Planck intermediate results: Diffuse Galactic components in the Gould Belt system

Planck Collaboration

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Planck intermediate results. XII: Diffuse Galactic components in the Gould Belt System

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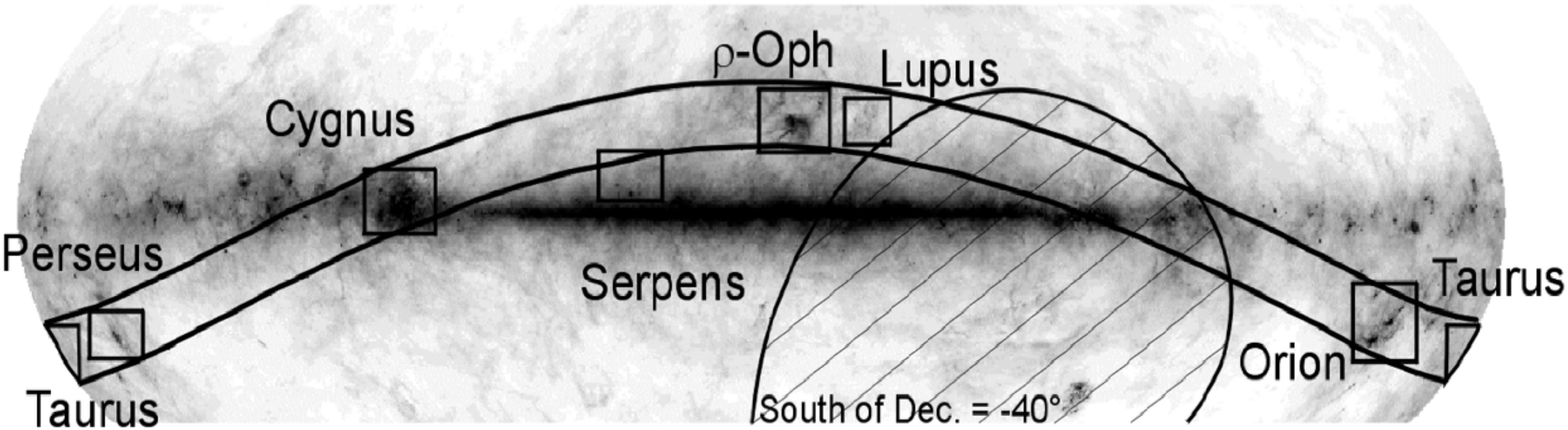
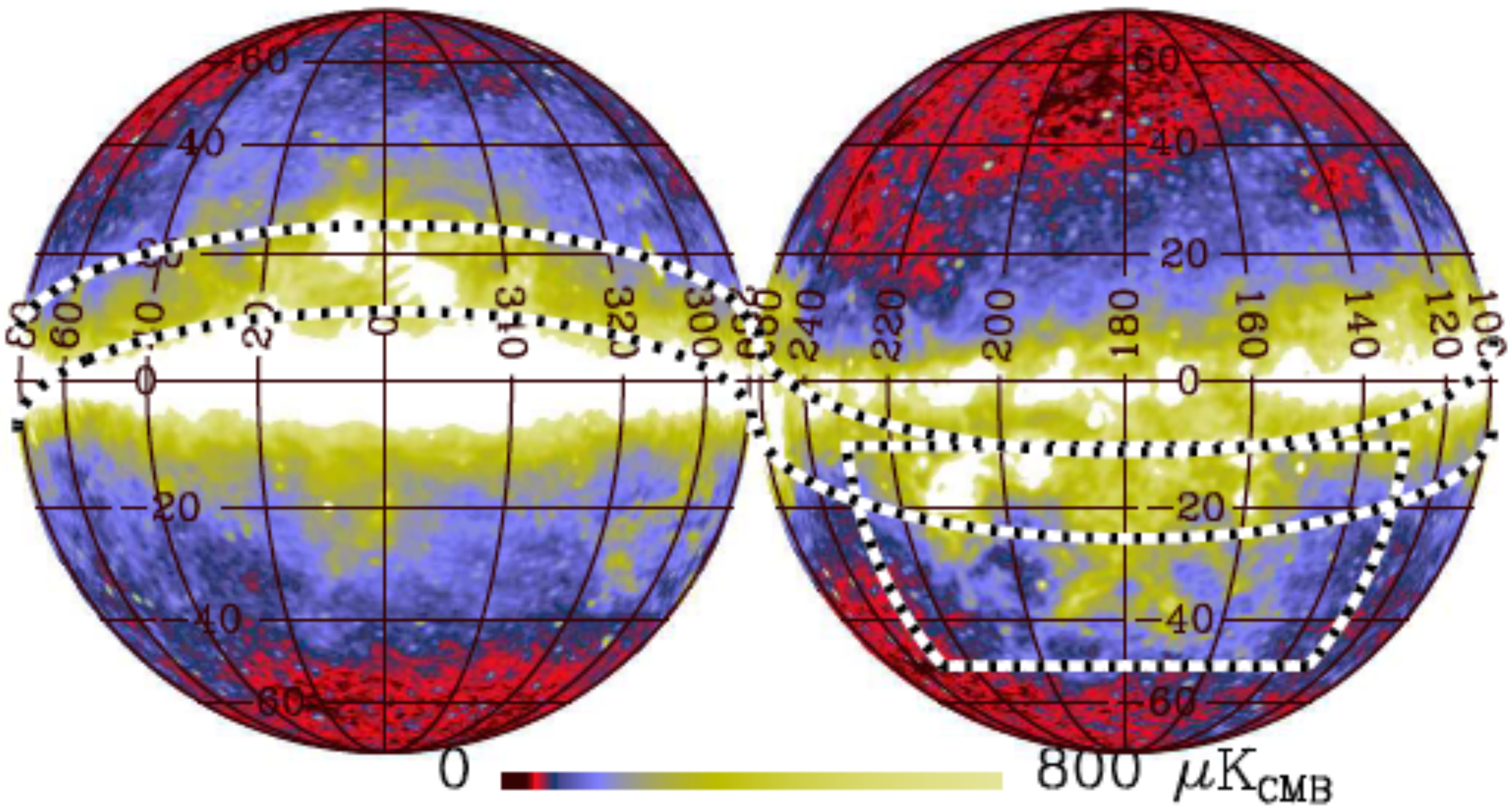
Scientific objectives

- Separation of diffuse synchrotron, free-free, thermal dust and AME
  - Why it is important
    - Understand the origin and physics of the AME
    - Good cleaning of the CMB signal
    - Good recovery of the other Galactic components
  - Why it is difficult
    - Many components in the same frequency range
    - Similar frequency spectrum (in 20-60 GHz range)
- Diffuse AME:
  - Frequency spectrum: peak frequency and slope
  - Is it spinning dust? Comparison with spinning-dust models
- Diffuse free-free:
  - Electron temperature by comparing with Hα

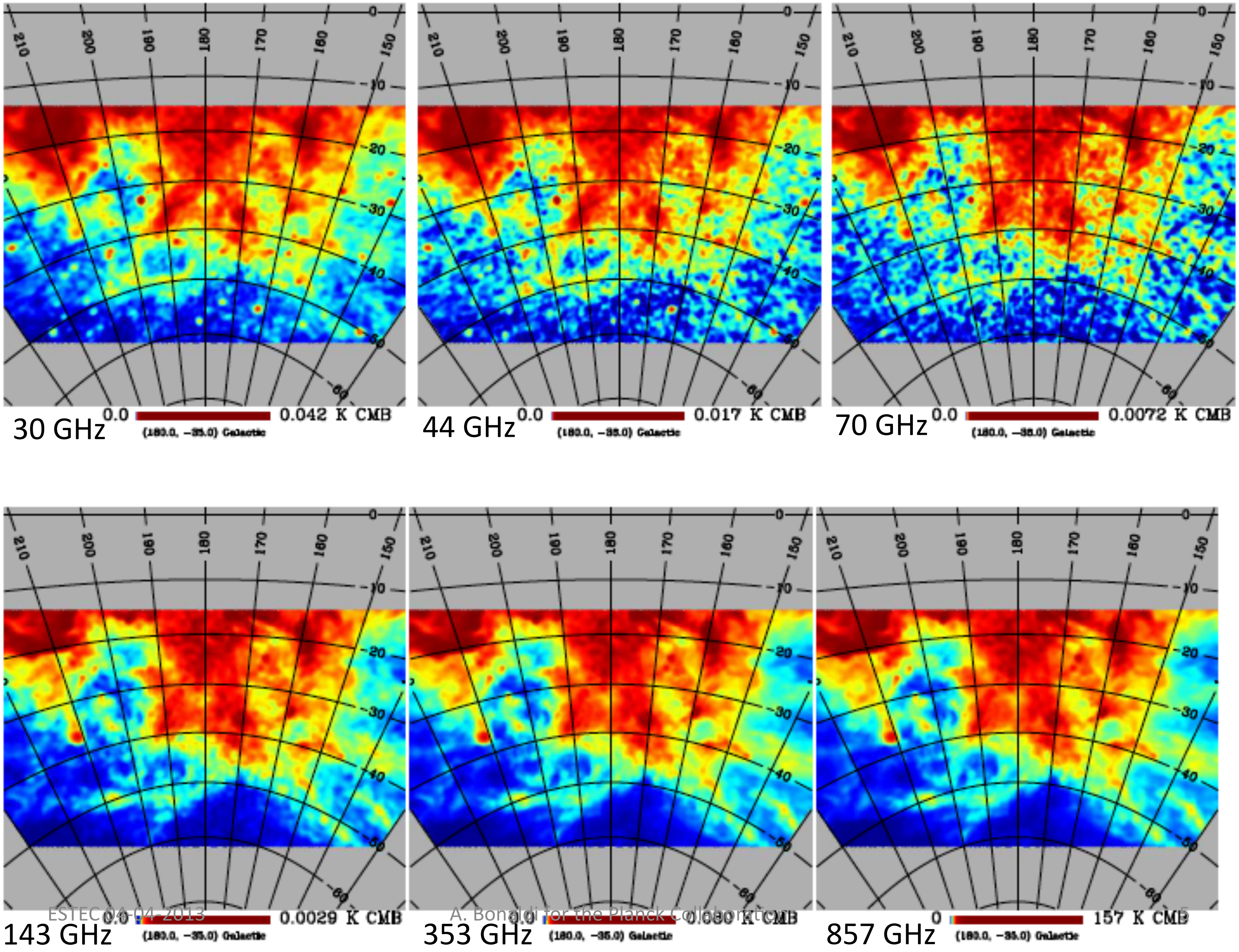
Gould Belt



ρ-Oph
Lupus
Cygnus
Perseus
Serpens
Taurus
Taurus
Orion
South of Dec. = -40°



We consider the Gould Belt South, l=130°-230°, b=-10°-50°
Fainter Galactic Plane -> cleaner view of the Gould Belt

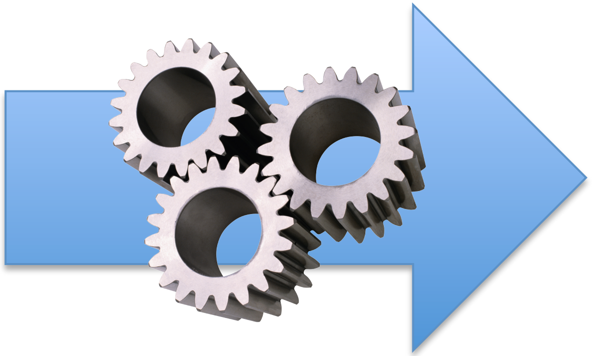

30 GHz
0.0
0.042 K CMB
(180.0, −35.0) Galactic
44 GHz
0.0
0.017 K CMB
(180.0, −35.0) Galactic
70 GHz
0.0
0.0072 K CMB
(180.0, −35.0) Galactic
143 GHz
0.0029 K CMB
(180.0, −35.0) Galactic
353 GHz
(180.0, −35.0) Galactic
857 GHz
0
157 K CMB
(180.0, −35.0) Galactic

AME frequency spectrum

- Method: Correlated Component Analysis (CCA)
  Bonaldi et al. (2006), Ricciardi et al. (2010)
- Use 2nd order statistics of data to estimate parameterised spectra of the components
- Model:
  - AME: parameterised in terms of peak frequency and slope at 60 GHz (Bonaldi et al. 2007)
  - CMB (blackbody), synchrotron (βs=-2.9), thermal dust (Td=18 K, βd), free-free (Te=7000 K)

Component separation

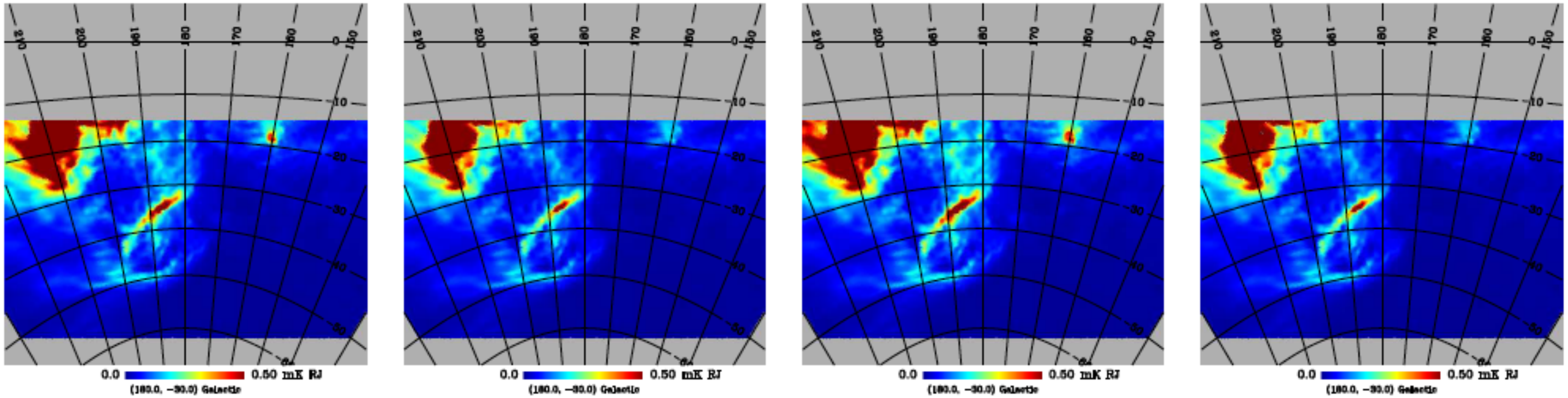
- Planck
  - 30 GHz
  - 44 GHz
  - 70 GHz
  - 143 GHz
  - 353 GHz
- WMAP K band (23 GHz)
- Haslam 408 MHz map
- 23 GHz free-free template



- CMB
- Synchrotron
- Free-free
- Thermal dust
- AME

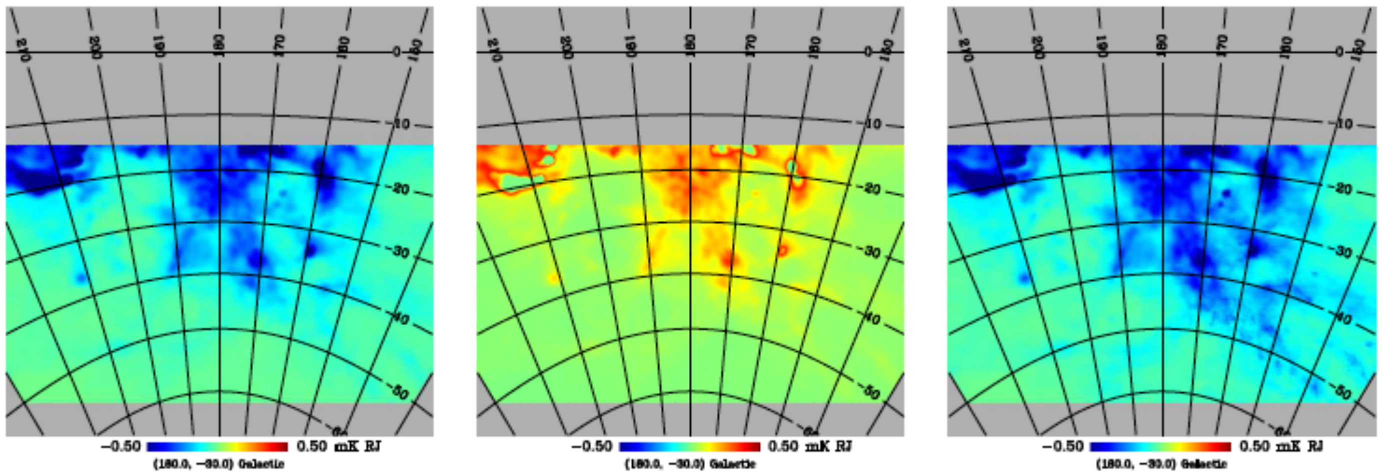
Free-free templates

Reference FF1 FF2 FF3

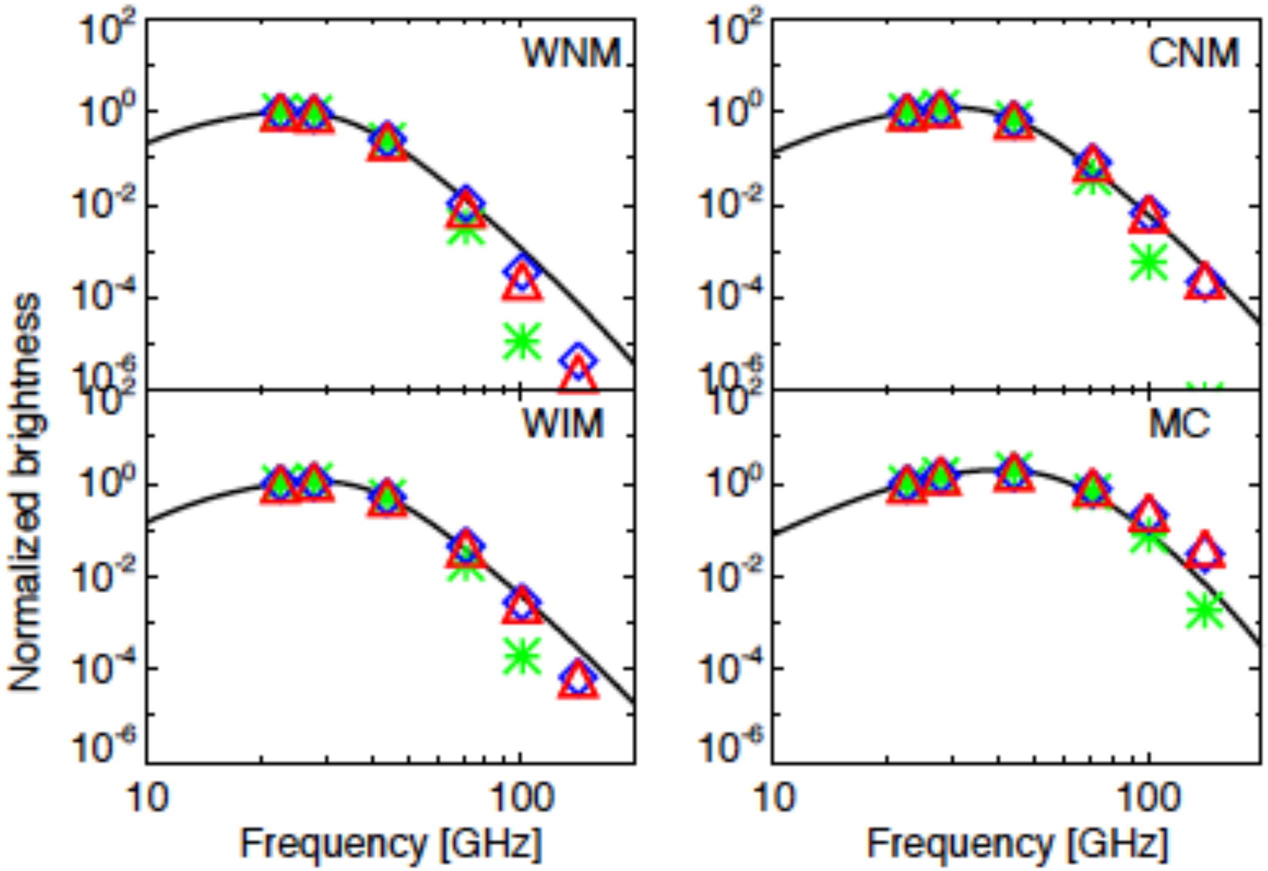


(FF#-Ref)/Ref

up to 60%,
dust-correlated



Parametric spectral models for AME

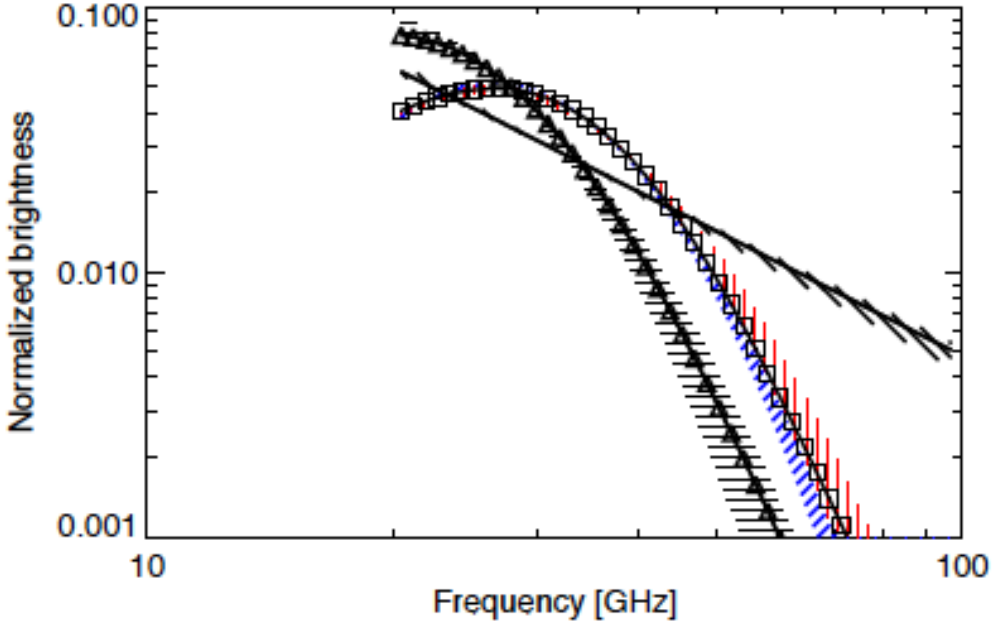


CCA
Commander
Tegmark et al. (2000)

$$\log T_{\mathrm{RJ,AME}}(\nu) \propto \left(\frac{m_{60} \log \nu_p}{\log(\nu_p/60)} + 2 \right) \log \nu + \frac{m_{60} (\log \nu)^2}{2 \log(\nu_p/60)}.$$

Simulated dataset

- CMB realization for WMAP7 best-fit model
- Synchrotron template: Haslam et al. (1982); spectrum: power law, Giardino et al. (2002) spectral indices
- Dust template: Schlegel et al. (1998) 100μm, spectrum: grey-body Td=18, <βd>=1.8 spatially-varying
- Free-free template: Dickinson et al. (2003) (fd=0.33); spectrum: Te=7000 K
- AME template: Schlegel et al. (1998) E(B-V); normalization: Ghosh et al. (2012); spectrum: Spdust
- Instrument noise: Gaussian spatially-varying; beams: Gaussian nominal; bandpasses: monochromatic

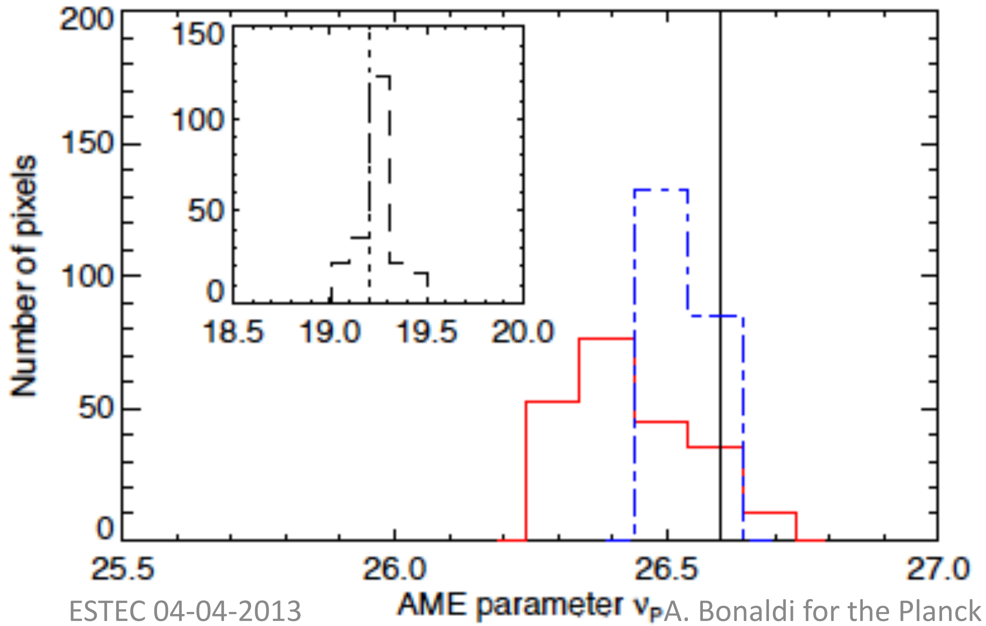


SIMULATIONS

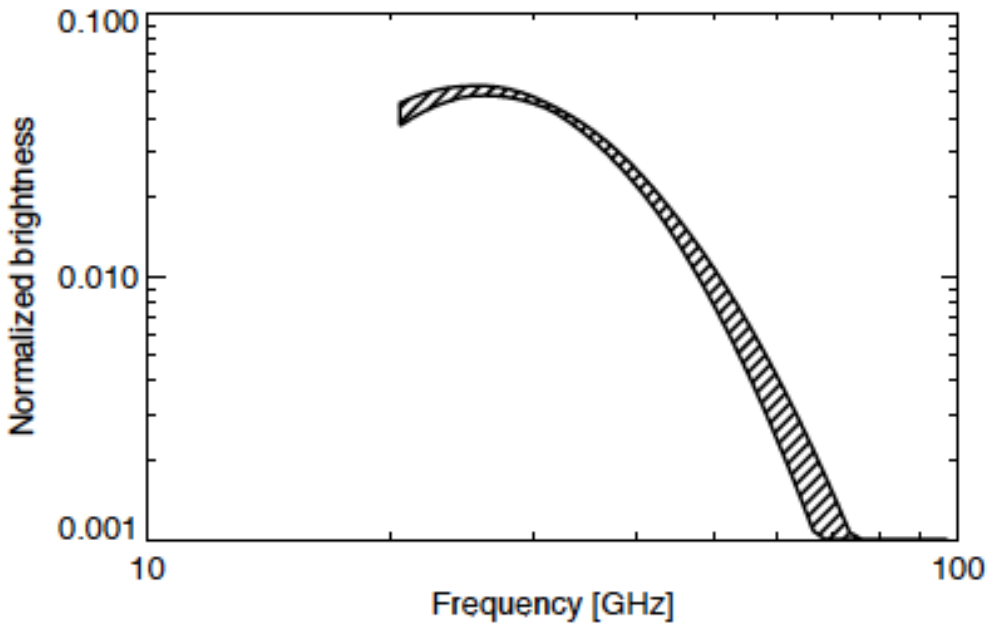
“True” free-free= Ref

use for the estimation:

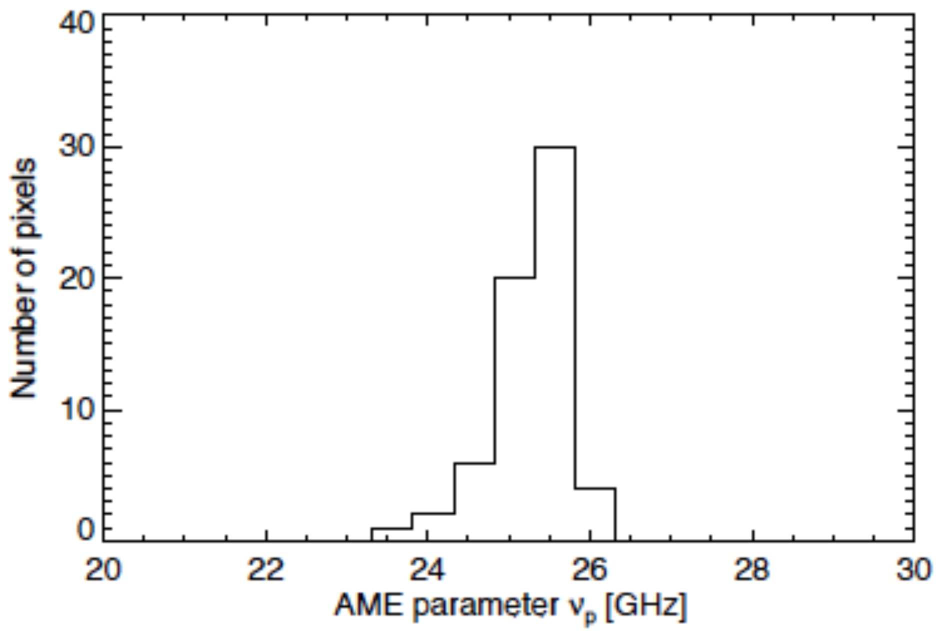
FF1 FF2



- CCA does a good job!
- Errors of few GHz on peak frequency ν_p
- Possible biases on AME high-frequency slope m_{60}

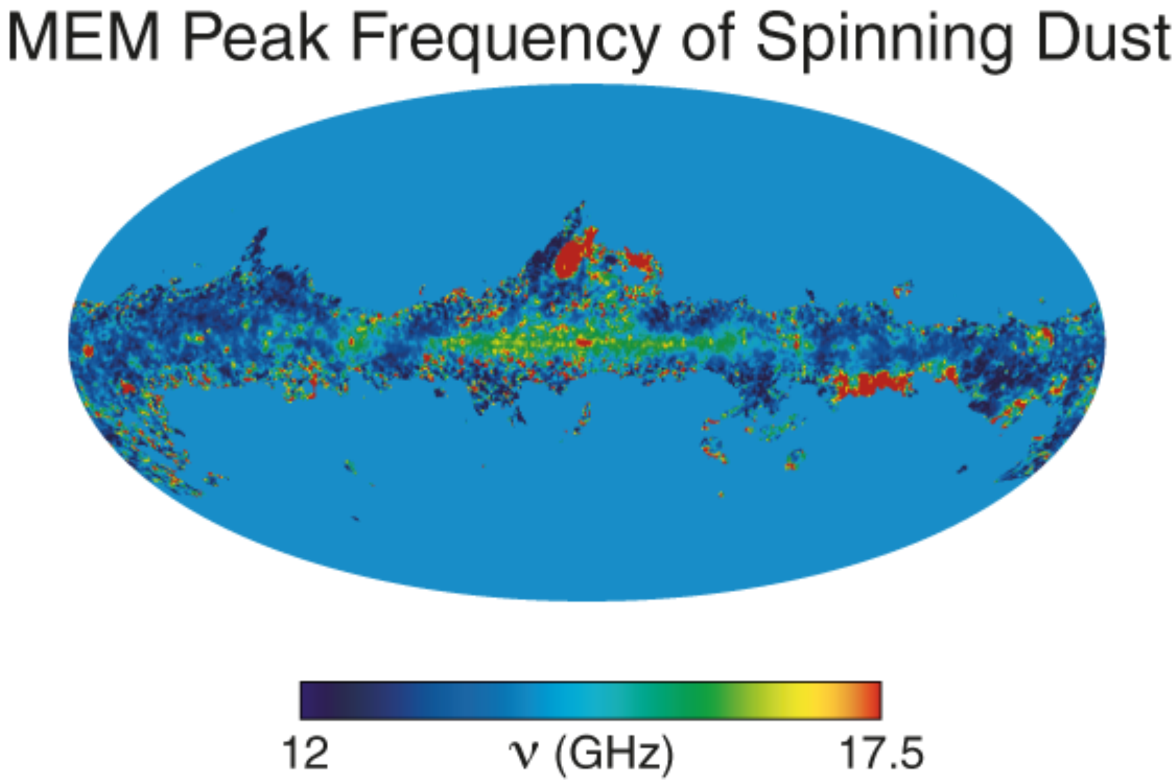


DATA



Peak ~ 25.5 GHz
mild spatial variations compatible with errors

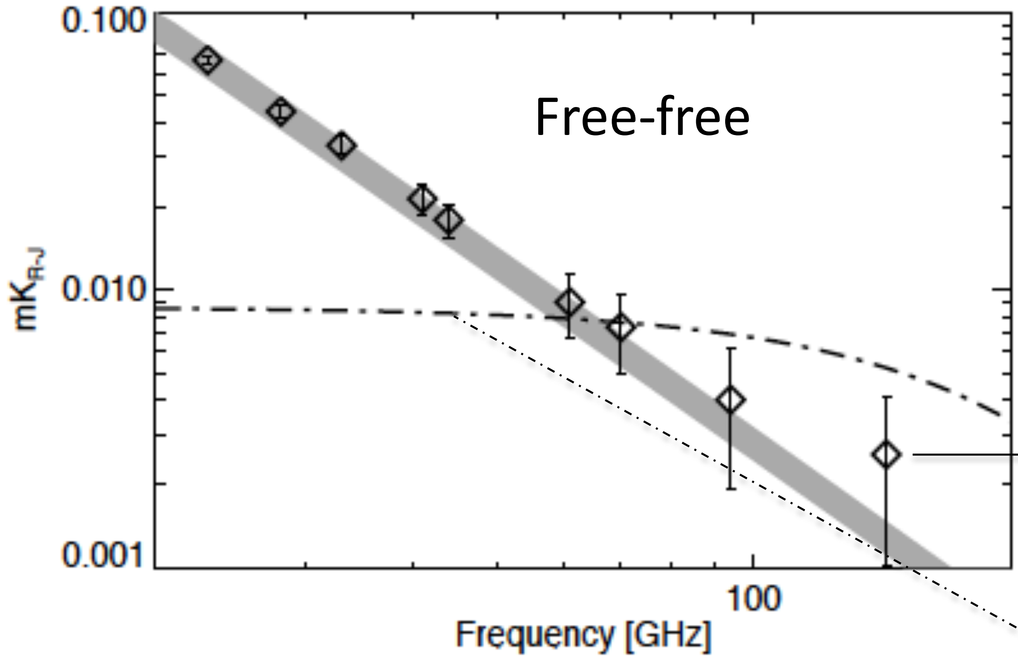
Bennett et al. 2013 WMAP 9-Yr paper

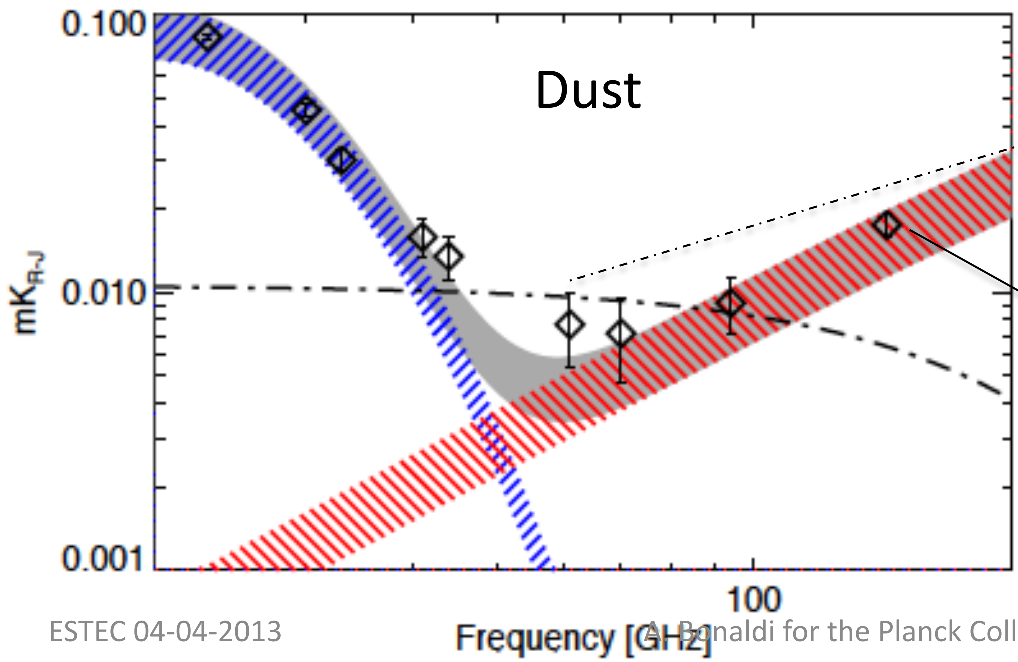


Flux vs K-RJ units!

ν^2 factor brings peak freq 15 -> 30 GHz

Comparison with standard CC analysis





Correlation with Hα template

Template-CMB chance correlation

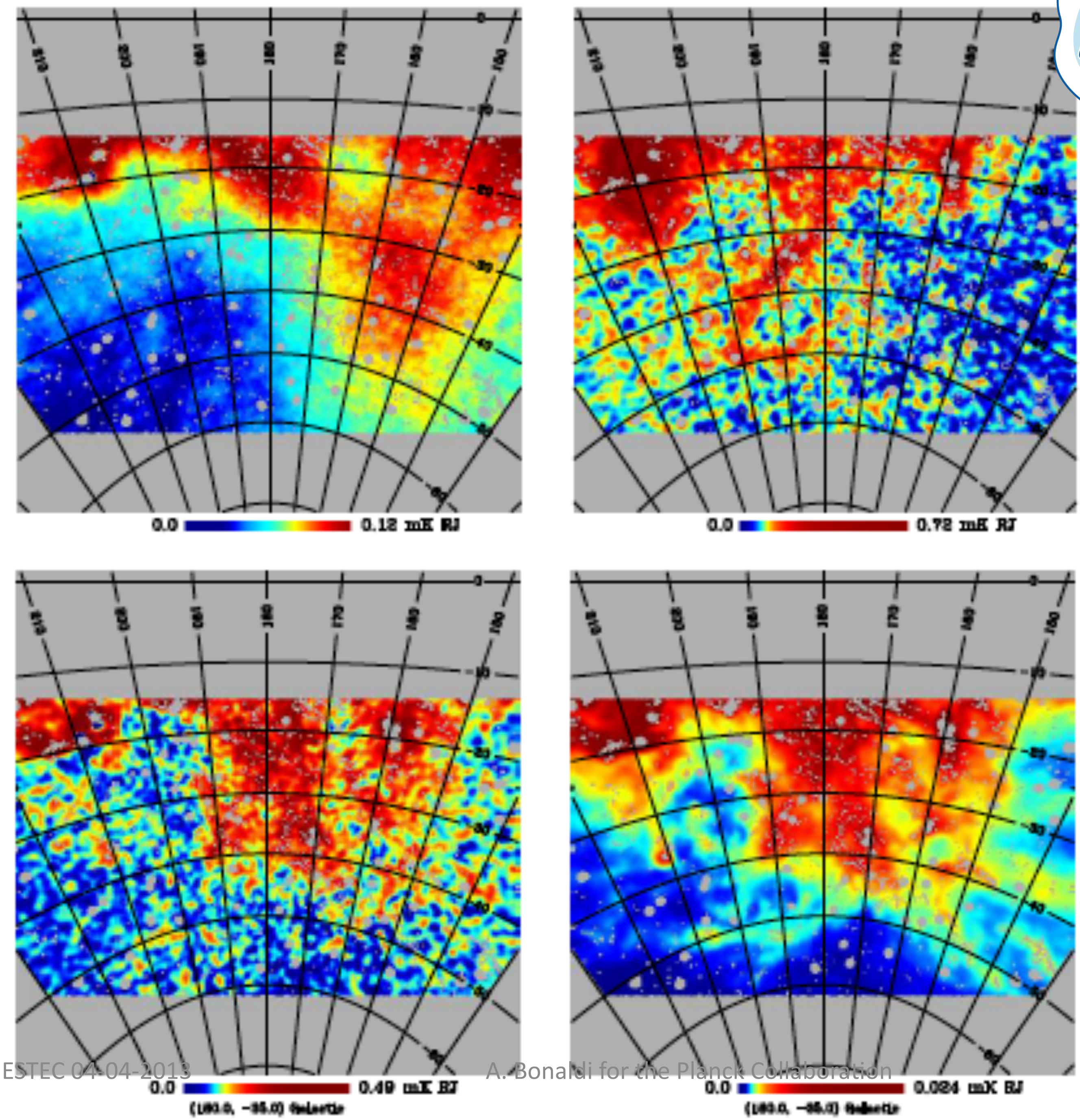
Correlation with FDS98 dust template

Reconstruction of amplitudes

- Generalised Least Square (GLS) solution
- We combine equalized-resolution (1deg) data
  - WMAP K band (23 GHz)
  - Planck 30, 44 70, 143, 353 GHz
  - Haslam 408 MHz map
  - ~~23 GHz free-free template~~

Synchrotron

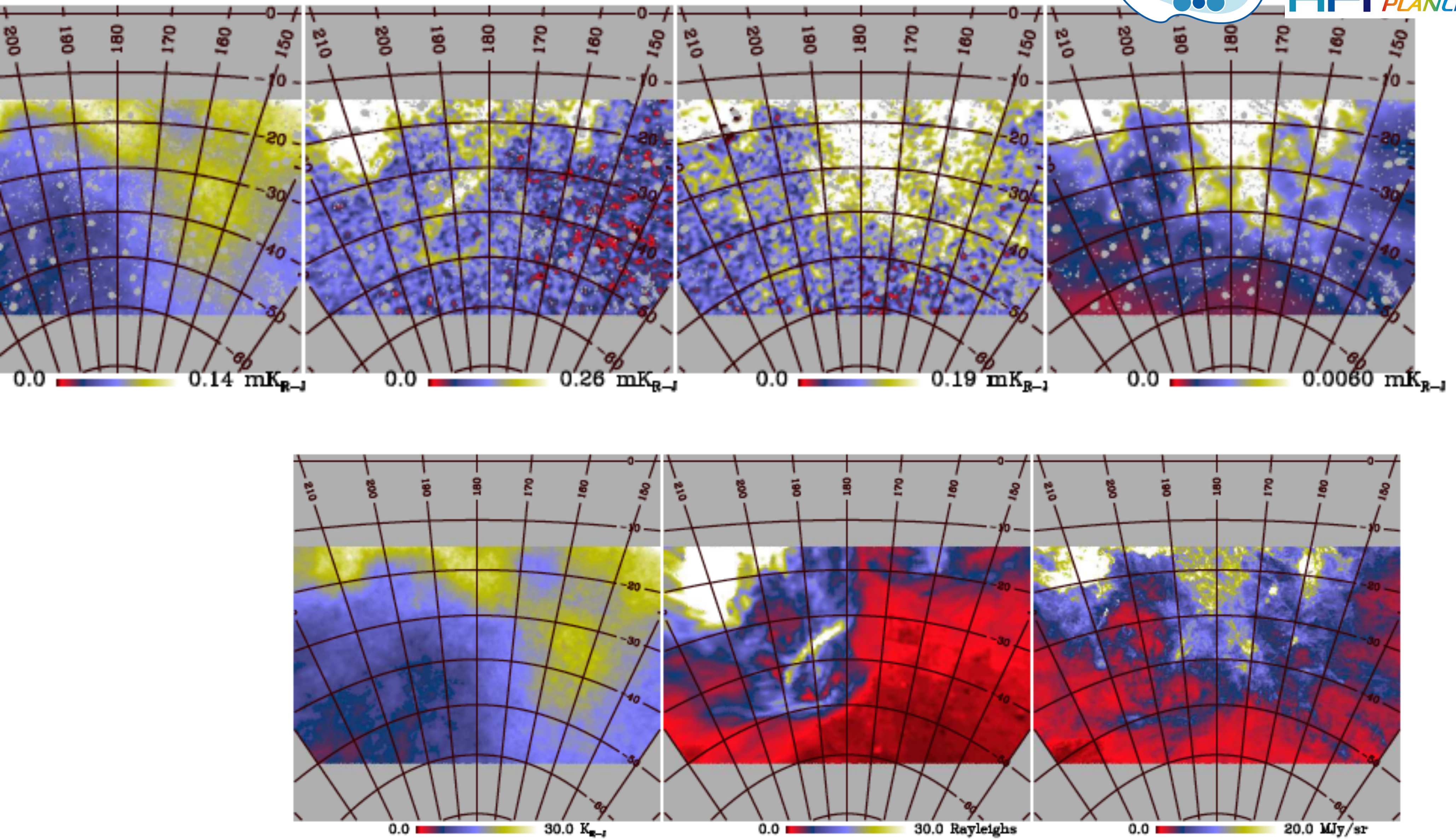
Free-free



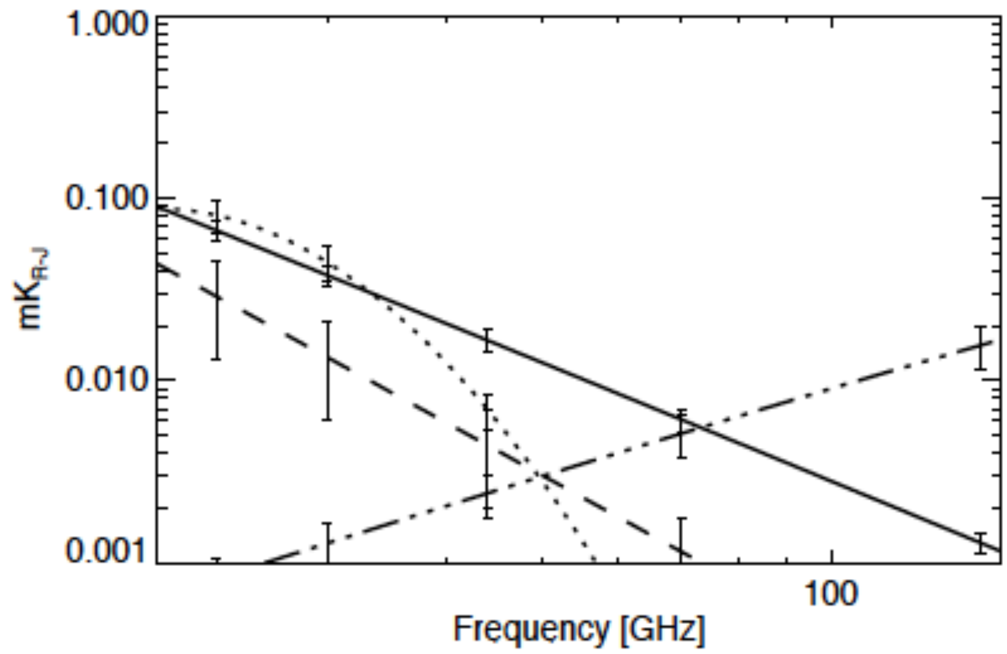
AME

Thermal dust

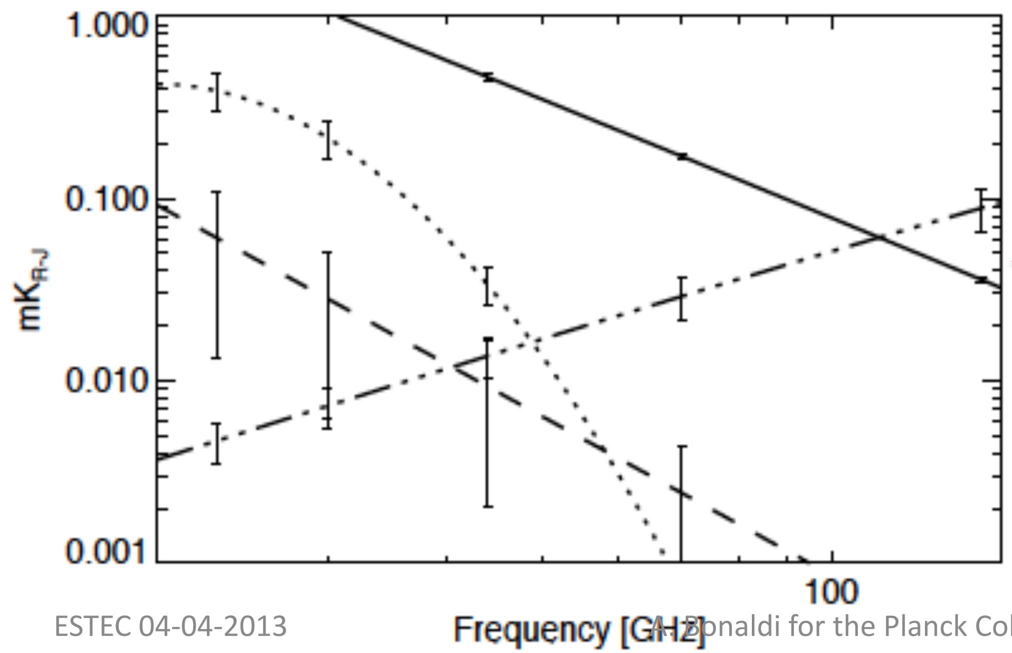
free-free AME thermal dust

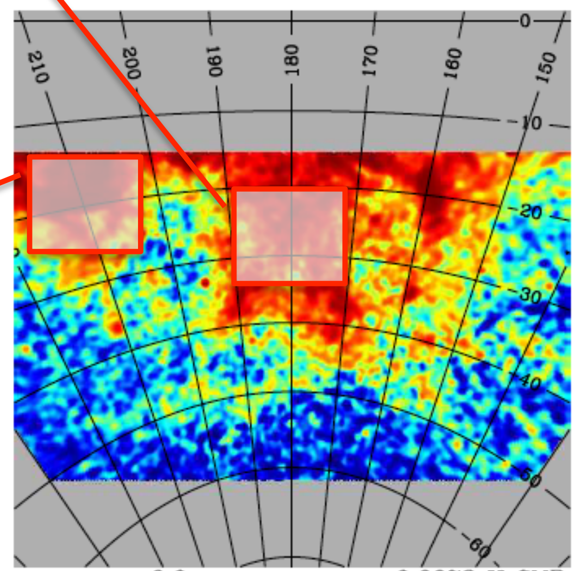


408 MHz Hα 100 μm

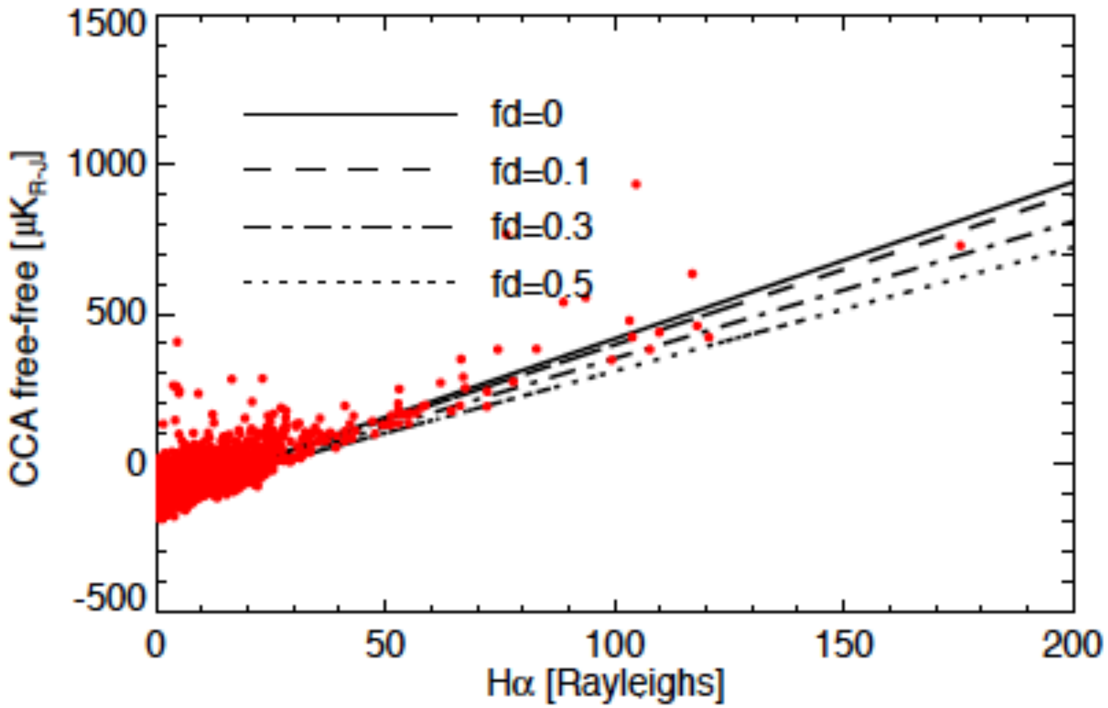


Synchrotron
Free-free
Thermal dust
AME





$$\frac{T_{ff}(\nu)[\mu K\,RJ]}{H_\alpha[\text{Rayleighs}]} = 14.0\,T_4^{0.517}\cdot 10^{0.029/T_4}\cdot 1.08\,F(\nu)$$



Te=T4 * 10^4 K ;

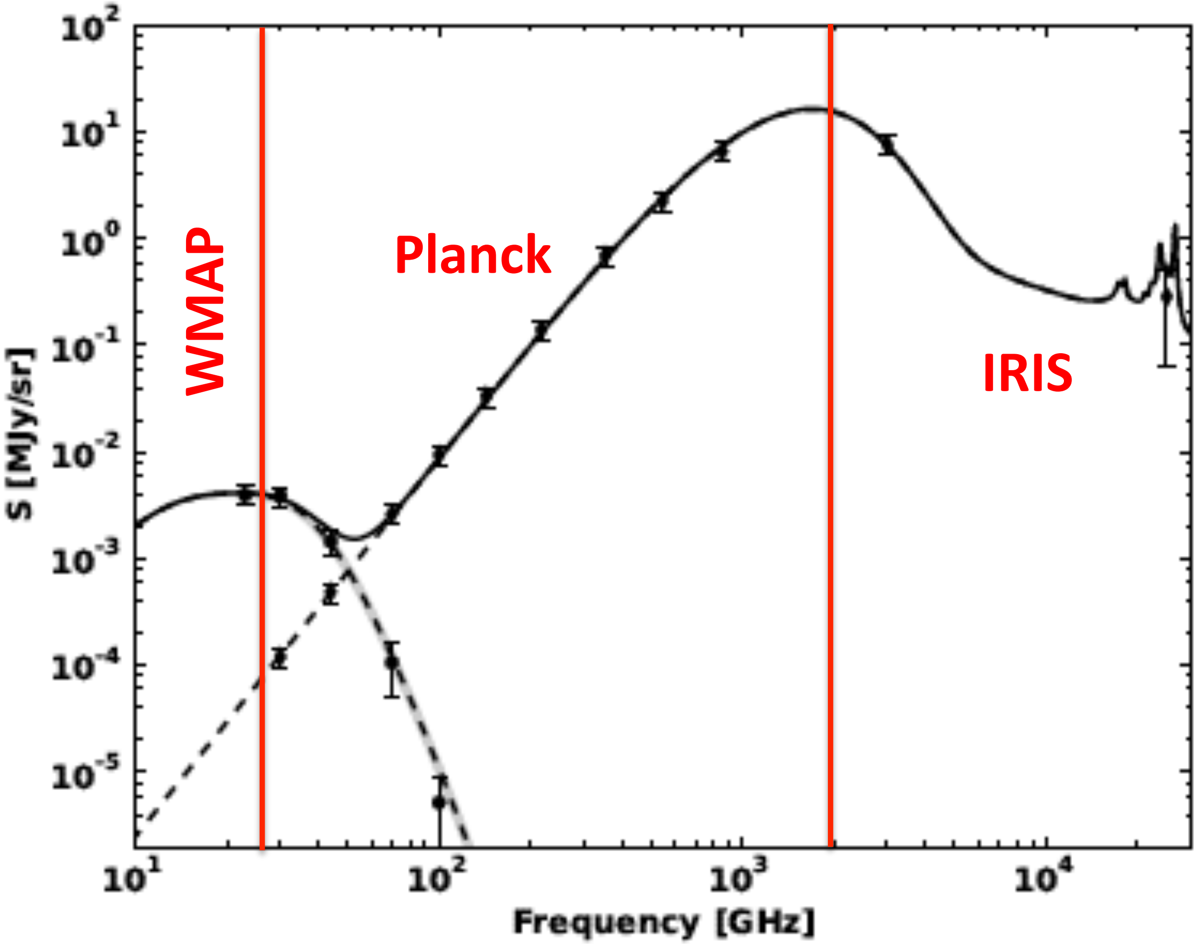
fd = dust absorp. fraction

Dickinson et al. 2003 free-free: Te=4700 ± 2200 for fd=0.3

Finkbeiner 2003 free-free: Te=5500 ± 2400 for fd=0.3

Consistent results with cross-correlation of freq. maps with templates

AME as spinning dust



- Radiation field G_0
- Column density N_H
- Density n_H

Ysard et al. (2011): SpDust + DustEM

Conclusions

- Separation of diffuse foregrounds in the Gould Belt South with *Planck* + ancillary data
  – Synchrotron
  – Free-free
  – Thermal dust
  – AME
- Significant diffuse AME:
  – Convex spectrum peaking ~25 GHz
  – Can be modelled well as spinning dust
- Significant free-free emission:
  – Electron temperature from TT plot and cross-correlation $T_e \approx 5000$ K for fd=0.3

The scientific results that we present today are the product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada

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