What are gravitational waves?

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Operated by Caltech and MIT

What are gravitational waves?

Strains in space

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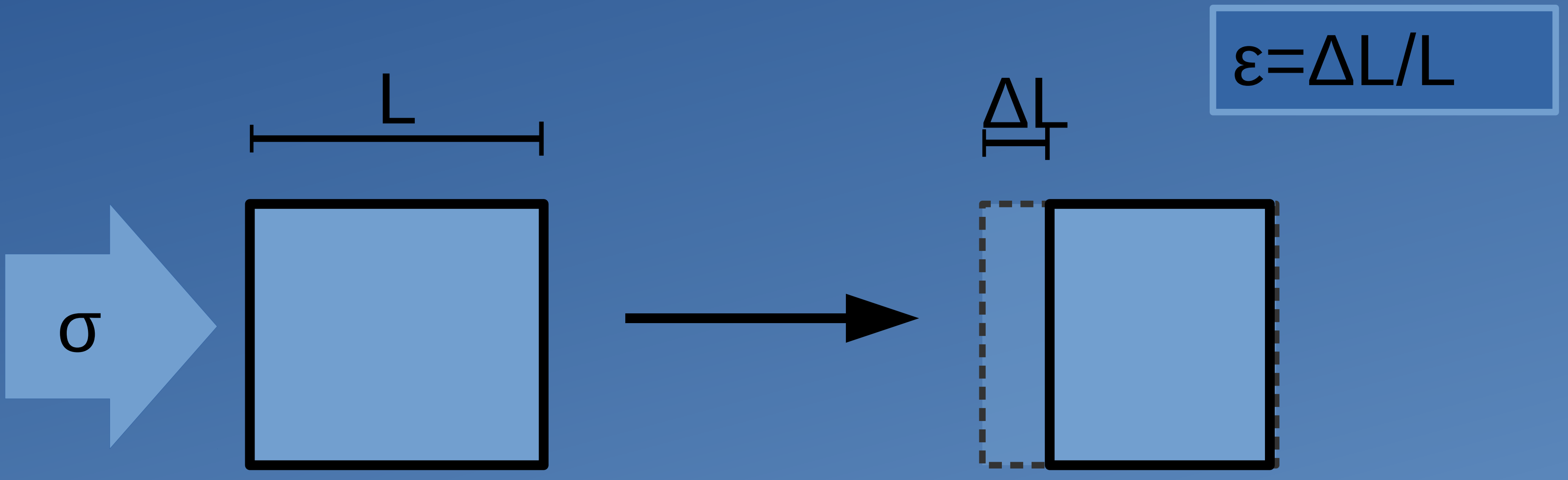
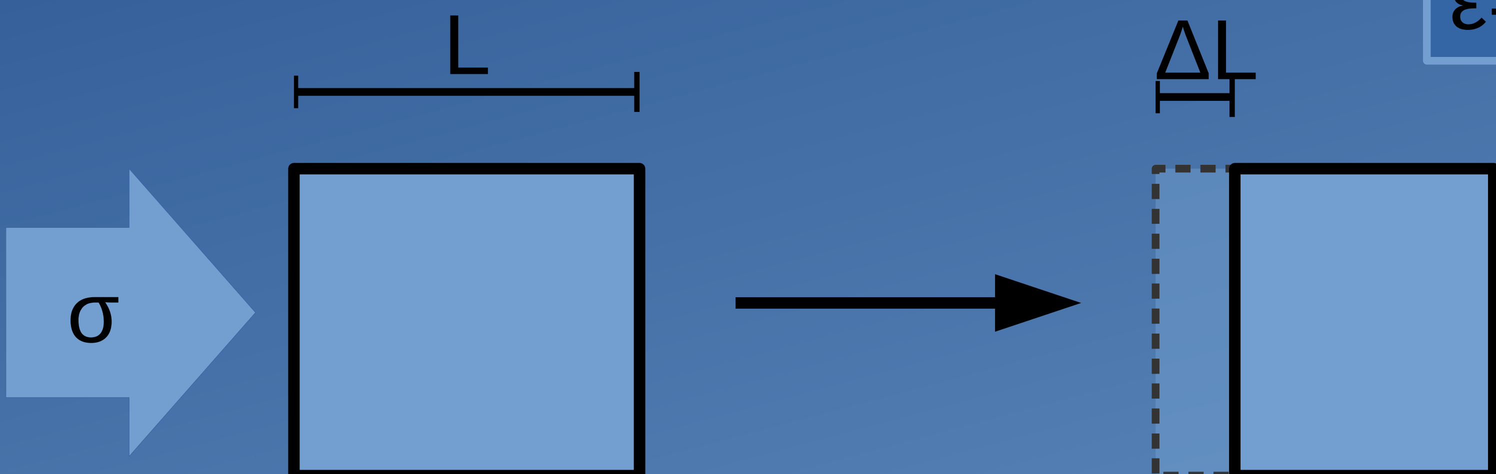
Stress and Strain



Stress and Strain

$\varepsilon = \Delta L / L$



$$\epsilon = \frac{\sigma}{Y}$$

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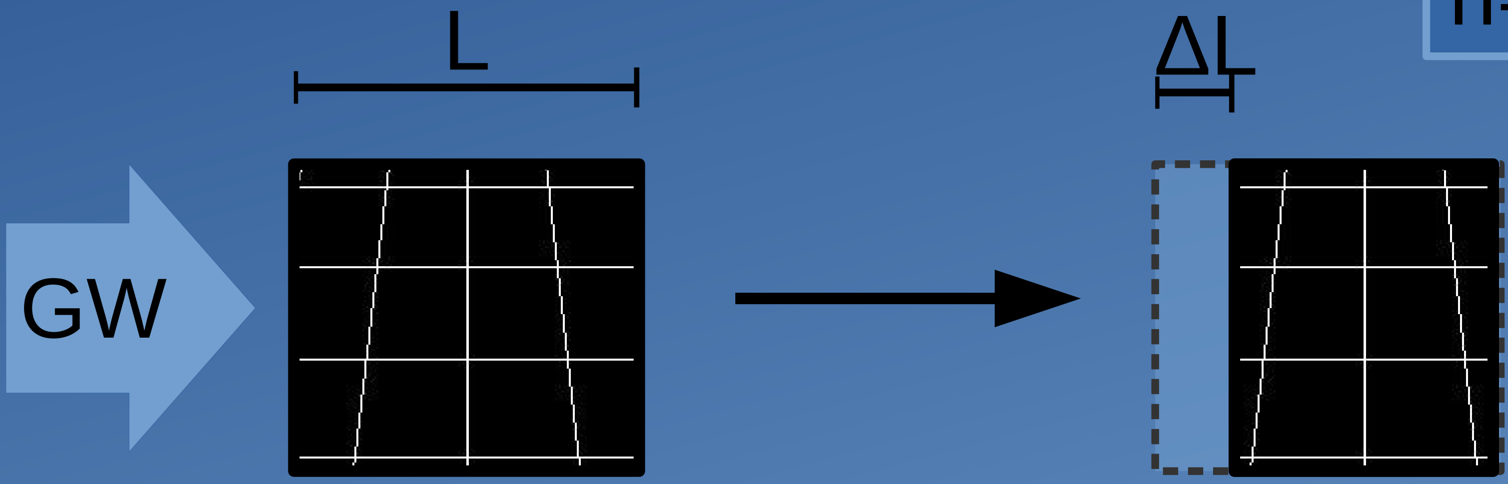
Stress and Strain

$h = \Delta L / L$



$$h = \frac{2}{r}\frac{G}{c^4}\frac{\partial^2}{\partial t^2}\left[D_{[jk]}\left(t - R/c\right)\right]^{TT}$$

Stiffness of Space

$$\epsilon = \frac{\sigma}{Y}$$

$$h = \frac{2}{r}\frac{G}{c^4}\frac{\partial^2}{\partial t^2}\left[D_{[jk]}\left(t - R/c\right)\right]^{TT}$$

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Stiffness of Space

Typical Material:
Y ~ 10^{10}

$$\epsilon = \frac{\sigma}{Y}$$

$$h = \frac{2}{r}\frac{G}{c^4}\frac{\partial^2}{\partial t^2}\left[D_{[jk]}\left(t - R/c\right)\right]^{TT}$$

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Stiffness of Space

Typical Material:
$Y \sim 10^{10}$

$$\epsilon = \frac{\sigma}{Y}$$

Space:
$c^4/G \sim 10^{44}$

$$h = \frac{2}{r}\frac{G}{c^4}\frac{\partial^2}{\partial t^2}\left[D_{[jk]}\left(t - R/c\right)\right]^{TT}$$

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Stiffness of Space

Typical Material:
Y ~ 10^{10}

$$\epsilon = \frac{\sigma}{Y}$$

Space:
$c^4/G \sim 10^{44}$

Space is stiff!
Gravitational waves are tiny!

$$h = \frac{2}{r}\frac{G}{c^4}\frac{\partial^2}{\partial t^2}\left[D_{[jk]}\left(t - R/c\right)\right]^{TT}$$

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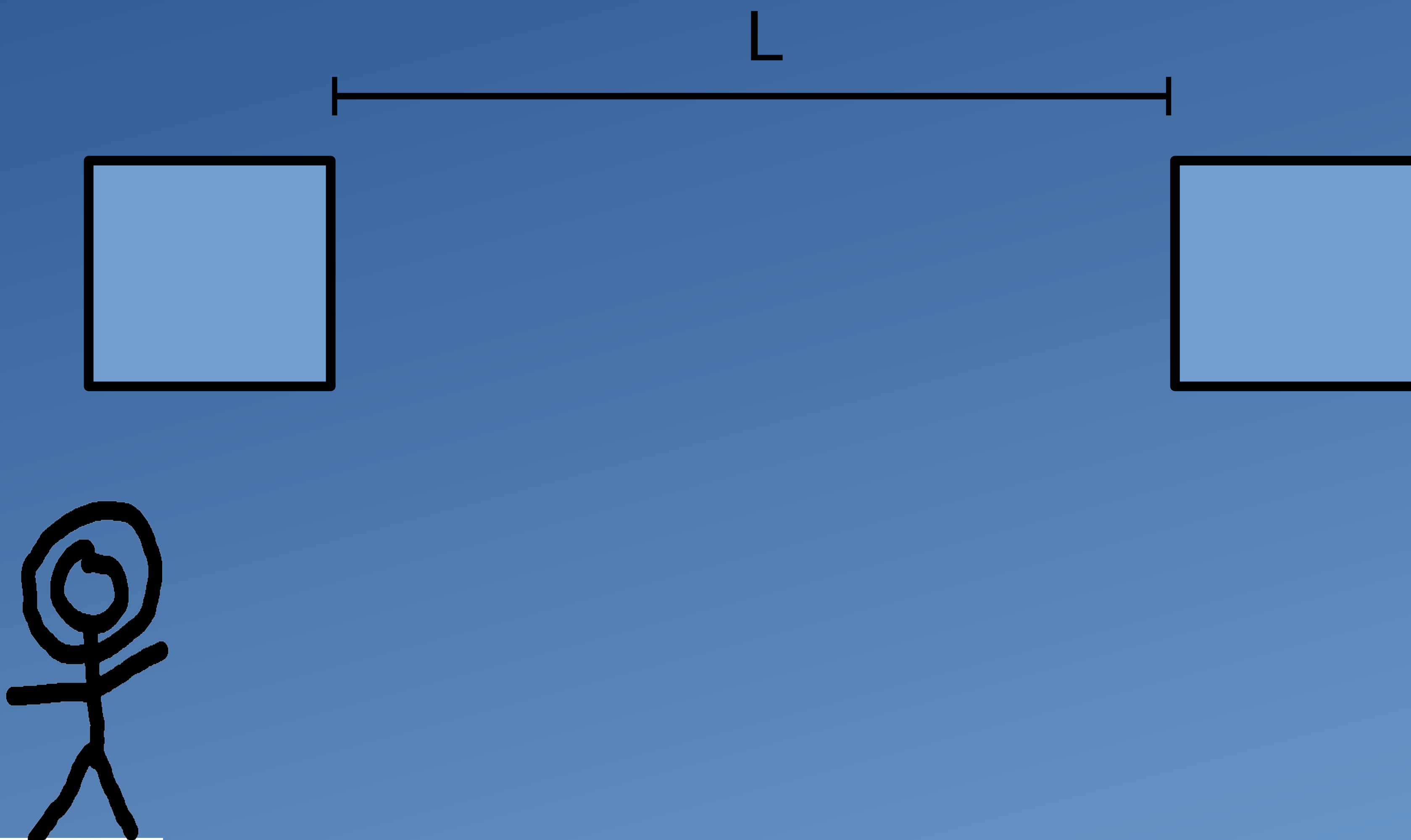
Gravitational Wave Effects



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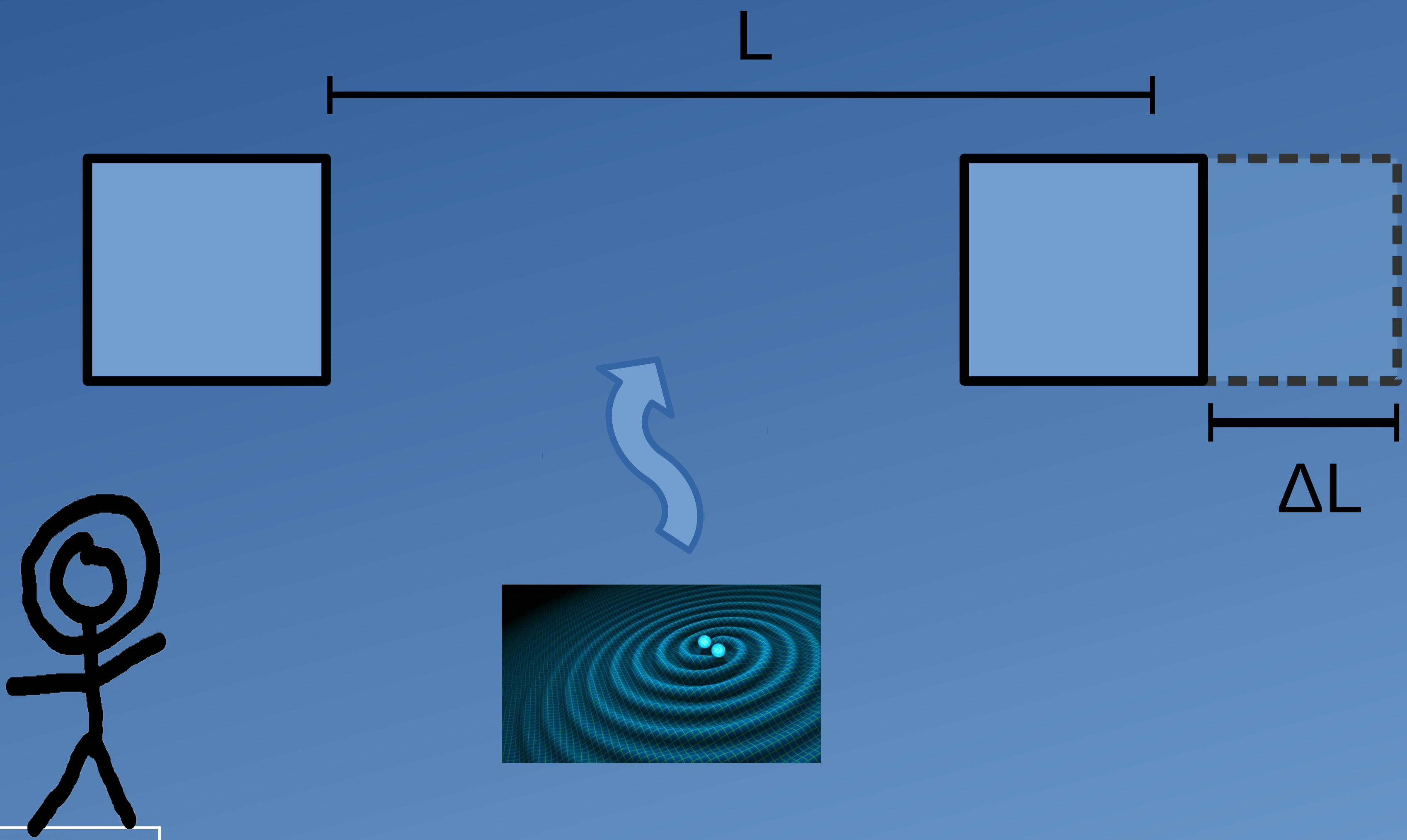

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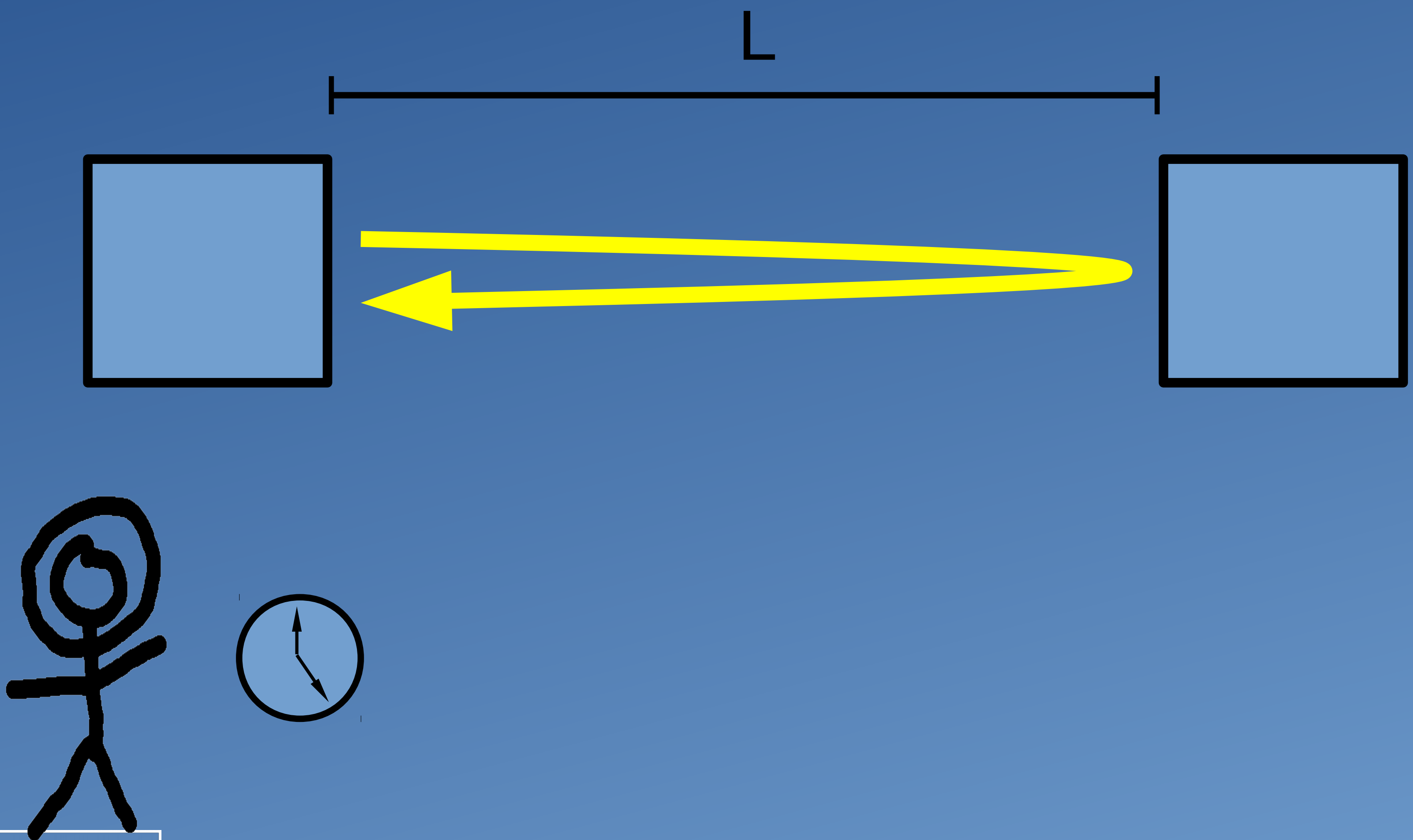
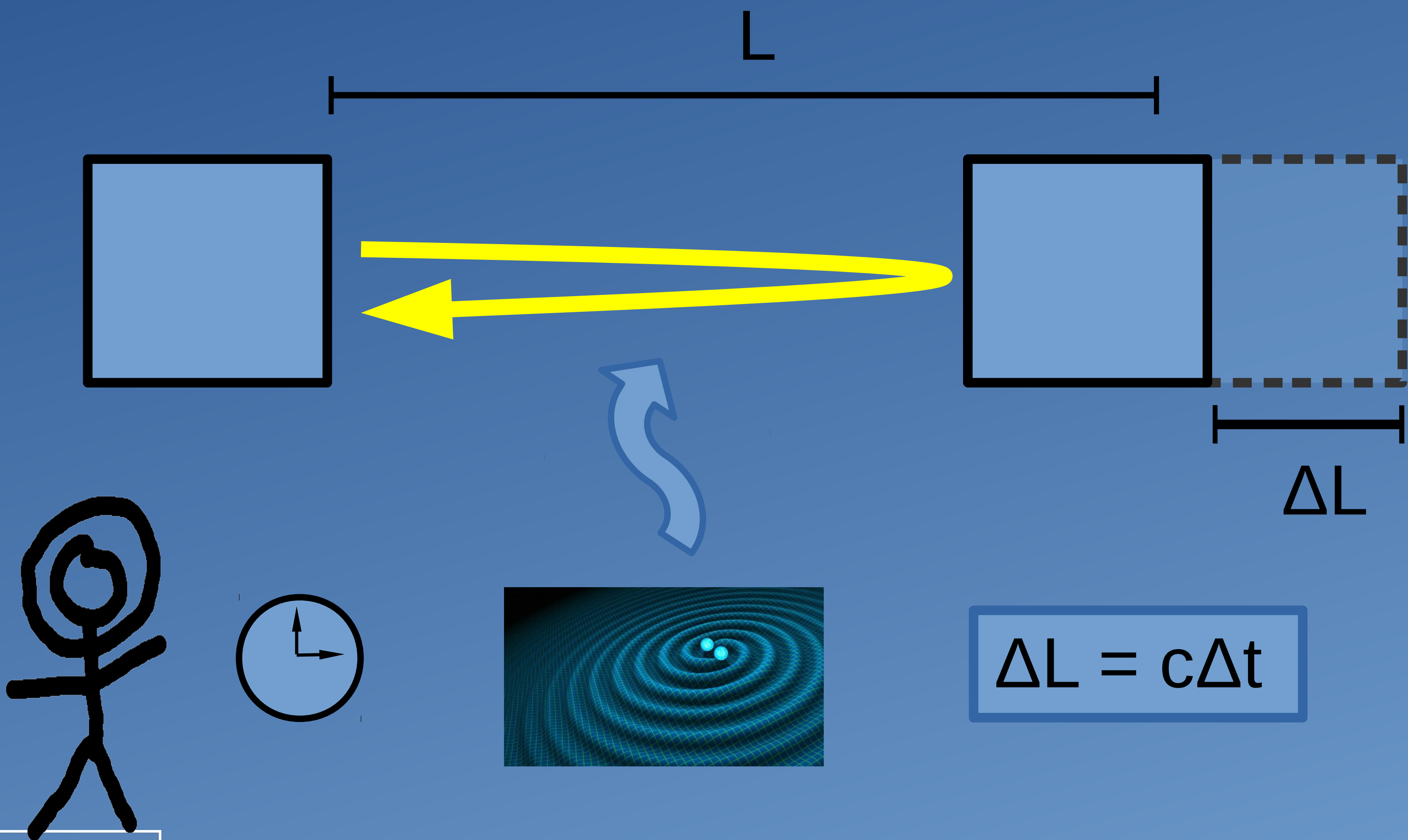
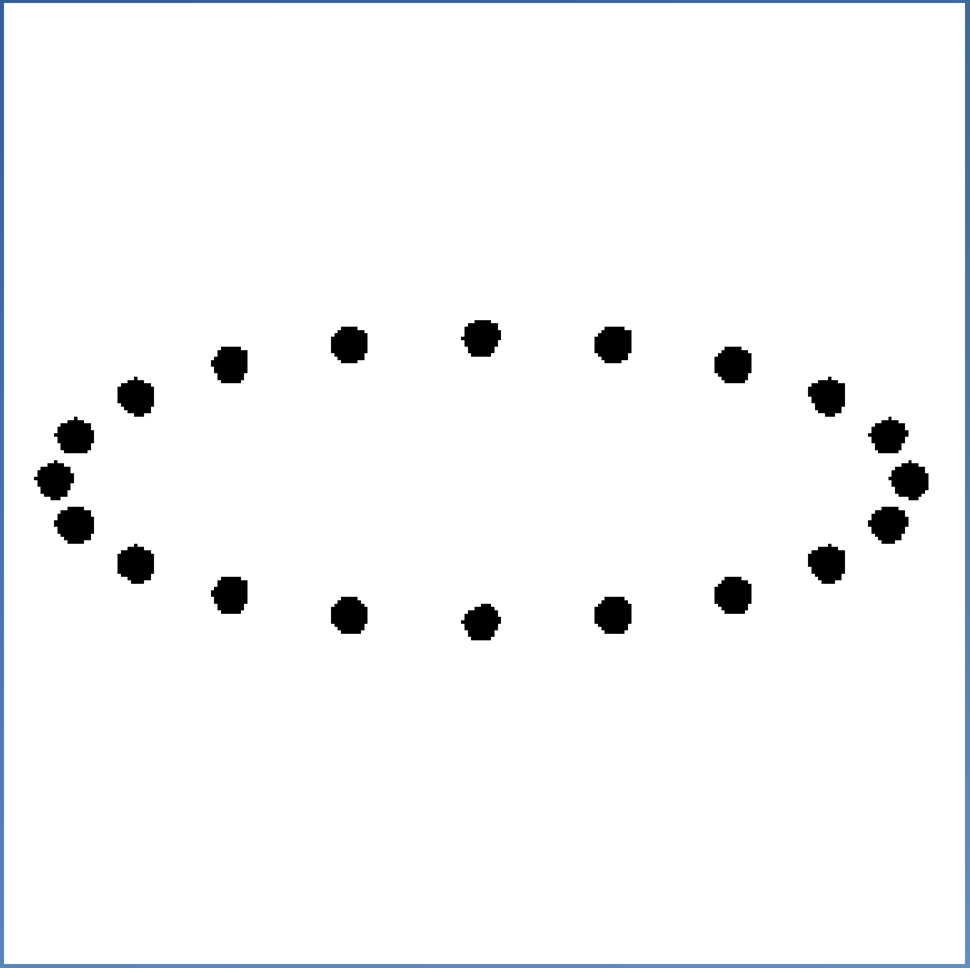


Gravitational Wave Effects



$$\Delta L = c\Delta t$$

Gravitational Wave Effects



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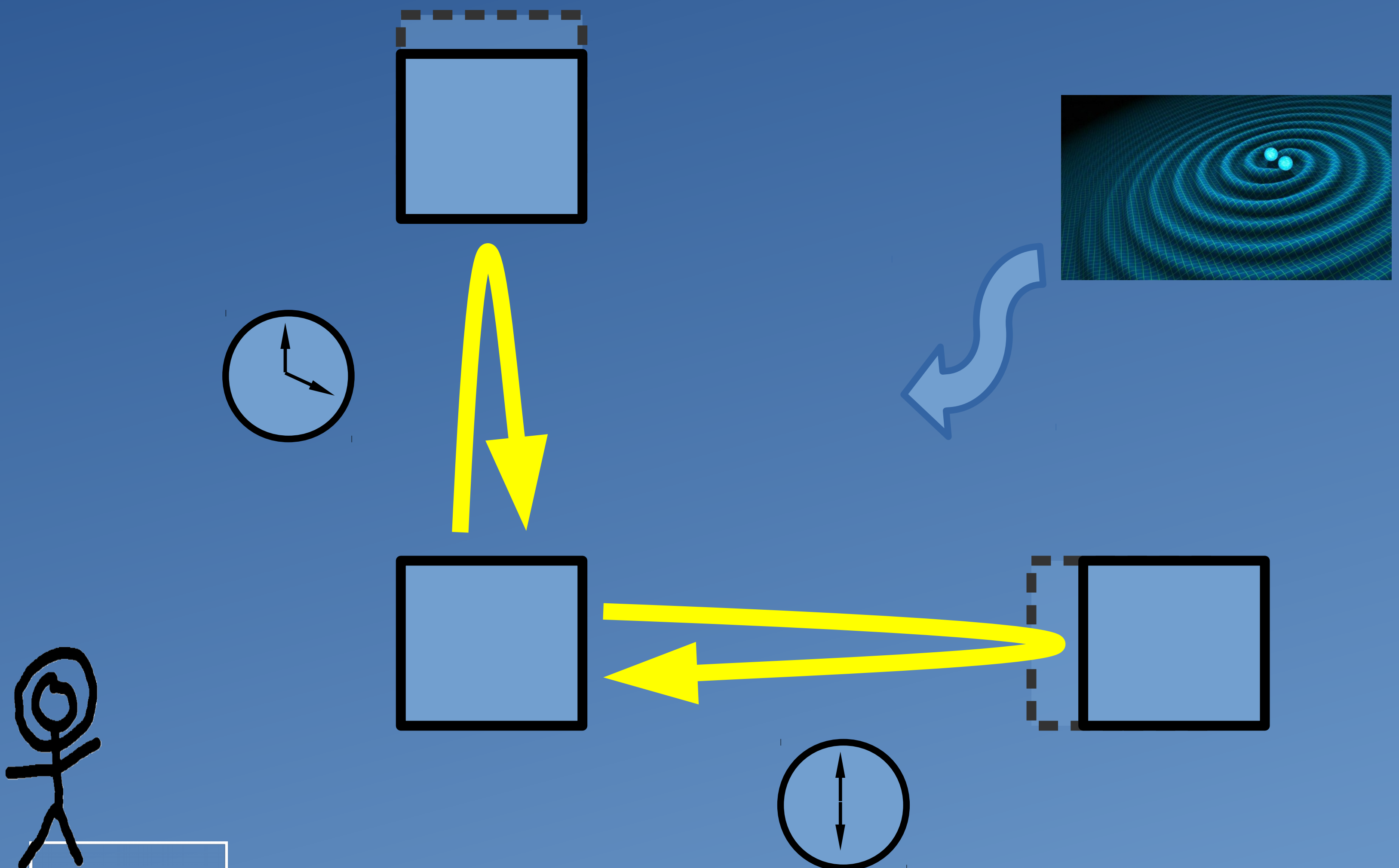
Gravitational Wave Effects



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How are gravitational waves really detected?

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How are gravitational waves really detected?

Interferometers

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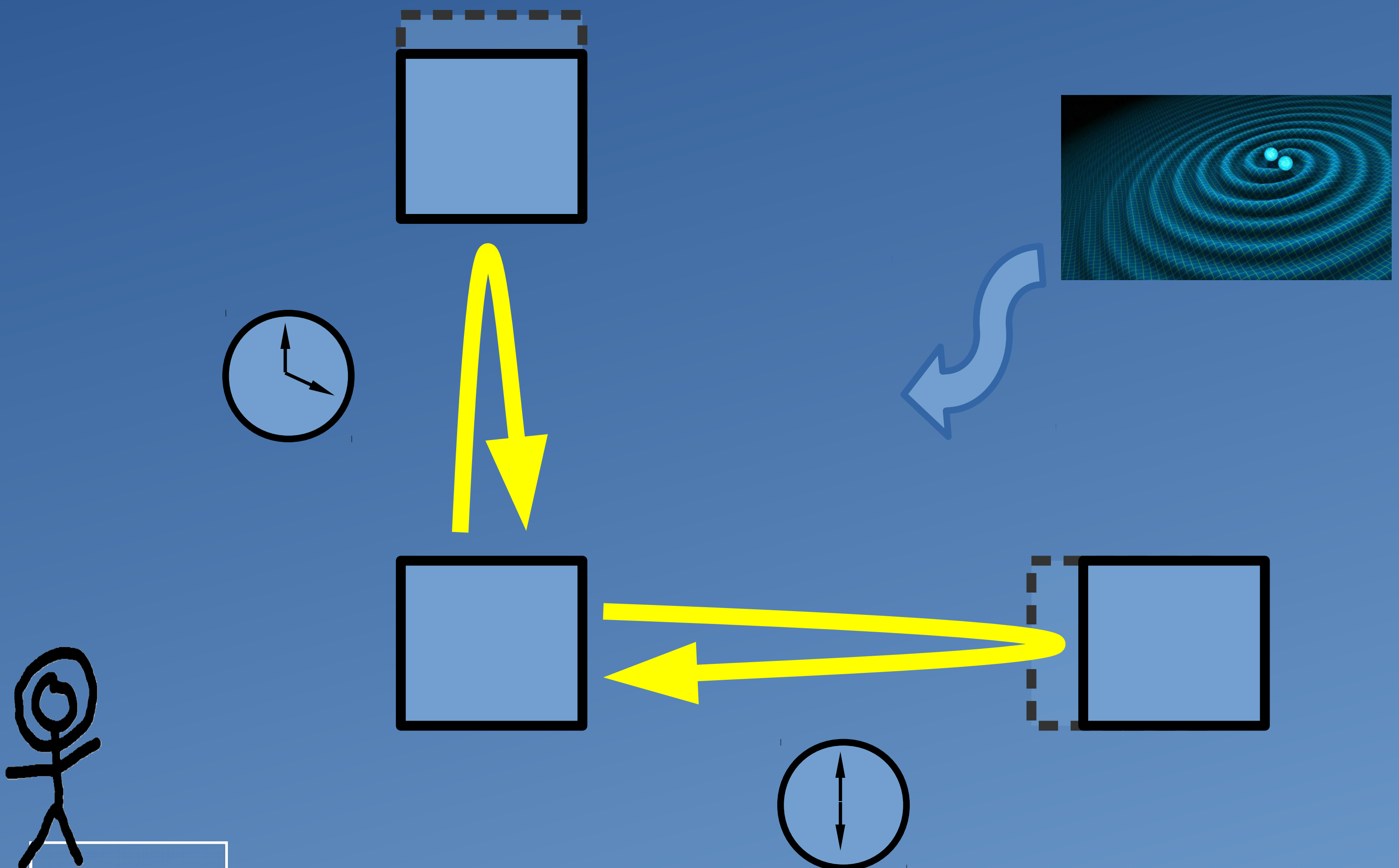
Gravitational Wave Detection



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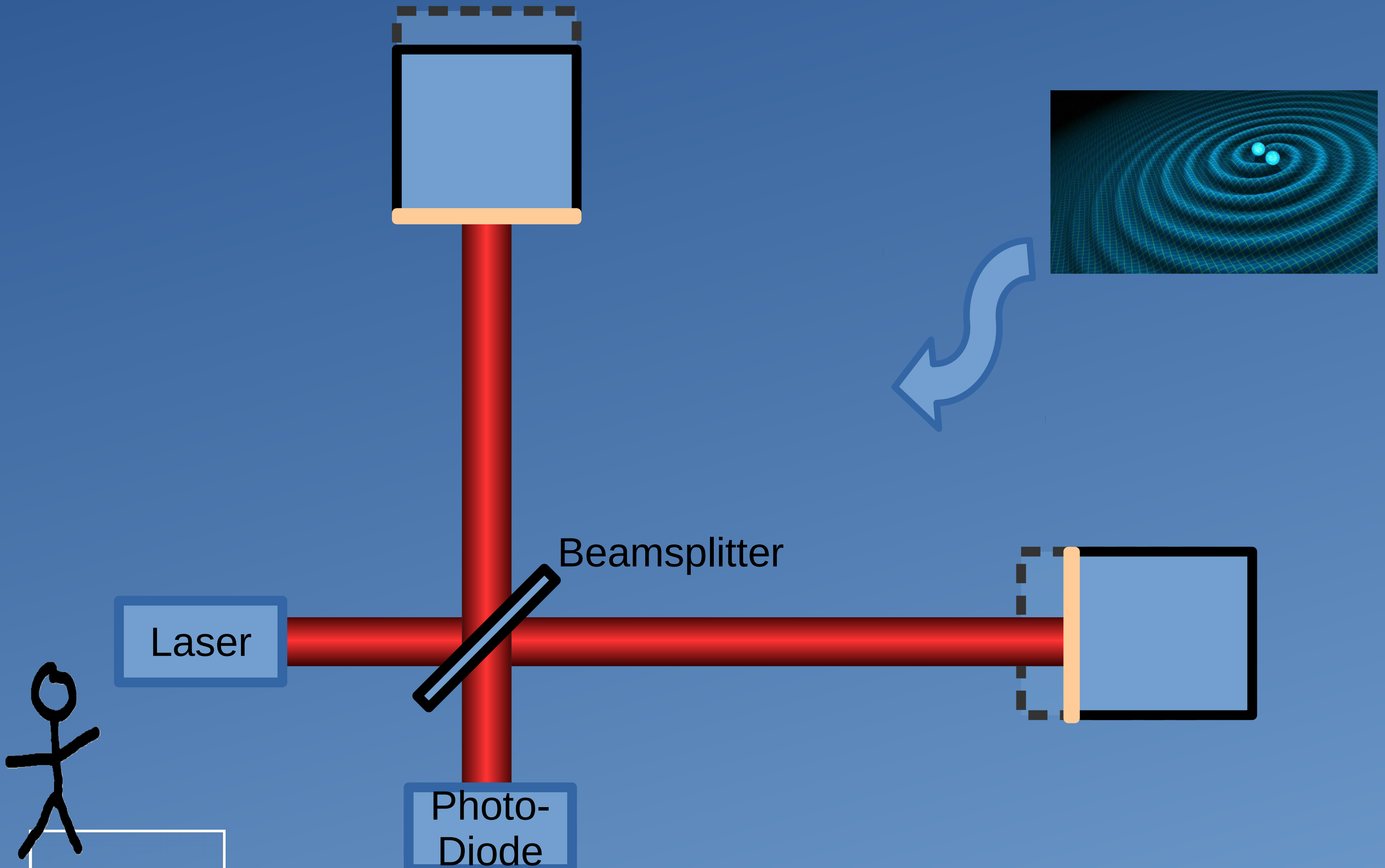
Gravitational Wave Detection



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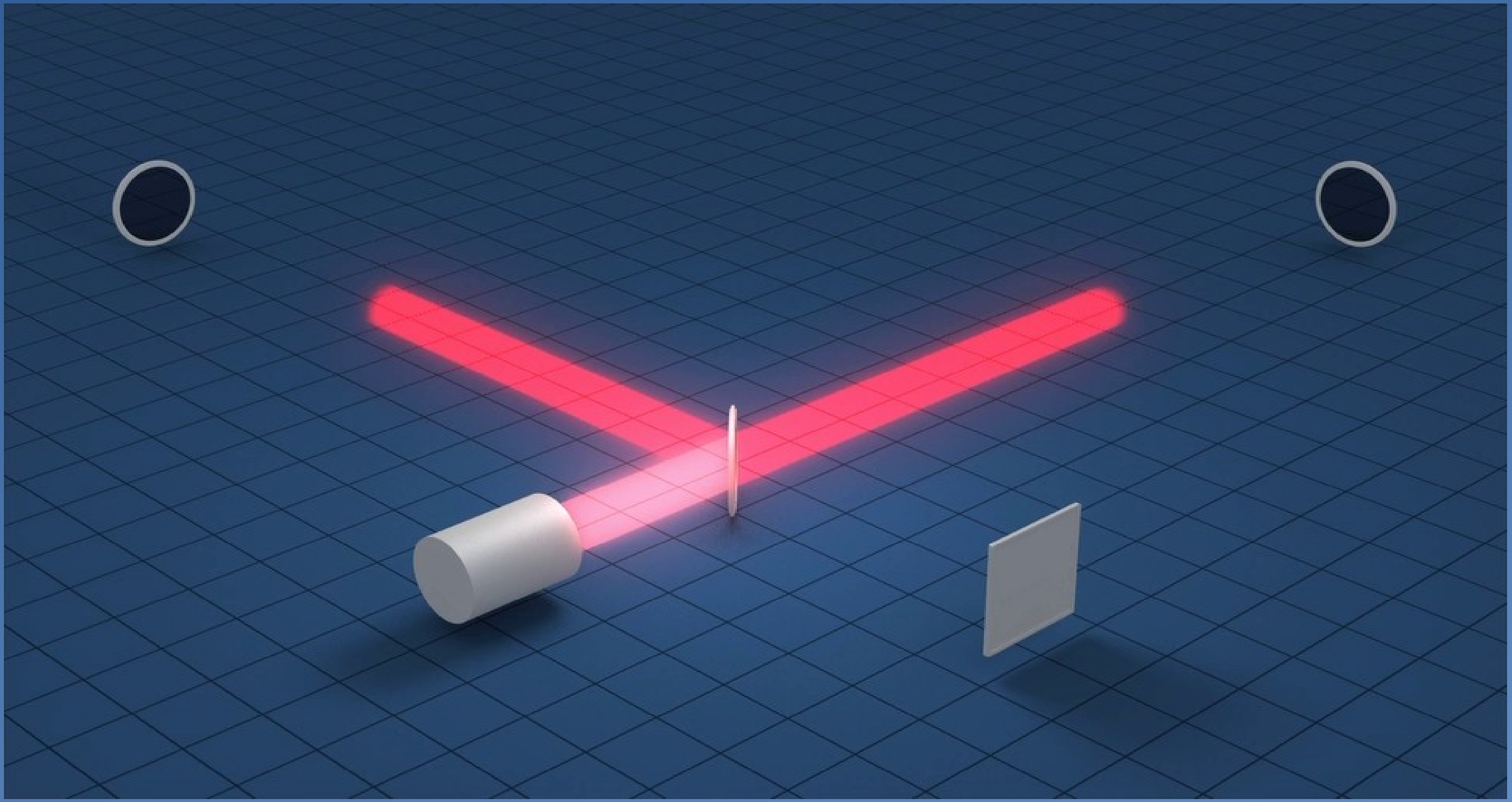
Gravitational Wave Detection



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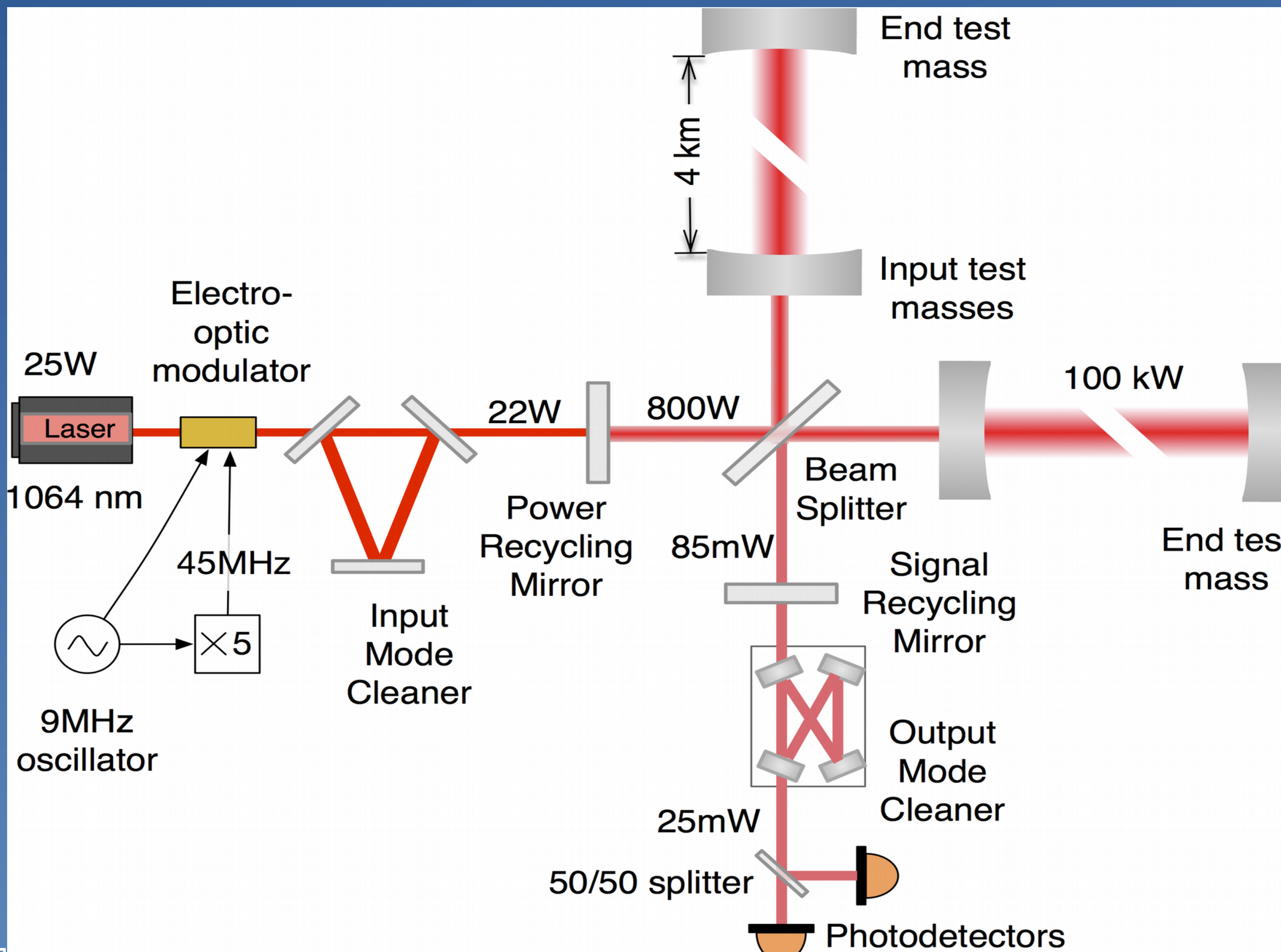

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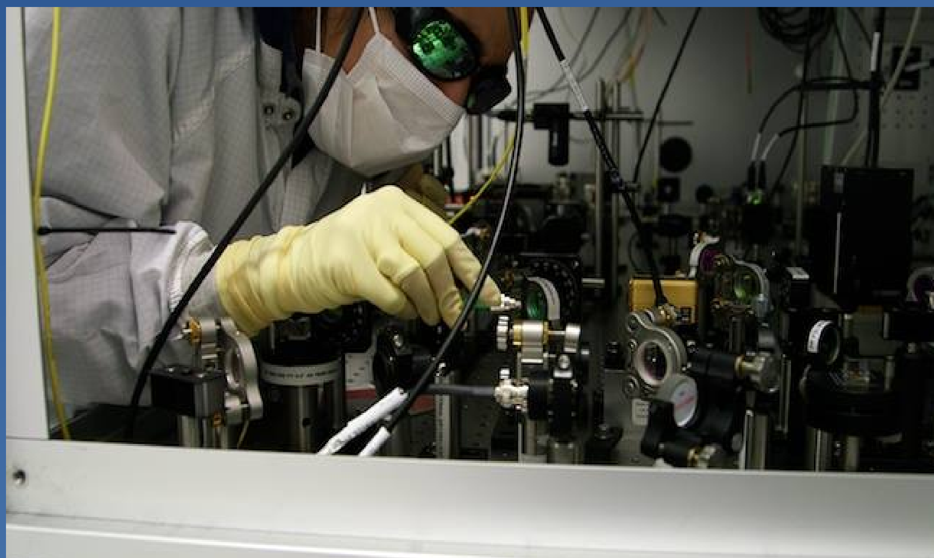

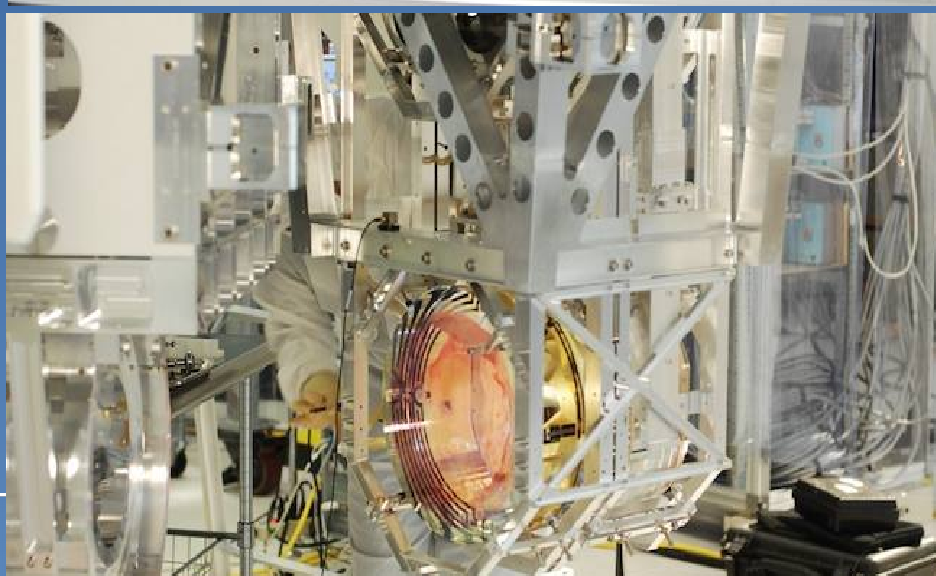

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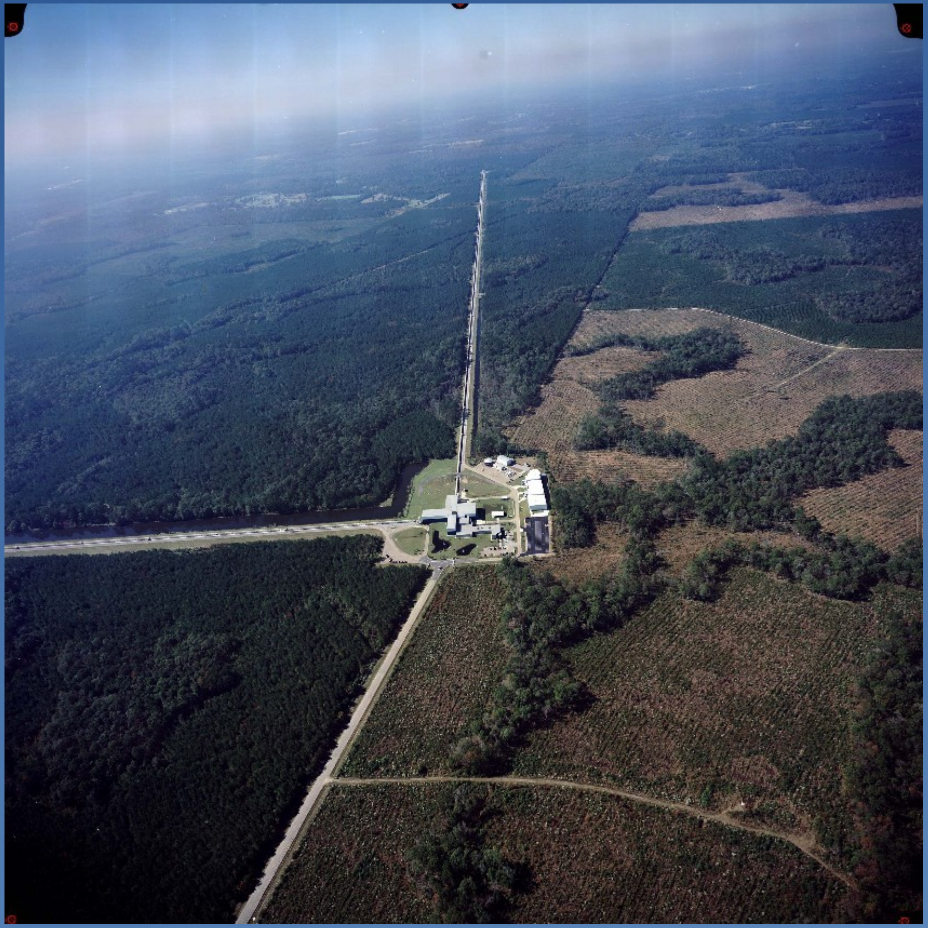
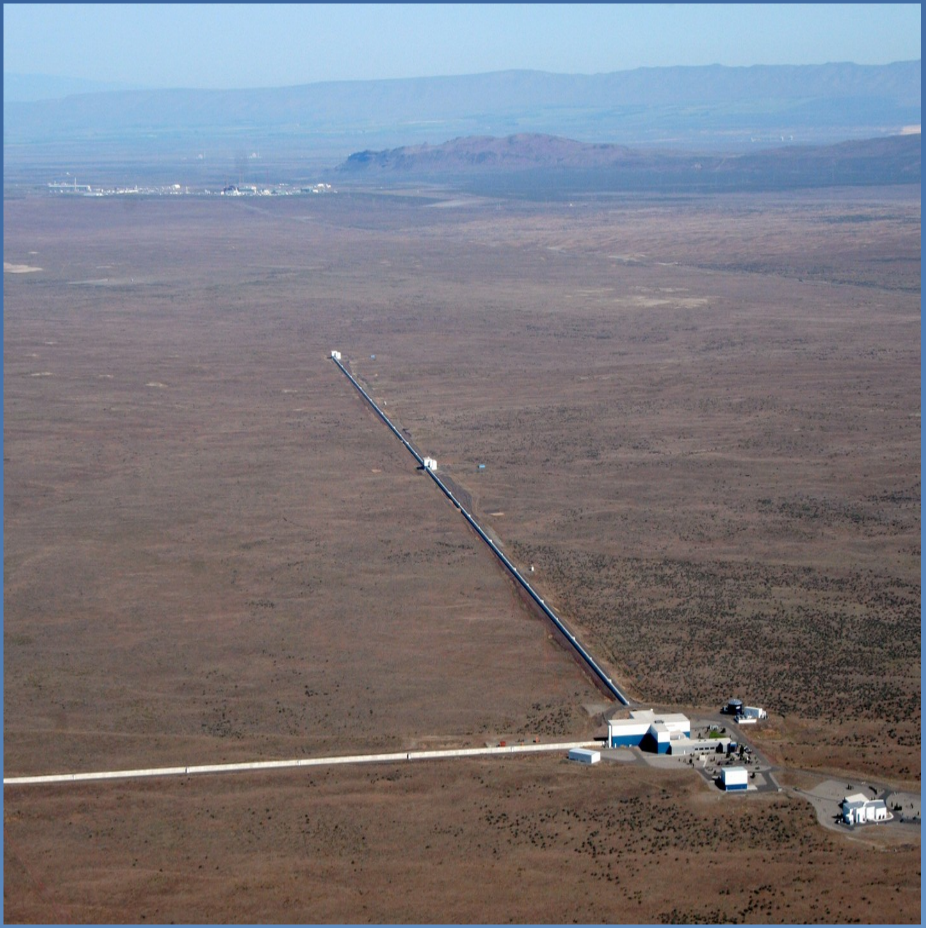
Gravitational Wave Detection





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LIGO

LSC

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Trinity University
University of Maryland
Andrews University
Washington State University
California State University Fullerton
The University of Alabama in Huntsville
Whitman College
American University
Sonoma State University
indigo
Montclair State University
University of Glasgow
Australian National University
University of the West of Scotland UWS
Texas Tech University
Tsinghua University
R·I·T
University of Strathclyde
Michigan
Max Planck Institute for Gravitational Physics Albert Einstein Institute
The University of Western Australia
CITA ICAT
Università degli Studi del Sannio
NASA Goddard Space Flight Center
University of Cambridge
ICTP SAIFR
The University of Chicago
Montana State University
Caltech
University of Minnesota
The University of Mississippi
The University of Adelaide Australia
Southern University and Agricultural & Mechanical College
Columbia University in the City of New York
University of Birmingham
The University of Melbourne
UIB Universitat de les Illes Balears
University of Washington
UTRGV
UW Milwaukee
Syracuse University
Cardiff University Prifysgol Caerdydd
Northwestern
Monash University
INPE
UF University of Florida
Georgia Institute of Technology
Korean Gravitational-Wave Group
LSU Louisiana State University
ACIGA
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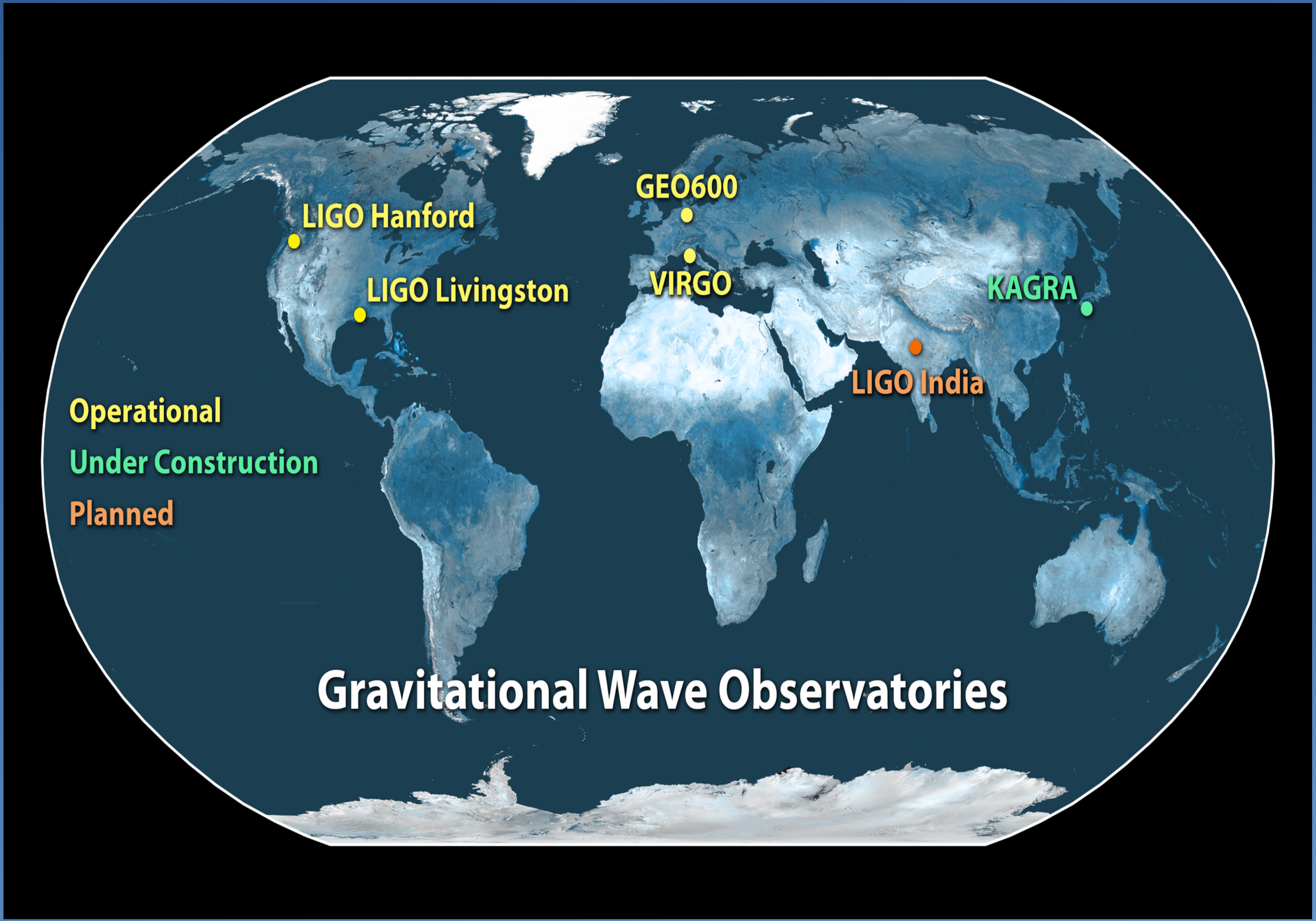

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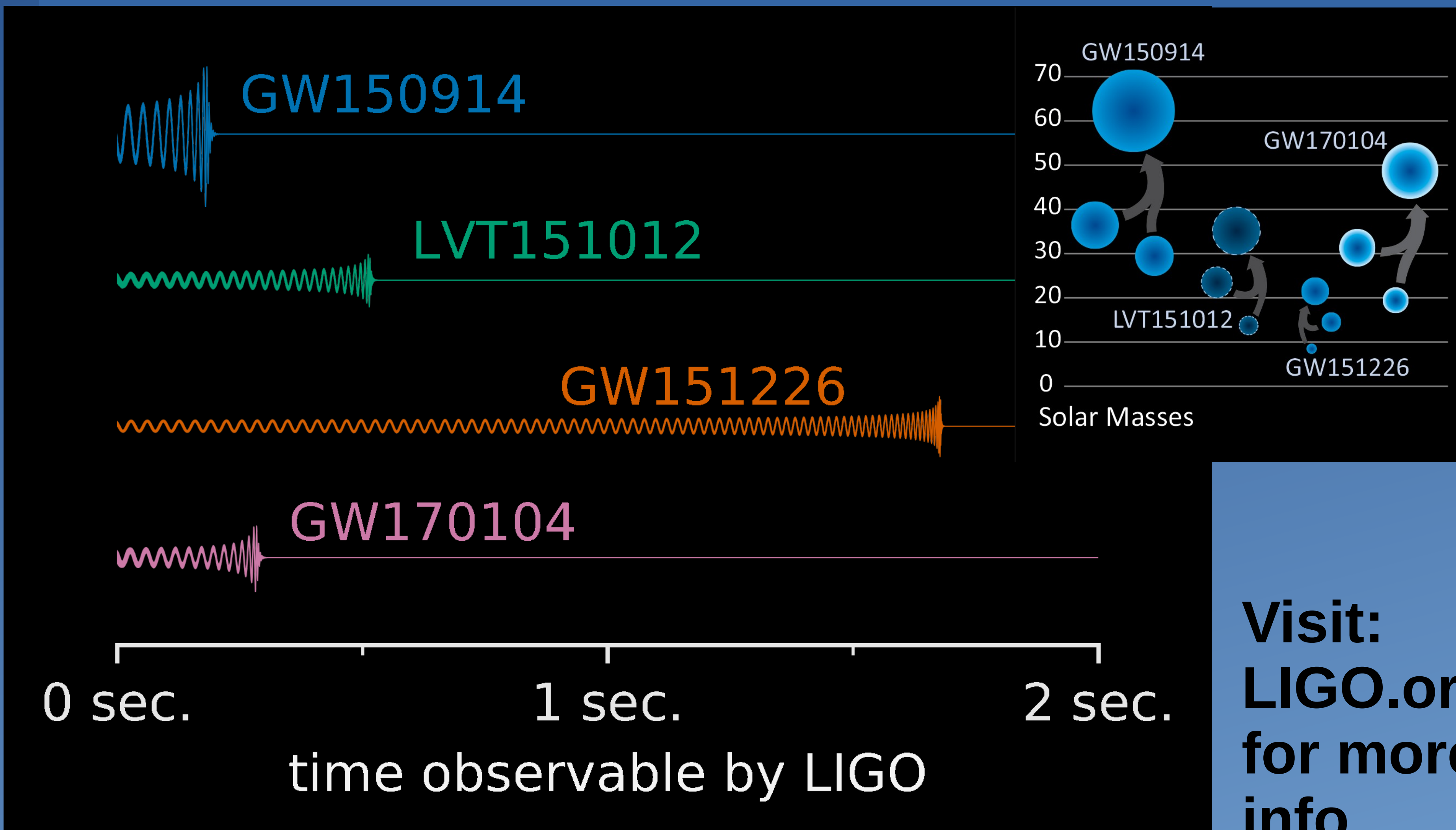
It Works!



Visit: LIGO.org for more info.

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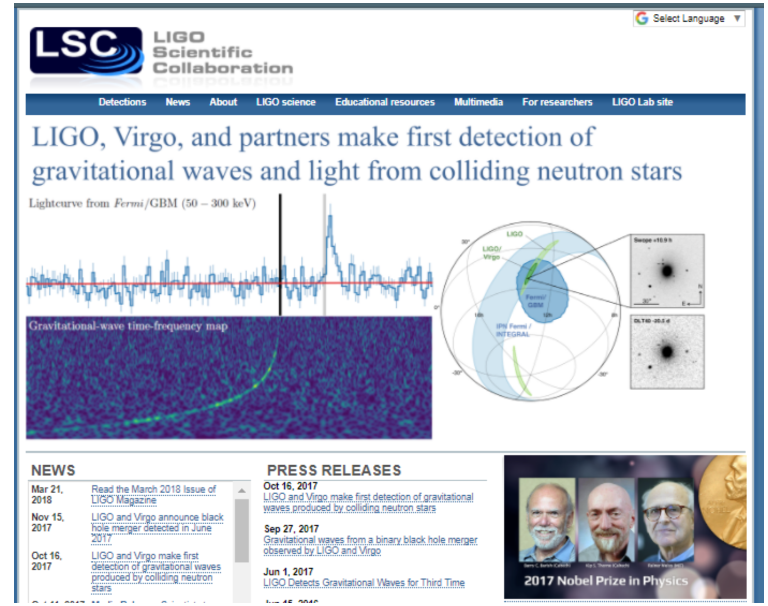
ligo.org

LSC's main global communication tool.

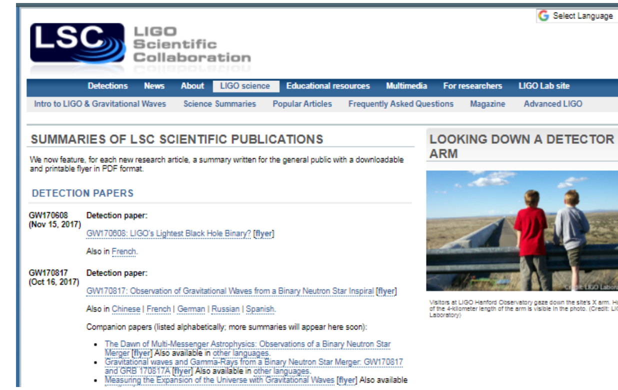
Key products:

- updates on LSC news/events.
- "detection" pages
  (links to publications, press releases,
  related multimedia).
- science summaries.
- collecting/curating resources
  of the EPO group.
- general info about the LSC.

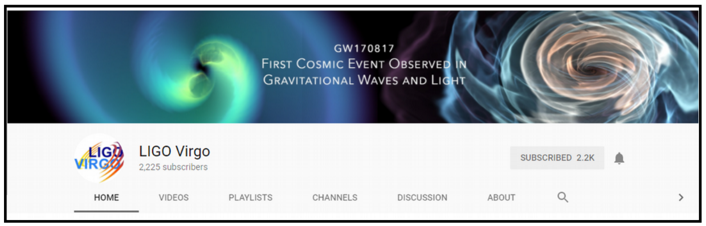


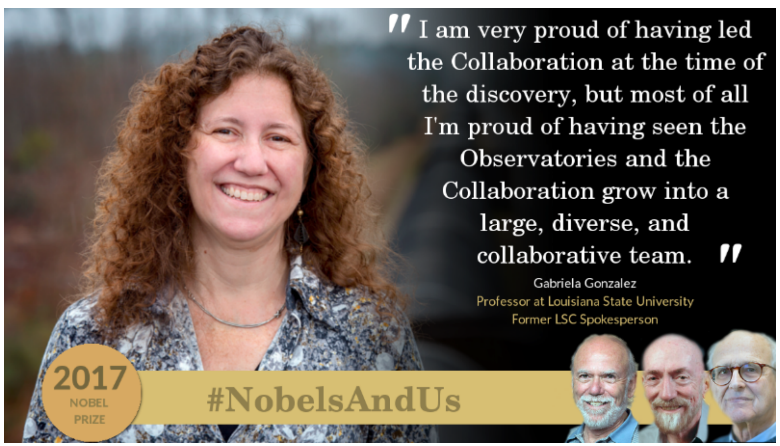
Science summaries

- *one of our key EPO products.*
- web page summaries of published papers; also pdf “flyer” versions for handouts at booths/ events.
- produced by members of paper writing teams and further edited by EPO.
- translations (~5 languages) for detection summaries.
- **More than 80 summaries since 2011**
- Now core part of PWT responsibilities, assisted by EPO group



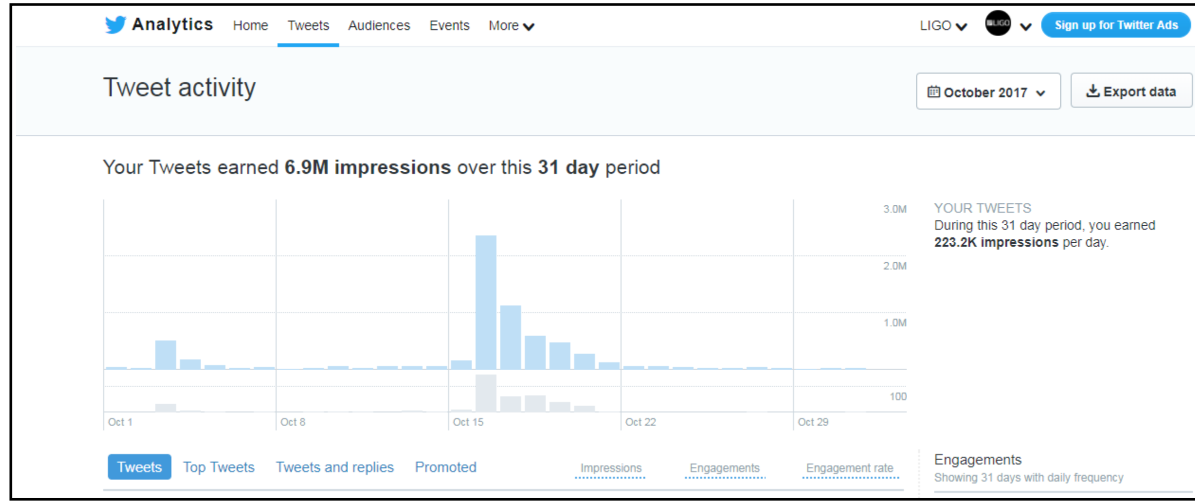
EPO Social Media:

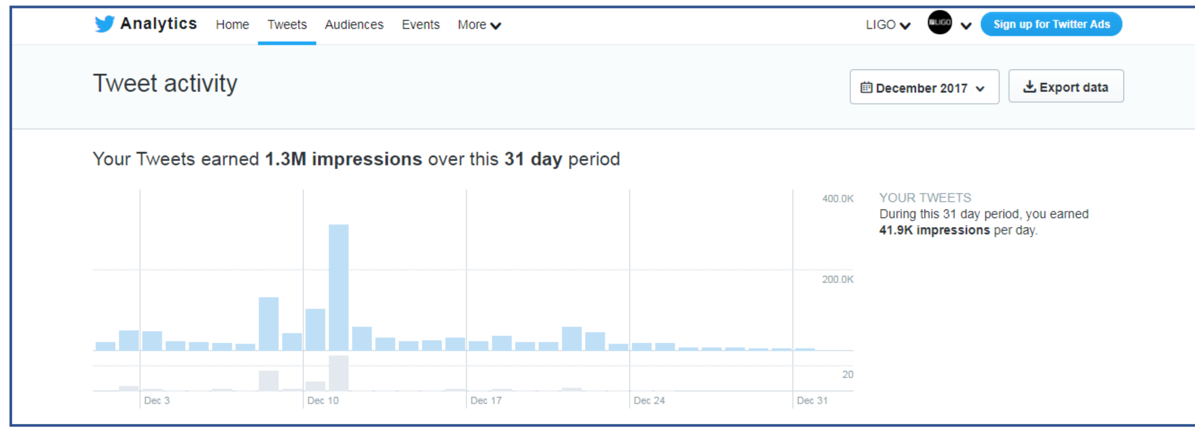


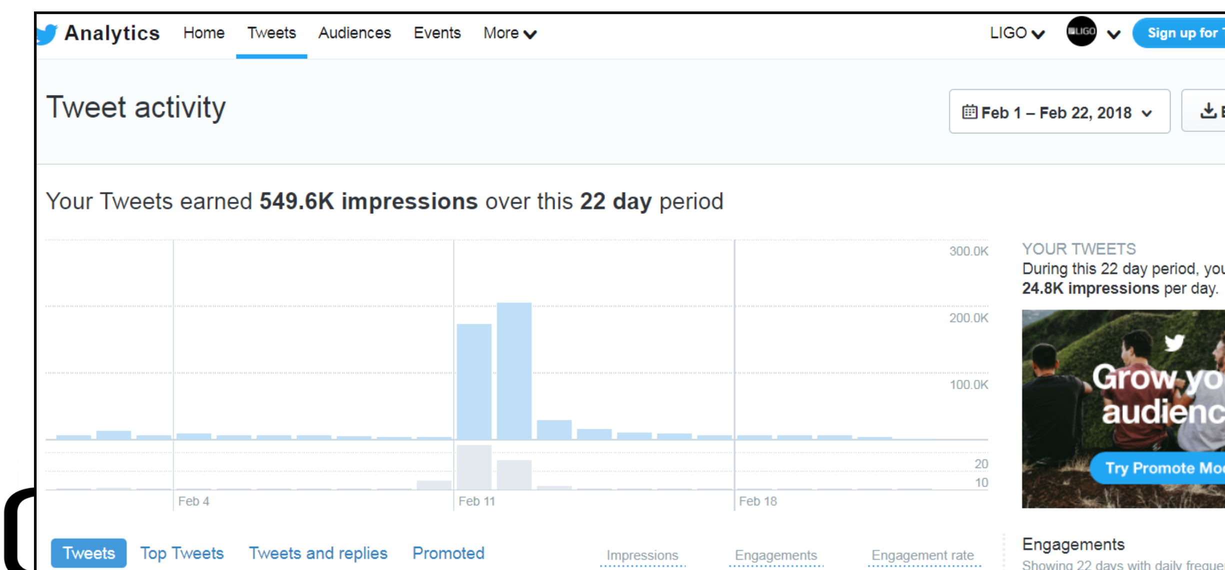


Aiming to improve social media coordination with laboratories, institutions, consortia and other GW projects.

Thinking hard about how best to support O3 public alerts

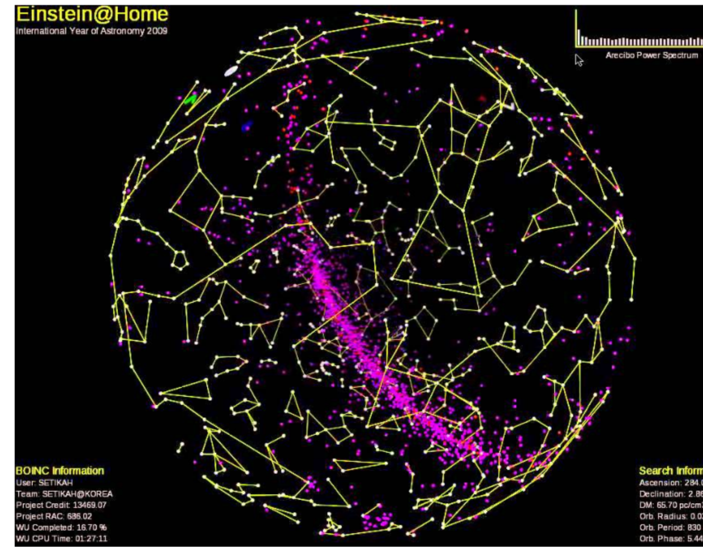






Citizen science: Einstein@home

- distributed computing project; analyzes data during your computer's idle time.



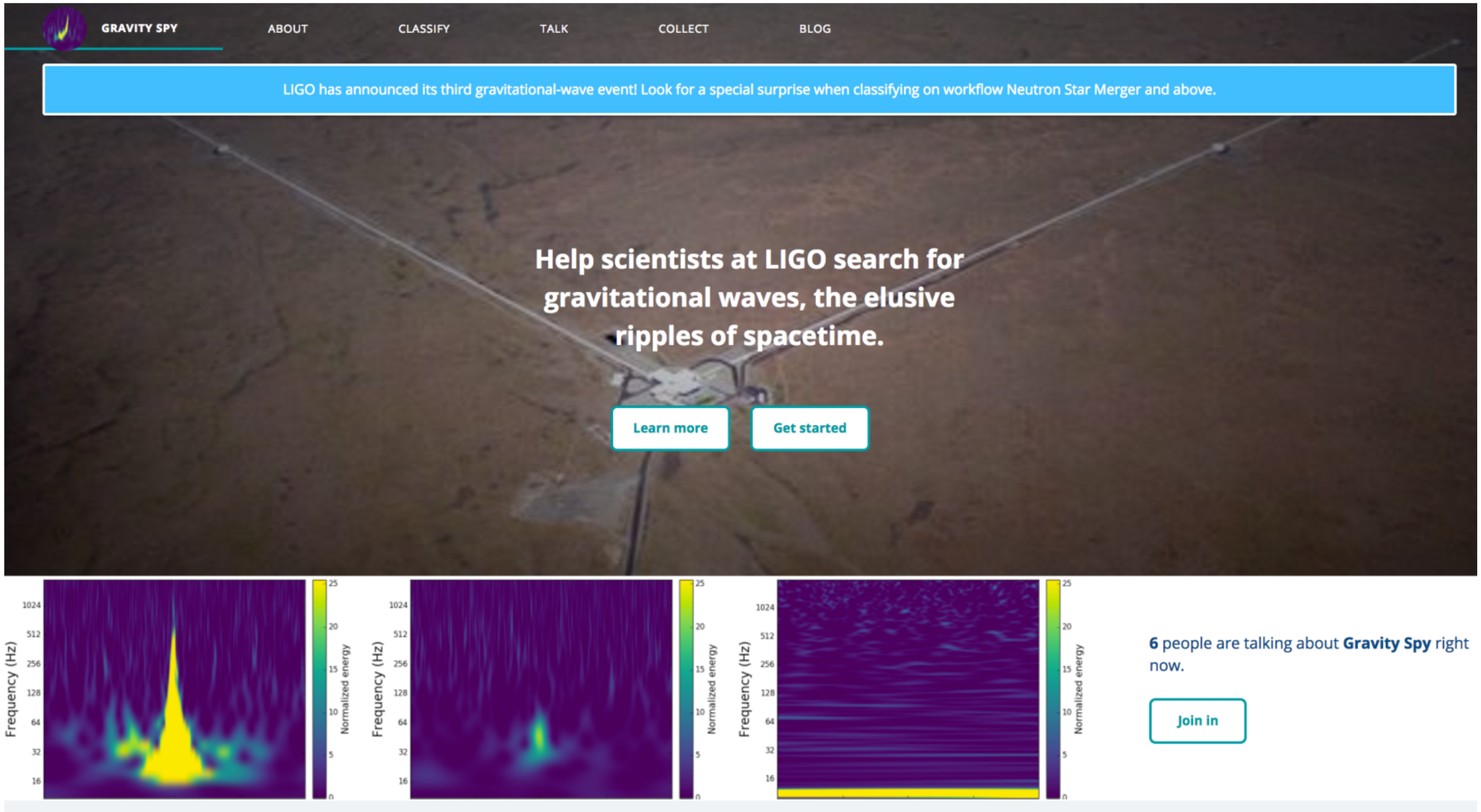
- search for continuous GWs from spinning neutron stars. Also look for new pulsars in radio or gamma-ray data.

- Key recent results:
  - 13 new gamma-ray pulsars (Jan. 2017).
  - most massive double neutron star system (Nov. 2016).
  - measurement of braking index of new gamma-ray pulsar (Nov. 2016).
  - 13 new radio pulsars discovered (Aug. 2016).
  - limits on GW amplitude and ellipticity from spinning neutron stars (Sep. 2016).

(einsteinathome.org)

Citizen science: GravitySpy.org

- volunteers help classify LIGO glitches; train machine learning algorithm and identify new glitch classes.
- ~9000 volunteers, ~2.2 million glitches classified. (Aug 2017)
- currently using O2 data.



LIGO Open Science Center (LOSC)

Main public portal
for LIGO data:

https://losc.ligo.org/

key products:

- h(t) data segments near detected events.
- past (S5, S6) and future data releases for science/observing runs.
- some data from publication figures.
- documentation and software tools for using data.
- python-based tutorials: play with data to extract detected signals.
- ~100 users/day

Open F2F workshop in March 2018