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ICRANet
International Center for Relativistic Astrophysics Network

General Relativity in the Theater of the Absurd

Parallel session: Education

Teaching Einsteinian Physics to School Students

08.07.2021, 17:20

MG16 5-10 JULY 2021
SIXTEENTH MARCEL GROSSMANN MEETING
ON RECENT DEVELOPMENTS IN THEORETICAL AND EXPERIMENTAL GENERAL RELATIVITY, ASTROPHYSICS AND RELATIVISTIC FIELD THEORIES

VIRTUAL MEETING
websites: http://www.icra.it/mg/mg16/ https://indico.icranet.org/event/1/
email: mg16@icranet.org
6:30-19:30 CENTRAL EUROPEAN SUMMER TIME

50TH ANNIVERSARY OF "INTRODUCING THE BLACK HOLE"

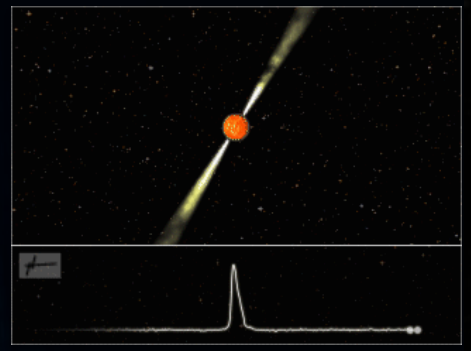
Two apparently absurd statements

The different phases of a neutron star collision are like a collection of different ballroom dances

The German Reichstag building is probably the best illustration of the essential properties of a black hole

In popular science lectures that deal with the complicated content of general relativity, the inclusion of bizarre examples that initially seem absurd can bring the listener to increased attention.

Binary neutron star systems



Pulsars are rotating neutron stars with a strong magnetic field

<u>Binary Pulsar Systems</u>
Example:
The Double Pulsar
(PSR J0737-3039A/B):

Discovered in 2003

Distance between the stars only 800,000 km

Distance is slowly decreasing due to the radiation of gravitational waves

The two neutron stars will only collide in 85 million years

<u>Talk on Monday</u>
Michael Kramer
New results from testing relativistic gravity with radio pulsars

Kramer, Wex, Class. Quantum Grav. 2009

McGill NCS Multimedia Services Animation by Daniel Cantin, DarwinDimensions)

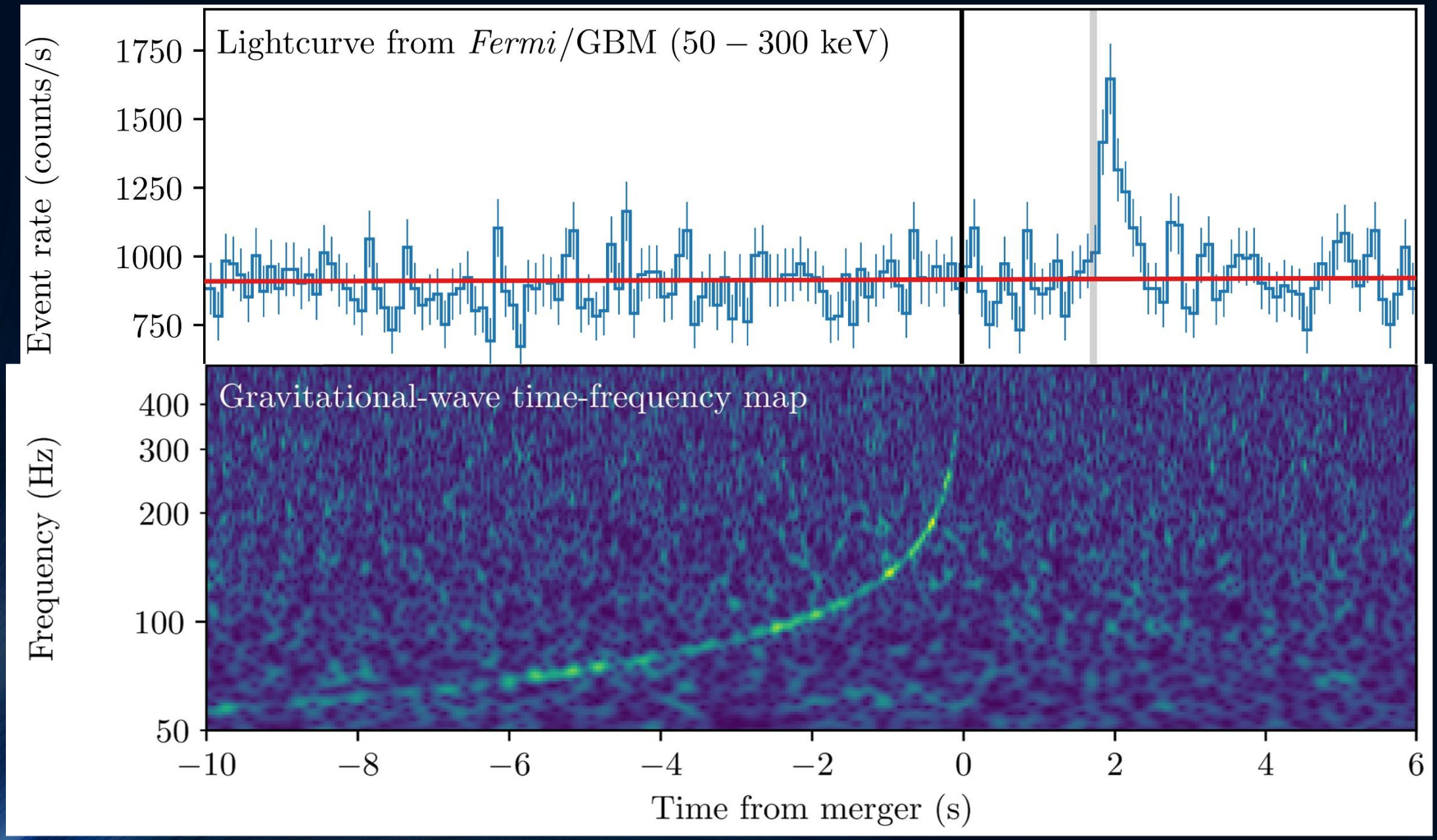
The long awaited event GW170817

	Low-spin priors ($\lvert\chi\rvert \leq 0.05$)	High-spin priors ($\lvert\chi\rvert \leq 0.89$)
Primary mass m_1	1.36–1.60 $M_\odot$	1.36–2.26 $M_\odot$
Secondary mass m_2	1.17–1.36 $M_\odot$	0.86–1.36 $M_\odot$
Chirp mass $\mathcal{M}$	$1.188^{+0.004}_{-0.002} M_\odot$	$1.188^{+0.004}_{-0.002} M_\odot$
Mass ratio m_2/m_1	0.7–1.0	0.4–1.0
Total mass $m_{\rm tot}$	$2.74^{+0.04}_{-0.01} M_\odot$	$2.82^{+0.47}_{-0.09} M_\odot$
Radiated energy $E_{\rm rad}$	$> 0.025 M_\odot c^2$	$> 0.025 M_\odot c^2$
Luminosity distance $D_{\rm L}$	40^{+8}_{-14} Mpc	40^{+8}_{-14} Mpc
Viewing angle Θ	$\leq 55°$	$\leq 56°$
Using NGC 4993 location	$\leq 28°$	$\leq 28°$
Combined dimensionless tidal deformability $\tilde{\Lambda}$	≤ 800	≤ 700
Dimensionless tidal deformability $\Lambda(1.4 M_\odot)$	≤ 800	≤ 1400

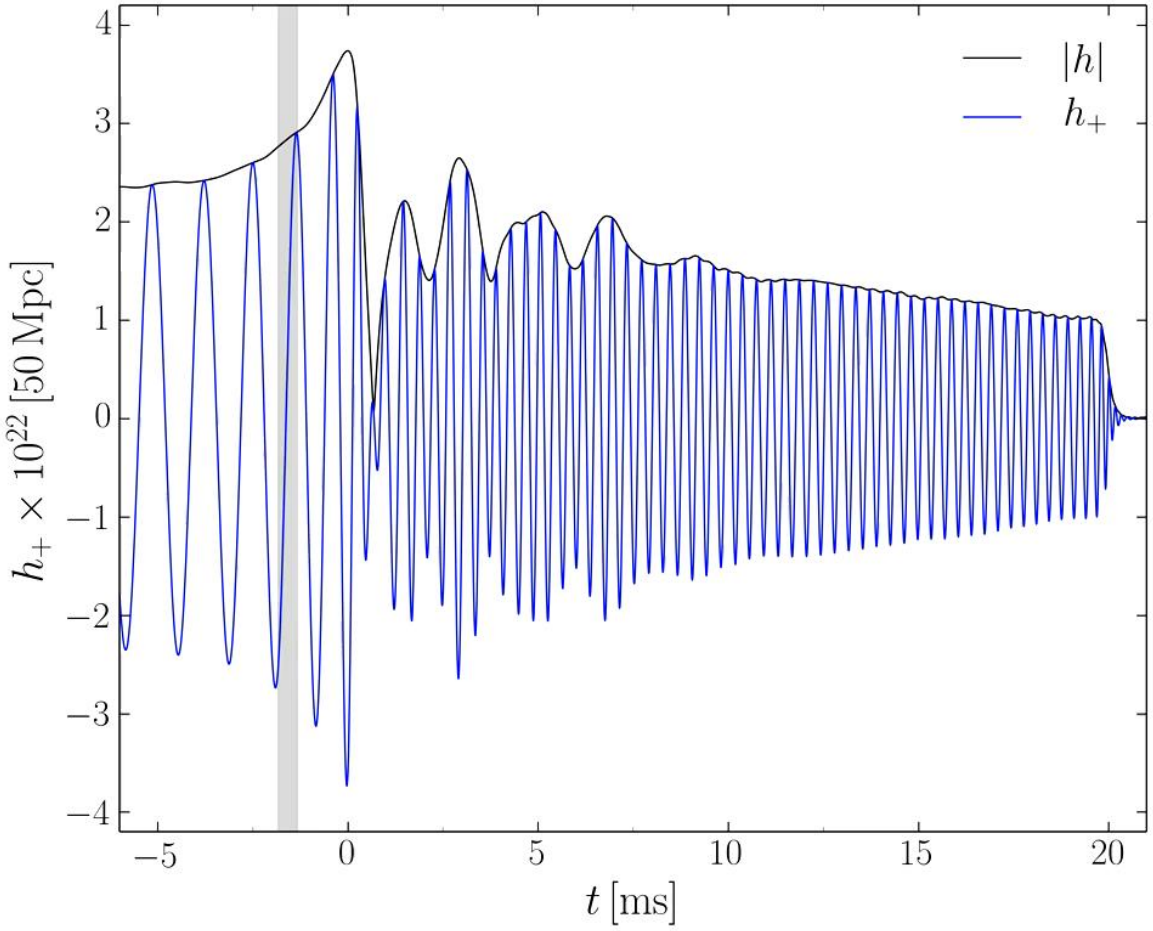
17. August 2017

First detection of a gravitational wave from a binary neutron star merger event!

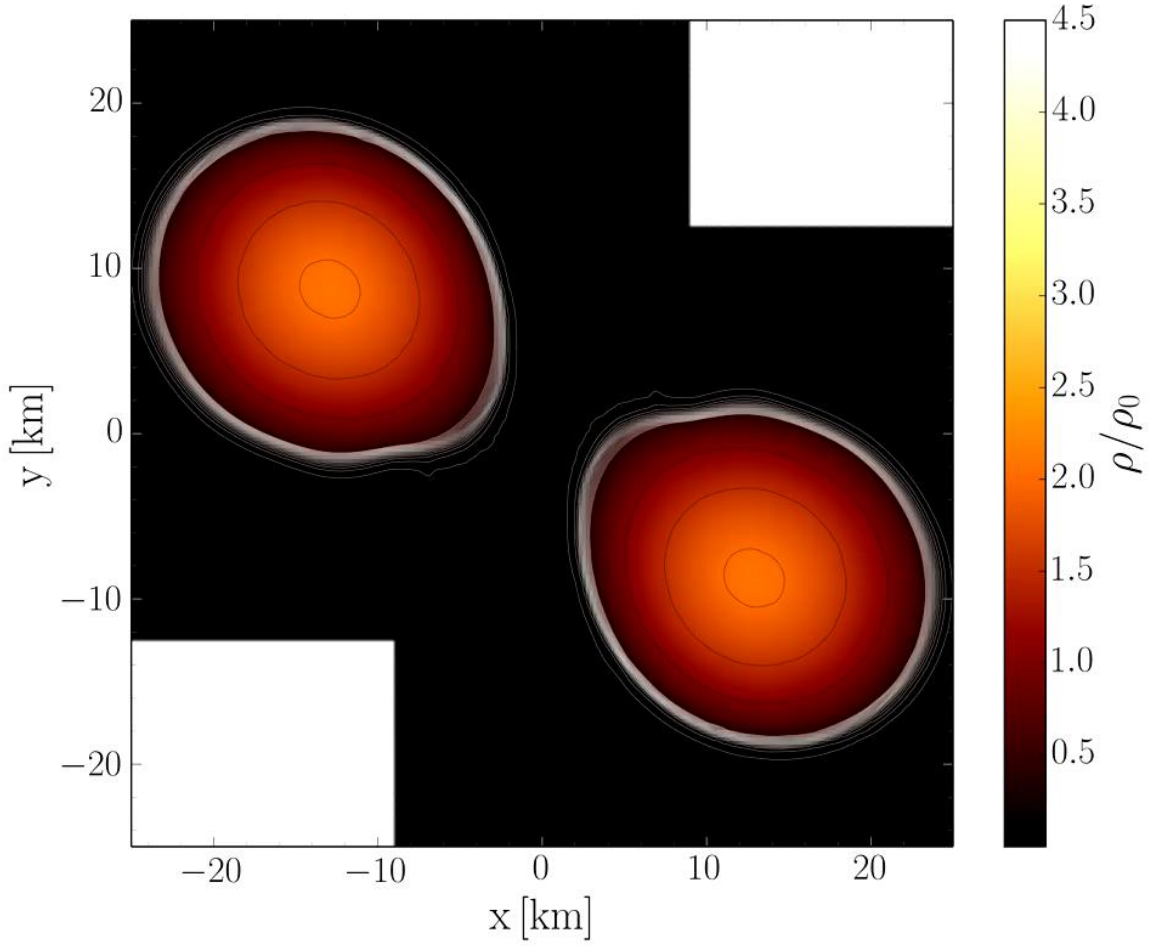
Gravitational Wave GW170817 and Gamma-Ray Emission GRB170817A



What happens between the merger and the collapse to the black hole?
General relativistic computer simulations provide insights



Amplitude of the emitted gravitational wave



Density profile in the equatorial plane

The different Phases of a Binary Neutron Star Merger Event

Late inspiral and merger phase

Transient early postmerger phase

Postmerger phase

Collapse to the Kerr black hole and ringdown phase

Wiener Walzer

Disco-Fox

Merengue

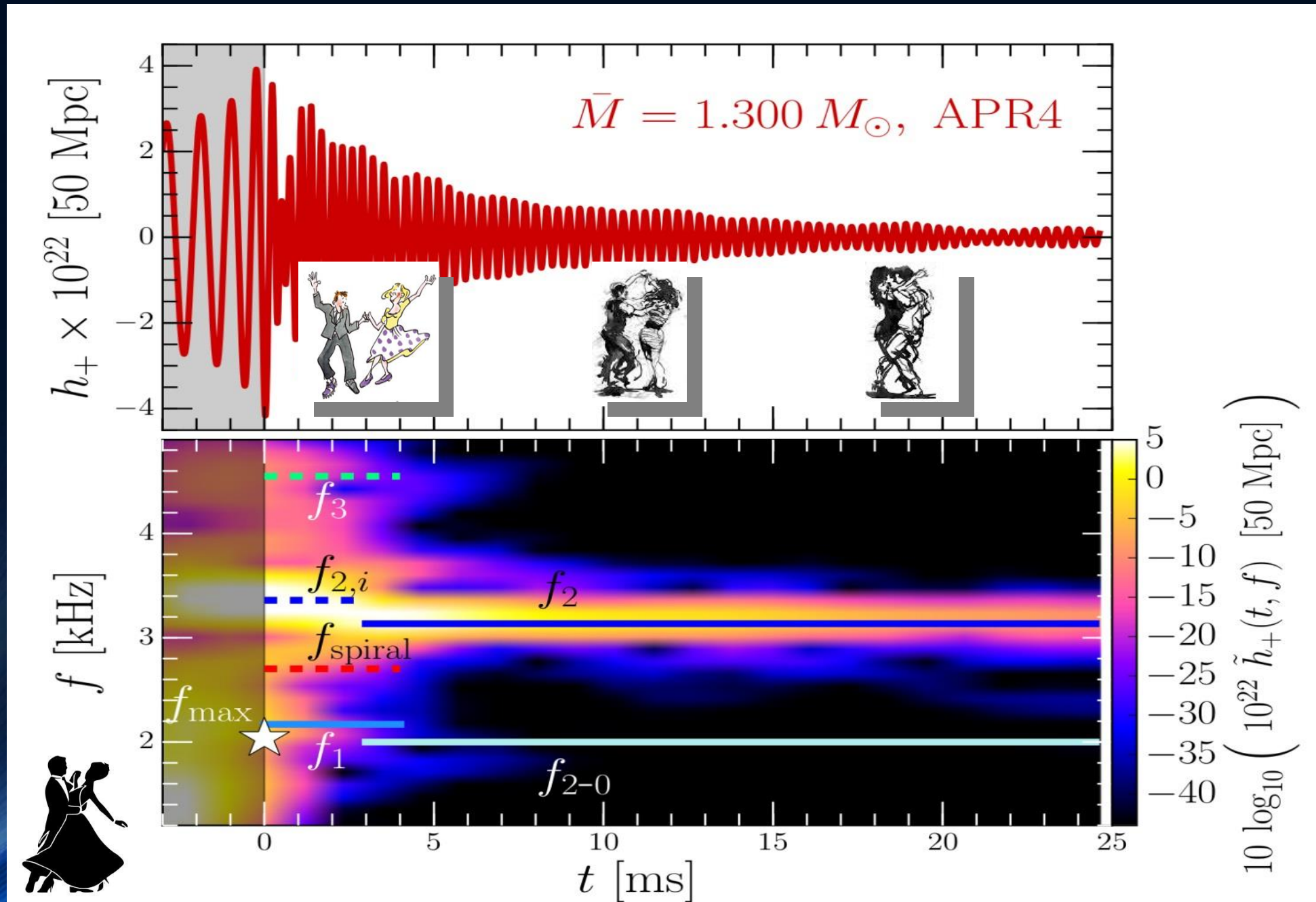
Tango

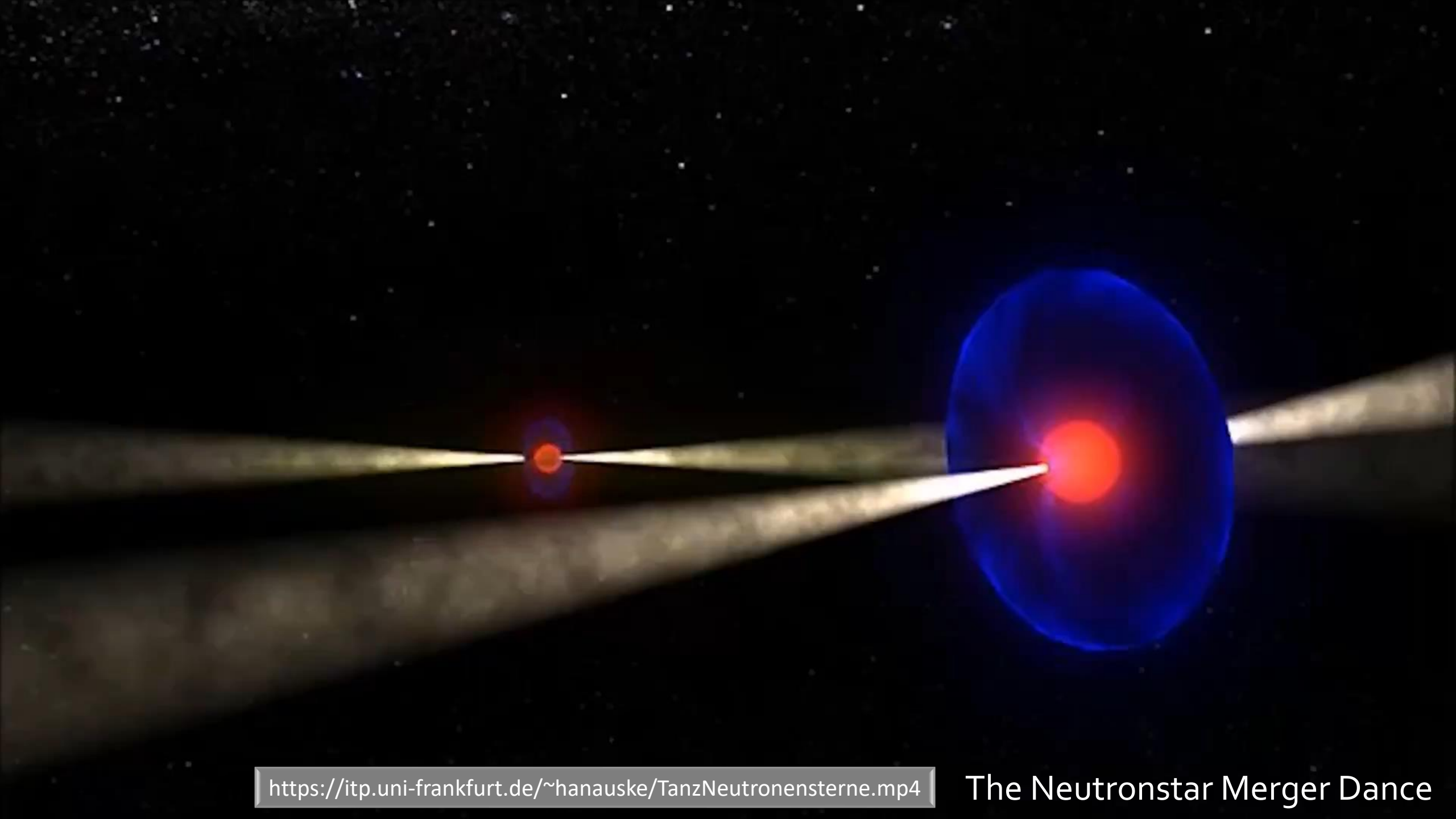
Wy exactly these dances?
Details in

"Binary Compact Star Mergers and the Phase Diagram of Quantum Chromodynamics", Matthias Hanauske and Horst Stöcker, Discoveries at the Frontiers of Science, 107-132; Springer, Cham (2020)

https://itp.uni-frankfurt.de/~hanauske/TanzNeutronensterne.mp4

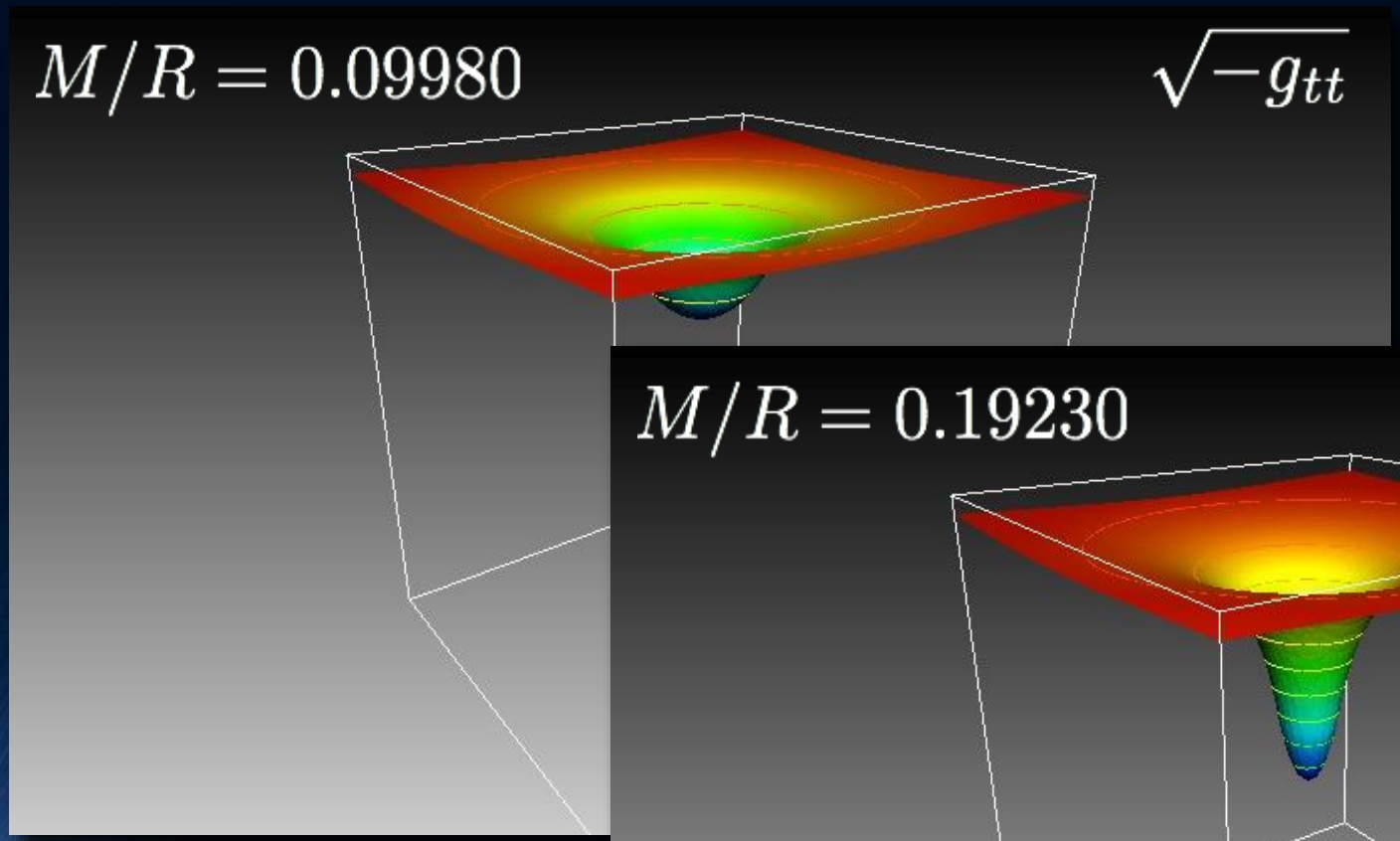
Frequency spectrogram of the emitted gravitational wave

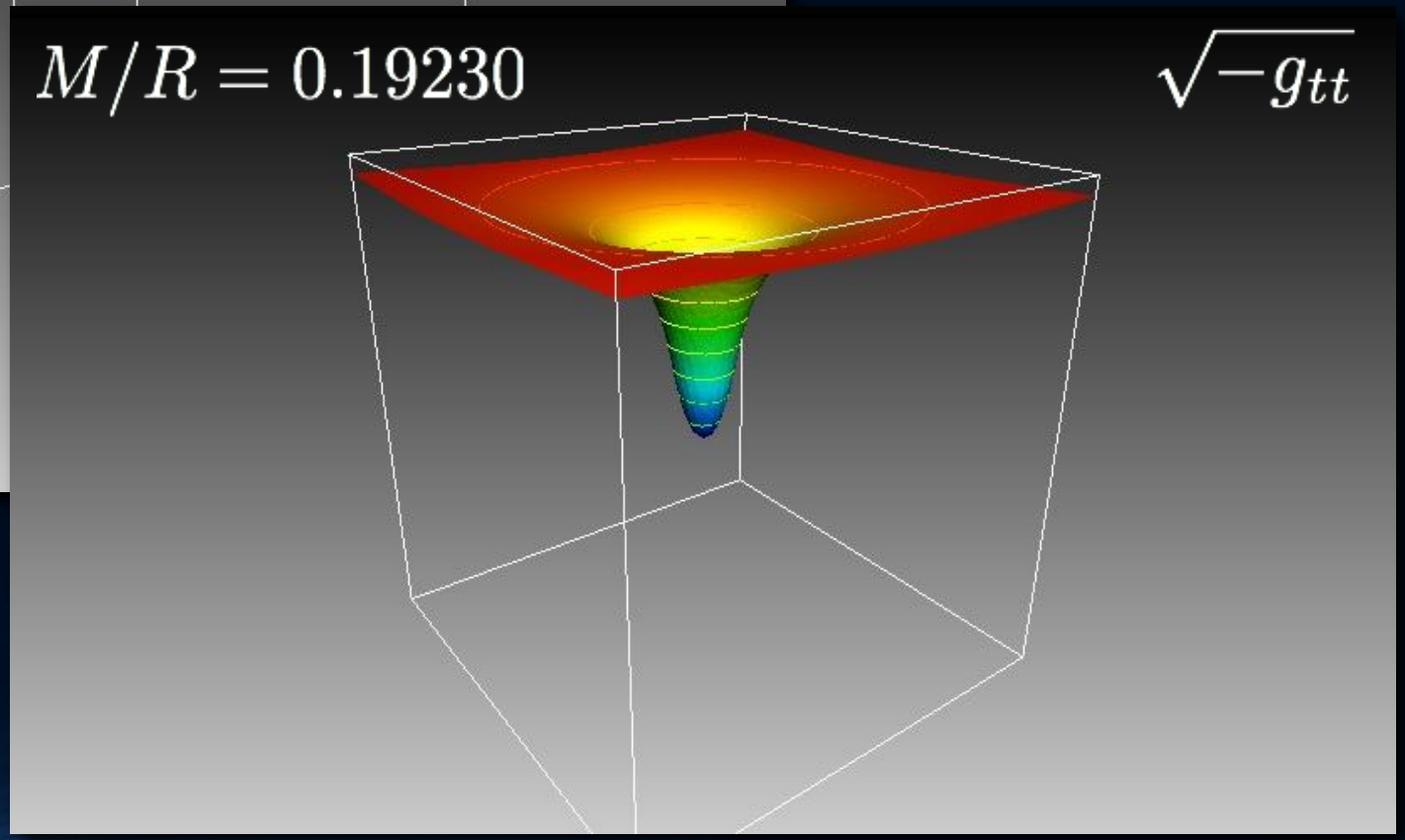




The Neutronstar Merger Dance

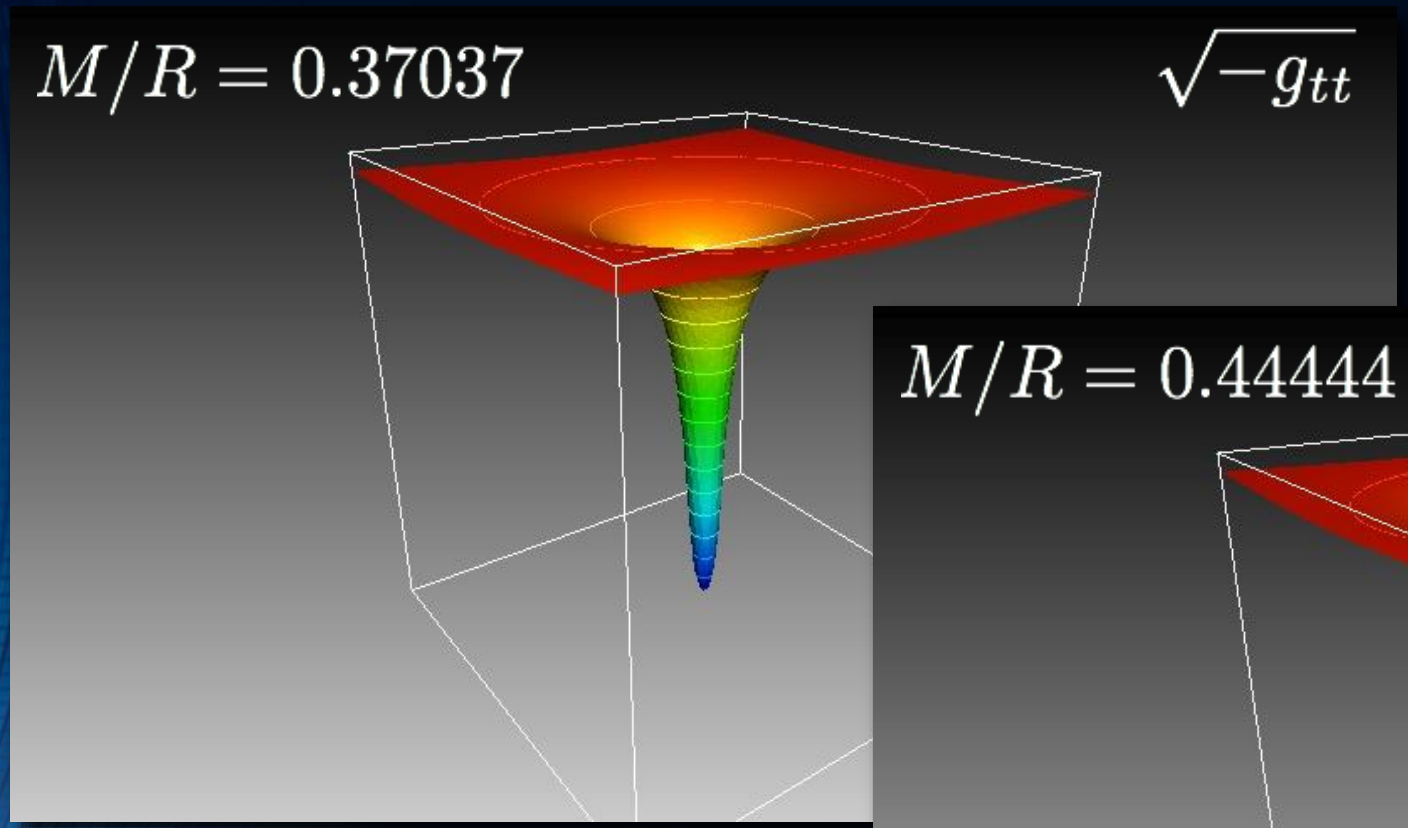
Black holes and the spacetime funnel

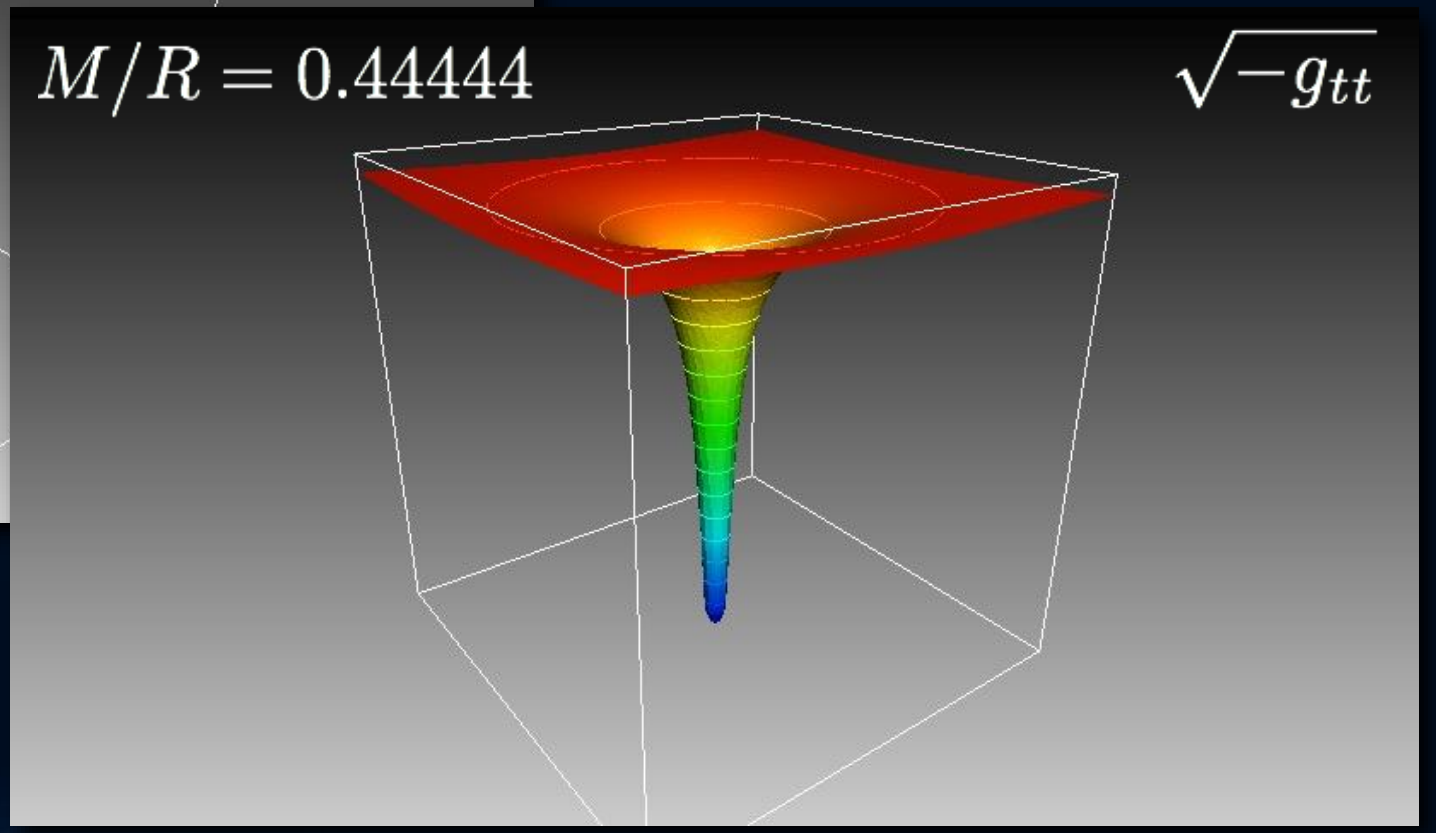




M: mass of the object
R: radius of the object
g_{tt}: space-time metric

Black holes and the spacetime funnel





M: mass of the object
R: radius of the object
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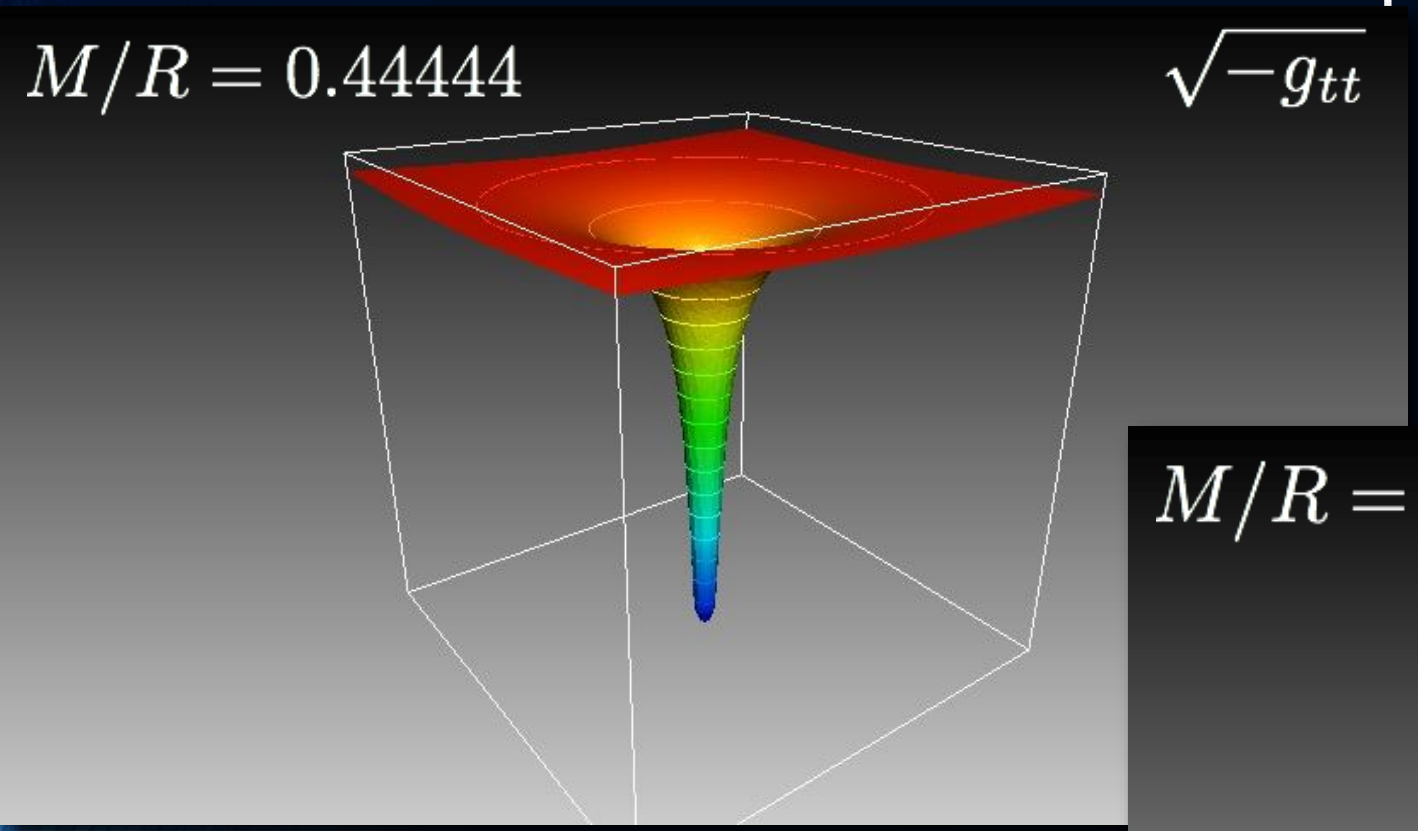
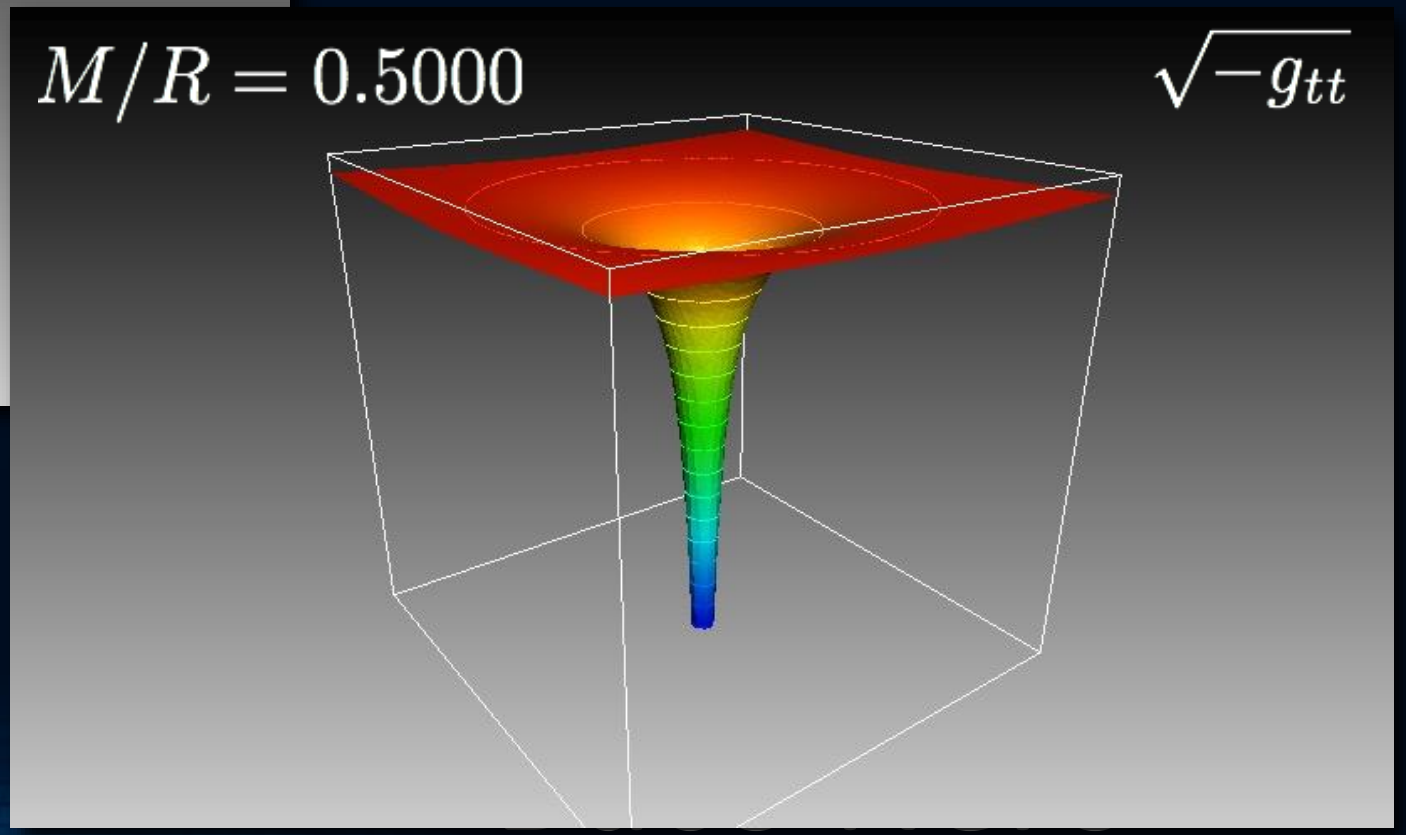
Stability limit: Stable objects (neutron stars) are no longer possible

Black holes and the spacetime funnel

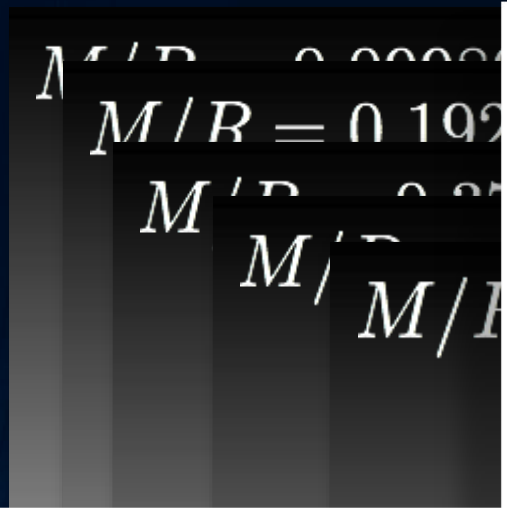


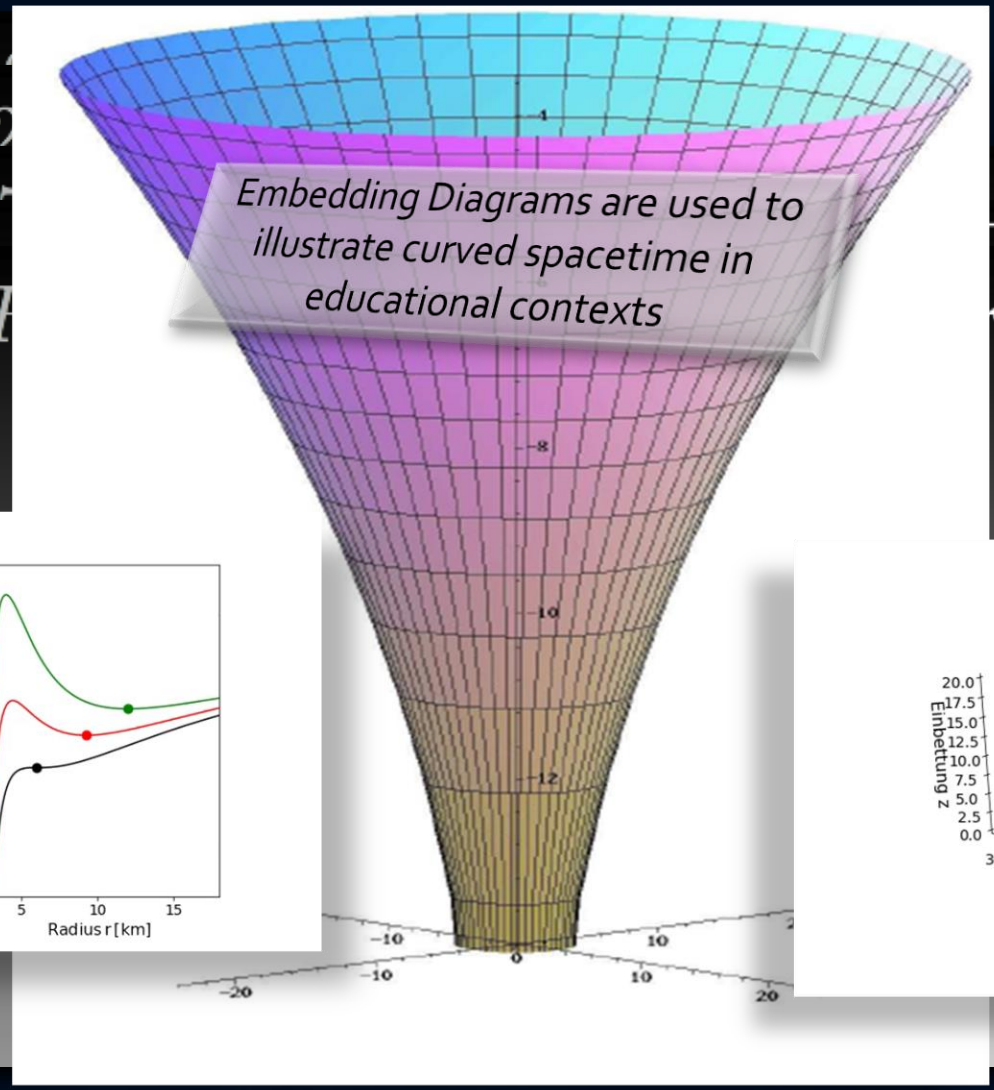
M: mass of the object
R: radius of the object
g_{tt}: space-time metric

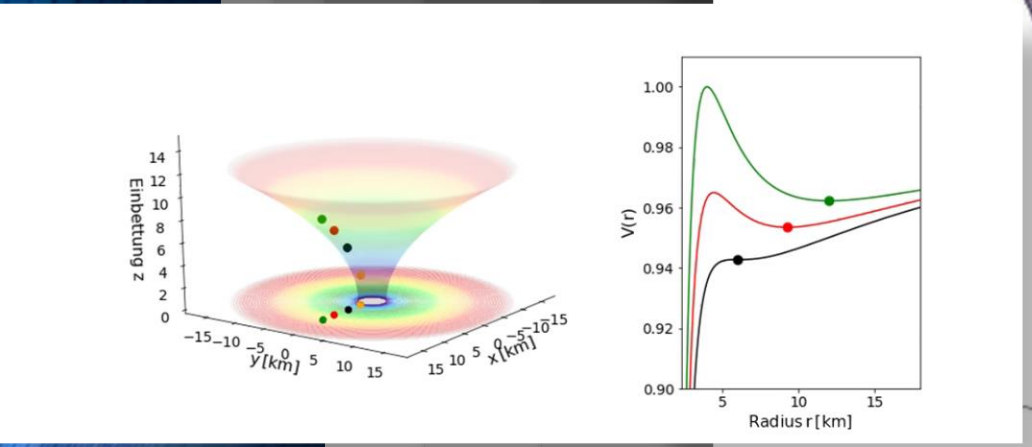
We got over the limit and created a black hole!

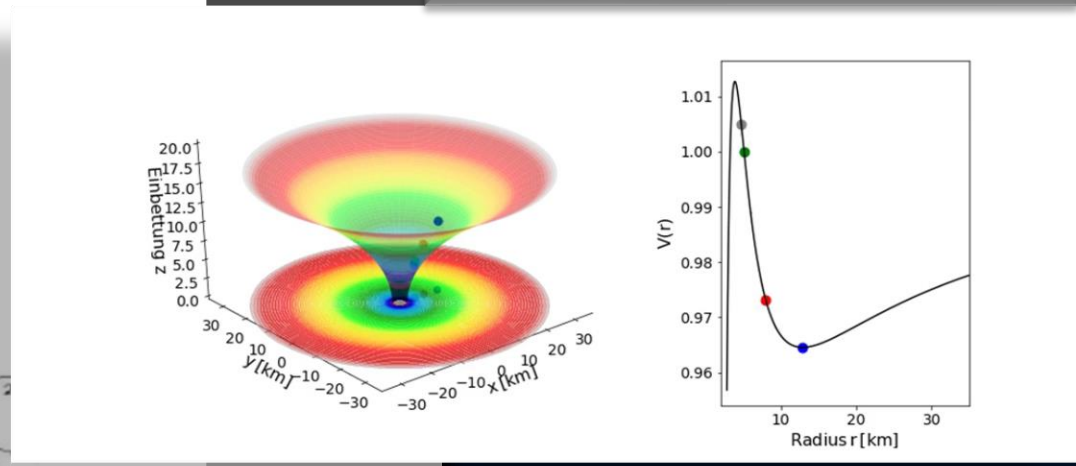


Black holes and the spacetime funnel









Animations from the

Online Lecture

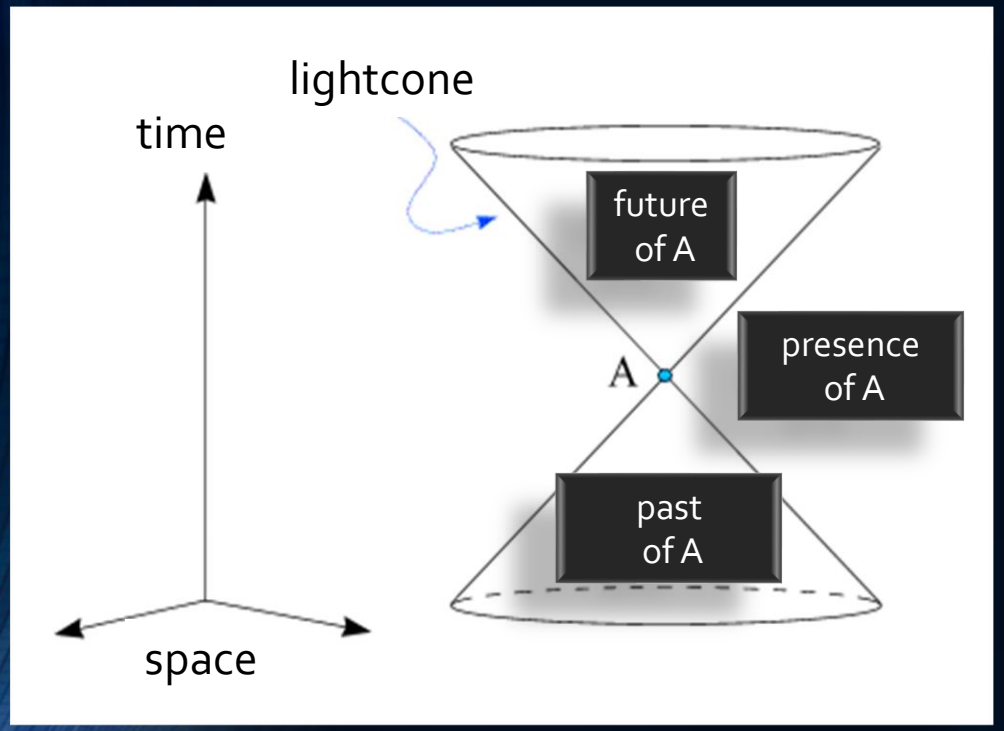
General Relativity on the Computer

https://itp.uni-frankfurt.de/~hanauske/VARTC/VARTC2021.html

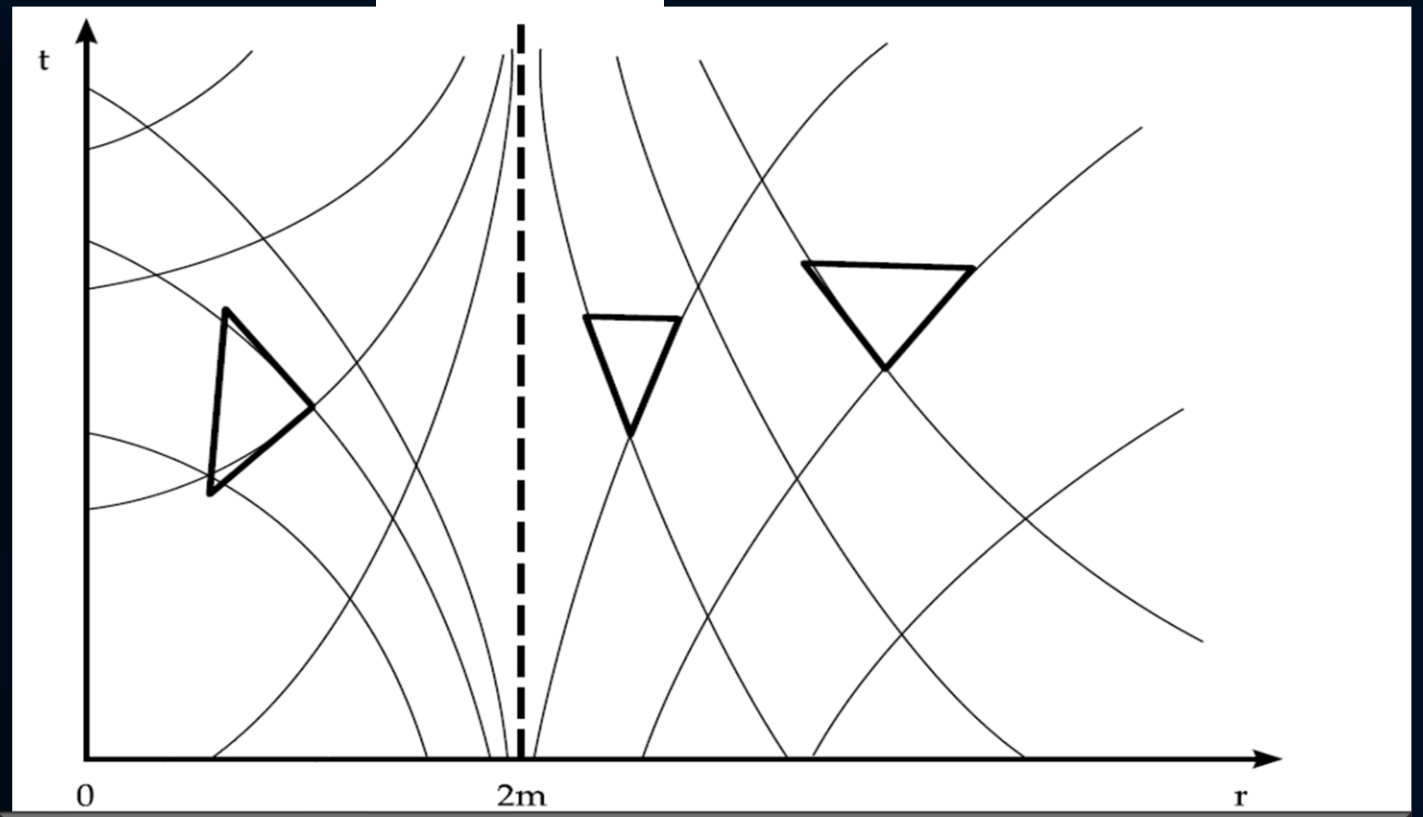
Stability limit: Stable objects (neutron stars) are no longer possible

Space-time diagram of a black hole

View of stationary observer at infinity



Spacetime structure
in flat space

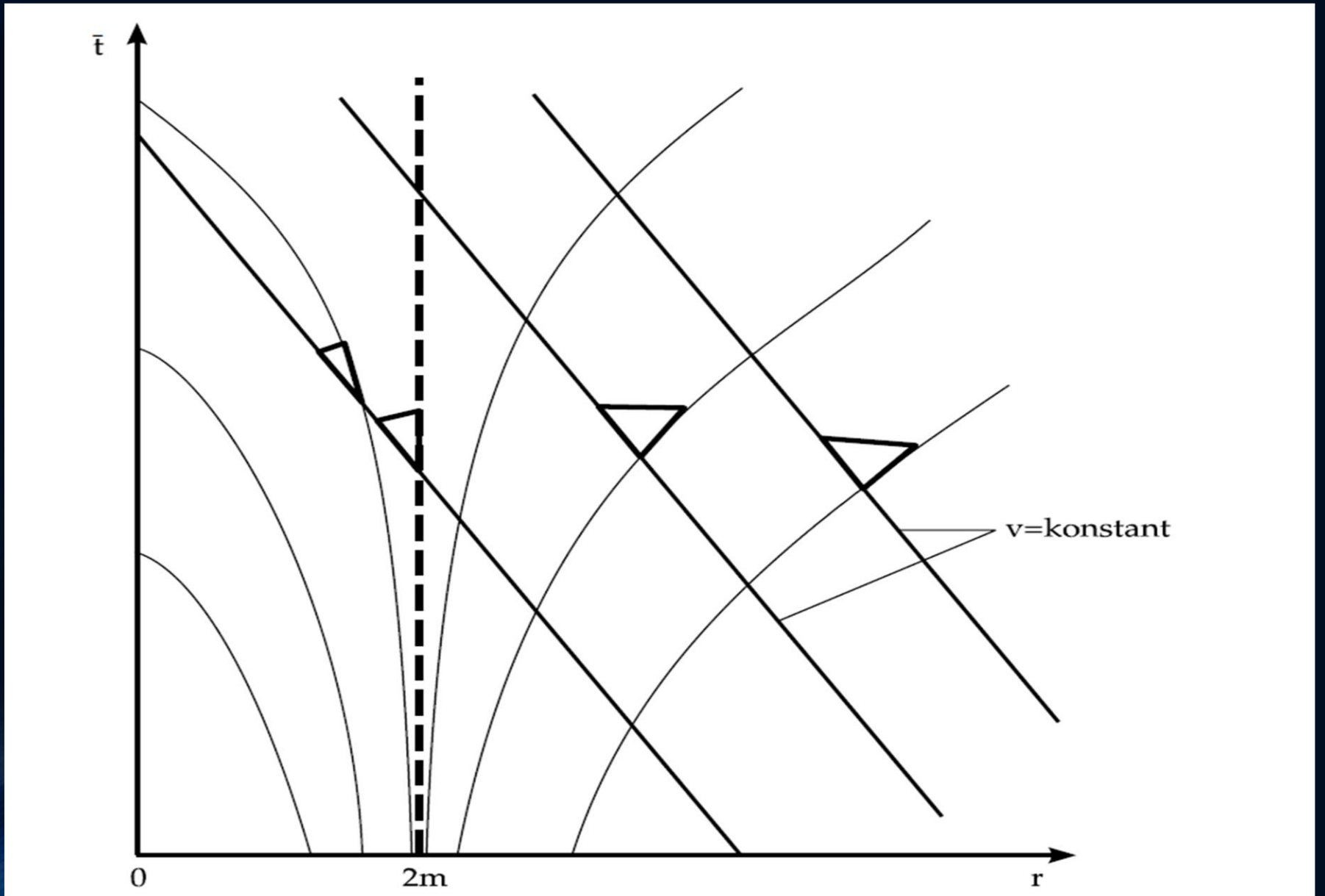


Spacetime diagram of the Schwarzschild metric
in Schwarzschild coordinates

Spacetime structure around a black hole

Space-time diagram of a black hole

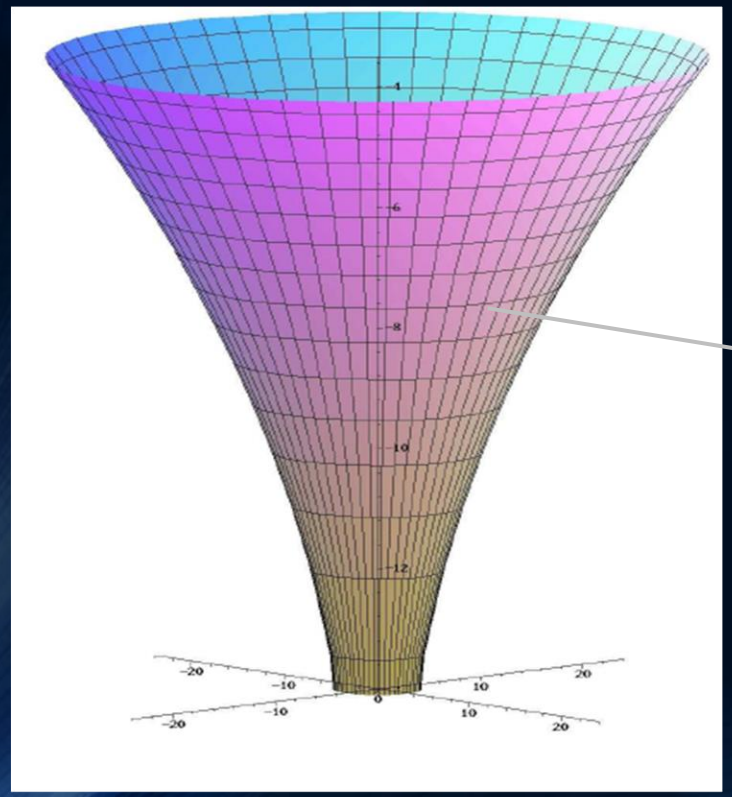
Perspective of an observer falling into the black hole



The German parliament building

probably the best illustration of the essential properties of a black hole

The space-time funnel in the Reichstag building



The German Reichstag

and the event horizon of German history

Circular barrier from where visitors can peer down to the bottom of the funnel

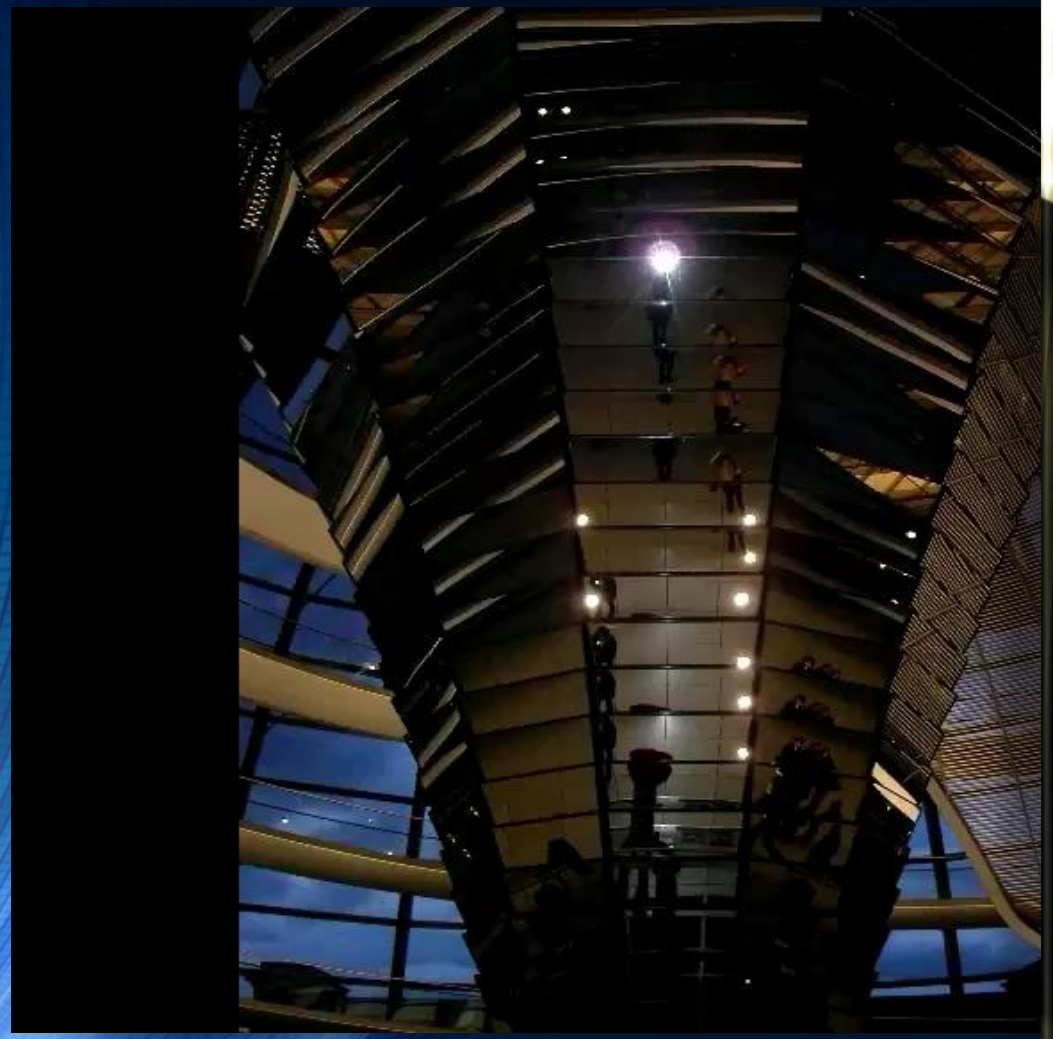
Event horizon

Along the barrier are displayed various photographs of decisive events in German history that are designed to remind visitors of their responsibilities to the future. They are a warning against forgetfulness and against the repression of the Nazi era.

Historical scenes frozen on the event horizon

The German parliament building

probably the best illustration of the essential properties of a black hole



The elevator in the Reichstag building is approximately at 3/2 Rs

physicsweb.org

Black holes and the German Reichstag

One day a couple of years ago I was attending a meeting of the German Astronomical Society in Berlin, when I was gripped with an almost irrepressible sense of inner unrest. There was no other option – I simply had to leave the lecture halls of the Technical University and enjoy the gorgeous day outside. Before I left, however, I carefully taped my poster to the wall between the entrances to the men's and women's toilets, which seemed the perfect spot for it. Every congress delegate would now be forced – sublimi-nally at least – to notice my creation.

After leaving the university buildings, I first soaked up the summer sunshine in the zoological gardens before heading towards the Reichstag – the home of the German parliament. As I did so, my thoughts wandered off in a different direction. What a waste of time, it occurred to me, all those boring lectures are. What physics desperately needs, I reasoned, is a new and exciting way of presenting the subject.

Unfortunately, modern physics is impossible to comprehend using intuition alone. How can bizarre concepts such as the curvature of space–time or the event horizon of a black hole be understood? What possible imagery could help non-scientists to grasp the significance and vital importance of some of the major insights of theoretical physics? What a simple way of conveying those ideas

up and realized I had almost the modern glass dome ichstag building closely, I

The funnel looks exactly like the diagrams used to illustrate the curvature of a black hole

Along the barrier are displayed various photographs of decisive events in German history that are designed to remind visitors of their responsibilities to the future. They are a warning against forgetfulness and against the repression of the Nazi era.

Suddenly I saw the significance of the information frozen on the pictures. Just as the politicians sit in the inner area of the black hole from which no useful information ever escapes, so the pictures represent external

Article:

Matthias Hanauske

Black holes and the german reichstag

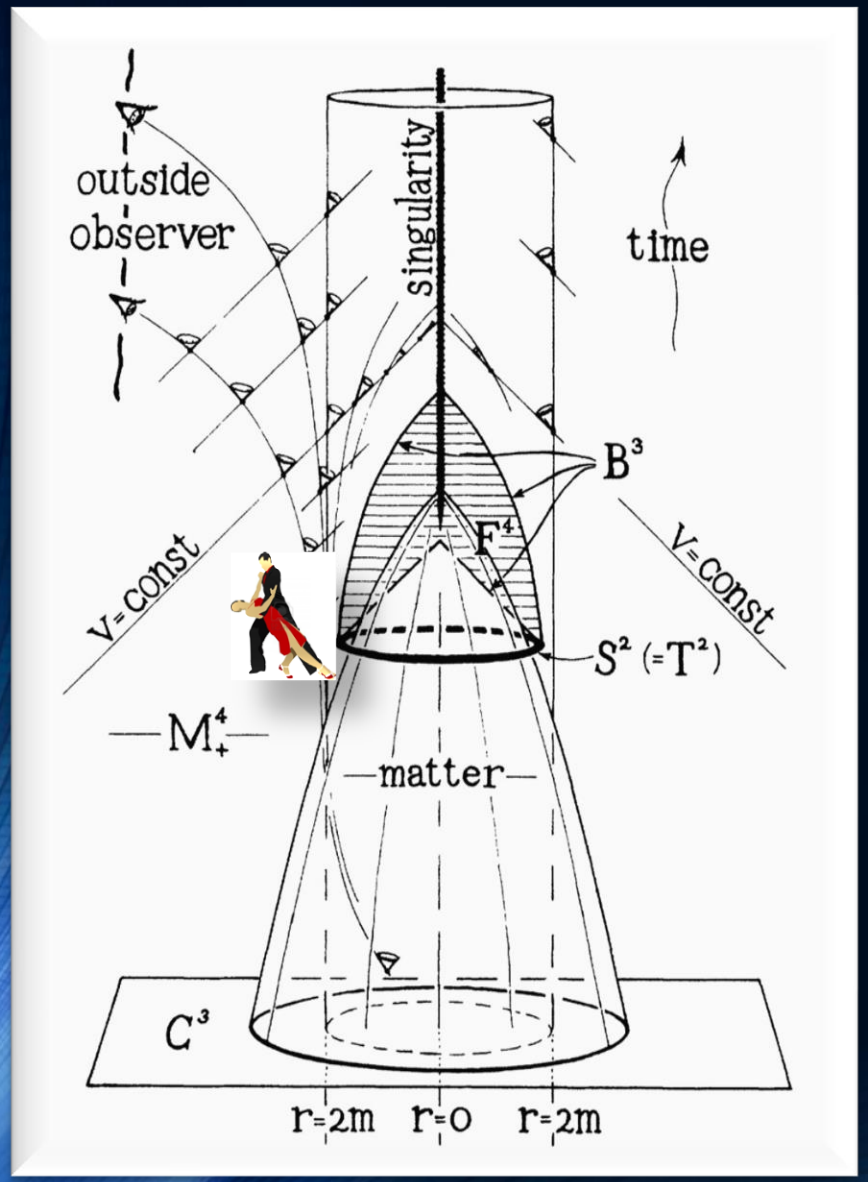
Physics World 18.10, p.64 (2005)

Additional material:

http://th.physik.uni-frankfurt.de/~hanauske/new/LateralThougts.html

GRAVITATIONAL COLLAPSE AND SPACE- TIME SINGULARITIES

Nobel Price 2020: R.Penrose, PRL Vol.14 No.3 (1965)



Self-drawn space-time diagram by R.Penrose (1965)

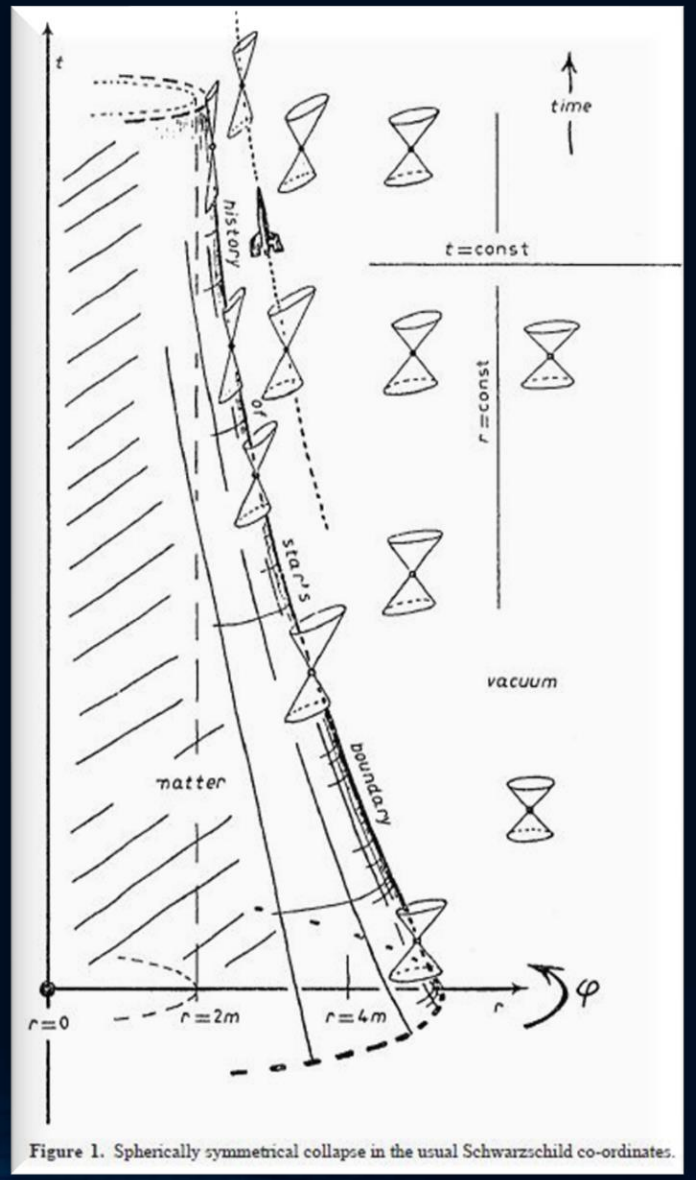


Figure 1. Spherically symmetrical collapse in the usual Schwarzschild co-ordinates.

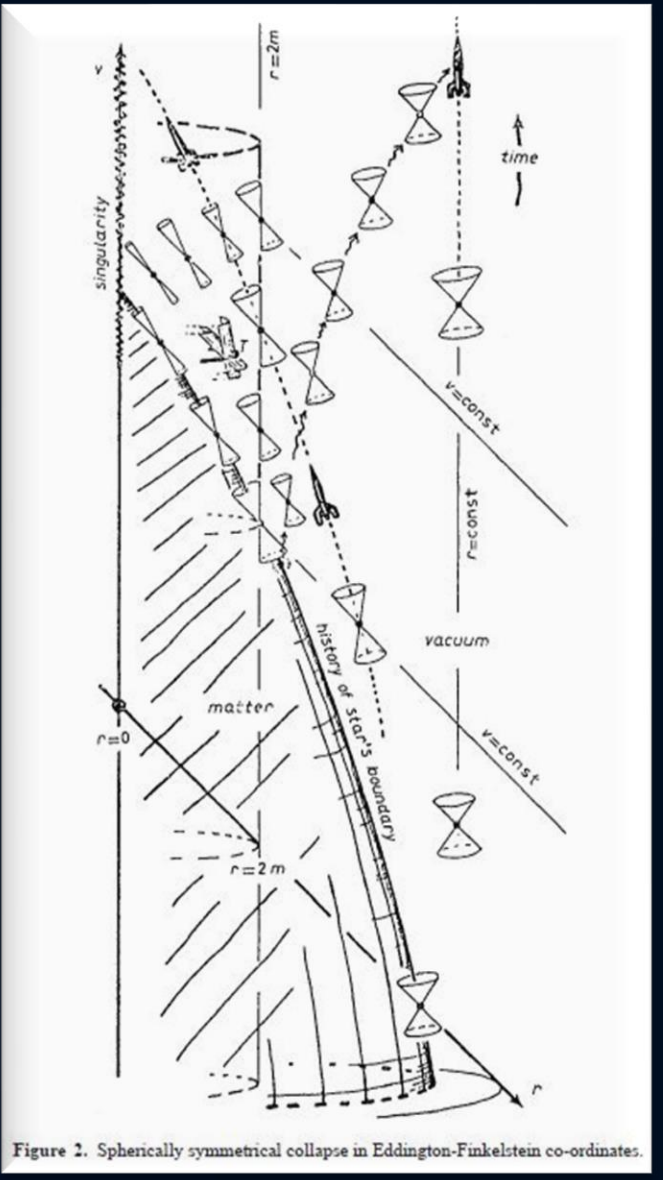
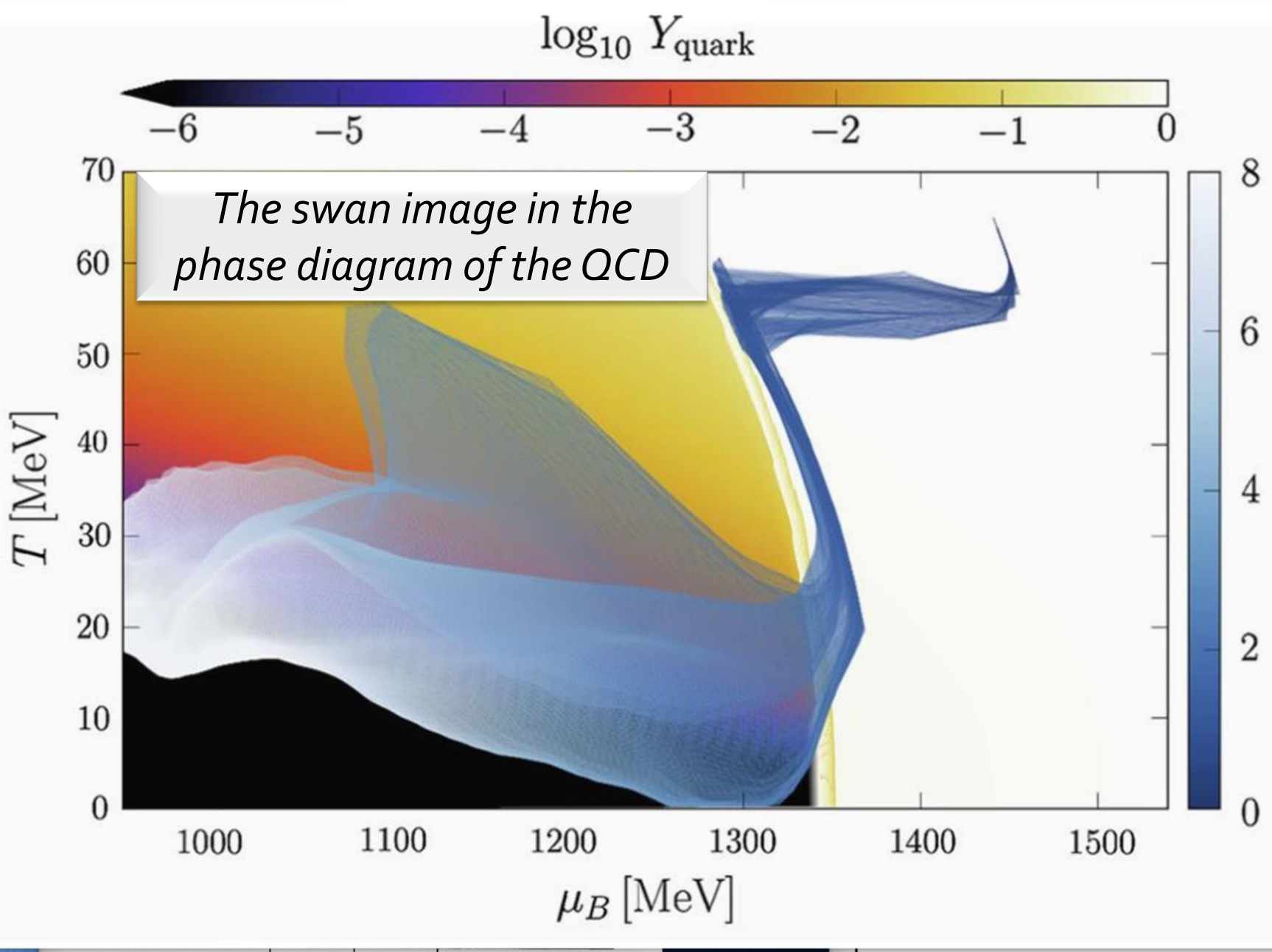


Figure 2. Spherically symmetrical collapse in Eddington-Finkelstein co-ordinates.

R.Penrose in Rivista del Nuovo Cimento, Num.Spez. I, 257 (1969)

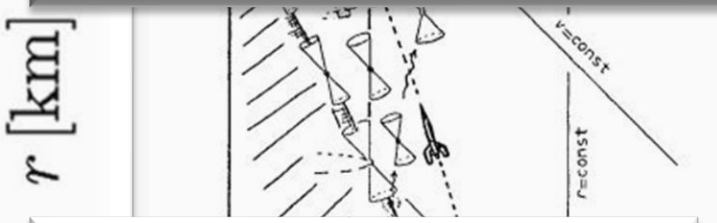


Talk on Thursday

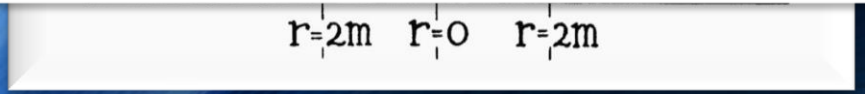
On the properties of metastable hypermassive hybrid stars

Parallel session

Neutron stars: Dense matter in compact stars, 08.07.2021, 18:10



The last picture what an outside observer sees is the frozen picture of a dying swan



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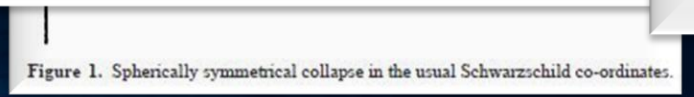

Figure 1. Spherically symmetrical collapse in the usual Schwarzschild co-ordinates.

Figure 2. Spherically symmetrical collapse in Eddington-Finkelstein co-ordinates.

R.Penrose in Rivista del Nuovo Cimento, Num.Spez. I, 257 (1969)

I then left the Reichstag building and headed for the Brandenburg Gate, the former dividing line between eastand west Berlin. As I sauntered through the gate, I noticed an area of land to my right that was entirely vacant except for some statues of bears, which are the symbol of the city of Berlin. About 6o bears were arranged in a circle, each representing a country of the world by virtue of the images printed on it. One bear, however, stood off to one side, apart from allthe others. Its surface bore an image of Einstein and a quotation by the great physicist, who rose to fame while work-ing in Berlin. As a guide explained to a group of tourists that an American embassy would soon be built on the site, I read Einstein's timeless words: