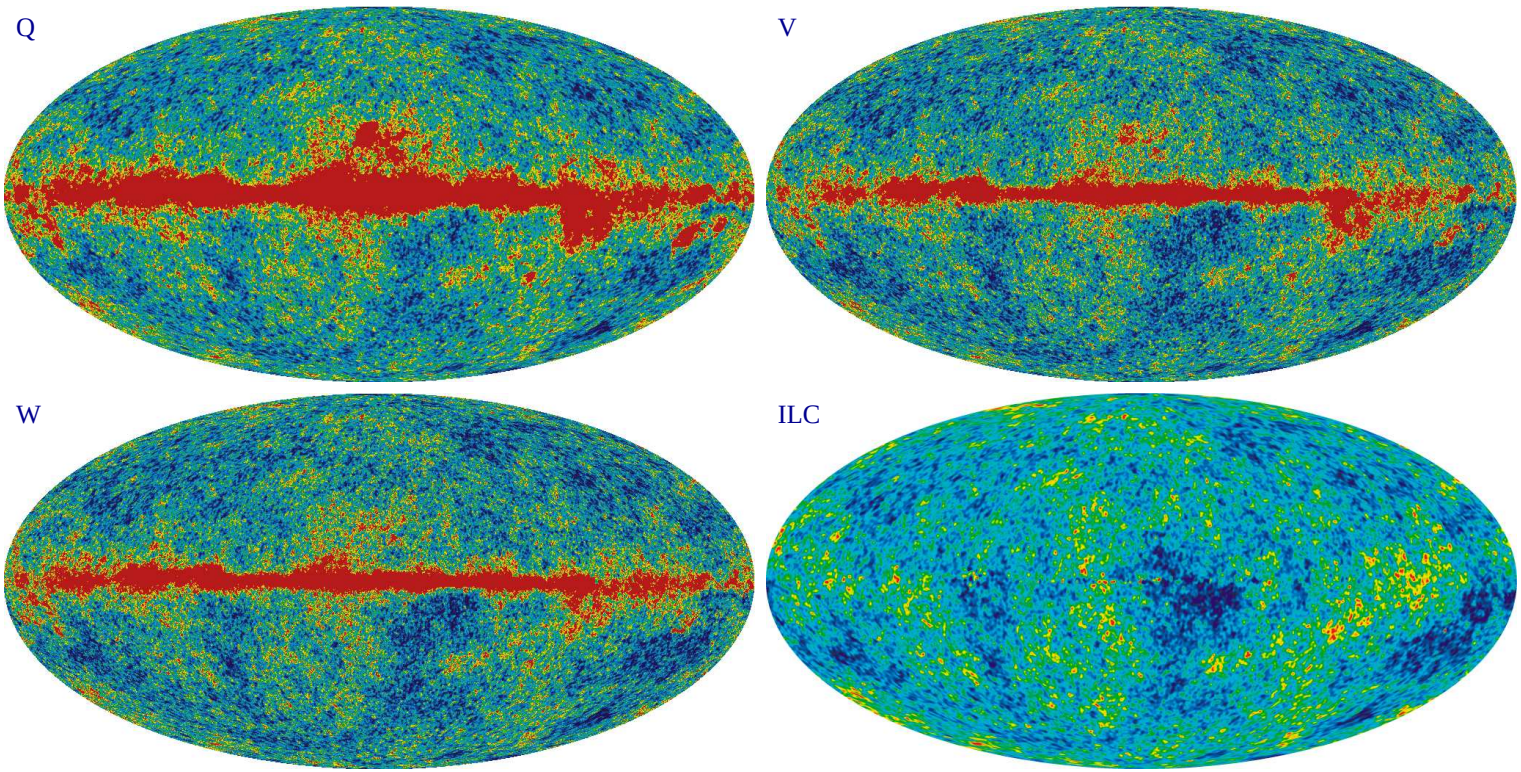
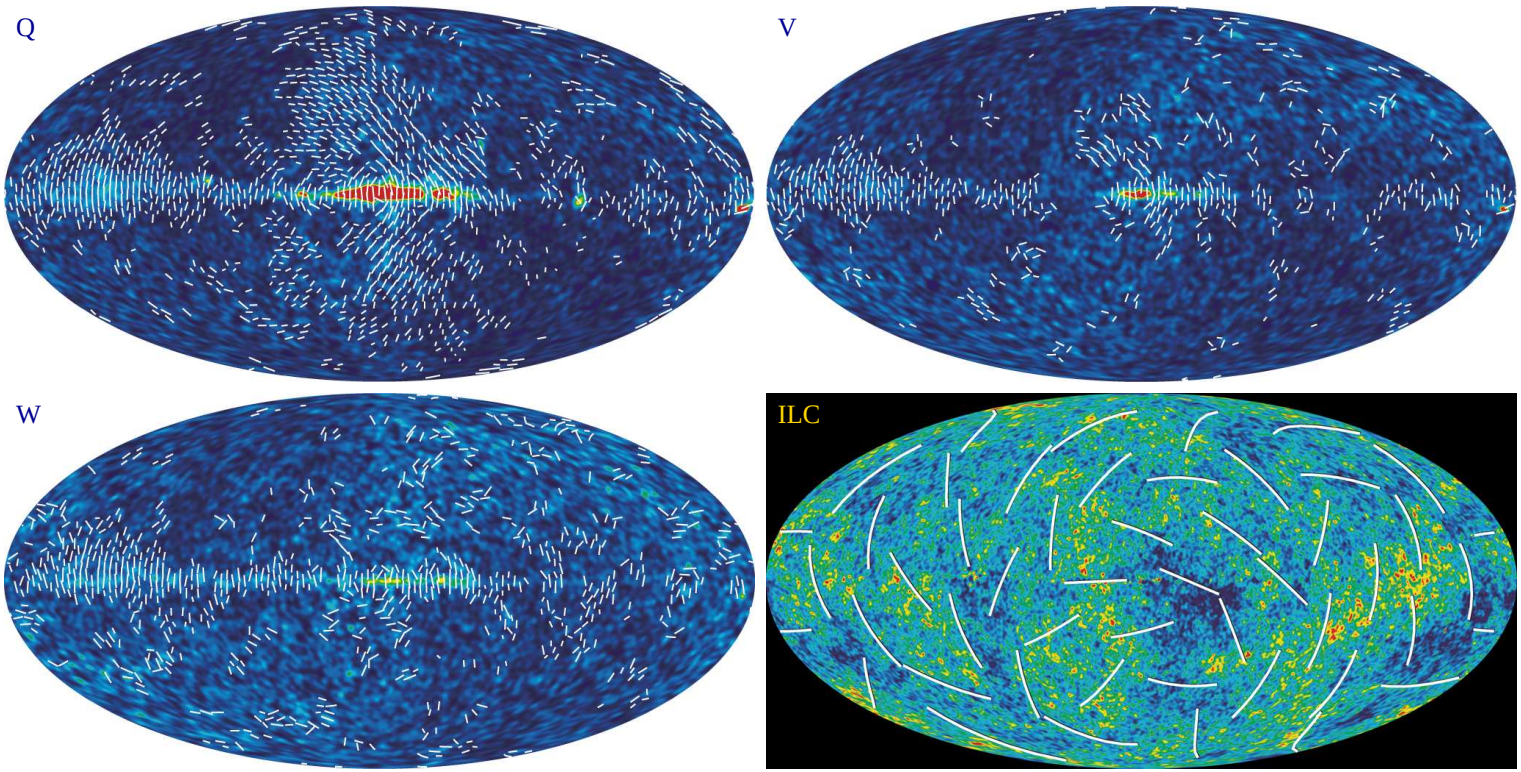
CMB OBSERVATIONS: WMAP 3yr DATA.

WMAP Temperature Data.



WMAP Polarization Data.



CMB Temperature Field.

♠ The basic observable of the CMB is its intensity as a function of frequency and direction on the sky $\hat{n}$.

♠ The CMB spectrum is an extemely good blackbody (Fixsen et al, ApJ 1996) with a nearly constant temperature across the sky.

♠ The temperature field is generally described in terms of its fluctuation:

$$\frac{\Delta T}{T_o}(\hat{n}) = \frac{T(\hat{n}) - T_o}{T_o} = \sum_{lm} a_{lm} Y_{lm}(\Omega_{\hat{n}}) \qquad \Longleftrightarrow \qquad a_{lm} = \int d\Omega_{\hat{n}} Y^*_{lm} \frac{\Delta T}{T_o}(\hat{n})$$

♠ If the temperature fluctuations are Gaussian, multipole moments are fully characterized by their power spectrum:

$$\langle a^*_{lm} a_{l'm'} \rangle = \delta_{ll'} \delta_{mm'} C_l$$

How accurately can the spectra be measured?.

♣ Models of structure formation predict the power spectrum of the radiation field, C_l. For each l we have $2l+1$ independent measurements. If the a_{lm}'s are Gaussian distributed, an optimal and unbiased estimate of the power at each l is:

$$C_l = \frac{1}{2l+1}\sum_{m=-l}^{m=+l}|a_{lm}|^2 \qquad \text{with rms} \qquad \Delta C_l = \sqrt{\frac{2}{2l+1}}C_l^{CMB}$$

The error introduced by having only $2l+1$ independent samples of power at each multipole moment is known as **Cosmic Variance**.

♣ If we average the power at different l in bands of width $\Delta l \approx l$, the error in the band-power is further reduced by a factor $l^{-1/2}$: the error on a band of width $(50-150)$ centered on $l=100$ is $\sim 1\%$.

♣ Any source of noise, astrophysical or instrumental, increases the errors. If the noise is also Gaussian, with a known power spectrum then $\Delta C_l \sim C_l^{CMB} + C_l^N$.

♣ If the experiment does not sample the whole sky but only a fraction f_{sky}, then the errors increase by a fraction $f_{sky}^{-1/2}$. The resulting variance

$$\Delta C_l = \sqrt{\frac{2}{(2l+1) f_{sky}}} (C_l^{CMB} + C_l^N)$$

is known as **Sample Variance**.

Radiation Power Spectrum.