Testing for inhomogeneities in *real time*

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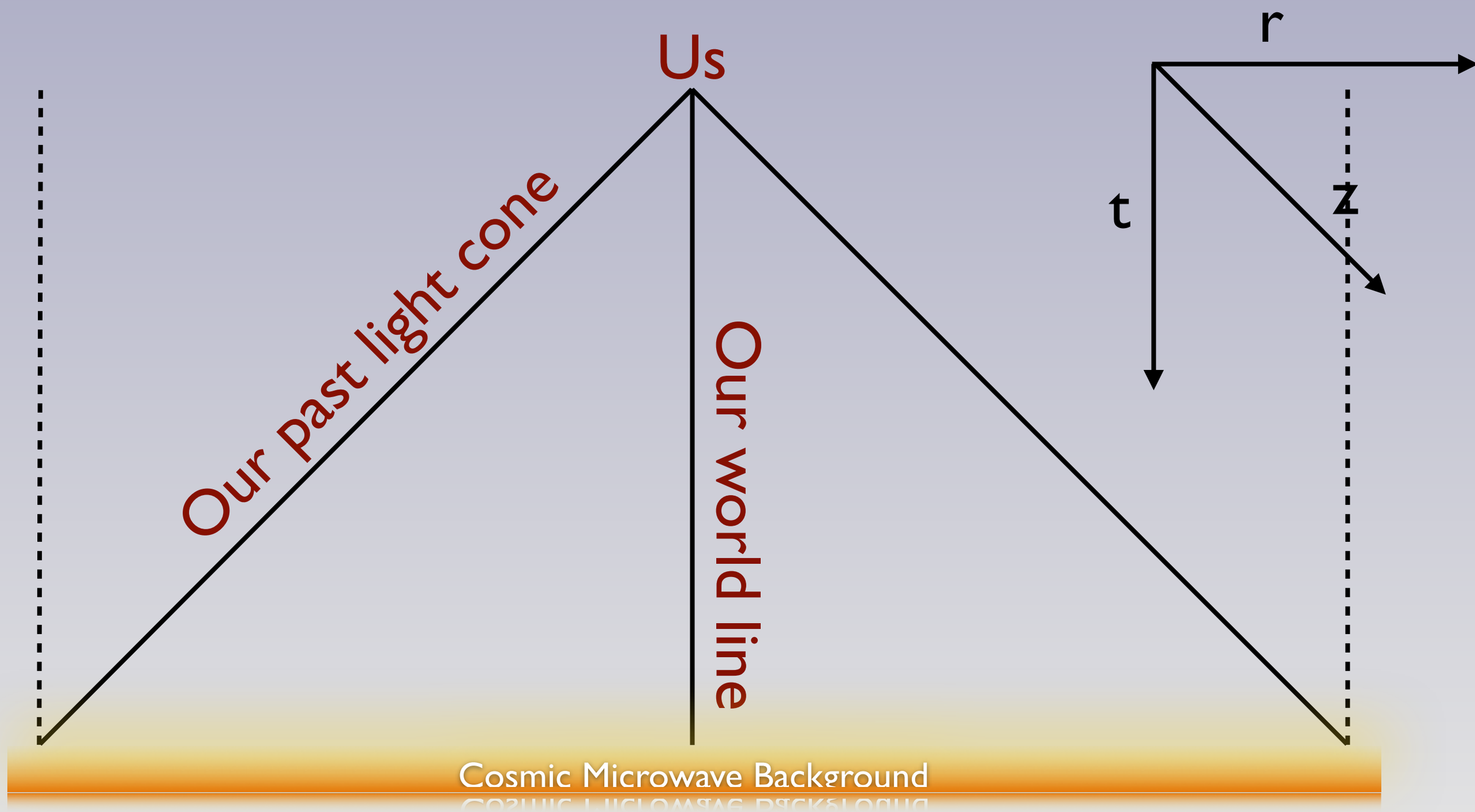
Based on: Amendola, WV et al., JCAP (2013)

Take home message

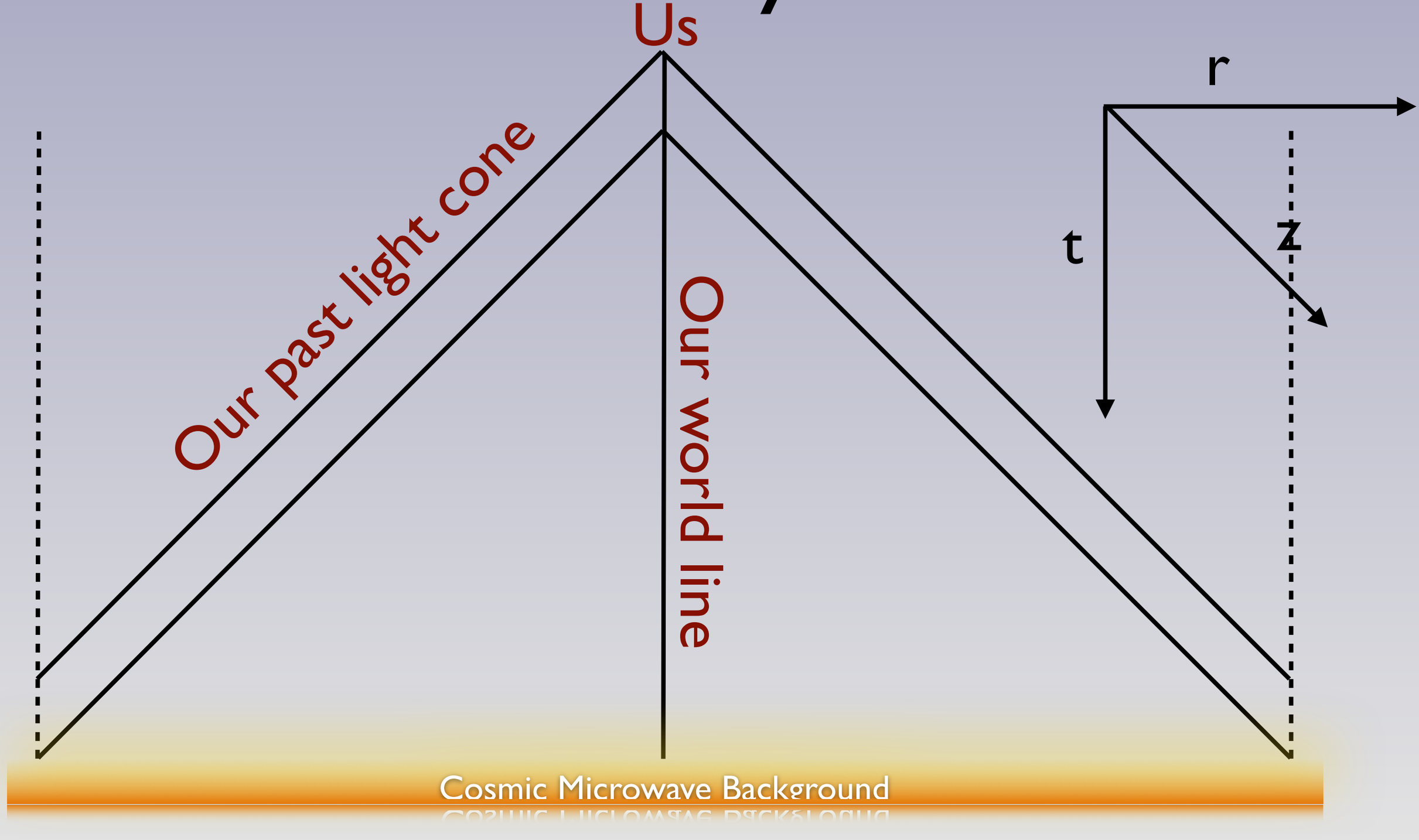
- Proof on concept of a tool:
  - Real-time cosmology can be used to observe different inhomogeneous models
- Focus on angular motion using multipole vectors
- This talk: no focus on redshift drift

Based on: Amendola, WV et al., JCAP (2013)

More insight inside the light cone: realtime cosmology



Realtime cosmology: observe the same 10 yrs later



Real time cosmology

- With e.g. GAIA have enough precision and volume
- only need some more time
- 500.000 quasars
- cross correlate maps from different times

Amendola, WV et al., JCAP (2013)

Real time cosmology

The GIQC_5 in a nutshell

[Andrei et al. 2014]

Number of sources	1,248,372
Sources with magnitude	1,246,512
Sources with redshift	1,157,285
Astrometry precision	1 arcsec
Magnitude precision	0.5
Redshift precision	0.01
Average density	30.3 sources/deg^2
Average neighbor distance	3.7 arcmin (σ 4.9 arcmin)
Maximum distance to neighbor	5.2 deg
Maximum distance to neighbor (average of 100 larger values)	3.0 deg (σ 0.6 deg)

$$F[\hat{n}_1, \hat{n}_2, \hat{n'}_1(\hat{n}_1, \vec{q}_1), \hat{n'}_2(\hat{n}_2, \vec{q}_2)] \equiv \cos\gamma_{12} - \cos\gamma'_{12}$$

$$\langle F \rangle(\theta, \phi) \equiv \int_{r_{\rm min}}^{r_{\rm max}} {\rm d}r \; n_{\rm obj}(r) \int_{r_{\rm min}}^{r_{\rm max}} {\rm d}r' \; n_{\rm obj}(r') \int \frac{{\rm d}\Omega'}{4\pi} F,$$

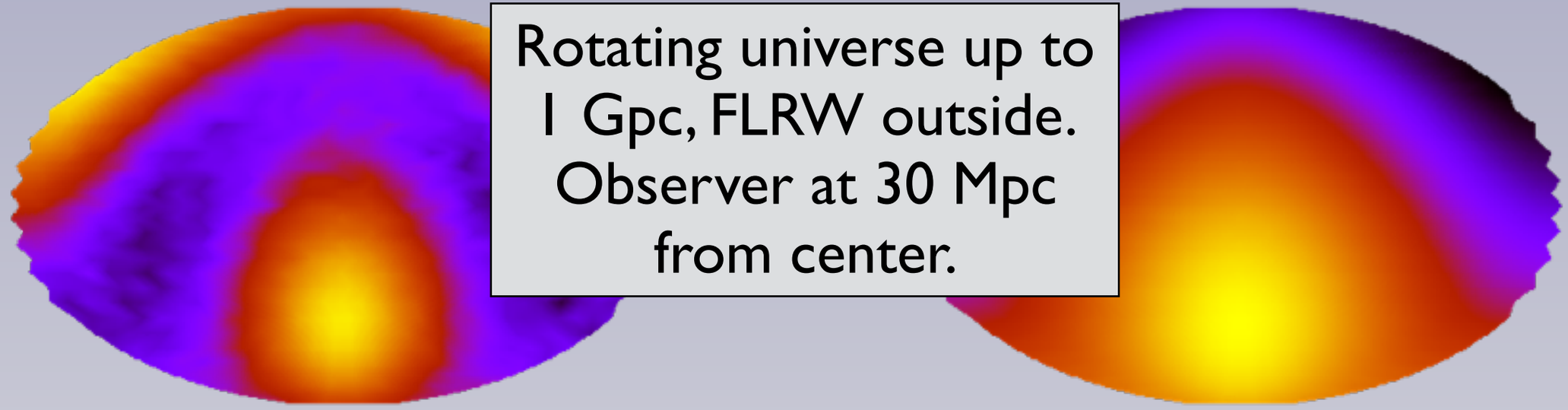
$$\langle F \rangle(\theta, \phi) = \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m} Y_{\ell m}(\theta, \phi)$$

Amendola, WV et al., JCAP (2013)

Simulate different anisotropic models

1/r-rotation $\langle F^2 \rangle$

1/r-rotation $\langle F \rangle$



Rotating universe up to 1 Gpc, FLRW outside. Observer at 30 Mpc from center.

LTB Void $\langle F^2 \rangle$

LTB Void $\langle F \rangle$

Λ-replacing void, observer at 30 Mpc from center.

Amendola, WV et al., JCAP (2013)

Compare orientations of different multipoles: analysis of axis of symmetry of different models

- Decompose <F(θ, φ)> maps in multipoles
- Compute multipole vectors to quantify directions of anisotropy

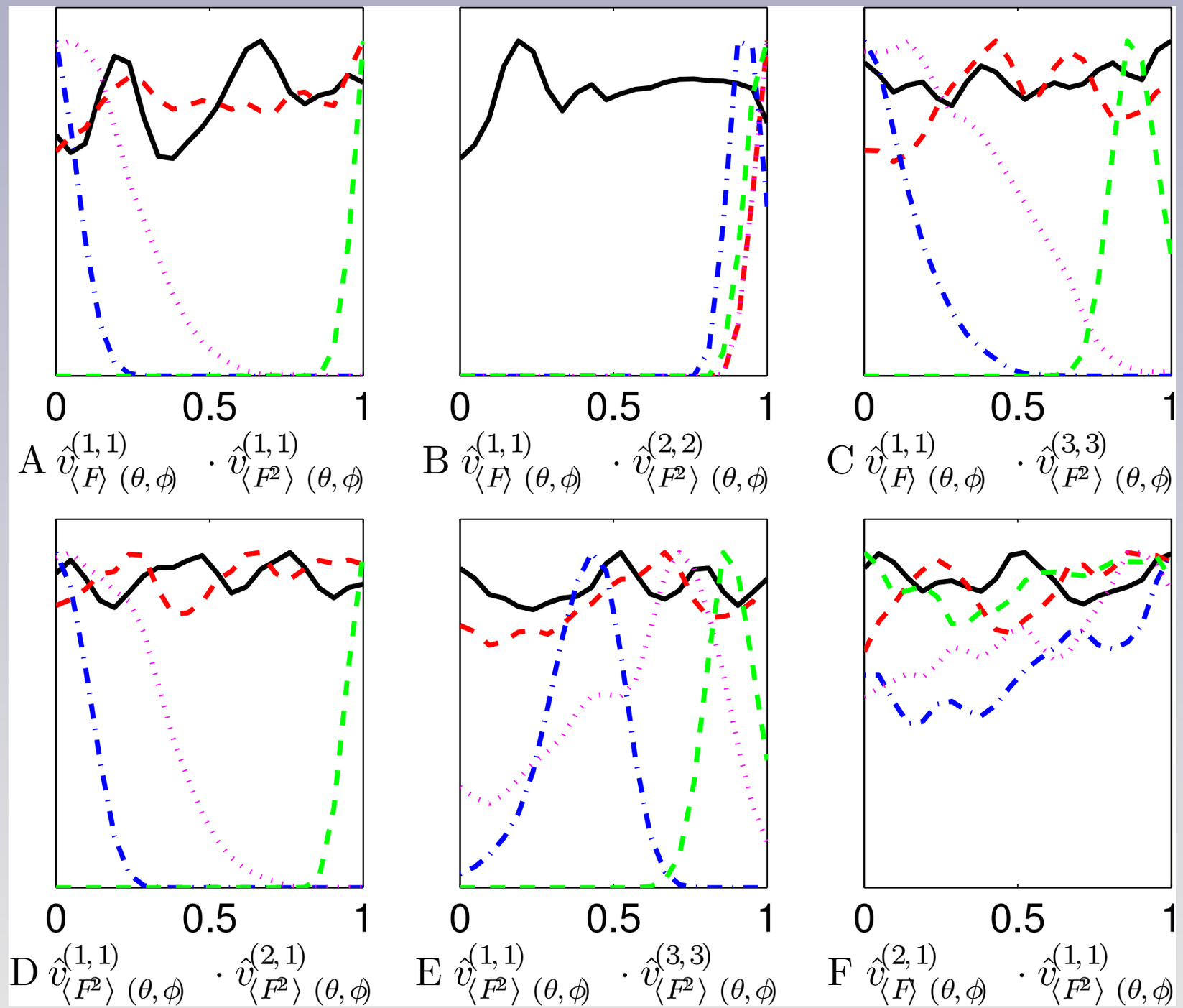
Copi et al. (2003)

- Compute inner products of different vectors: coordinate independent handle on directions.
- e.g. dipole orthogonal to quadrupole? Parallel?

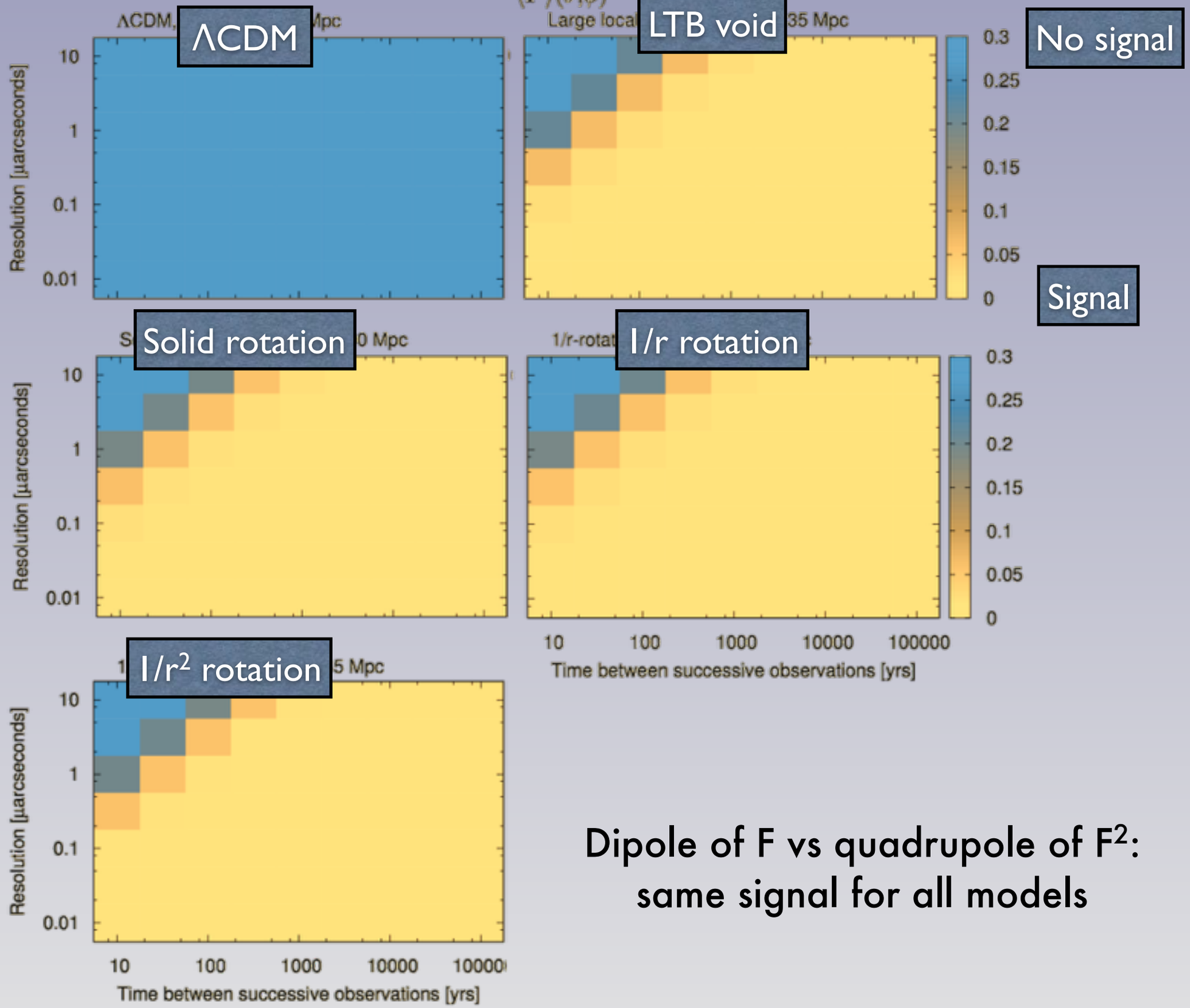
Amendola, WV et al., JCAP (2013)

Compare orientations of different multipoles: analysis of axis of symmetry of different models

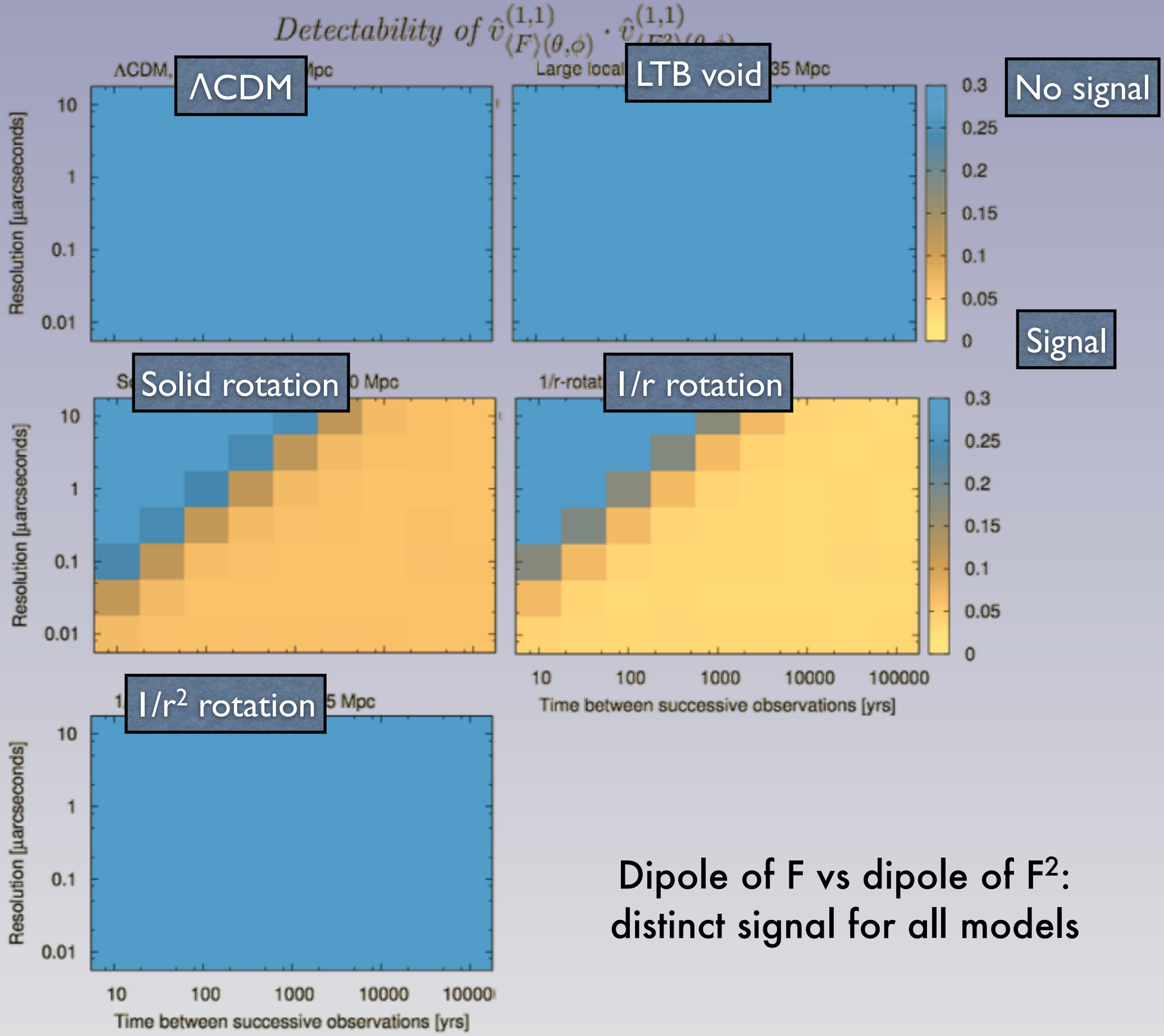
For an extreme situation: 1000 years of observation time, and high velocities on rotating models.



Amendola, WV et al., JCAP (2013)



Dipole of F vs quadrupole of F^2: same signal for all models



Dipole of F vs dipole of F^2: distinct signal for all models

Conclusion

- Proof on concept of a tool:
- Real-time cosmology can be used to observe different inhomogeneous models
- Using multipole vectors

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