

ET: Einstein Telescope

A new gateway to knowledge

T. Csörgő

MTA Wigner RCP, Budapest,
KRF, Gyöngyös, Hungary



<http://wpcf2014.karolyrobert.hu/>

<http://www.et-gw.eu/>



<http://epiphany.ifj.edu.pl/>

Einstein Telescope or the sounds of a Big Bang

How to make a perfect new telescope?

Far away mountain:

without scattered background light

must be high elevation

(min. moisture and noise from air conditions)

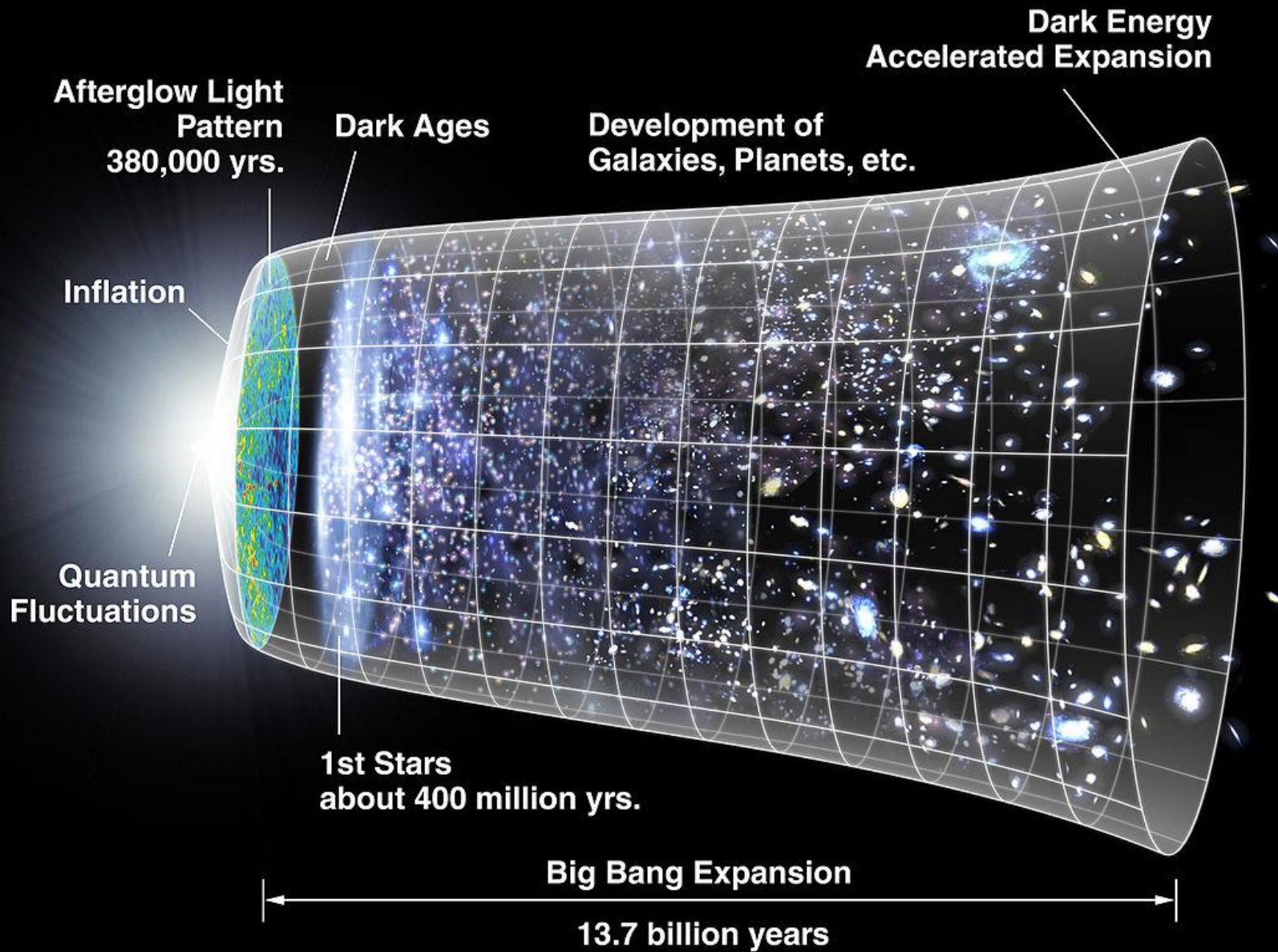
giant mirror needed

most modern light sensors

must look for primordial light sources

However...

Our Universe becomes transparent to light only $\sim 380\,000$ years after the Big Bang



Einstein „Stetoscope“ or the „sounds“ of the Big Bang

How to observe the Early Universe?

**Light cannot shed more light on the first
380 000 years: but gravitational waves can!**

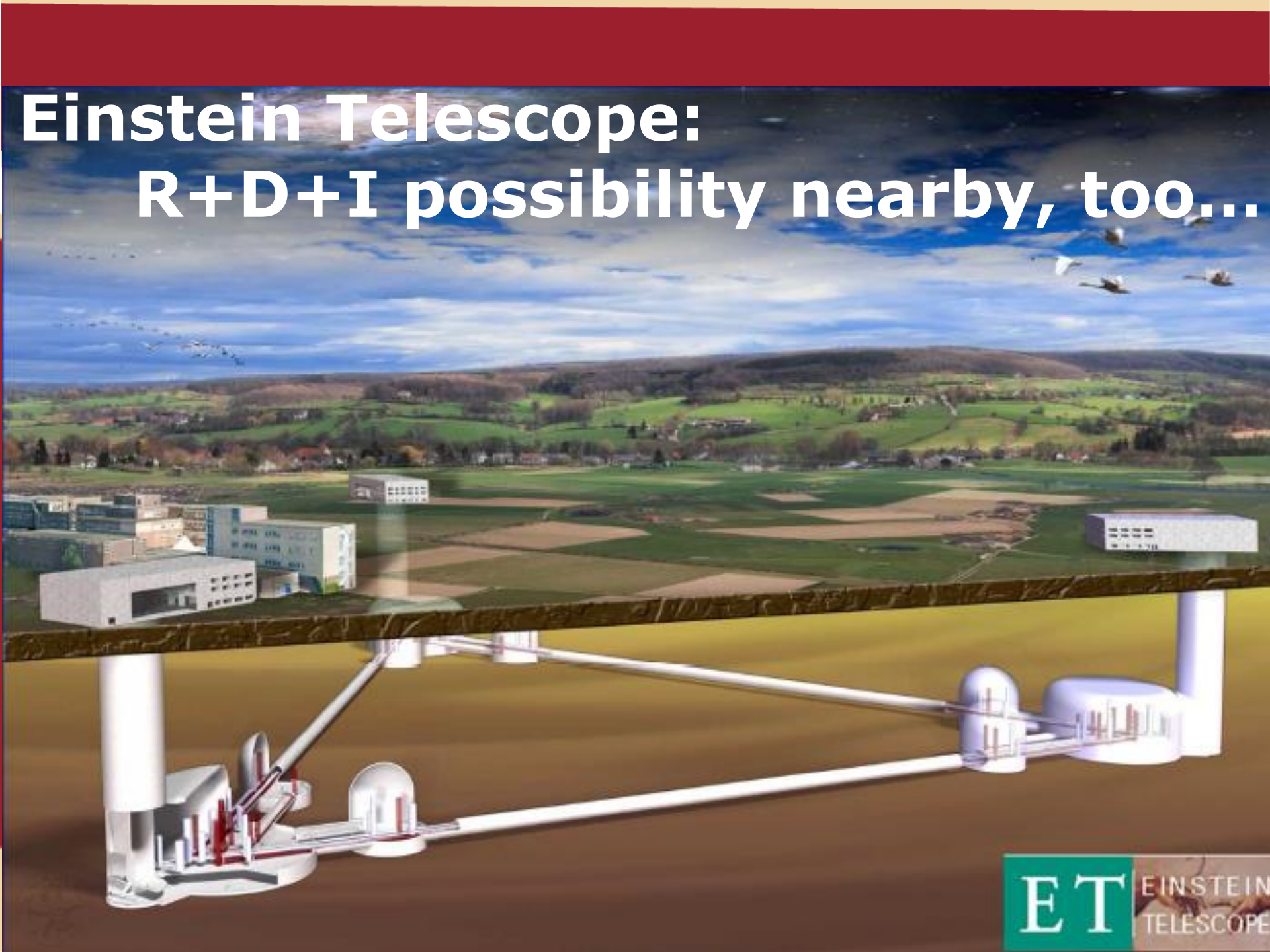
**a need for a place where there is minimal noise
underground (with minimal seismic noise)
large facility (10x10x10 km)
laser interferometer as sensor
to detect the tiniest ripples of space-time**

However...

Site can be also located on satellites...

Perhaps also on the South Pole ...

Einstein Telescope: R+D+I possibility nearby, too...



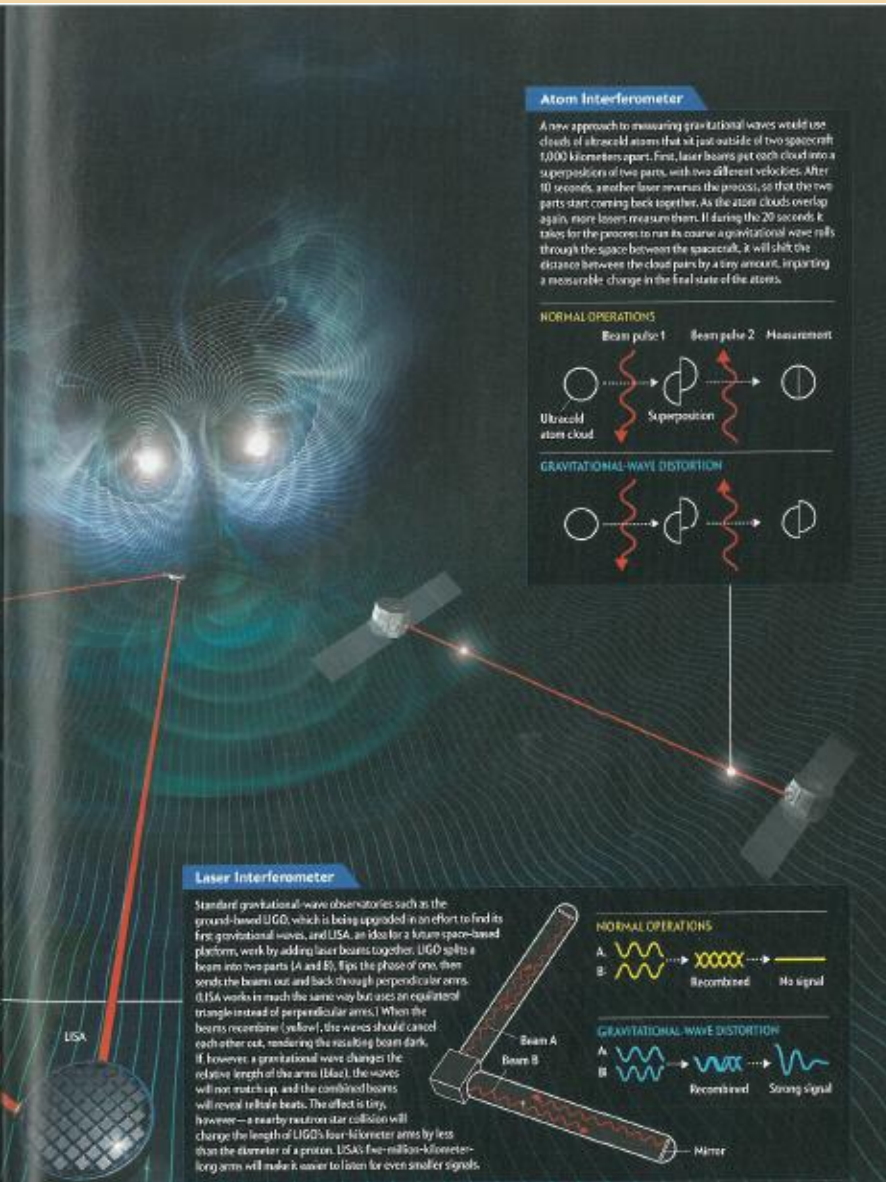
LISA: satellite system, an „ear“ To listen to the Big Bang

HOW IT WORKS

The Universe According to Gravitational Waves

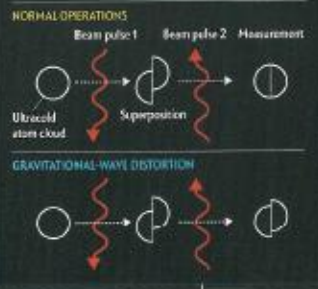
Albert Einstein taught us that matter and energy can bend the very fabric of spacetime. Move enough mass, and the motion will create spacetime ripples that undulate across the universe. Such gravitational waves are the only way we can observe events that cannot be seen using light—the crash of two black holes, for example, or the tumult of quantum fluctuations in the nanoseconds after the big bang.

Big bang echoes will be exceptionally difficult to detect, however, only a space-based observatory would be up to the task. The two concepts on this page are the drawing-board versions of a future mission that would have the power to hear the universe's first echoes.



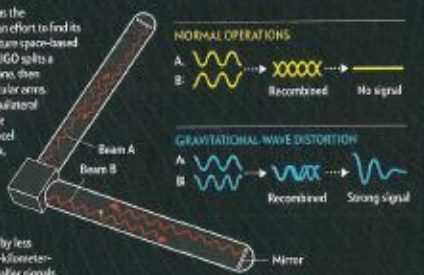
Atom Interferometer

A new approach to measuring gravitational waves would use clouds of ultracold atoms that sit just outside of two spacecraft 1,000 kilometers apart. First, laser beams get each cloud into a superposition of two parts, with two different velocities. After 10 seconds, another laser reverses the process, so that the two parts start coming back together. As the atom clouds overlap again, more lasers measure them. If during the 20 seconds it takes for the process to run its course a gravitational wave ripples through the space between the spacecraft, it will shift the distance between the cloud pairs by a tiny amount, imparting a measurable change in the final state of the atoms.



Laser Interferometer

Standard gravitational-wave observatories such as the ground-based LIGO, which is being upgraded in an effort to find its first gravitational waves, and LISA, an idea for a future space-based platform, work by adding laser beams together. LIGO splits a beam into two parts (A and B), flips the phase of one, then sends the beams out and back through perpendicular arms. LISA works in much the same way but uses an equilateral triangle instead of perpendicular arms. When the beams recombine (yellow), the waves should cancel each other out, rendering the resulting beam dark. If however a gravitational wave changes the relative length of the arms (blue), the waves will not match up, and the combined beams will reveal a little beats. The effect is tiny, however—a nearby neutron star collision will change the length of LIGO's four-kilometer arms by less than the diameter of a proton. LISA's five-million-kilometer-long arm will make it easier to listen for even smaller signals.



- Length scales: 5 million km equilateral triangle
- Laser or atom interferometer
- Design phase (NASA)
- Main advantage: sensitivity
- Drawback: expensive & far away

BICEP2: On the South Pole

First indirect observation of GW

Whispers from Creation

The recent discovery of gravitational waves emerging from the big bang may point a way forward



DARK POLE: Telescopes at the South Pole search for clues about the universe's first moments.

Start of a new era?

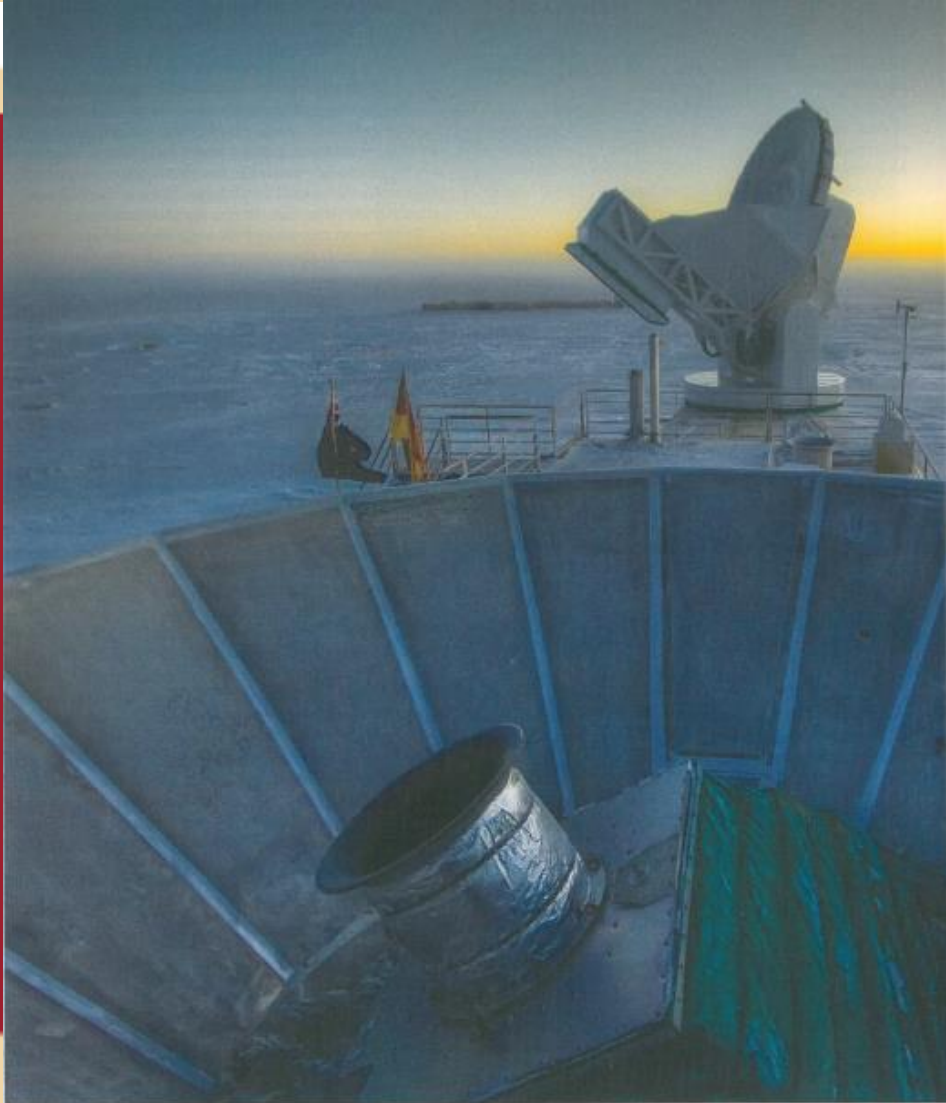
**Main result:
First indirect
observation of
Early Universe**

**Drawback:
Results to be
confirmed**

**1-2 years from now:
Control
measurements
to be published**

BICEP2:

Polarized light: indirect observation



POLAR EYES: The BICEP2 telescope at the Amundsen-Scott South Pole Station observed the same small patch of sky from January 2010 through December 2012, searching for signatures of primordial gravitational waves in ancient light.

Discovery potential:

UNIverse?

Or, possibly, a

MULTIverse, World of Worlds?

**Big Bang, or
Big Bangs?**

**1-2 years from now:
Control measurements to be
analyzed**

Back to Europe: „GW-Stetoscope“ The VIRGO GW detector in Italy



Olaszország, Tuscany, Cascina

2 arms, 3 km each, laser interferometer realized

First generation stage passed, no discovery yet

1-2 years: 2nd generation

Existing GW detectors: LIGO, VIRGO, GEO, Indigo, KAGRA



LIGO

LIGO Hanford, 4 km:
2 ITF at the same site!



LIGO

LIGO Livingston, 4 km

GEO, Hannover, 600 m



VIRGO

Virgo, Cascina, 3 km



KAGRA, Kamioka,
3 km, 2.5 gen.



America, Germany, Italy, India, Japan:

Who will be the first to observe gravitational waves directly?

EU: a chance for Central Europe

Favourable geography nearby

Why the 3rd Generation?

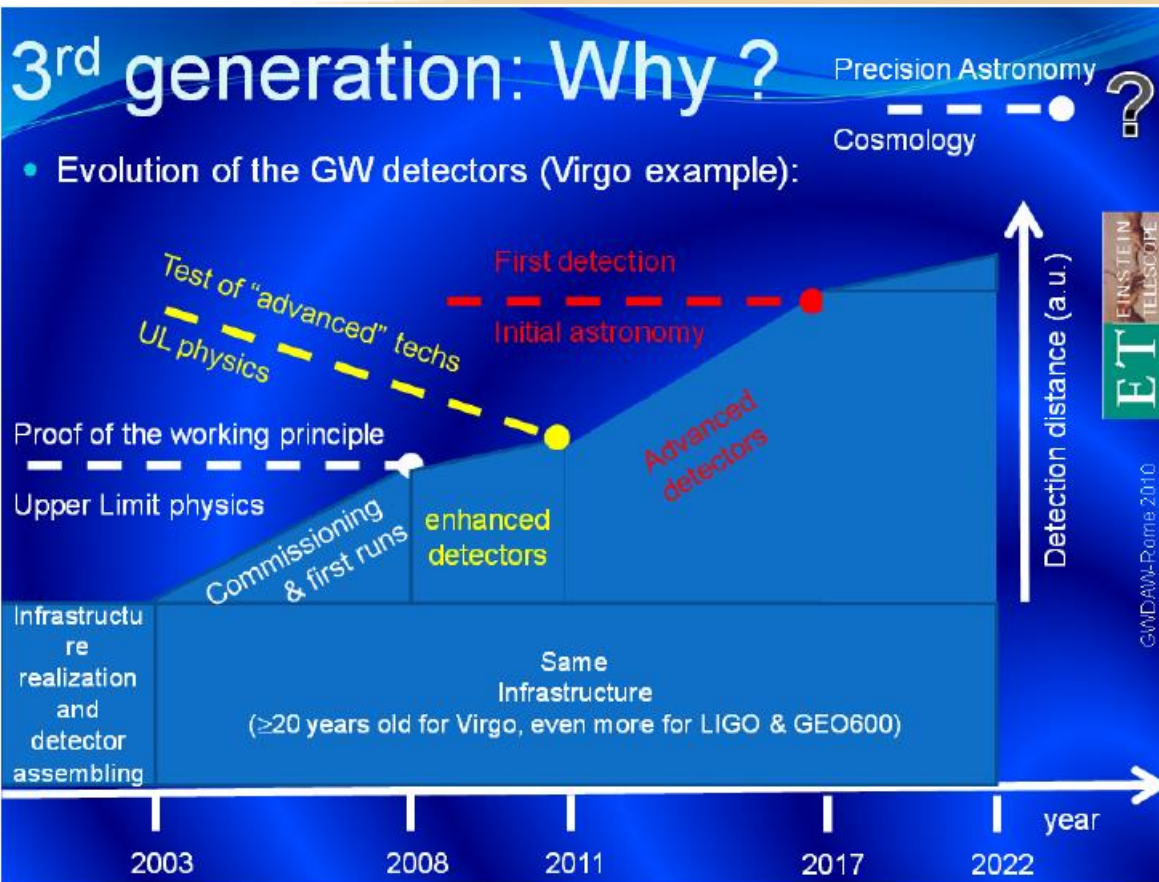


Figure 1: Evolution of the first and second generation GW detectors. Time is on the horizontal axis, detector performance in the vertical one. When the advanced detectors will be operative the hosting infrastructures will be more than 20 years old and any further improvement of performance (sensitivity) will be suppressed by the limitation imposed by the infrastructures. (slide presented by M. Punturo at the GWDAAW meeting, Rome Jan. 2010).

First generation:
Goal: test of operation (worked)

Second generation
Goal: direct observation, discovery

Very precise detectors are needed to study some of the basic questions, e.g.

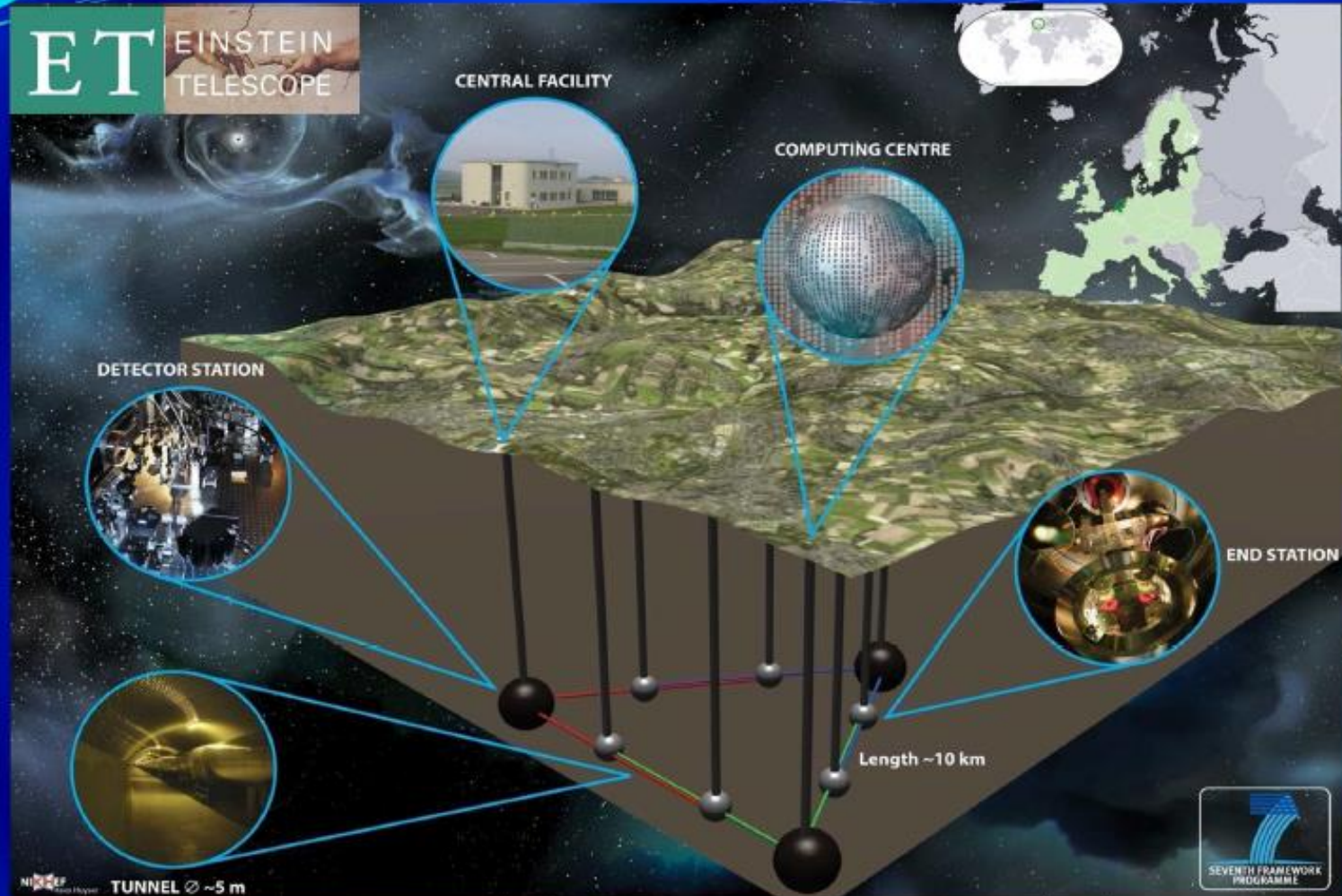
How boils the Quark Gluon Plasma in the Early Universe?

1 -> 2 ->
3rd generation of detectors

Einstein Telescope:
site selection in progress

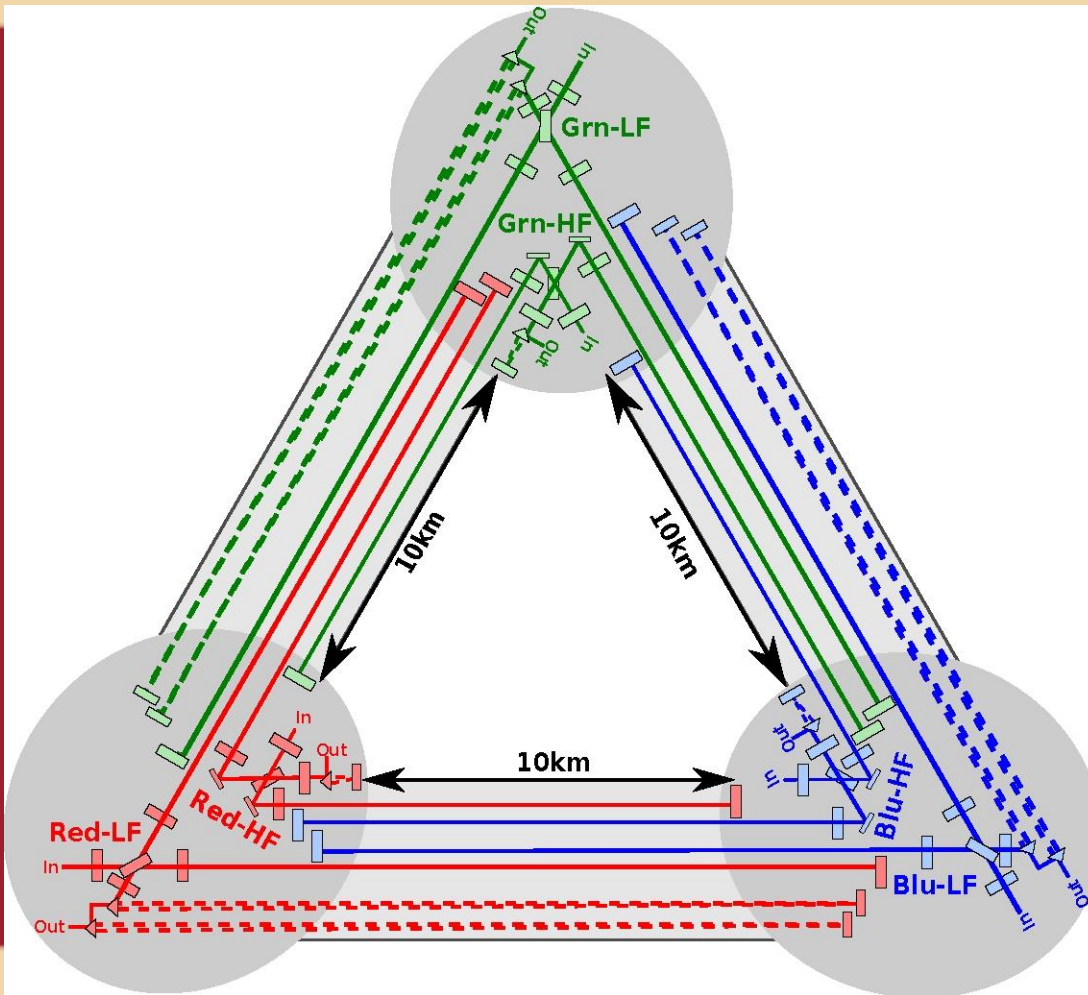
EGO and the ET project

European Gravitational Observatory



To reduce the gravity gradient noise and to achieve the desired precision an underground infrastructure is needed

Technical details



VIRGO: 3 km + 3 km
LIGO: 2x(4 km + 4 km)

ET: 10 km x 10 km x 10 km

2nd generation:
Few events / 10 years

3rd generation:
Few hundreds of events / year

For example, collisions of
Black holes

ET: site selection in progress
Shortlisted:

- Corsica (France)**
- Pirennians (Spain)**
- Mátra hills (Hungary)**

A possibility for top level V4
collaboration for
Visegrad counties
(Czech R., Hungary, Poland, Slovakia)

ET project, roadmap

The usual steps of constructing a research infrastructure

- **Preparatory Phase – A 2008–11**

Conceptual Design Study
(Published on 20 May 2011, Cascina, Italy)
Funded by EC FP7 by 3 M€

- **Preparatory Phase – B 2012–16**

Aspera, Elites, GraWIToN

- 3rd ASPERA common call:
The project officially started May 2013 and lasts for three years
Essential R&D tasks in preparation for a technical design phase
Funded by Aspera 1.2M€

- Elites: for 4 years, March 2012 – February 2016
Focused on the common aspects of KAGRA and ET

- GraWIToN is a FP7 ITN (Initial Training Network)
Starts February 2014 for 4 years, Funded by EC with ~ 3.7M€

- **Implementation Phase 2017–21**

Supporting funds ??? and licenses

The ESFRI list is going to be refreshed: 2016-17
ET is an excellent candidate but feasibility report will require
guaranties from involved States

- **Construction Phase 2022–26 (???)**

We have to be prepared in time!



ET R&D Participants

Participants	Country	Legal Entity Name	Department/Division/laboratory
Full Partners	Netherlands	NIKHEF: National Institute for subatomic Physics	
	Germany	LUH-AEI: Leibniz Universität Hannover, Albert Einstein Institut	Institut für Gravitationsphysik
		FSU: Friedrich-Schiller-Universität Jena	Institut für Festkörperphysik
	Russia	The Russian ET Consortium	MSU-SAI: Moscow State University, Sternberg Astronomical Institute (lead) MSU-PD: Moscow State University, Physics Department INR RAS: Institute of Nuclear Research Russian Academy of Science
	Poland	The Polish ET Consortium	University of Warsaw (lead), University of Zielona Gora, University of Bialystok, Warsaw University of Technology, Polish Academy of Science (Inst. of Mathematics), Polish Academy of Science (Nicolaus Copernicus Astronomical Centre)
	United Kingdom	UNIBHAM: Birmingham University	School of Physics and Astronomy
		UNIGLASGOW: University of Glasgow	Institute for Gravitational Research
		UNICARDIFF: Cardiff University	School of Physics and Astronomy
		UWS: University of the West of Scotland	

Participants	Country	Legal Entity Name	Department/Division/laboratory	Scientist in Charge
Associated Partners	Italy	EGO: European Gravitational Observatory		M. Punturo
		UNIROMA1: University di Roma La Sapienza	Dipartimento di Fisica	F. Ricci
		INFN Napoli		F. Barone
		INFN Pisa		C. Bradaschia
	France	LMA: Centre national de la recherche scientifique	LMA Lyon	R. Flaminio
		ARTEMIS : Observatoire de la Côte d'Azur, Nice		T. Regimbau
	Hungary	RMKI: Hungarian Academy of Sciences	KFKI Research Institute for Particle and Nuclear Science	I. Racz (KFKI)
			Geodetic and Geophysical Research Institute	G. Papp (Geophys.)
	Russia	BNO RAS: Russian Academy of Science	Baksan Neutrino Observatory INR	V. V. Kuzminov

Poland: full member, participants from Warsaw

Hungary: associated member

Participation in Hungary: to be increased (Miskolc University, KRF)

ET plans for implementation

The implementation phase could be financed by **Horizon 2020** framework.

HORIZON 2020 – WORK PROGRAMME 2014-2015

European research infrastructures (including e-Infrastructures)

“Integrating gravitational wave research. This activity aims at integrating the communities of researchers studying gravitational waves and their astrophysical sources: both laser and atom interferometers with their extreme technological requirements; observations of gravitational-wave sources through electromagnetic waves and high-energy particles; numerical/theoretical studies of such sources. It should address also the computing and data handling needs of these communities.”

The EU – GW community, preparing a joint proposal

Expected amount of € per project:

- In FP7, 9-10M€
- In H2020, ? (rumors 8M€)

The community:

- **EGO – European Gravitational Observatory:** VIRGO detector, INFN & CNCR
- **AEI – Albert Einstein Institute, Hanover:** GEO600
- **NIKHEF – National Institute for subatomic Physics, Amsterdam**
- **UNIGLASGOW – University of Glasgow**
- **UNICARDIFF – Cardiff University**
- **FSU – Friedrich-Schiller-Universität Jena**
- **POLGRAW – Polish Academy of Sciences (12 – 15)**
- **WIGNER RCP (since 2009) – Hungarian Academy of Sciences**
 - (8 – 10) → **HUNGRAW** to increase our contribution

Germany
Netherlands
Russia
Poland
United Kingdom
Italy
France
Hungary

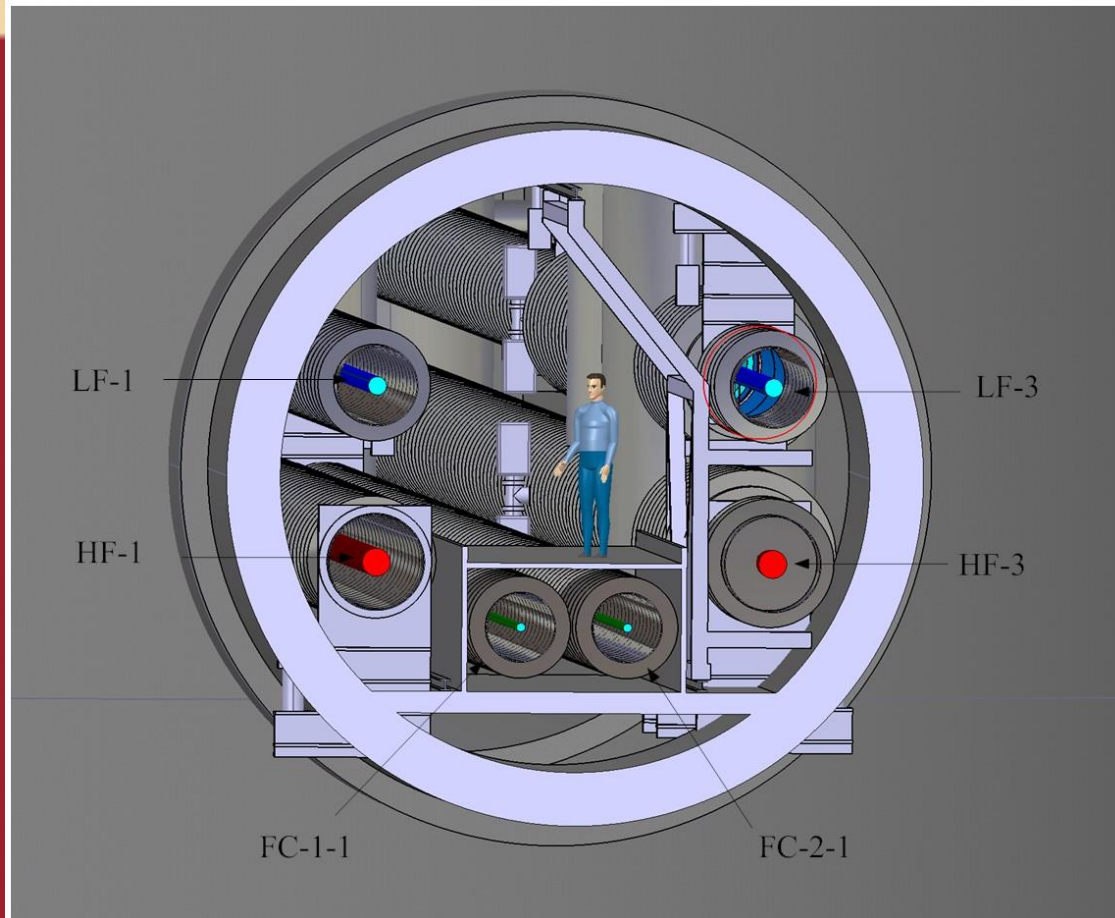
(250 – 300)

Local S3 projects:

Eger, Gyöngyös, Hatvan Regions (Mátra region) site support confirmed

ET: Hungarian S3 project for regional development

SUMMARY



ET: Einstein Telescope

**Instead of looking for light
Listening to gravitational waves
from the early Universe**

Biggest possible discovery:

Universe?

Or, possibly

MULTIverse, Word of Worlds?

Big Bang, or Big Bangs?

Promise:

**completion of Copernican idea,
in the broadest possible sense**

SUMMARY: ET for V4

