gdzie znaleźć ten plik pdf

http://adjani.astro.uni.torun.pl/∼boud/monog041105.pdf

OCRA, SZE + XMM-LSS survey

- SZ Effect — galaxy clusters' role in cosmology
- more data to try to explain the $\Omega_m = 1$ minority claim
- XMM-LSS - large scale structure survey
- SZ, OCRA and dark energy
- Extended SZ Effect possibly up to 1 degree

basic cosmology questions: geometry

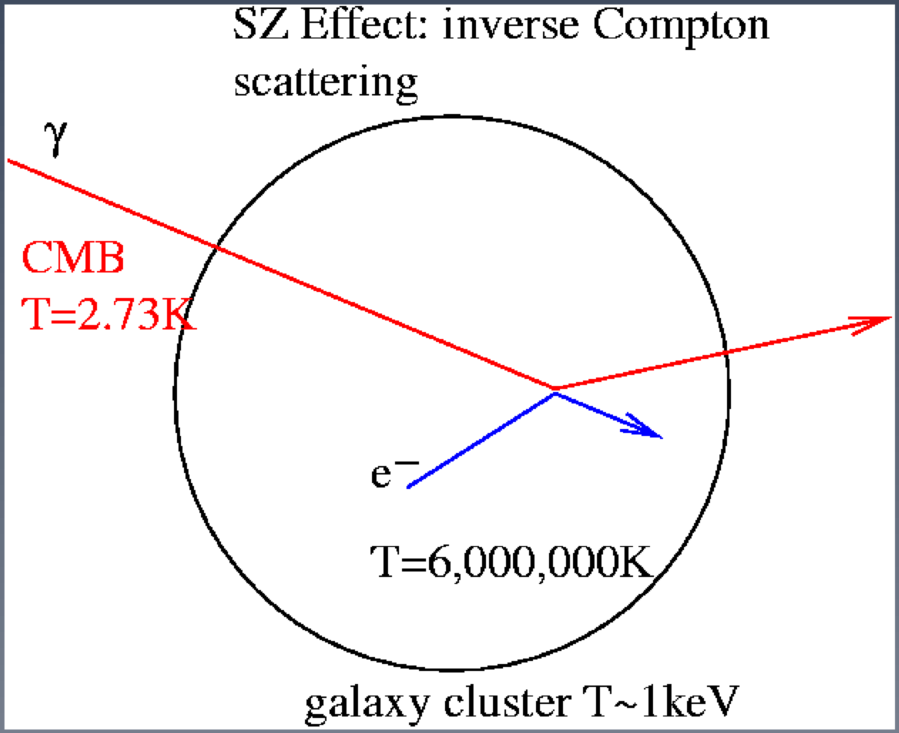
flat	$\Omega_m + \Omega_\Lambda = 1$
"spherical"	$\Omega_m + \Omega_\Lambda > 1$
hyperbolic	$\Omega_m + \Omega_\Lambda < 1$
multiply connected	any Ω_m, Ω_Λ

cosmic web

structure on scales ∼100 Mpc

- bottom-up structure building from perturbations
- biggest objects at knots of cosmic web = clusters
- biggest clusters have only recently formed
- cluster statistics are sensitive probe to whole theory of structure formation

Sunyaev Zel'dovich Effect

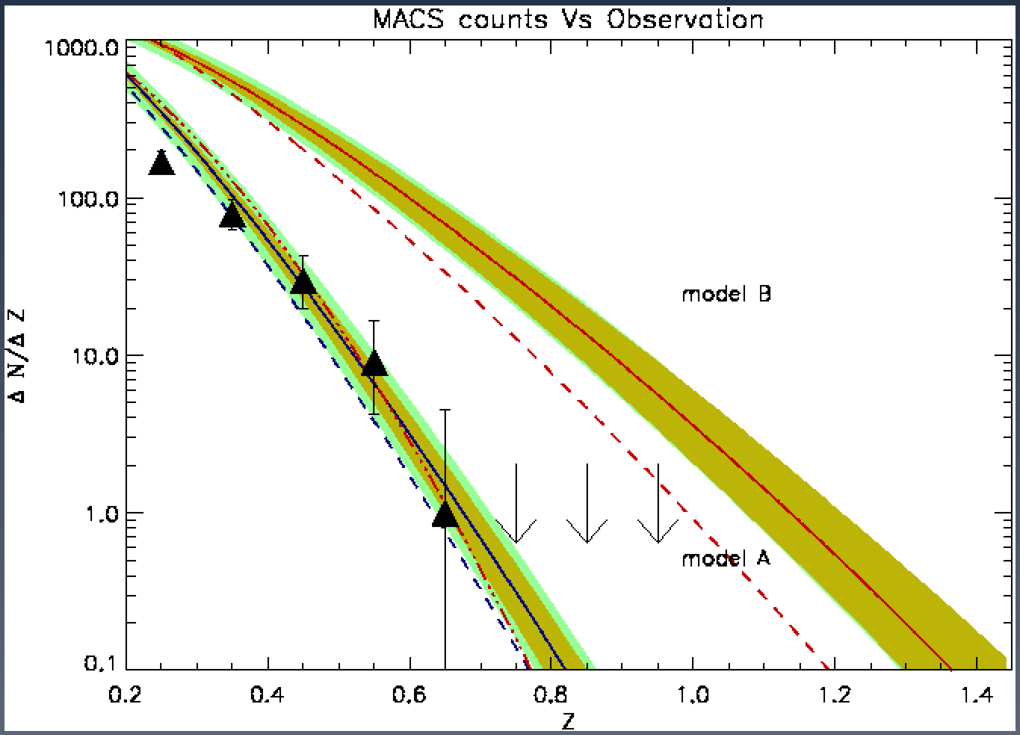


Rayleigh-Jeans part of spectrum:

$$\Delta T_{RJ} \approx -45 \frac{L_X}{10^{44}\mathrm{erg/s}}^{1/2} \frac{T_e}{1\mathrm{keV}}^{3/4} \mu K \qquad (1)$$

OCRA $\Rightarrow$ SZ detection of clusters

Cosmological constant: yes or no?



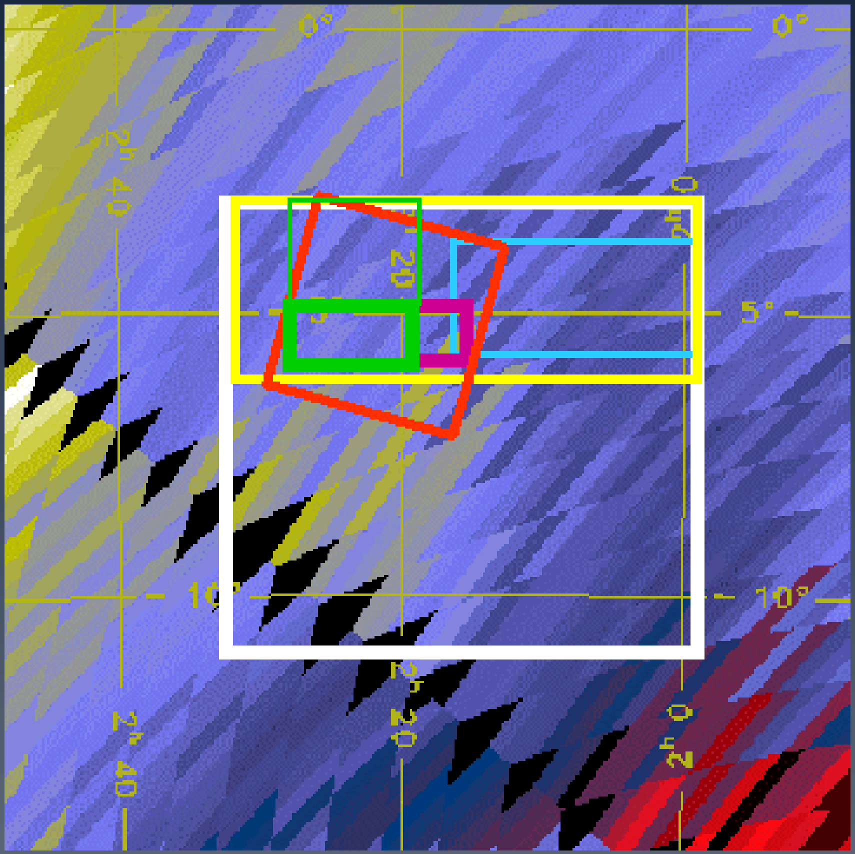
Vauclair et al. 2003, A&A 412, L37, astro-ph/0311381

$\Rightarrow$ strongly favour $\Omega_m \approx 1$

XMM-LSS - large scale structure survey

http://vela.astro.ulg.ac.be/themes/spatial/xmm/LSS/index_e.html

- X-ray survey should find about 900 clusters $z < 1$
- $8^\circ \times 8^\circ$ solid angle
- 5 $\times 10^{10-15}$ erg cm^{-2} s^{-1}, 0.5-2 keV
- 24 x 24 10 ks XMM/EPIC exposures; 20 arcmin offsets.



$2^h 18^m 00^s,\ -7^\circ 00' 00''$ (J2000)

OCRA followup

• some of the clusters detected in X will have $z \gg 1$

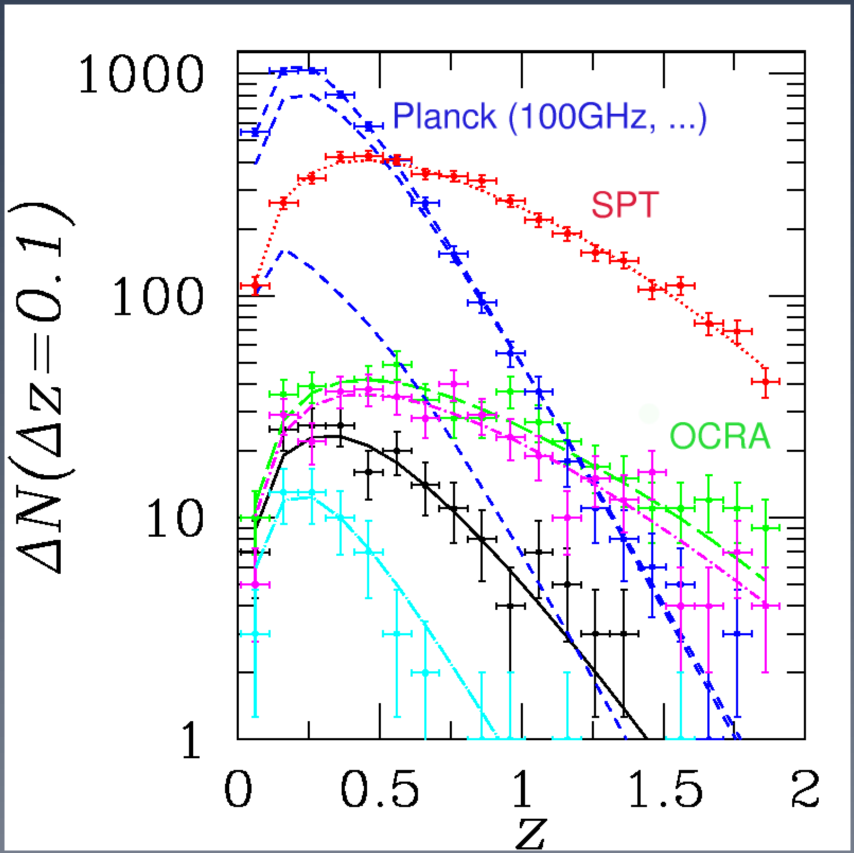
• OCRA followup should find more high z clusters than XMM in the same field

• there should be $N \sim 300$ clusters $L_X > 10^{44}$ erg/s in the field

(1) SZ maps of known clusters $L_X > 10^{45}$ erg/s

(2) blind SZ survey, resolution 1 arcmin, sensitivity 100 μK

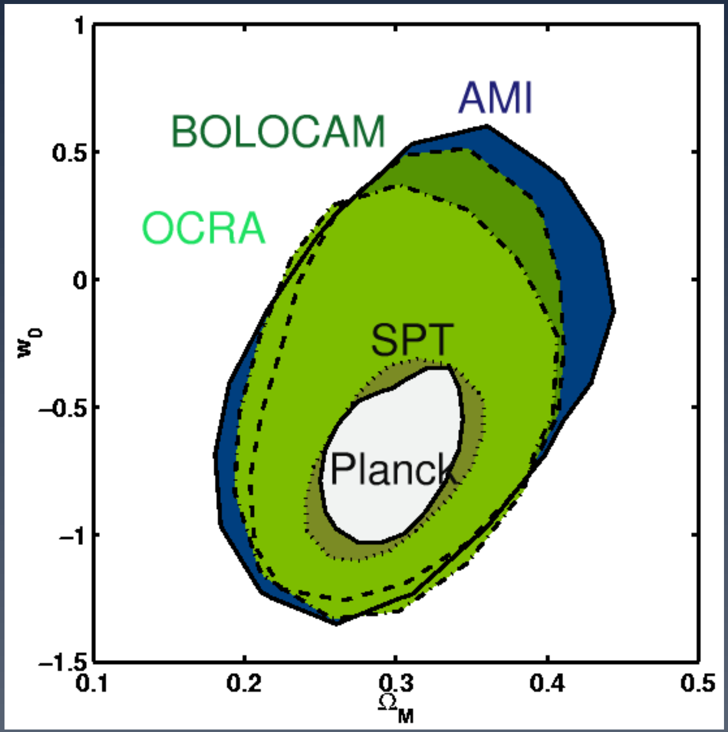
dark energy from SZ/OCRA?

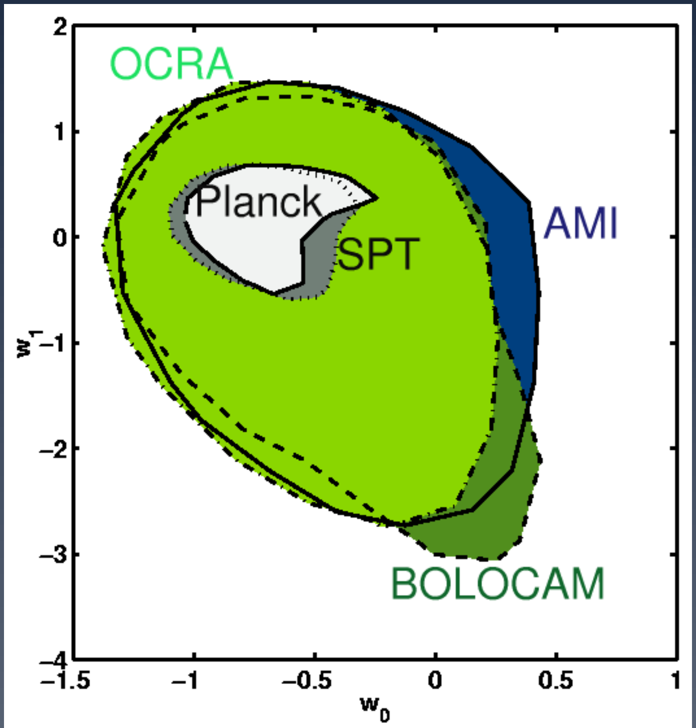


OCRA assumptions: $S_{\text{lim}} = 0.30$ mJy, $\theta_{\text{FWHM}} = 1.1'$, $\Delta\Omega = 140\text{deg}^2$

Battye, Weller, 2003, Phys.Rev. D68 (2003) 083506, astro-ph/0305568

Ω_m, w_0, w_1


AMI
BOLOCAM
OCRA
SPT
Planck
w_0
Ω_M
1
0.5
0
−0.5
−1
−1.5
0.1
0.2
0.3
0.4
0.5

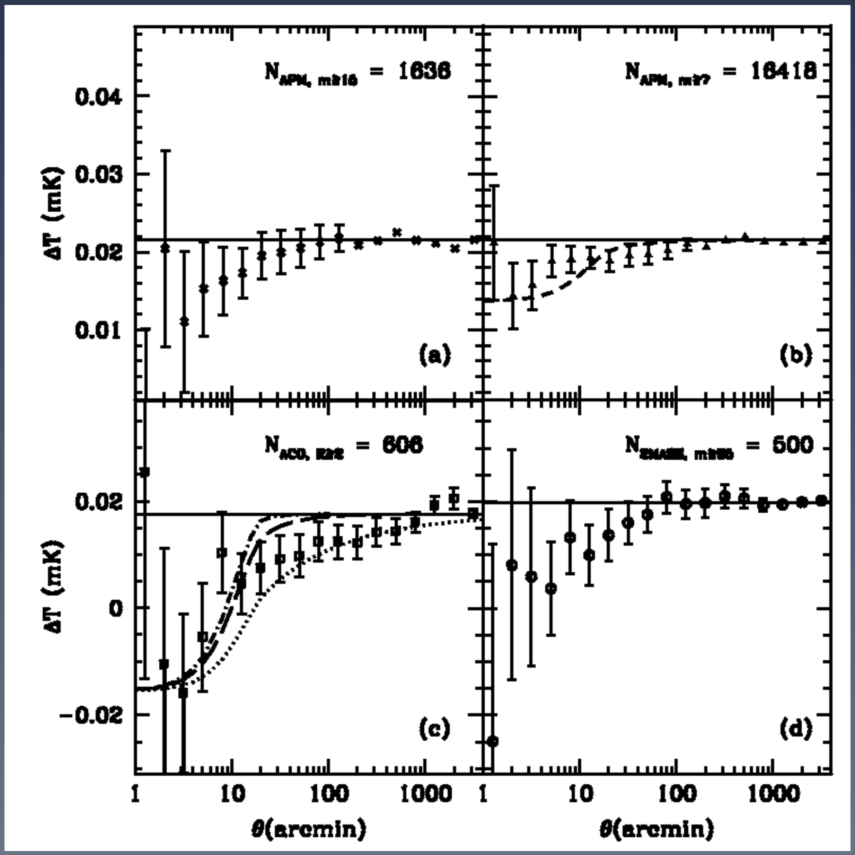

OCRA
Planck
SPT
AMI
BOLOCAM
w_1
w_0
2
1
0
−1
−2
−3
−4
−1.5
−1
−0.5
0
0.5
1

Extended SZ Effect

- possibly up to 1 degree

Myers, Shanks, Outram, Frith, Wolfendale (2004), MNRAS-L in press, astro-ph/0306180

mean WMAP ΔT in annuli around clusters



$\Rightarrow$ OCRA may be an optimal instrument for measuring the gas falling into clusters at $\sim$ 10-20 h^{-1}Mpc from the cluster centres

Summary

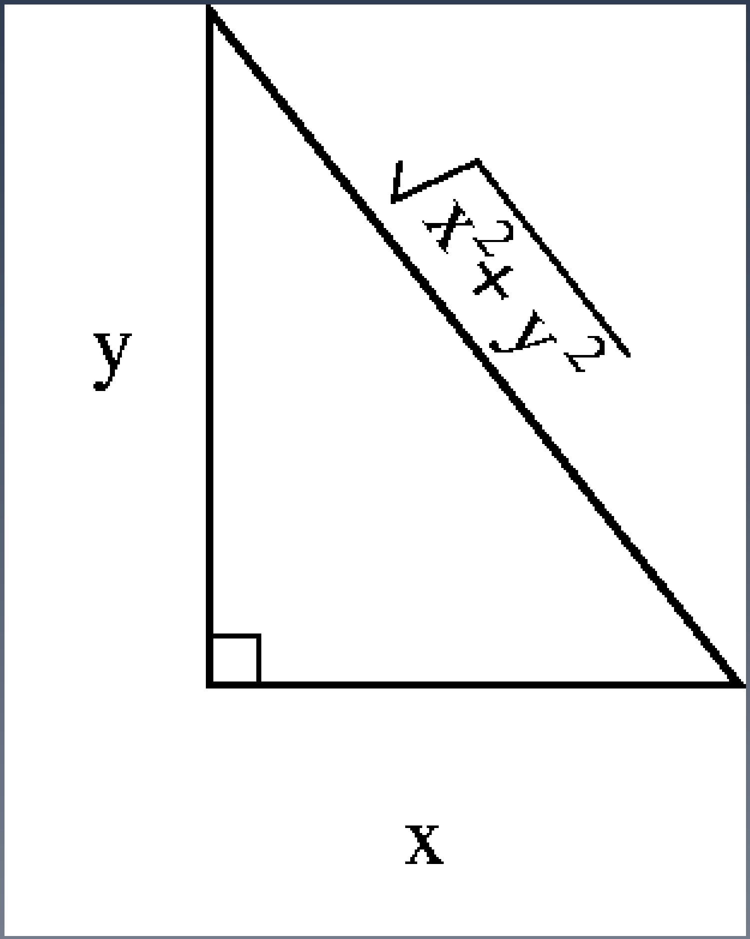
→ OCRA main points

Testy obserwacyjne topologii Wszechświata

Boud Roukema

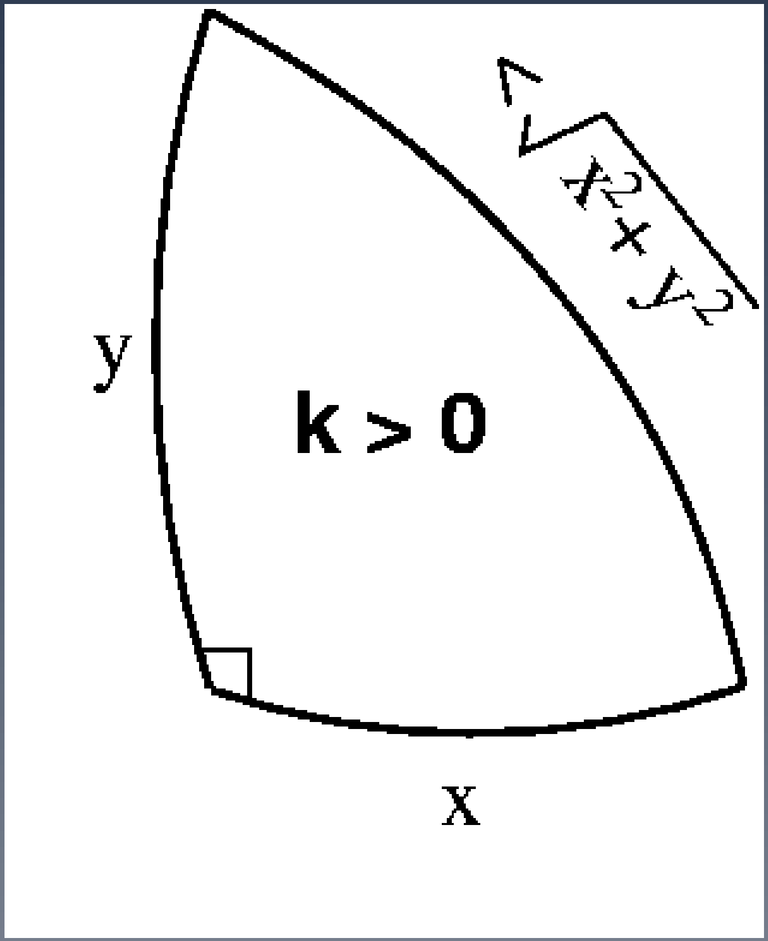
Centrum Astronomii UMK

geometria: krzywizna + topologia



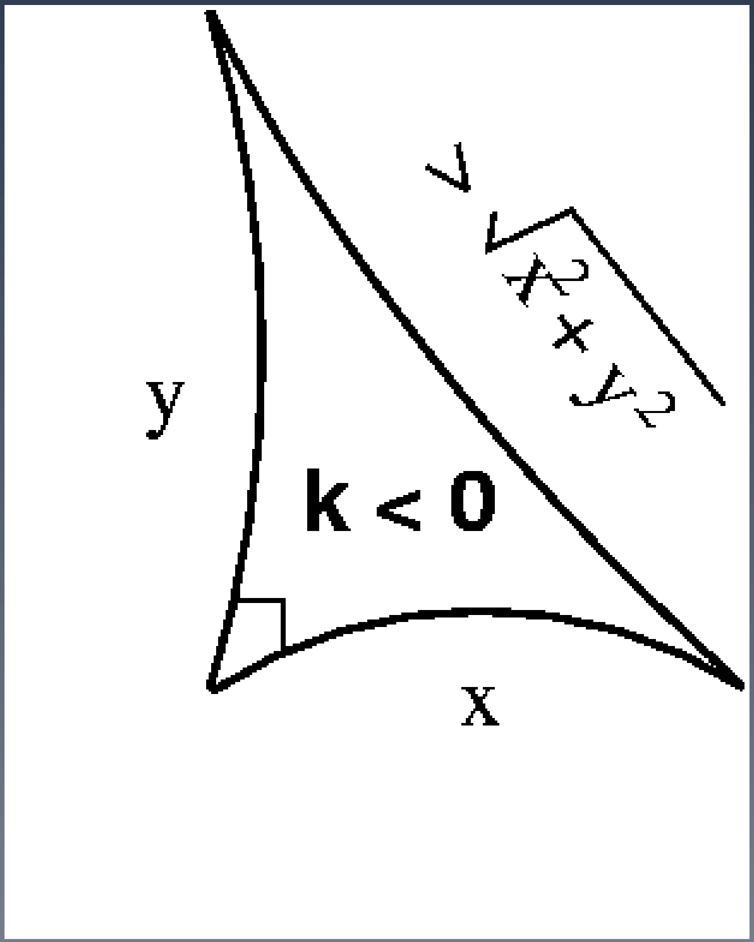
0 + - multi-connected

geometria: krzywizna + topologia



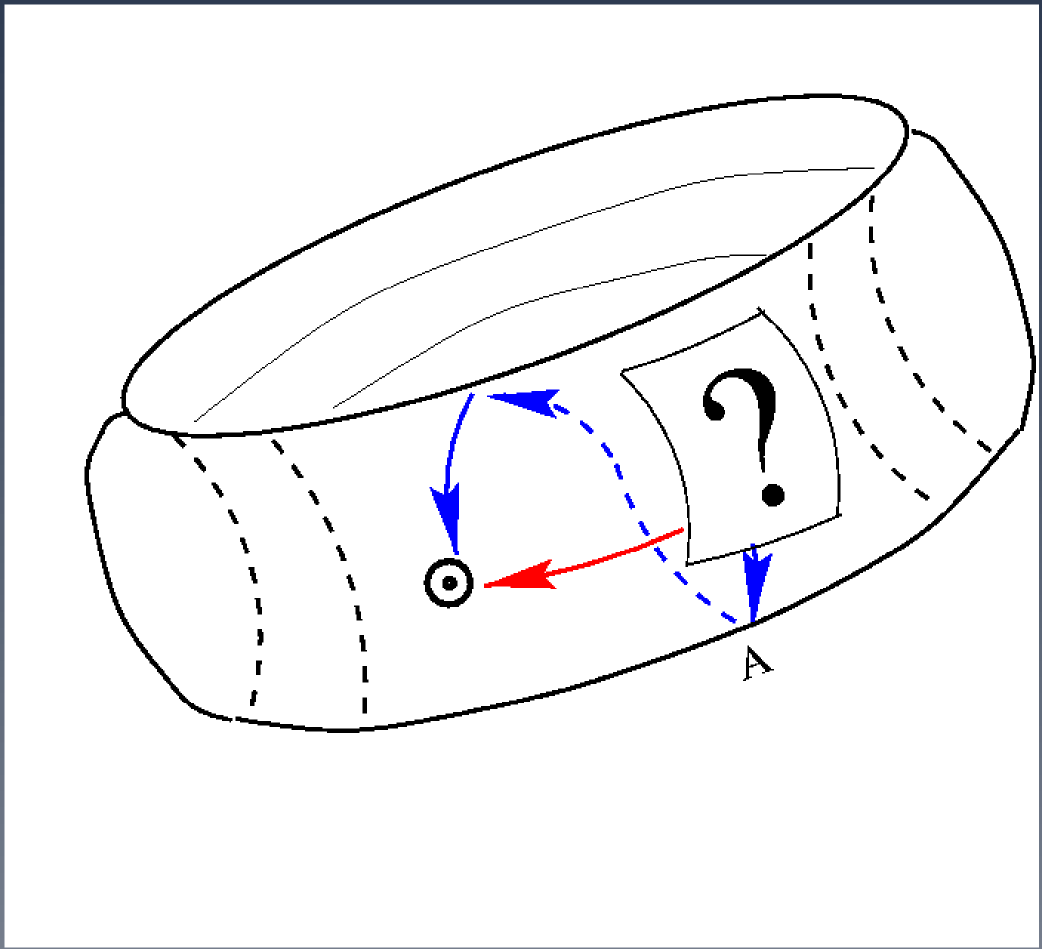
0 + - multi-connected

geometria: krzywizna + topologia



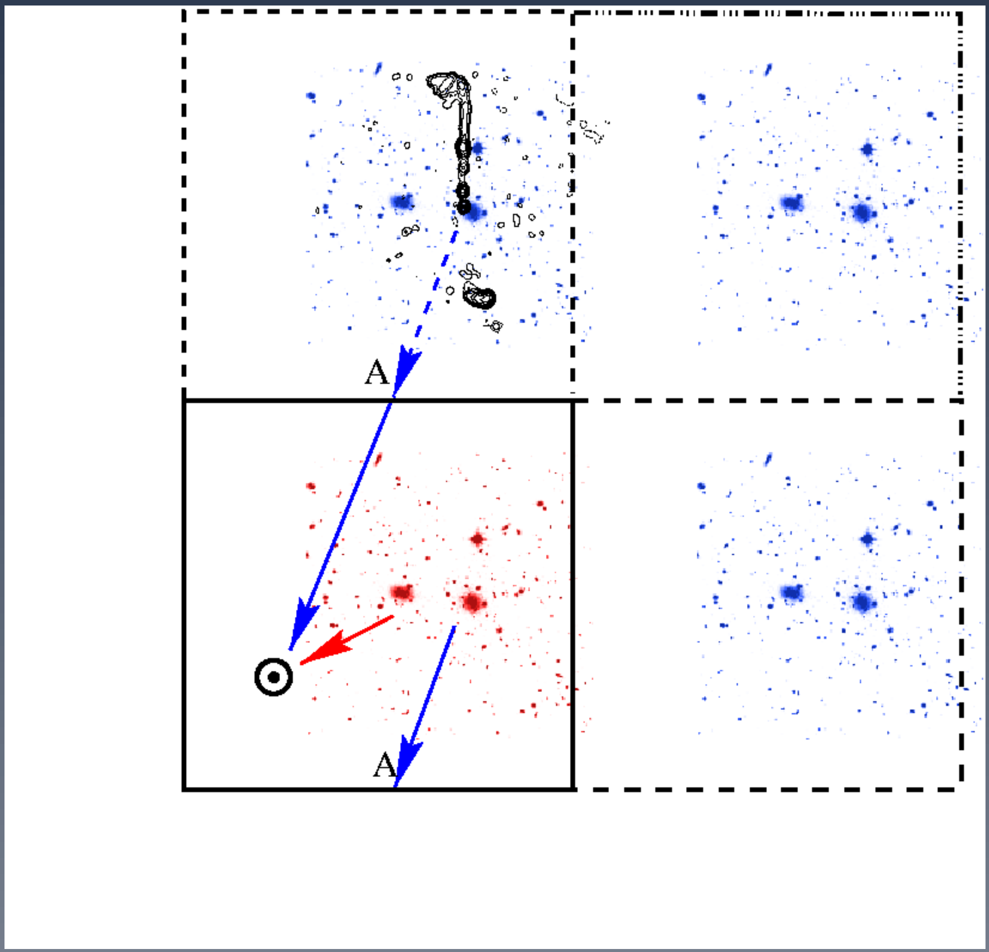
0 + - multi-connected

geometria: krzywizna + topologia



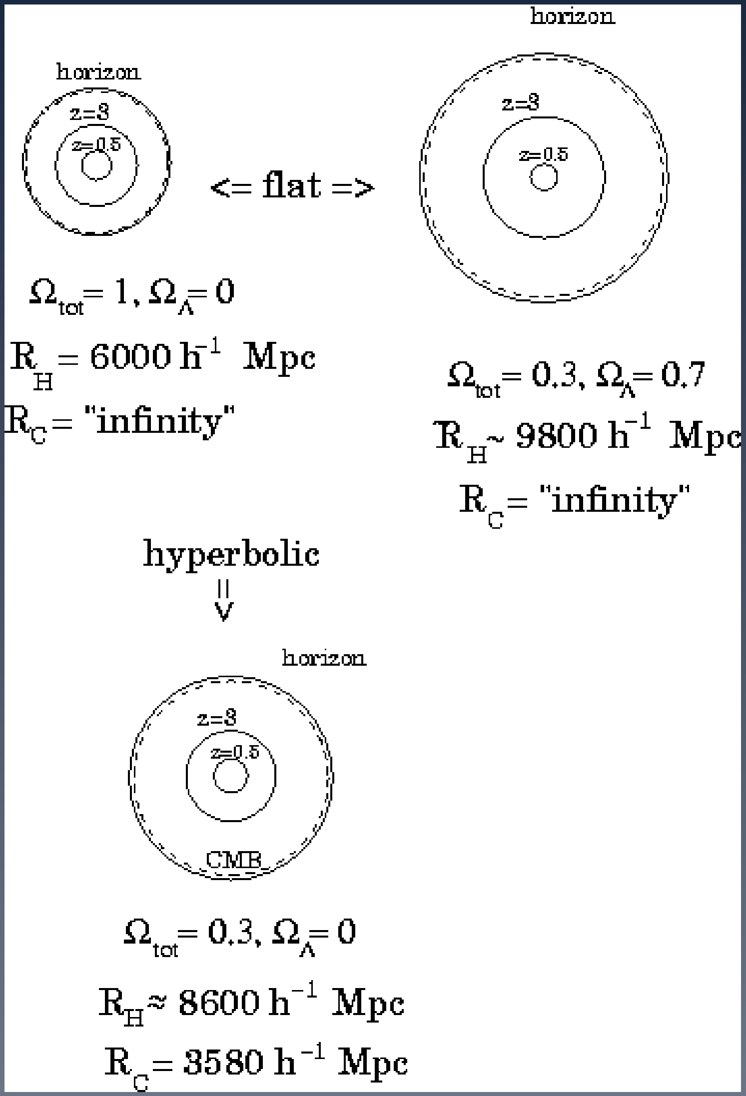
0 + - multi-connected

geometria: krzywizna + topologia



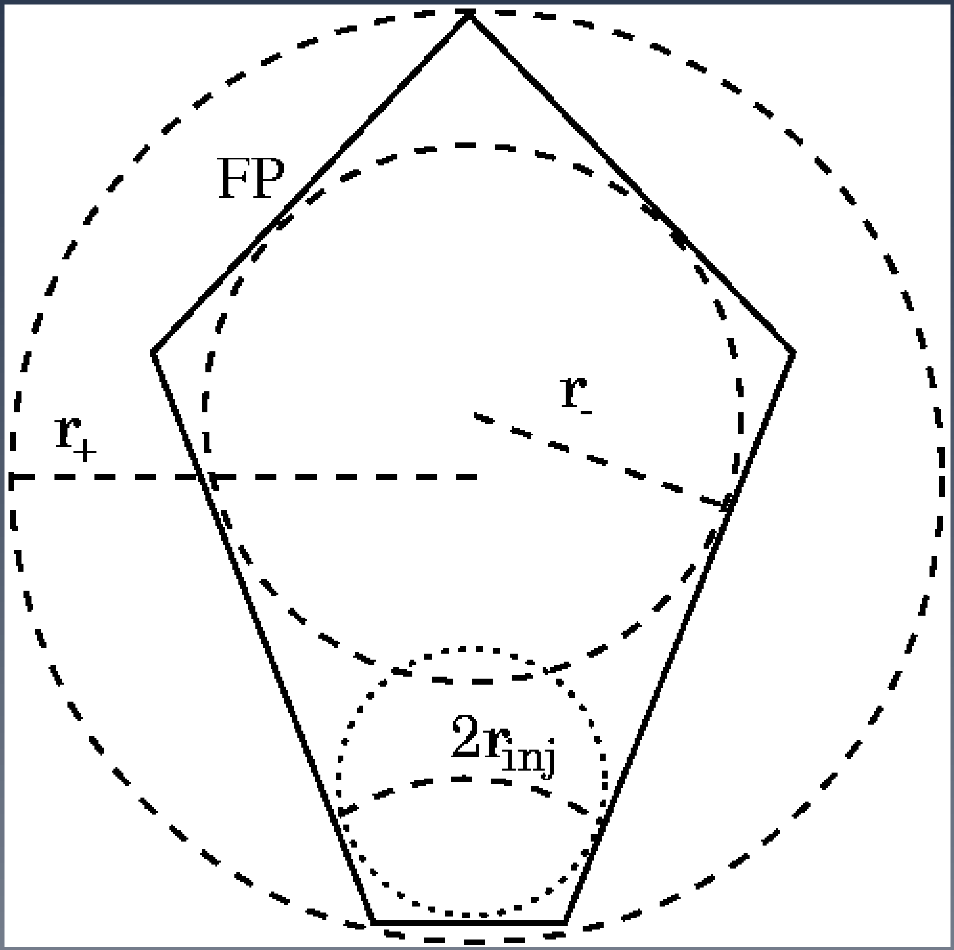
0 + - multi-connected

geometria: krzywizna + topologia



0 + - multi-connected

geometria: krzywizna + topologia



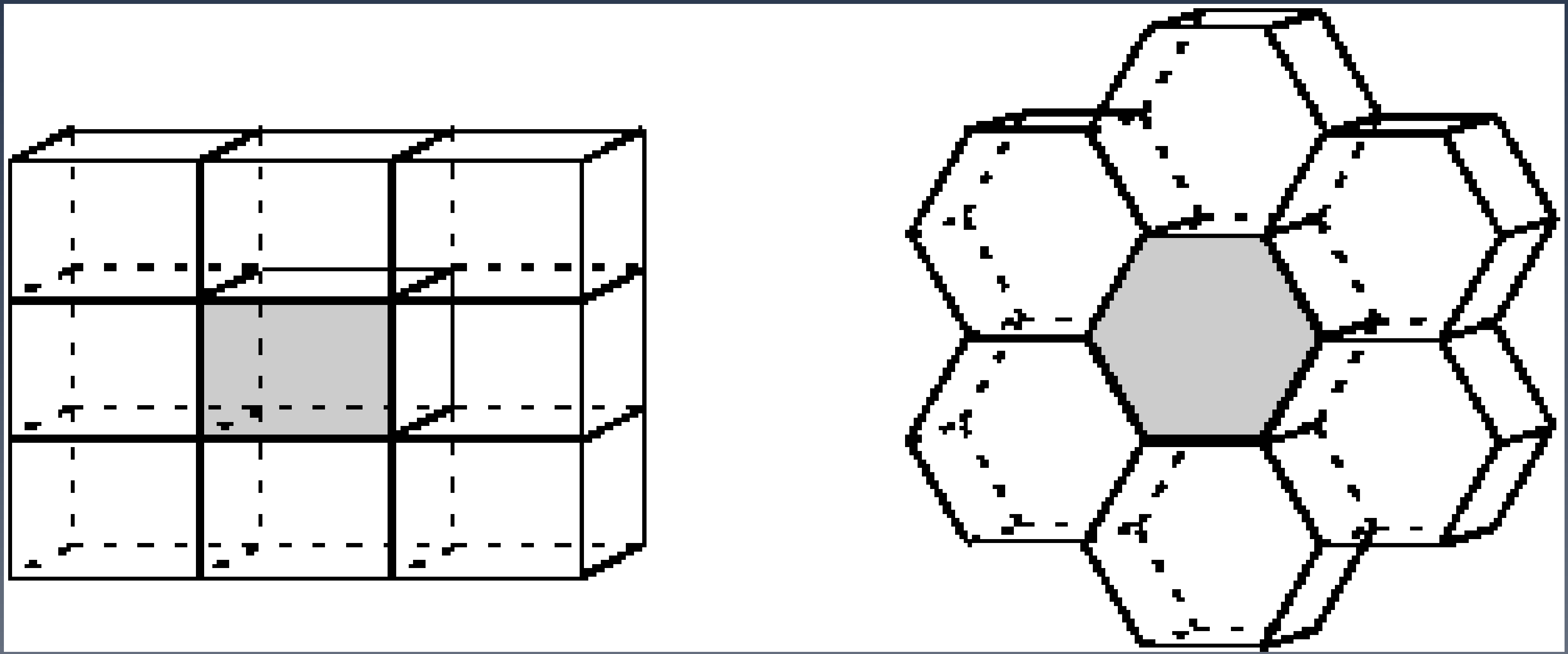
r_- : biggest sphere *inside* FD

r_+ : smallest sphere *containing* FD

$2r_{\rm inj}$: smallest closed spatial geodesic

0 $+$ - multi-connected

Geometry: Curvature + Topology



0

+ - multi-connected (Luminet & Roukema 1999: http://arXiv.org/abs/astro-ph/9901364)

Strategies - 3D

http://arXiv.org/abs/astro-ph/0010189

A. multiple topological images:

A.i 3D (grav collapsed objects):

A.i.1 local isometries - many "type I pairs" or "local pairs"

A.i.2 cosmic crystallography - many "type II pairs" or "generator pairs",

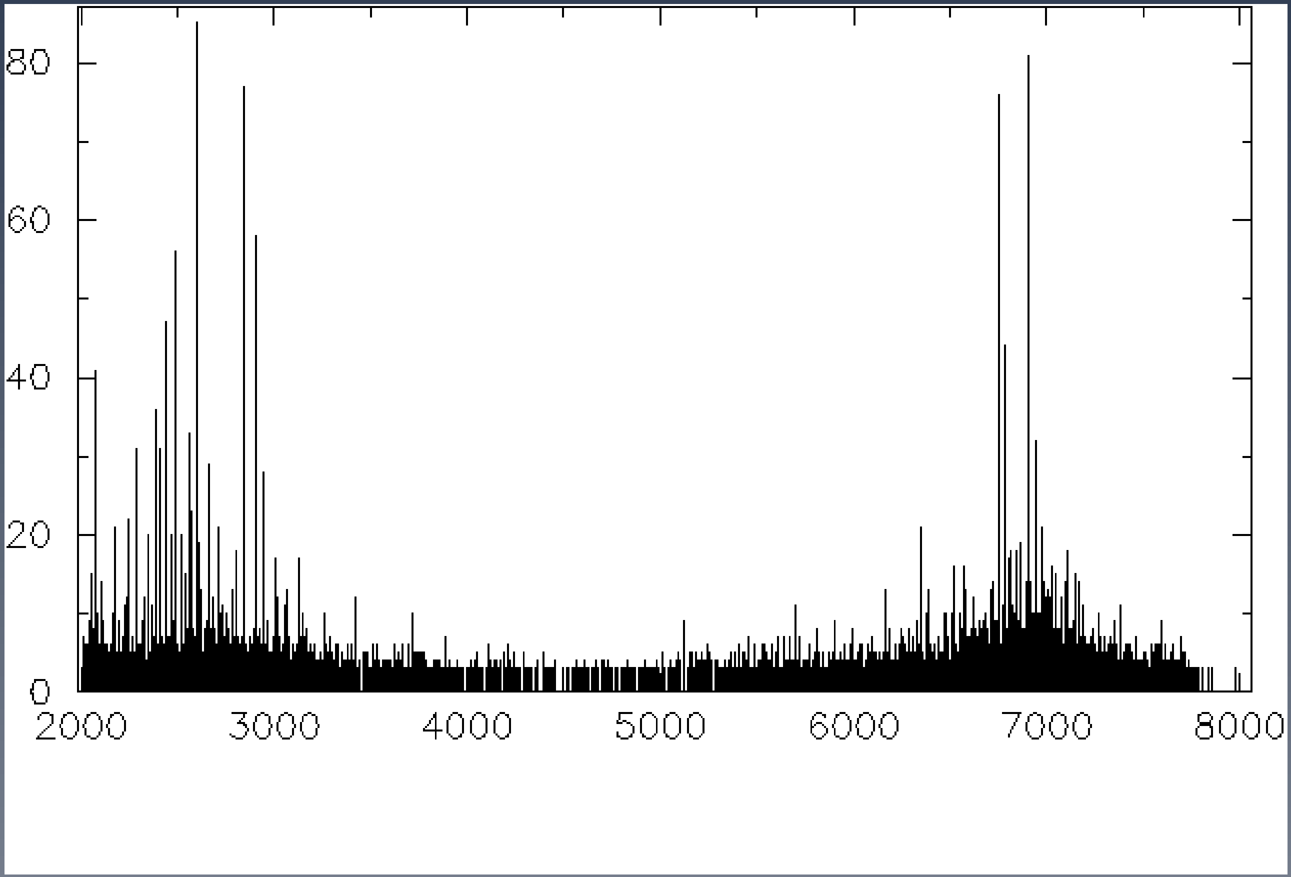
A.i.3 characteristics of individual objects

Strategies - 2D and non-multiple-imaging

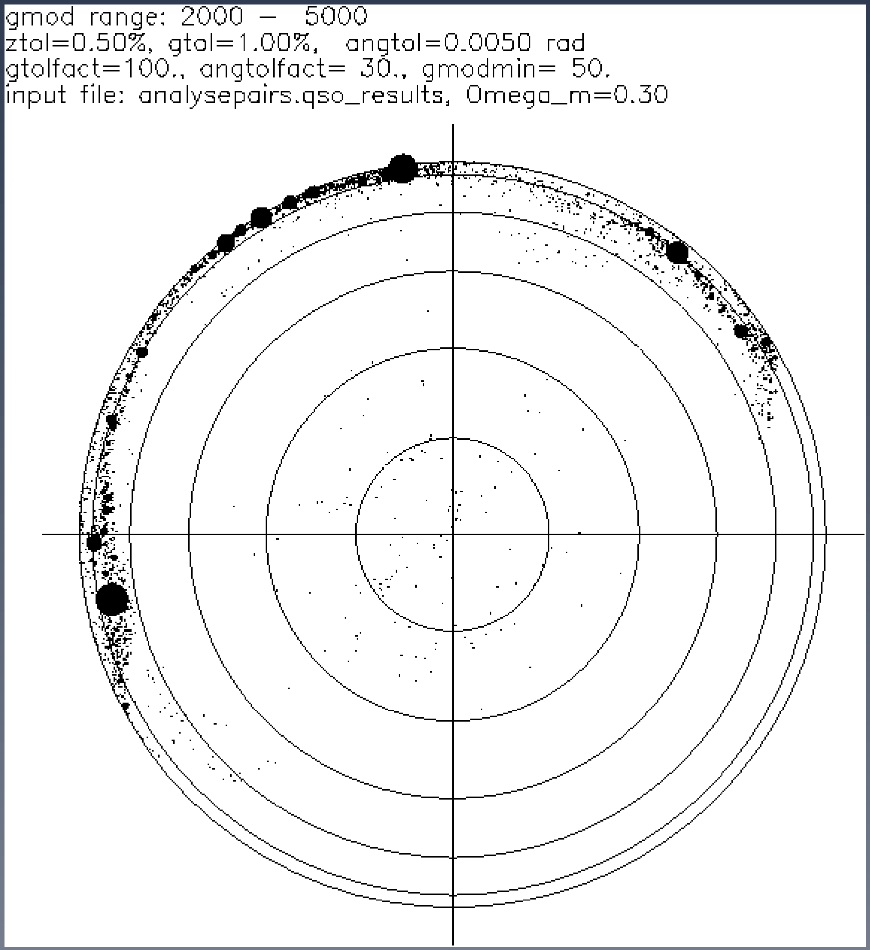
- A.ii 2D (microwave background, CMB):
  - A.ii.1 identified circles principle:
  - A.ii.2 patterns of spots
  - A.ii.3 perturbation statistics assumptions
- B. other:
  - B.i cosmic strings
  - B.ii nested crystallography

AGN Catalogues

Marecki, Roukema, Bajtlik

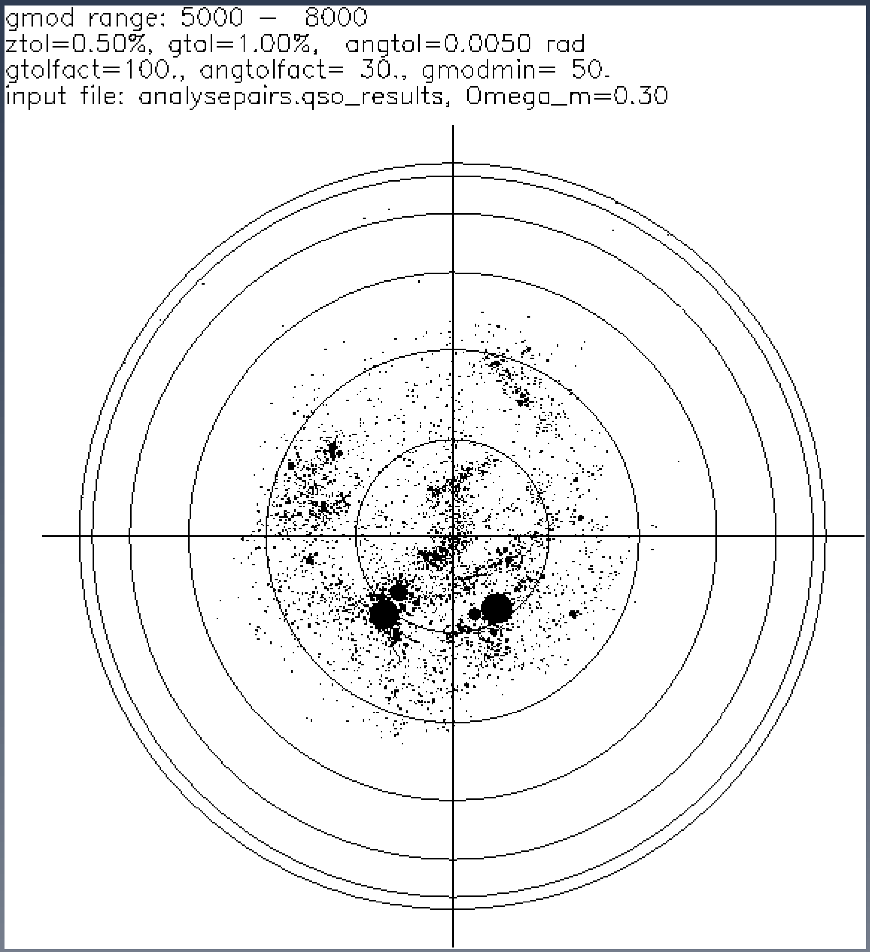


AGN Catalogues



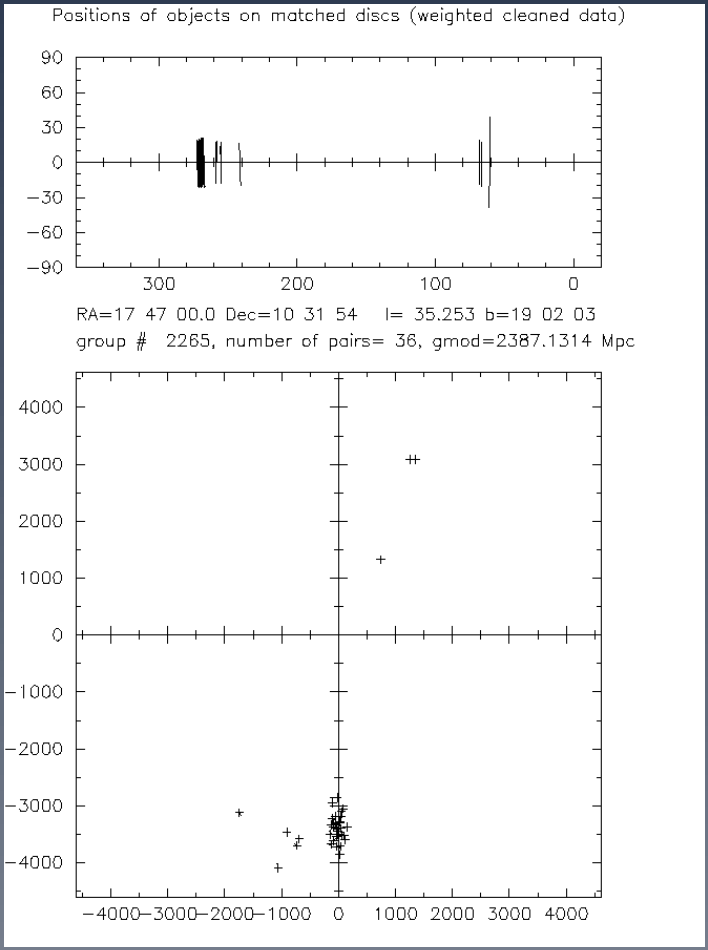
0 + - multi-connected

AGN Catalogues



0 + - multi-connected

AGN Catalogues



0 + - multi-connected

AGN: Conclusion

- AGN short lifetimes implies redshift filter to improve S/N
- application to large AGN catalogue compilation reveals apparent signals
- closer analysis ⇒ these are selection effects
- no signal found in compilation of radio-loud AGNs (RLAGNs)

Marecki, Roukema, Bajtlik (in preparation)

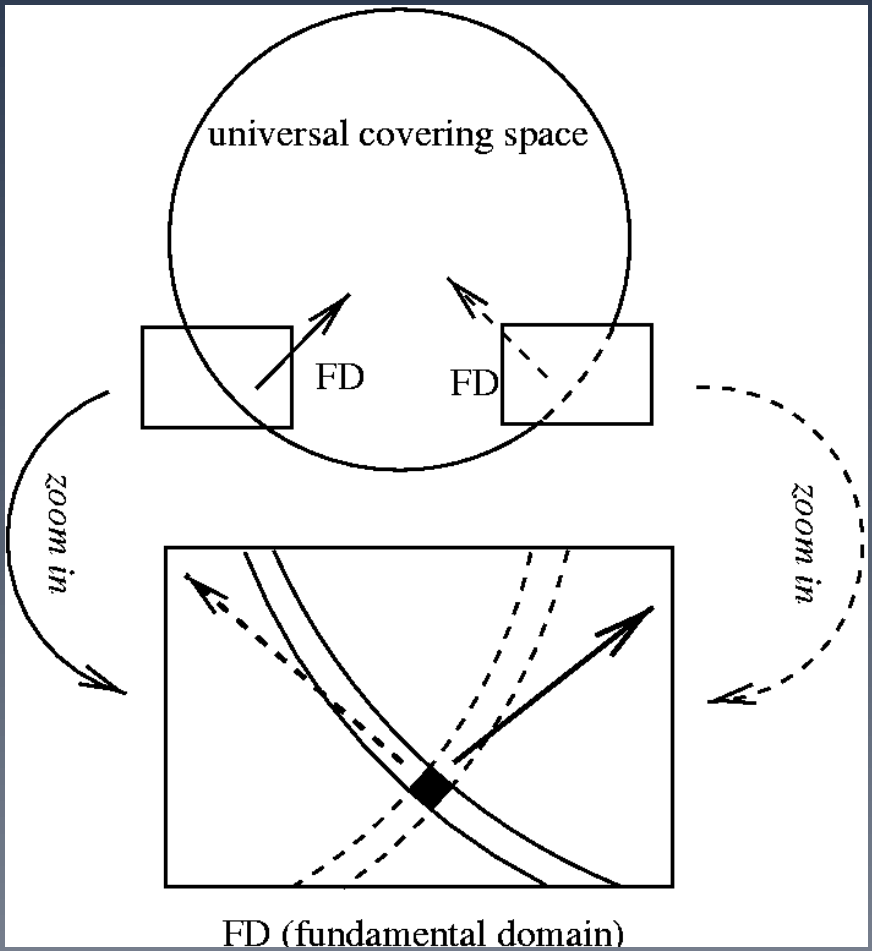
The Identified Circles Principle

Discovery of principle: Cornish, Spergel & Starkman (1996)

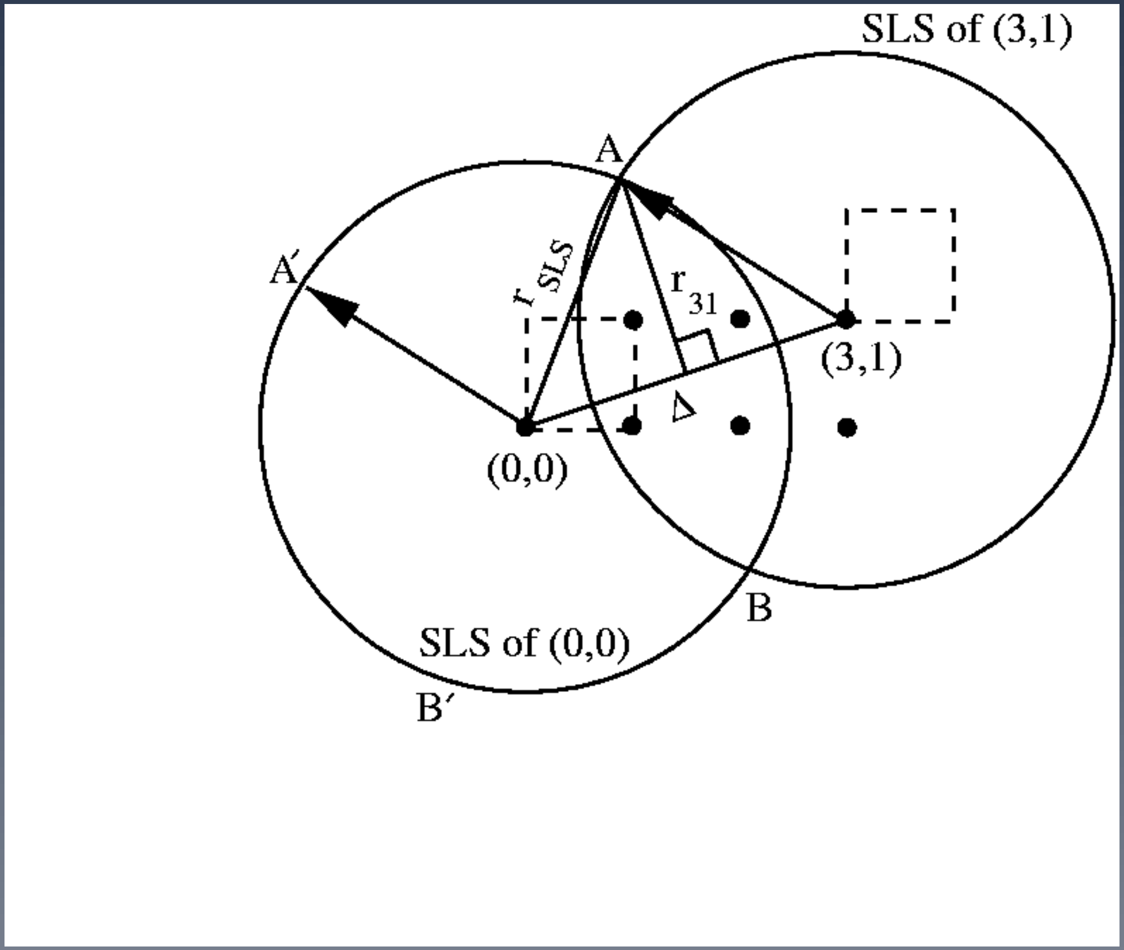
http://arXiv.org/abs/astro-ph/9602039

CQG, 15, 2657 (1998)

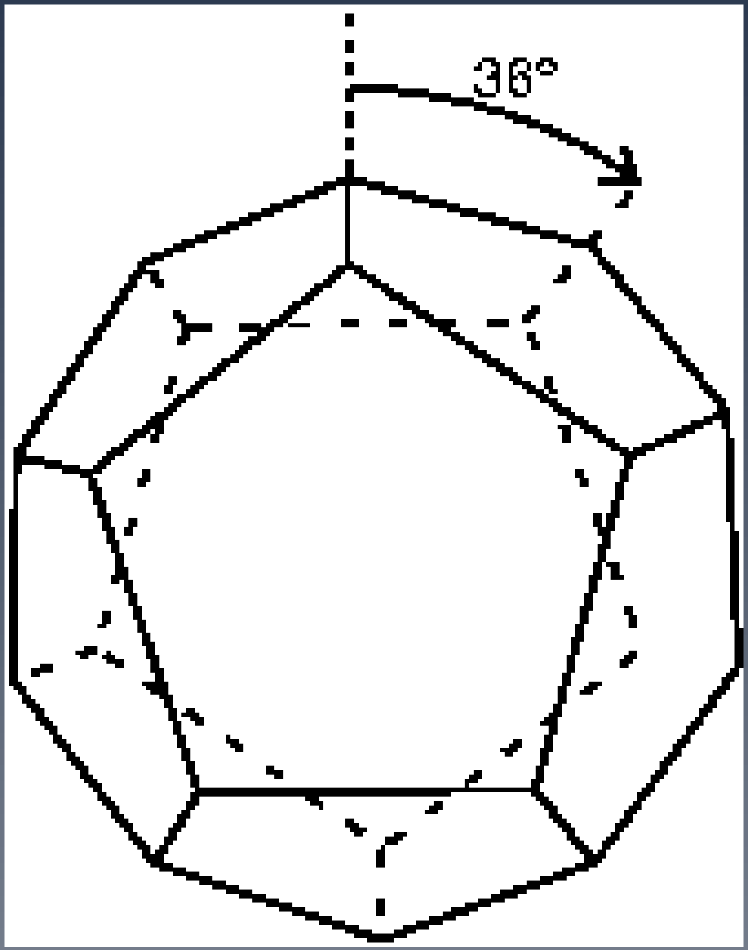
The Identified Circles Principle



The Identified Circles Principle



The Poincaré Dodecahedral 3-Manifold



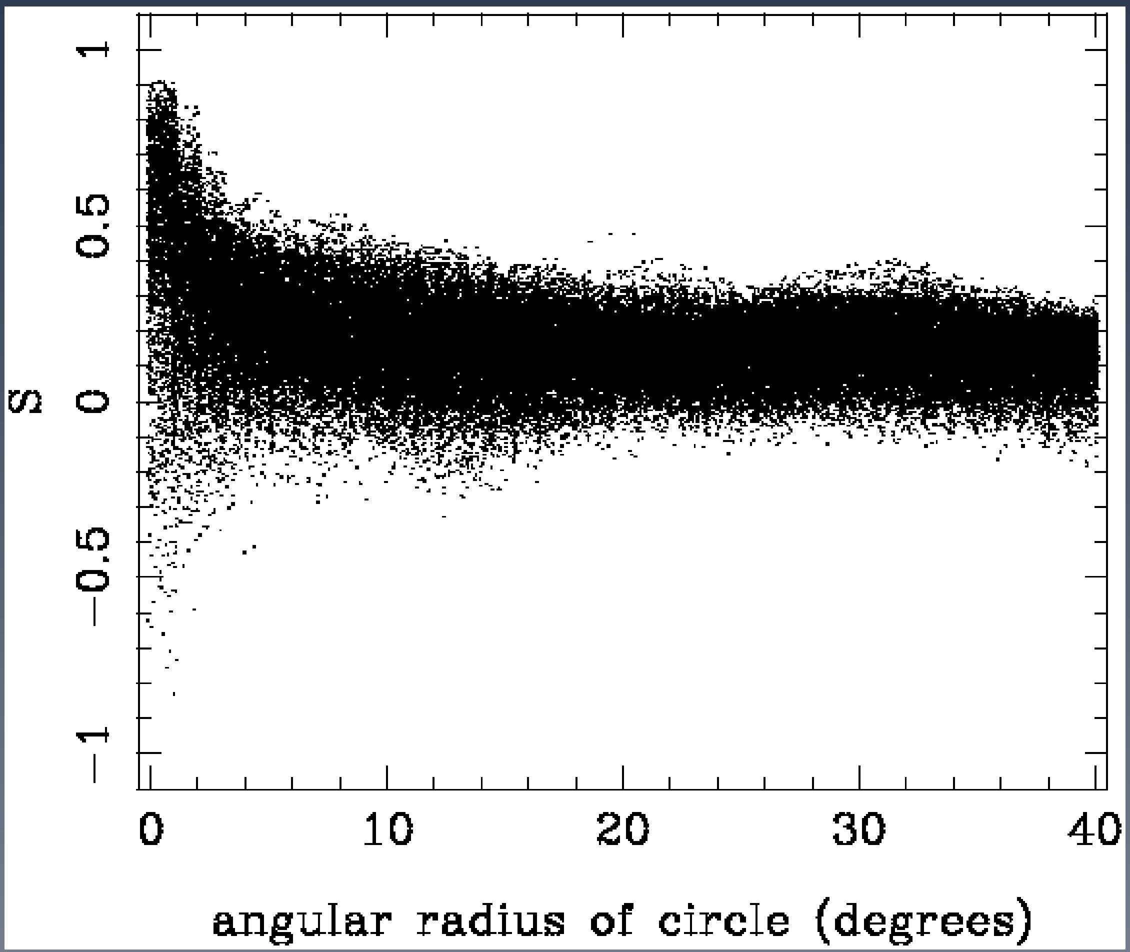
- FD = positively curved dodecahedron covering space is S^3 (hypersphere)
- 120 copies of FD tile S^3
- Luminet et al. (2003) find this favoured by WMAP statistics

The Poincaré Dodecahedral 3-Manifold

Correlation statistic to detect best circle matches:

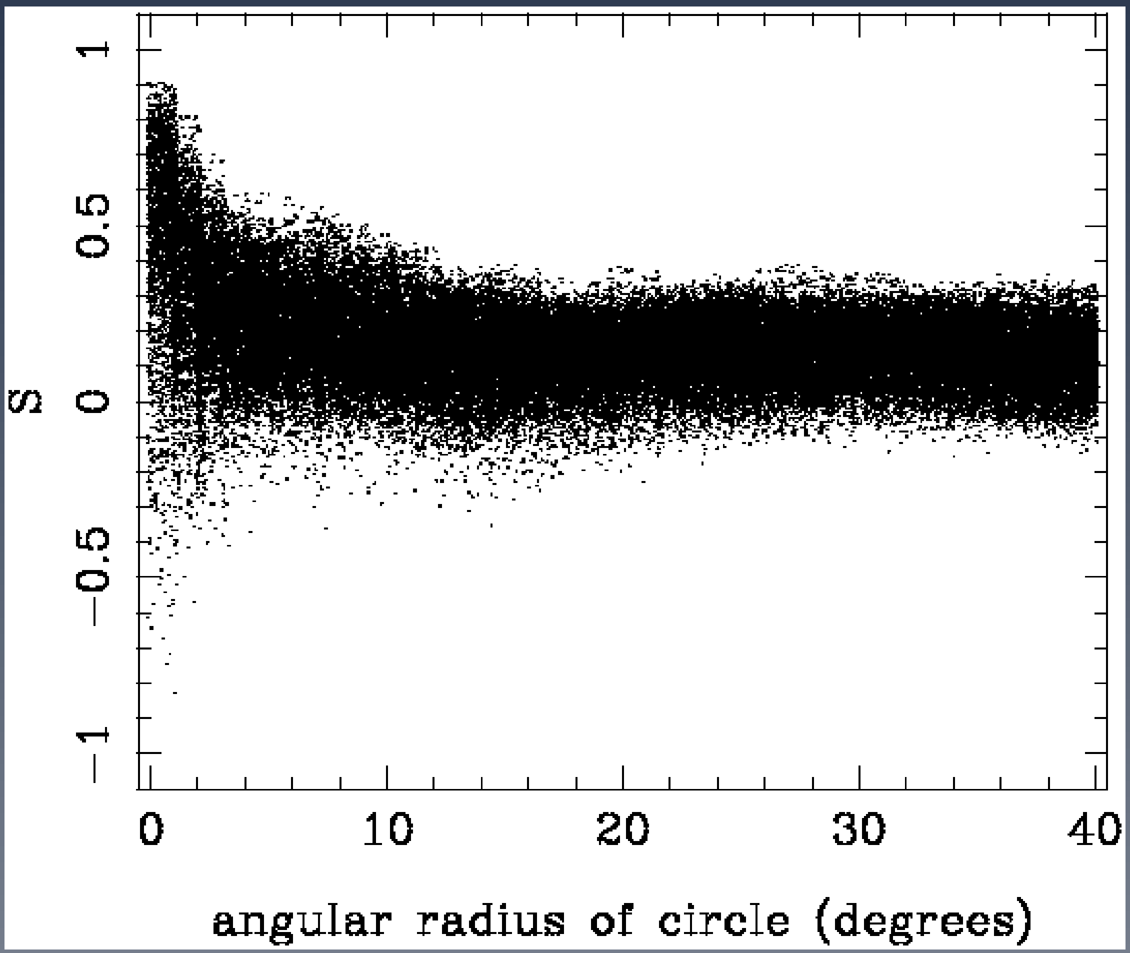
$$S \equiv \frac{\left\langle 2 \left(\frac{\delta T}{T}\right)_i \left(\frac{\delta T}{T}\right)_j \right\rangle}{\left\langle \left(\frac{\delta T}{T}\right)_i^2 + \left(\frac{\delta T}{T}\right)_j^2 \right\rangle} \quad (2)$$

The Poincaré Dodecahedral 3-Manifold



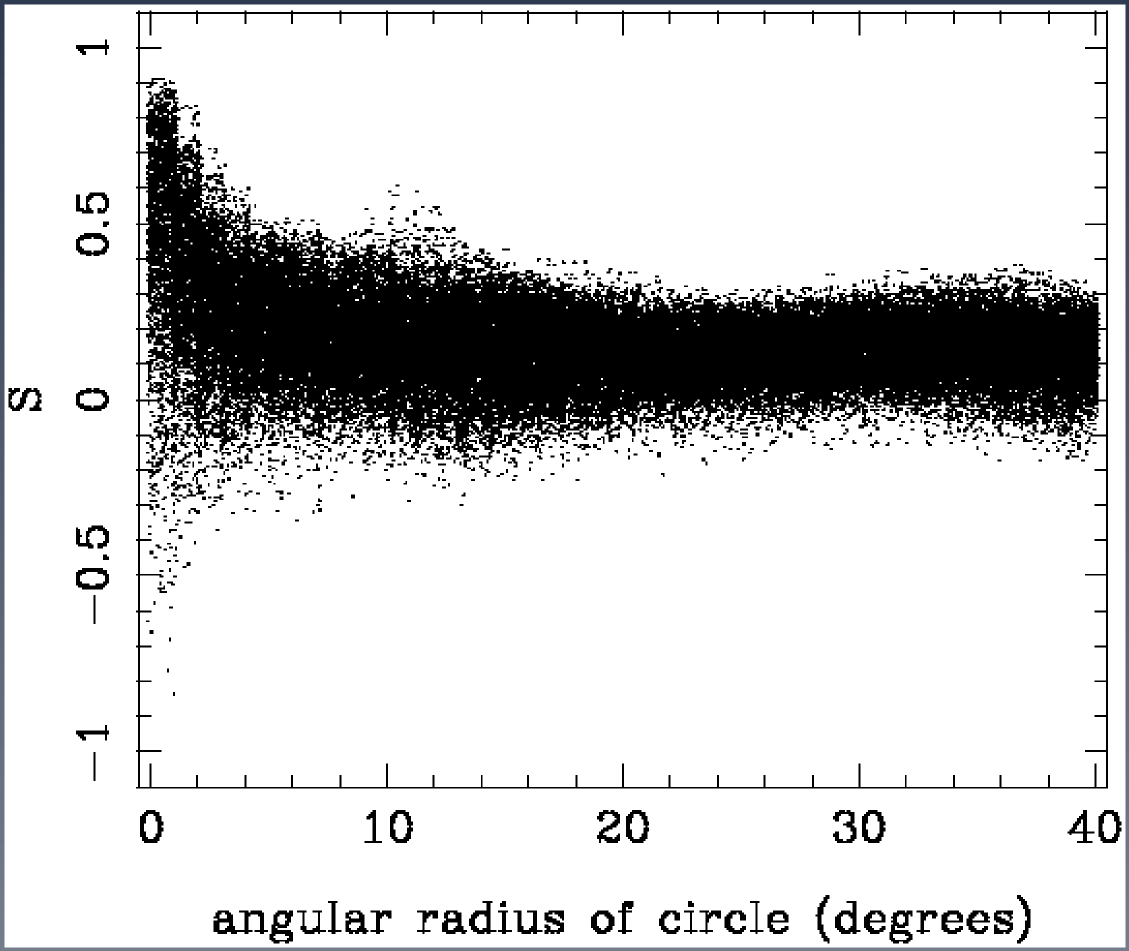
zero rotation

The Poincaré Dodecahedral 3-Manifold



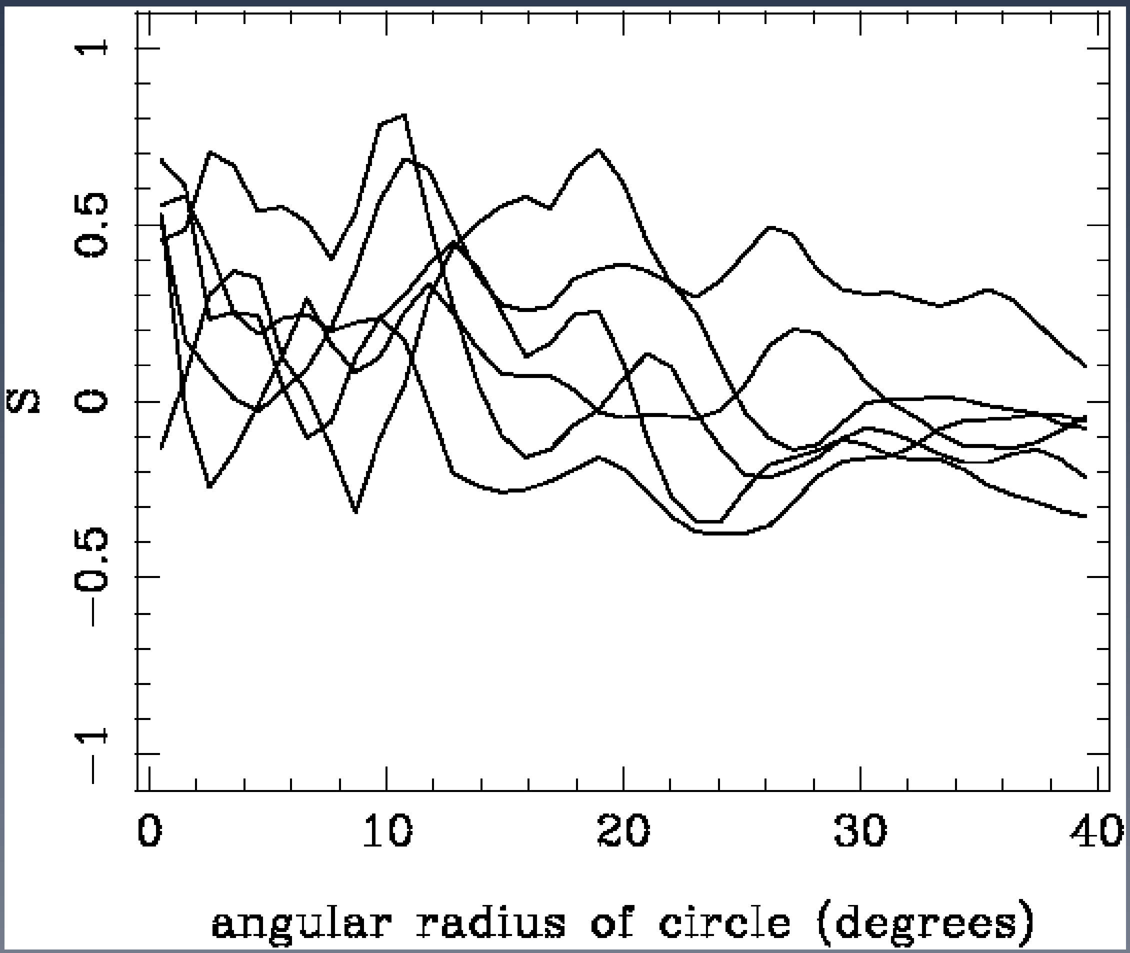
$+36^\circ$ rotation

The Poincaré Dodecahedral 3-Manifold



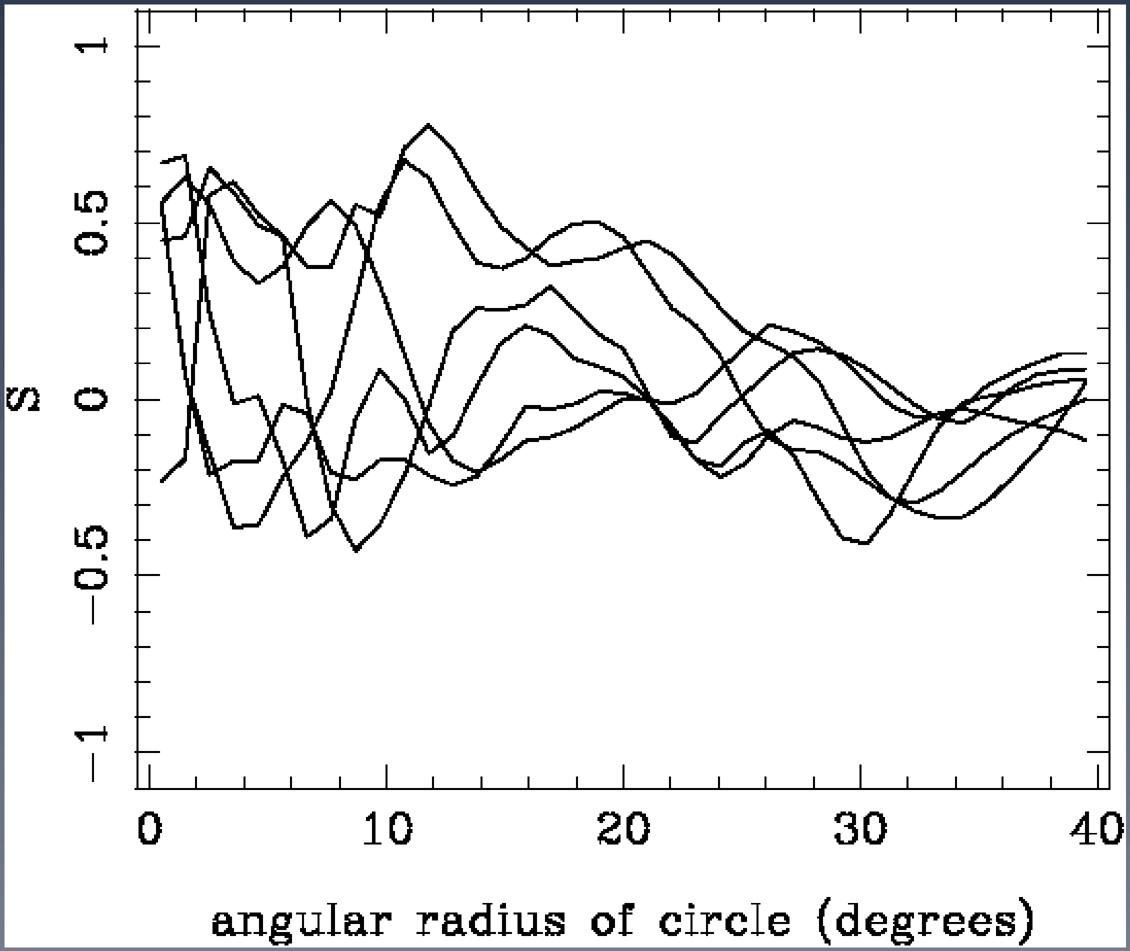
-36° rotation

The Poincaré Dodecahedral 3-Manifold



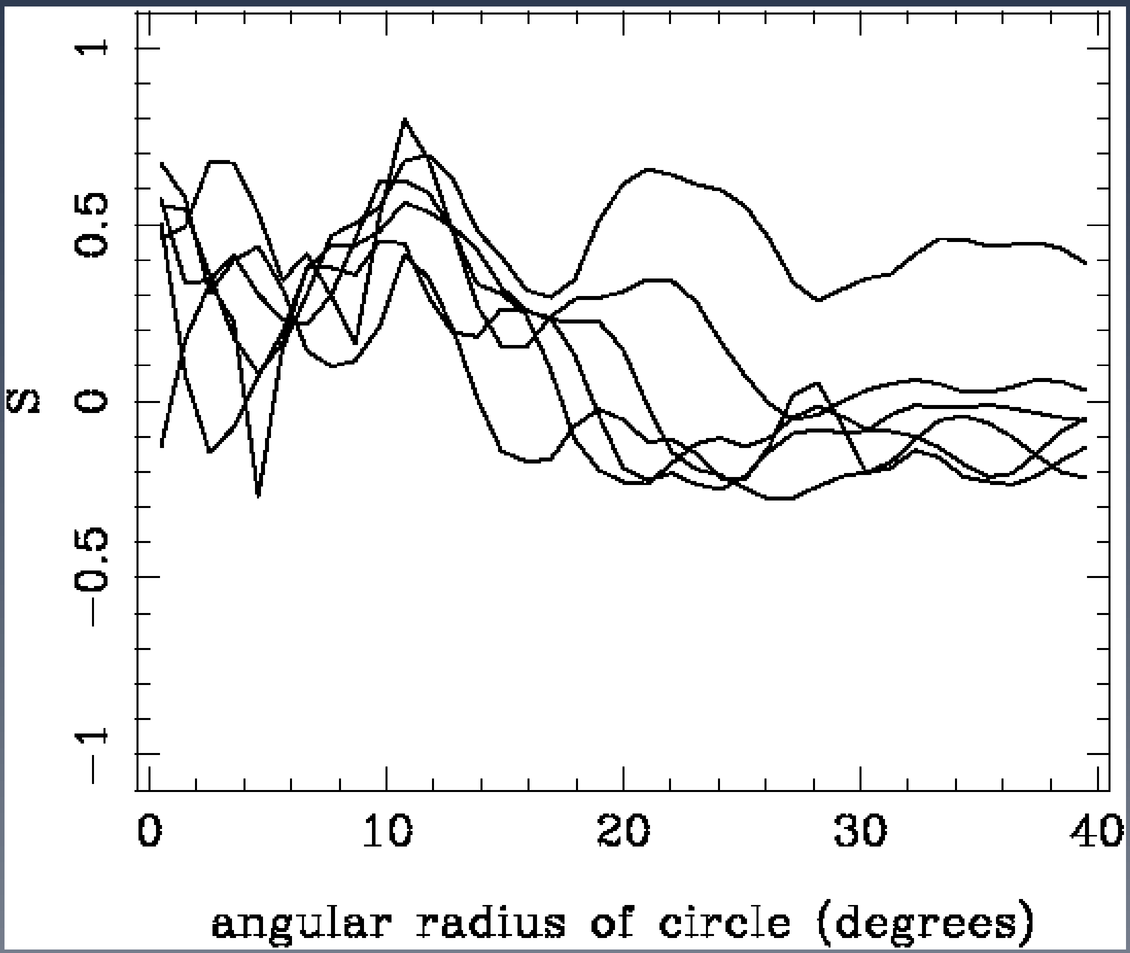
zero rotation

The Poincaré Dodecahedral 3-Manifold



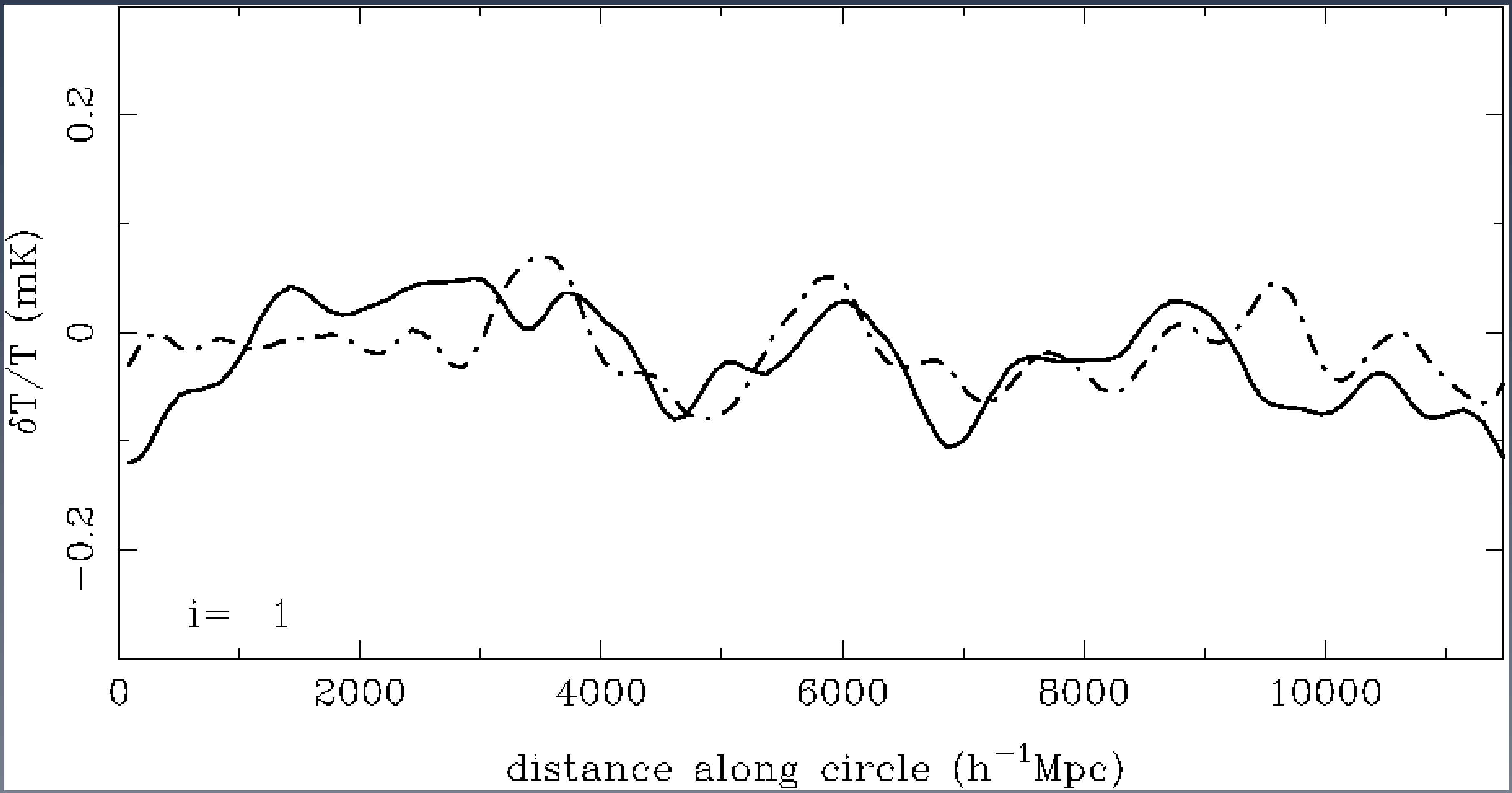
$+36^\circ$ rotation

The Poincaré Dodecahedral 3-Manifold

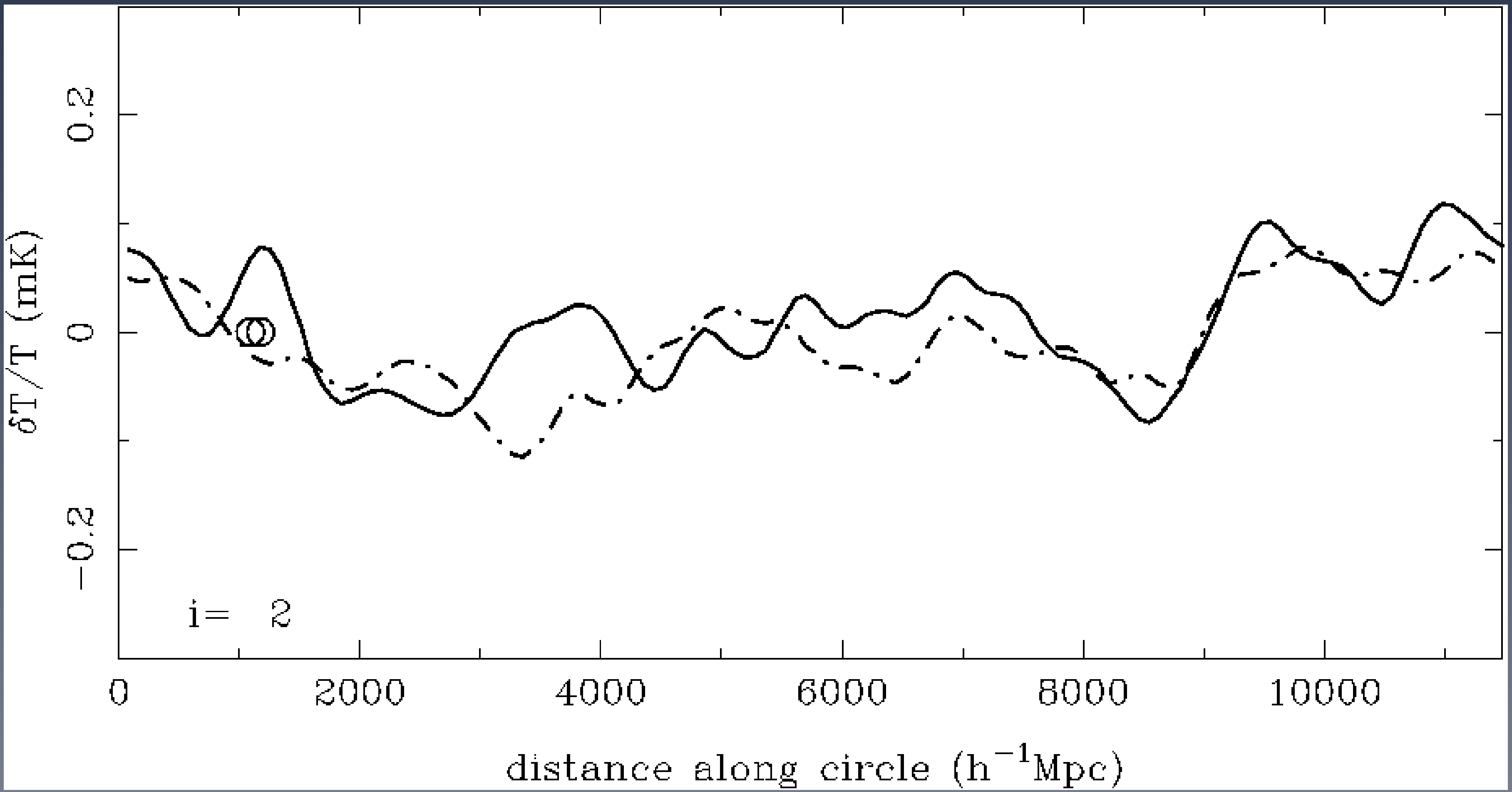


-36° rotation

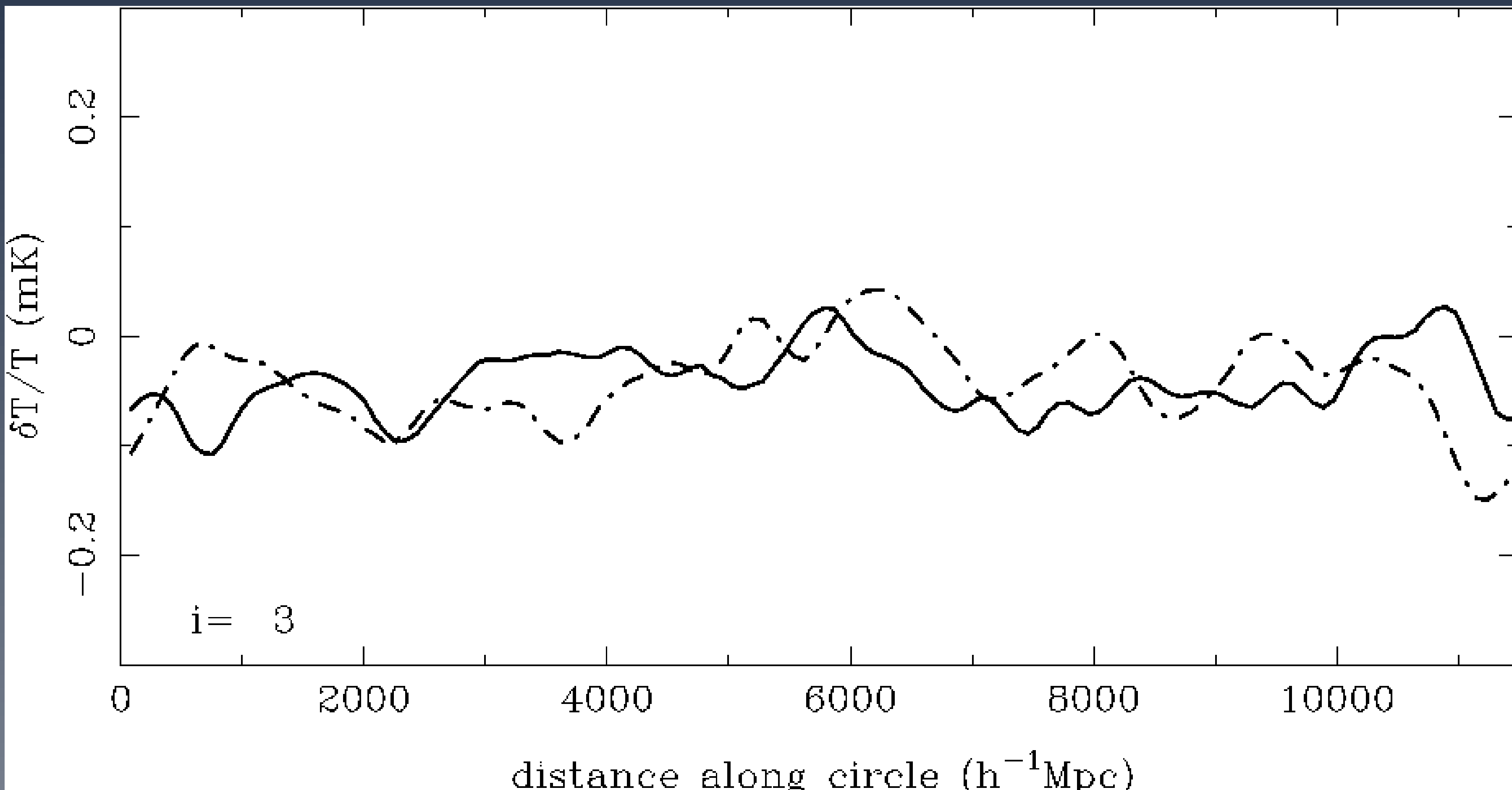
The Poincaré Dodecahedral 3-Manifold



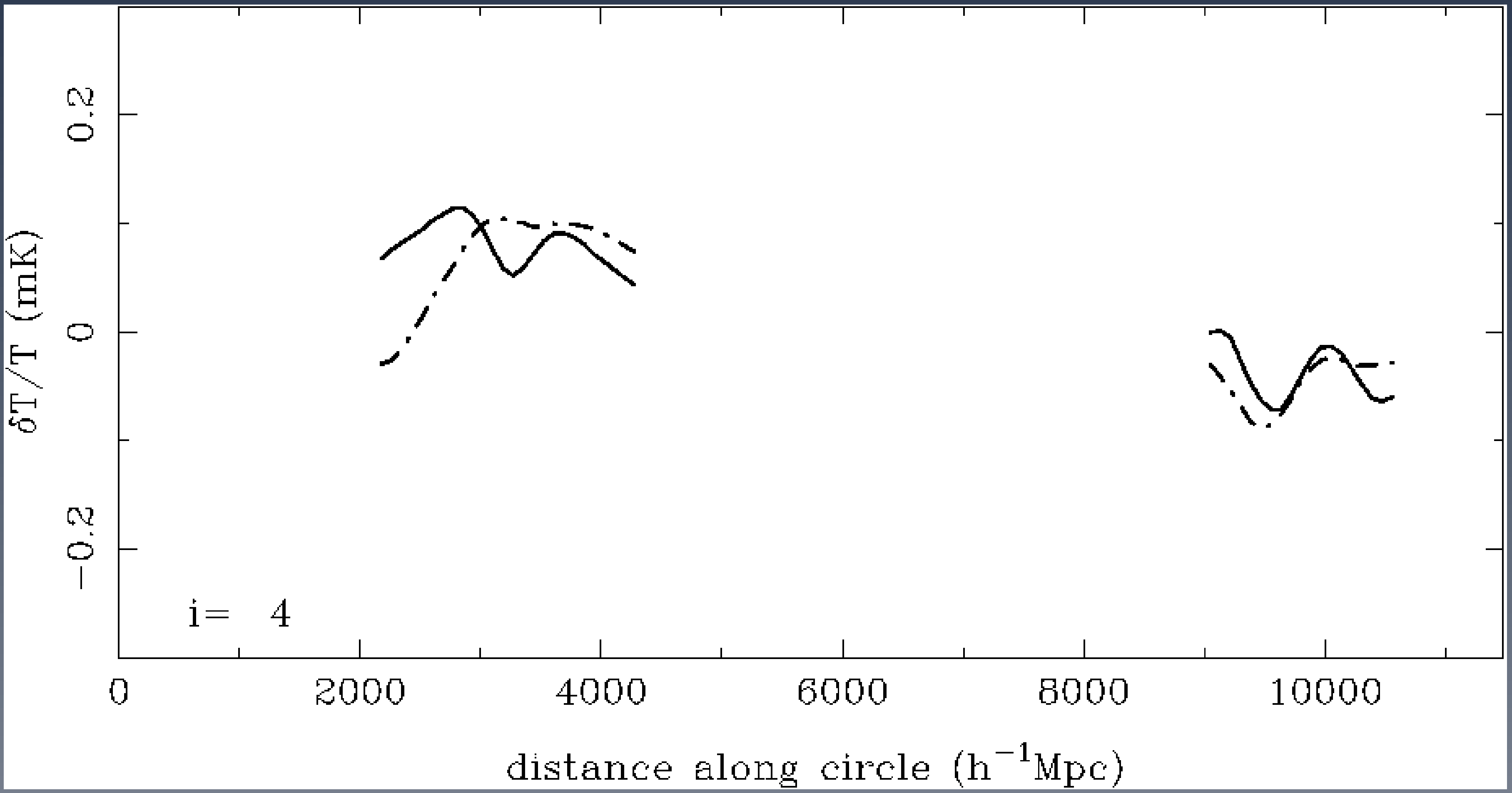
The Poincaré Dodecahedral 3-Manifold



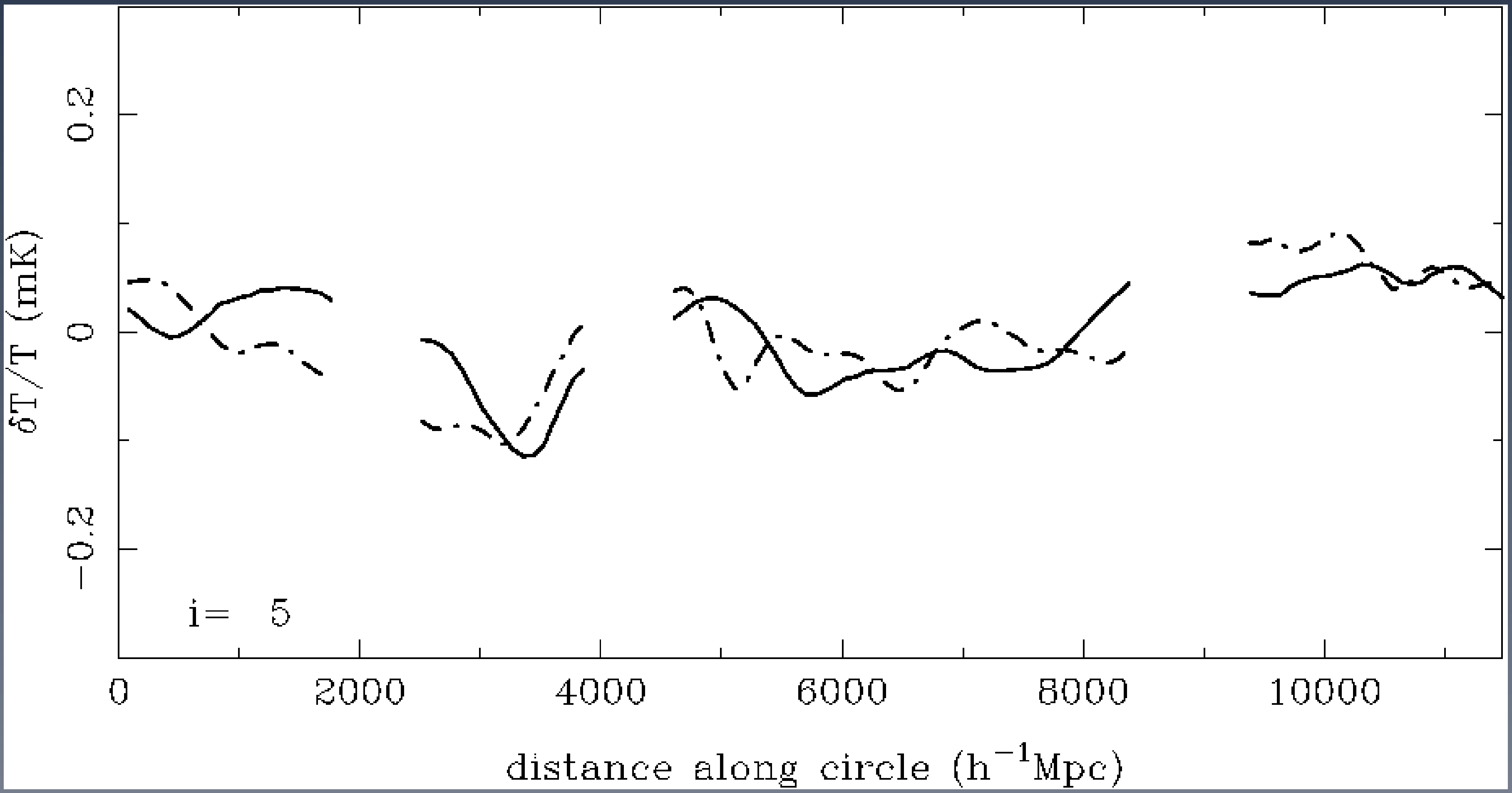
The Poincaré Dodecahedral 3-Manifold



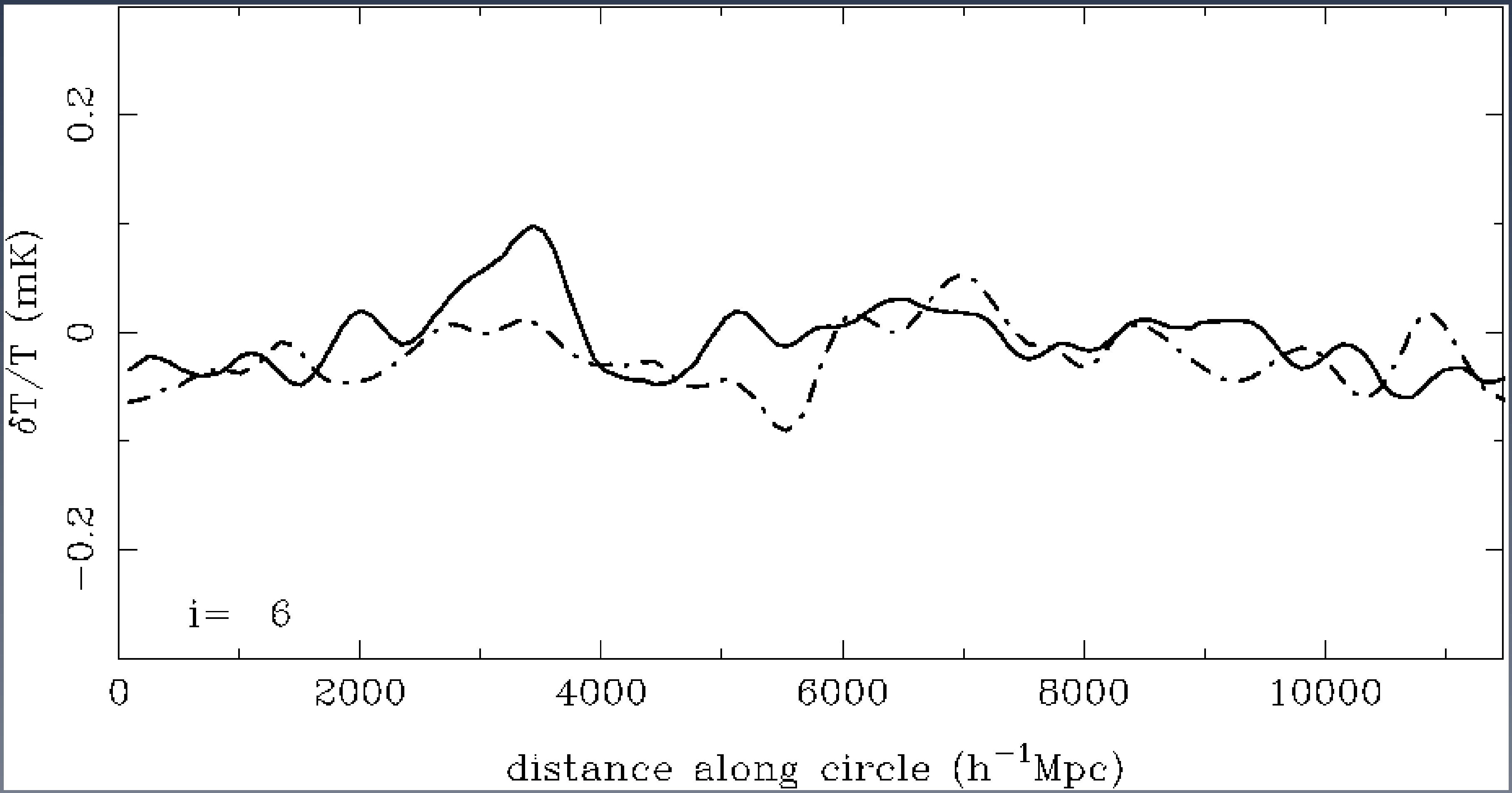
The Poincaré Dodecahedral 3-Manifold



The Poincaré Dodecahedral 3-Manifold



The Poincaré Dodecahedral 3-Manifold



Dodecahedral Hypothesis: Conclusions

- best Poincaré dodecahedral solution has $11 \pm 1^\circ$ matched circles
- the six circle pairs independently have high correlations

Dodecahedral Hypothesis: Conclusions

i	l^{II} in °	b^{II} in °	α in °
1	252.4	64.7	9.8
2	50.6	50.8	10.7
3	143.8	37.8	10.7
4	207.5	9.5	10.7
5	271.0	2.7	11.8
6	332.8	25.0	10.7

Roukema, Lew, Cechowska, Marecki, Bajtlik, A&A in press (2004)

http://arXiv.org/abs/astro-ph/0402608

Quasars

Roukema B. F.
1996, Monthly Notices of the Royal Astronomical Society, 283, 1147
On Determining the Topology of the Observable Universe via 3-D Quasar Positions

Clusters of Galaxies Candidate

Roukema B. F., Edge A. C. (X-ray)

1997, Monthly Notices of the Royal Astronomical Society, 292, 105

Constraining Cosmological Topology via Highly Luminous X-ray Clusters

Clusters of Galaxies Candidate

Roukema B. F., Edge A. C. (X-ray)
1997, Monthly Notices of the Royal Astronomical Society, 292, 105
Constraining Cosmological Topology via Highly Luminous X-ray Clusters

Roukema B. F., Bajtlik, S. (optical)
1999, Monthly Notices of the Royal Astronomical Society, 308, 309
Transverse Galaxy Velocities from Multiple Topological Images

Clusters of Galaxies Candidate

Roukema B. F. (microwave background)
2000a, Monthly Notices of the Royal Astronomical Society, 312, 712 *COBE and Global Topology: An Example of the Application of the Circles Principle*

Application: Constraints on Curvature

Roukema B. F., Luminet, J.–P.
1999, Astronomy & Astrophysics, 348, 8
Constraining Curvature Parameters via Topology

Cosmic Microwave Background (COBE)

Roukema B. F.

2000b, Classical & Quantum Gravity, 17, 3951

A Counterexample to Claimed COBE Constraints on Compact Toroidal Models

Radio-Loud Active Galactic Nuclei (RLAGNs) + Cosmic Microwave Background (WMAP)

work under progress at Toruń Centre for Astronomy, UMK

Radio-Loud Active Galactic Nuclei (RLAGNs) + Cosmic Microwave Background (WMAP)

work under progress at Toruń Centre for Astronomy, UMK

- Marcin Gawroński, Magdalena Kunert, Andrzej Marecki, Sebastian Soberski (RLAGNs)

Radio-Loud Active Galactic Nuclei (RLAGNs) + Cosmic Microwave Background (WMAP)

work under progress at Toruń Centre for Astronomy, UMK

- Marcin Gawroński, Magdalena Kunert, Andrzej Marecki, Sebastian Soberski (RLAGNs)
- Magdalena Cechowska, Bartosz Lew (WMAP)

Radio-Loud Active Galactic Nuclei (RLAGNs) + Cosmic Microwave Background (WMAP)

work under progress at Toruń Centre for Astronomy, UMK

- Marcin Gawroński, Magdalena Kunert, Andrzej Marecki, Sebastian Soberski (RLAGNs)
- Magdalena Cechowska, Bartosz Lew (WMAP)
- http://adjani.astro.uni.torun.pl/cosmo

Theory: Cosmic Topology vs Inflation

Peaks in the Hartle-Hawking Wave Function from Sums over Topologies
Anderson, Carlip, Ratcliffe, Surya, Tschantz, 2003
http://arXiv.org/abs/gr-qc/0310002

• some topologies are much more probable than others

• spatial metrics of constant (negative) curvature are favoured

• work incomplete, but hints at predictability

Fine-Tuning

• observable $\Omega_\Lambda > 0 \Rightarrow$ fine-tuning of inflation

• observable cosmic topology $\Rightarrow$ fine-tuning of inflation

• both might be the result of the same fine-tuning of inflation, or else of some other mechanism (e.g. peak in Hartle-Hawking wave function from sums over topologies)

ArFus: Galaxy Formation Software for the Ordinary User

(printed transparencies)

Distance calculations in cosmology

- light-travel distance:

$$d_{\text{light-travel}} = \int_{t}^{t_0} c\, \mathrm{d}t' \qquad (3)$$

proper distance = comoving distance =

$$\chi = \int_t^{t_0} \frac{c\,\mathrm{d}t'}{a(t')}$$

proper distance = comoving distance =

$$\chi = \int_t^{t_0} \frac{c\,\mathrm{d}t'}{a(t')} = \frac{c}{H_0}\int_{1/(1+z)}^{1} \frac{\mathrm{d}a}{a\sqrt{\Omega_\mathrm{m}/a - \Omega_\kappa + \Omega_\Lambda a^2}} \qquad (4)$$

http://www.wikipedia.org/wiki/Comoving_coordinates proper motion distance = coordinate distance =

$$d_{\rm pm} = \begin{cases} R_C \sinh \frac{\chi}{R_C} & k = -1 \\ \chi & k = 0 \\ R_C \sin \frac{\chi}{R_C} & k = +1 \end{cases} \tag{5}$$

proper motion distance = coordinate distance =

$$d_{\mathrm{pm}} = \begin{cases} R_C \sinh \frac{\chi}{R_C} & k = -1 \\ \chi & k = 0 \\ R_C \sin \frac{\chi}{R_C} & k = +1 \end{cases} \tag{5}$$

$$d_{\mathrm{L}} = (1+z) d_{\mathrm{pm}} = (1+z)^2 d_{\mathrm{a}} \tag{6}$$

FLRW metric

$$\mathrm{d}s^2 = c^2\mathrm{d}t^2 - a^2(t)\left[\mathrm{d}\chi^2 + \mathrm{d}d_{\mathrm{pm}}^2(\mathrm{d}\theta^2 + \cos^2\theta\mathrm{d}\phi^2)\right] \quad (7)$$

Non-radial spatial geodesics

What is the comoving distance between two objects at different celestial positions and different redshifts, for an arbitrary curvature 0 + - ?

Distances on the 2-sphere

$$\begin{aligned} x_i &= R \cos \delta_i \cos \alpha_i \\ y_i &= R \cos \delta_i \sin \alpha_i \\ w_i &= R \sin \delta_i \end{aligned} \tag{8}$$

Distances on the 2-sphere

$$\begin{aligned} x_i &= R\cos\delta_i\cos\alpha_i \\ y_i &= R\cos\delta_i\sin\alpha_i \\ w_i &= R\sin\delta_i \end{aligned} \quad (8)$$

$$\langle a_1, a_1 \rangle = x_1 x_2 + y_1 y_2 + w_1 w_2 \quad (9)$$

(cf 13, 15)

but also:

$$\langle a_1, a_1 \rangle = R^2 \cos \theta_{12}. \tag{10}$$

but also:

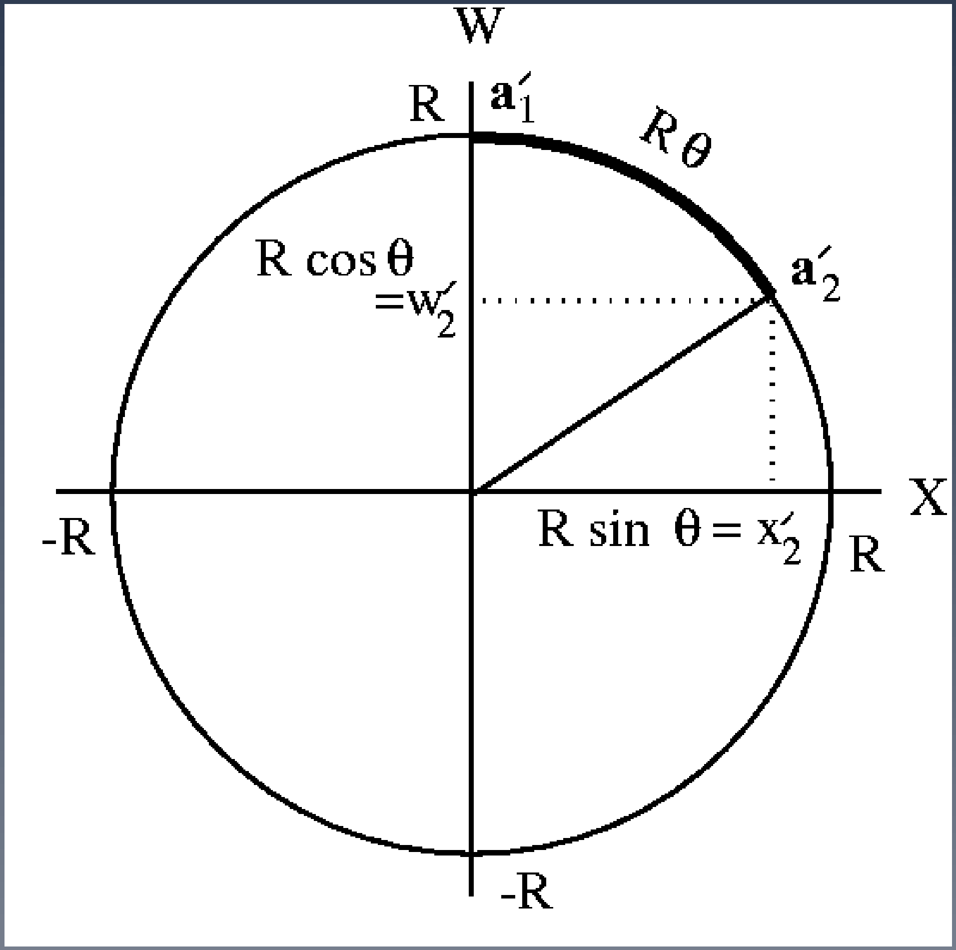
$$\langle a_1, a_1 \rangle = R^2 \cos\theta_{12}. \tag{10}$$

a distance in $\mathcal{S}^2$ = arc-length in $\mathcal{R}^3$:

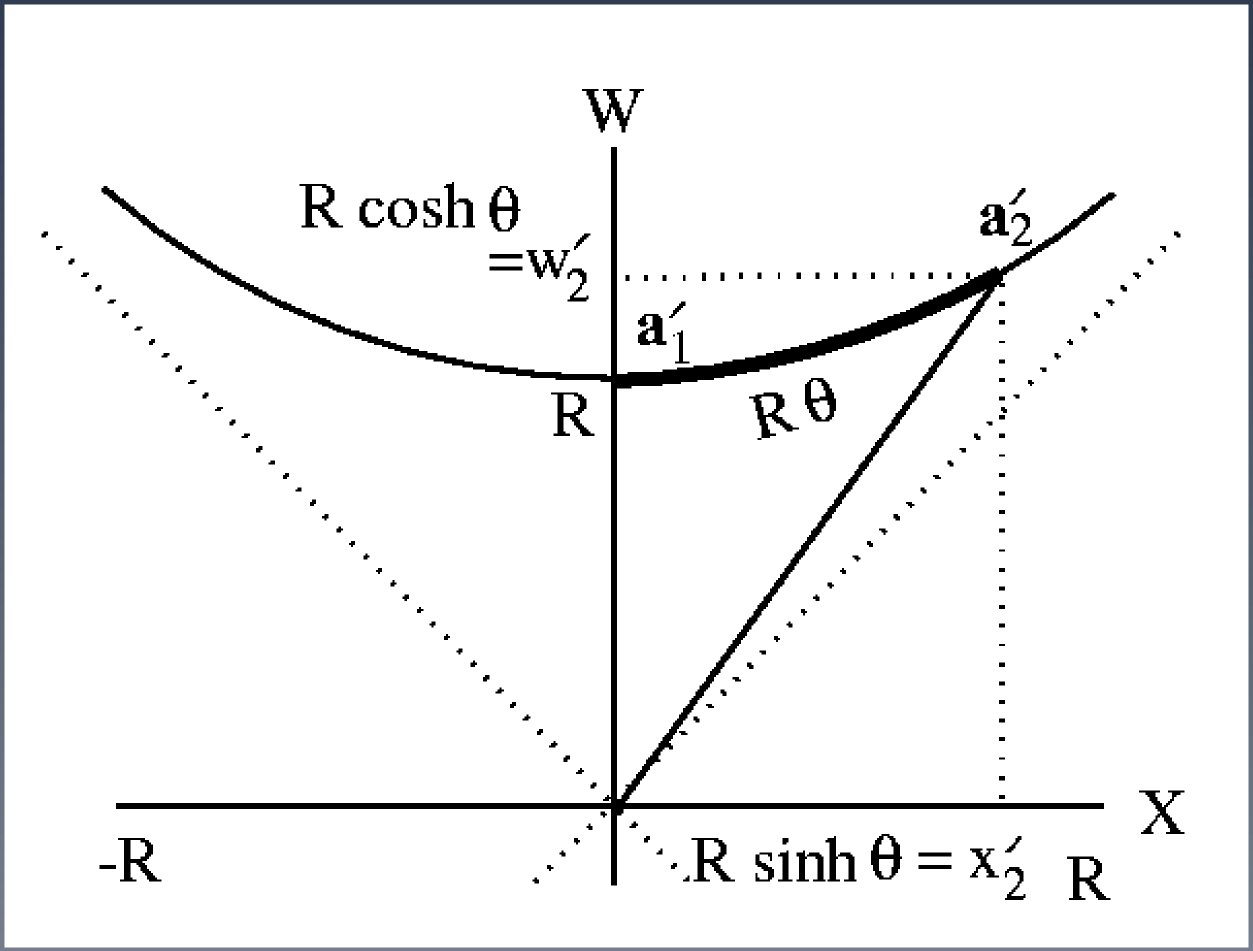
$$\chi_{12} = R\,\theta_{12} = R\ \cos^{-1}\left[\langle a_1, a_2 \rangle / R^2\right]. \tag{11}$$

(cf 16)

positive curvature



negative curvature



Distances on the 3-sphere (3-hyperboloid)

$$\Sigma(\chi_i) \equiv \begin{cases} R\ \sinh(\chi_i/R) & k \equiv -1 \\ \chi_i & k \equiv 0 \\ R\ \sin(\chi_i/R) & k \equiv +1 \end{cases} \tag{12}$$

$$\begin{aligned} x_i &= \Sigma(\chi_i)\cos\delta_i\cos\alpha_i \\ y_i &= \Sigma(\chi_i)\cos\delta_i\sin\alpha_i \\ z_i &= \Sigma(\chi_i)\sin\delta_i \\ w_i &= \begin{cases} R\ \cosh(\chi_i/R) & k = -1 \\ 0 & k = 0 \quad \text{(cf eq. (8))} \\ R\ \cos(\chi_i/R) & k = +1 \end{cases} \end{aligned} \tag{13}$$

metric on $\mathcal{S}^3$ (or $\mathcal{R}^3$ or $\mathcal{H}^3$):

$$\mathrm{d}s^2 = \begin{cases} k\,(\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2) + \mathrm{d}w^2 & k = \pm 1 \\ \mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2 & k = 0. \end{cases} \tag{14}$$

inner product (cf 9):

$$\langle a_1, a_2 \rangle \equiv \begin{cases} k\,(x_1 x_2 + y_1 y_2 + z_1 z_2) + w_1 w_2 & k = \pm 1 \\ x_1 x_2 + y_1 y_2 + z_1 z_2 & k = 0. \end{cases} \tag{15}$$

generalisation of eq. (11):

$$\chi_{12} = \begin{cases} R \cosh^{-1}\left[\langle a_1, a_2 \rangle / R^2\right] & k = -1 \\ \sqrt{\langle a_1 - a_2, a_1 - a_2 \rangle} & k = 0 \\ R \cos^{-1}\left[\langle a_1, a_2 \rangle / R^2\right] & k = +1. \end{cases} \quad (16)$$

a distance in $\mathcal{S}^3$ is an arc-length in $\mathcal{R}^4$

generalisation of eq. (11):

$$\chi_{12} = \begin{cases} R\cosh^{-1}\left[\langle a_1, a_2\rangle / R^2\right] & k = -1 \\ \sqrt{\langle a_1 - a_2, a_1 - a_2\rangle} & k = 0 \\ R\cos^{-1}\left[\langle a_1, a_2\rangle / R^2\right] & k = +1. \end{cases} \quad (16)$$

a distance in $\mathcal{S}^3$ is an arc-length in $\mathcal{R}^4$

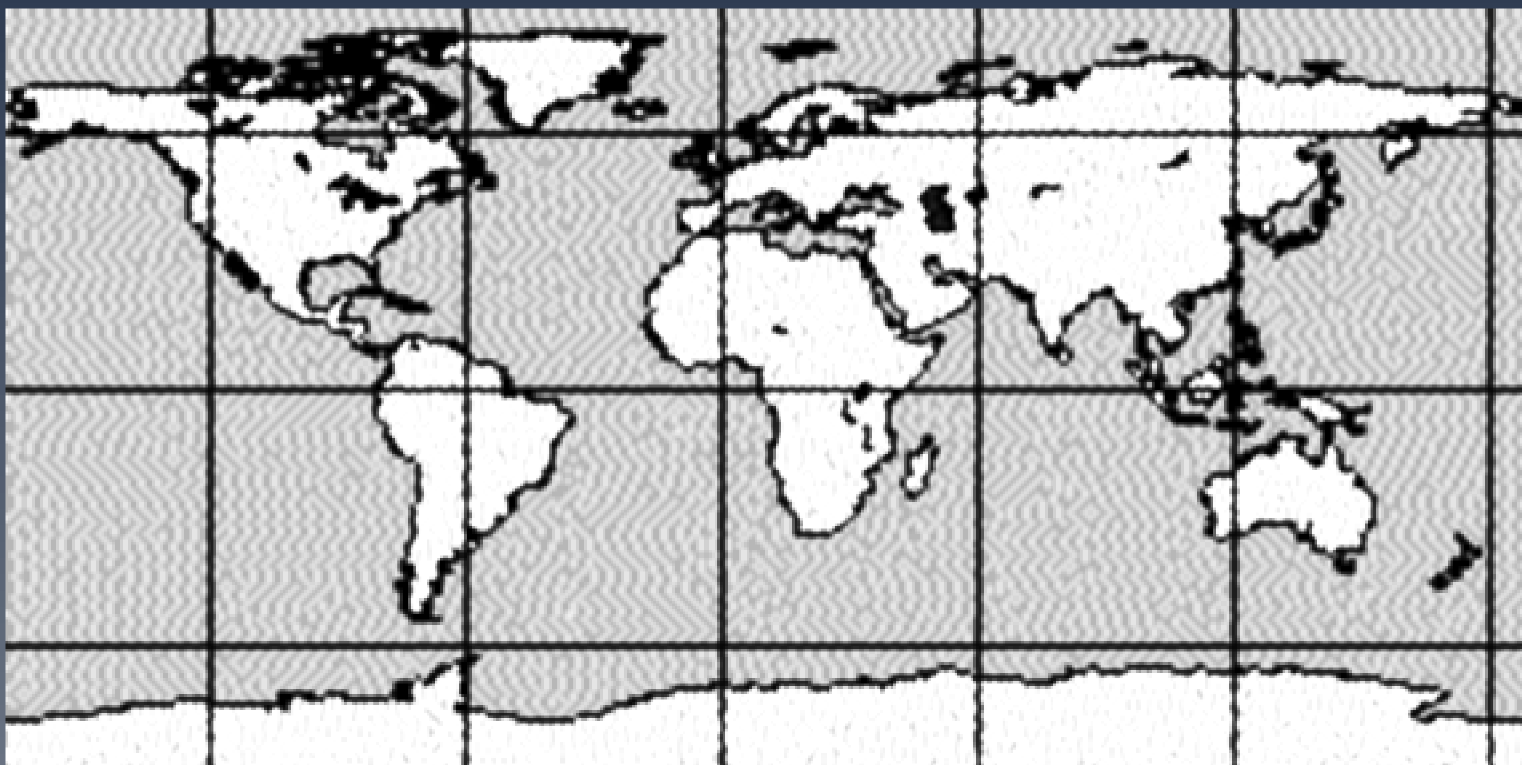
a distance in $\mathcal{H}^3$ is an arc-length in $\mathcal{M}^4$

http://arXiv.org/abs/astro-ph/0102099

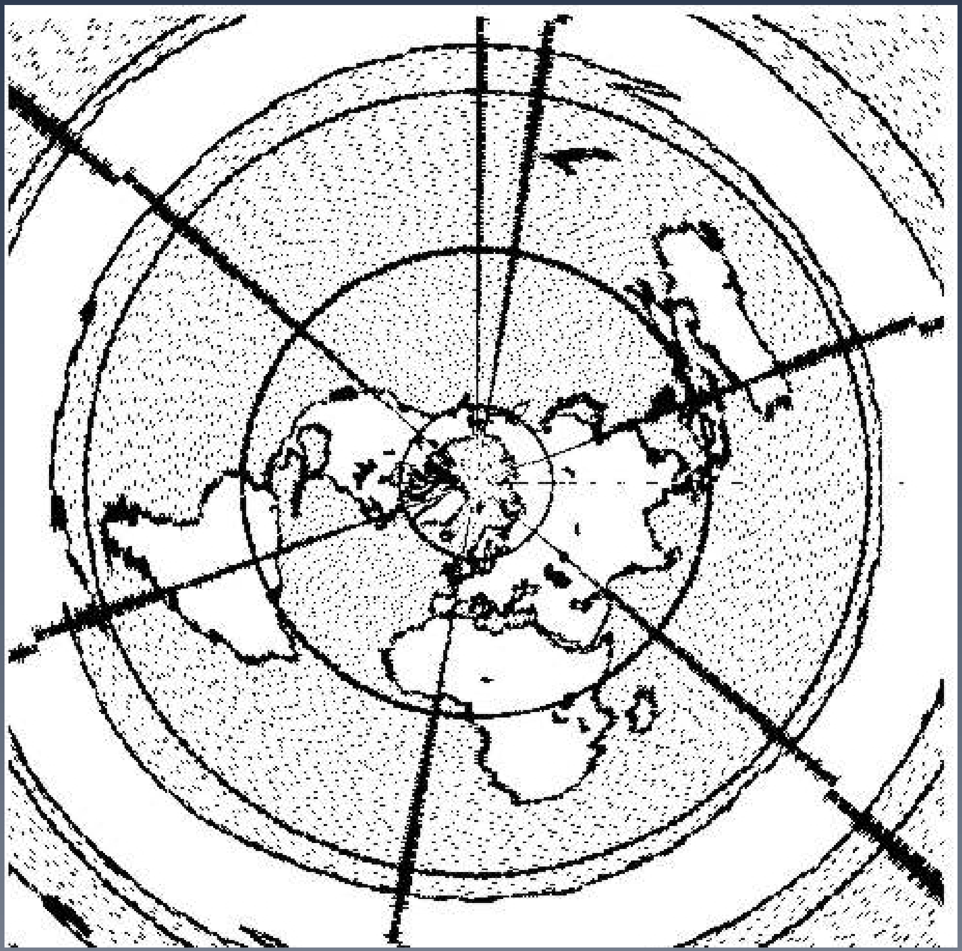
Czy Wszechświat jest krzywizony jak sfery?

- How can we think of curvature?
- How can we measure curvature?
- Finding a standard ruler
- Using a standard ruler - LSS
- 2dF Quasar redshift survey - 2QZ

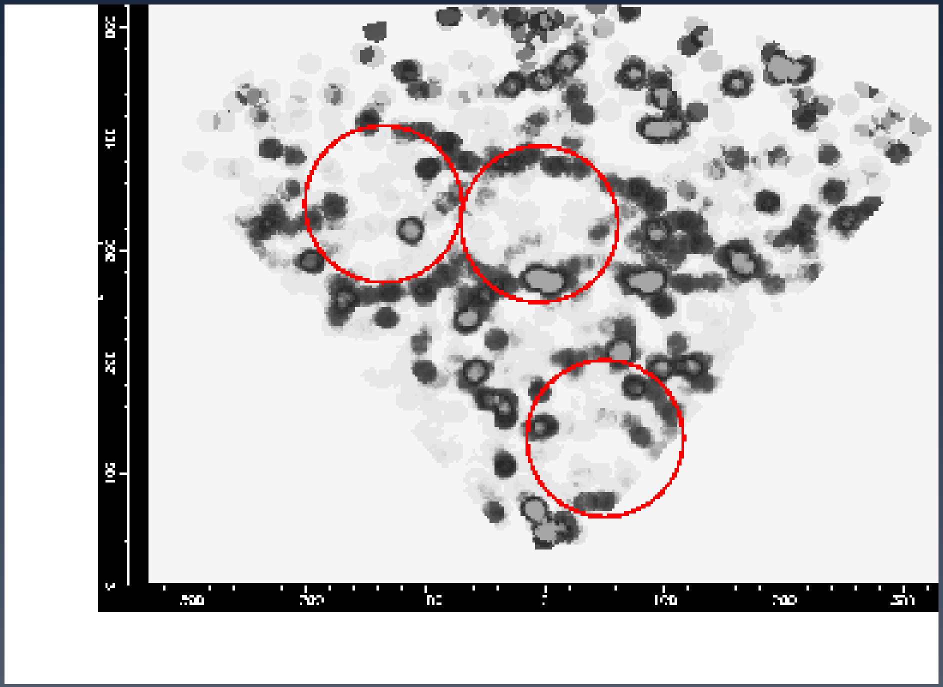
Płaska Ziemia?



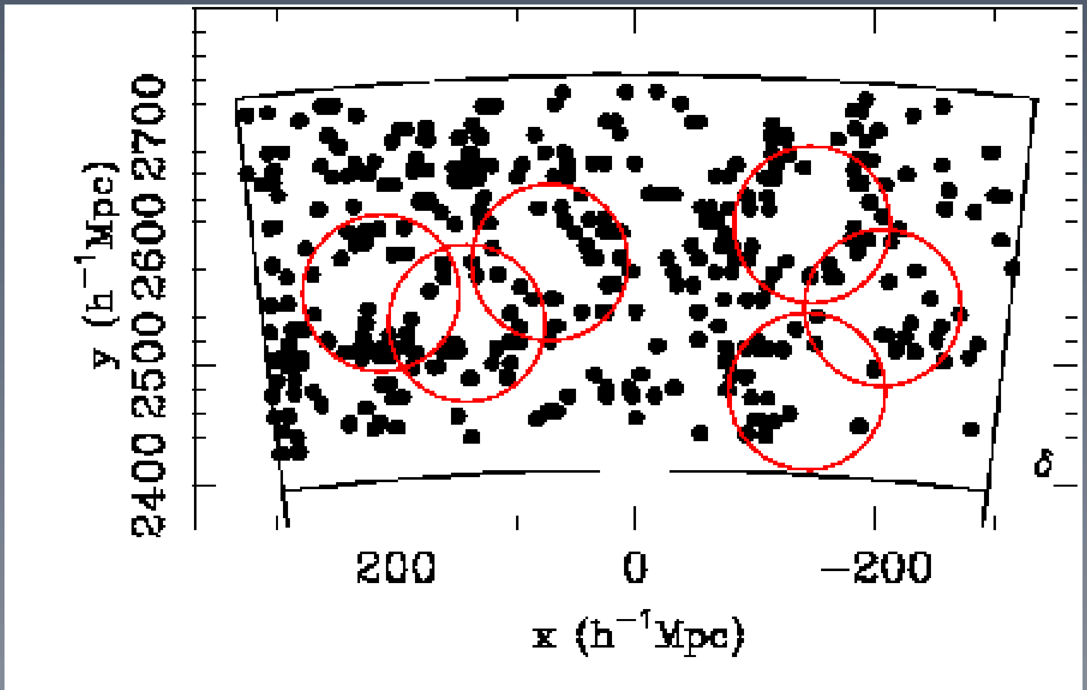
Druga płaska Ziemia?



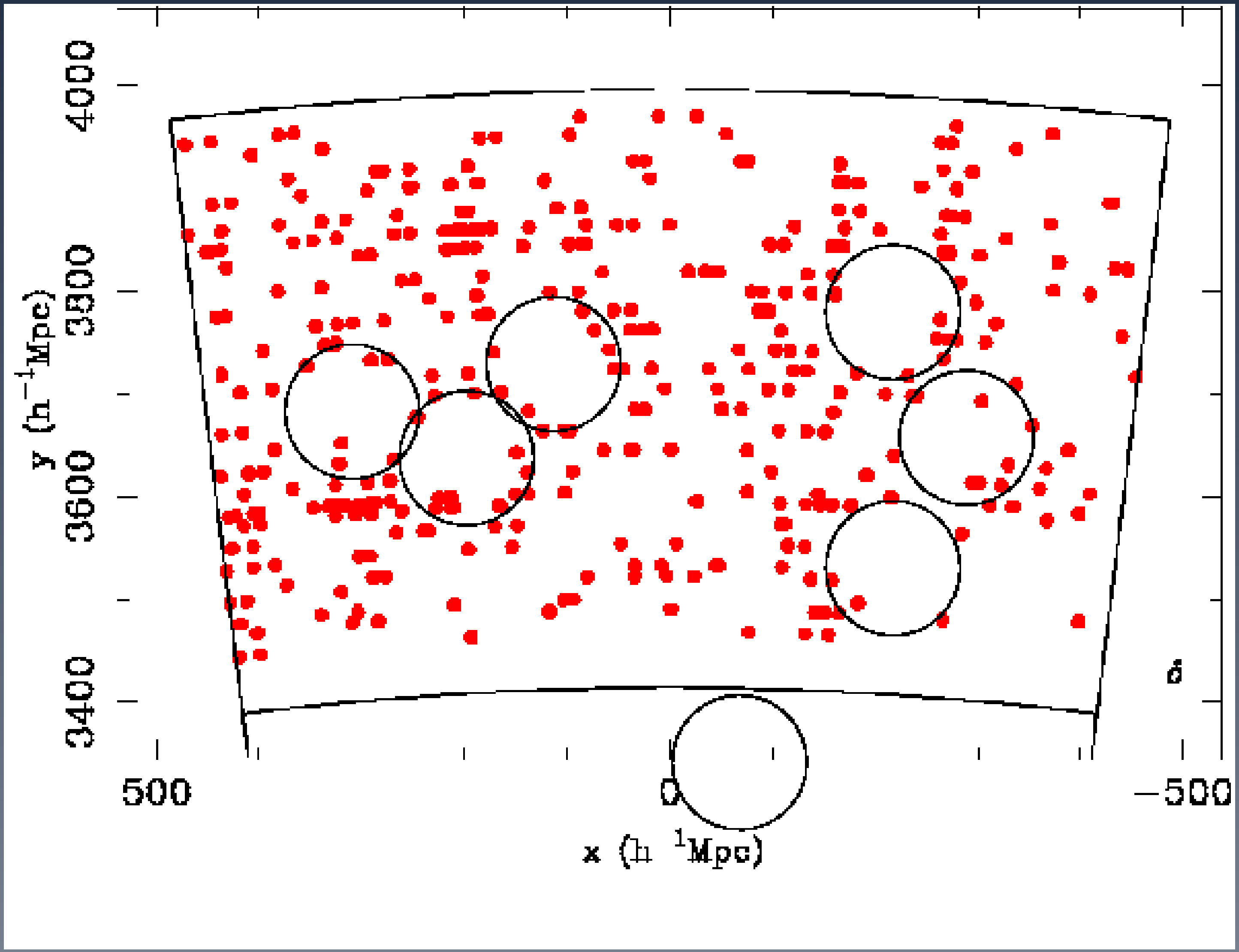
A Standard Ruler: LS Structure Bubbles



$z0\ \Lambda0\ \Lambda$



Distant quasars: flat WITH cosm constant



$z0\ \Lambda 0\ \Lambda$

Standard Ruler Constraints on Ω_Λ and $\Omega_{\rm m}$ from the 2dF QSO z Survey – 2QZ-10K

Collaborators :

- Gary Mamon (IAP; ObsParis–Meudon)
- Stanislaw Bajtlik (CAMK)
- results from the Iovino, Clowes & Shaver (1996) catalogue:

tangential: Roukema & Mamon (2000, A&A, 358, 395)

3-D: Roukema & Mamon (2001, A&A, 366, 1)

- results from the 2dF Quasar z survey early release (2QZ-10K):

Roukema, Mamon & Bajtlik (2001, A&A submitted, arXiv:astro-ph/0106135)

Local Cosmological Geometry

- cosmological constant: $\mathbf{\Omega_\Lambda}$
- density parameter: $\mathbf{\Omega_m}$
- curvature (−,0 or +): $\mathbf{\Omega_\kappa \equiv \Omega_m + \Omega_\Lambda - 1}$
- comoving "proper" distance: $\mathbf{d(z) = d(\Omega_m, \Omega_\Lambda, z)}$

A Good Standard Cosmological Ruler

- should be fixed in “physical” coordinates or in comoving coordinates
- should be on scale too large to evolve in a Hubble time
- $\Rightarrow$ comoving ruler best
- $\Rightarrow$ fine feature in $\mathbf{P}(\mathbf{k})$ or the 2-point spatial correlation function $\xi(\mathbf{r})$ of density perturbations

Observational data sets Iovino, Clowes & Shaver (1996): RM00, RM01

- $\mathbf{N = 812}$ high-quality quasar candidates

2QZ-10K: RMB01

- 11000 quasars in initial "10K" release

http://www.2dFquasar.org/ – includes spectra!!

- 10K release: $> \mathbf{85}\%$ "spectroscopic" completeness

- $\mathbf{N} = \mathbf{2378}$ of these fall in regions above 80% "coverage" completeness

- 6 fields $\Rightarrow$ 6 independent measurements of $\xi(\mathbf{r})$ for any given redshift interval

- three redshift intervals:

$$\mathbf{0.6 < z < 1.1,\ 1.1 < z < 1.6,\ 1.6 < z < 2.2}$$

Analysis method

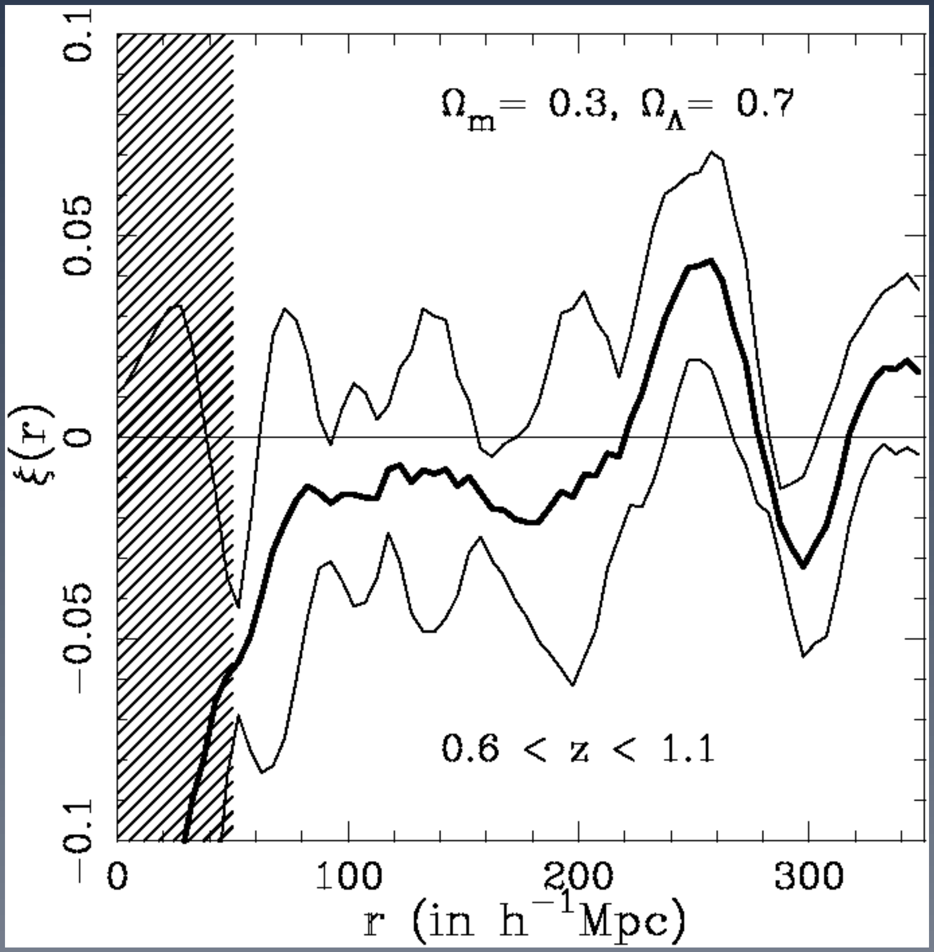
$$\underline{\xi(\mathbf{r}) = (\mathbf{DD} - \mathbf{2DR}/\mathbf{n} + \mathbf{RR}/\mathbf{n^2})/(\mathbf{RR}/\mathbf{n^2})}$$

- $\mathbf{DD} =$ number of Data-Data pairs in the $\mathbf{i^{th}}$ bin $\mathbf{r_1 + (i - 1)\Delta r < r < r_1 + i\Delta r}$
- $\mathbf{DR} =$ number of Data-Random pairs in $\mathbf{i^{th}}$ bin
- $\mathbf{RR} =$ number of Random-Random pairs in $\mathbf{i^{th}}$ bin
- $\mathbf{n} = \mathbf{N}$(Random points)$/\mathbf{N}$(Data points)

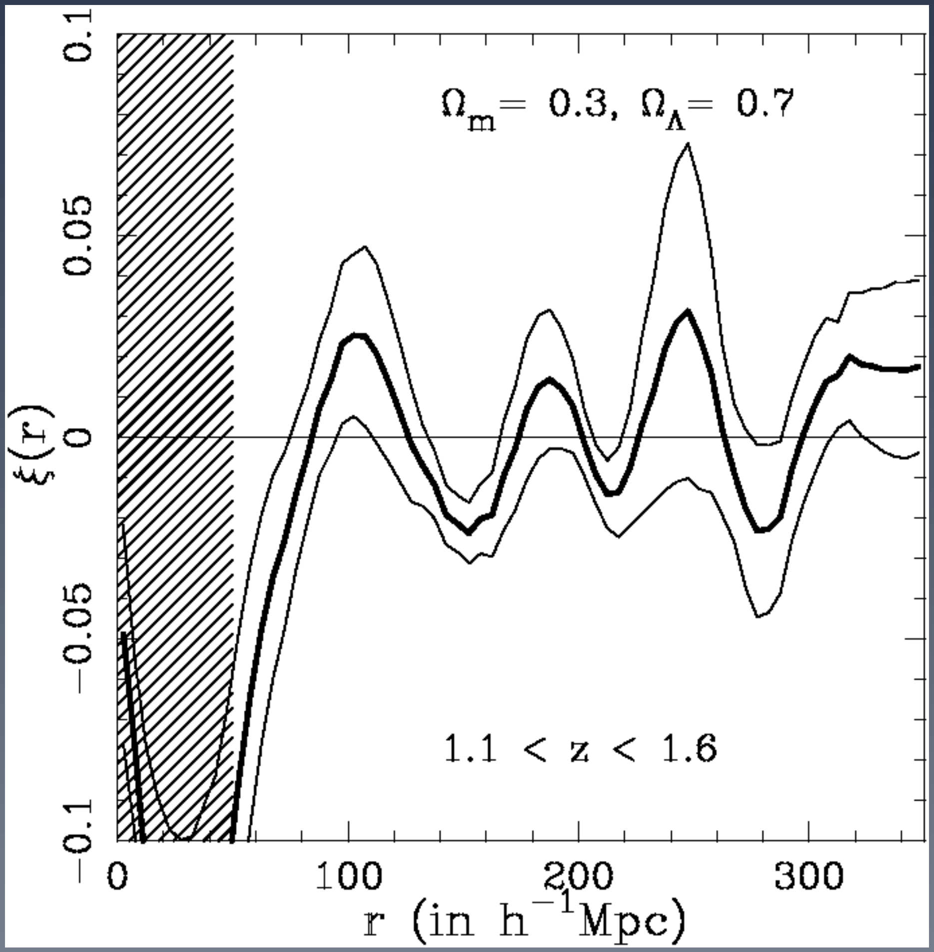
z-scrambling (Osmer 1981):

- angular positions of random data sets = those of the observations
- redshifts of random data sets = those of the observations, but in a randomised order
- $\Rightarrow$ selection effects in z and angle are cancelled
- $\Rightarrow$ conservative results – the real correlations might partly be cancelled along with selection effects

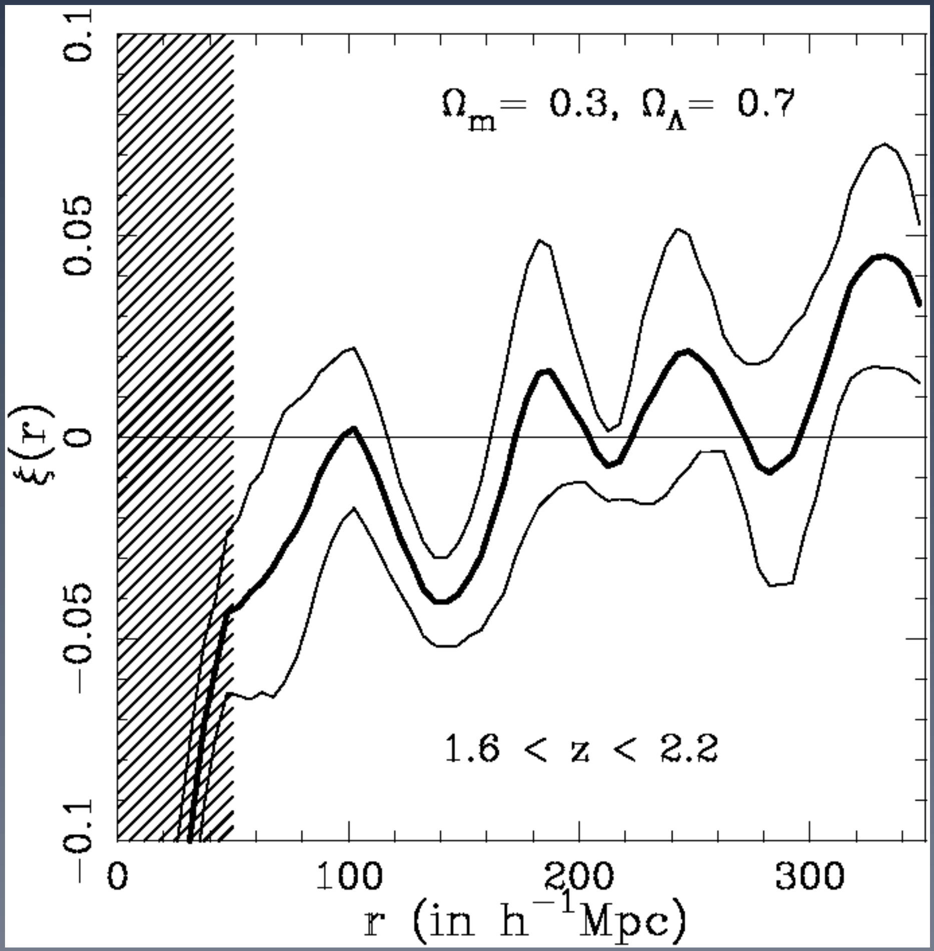
$0.6 < z < 1.1, \Omega_{\rm m} = 0.3, \Omega_\Lambda = 0.7$



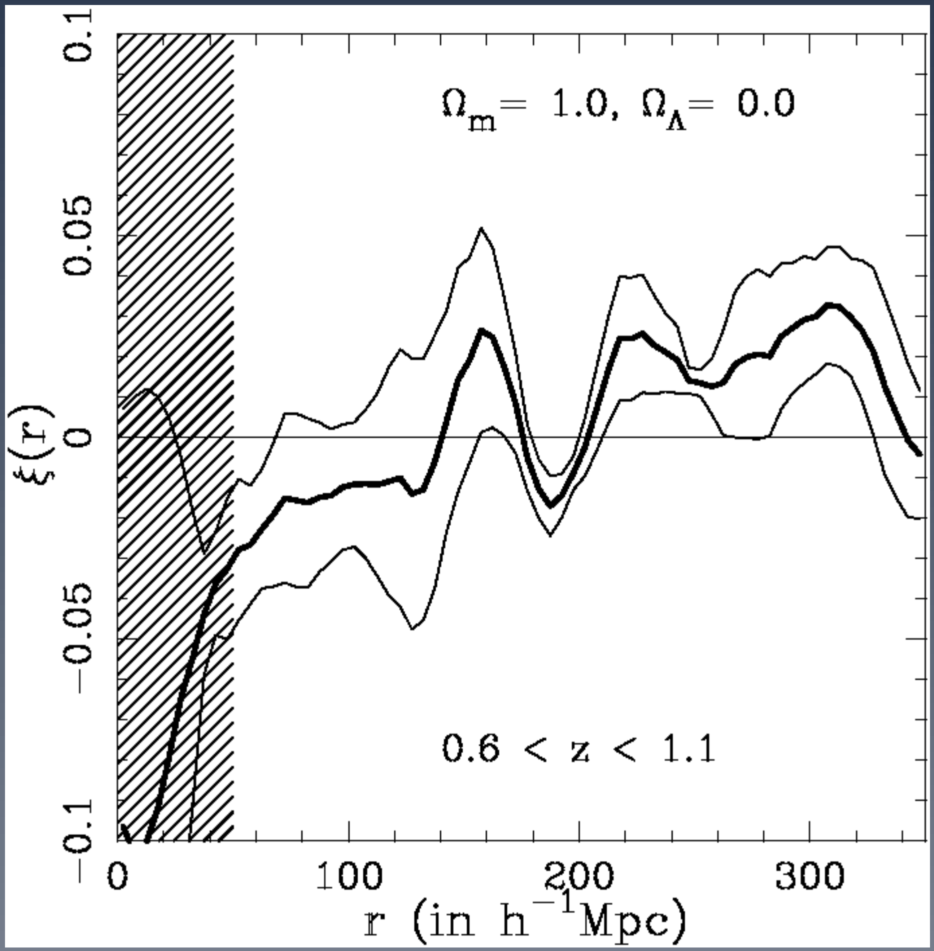
$1.1 < z < 1.6, \Omega_{\mathrm{m}} = 0.3, \Omega_{\Lambda} = 0.7$



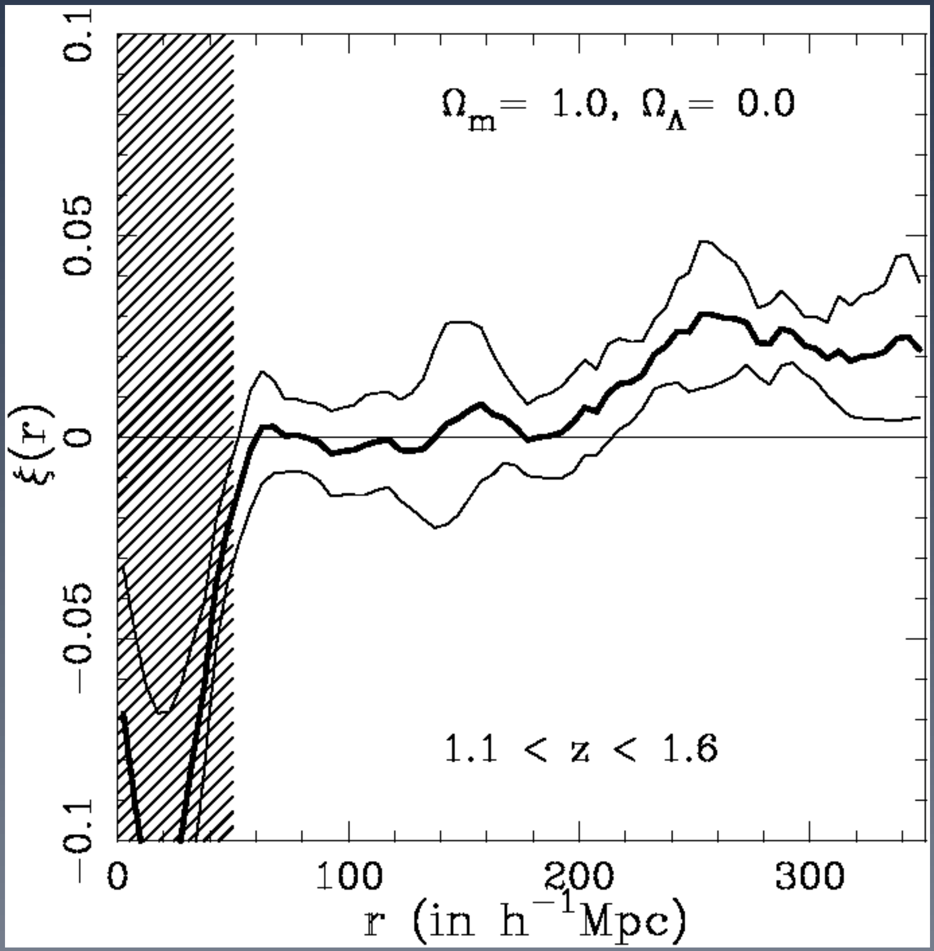
$1.6 < z < 2.2, \Omega_\mathrm{m} = 0.3, \Omega_\Lambda = 0.7$



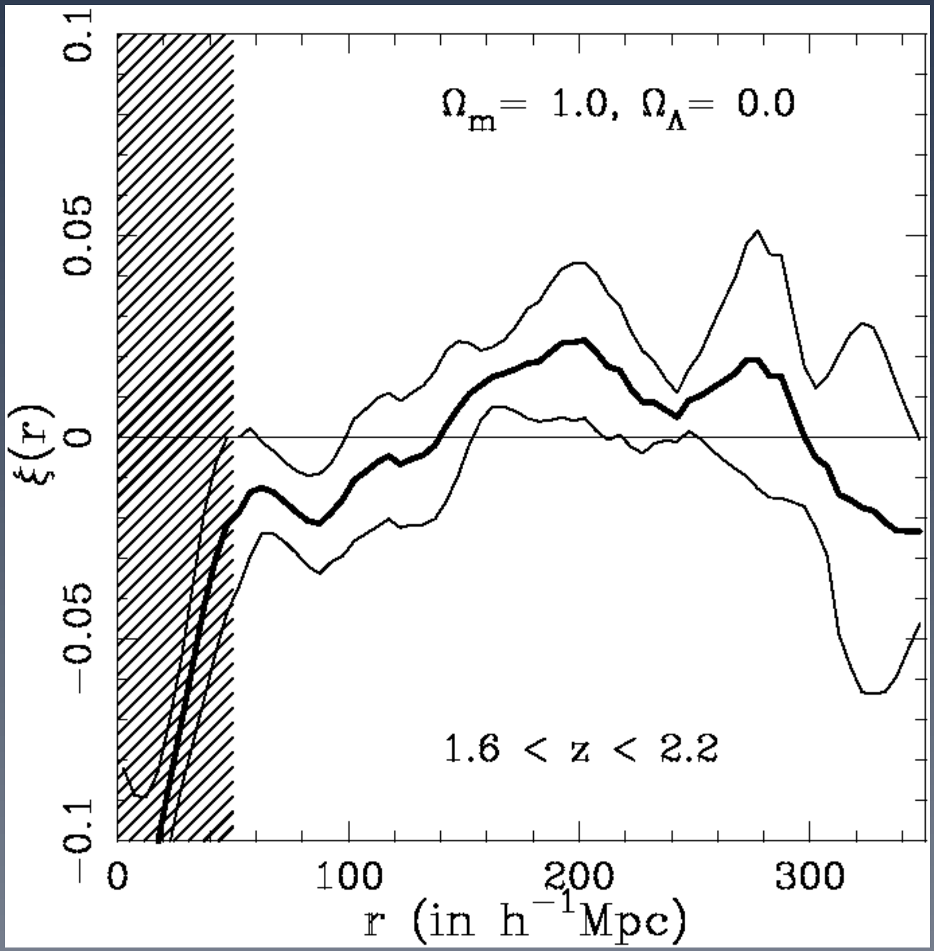
$0.6 < z < 1.1, \Omega_{\rm m} = 1.0, \Omega_\Lambda = 0.0$



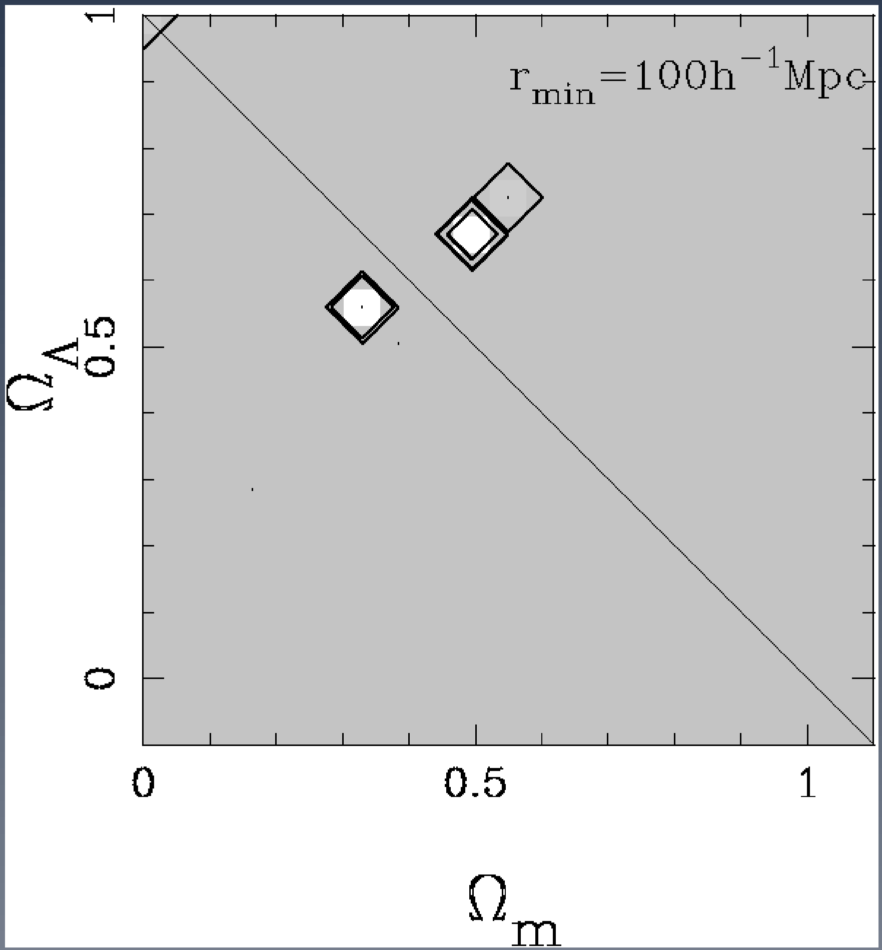
$1.1 < z < 1.6, \Omega_{\rm m} = 1.0, \Omega_\Lambda = 0.0$



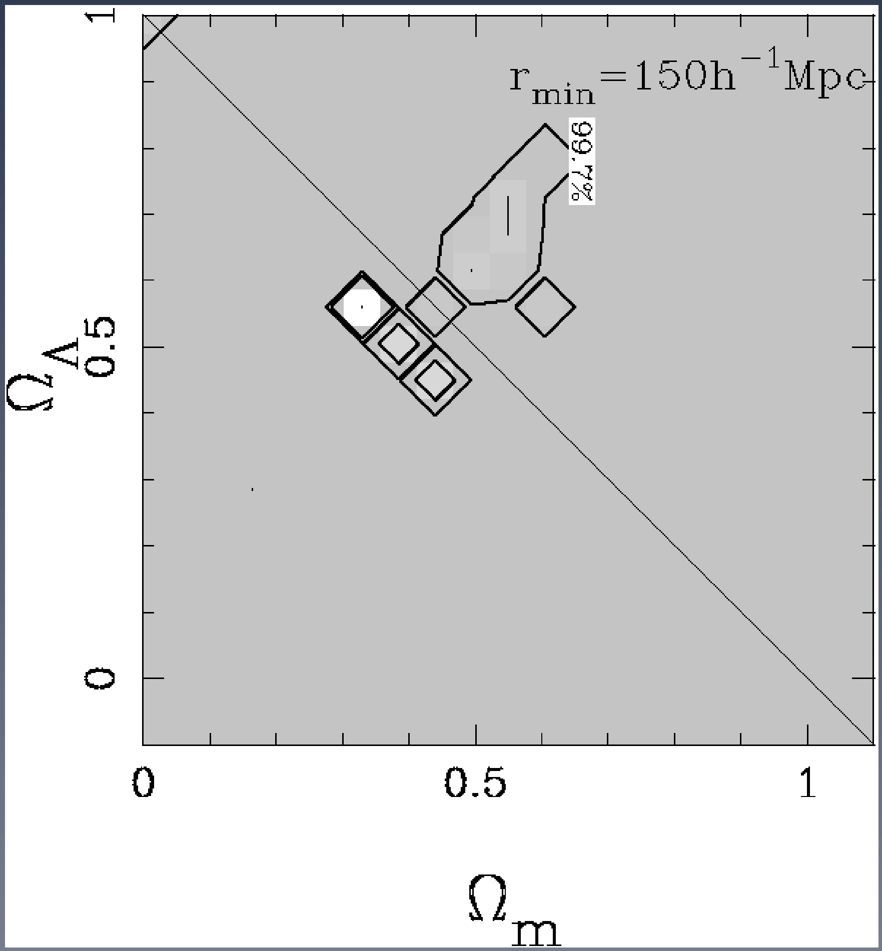
$1.6 < z < 2.2, \Omega_m = 1.0, \Omega_\Lambda = 0.0$



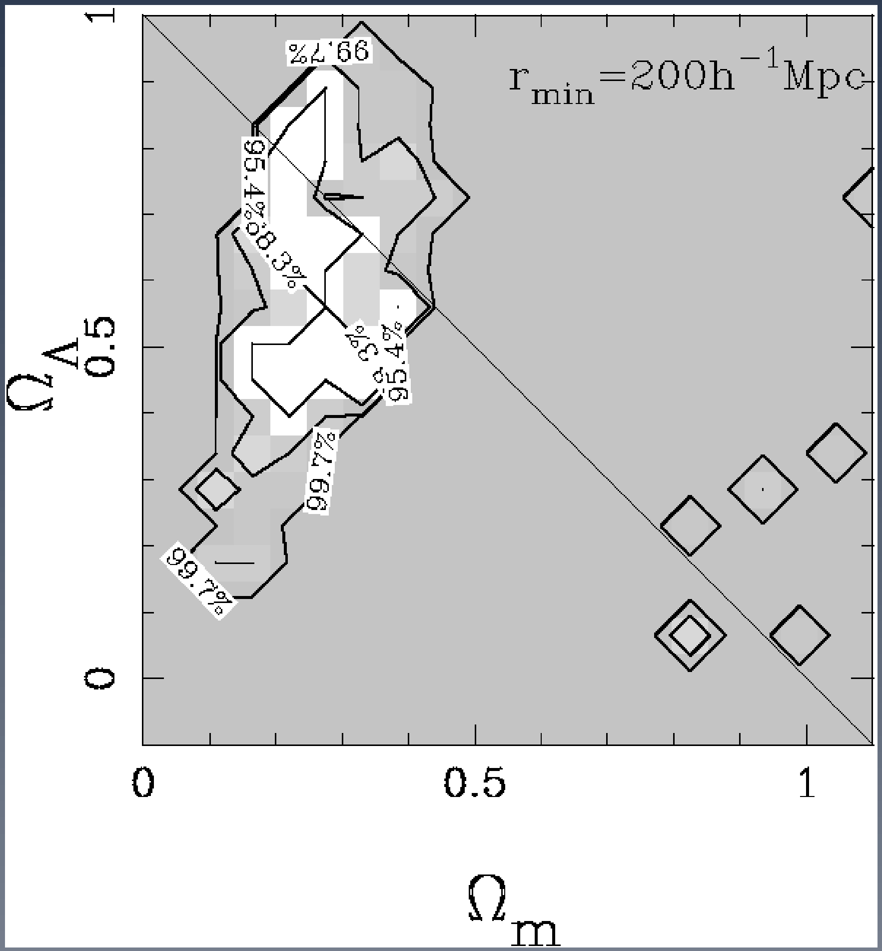
Ω_m, Ω_Λ plane



Ω_m, Ω_Λ plane



Ω_m, Ω_Λ plane



Conclusions

- a local maximum in $\xi(\mathbf{r})$ is present in all three redshift ranges of the 2QZ-10K in only one region of the $\mathbf{\Omega_m, \Omega_\Lambda}$ plane, its scale is:
$\mathbf{2L = 244 \pm 17}\mathrm{h}^{-1}$ Mpc

Conclusions

- a local maximum in $\xi(\mathbf{r})$ is present in all three redshift ranges of the 2QZ-10K in only one region of the $\boldsymbol{\Omega_m}, \boldsymbol{\Omega_\Lambda}$ plane, its scale is:
$\mathbf{2L = 244 \pm 17}\mathrm{h}^{-1}$ Mpc

- this region is:
$\boldsymbol{\Omega}_\mathrm{m} = \mathbf{0.25 \pm 0.10}, \boldsymbol{\Omega}_\Lambda = \mathbf{0.65 \pm 0.25}$ (68% confidence),
$\boldsymbol{\Omega}_\mathrm{m} = \mathbf{0.25 \pm 0.15}, \boldsymbol{\Omega}_\Lambda = \mathbf{0.60 \pm 0.35}$ (95% confidence)

Conclusions

- a local maximum in $\xi(\mathbf{r})$ is present in all three redshift ranges of the 2QZ-10K in only one region of the $\mathbf{\Omega_m}, \mathbf{\Omega_\Lambda}$ plane, its scale is:
$\mathbf{2L = 244 \pm 17}\mathrm{h}^{-1}$ Mpc

- this region is:
$\mathbf{\Omega_{\mathrm{m}} = 0.25 \pm 0.10, \Omega_\Lambda = 0.65 {\pm} 0.25}$ (68% confidence),
$\mathbf{\Omega_{\mathrm{m}} = 0.25 \pm 0.15, \Omega_\Lambda = 0.60 {\pm} 0.35}$ (95% confidence)

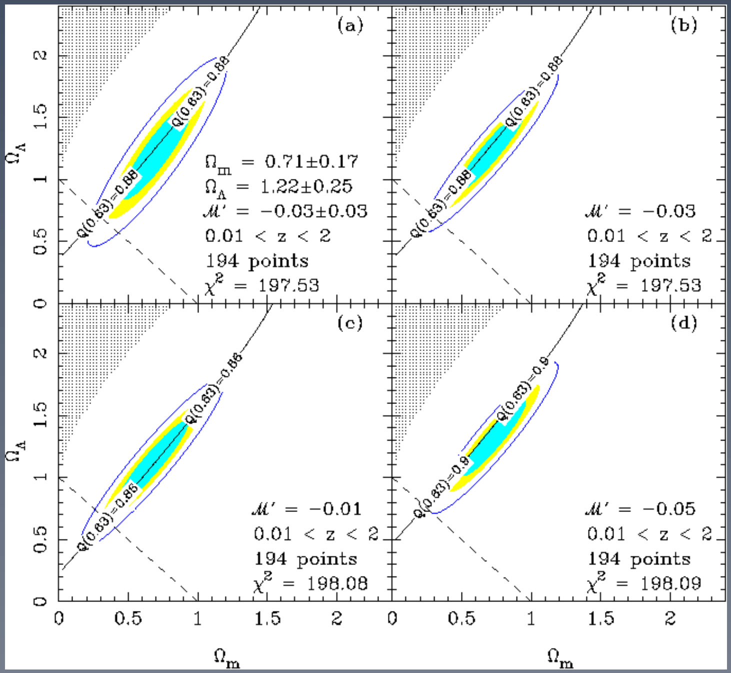
- independently of the SNe Ia data, $\mathbf{\Omega_\Lambda = 0}$ is rejected at 99.7% confidence

In simple words:

Using the large scale structure "bubbles" traced by galaxies and quasars as a standard ruler, distant structures match nearby structures best if the Universe is approximately flat with about 70% of matter-energy density in a cosmological constant.

194 SNe — Roy Choudhury & Padmanabhan (2003)

http://arxiv.org/abs/astro-ph/0311622



quintessence parameters: w_0, w_1