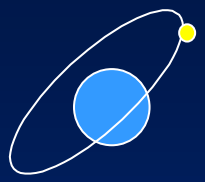


Proposal for collaboration in the experiment:

LUNAR ORBITAL RADIO DETECTOR

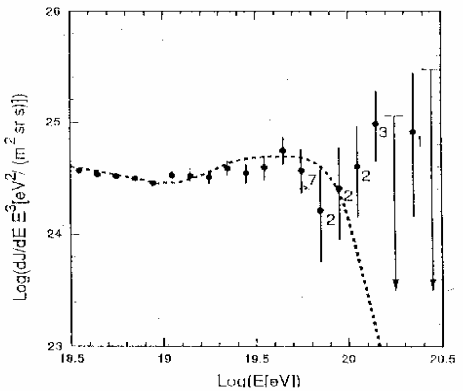
LPI, Lavochkin Association, MSU, IAS, JINR +…

Scientific goal: study of UHECR & UHEN

Situation: controversial and puzzling.

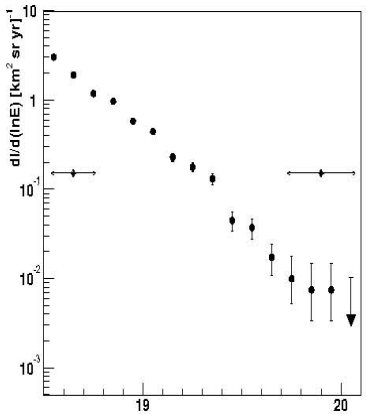
GZK cut-off $\Rightarrow$ UHECR with $E > E_{GZK}$ should not be observed

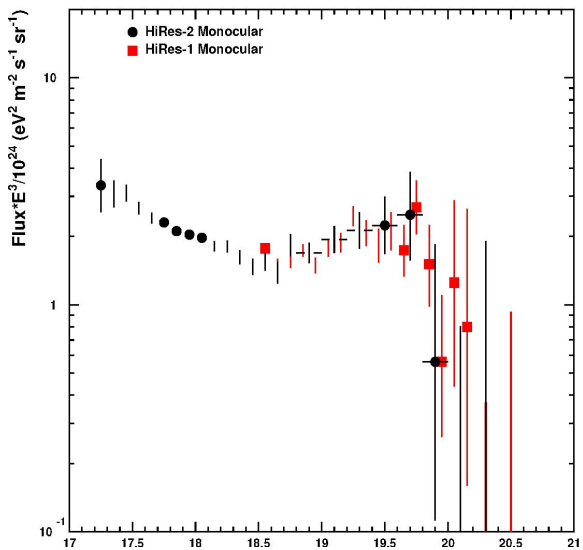
AGASA



Высокоэнергичная область спектра космических лучей по результатам наблюдений AGASA. Цифры возле экспериментальных точек показывают количество событий в соответствующем энергетическом интервале. Стрелки показывают верхние пределы 90% уровня совпадений. Пунктирная линия - ожидаемый спектр в случае, если источники распределены космологически.

Preliminary data from AUGER and HiRes





Summary from 29th ICRC (2005): **super-GZK events are observed**

Models for super-GZK:

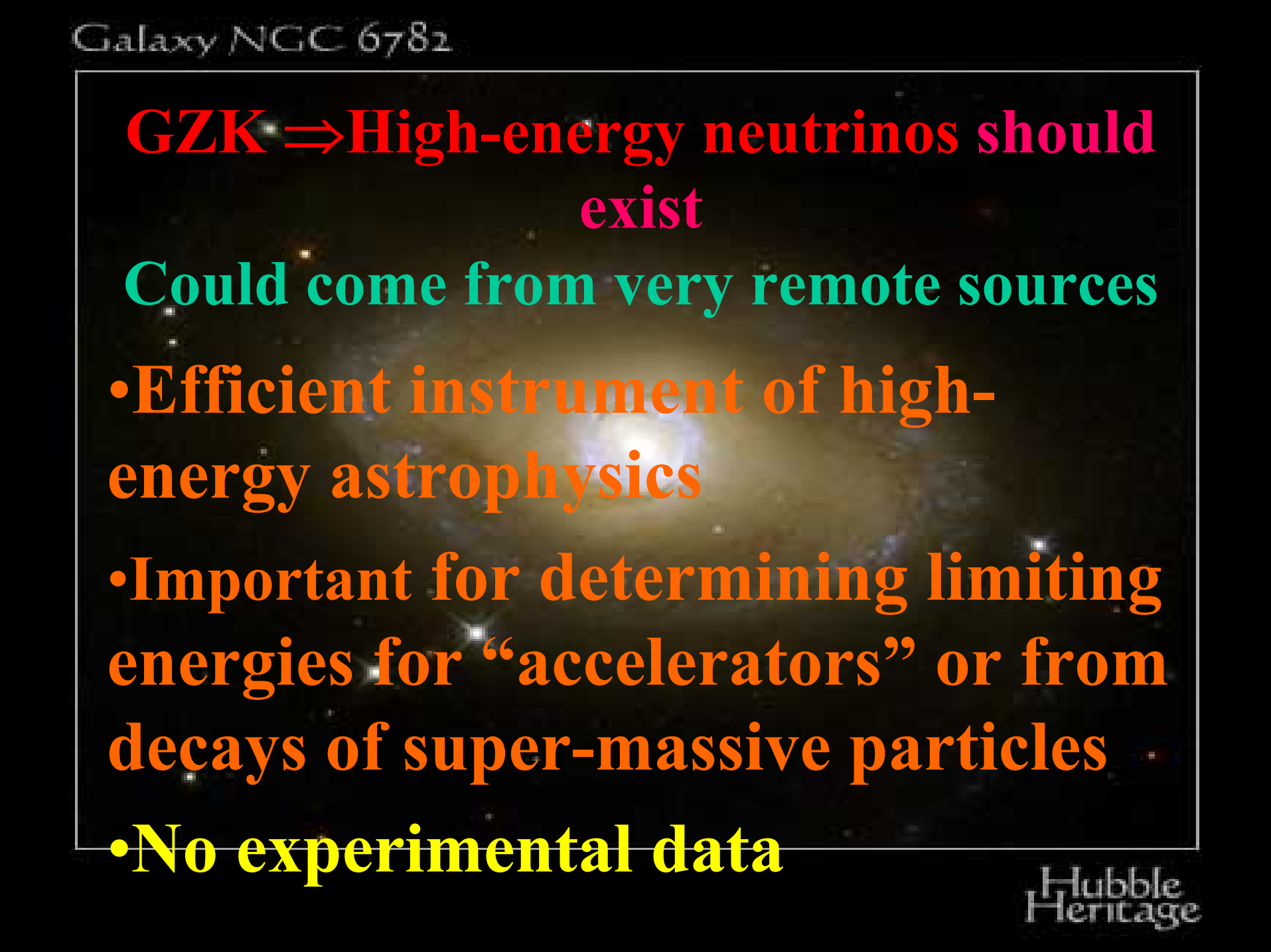
- **various modifications of the traditional models of the acceleration in astrophysical objects**
- **new particles with some special properties**
- **violation of the Lorentz invariance or general relativity above some high-energy scale**

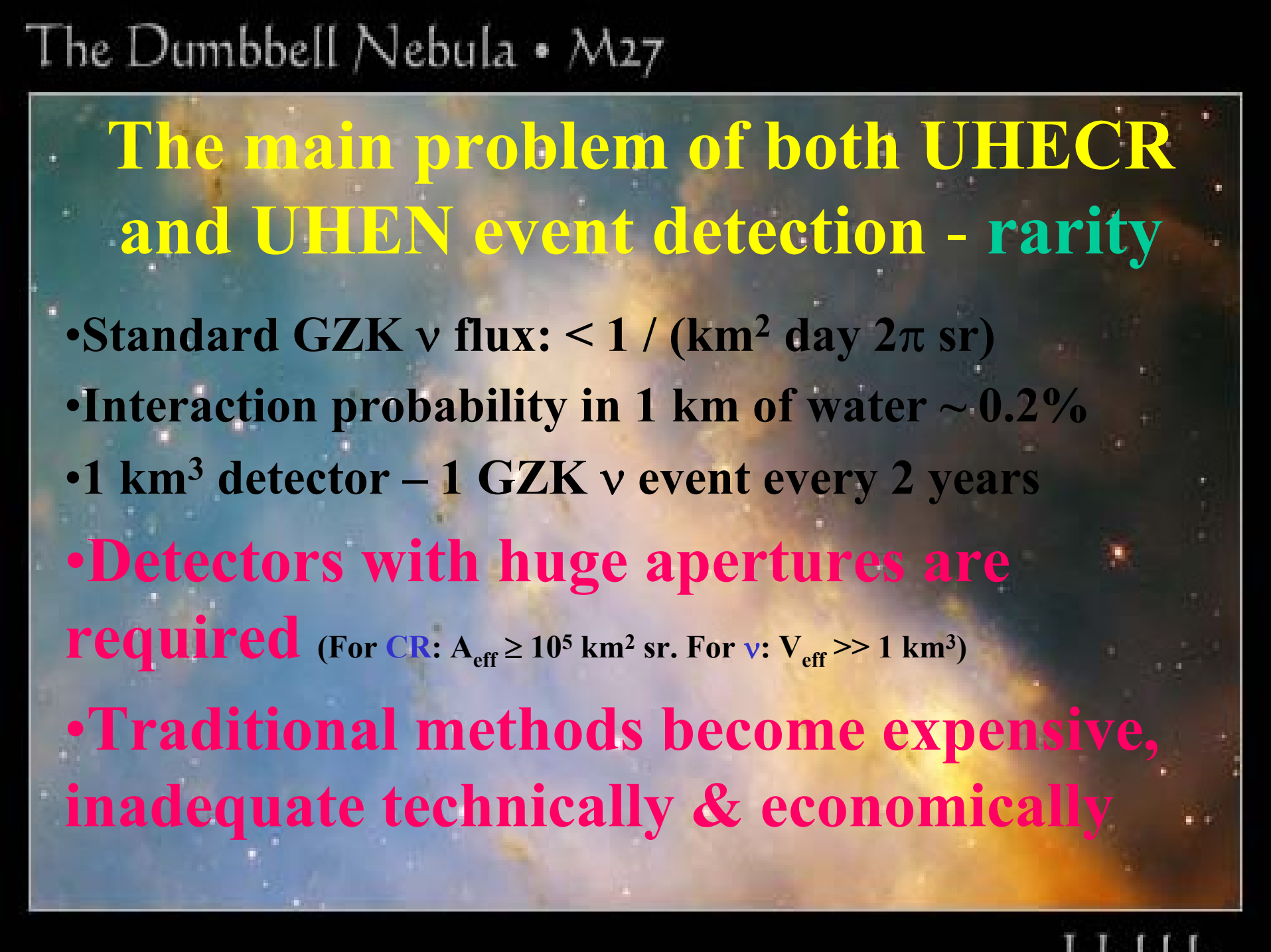
Further interest to the UHECR:

- New "astronomical" channel for exploration of the Universe

- E - beyond reach of terrestrial accelerators $\Rightarrow$

unique chance for investigating physics at ultrahigh-energy scale


Galaxy NGC 6782
GZK ⇒High-energy neutrinos should exist
Could come from very remote sources
•Efficient instrument of high-energy astrophysics
•Important for determining limiting energies for "accelerators" or from decays of super-massive particles
•No experimental data
Hubble Heritage



The main problem of both UHECR and UHEN event detection - rarity

- Standard GZK ν flux: < 1 / (km^2 day 2π sr)
- Interaction probability in 1 km of water ~ 0.2%
- 1 km^3 detector – 1 GZK ν event every 2 years
- **Detectors with huge apertures are required** (For CR: $A_{eff} \geq 10^5$ km^2 sr. For ν: $V_{eff} >> 1$ km^3)
- **Traditional methods become expensive, inadequate technically & economically**

LORD: Experimental method

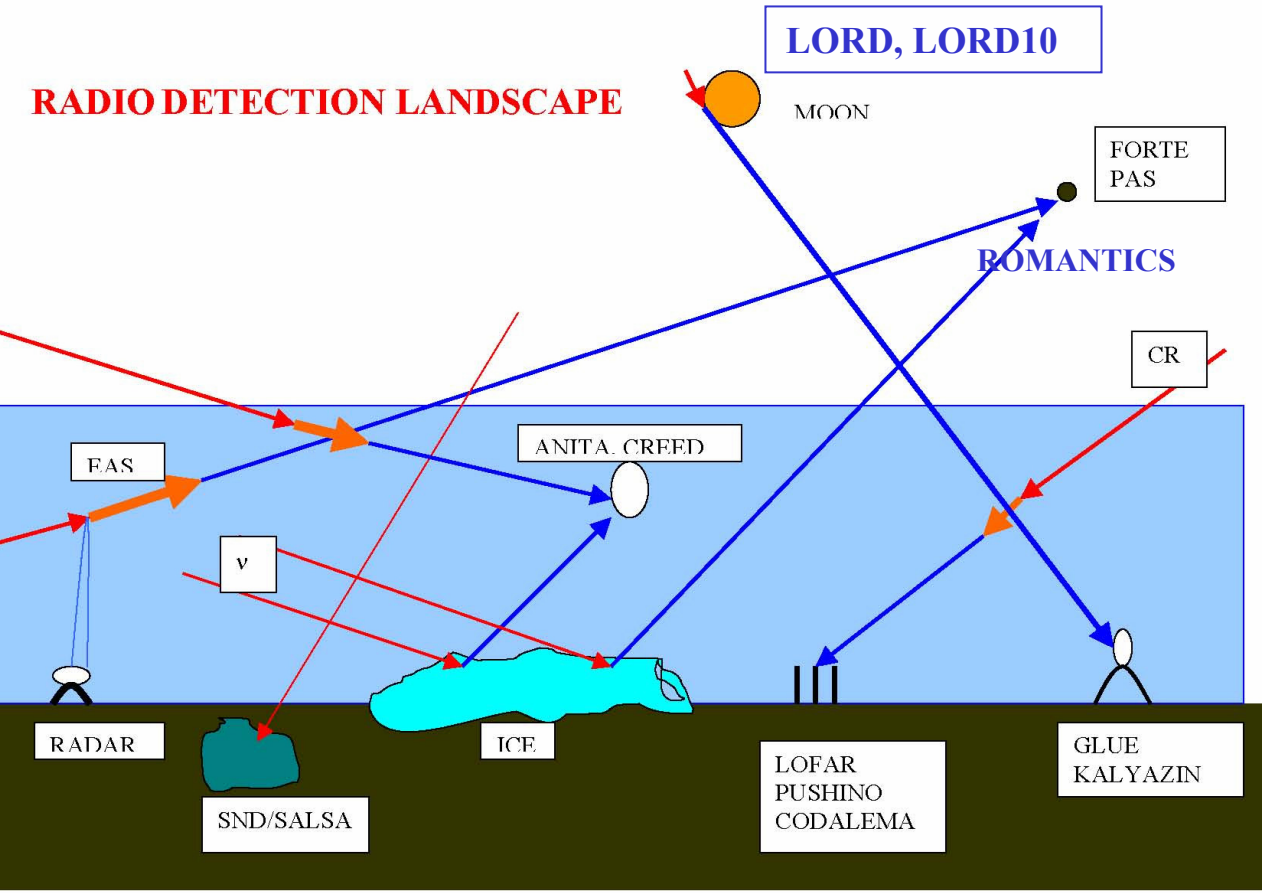
Coherent Cherenkov radio emission

LPI, Askaryan, 1961

Main merits:

- Long propagation length of radio waves ⇒ scanning large radio-transparent target volumes
- Calorimetric energy measurements
- Quadratic rise with initial particle energy
- Well established radio technique
- Experimentally demonstrated (SLAC)

Current initiatives on UHECR and UHEN radio detection



- **Ice**: RICE - ongoing, started in 1996
- FORTE, was active in 1997—1999
- ANITA – proposal (2001)
- CREED – proposal (2003)
- ROMANTICS—proposal (2005)

- **Salt**: SALSA – proposal (testbed)
- SND – proposal (testbed)

- **Moon**: KALYAZIN (suspended)
- GLUE – ongoing, started in 1998
- LORD – proposal (2004)

- **EAS**: PUSHINO, CASA-MIA, CODALEMA, LOFAR

LORD: Moon as a target for UHECR and UHEN

- R_{moon} = 1760 km,
- Regolith:

aggregate of fine particles & small rocks ejected from lunar surface by meteorites;

- Mostly silicates, 10—100 m depth,
- $\Lambda \sim 20$ m / f (GHz); $\rho \approx 1.7$ g / cm^3
- $V_{eff} \sim 2 \cdot 10^5$ (km.w.e.)^3;

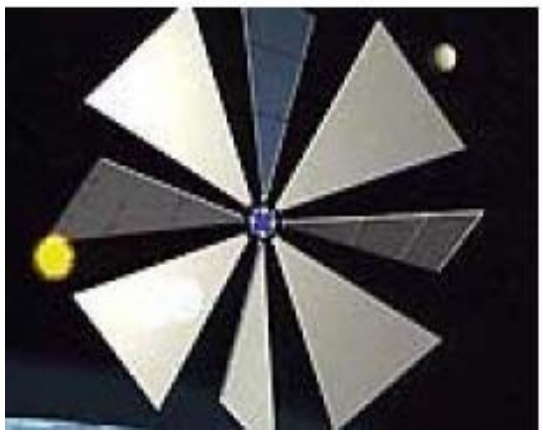
Merits:

- Huge target mass $V_{eff} \sim 10^5$ (km.w.e.)^3
- Very favorable background conditions
- Short (and variable) distance – high signal
- No atmosphere & magnetic field $\Rightarrow$ both UHECR & UHEN

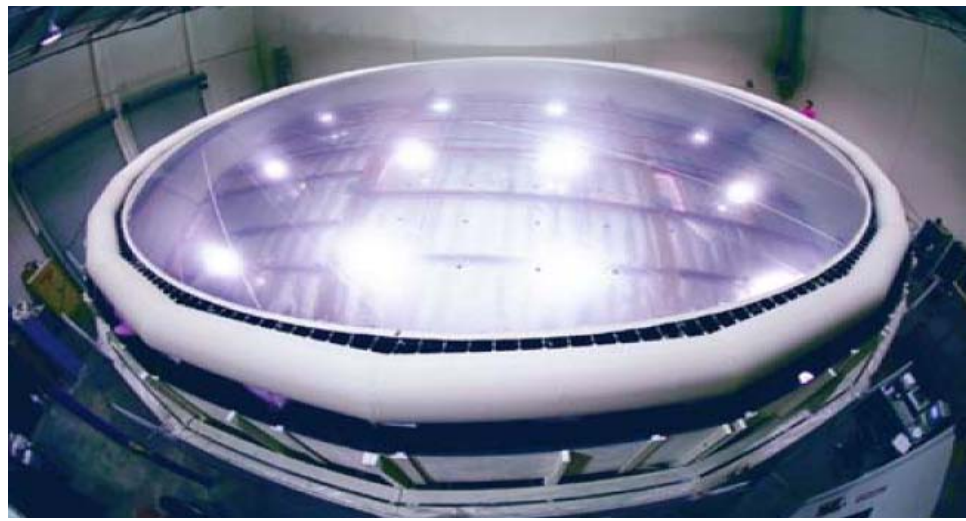
LORD - two cornerstones:

1. **FAS. "Solar Sail" programs** in Europe, USA, Russia, Japan stimulated development of technology of large-area thin-film constructions: "Film astrophysical constructions", "Inflatable (Deployable Space) Structures" – **large-scale antennas-tested in space**

Solar Sail



Inflatable Deployable Space Antennas



2. LUNAR PROGRAM

Currently in many countries – **revival of interest to lunar programs**: the Moon is naturally considered as the first milepost in human's expansion into the Solar System and excellent platform to observe the Universe.

USA, Europe, China, Japan, India.

RUSSIA

«Program of the Moon Exploration for Developing Long-Range Trends in Applied and Fundamental Sciences»

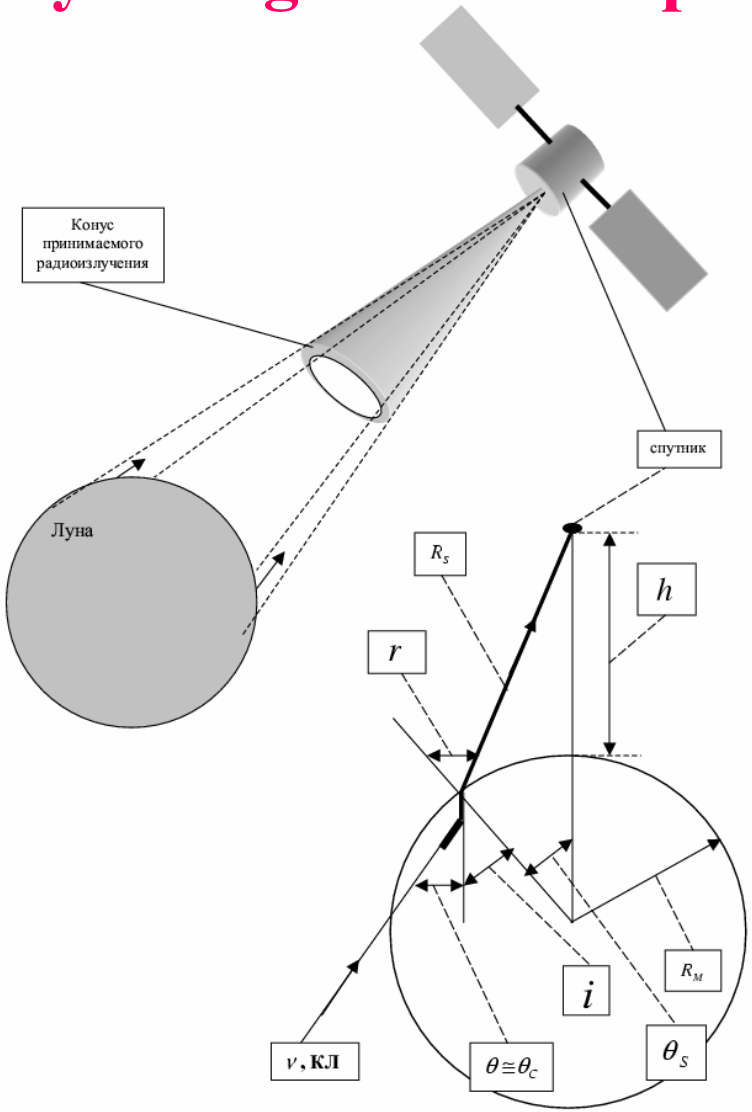
Lebedev Physical Institute, Kurchatov Research Center, Institute for Space Researches, Vernadskii Institute of Geochemistry, Shternberg Astronomical Institute, NPO Astrofizika, Lavochkin Space Research Center ……..

The Program Concept

- First stage – complex studies from lunar satellite orbit; ← LORD
- Second stage – developing methods and technologies of search for and extraction of water, microelements, ^{3}He, and their return to Earth;
- Third stage – construction of elements of the stationary lunar base.

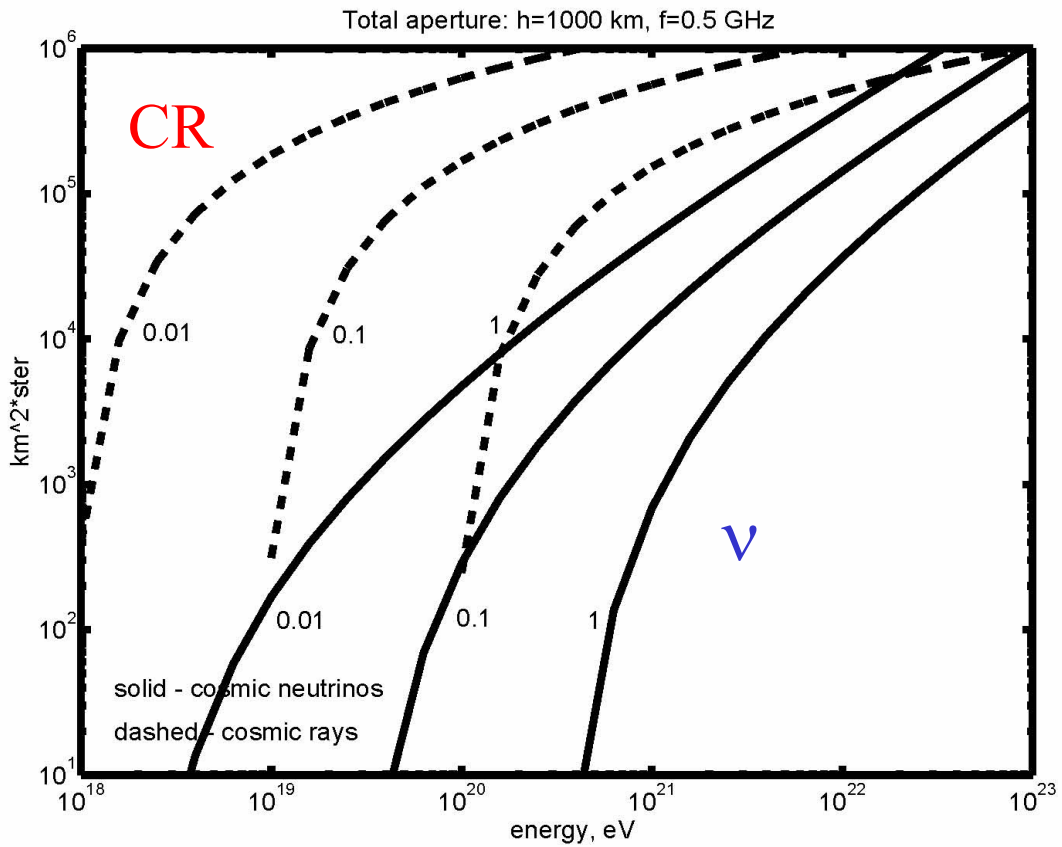
Feasibility study ⇒ high scientific potential

Moon

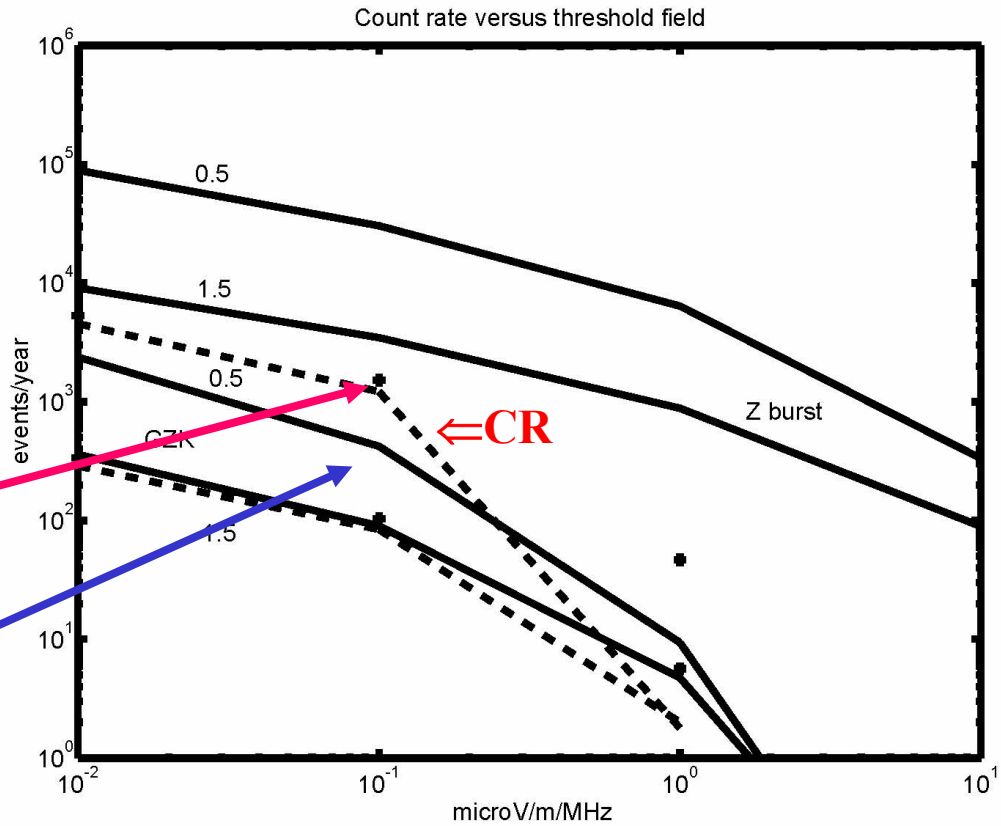


Geometry of the LORD experiment

10^6 km^{2}sr



Total aperture for f = 0.5 GHz, E_{th} = 0.01; 0.1; 1 μV/m MHz



UHECR: ~1000

UHEN: a few hundreds

N(events/year; E_{th}) for **$W \geq 10^{20}$ eV**

LORD and LORD10 limits on ν flux

1 year

LORD:

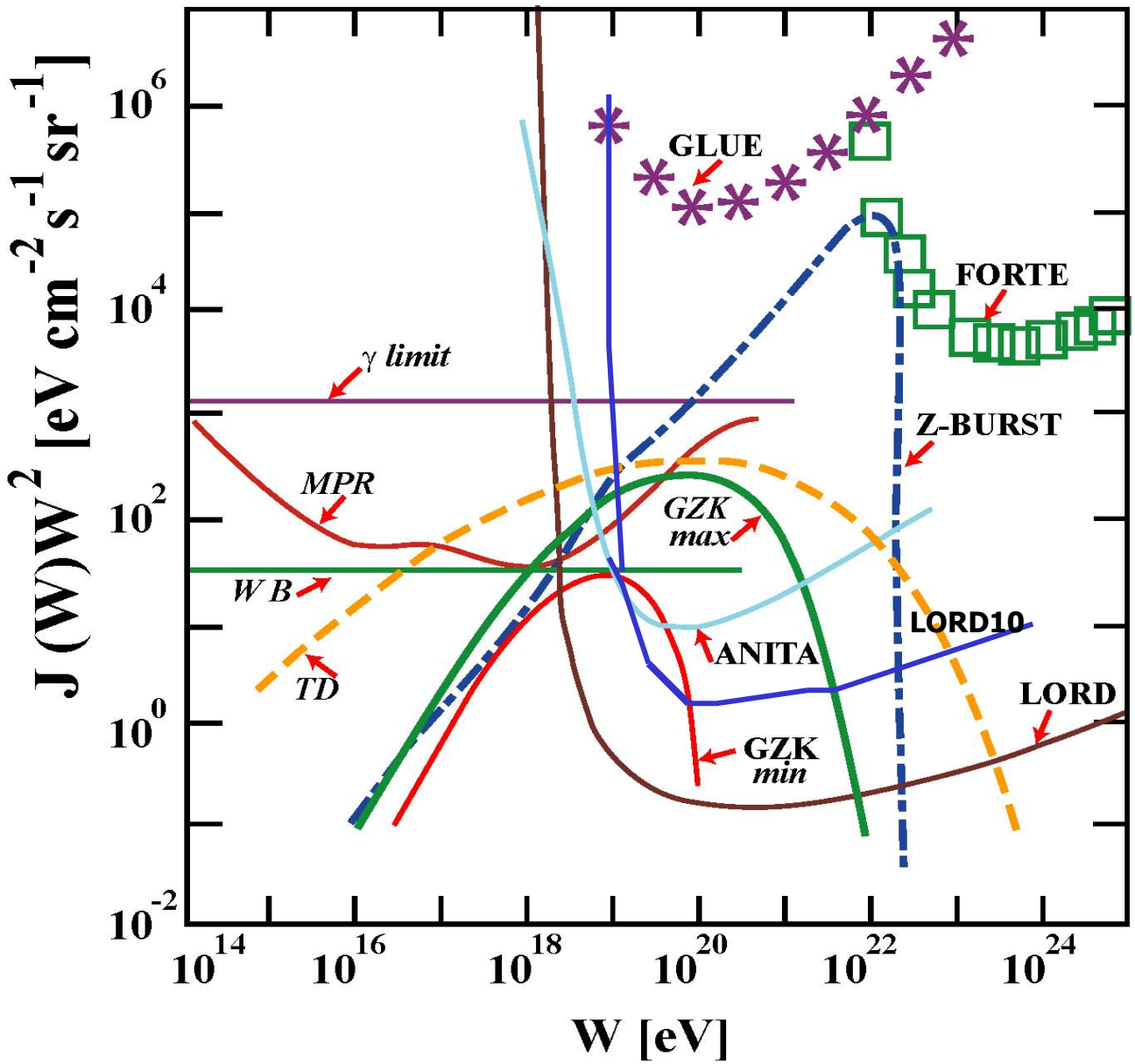
azimuth=2π

E_{th}=0.01μV/m MHz

LORD10:

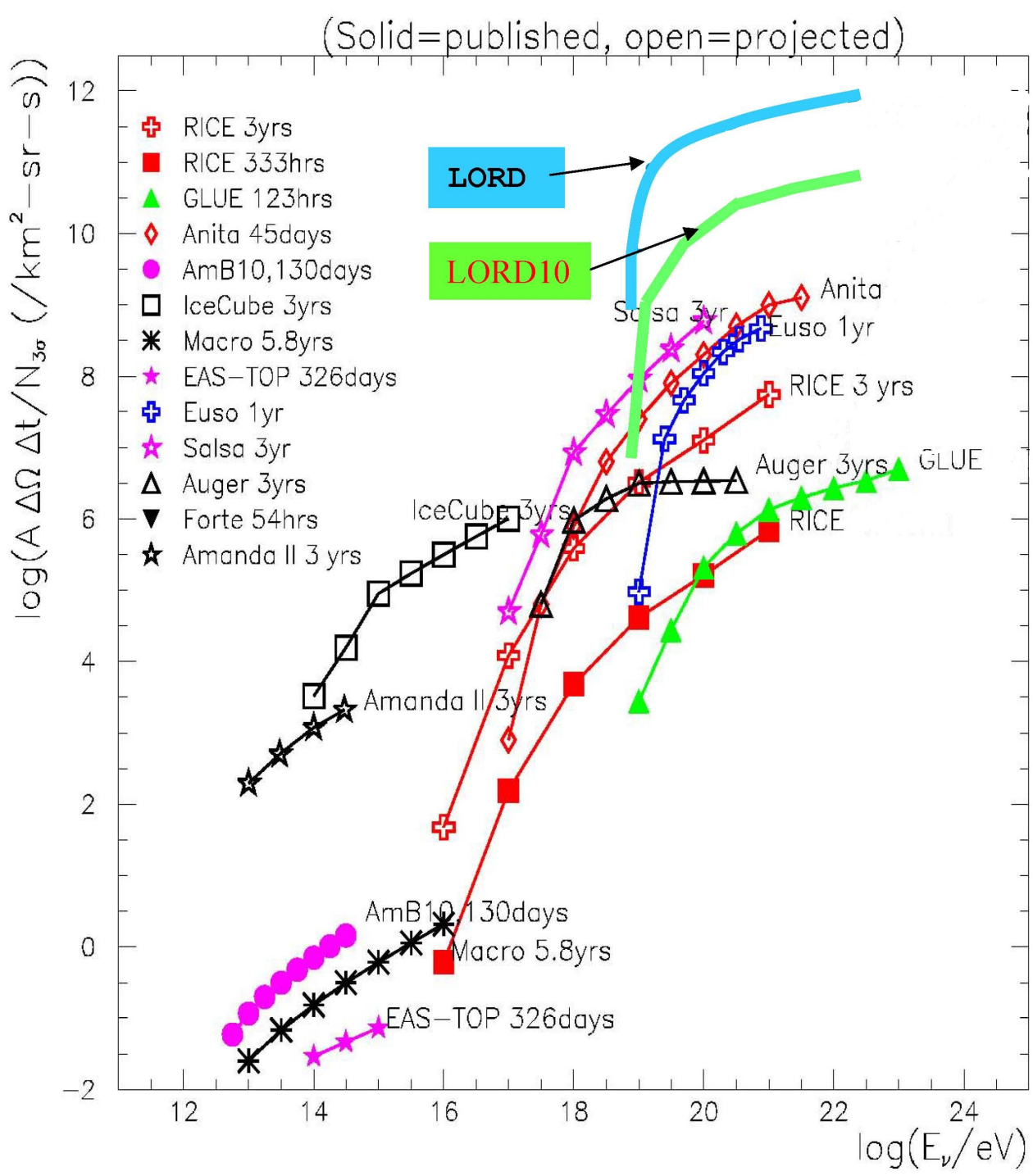
Eth=0.07μV/m MHz

azimuth=0.3



Models: TD – topological defects; MPR – Mannheim, Proteroe, Rachen;

WB – Waxman, Bahcal; GZK ⇒ min: $N_p \propto E_p^{-2}$, max: $N_p \propto E_p^{-1}$



Conclusion:

LORD will be

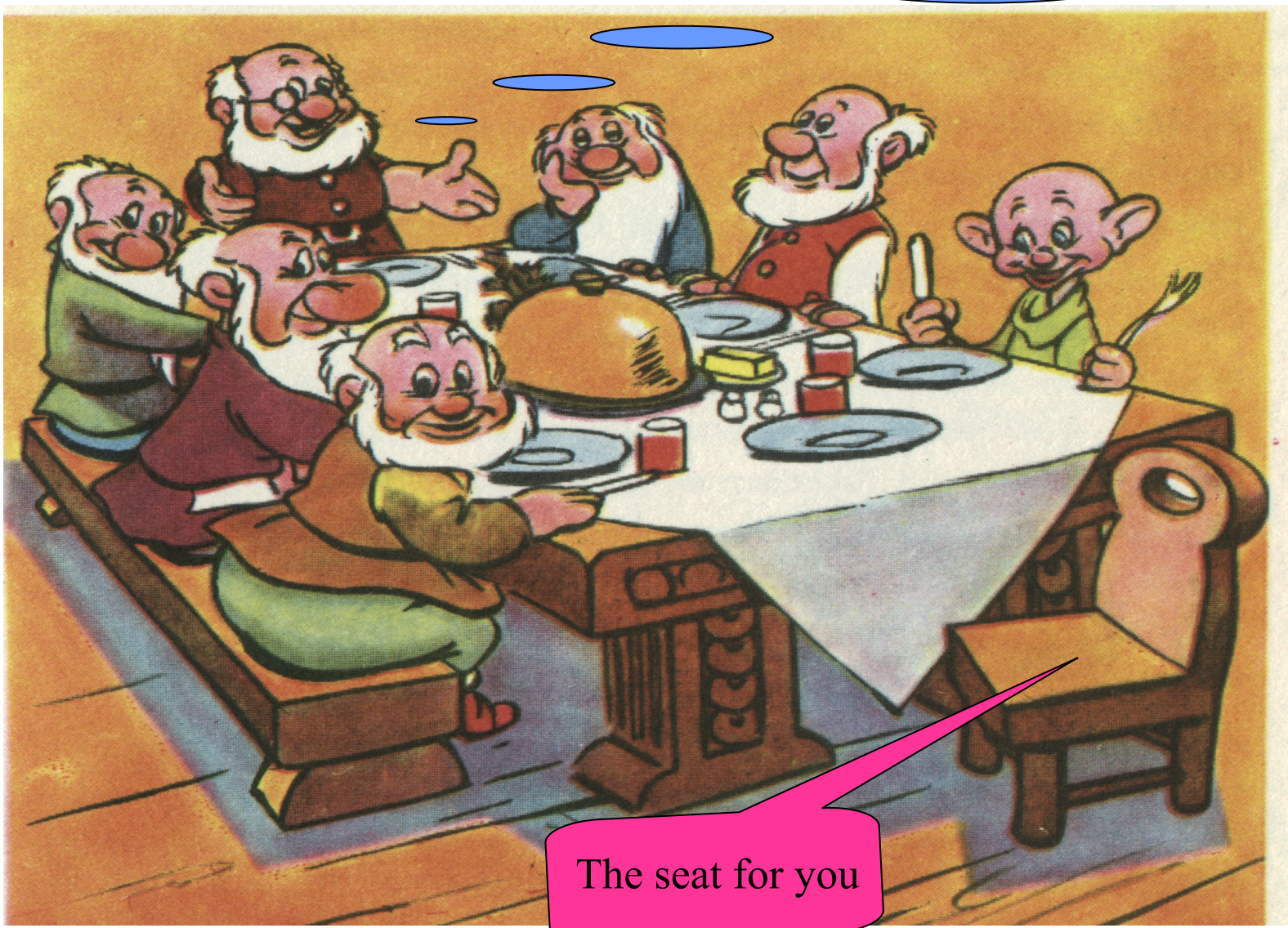
-Highly sensitive to UHECR & UHEN

-Study in presently controversial region

-Extend up to higher energies

-Competitive with the most ambition projects

BENVENUTO to the LORD collaboration !

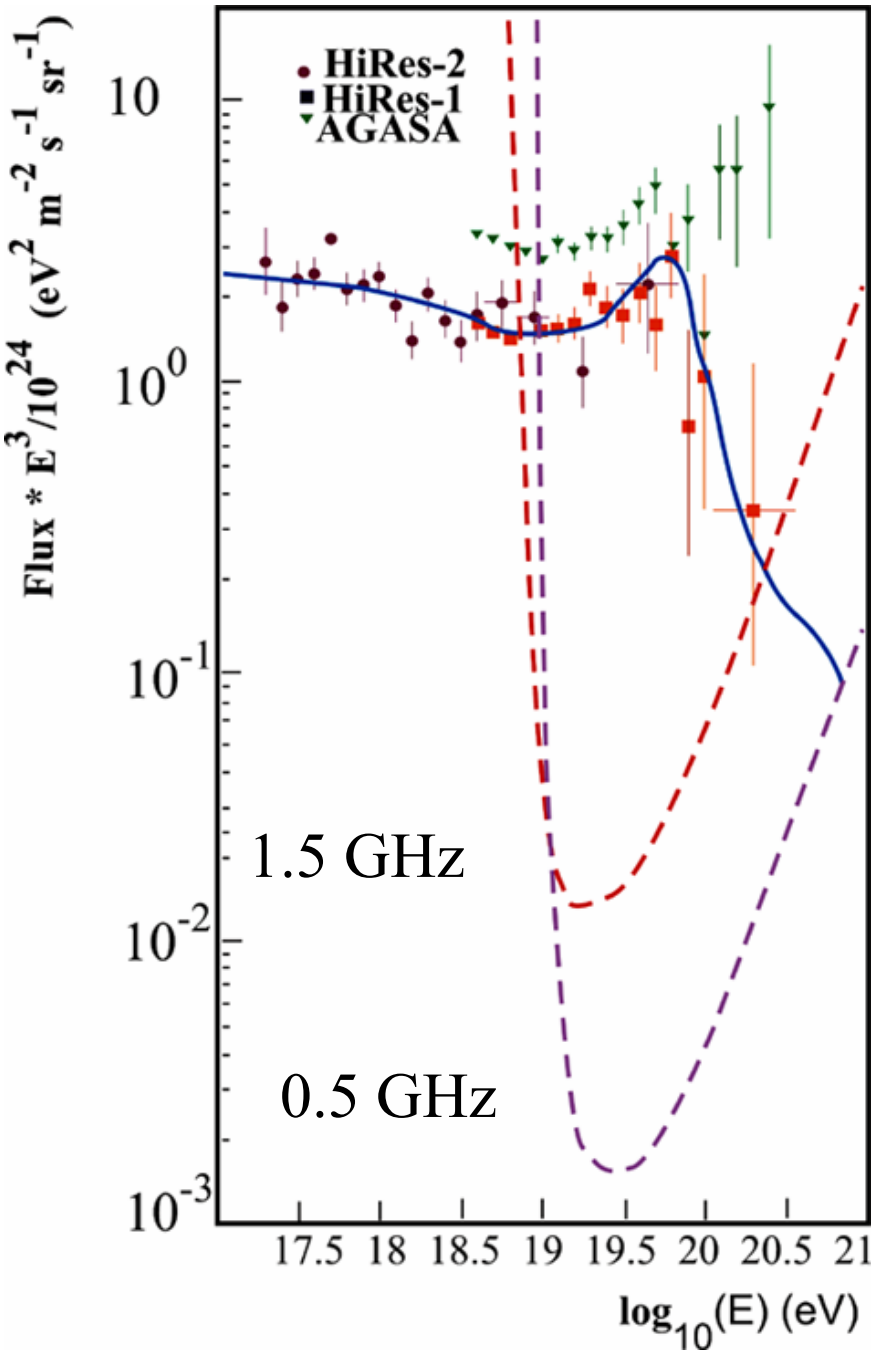


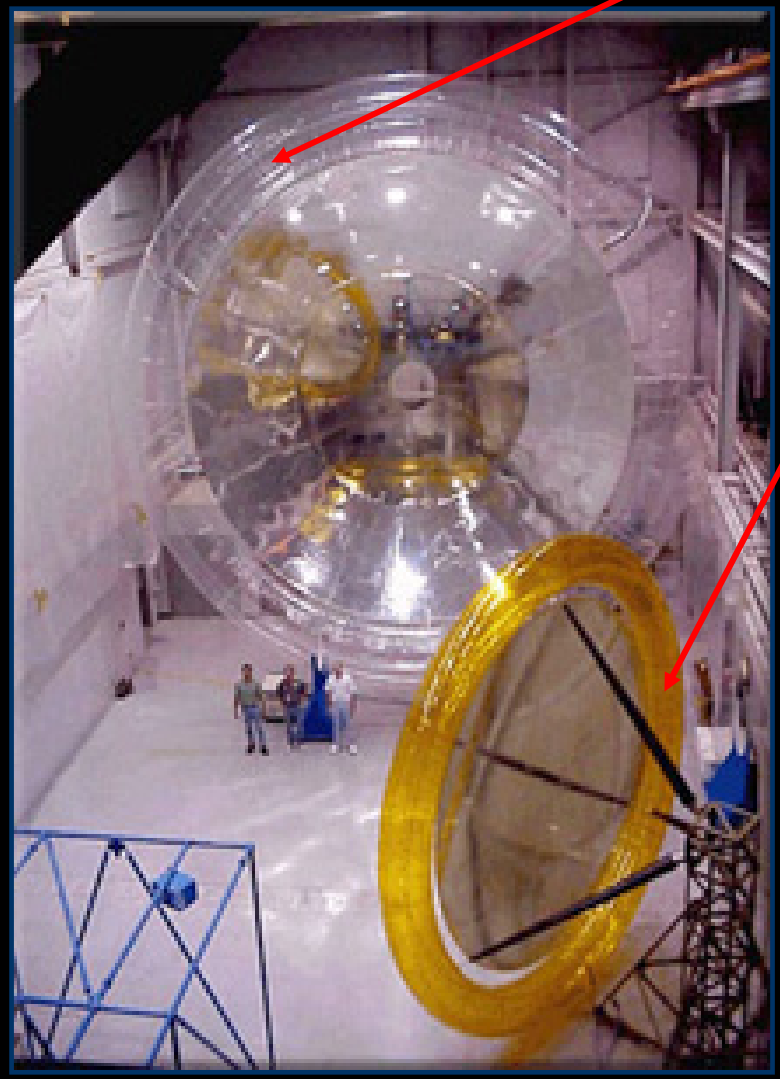
LORD: sensitivity to the CR flux.

f = 0.5; 1.5 GHz

E_{th} = 0.1 μV/m MHz

T = 1 year



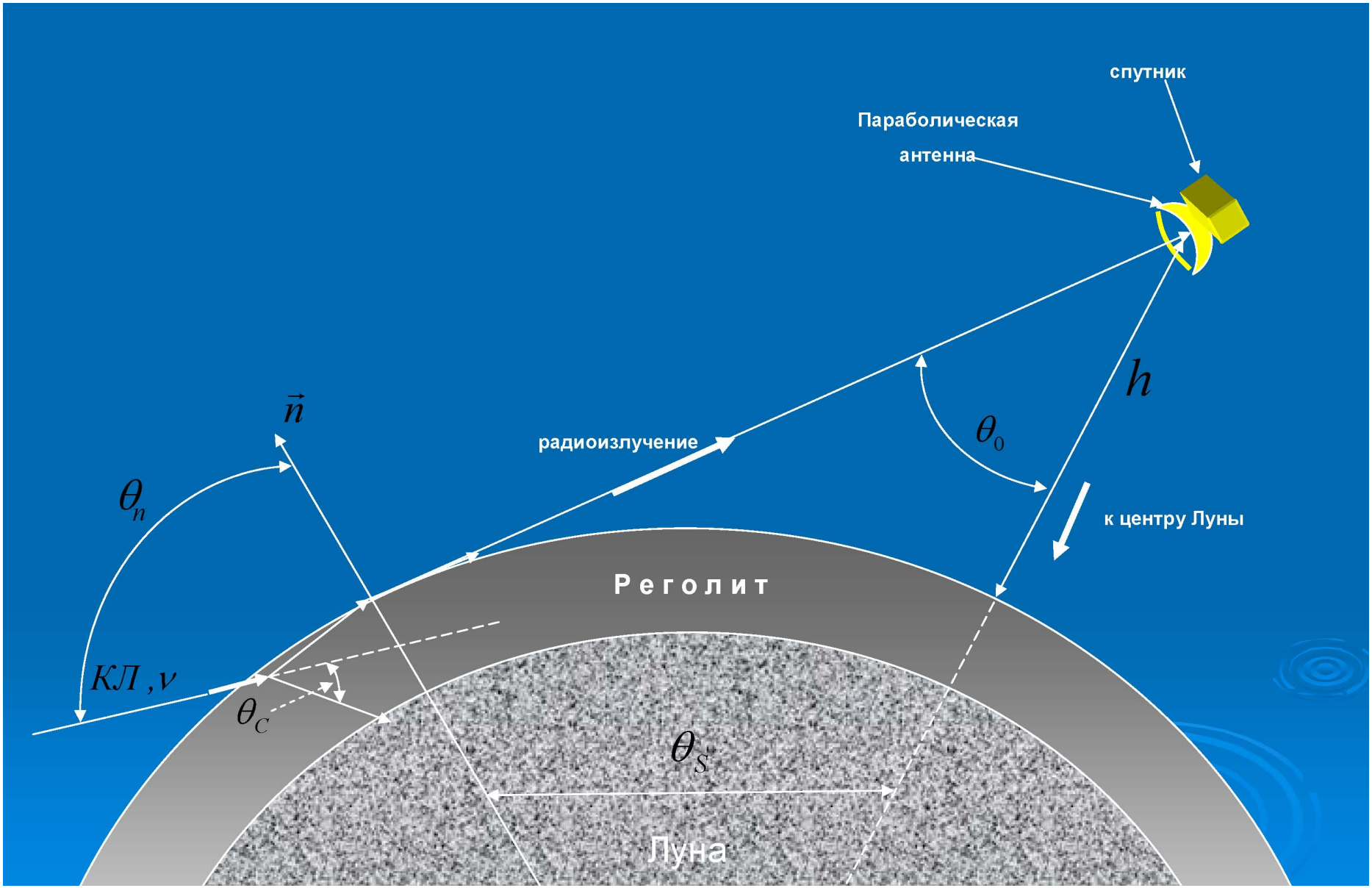


10 m

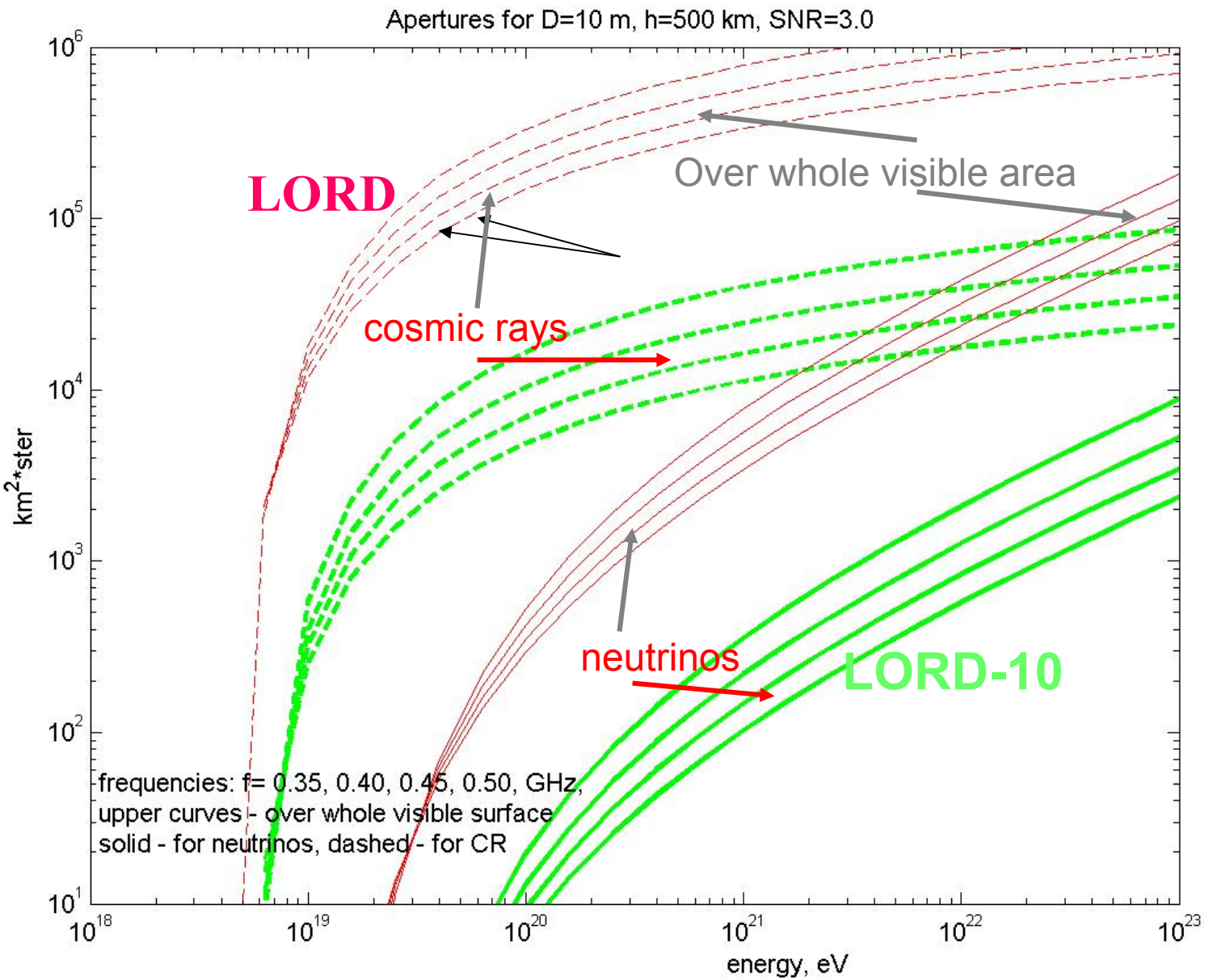
5 m

Parabolic antenna of diameter D=10-20 m:
film astrophysical structure + inflatable skeleton

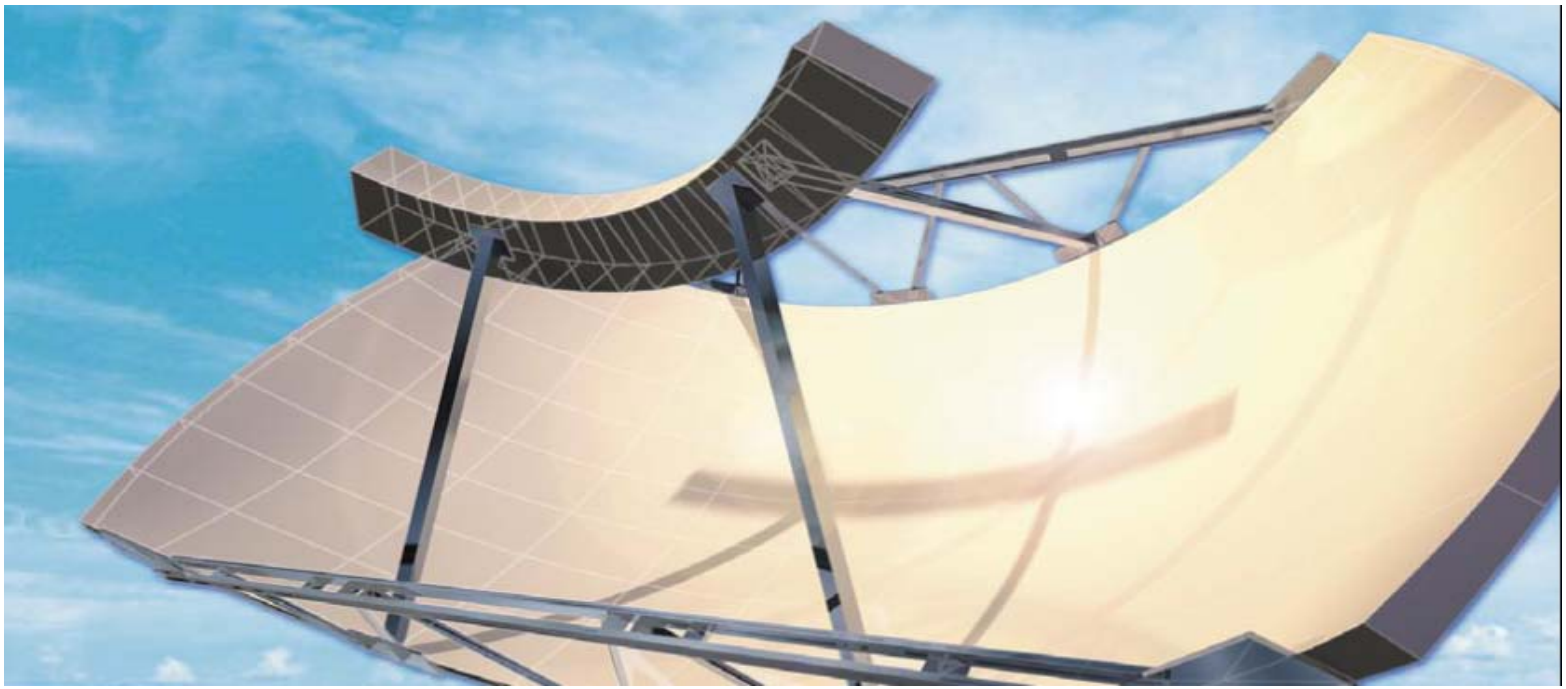
Three biconical offset feeds


спутник
Параболическая
антенна
h
θ_0
радиоизлучение
к центру Луны
$\vec{n}$
θ_n
КЛ , ν
θ_C
Реголит
θ_S
Луна

CR and NU apertures: SNR=3



Torus parabolic multibeam antenna



Frequency	3.7-4.2 GHz
Gain	46 dBi
Reflector size	7 m x 12.8m
Beamwidth	1 x 2 degrees
Arc Coverage	75 degrees
Number of feeds	37