# A Practical Description of Spinning Dust Emission

Matthew Stevenson

# Outline

- Some Observations (quickly!)
  - C-BASS at the NCP.
  - Planck Cold Clumps with CARMA.
- A Practical Description of Spinning Dust.

# Collaborators

## C-BASS

Dayton Jones, Oliver King, Charles Lawrence, Stephen Muchovej, Tim Pearson, and Matthew Stevenson.

Charles Copley, Christian Holler, Jaya John John, Mike Jones, Jamie Leech, Angela Taylor, and Joe Zuntz

Roy Booth and Justin Jonas.

Rod Davies, Richard Davis, Clive Dickinson, Melis Irfan, and Patrick Leahy.

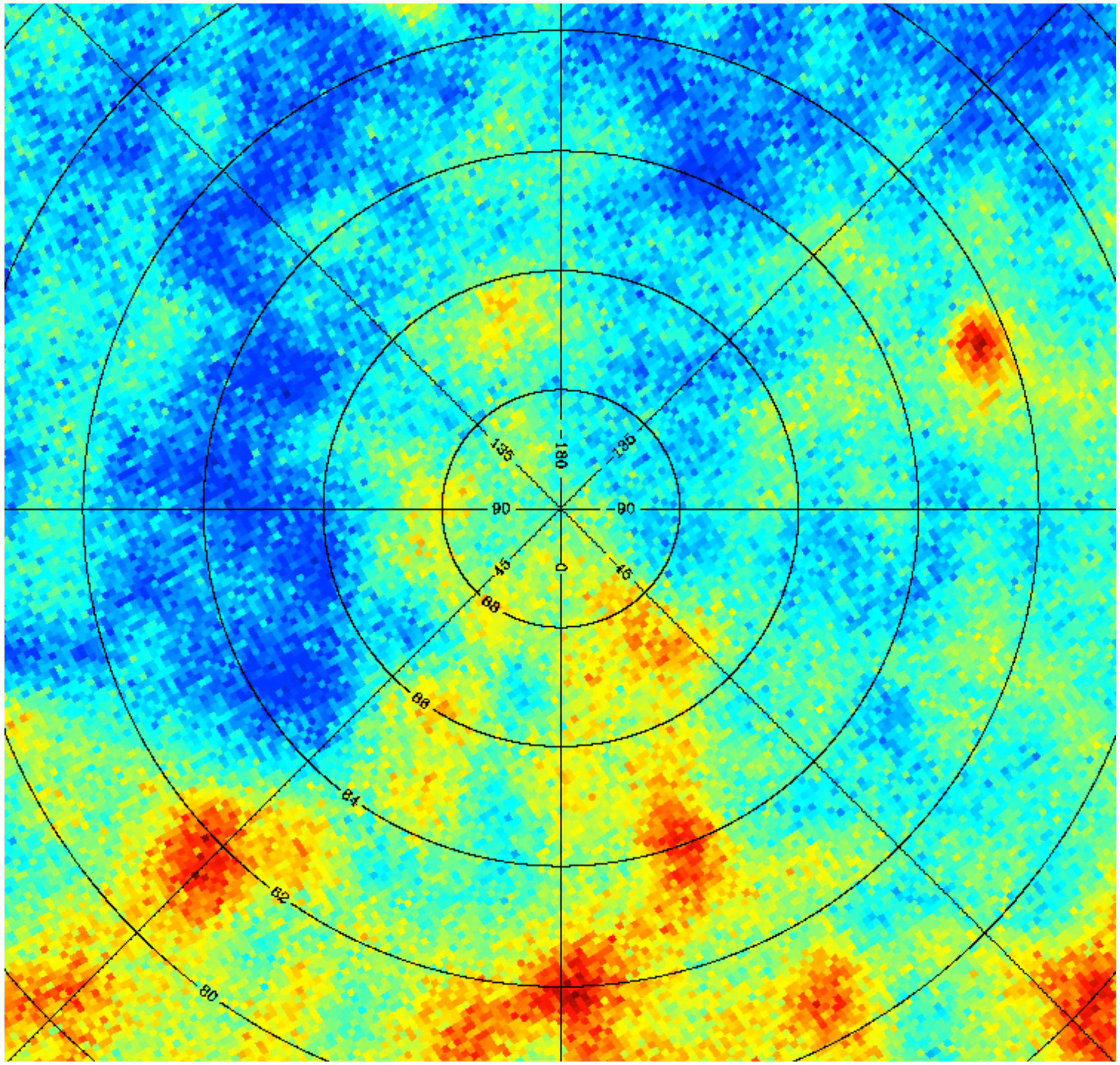
Yaser Hafez

## Other

Kieran Cleary
Chris Hirata
Roberta Paladini
Chris Tibbs
Jackie Villadsen

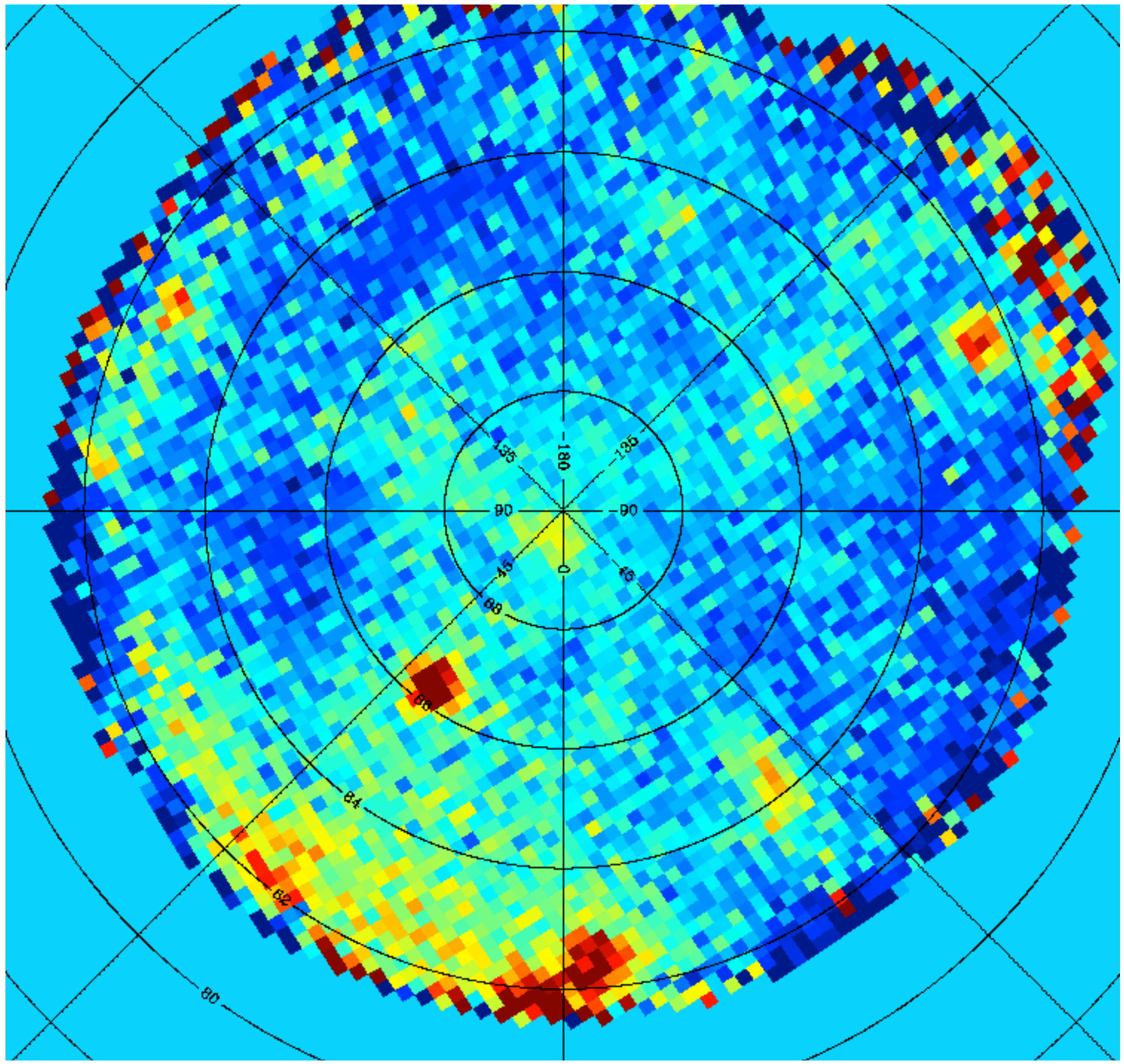
# C-BASS at the NCP

# Diffuse Emission at the NCP



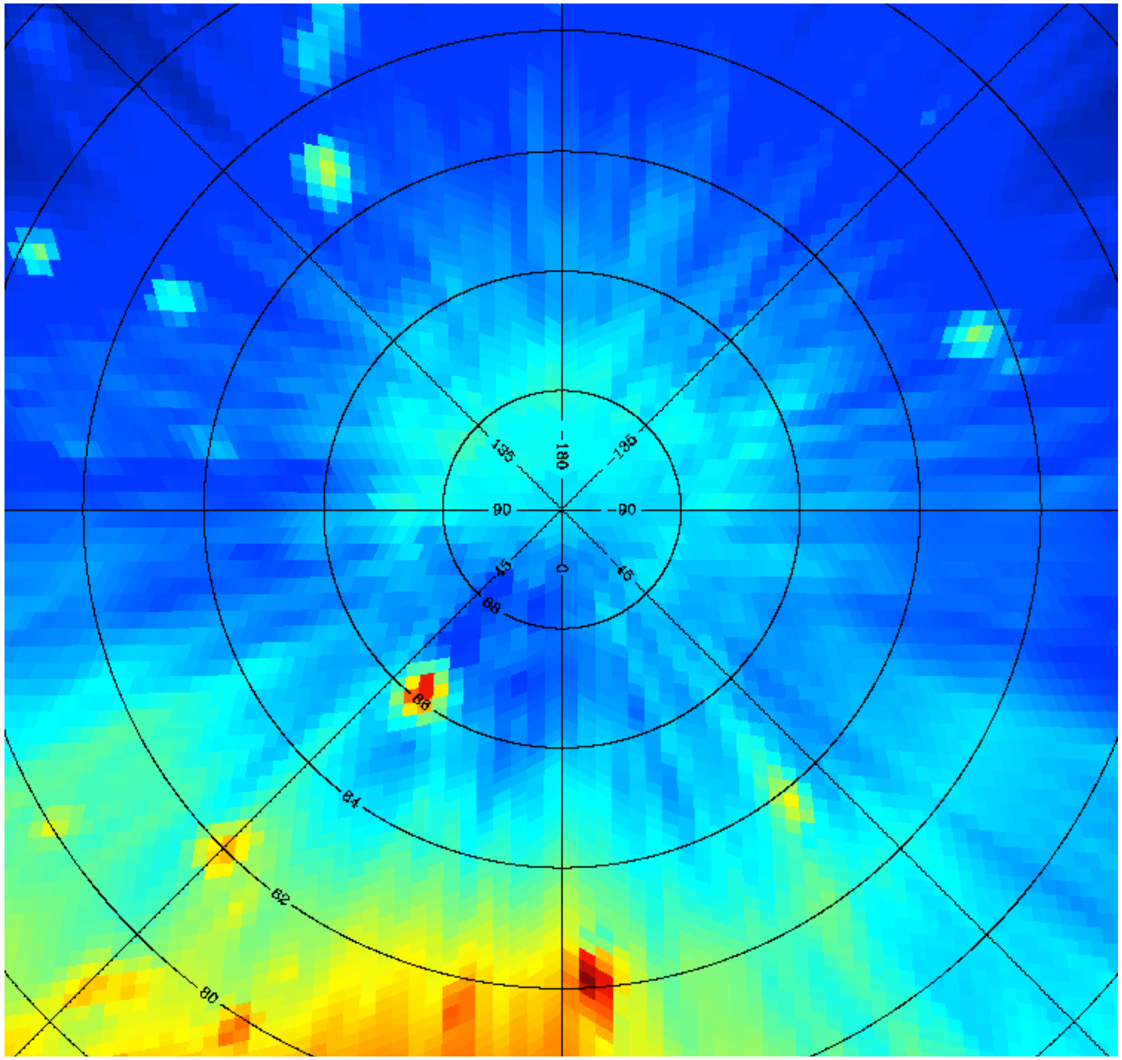

WMAP 23GHz (Jarosik et al. 2011)

# Diffuse Emission at the NCP



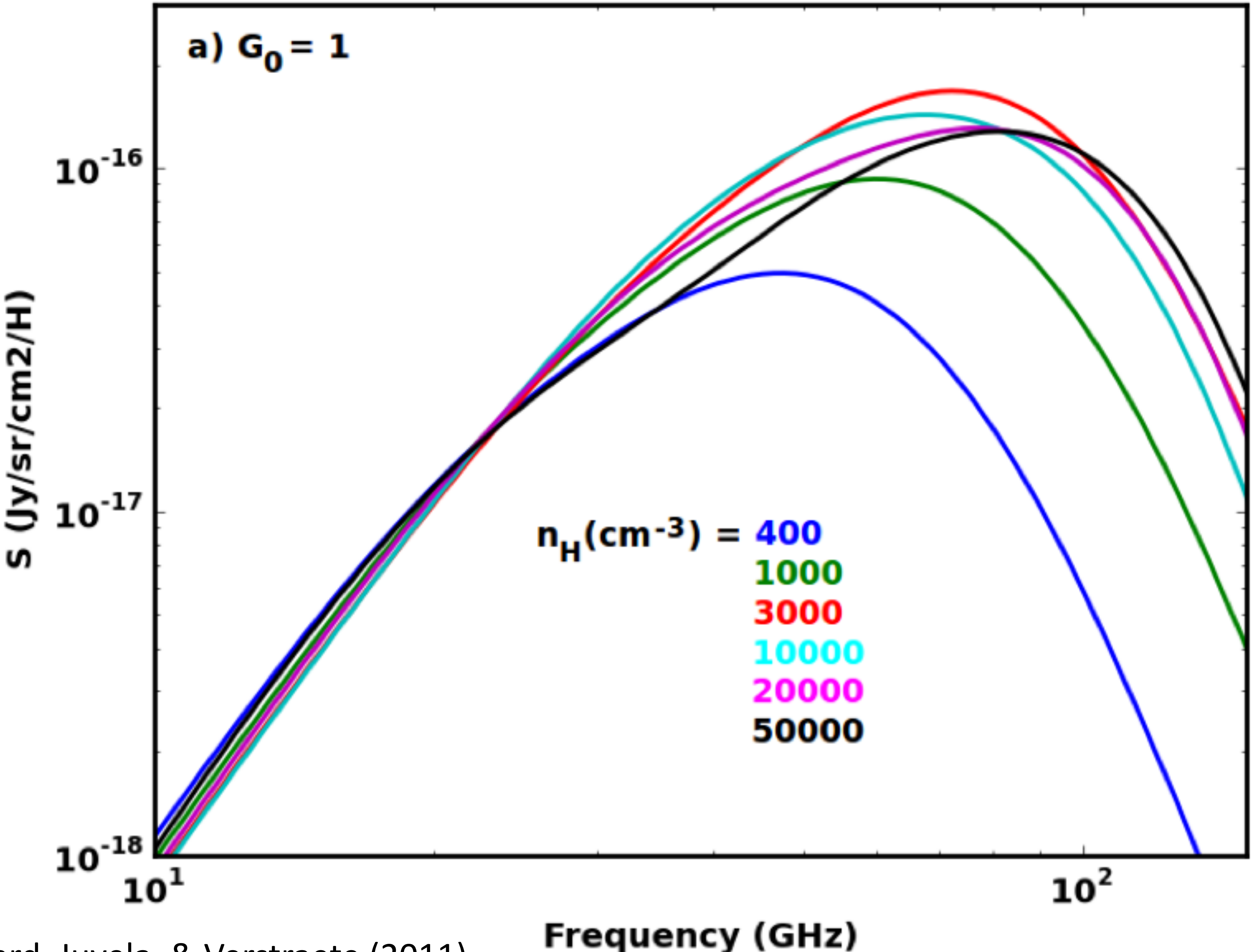

C-BASS 5GHz (3 months)

# Diffuse Emission at the NCP

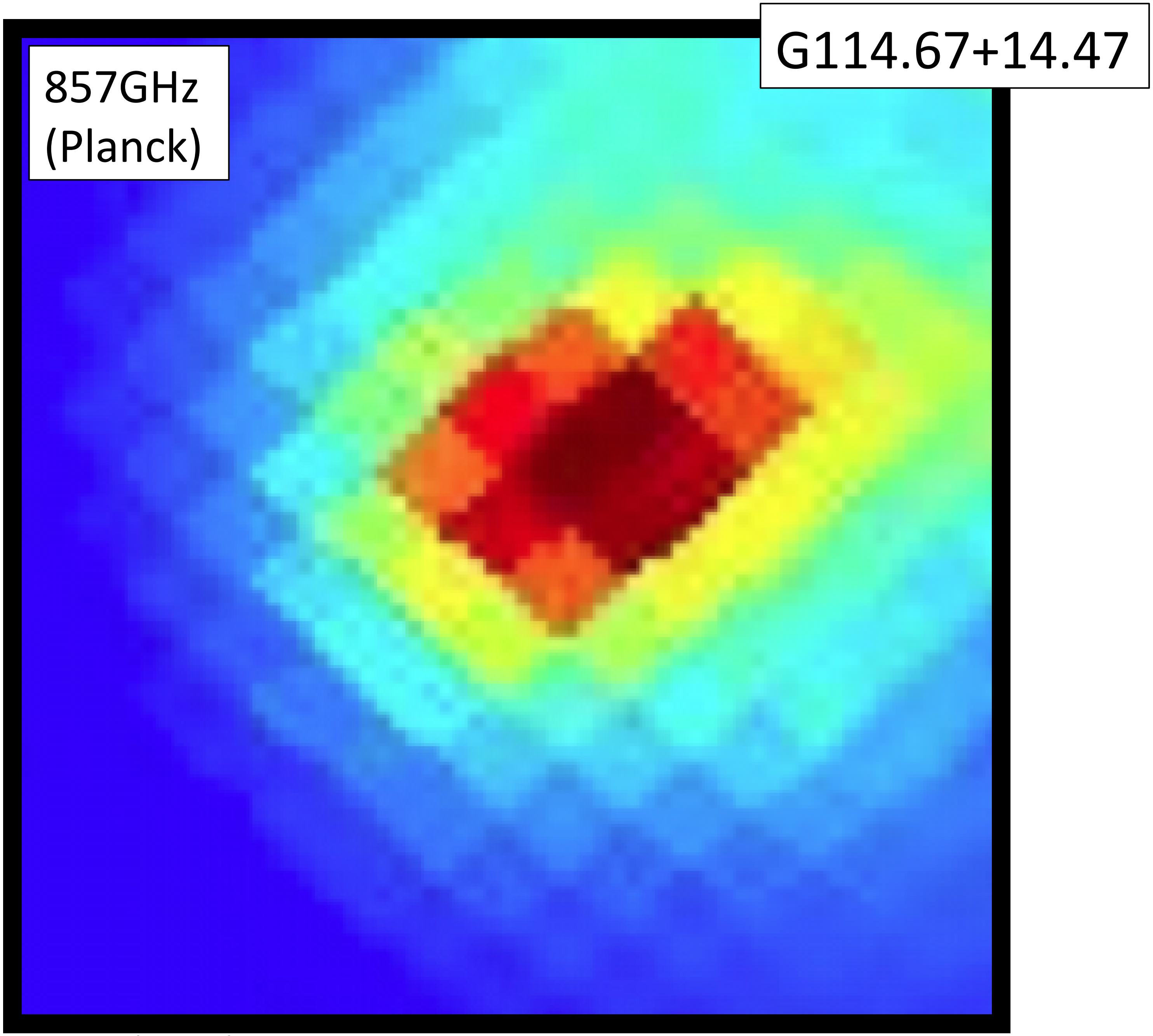



1.4GHz (Reich & Reich 1986)

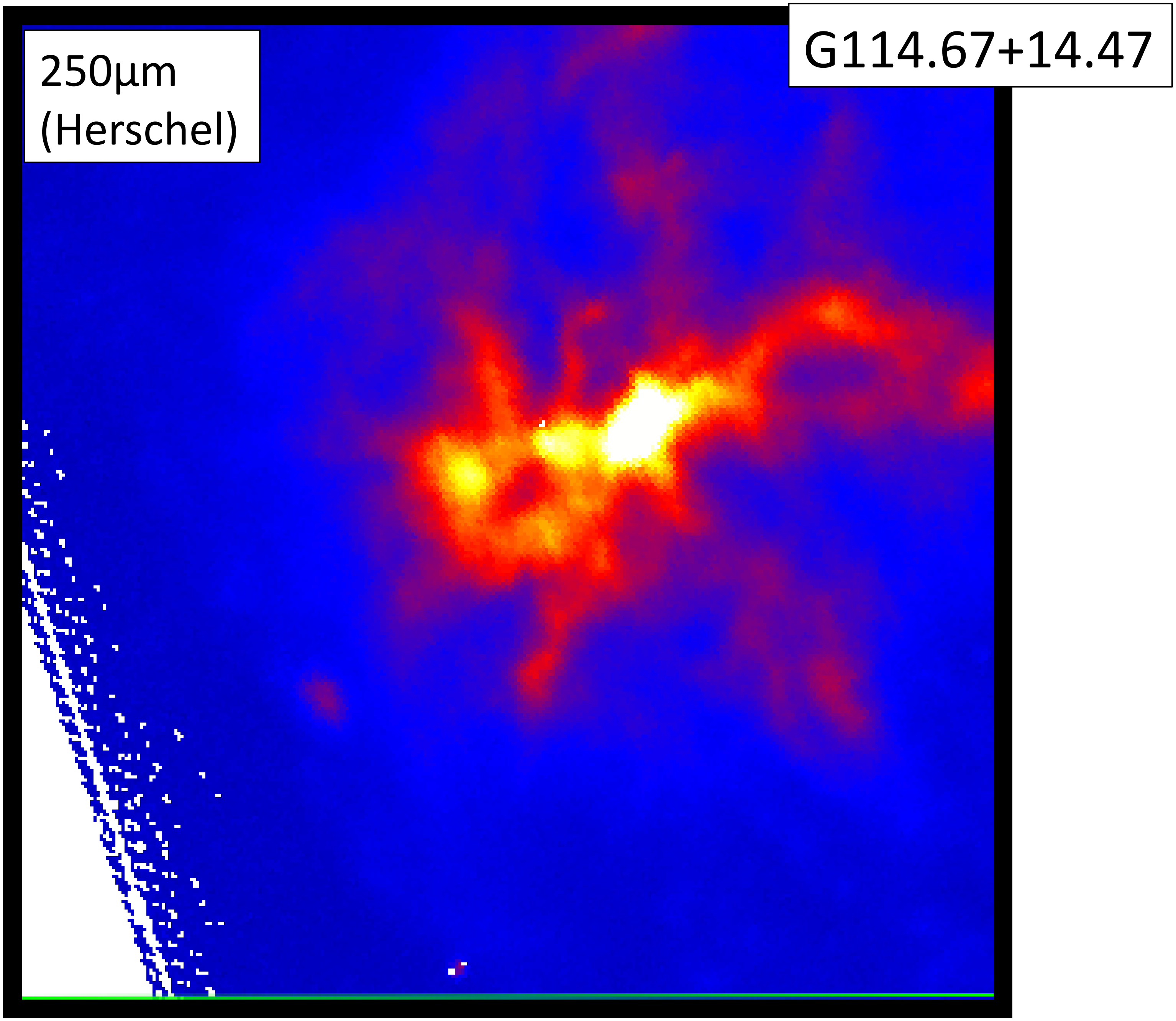
# Planck Cold Clumps with CARMA

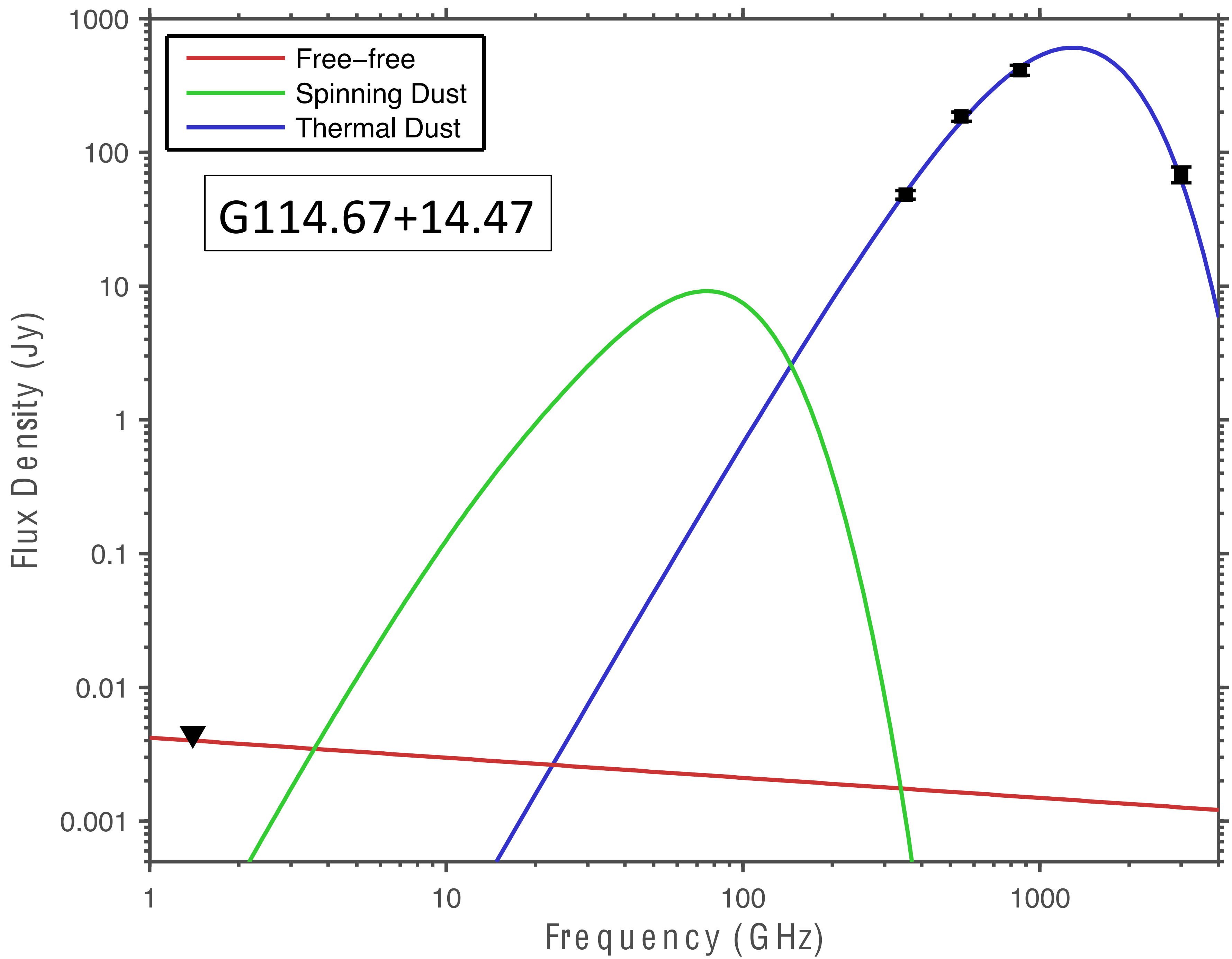



Ysard, Juvela, & Verstraete (2011)

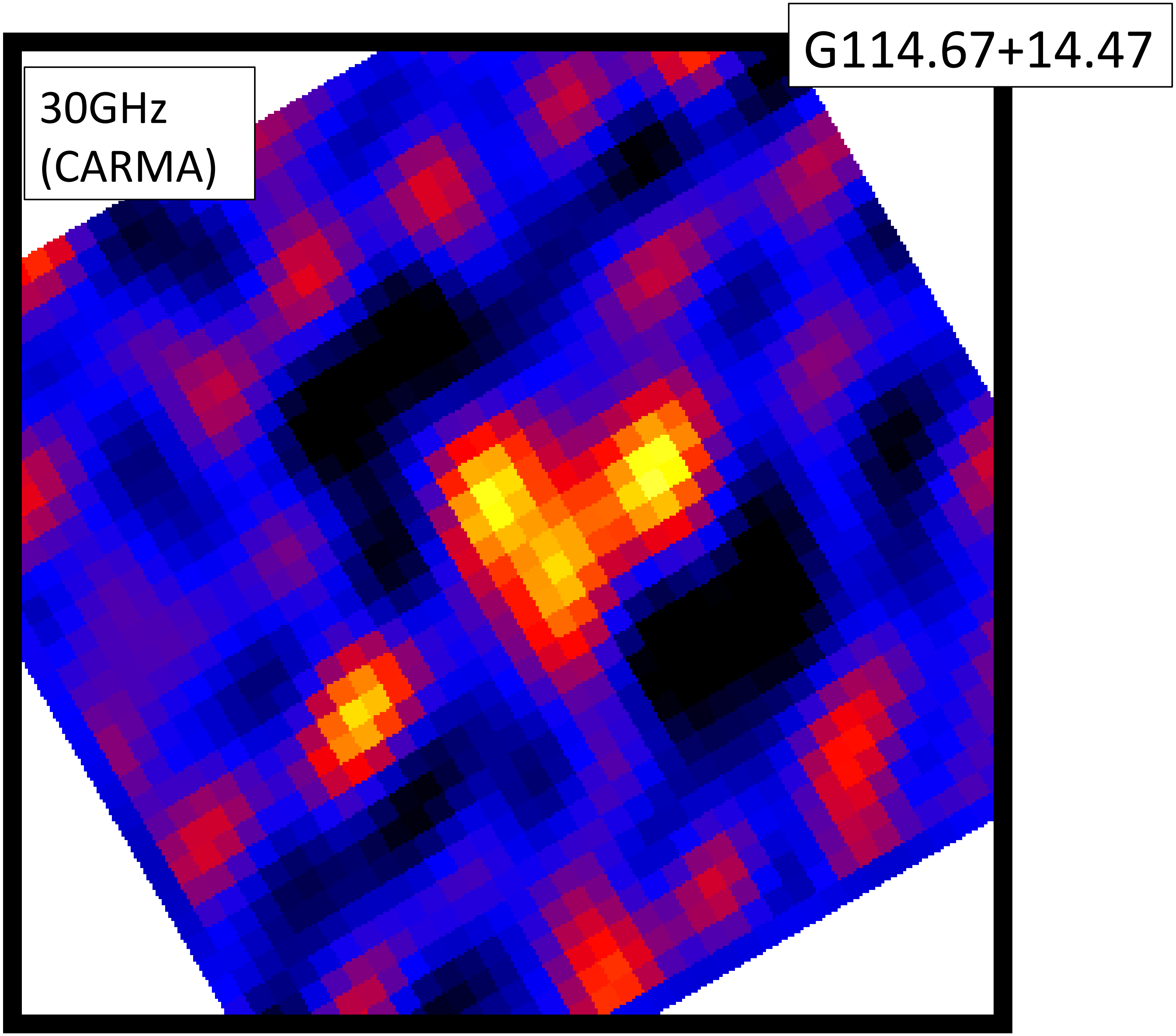


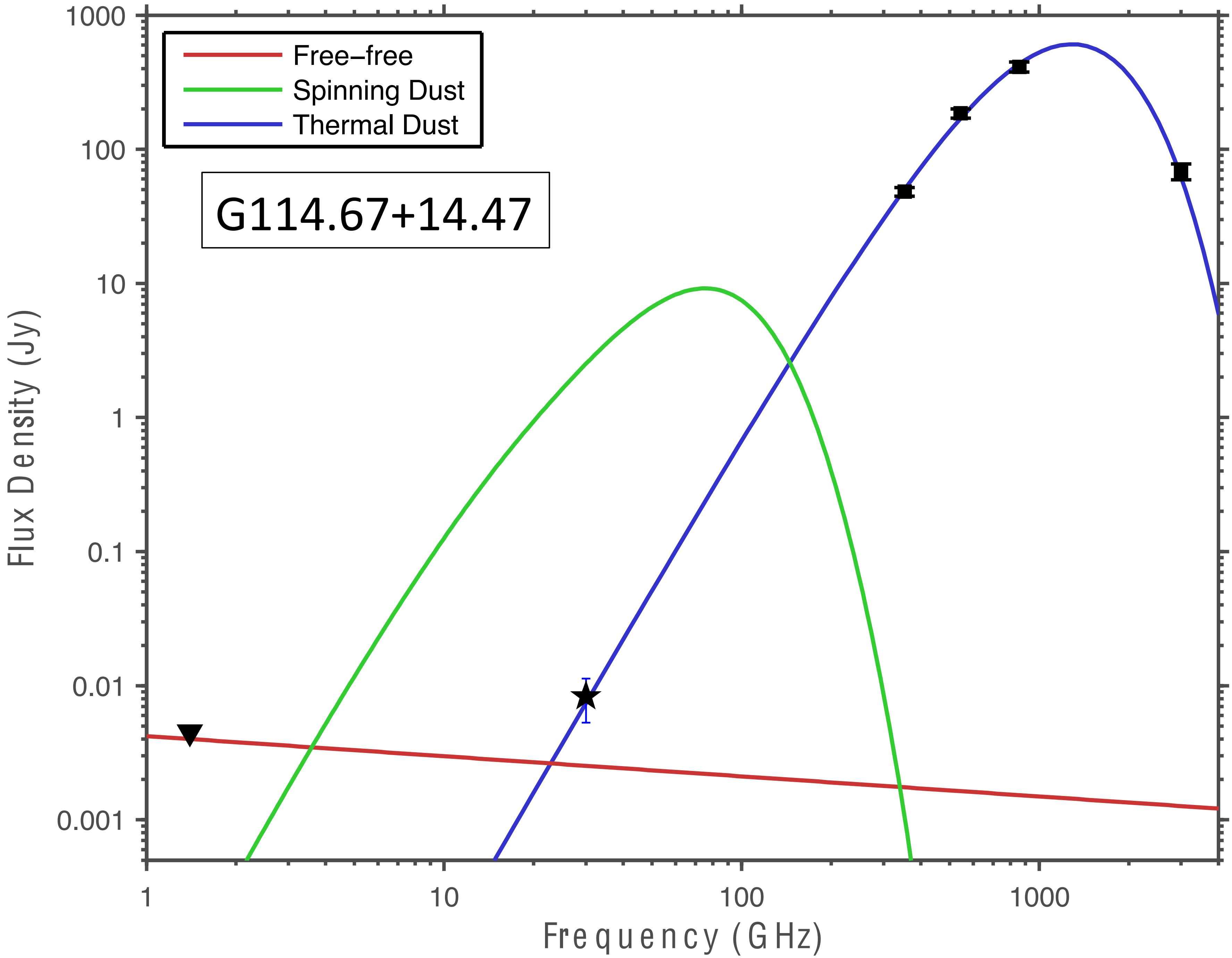

Planck Collaboration (2011)


250µm
(Herschel)
G114.67+14.47



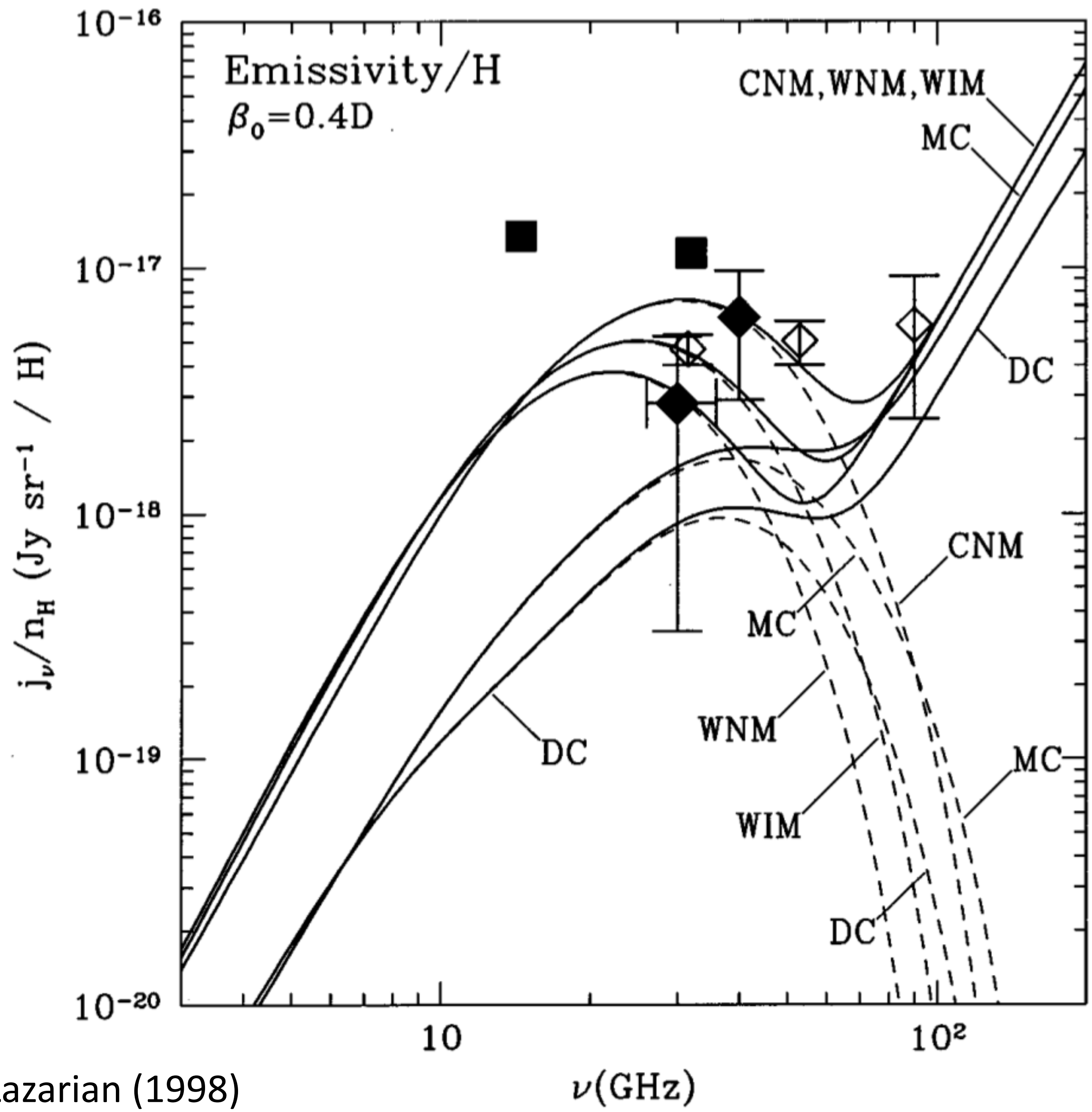
Free–free
Spinning Dust
Thermal Dust
G114.67+14.47
Flux Density (Jy)
1000
100
10
1
0.1
0.01
0.001
1
10
100
1000
Frequency (GHz)


30GHz
(CARMA)
G114.67+14.47

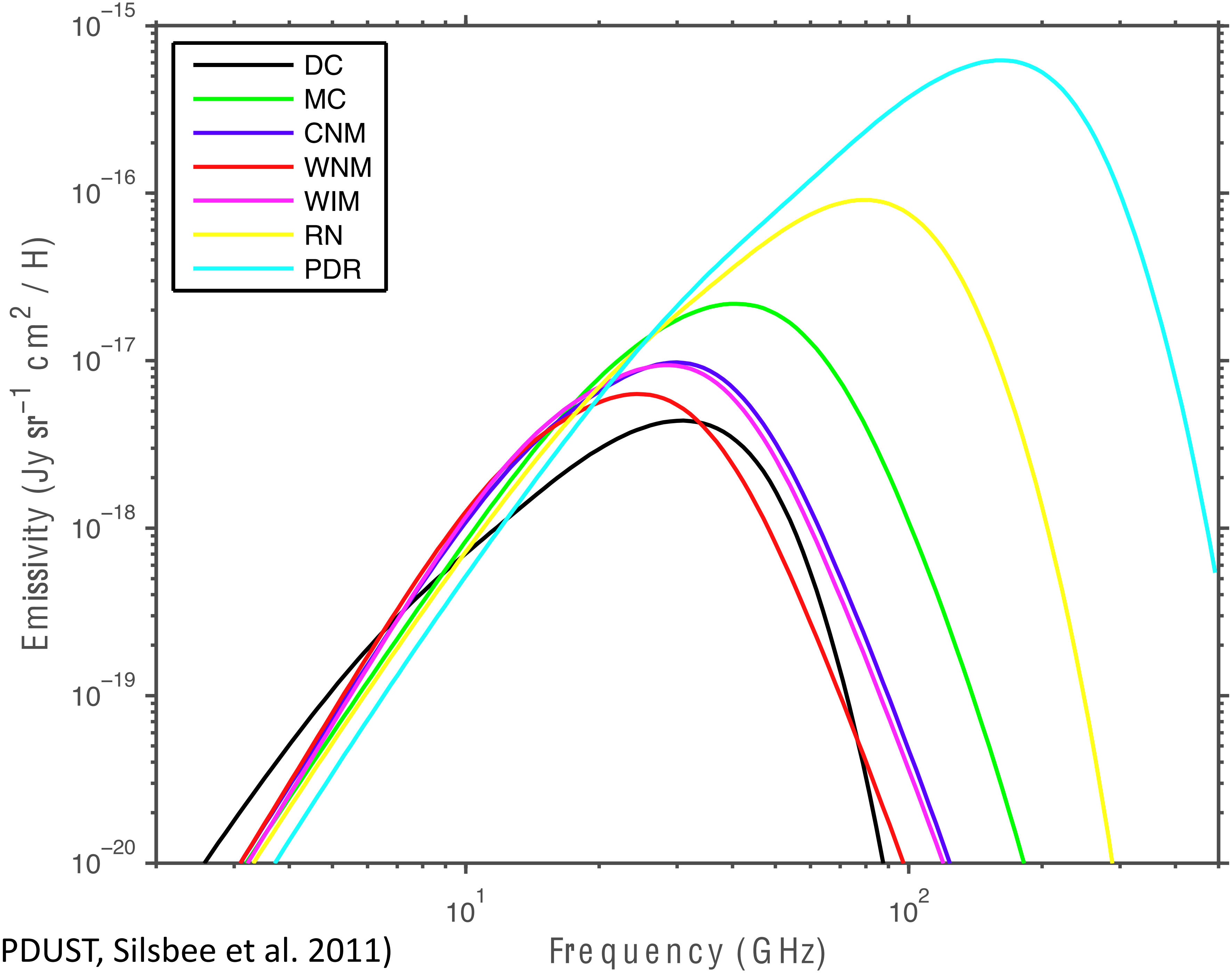


Free–free
Spinning Dust
Thermal Dust
G114.67+14.47
Flux Density (Jy)
Frequency (GHz)
1000
100
10
1
0.1
0.01
0.001
1
10
100
1000

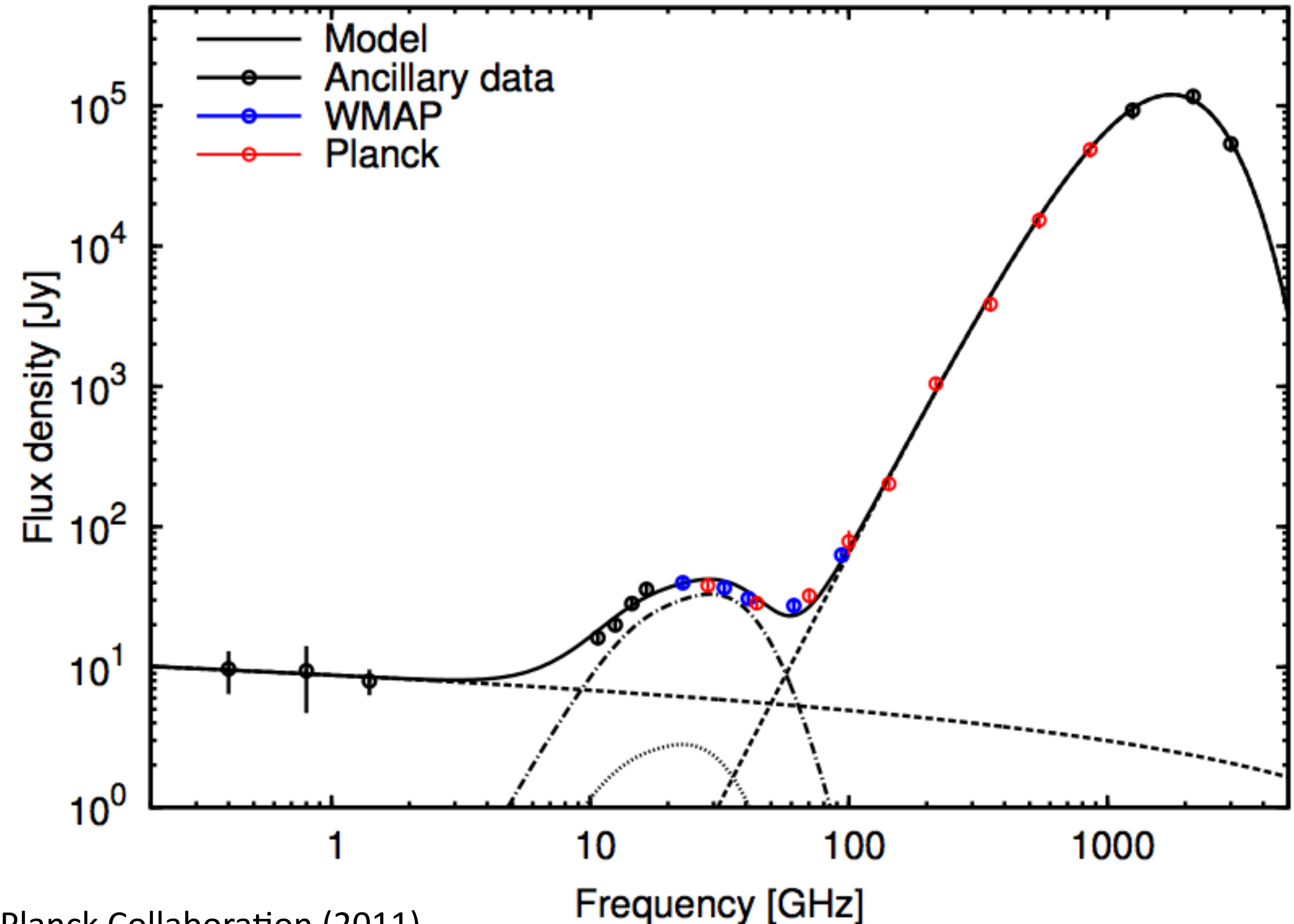
# A Practical Description of Spinning Dust Emission



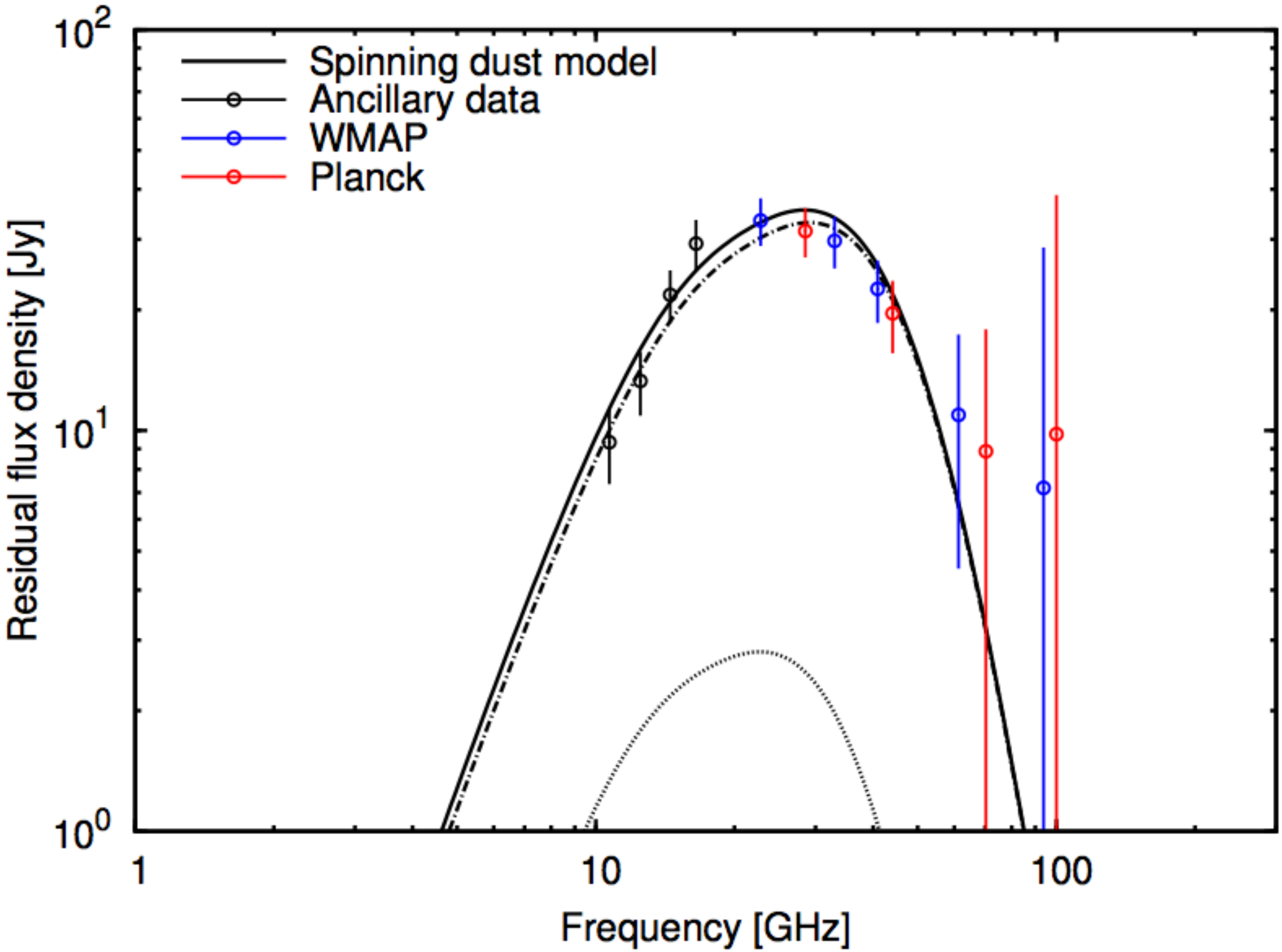

Draine & Lazarian (1998)




(SPDUST, Silsbee et al. 2011)




Planck Collaboration (2011)



Planck Collaboration (2011)

# Examples of Other Non-physical Parameterizations

- Thermal Dust Greybody $$S_\nu = Q_0 \left( \frac{\nu}{\nu_0} \right)^\beta B_\nu(\nu, T)$$

- Synchrotron Emission $$T = T_0 \left( \frac{\nu}{\nu_0} \right)^\beta$$

- And many more!

# Functional Forms

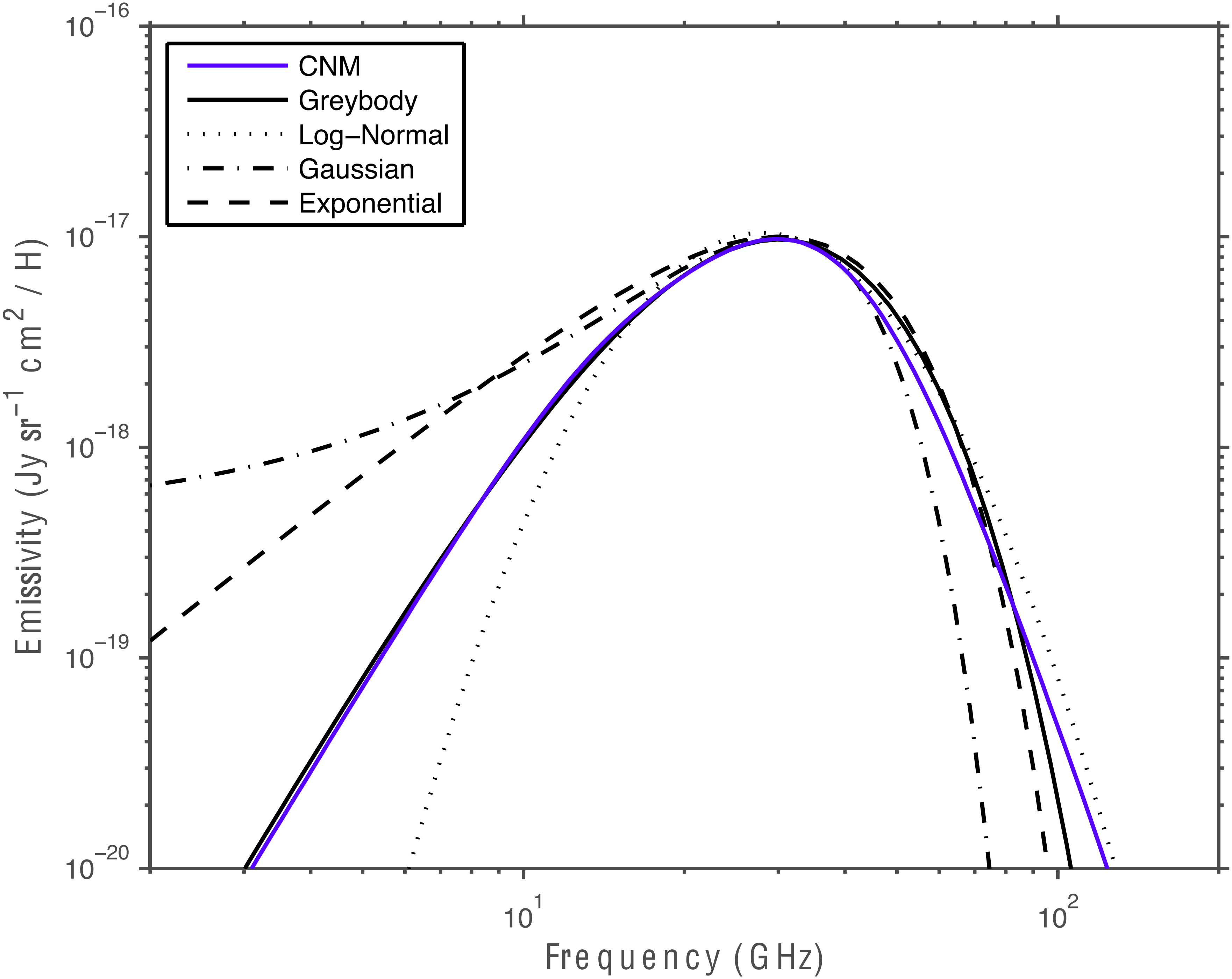
- Shifted CNM from DL98
  - (Gold et al. 2009)
- Greybody
  - (Bonaldi et al. 2007; Gold et al. 2009)
- Log-normal
  - (Bonaldi et al. 2007)
- Exponential Cut-off
  - (Draine & Hensley 2012)
- Gaussian

$$S_\nu = A_{SD} \frac{\left(\nu/\nu_{SD}\right)^{\beta_d+1}}{e^{\nu/\nu_{SD}} - 1}$$

$$S_\nu = A_{SD} \exp\left[-\frac{1}{2}\left|\frac{\ln\left(\nu/\nu_{SD}\right)}{\sigma}\right|^2\right]$$

$$S_\nu = A_{SD}\left(\frac{\nu}{\nu_0}\right)^2 \exp\left[1 - \left(\nu/\nu_0\right)^2\right]$$

$$S_\nu = A_{SD} \exp\left[-\frac{1}{2}\left(\frac{\nu - \nu_{SD}}{\sigma}\right)^2\right]$$

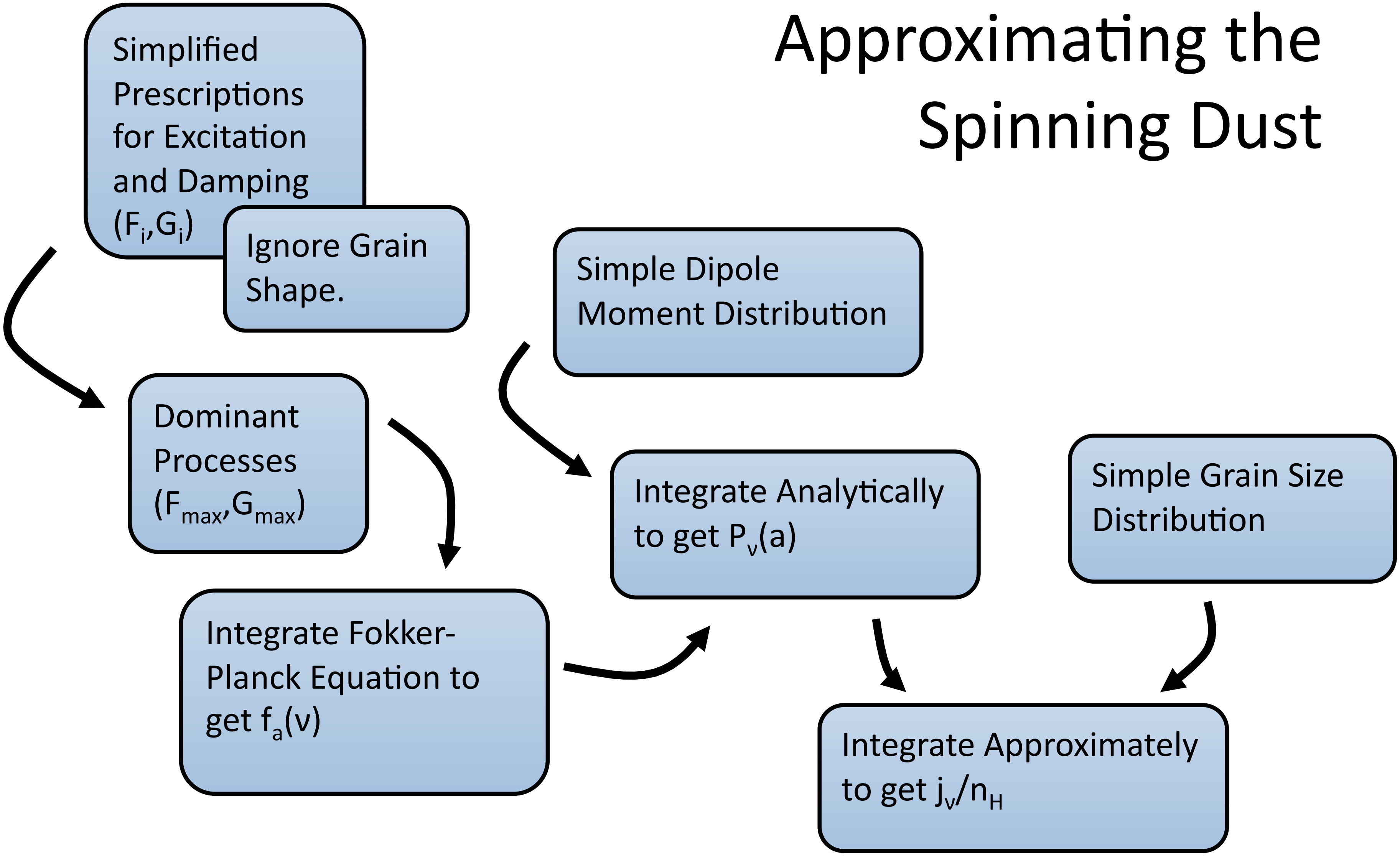


CNM
Greybody
Log–Normal
Gaussian
Exponential
Emissivity (Jy sr$^{-1}$ cm$^{2}$ / H)
Frequency (GHz)
$10^{-16}$
$10^{-17}$
$10^{-18}$
$10^{-19}$
$10^{-20}$
$10^{1}$
$10^{2}$

## Goals

- Simple form
- Adequate for data
- Adequate for theory
- Well-understood relation to physics
- Well-understood degeneracies between physical parameters

# Approximating the Spinning Dust

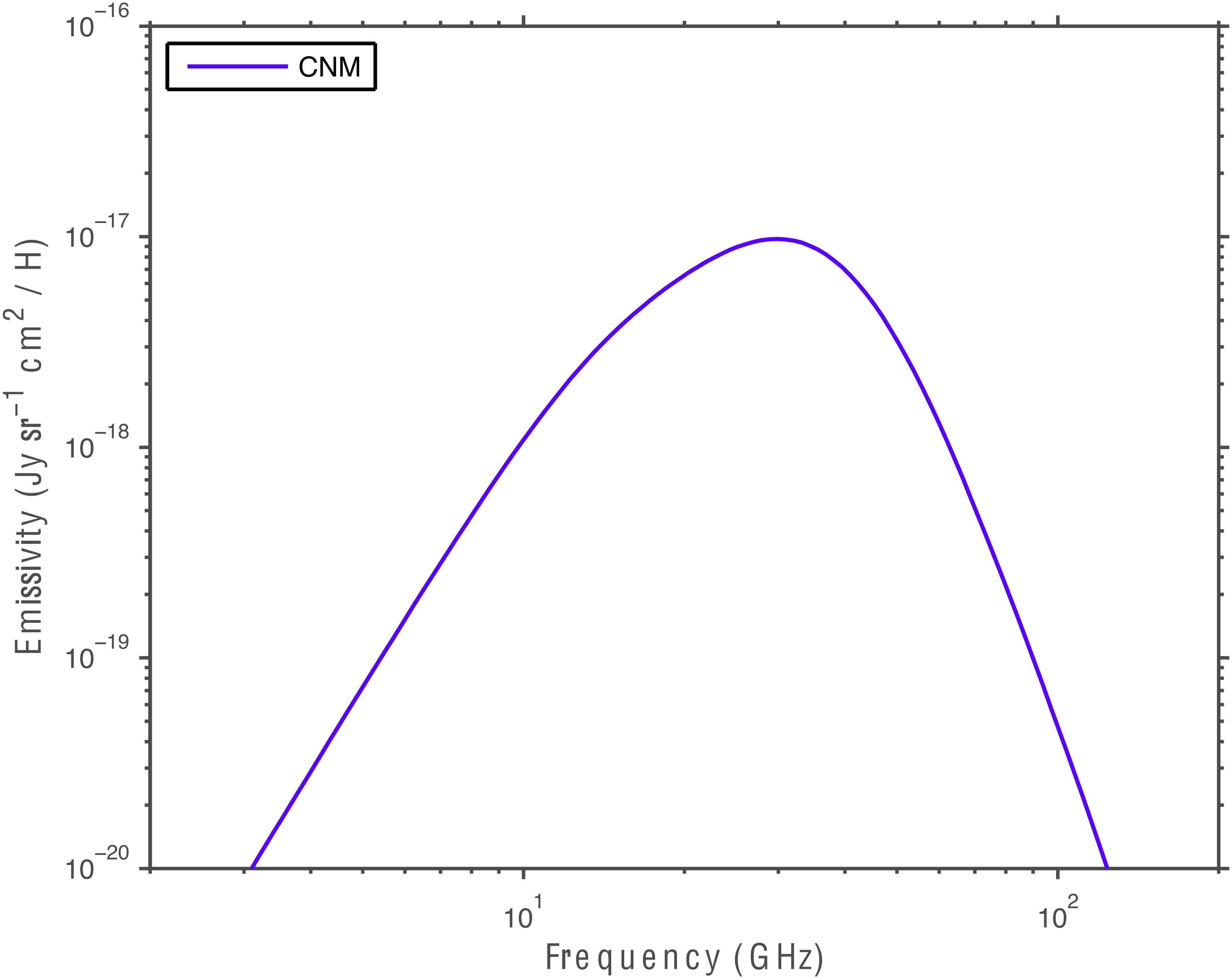


$$f_a(\nu) \propto \exp\left[-\frac{I\omega^2}{2kT}\frac{F_{\max}}{G_{\max}}\right]$$

$$\frac{F_{\max}}{G_{\max}} \propto a^{n_a}\beta^{n_\beta}T^{n_T}\chi^{n_\chi}n_H^{n_n}\nu^{n_\nu}$$

$$P(\beta) \propto \beta^2 \exp\left[-\frac{3}{2}\frac{\beta^2}{\langle\beta^2\rangle}\right]$$

$$\frac{1}{n_H}\frac{dn_{gr}}{da} \propto \frac{1}{a}\exp\left[-\left|\frac{\ln(a/a_{\min})}{\sigma}\right|^2\right] \quad a > a_{\min}$$


CNM
Emissivity (Jy sr$^{-1}$ cm$^2$ / H)
Frequency (GHz)
$10^{-16}$
$10^{-17}$
$10^{-18}$
$10^{-19}$
$10^{-20}$
$10^{1}$
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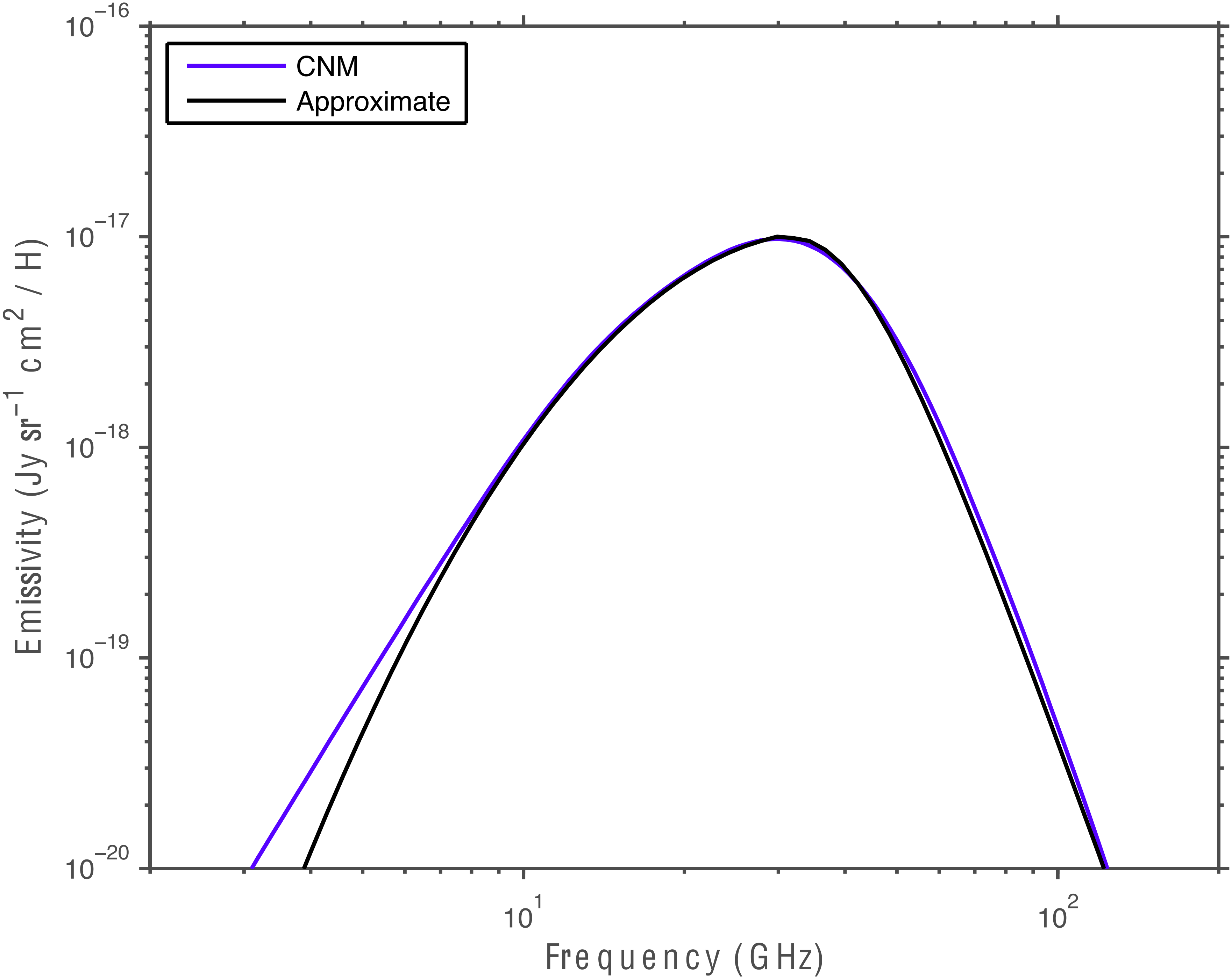

CNM
Approximate
Emissivity (Jy sr$^{-1}$ cm$^{2}$ / H)
$10^{-16}$
$10^{-17}$
$10^{-18}$
$10^{-19}$
$10^{-20}$
$10^{1}$
$10^{2}$
Frequency (GHz)

CNM

$$\frac{j_\nu}{n_H} \propto a_{\min}^2 \left\langle \beta^2 \right\rangle \nu^3 \begin{cases} \left(\frac{2\nu_0}{3\nu}\right)^{\frac{4}{3}} \exp\left[-\frac{1}{2}\left|\frac{\ln(3\nu/2\nu_0)}{3\sigma/2}\right|^2\right] & \nu < \nu_0 \\ \left(\frac{3}{2}\right)^2 \left(\frac{\nu}{\nu_0}\right)^3 \left[\frac{5/3}{1+(2/3)(\nu/\nu_0)^4}\right]^{\frac{13}{4}} & \nu > \nu_0 \end{cases}$$

# Next Steps

- Continue comparing the functions to theory
- Compare the functions to data
- Characterize the degeneracies between physical parameters
- Show what can be learned by observations at different frequencies