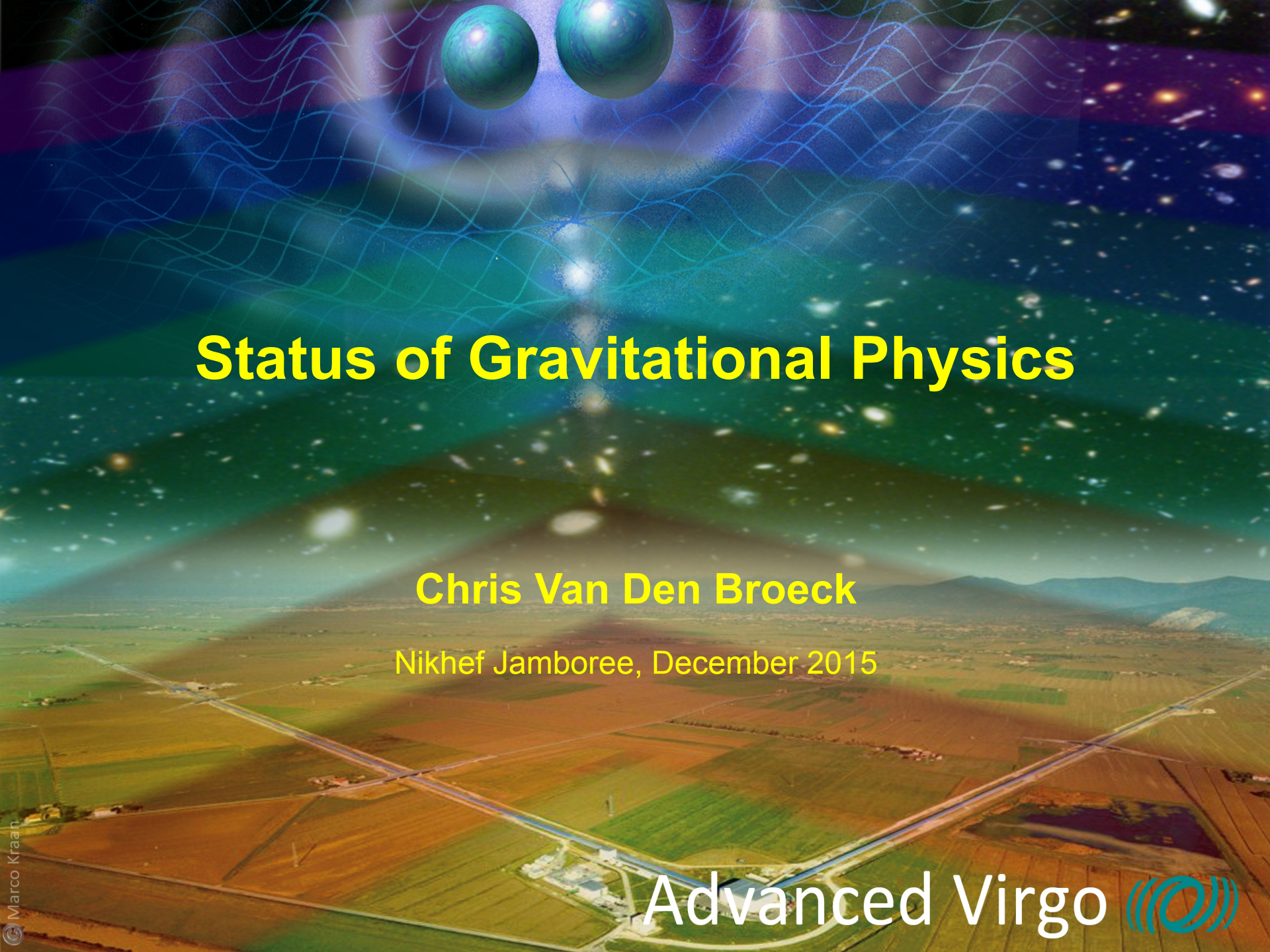

Status of Gravitational Physics
Chris Van Den Broeck
Nikhef Jamboree, December 2015
Advanced Virgo
© Marco Kraan

Network of detectors:

- **Detection confidence**
- **GW science**
- **Sky localization (EM follow-up)**

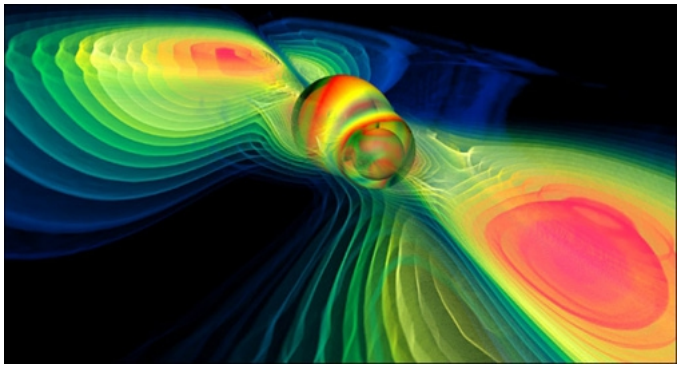
LIGO-Virgo Collaboration observations resumed with Advanced LIGO instruments in Sept. 2015

First joint Advanced LIGO-Virgo run in 2016

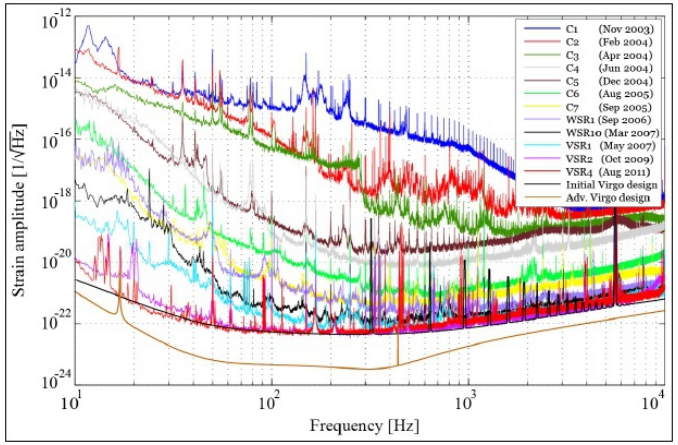
KAGRA joins ~2020

Scientific focus

- Scientific promise
  - Direct detection of gravitational waves
  - Test strong-field dynamics of GR
  - Cosmography
  - Signals from the early Universe



- Sources exist
  - Binary systems of neutron stars and black holes
  - Signal shape known in GR → template waveforms
  - Strong data analysis effort in place
- From initial to advanced detectors
  - Initial detectors have provided validation of the technology
    - Design sensitivity reached
  - Advanced detectors
    - Factor 10 more sensitive
    - First detections over the next years

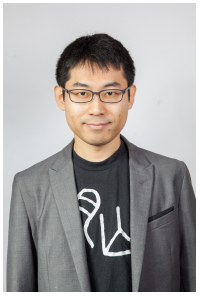


People

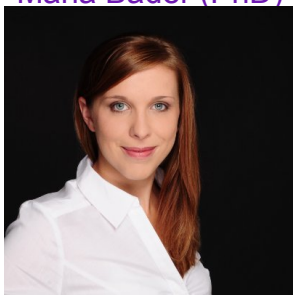
Jo van den Brand

Chris Van Den Broeck

Kazuhiro Agatsuma (postdoc)



Maria Bader (PhD)



Soumen Koley (PhD)

Alessandro Bertolini

Henk Jan Bulten

Niels van Bakel

Boris Boom (PhD)

Joris v Heijningen (PhD)

Reinier Jonker (PhD)

Martin v Beuzekom

JW v Holten

Satish Kumar (PhD)

Giuseppe d'Ambrosi (PhD)

Laura vd Schaaf (PhD)

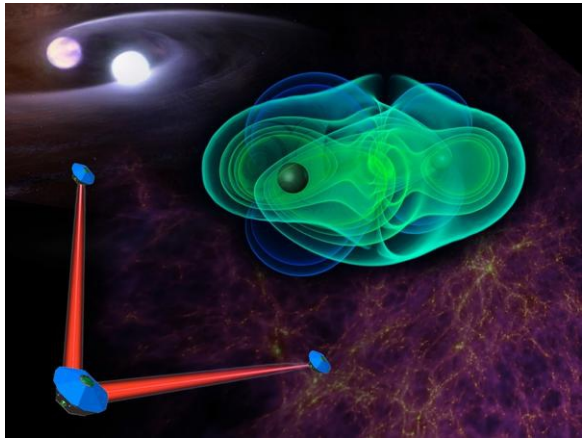
Jeroen Meidam (PhD)

LIGO-Virgo Collaboration

- Advanced LIGO
  - First observing run started in September, will end in mid-January
  - Current range for binary neutron stars: 60-80 Mpc
    - Final design sensitivity: ~200 Mpc
  - Commissioning to continue in 2016
- Advanced Virgo
  - Installation in progress
  - 2016-17: 6-month science run joint with Advanced LIGO

LISA Pathfinder successfully launched!

- eLISA: a space-borne gravitational wave detector
  - 3 probes at 10^6 km exchanging laser beams
  - In orbit around Sun
  - Approved by ESA for 2034 launch
  - Nikhef-AEI collaboration on phase meters
  - NL-eLISA consortium

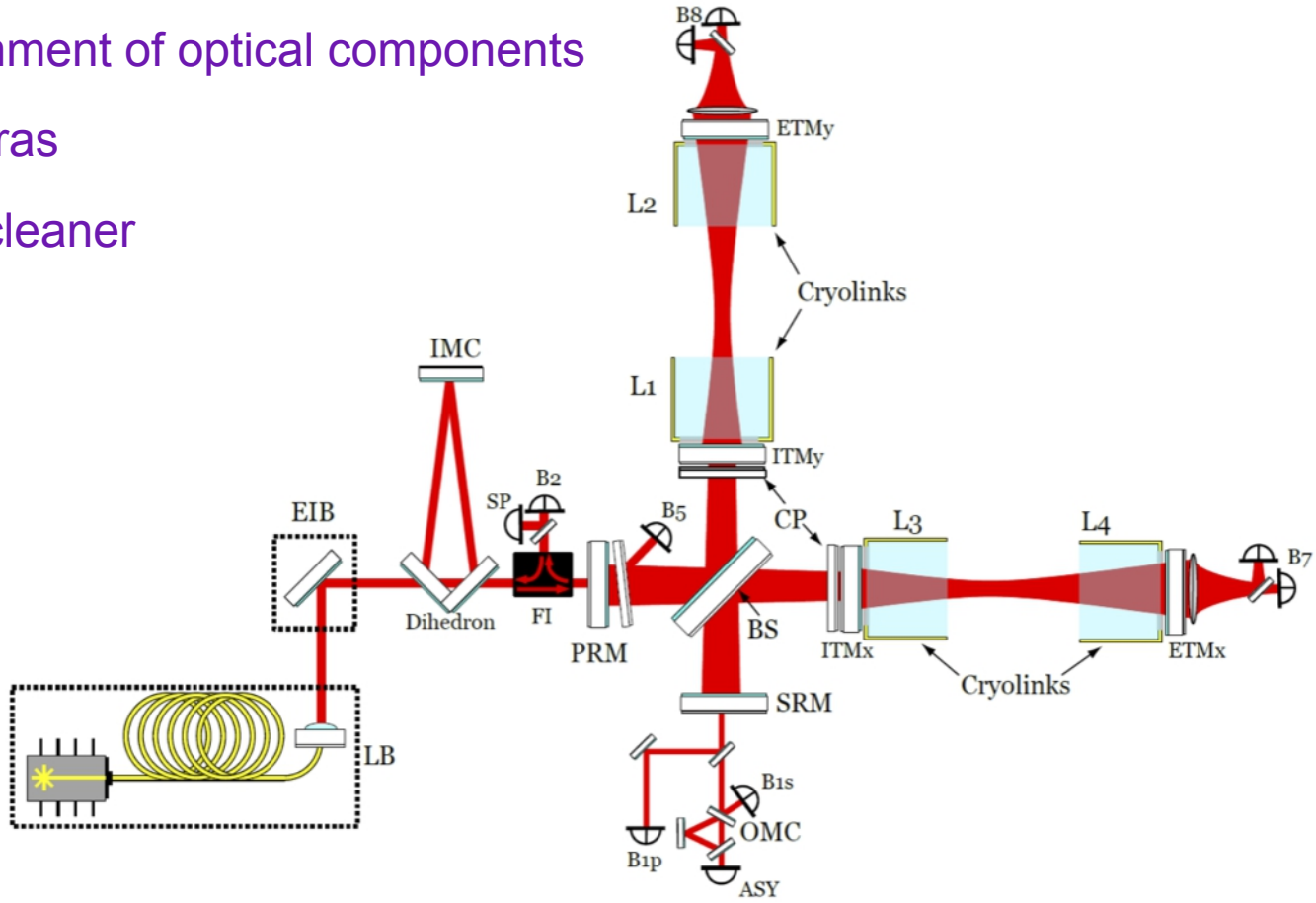


- LISA Pathfinder
  - Proof-of-principle of key technologies
  - Successfully launched 3 December 2015

Advanced Virgo construction

Nikhef responsibilities:

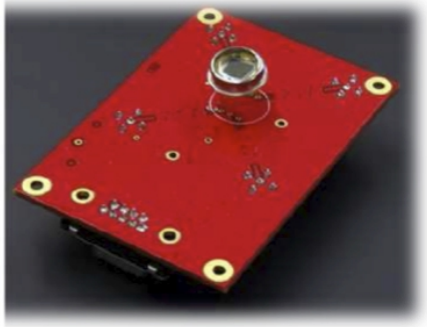
- Cryolinks
- Vibration isolation
- Angular alignment of optical components
- Phase cameras
- Input mode cleaner

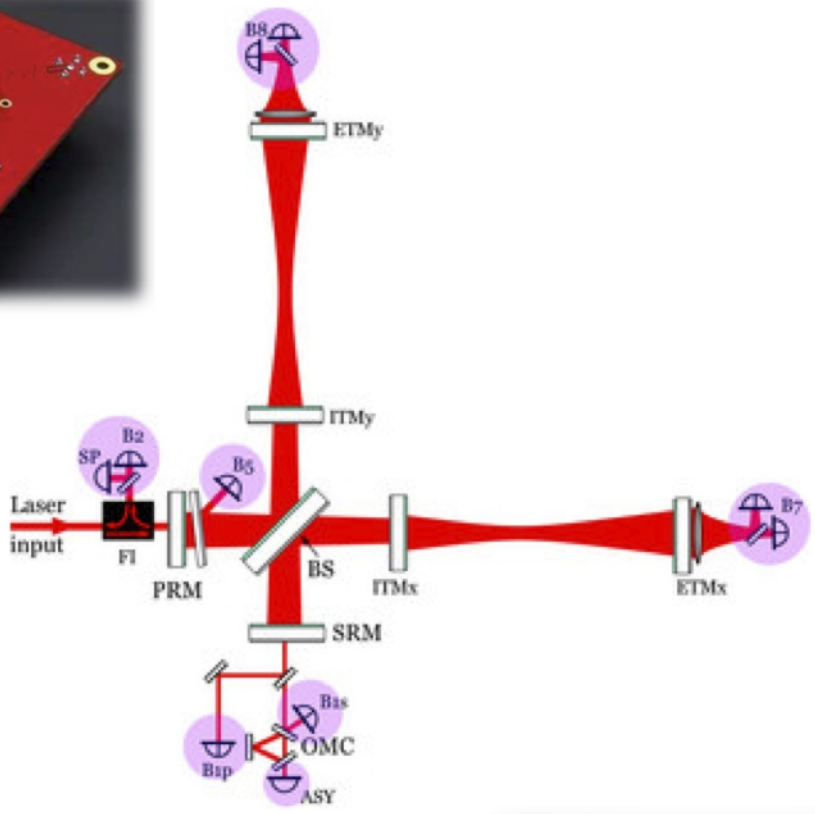


Cryolinks

- Four liquid nitrogen links: 10^{-10} mbar region
- Designed by Nikhef
- Commissioned and fully operational

Angular alignment of optical components

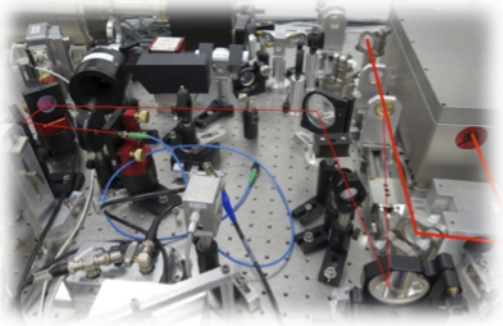


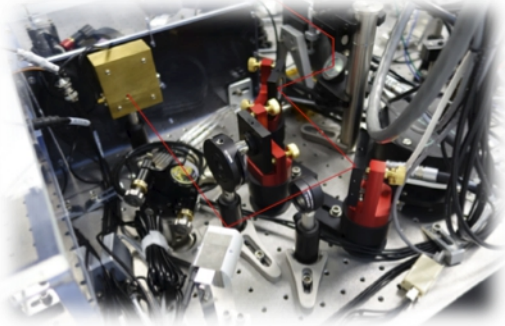


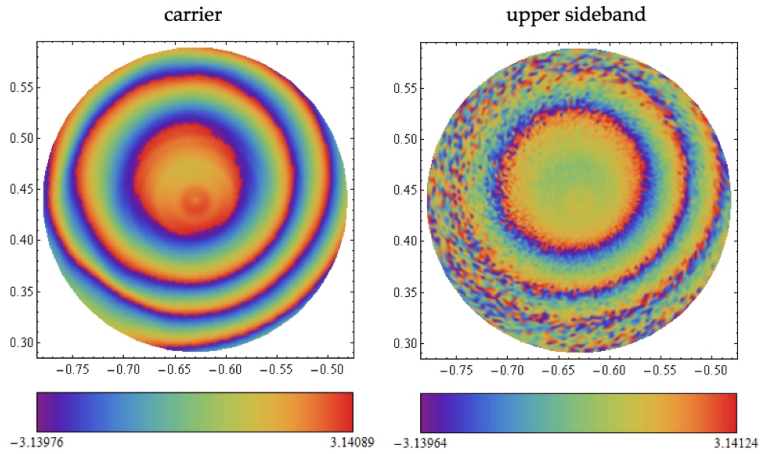
Installed at Virgo

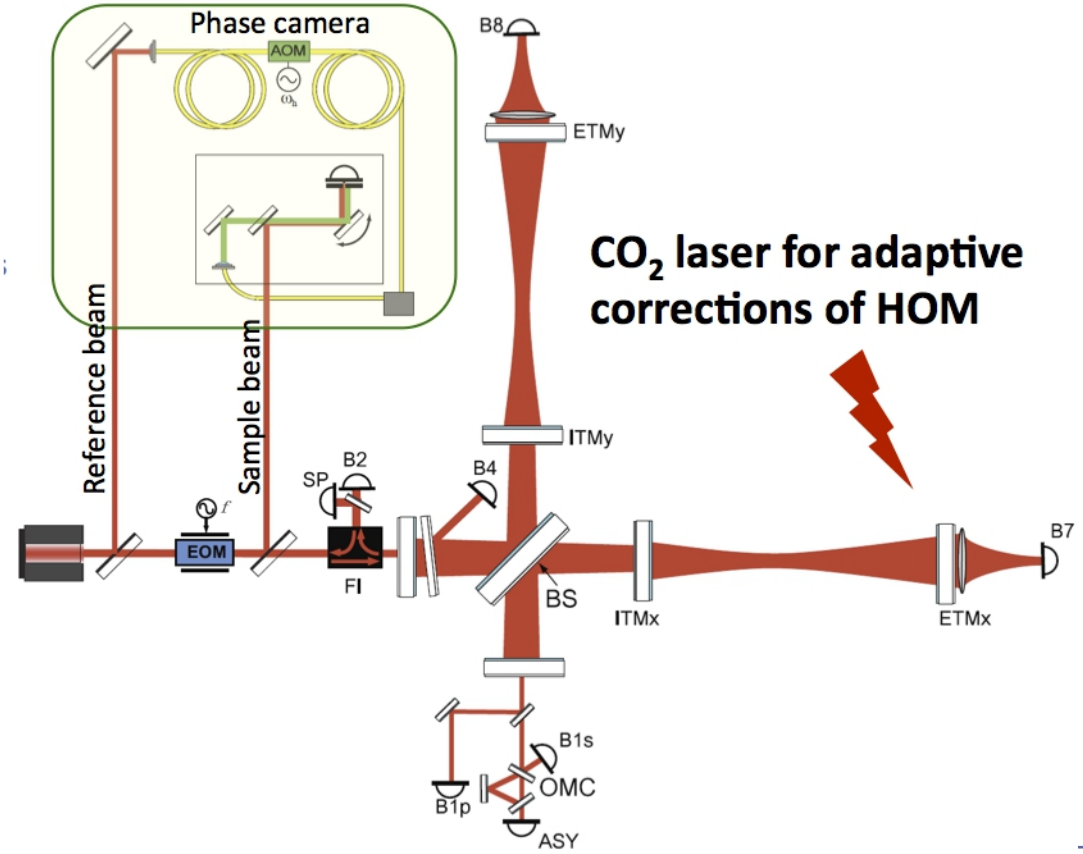
- **Niels van Bakel**

Phase cameras







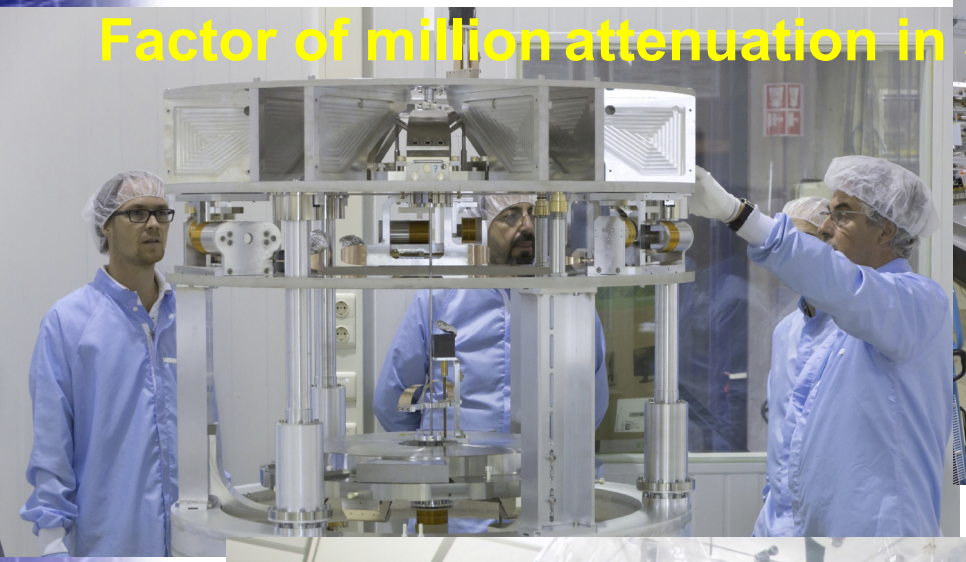


Wavefront mapping for use in adaptive optics

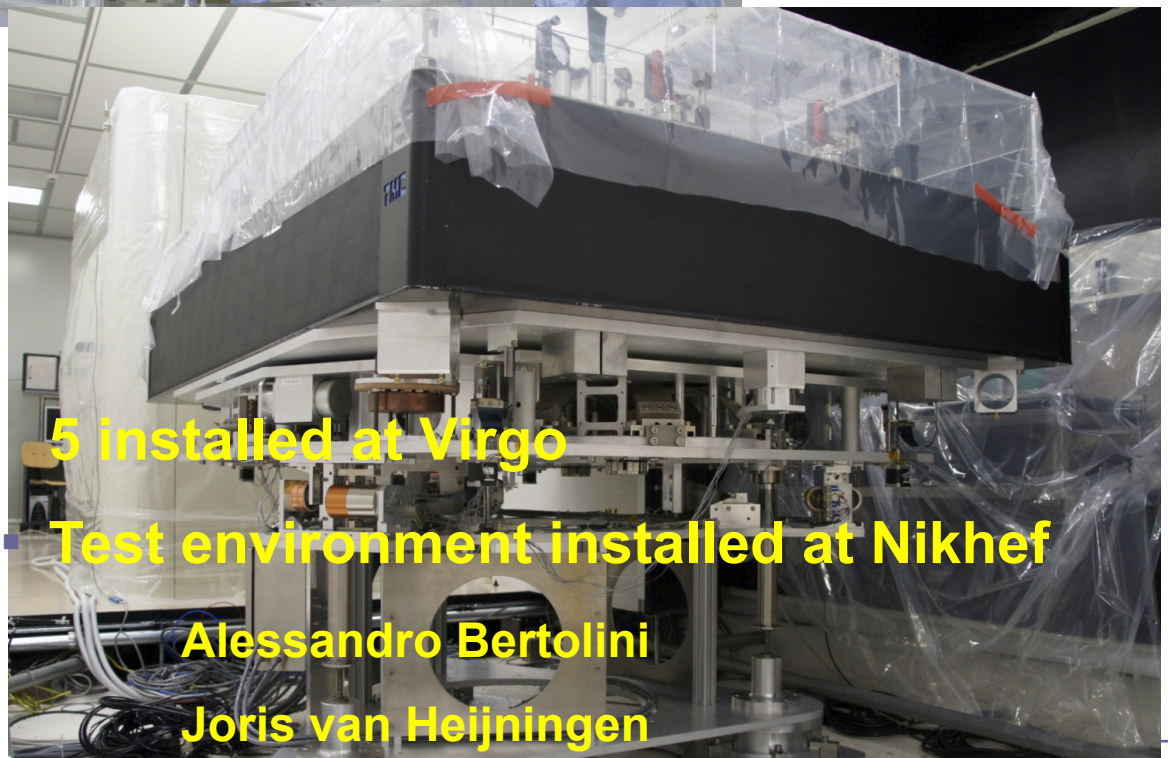
Undergoing testing at the Virgo site

- **Martin van Beuzekom**
- **Kazuhiro Agatsuma**
- **Laura vd Schaaf**

Multi-stage seismic attenuation systems



Factor of million attenuation in six degrees of freedom



5 installed at Virgo

Test environment installed at Nikhef

Alessandro Bertolini

Joris van Heijningen

Input mode cleaner

Designed at Nikhef, fabricated by Optronica

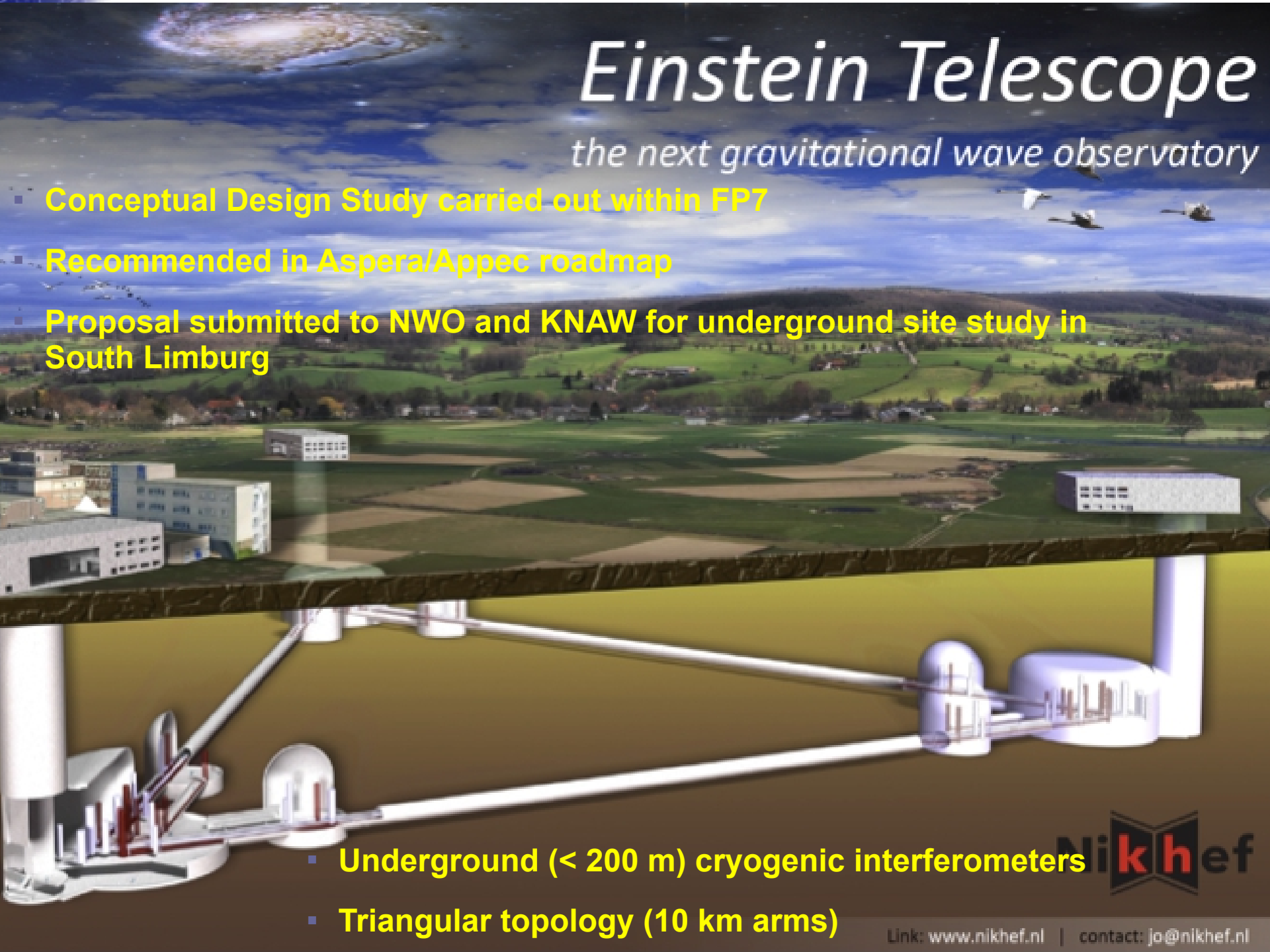
Mirror positioning accurate to 10^{-15} m/√Hz level

Thomas Bauer (retired)

Einstein Telescope

the next gravitational wave observatory

- Conceptual Design Study carried out within FP7
- Recommended in Aspera/Appec roadmap
- Proposal submitted to NWO and KNAW for underground site study in South Limburg



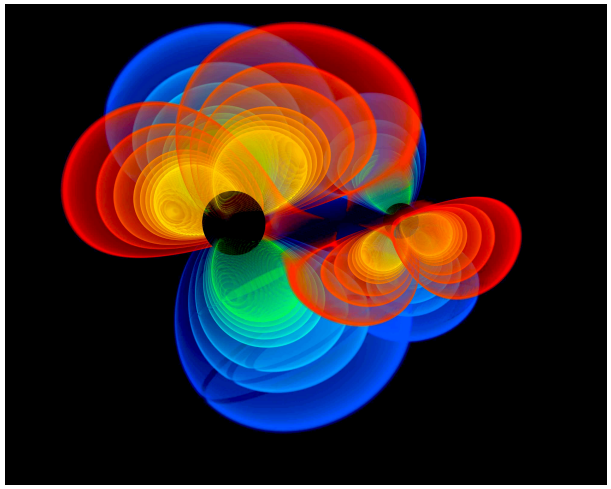
- Underground (< 200 m) cryogenic interferometers
- Triangular topology (10 km arms)

Nikhef

Link: www.nikhef.nl | contact: jo@nikhef.nl

Data analysis

- Software infrastructure to test general relativity with binary neutron stars has been extended to black holes (see talk by Jeroen Meidam)



- Pipeline to search for signals from fast-spinning neutron stars in binaries that are not merging
  - GPU implementation
  - Participation in Mock Data Challenges

Summary

- LIGO-Virgo Collaboration is jointly analyzing data from the first Observing Run of the advanced detector era
  - For now only Advanced LIGO instruments
  - Joint Advanced LIGO-Virgo run in 2016
- Nikhef instrumentation contributions to Advanced Virgo are on-site and being tested
- Involvement in planning for future infrastructures:
  - Nikhef-AEI collaboration on eLISA phase meters
  - Proposal to NWO/KNAW for Einstein Telescope underground site investigations
- Data analysis preparations in a mature state
  - Software to test general relativity with binary black holes
  - Software to search for fast-spinning neutron stars in binaries