Introduction to General Relativity (aka Gravity)

Reed Clasey Essick
KICP

28 September 2019
Compton Lectures
University of Chicago

"All the News That's Fit to Print"

The New York Times

Late Edition
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VOL. CLXV . . . No. 57,140 + NEW YORK, FRIDAY, FEBRUARY 12, 2016 $2.50

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CALTECH-M.I.T.-LIGO LABORATORY

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WITH FAINT CHIRP, SCIENTISTS PROVE EINSTEIN CORRECT

A RIPPLE IN SPACE-TIME

An Echo of Black Holes Colliding a Billion Light-Years Away

By DENNIS OVERBYE

A team of scientists announced on Thursday that they had heard and recorded the sound of two black holes colliding a billion light-years away, a fleeting chirp that fulfilled the last prediction of Einstein's general theory of relativity.

That faint rising tone, physicists say, is the first direct evidence of gravitational waves, the ripples in the fabric of space-time that Einstein predicted a century ago. It completes his vision of a universe in which space and time are interwoven and dynamic, able to stretch, shrink and jiggle. And it is a ringing confirmation of the nature of black holes, the bottomless gravitational pits from which not even light can escape, which were the most fore-

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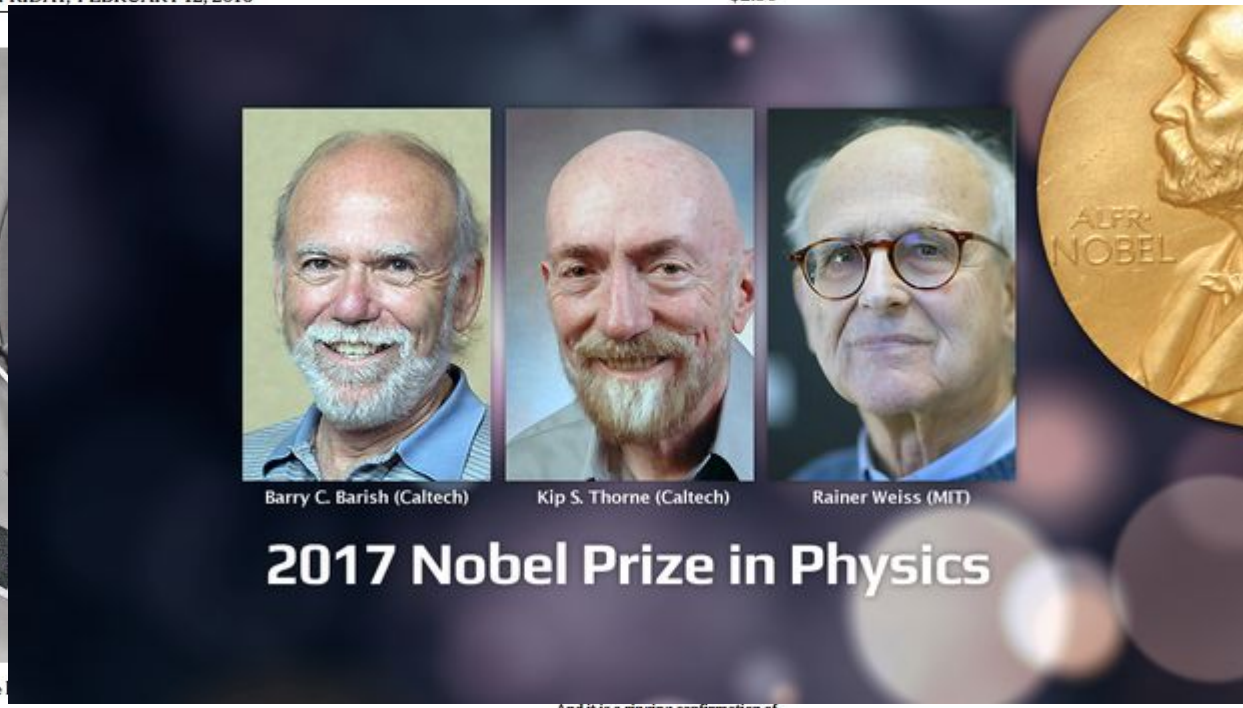

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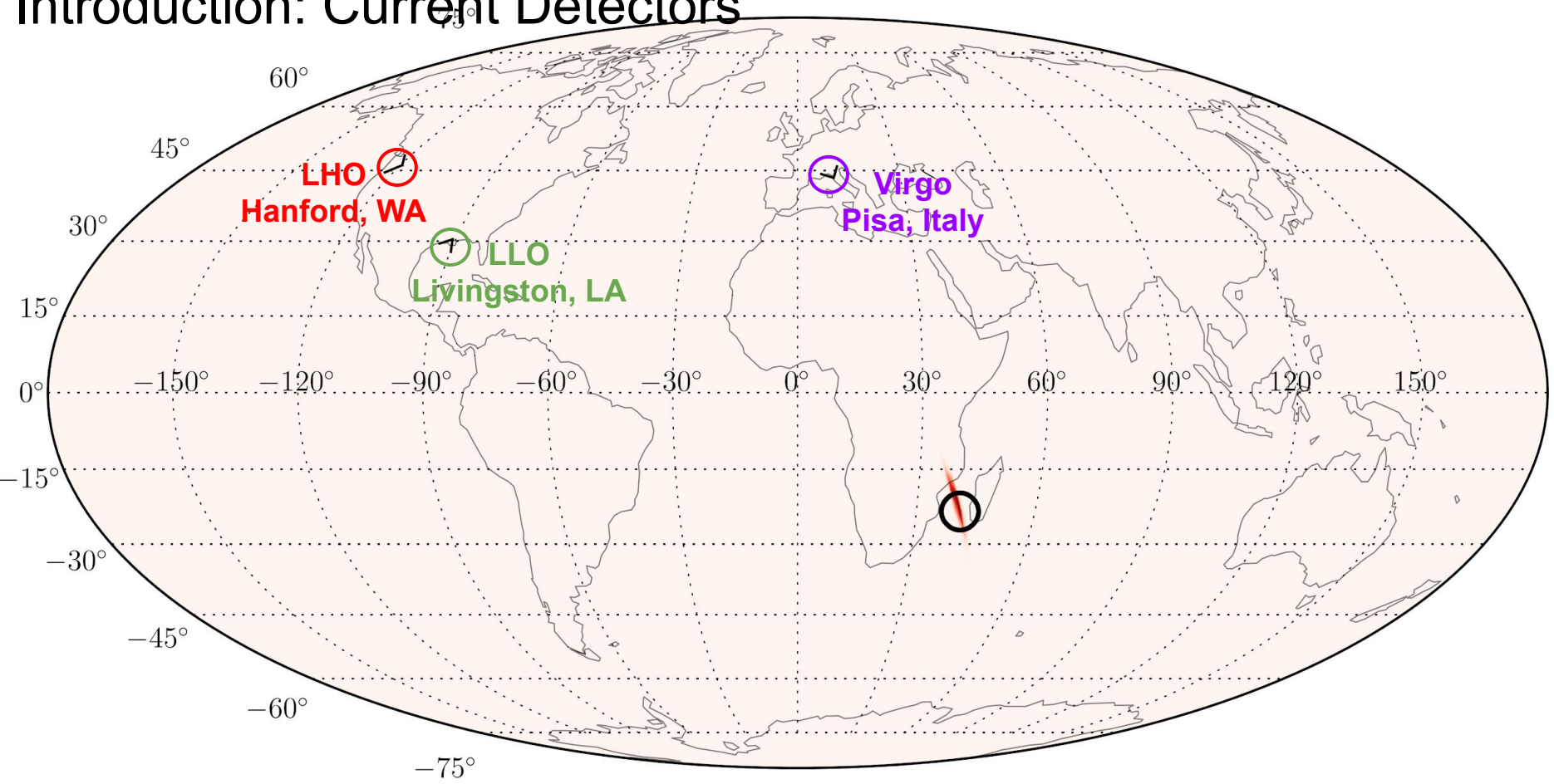

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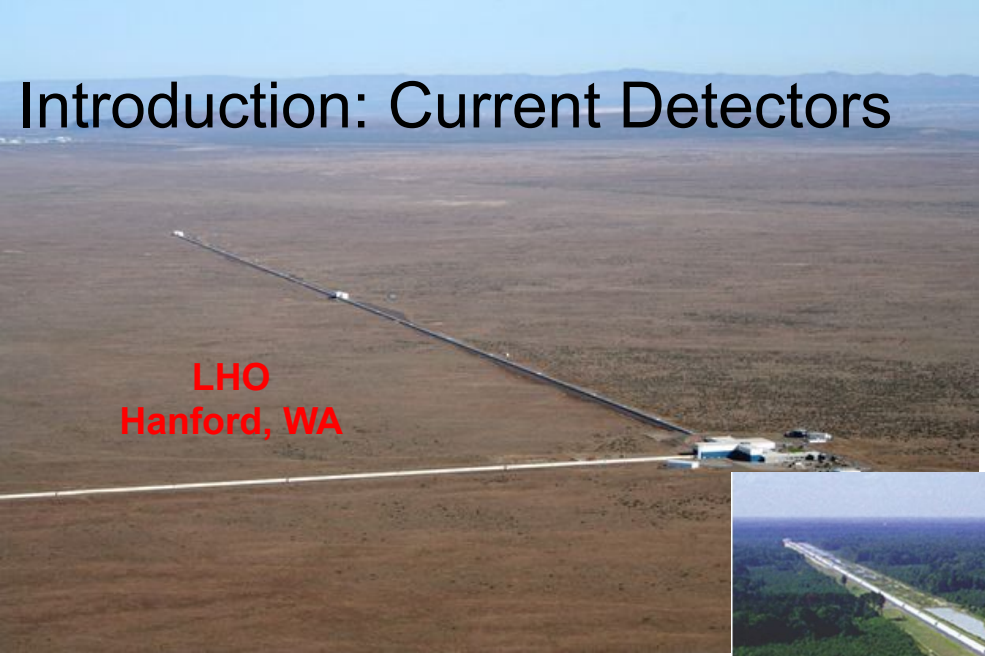

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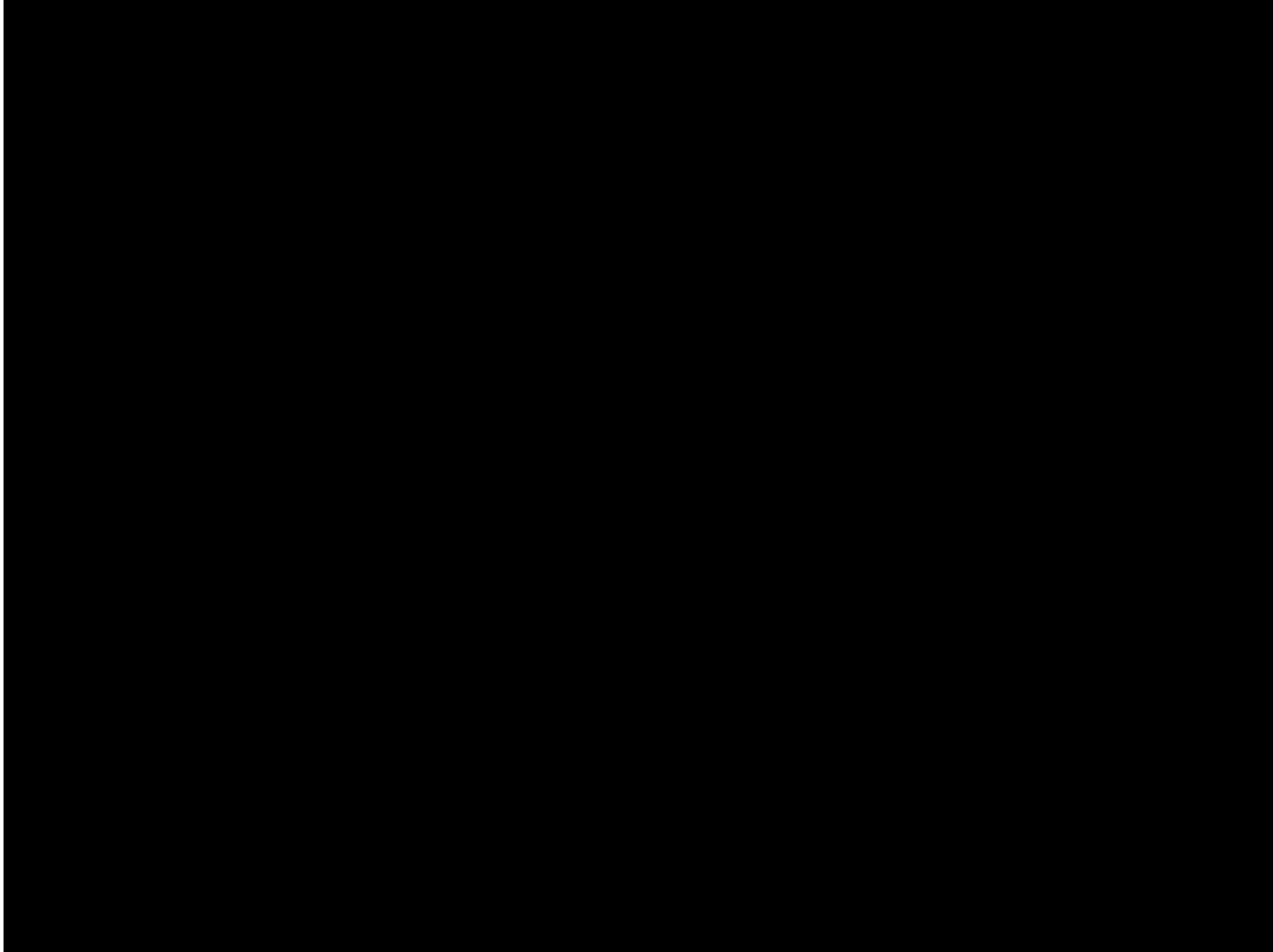

Introduction: Astrophysical Objects

Neutron Stars and **Black Holes**

They go by many names

- Pulsar
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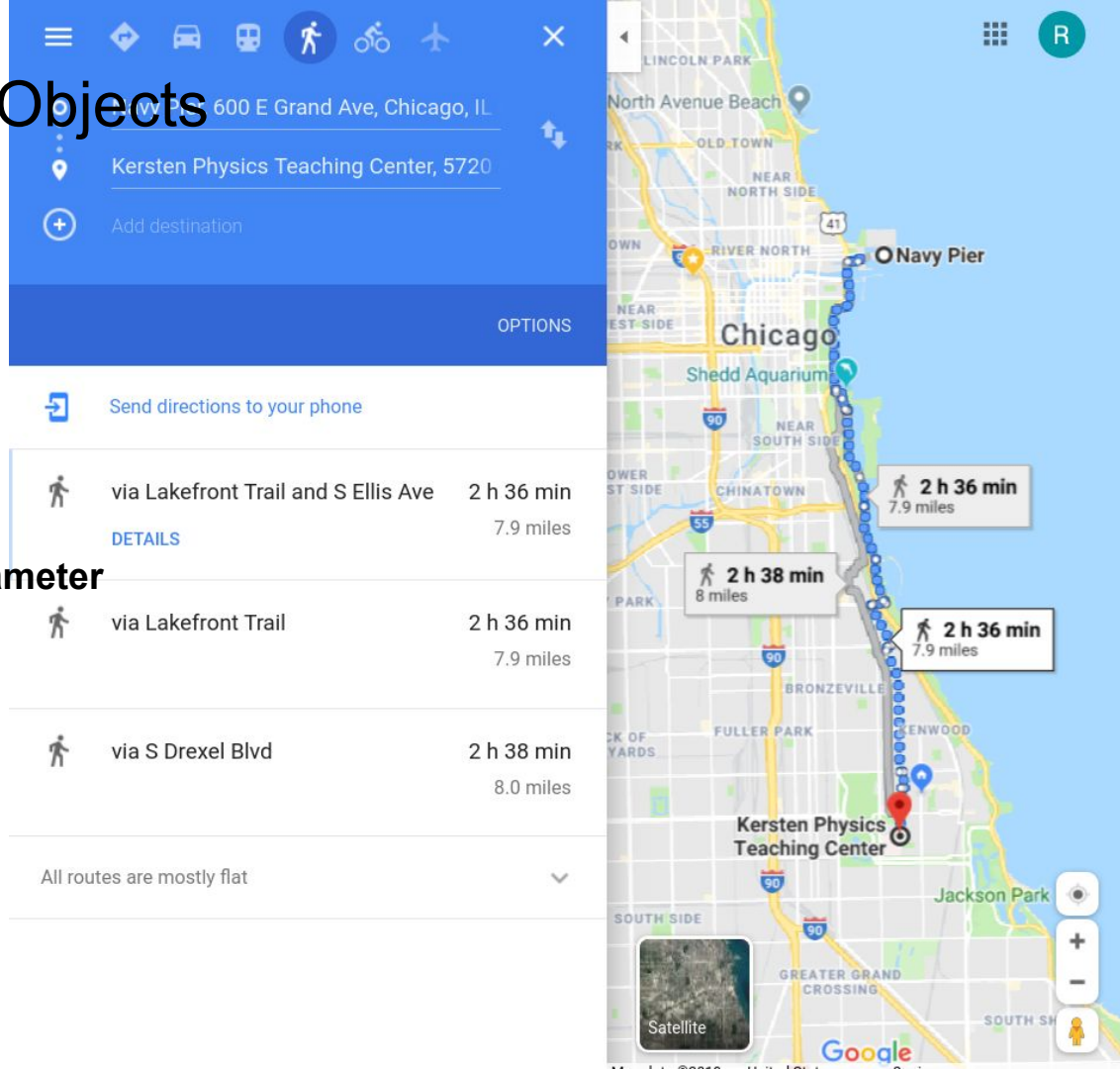

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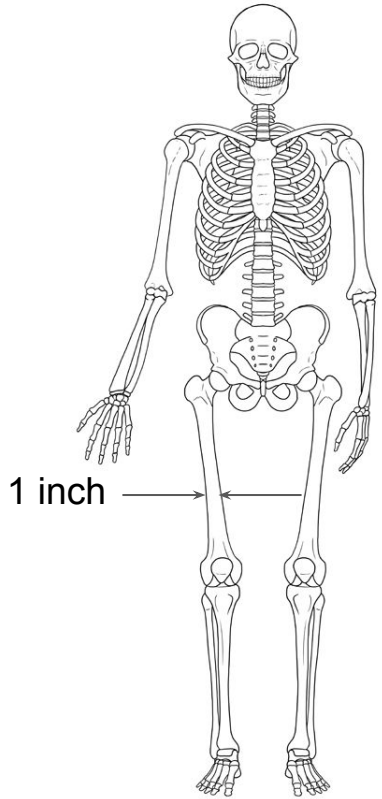

$$
\begin{aligned}
2 \times A_{\text{femur}} \times E_{\text{bone}} &= 2 \times \pi (1.2\,\text{cm})^2 \times 170\,\text{MPa} \\
&= 154000\,\text{N} \\
&= 7,134\,\text{lbs} \approx 3.5\,\text{tons}
\end{aligned}
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Neutron Stars and **Black Holes** are the end states of massive stars

M_*

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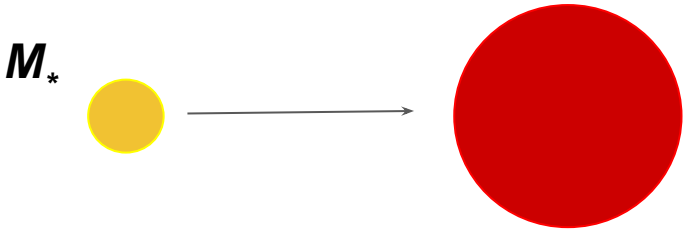

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giant branch
He, C, …, Fe

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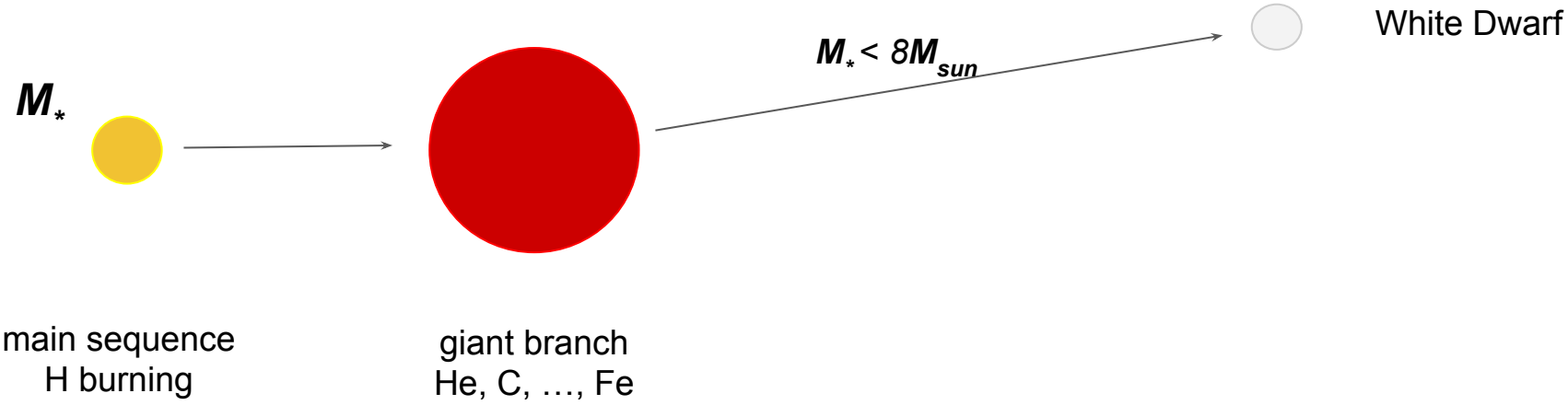

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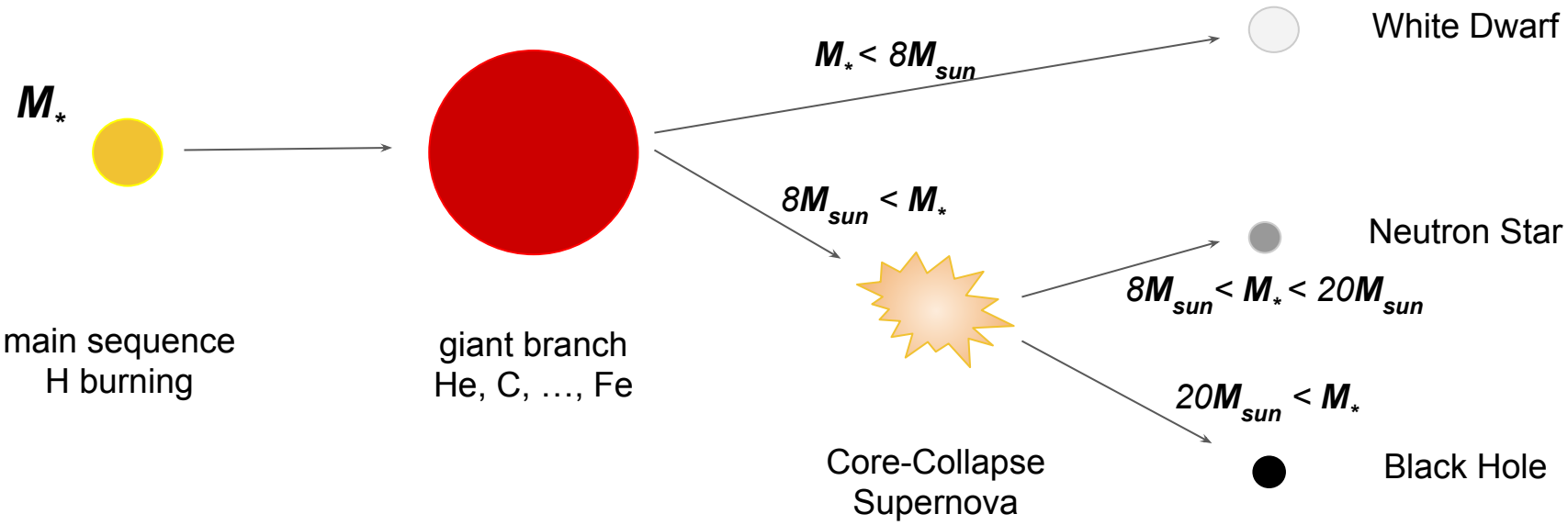

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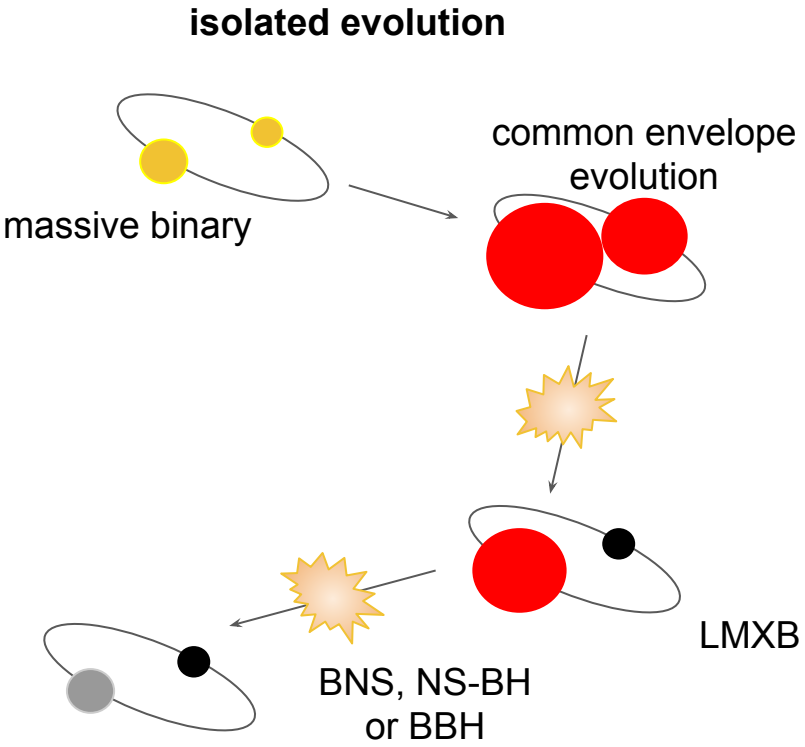

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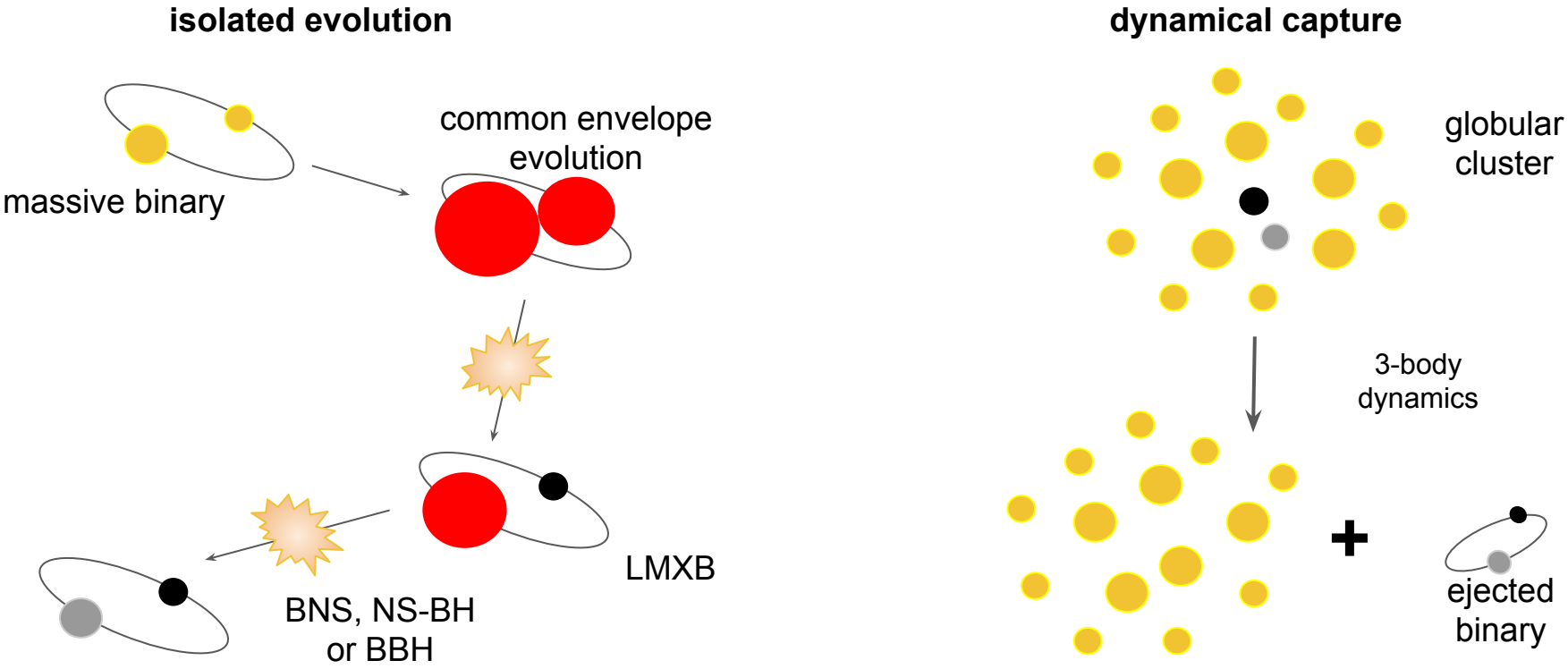

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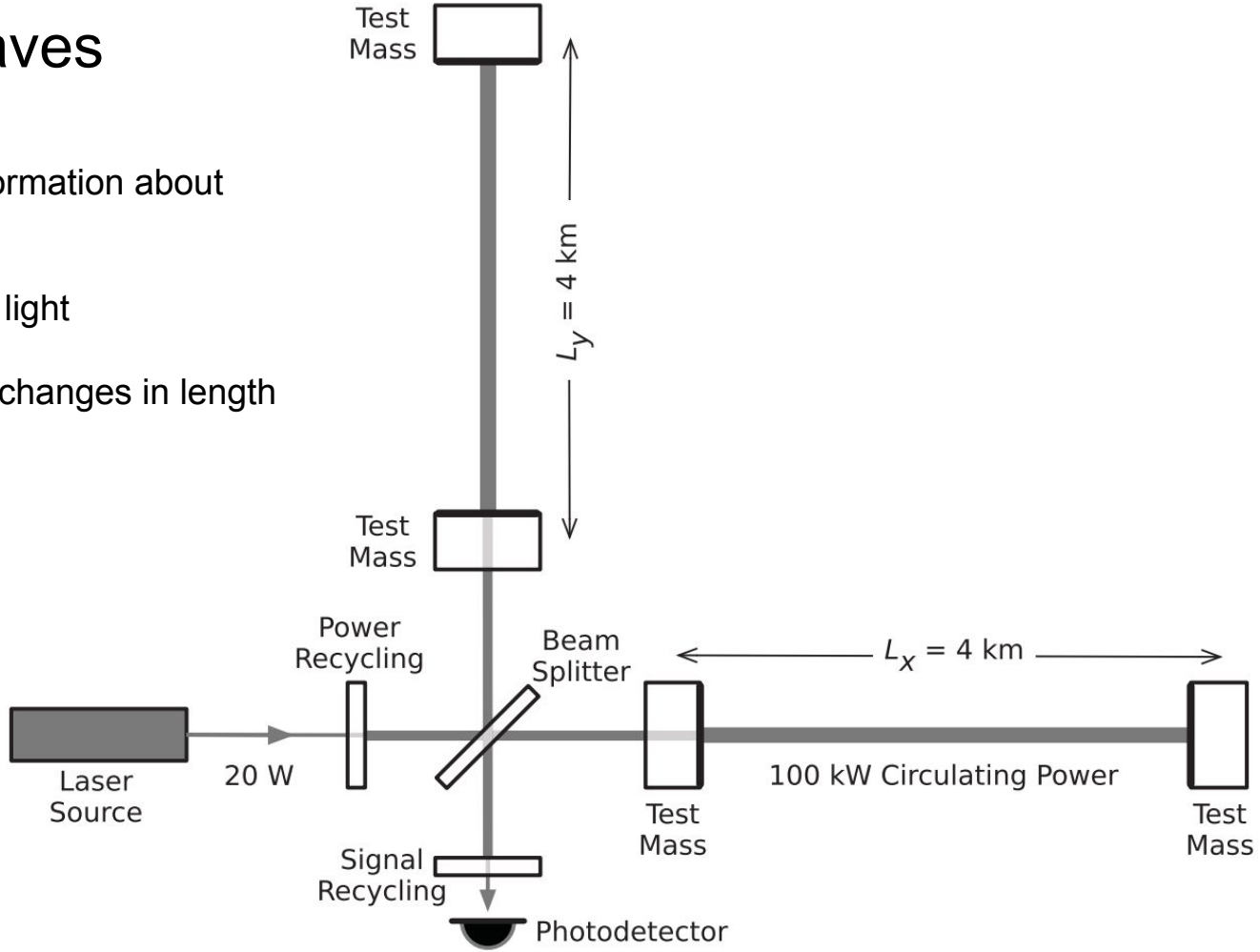

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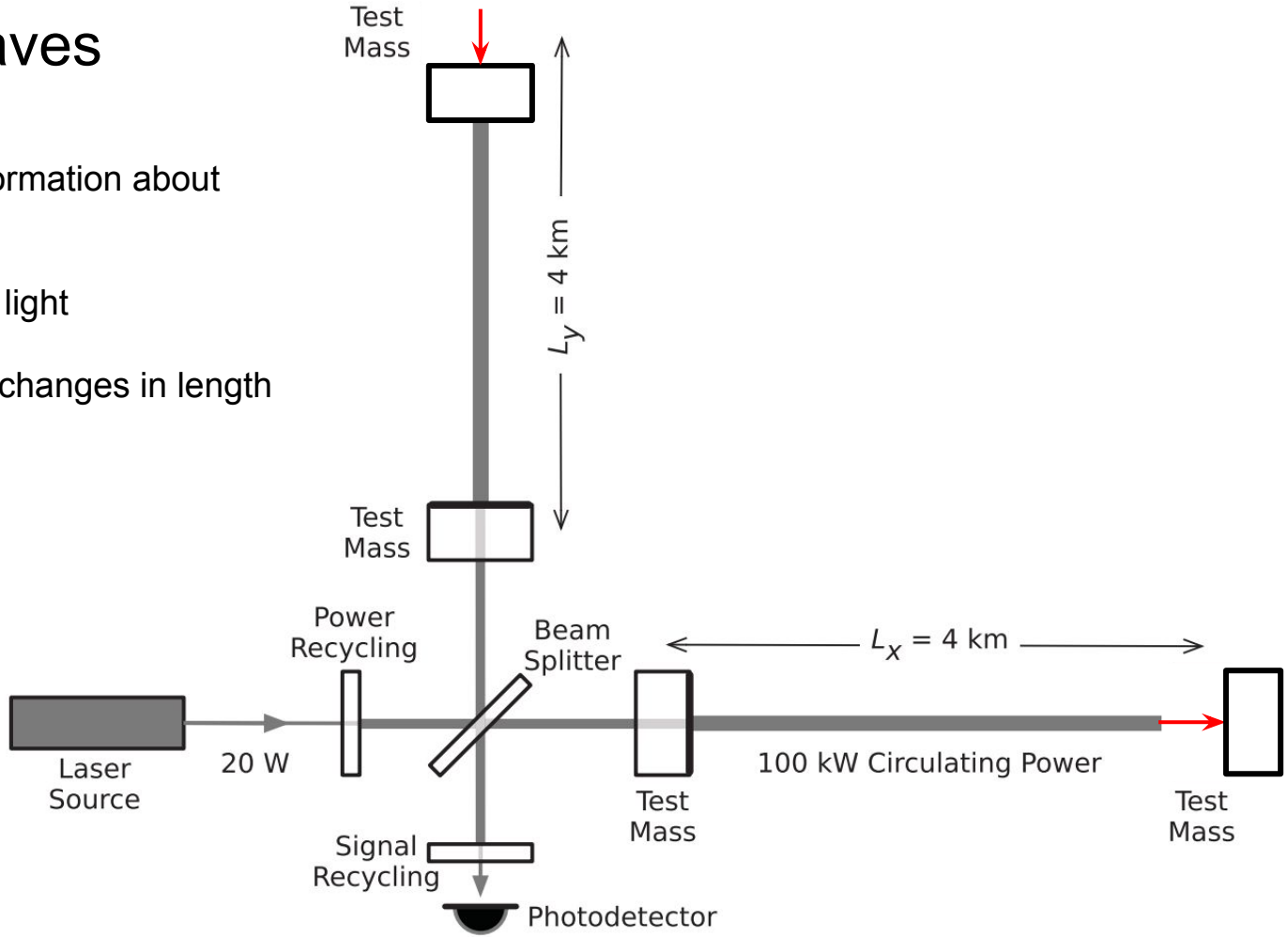

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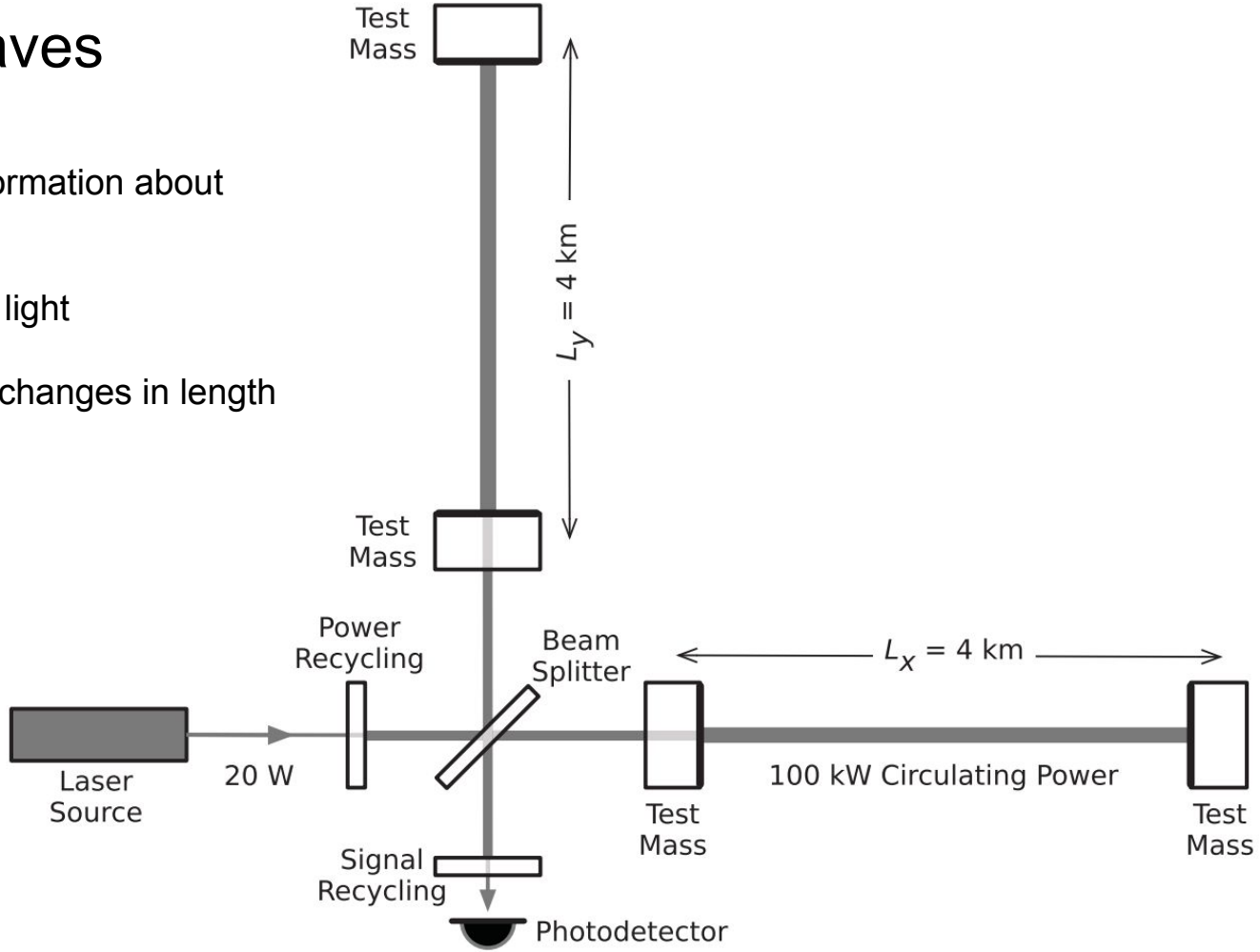

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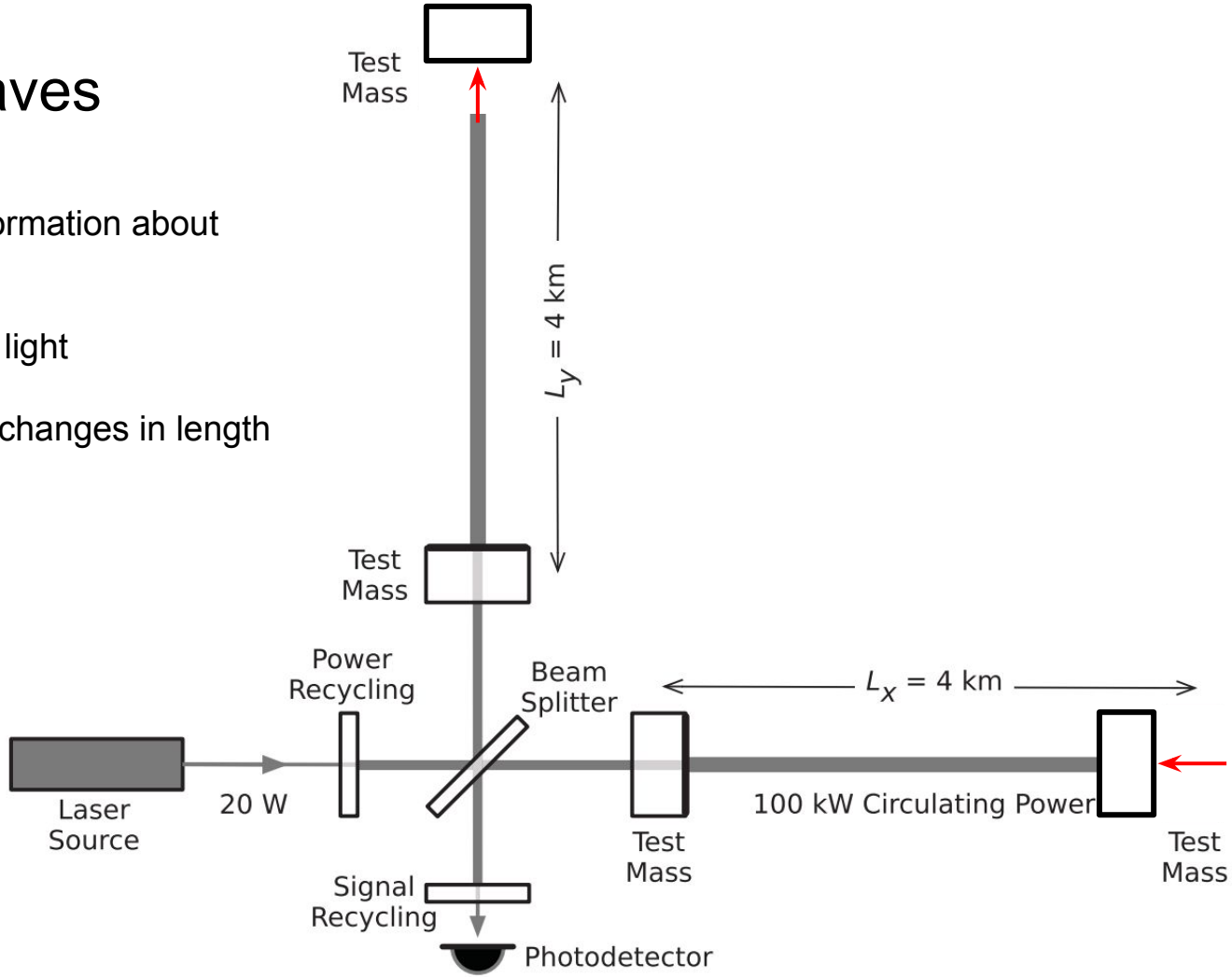

Next time

Astrophysical Sources of Gravitational Waves

- Why we use big objects in space
- More about the types of big objects we use, where they come from, what happens to them
- How these things are connected to the rest of the universe

Suggested Reading

- *Black Holes and Time Warps*. Kip S Thorne.
- *The Universe in a Nutshell*. Stephen Hawking.
- *Was Einstein Right?: Putting General Relativity to the Test*. Cliff Will