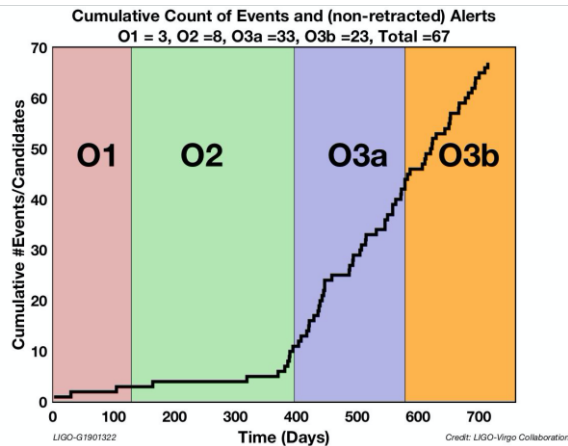


# LIGO-Virgo observations: the latest harvest

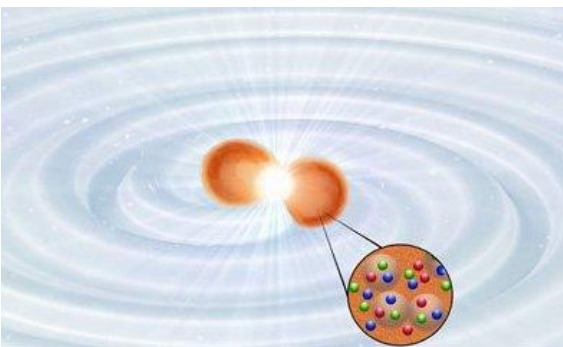
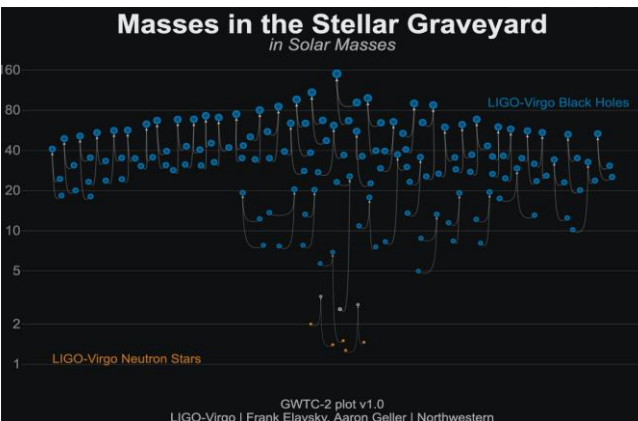


## ➤ Now in the era of routine detections:

- 50 fully analyzed, 17 more candidates under investigation
- **Nikhef/UU contributions:** detection, testing the strong-field dynamics of gravity, neutron star equation of state, gravitational wave lensing

## ➤ Some special events!

- GW190425: consistent with binary neutron star, but higher total mass than any binary neutron star in our galaxy (from radio observations)
    - New population of binary neutron stars?
  - GW190814:  $23+2.6 M_{\text{sun}}$ 
    - Lighter object too heavy for a neutron star, too light for a black hole?
      - No electromagnetic counterpart; nature of the object unknown
    - First observation of *higher harmonics* of the signal
      - Suggests novel tests of GR: “Binary black hole no-hair conjecture”
  - GW190521:  $85+66 M_{\text{sun}}$ 
    - Implausible that either component was created directly from a star
    - The components must have been the results of previous mergers
    - Remnant  $\sim 142 M_{\text{sun}}$
- ➡ Starting to see growth of black holes through successive mergers!



## ➤ Neutron stars: astrophysics and cosmology

- Paper in *Science* co-authored by PhD student Peter T.H. Pang: <https://science.sciencemag.org/content/370/6523/1450>
- Combines information from GW + gamma + X-ray + optical + radio + nuclear physics theory:
  - Strongest constraints to date on the neutron star equation of state
  - Sharper measurement of the Hubble constant

# GW: Virgo upgrades & Einstein Telescope



## Virgo upgrades – *near completion*

Despite COVID-19, Virgo upgrade progressing extremely well  
Most of our hardware sent to Italy & installed or being installed

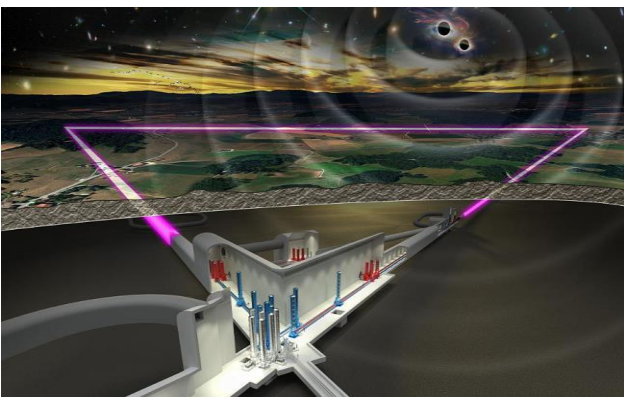
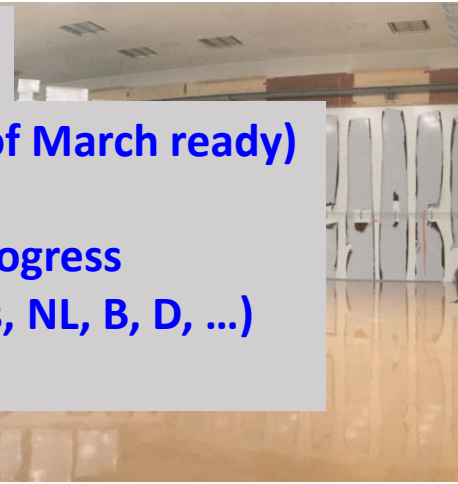
*Picture:*

balancing upper part suspension of filter cavity input mirror



## Etpathfinder – *lots of progress*

- Cleanroom progressing well (end of March ready)
- Vacuum vessel contract awarded
- Several (many) other tenders in progress
- Weekly meetings (35+ participants, NL, B, D, ...)
- Enormous project ...



## Einstein Telescope – *lots of actions*

- *Prepare ESFRI interview (14 April)*
- *Shape up collaboration/governance/efficiency/...*
  - *Many boards (ISB, SPB, IFB, OSB, ...) installed & running*
- *NL-political/funding level: many meetings, proposals, ...*
- *More geology studies: passive/active seismic, drill holes*



# Einstein Telescope