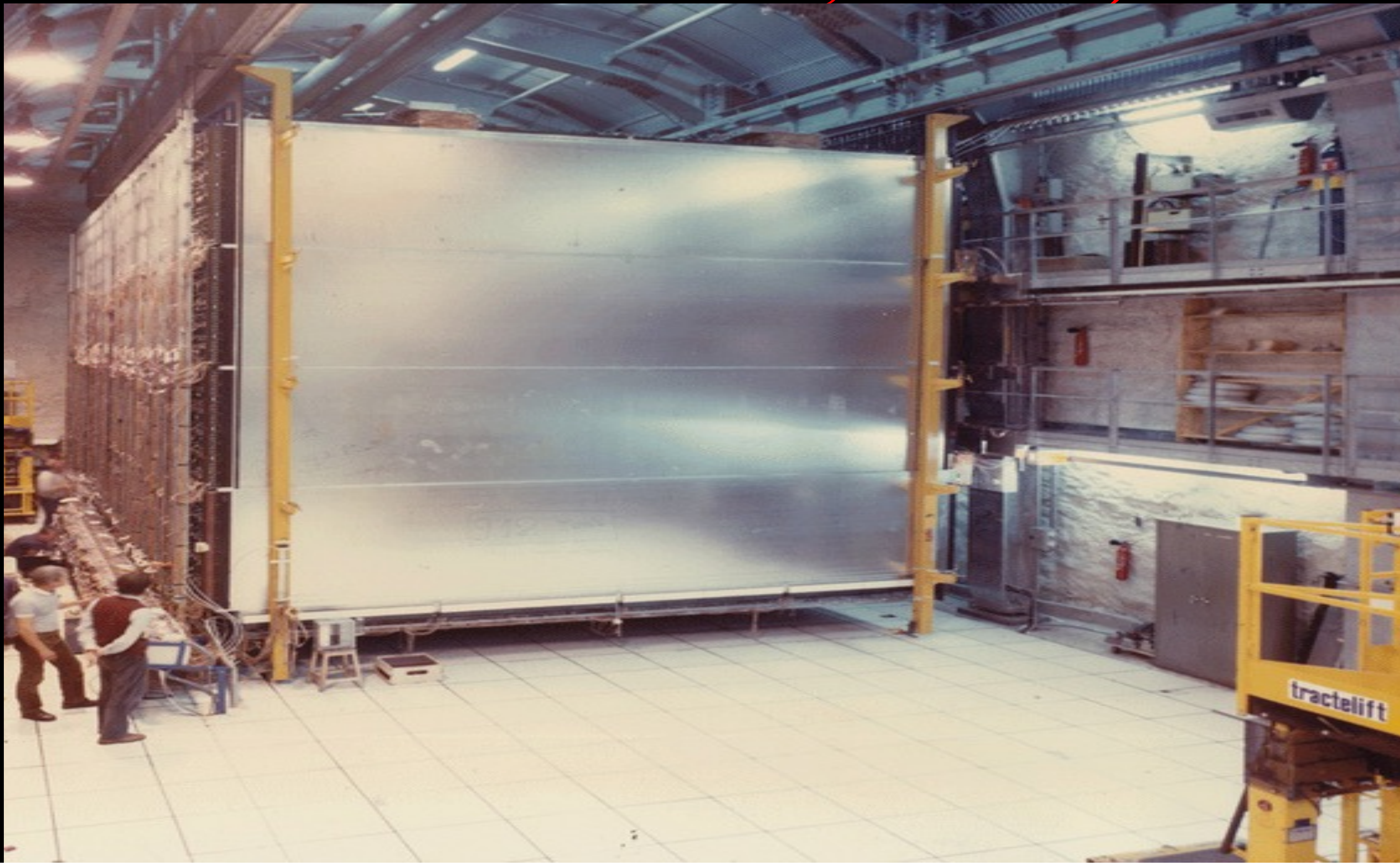
The onset of astroparticle physics (multi messenger astronomy) in France: a tribute to Stavros, a scientist, a philosopher, a poet

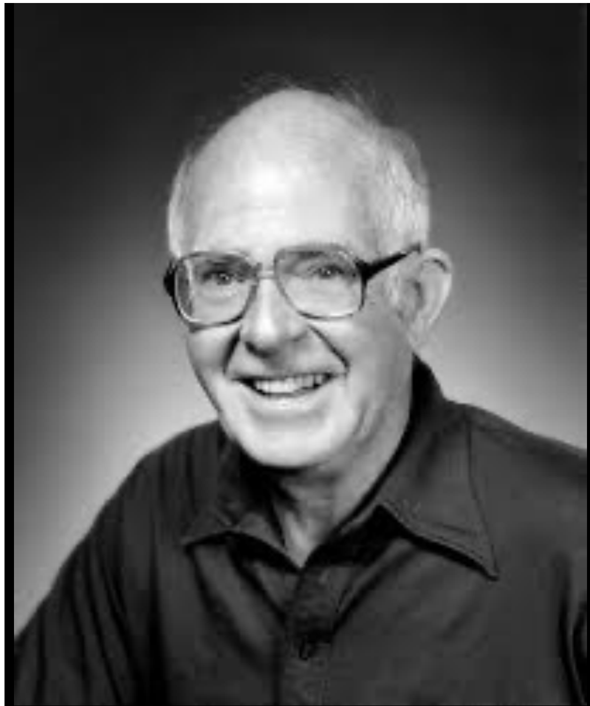
Using the font and some slides at the end, of S. Katsanevas EGO Director in his presentation 24 November 2022

Early times: Louis Leprince Ringuet and M. Lhéritier

1944: 10 000 pictures Wilson Cloud Chamber
Largentière- La Bessée
First evidence for a new particle which turned to be the K meson

Expérience durée de vie du proton LSM 1983 (Rousset, Barloutaud, Julian..)





Three important results in 1985
1. solar neutrinos deficit enigma

Homestake mine

Expected Solar Neutrino Spectrum , flux measured by Homestake, three times less than expected (J. Bahcall, debate with S. Turck-Chièze))

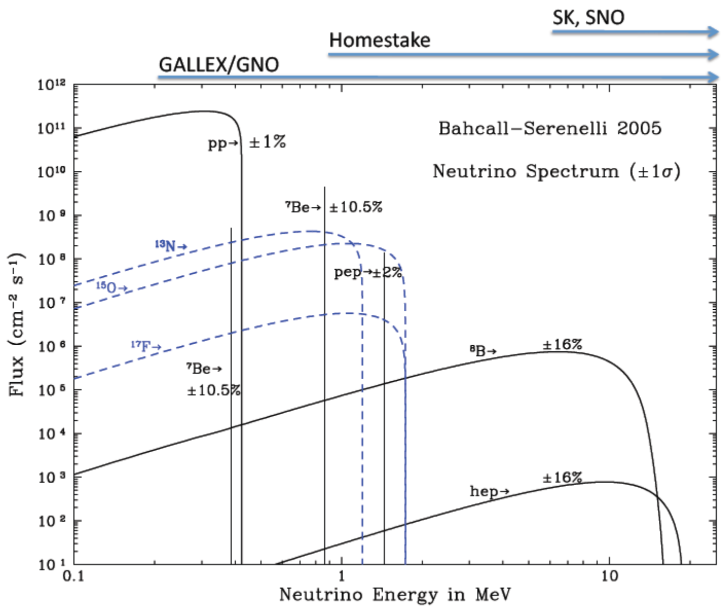


Figure 1: Neutrino fluxes (with percentage uncertainties) as predicted by the Bahcall-Serenelli

GALLEX (Italy, Germany, France..)
in Gran Sasso 100t $GaCl_3$

Reaction

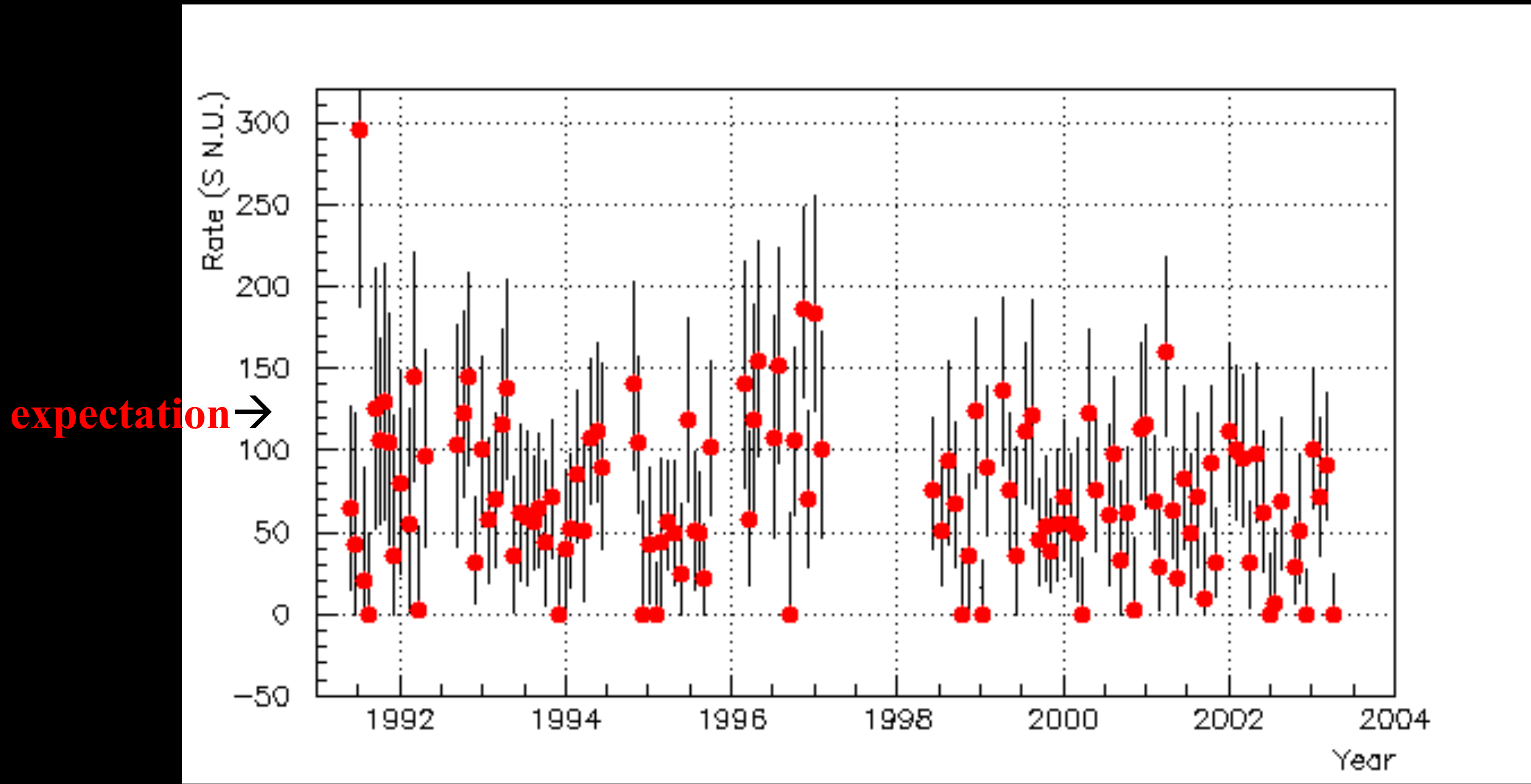
$^{71}Ga(\nu_e,e)^{71}Ge$ (E_{thr} = 233 keV)
EC τ = **16.5** d
^{71}Ga

Source of the signal

pp + pep 73 SNU (55 %)
^{7}Be 35 SNU (27 %)
CNO 8 SNU (8 %)
^{8}B 13 SNU (10 %)
Tot 129 SNU $^{+9}_{-7}$ 1σ

Expected Signal (SSM)

1.2 ν int. per day, but due to decay during exposure + ineff., 9 ^{71}Ge decay detected per extraction
(28 days exposure)


expectation→
Rate (S.N.U.)
300
250
200
150
100
50
0
−50
1992
1994
1996
1998
2000
2002
2004
Year

Z. Phys. C – Particles and Fields 32, 499–511 (1986)

Zeitschrift für Physik C Particles and Fields

Matter Effects for Solar Neutrino Oscillations

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Abstract. Possible solar neutrino oscillations are reviewed in the two-neutrino case taking into account the effect of coherent forward scattering when neutrinos travel through the sun and earth. As recently pointed out by Mikheyev and Smirnov this effect can induce a large suppression of the solar ν_e flux for values of Δm^2 around $10^{-4}-10^{-8}\,\mathrm{eV}^2$ even for small values of the mixing angle. It also may cause substantial modifications of the solar neutrino spectrum shape. All this may be used for determining Δm^2 and $\sin^2 2\theta$ in a large domain from the experimental results of the chlorine, gallium, indium and heavy water detectors.

1. Introduction

As was first suggested by Pontecorvo [1], if neutrinos are massive and if there is nonconservation of the lepton family number, the mass eigenstates ν_1 and ν_2 (of masses m_1 and m_2) may differ from ν_e and ν_μ, leading to operative only for ν_e. For neutrinos the phase mismatch φ_m obeys [5]:

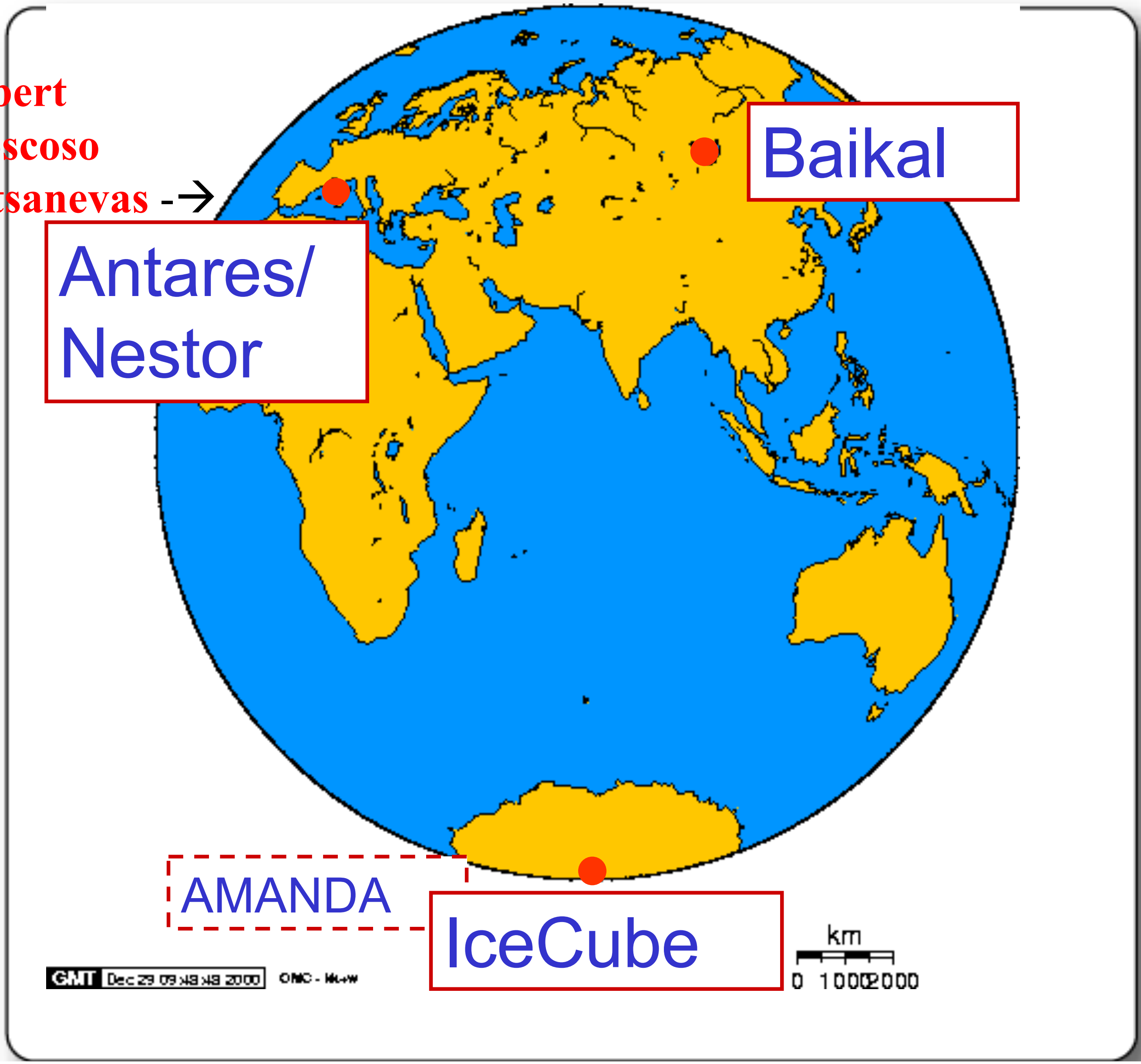
$$d\varphi_m/dt = k(x) = \sqrt{2}\cdot G\cdot N(x)$$

where $x = ct$ and where $N(x)$ is the electron density in cm^{-3} and G is the Fermi coupling constant. The net effect of this new phase is that the propagation eigenstates in matter are no longer the mass eigenstates ν_1 and ν_2, therefore oscillation parameters in matter differ from those in vacuum. This formalism was extended to three neutrino oscillations by Barger et al. [6]. More recently Mikheyev and Smirnov [7] showed that the difference might introduce dramatic effects for solar neutrinos, which may lead to a very strong suppression of the ν_e flux measured on earth, even if the vacuum mixing angle is small.

In this paper we develop the formalism of two-neutrino oscillations in matter in a way exhibiting the possible approximations and their limits. We then apply it to the solar neutrino case and demonstrate the

High energy neutrino detectors: neutrinos come from below and interact in the rock or in water/ice

Jj Aubert
L. Moscoso
S. Katsanevas -→



Testimony of Fabrice Feinstein (1/3)

La première fois que nous nous étions rencontrés, à Athènes en 1995, c'était pour notre participation au télescope à neutrinos NESTOR.

Je me souviens alors d'un physicien jeune, dynamique, éminemment sympathique, qui s'enthousiasmait pour le développement d'une ferme de processeurs qui traiterait les données issues du site de Pylos.

Puis, j'ai appris qu'il avait réussi un concours de Prof. à Lyon.

Ah, que l'Université française est belle quand elle attire des chercheurs comme lui.

Et que notre système d'UMR est précieux, quand il favorise notre étroit partenariat avec le CNRS.

Un jour, en 2002, il m'appelle pour me parler d'une idée d'application médicale d'un circuit intégré développé pour ANTARES. Puis, juste après, il me recontacte pour s'excuser : il n'a plus le temps, il venait d'être nommé à l'IN2P3…

Testimony of Fabrice Feinstein(2/3)

Il m'a fallu longtemps pour comprendre un des traits les plus orientaux, et paradoxalement déroutants, de sa façon d'interagir : il ne disait jamais non, par correction et respect pour son interlocuteur.

Mais, son OUI unique avait plusieurs sens, dans sa bouche. Il fallait interpréter!

le OUI réservé : Oui, je t'ai entendu et compris…

le OUI intrigué : Oui, c'est intéressant, on va creuser…

le OUI convaincu : Oui, on devrait le faire, mais je n'ai pas les moyens, pour l'instant…

le OUI ferme et définitif : Oui, on va le faire, (même si je n'ai toujours pas les moyens) !

Et on le faisait !

Testimony of Fabrice Feinstein(3/3)

J’ai trouvé quatre vers du poème yiddish *Dona Dona* (légèrement récrits) qui lui vont comme un gant :

Haut dans le ciel, une hirondelle vole,

S’amuse et se rie des protocoles.

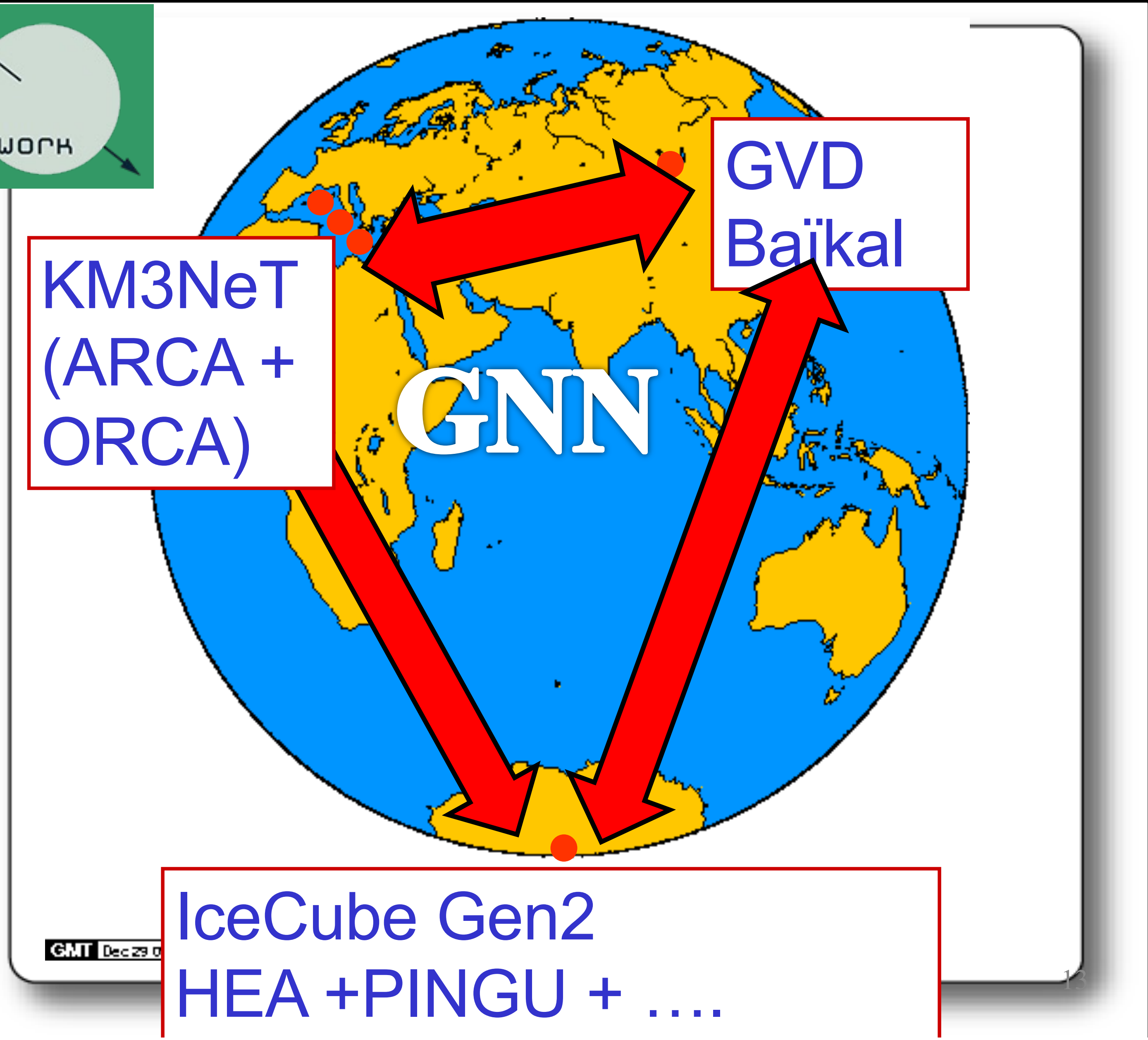
Celui qui a des ailes, le monde lui appartient.

Personne, sous son emprise ne le tient.

Efcharistó polý gia ti fysikí

Merci Stavros d’avoir existé

GNN
The Global Neutrino Network



Three important results in 1985
2. Cygnus X3

proton decay experiment has obtained additional evidence for underground muons associated with the x-ray pulsar Cygnus X-3. We report the preliminary analysis of data recorded during the October 1985 radio outburst of Cygnus X-3, which show a significant excess of muons for a narrow range of Cygnus X-3 pulsar phases.

Trevor Weekes: After decades of fruitless search, astronomers have found a source (Cygnus X3) of high energy charged particles and TeV gamma rays bombarding the earth

Finally this turned out to be wrong *(G. Chardin anticipated)* , but one source of TeV gamma rays was discovered by Whipple (the crab nebula supernova remnant), which is by now the reference (brightest) source in this energy range

ASGAT 1988 , Themistocle 1988 CAT 1996, CELESTE 1997 → 2004:
La France, pionnière en astro gamma: P. Goret, G. Fontaine, B. Desgranges, E. Paré, P. Fleury, M. Urban, M. Rivoal, C. Guesquière

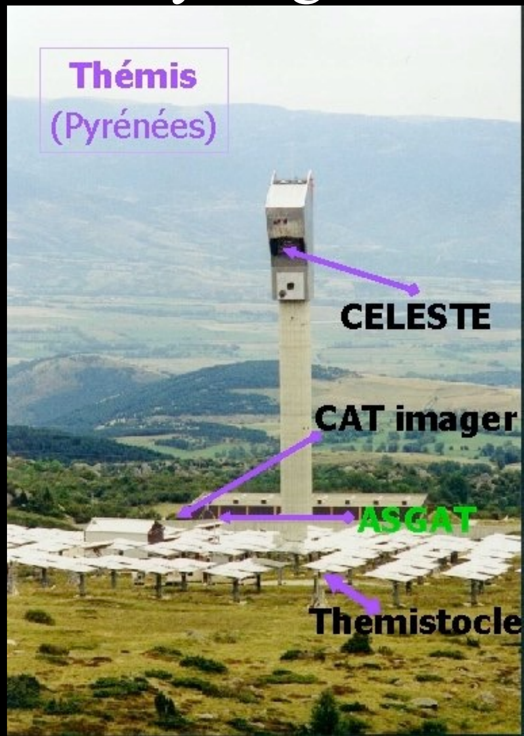
Themistocle and ASGAT: sampling techniques: many parabola with photomultipliers at the focus

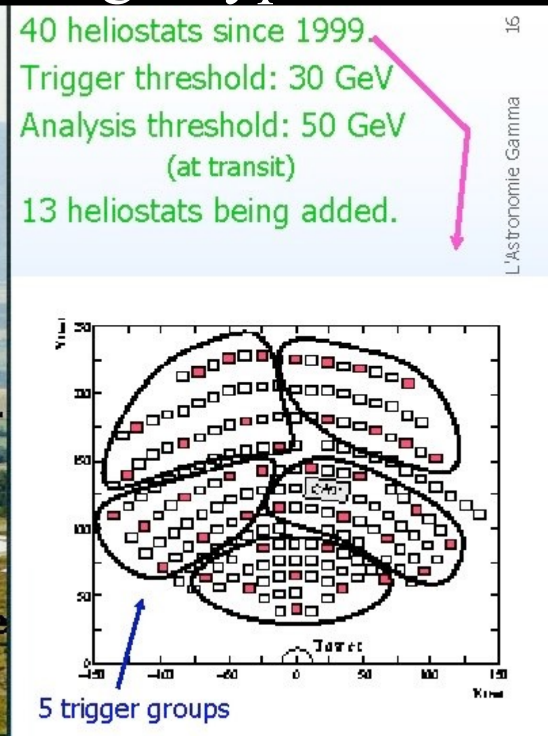
CAT: imaging technique→ one large mirror with many photomultipliers at the focal plane to image the shower

CELESTE uses the full (40 heliostats) solar plant to focus the light at the top of the tower→ low threshold

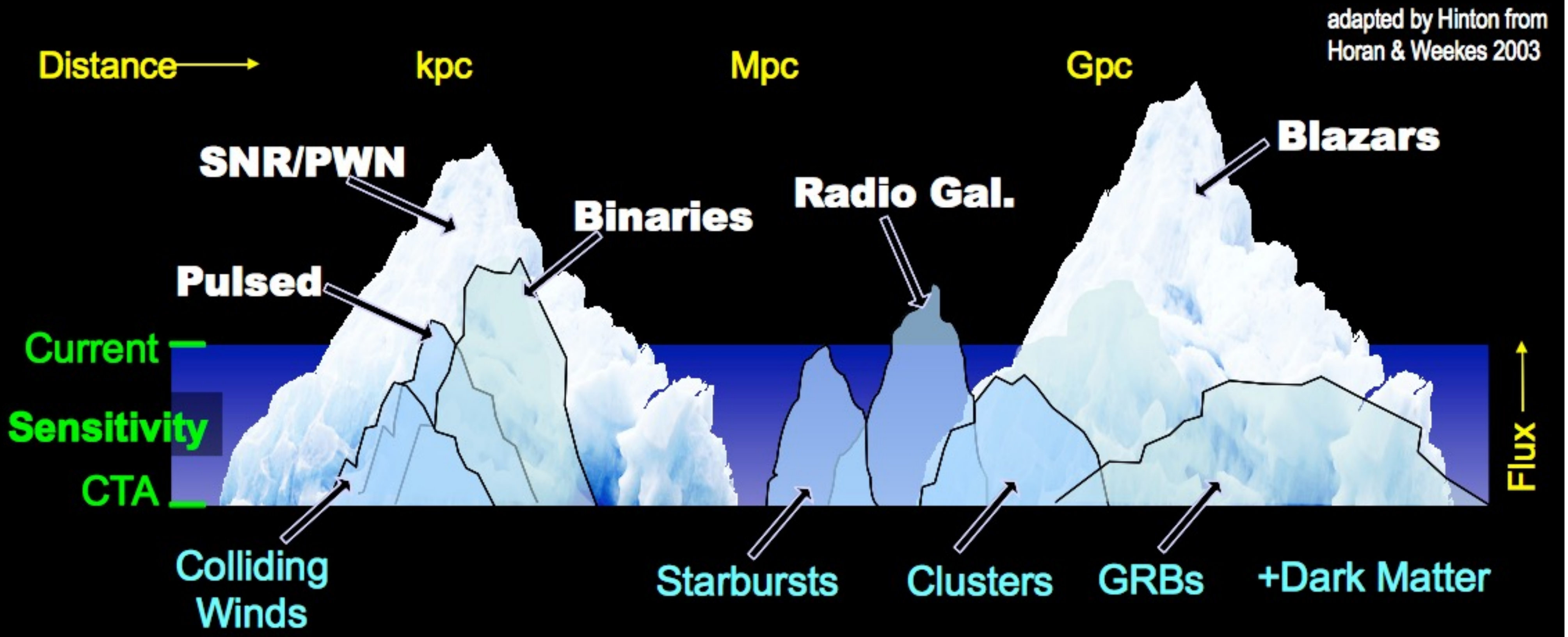
3rd generation will use many large CAT imager type mirrors plus focal plane imagers:

HESS





What's next?



- Current instruments have passed the critical sensitivity threshold and reveal a rich panorama, **but this is clearly only the tip of the iceberg**

cta
cherenkov telescope array

Summary on Gamma Rays

CTA after HESS will open a new era in gamma-ray astronomy

It will be flanked by wide-angle arrays like HAWC (TeV range), SWGO? and LHAASO, TAIGA (reaching into PeV range)

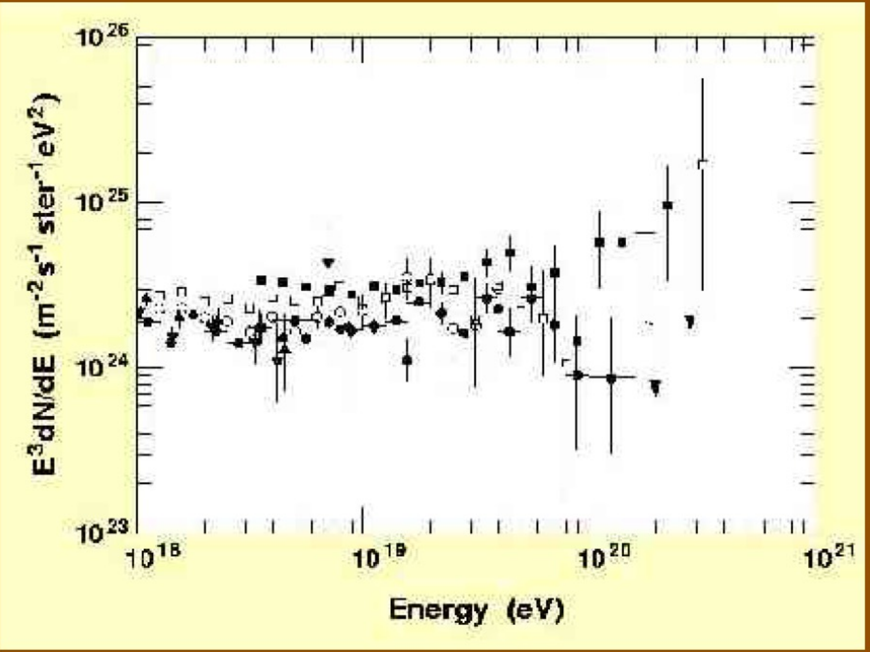
Follow-up of Fermi satellite is still debated

James Cronin
Alan Watson
Murat Boratav
(avec Antoine
Letessier et
Tina Suomijarvi!)

1989

Three important results in 1985
3. Cosmic Rays above the GZK cut-off

Experimental data: The spectra measured by several experiments have absolute normalization different by 40%. Note that the differential flux is multiplied by E^3 to emphasize the shape of the spectrum. The results are obtained with the same hadronic interaction model.



The AGASA and HiRes experiments have the highest current statistics around the GZK cut-off. AGASA shows no cut-off, while HiRes does.

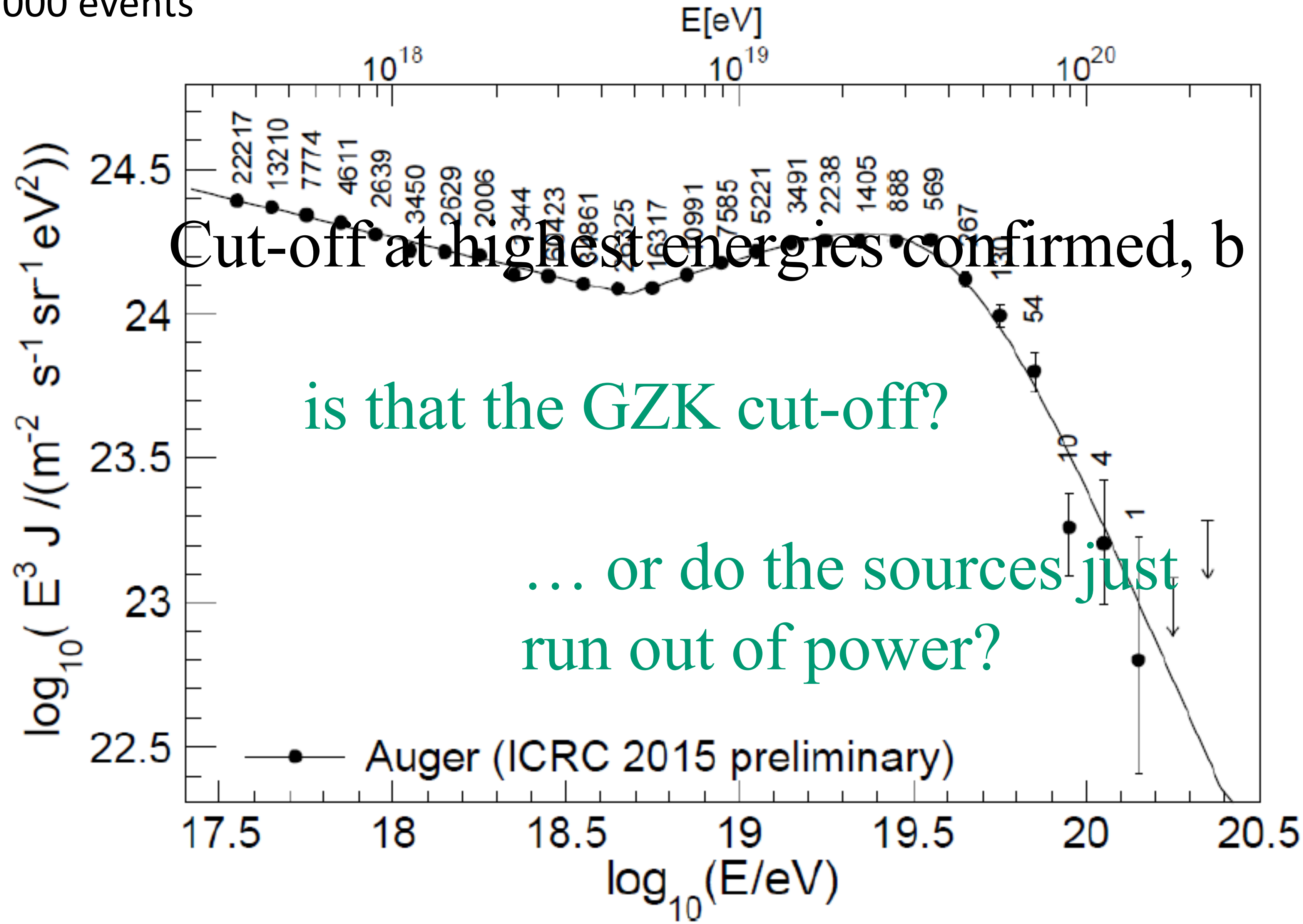
Pierre Auger Observatory

1660 detector stations on 1.5 km grid

27 fluores. telescopes at periphery

130 radio antennas

190 000 events



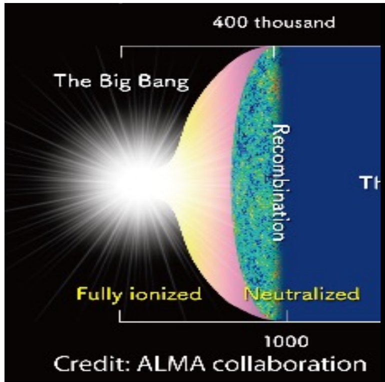
Cut-off at highest energies confirmed, b

is that the GZK cut-off?

… or do the sources just run out of power?

Project initiated in France by A. Brillet.
Project accepted after the P. Fleury review panel examination (1990)

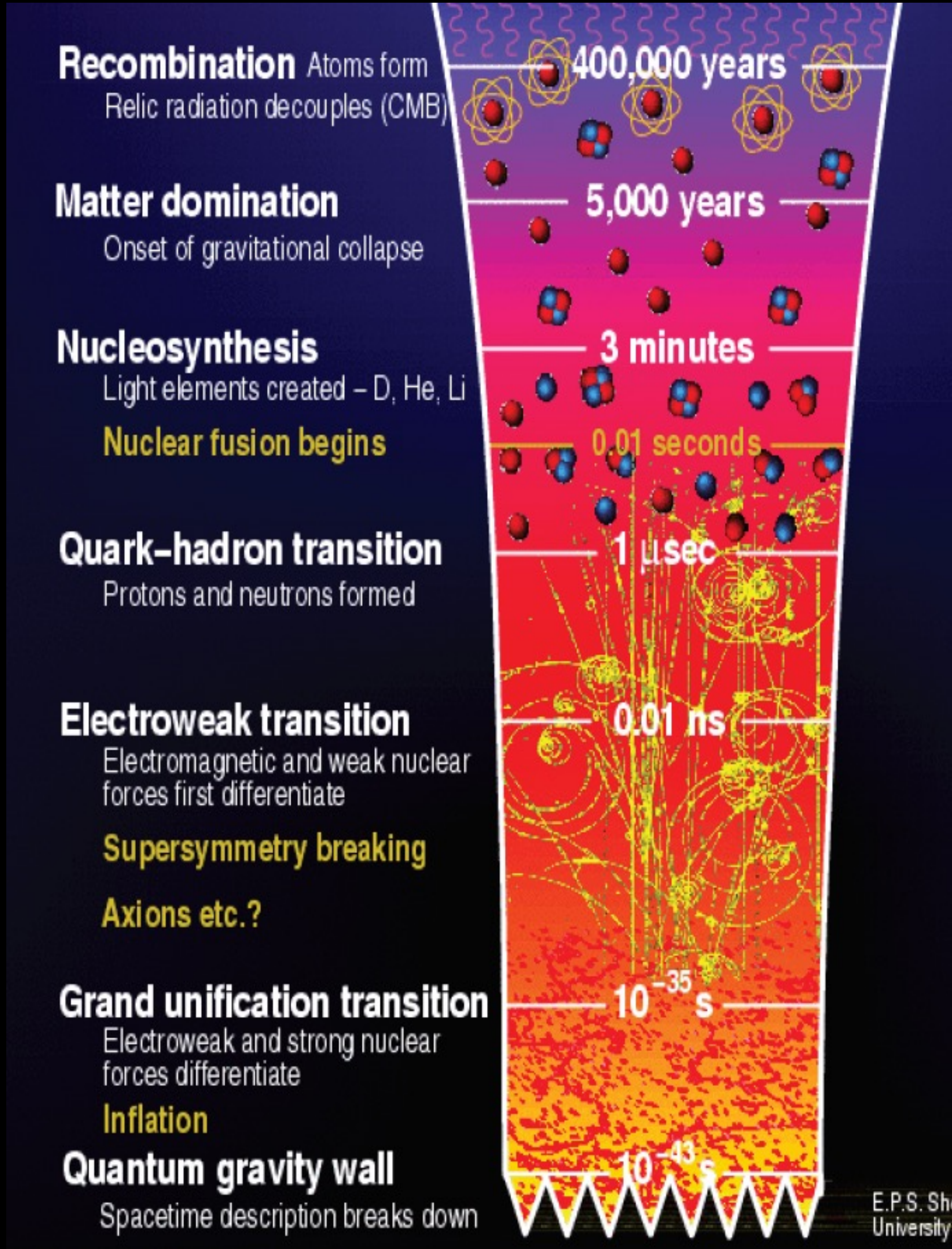
S. K. Katsanevas EGO Director 2018 - 2022



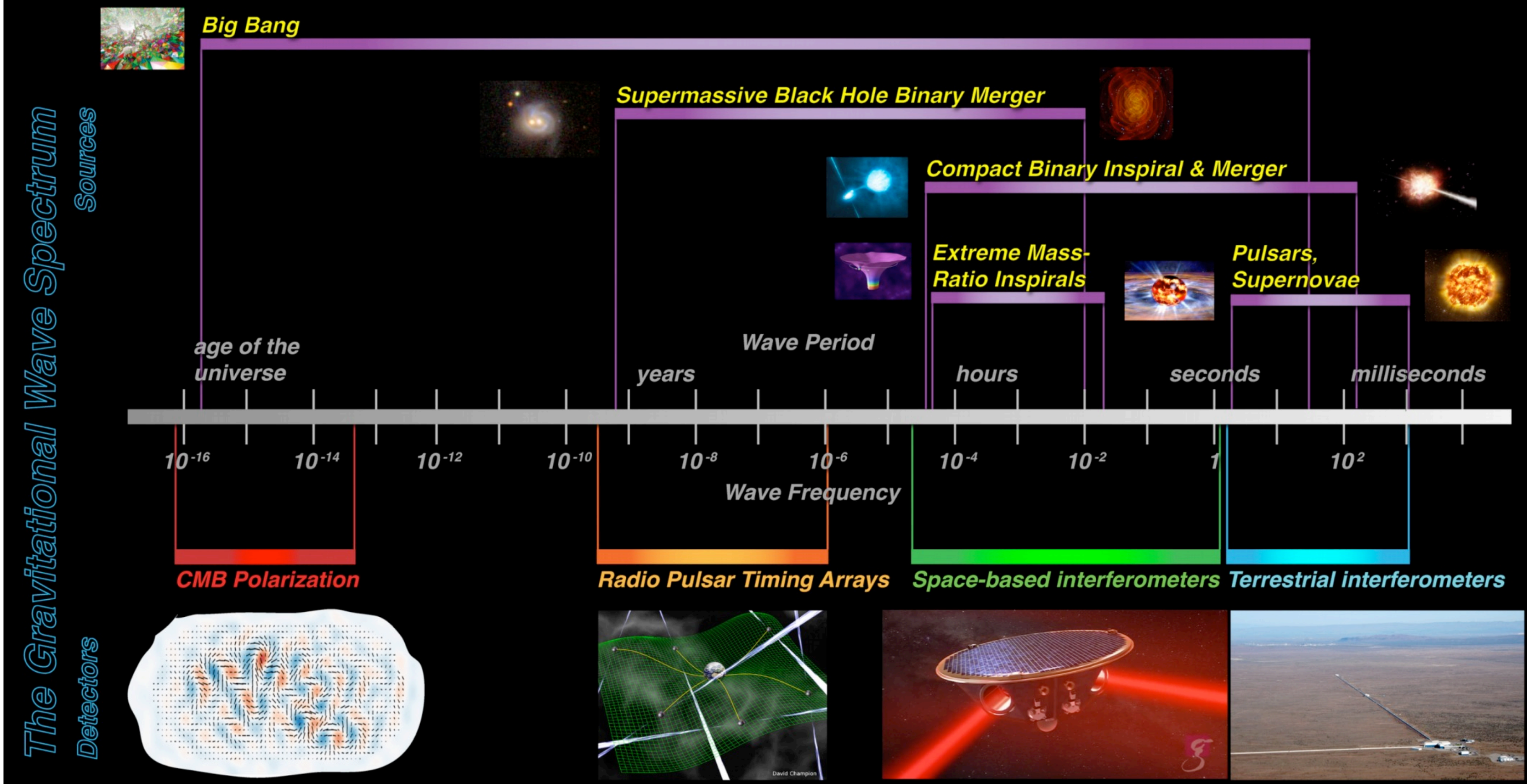
The first 400.000 years Cosmology up to the recombination wall

GW a dominant probe

1. Inflation
2. Grand Unification Transition: Electroweak and Strong interaction differentiate
3. Quark-hadron Transition: Protons and Neutrons form
4. Nucleosynthesis Transition : Light elements (D,He, LI) form
5. Matter Domination Transition: Onset of gravitational collapse
6. Recombination Transition: Atoms form, Universe becomes transparent relic radiation decouples and travels to earth (CMB)



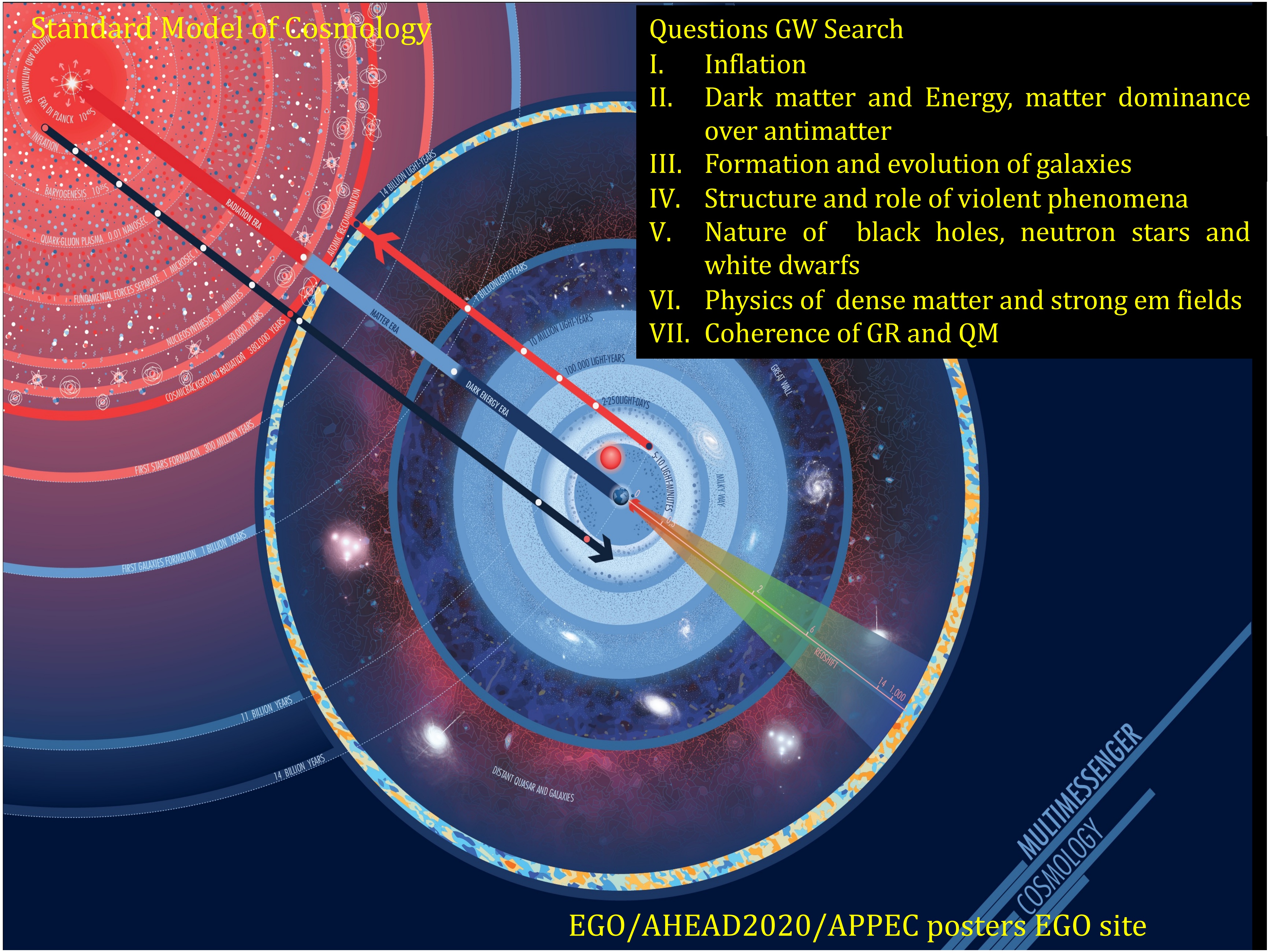
Gravitational Waves « Frequency Domain » Analysis



LISA

2G/3G GW

Standard Model of Cosmology



Questions GW Search

I. Inflation

II. Dark matter and Energy, matter dominance over antimatter

III. Formation and evolution of galaxies

IV. Structure and role of violent phenomena

V. Nature of black holes, neutron stars and white dwarfs

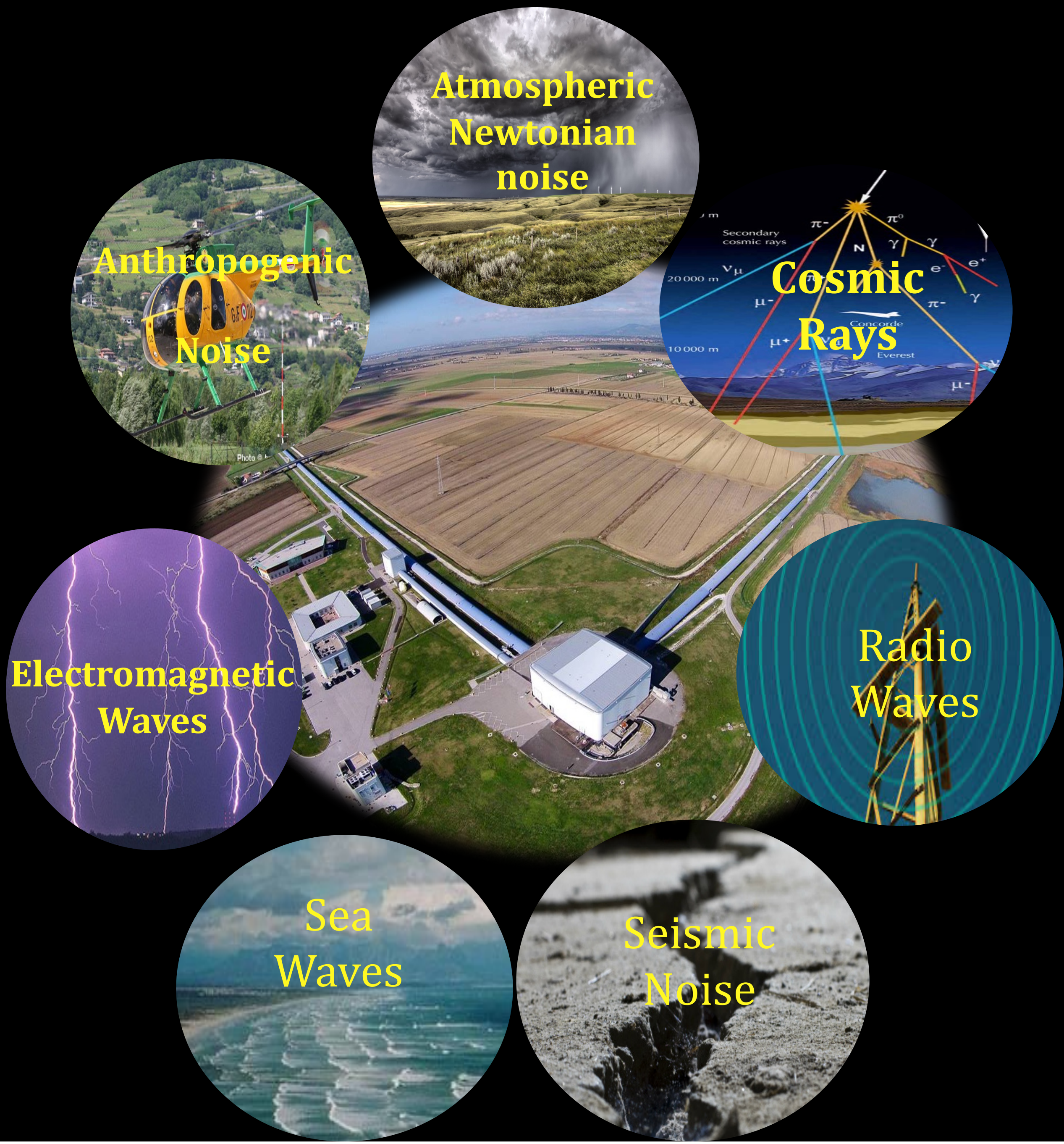
VI. Physics of dense matter and strong em fields

VII. Coherence of GR and QM

EGO/AHEAD2020/APPEC posters EGO site

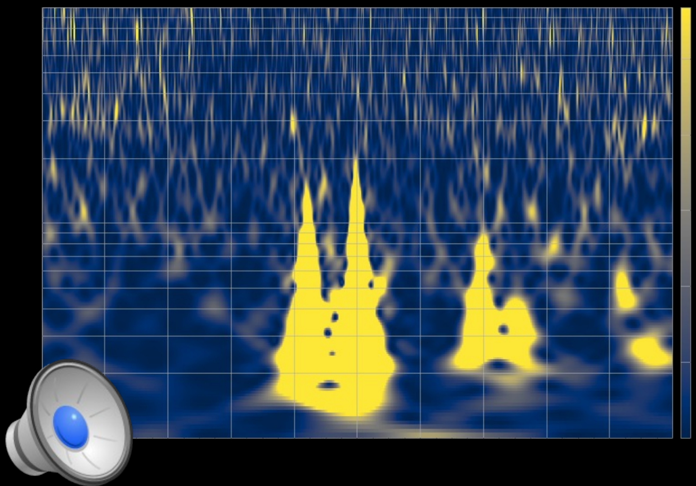
EGO EUROPEAN GRAVITATIONAL OBSERVATORY

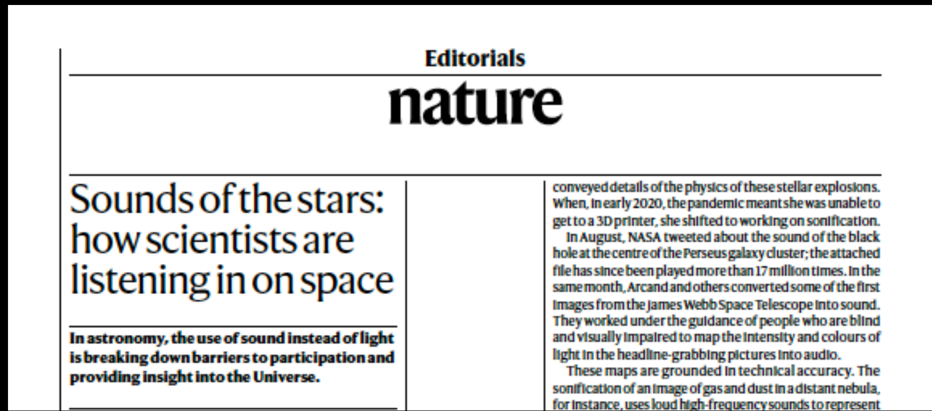
Imbedding of Virgo/EGO in the Environment



Inclusion for augmenting humanities perception capabilities from Multi-Messenger to Multi-sensorial (radiation and vibration)

- From multi-messenger to multisensorial apprehension of reality
- Not only increasing inclusion . Also increasing the researchers discrimination power of signal over background through the use of sound.




Editorials

nature

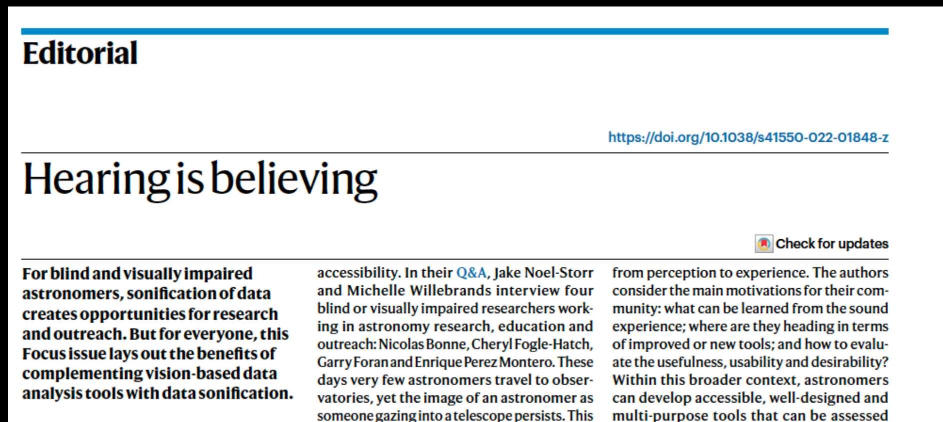
Sounds of the stars: how scientists are listening in on space

In astronomy, the use of sound instead of light is breaking down barriers to participation and providing insight into the Universe.

conveyed details of the physics of these stellar explosions. When, in early 2020, the pandemic meant she was unable to get to a 3D printer, she shifted to working on sonification.

In August, NASA tweeted about the sound of the black hole at the centre of the Perseus galaxy cluster; the attached file has since been played more than 17 million times. In the same month, Arcand and others converted some of the first images from the James Webb Space Telescope into sound. They worked under the guidance of people who are blind and visually impaired to map the intensity and colours of light in the headline-grabbing pictures into audio.

These maps are grounded in technical accuracy. The sonification of an image of gas and dust in a distant nebula, for instance, uses loud high-frequency sounds to represent


Editorial

https://doi.org/10.1038/s41550-022-01848-z

Hearing is believing

Check for updates

For blind and visually impaired astronomers, sonification of data creates opportunities for research and outreach. But for everyone, this Focus issue lays out the benefits of complementing vision-based data analysis tools with data sonification.

accessibility. In their Q&A, Jake Noel-Storr and Michelle Willebrands interview four blind or visually impaired researchers working in astronomy research, education and outreach: Nicolas Bonne, Cheryl Fogle-Hatch, Garry Foran and Enrique Perez Montero. These days very few astronomers travel to observatories, yet the image of an astronomer as someone gazing into a telescope persists. This

from perception to experience. The authors consider the main motivations for their community: what can be learned from the sound experience; where are they heading in terms of improved or new tools; and how to evaluate the usefulness, usability and desirability? Within this broader context, astronomers can develop accessible, well-designed and multi-purpose tools that can be assessed

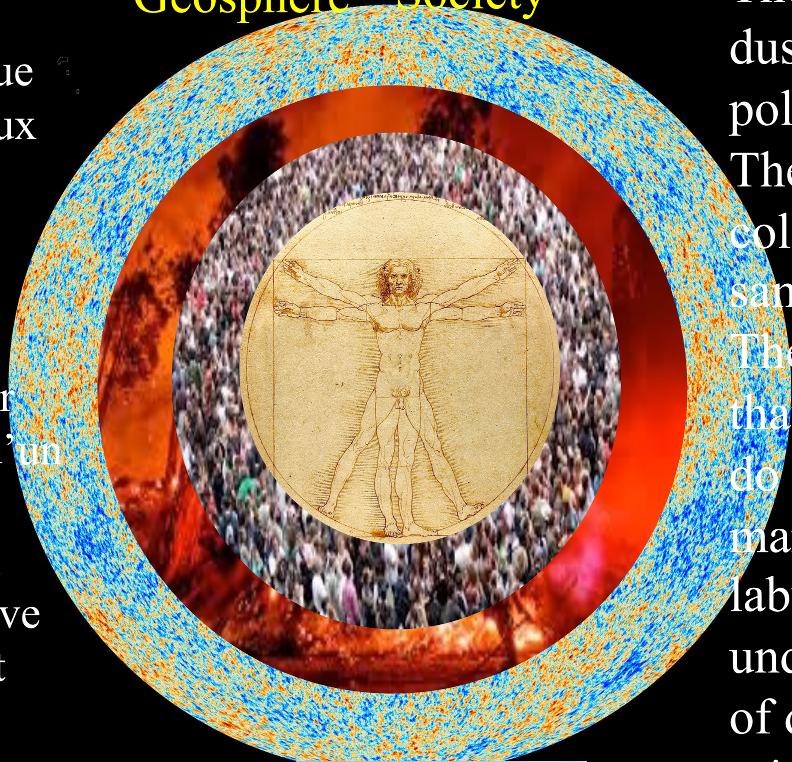
Recent Nature Editorial, and NAture Astronmy published 6 articles on sonification 18 Nov.

Stressing the pioinnering role of WAnd Diaz-MErced

Conclusion the 4 cosmos

Universe Atmosphere

Geosphere Society



Les translucides mains du Juif polissent Dans la pénombre le dur cristal et
Le soir qui se meurt n 'est que froid et peur. (Chaque soir aux autres soirs ressemble.)
Les mains et l'espace de jacinthes,
Qui pâlissent aux confins du ghetto, N'existent guère pour l'homme paisible Qui rêve d'un diaphane labyrinthe.
La gloire ne le trouble point, vague Reflet d'un rêve au rêve d'un miroir, Ni les tendres et craintives amours. Libre du mythe et de la métaphore Il polit le cristal : carte infinie De Celui qui est toutes ses étoiles. Jorge Luis Borges, *Spinoza*, 1964

The Jew's hands, translucent in the dusk,
polish the lenses time and again.
The dying afternoon is fear, is cold, and all afternoons are the same.
The hands and the hyacinth-blue ai
that whitens at the Ghetto edges
do not quite exist for this silent man who conjures up a clear labyrinth—
undisturbed by fame, that reflection of dreams in the dream of another mirror, nor by maidens' timid love.
Free of metaphor and myth, he grinds
a stubborn crystal: the infinite map of the One who is all His

Que le monde soit cosmos fut une des décisions constitutives de notre histoire intellectuell*e*
H. Blumenberg