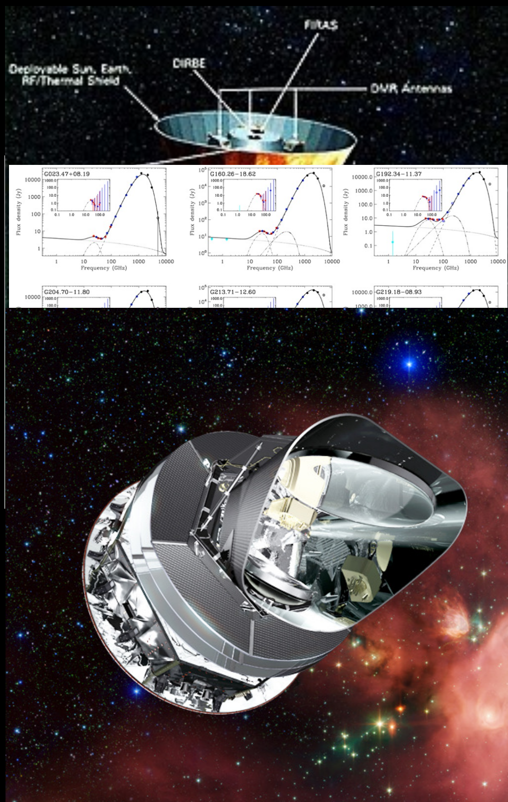

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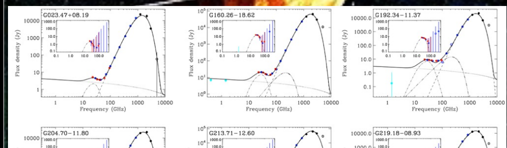

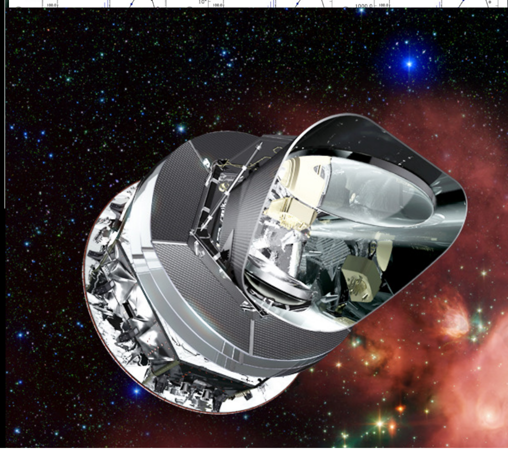

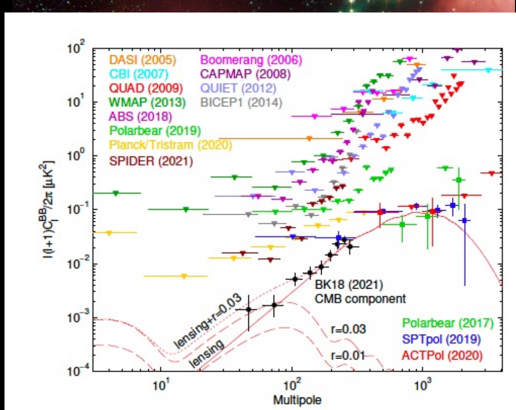

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AME: INTERPRETATION

- Classical explanations:
  - Comparison with H-alpha→no free-free
  - Ultra compact HII regions→unlikely
  - Synchrotron cannot explain the spectrum

- Draine & Lazarian (1999) → magnetic dipole emission (can be highly polarized)

- Most likely its origin is due to Spinning dust: rapidly rotating ultra-small dust grains with electric dipole (Draine & Lazarian 1998).

- To emit appreciably at ~20GHz, grain dimension need to be <1nm in size Polycyclic Aromatic Hydrocarbons (PAH) and very small grains could be responsible

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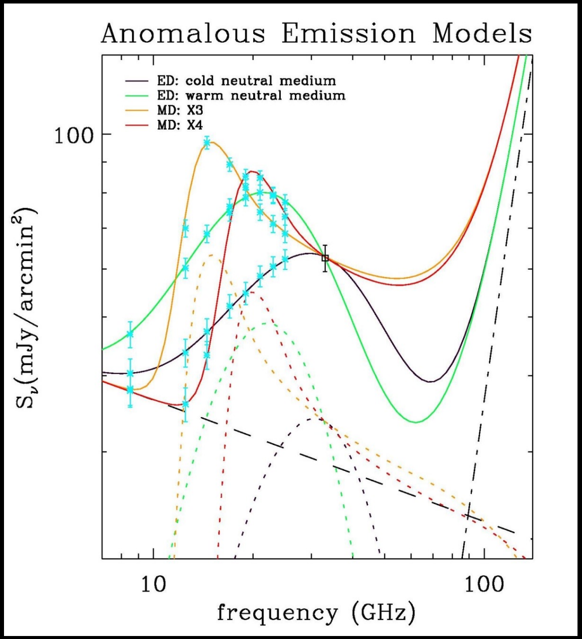

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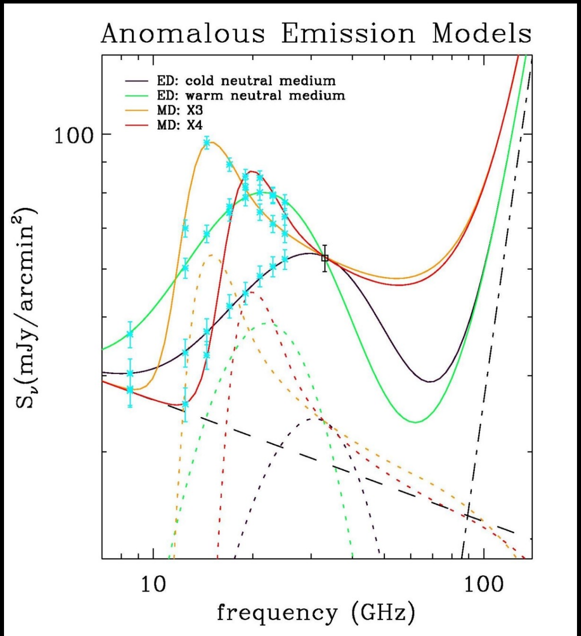

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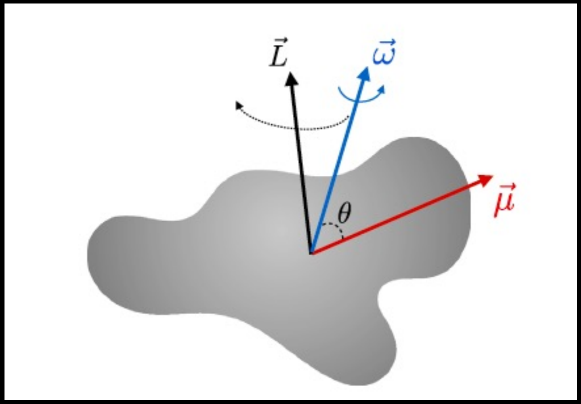

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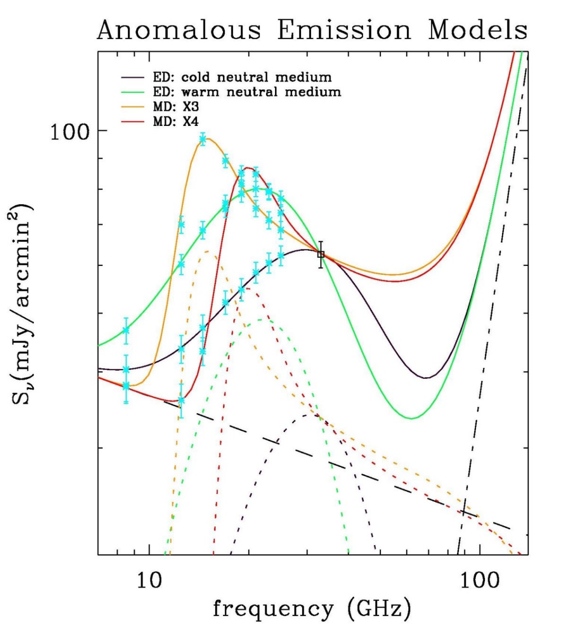

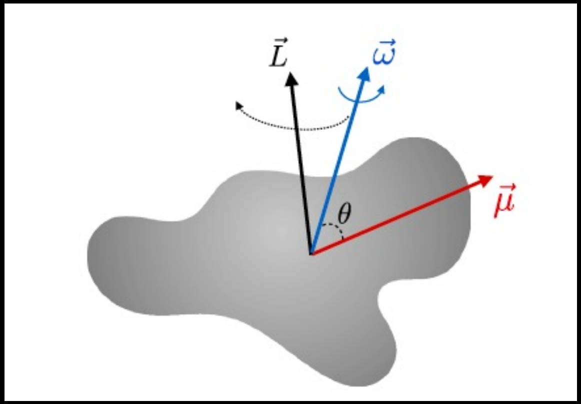

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SPINNING DUST

- Spinning-PAH (carbonaceous): probable candidate

- Spinning-PAH should emit rotational line (Ali-Haïmoud, 2014): it would be a smoking gun

- Spinning-PAH have been questioned: Hensley et al. (2016) found no abundance correlation

- Spinning-VSG: Nanosilicate grains (EDE), iron grains (MDE) are the most probable candidate

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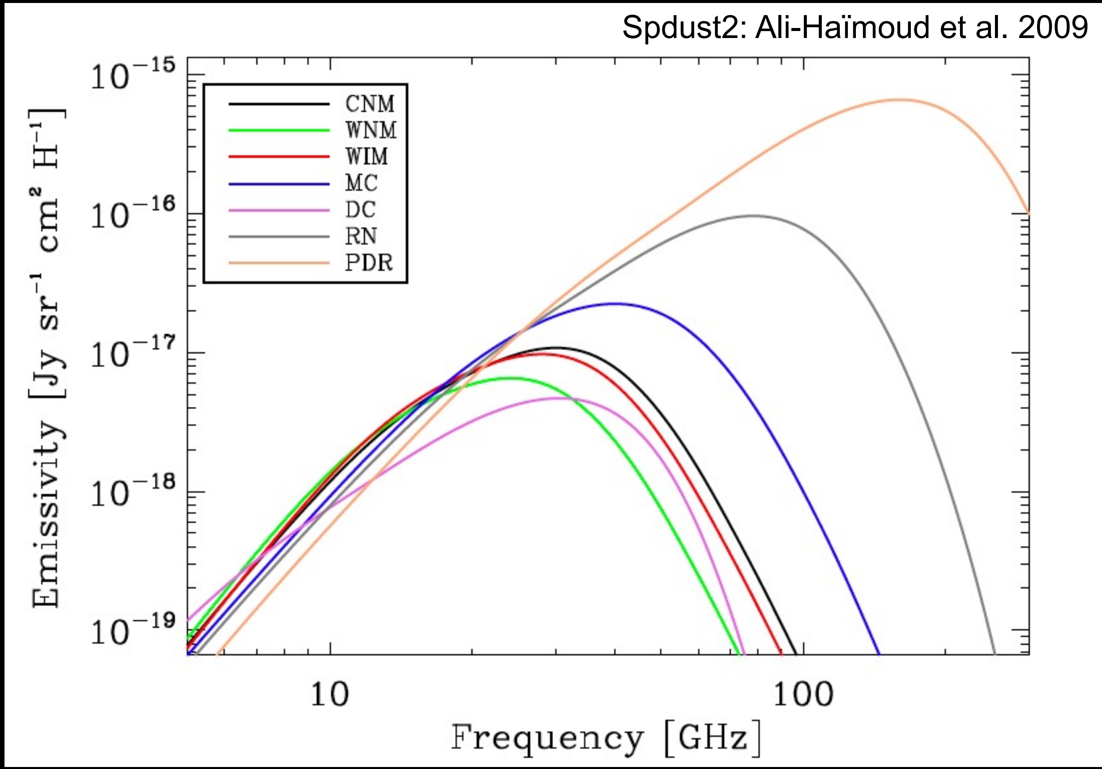

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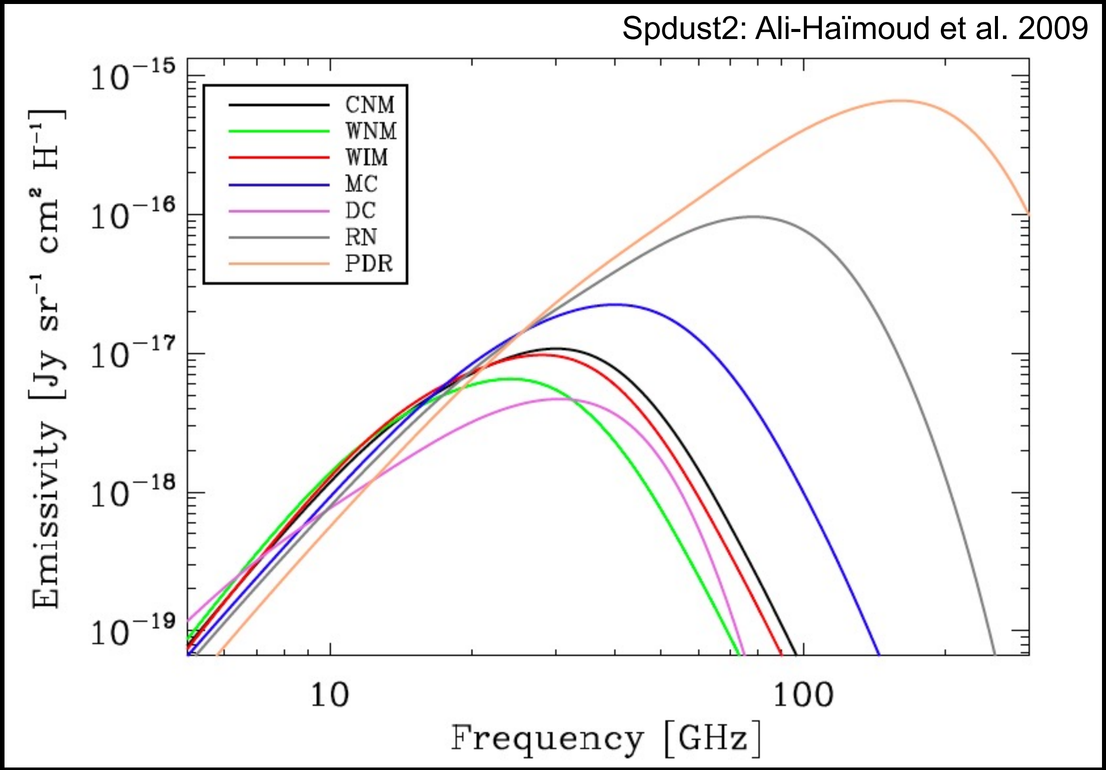

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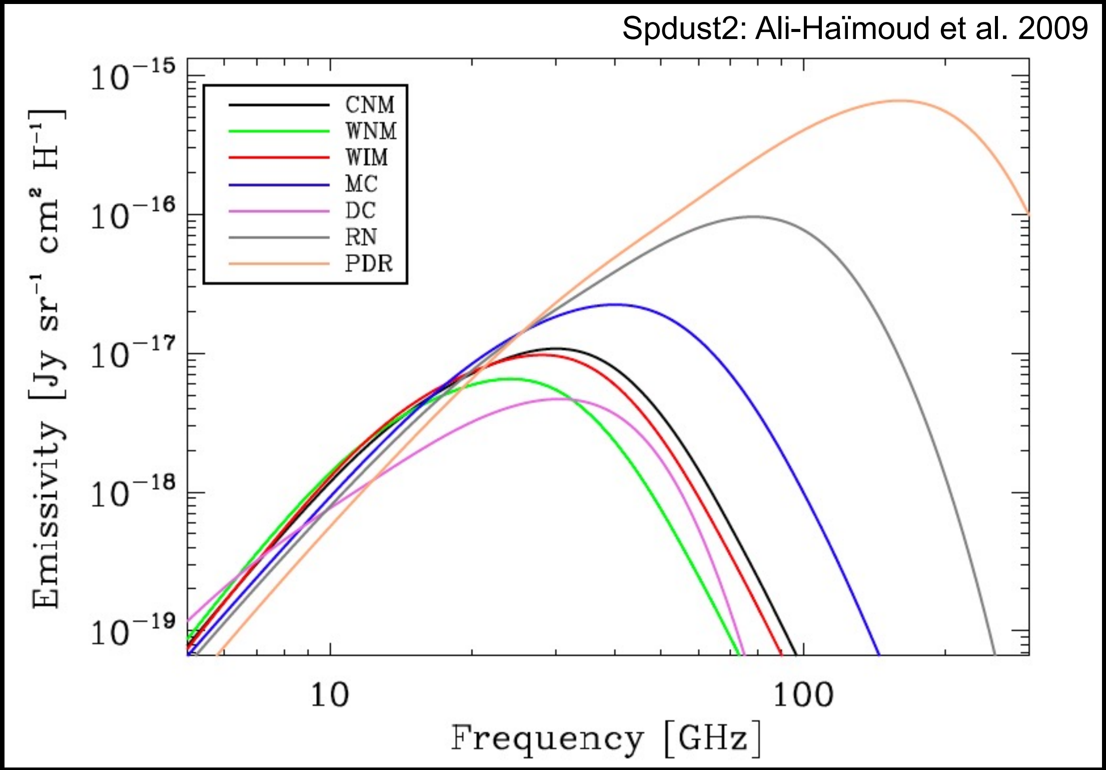

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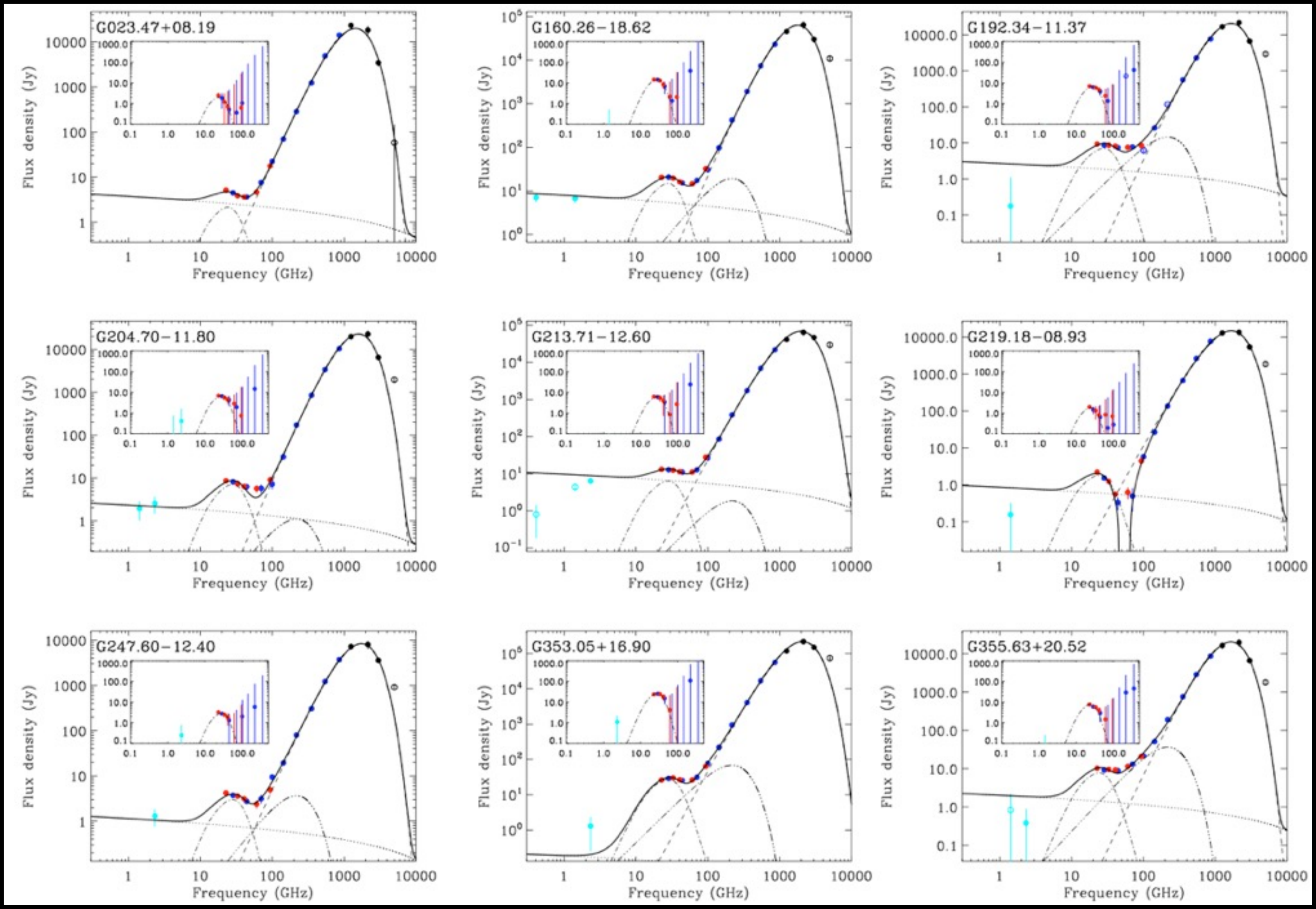

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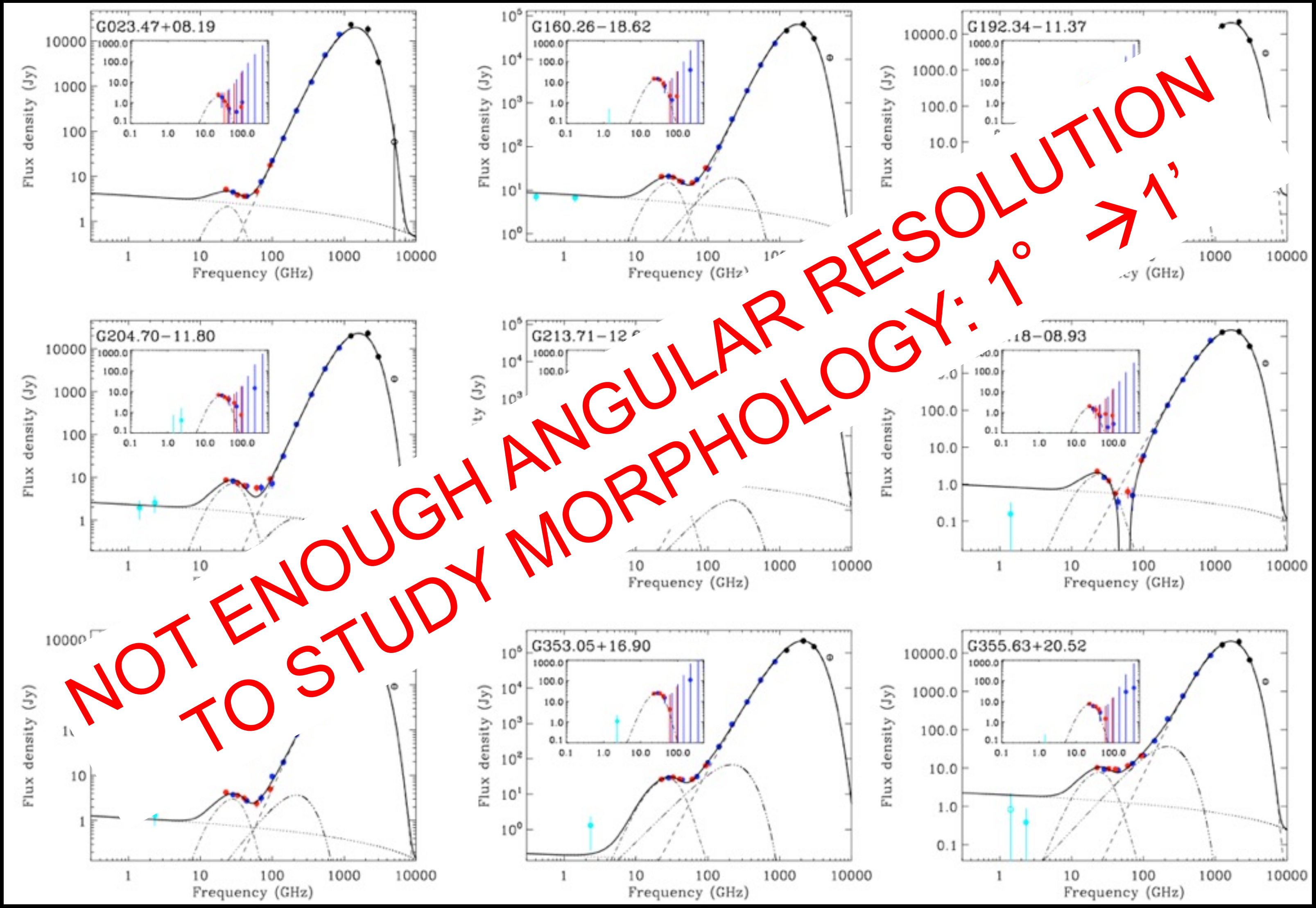
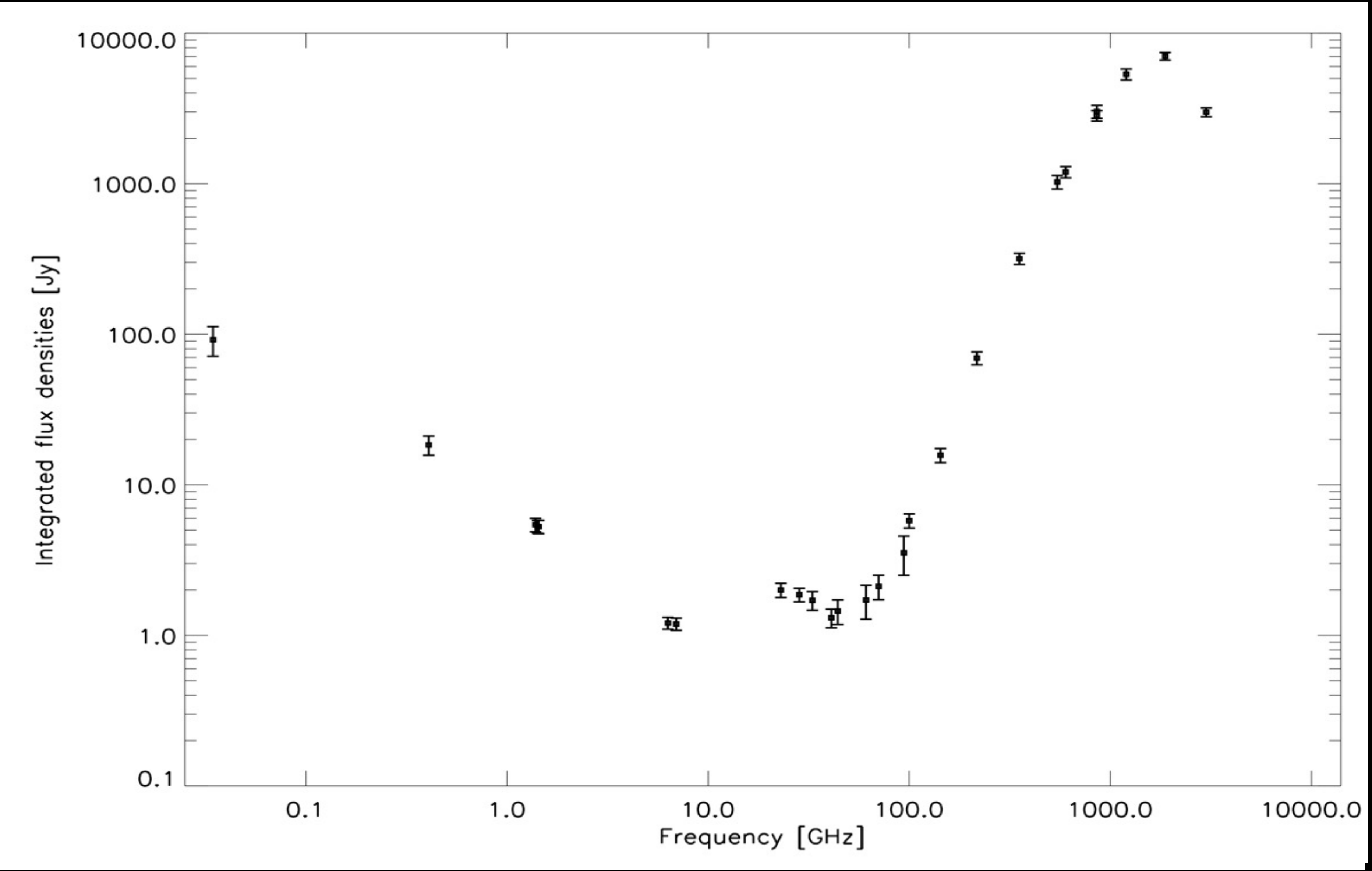


NOT ENOUGH ANGULAR RESOLUTION TO STUDY MORPHOLOGY: 1° →1’

M31 SED: EVIDENCE OF EXTRAGALACTIC AME



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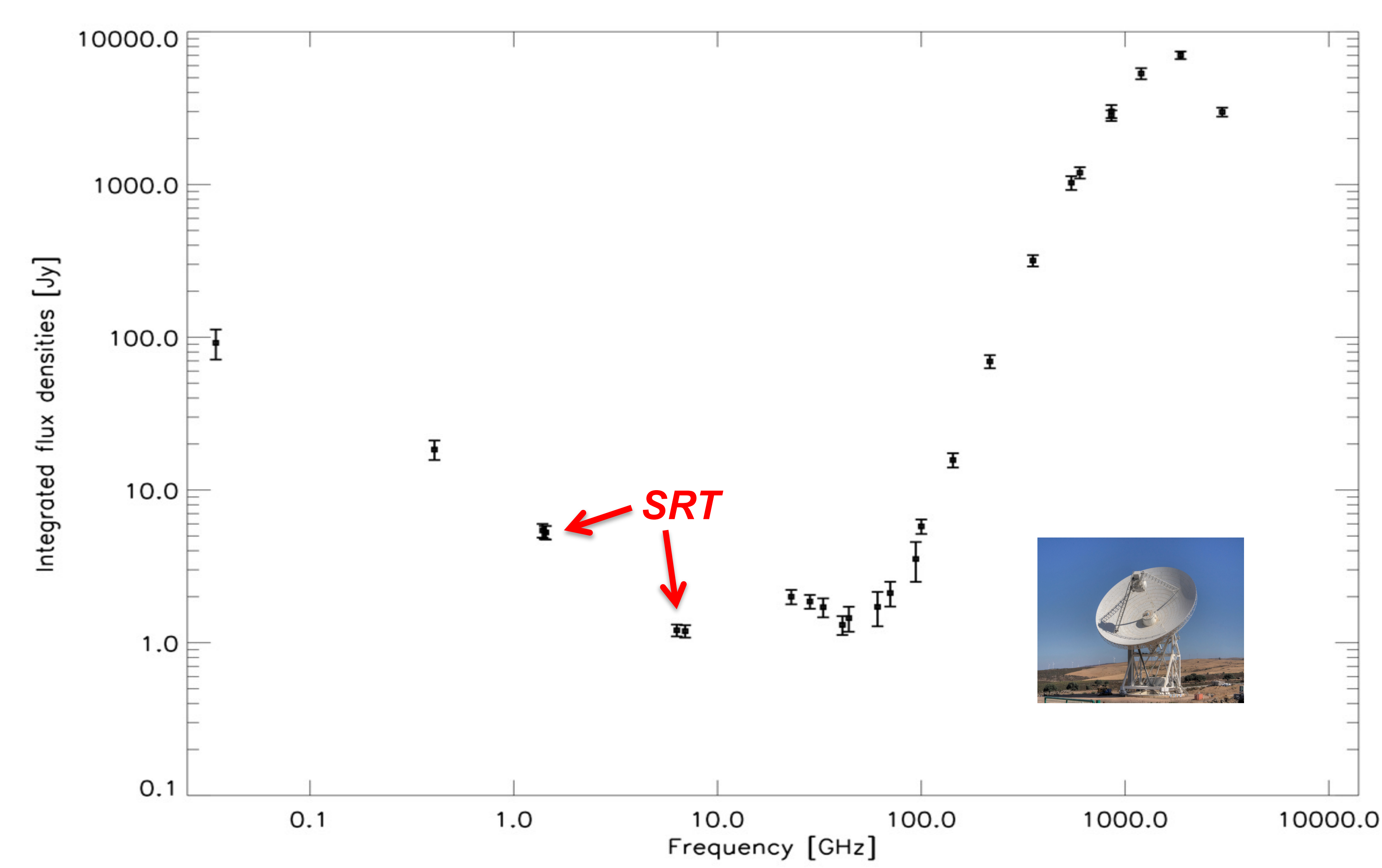

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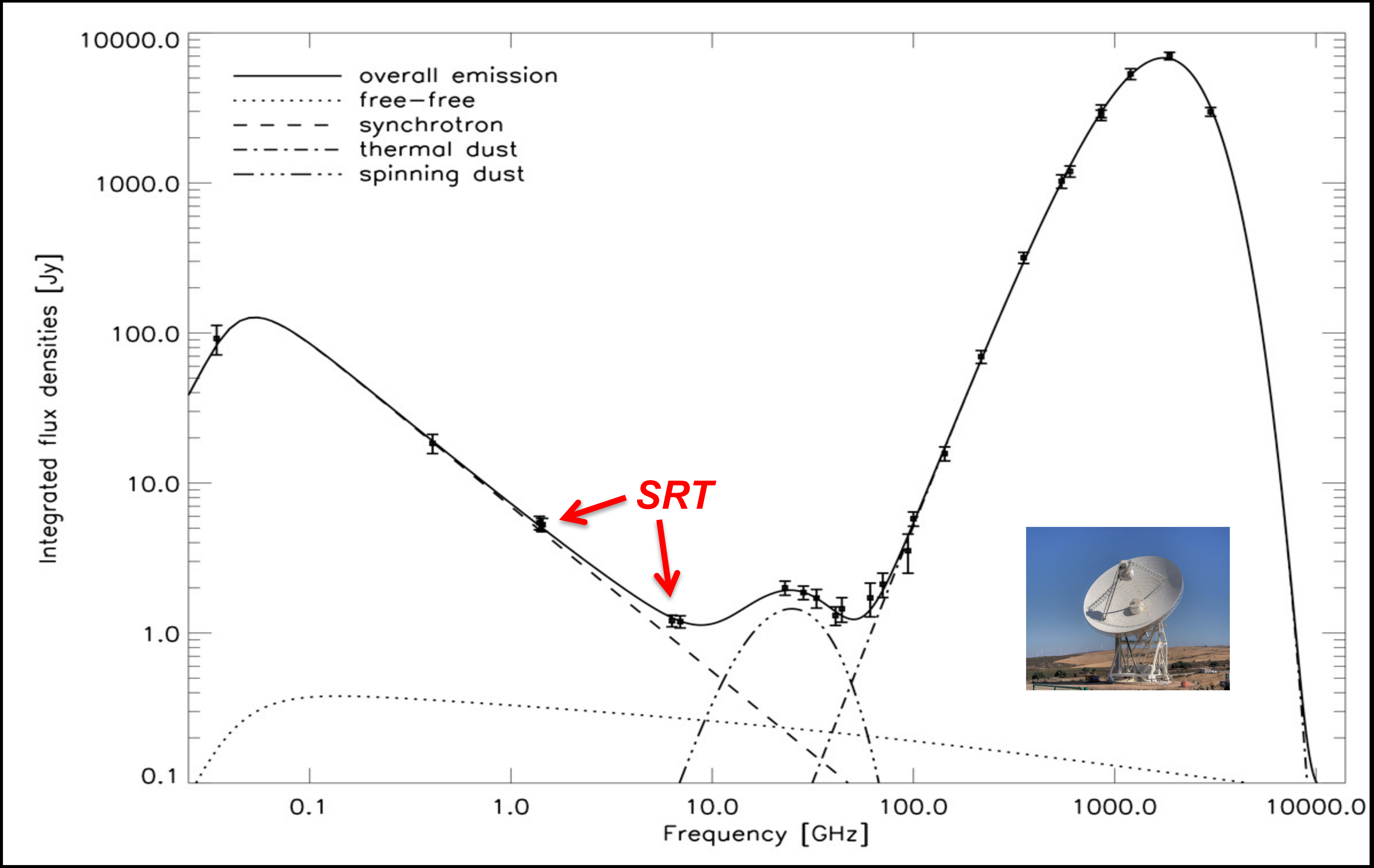

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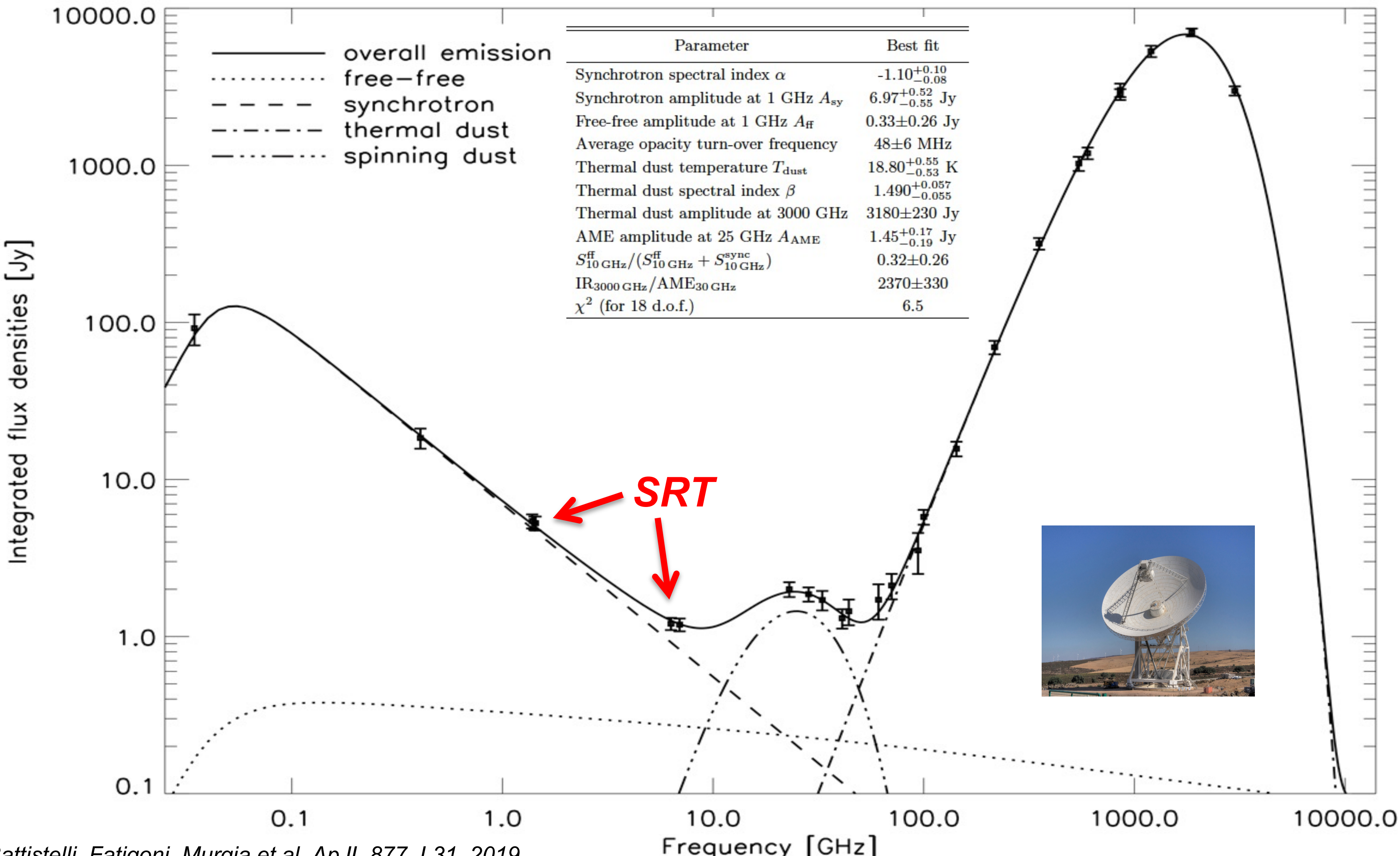

Parameter	Best fit
Synchrotron spectral index α	$-1.10^{+0.10}_{-0.08}$
Synchrotron amplitude at 1 GHz A_{sy}	$6.97^{+0.52}_{-0.55}$ Jy
Free-free amplitude at 1 GHz A_{ff}	0.33 ± 0.26 Jy
Average opacity turn-over frequency	48 ± 6 MHz
Thermal dust temperature T_{dust}	$18.80^{+0.55}_{-0.53}$ K
Thermal dust spectral index β	$1.490^{+0.057}_{-0.055}$
Thermal dust amplitude at 3000 GHz	3180 ± 230 Jy
AME amplitude at 25 GHz A_{AME}	$1.45^{+0.17}_{-0.19}$ Jy
$S^{ff}_{10\,GHz}/(S^{ff}_{10\,GHz}+S^{sync}_{10\,GHz})$	0.32 ± 0.26
$IR_{3000\,GHz}/AME_{30\,GHz}$	2370 ± 330
χ^2 (for 18 d.o.f.)	6.5

Battistelli, Fatigoni, Murgia et al. ApJL 877, L31, 2019

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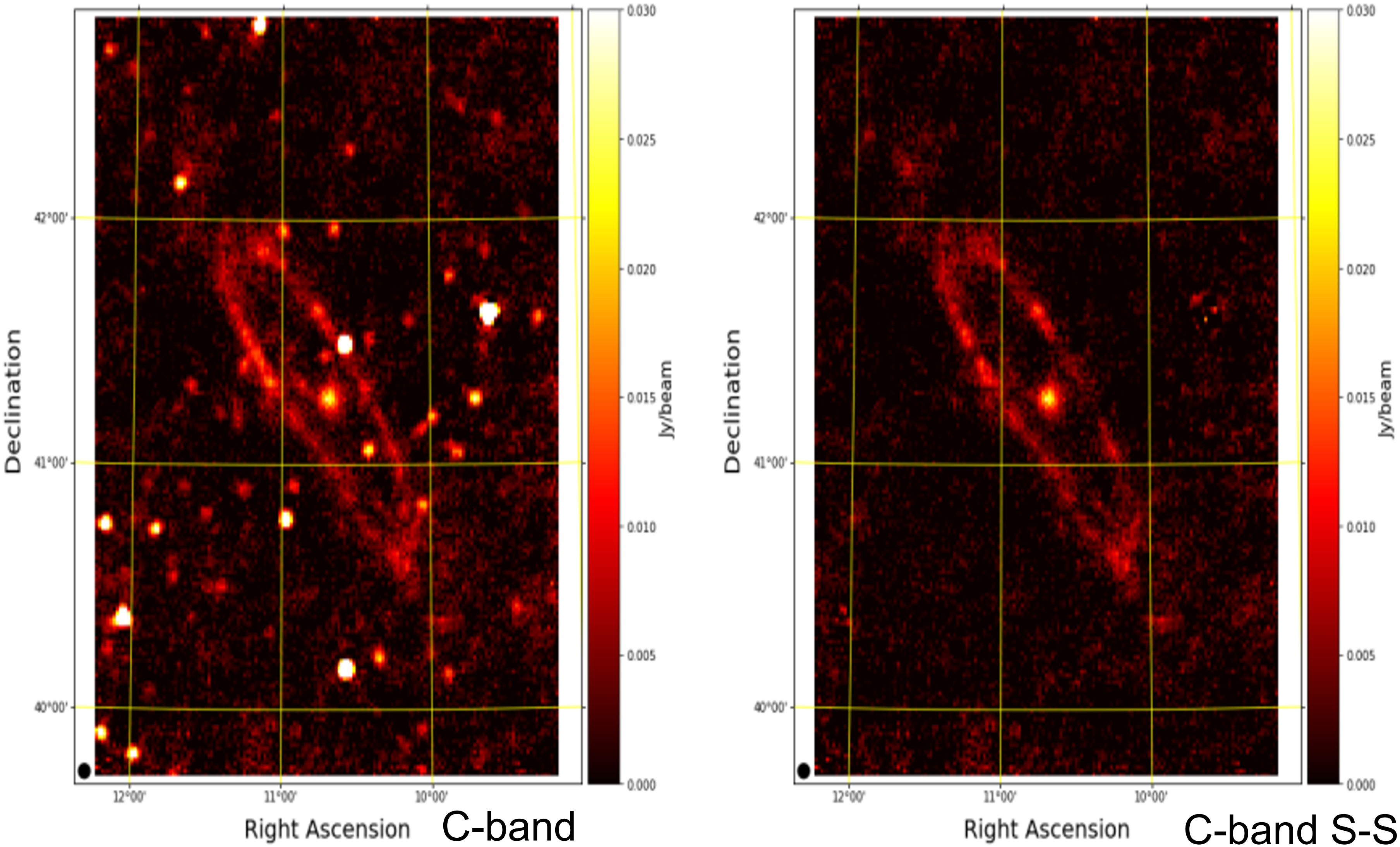

Fatigoni, Radiconi, Battistelli, Murgia et al. A&A 651, 98, 2021

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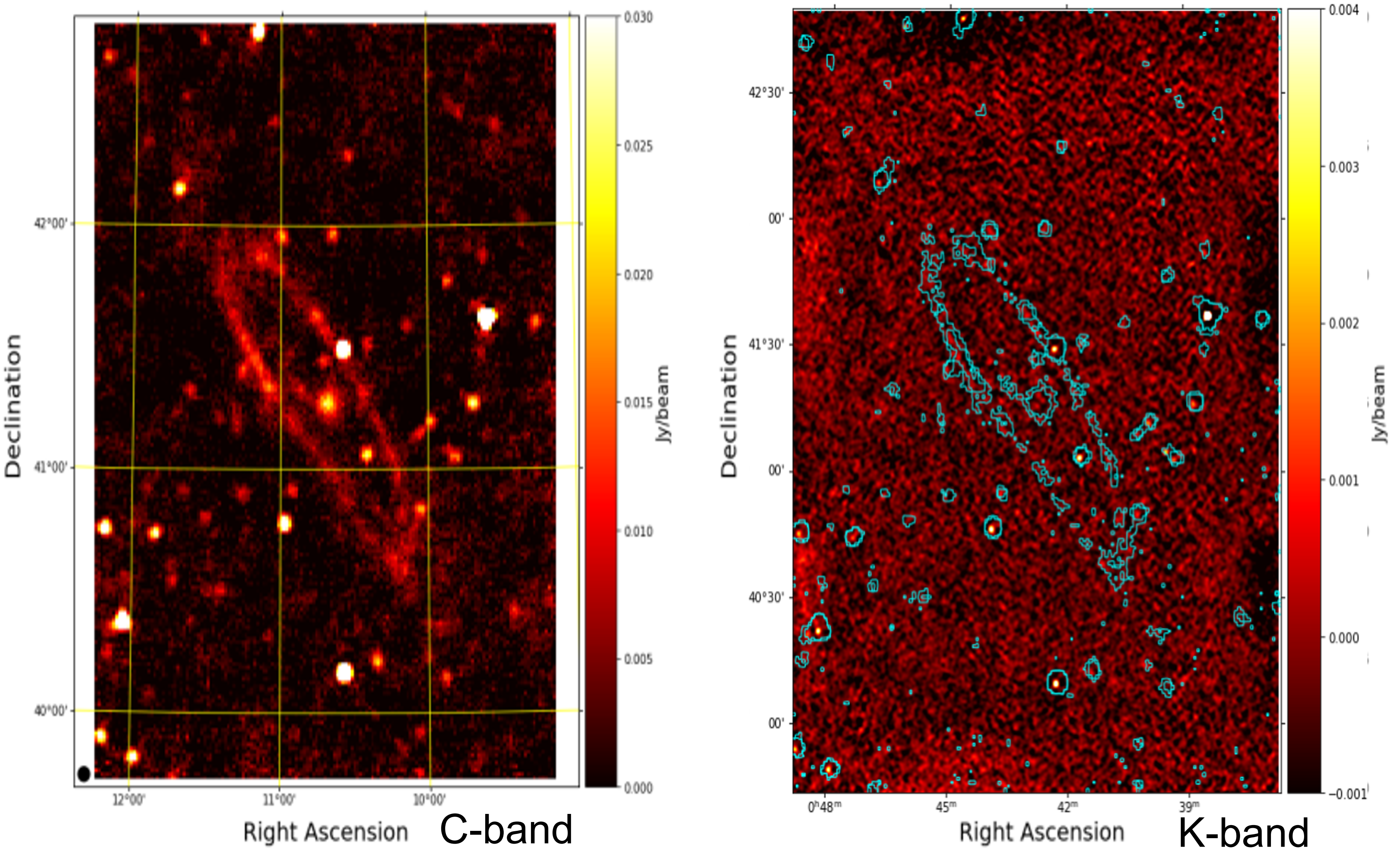

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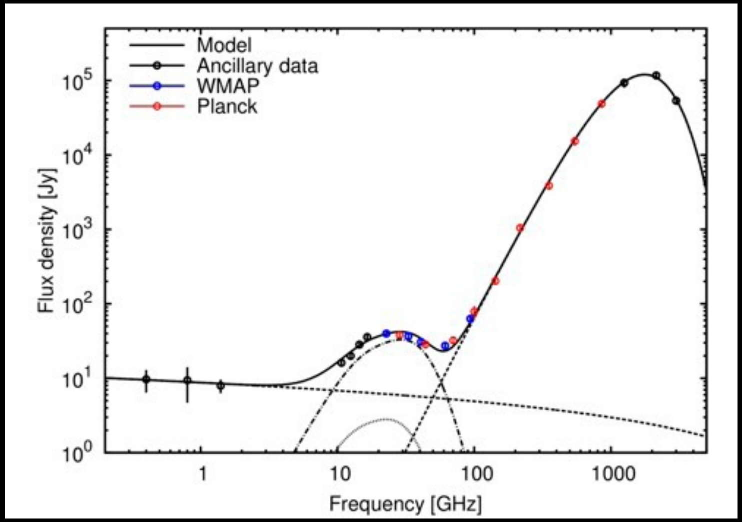
AME AS SEEN BY SKA

- Galactic studies would benefit from better characterization of free-free/synchrotron/AME em. of:
    - Photo dissociation regions (PDR);
    - dense cores;
    - circumstellar disks (believed to host ~nm dust);
    - pre-stellar cores (AME study would provide dust grains properties);

- SKA1-MID would sample free-free/synchrotron/AME where AME spectrum rises.



- Once AME is understood, it can be used to study dust grains properties: ISM properties and parameters otherwise difficult to obtain

- Extragalactic AME study is still at the beginning and is key to study mechanisms only studied (and not very well understood) in our Galaxy

- Required angular resolution can range from ~1.4arcsec (for shorter baselines) to 0.04arsec: this would allow us to enter into the “resolved” AME investigation

- PAH rotational emission would require tens of μJy/beam level sensitivity for 1MHz resolution

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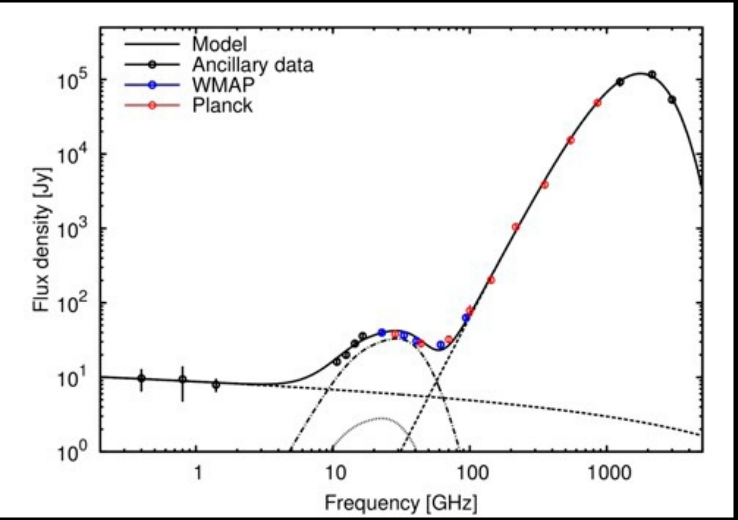

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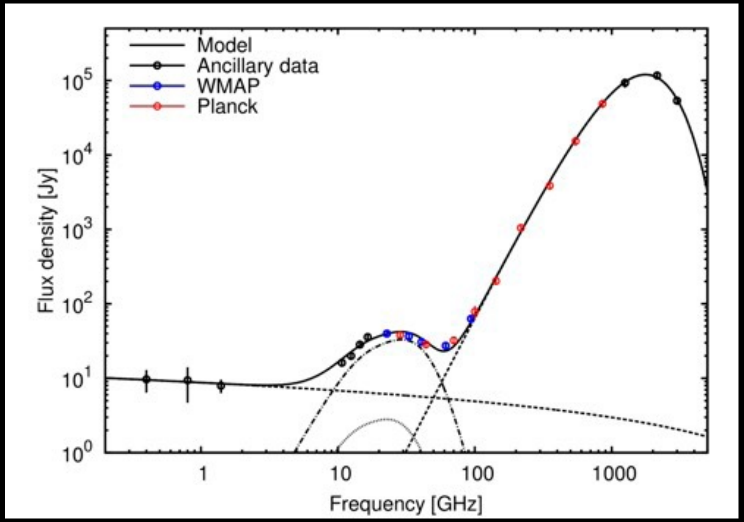

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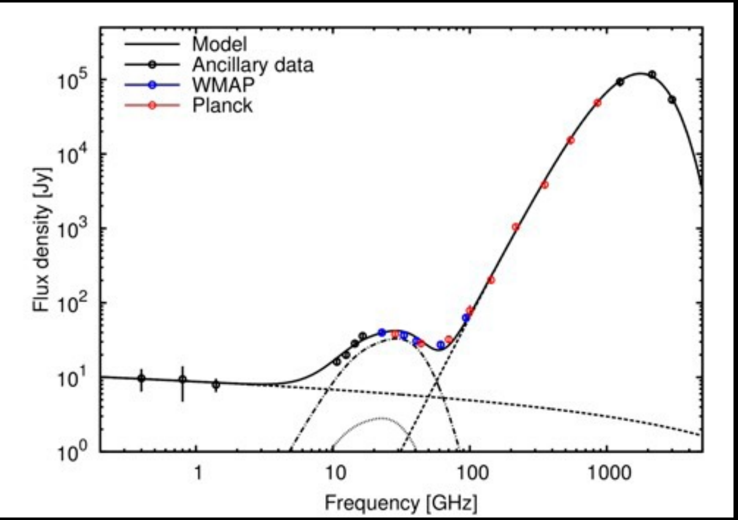

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AME AS SEEN BY SKA: BEYOND 15GHz

- Band 6 (beyond 15GHz) would be a unique possibility to advance in this field
- The SKA angular resolution would allow to study the lack of coincidence and correlation between microwave and IR maps and particularly the lack of correlation between AME and PAH
- SKA will address most of this science particularly if supplemented by single dish observations

4 Stellar Evolution and the Galactic Ecosystem

4.1 Anomalous Microwave Emission: an open question for modern astrophysics

Elia Stefano Battistelli (Sapienza University of Rome), Eric Murphy (National Radio Astronomy Observatory), Fatemeh Tabatabaei (Institute for Research in Fundamental Sciences-IPM), Ricardo Genova-Santos (Instituto de Astrofisica de Canarias), Matteo Murgia (Osservatorio Astronomico di Cagliari), Frederick Poidevin (Instituto de Astrofisica de Canarias), Rafael Rebolo-Lopez (Instituto de Astrofisica de Canarias)

This chapter focuses on the open question of Anomalous Microwave Emission. We describe its evidence both in the Galactic and extragalactic environment, open questions, and focus on the improvement that an experiment like SKA, with an extension in frequency to band 6, can achieve.

4.1.1 Introduction

The emission budget from astrophysical sources at microwave frequencies is mostly dominated by the well-studied and well-understood free-free, synchrotron, and thermal dust emission. Nevertheless, observations mainly carried out in our Galaxy have revealed an unexpected excess of emission in the

SKA
SQUARE KILOMETRE ARRAY

Memo 20-01

SKA1 Beyond 15GHz:
The Science case for Band 6

J. Conway, R.Beswick, T.Bourke, M.Coriat, C.Ferrari, I.Jimenez-Serra, S.Muller, M.Sargent

February 2020

www.skatelescope.org/memos

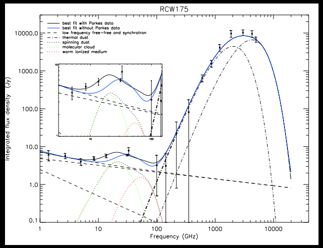
AME AS SEEN BY SKA: HIGH z SOURCES

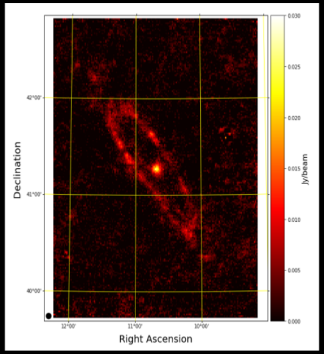
- Redshifted sources could have their AME peak at ν<15GHz: observable at MID Band 5a (4.6 - 8.5 GHz) and/or 5b (8.3 - 15.3 GHz)
- The higher star formation rate and the increased dust production at high z may result in larger fraction of AME
- This would allow us to monitor if grains properties are self similar to local galaxies
- Back of the envelope calculation would result in a size (67.5 kpc) and flux (assuming a conservative 2Jy) for M31-like galaxy as:

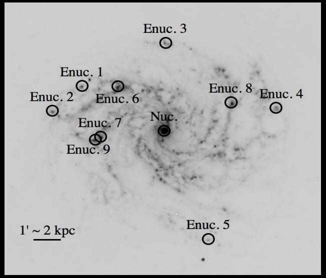
z	Size M31-like	Signal M31-like
0.5	10.7”	0.147μJy
1.0	8.1”	0.026μJy
1.5	7.8”	0.010μJy
2.0	7.9”	0.005μJy
3.0	8.6”	0.002μJy

Well resolved and detectable by SKA1-MID (res=1.4” and f.o.v. ~2arcmin)

CONCLUSIONS







- High angular resolution AME observations (as well as spectro-polarimetry data) are key to disentangle models
- Arcmin resolution data are doing a very good job
- SKA can observe galactic sources with SKA-MID band 5
- If band 6 is approved, SKA can do even more especially for extra-galactic science
- It would be great to be looking at redshifted sources even with SKA-MID band 5 configuration