



Richard Feynman:
Gravitational waves do physical work and must be real.

1957



Joseph Weber suggests ideas for detecting gravitational waves.

1959



John Wheeler popularizes the term "black hole."

1968



Rainer Weiss conceives of a laser-based technique that forms one of the roots of LIGO.



GRBs shown to be a new cosmic phenomenon.

1973



NASA's Explorer 11 detects first gamma rays in space.

1961

1950

1960

1970

1980

Vela satellites detect what's later shown to be the first gamma-ray burst (GRB).

1967

NASA's Small Astronomy Satellite 2 provides first detailed look at gamma-ray sky.

1972



First neutrinos from the Sun observed.

1968

1956

Neutrinos discovered — first of three types recognized.



1

00:00:00,600 --> 00:00:05,680

In 2017, NASA's Fermi Gamma-ray Space Telescope connected

2

00:00:05,680 --> 00:00:09,170

gamma rays, the highest-energy form of light, with new

3

00:00:09,170 --> 00:00:13,280

cosmic messengers--gravitational waves and high-energy neutrinos.

4

00:00:13,280 --> 00:00:17,470

For the first time, the discoveries linked these new signals to

5

00:00:17,470 --> 00:00:21,570

the one sky watchers have known for millennia -- light.

6

00:00:21,570 --> 00:00:25,710

First, gravitational waves and gamma rays were emitted from merging neutron

7

00:00:25,710 --> 00:00:29,850

stars. Fermi saw the first-ever light detected from

8

00:00:29,850 --> 00:00:33,970

a gravitational wave event. Then, just weeks later, Fermi

9

00:00:33,970 --> 00:00:38,020

connected a high-energy neutrino seen by the IceCube experiment at the

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00:00:38,020 --> 00:00:42,080

South Pole to a black-hole-powered galaxy, which fires a jet of matter

11

00:00:42,080 --> 00:00:46,300

that emits both neutrinos and gamma rays. This is no

12

00:00:46,300 --> 00:00:50,360

overnight success story. The origins of both these breakthroughs

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00:00:50,360 --> 00:00:54,420

span more than a century. As the

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00:00:54,420 --> 00:00:58,480

19th century closed, scientists worked to understand many new phenomena

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00:00:58,480 --> 00:01:02,580

including radioactivity, and new forms of light --

16

00:01:02,580 --> 00:01:06,640

X-rays and gamma rays. Light was expected to need a medium, called

17

00:01:06,640 --> 00:01:10,730

the "aether," in order to move through space, which meant its speed should change when measured

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00:01:10,730 --> 00:01:14,770

in different directions on the moving Earth. Yet no changes were seen.

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00:01:14,770 --> 00:01:18,850

Solving this puzzle led to Einstein's special theory

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00:01:18,850 --> 00:01:22,940

of relativity, which assumed light in a vacuum moves at a constant speed that

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00:01:22,940 --> 00:01:27,030

nothing can exceed. His theory formed a theoretical basis for

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00:01:27,030 --> 00:01:31,070

particle physics... ...which in 1912 incorporated an unexpected

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00:01:31,070 --> 00:01:35,200

source -- a rain of particles from space called cosmic rays.

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00:01:35,200 --> 00:01:39,290

Einstein's general theory of relativity, his theory

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00:01:39,290 --> 00:01:43,390

of gravity, regarded space-time as the fabric of the cosmos.

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00:01:43,390 --> 00:01:47,470

Space-time tells matter how to move, and matter tells space-time how to

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00:01:47,470 --> 00:01:51,540

curve. As scientists probed the subatomic

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00:01:51,540 --> 00:01:55,640

realm, one type of radioactive decay suggested the presence

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00:01:55,640 --> 00:01:59,730

of a new lightweight particle, dubbed the "neutrino."

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00:01:59,730 --> 00:02:03,930

Later, Einstein and Nathan Rosen showed

31

00:02:03,930 --> 00:02:08,010

that accelerating masses can create gravitational waves that ripple

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00:02:08,010 --> 00:02:09,780

across space-time.

33

00:02:11,740 --> 00:02:15,820

Following World War II, technological advances permitted new kinds

34

00:02:16,160 --> 00:02:20,270

of observations. In the mid-Fifties, neutrinos were detected for the

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00:02:20,270 --> 00:02:24,320

first time. Richard Feynman showed that gravitational waves must

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00:02:24,320 --> 00:02:28,390

move matter, which means they're detectable. In a few years, the first

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00:02:28,390 --> 00:02:32,490

efforts to do so began. The 1960s brought

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00:02:32,490 --> 00:02:36,620

the first gamma rays seen in space, the first neutrinos

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00:02:36,620 --> 00:02:40,670

detected from the Sun's interior, and something new -- later called

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00:02:40,670 --> 00:02:44,740

gamma-ray bursts, or GRBs -- was caught by satellites looking for banned

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00:02:44,740 --> 00:02:48,880

tests of nuclear weapons. In 1971,

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00:02:48,880 --> 00:02:53,020

Rainer Weiss conceived of a way to detect gravitational waves

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00:02:53,020 --> 00:02:57,120

using lasers, one of the roots of LIGO.

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00:02:57,120 --> 00:03:01,190

1987 delivered the brightest supernova in nearly 400

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00:03:01,190 --> 00:03:05,240

years. Three experiments caught neutrinos from the star's collapse.

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00:03:05,240 --> 00:03:09,300

Instruments on balloons saw gamma rays from radioactive elements

47

00:03:09,300 --> 00:03:13,410

in the explosion's debris. The 1990s

48

00:03:13,410 --> 00:03:17,490

and 2000s brought: new satellites for exploring the

49

00:03:17,490 --> 00:03:21,570

gamma-ray universe; the construction and first operation of LIGO;

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00:03:21,570 --> 00:03:25,820

and AMANDA, a neutrino detector built under the ice at the South Pole.

51

00:03:28,460 --> 00:03:29,800

In 2005,

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00:03:29,810 --> 00:03:33,870

NASA's Swift satellite showed that short gamma-ray bursts likely come

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00:03:33,870 --> 00:03:37,930

from merging neutron stars. Soon after,

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00:03:37,930 --> 00:03:42,030

NASA launched Fermi, providing our best-ever view of the gamma-ray sky.

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00:03:42,030 --> 00:03:46,140

AMANDA morphed into IceCube, which was completed in 2010.

56

00:03:46,580 --> 00:03:50,180

It monitors a cubic kilometer of ice under the South Pole

57

00:03:50,180 --> 00:03:54,250

for neutrinos. The same year, LIGO shut down

58

00:03:54,250 --> 00:03:58,330

for years of upgrades. IceCube reported more than

59

00:03:58,330 --> 00:04:02,420

two dozen high-energy neutrinos -- likely arrivals from

60

00:04:02,420 --> 00:04:06,550

beyond our galaxy. In 2015, the upgraded LIGO

61

00:04:06,550 --> 00:04:10,650

saw the first gravitational waves. The source: merging black holes

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00:04:10,650 --> 00:04:14,730

over a billion light-years away. And in 2017,

63

00:04:14,730 --> 00:04:18,810

gamma-ray counterparts accompanied both a gravitational wave

64

00:04:18,810 --> 00:04:22,920

event and a cosmic neutrino source.

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00:04:26,160 --> 00:04:30,260

Multimessenger astronomy -- and its promise of greater insight into the most

66

00:04:30,380 --> 00:04:34,480

powerful processes in the universe -- has arrived.

67

00:04:43,430 --> 00:04:39,340

[Music]

68

00:04:47,500 --> 00:04:51,690

[NASA Astrophysics]