### Astro 6: class 3

Friday, November 1, 2013

### hot things give off light: blackbody radiation





The cosmic microwave background Radiation's "surface of last scatter" is analogous to the light coming through the clouds to our eye on a cloudy day.

We can only see the surface of the cloud where light was last scattered

TEMP.

90

### First (1990) detailed measurement of the cosmic microwave background (CMB): COBE (J. Mather, Swarthmore '66)



#### the temperature of the CMB across the sky is uniform



### COBE (early 1990s) - first detailed map of the CMB at several wavelengths, and over the whole sky



## going from raw observations to a measurement of the CMB

"Aitoff projection" - this is the sphere of the sky, as seen from the Earth's surface. The coordinate system is centered on the Galaxy



## going from raw observations to a measurement of the CMB

"Aitoff projection" - this is the sphere of the sky, as seen from the Earth's surface. The coordinate system is centered on the Galaxy



### COBE (early 1990s) - first detailed map of the CMB at several wavelengths, and over the whole sky



# COBE (early 1990s) - first detailed map of the CMB at several wavelengths, and over the whole sky

DIRBE 1.25, 2.2, 3.5 µm Composite



# COBE (early 1990s) - first detailed map of the CMB at several wavelengths, and over the whole sky



## COBE (early 1990s) - first detailed map of the CMB the contributions from the galaxy and the solar system can be removed



## COBE (early 1990s) - first detailed map of the CMB the contributions from the galaxy and the solar system can be removed



### COBE (early 1990s) - first detailed map of the CMB this is the dipole Doppler shift signal



### COBE (early 1990s) - first detailed map of the CMB this is the dipole Doppler shift signal



## COBE (early 1990s) - first detailed map of the CMB this is the residual CMB signal (after all the foreground subtractions)

#### DMR's Two Year CMB Anisotropy Result



## COBE (early 1990s) - first detailed map of the CMB these fluctuations in brightness are at the 1 part in 100,000 level

#### DMR's Two Year CMB Anisotropy Result





WMAP 5 year ILC



### inferred local $T_{CMB}$ from temperatures of gas clouds



as we look further away (and further back in time) the CMB is hotter