PHAESTOS

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PHYSICS OF THE
HIGHEST-ENERGY
ASTROPHYSICAL
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THROUGH
OPTOPOLARIMETRIC
SURVEYS

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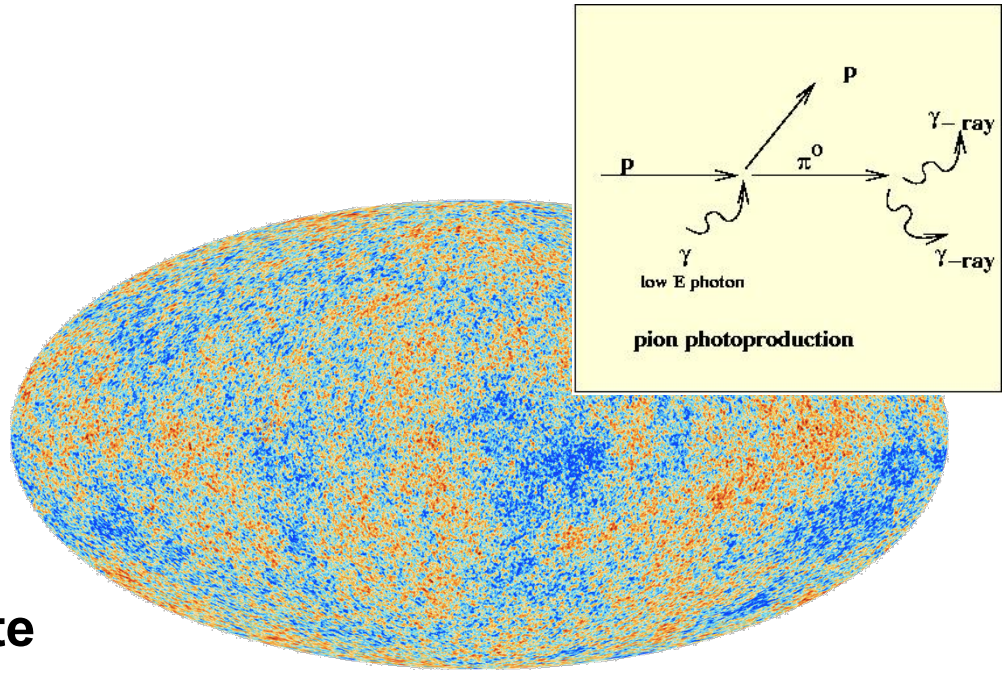
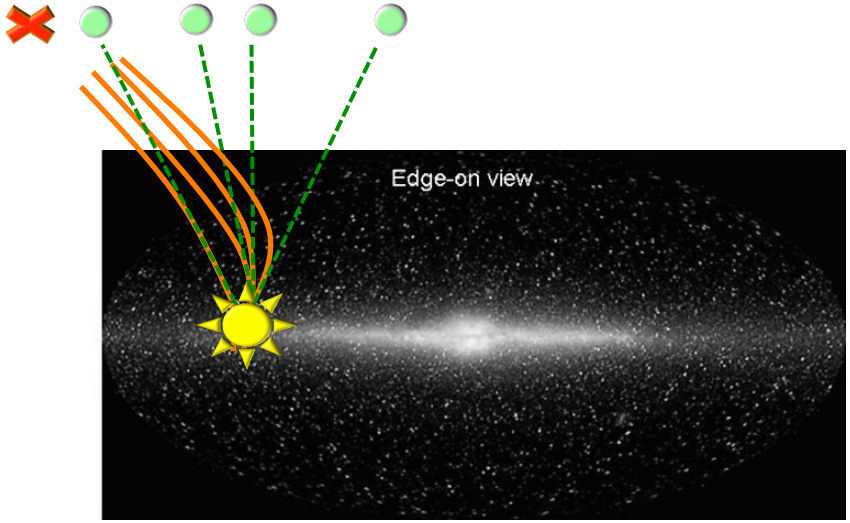
PHYSICS OF THE HIGHEST-ENERGY ASTROPHYSICAL ENVIRONMENTS AND SYSTEMS THROUGH OPTOPOLARIMETRIC SURVEYS

The puzzle: what makes UHECR?

- Ultra-high-energy cosmic rays: E>10^{19} eV, > 10^{6} x LHC Energy
  highest energy particles known
- Astrophysical? Exotic?
  zero sources detected
- CMB opaque
  have to come from nearby
  D < tens of Mpc
- Extreme requirements
  for astrophysical accelerators
  no obvious source candidate



Why are UHECR sources unknown?



- Charge + Galactic B = **Deflections**
- **Low statistics**

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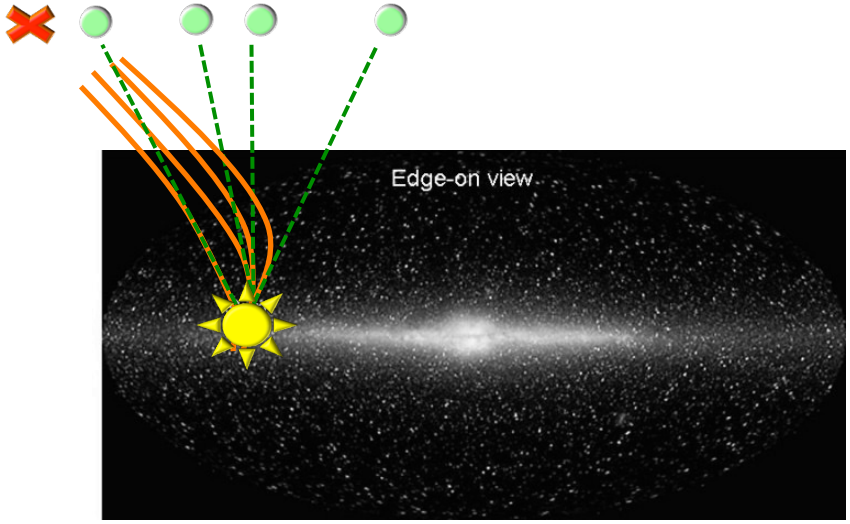

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Traditional Approach:

- Build bigger telescopes
- Integrate for longer

PHAESTOS:

- correct deflections
- contrast with background shoots up
- source stands out

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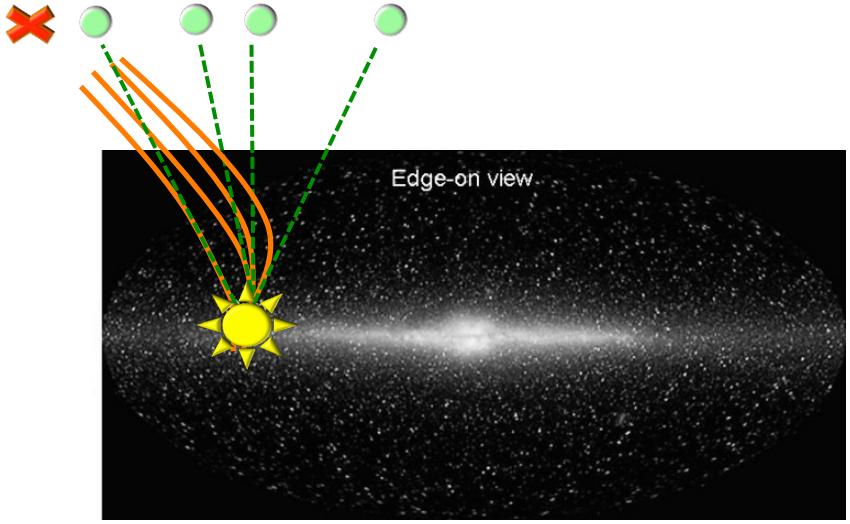

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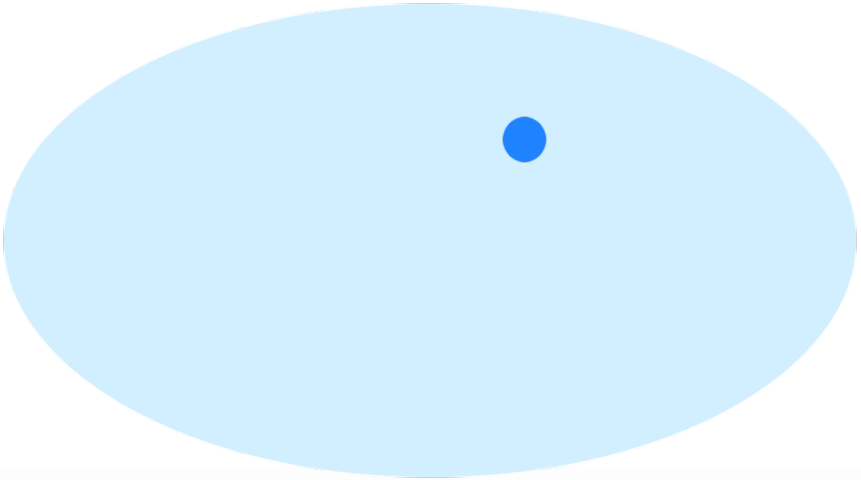

How can we find UHECR sources?

$$SNR = \frac{N_{source}}{\sqrt{N_{BG}}} = \frac{F_{source}}{\sqrt{I_{BG}}\sqrt{\pi}} \frac{\sqrt{\Delta t A_{eff}}}{\Delta\theta}$$

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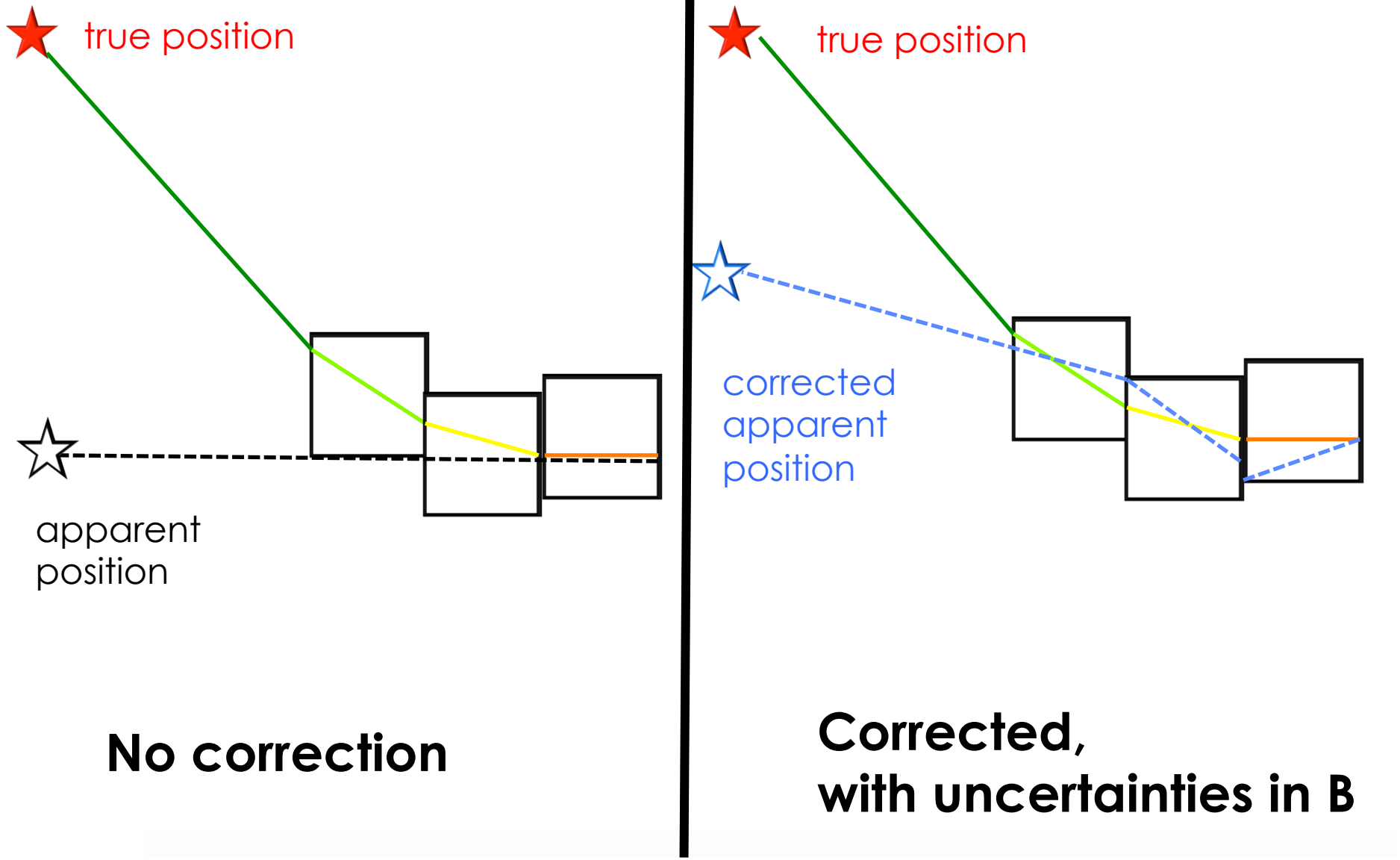
PSF (B-field)
Set by nature BUT
can measure and correct!

Tolerant to uncertainties in B? YES!



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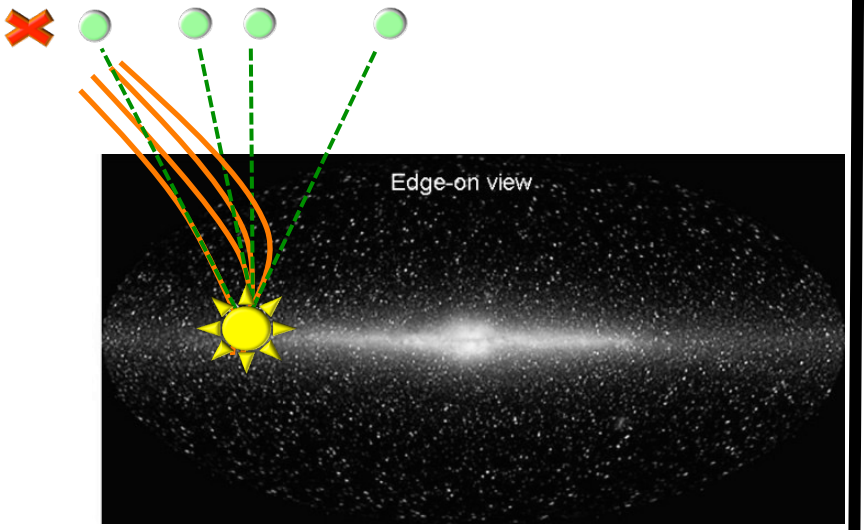
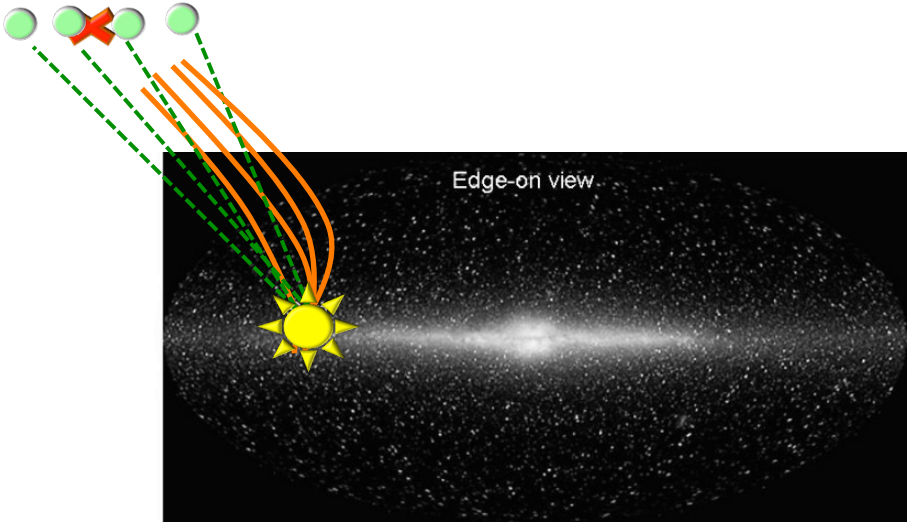
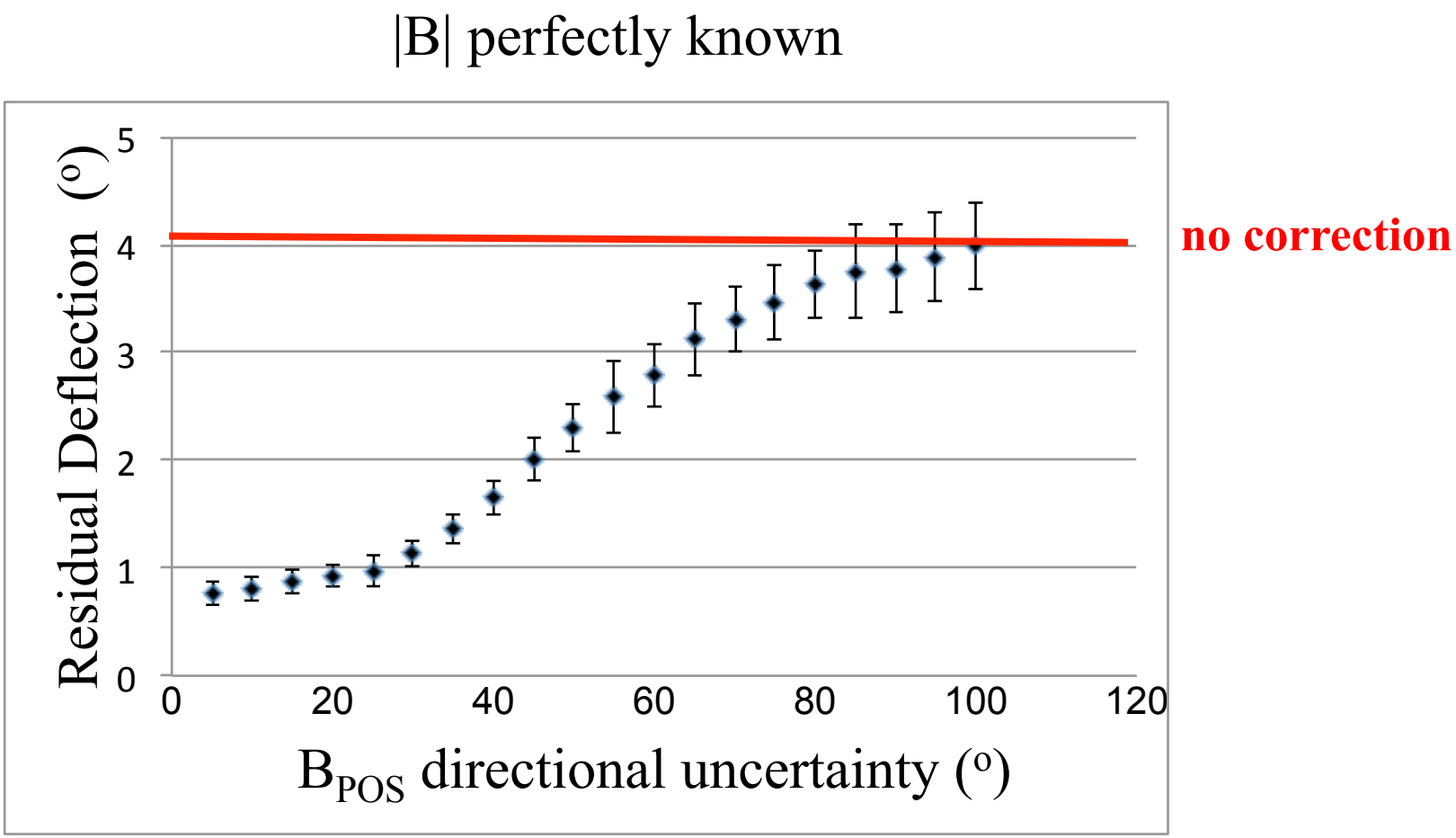


No correction



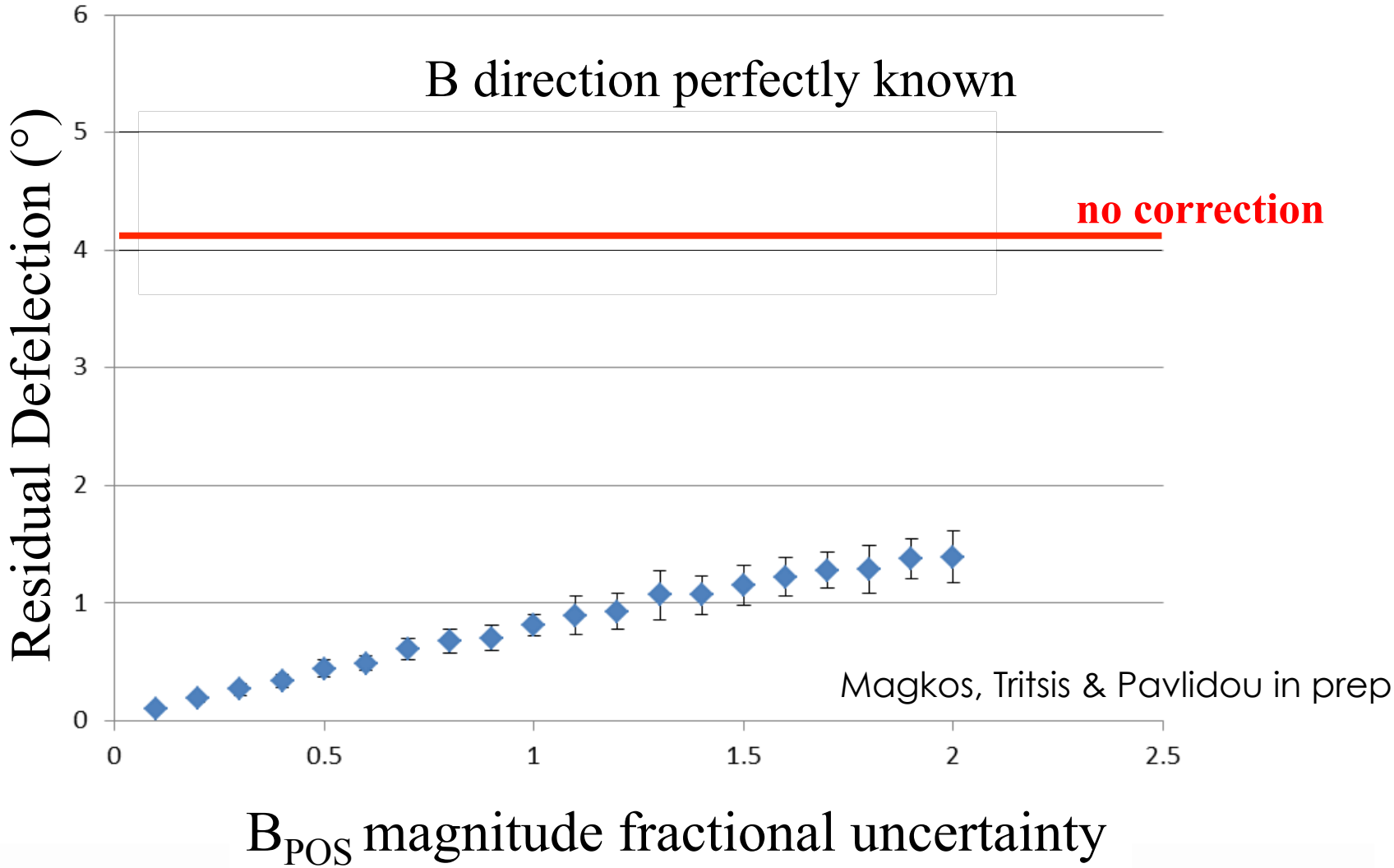
Corrected,
with uncertainties in B

How tolerant to uncertainties?



Magkos, Tritsis & Pavlidou in prep

How tolerant to uncertainties?



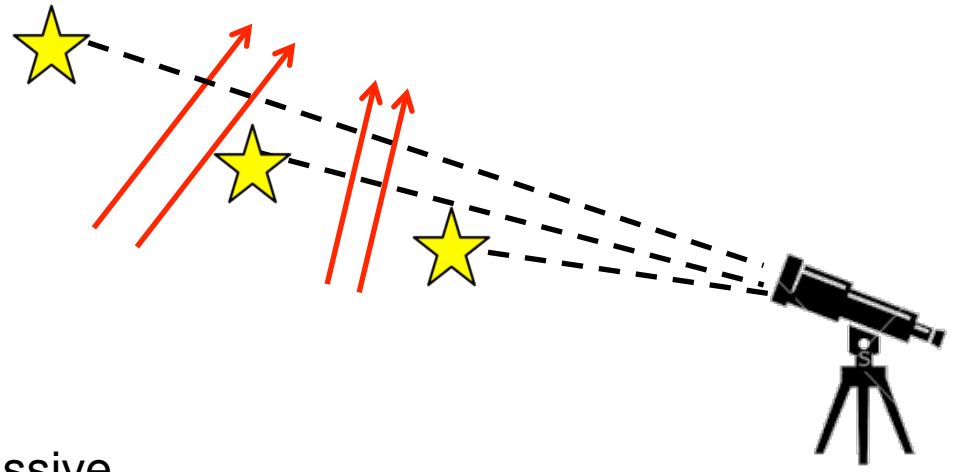
So where is the catch?

- **Need** TOMOGRAPHIC MEASUREMENT of B-field with independent, Gaussian uncertainties in magnitude, direction
- **Have** MODEL OPTIMIZATIONS of B-field with unknowable, systematic uncertainties in magnitude, direction

3-d Magnetic Tomography

- Use stars of **known distances** as lamp posts
- Measure **stellar polarization**

  → get B at different distances
- Possible **for the first time**:



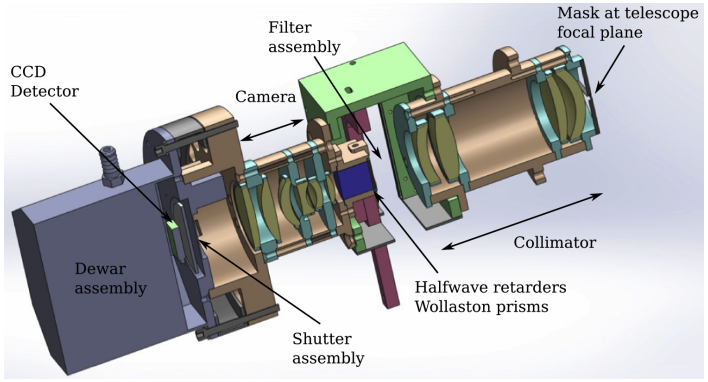
Tassis & Pavlidou 2015

GAIA distances
10^9 stars

PHAESTOS massive polarimetric survey

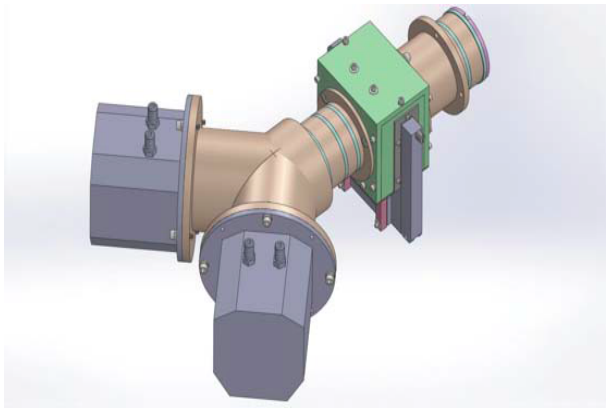
powered by WALOP

★ NEW SKINAKAS POLARIMETER



RoboPol

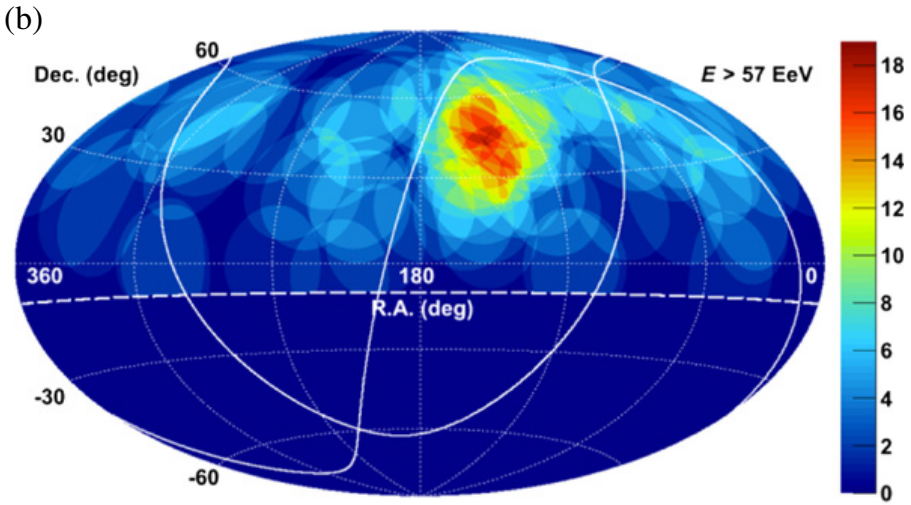
- no moving parts = **low systematics**
- 13'x13' field of view
- @ Skinakas 1.3m since 2013



Wide-Area Linear Optical Polarimeter (WALOP)

- Funded by Stavros Niarchos Foundation
  Under construction **now at IUCAA**, ready in 2019
- Extends RoboPol technology to
  4x **wider field**
- Increases **sensitivity x2** (4 CCD design)
- **Can cover the Telescope Array Excess area in only 20 nights**

The first PHAESTOS surcey

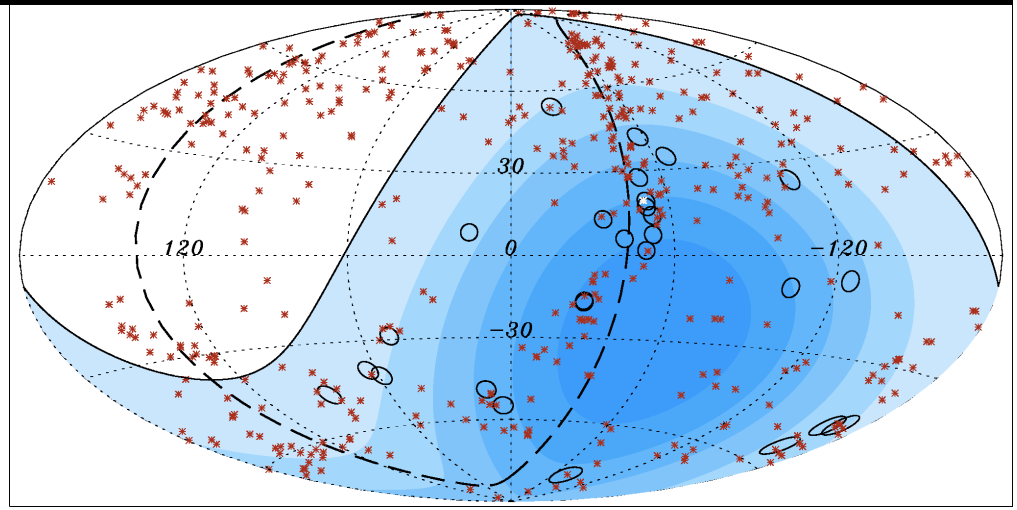


source: Abbasi et al. 2014

The Survey:

- ✓ 20 nights, 300 deg^2
- ✓ Rmag ≤ 15, ~90,000 stars
- ✓ measure p of 0.6% at 3σ
- ✓ B-field tomography at ≤ 20° accuracy, |B|~ factor of 2

What about the South?



- Partnership with **South African Astronomical Observatory**
- WALOP for SAAO 1.0m telescope currently in development for PASIPHAE project (optopolarimetric control of CMB B-mode foregrounds: U. Crete + SAAO + Caltech + IUCAA + U. Oslo)
- Skinakas/SAAO will also collaborate on **PHAESTOS** project
- Skinakas + SAAO WALOPs can deliver: **>250k stellar polarization measurements / year** (x 1000 improvement in state of the art) polarization systematics control at 0.1% accuracy

Conclusions

- GAIA parallaxes + advances in optopolarimetry:
  Galactic B-field tomography possible for the first time
- Can use to de-propagate UHECRs through Galactic B-field
- **UHECR astronomy possible with photon-sky statistical tools!**
- PHAESTOS surveys to begin with new, efficient WALOP polarimeters in 2019 in north + south