Csillagászat gravitációs hullámokkal

Raffai Péter

ELTE Fizikai Intézet

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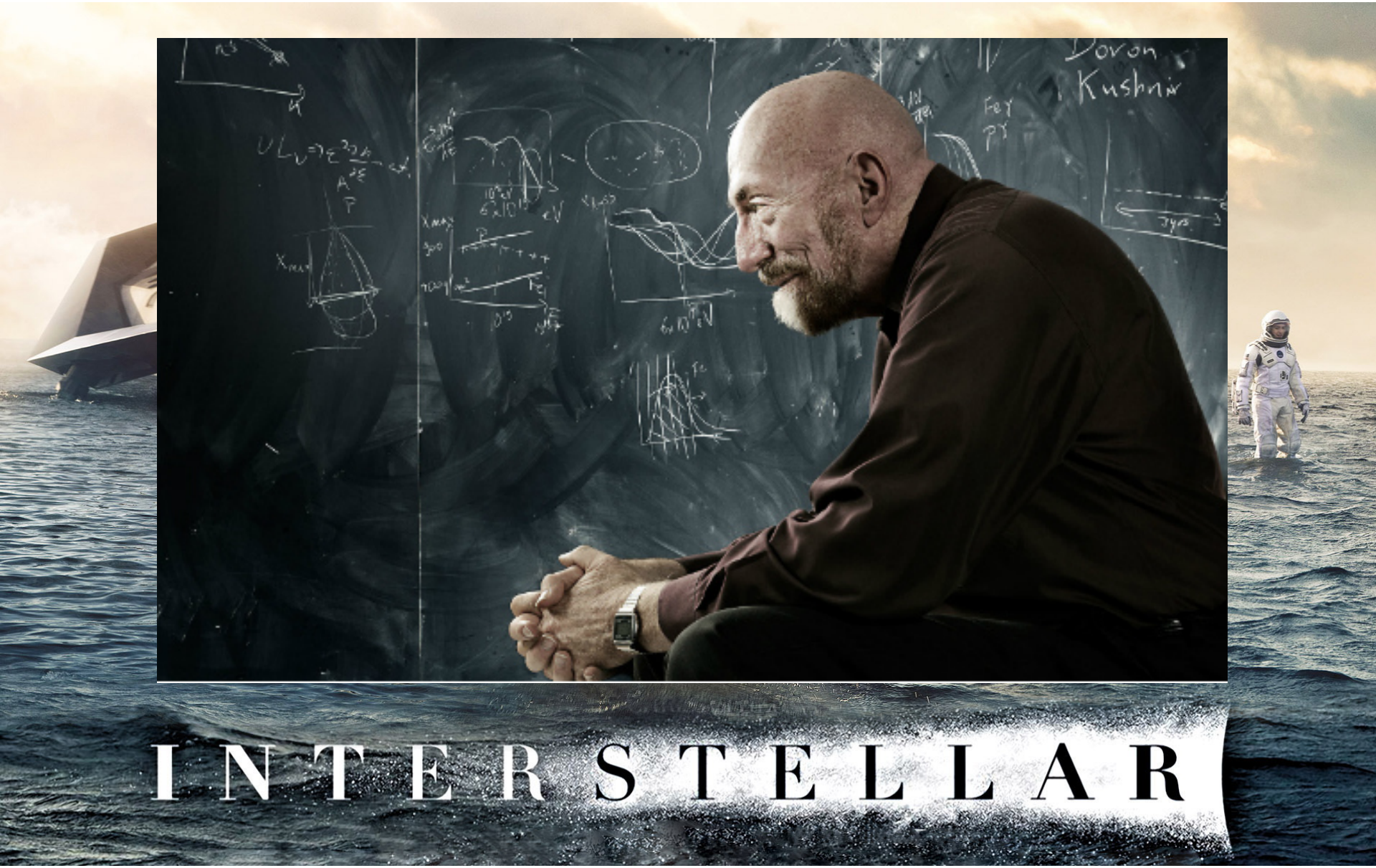
INTERSTELLAR


Doron
Kushnir
INTERSTELLAR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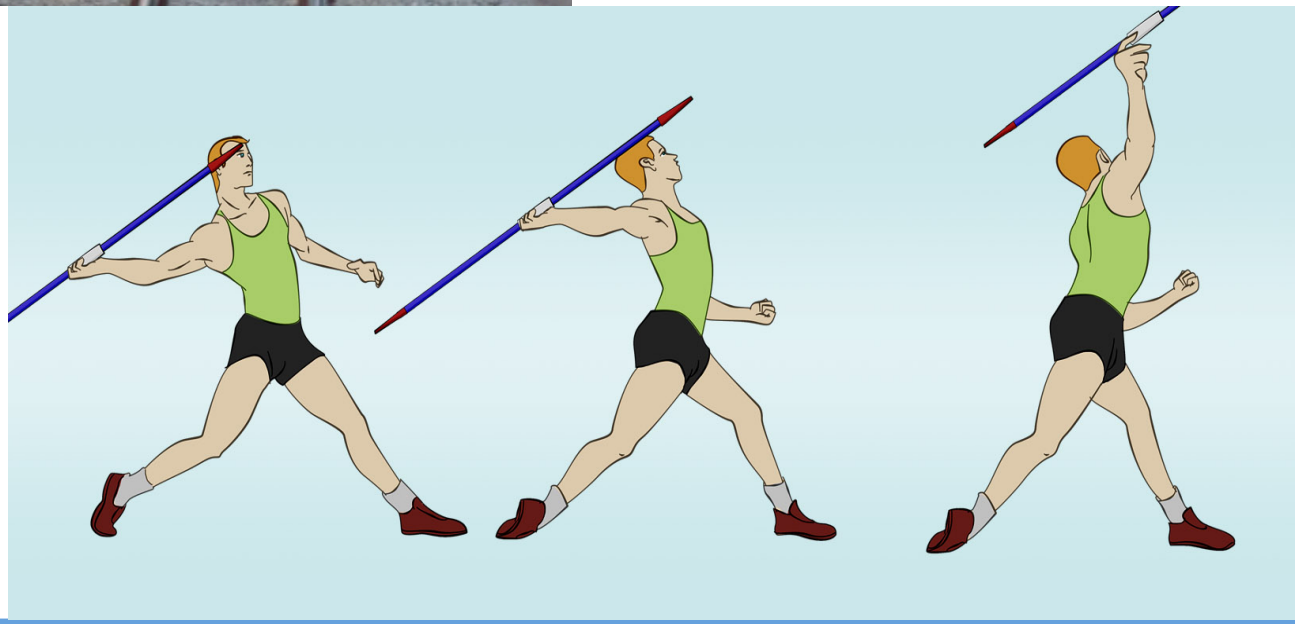
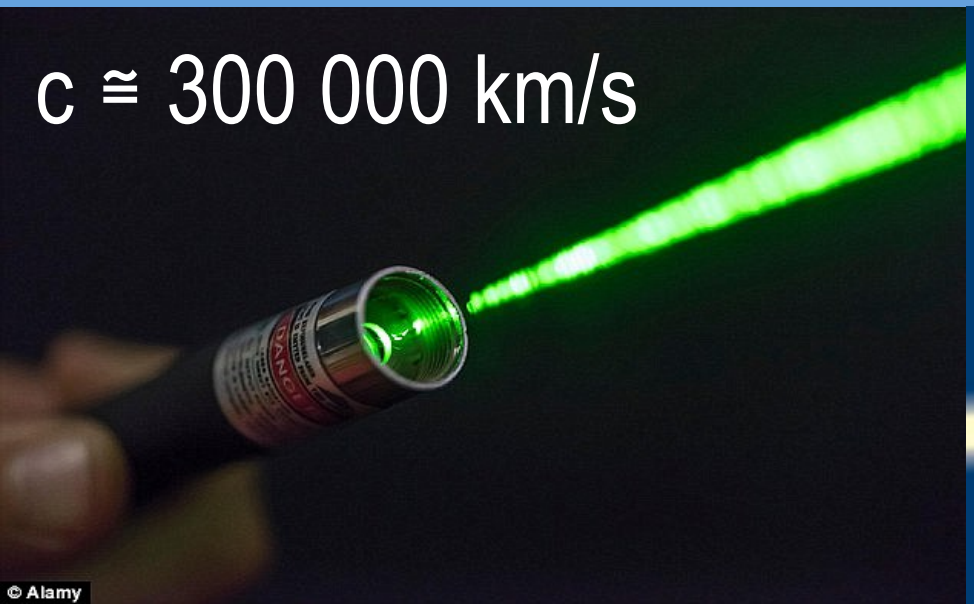
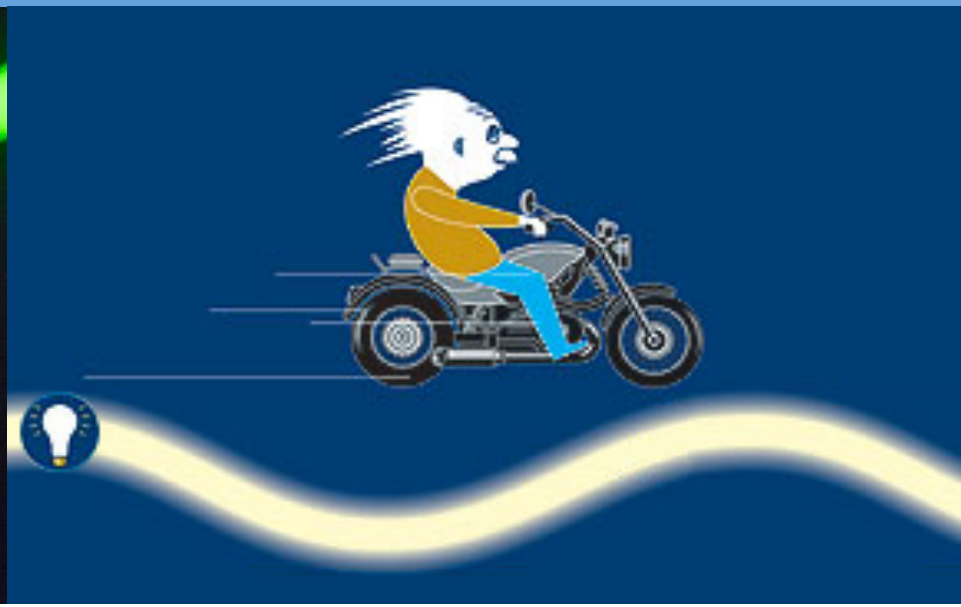
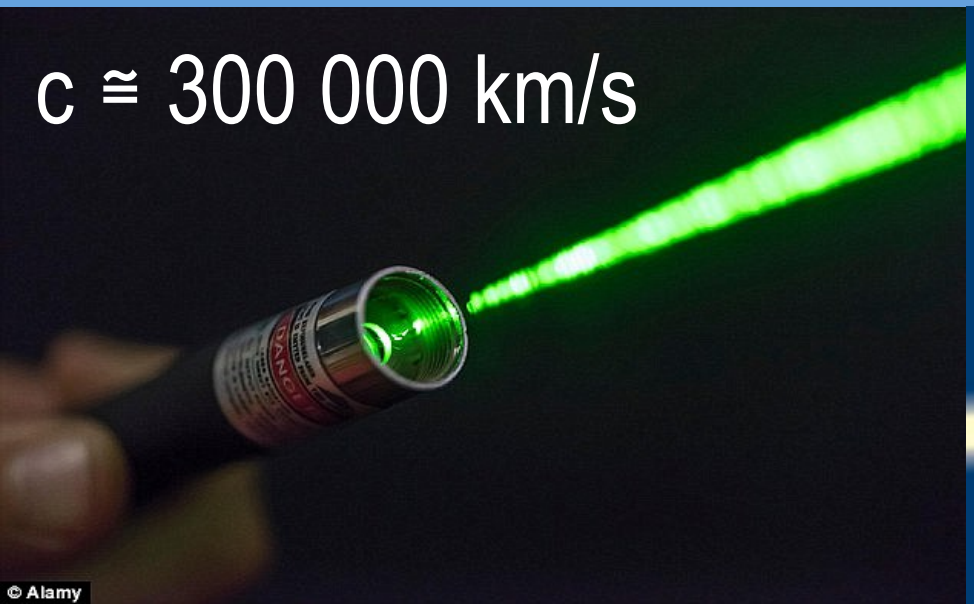
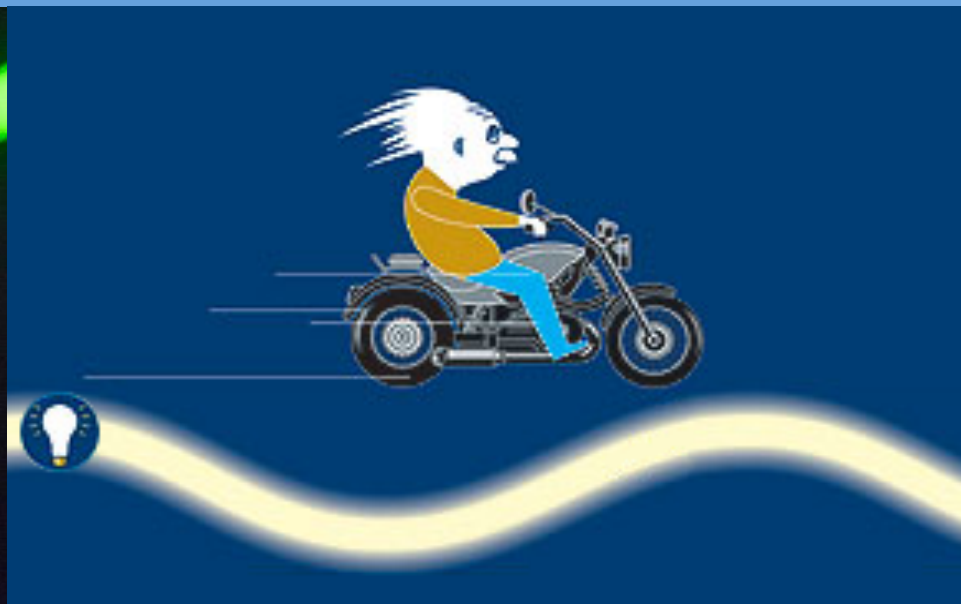
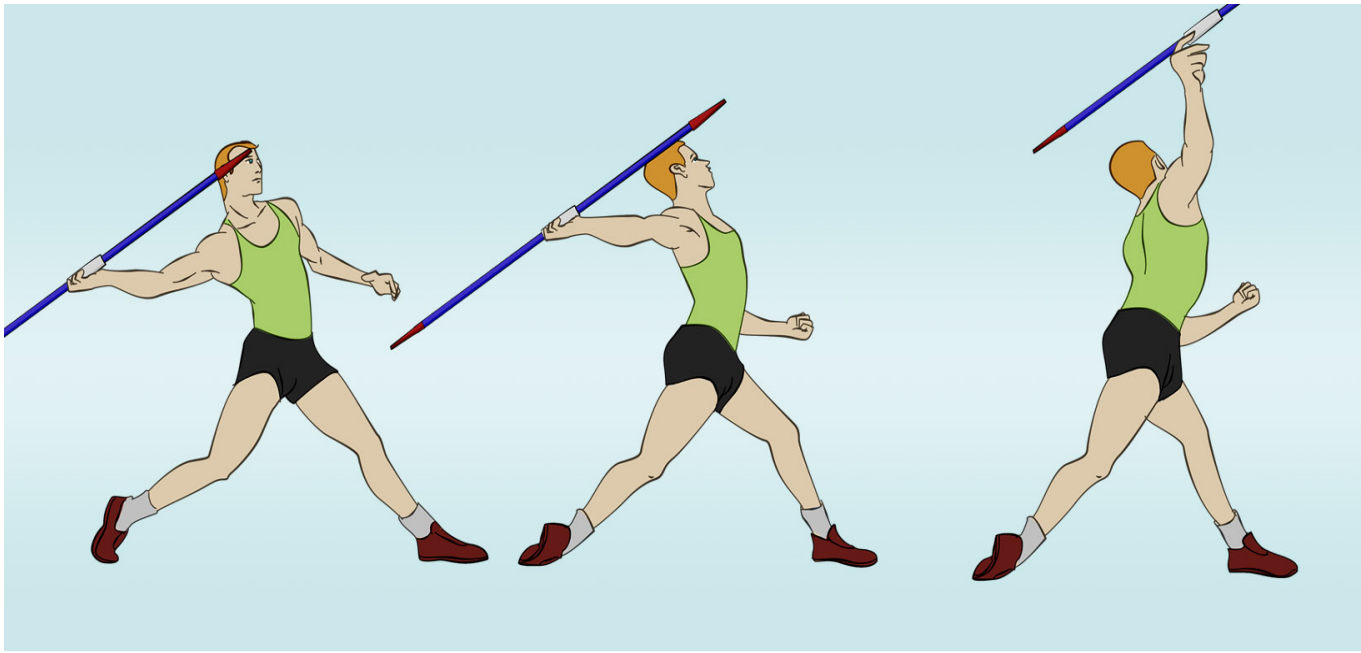


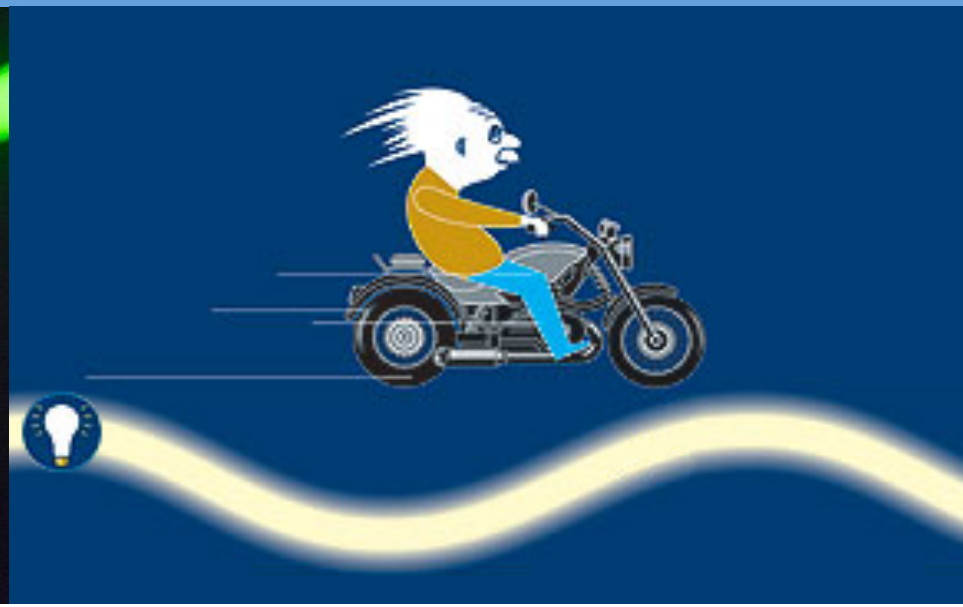

c ≅ 300 000 km/s
© Alamy

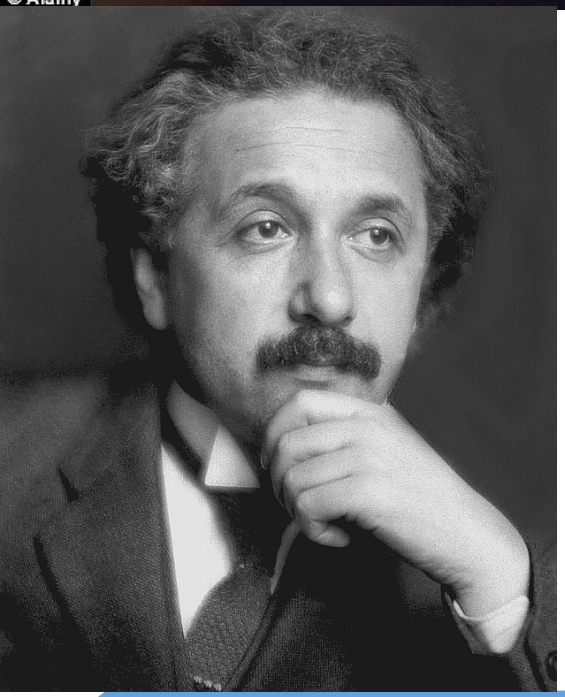



c ≅ 300 000 km/s
© Alamy





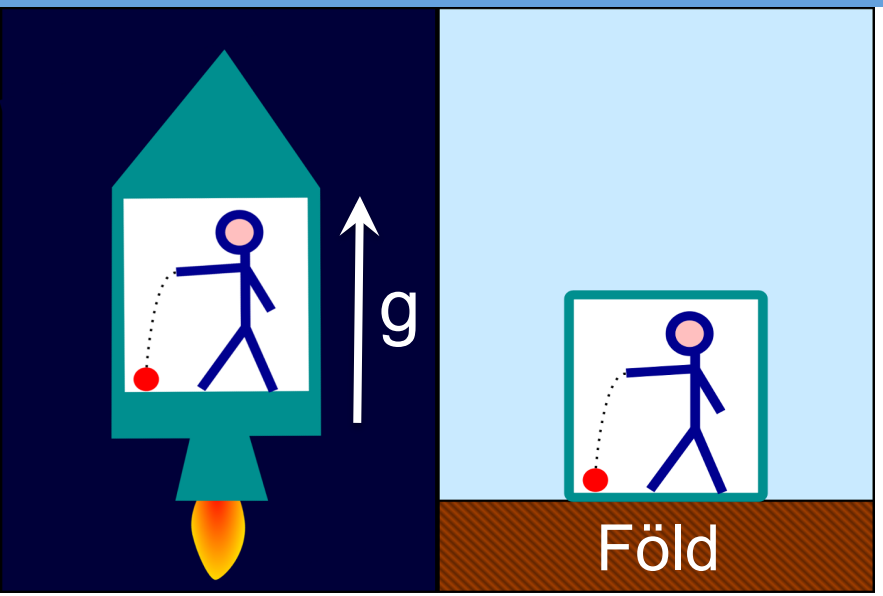




Albert Einstein:
Speciális relativitáselmélet (1905)

$$v' = \frac{u+v}{1+uv/c^2}$$

$$t' = t/\sqrt{1-\frac{v^2}{c^2}} \qquad L' = L\sqrt{1-\frac{v^2}{c^2}}$$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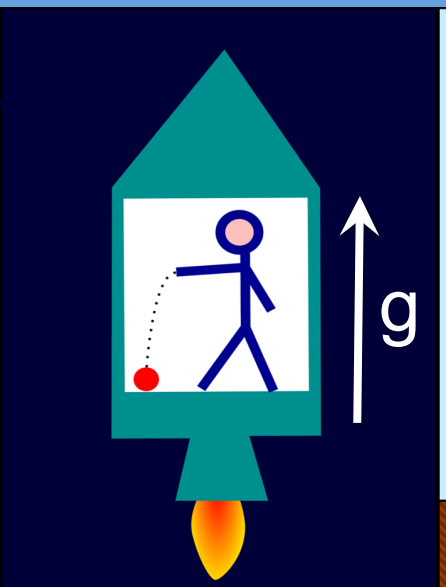
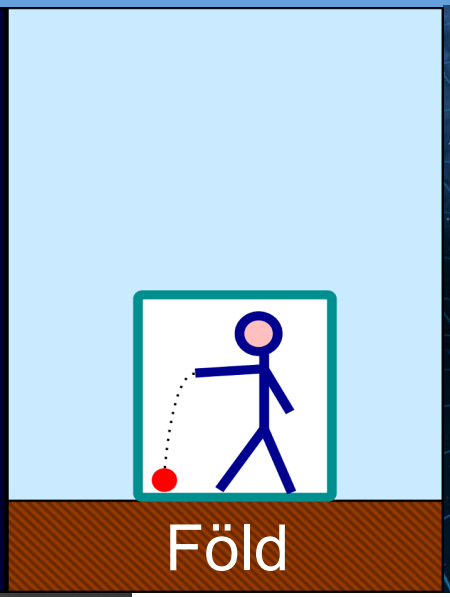
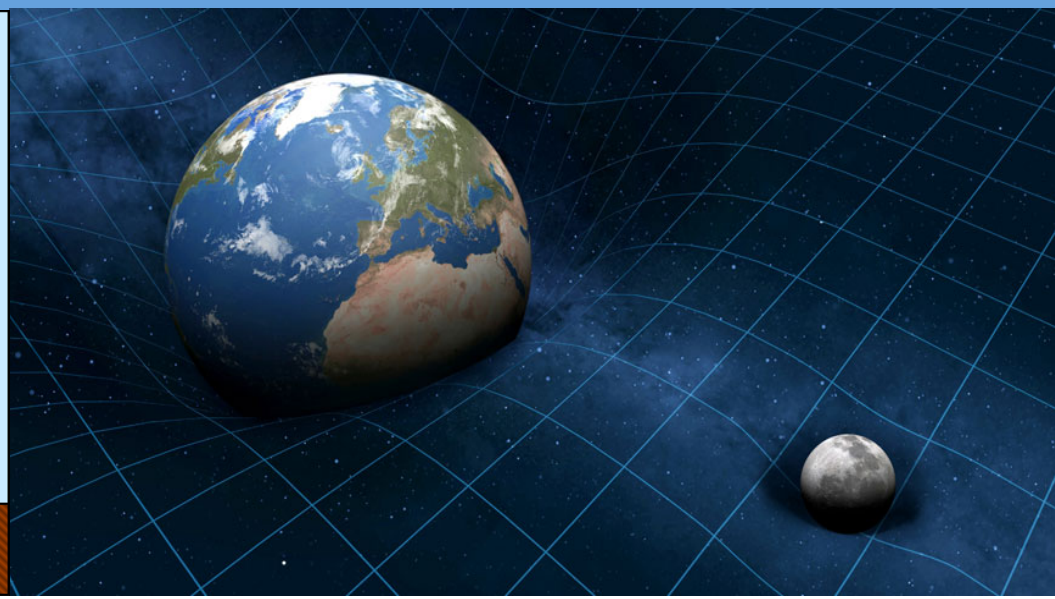
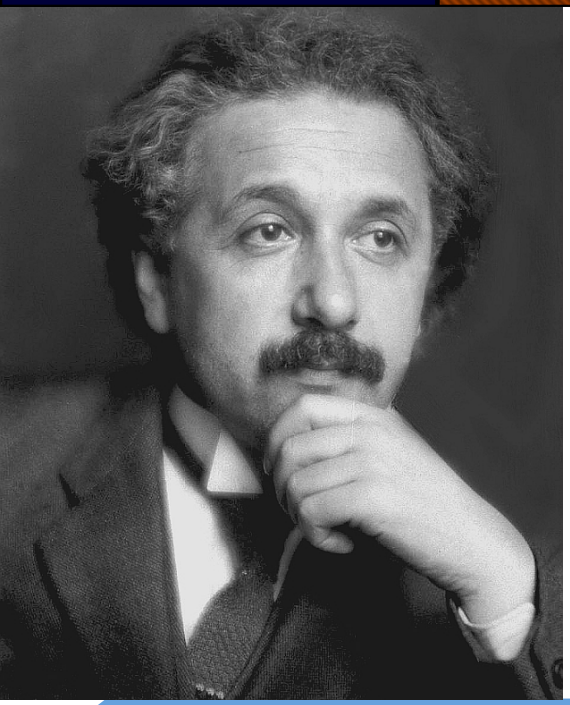
Föld





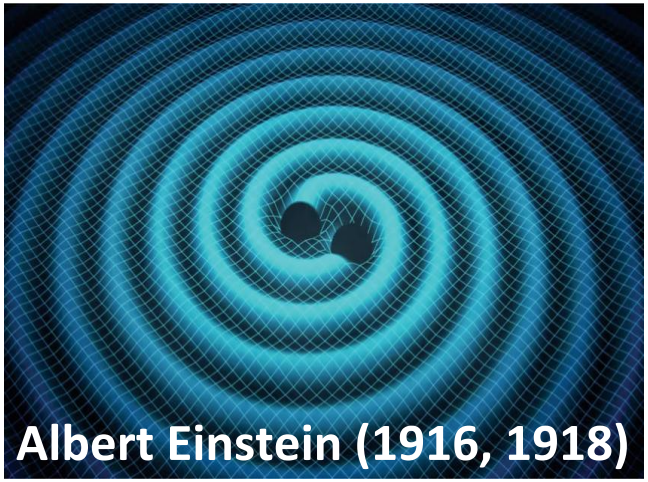




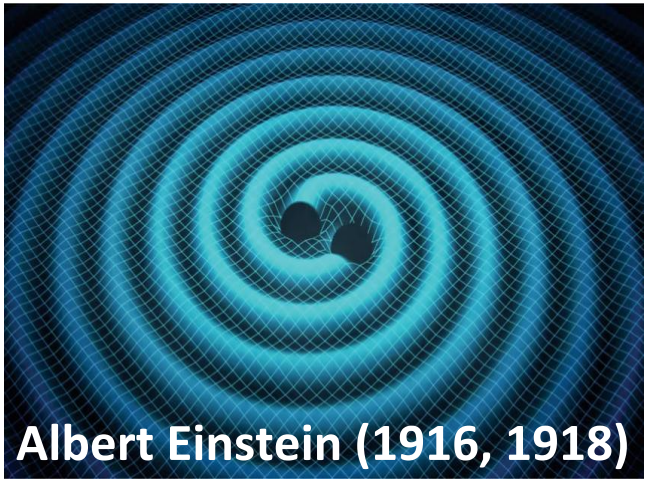
Albert Einstein:
Általános relativitáselmélet (1915)

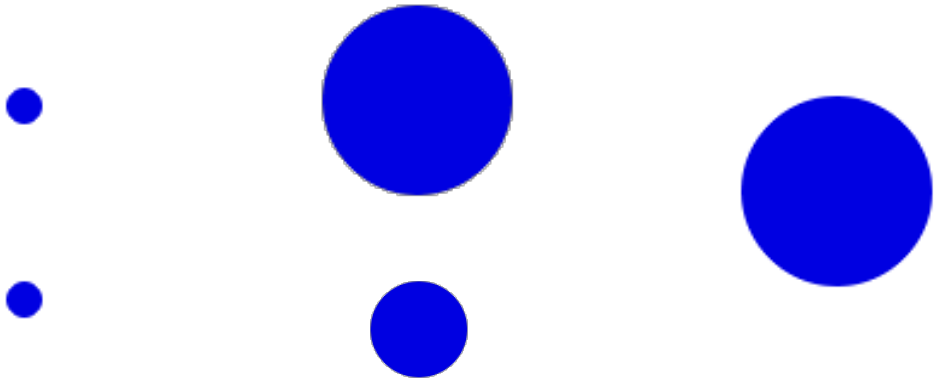
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

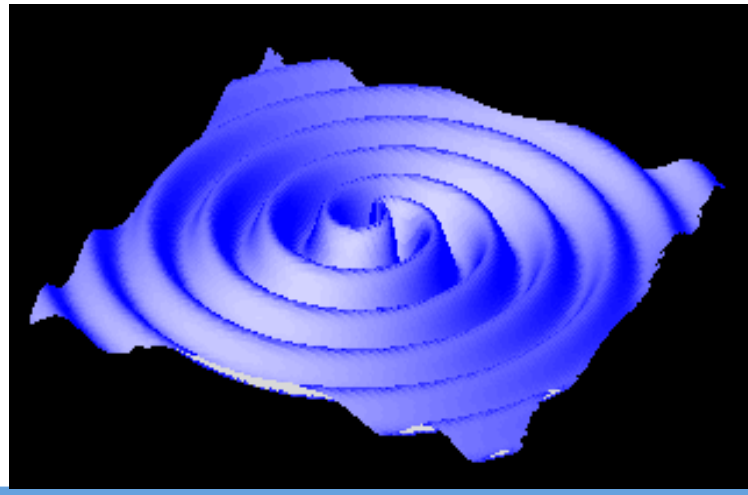
$$G_{\mu\nu} = 0$$

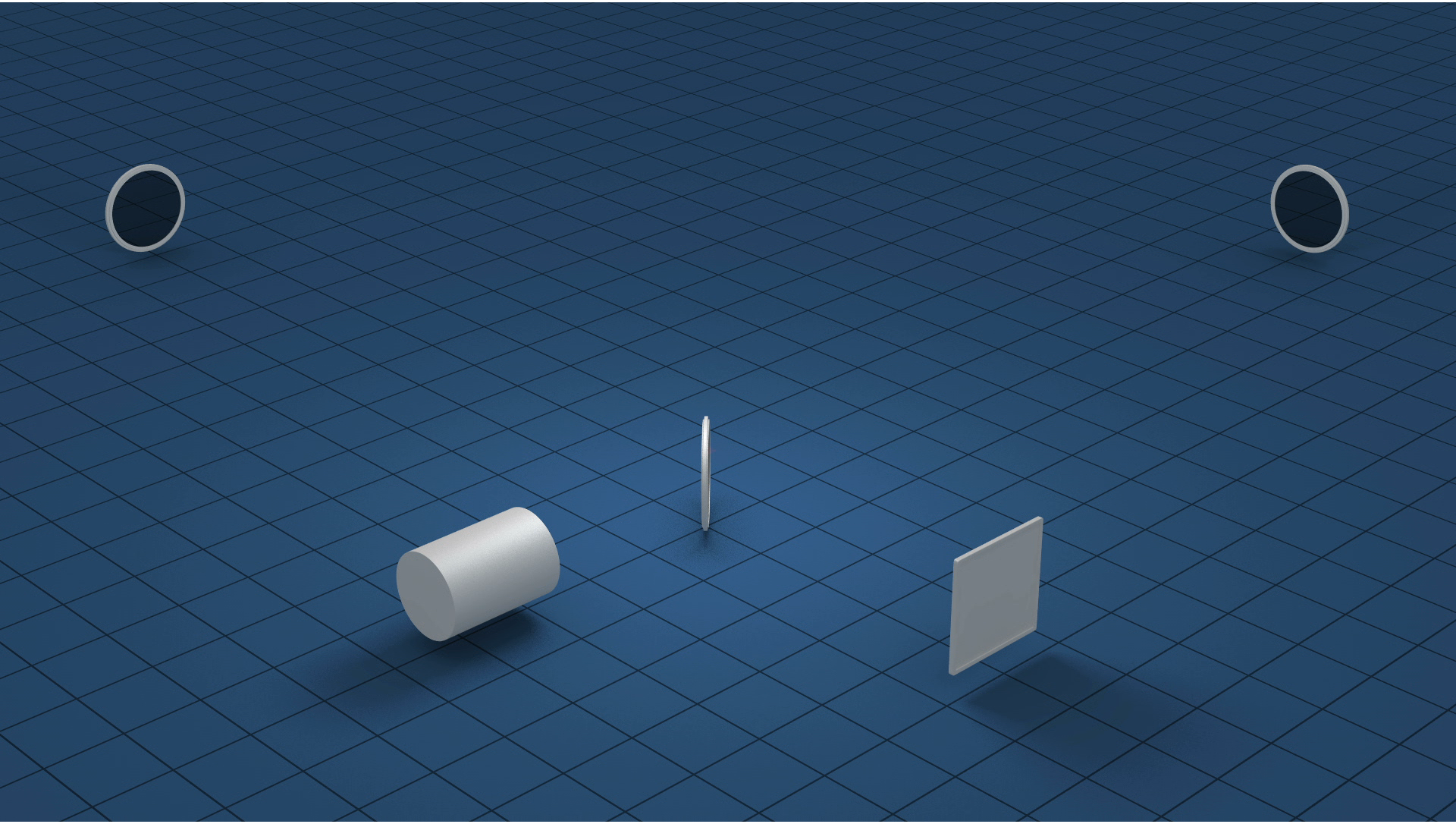


$$G_{\mu\nu} = 0$$

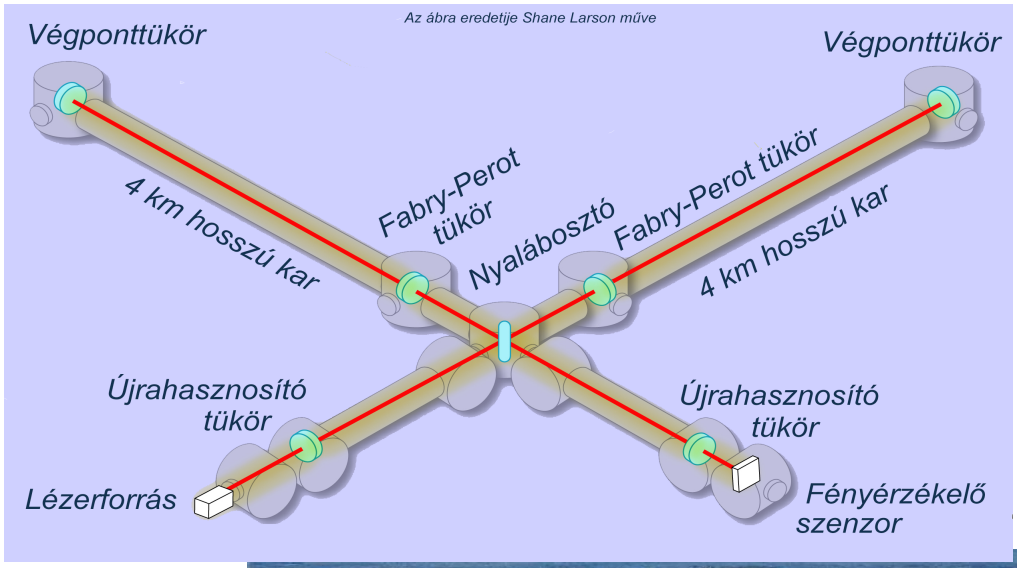


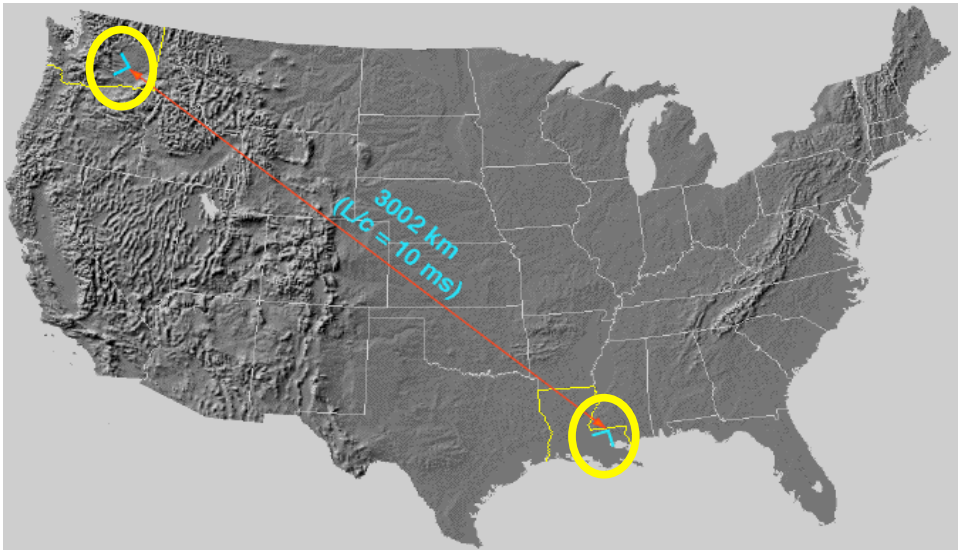


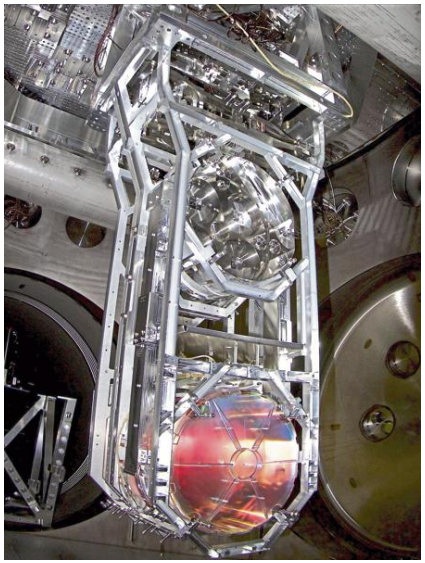


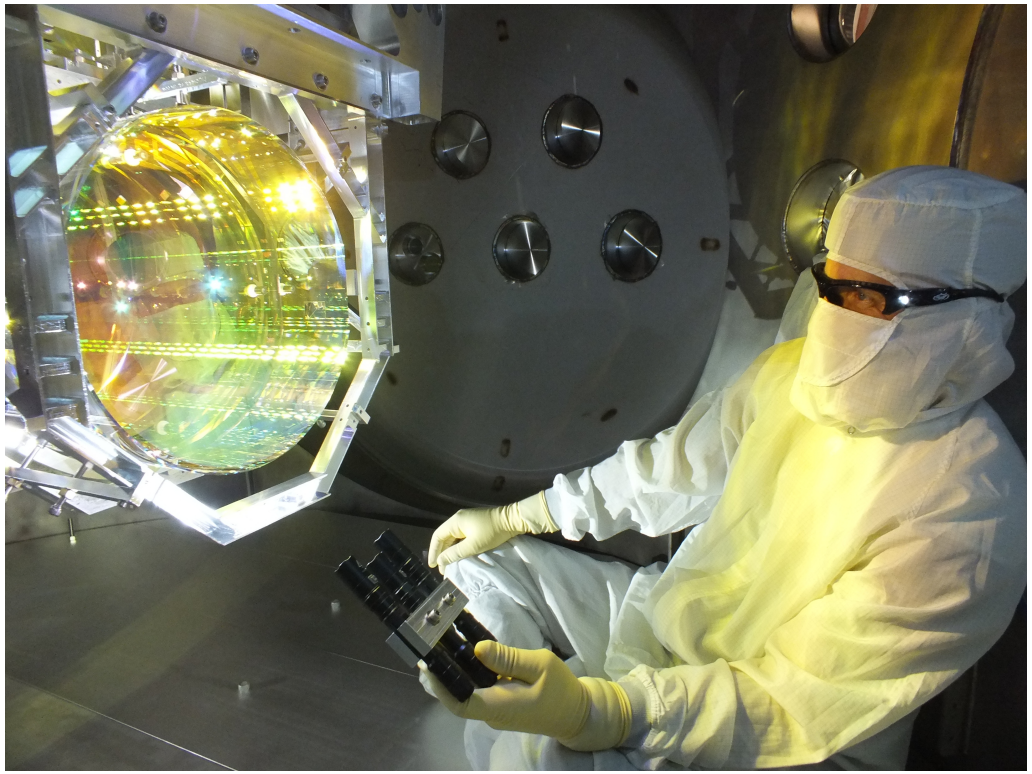


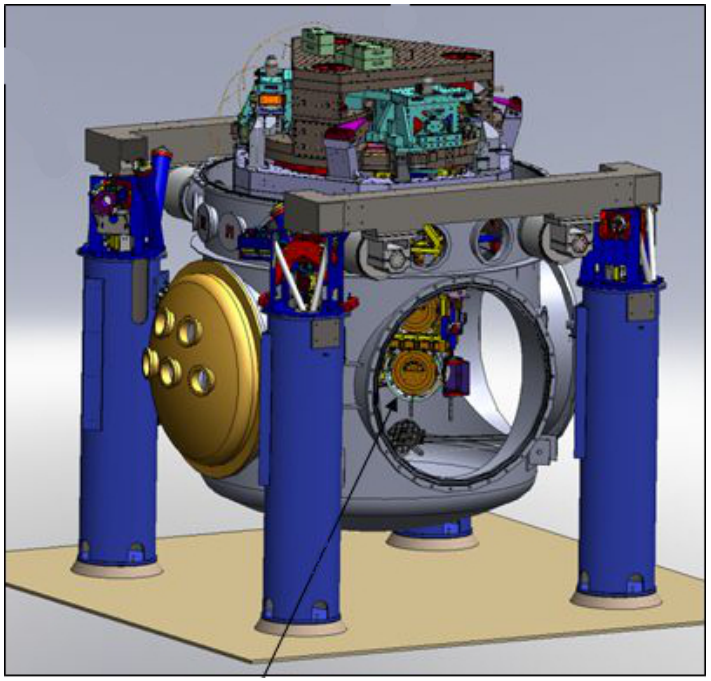
Laser Interferometer Gravitational-wave Observatory (LIGO)











GW150914

Megtörtént a felfedezés! - A GW150914 az elsőnek észlelt gravitációshullám-jel fekete lyukak összeolvadásából

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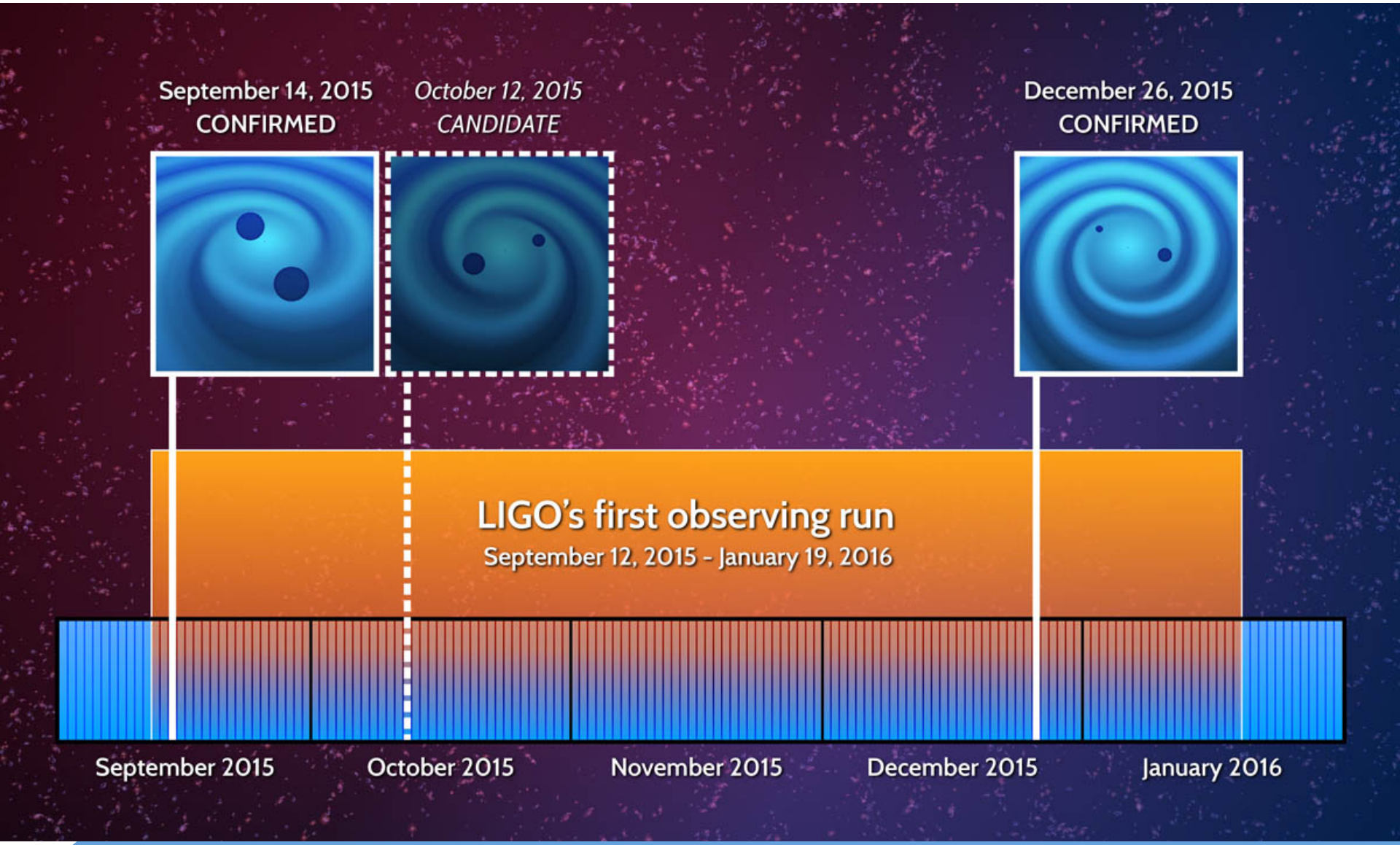
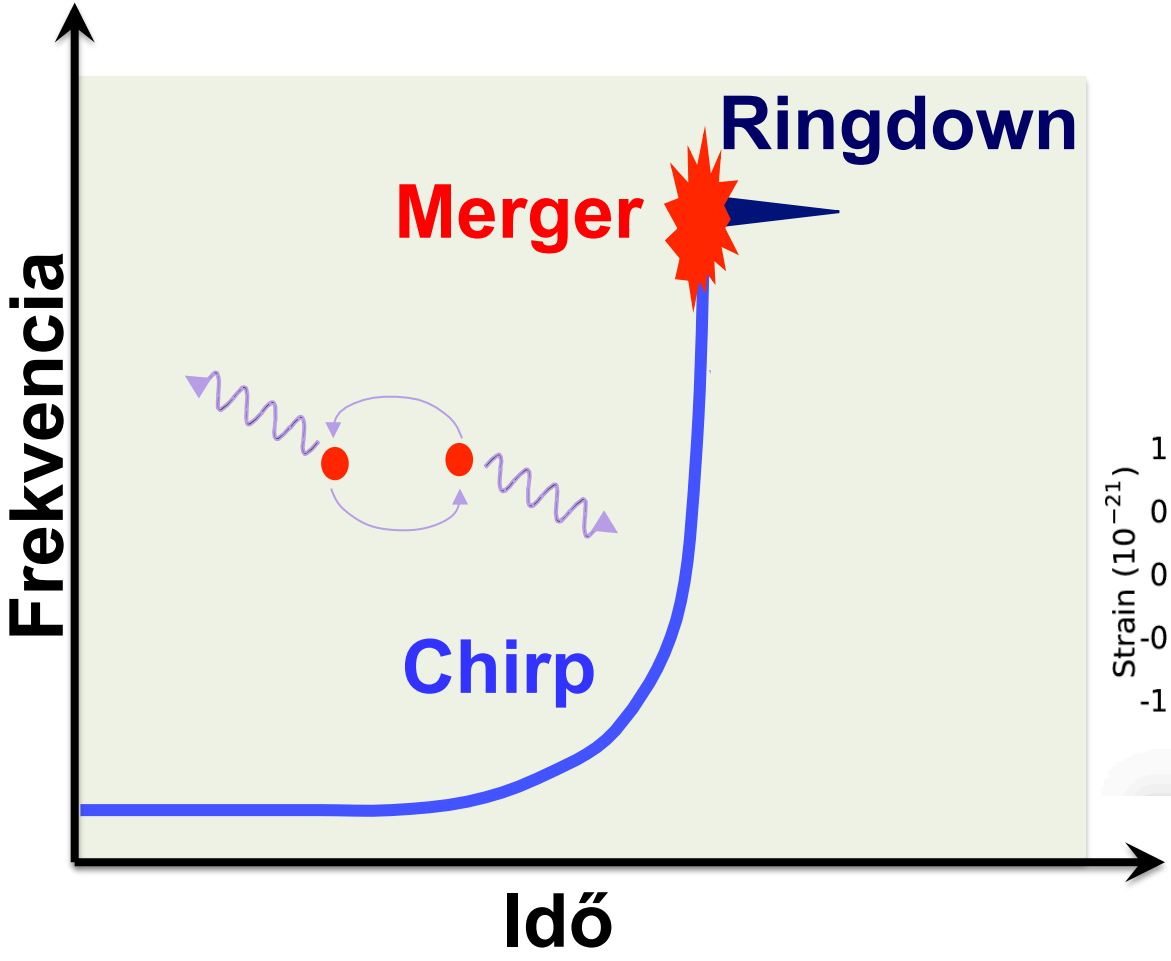
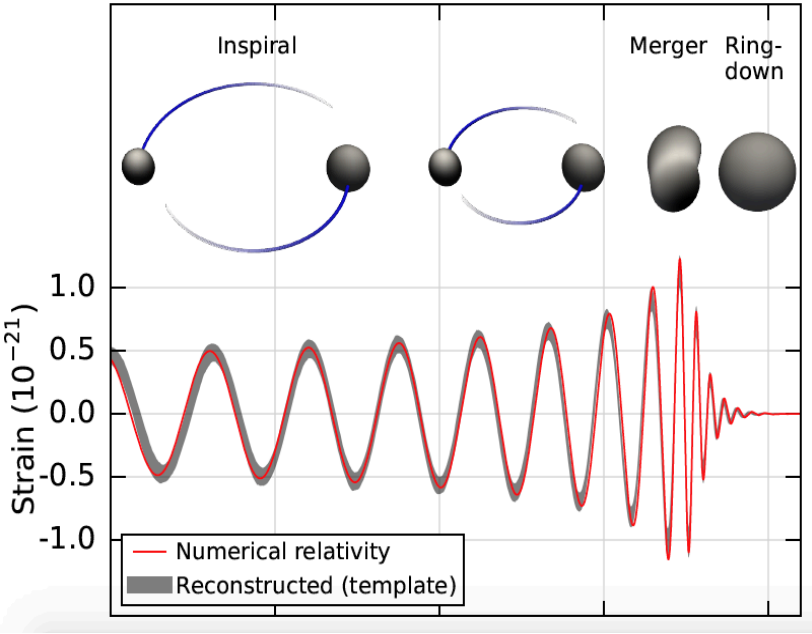
Észlelések (eddig…)



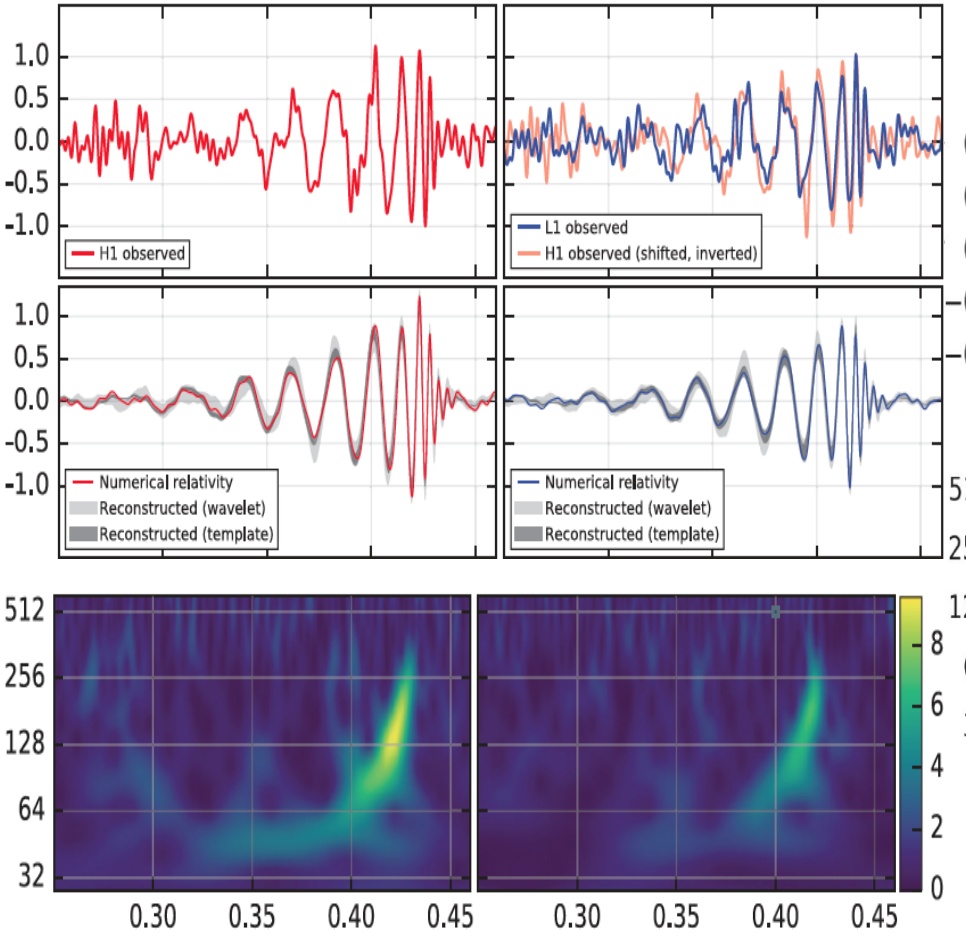
Összeolvadó kompakt kettősök





GW150914

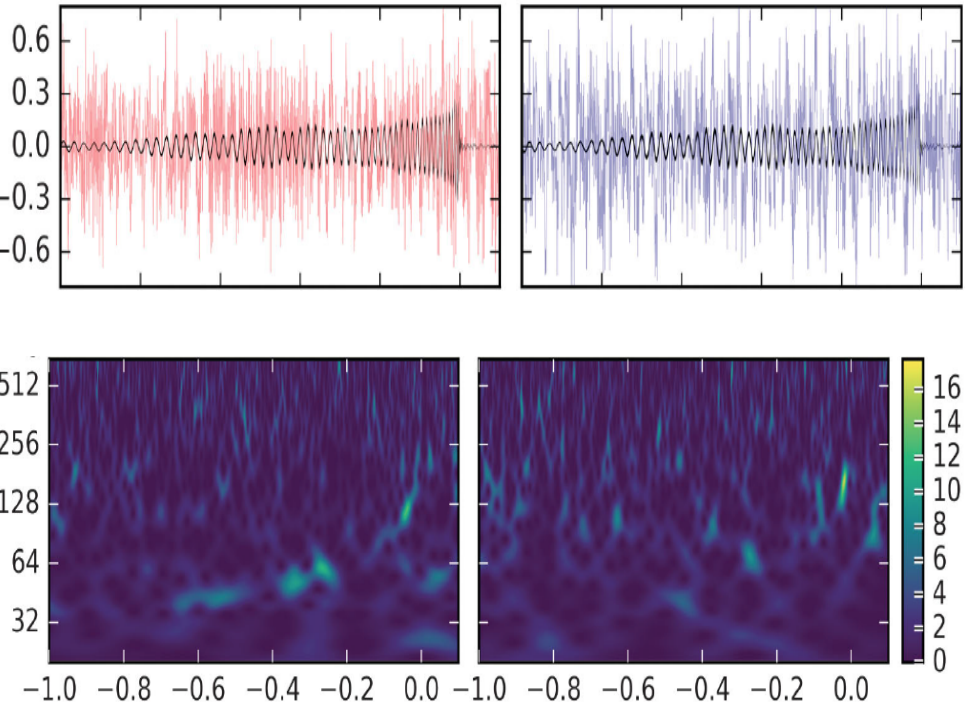
LIGO Hanford LIGO Livingston



Abbott et al. PRL 116, 061102 (2016)

GW151226

LIGO Hanford LIGO Livingston



Abbott et al. PRL 116, 241103 (2016)

Hogyan lesz ebből asztrofizika?

Paraméterbecslés és modellek tesztelése!

LIGO Kutatócsoport az ELTE-n

Bécsy Bence

Milyen forrás-paraméterek mekkora pontossággal rekonstruálhatók?

Bécsy et al. ApJ (2017)

Dálya Gergely

Mely galaxisokban formálódnak a gravitációshullám-források?

Dálya et al. MNRAS(?)

Szölgyén Ákos

Hogyan kell detektor-hálózatok működését adott tudományos célokra optimalizálni?

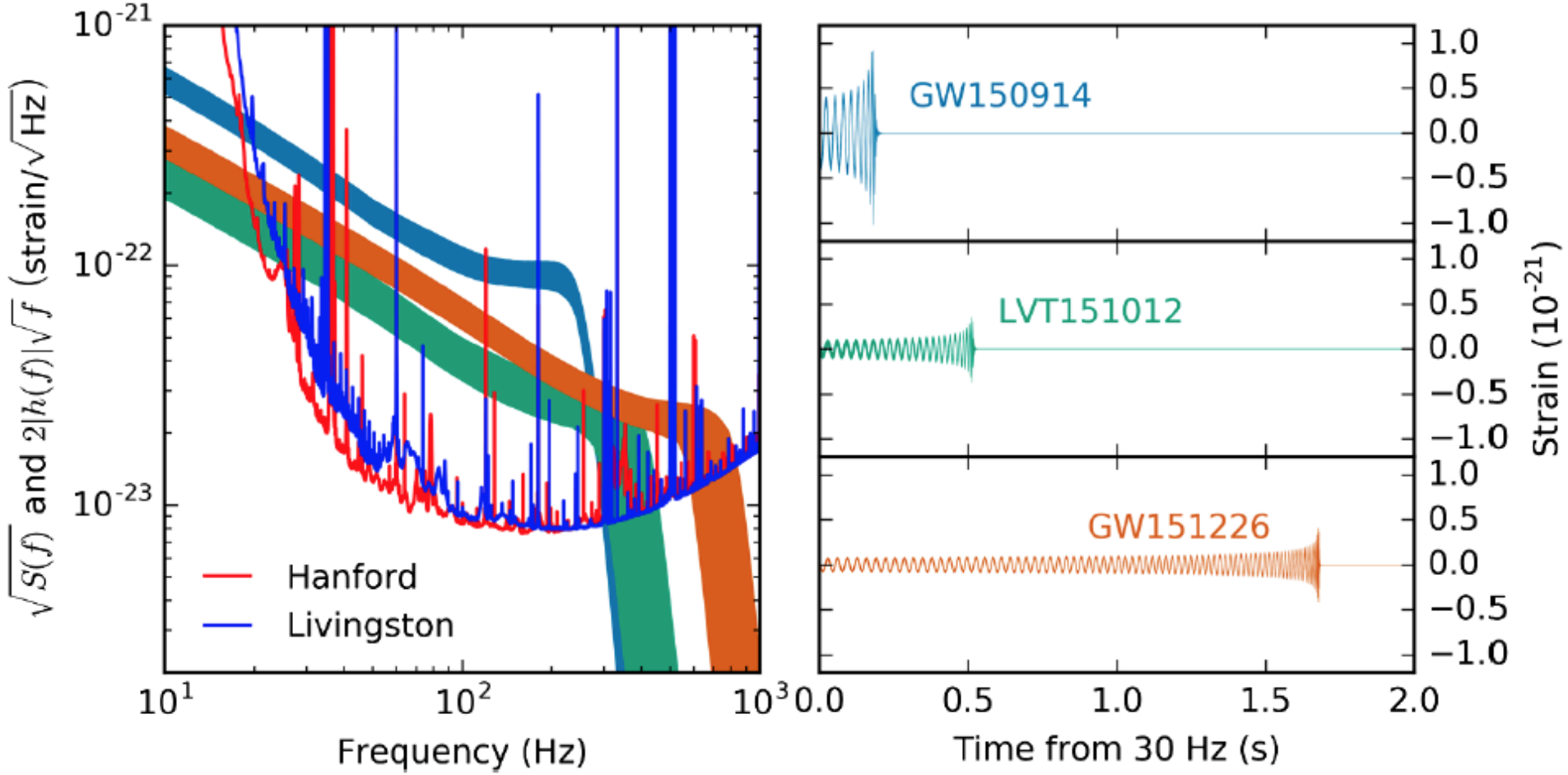
Szölgyén et al. CQG (2017)

Takátsy János

Milyen modellek tesztelhetők elnyúlt pályájú feketelyuk-kettősök észlelésével?

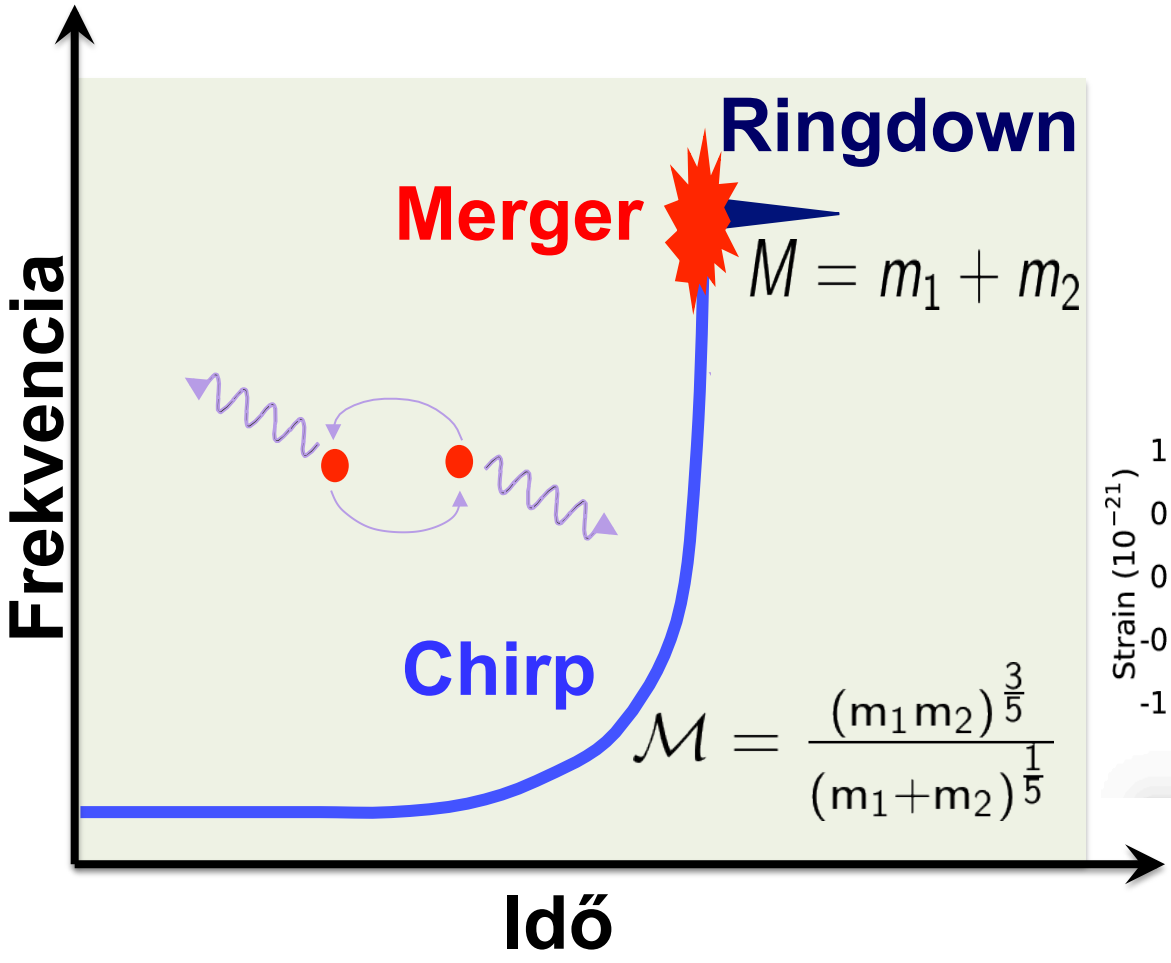
Takátsy et al. MNRAS(?)

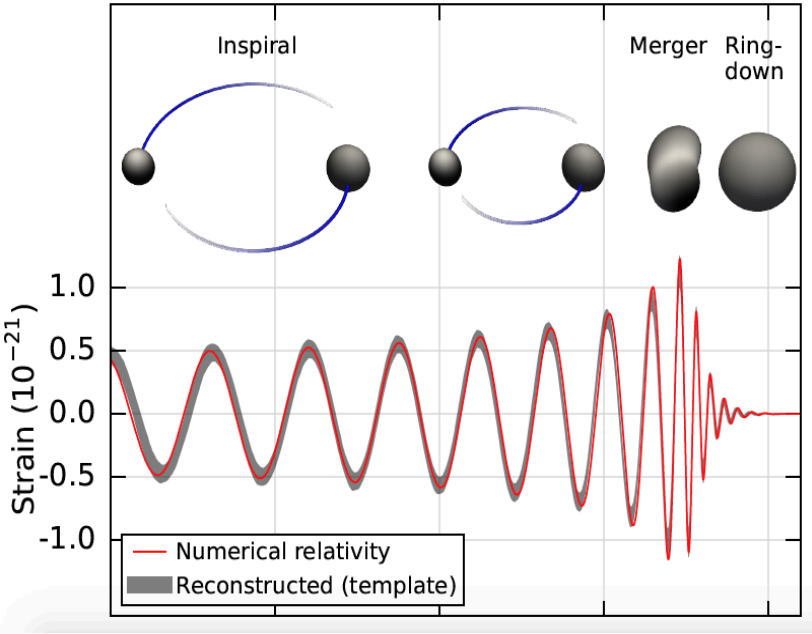
Észlelések (eddig…) II.



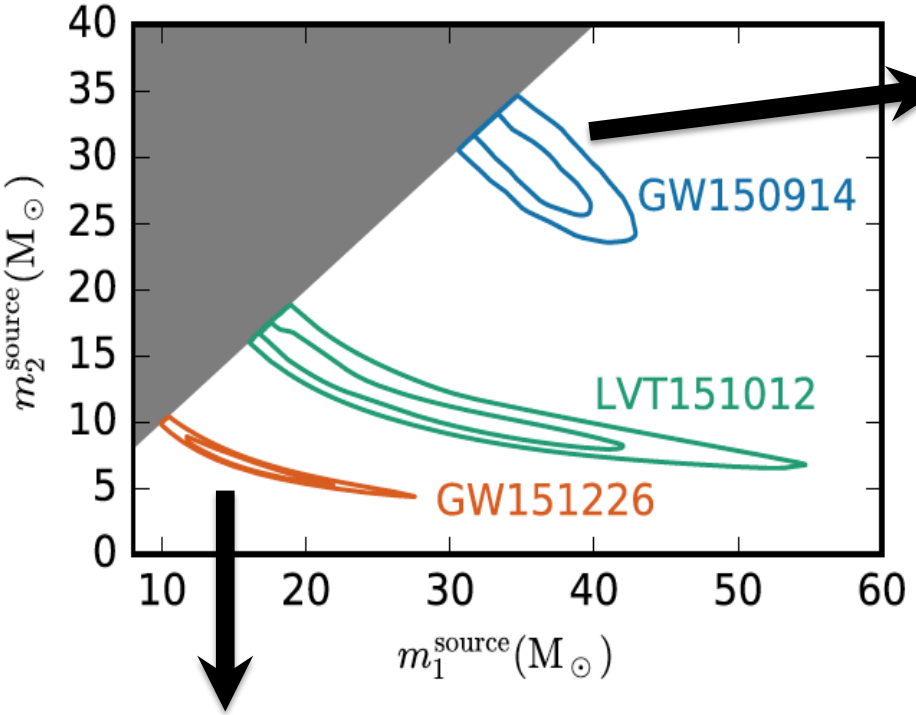
Abbott et al. PRX 6, 041015 (2016)

Tömeg- és távolságbecslés





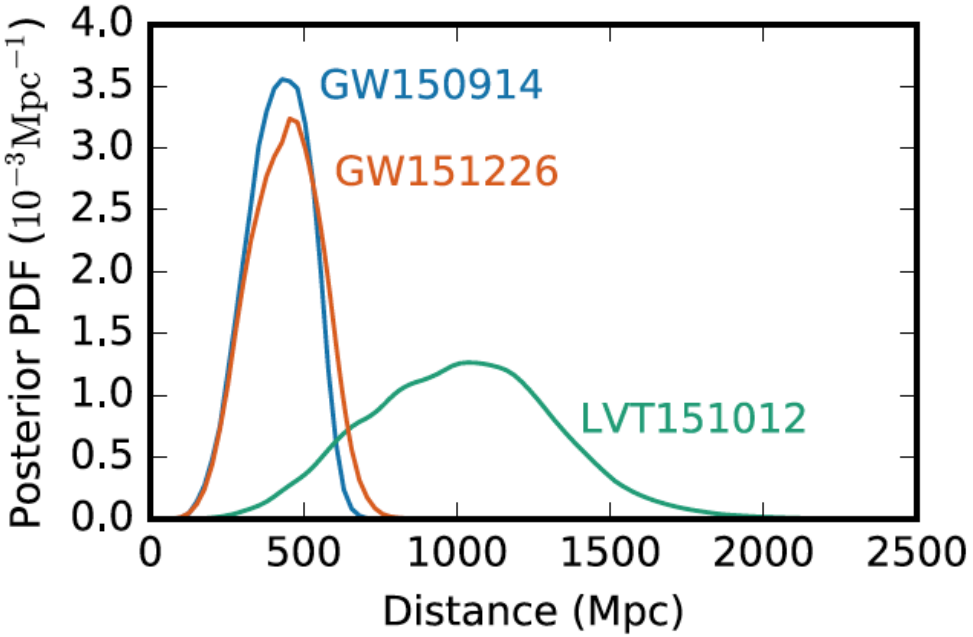
Tömegek és távolságok



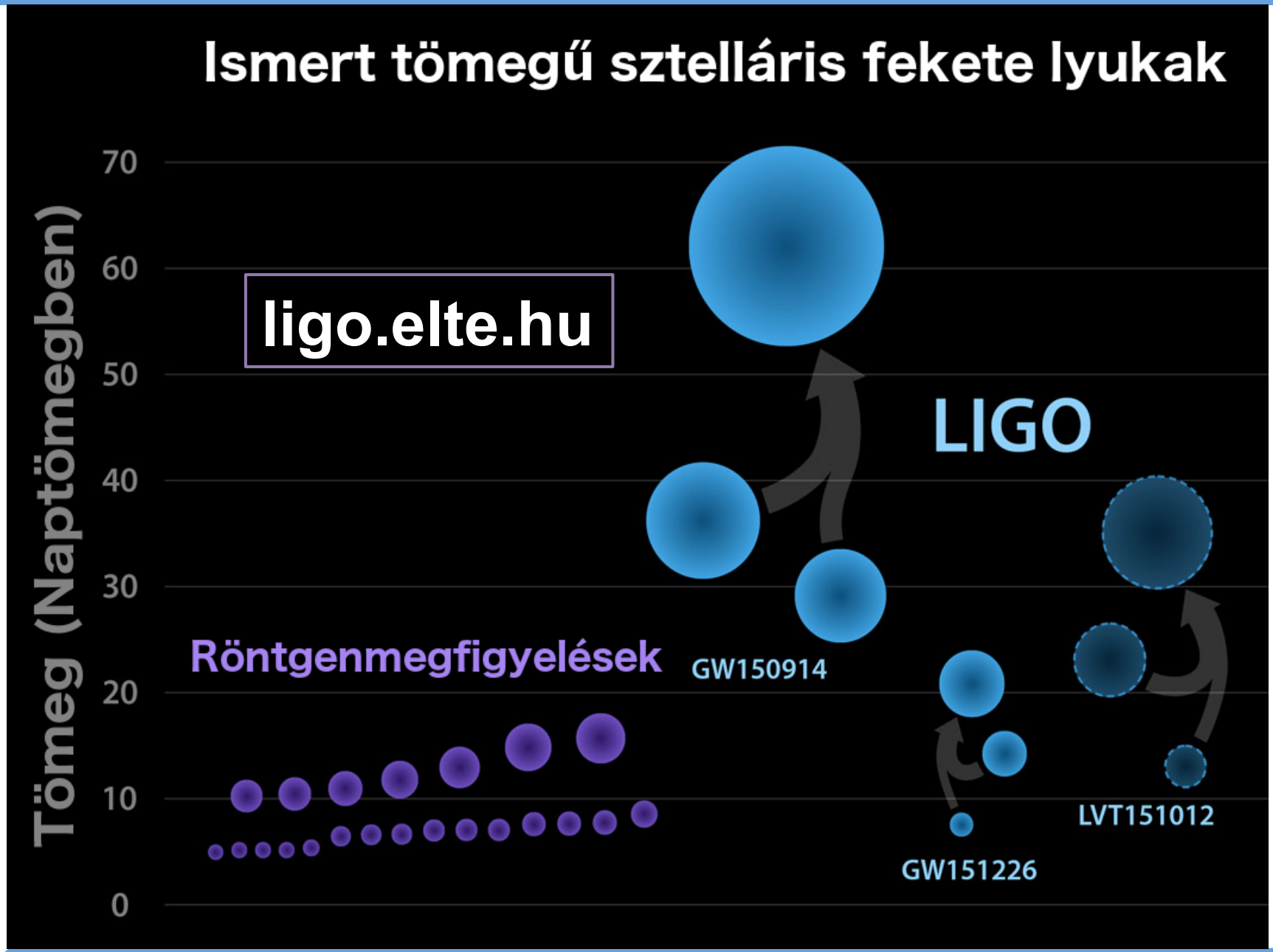
m_1 és m_2 a **belső kontúron** belül vannak **50%**, a **külső kontúron** belül **90%** valószínűséggel.

Chirp tömeg:

$$\mathcal{M} = \frac{(m_1 m_2)^{\frac{3}{5}}}{(m_1+m_2)^{\frac{1}{5}}}$$

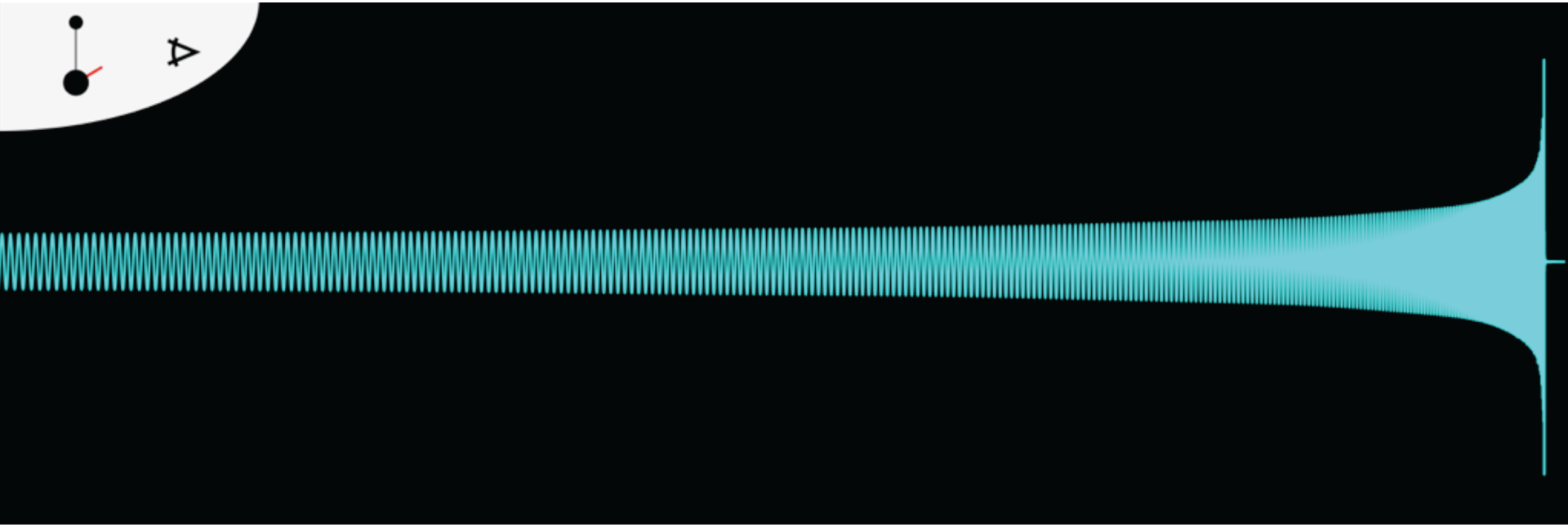


[1 Mpc = 3,3 millió fényév]


Ismert tömegű sztelláris fekete lyukak
Tömeg (Naptömegben)
70
60
50
40
30
20
10
0
ligo.elte.hu
LIGO
Röntgenmegfigyelések
GW150914
LVT151012
GW151226

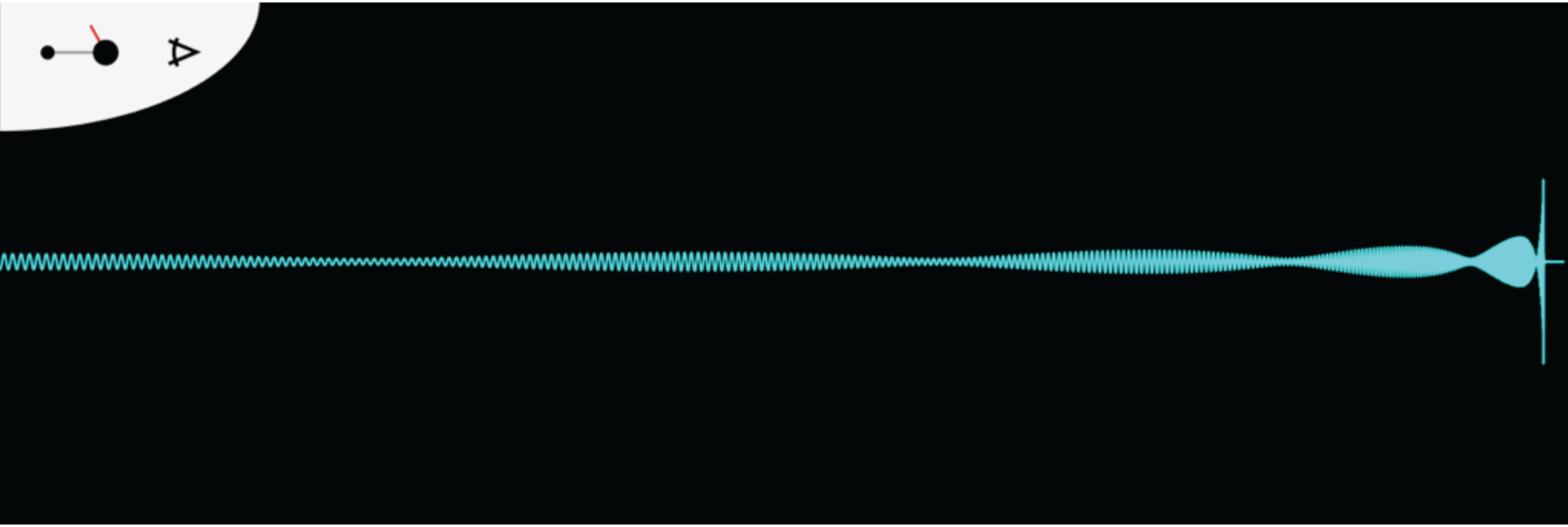
A tagok perdülete I.

Látóirányra merőleges keringés:



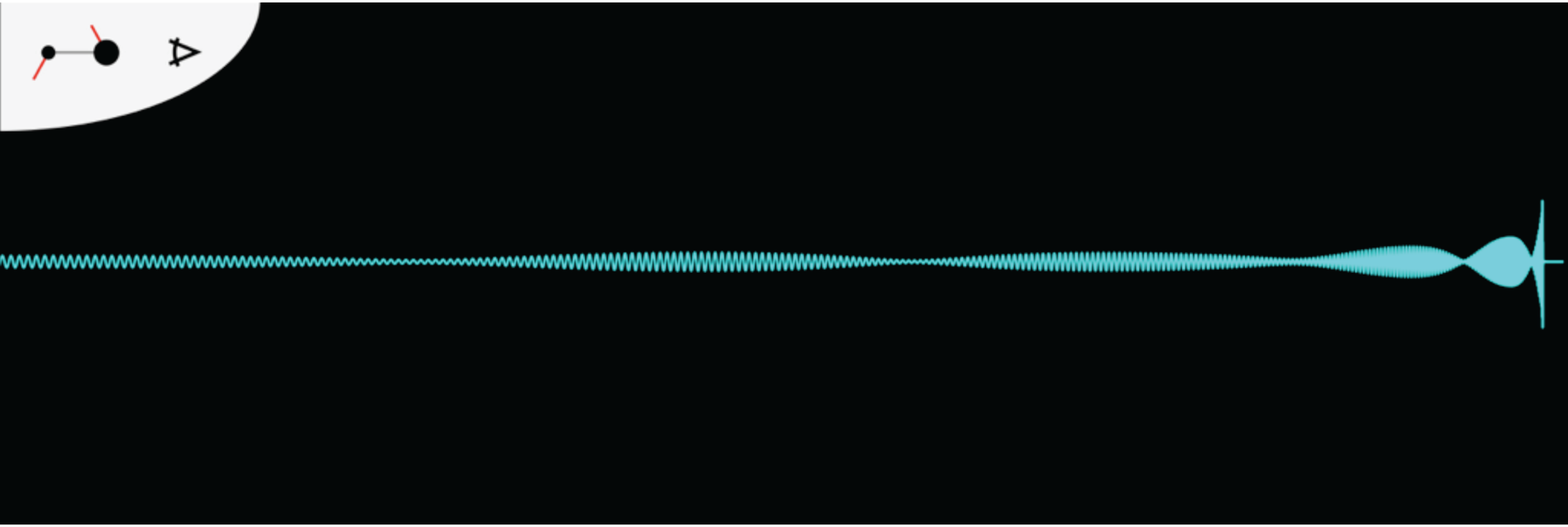
A tagok perdülete II.

Látóirányú keringés:



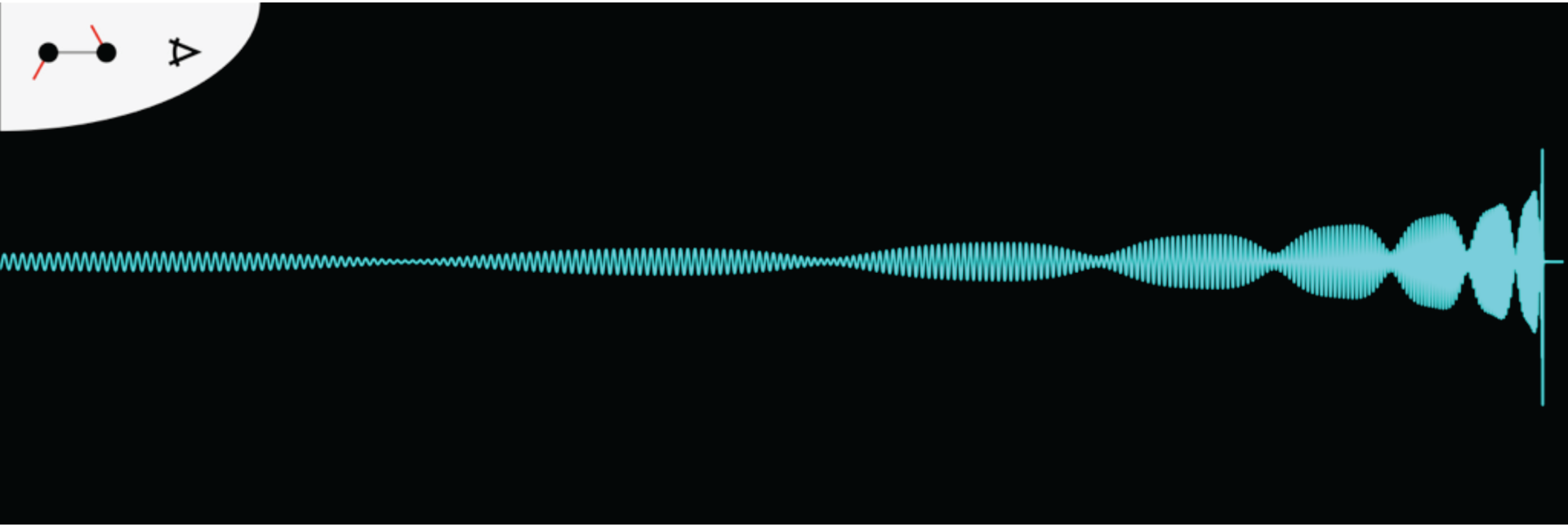
A tagok perdülete III.

A kisebb tagnak is van perdülete:

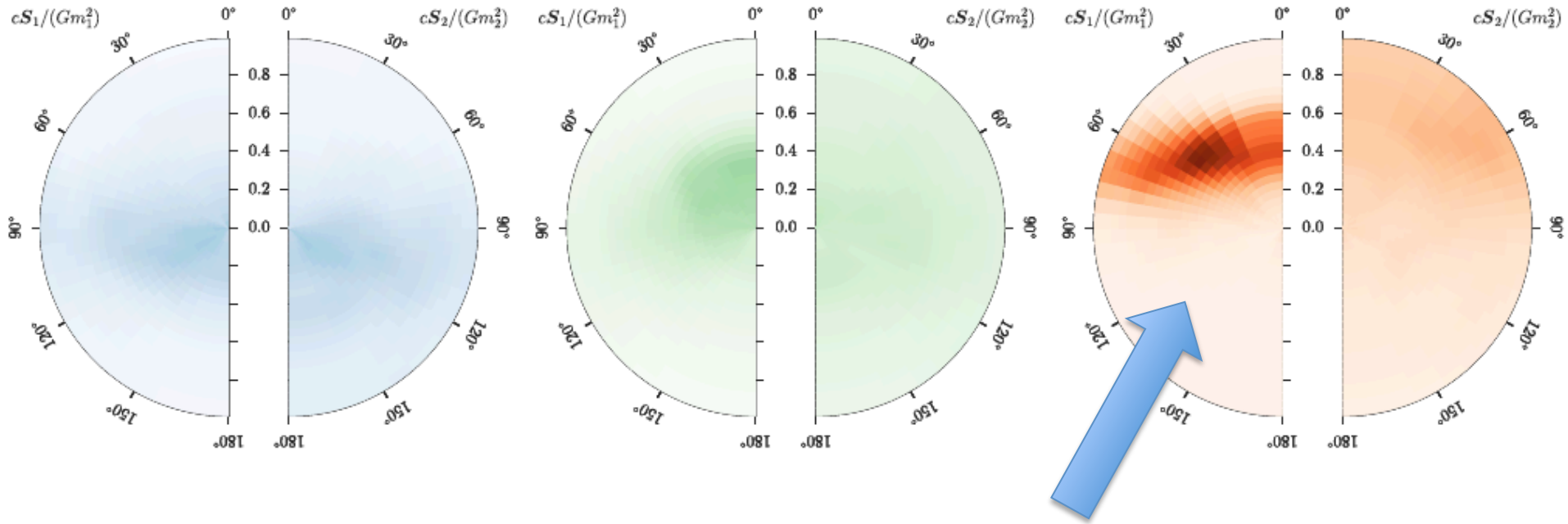


A tagok perdülete IV.

Azonos tömegű tagok:

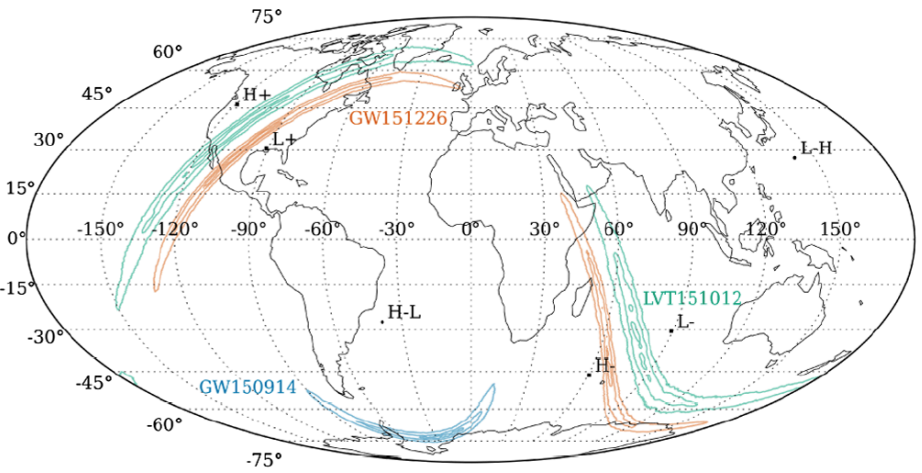


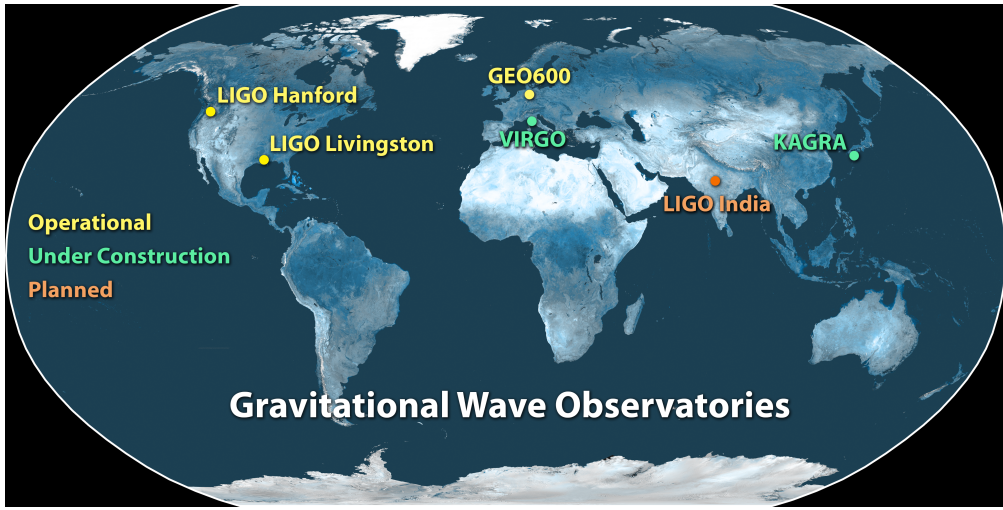
A tagok perdülete V.

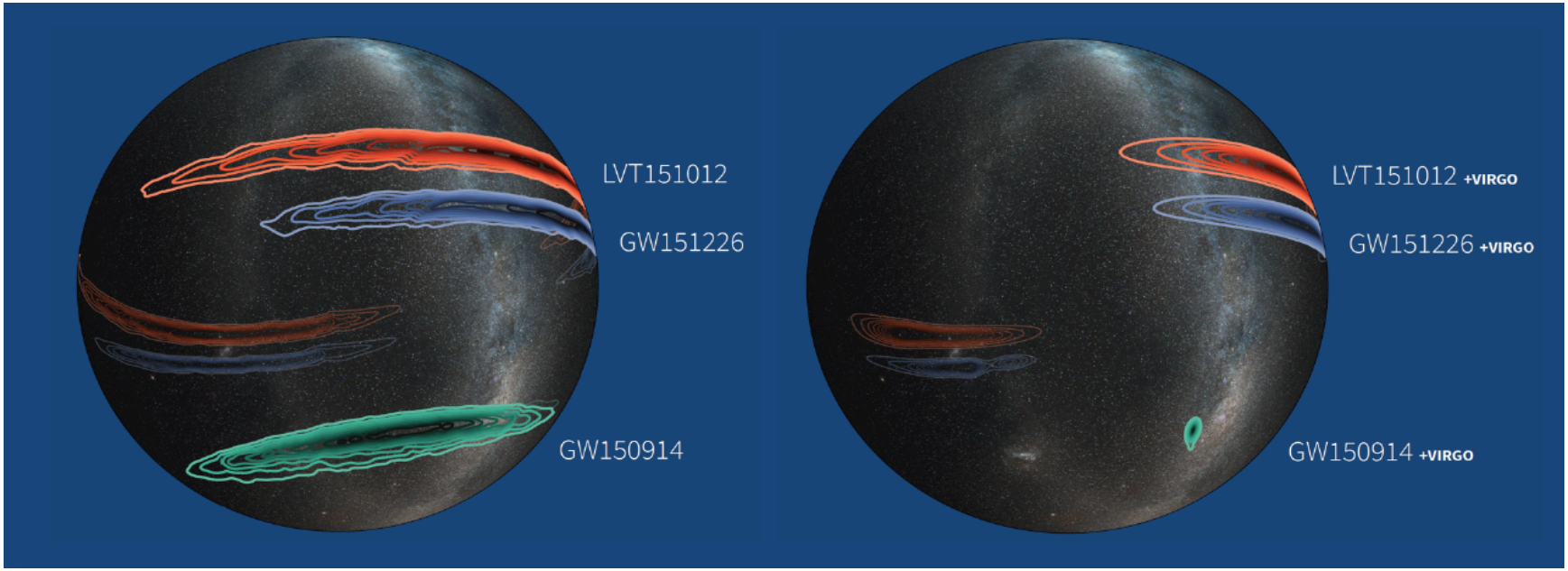


Legalább az egyik fekete lyuk forog! (GW151226)

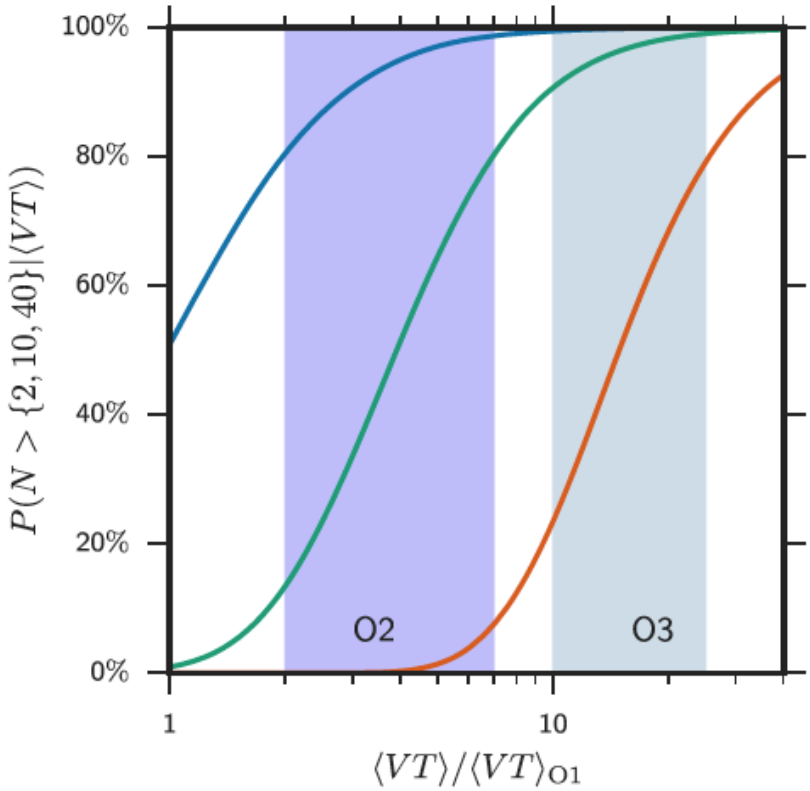
Forráslokalizáció



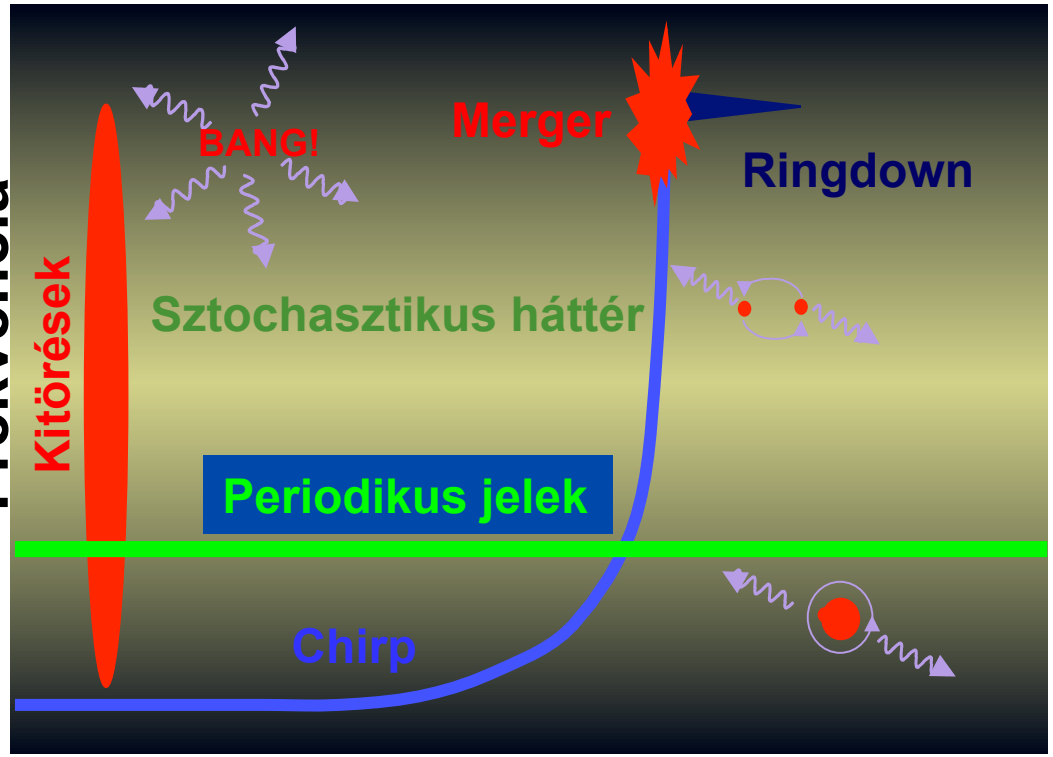


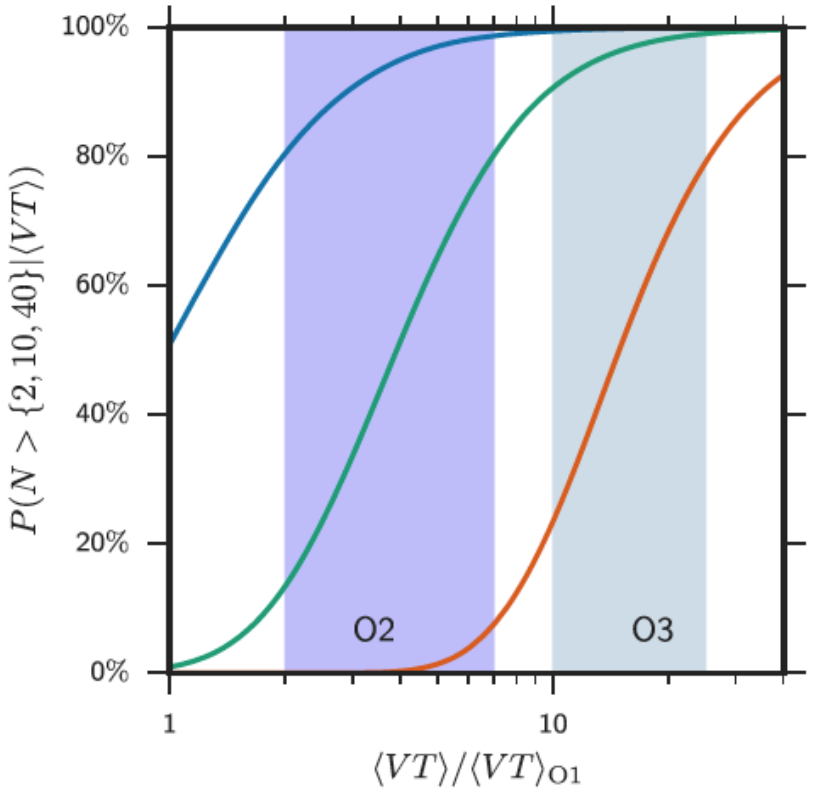


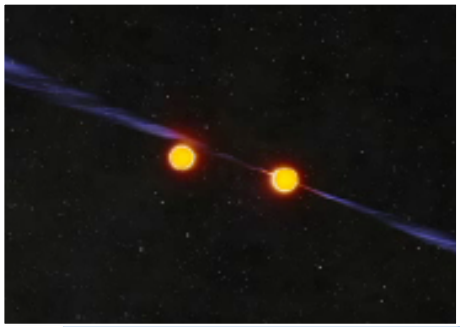
Mi jön még?

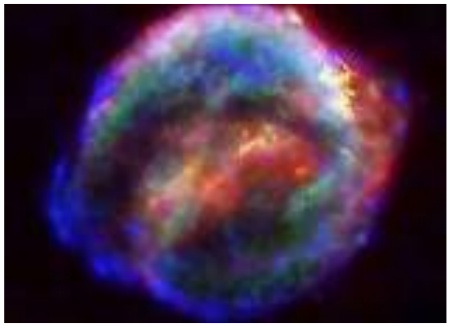

100%
80%
60%
40%
20%
0%
$P(N > \{2, 10, 40\}|\langle VT \rangle)$
O2
O3
1
10
$\langle VT \rangle / \langle VT \rangle_{O1}$

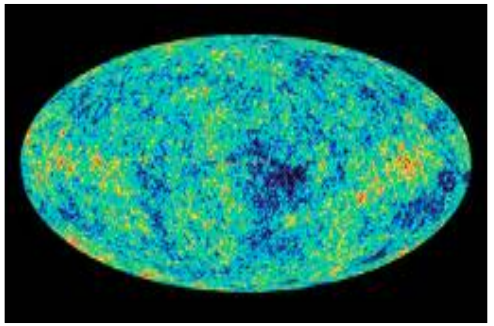
Mi jön még?


Frekvencia
Kitörések
BANG!
Merger
Ringdown
Sztochasztikus háttér
Periodikus jelek
Chirp
Idő

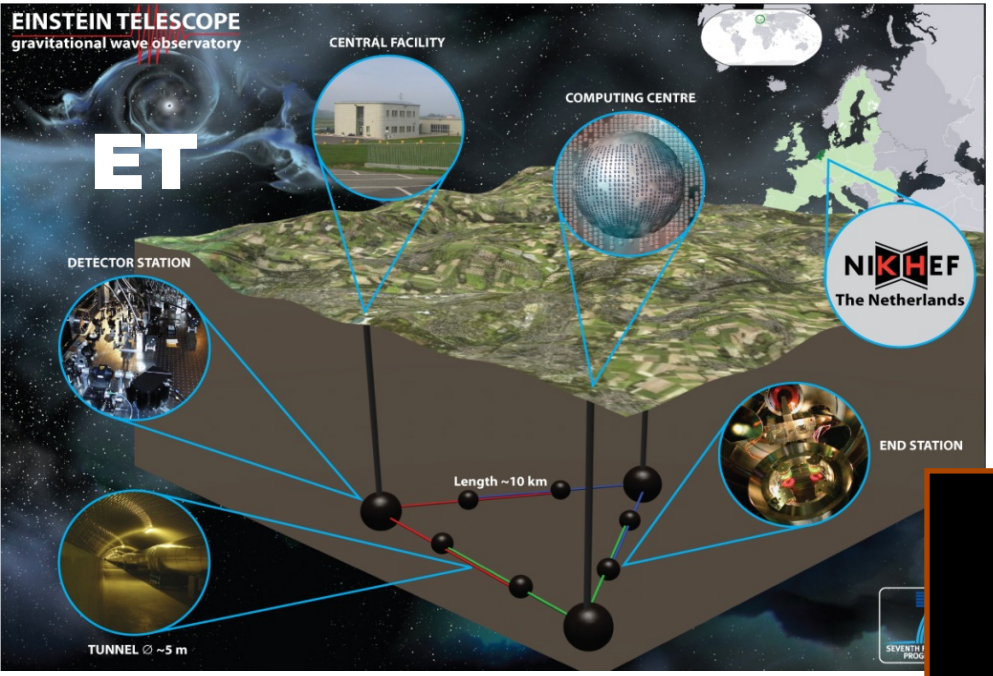

100%
80%
60%
40%
20%
0%
$P(N > \{2, 10, 40\}|\langle VT \rangle)$
O2
O3
1
10
$\langle VT \rangle / \langle VT \rangle_{O1}$

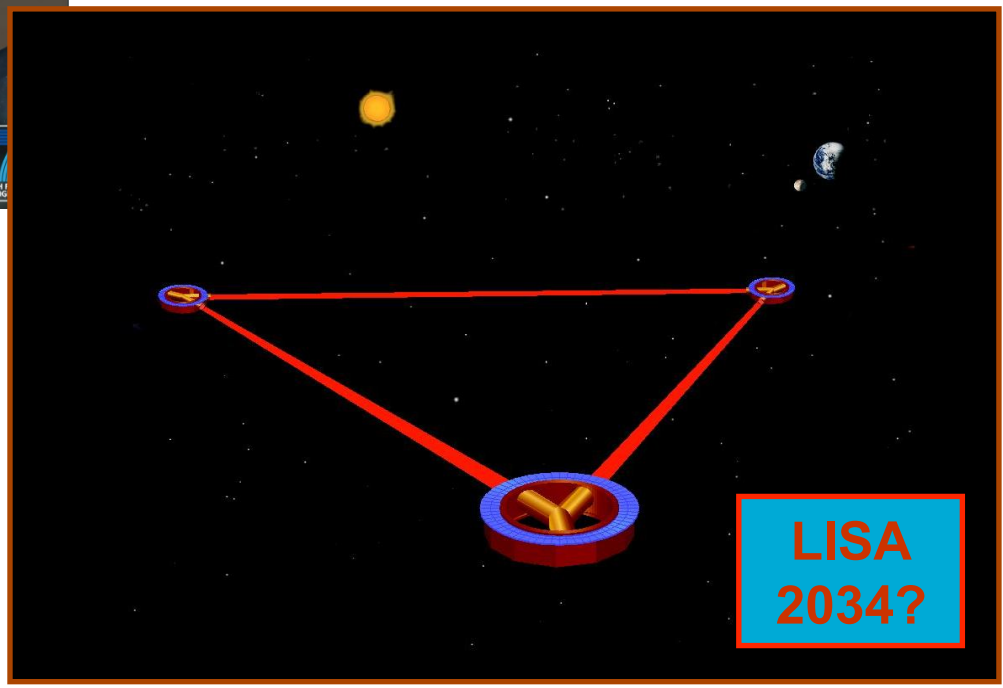






A jövő detektorai?





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