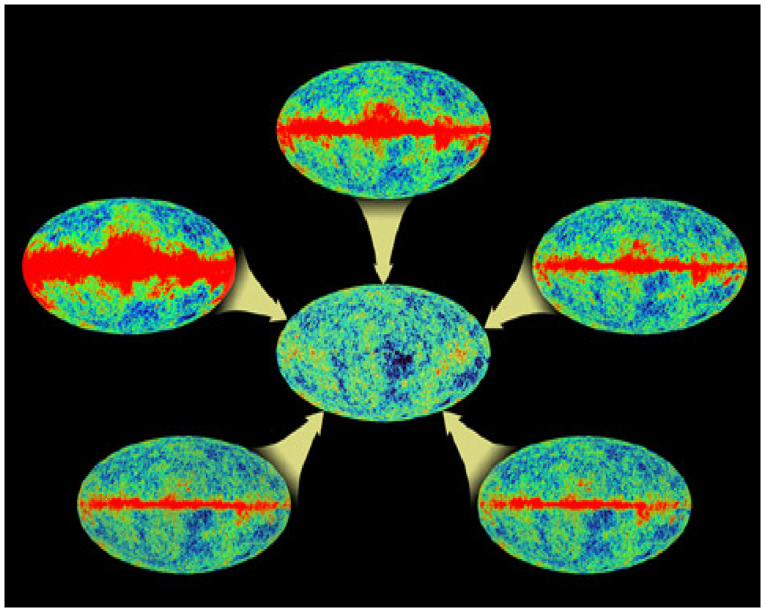
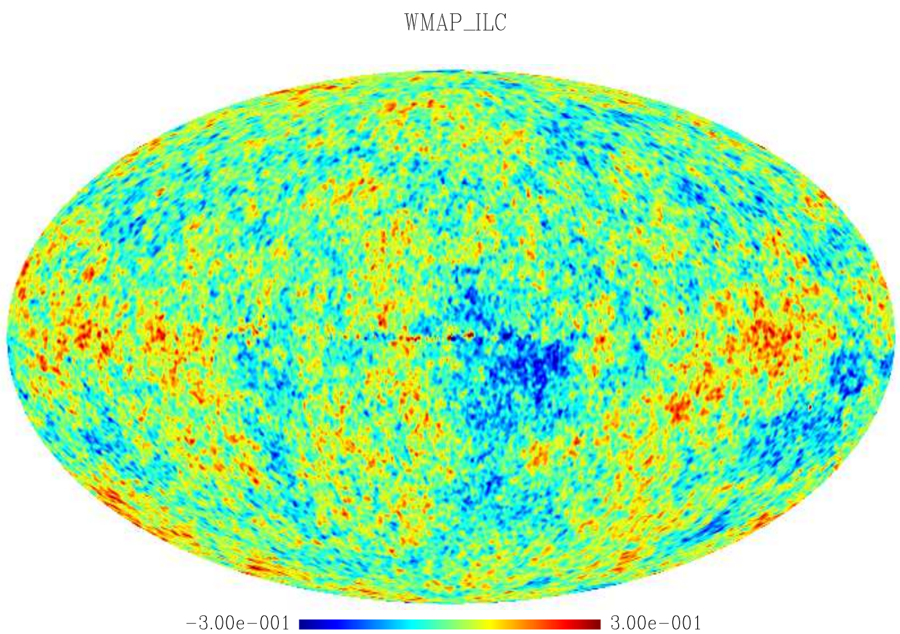
Correlating anomalies:

the Cold Spot and the North-South asymmetry

Armando Bernui
Grupo de Cosmologia Observacional, INPE



$\longrightarrow$



Cosmic Microwave Background (CMB) radiation from WMAP-5yr data

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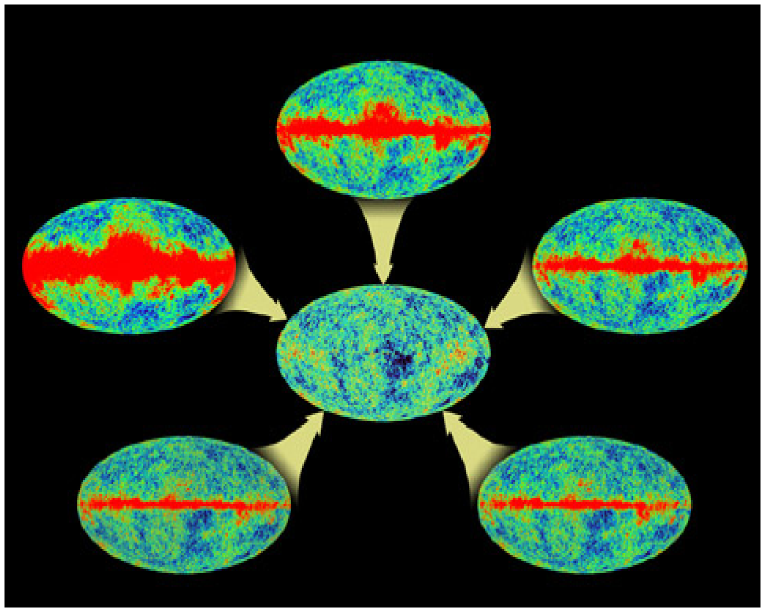

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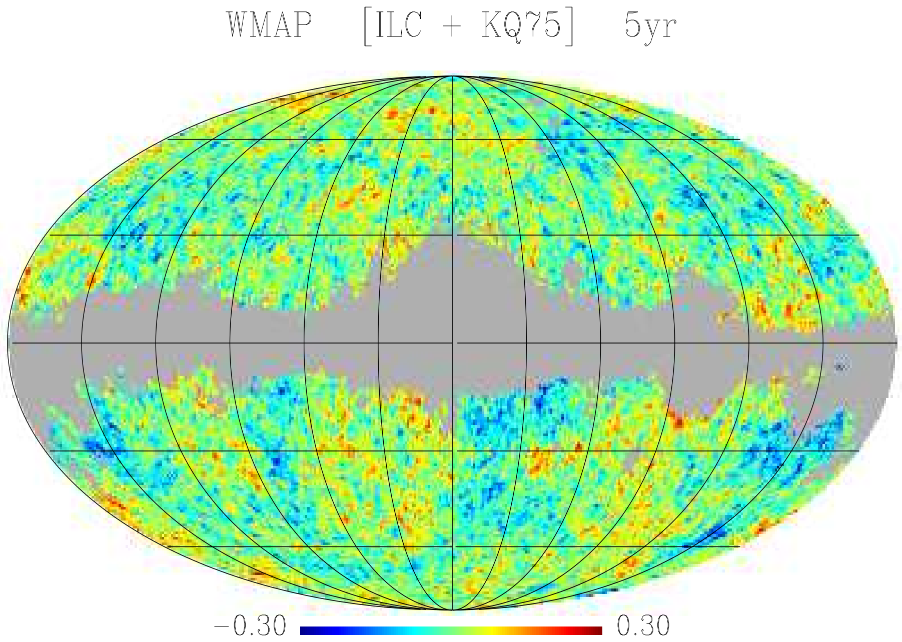
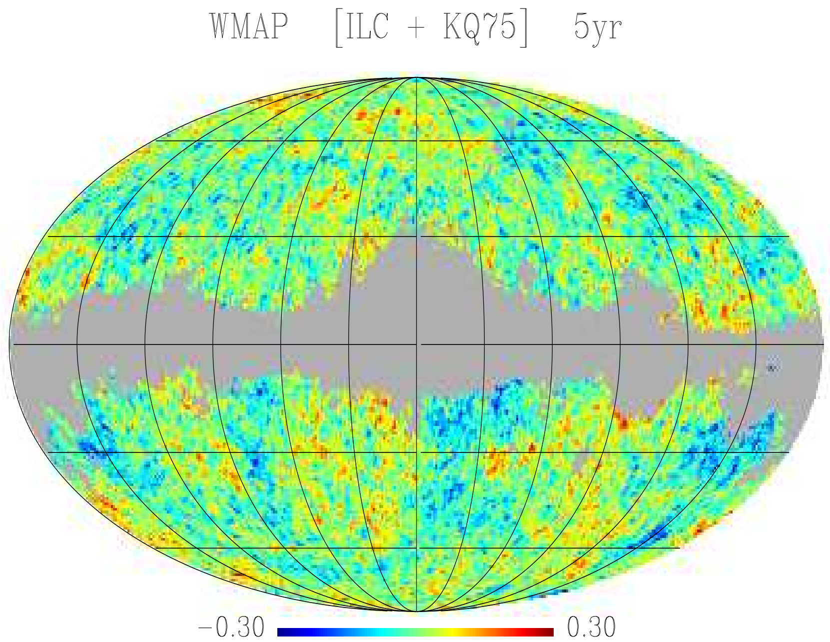


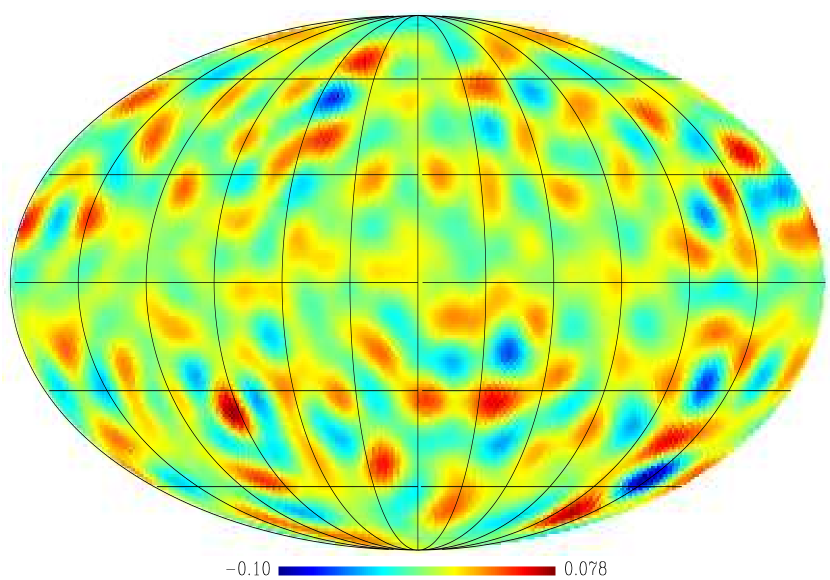
Cosmic Microwave Background (CMB) radiation from WMAP-5yr data

O Cold Spot nos mapas da RCF do WMAP

- O Cold Spot (CS) é uma mancha anomalamente fria nos mapas do WMAP. Descoberta a través de análises da **kurtosis** em escalas angulares $5^\circ - 10^\circ$. Ele é inconsistente, at $> 99\%$ CL, com mapas RCF simulados Gaussianos.
- Pelo seu tamanho, o CS é melhor observado nas escalas $\ell = 11 - 20$; está centrado em ($b = -57^\circ$, $l = 209^\circ$), e tem um raio de $\sim 8^\circ$.



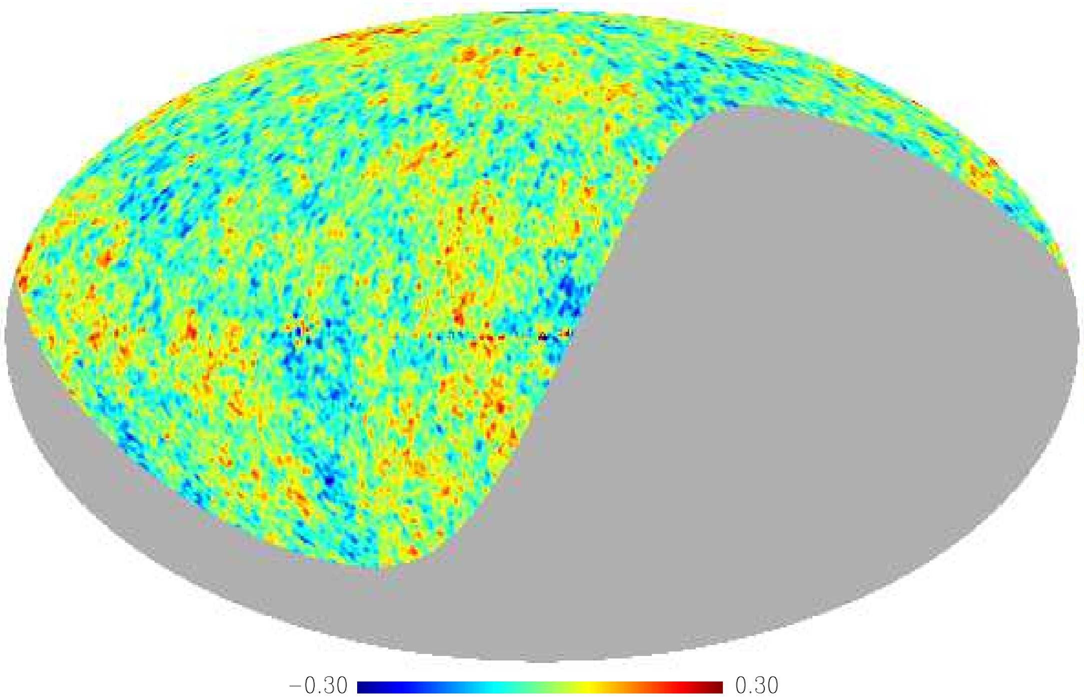
multipolos RCF: $\ell = 2 - 1024$

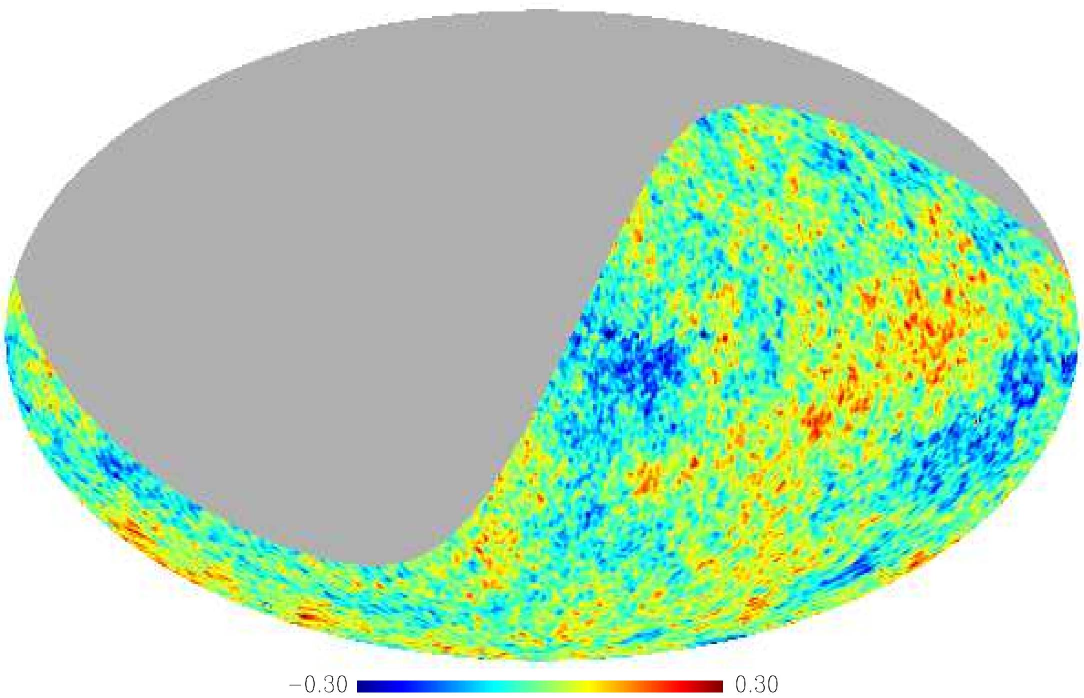


multipolos RCF: $\ell = 11 - 20$

A assimetria Norte-Sul (NS-asymmetry):

refere-se à diferentes intensidades nas correlações angulares nos hemisférios:



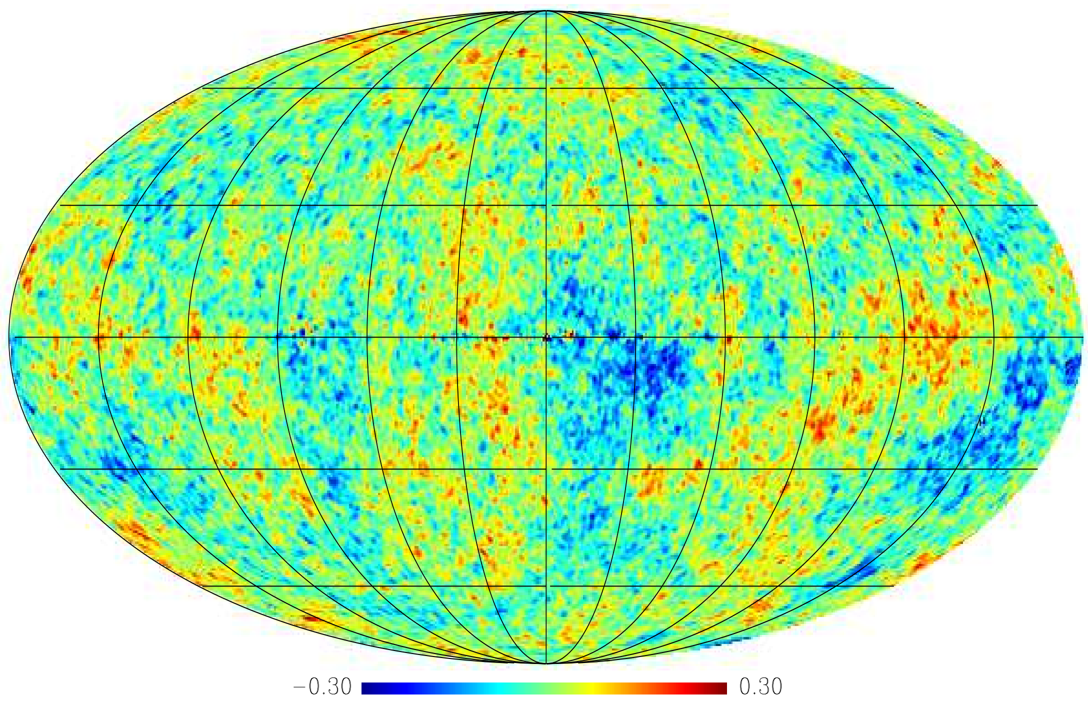


o qual é inconsistente, at $> 96\%$ CL, com Universos estatíst. isotrópicos.

Estarão correlacionados estes 2 fenômenos (CS & NS-asymmetry)?

Análise da distribuição angular: SIGMA-maps

Para medir correl. angs. definimos a transf. $\sigma : \Delta T(\theta,\phi) \to \sigma(\theta,\phi)$



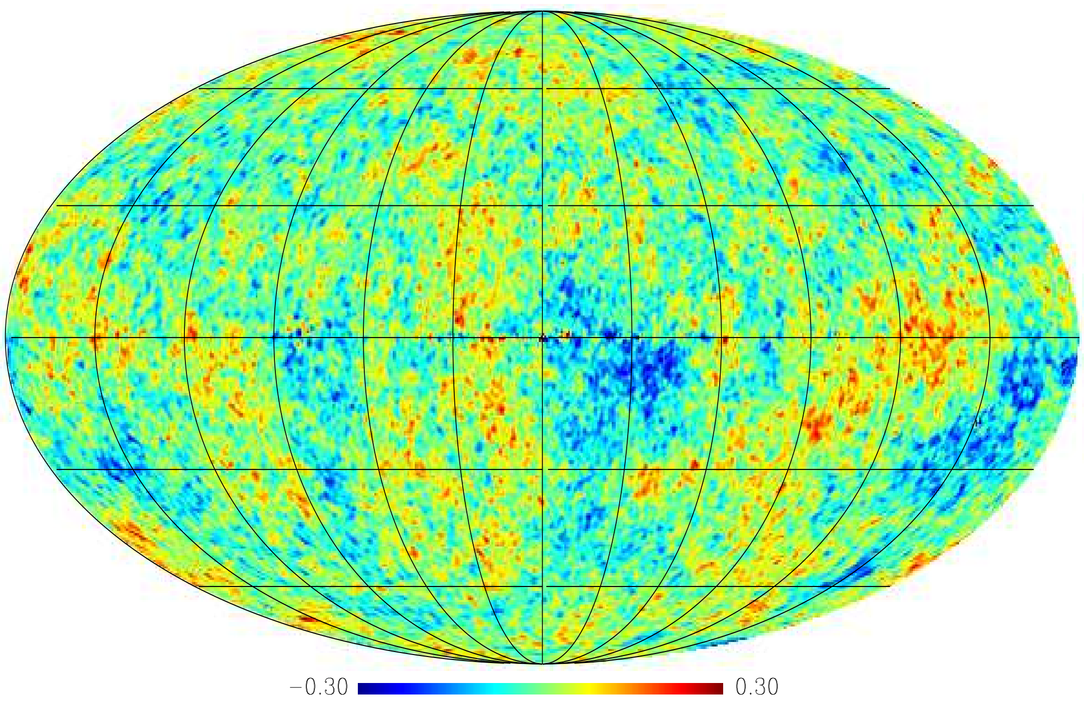
ΔT

$\sigma_j^2 \equiv \frac{1}{N_{\mathbf{bins}}} \Sigma_{k=1}^{N_{\mathbf{bins}}} [\mathrm{C}(\gamma_k)^j]^2$, **onde** $\gamma_k \in [(k-1)\delta,\ k\delta]$, $\mathrm{C}(\gamma)^j \equiv \langle\, \Delta T(\theta_i,\phi_i) \Delta T(\theta_{i'},\phi_{i'})\,\rangle$,

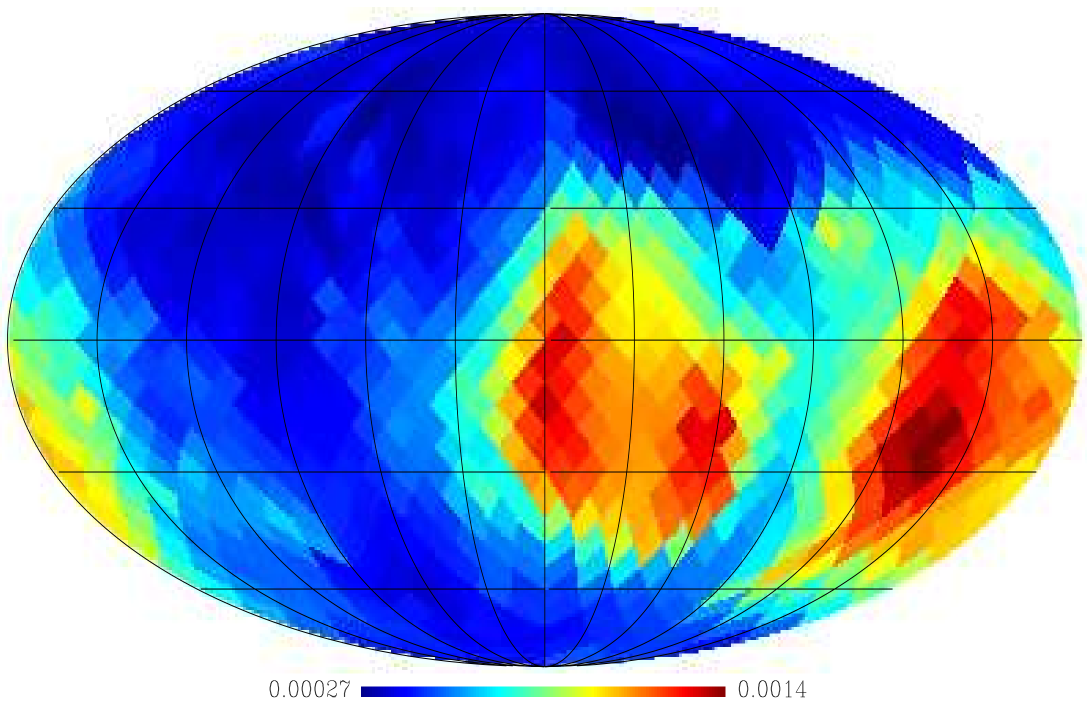
$\cos\gamma = \cos\theta_i \cos\theta_{i'} + \sin\theta_i \sin\theta_{i'} \cos(\phi_i - \phi_{i'})$: σ_j **é uma medida das correlações angs.**

Análise da distribuição angular: SIGMA-maps

assim encontramos o Sigma-map (i.e. a transf. do mapa de temp.):



ΔT



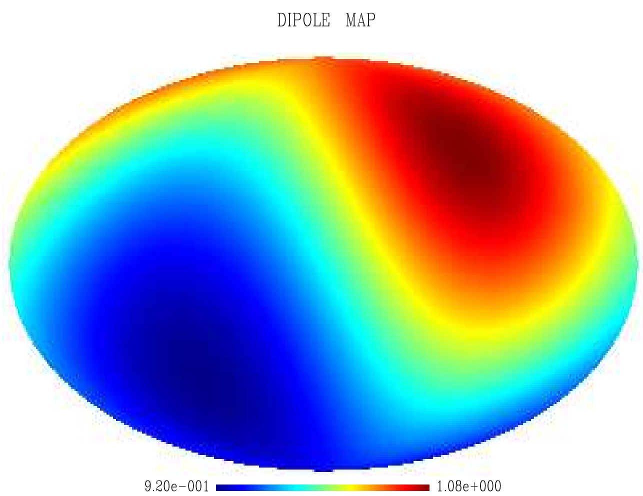
$\sigma = \{\sigma_j\}$

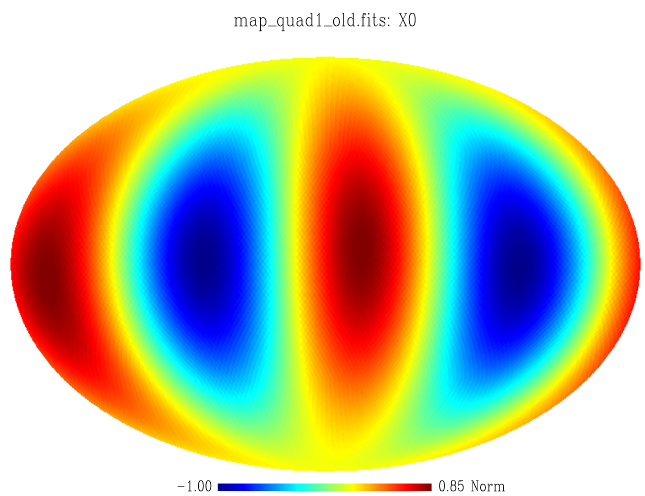
$\sigma_j^2 \equiv \frac{1}{N_{\mathbf{bins}}} \Sigma_{k=1}^{N_{\mathbf{bins}}} [\mathrm{C}(\gamma_k)^j]^2$, **onde** $\gamma_k \in [(k-1)\delta,\ k\delta]$, $\mathrm{C}(\gamma)^j \equiv \langle\, \Delta T(\theta_i, \phi_i) \Delta T(\theta_{i'}, \phi_{i'})\, \rangle$,

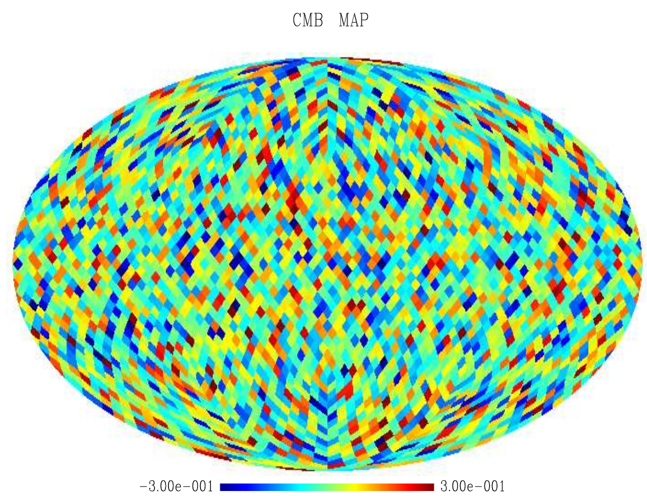
$\cos\gamma = \cos\theta_i \cos\theta_{i'} + \sin\theta_i \sin\theta_{i'} \cos(\phi_i - \phi_{i'})$: σ_j **é uma medida das correlações angs.**

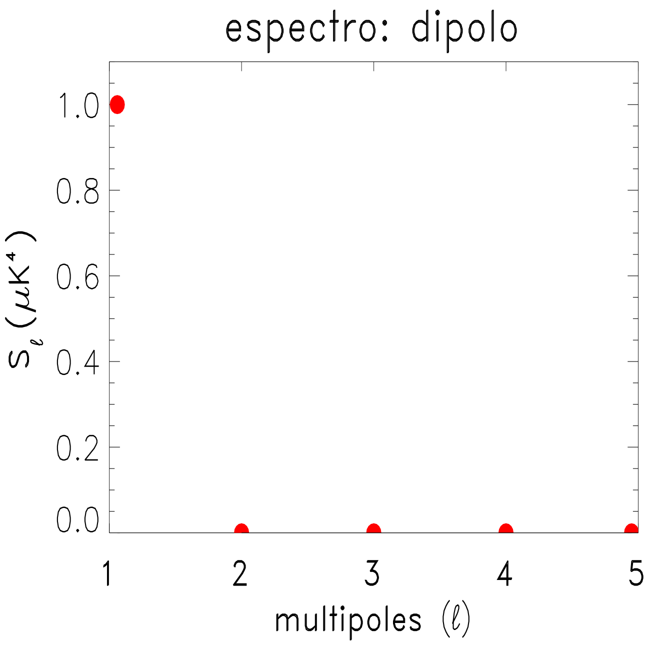
Análise espectral de mapas coloridos:

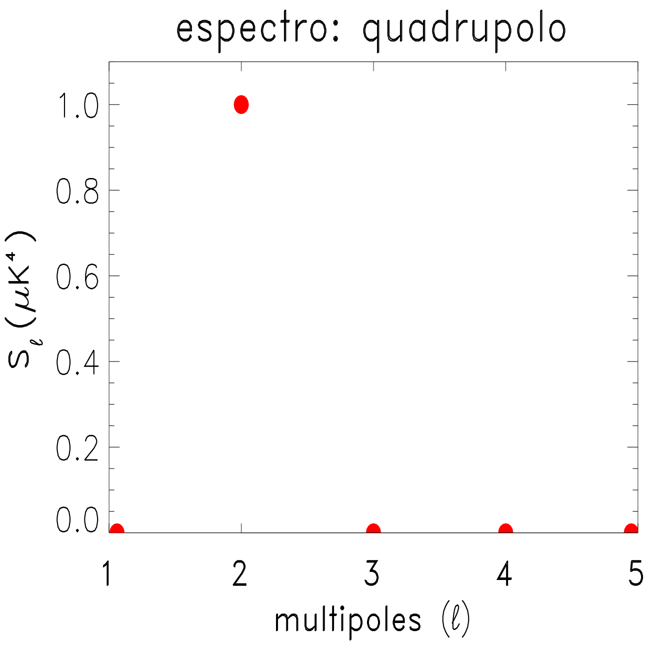
dipolo, quadrupolo, estat. isotrópico, ...

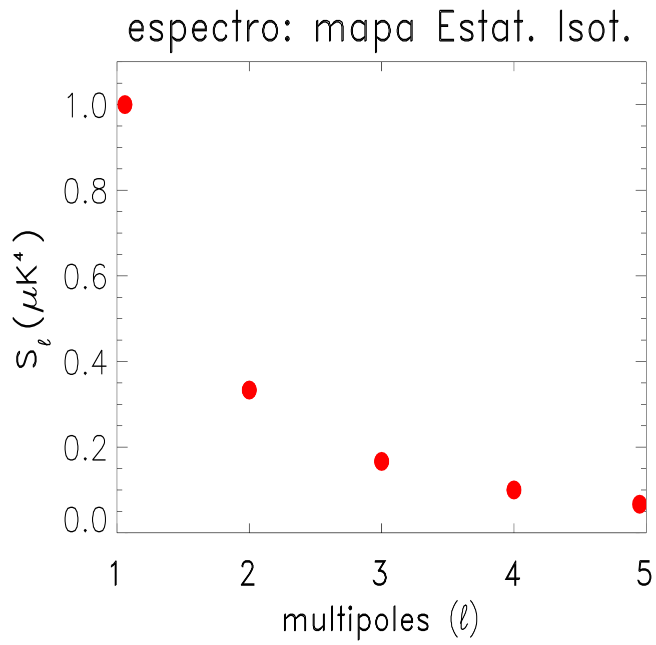






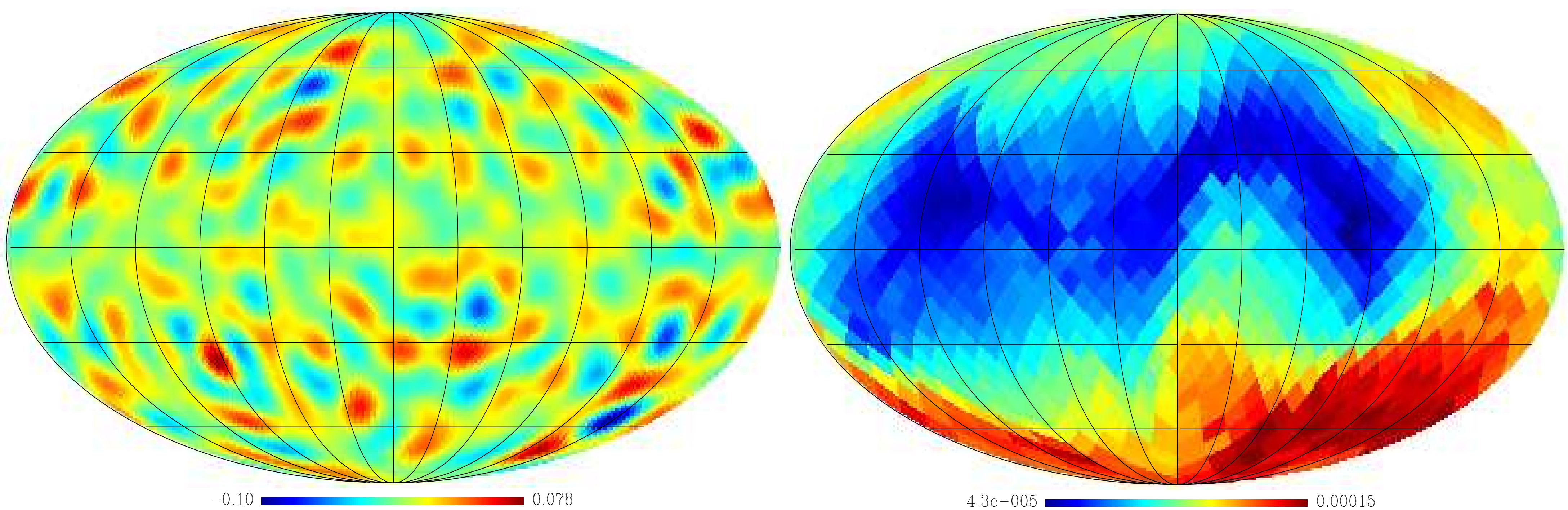






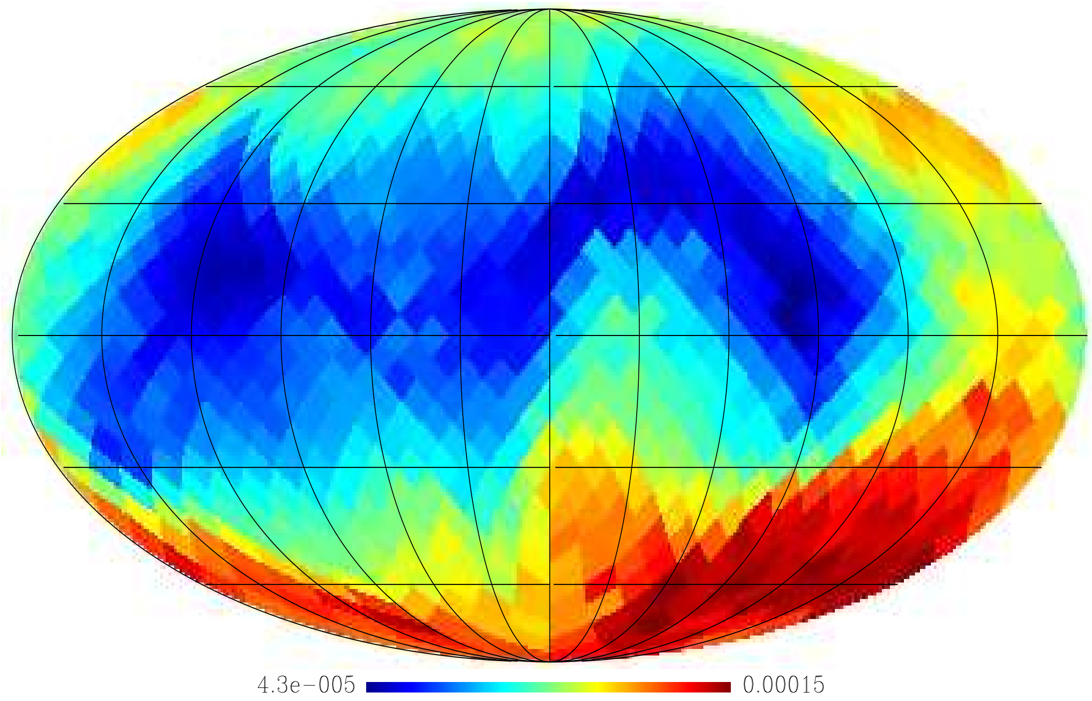
Análise da distribuição angular: SIGMA-map

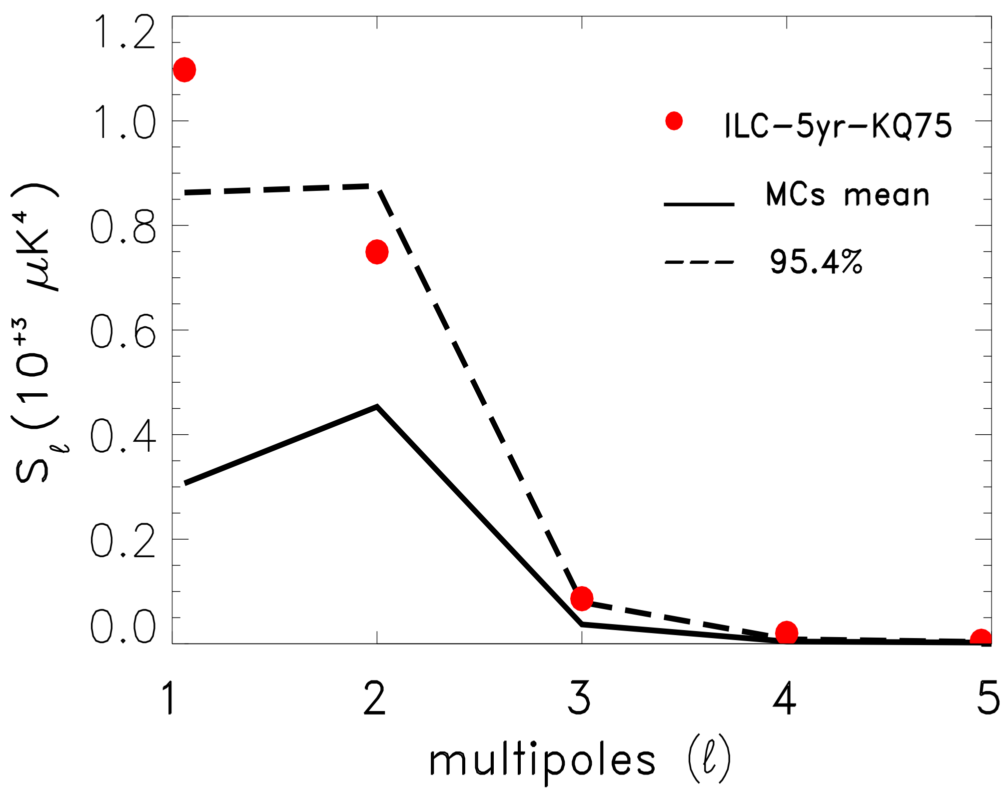
Vejamos o caso das flutuações de temperatura da RCF na escala angular $\ell = 11 - 20$**:**



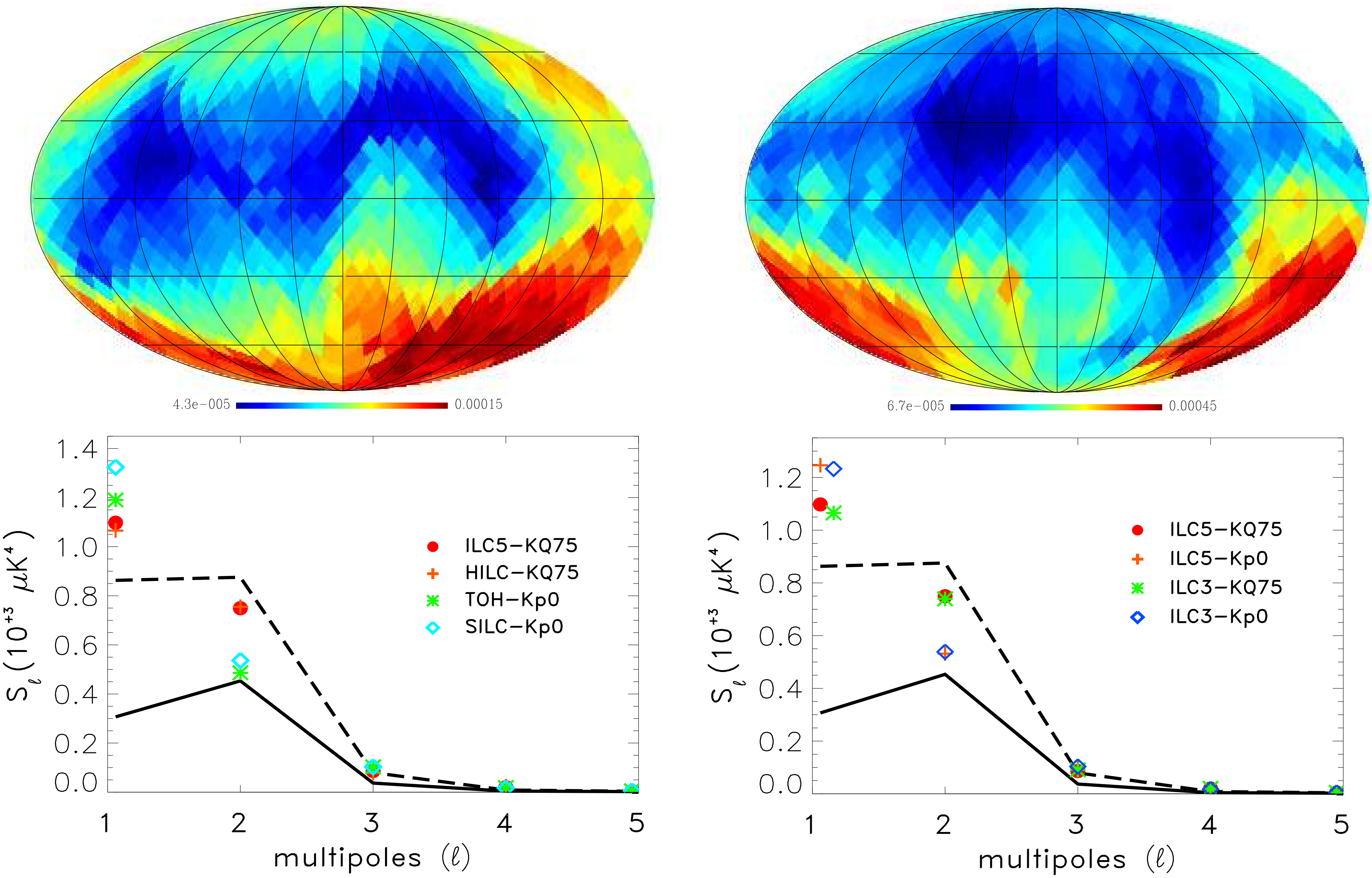
ΔT**:** $\ell = 11 - 20$ $\qquad$ $\sigma = \{\sigma_j\}$

Resultados: análise espectral do Sigma-map

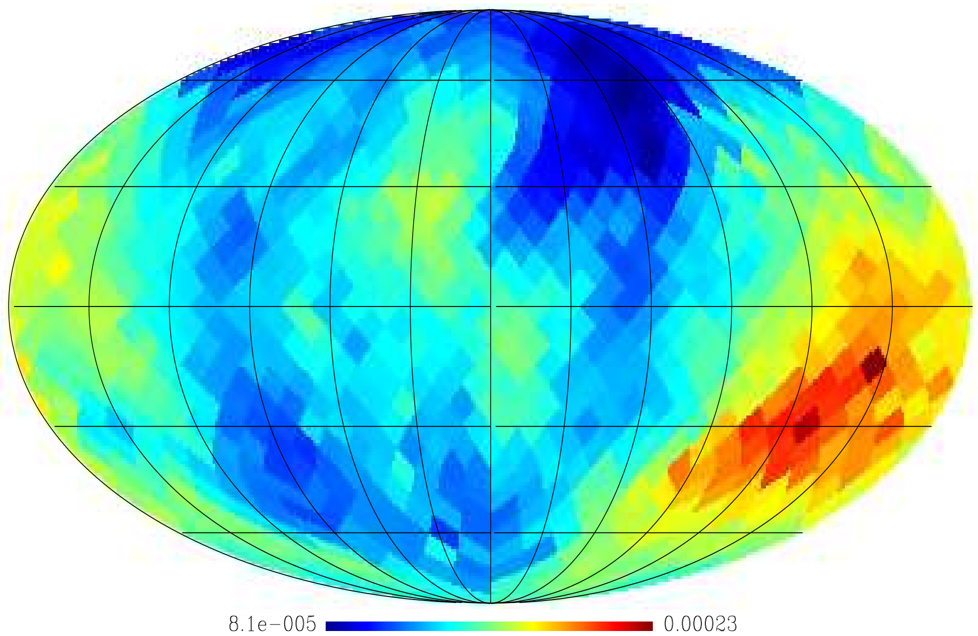


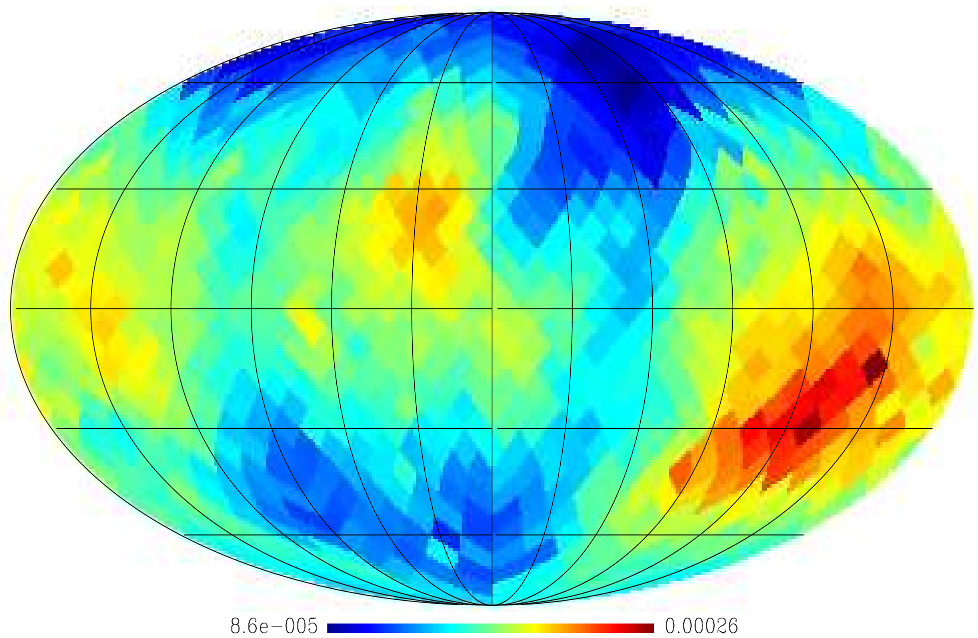


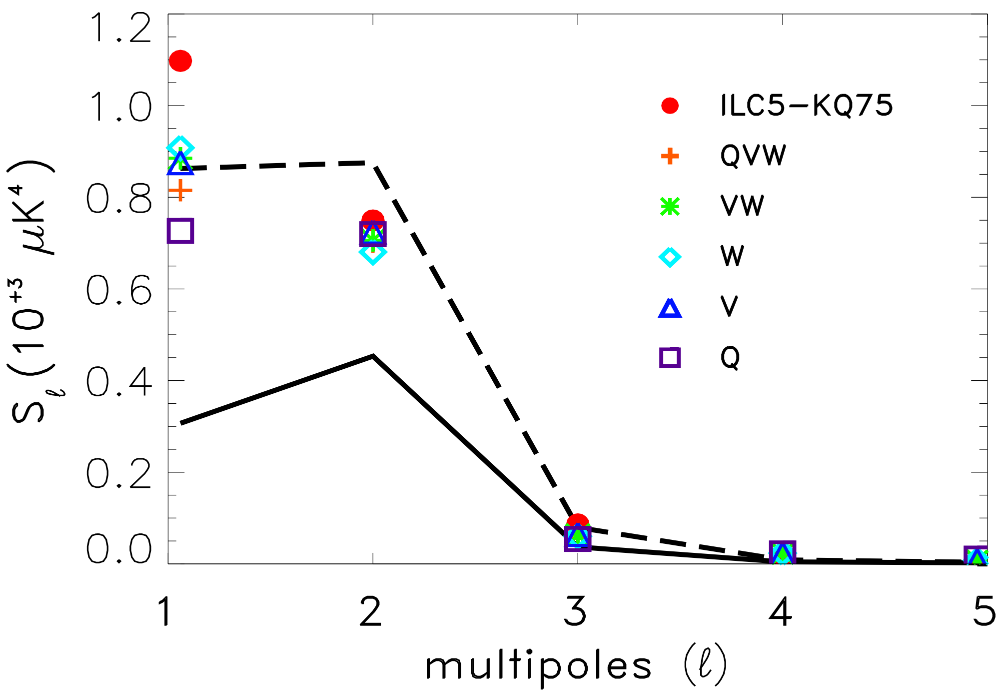
Resultados: análise espectral do Sigma-map: KQ75 vs. Kp0

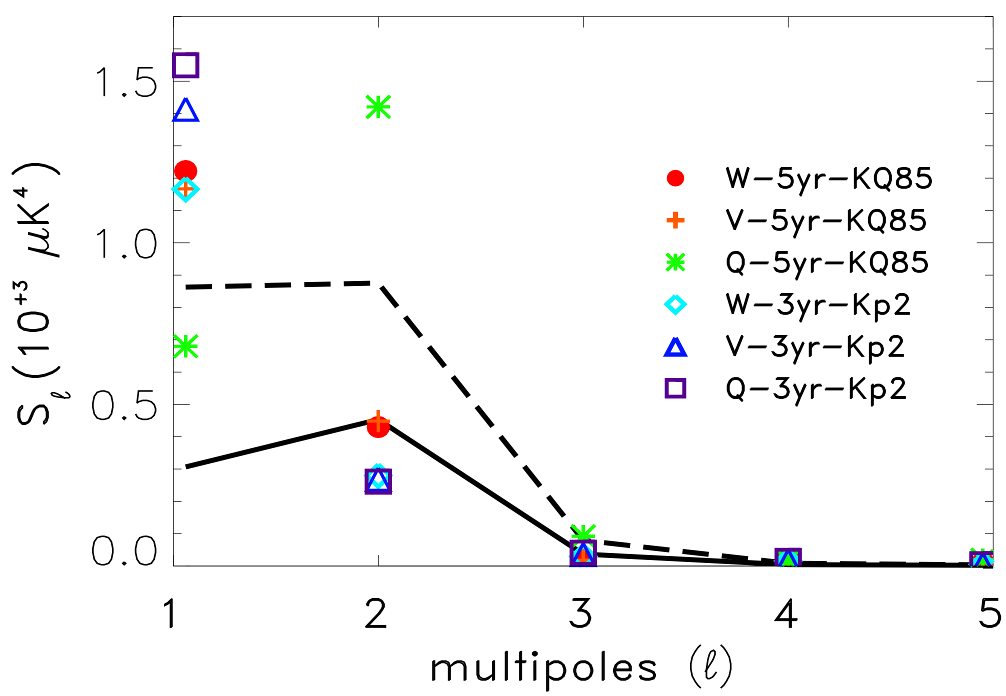


Resultados: análise espectral do Sigma-map: **QVW & Q, 3yr & 5yr**

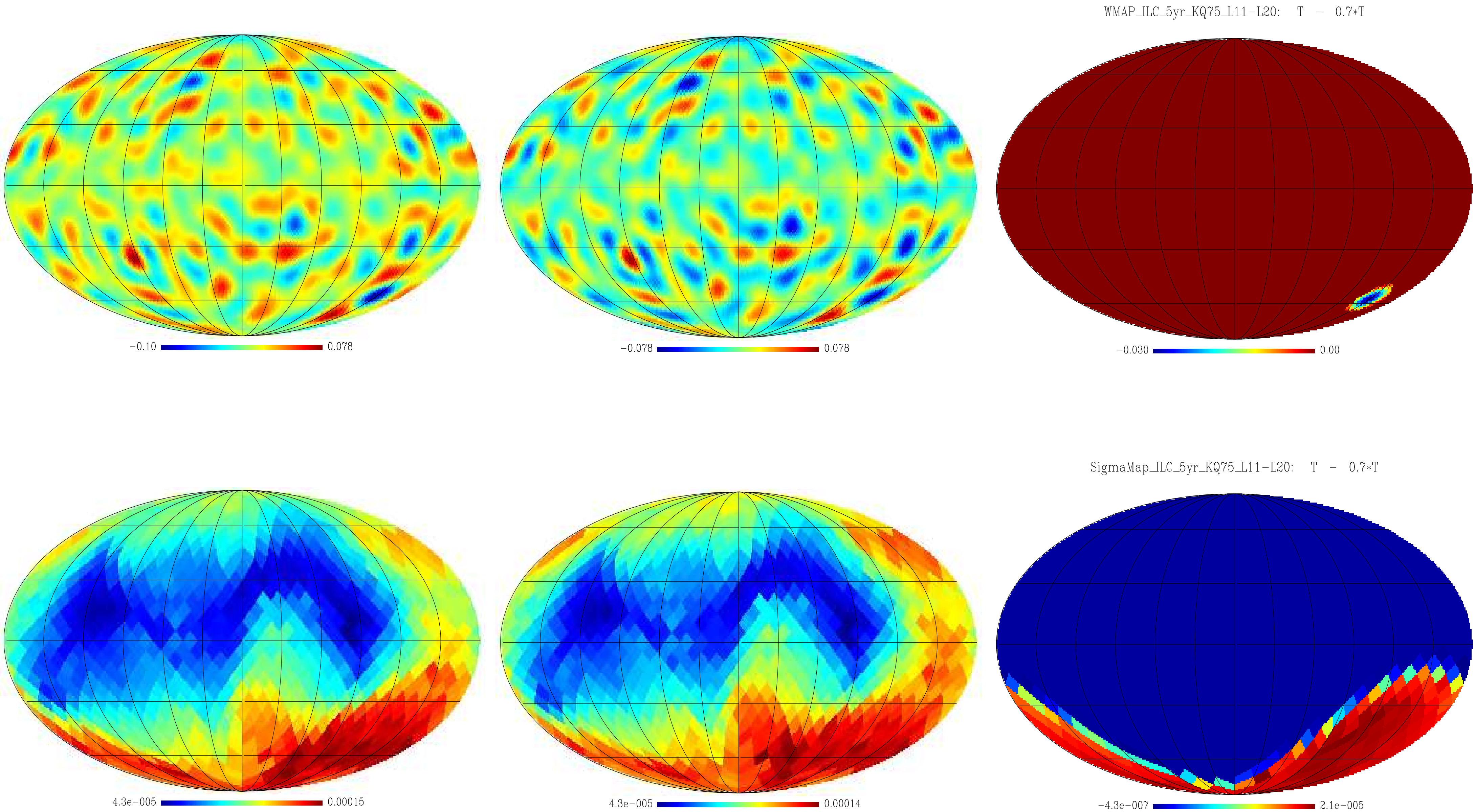




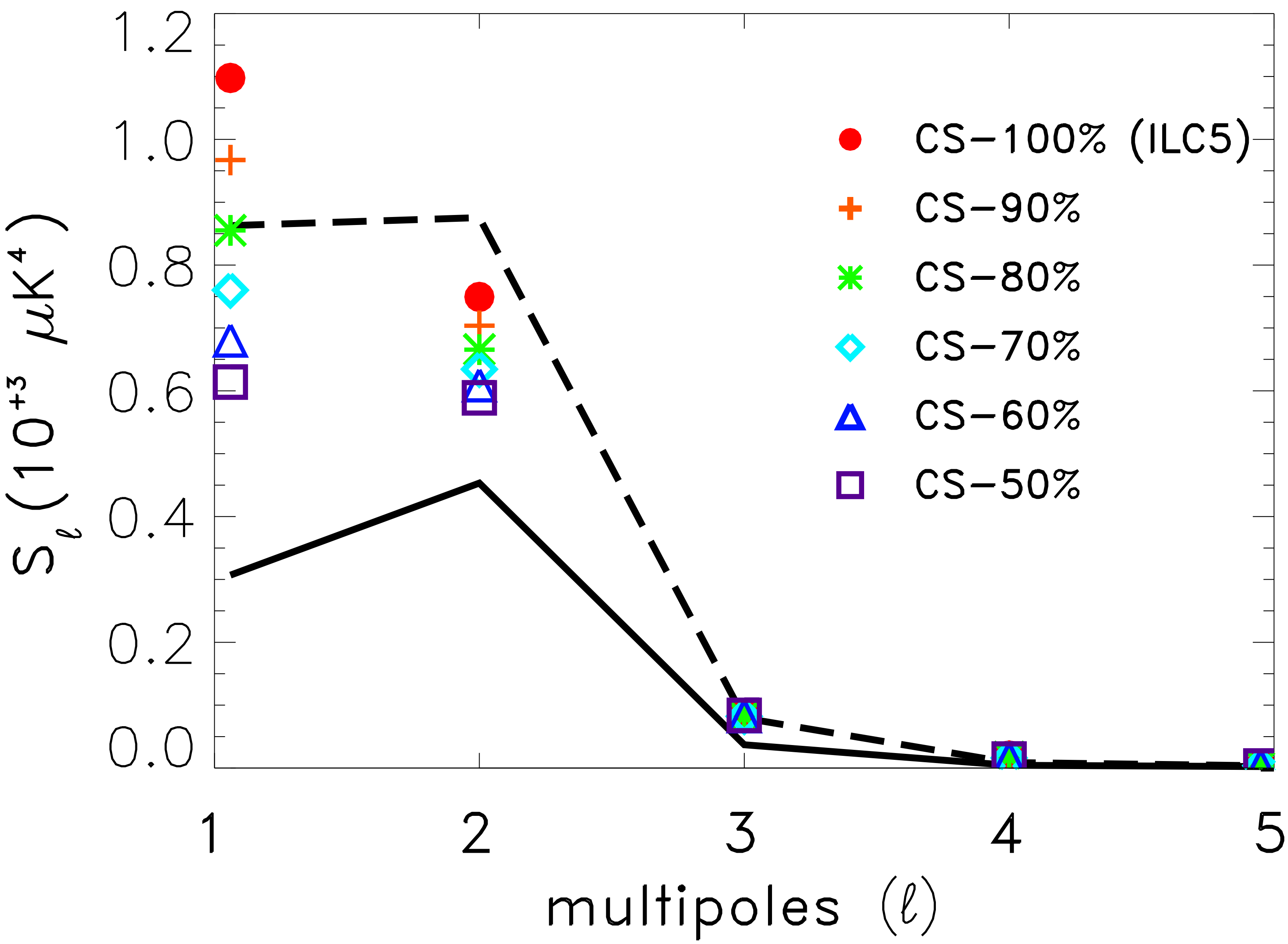




Experimentos com o CS



Experimentos com o CS: resultados



Conclusões

- **A assimetria Norte-Sul, nas escalas angulares $\ell = 11 - 20$, é robusta pois ela é obtida: para $\neq$ freqüências (Q, V, & W), para $\neq$ máscaras, para $\neq$ mapas "limpos", etc.**

- **O Cold Spot causa a distribuição angular anômala, i.e. a assimetria Norte-Sul, nas flutuações de temperatura da RCF nas escalas angulares $\ell = 11 - 20$.**

Experimentos com o CS: resultados