

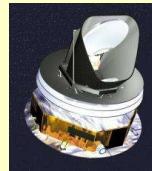
Cosmological foregrounds

- short introduction to **astronomical sources** that
 - affect CMB observations
 - will be studied with the same data (Planck)

★ the Milky Way

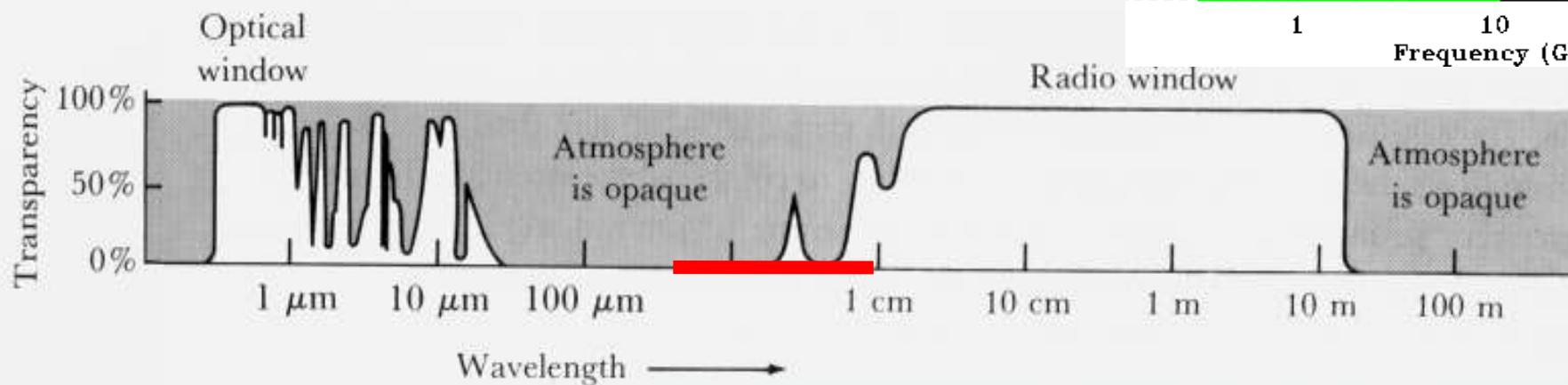
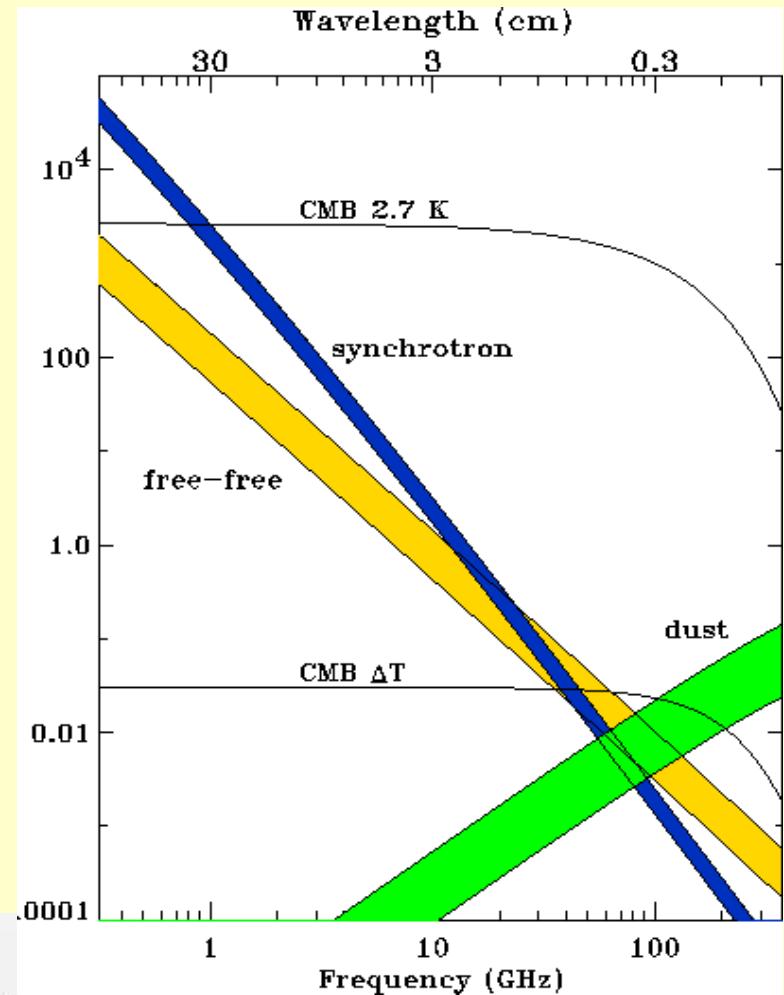
★ Solar system





Planck Surveyor

- nine frequencies 30GHz - 857GHz (0.3mm-1cm)
- resolution between 5 and 30 arc minutes
- sensitivity $\Delta T/T = 10^{-6}$, 10-40 mJy per pixel

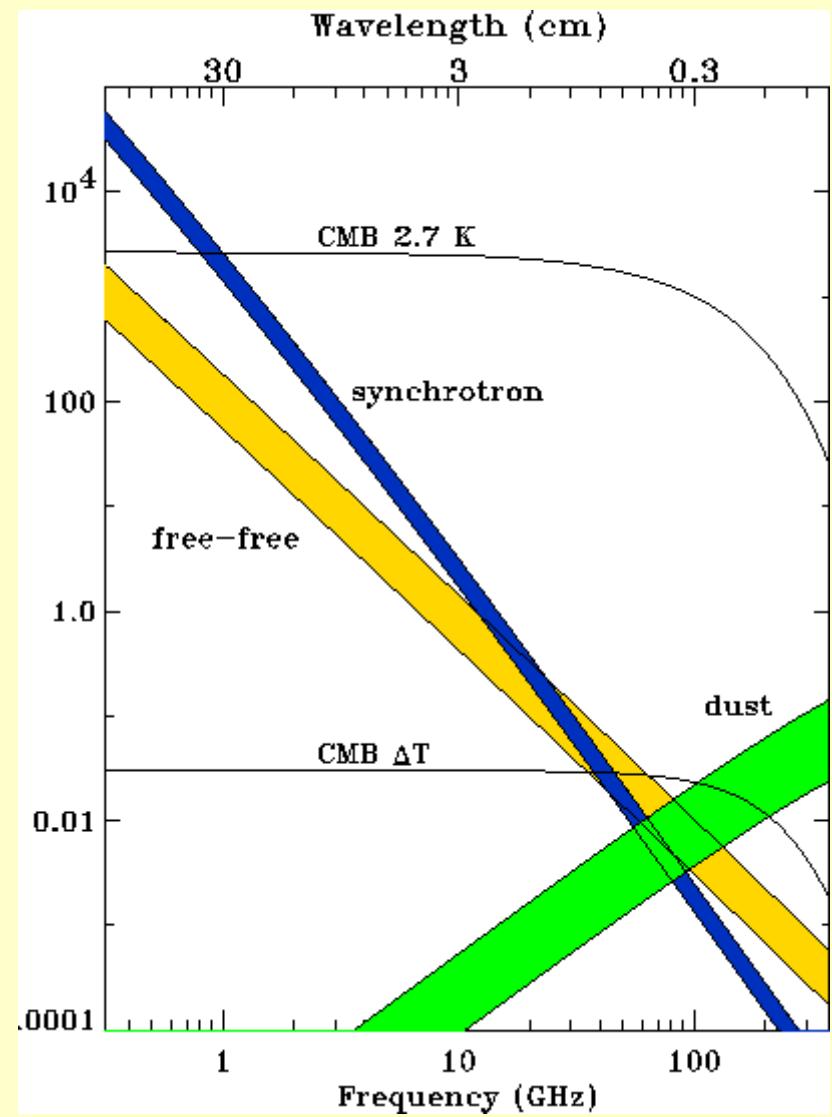


The Galaxy

- three main emission components
 - **dust emission**
 - dust in interstellar clouds ($\sim 1\%$ of interstellar medium)
 - Rayleigh-Jeans end of the normal vibrational emission and possibly some emission from rotating grains
 - **free-free emission**
 - ionized gas associated with star formation
 - **synchrotron emission**
 - energetic electrons moving in the Galactic magnetic field

The Galaxy

- **synchrotron** emission
 - $T_A \sim f^{-2.9}$
- **free-free** emission
 - $T_A \sim f^{-2.15}$
- **thermal dust** emission
 - $T_A \sim f^3$

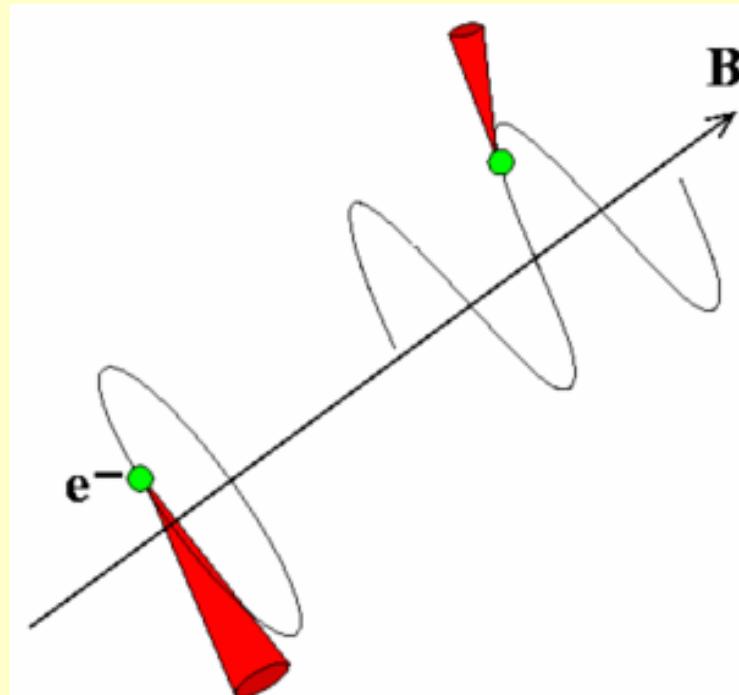


Burigana et al. 1997



Galactic synchrotron emission

- emission from energetic electrons moving in the Galactic magnetic field
- result of numerous supernova explosions that fill a significant part of the ISM with hot plasma

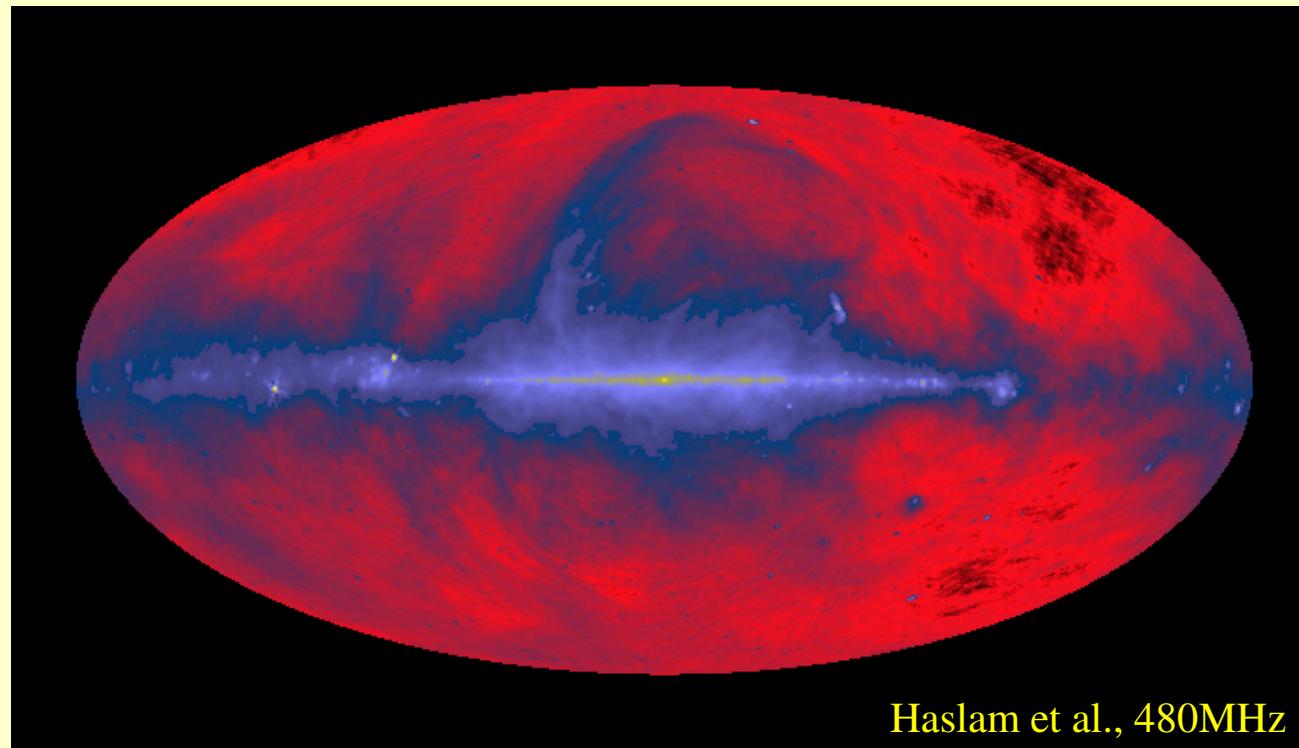


... synchrotron emission

- Planck will provide accurate maps at least up to Galactic latitudes $\sim 30^\circ$
- for predictions the problem is extrapolation from low frequency observations to Planck wavelengths
- .. especially for the polarized signal
 - radiation is intrinsically highly polarized
 - **Faraday rotation** causes depolarization that depends on the wavelength ($\theta \sim \lambda^2$)

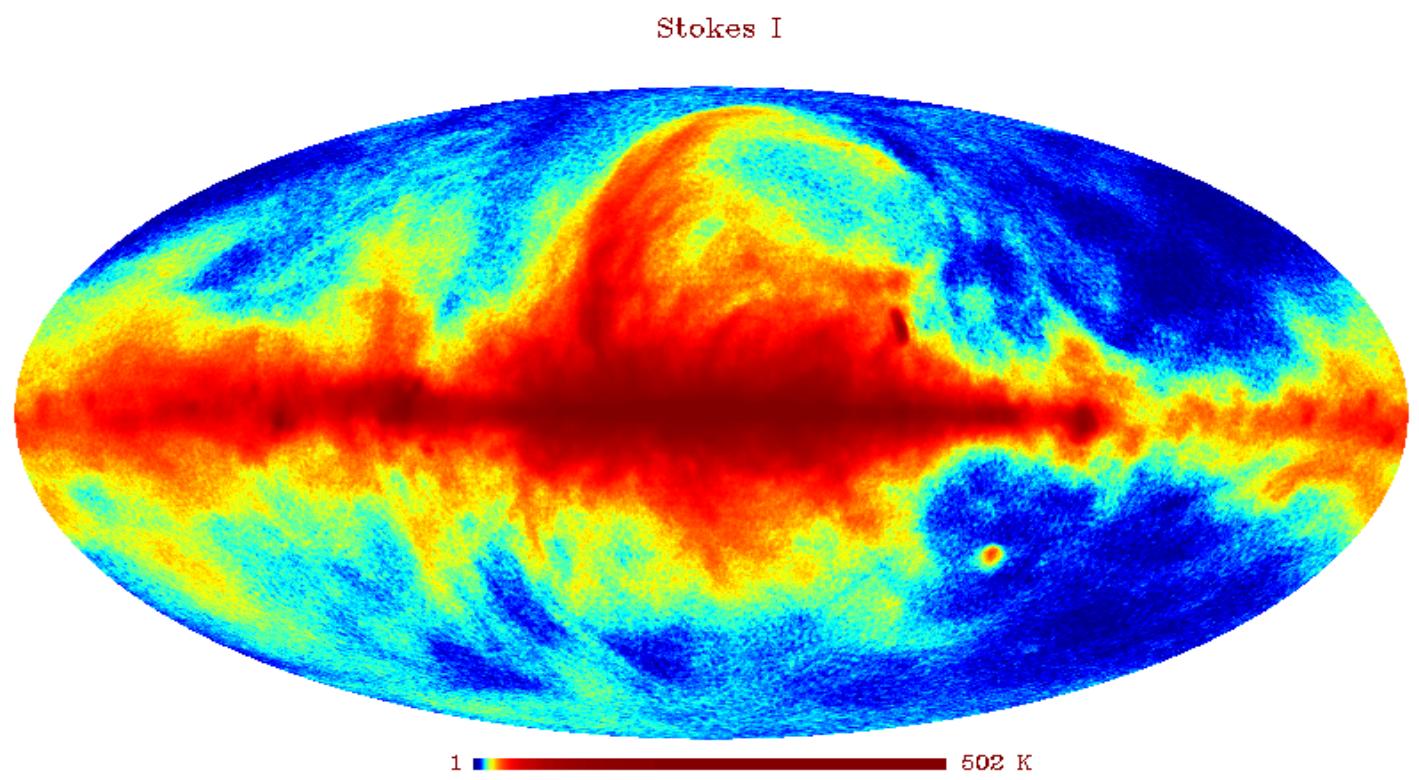
...synchrotron emission

- current knowledge is based on 480MHz all-sky map (Haslam et al., 50') and 1.4GHz (Bonn, 34')
 - the two provide an all-sky map of variations in the synchrotron **spectral index**



... synchrotron emission

- many more observations under way
 - Bonn
 - 1.4 and 2.7 GHz
 - resolution $10'$
 - coverage $|b| < 10^\circ$
 - CGPS
 - 408MHz, 1420GHz
 - resolution $1'$
 - $-3.6^\circ < b < 5.6^\circ, 74^\circ < l < 147^\circ$



G. Giardino et al.

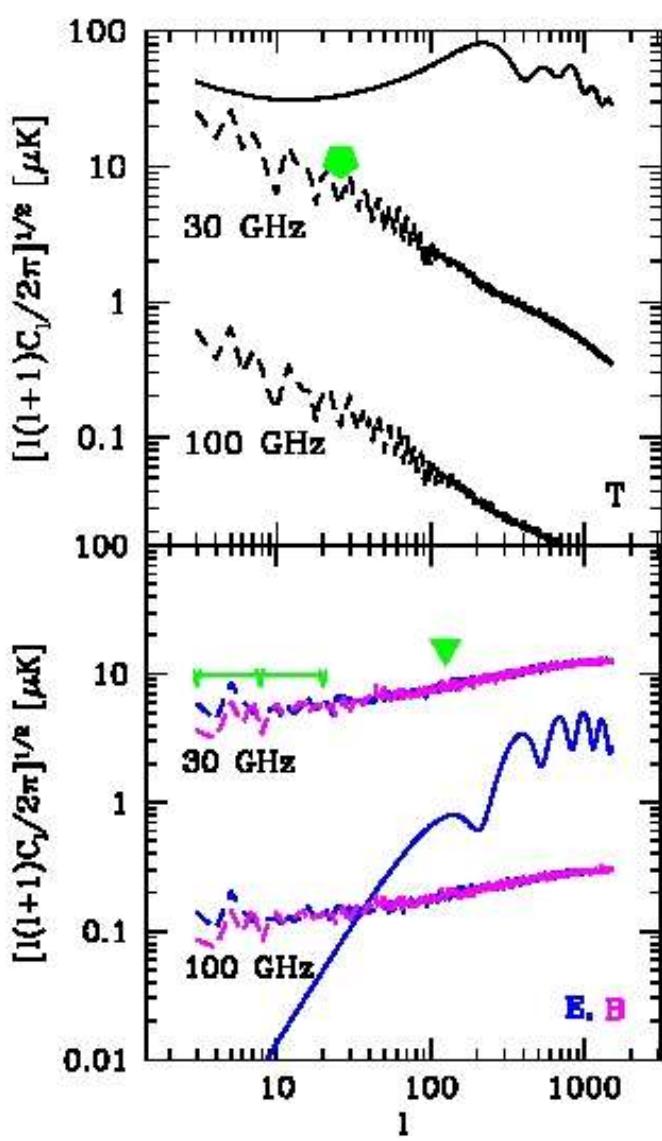
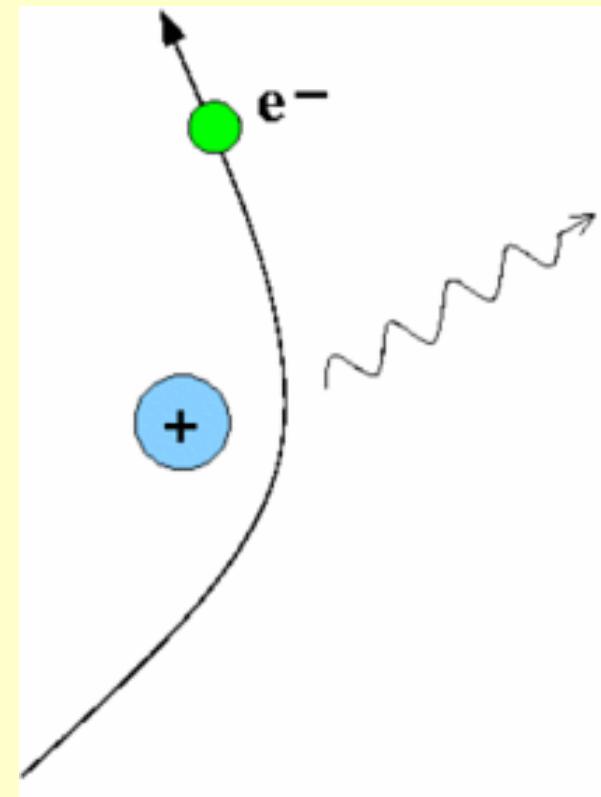


Fig. 11. The power spectra of the T , E and B components of the synthetic maps of Galactic synchrotron polarisation at 30 and 100 GHz (dashed lines), for $|b| > 20^\circ$, compared with the signal expected from the CMB (continuous line). The point with pentagonal shape indicates the COBE DMR upper limit to synchrotron temperature fluctuations at 31.5 GHz. The horizontal line is the upper limit to polarised signal by Keating et al. (2001) in the frequency band 26–36 GHz. The triangular point is the upper limit to polarised signal by Netterfield et al. (1995) in the frequency band 26–46 GHz.



Galactic free-free emission

- emission from more dense, ionized regions (electron-ion collisions)
- concentrated more in the galactic plane where most of the stars are formed
 - some **diffuse emission** from ionized interstellar clouds ionized by the general ISRF
 - a number of individual sources: **HII regions** surrounding newly born massive stars



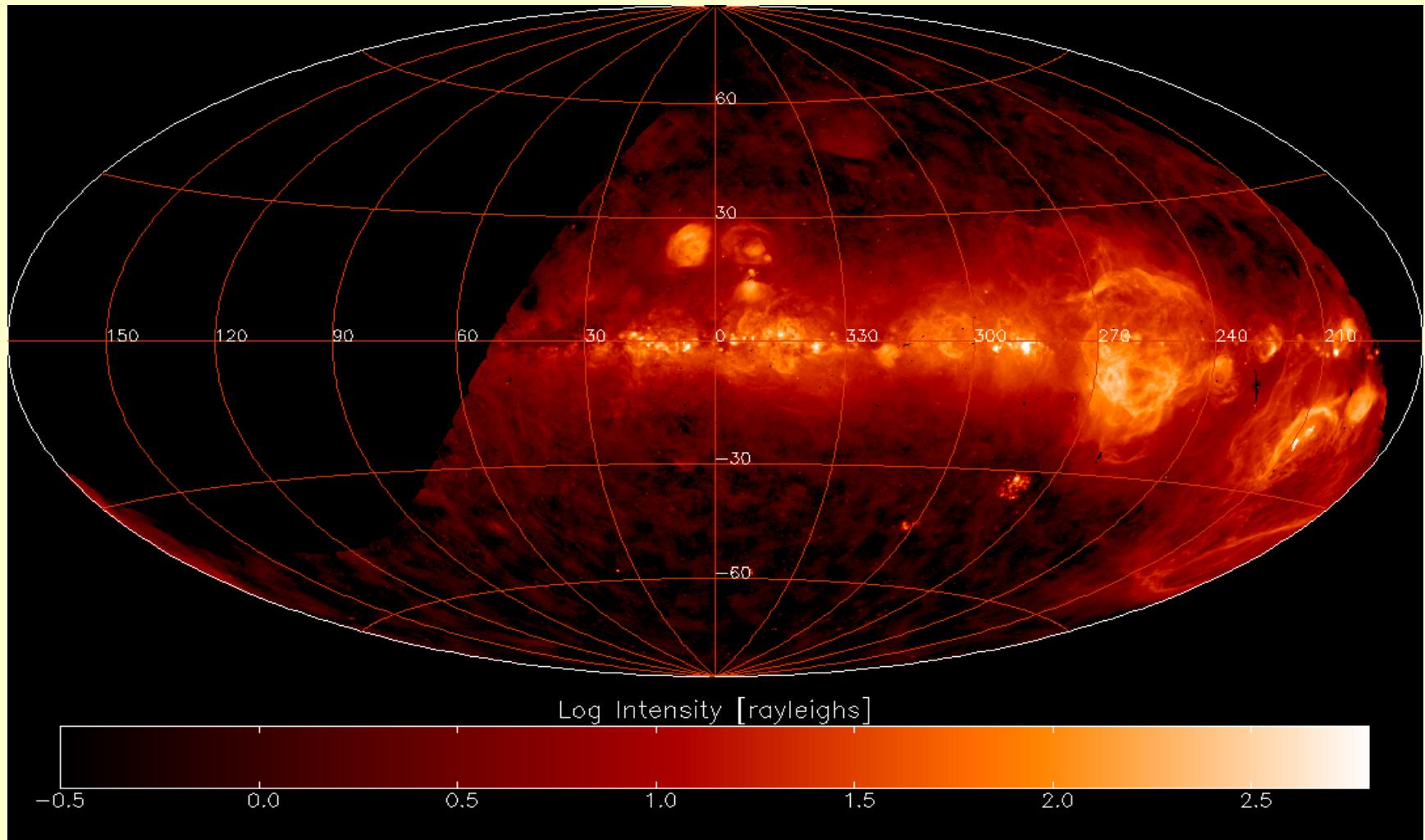
... free-free emission

- current templates are indirect and are based on observed **H α** emission and the **dust** distribution
 - where there is ionized gas there will be recombinations of H-atoms => line radiation including the **H α -line** (0.66 μm)
 - unlike free-free emission the short wavelength H α -line does suffer significant **extinction** due to dust
 - if dust distribution wrt emission regions and the dust properties are known the H α emission can be corrected => **free-free = H α × some factor**



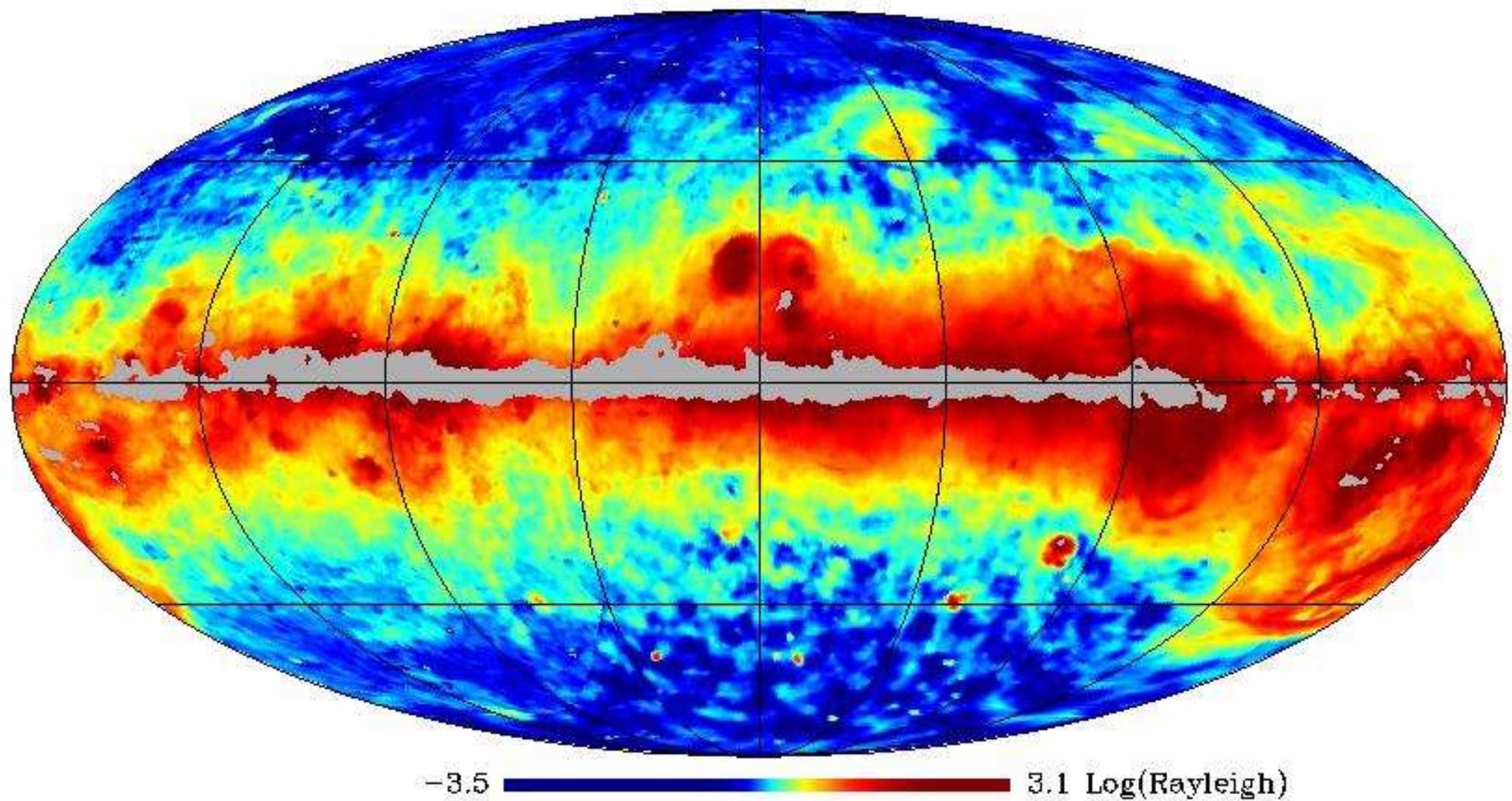
- arc minute scale observations of H α :

- southern sky SHASSA (Gaustad et al., 5')
- northern sky WHAM (60'), VTSS ($\sim 2'$)



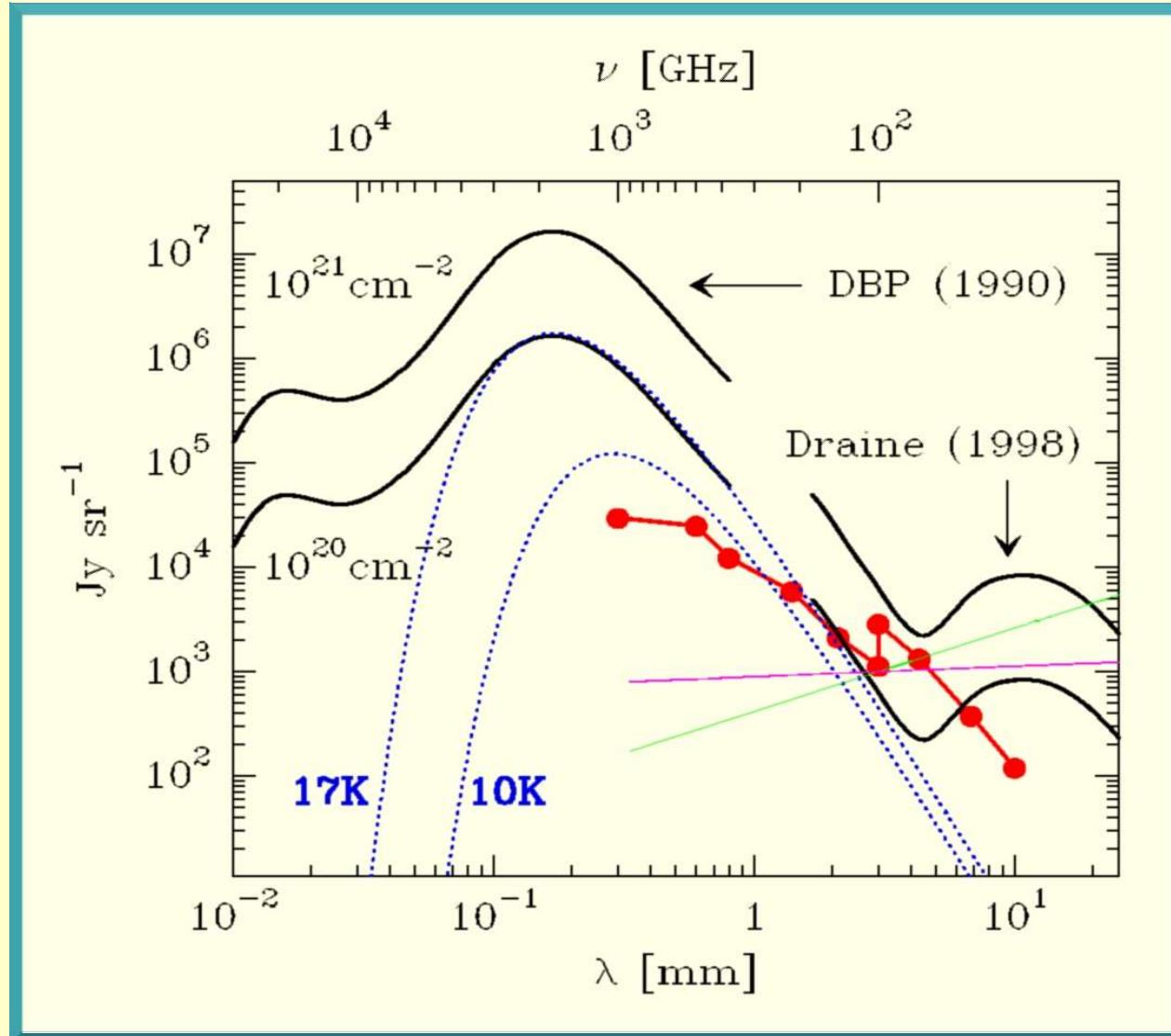
- free-free template: Dickinson et al. (2002)

Full-sky dust corrected Halpha map



Dust emission

- dominates at low b , short λ



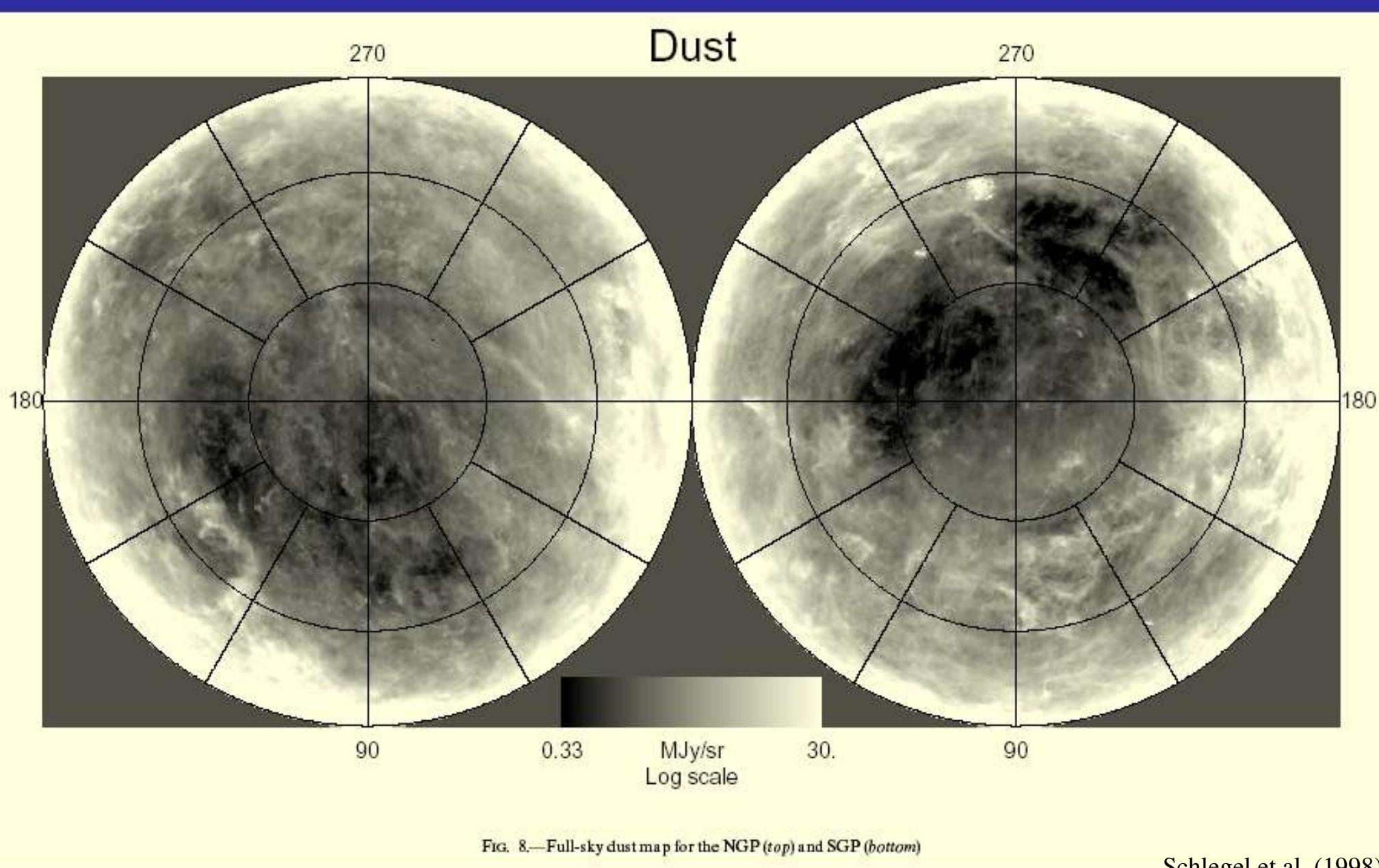


FIG. 8.—Full-sky dust map for the NGP (*top*) and SGP (*bottom*)

Schlegel et al. (1998)



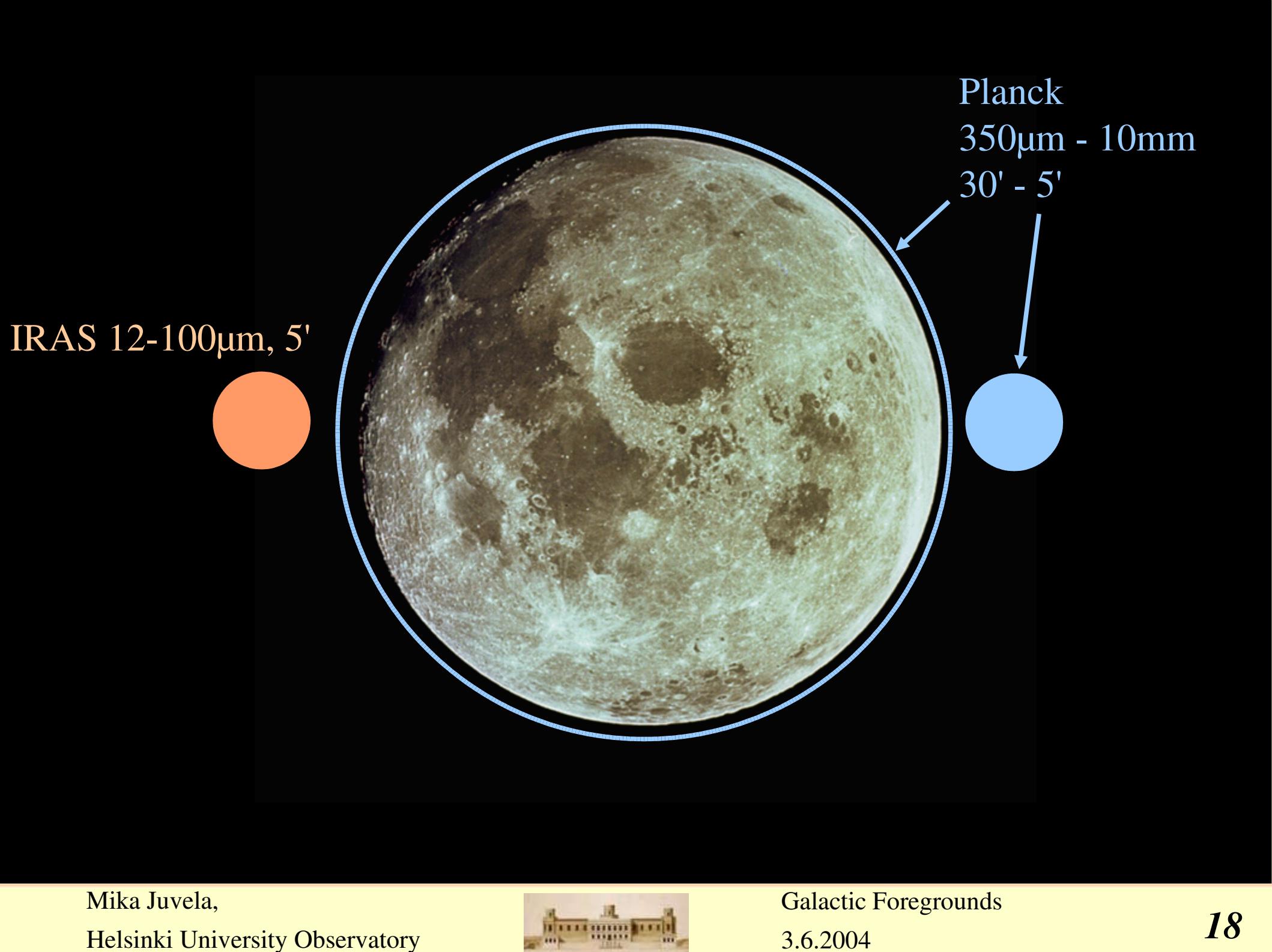
Dust emission

- goals for the study of dust emission with Planck
 - distribution of the very **cold dust**
 - variations in dust **properties** (emissivity, spectral index) as the function physical environment
 - connection of dust properties and **star formation**
 - variations in **gas-to dust ratio**
- additionally
 - study of **individual objects** e.g. dense cloud cores
 - **large scale structure** of the Galaxy and ISRF

FIRAS, 0.1-10mm, 7°

DIRBE, 1.25-240μm, 40'

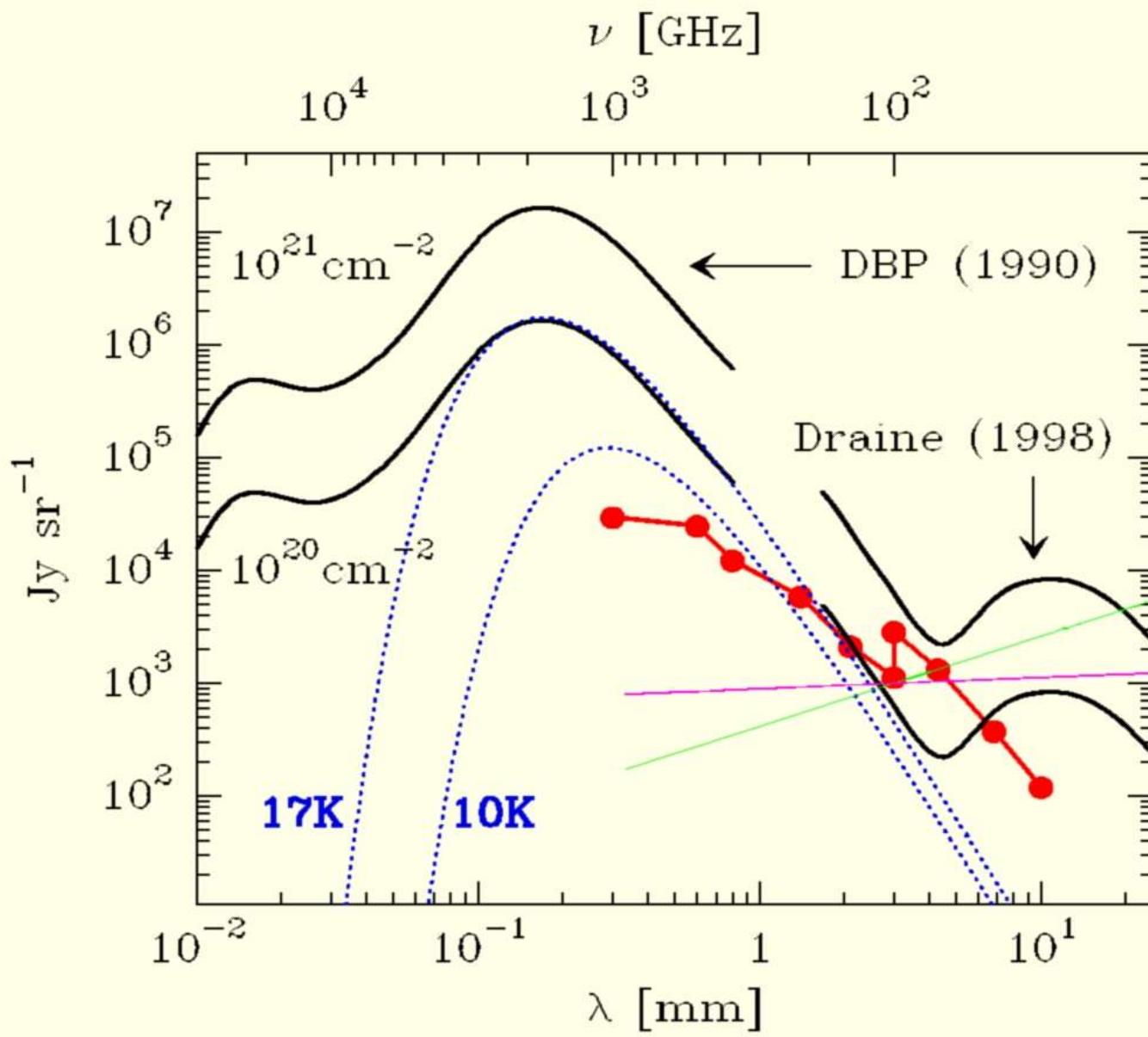




Cold cores

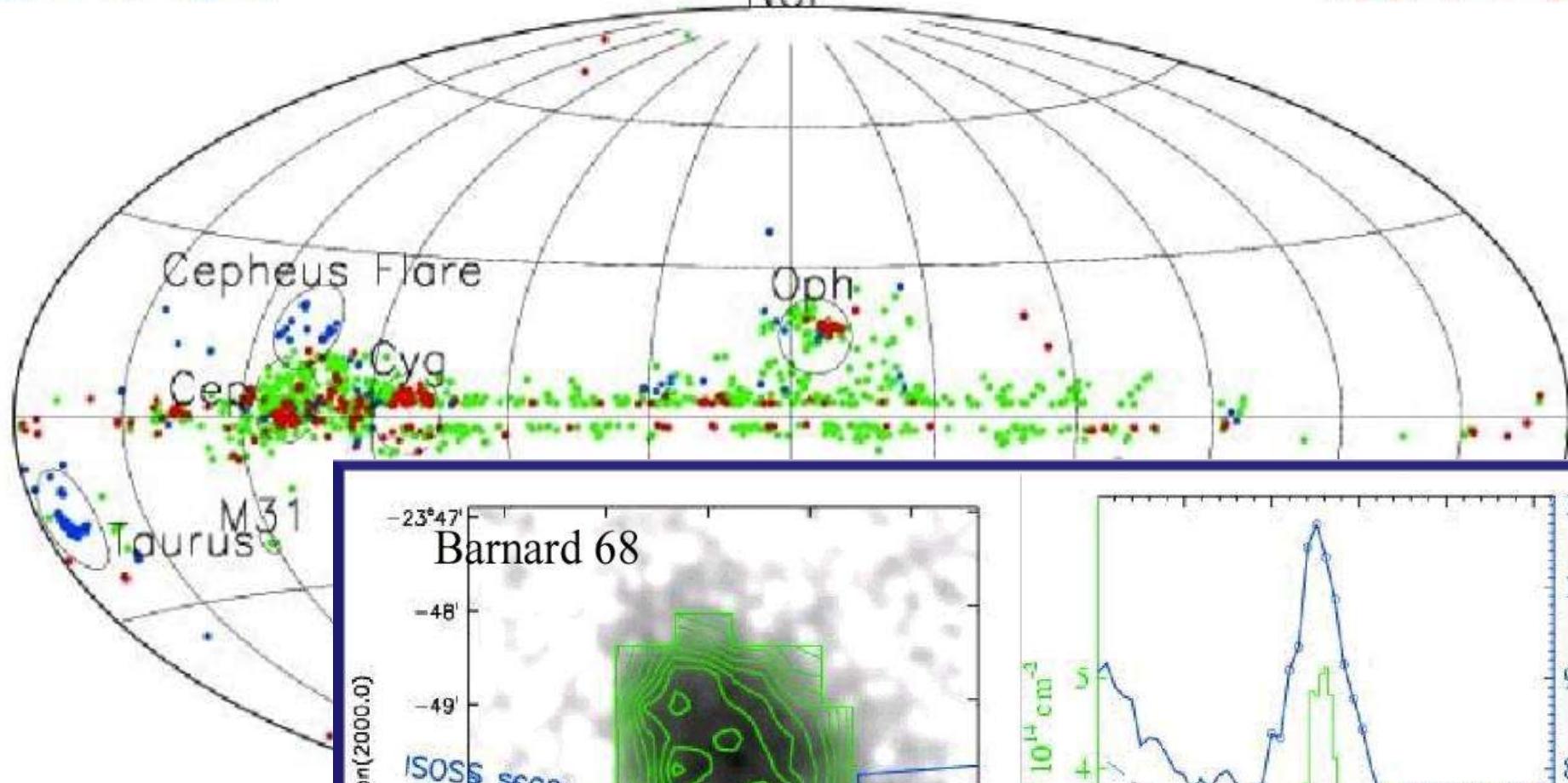
- previous infrared all-sky surveys were not sensitive to *very* cold dust (see prev. figure!)
 - IRAS covered range 12-100 μ m
 - Dirbe covered 2 μ m-240 μ m ... but at 40 arcmin resolution => no small objects would be detected
- ISO (Infrared Space Observatory) did *pointed* observations up to 200 μ m
 - 170 μ m detector was on when satellite was slewing from one object to the next => ISO Serendipity Survey
 - with IRAS this revealed a number of cold cores



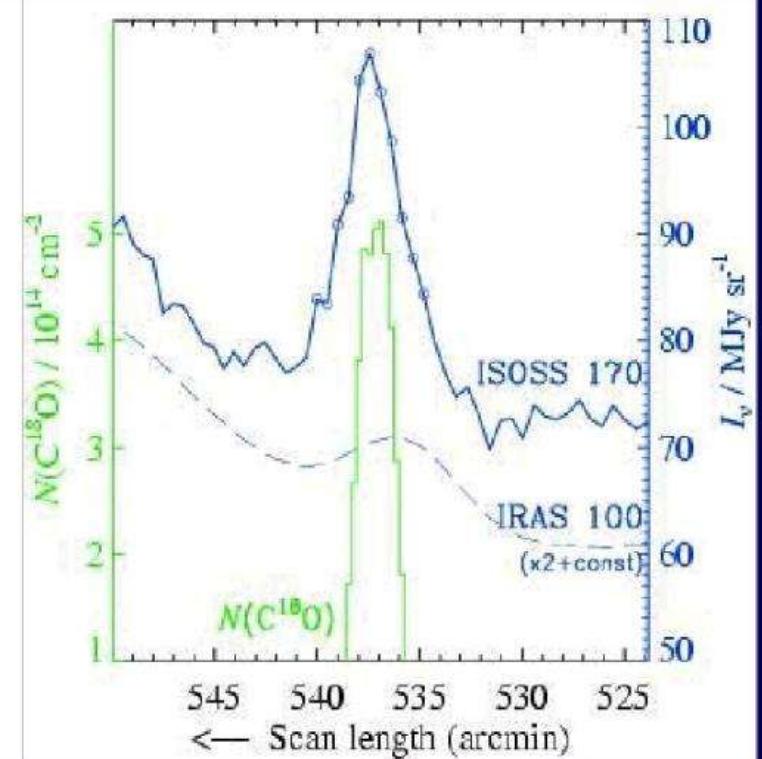
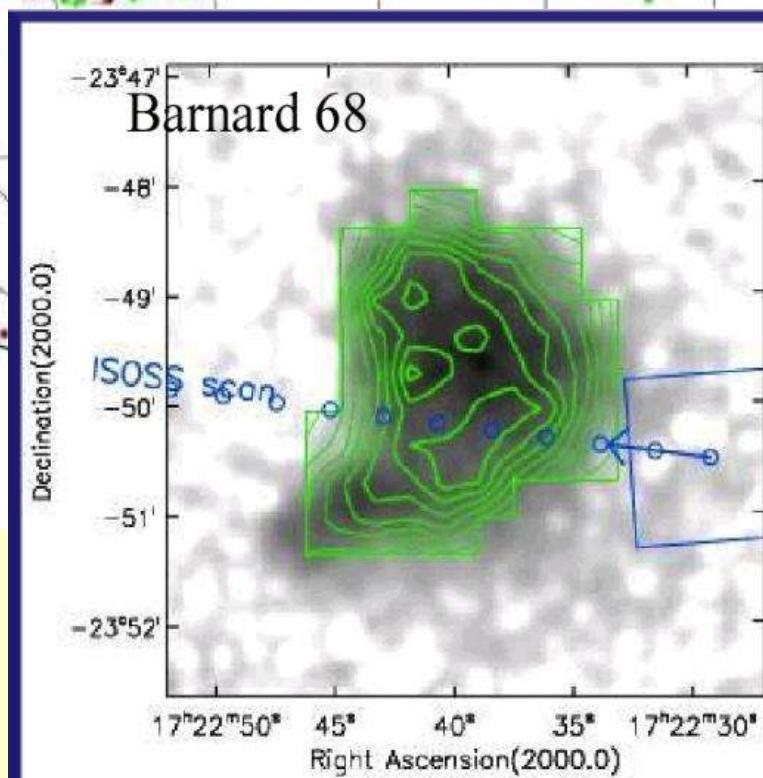


Blue: $T < 13$ K

Red: $T > 25$ K



Green: $T = 17$ K

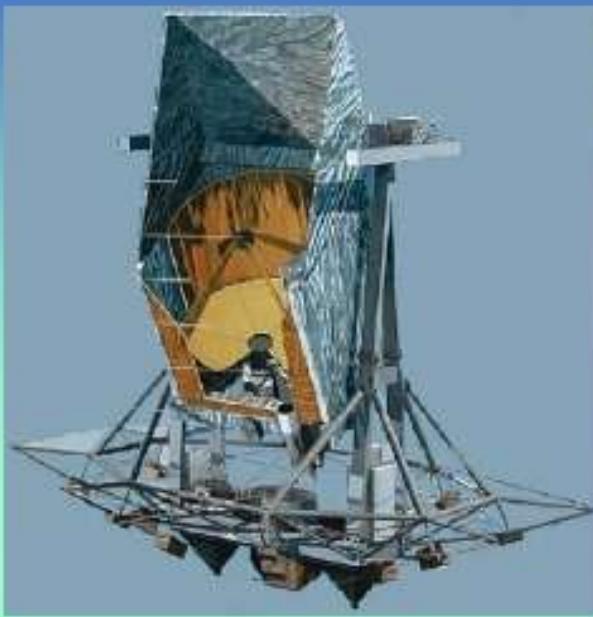


Dust: sub-mm emissivity

- dust properties appear to change already at modest extinction: **sub-mm excess**
 - formation of aggregate grains and/or icy dust mantles
- e.g. PRONAOS observations

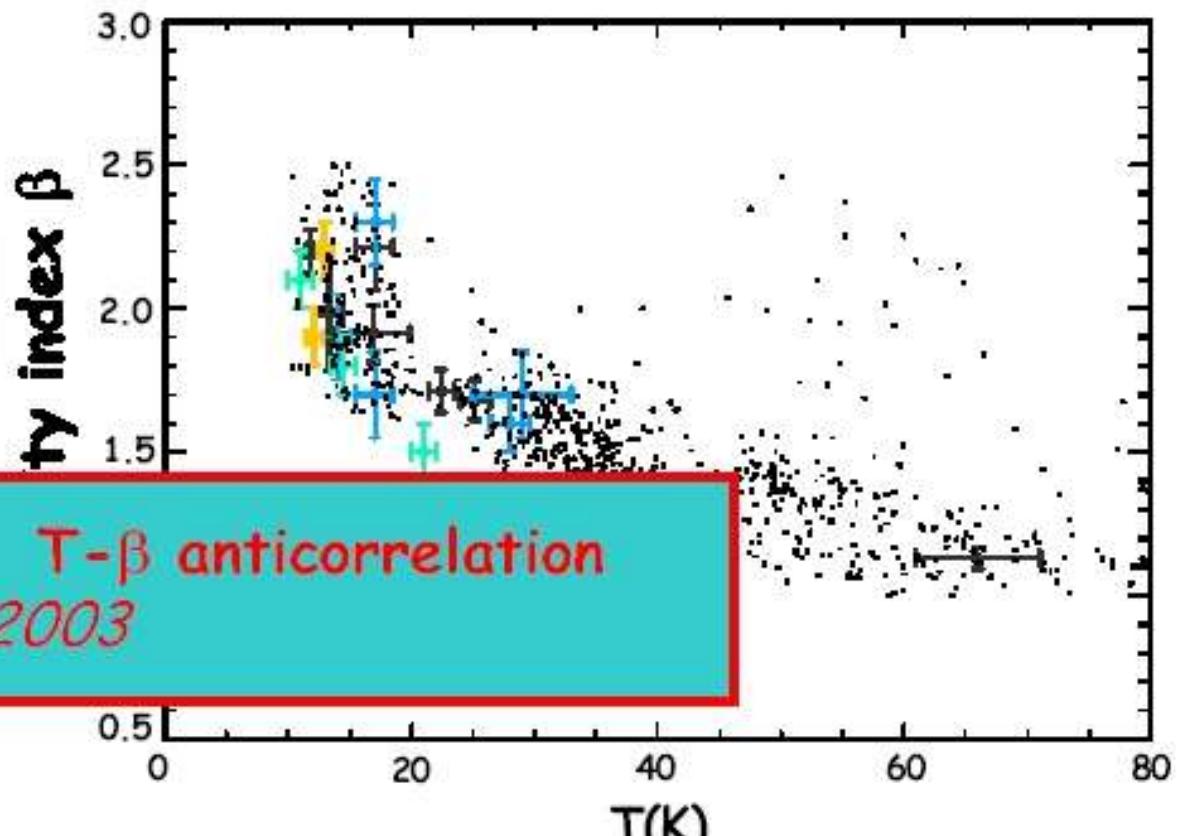


1st observational fact : synthesis over PRONAOS observations



PRONAOS measured the emission of the MIS grain component radiating at thermal equilibrium

$$I_\lambda = \tau_\lambda \cdot B_\lambda(T) = K \cdot Q_{\text{abs}}(\lambda) \cdot B_\lambda(T) = C \cdot \lambda^{-\beta} \cdot B_\lambda(T)$$



A significant $T-\beta$ anticorrelation
Dupac et al., 2003

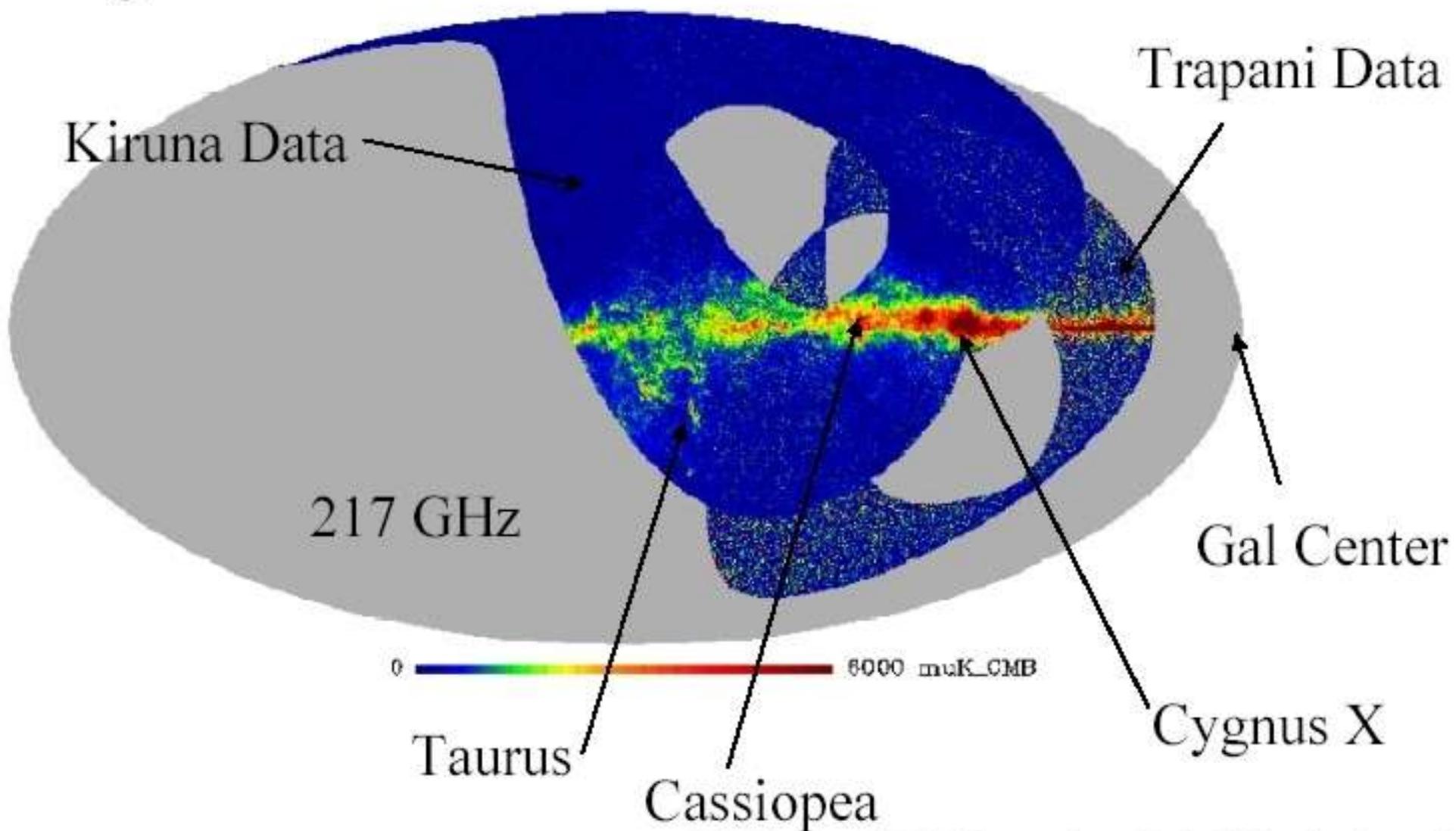
(Dupac et al., ApJ 2001), (Dupac et al., A&A 2002)

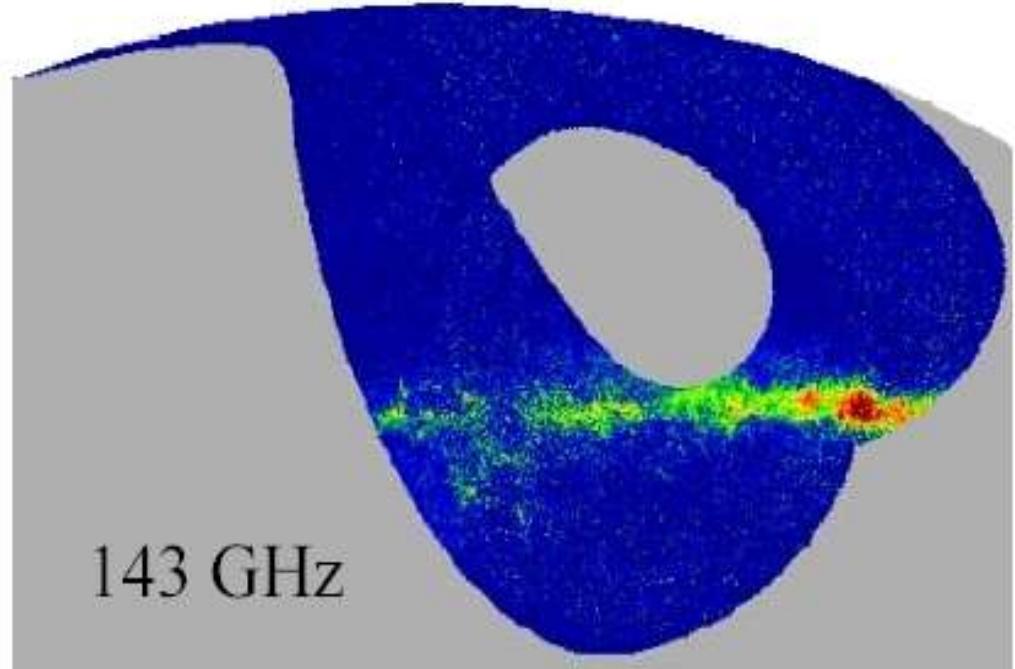
Dust: mm excess

- Archeops data have shown another peculiar feature: spectral index changes around 1mm => **mm-excess**



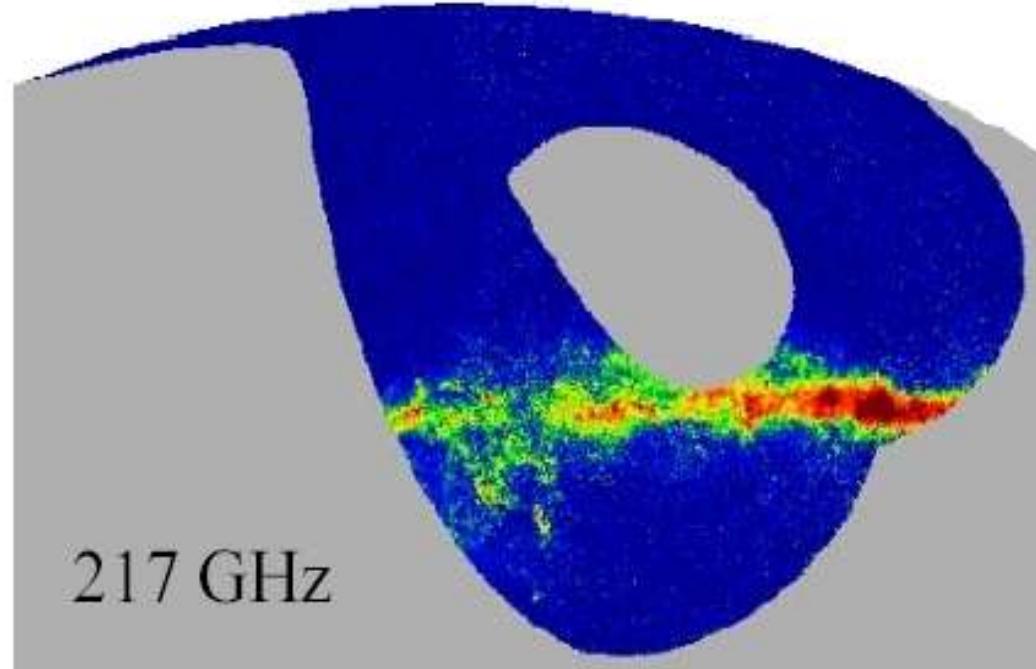
- Trapani 99 : Technological flight.
Strong parasitic signal -> filtering applied to the data.
- Kiruna 02: Full focal plane. Much better S/N.
- Angular resolution 10-20'





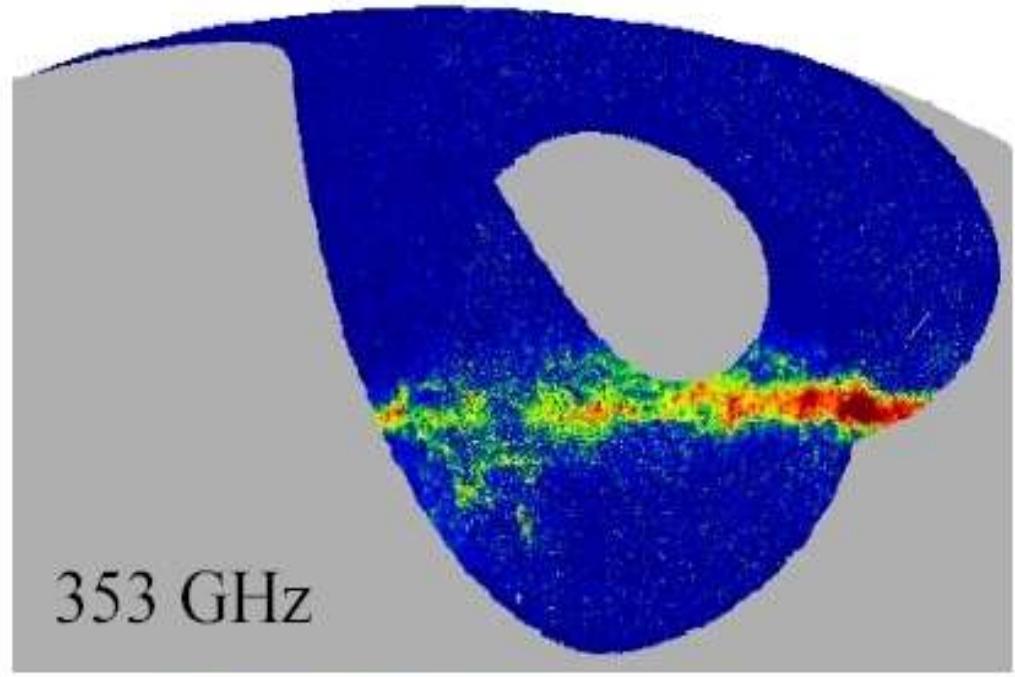
143 GHz

0 ————— 4000 μK_{CMB}



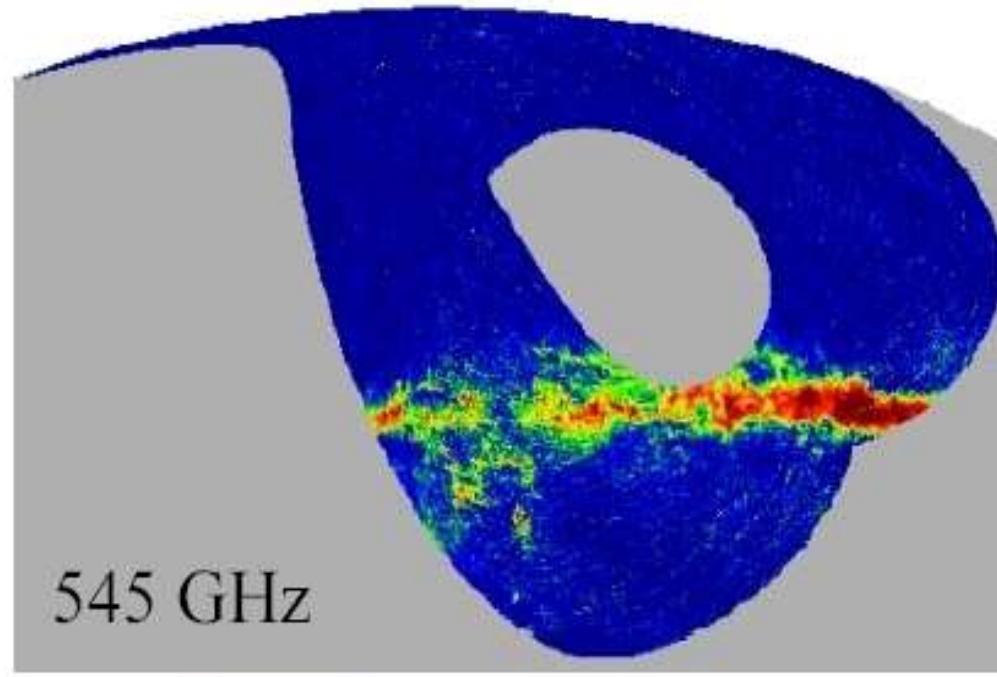
217 GHz

0 ————— 6000 μK_{CMB}



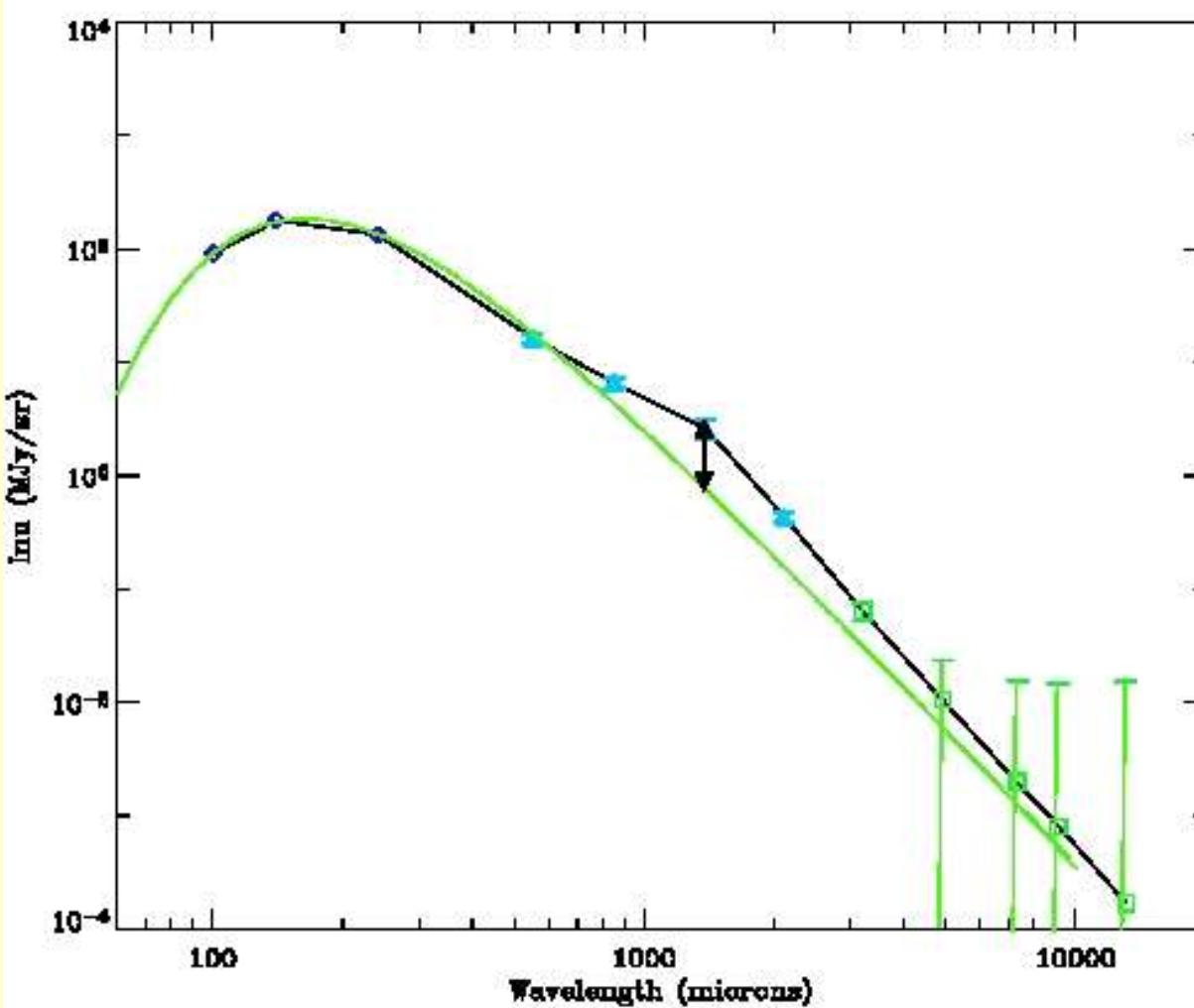
353 GHz

0 ————— 30000 μK_{CMB}



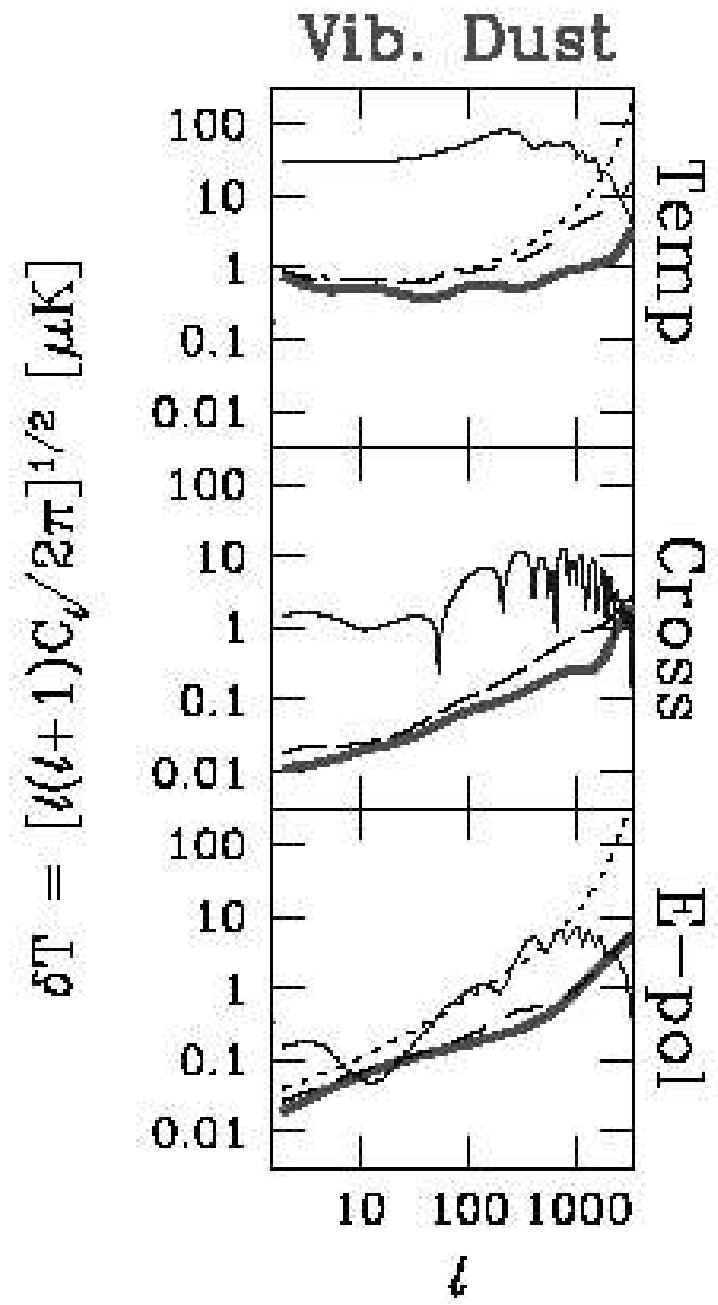
545 GHz

0 ————— $3.00 \times 10^5 \mu\text{K}_{\text{CMB}}$
J.P. Bernard, WG7 meeting, Jodrell Bank, June 30th 03



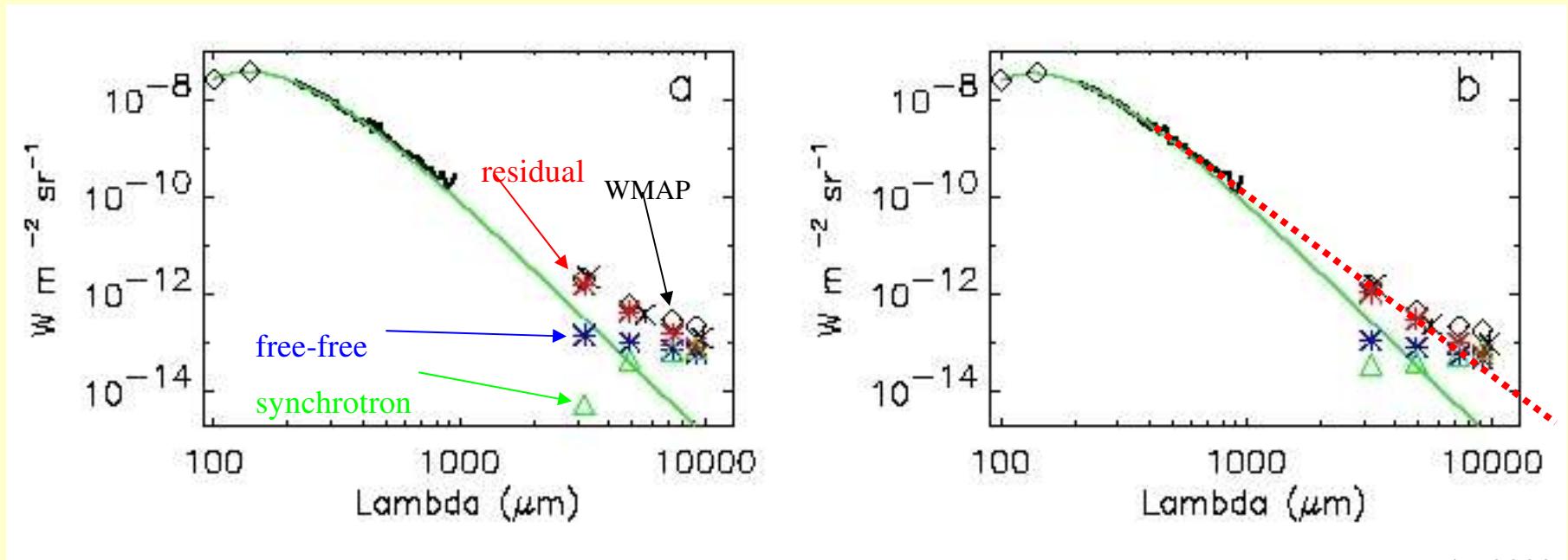
- Excess is not really a surprise:
 - Reach et al. 95
 - Finkbeiner et al. 99
 - Bourdin et al. 2000
 - Galiano et al 2003
- Attributed to very cold dust:
(5-7 K)
- but
 - Archeops and WMAP data constrain the spectrum at $\lambda > 1$ mm
 - Archeops angular resolution allows to analyze the spatial distribution of the excess.





Anomalous microwave emission

- emission between 10 and 100GHz
 - exceeds the intensity expected from free-free and synchrotron emission
 - evidence is (~) convincing but the explanation is so far uncertain

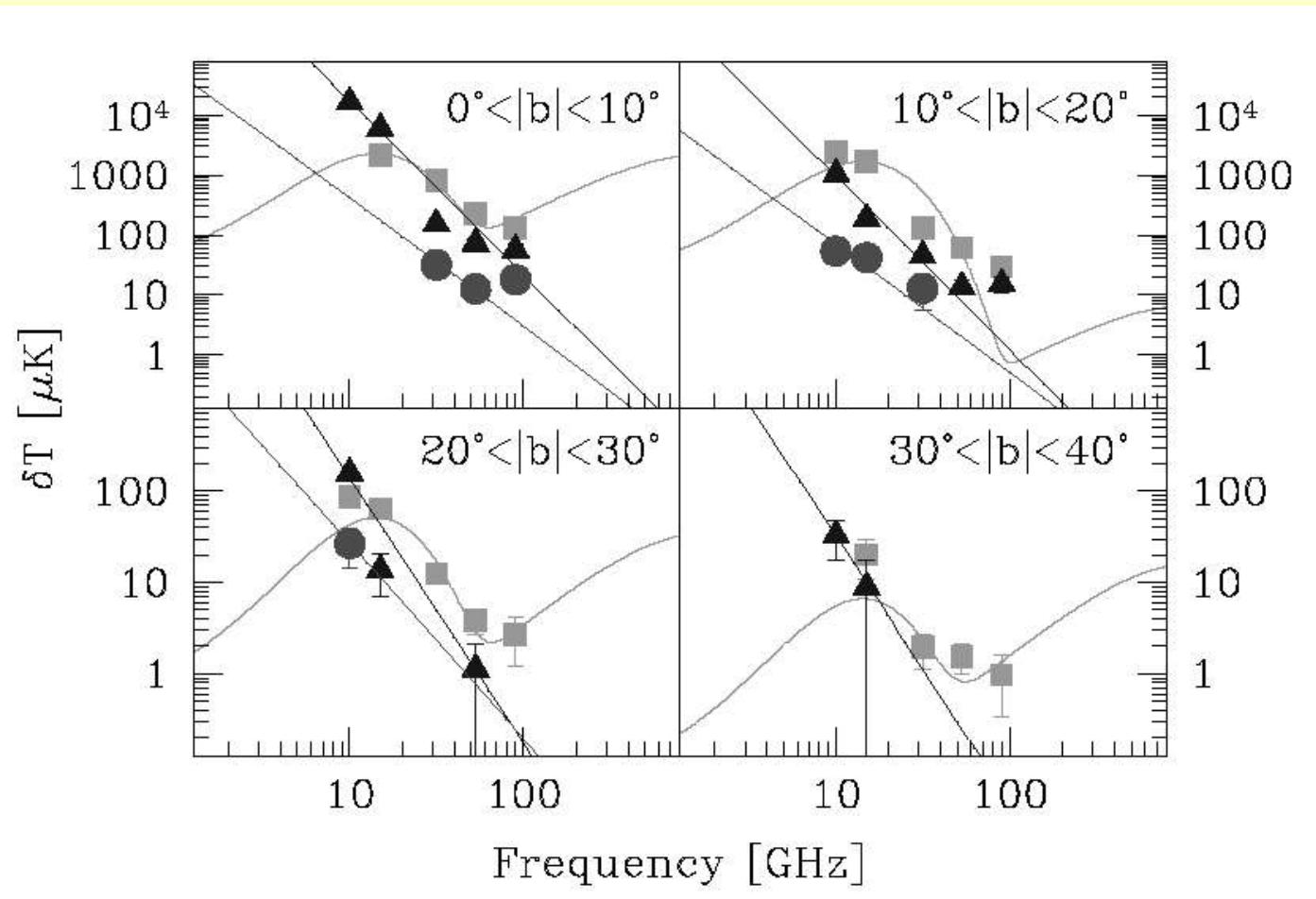


Lagache 2003



Anomalous microwave emission

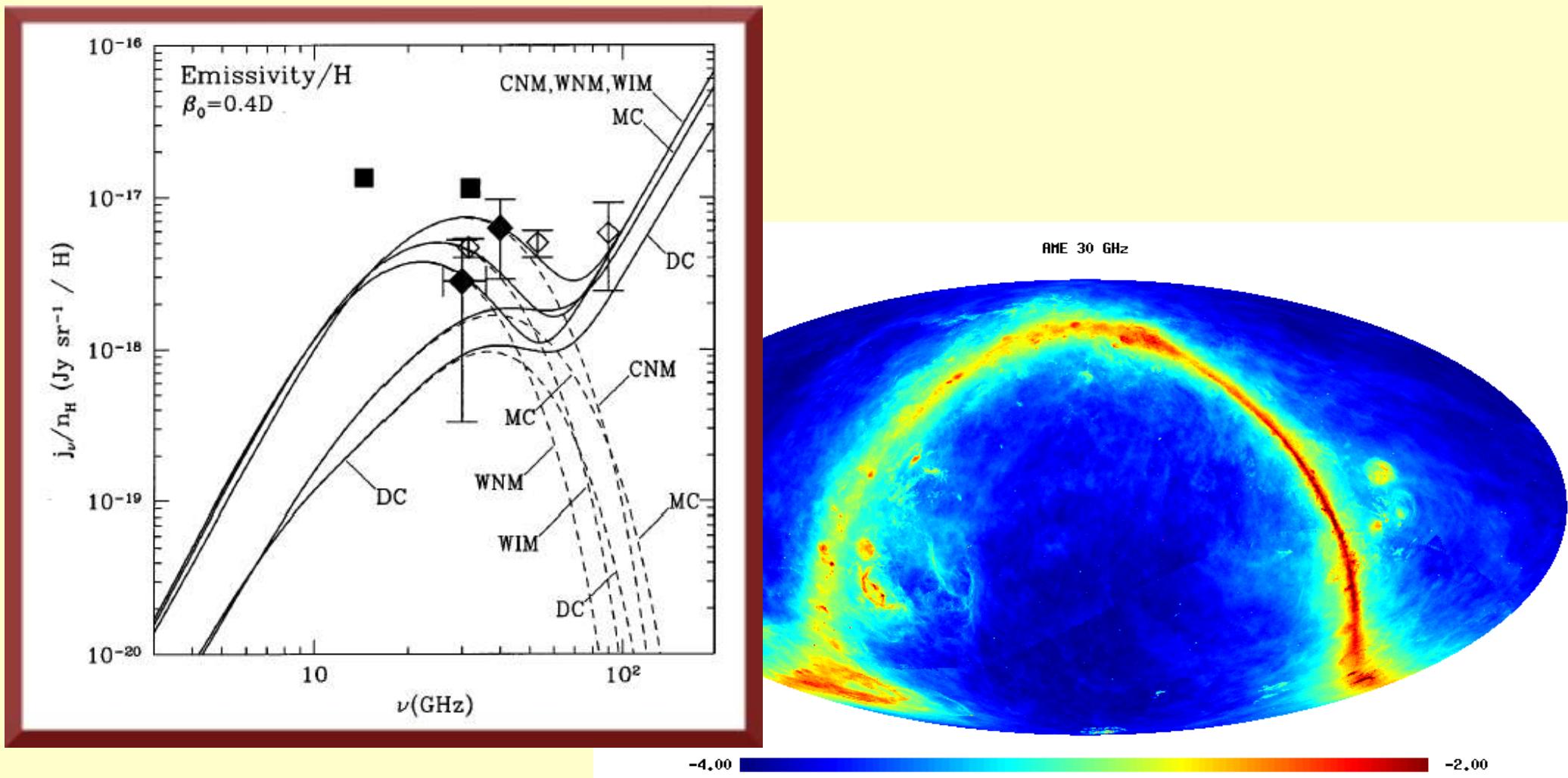
de Oliveira-Costa et al. (2002): Tenerife 10, 15GHz & DMR



- dust correlated emission
- ▲ synchrotron
- free-free

Anomalous microwave emission

- one possible explanation: emission from spinning, very small dust grains (Draine & Lee 1998)

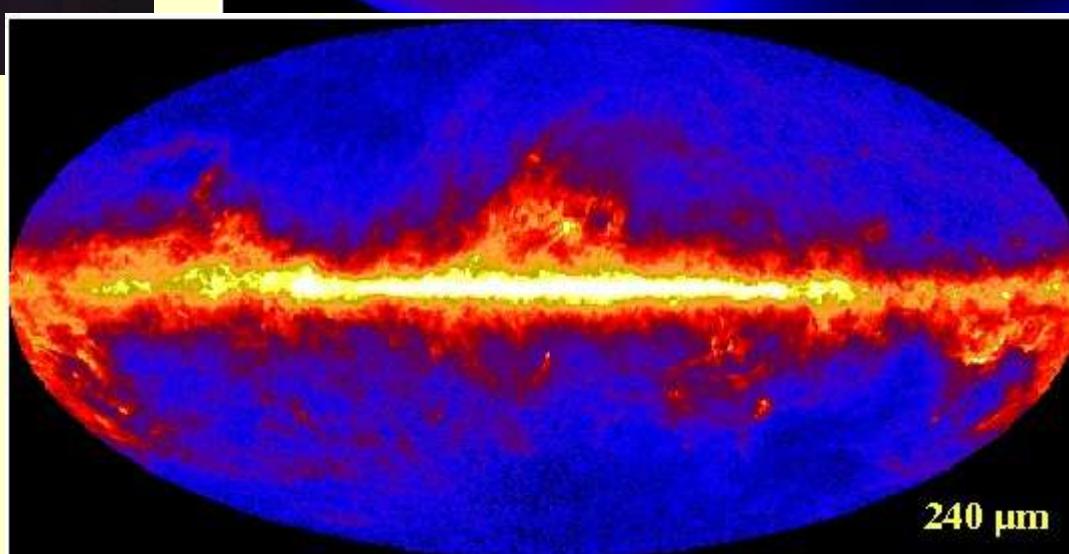


Solar system

- **planets**
- only a few hundred **asteroids** will be detected by Planck
 - still, an asteroid in about 30% of all sky circles
- additionally some of the brighter **comets**
- possible signal from interplanetary dust: the **zodiacal light**
 - a function of direction and time !
 - simulations do exist (long extrapolation in λ ...)



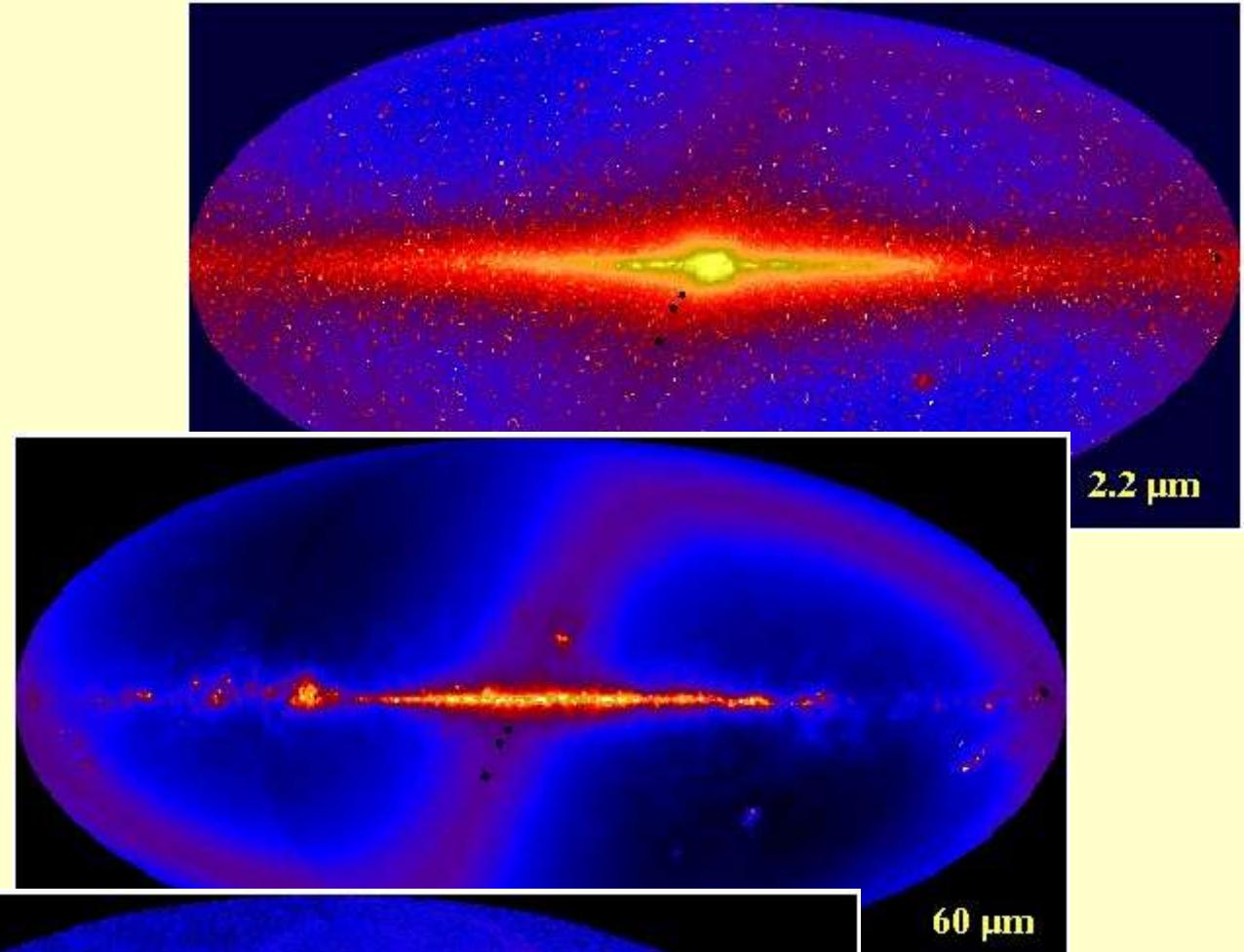
© David Malin



Mika Juvela,
Helsinki University Observatory



Galactic Foregrounds
3.6.2004



Component Separation

- component separation algorithms based on
 - known **spectral** dependence of the components
 - ... for most part an extrapolation from lower or higher frequencies
 - **spatial** distribution
 - spatial power spectra or template maps
 - ... varying spectral indices, extrapolation to smaller spatial scales, extrapolation in frequency
 - point sources mostly known
 - ... extrapolation in frequency
 - ... variable sources, new classes of sources



Summary of Galactic components

- synchrotron
 - extrapolation from low frequencies
- free-free
 - extinction corrected H α observations
- dust emission
 - extrapolation from high frequencies
- vibrational dust emission
 - detection + some theoretical predictions
- planets, asteroids, zodiacal light
 - ZL: long extrapolation from high frequencies

