Compact binary sources of GWs

Vasúth Mátyás PhD, MTA Wigner FK

Leader of the Wigner VIRGO group

Wigner,
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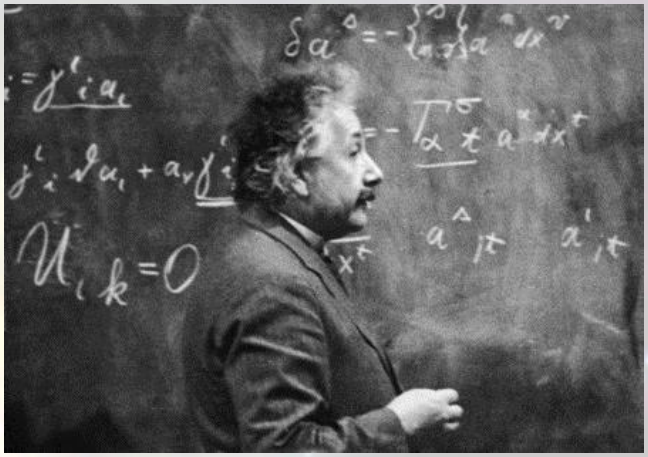
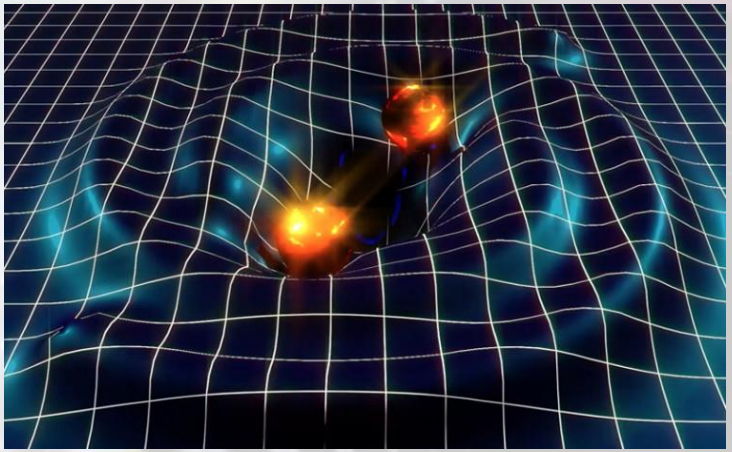
Gravitational waves

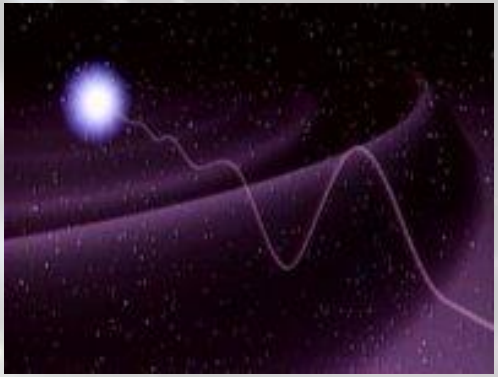


- General relativity, connects the Einstein tensor describing the curvature of spacetime with the energy momentum, representing the motion of the source

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



- Gravitational waves, change of the gravitational field which propagates with the speed of light, ripples in spacetime



- Linear approximation, far from the source GWs are described as perturbations of the flat metric

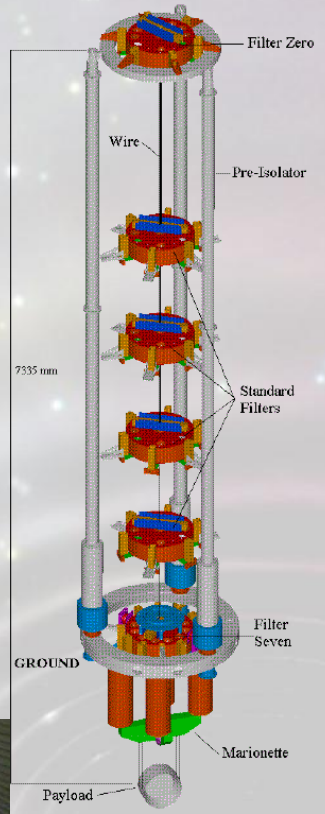
$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$\eta^{\rho\sigma} h^{\mu\nu}{}_{,\rho\sigma} = -16\pi\tau^{\mu\nu}$$

Observatories worldwide

VIRGO

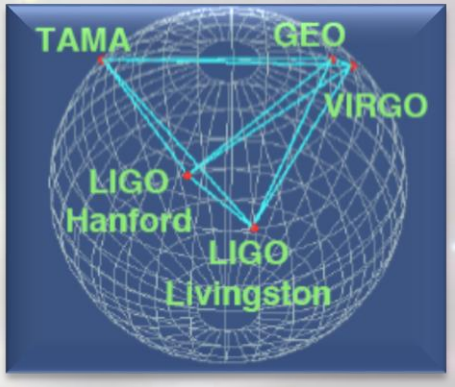
Arm length: 3 km



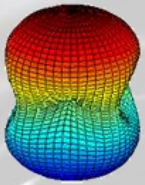
- Measurements: 2004 – 2011
- 6800 m^3, 10^{-10} mbar vacuum
- Sampling rate at 20 kHz, analysis at 4/16 kHz, 200 TB/detector data / year
- Seismic isolation (superattenuator) 10^{-9} - 10^{-13} attenuation (4 – 200 Hz)
- Under upgrade,
  First scientific measurements: 2016, O2

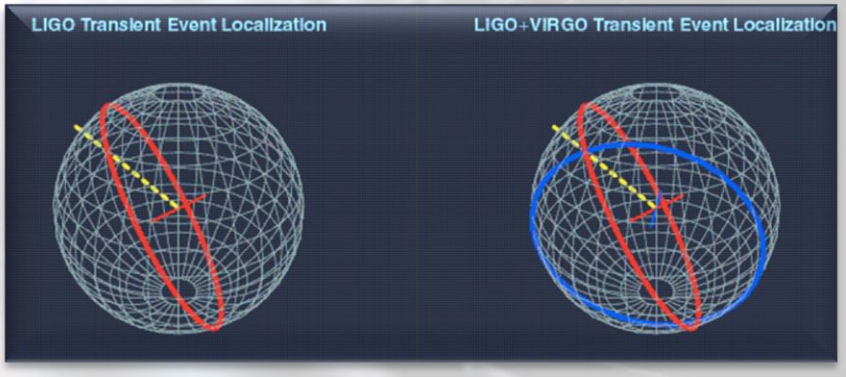
VIRGO

LV collaboration



- Worldwide network of GW detectors, collaboration between LIGO and Virgo since 2007, sharing of data, analysis methods, computational resources
- Coincidence measurements, filtering out false signals
- Accurate sky location

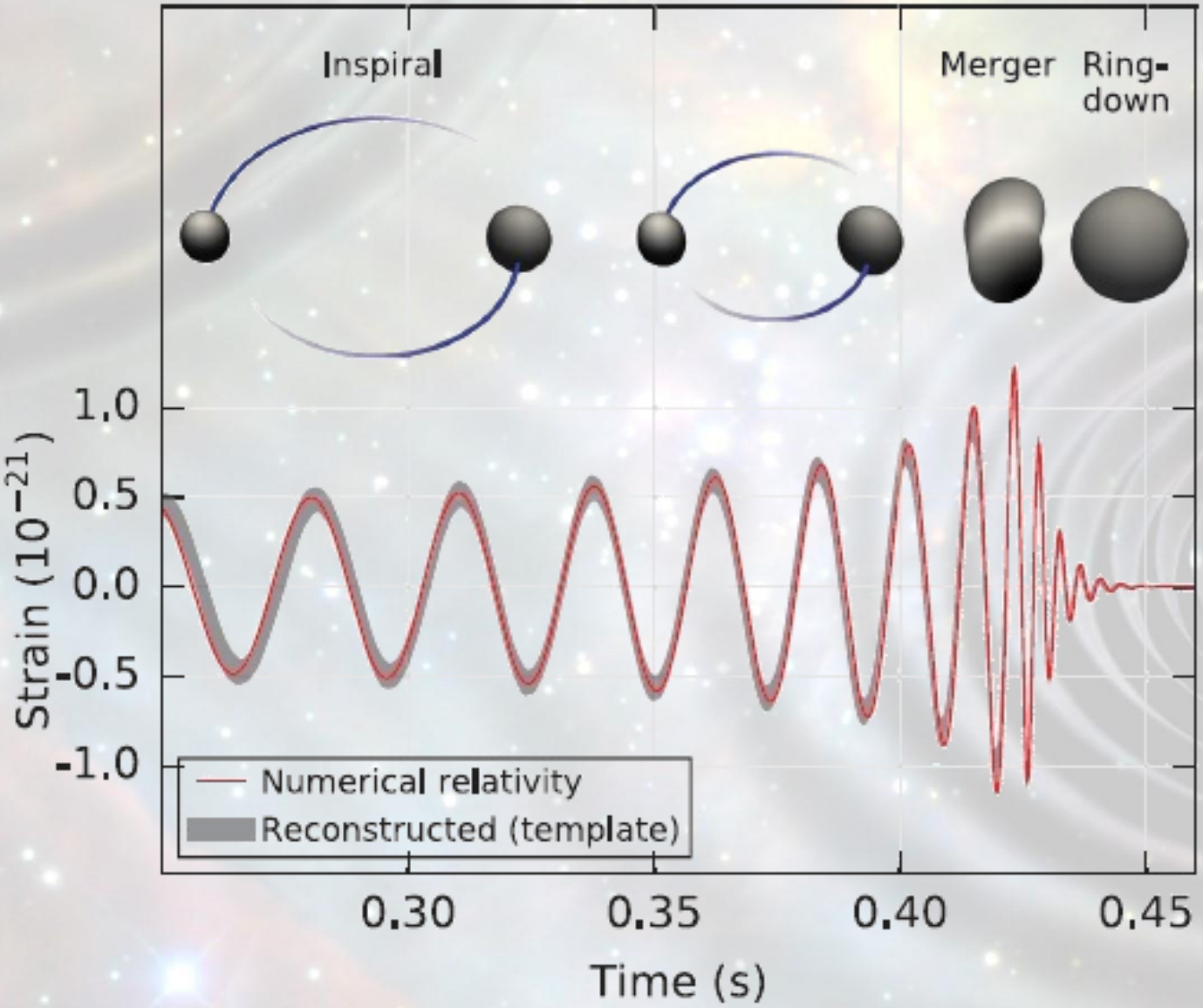




LSC LIGO Scientific Collaboration

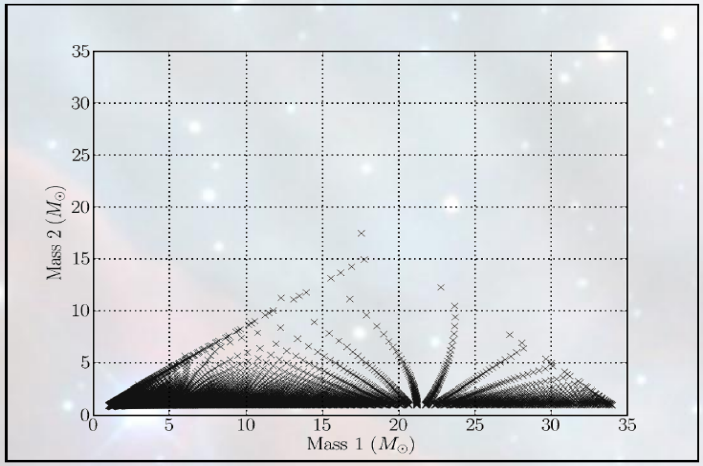
VIRGO

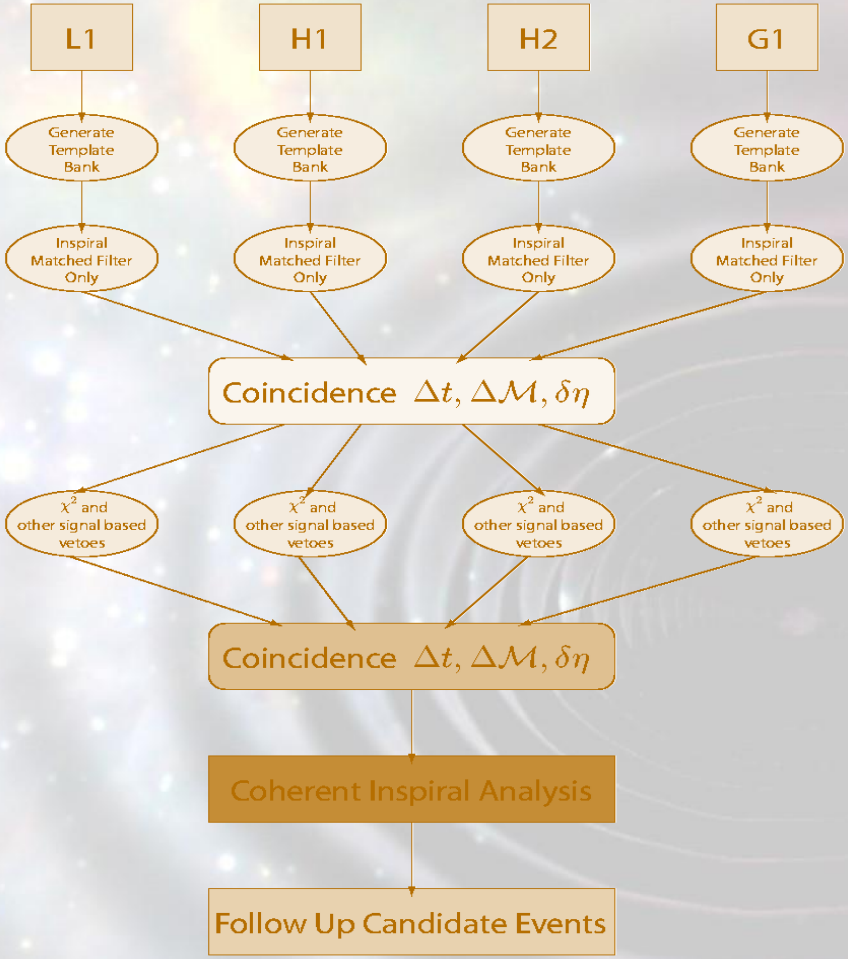
Data analysis



Data analysis – certified algorithms

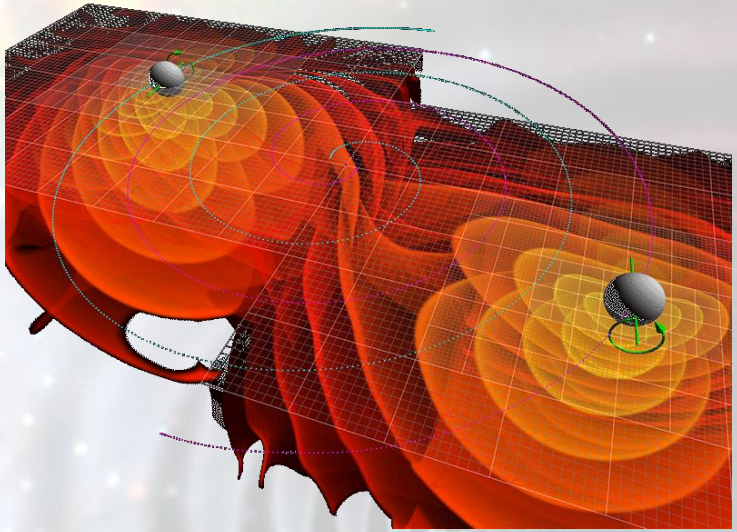
- Generation of waveform templates
  (a few % deviation, large parameter space)
- matched filtering
- grouping of coincident events
- χ^2 and other signal based tests
- In case of multiple coincidences other tests, …

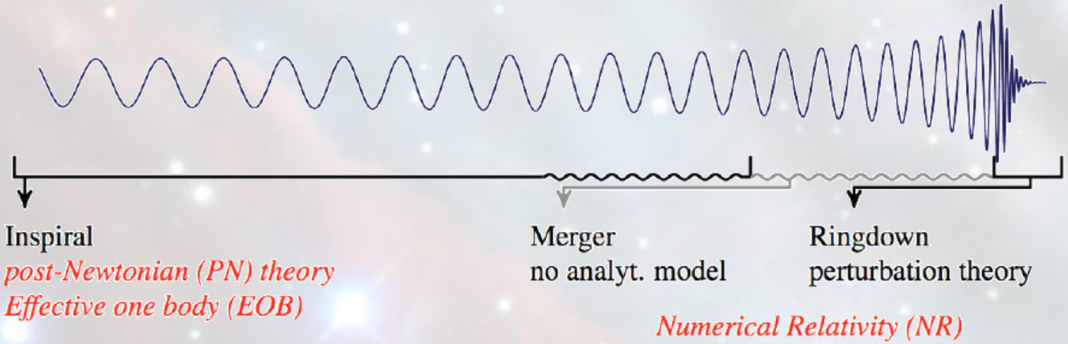




PyCBC

- Python software package for GW data analysis
- Searching for inspiralling compact binaries, matched filtering, post-Newtonian approximation, spinning components, IMR waveforms
- Many core applications, CPU/GPU
- Participation in the development
- Data analysis, parameter estimation





Data processing

- Participation in the development of the interconnectivity between different Grid infrastructures:

  EGI Grid ↔ OSG ↔ LDG

  - The recorded scientific data (160 TB/year/IF) of the Interferometers has to be transferred, processed, analyzed, etc.

  - Data analysis: Hannover, Bologna, Bp. and US clusters

- Development and implementation of search algorithms on GPUs (Graphical Processing Units, many core computing), which can be parallelized and/or independent calculations can be performed at the same time.

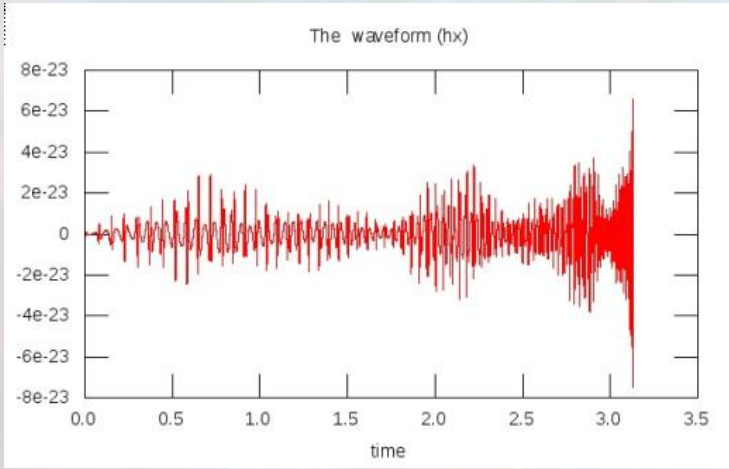
  Projects: - Compact binary coalescence search algorithms,
  - Continuous wave searches (F-statistics, Hough method)

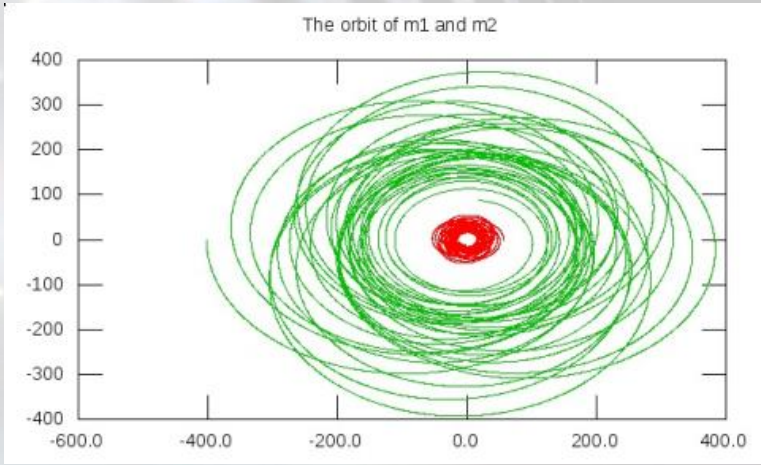
Solution of Einstein equations, gravitational waveform

- CBwaves

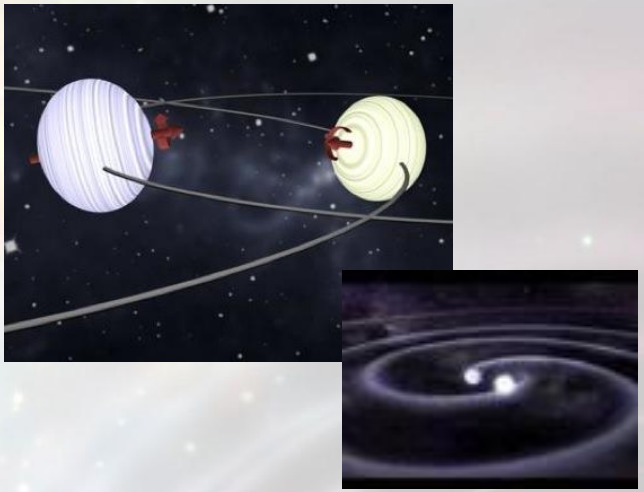
  Integration of the (post-Newtonian) equations of motion for compact binaries (with eccentricity and rotating components), generation of inspiral waveform

  - Analytical description up to 3.5PN order
  - 3PN spin precession equations
  - Determination of the radiation field up to 2PN in parallel with the description of motion, time and frequency domain general eccentric templates





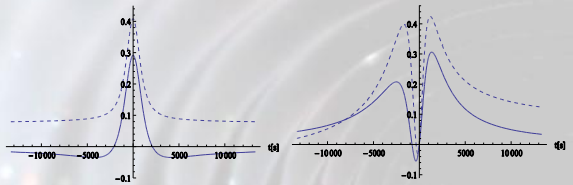
Binary source



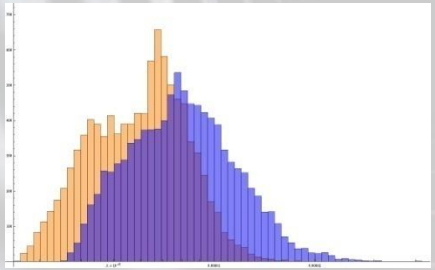
- Motion of spinning compact binaries
  (post-Newtonian approximation)

  Study of GW polarization states

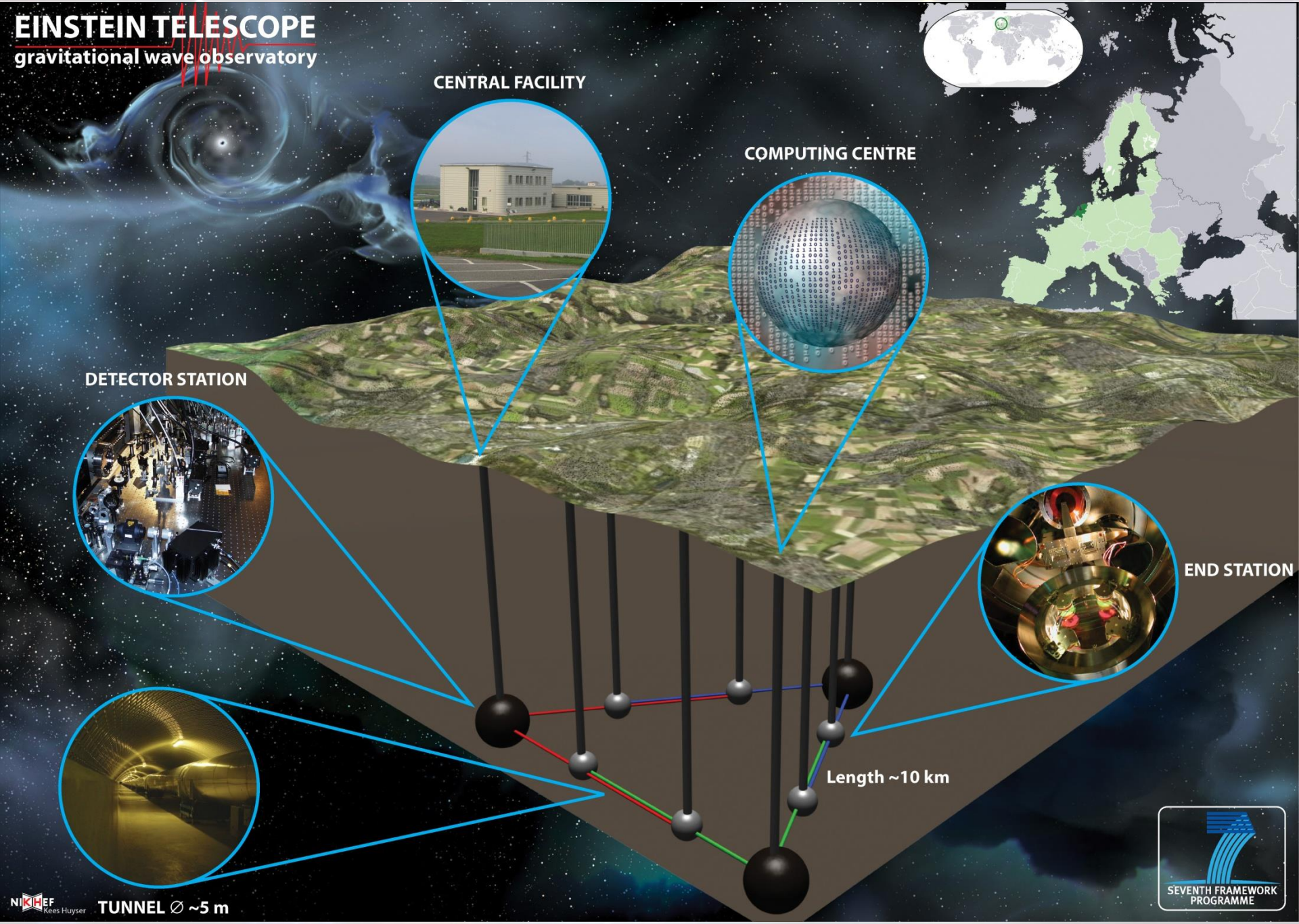
  Gravitational waveforms emitted by binaries
  on parabolic and hyperbolic orbits



- Parameter estimation of (eccentric) binaries (Fisher matrix analysis) for massive black holes (LISA)

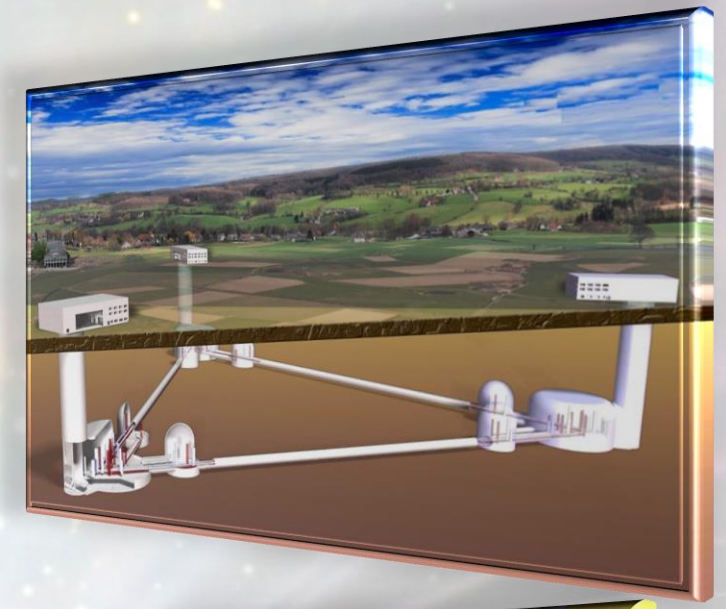


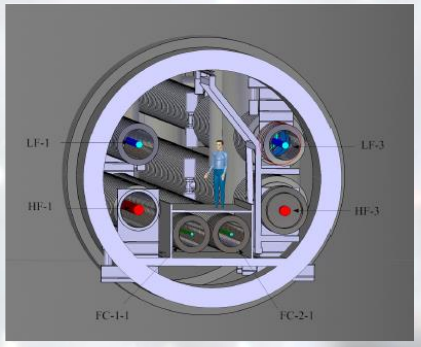
- Reduced basis approach for eccentric sources

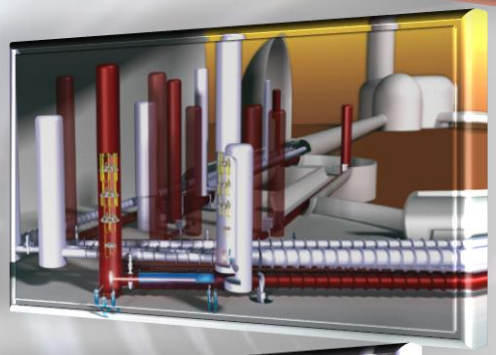

EINSTEIN TELESCOPE
gravitational wave observatory
CENTRAL FACILITY
COMPUTING CENTRE
DETECTOR STATION
END STATION
Length ~10 km
TUNNEL ∅ ~5 m
Kees Huyser
SEVENTH FRAMEWORK PROGRAMME

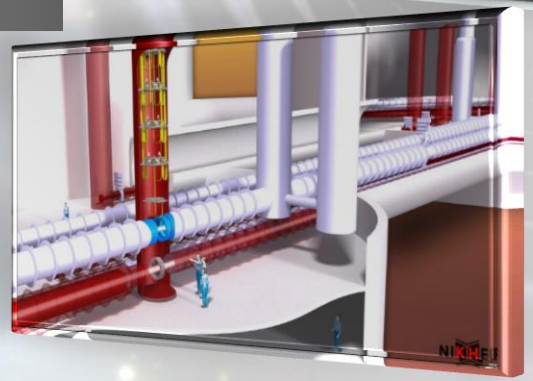
3. gen. GW detector

- Sensitivity improvement with 1 order
  1000x event rate
- Underground facility
  tunnel diameter 5.5m, thickness: 0.5m
- Arm length: 10 km
- New geometry
- MW laser
- 200 kg mirrors



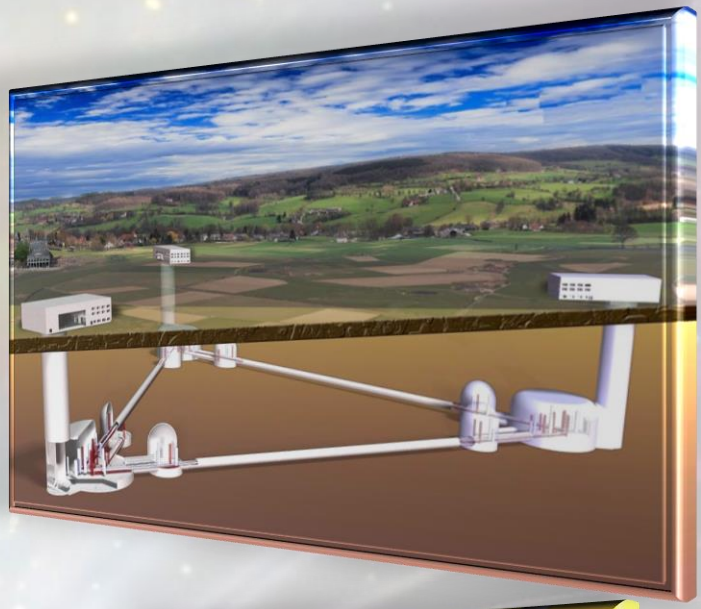




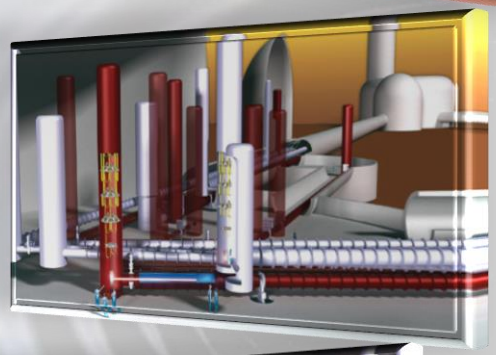


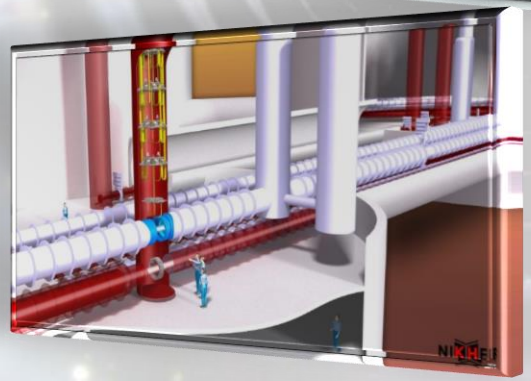
www.et-gw.eu

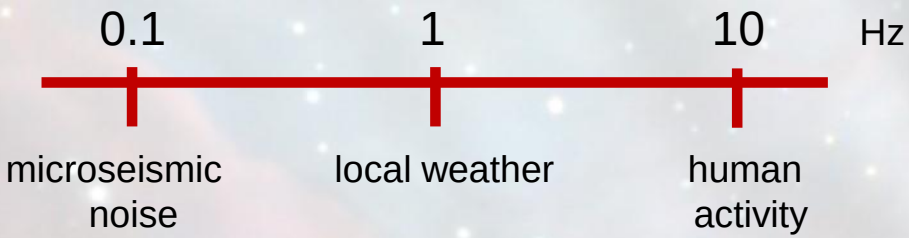
3. gen. GW detector - Schedule



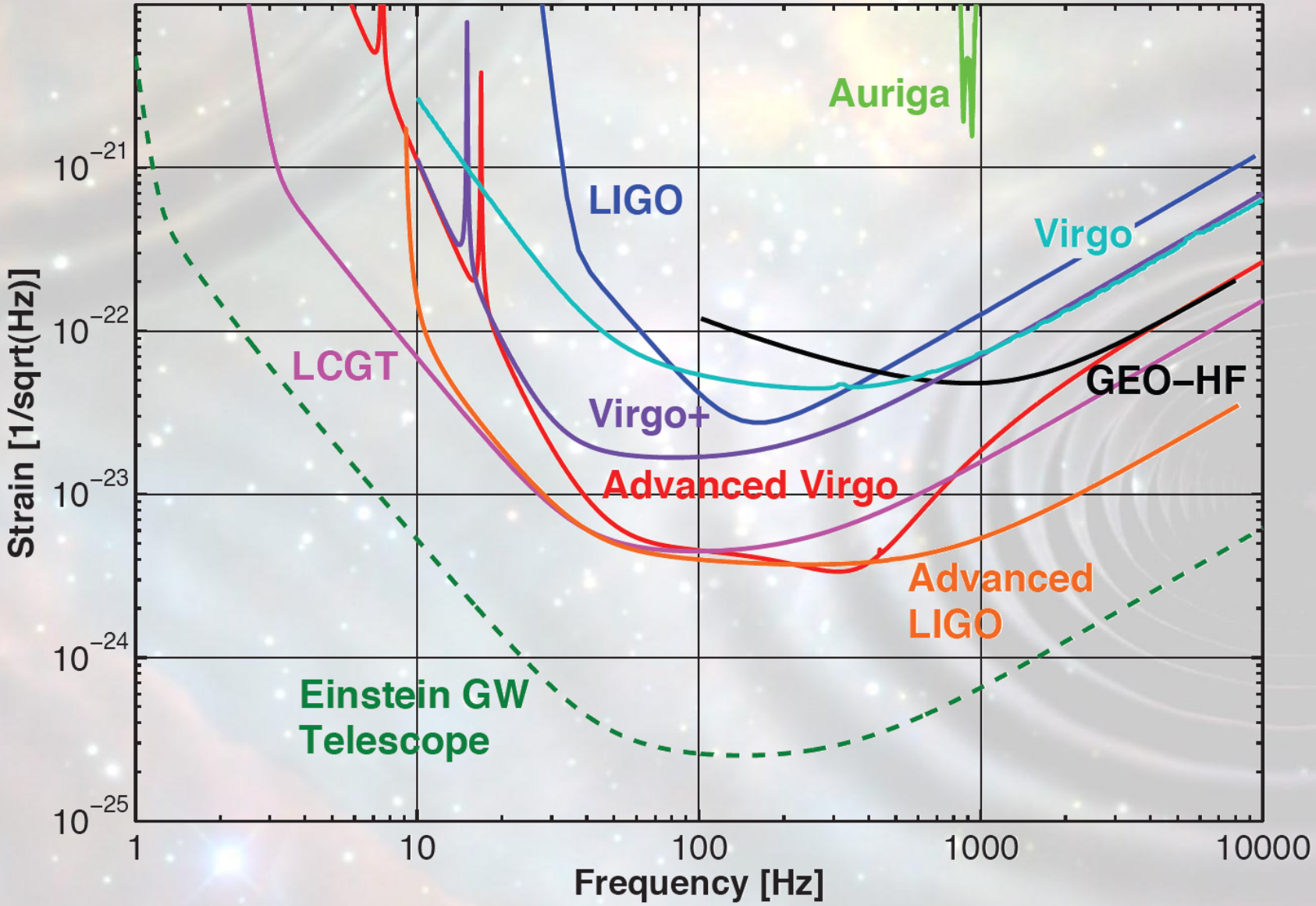
- The construction depends on different factors
  - Completion of design study
  - First direct detection of GWs
  - Official decisions
- Site selection 2018-19
- Site construction until 2021
- Installation of the first detector until 2026
- Measurements 50 years
- Important frequency band:







Einstein telescope

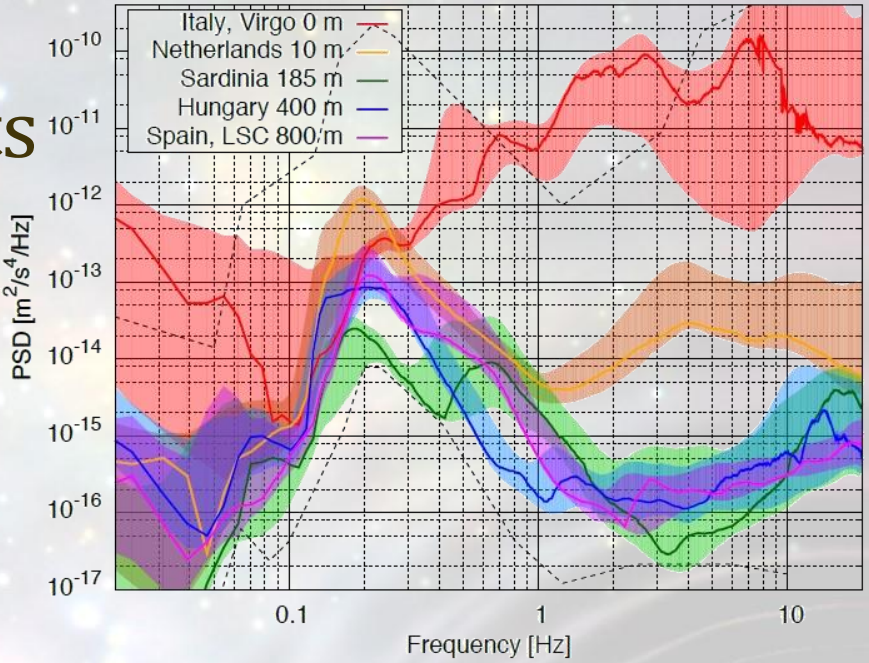


Site selection

Preliminary measurements Mátra

- April 2-5, 2010

seismological measurements, Dutch colleagues, Trillium 240



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