# SEARCH FOR COSMIC RAY ANISOTROPY WITH THE TELESCOPE ARRAY

**P. Tinyakov**[1,2]
for the Telescope Array Collaboration

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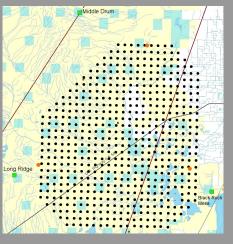
# Outline

TA detector

Data set

Correlation with AGN

Autocorrelations

Correlation with LSS

Conclusions

# TELESCOPE ARRAY HYBRID DETECTOR



- ▶ Situated in Utah, USA
- ▶ 507 scintillator detectors covering 680 km$^2$
- ▶ 3 fluorescence sites, 38 telescopes
- ▶ Surface detector fully operational from March 2008

SD relative size: TA $\sim 9 \times$ AGASA $\sim$ PAO/4

# DATA SET

▶ 28 months (May 2008 → September 2010) of surface detector data

▶ 655 events above 10 EeV
  35 events above 40 EeV
  15 events above 57 EeV

▶ angular resolution 1.5°

▶ geometrical acceptance

# DATA SET

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- geometrical acceptance

# Angular resolution

# DISTRIBUTION OVER THE SKY,
$E > 10$ EeV

E>10 EeV



Equatorial coordinates

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TA detector

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Correlation with
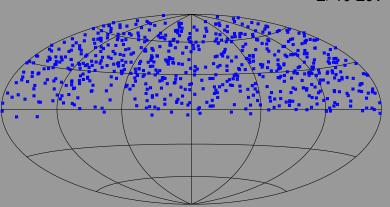AGN

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# Comparison with geometrical exposure
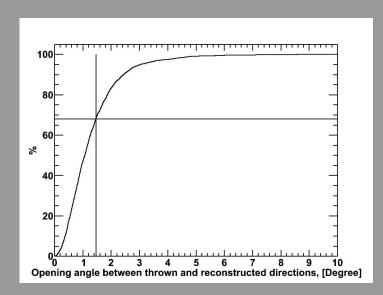
# DISTRIBUTION OVER THE SKY, $E > 40$ EeV

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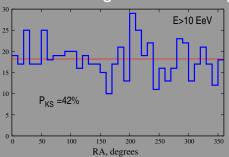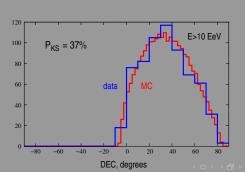Collaboration

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Equatorial coordinates

# Comparison with geometric exposure

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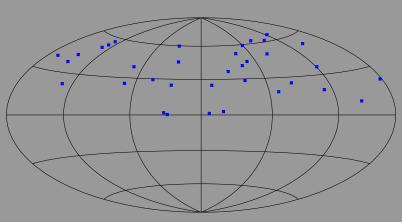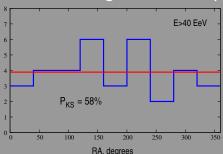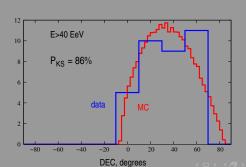TELESCOPE
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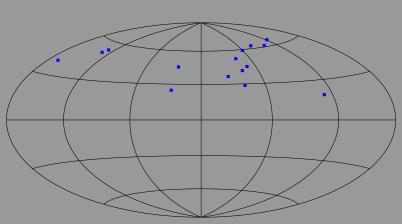
# Correlations with AGN (Science'2007)

- ▶ 472 AGN from 2006 Veron catalog with $z < 0.018$ ($D < 75$ Mpc)
- ▶ separation angle $3.1°$



CR E>57 EeV

AGN z<0.018

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# Correlations with AGN (Science'2007)

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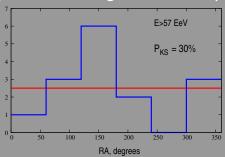
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Observed: 15, background: 3.6, $p = 16\%$ $\Longrightarrow$ compatible with background

# Autocorrelation analysis

$E > 10$ EeV



$\implies$ no excess over background

# Autocorrelation analysis

$E > 40$ EeV



⟹ no excess over background

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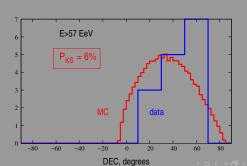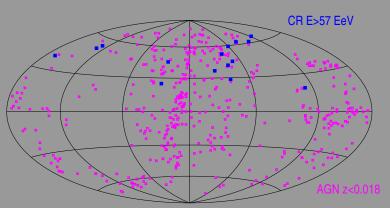Collaboration
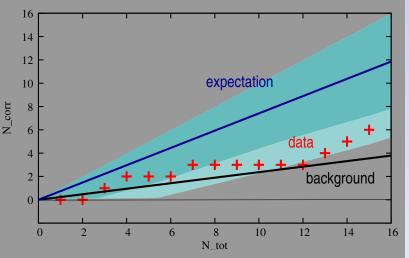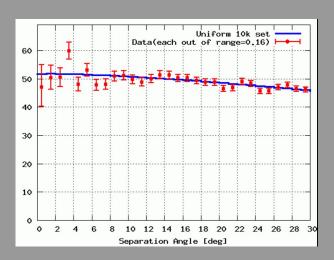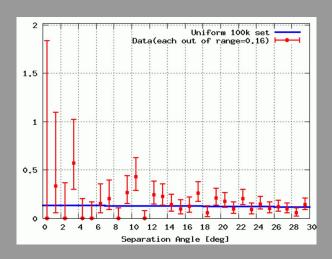
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# Correlation with LSS

- UHECR flux at high energies is expected to be anisotropic because matter distribution is not uniform at distances $\sim 100$ Mpc

- The matter distribution can be modeled out to $\sim 250$ Mpc from the XSCz catalog (*T. Jarrett, in preparation*) containing over 700 000 galaxies with spectroscopic redshifts

- From the matter distribution the UHECR flux map may be calculated and compared to observation

- This involves a single important parameter — the smearing angle $\theta$ representing deflections in magnetic fields and finite angular resolution
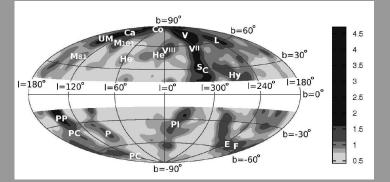
C: Centaurus supercluster (60 Mpc); Ca: Canes I group (4 Mpc) and Canes II group (9 Mpc); Co: Coma cluster (90 Mpc); E: Eridanus cluster (30 Mpc); F: Fornax cluster (20 Mpc); He: Hercules superclusters (140 Mpc); Hy: Hydra supercluster (50 Mpc); L: Leo supercluster (130 Mpc), Leo I group (10 Mpc), and Leo II group (20 Mpc); M81: M81 group (4 Mpc); M101: M101 group (8 Mpc); P: Pegasus cluster (60 Mpc); PI: Pavo-Indus supercluster (70 Mpc); PC: Pisces- Cetus supercluster (250 Mpc); PP: Perseus-Pisces supercluster (70 Mpc); S: Shapley supercluster (200 Mpc); UM: Ursa Major supercluster (240 Mpc), Ursa Major North group (20 Mpc), and Ursa Major South group (20 Mpc); V: Virgo cluster (20 Mpc); VII: Virgo II group (20 Mpc); VIII: Virgo III group (20 Mpc).
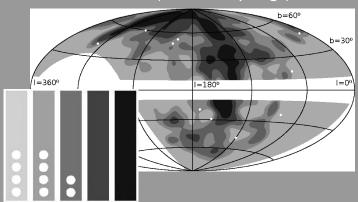
# The statistical test ("flux sampling")

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**Conclusions**

- ▶ Events following the model would produce uniform distribution over the bands

- ▶ No binning is needed (on the picture it is for illustration only): two distributions may be compared by the KS test

# Correlations with LSS

$E > 10$ EeV



Galactic coordinates

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# Correlations with LSS

*E* > 40 EeV



Galactic coordinates

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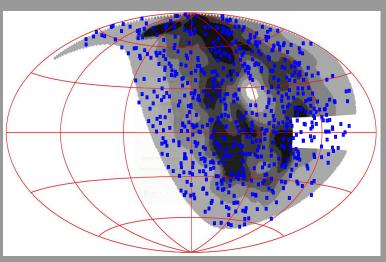for the Telescope
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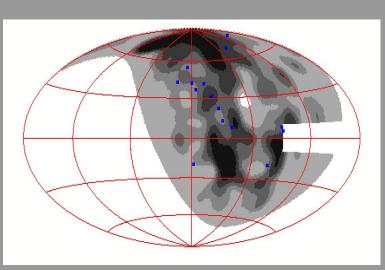
# Correlations with LSS

*E* > 57 EeV



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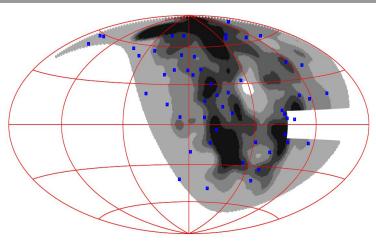
**TA detector**

**Data set**

**Correlation with AGN**

**Autocorrelations**

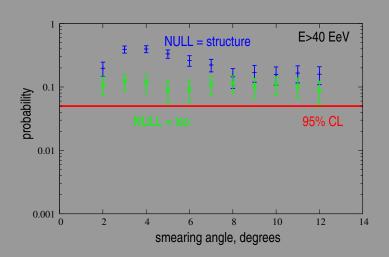**Correlation with LSS**

**Conclusions**

# Results of the statistical tests

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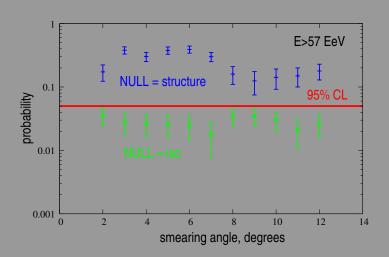TA detector

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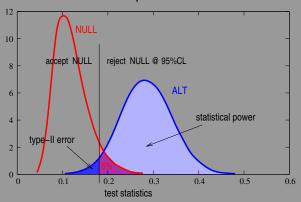Correlation with
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# Statistical power

▶ Defined as the complement of the type-II error; characterizes separation of two distributions



▶ Meaningful when close to 1 (when two distributions separate).

Power as a function of the smearing angle for different number of events. Gray region shows typical deflections in GMF.

$E > 40$ EeV



NULL=structure  ALT=iso  E>40EeV

Deflections in GMF
7.7+-5.1 deg

N=120
N=100
N=80
N=60
N=40

statistical power

θ,  degrees

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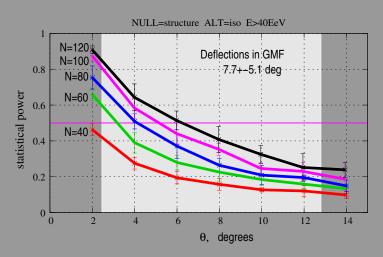for the Telescope Array Collaboration

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$E > 57$ EeV

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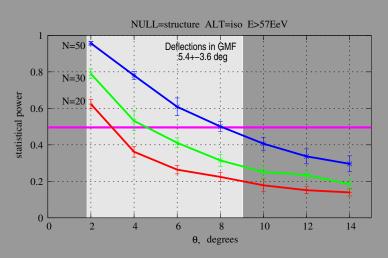TELESCOPE
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# Conclusions

- AGN correlation: 6/15 events correlating; compatible with the background
- Clusters: no significant clustering at $E > 40$ EeV and $E > 10$ EeV
- Correlation with LSS:
  - data with $E > 40$ EeV are compatible both with structure and isotropy;
  - data with $E > 57$ EeV are compatible with structure and incompatible with isotropy at 95% CL;