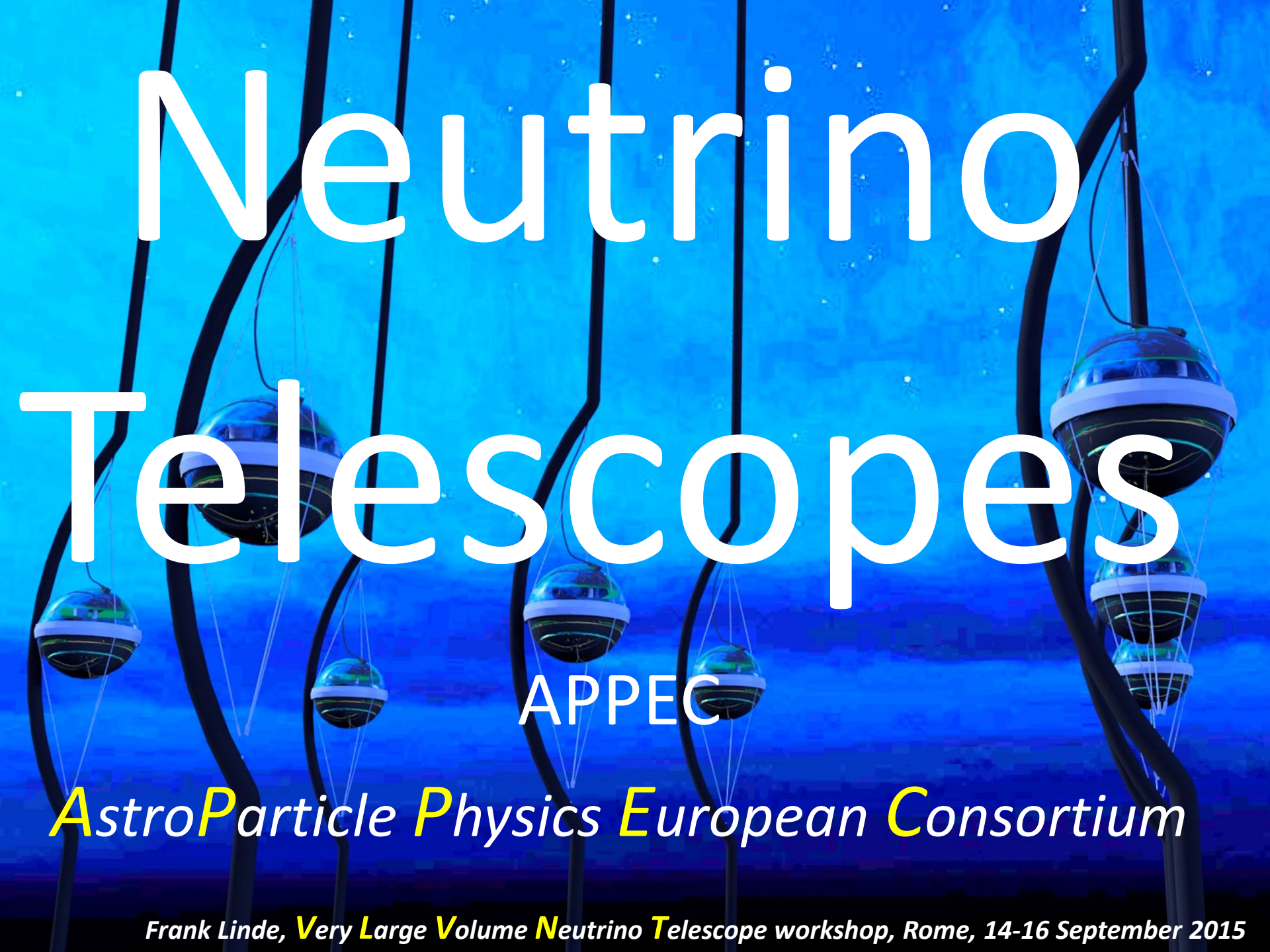

Neutrino
Telescopes
APPEC
AstroParticle Physics European Consortium

APPEC *organisation*

APPEC
functional centers

STFC - UK
Outreach

DESY - Hamburg/D
Management, Computing & Industry

APC - Paris/F
Roadmapping, Common Calls, Interdisciple

LSC - Canfranc/S
Web pages

LNGS - L'Aquila/I
Networking, Theory, Graduate Schools

APPEC

70-80 k€/year …
+ manpower

The good news:

EU-FAs spending ~70 M€/yr

The "bad" news:

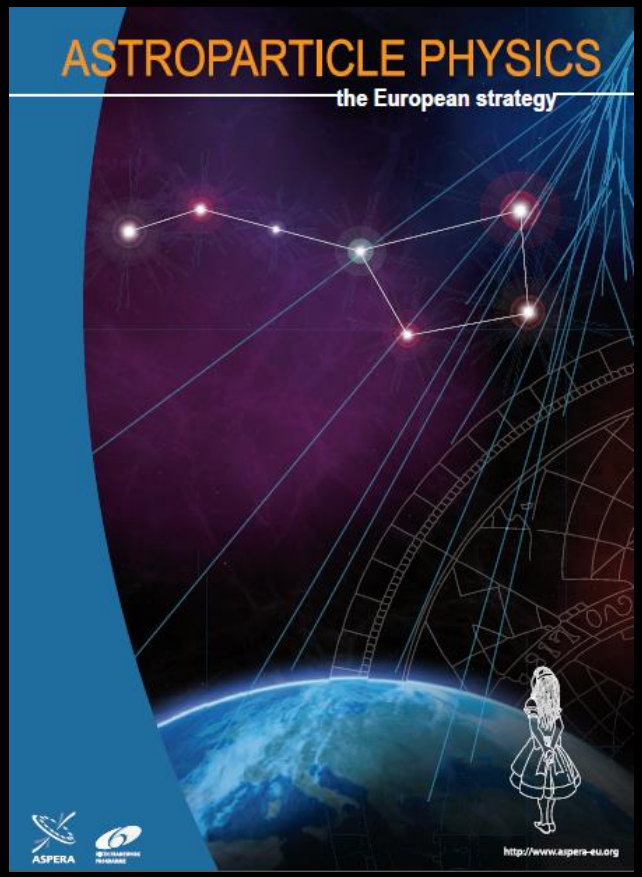
We (=you) want more

APPEC *impact …*

- Direct investment subsidies: no, sorry
- Nevertheless: APPEC members represent or have access to national funding agencies
- Indirect support:
  - *Roadmapping (in my opinion: very important … if done right)*
  - Inter-agency discussions on investment funding (roadmap)
  - Common calls i.e. people (e.g. LE neutrinos)
  - Workshops aimed at funding opportunities (e.g. H2020)
  - Support letters (KM3NeT's ESFRI application…)

APPEC *roadmapping*

2008



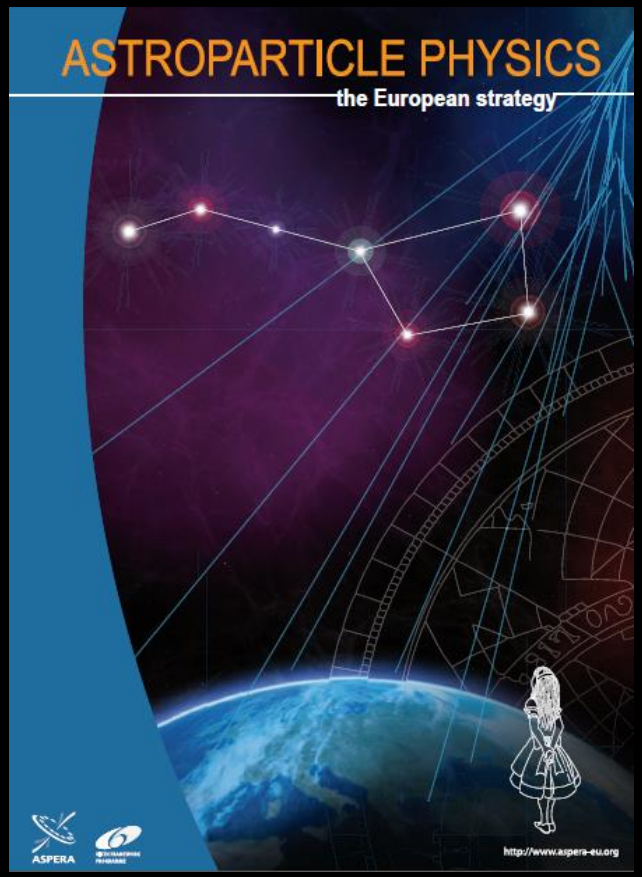
6.3 High-energy neutrino astronomy

As of today, the sky-map of extraterrestrial high energy neutrinos is still empty – a challenging terra incognita. Such neutrinos must be emitted as a by-product of high- energy collisions of charged cosmic rays with matter. Since they can escape much denser celestial bodies than light, they can be tracers of processes which stay hidden to traditional astronomy. Undisturbed by anything, they reach us from the remotest regions of the Universe and may let us peer deeper into the universe than with any other messenger. Nevertheless, at the same time their extremely low interaction probability makes their detection extraordinarily difficult.

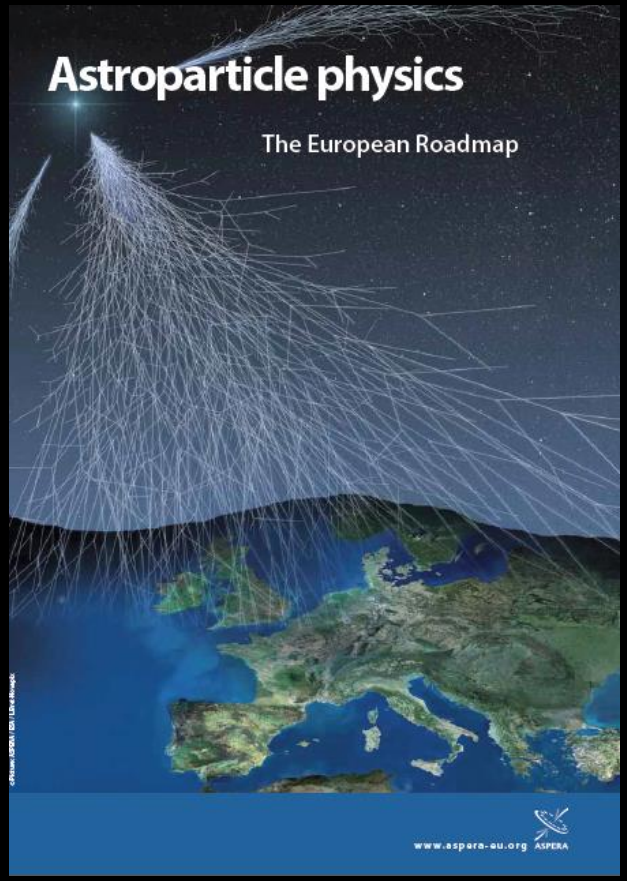
……

APPEC *roadmapping*

2008



2011



2.4 High-energy neutrinos

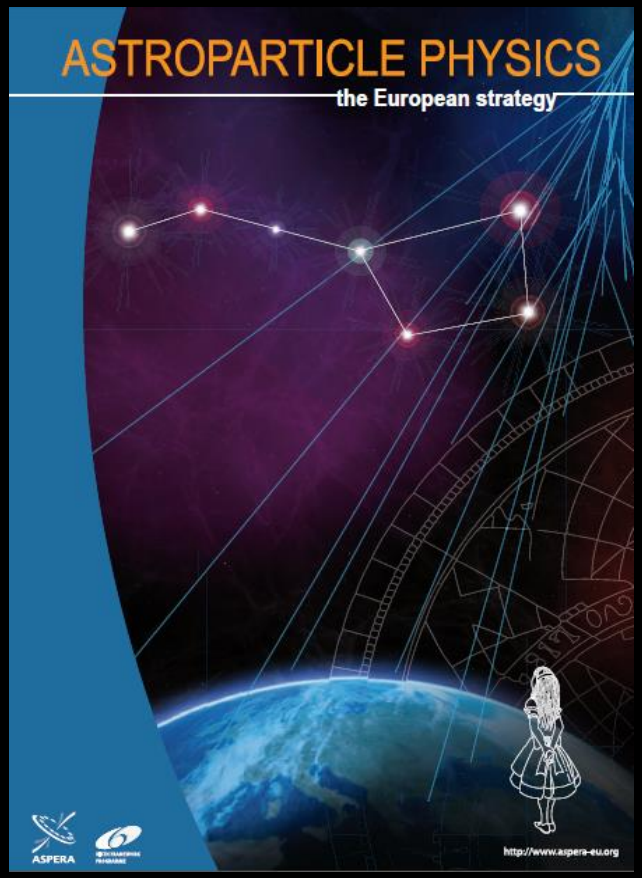
……

However, whereas neutrino astronomy in the MeV energy domain has been established with the impressive observation of neutrinos from the Sun and Supernova SN1987A, extraterrestrial neutrinos with energies of GeV and above, which must accompany the production of high-energy cosmic rays, still await discovery.

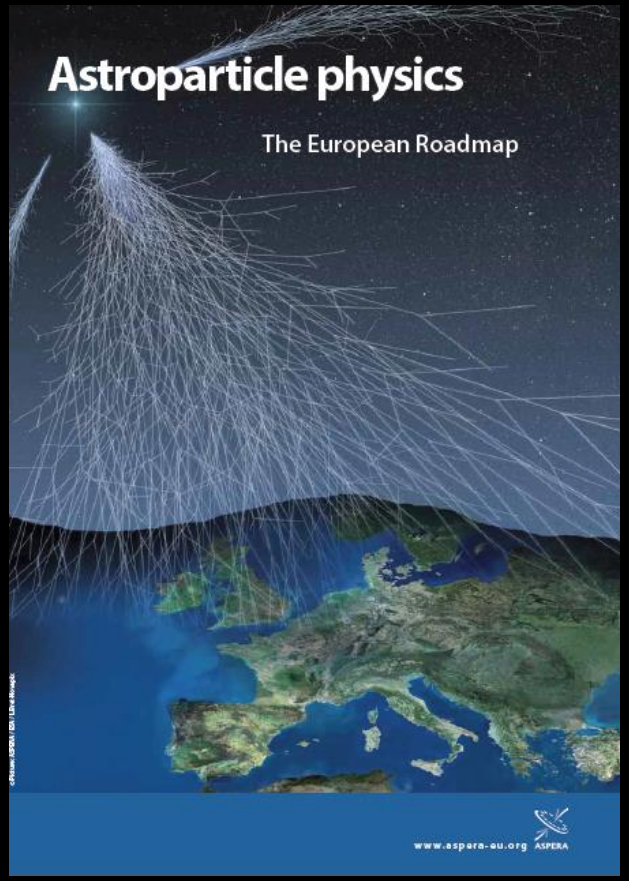
……

APPEC *roadmapping*

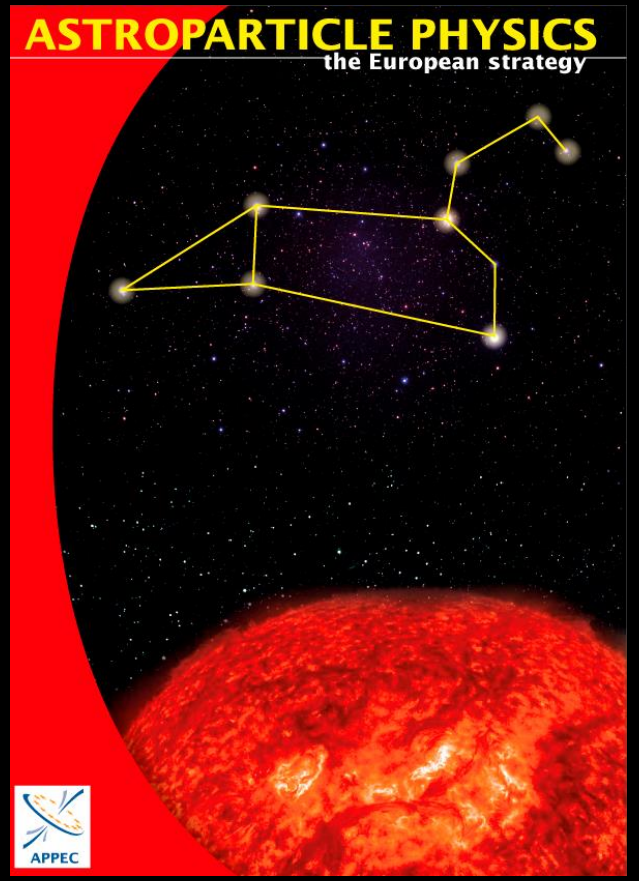
2008



2011

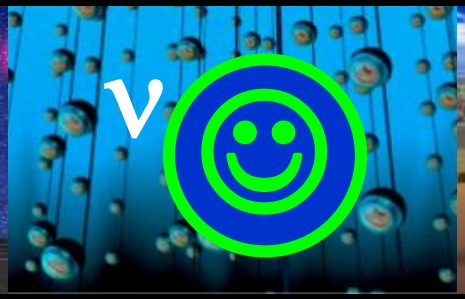


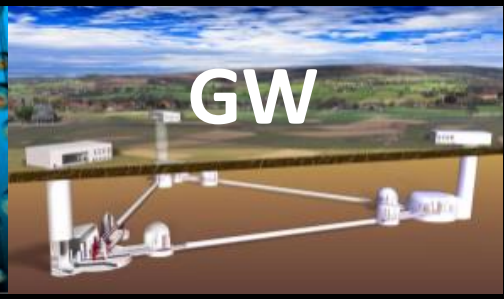
2016?



APPEC *research themes*

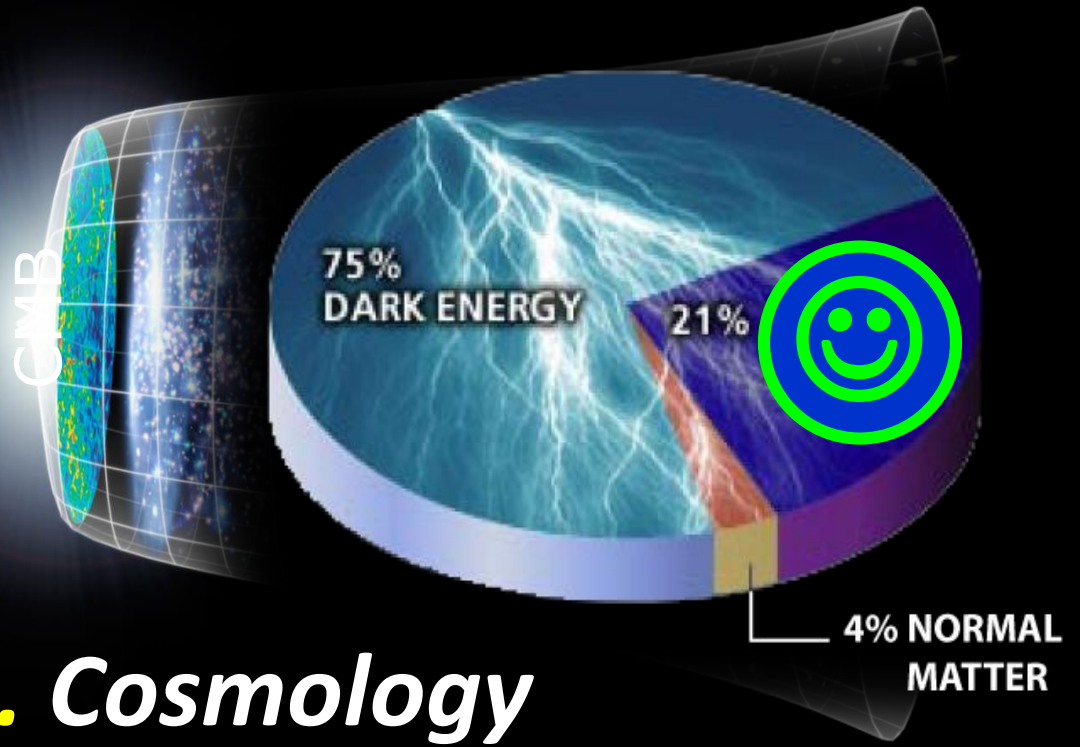
1. High-energy Universe: multi-messengers





2. Neutrino's

3. Cosmology



APPEC roadmap: *contents/timeline*

APPEC view → final roadmap. Remainder: as Frank Linde, not as APPEC Chair.

- *Executive summary*
- *Introduction*
- *Research themes (3)*
- *Theory, R&D, Computing*
- *EU APP community*
- *Global aspects*
- *Societal relevance*
- *Inter-disciplinary aspects*
- *Organizational aspects*
- *Recommendations*

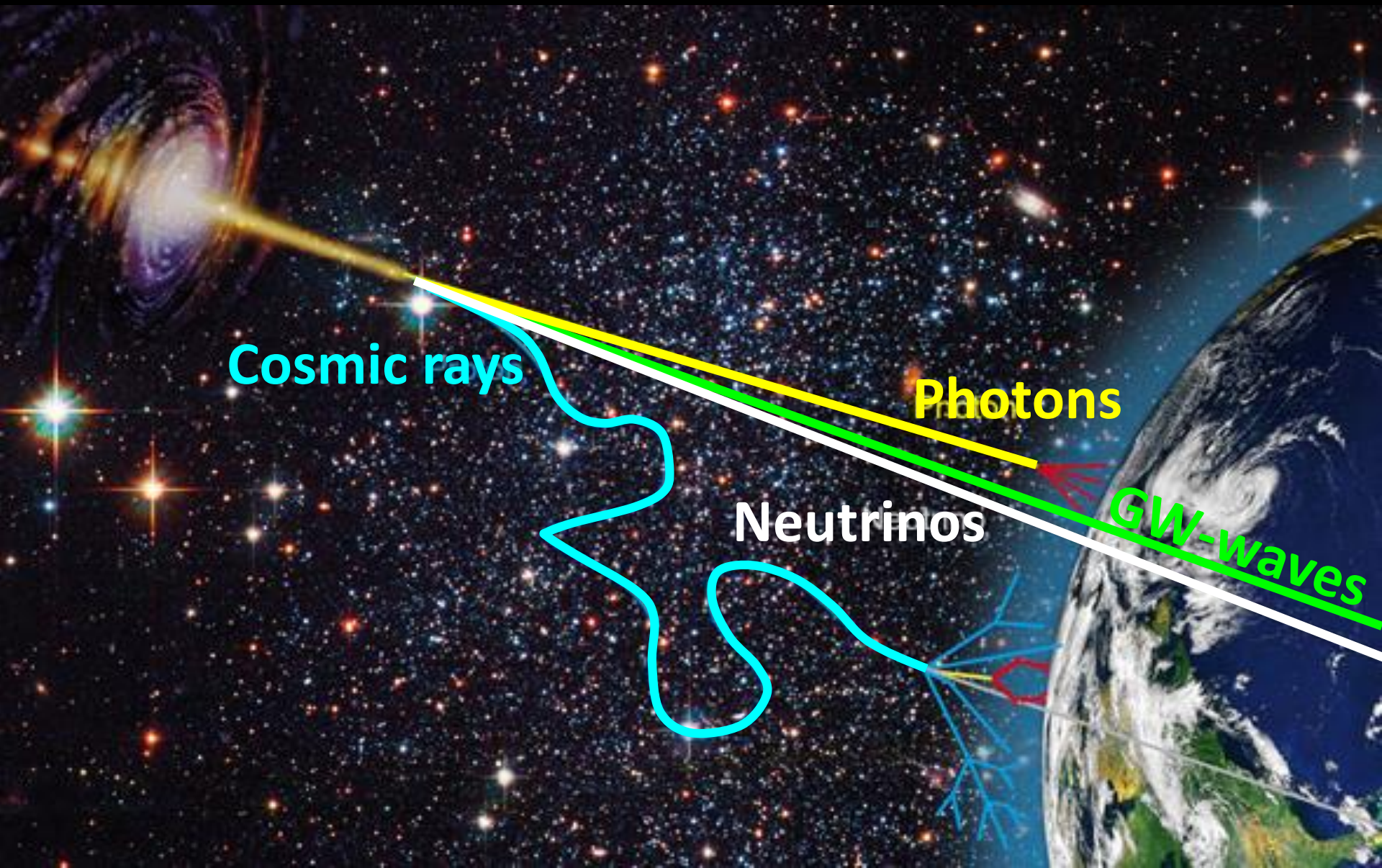
→ draft roadmap
SAC & APPEC-GA

→ town meeting
anyone interested

→ final roadmap

→ *roadmap implementation!*

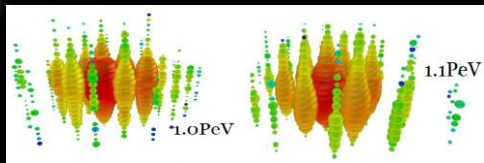
HE-universe: *multi messengers*



Breakthroughs - I

ICECUBE

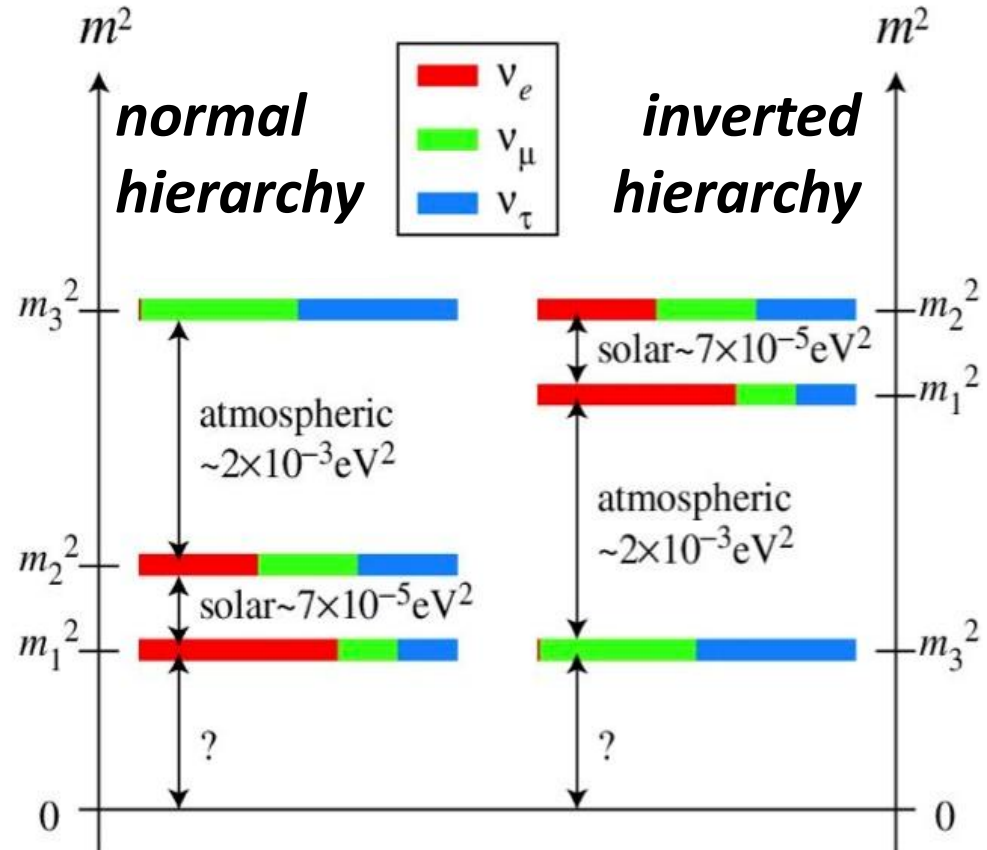
'PeV' ν-astronomy on our doorstep!



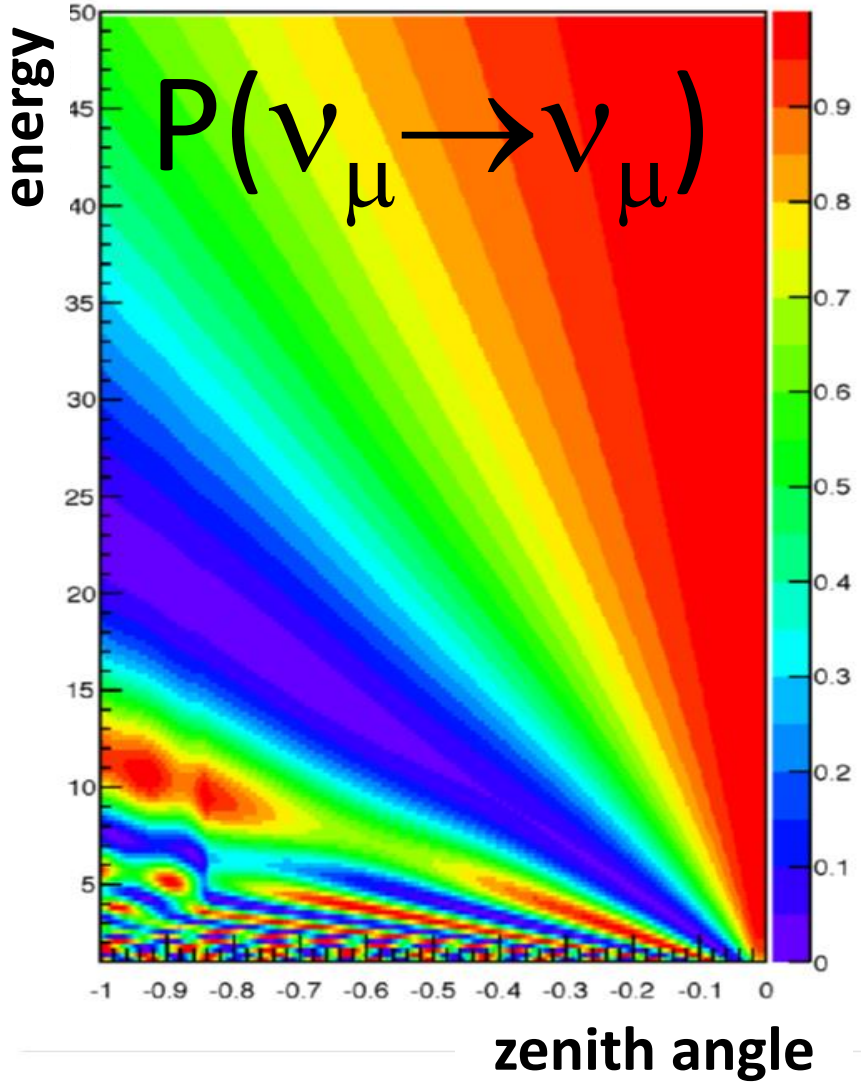
Francis: Congratulations with the Balzan Prize!

Breakthroughs - II

ICECUBE/PINGU
KM3NeT/ORCA



normal hiearchy



Breakthroughs - III

Breakthroughs - IV

GVD

CERN Courier July/August 2015

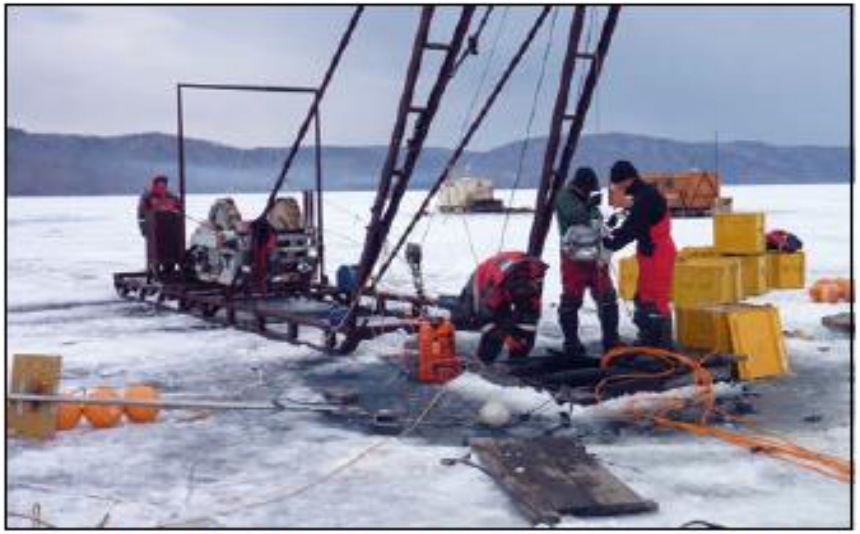
Detectors

A new neutrino telescope for Lake Baikal

deployment started

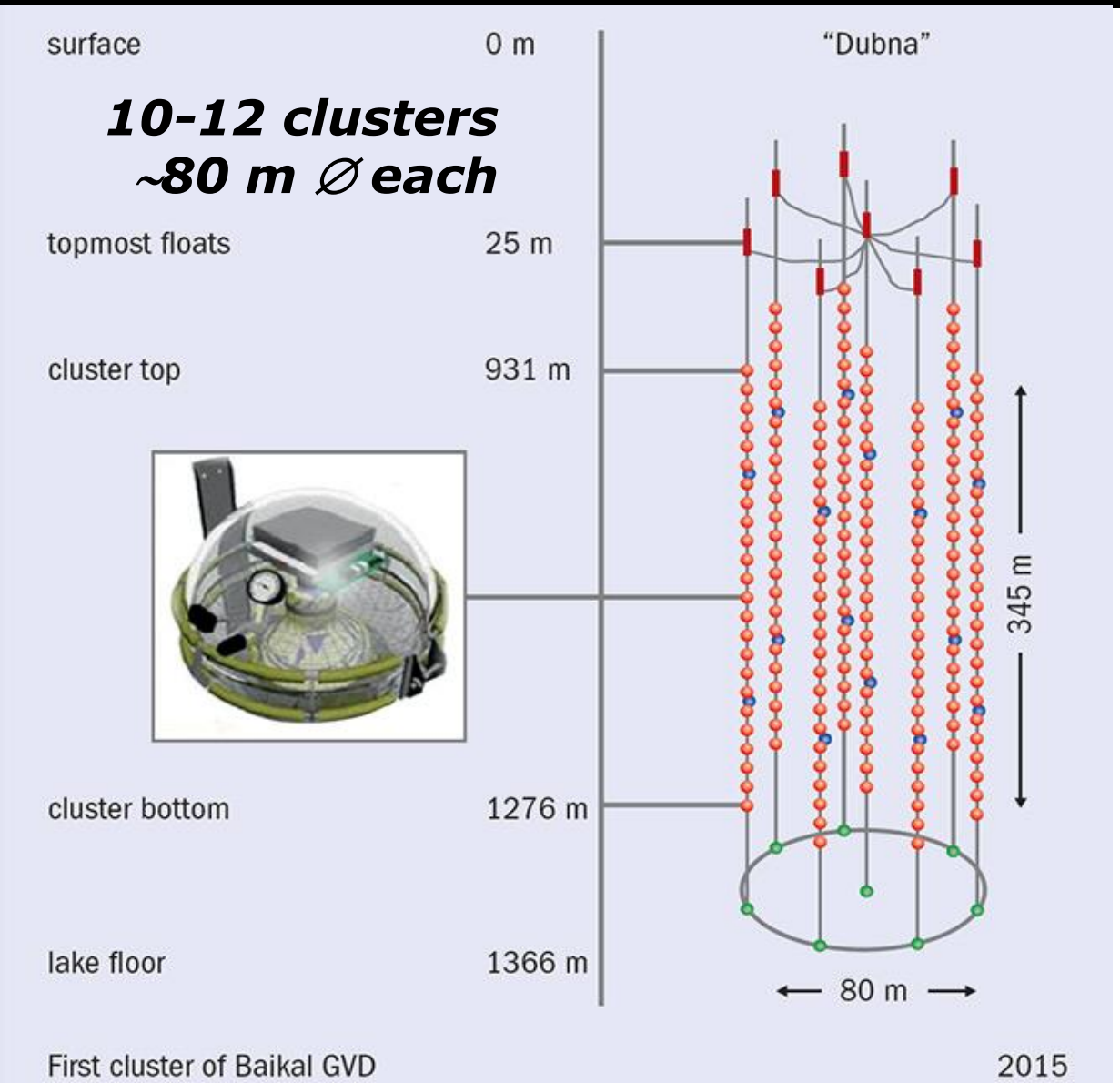
Baikal-GVD takes the first step to becoming a next-generation deep-underwater neutrino telescope.

In early April, members of the Baikal collaboration deployed and started operation of the first cluster of the Gigaton Volume Detector (Baikal-GVD). Named "Dubna", the cluster comprises 192 optical modules arranged at depths down to 1300 m. The modules are glass spheres that house photomultiplier tubes to detect Cherenkov light from the charged particles emerging from neutrino interactions in the water of the lake. By 2020, GVD is set to consist of 10–12 clusters covering a total volume of about 0.4 km^3 (GVD phase-1). This is about half the size of the present world leader – the IceCube



Assembling strings of optical modules. (Image credit: INR RAS.)

‘Simplistic’ view: *do it all (fine!)*



ICECUBE:

10 km³ volume

PINGU infill

≥2020 *O(100M$)*

schedules driven by funding …

Current status

- ICECUBE
  Has established itself as a global collaboration successfully operating a HE ν-telescope deep in the Antarctic ice. *Discovered PeV neutrinos.*
- GVD
  Deployed its first cluster (8 lines) in Lake Baikal.
- KM3NeT (follow-up of ANTARES, NEMO, NESTOR)
  Collaboration established. Technical design approved, ready for implementation.
  First full scale string will be deployed in the Mediterranean Sea in November 2015.

Observations - I

1. ν-telescopes are an essential & integral part of the multi-messenger (astronomy) program and with the discovery of PeV neutrinos the excitement is tangible
   $\rightarrow$ *it is time for the next steps in volume & coverage*
2. ν-mass hierarchy is main stream particle physics &
   --- *provided the funding becomes available soon* ---
   PINGU and/or ORCA could decide this issue!
   If delayed: be aware of JUNO (China), DUNE (USA), …
   $\rightarrow$ *PINGU and/or ORCA should not be delayed*

Hence:

the science case for ν-telescopes is excellent <u>NOW</u>

personal note: I love indirect DM searches as well

Observations - II

3. Multiple versus single experiment
   (multiple is always better … but … costs more money)
   - HE (ν-astronomy) :
     * *important to cover full hemisphere $\rightarrow \geq$2 experiments*
     * *important to cross-check systematics (water $\leftrightarrow$ ice)*
     * *detector volume &* $\Delta\theta^{(2)}$ are crucial
   - LE (ν-mass hierarchy, …):
     * detector volume, PID, ΔE & $\Delta\theta$ are important
     * *atmospheric ν's have little geographic preference*

My guess: APPEC roadmap will comment on multiple $\leftrightarrow$ single experiment issue (in particular in view of investment funding)

Observations - IIIa

4. Next steps … funding is hard to get …

– ICECUBE:

** **present ICECUBE – IC86 since 2011:***

- is leading the ν-telescope field

** several **ICECUBE upgrades are considered:***

- PINGU dense array for ν-mass hierarchy

- 10 km^3 sparse array for ν-astronomy/(GZK ν's?)

- larger ICETOP surface array? …

as far as I know no "formal/specific" funding requests have been submitted yet.

Observations - IIIb

4. Next steps … funding is hard to get …
   - KM3NeT:
     * ***KM3NeT phase-1:***
       - 31 strings + seafloor netwerk (~30 M€)
       is ongoing and will be completed in 2016
     * ***KM3NeT 2.0:***
       - ARCA HE array (2×115 strings, 1-2 km^3) in Italy
       - ORCA LE array (115 strings) in France
       could follow immediately, provided submitted funding requests (~90 M€) are largely granted

Investment funding

- Unlikely to expect hat all upgrade ambitions will be funded within the requested/desirable time frame
- Exploitation expenses are attracting attention
  (in my opinion: excellent & positive for you)
- (total) cost $\leftrightarrow$ performance comparisons will eventually have to be made, but … *Not easy to pool funding …*
  - *Various funding sources tied to a particular location*
  - *Collaborations have heavily invested in "their" site: South Pole, Mediterranean Sea & Lake Baikal*

My guess: APPEC roadmap will include a recommendation to charge a dedicated committee to help to make progress in the field of on ν-telescopes by 2020 (I agree: cheap …)

My recommendations

To the community:

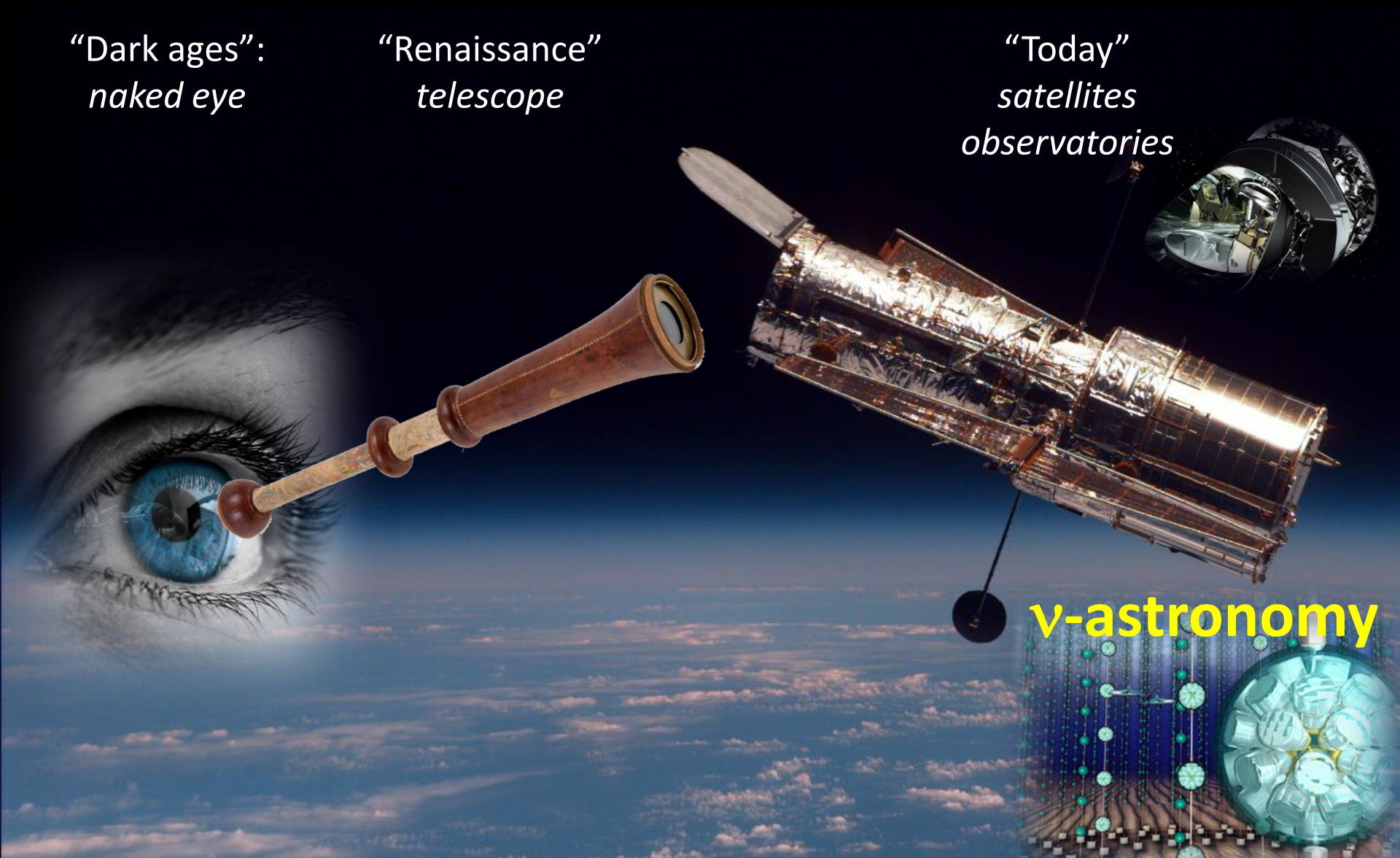
- *It is time to scale-up ν-telescope instrumentation both in view of the HE (PeV) ν-astronomy (sources!) & in view of the ν-mass hierarchy opportunity (I do not need to tell you … I know)*
- *In particular regarding the ν-mass hierarchy option it might be advisable/necessary to join forces (GNN) to avoid delays & risk to become #2 (JUNO? DUNE?)*
- *Low, Order(2%), exploitation expenses are a major advantage, make it come thru and rub it in!*
- *KM3NeT: you deserve a bonus for securing substantial regional/structural EU funding!*

My recommendations

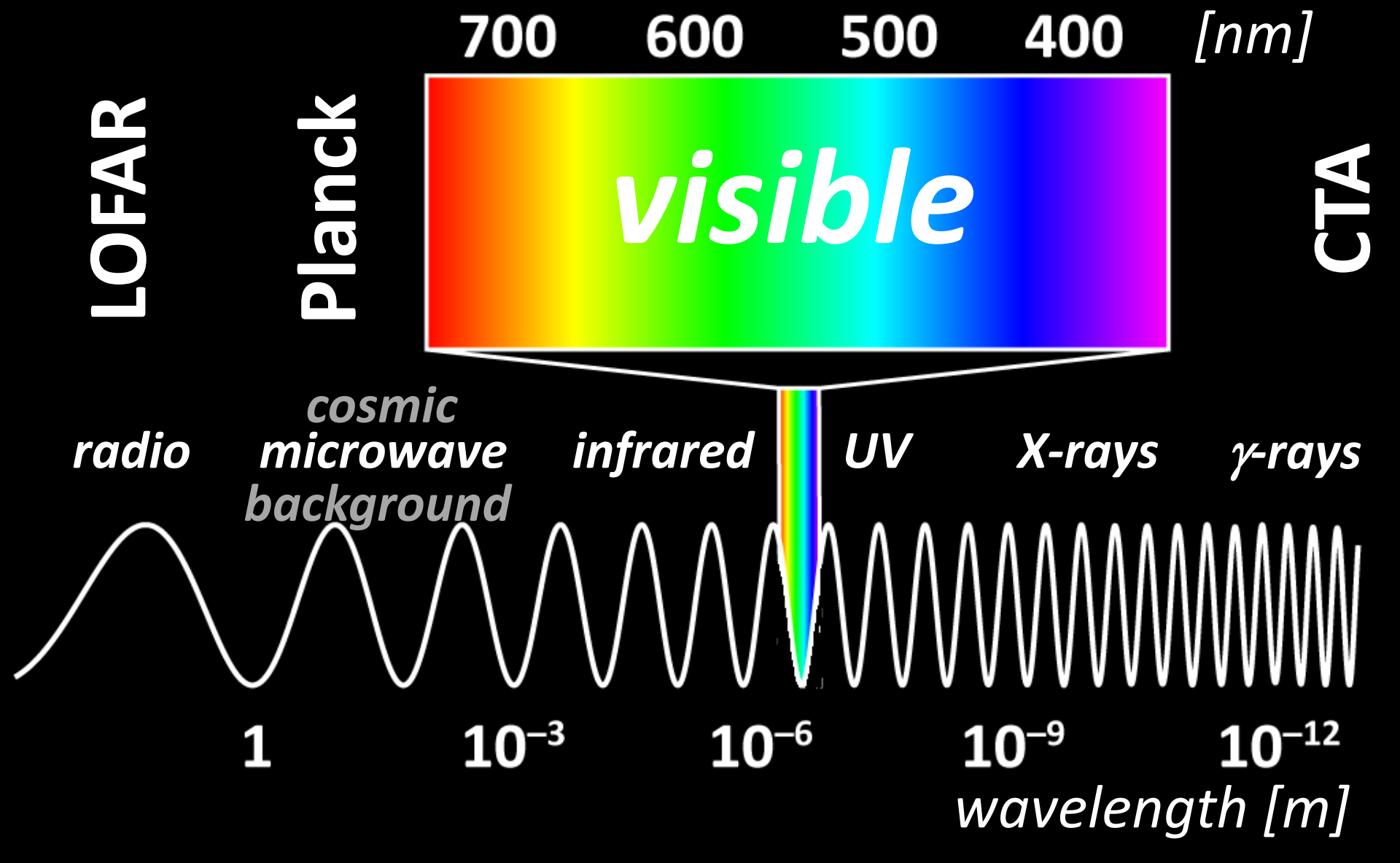
To our (European) funding agencies:

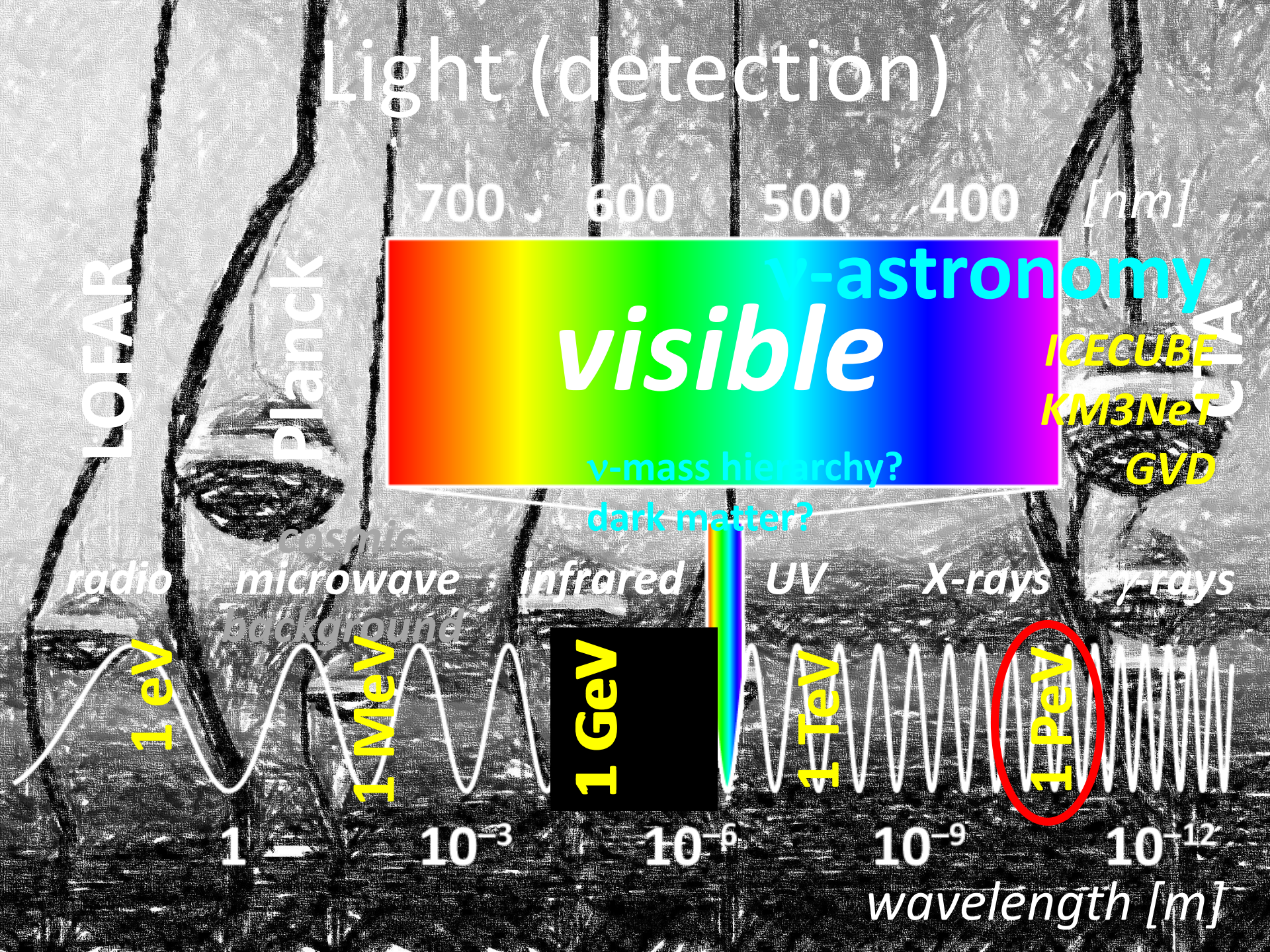
- *Realise that ν-telescopes open a new and exciting window onto our universe. Exciting science. <u>NOW</u>*
- *Specifically for KM3NeT:*
  - *do not rely primarily on regional/structural funds. ν-telescopes deserves substantial core funding as well*
  - *cherish facts that over time KM3NeT:*
    - *has reduced investment request from 220-250 M€ $\rightarrow$ 125 M€;*
    - *aims at 1-2 km^3 + ORCA compared to the original 1 km^3;*
    - *promises very modest exploitation expenses: Order(2%)*
    - *has an excellent & diverse scientific programme*

Millennia of e.m. astronomy …



Light (detection)




Light (detection)
700
600
500
400
[nm]
LOFAR
Planck
CTA
γ-astronomy
visible
ICECUBE
KM3NeT
GVD
ν-mass hierarchy?
dark matter?
cosmic
background
radio
microwave
infrared
UV
X-rays
γ-rays
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1 MeV
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1 TeV
1 PeV
1
10^{-3}
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wavelength [m]