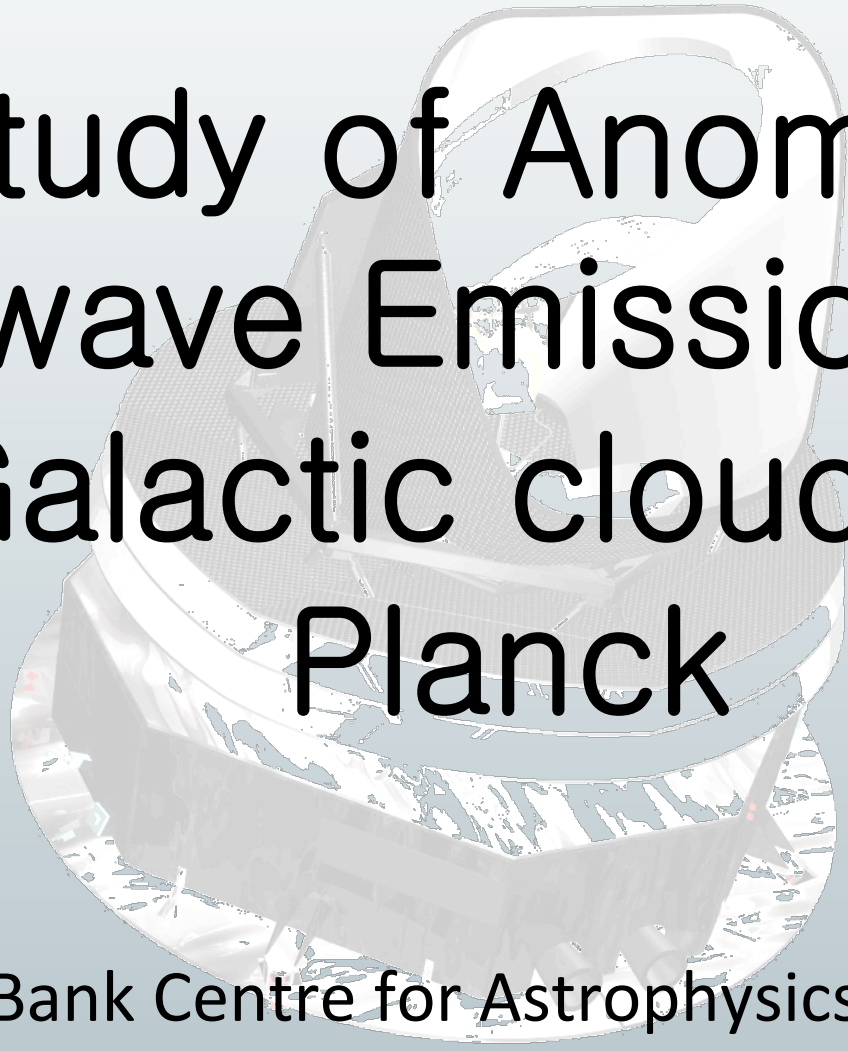

A study of Anomalous Microwave Emission (AME) in Galactic clouds with Planck

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On behalf of the Planck collaboration

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 100 scientific institutes in Europe, the USA and Canada

esa planck

cnes agenzia spaziale italiana

NASA cnrs DTU Space National Space Institute

Science & Technology Facilities Council

INAF ISTITUTO NAZIONALE DI ASTROFISICA

CSIC

National Research Council of Italy

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

CSA ASC DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.

UK SPACE AGENCY

MAX-PLANCK-GESELLSCHAFT

HFI PLANCK a look back to the birth of Universe

PLANCK LFI

IAS orsay

IAP

INAF - IASF BO ISTITUTO NAZIONALE DI ASTROFISICA ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA DI BOLOGNA

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Manchester · MilliLab · Max-Planck-Institut für Astrophysik · NUI Maynooth · INAF Osservatorio Astronomico di Padova · Department of Physics University of Oxford · Dipartimento di Fisica Sapienza Università di Roma · Science & Technology Facilities Council Rutherford Appleton Laboratory · Tor Vergata · Observatoire Astronomique de Paris · UBC · UC Universidad de Cantabria · UCSB · SISSA

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Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

Overview of AME

- Anomalous Microwave Emission (AME)
  - *Additional source of diffuse radio emission at ν ~10-60 GHz*
  - *Strongly correlated with Far Infrared emission*
  - *Does not appear to be strongly polarized (P~1% or less)*
  - *Observed in a range of environments*
  - *Still only a very few (~5 at best) convincing detections*

- Several explanations have been proposed
  - *Most likely electric dipole radiation from spinning dust grains*
  - *First predicted by W.C. Erickson (1957)*
  - *More data and studies needed!*

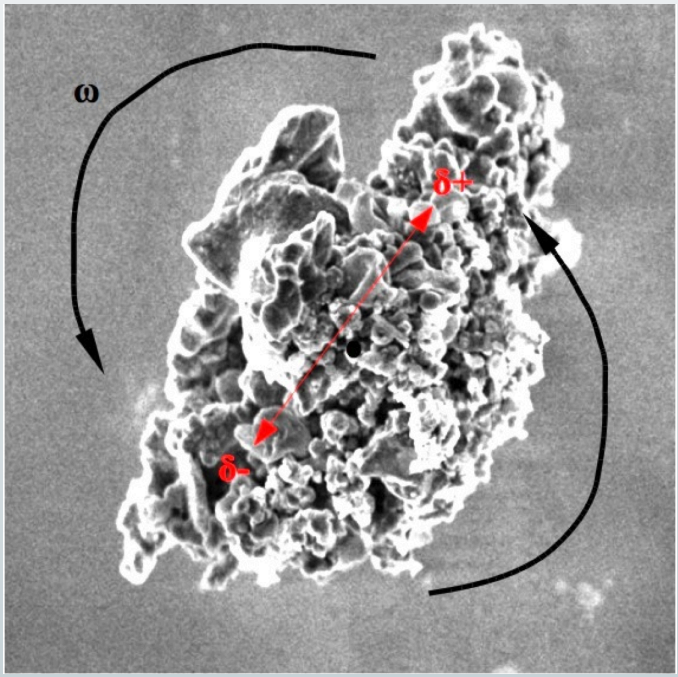
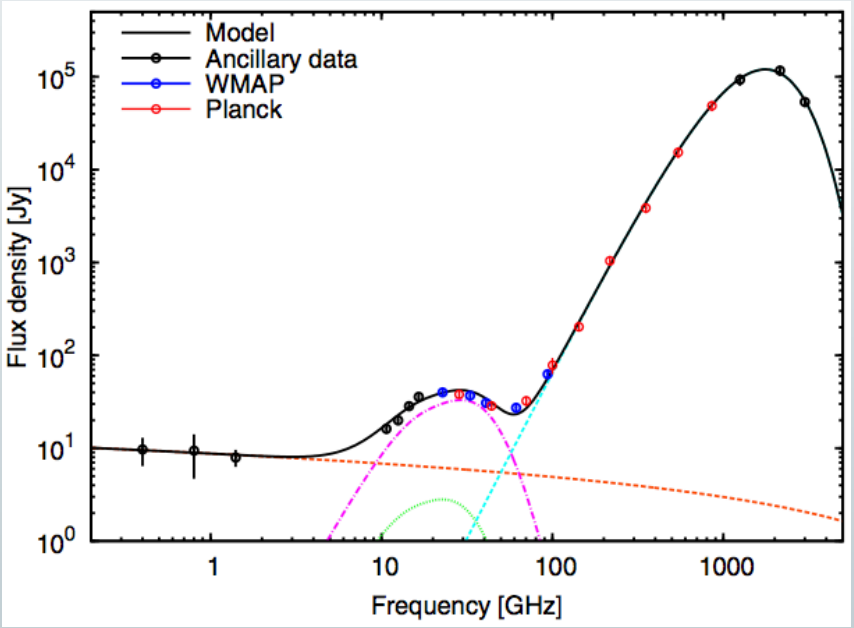
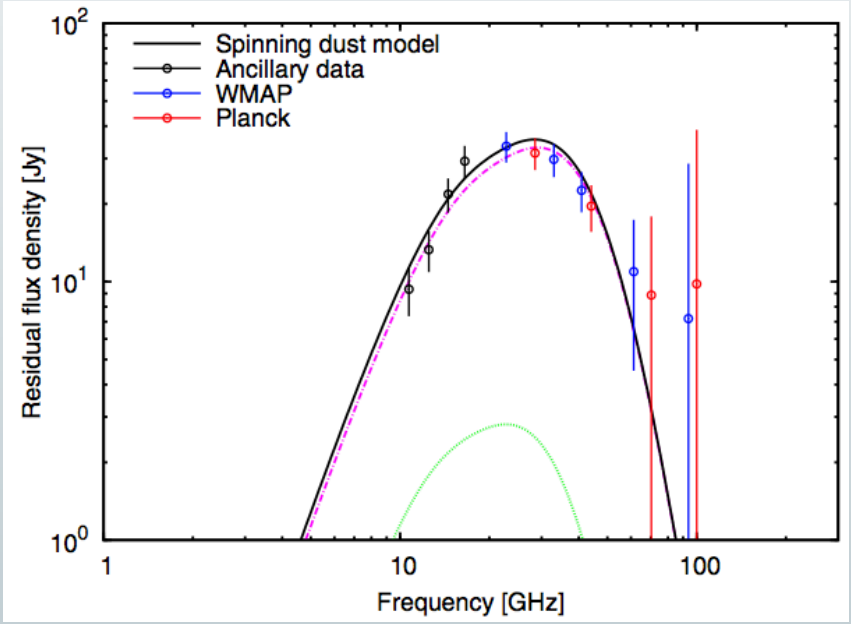


Image courtesy of Anna Scaife

Planck early paper XX

- Planck collaboration et al., 2011, A&A, 536, A20
  - *Most precise spectra to-date (Perseus & ρ Ophiuchi)*
  - *Strong evidence for spinning dust model*

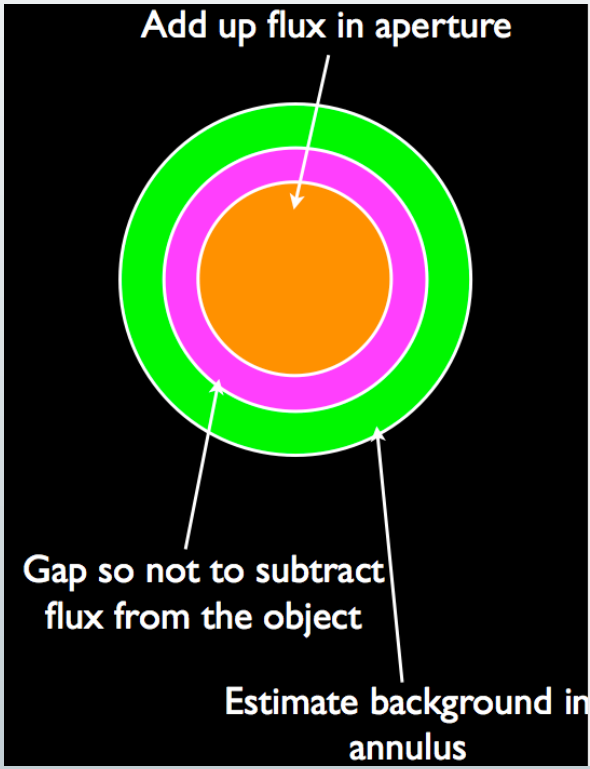




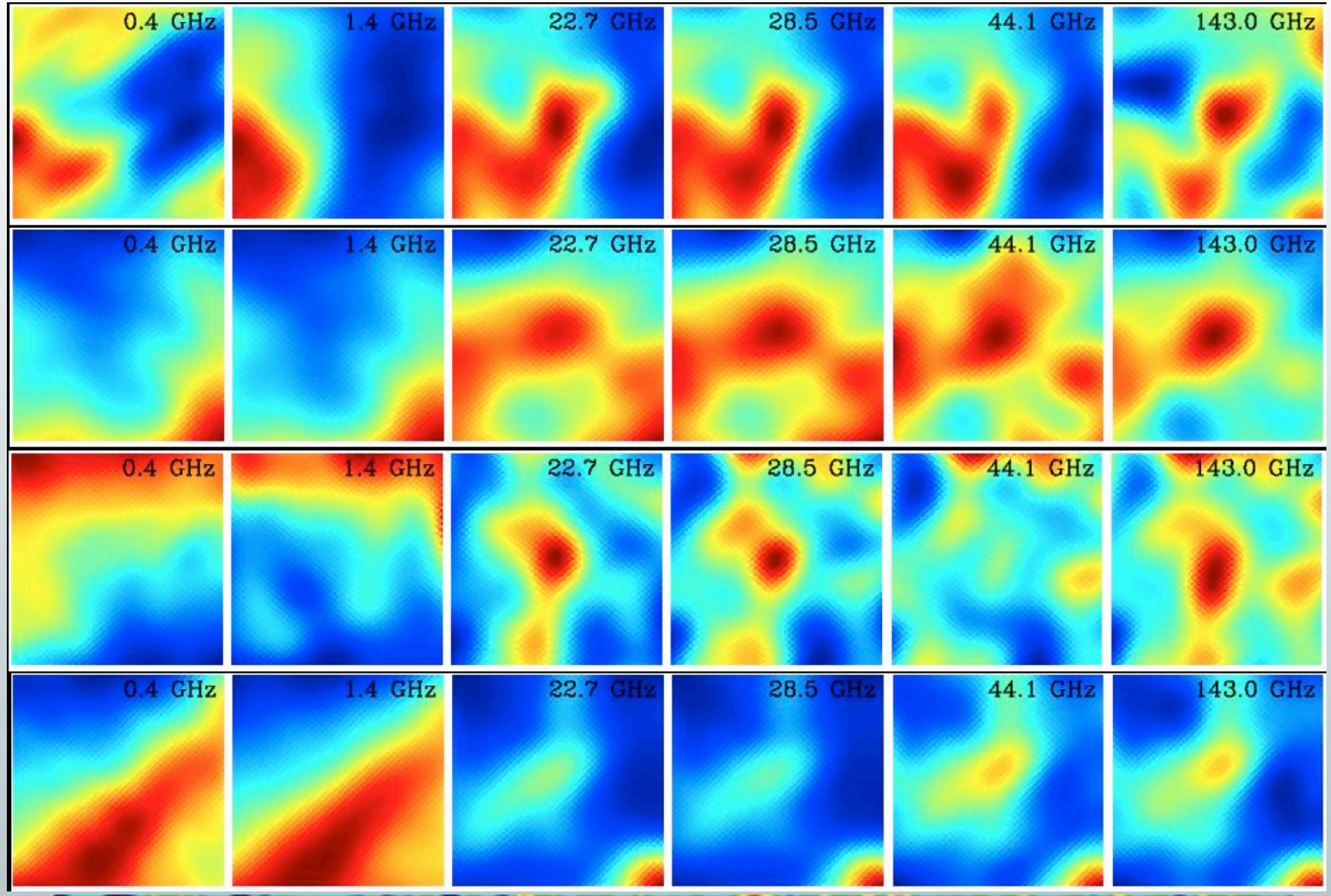
G160.26-18.62 (Perseus molecular cloud)

Planck intermediate paper: methods

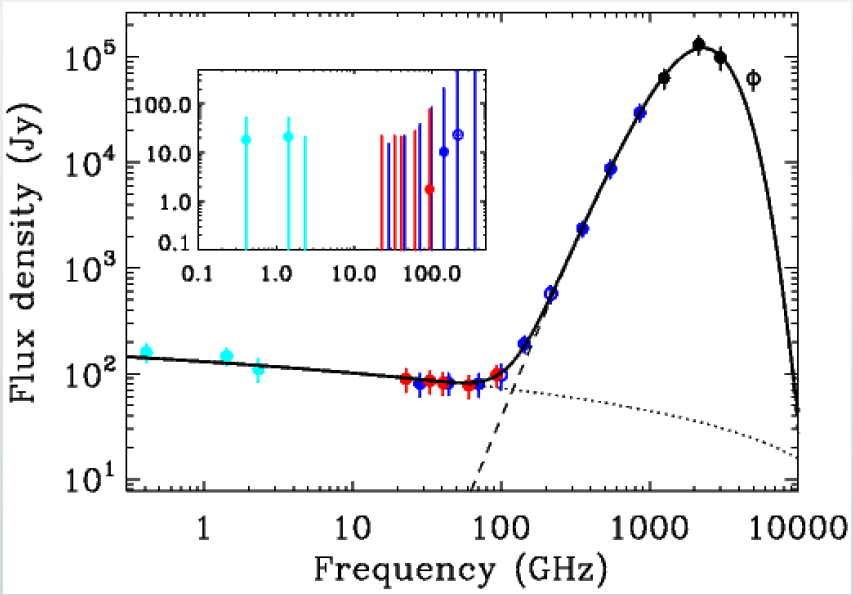
- Planck collaboration et al., in prep.
  - *To be submitted soon!*
- Sample of 98 sources
  - *Source detection (SEXtractor) at 70 GHz & template removal*
  - *Remove sources via cross-match with 30 and 100 GHz, extragalactic, SNRs etc.*
  - ***Not a complete sample!*** *(in any sense)*
- SEDs from aperture photometry
  - *Planck, WMAP, IRAS/DIRBE, low frequency radio data (1 deg smoothed)*
- Fit simple model to the SEDs

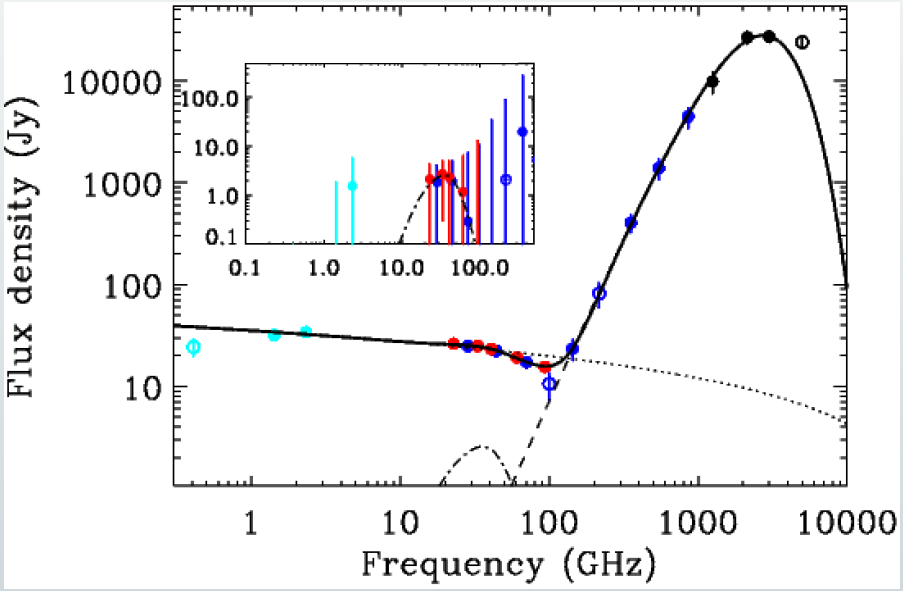


Example maps of new AME regions



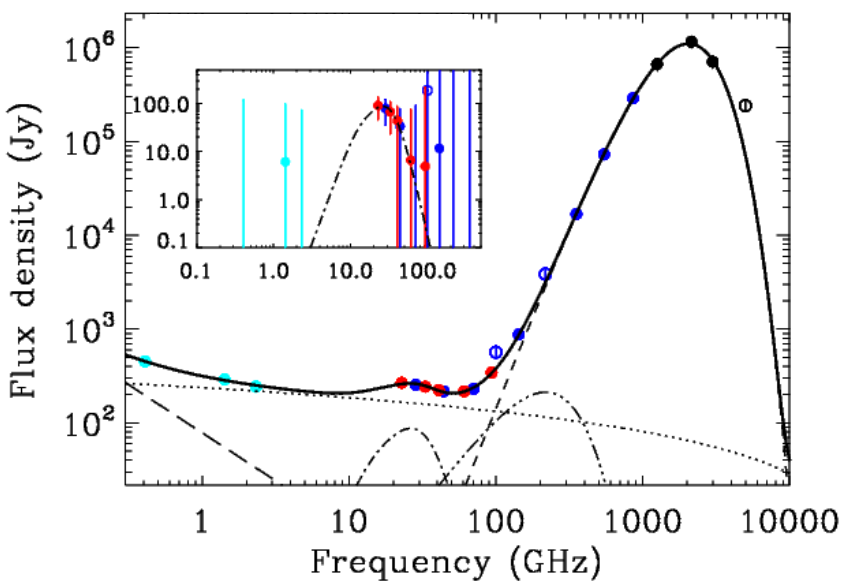
Example SEDs (1)

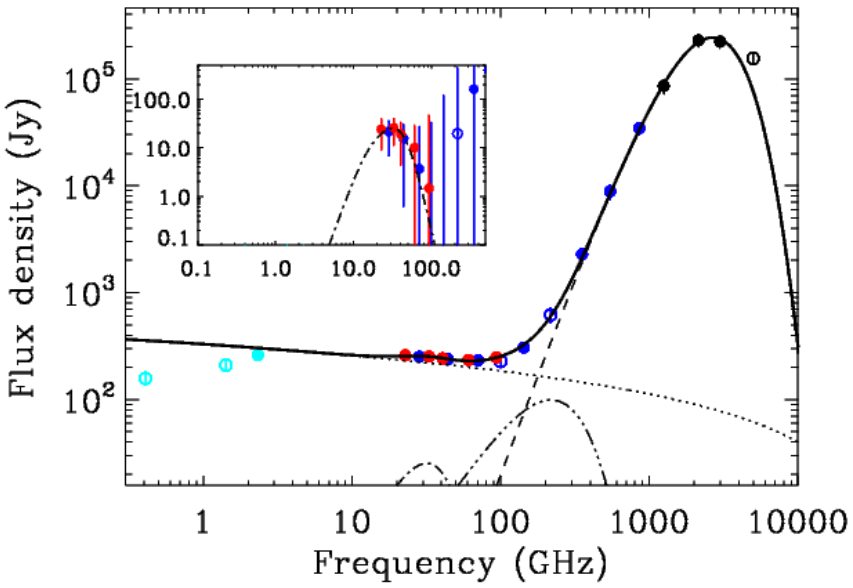




Most SEDs are a good fit to optically thin free-free, CMB fluctuation, single component thermal dust with possible small contribution from spinning dust

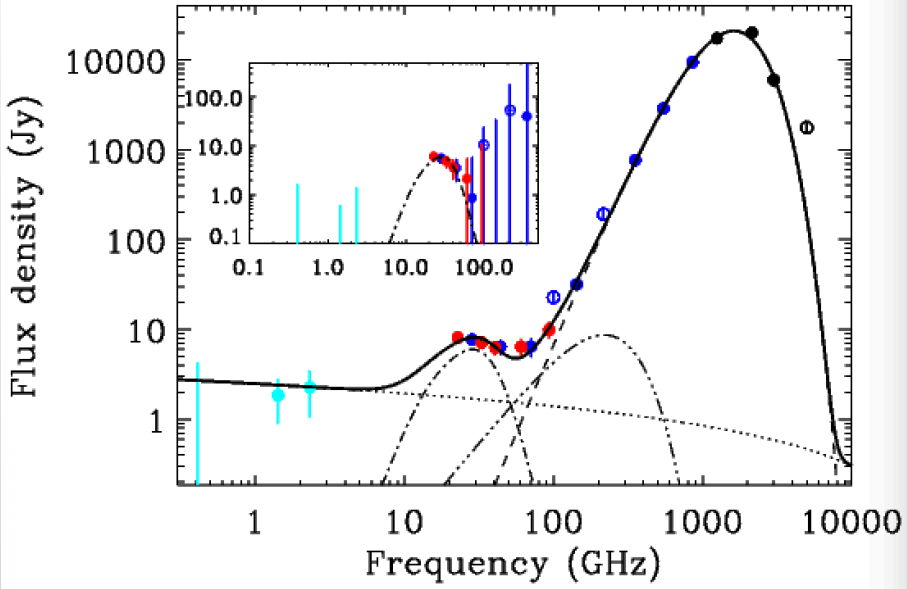
Example SEDs (2)

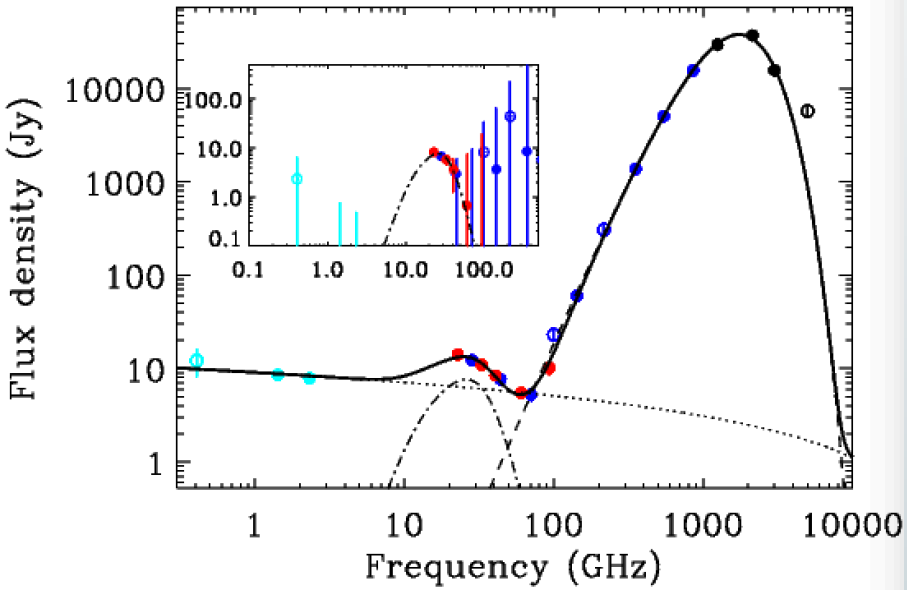




Synchrotron power-law needed for a few sources.
Low frequency data sometimes omitted (e.g. if optically thick)

Example SEDs (3)

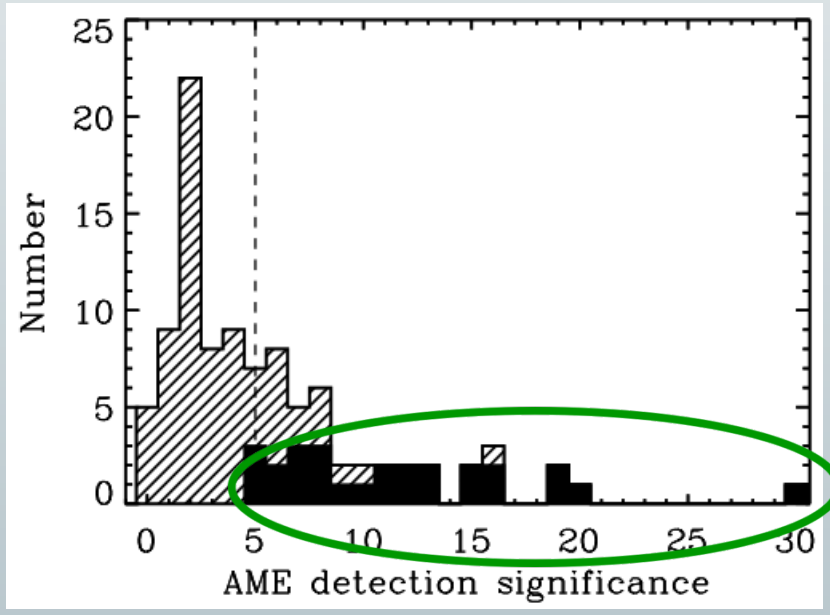


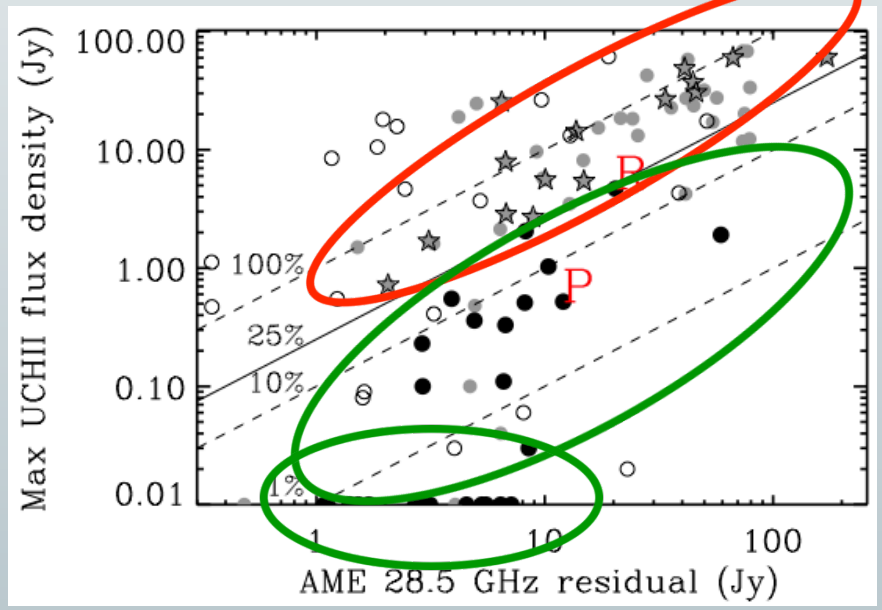


A significant number (~40) have a very strong “detection” of excess emission at ~20-60 GHz that is well-fitted by spinning dust

Significance

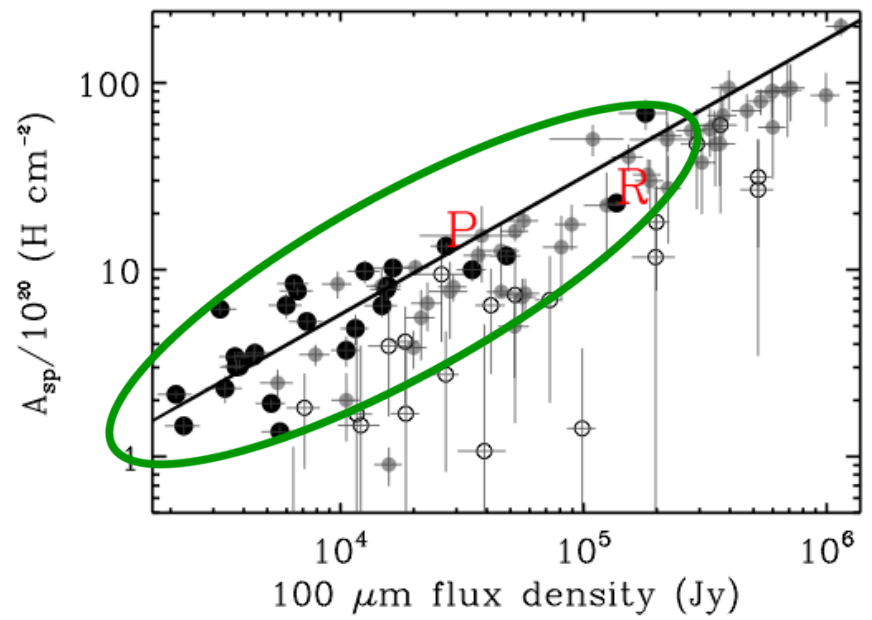
- Many sources show excess emission ~20-60 GHz
  - *~40 show high significance (>5σ)*
  - *~15 could be contaminated at >25% level by optically thick free-free emission from UCHII regions*
    - Strict upper limits of UCHII contamination estimated using IRAS PSC colours and radio/FIR ratios (Dickinson et al. 2012)

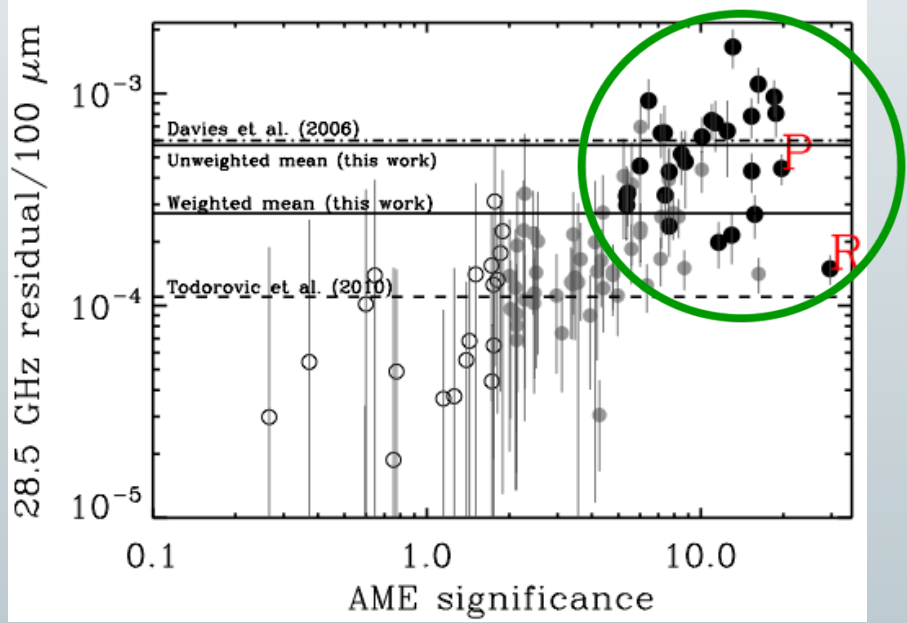




AME vs 100 micron

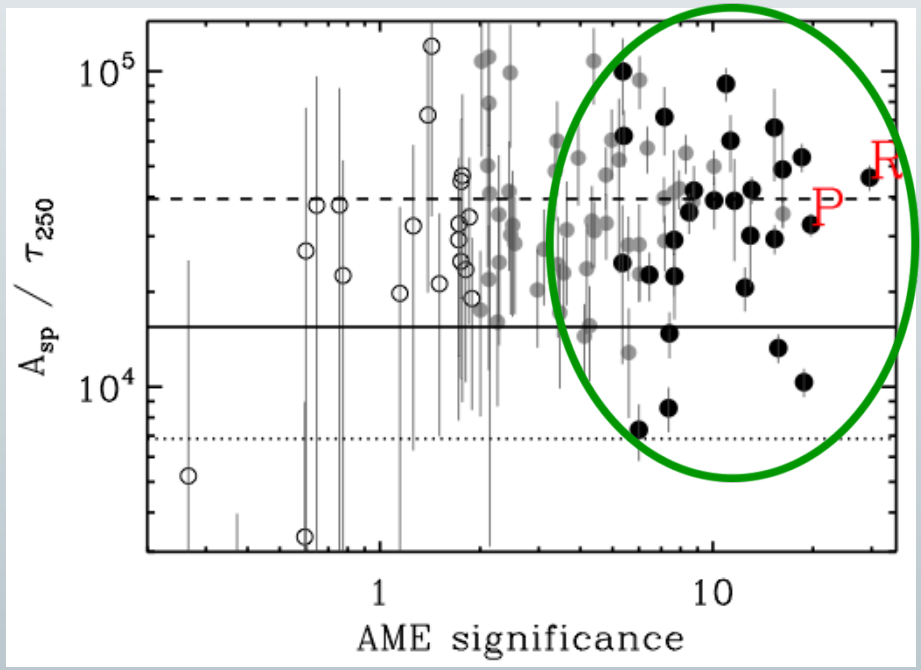
- Strong correlation with thermal dust
  - *AME sources show tight correlation with FIR*
  - *Emissivity has a large range but comparable to previous detections*
    - ~1 Jy @ 30 GHz for 3000 Jy @ 100 μm





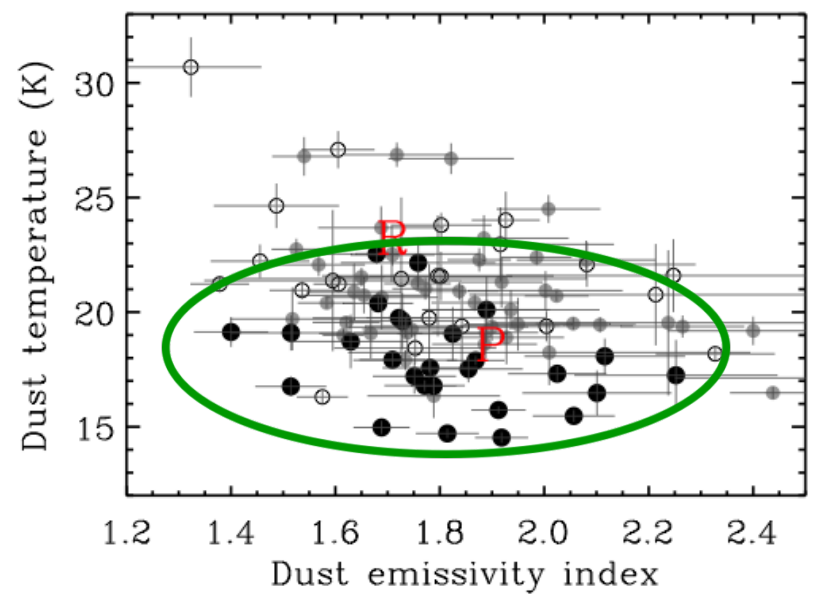
AME emissivity

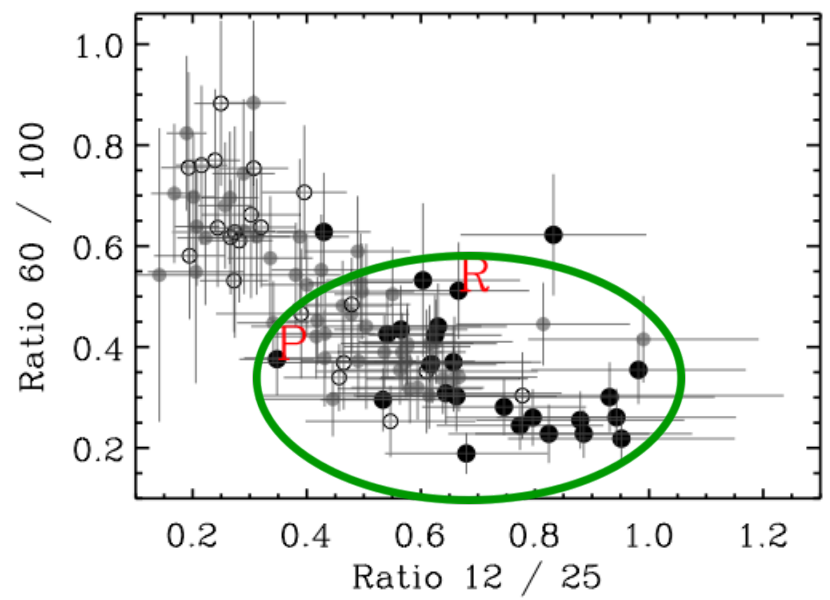
- Emissivity of spinning dust relative to 100 μm flux density is dependent on dust temperature
  - *Emissivity relative to dust optical depth is not!*
- Significant variation (factor of ~10)
  - *Many regions at the same level! (but large errors)*



Dust properties

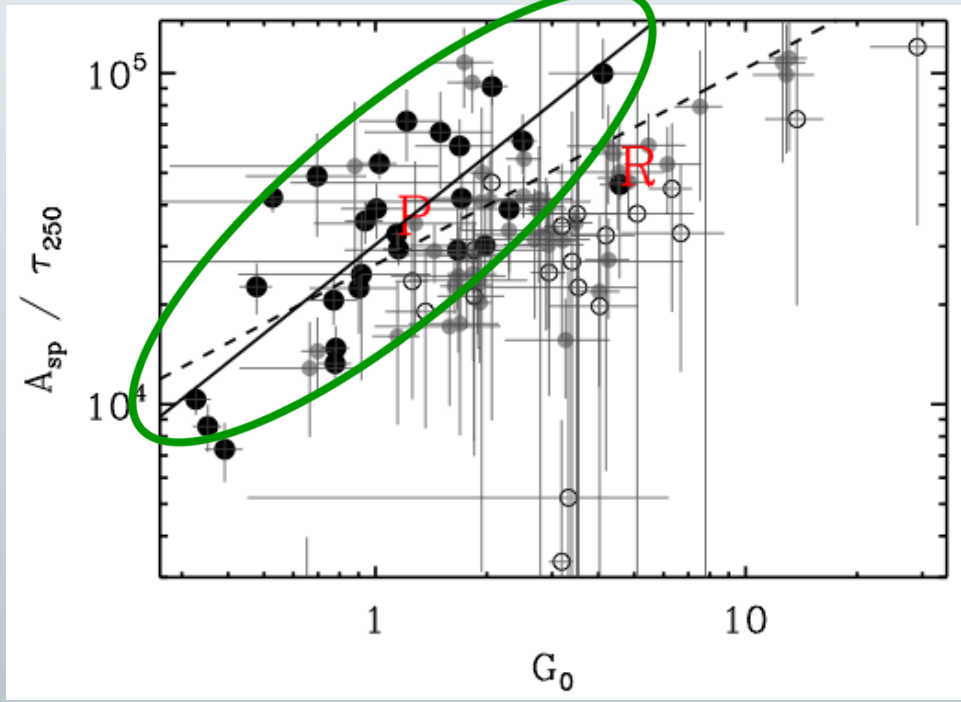
- Interesting trends found!
  - *AME sources tend to be cooler*
  - *Higher 12/25 ratios -> smaller grains more abundant*
- Caution: selection effects could be affecting these results!
  - *E.g. it is easier to detect cooler objects with less free-free emission*





ISRF

- Strength of interstellar radiation field (ISRF), G_0, seems to be important
  - *AME emissivity appears to be correlated with G_0*
    - Trend has been seen in other studies (e.g. Tibbs et al. 2011)
  - *Can be explained within spinning dust model*



Conclusions

- Planck early paper
  - *Definitive evidence for spinning dust*
- Planck Intermediate paper:
  - *New sample of clouds: ~40 show >5σ excess @ ~20-60 GHz*
  - *UCHII contribution could be important for ~15 of these*
  - *Spinning dust generally fits well with a wide range of emissivities*
  - *Some interesting trends observed e.g. T_{dust}, G_0*
- High-resolution multi-frequency follow-up observations needed! (e.g. AMI, SZA/CARMA)
- Watch out for the published paper coming soon!