Let's listen to a melody from the universe !



Studium Generale 2019. 11. 15 Nagoya University Seiji Kawamura (Nagoya University)

Question 1

Do you think we can listen to a melody from the universe?



What is gravitational wave? Derived from general relativity by Einstein Detected for the first time recently Can propagate in vacuum Same speed as light 3/46

We should be able to hear GWs!



Too small to hear



Super ear aid



Answer 1

Yes, we can listen to a melody from the universe with a super ear aid.



Detection method



GW detectors around the world





12/46

We did it ! (February 2016)

Video removed due to copyright restrictions

Coalescence of black hole binary 1.3 G light year away

Video removed due to copyright restrictions

29 solar mass

36 solar mass

62 solar mass after coalescence

SXS 14/46





Barry C. Barish (Caltech)



Kip S. Thorne (Caltech)

Rainer Weiss (MIT)

2017 Nobel Prize in Physics

https://www.ligo.c altech.edu/news/li go20171206 Video removed due to copyright restrictions

Video removed due to copyright restrictions

Coalescence of neutron star binary (August 2017)

https://www.ligo_caltech.edu/image/ ligo20171016d 19/46 Video removed due to copyright restrictions

Detected real GW melody

Detected real GW melody

22/46

Spectrogram



LIGO-Virgo/Geoffrey Lovelace, Duncan Brown, Duncan Macleod, Jessica McIver, Alex Nitz

Question 2

Do you think the universe is expanding?



Einstein equation

Einstein tensor Energy momentum tensor



Sora

Solution for the universe



Mathematically predicted the expansion of the universe from the Einstein equation

Alexander Friedmann

Einstein's belief



The universe must be eternally static!

Sora

Cosmological constant

Einstein tensor Energy momentum tensor



Observation

https://en.wikipedia.org/wiki/Edwin _Hubble

Edwin Hubble

The universe was found to be actually expanding!

Answer 2



Yes, the universe is expanding.

Biggest blunder

Einstein labelled the cosmological constant his "biggest blunder".



Question 3

Do you think Einstein really made biggest blunder?



Acceleration of the expansion of the universe



The expansion of the universe was found to be accelerating!

Adam G. Riess https://hub.jhu.edu/201 4/11/10/adam-riessbreakthrough-prize/

Dark energy

Essentially very similar to the cosmological constant

Figure removed due to copyright restrictions

Star wars 34/46

The universe consists of...



Dark = invisible



The little prince

Answer 3

Yes, Einstein made a mistake in saying that he made biggest blunder.

Question 4

Do you think we can listen to the birth cry of the universe?



Looking far to see the past



M78 nebula: 3 million years ago

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https://ja.wikipedia.org/wiki/M7 8_(天体)

Sirius: 9 years ago



©pixabay Moon: 1 second ago



Sora 39/46

Going backward in time

©pixabay

13.8 billion year



Inflation

•10⁻³⁵ second

•Expanded by 10²⁰

Similar to dark energy?

GWs expected to emit



Answer 4

Yes, we can listen to the birth cry of the universe with DECIGO.

Sora

I want to listen to the birth cry of the universe

Illustarion: Sora



If you want to know more details

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