Physics in Space

or

Phenomenology and Fundamentals of our Universe

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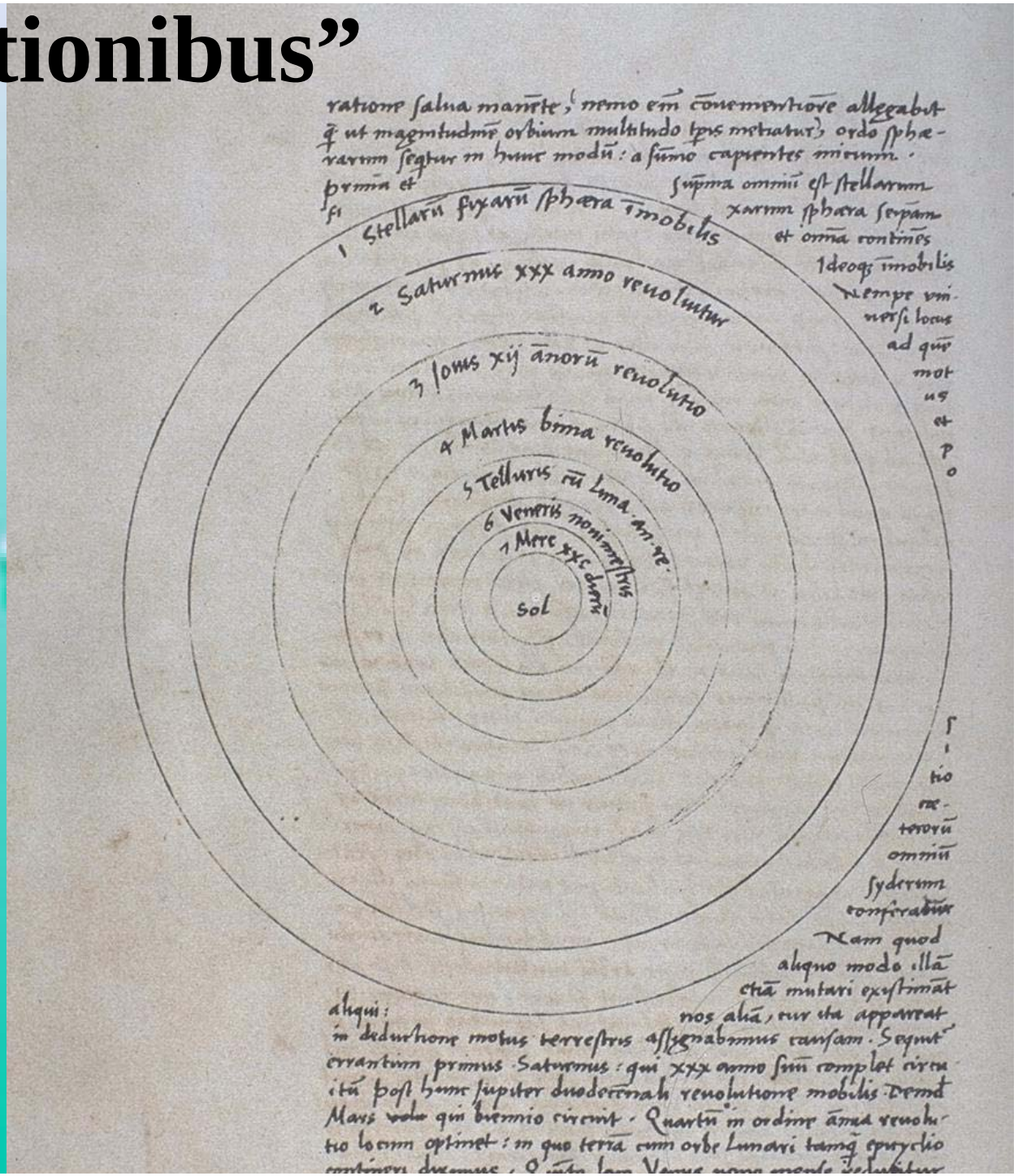
4000

years of naked-eye astronomy


登封观星台

“De Revolutionibus”



400

years of astronomy with telescopes

Padova, 1609


GALILAEUS GALILAEI PATRICIUS FLOR.
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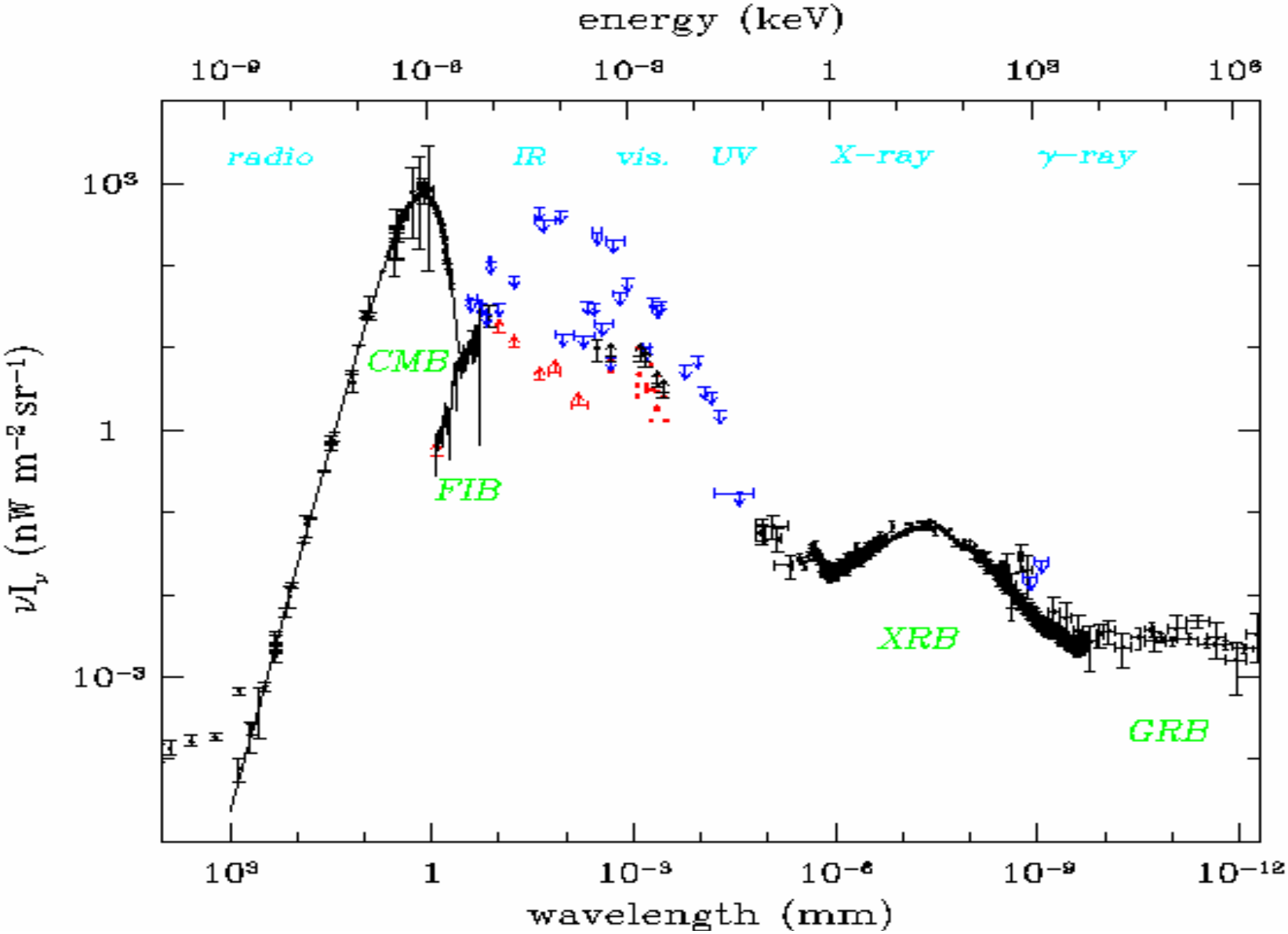
40
years of space astronomy

August 1957 Vostok

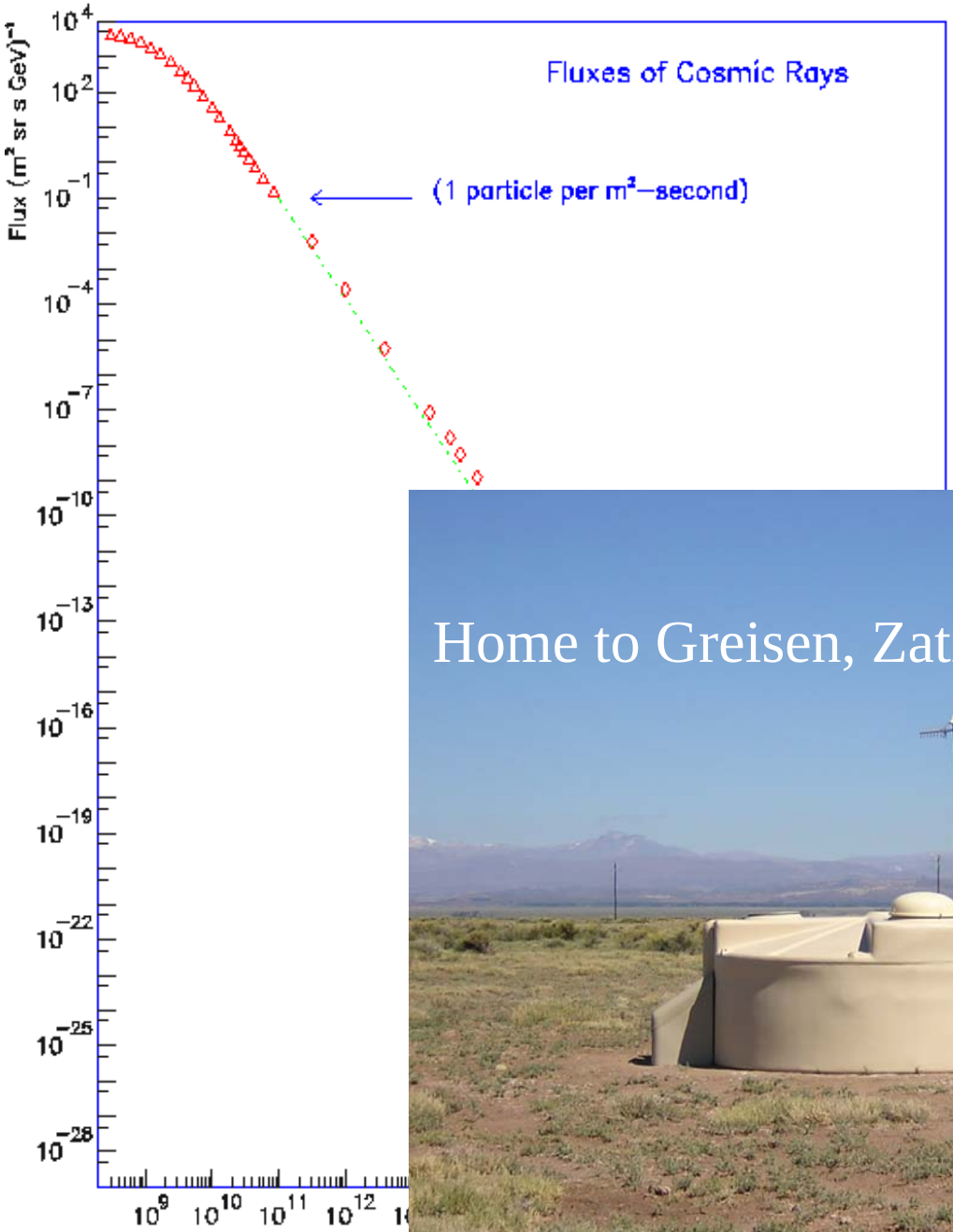
Sergei Korolev

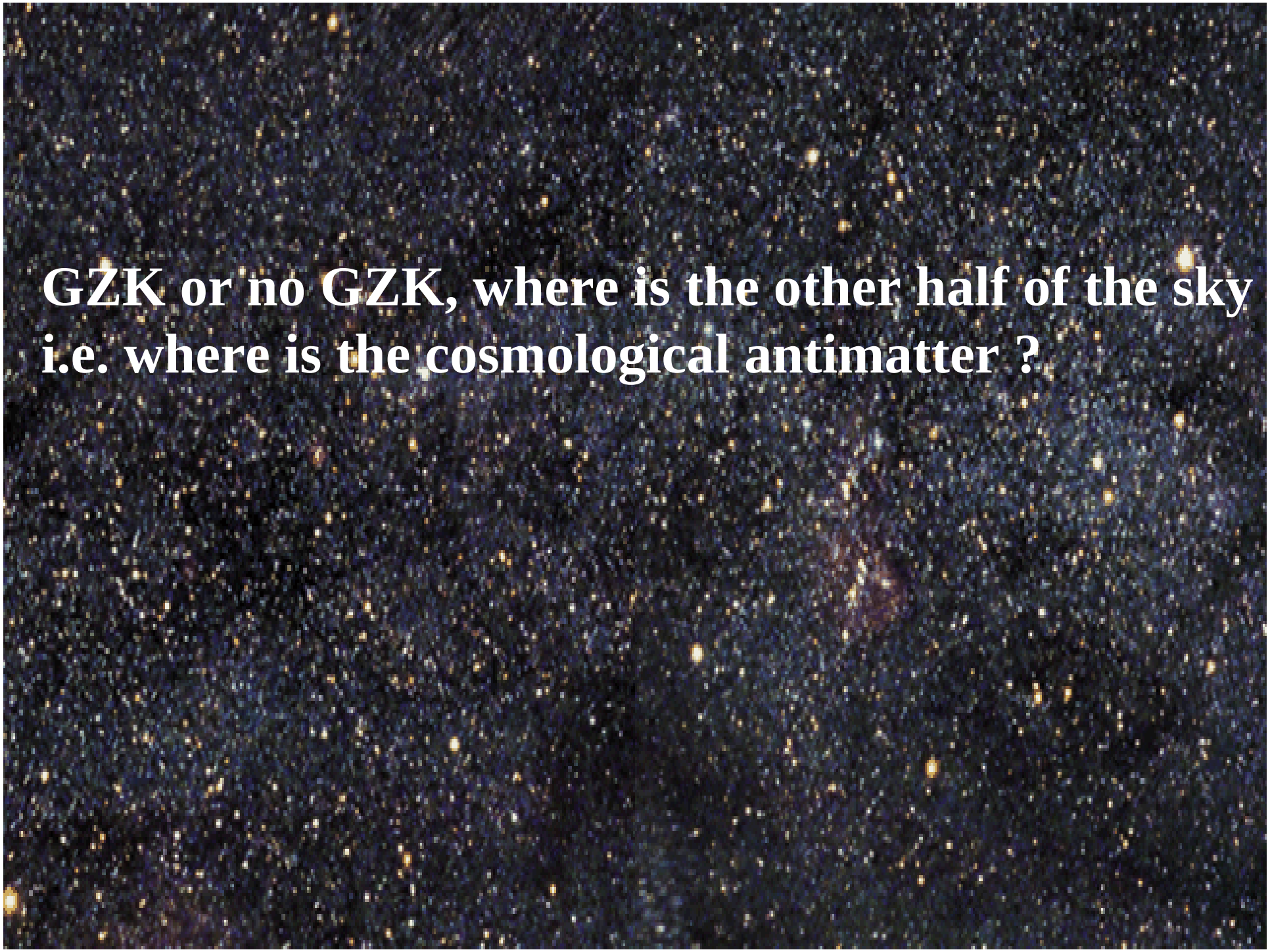

ARMY

Cosmic background from radio to gamma rays



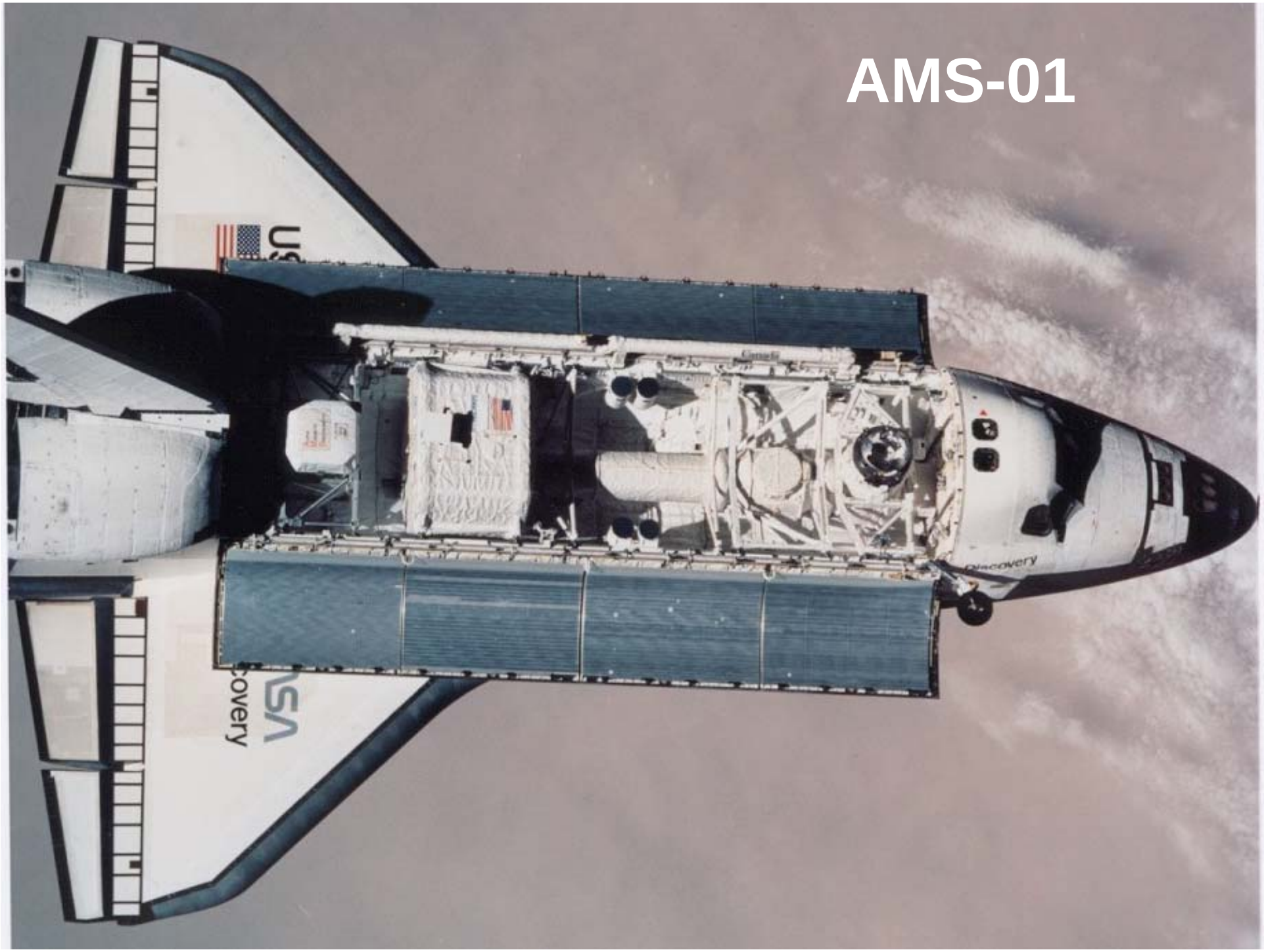
The "All Particle Spectrum"



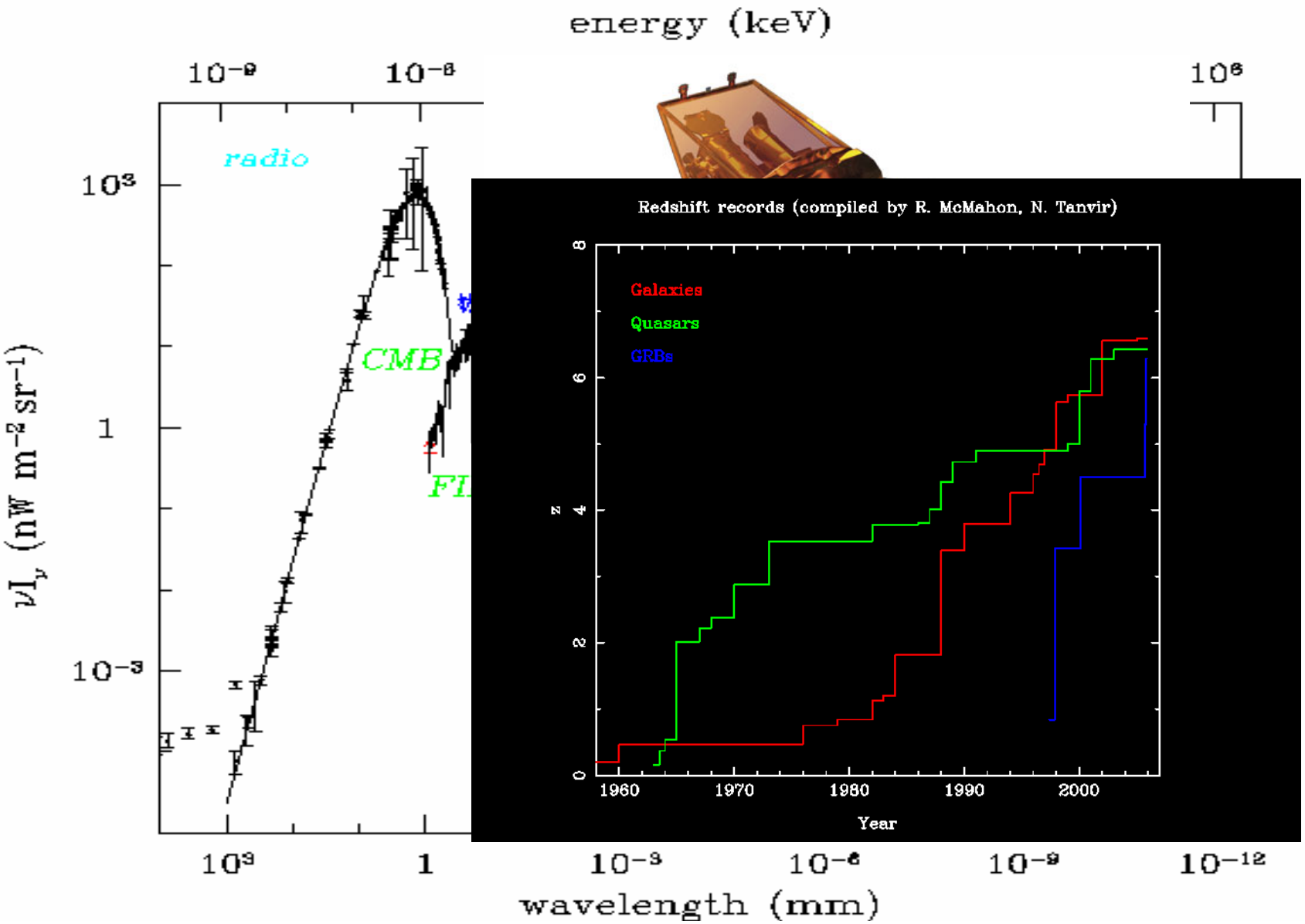


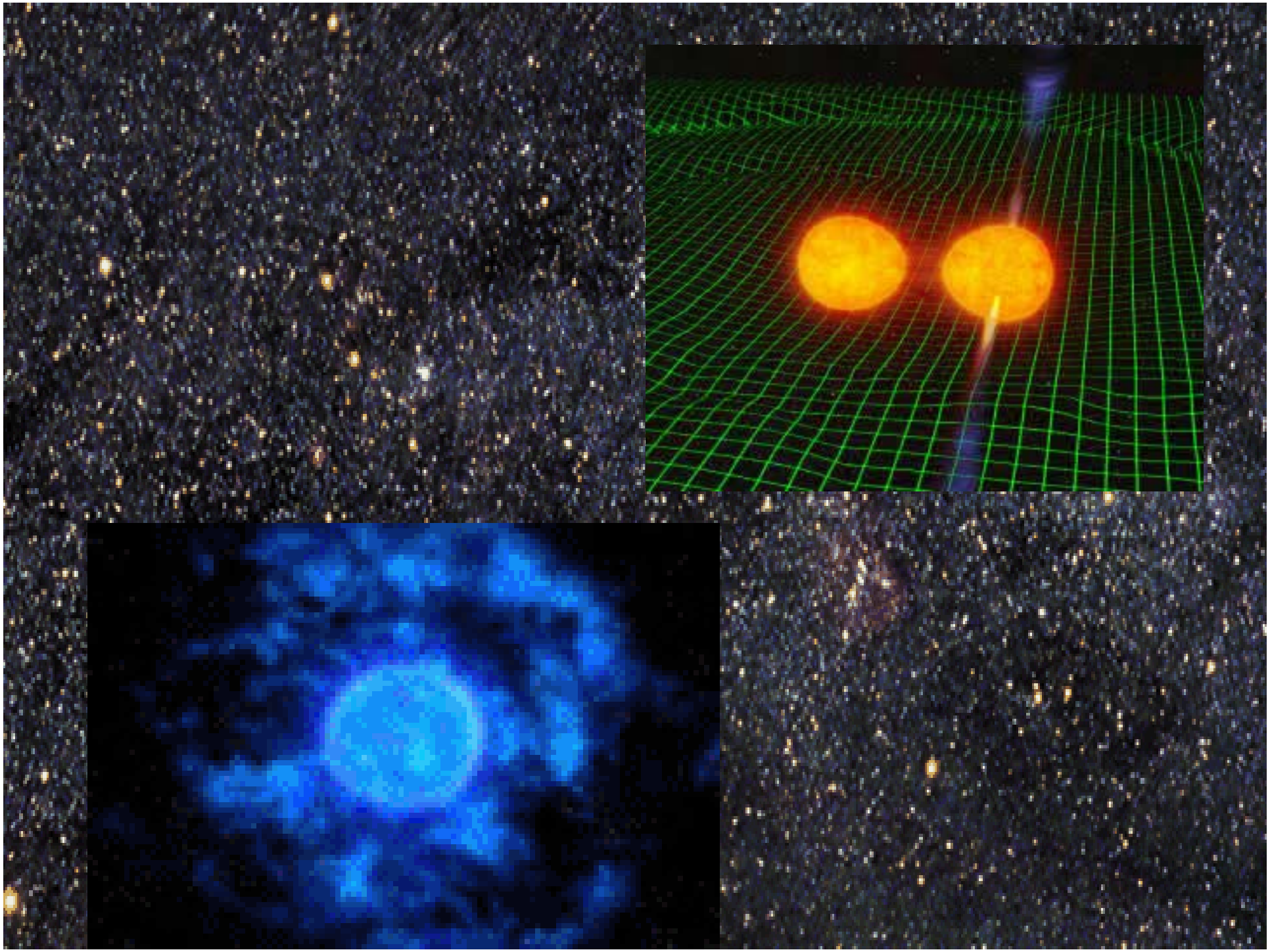
GZK or no GZK, where is the other half of the sky i.e. where is the cosmological antimatter ?

AMS-01



Cosmic background from radio to gamma rays



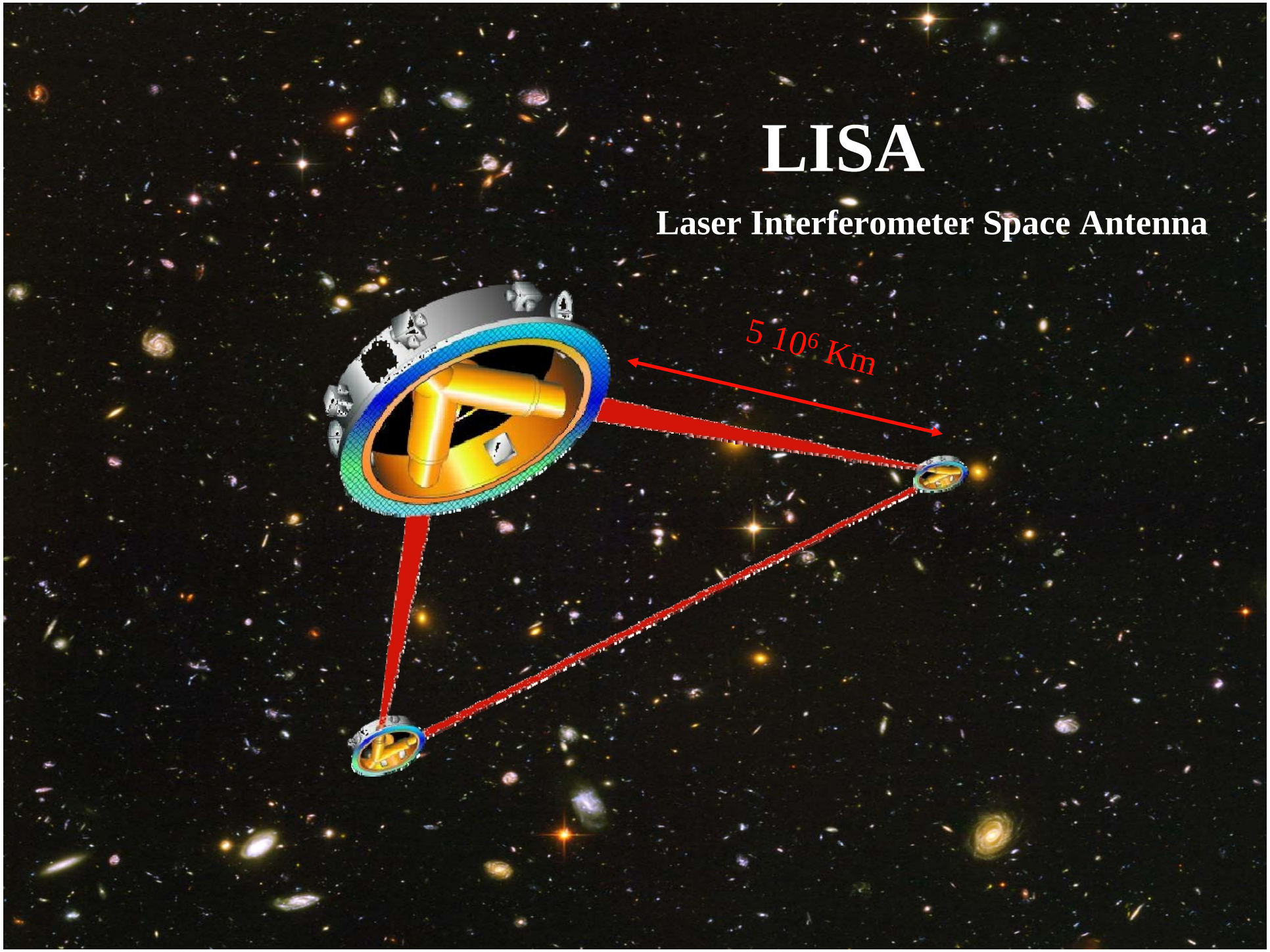


Those ripples in the spacetime metric bring us to a new, non-electromagnetic astronomy with

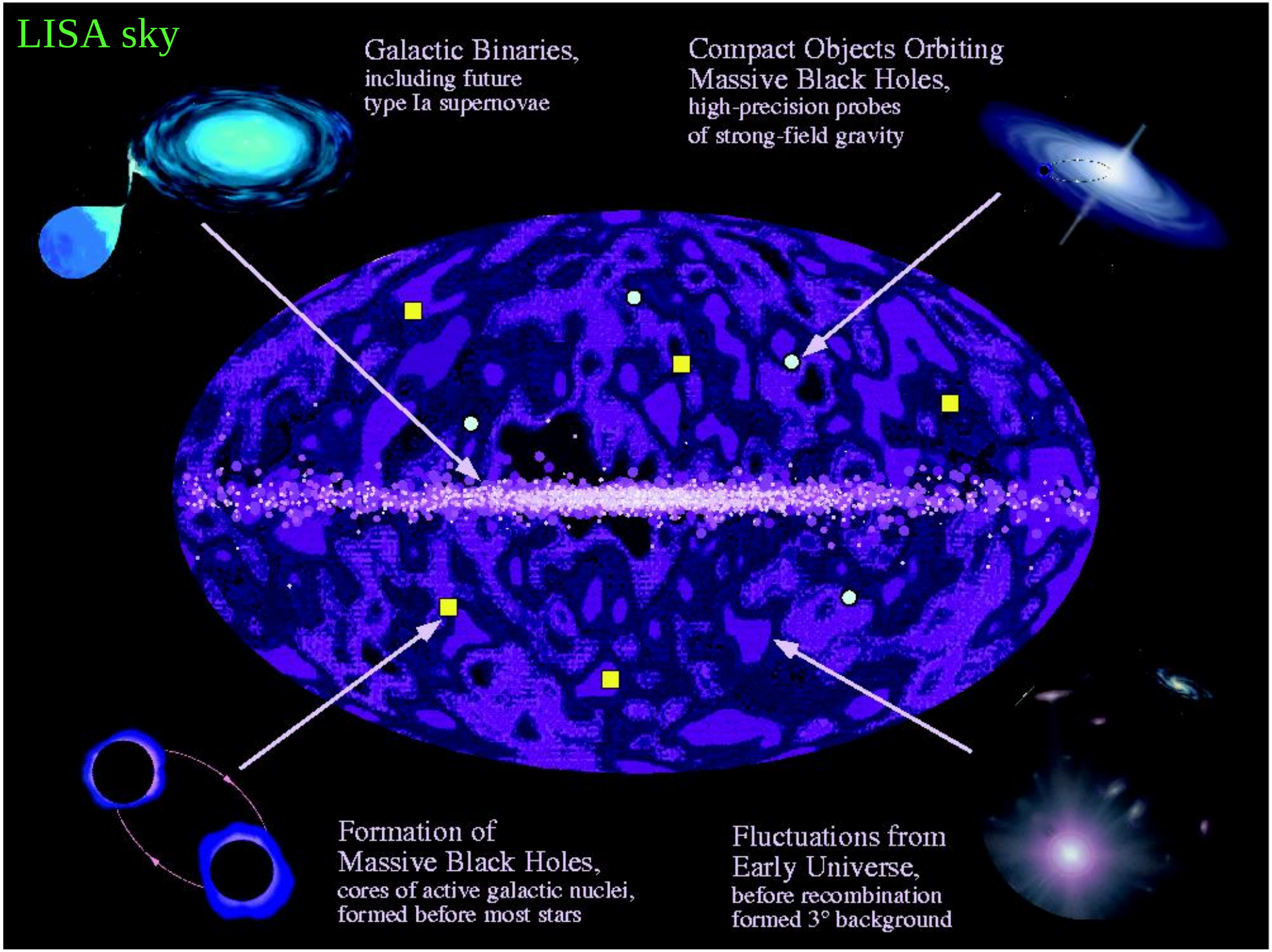
GRAVITY WAVES

LISA

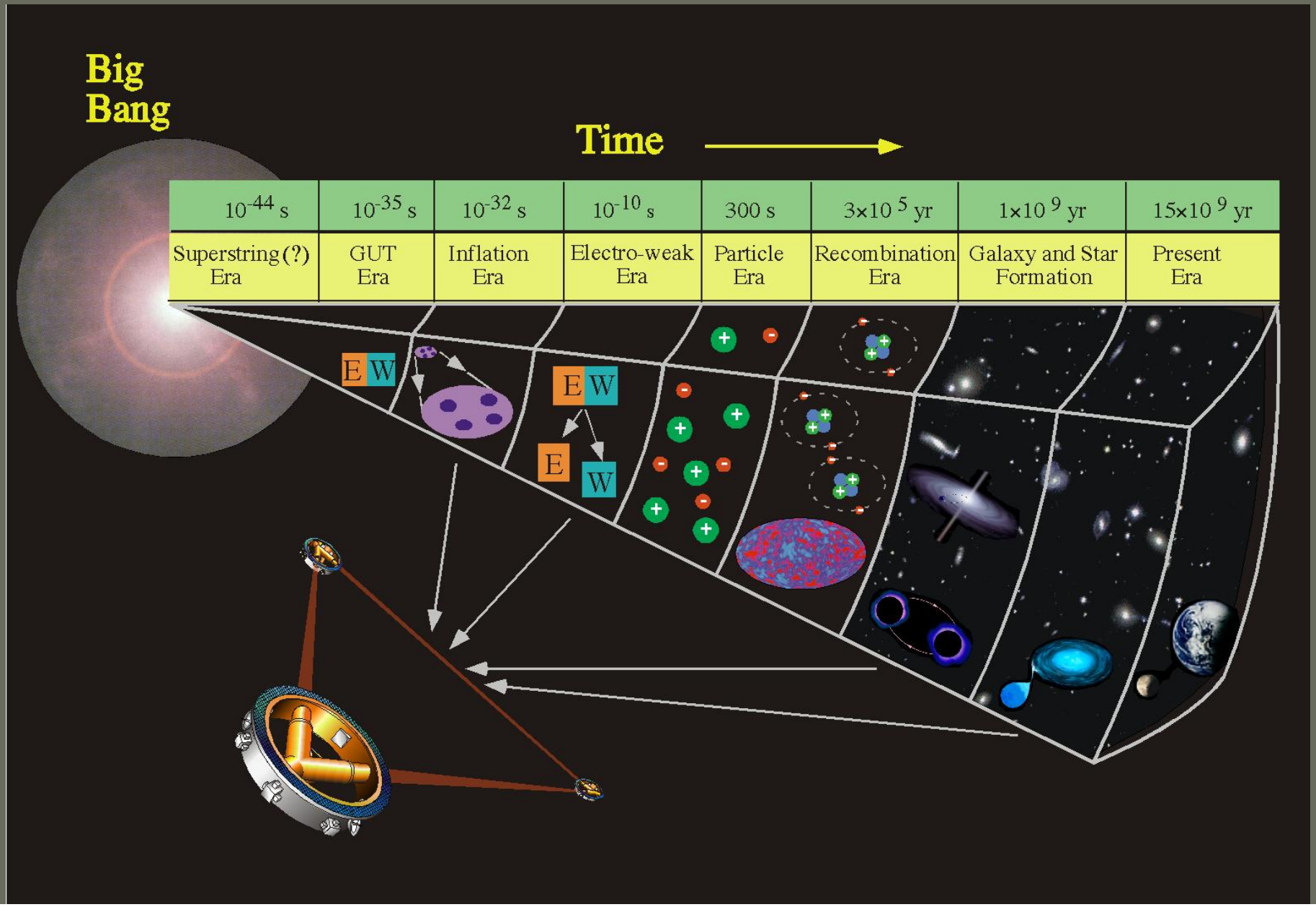
Laser Interferometer Space Antenna



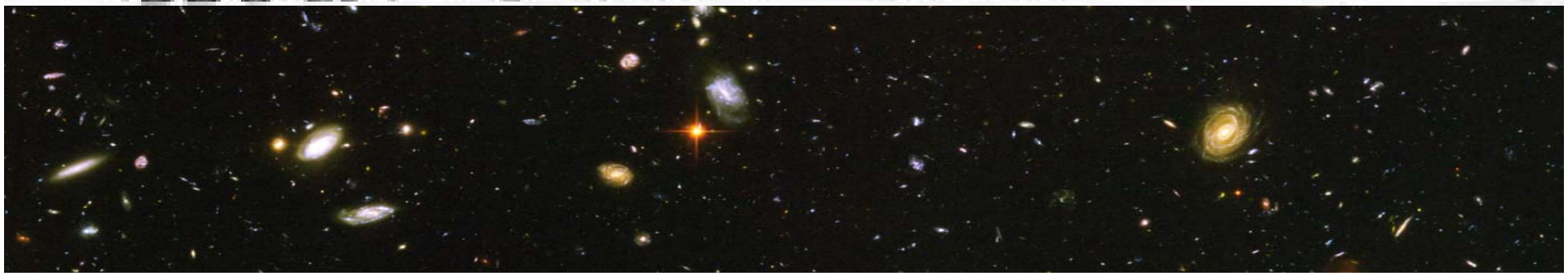
LISA sky


Galactic Binaries,
including future
type Ia supernovae
Compact Objects Orbiting
Massive Black Holes,
high-precision probes
of strong-field gravity
Formation of
Massive Black Holes,
cores of active galactic nuclei,
formed before most stars
Fluctuations from
Early Universe,
before recombination
formed 3° background

Primordial universe and LISA




THIS INSTANTANEOUS CREATION OF THE UNIVERSE IS LIKE A PARTY GIRL JUMPING OUT OF A BIRTHDAY CAKE, IT'S RIDICULOUS, I CALL IT THE BIG BANG. NOW, ON THE OTHER HAND, MY OWN STEADY STATE THEORY...
BBC



Science

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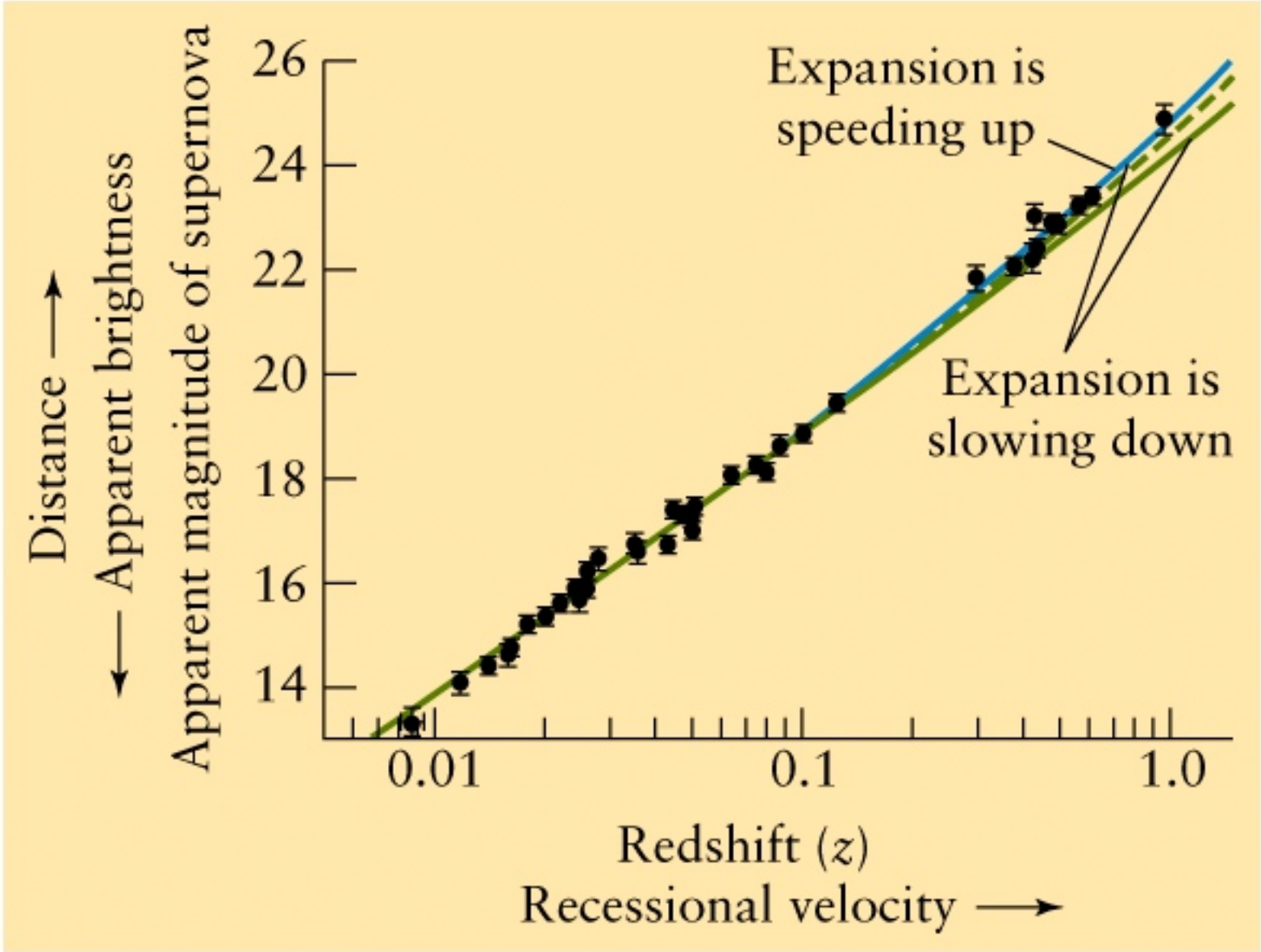
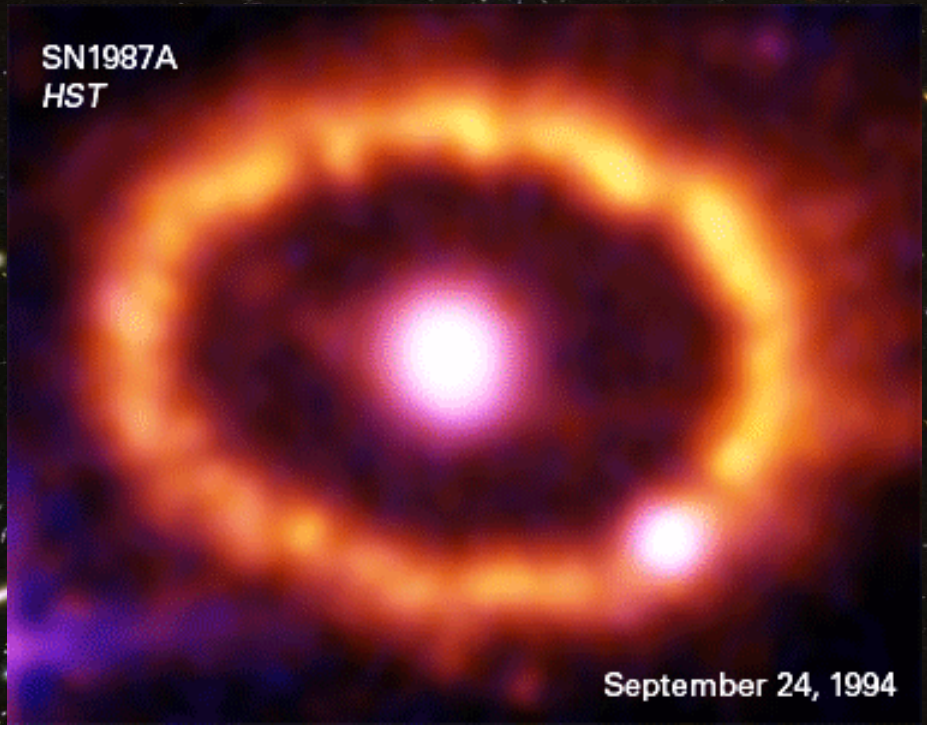


Supernovae lead us naturally to another baby, non e-m astronomy :

neutrinos

(12 out of 10^{58}) from:



The other astronomical neutrino source, the Sun,

has also taught us a nice piece of physics (even if it took several decades):

neutrinos oscillate and have mass

ν-oscillations have a QED analogous :

(2)γ - LPB oscillations

- LPBs are predicted by Standard Model extensions, such as Kaluza-Klein or superstring theories

- Best know LPB is the Peccei-Quinn AXION

- What mass m and what two-photon coupling constant M for an LPB (axion)?

Zavattini et al (softly) say:
m= 10^{-3} eV
M= 3.8 10^{5} GeV

PRL 96,110406 (2006)

If true: New Physics

COSMOLOGY

Magnet Experiment Appears to Drain Life From Stars

It's an unassuming experiment: to see how a magnetic field affects polarized laser light. And the rotation the researchers saw was tiny, a mere 100,000th of a degree. If the result is true, however, the implications are huge. According to researchers in Italy who conducted the experiment, this slight twist in the beam—the result of disappearing photons—suggests the existence of a small, never-before-seen neutral particle, which, if made in stars, would siphon off all their energy.

Even theorists who find that scenario far-fetched are struggling to explain the disappearance of the photons. "I'm skeptical of the particle interpretation," says theoretical physicist Georg Raffelt of the Max Planck Institute for Physics in Munich, Germany. "But there are no other obvious explanations."

Standard physics predicts a very small rotation in a beam's polarization in a magnetic field due to ordinary particles popping in and out of the vacuum. But when researchers at the PVLAS experiment at Legnaro National Laboratory of Italy's National Institute for Nuclear Physics turned on their 5-tesla magnet in 2000, they immediately saw a rotation 10,000 times larger than expected, says PVLAS member Giovanni Cantatore of the University of Trieste. The rotation is caused by the loss of a small number of photons whose electric fields line up with the magnetic field. This selective disappearance is what physicists would see if the missing photons were converting into neutral particles about 1 billionth of the mass of electrons.

"If you believe the signal is real, then the interpretation is a new particle," says theoretical physicist Andreas Ringwald of DESY, Germany's particle physics center near Hamburg. But Ringwald thinks most physicists believe the rotation comes from some subtle artifact of the instruments. The PVLAS team has spent 5 years looking for such systematic effects: They have rotated and reduced the magnetic field, added air to their vacuum system, and changed the frequency of the laser. "All this time we have tried to make the signal go away," Cantatore says. It hasn't. The PVLAS team doesn't claim to have discovered a new particle. "It is important to be careful," Cantatore says. A paper in *Physical Review Letters* is due this month.

"These are very serious, very competent people," says Pierre Sikivie of the University of Florida, Gainesville, who also looks for novel particles with magnetic fields. Still, he has a "wait-and-see attitude," because the implications would be "revolutionary."

The PVLAS particle, if it exists, has the makings of an axion, a hypothetical particle that

A twist in the tale. By rotating a laser beam with magnets, this experiment may have found never-before-seen particles.

CREDIT: THE PVLAS COLLABORATION

some cosmologists propose is the invisible missing dark matter that makes up a large chunk of the mass of the universe. However, the particle suggested by the PVLAS experiment is not what the theorists ordered. It couples so strongly to photons that the axion-search experiments currently scattered around the globe should have seen loads of them coming from the sun (*Science*, 15 April 2005, p. 339). Such a stream of invisible particles out into space would drain a star of its energy in a few thousand years. But we know stars, including our sun, last for billions of years. Raffelt says the PVLAS particle would need "crazy properties" to match astrophysical constraints, but there is no fundamental reason they can't behave that way.

The PVLAS collaboration plans to settle the question with an experiment involving two magnets separated by a wall. On one side, part of a laser beam would be converted into a flux of PVLAS particles, which would fly straight through the wall. On the other side, the second magnet would reconvert some of the particles back into photons, at a rate of one every 2 seconds, Cantatore predicts. Ringwald is proposing a similar experiment at DESY, and CERN, the European particle physics lab near Geneva, Switzerland, is also considering one.

Although most physicists doubt the reality of this particle, they are curious to see what comes of it. "People want to give the idea a fair hearing," Sikivie says. "If it turns out to be true, it will be a theoretical challenge to explain, but also an opportunity." —MICHAEL SCHIRBER

But, at CERN, CAST says NO by 5 orders of magnitude …

PRL 95, 211302 (2005) PHYSICAL REVIEW LETTERS week ending 18 NOVEMBER 2005

Looking for Light Pseudoscalar Bosons in the Binary Pulsar System J0737-3039

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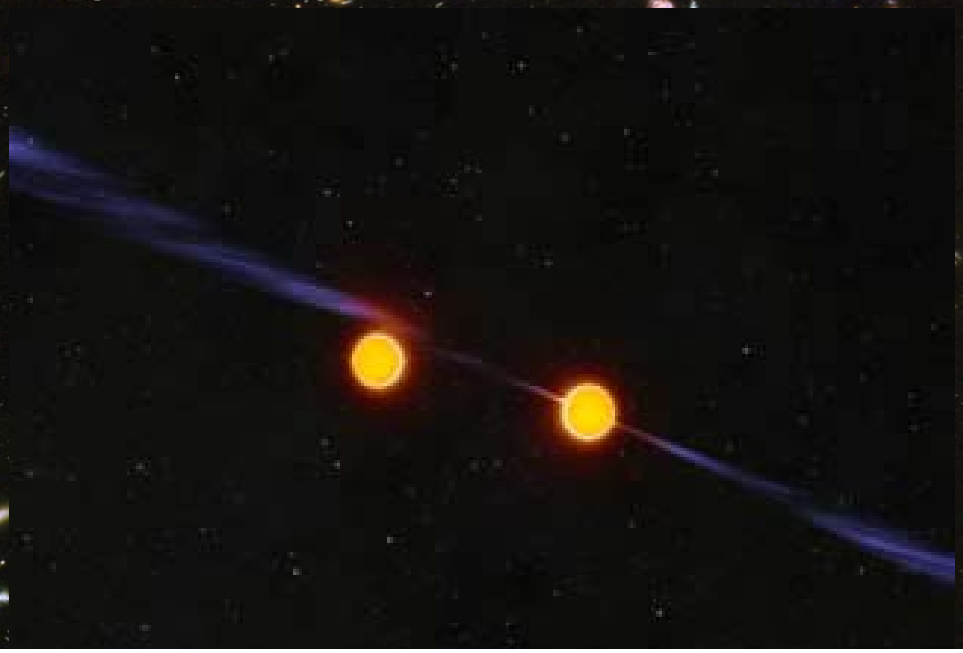

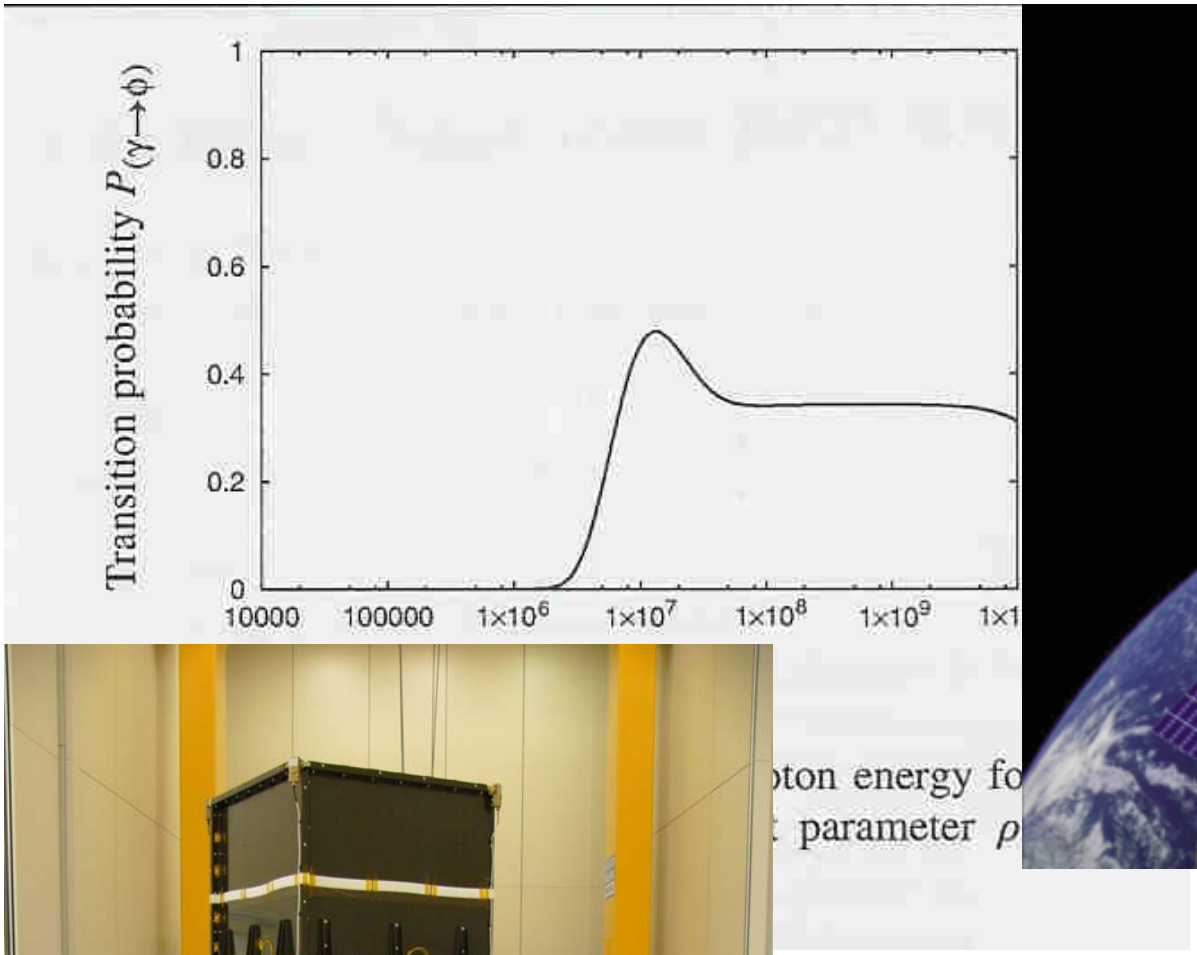

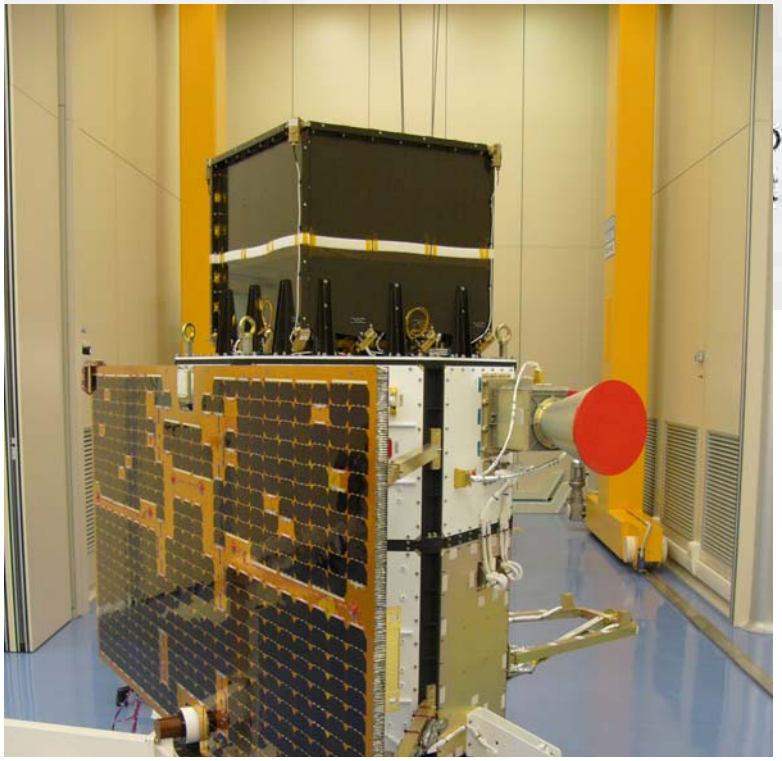

Gamma ray observatories soon to have a look

PRL 95, 211302 (2005) PHYSICAL REVIEW LETTERS week ending 18 NOVEMBER 2005

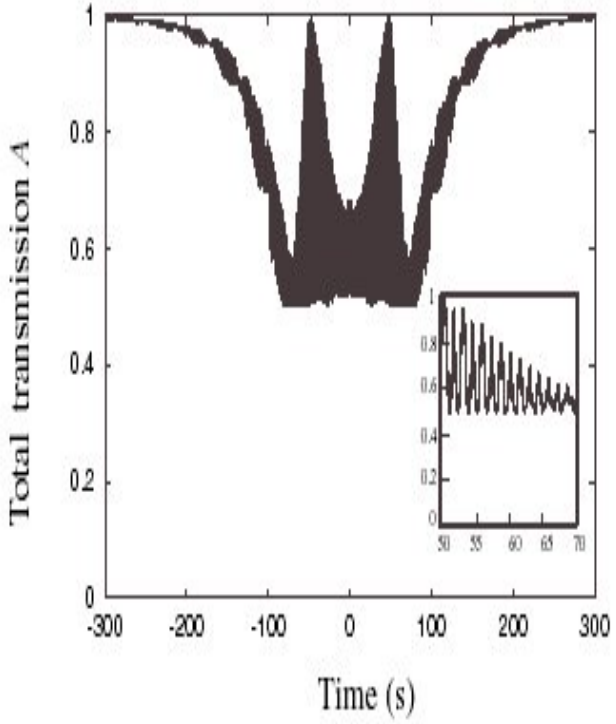

FIG. 3. Total transmission of the γ photon beam emitted by pulsar A versus time. Inset shows the modulation mainly due to the rotation of the magnetic dipole moment of pulsar B.

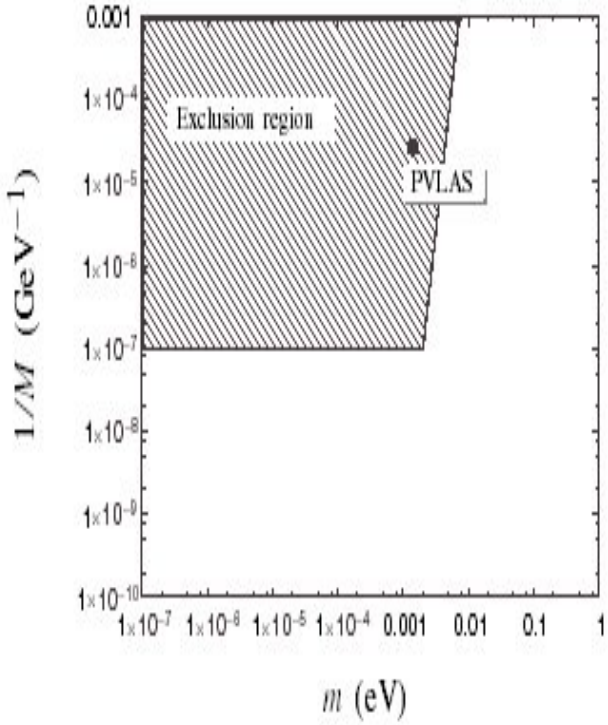

FIG. 4. Exclusion region in the case that the existence of the attenuation is excluded at 10% level.

Astronomy check of PVLAS claim, just as well, if it is a scalar boson

QED vacuum effects close to neutron stars, where photons propagate in a highly magnetized vacuum:

Observing Quantum Vacuum Lensing in a Neutron Star Binary System

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Giovanni F. Bignami
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Dipartimento di Fisica Nucleare e Teorica, Universita di Pavia, Italy

Quantum vacuum birefringence for B close to Bcrit creates orbital and rotational modulation of X-rays from the 0737 system
PRL 94,161101 (2005)

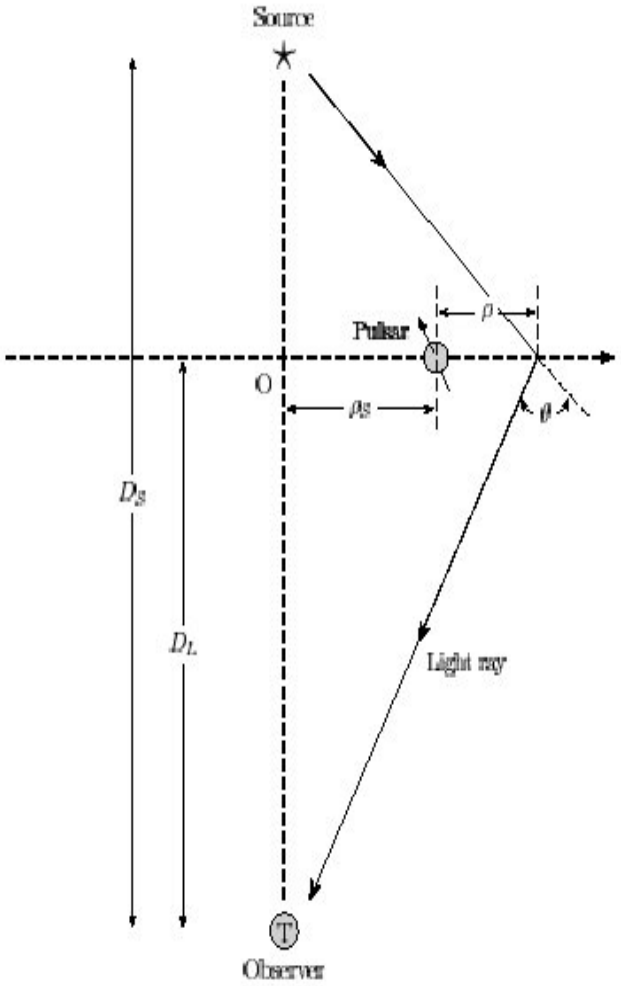


FIG. 2: Geometry of the deflection effect. The light rays are deflected near the pulsar by the angle θ.

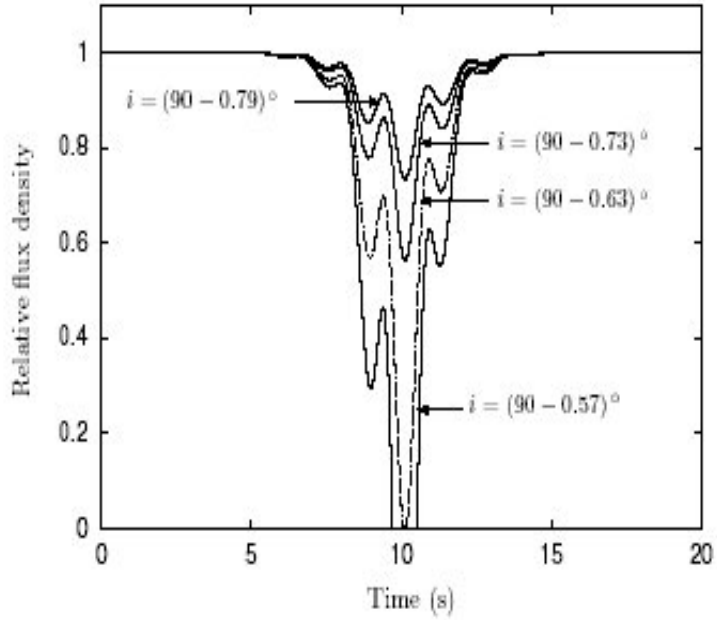
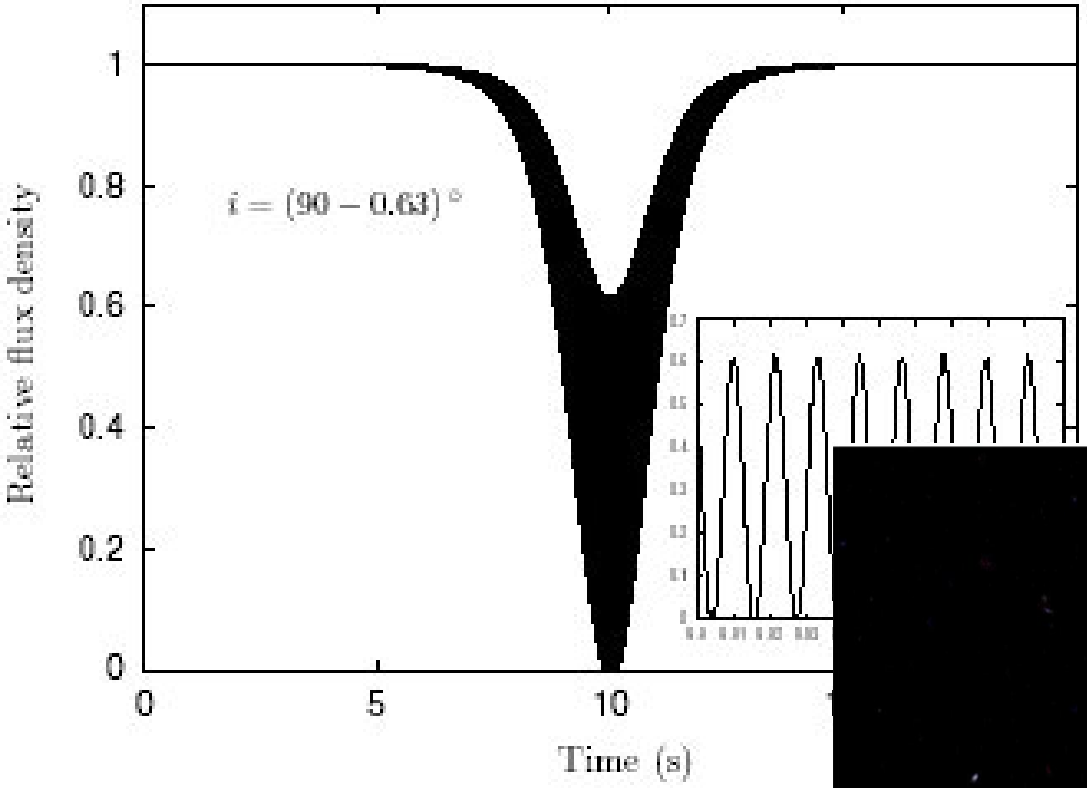


FIG. 3: Relative flux density of pulsar A versus time for different values of the orbital inclination i. The value of the magnetic field at the surface of pulsar B is $B_0 = 10^8$T. Flux densities have been normalized to unity when the magnetic



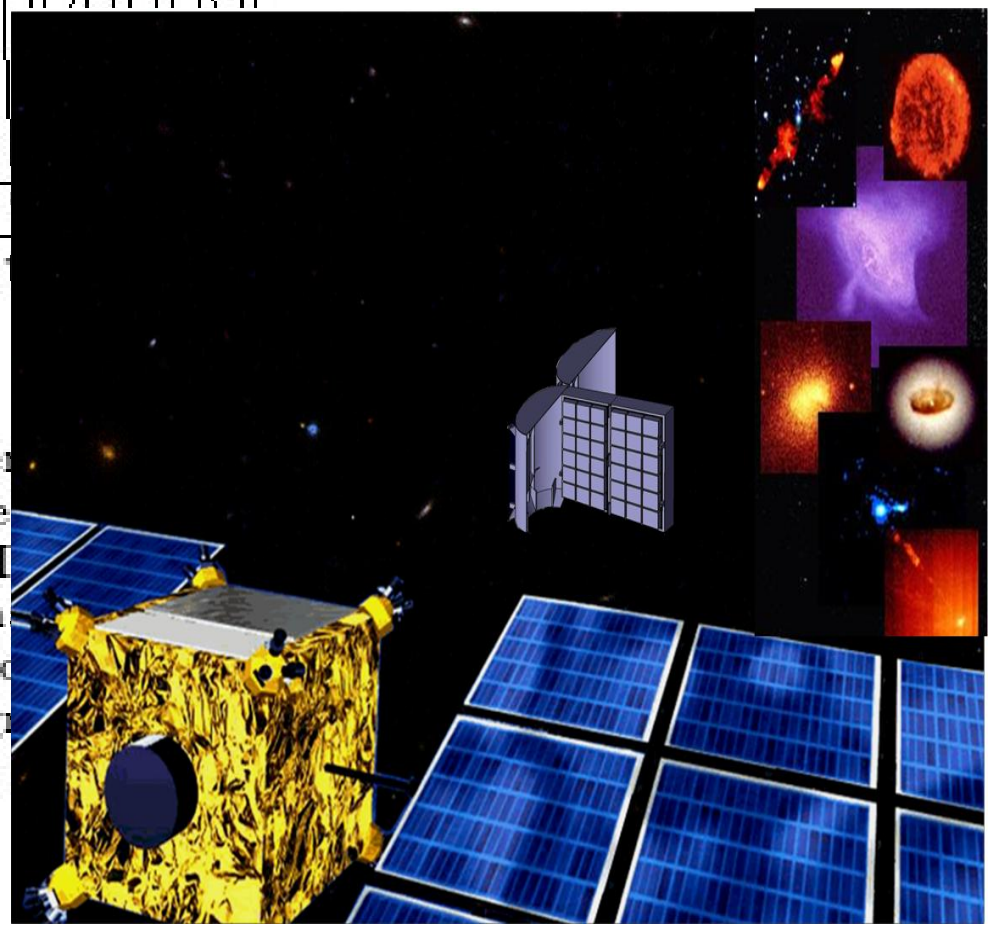


FIG. 4: Relative flux density of pulsar B ve
orbital inclination $i = (90-0.63)^\circ$. The value
field at the surface of pulsar A is $B_0 = 10^8$T
have been normalized to unity when the m
negligible. Gravitational lensing is taken int
shows the small modulation period of the sig
This modulation is so rapid that it appears
in the main figure.

Quantum vacuum magnetization has more surprises in store, including for isolated ne

- Quantum Vacu
  QVF energy loss i

- QED suppression of vacuum dicroism creates extra elliptical polarization for light travelling close to magnetars

  (Dupays and Roncadelli in press)

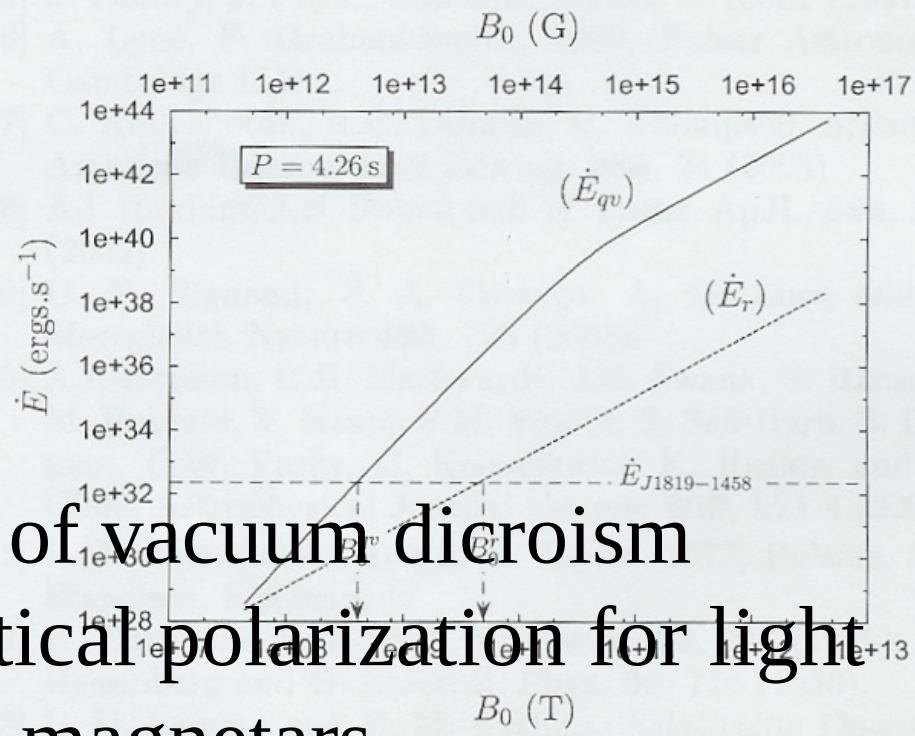


FIG. 2: Quantum Vacuum Friction energy rate $\dot{E}_{qv}$ and classical electromagnetic energy loss rate $\dot{E}_r$ as a function of the magnetic field B_0 at the surface of the J1819-1458 magnetar with a spinning period $p = 4.26$ s and the angle between the rotation axis and magnetic moment $\theta = \pi/2$. Dashed horizontal line corresponds to the observed energy loss rate for J1819-1458.

Dupays et al PRL submitted

Where to with Space Part?

- **Gravitational waves : need 1 source!**
  Correlation with Planck
  Correlation with GRBs
- **Neutrino astronomy (need > 2 sources)**
- **GZK or no GZK? post-Auger EHE CRs**
- **NEW PHYSICS: QED close to neutron stars?**
  LPBs (or LSBs) -> DM candidates (one of many…)
  QVL, QVF, QVP (high energy missions)
- **Bring Cold Atoms in space**

ESA COSMIC VISION asks

What are the Laws of our Universe?

You have the chance to give an aswer : watch for ESA AO