



Transparency of the Universe, gamma-ray/axion conversion and a medium-scale axion helioscope in Troitsk (TASTE)

Sergey Troitsky
(INR, Moscow)
[for a large team]

BNO-50 session, Nalchik, June 8, 2017

1. Motivation:

Gamma-ray observations of blazars suggest an ALP with the photon coupling just below the CAST limits.

2. Proposal:

Build an axion helioscope with the sensitivity 3 times better than CAST?

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Troitsk
Axion
Solar
Telescope
Experiment

1. Motivation:

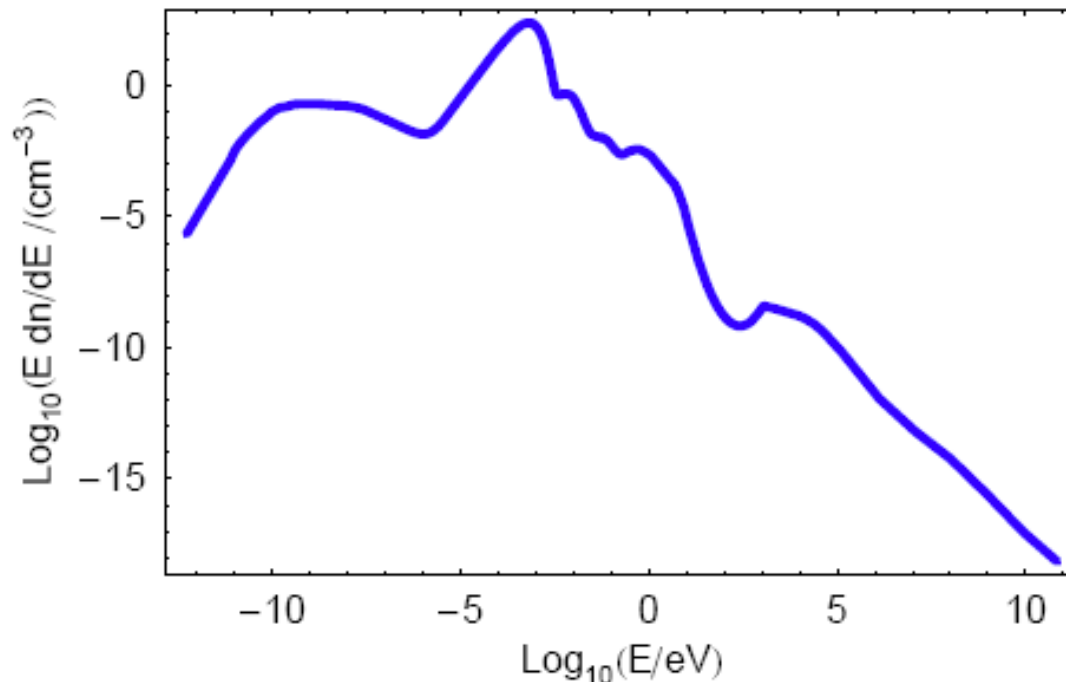
Gamma-ray observations of blazars suggest an ALP with the photon coupling just below the CAST limits.

Gamma-ray propagation: *the Universe is opaque for gamma rays*

Why opaque?

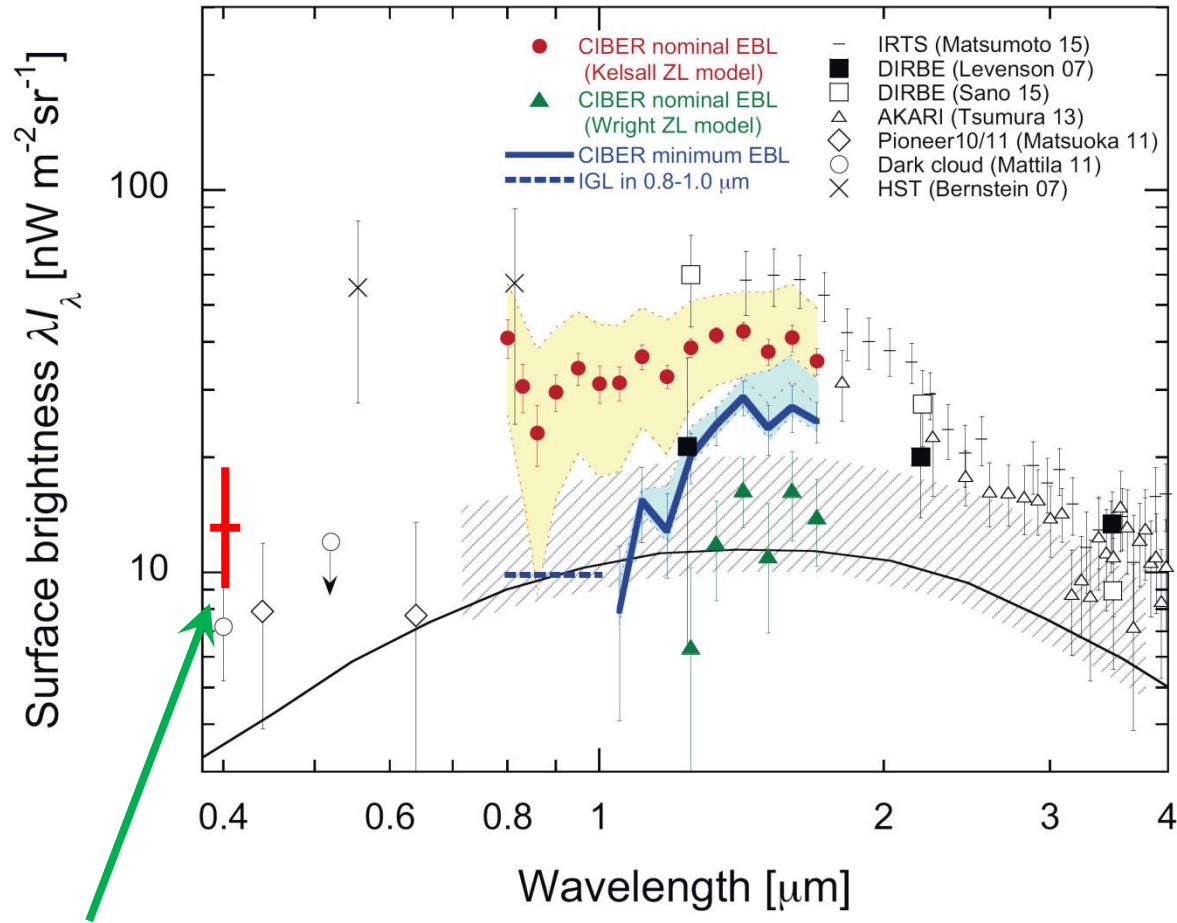
Pair production on background radiation
Nikishov 1962

The Universe is filled by radiation:



Extragalactic background light density

Matsuura et al. 2017



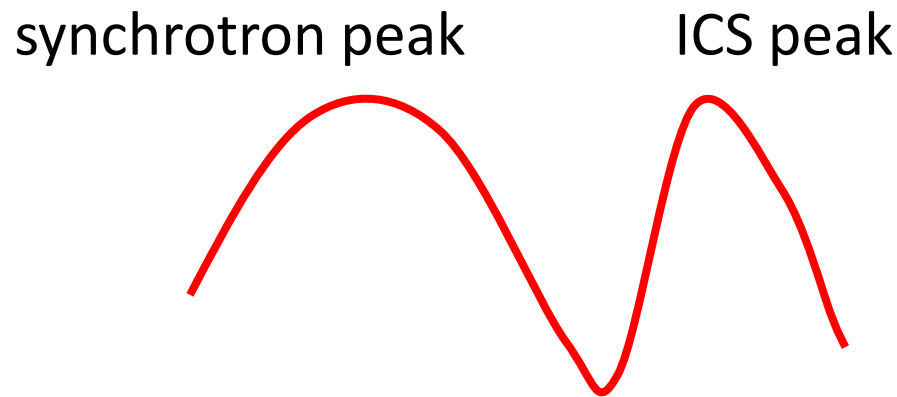
Mattila et al. 2017

The IR/TeV crisis?

very distant gamma-ray sources observed (blazars)
optical depths >2

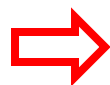
The IR/TeV crisis?

- very distant gamma-ray sources observed (blazars)
- blazar spectra are well studied:



inverse Compton scattering

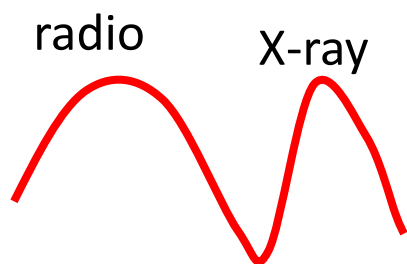
the same photons and electrons contribute to both peaks



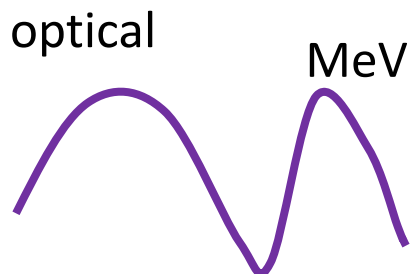
two peaks related

The IR/TeV crisis?

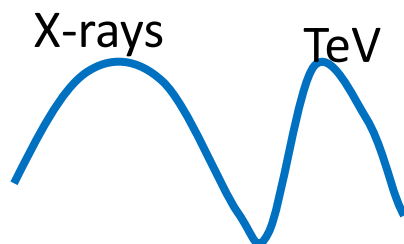
blazar spectra are well studied :
the blazar sequence...



FSRQ –
flat-spectrum radio quasars



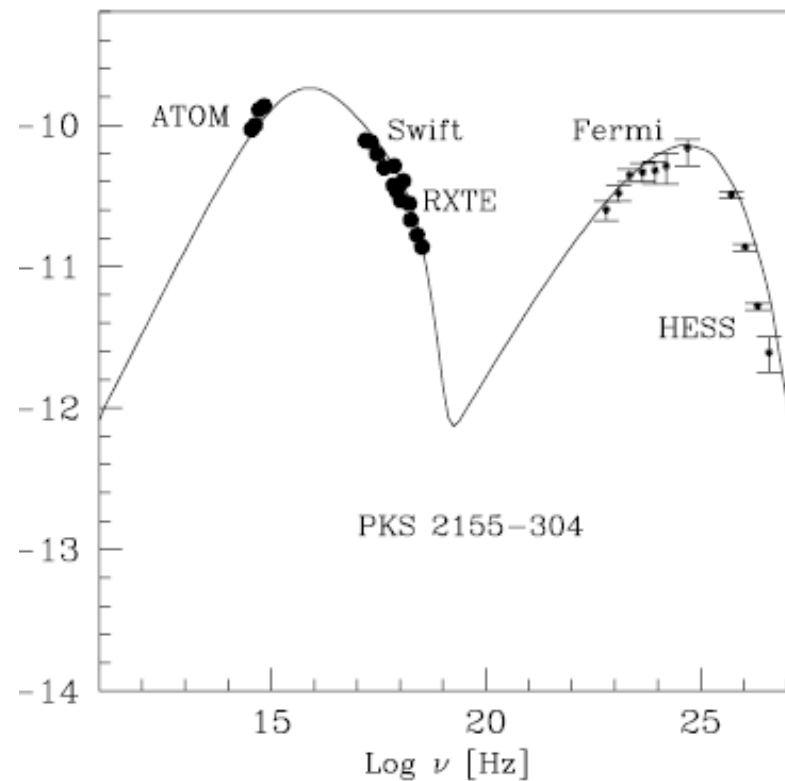
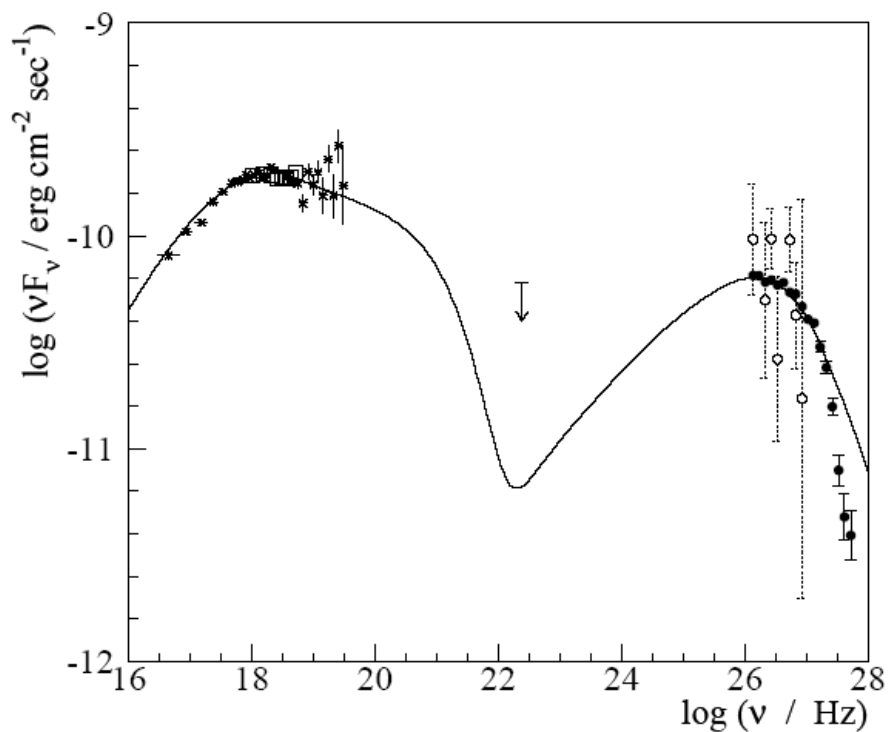
LBL – low-frequency-peaked BL Lacs



HBL – high-frequency-peaked BL Lacs

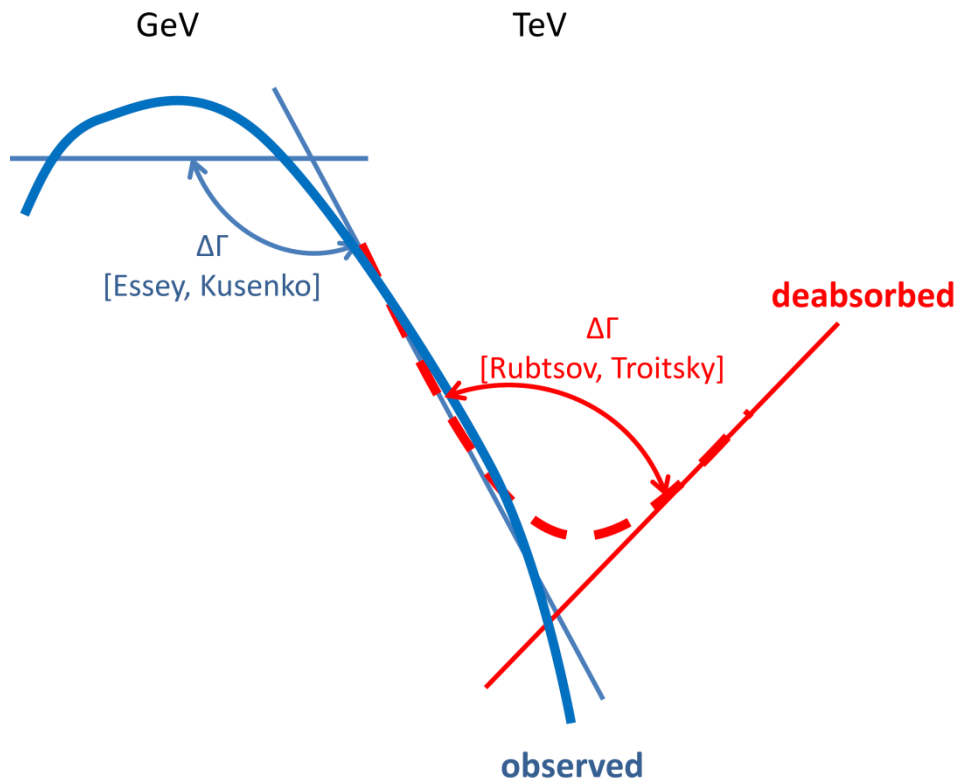
The IR/TeV crisis?

blazar spectra are well studied :
the blazar sequence...



The IR/TeV crisis?

- very distant gamma-ray sources observed (blazars)
optical depths >2
- spectra corrected for absorption
- upward breaks at high energies in addition to 2 peaks
(distant sources only)

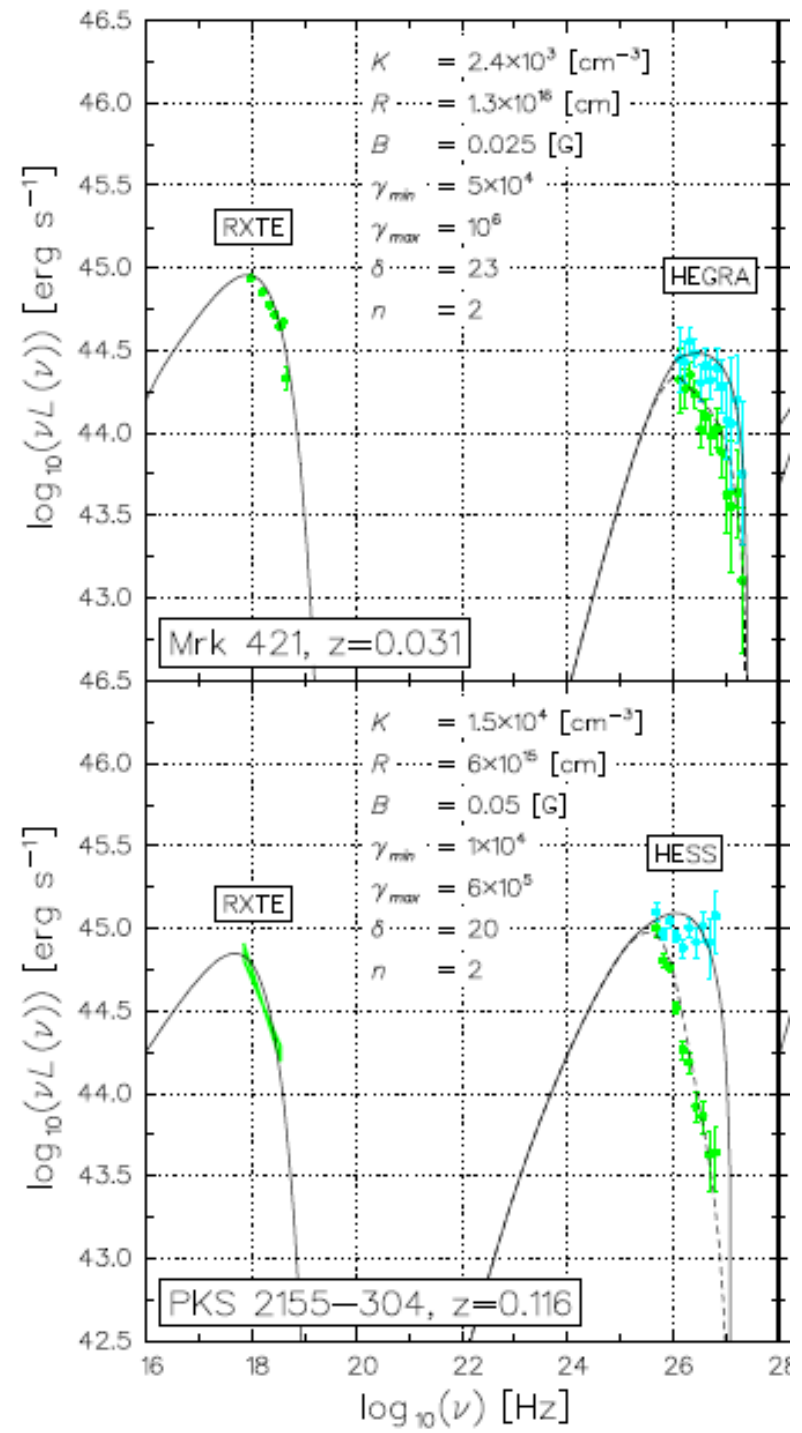


The IR/TeV crisis?

- need upward break to explain the data
- the break does not depend on the class (HBL, LBL, FSRQ)
- the break depends on the distance

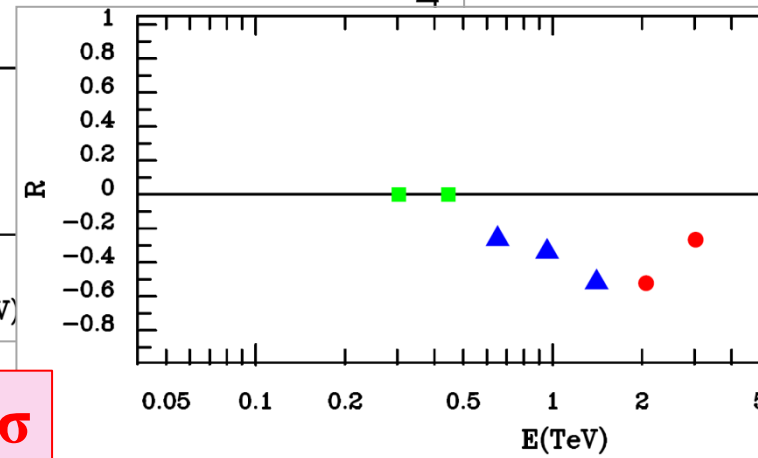
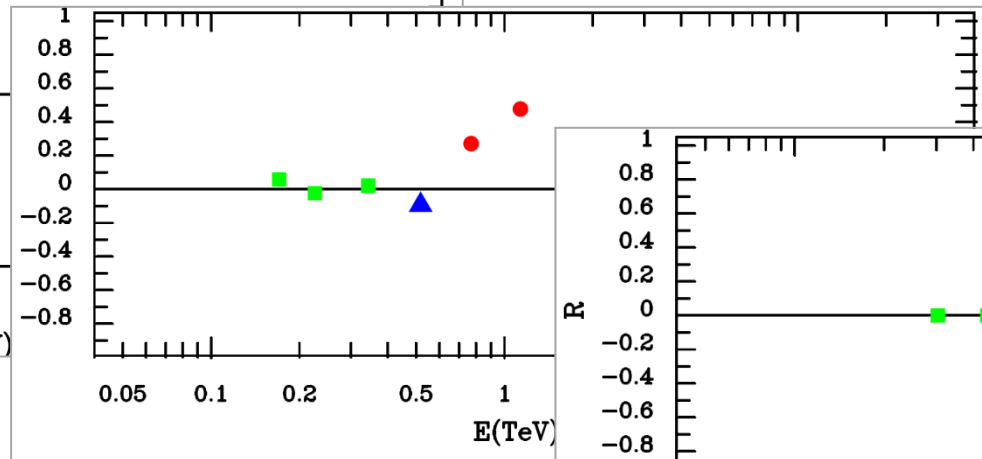
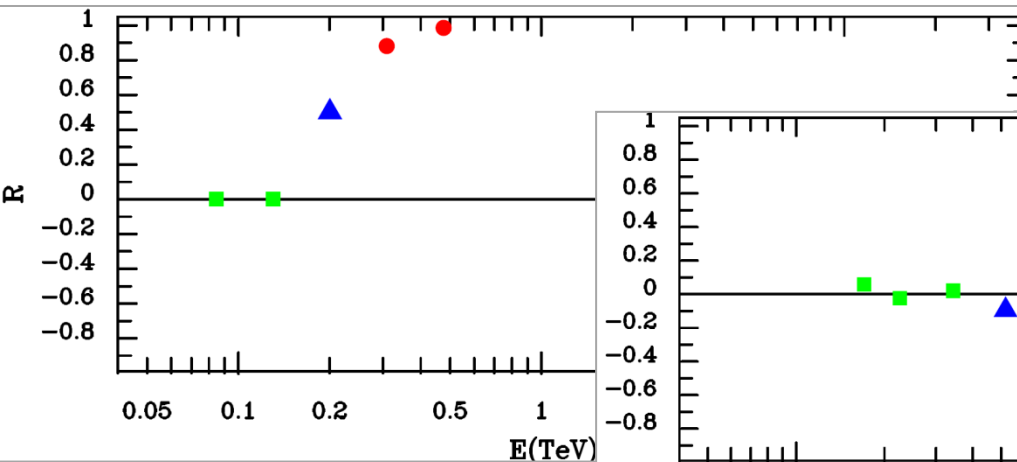
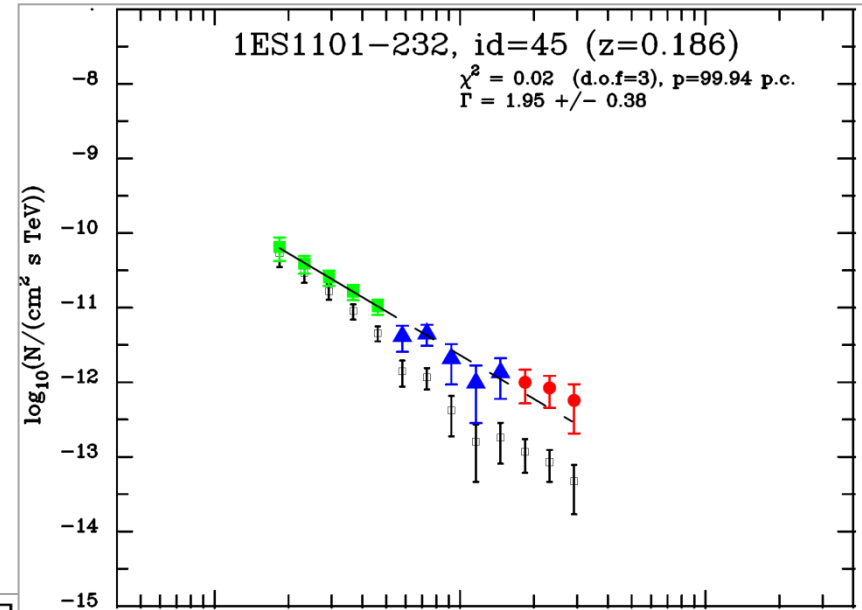
➔ looks strange...

Kneiske ~2008



The IR/TeV crisis?

7 blazars, IACT
opacity >2 , $z \leq 0.536$
redshift-dependent
break positions
in deabsorbed spectra



Horns, Meyer 2012

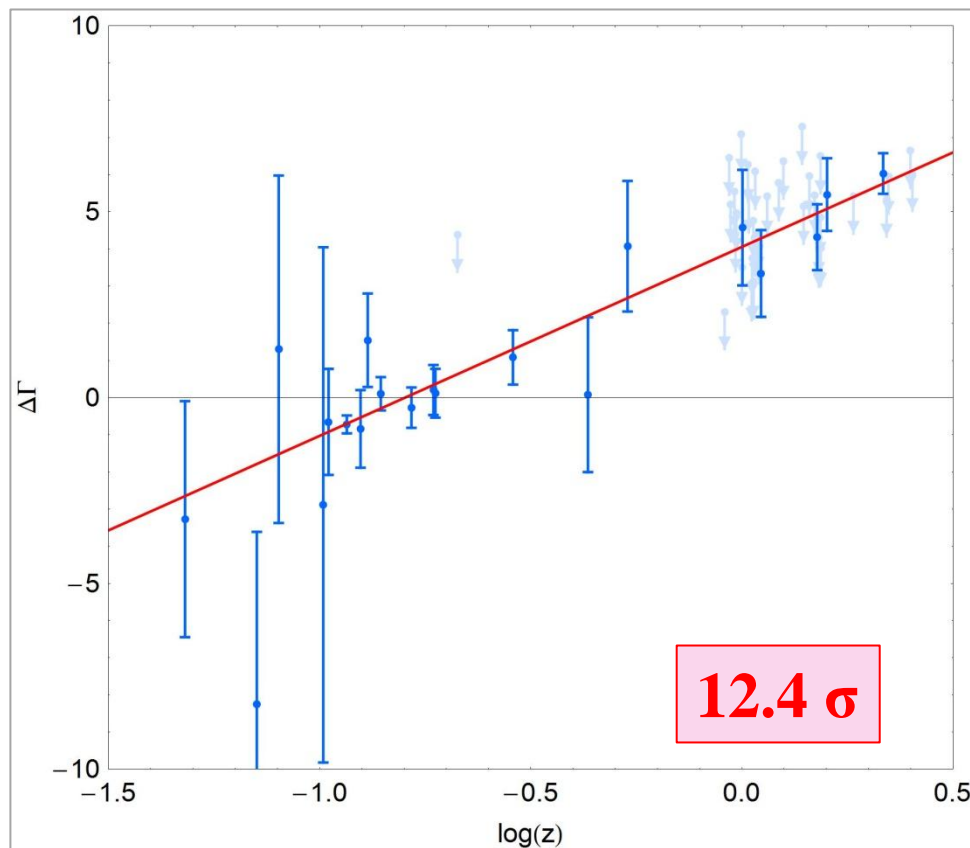
4.2 σ

20 blazars, 15 IACT + 5 FERMI LAT

opacity >1 , $z \leq 2.156$

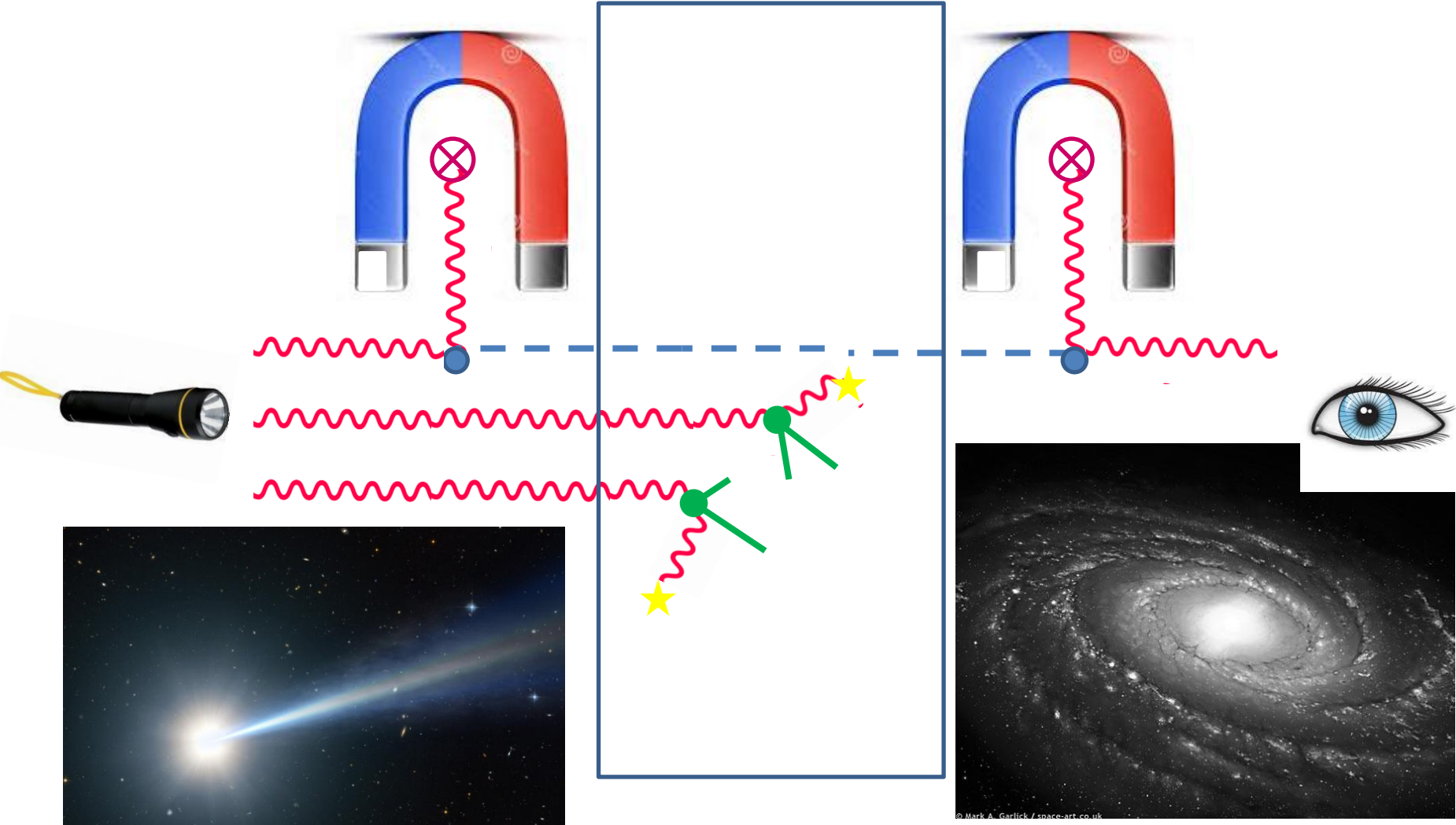
redshift-dependent **break strength** in deabsorbed spectra

- **BREAK STRENGTHS DEPEND ON DISTANCE (not on the source type)**

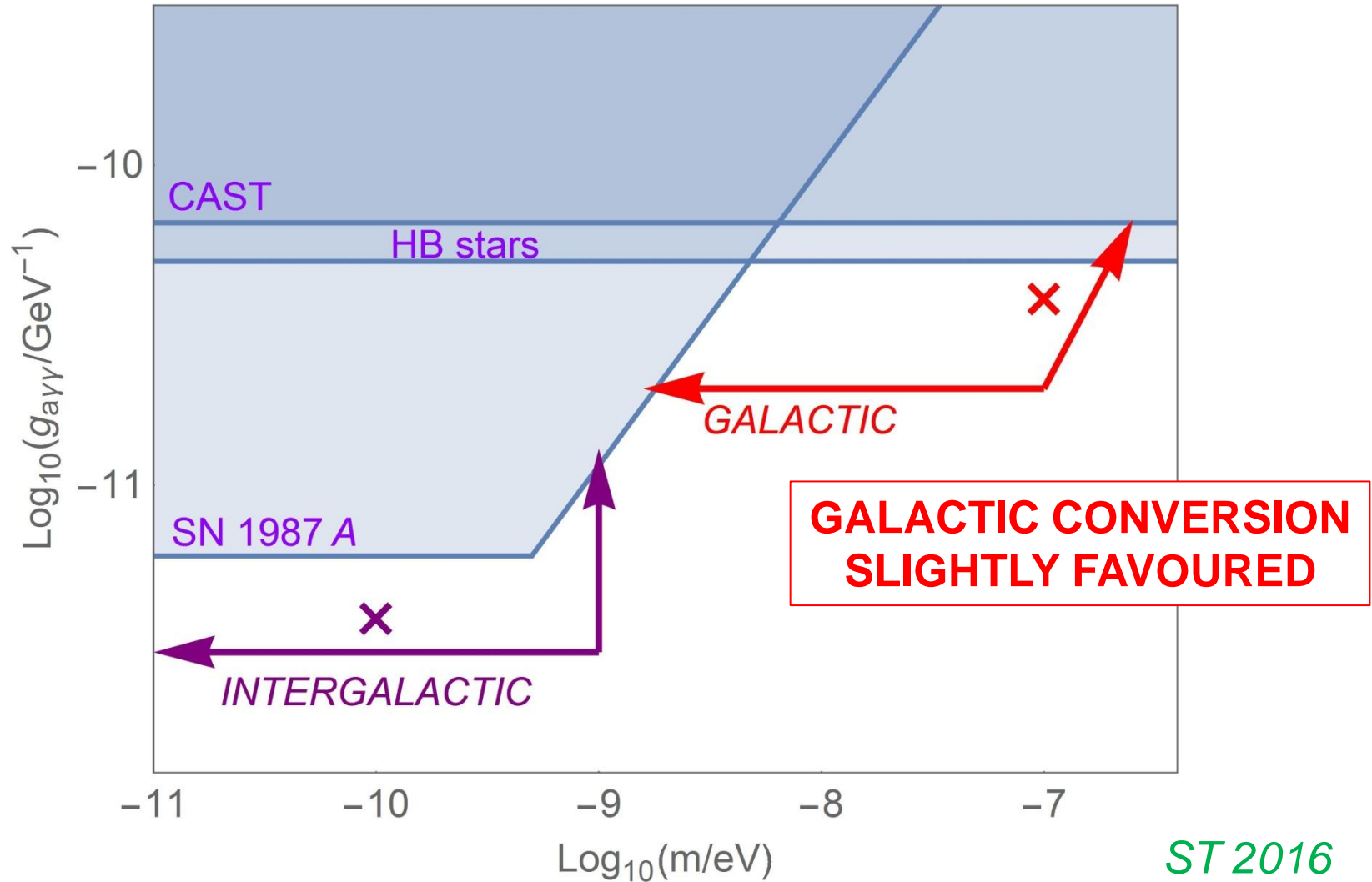


Shining light through the Universe: **Galactic** conversion

Simet et al. 2008, Fairbairn et al. 2009



Required ALP parameters



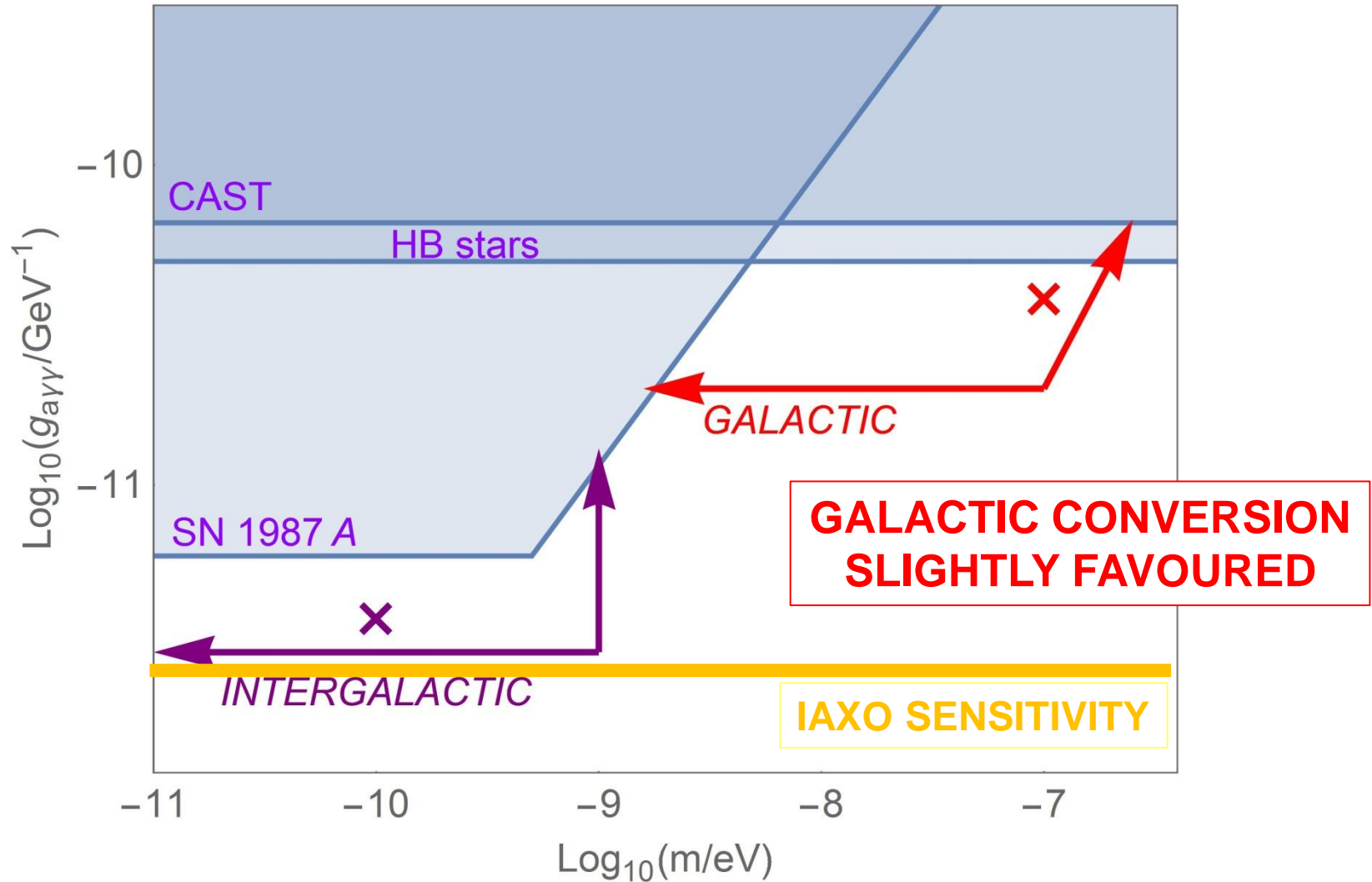
Required ALP parameters (benchmark)

$$m \sim 10^{-7} \text{ eV}, \quad g_{a\gamma} \sim 4 \times 10^{-11} \text{ GeV}^{-1}$$

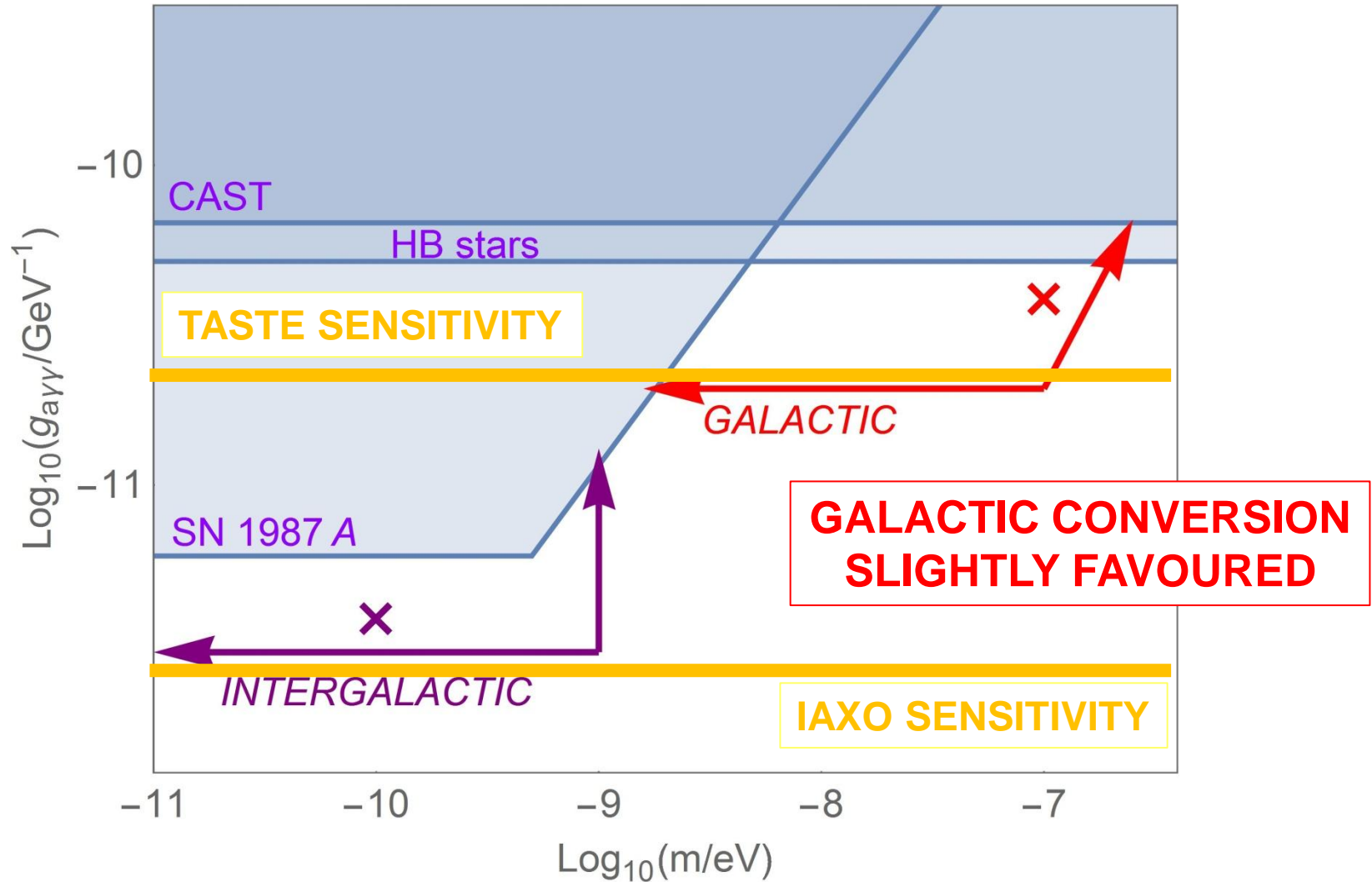
(theoretical motivation wanted...)

(experimental discovery wanted...)

Required ALP parameters



Required ALP parameters



2. Proposal:

Build an axion helioscope with the sensitivity 3 times better than CAST?

**Troitsk
Axion
Solar
Telescope
Experiment**

PRELIMINARY TASTE PROPOSAL

Towards a medium-scale axion helioscope

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I. Tkachev³, S. Troitsky³, K. Zioutas⁸

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³ Institute for Nuclear Research of RAS, Moscow, Russia

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⁵ Space Research Institute of RAS, Moscow, Russia

⁶ Joint Institute for Nuclear Research, Dubna, Russia

⁷ Physics Department, Moscow State University, Moscow, Russia

⁸ Patras University, Patras, Greece

Parameters of a possible design (minimal)

Magnet: $B=3.5$ T, $L=12$ m, $D=60$ cm

magnet figure of merit = $B^2 L^2 A \sim 30 \times \text{CAST}$

Tracking time $\sim 12\text{h/day} \sim 3 \times \text{CAST}$

Possible improvements in photon detection

Overall figure of merit: $\sim 100 \times \text{CAST}$



improvement in $g_{\alpha\gamma\gamma} \sim 100^{1/4} \sim 3$

Ingredients

Available:

- ✓ superconducting wire, NbTi, 35 km, 4 kA, 5 T *made in USSR*
- ✓ cryogenics (Troitsk-v-mass), *including* He liquefier + team
- ✓ lab space + place for the instrument + power supply
- ✓ X-ray telescope, D=60 cm (SODART) (?)
- ✓ photodetectors under development by astronomers
- ✓ low-background experience (Baksan neutrino observatory)

Missing:

- moving platform (*options below*)
- 2 to 4 MEuro depending on the design

Institutions

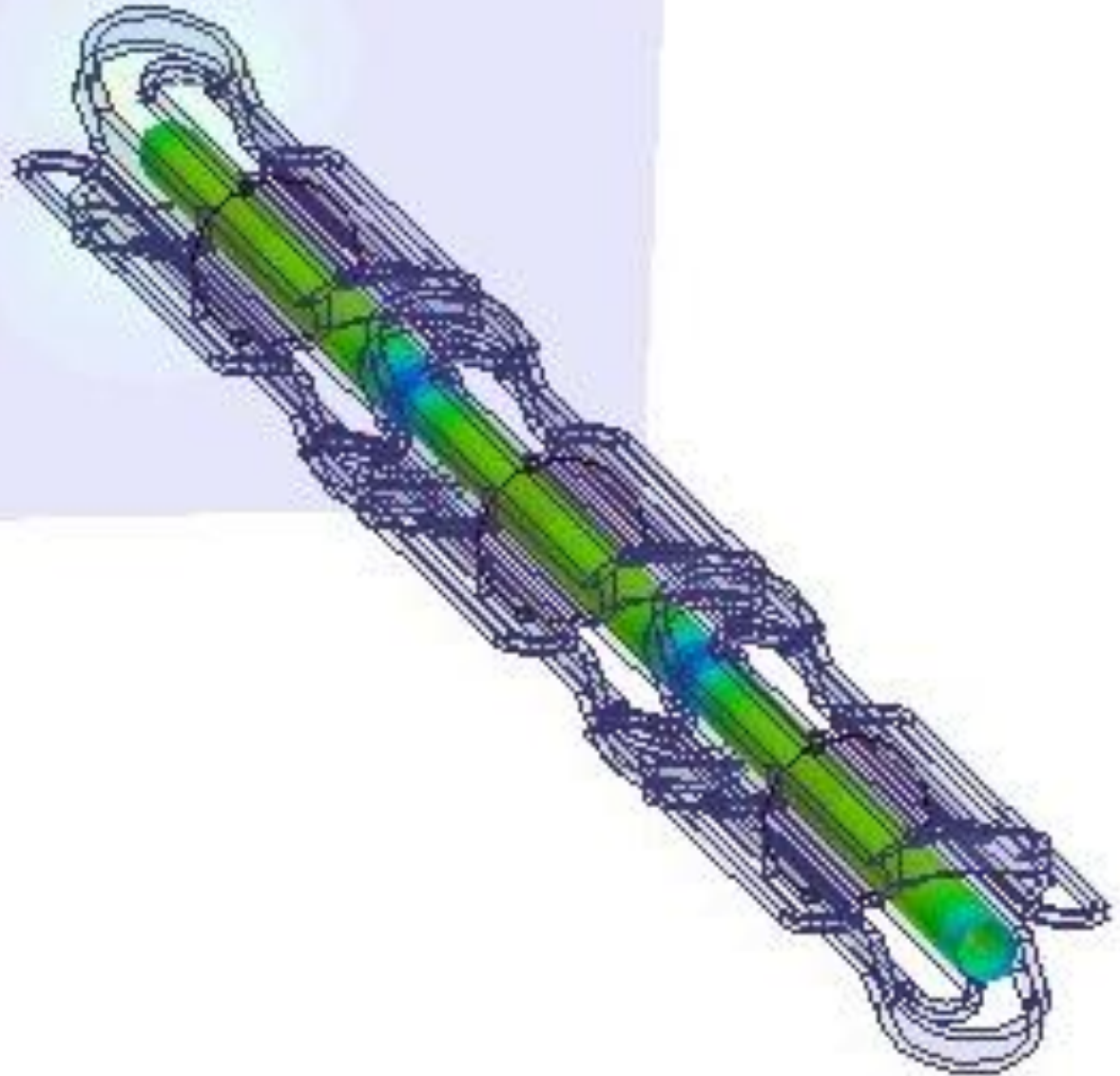
- INR (Institute for Nuclear Research), Moscow
concept, magnet, cryogenics, infrastructure
 - IKI (Space Research Institute), Moscow
X-ray telescope, photodetectors
 - BNO INR (Baksan) + PNPI (St. Petersburg)
low-background equipment
 - Ioffe Institute, St. Petersburg
platform, photodetectors
- + possible contributions from JINR (Dubna), IHEP (Protvino)
magnet

COLLABORATORS WELCOME!

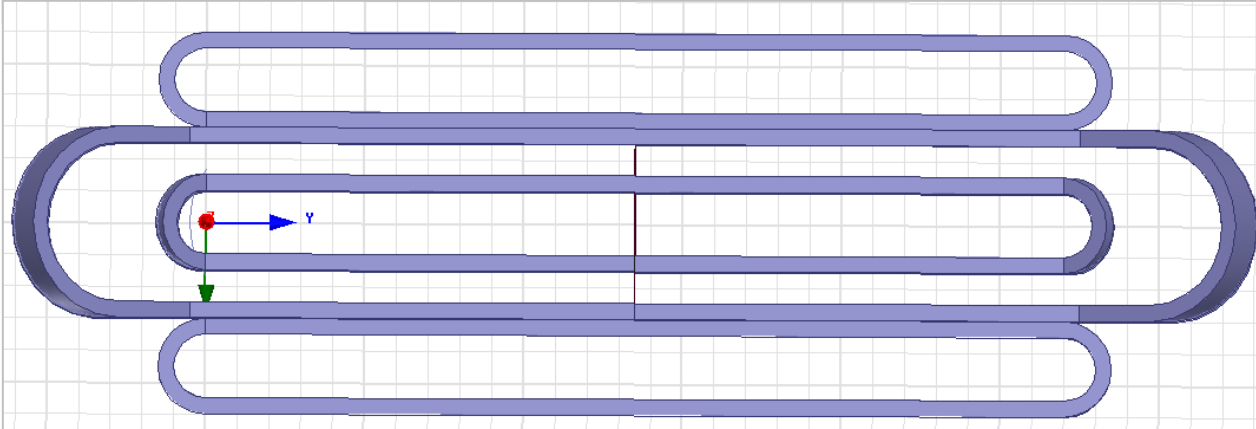
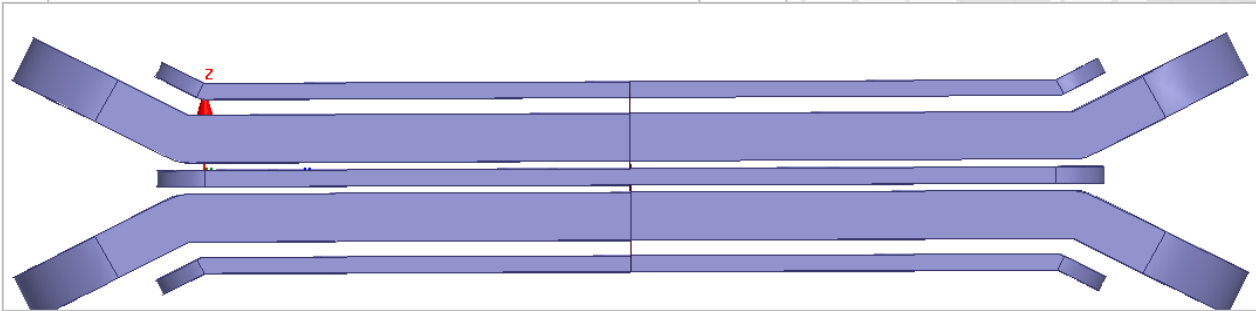
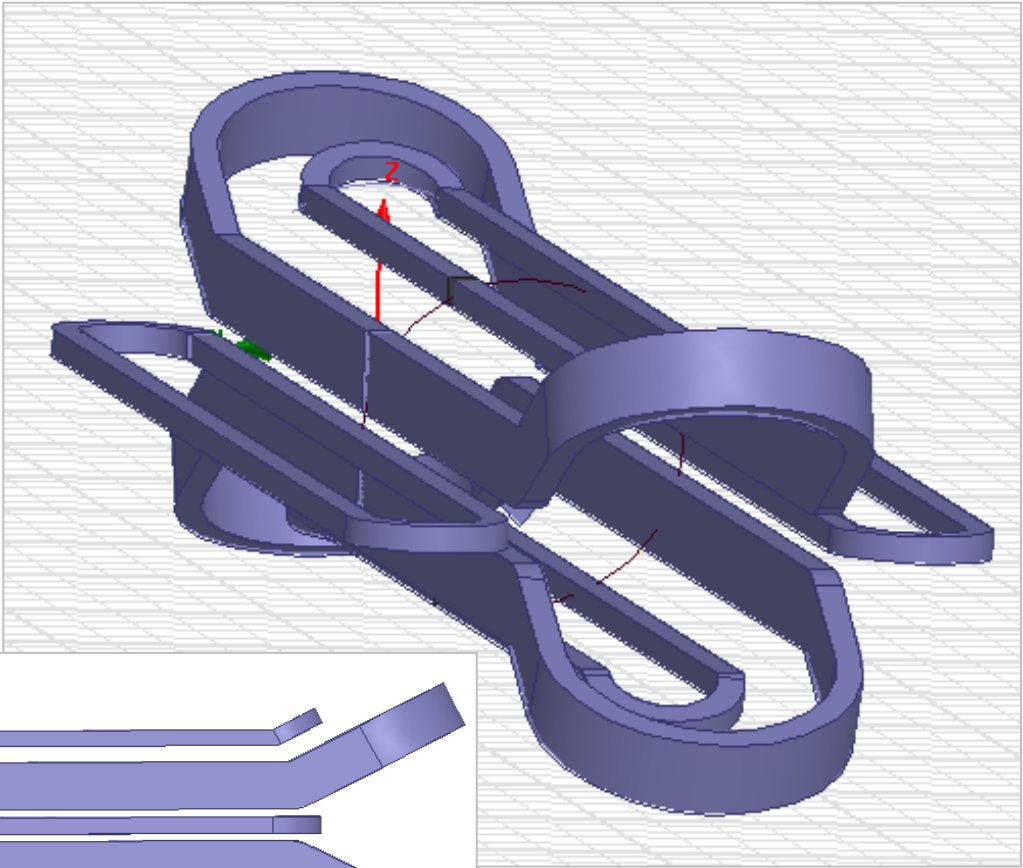
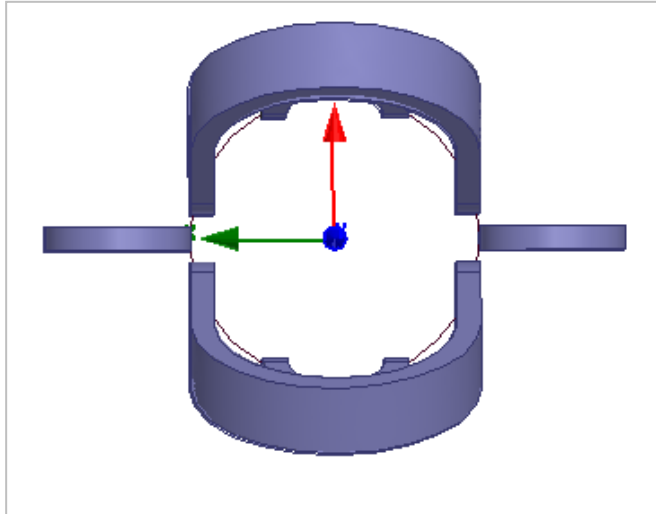
Magnet

- active shielding (iron free) design inspired by proposed detectors for the Future Circular Collider (FCC)
- very preliminary minimal design using available wire (35 km) and cryogenics
- $B=3.5$ T, $L=12$ m, $D=60$ cm

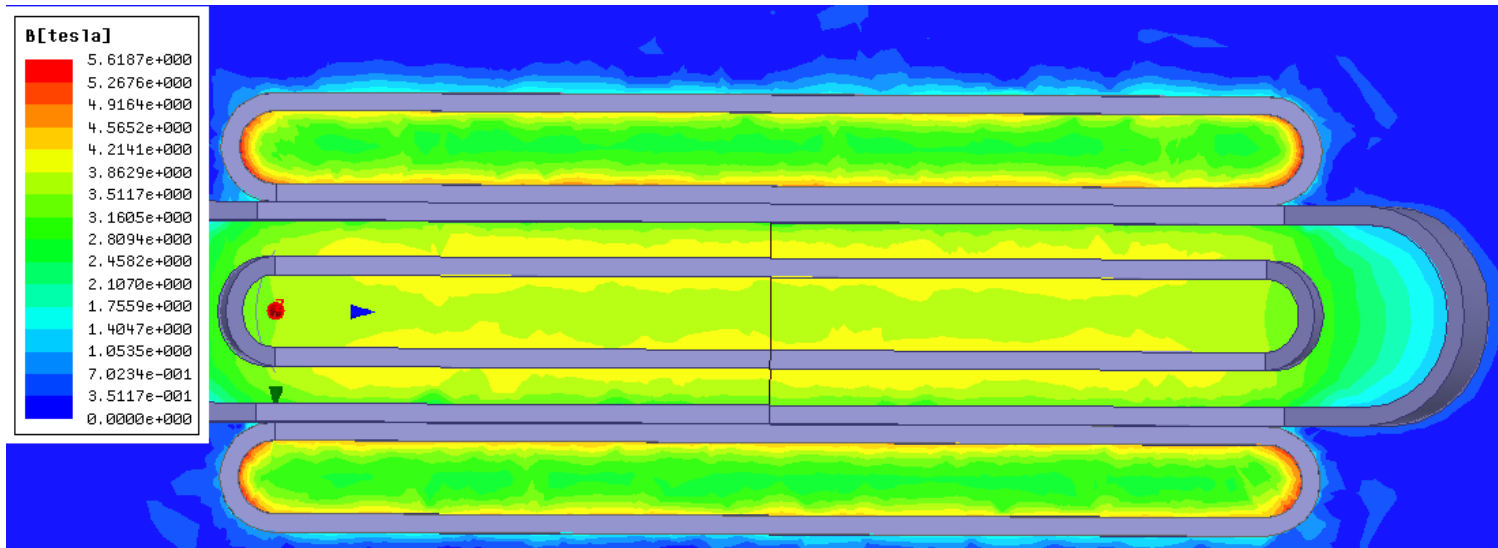
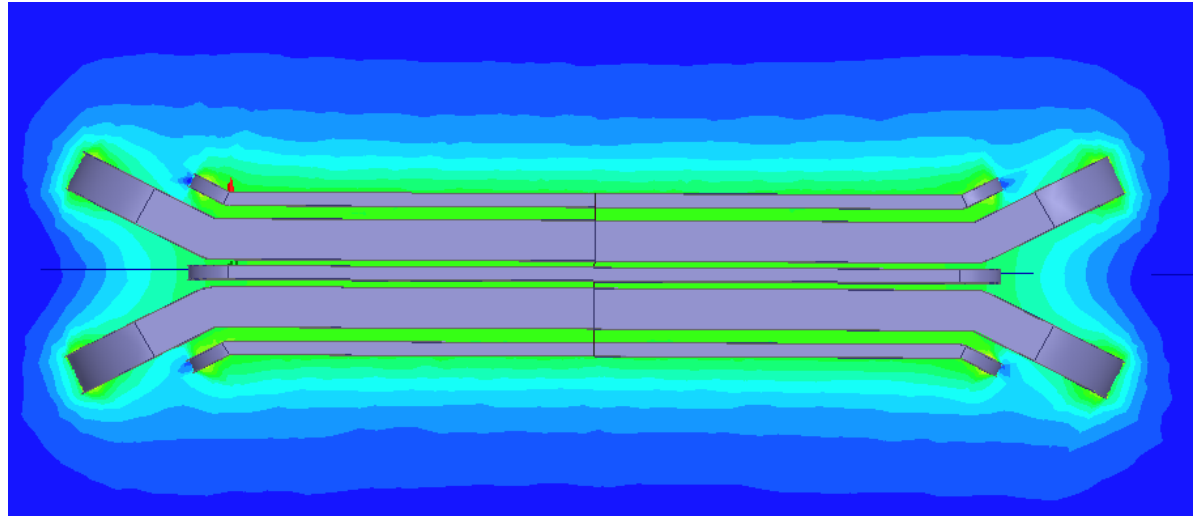
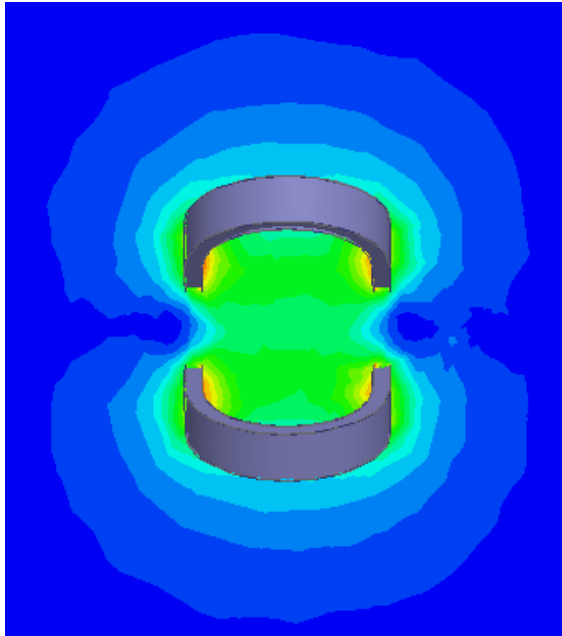
Magnet



Magnet section



Magnet section

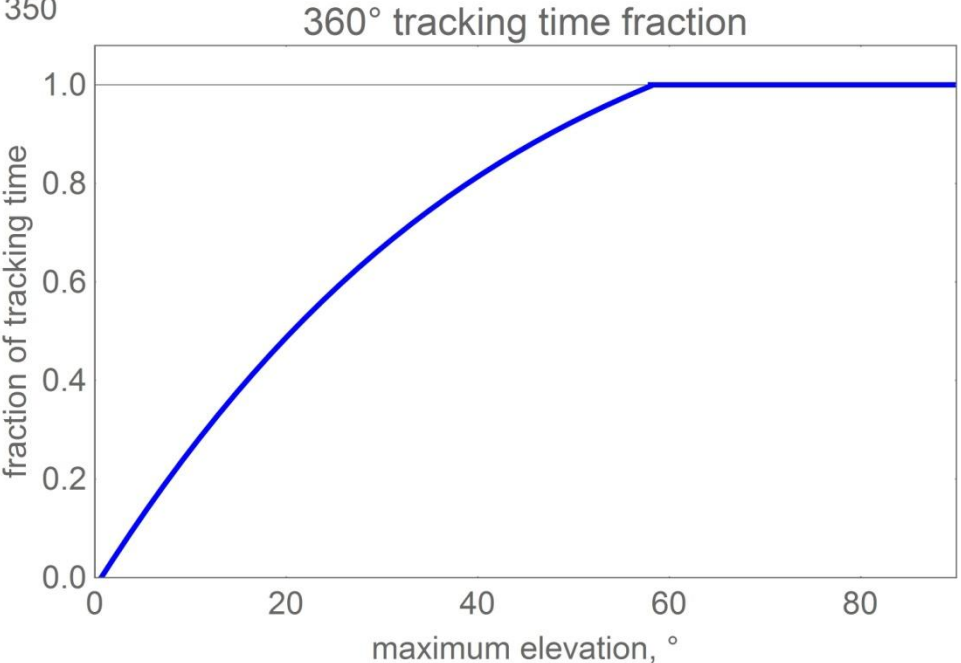
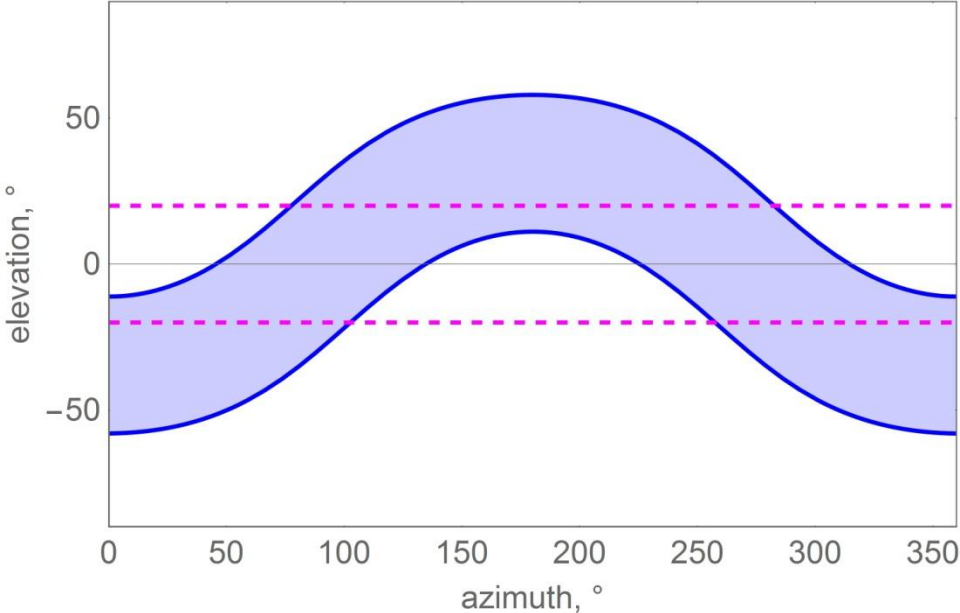


X-ray telescope (?)

- SODART: SOviet-DANish Roentgen Telescope
- manufactured to be launched in 1990s
- never launched, kept in Lavochkin NPO
- $D=60$ cm, focal length=8 m, focusing spot~2 mm



Solar tracking time



Platform (inspirations...)

RADIO/VHE GAMMA-RAY TELESCOPES

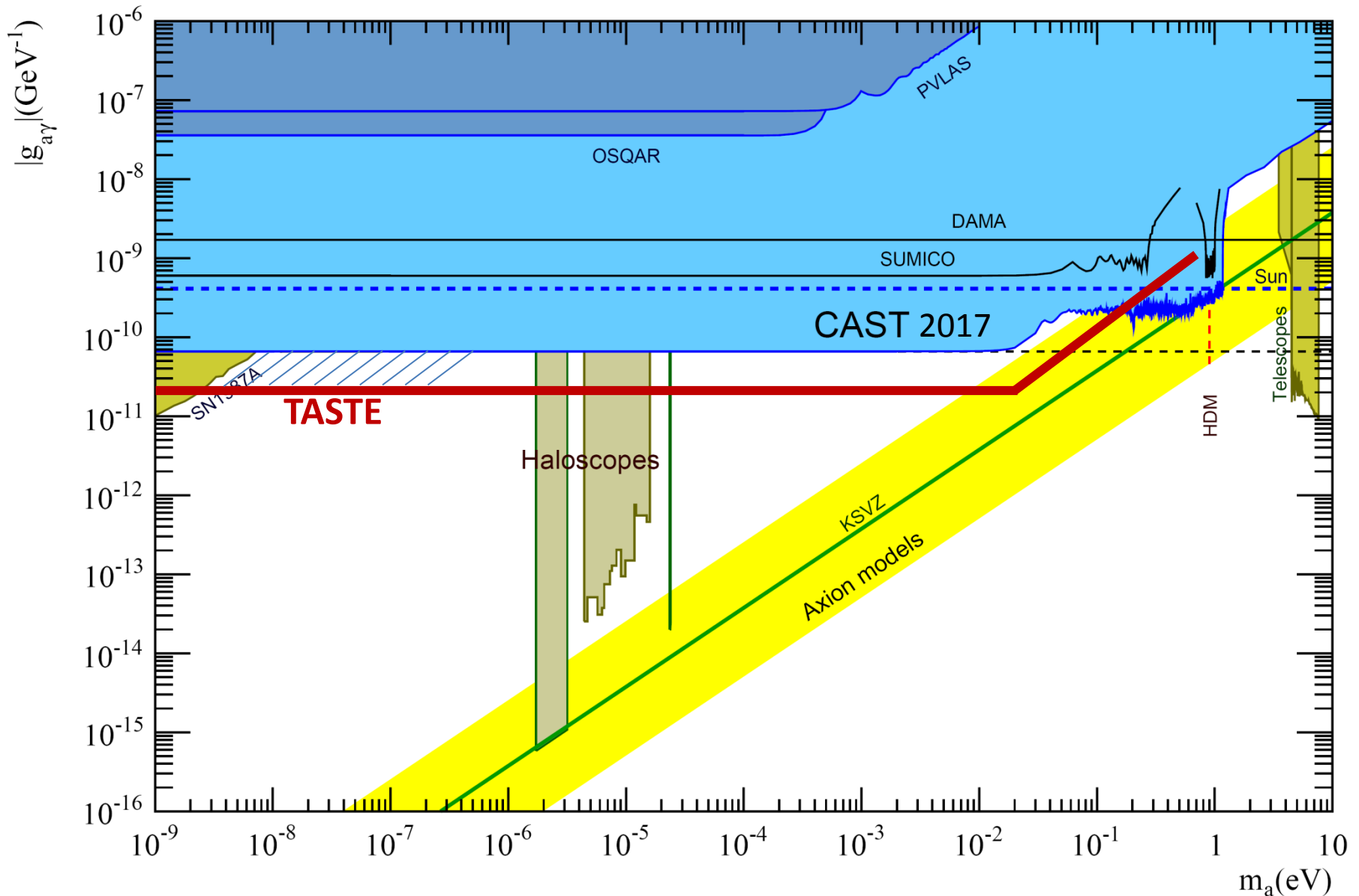


St. Petersburg MOVING BRIDGES

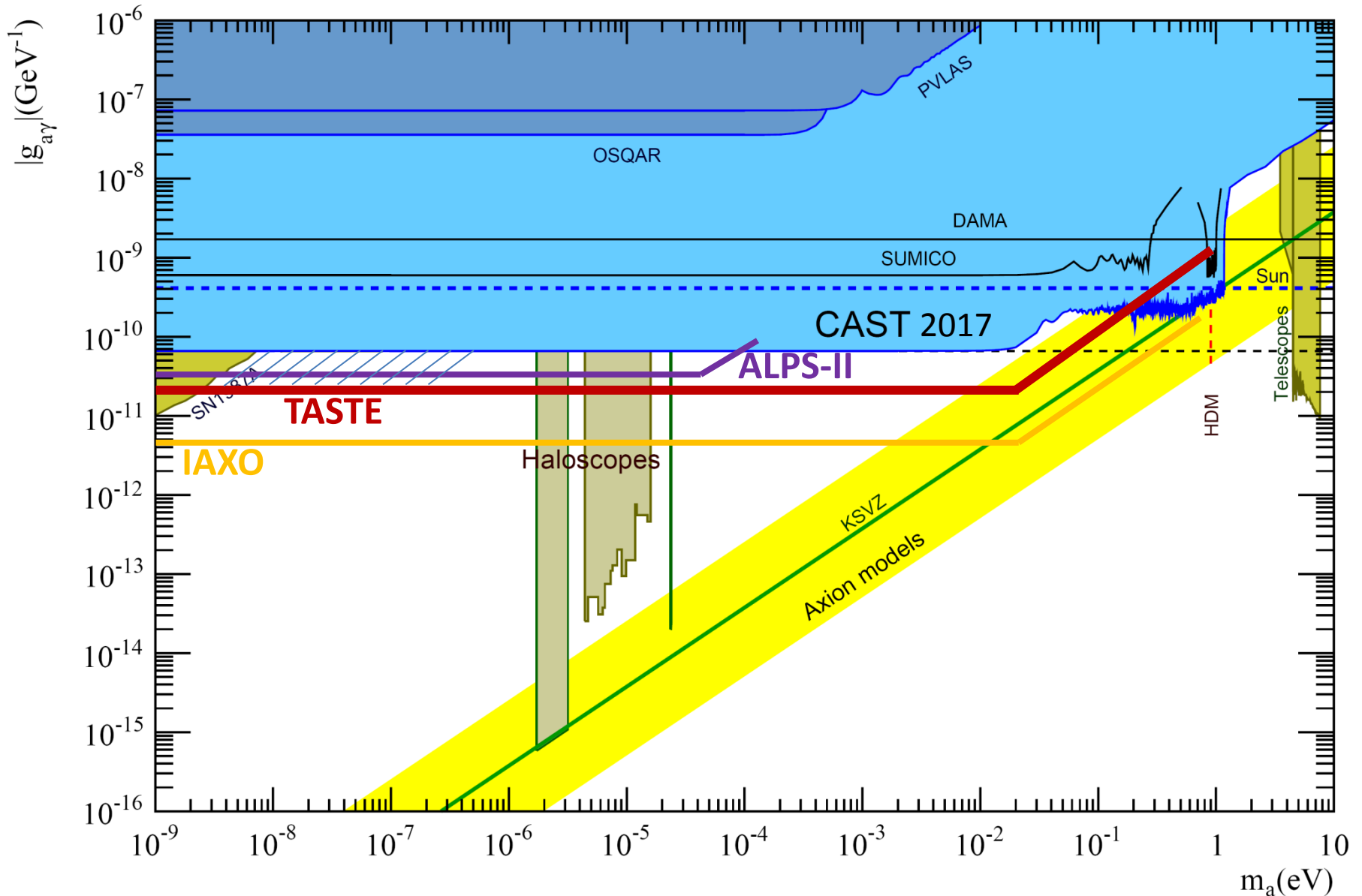


NAVY

Preliminary sensitivity estimate



Preliminary sensitivity estimate



□ ANOMALOUS TRANSPARENCY OF THE UNIVERSE
for GAMMA RAYS:

**CASE FOR GALACTIC ALP/gamma
CONVERSION STRENGTHENS**

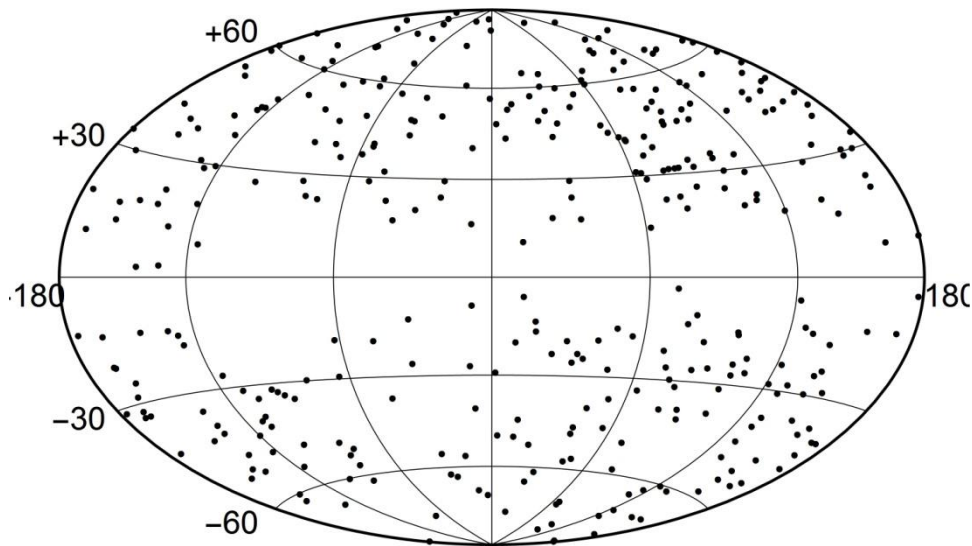
□ WHY SHOULD NOT WE CONSTRUCT AN
INSTRUMENT TO DISCOVER THE ALP???

**A HELIOSCOPE with CASTx3 SENSITIVITY
WOULD WORK**

□ PRE-PROPOSAL: **TASTE**
WELCOME TO JOIN!

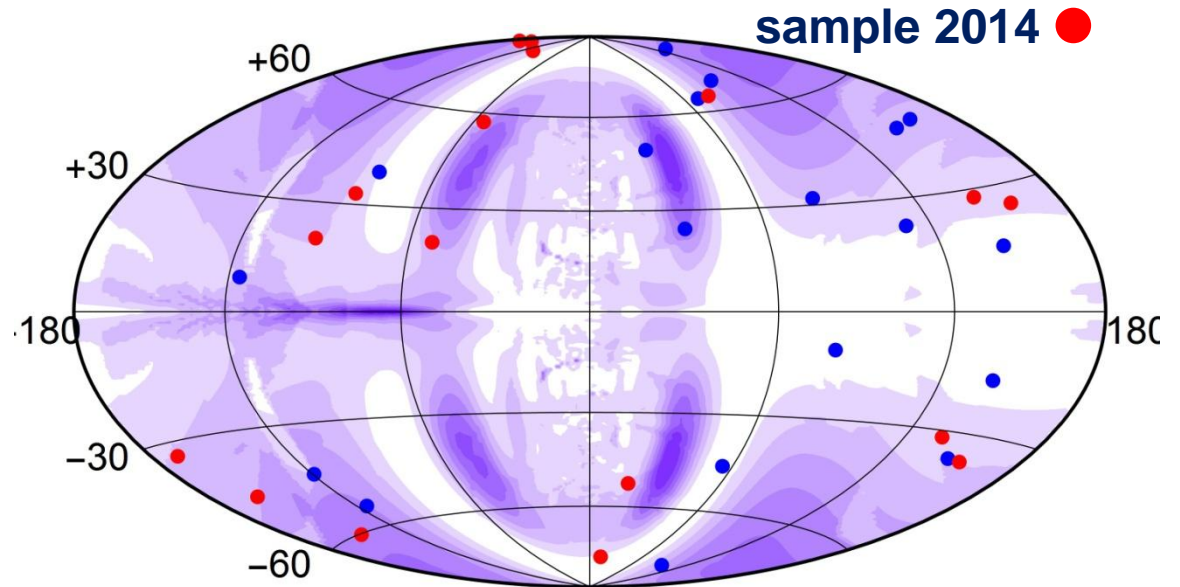
**Troitsk
Axion
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Milky Way: anisotropy



[more] complete sample:
FERMI LAT 3FHL catalog 2017
 $z > 0.2$

blazars detected
at optical depth > 1 ●



sample 2014 ●