Low WMAP Quadrupole / Octopole: significance and aligment

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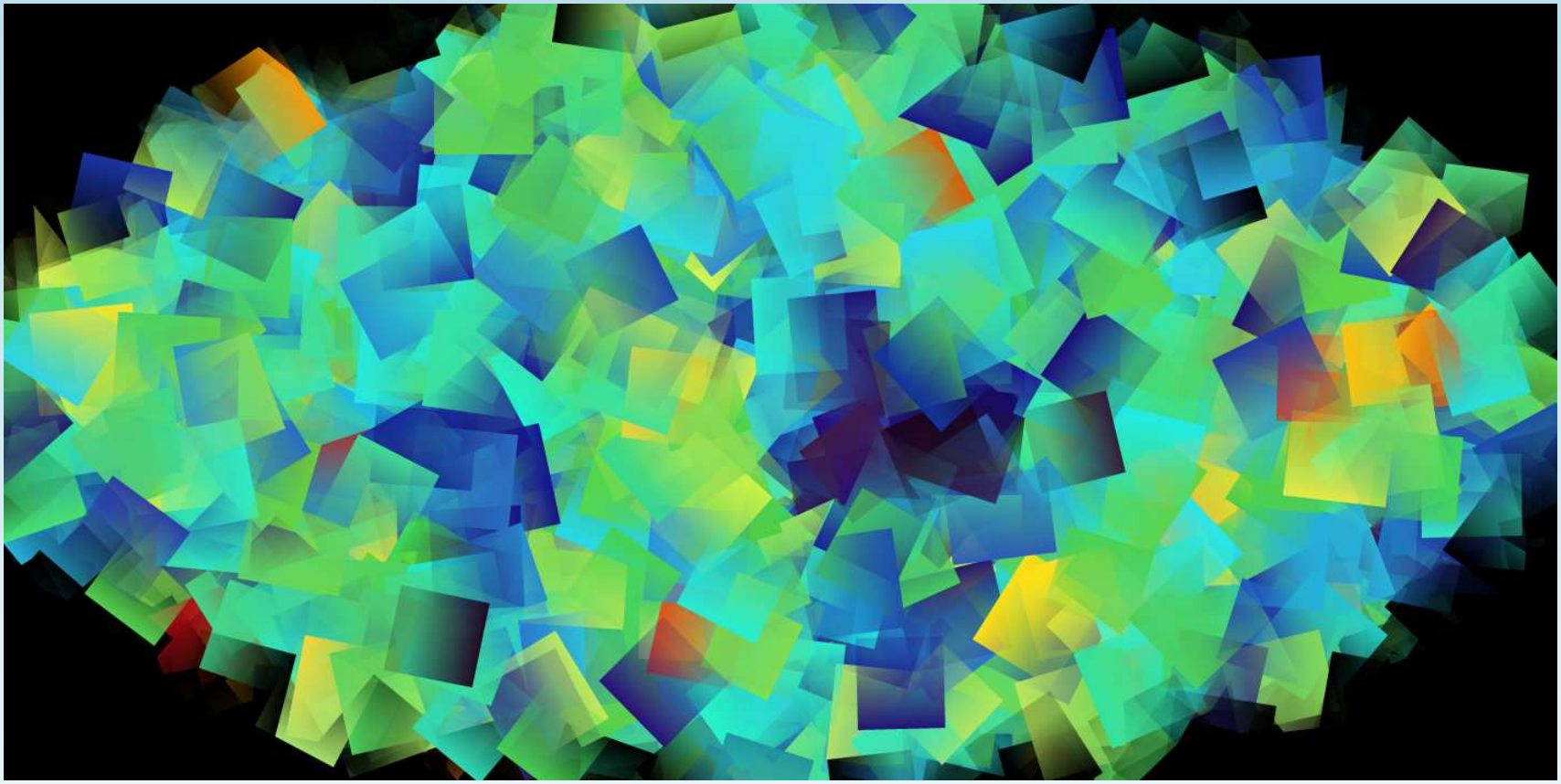
1 – Introduction



Quadrupole and Ocutpole:

- Very low amplitude : how statistically significant is that?
- “Aligment” of quadrupole and ocutpole: how statistically significant is that?

2 – Introduction II

A lot of excellent work has been done on this (Efstathiou, Tegmark, etc.), mostly based on ILC map using QML estimator.

Our approach is better:

- We use the exact method on low resolution maps
- We use single frequency maps with well under-stood noise propreties
- We project out unwanted contaminants rather subtract them
- For parameter estimation we use exact method at low ℓ and PCL at high ℓ

Operation surprisingly fast: $\sim$ 6 sec on a 2.6GHz PC on $\sim$ 2600 pixels.

3 – Data

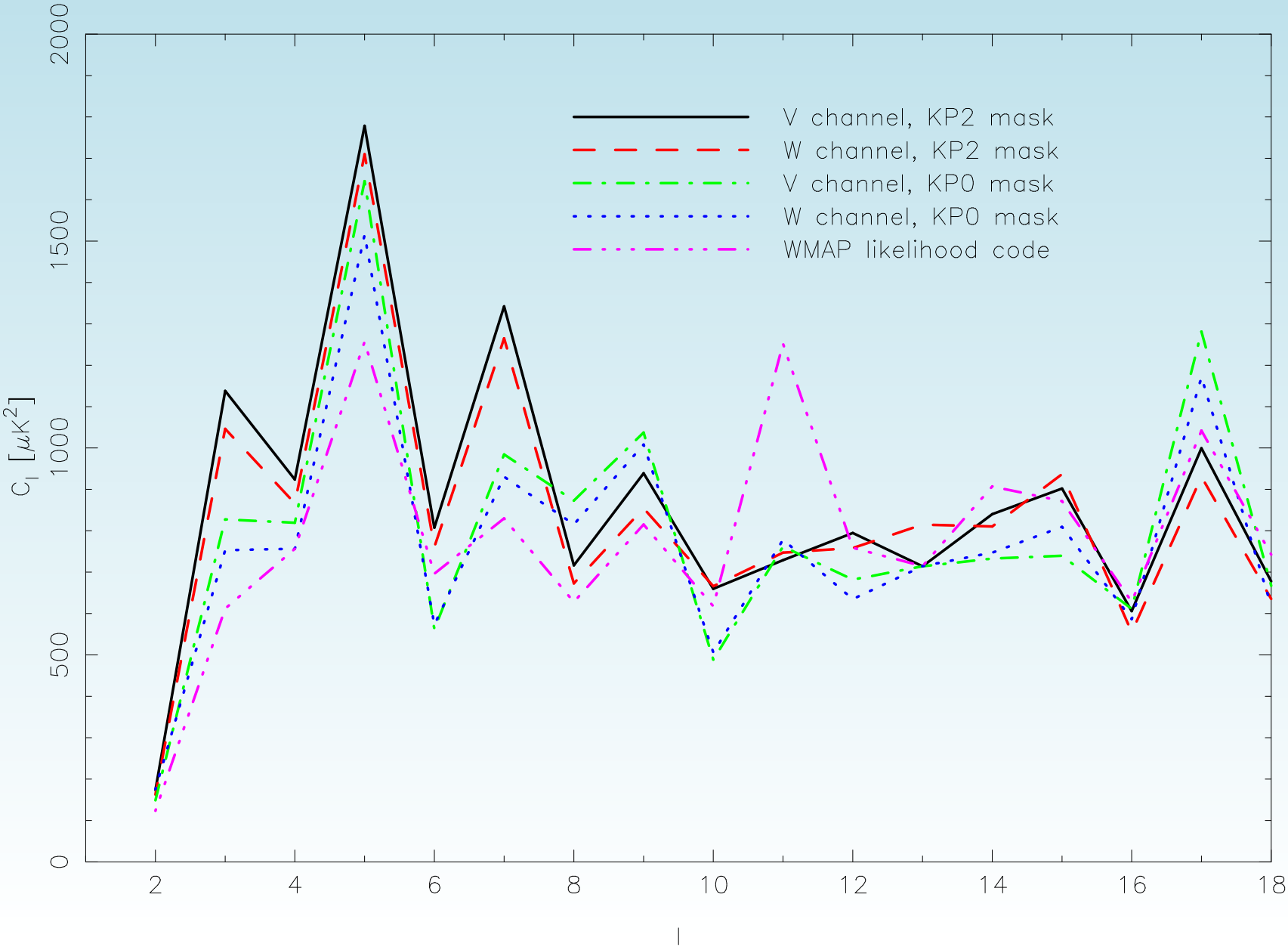
A lot of options:

- Frequency channel: V, W, ILC map
- Mask: None, KP2 (15%), KP0 (25%)
- Foregrounds: Free-Free, Dust, Synchrotron
- Marginalise or subtract foregrounds?
- Foreground maps: MEM, Templates
- Project Monopole / Dipole

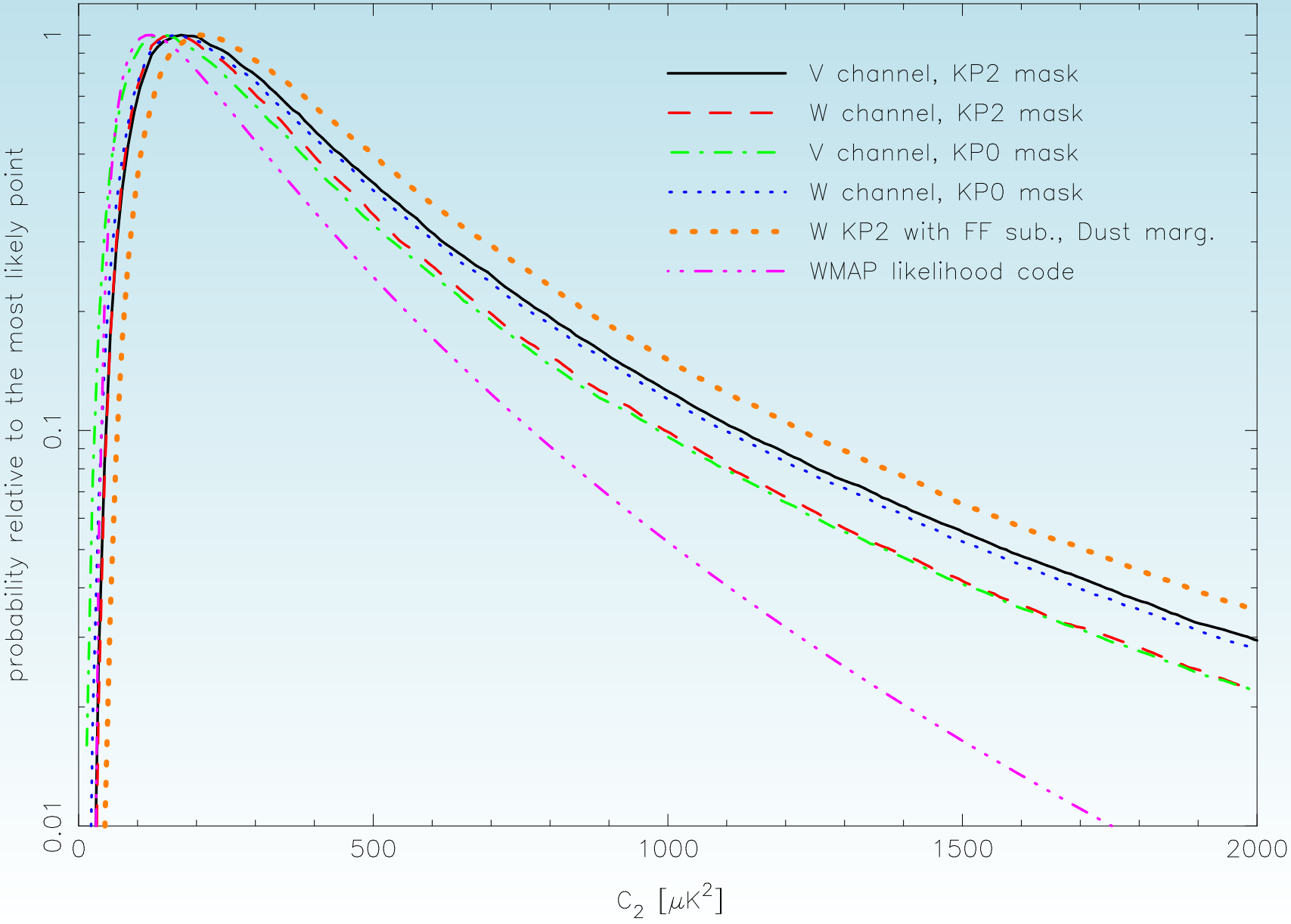
`WDUST` = W channel, FF subtracted, Dust marginalised, Synch. ignored.

`[V/W]KP[0,2]` = W/V channel, KP0/2 mask, all foregrounds marginalised.

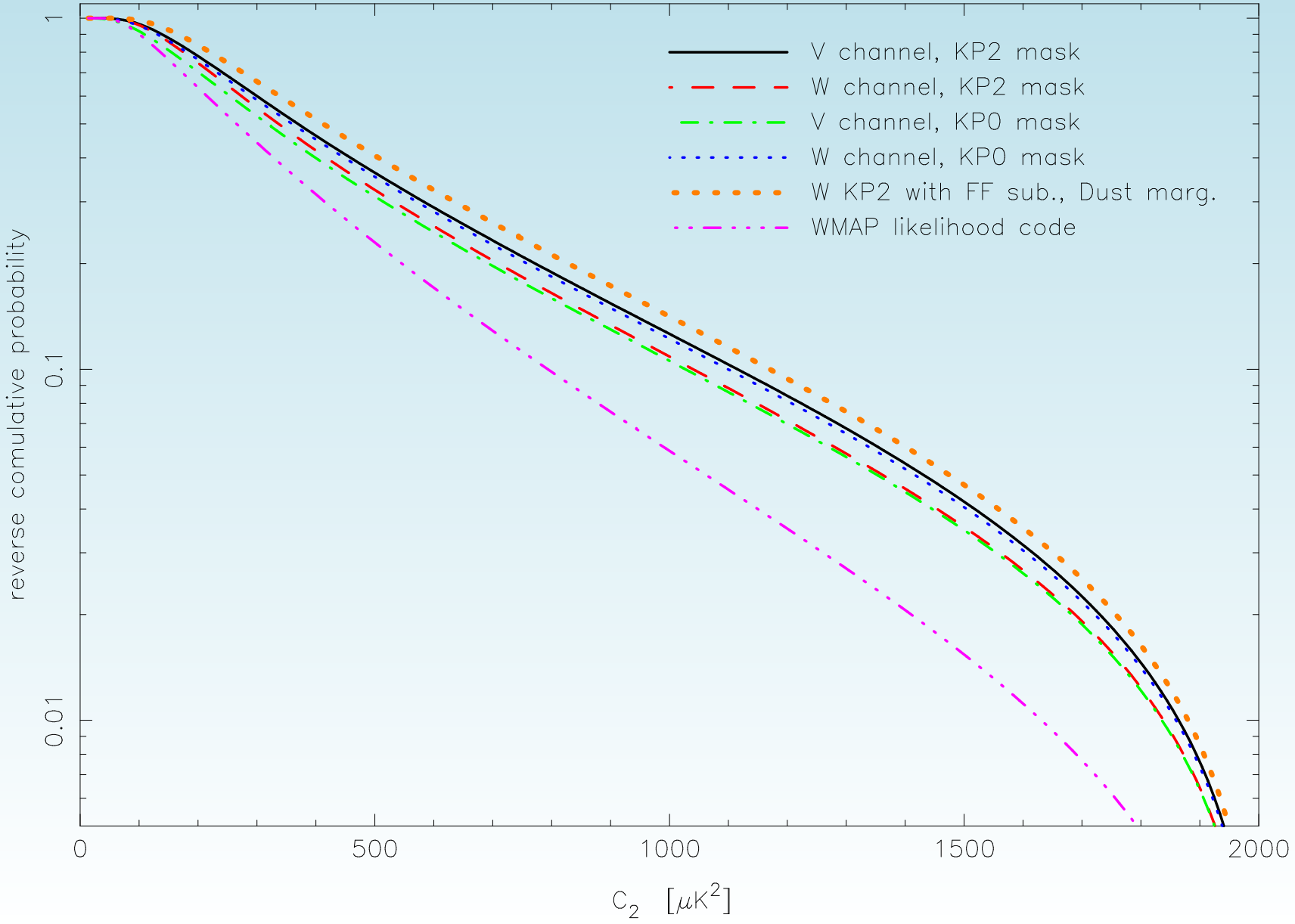
4 – The most-likely PS.



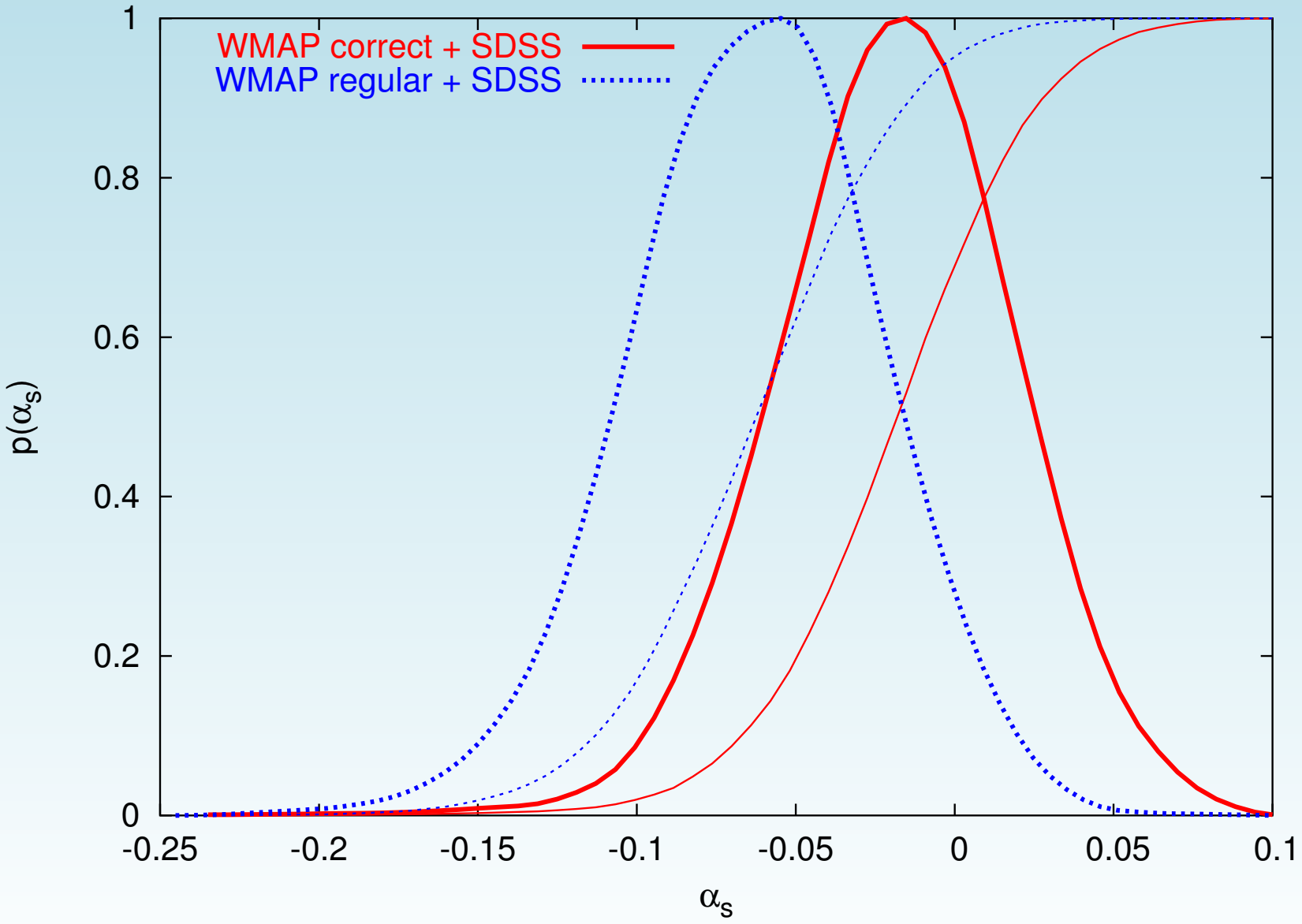
5 – Low quadrupole?



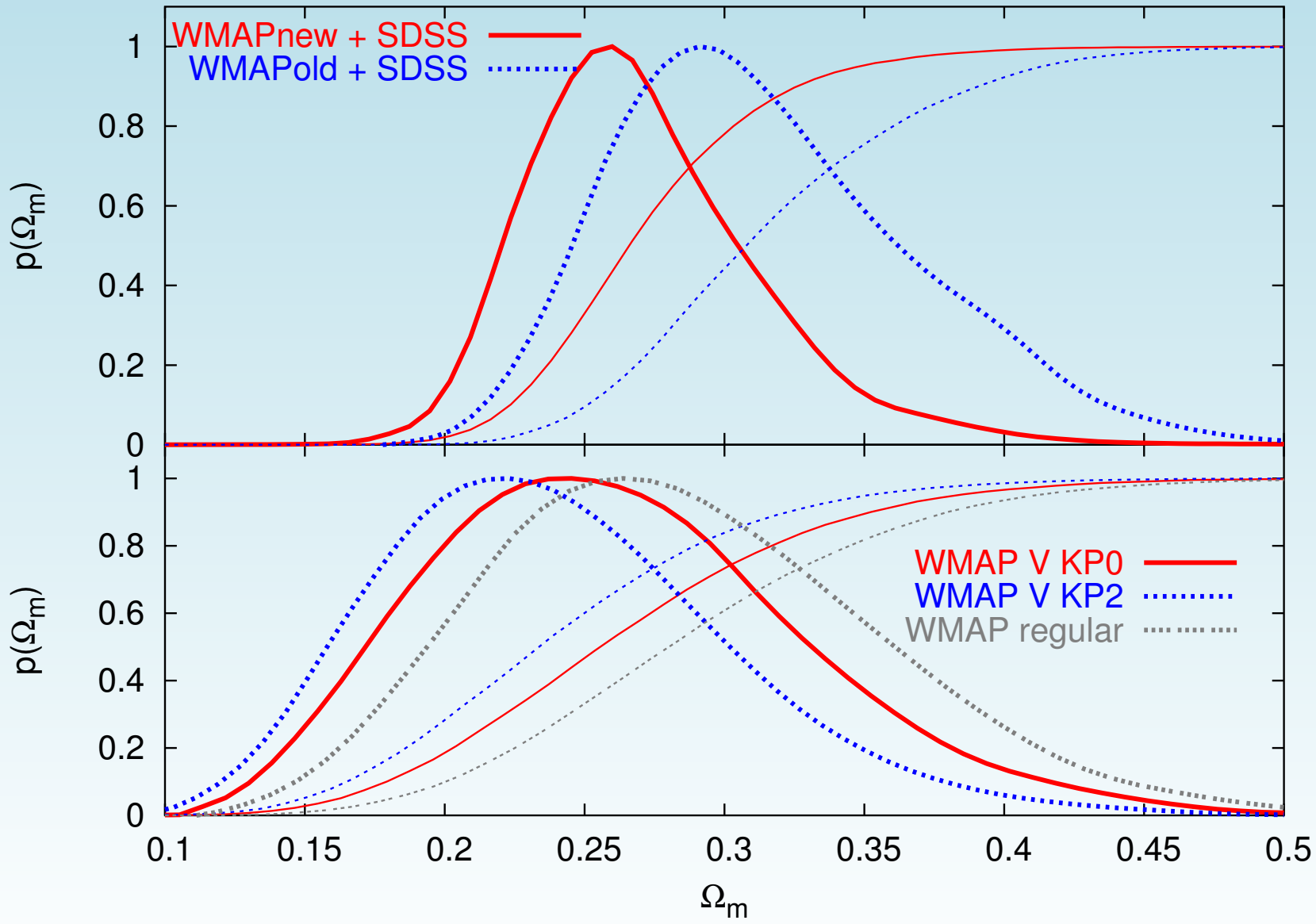
6 – Low quadrupole?



7 – Running.

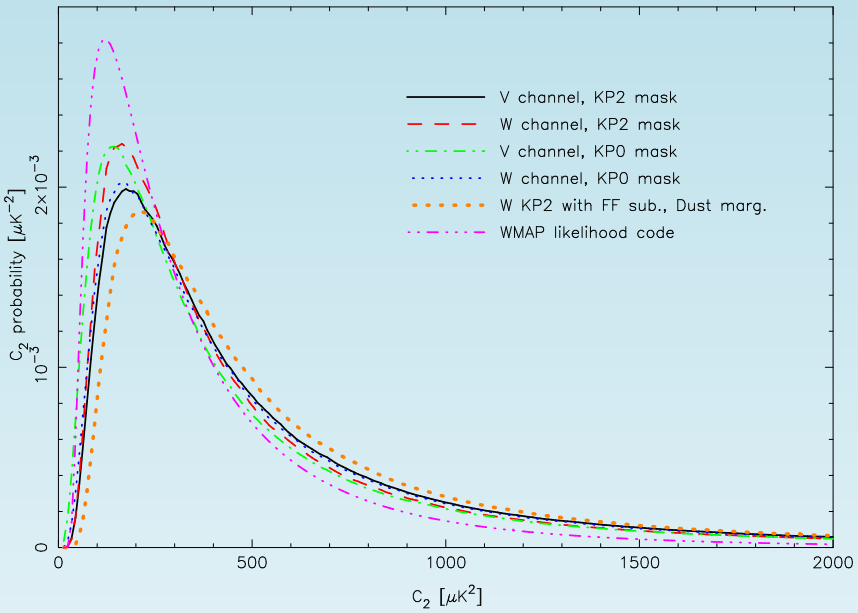

WMAP correct + SDSS
WMAP regular + SDSS
p(α_s)
α_s
1
0.8
0.6
0.4
0.2
0
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1

8 – Ω_m


WMAPnew + SDSS
WMAPold + SDSS
WMAP V KP0
WMAP V KP2
WMAP regular
p(Ωm)
p(Ωm)
Ωm
0
0.2
0.4
0.6
0.8
1
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

9 – Cosmic vs other variances

So far: astro-ph/0403073, PRD accepted



The uncertainity in C_ℓ above comes from:

- Cosmic variance (i.e. only $2\ell + 1$ degrees of freedom per mode)
- Uncertainty due to galaxy, contaminants, etc.

How are they connected?

10 – C_ℓ and D_ℓ

Say

$$D_\ell = \langle a_{\ell m} a^*_{\ell m} \rangle_m \tag{1}$$

then

$$P(C_\ell) = \int P(D_\ell) \times P(C_\ell | D_\ell) \mathrm{d}D_\ell \tag{2}$$

where $P(C_\ell | D_\ell)$ is the χ^2 distribution with $2\ell + 1$ degrees of freedom.

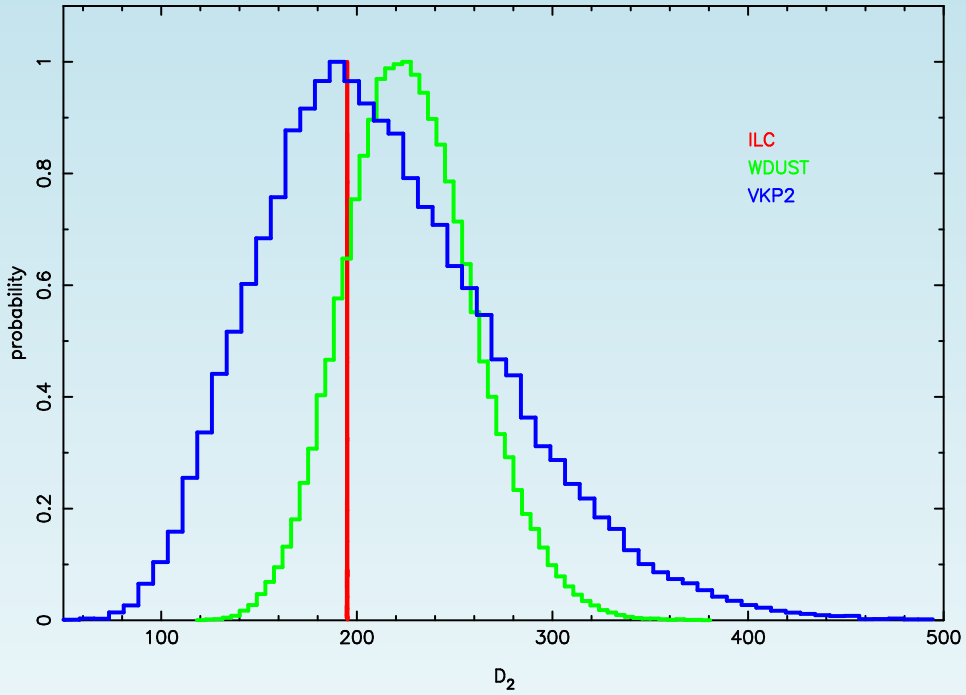
11 – How do we calculate D_ℓ?

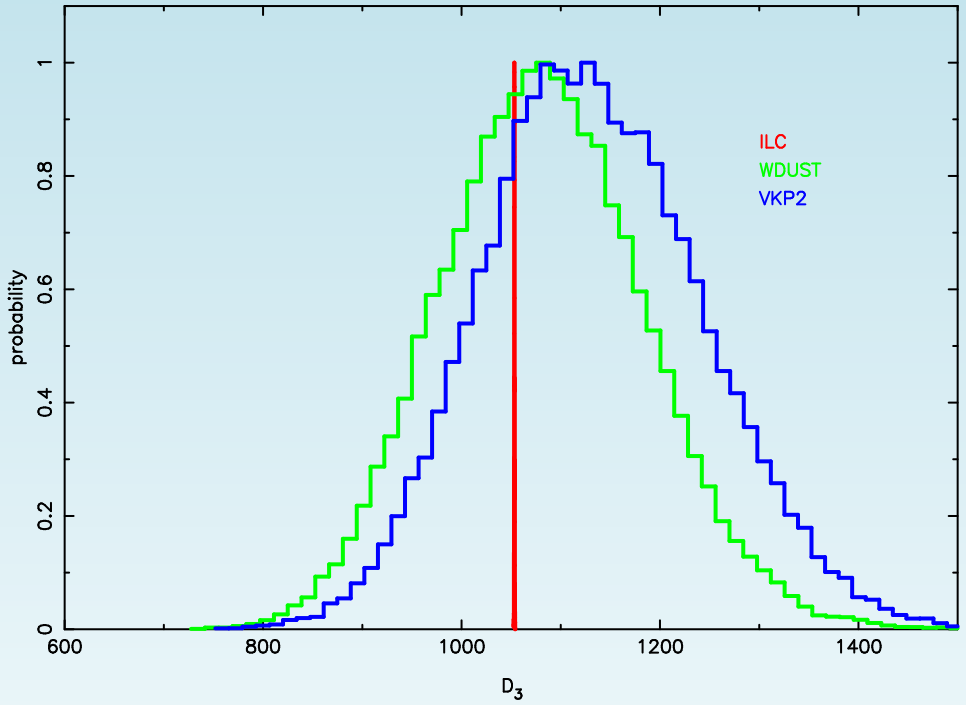
In principle could try to infer it using $P(C_\ell)$ - degeneracies

Instead, use MCMC to explore a_{lm}:

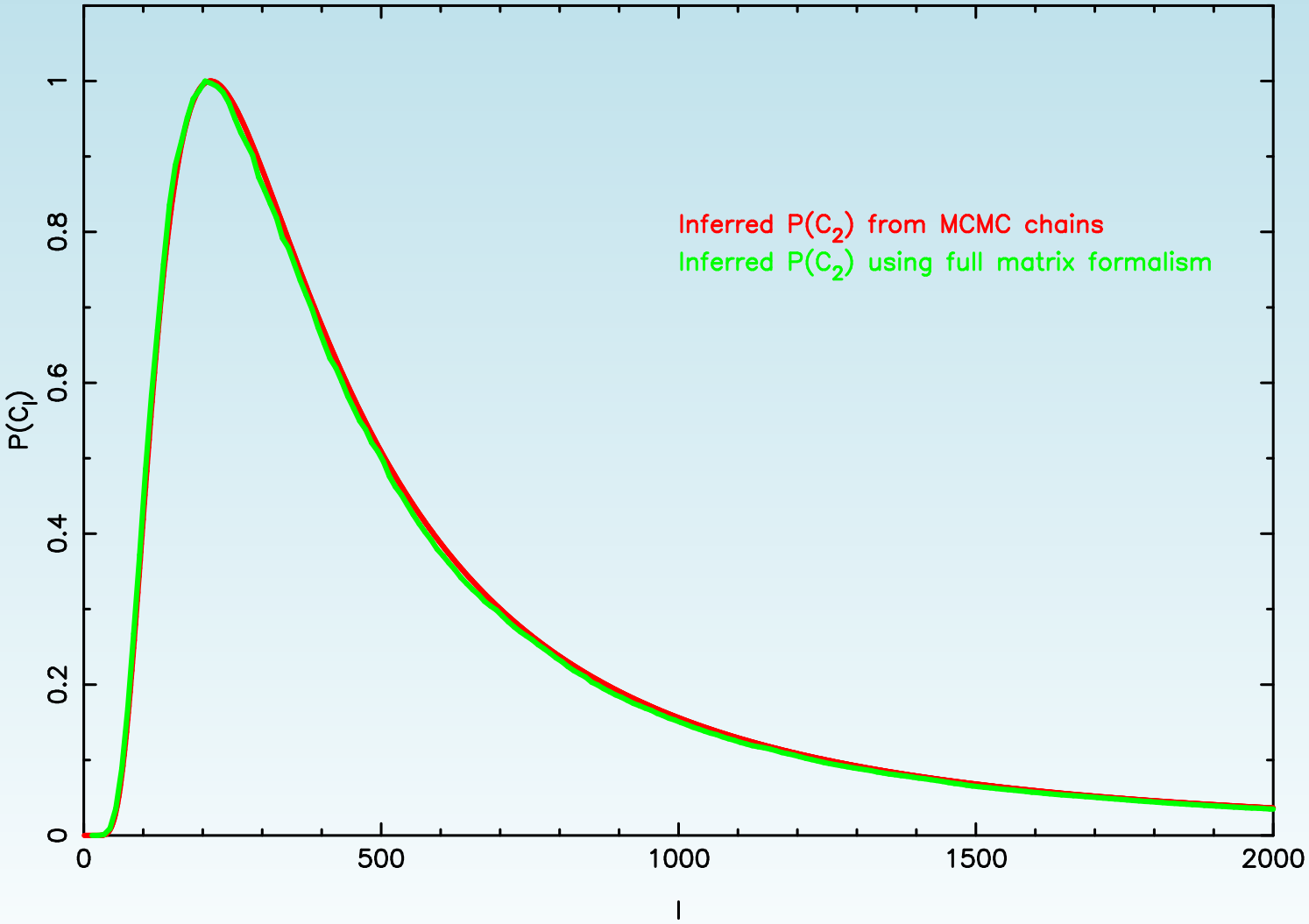
- We infer a_{2m} and a_{3m}: 12 dimensions
- Higher multipoles treated as noise with covariance corresponding to best fit PCL C_ℓ values
- Possible to infer probability distribution function for D_ℓ
- Possible to correctly asses the statistical significance of quadrupole, octuopole alignment.
- Got MCMC chains for three cases: full sky ILC, WDUST, VKP2

12 – D_2 and D_3

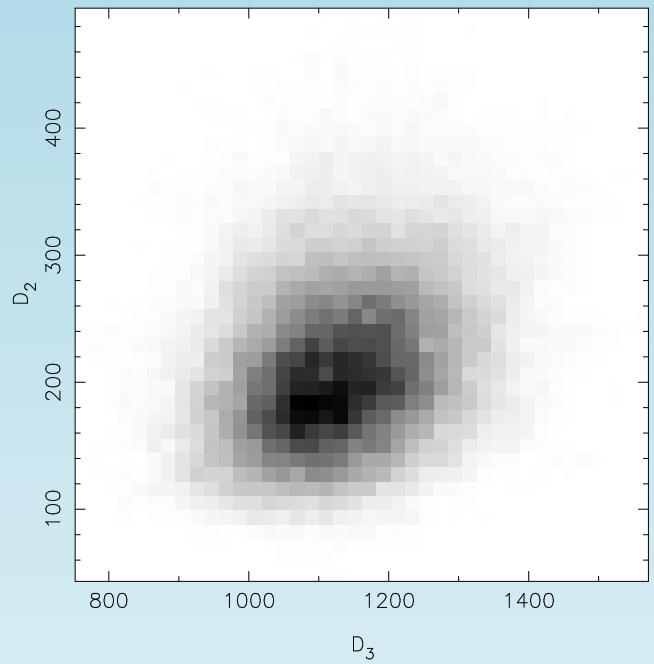

probability
0
0.2
0.4
0.6
0.8
1
100
200
300
400
500
D_2
ILC
WDUST
VKP2

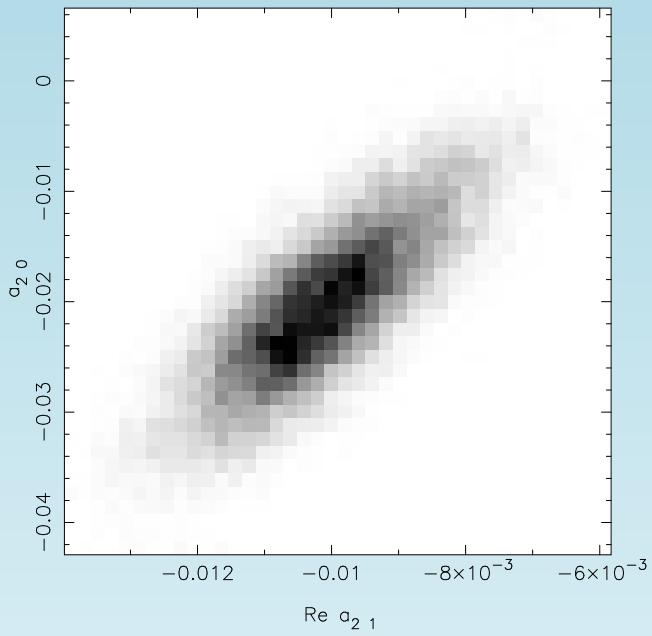

probability
0
0.2
0.4
0.6
0.8
1
600
800
1000
1200
1400
D_3
ILC
WDUST
VKP2

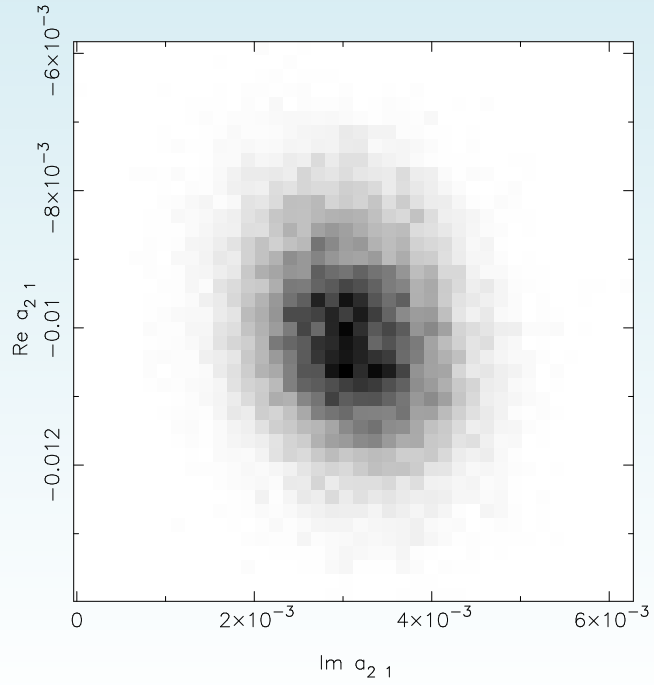
13 – $P(C_\ell)$ and Bayes biting butt

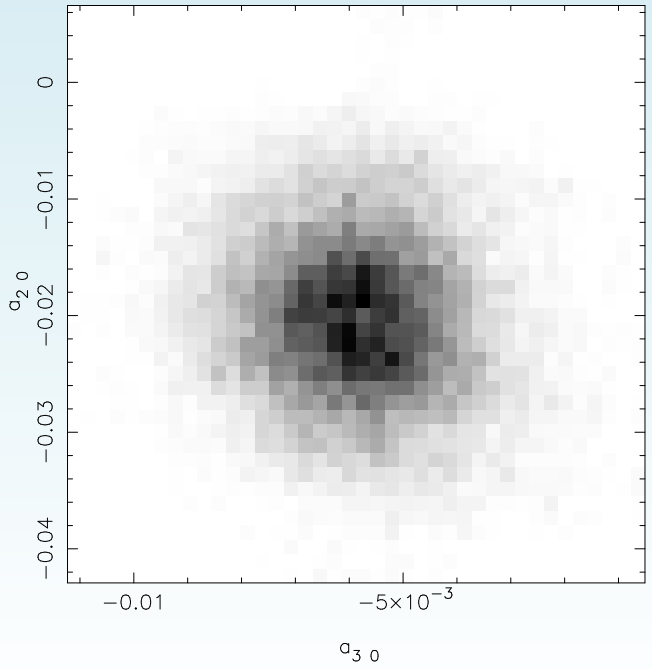


A muschi caveat: **A flat prior on a_{lm} does not correspond to a flat prior on C_ℓ.**


D2
400
300
200
100
800
1000
1200
1400
D3


a2 0
0
−0.01
−0.02
−0.03
−0.04
−0.012
−0.01
−8×10−3
−6×10−3
Re a2 1


Re a2 1
−6×10−3
−8×10−3
−0.01
−0.012
0
2×10−3
4×10−3
6×10−3
Im a2 1


a2 0
0
−0.01
−0.02
−0.03
−0.04
−0.01
−5×10−3
a3 0

14 – Statistical significance revisited

Following Efstathiou, 2003:

Frequentist: $P(D_2) < x$ **given** $C_2 = 1150\mu K^2$

- It's frequentist!
- WMAP team gets 0.9%
- I get: ILC: 2.6% ; WDUST: 3.8%; VKP2: 3.6%

Bayesian: $P(C_2) > 1150\mu K^2$ **given** $D_2 = x$**:**

- Reduces to matrix calculation as we already have $P(C_2)$
- Around 10% for flat prior on C_2 between 0 and $2000\mu K^2$
- Around 18% for no prior

15 – Quadrupole and Ocutpole Aligment

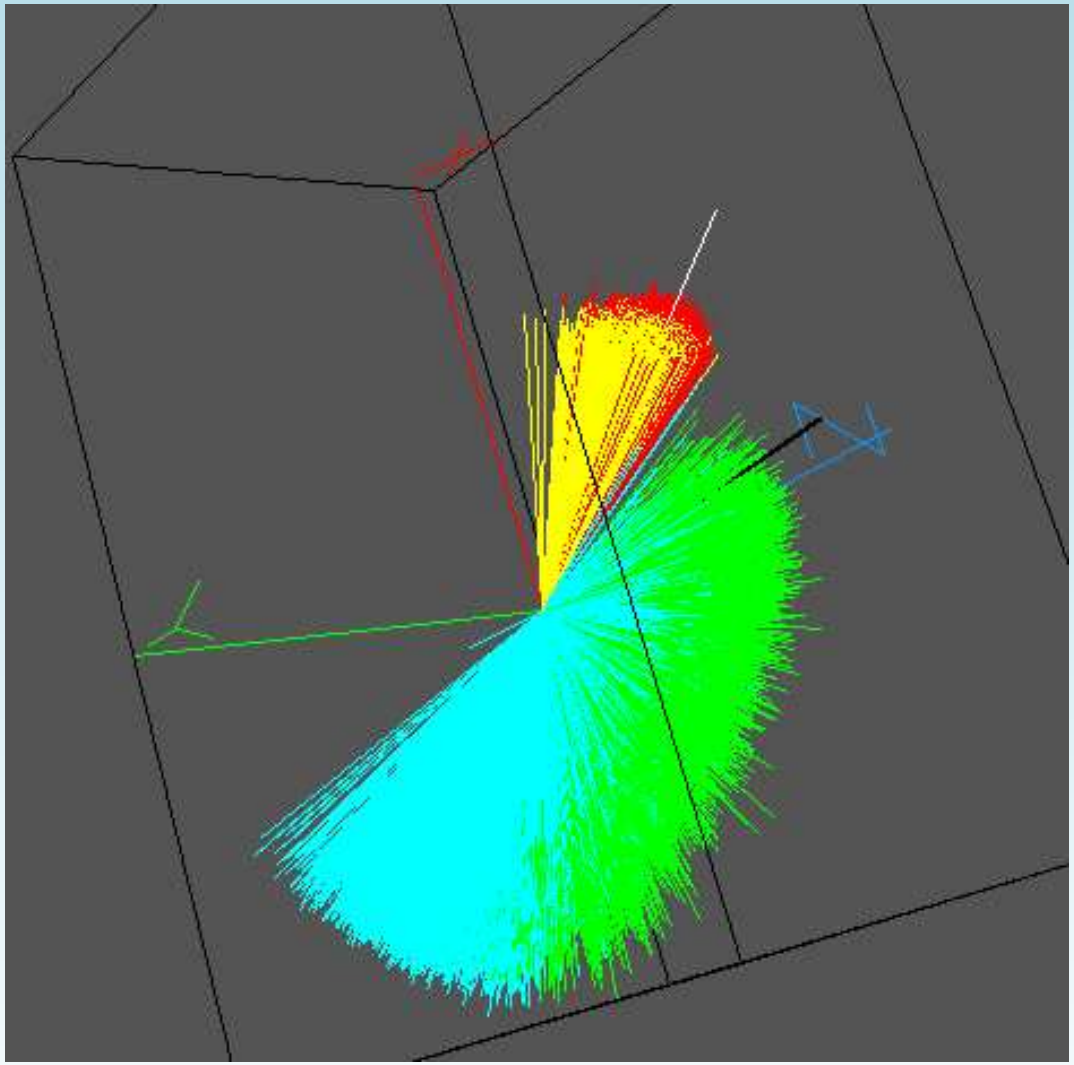
Tegmark introduces an axis assigned to each multipole.

This axis maximises the angular momentum dispersion

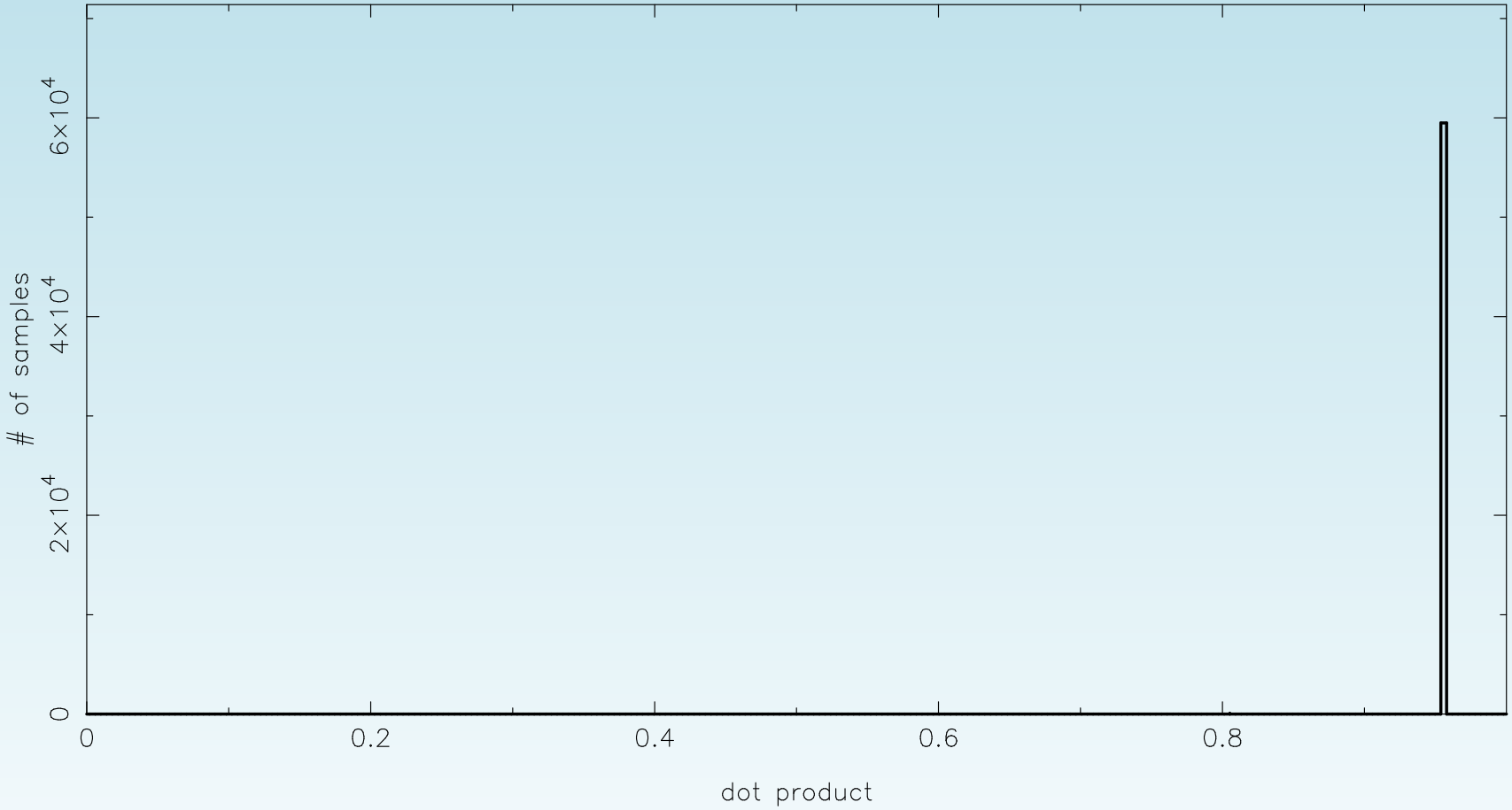
$$K = \sum_m a_{\ell m} a^*_{\ell m} m^2 \tag{3}$$

Using his version of ILC maps, the dot product for quadrupole and octopole 0.98.

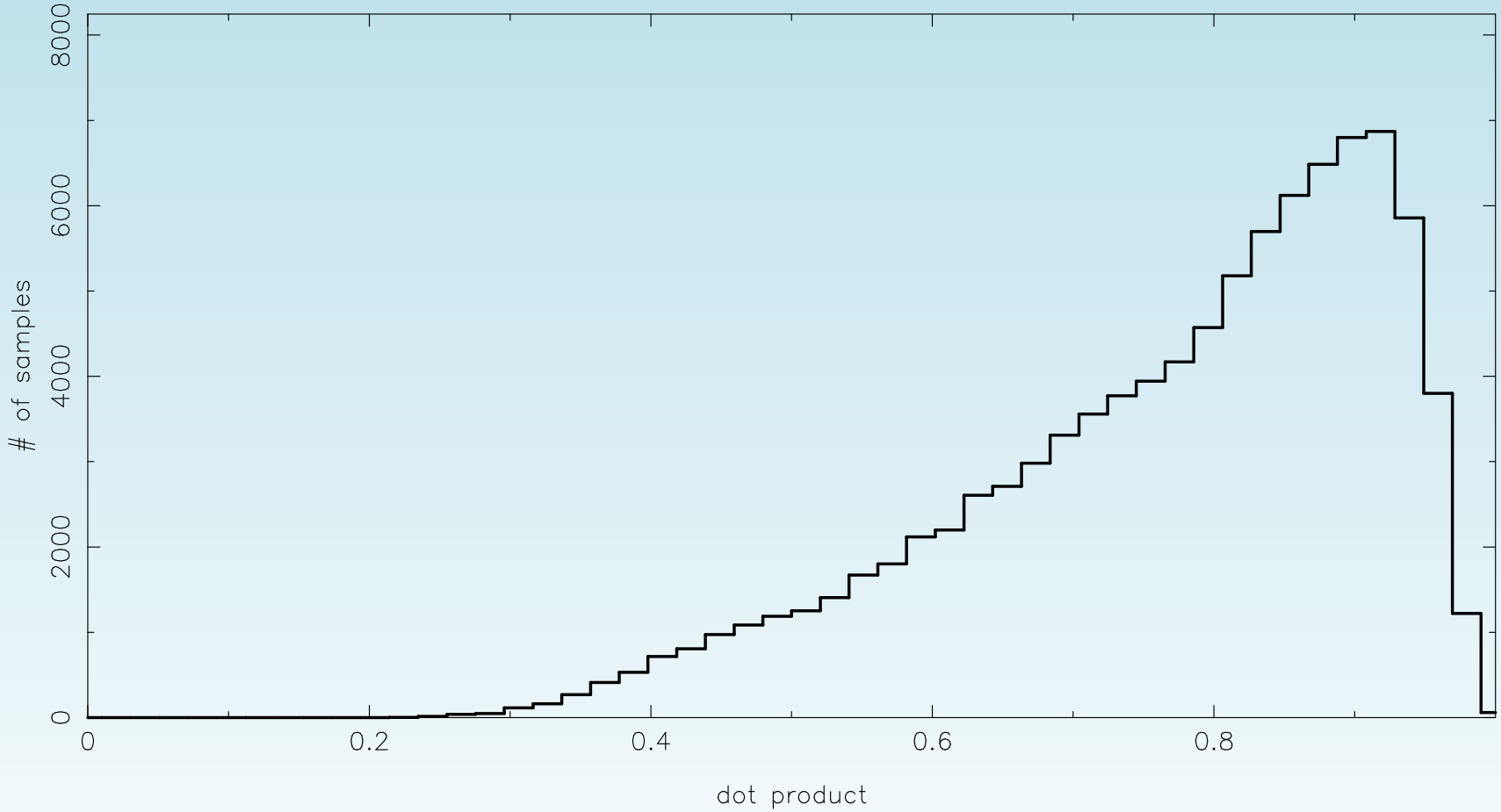
16 – Tegmark vectors



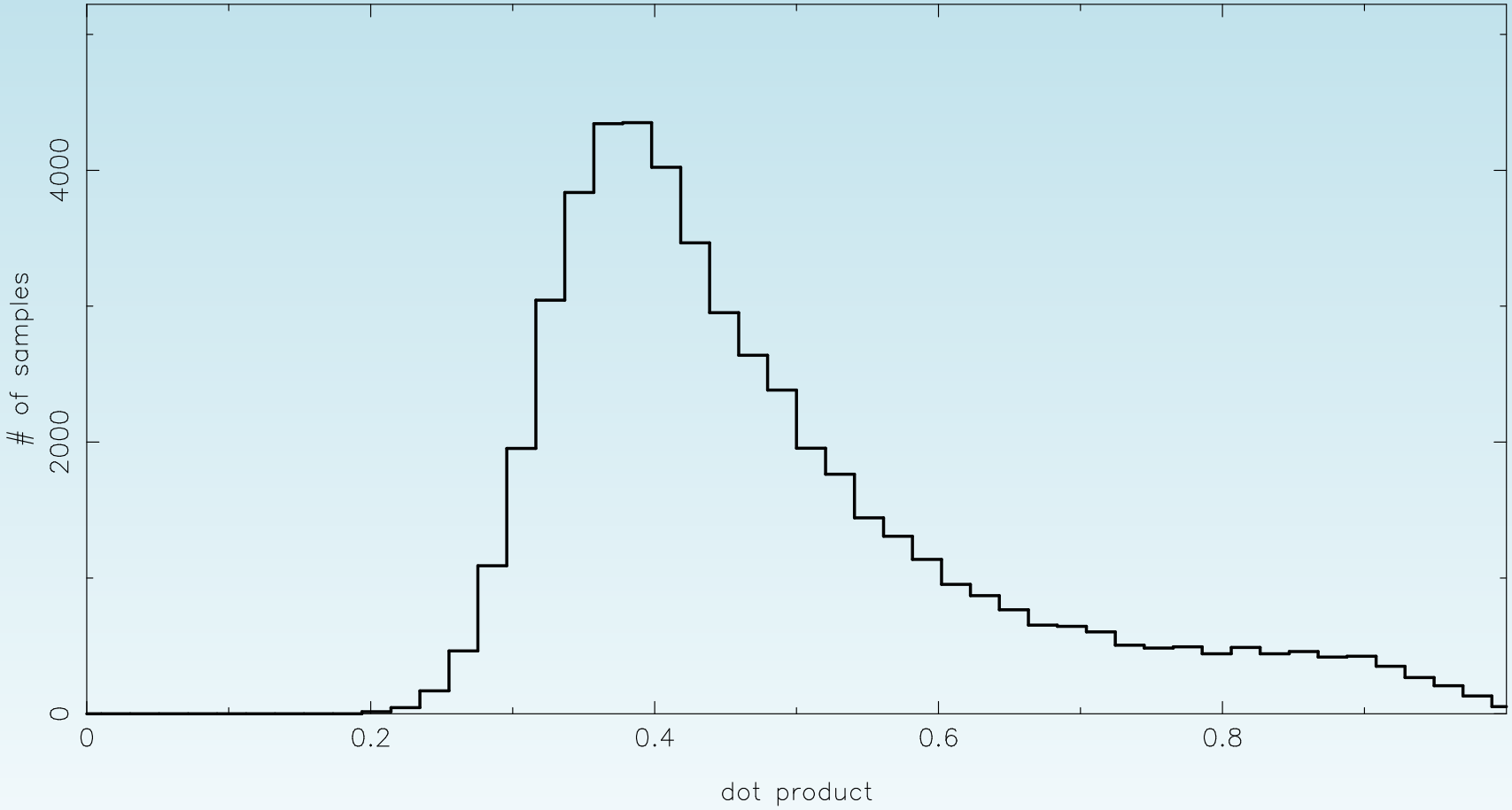
17 – Vector aligment: ILC



18 – Vector aligment: WDUST



19 – Vector aligment: VKP2



20 – Conclusions

- Exact likelihood analysis considerably widens the pdf for low multipoles in WMAP data
- Evidence for running is weakened
- Higher values of low multipoles favour lower values of Ω_m
- MCMC chains in a_{2m} and a_{3m} allow a novel study of low multipoles
- Aligment *alla Tegmark* seems to vanish once marginalisations and cuts are employed.
- Other aligment measures also exhibit negative results.