

L'alba di un'epoca d'oro per l'astronomia

Collisioni cosmiche - onde gravitazionali, onde
elettromagnetiche e neutrini



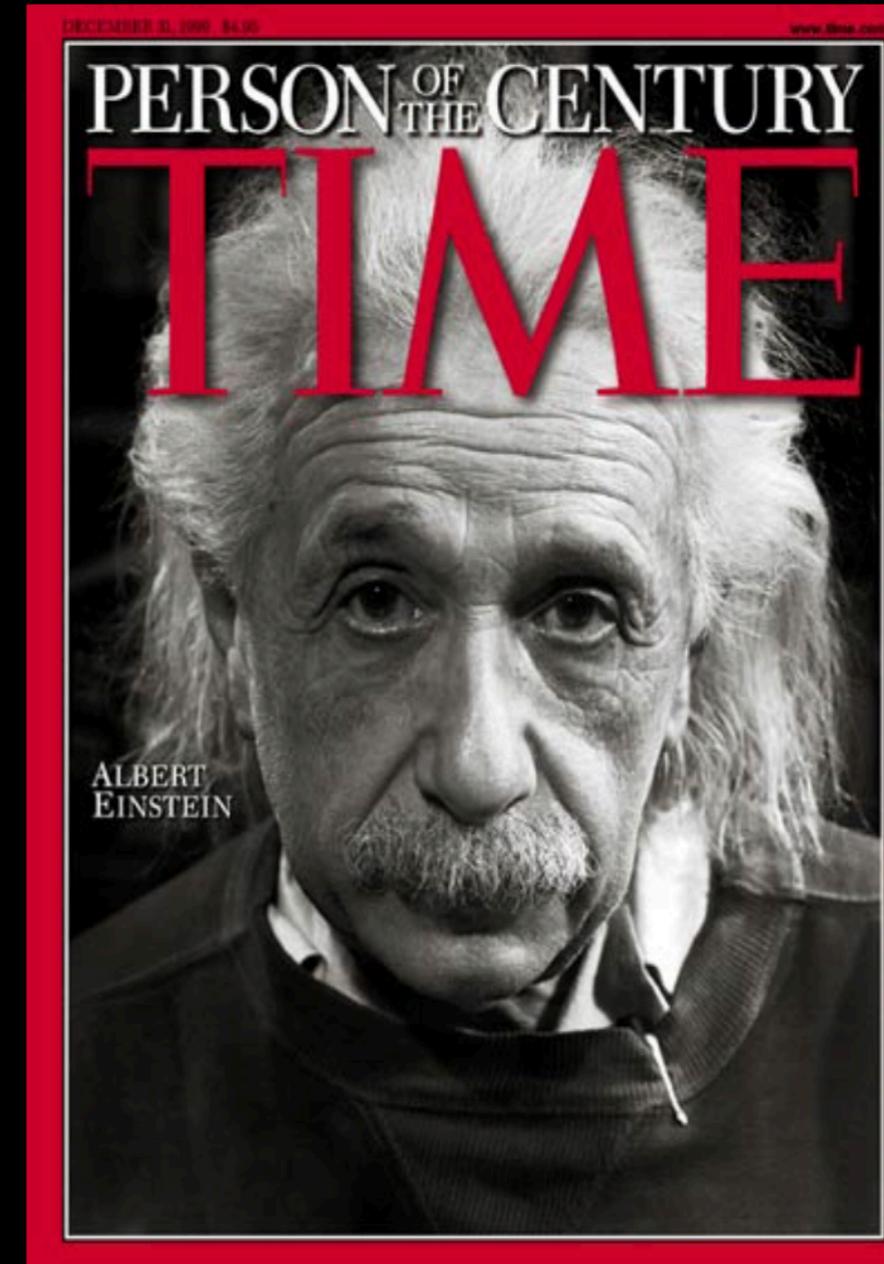
Stefano Covino et al.
INAF / Osservatorio Astronomico di Brera

RELATIVITA' GENERALE (1915)

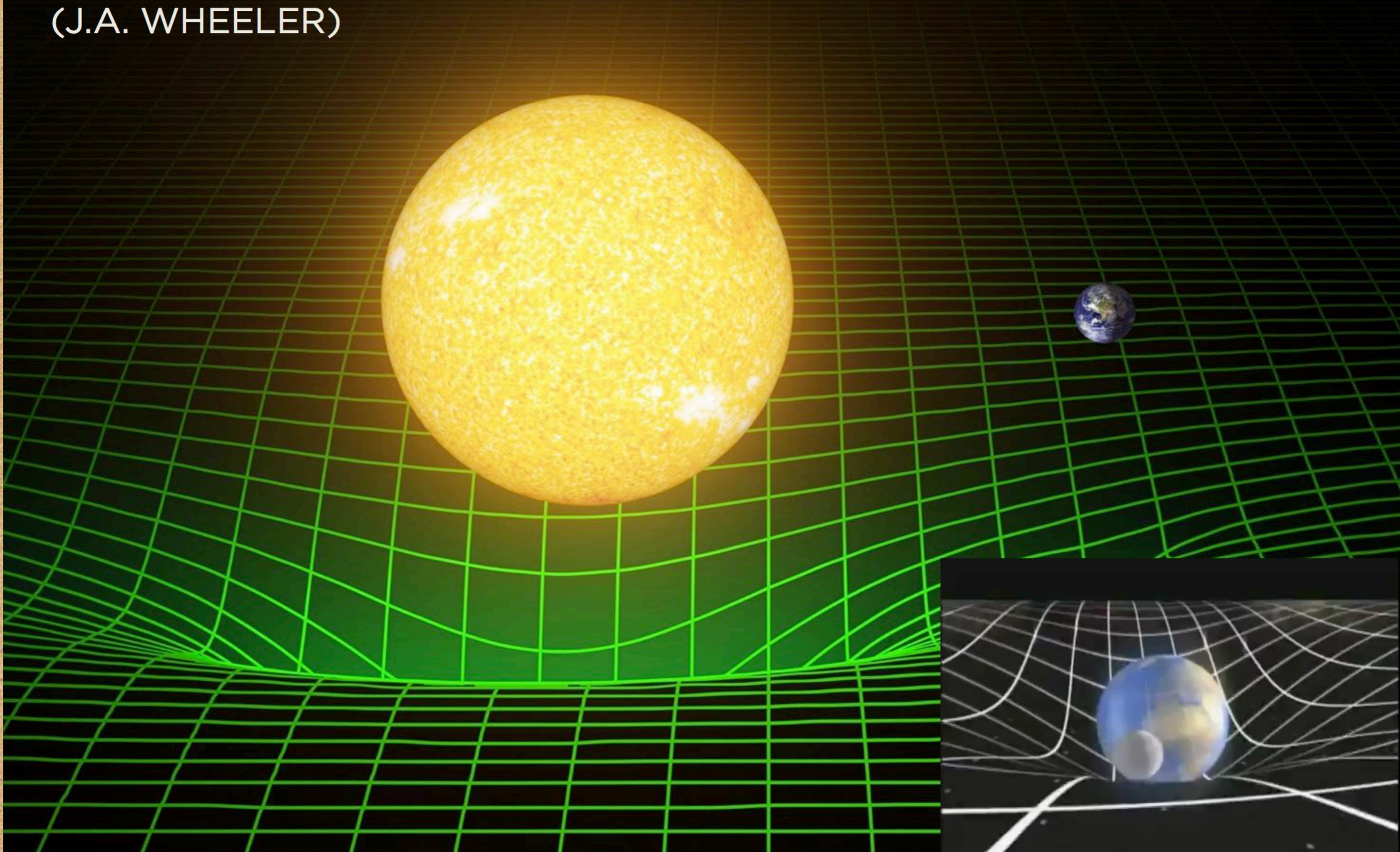
$$\mathbf{G}_{\mu\nu} = \frac{8\pi G}{c^4} \mathbf{T}_{\mu\nu}$$

GEOMETRIA
SPAZIO-TEMPO

MASSA-ENERGIA

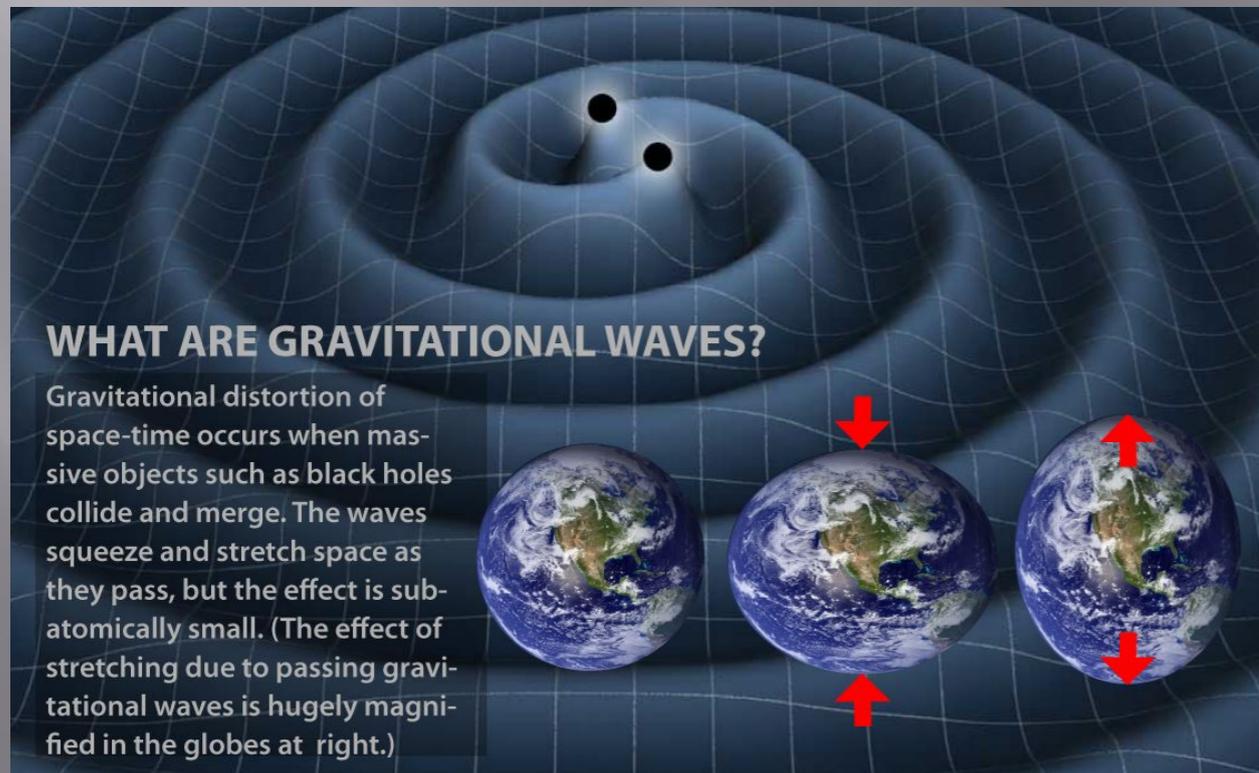


LA MATERIA DICE ALLO SPAZIOTEMPO COME INCURVARSI;
LO SPAZIOTEMPO DICE ALLA MATERIA COME MUOVERSI.
(J.A. WHEELER)

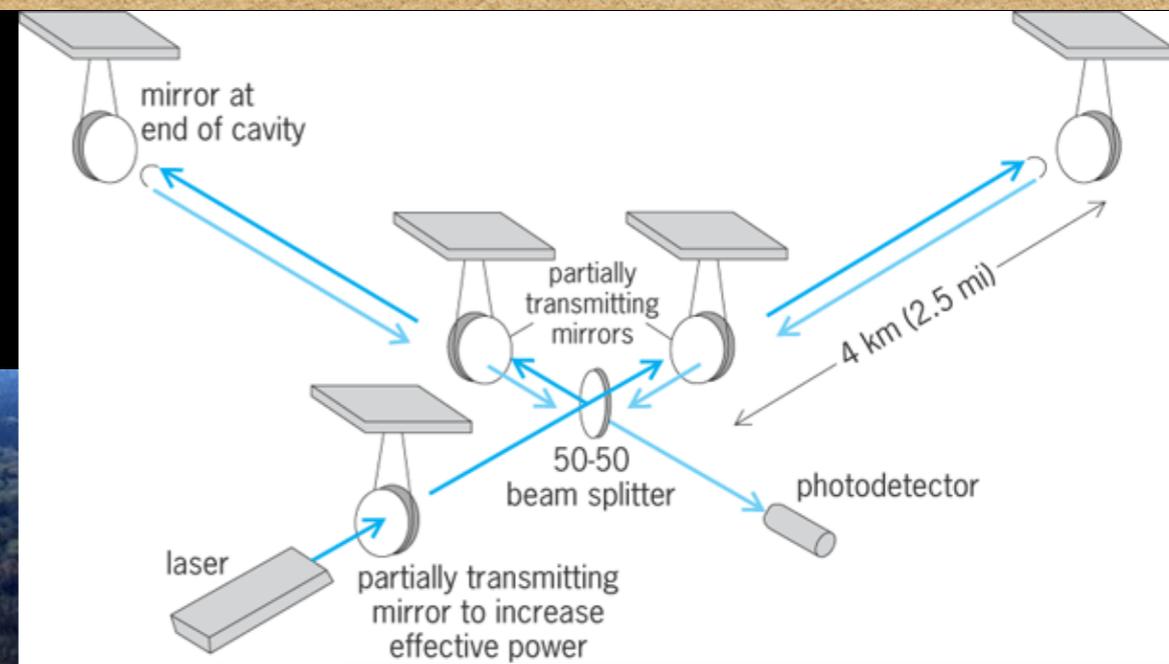


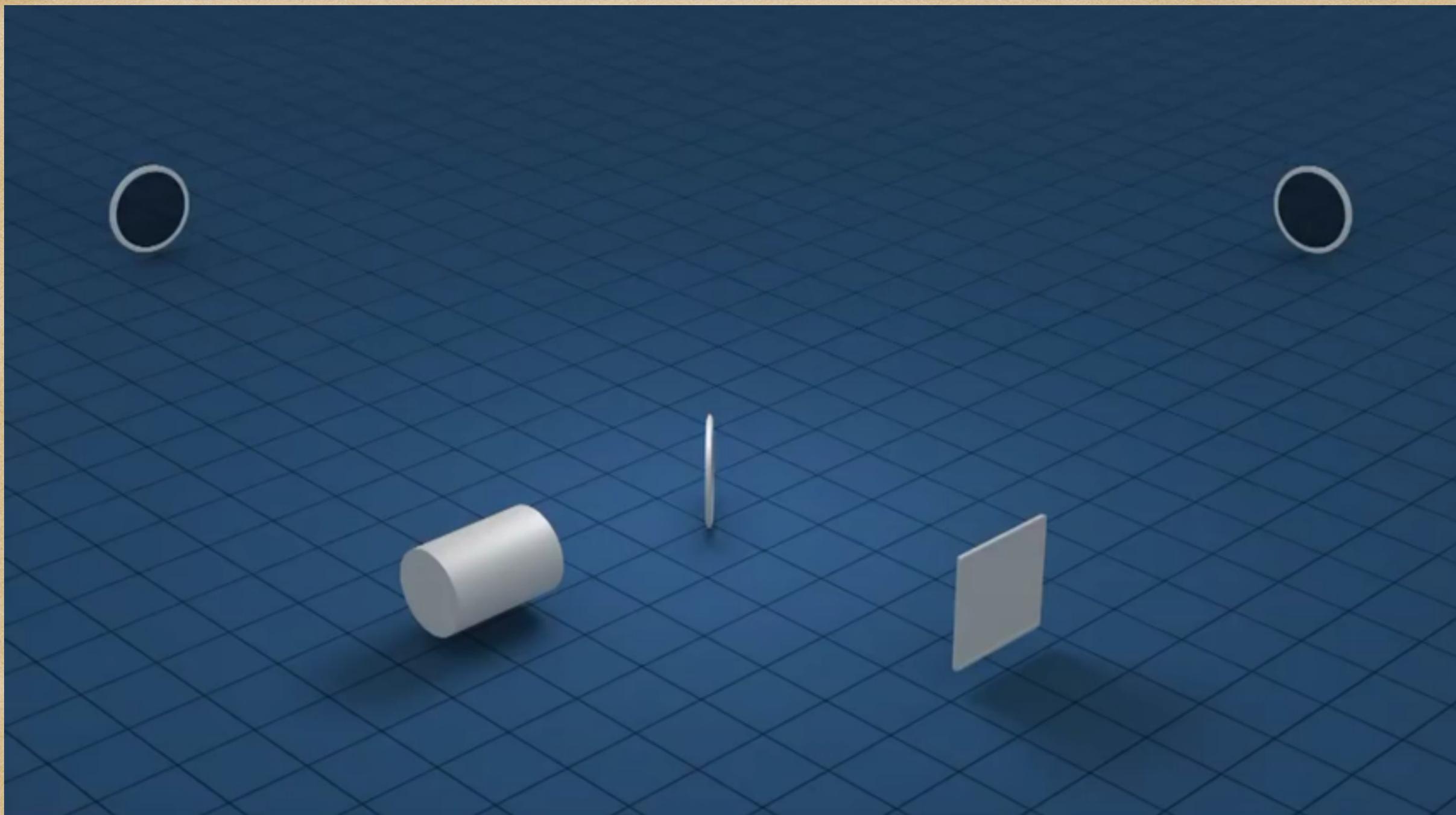
Come si osservano le onde gravitazionali?

 Essenzialmente al passaggio di un'onda gravitazionale, la forma degli oggetti cambia, e questo cambiamento con determinate tecniche può essere misurato!

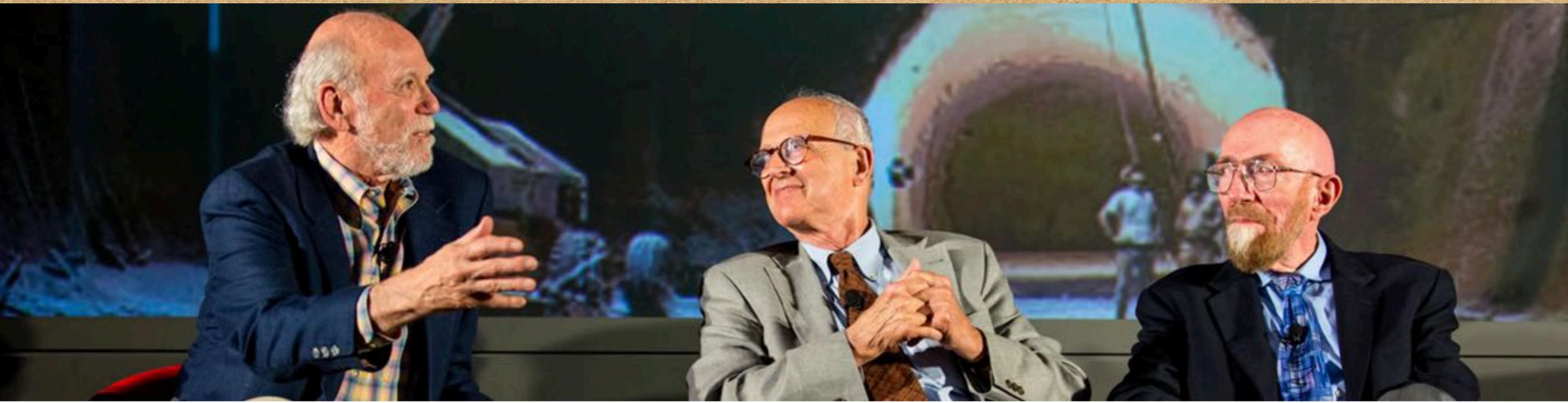


Gli Interferometri





Schema di funzionamento di un interferometro



PRESS RELEASE

3 October 2017

The Nobel Prize in Physics 2017

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2017

with one half to

Rainer Weiss

LIGO/VIRGO Collaboration

and the other half jointly to

Barry C. Barish

LIGO/VIRGO Collaboration

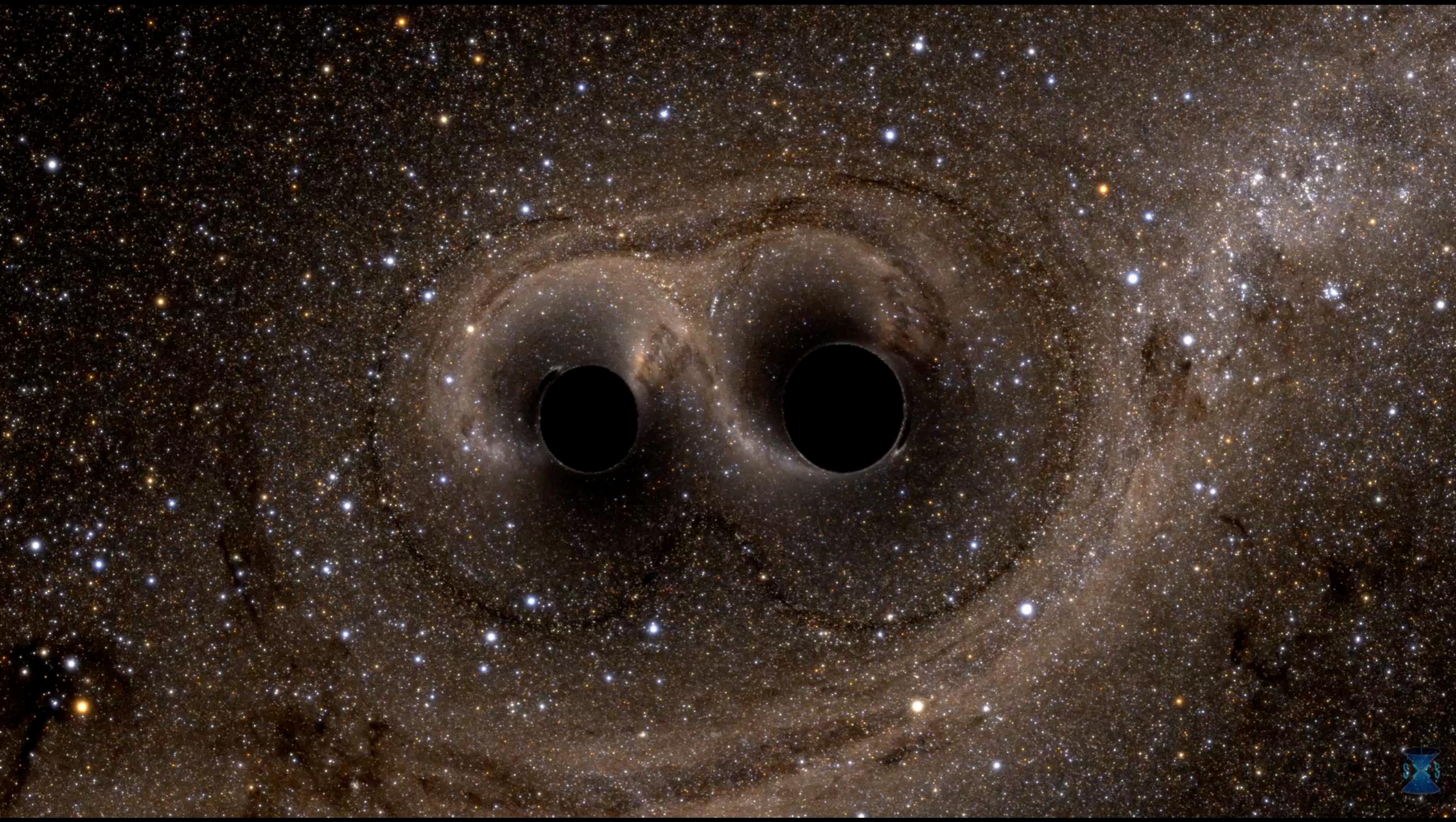
and

Kip S. Thorne

LIGO/VIRGO Collaboration

“for decisive contributions to the LIGO detector and the observation of gravitational waves”

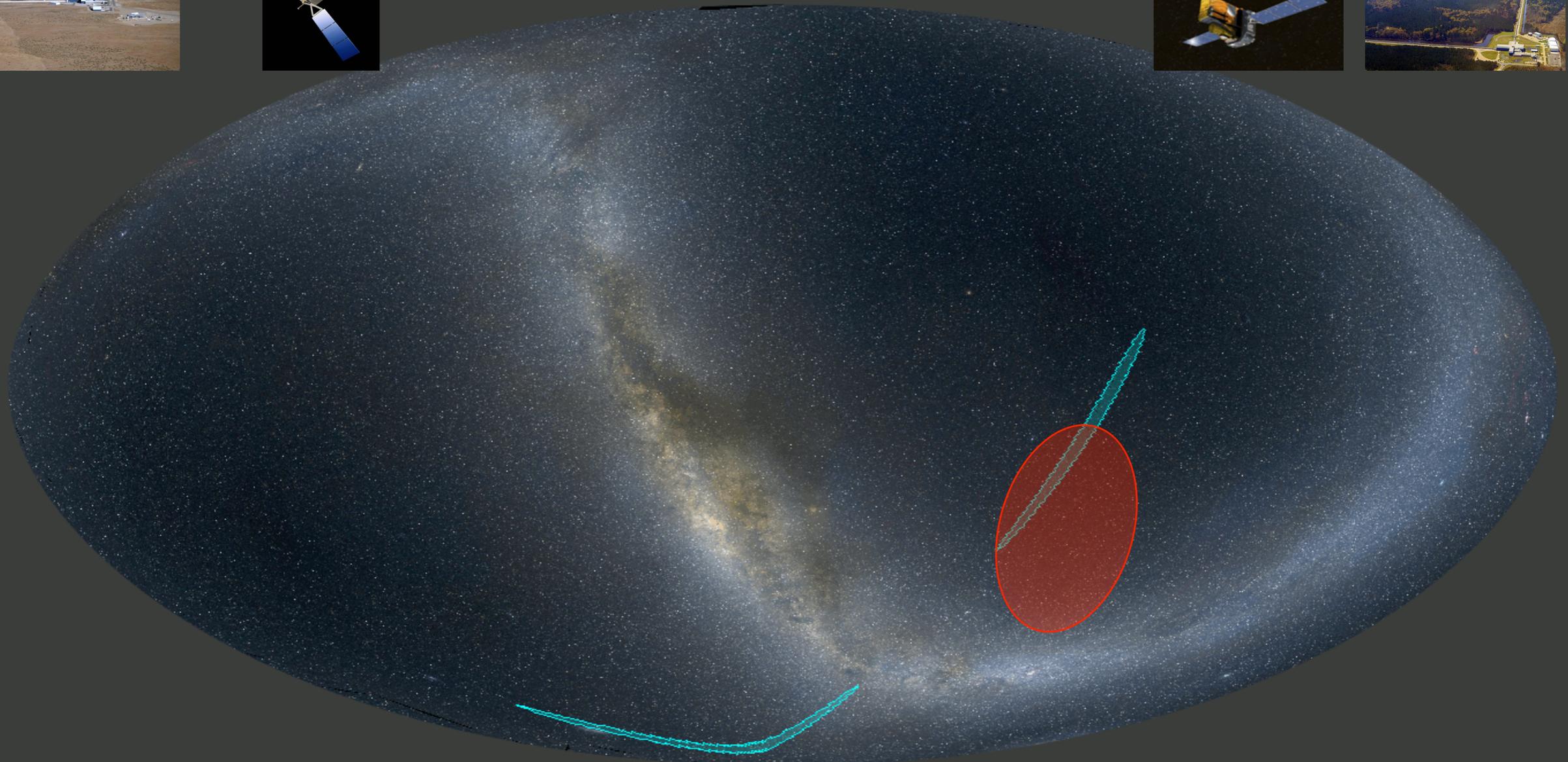
COSA SI É VISTO?



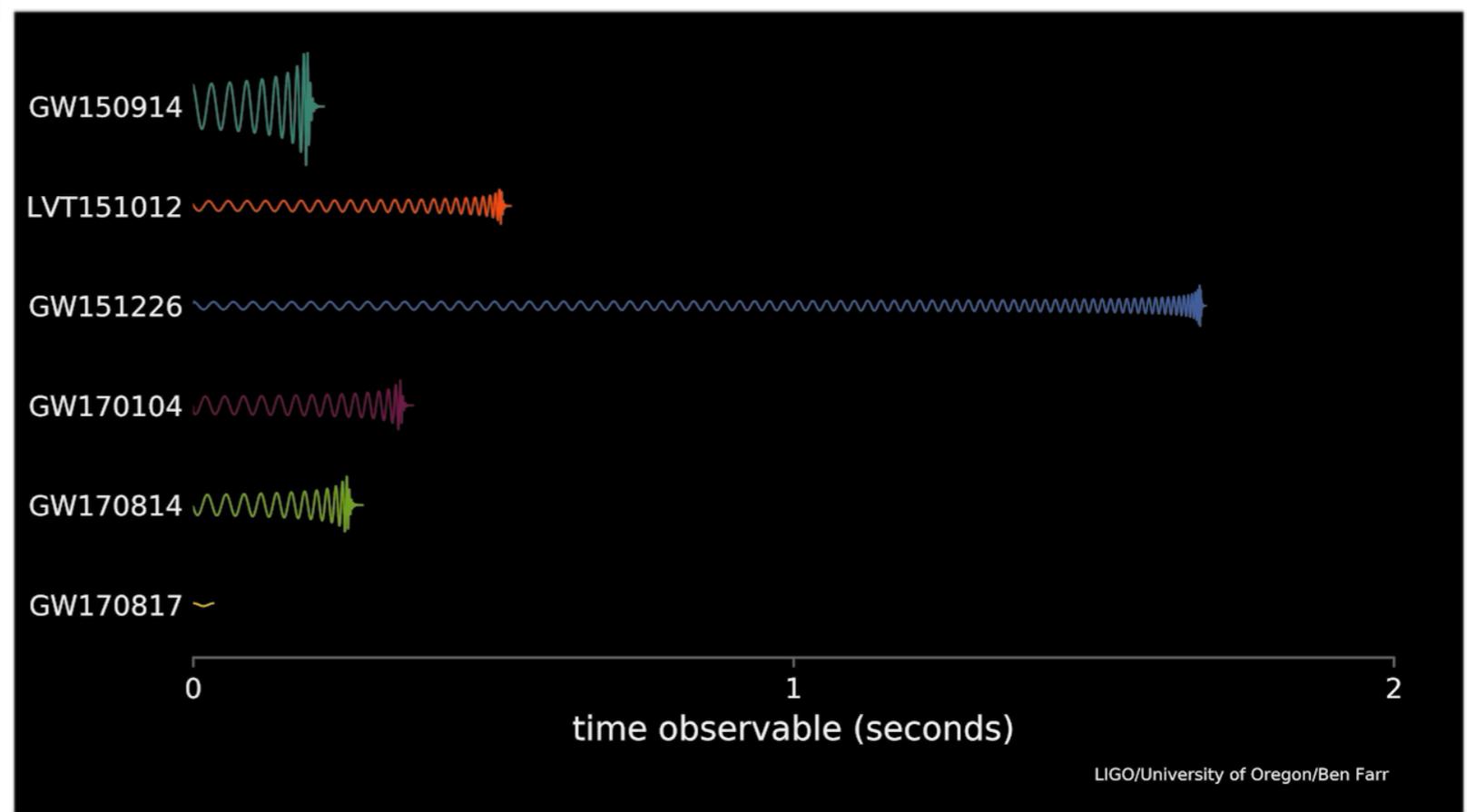
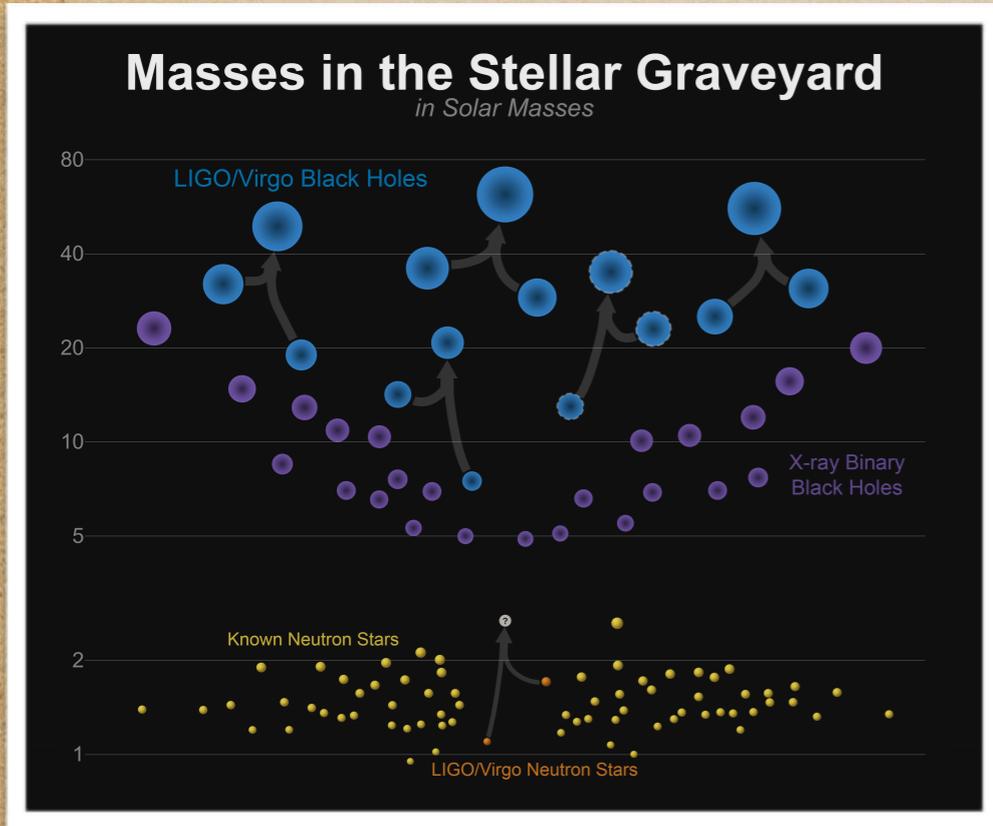
È in un tranquillo pomeriggio di mezza estate...

17
August

12:41:06 UTC



GW 170817



- Questo segnale è diverso
- Sistema binario di 2 stelle di neutroni
- "Vicino" (solo 130 milioni di anni luce)
- Quindi ci aspettiamo di vedere la controparte!!
(esplosione di kilonova)

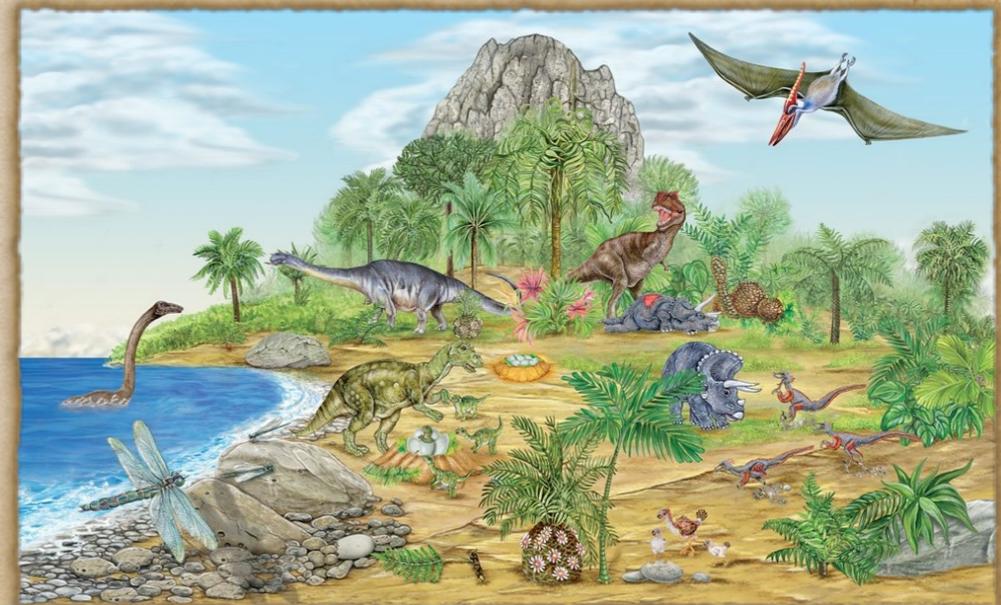
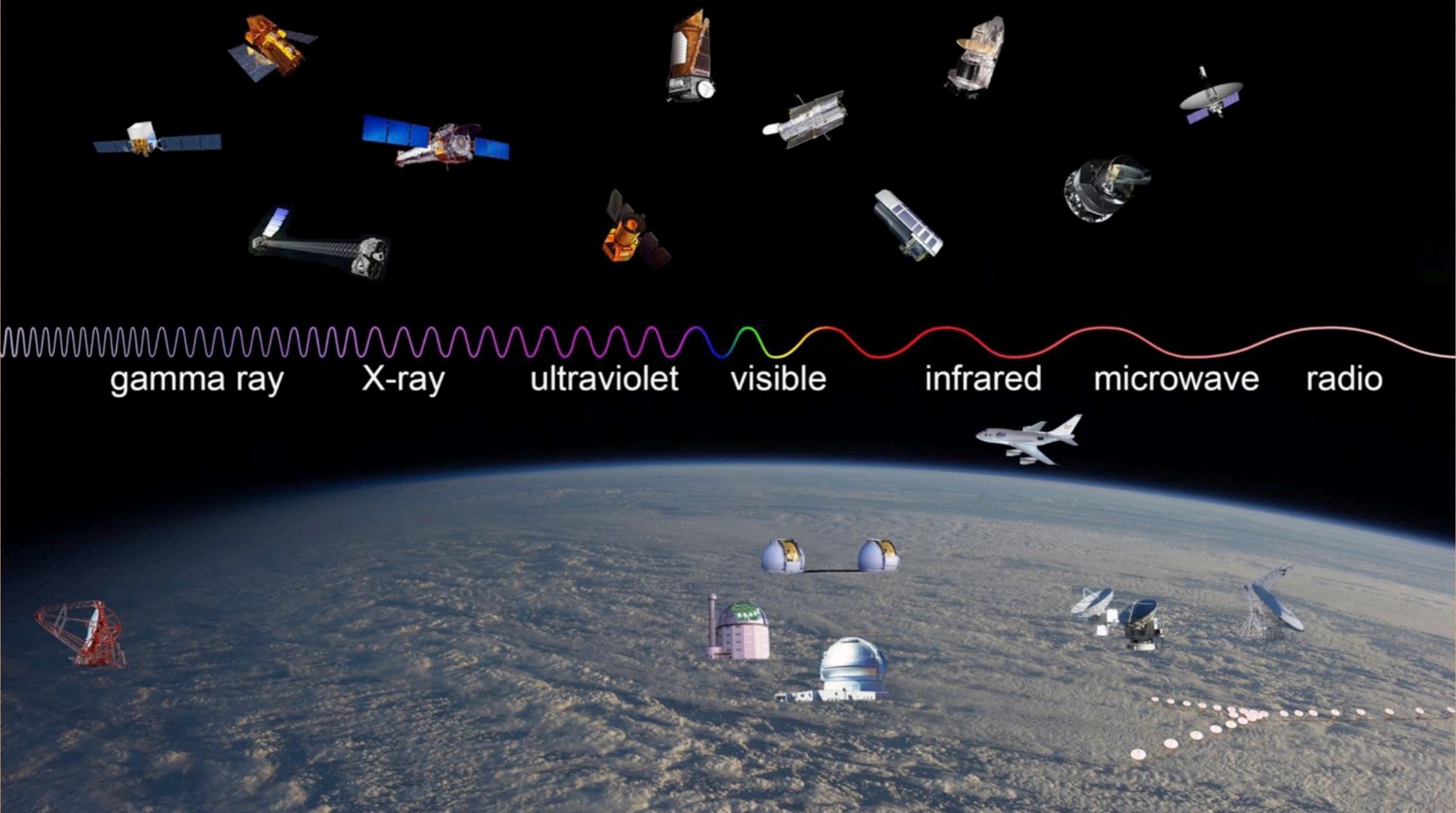


Image credit: NASA



gamma ray

X-ray

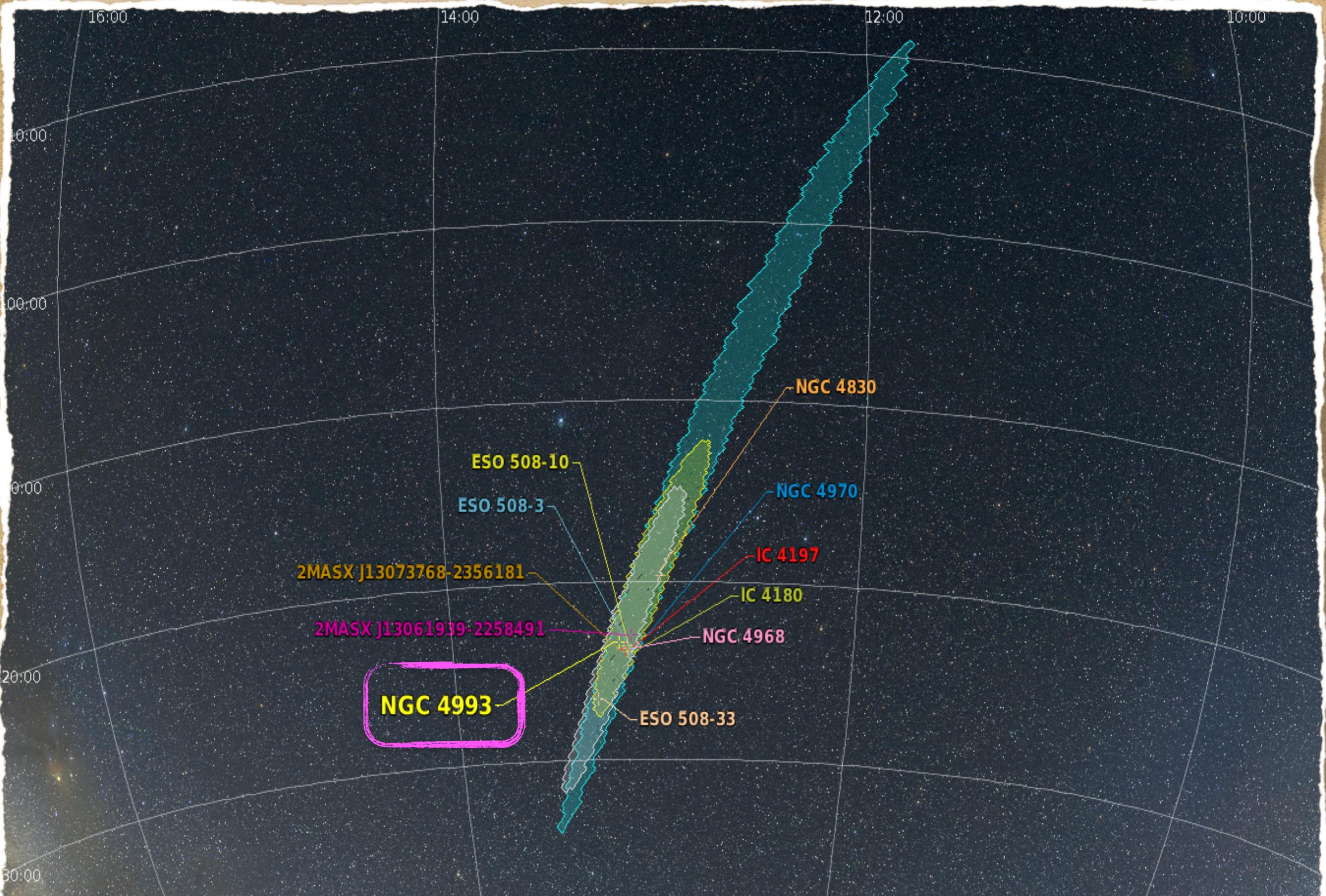
ultraviolet

visible

infrared

microwave

radio



NGC 4993

NGC 4830

NGC 4970

IC 4197

IC 4180

NGC 4968

ESO 508-33

ESO 508-10

ESO 508-3

2MASX J13073768-2356181

2MASX J13061939-2258491

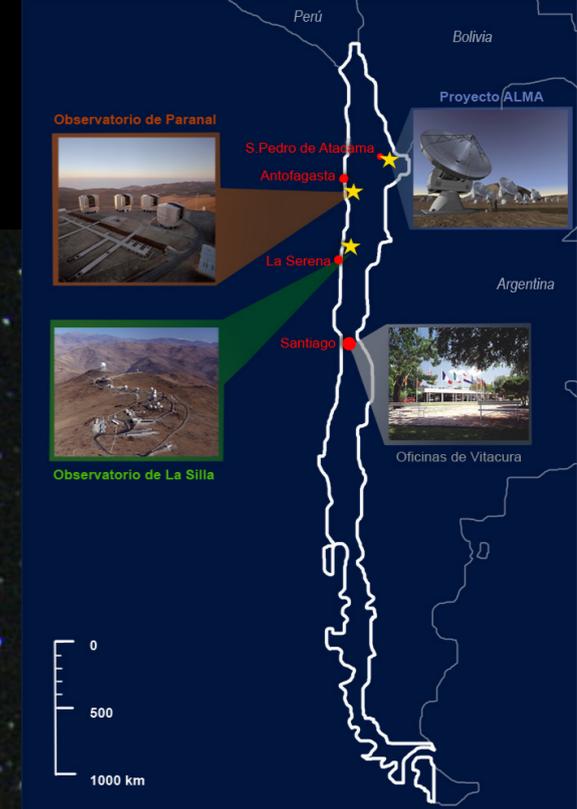
archival (pre-discovery)

Pan-STARRS

Credits: A. Melandri (INAF)

T+12h44m

REM



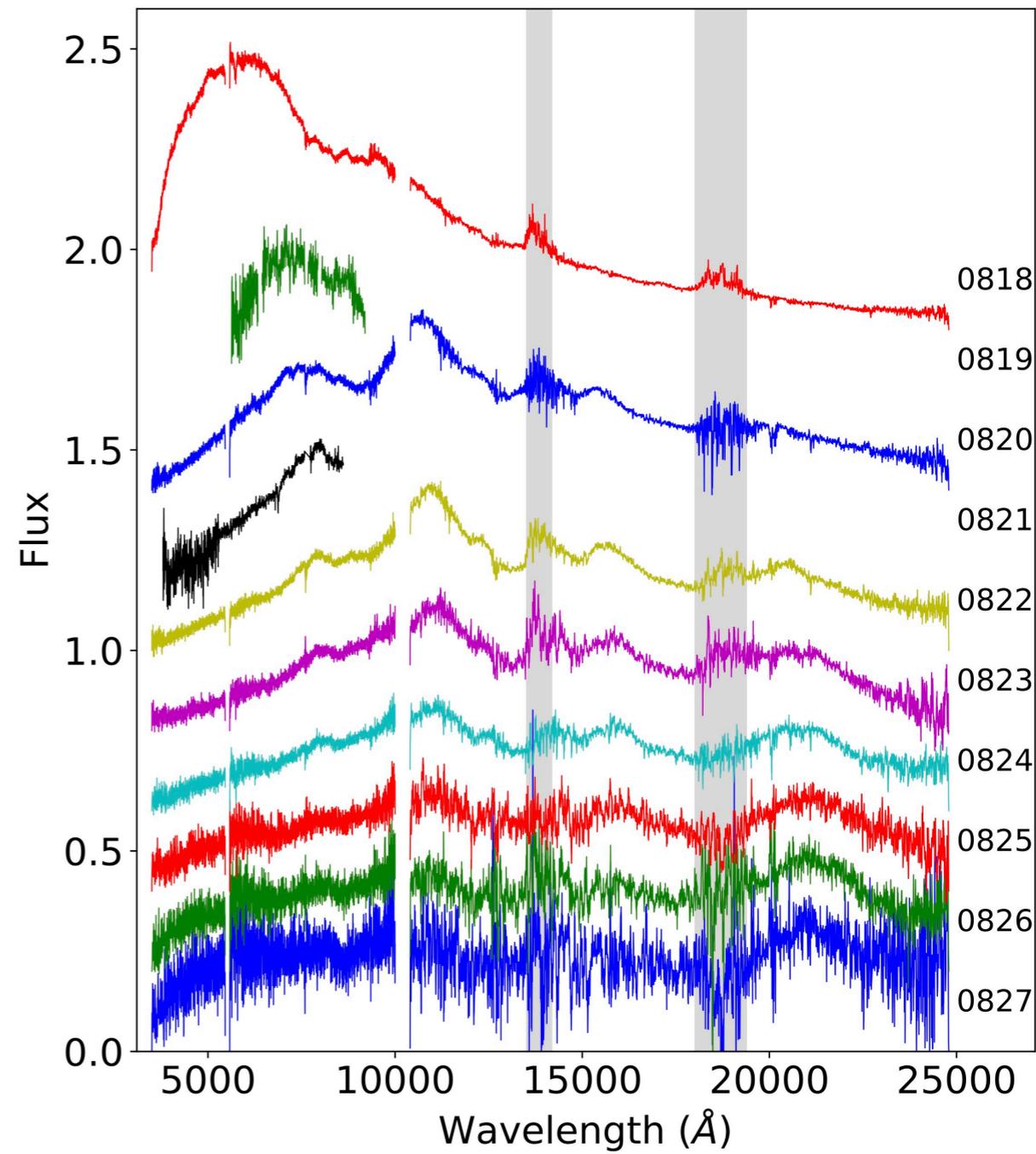
GRAWITA
GRAvitational Wave
Inaf TeAm

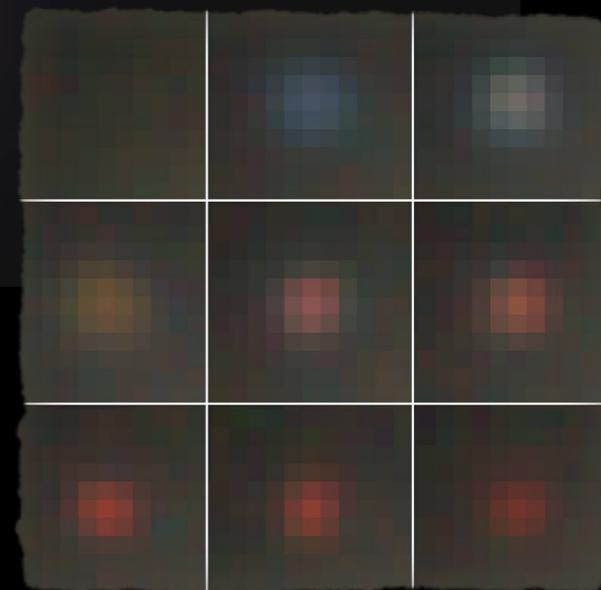
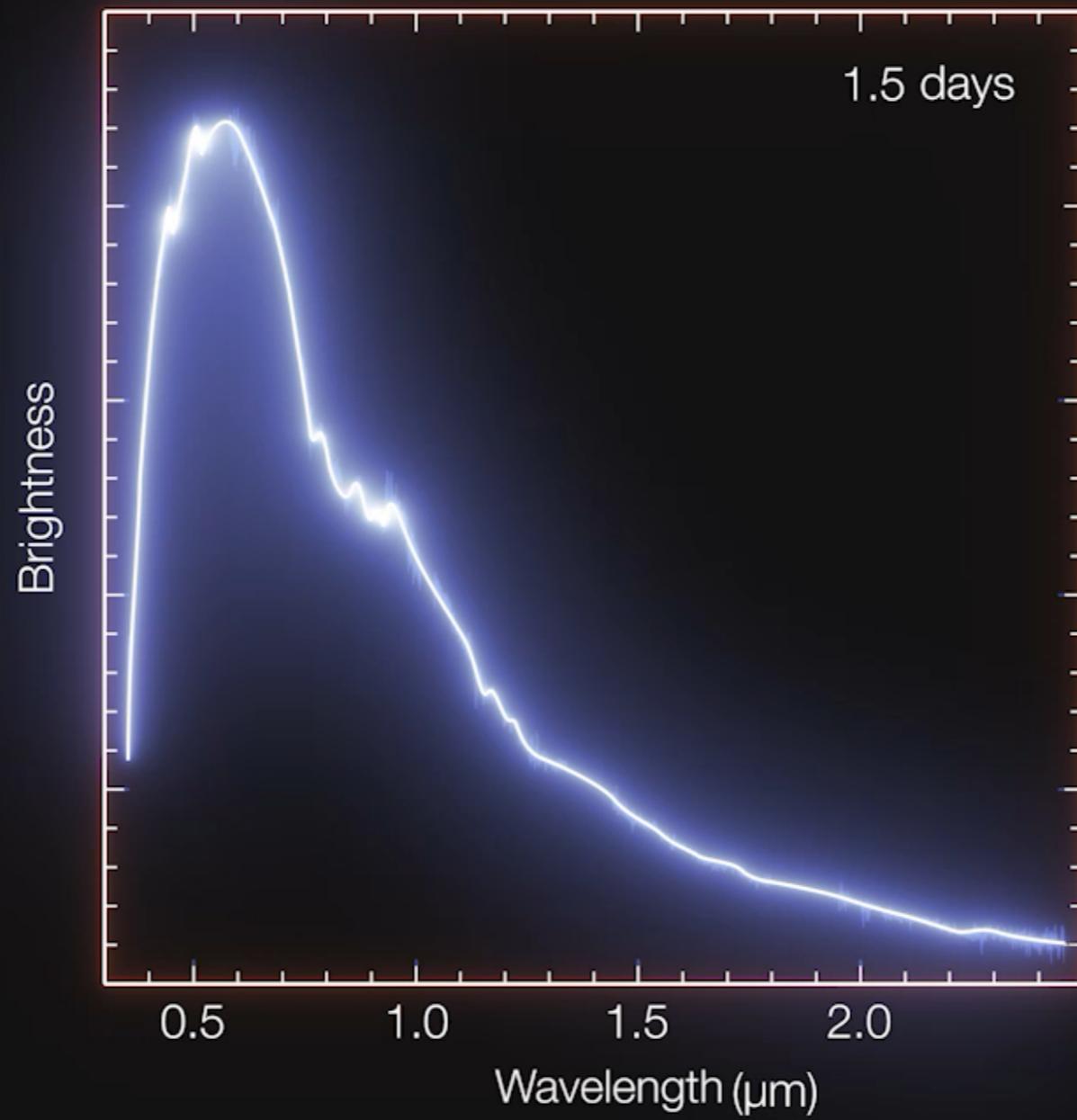
- Erano le 9 di sera quando abbiamo deciso quali galassie osservare
- Entro 5 ore sarebbe stato possibile osservare dal Cile (dove abbiamo un telescopio!!)
- Dopo 3 ore eravamo pronti davanti al pc (mezzanotte!!)

Non potevamo
crederci!!!

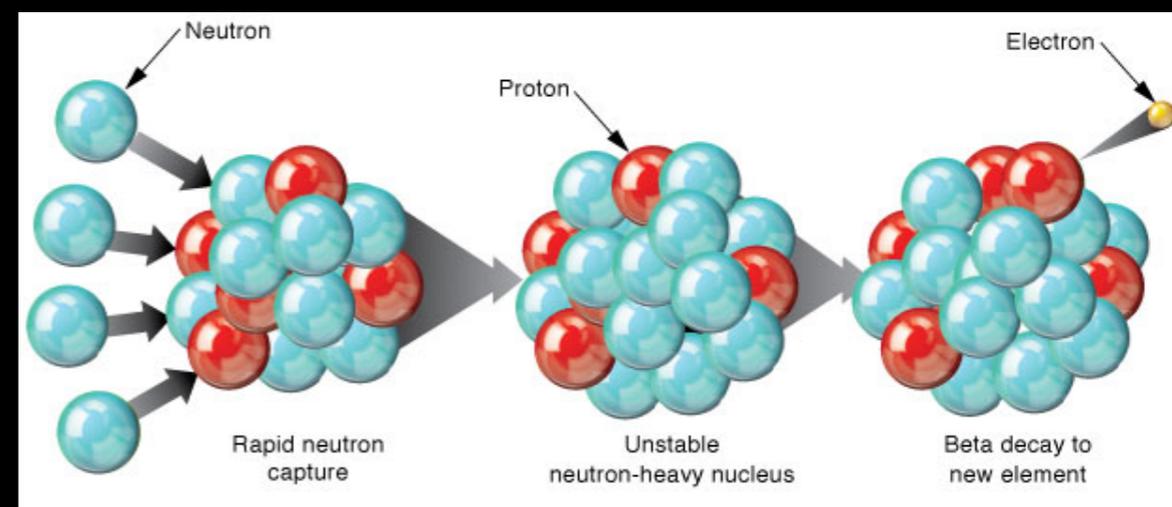
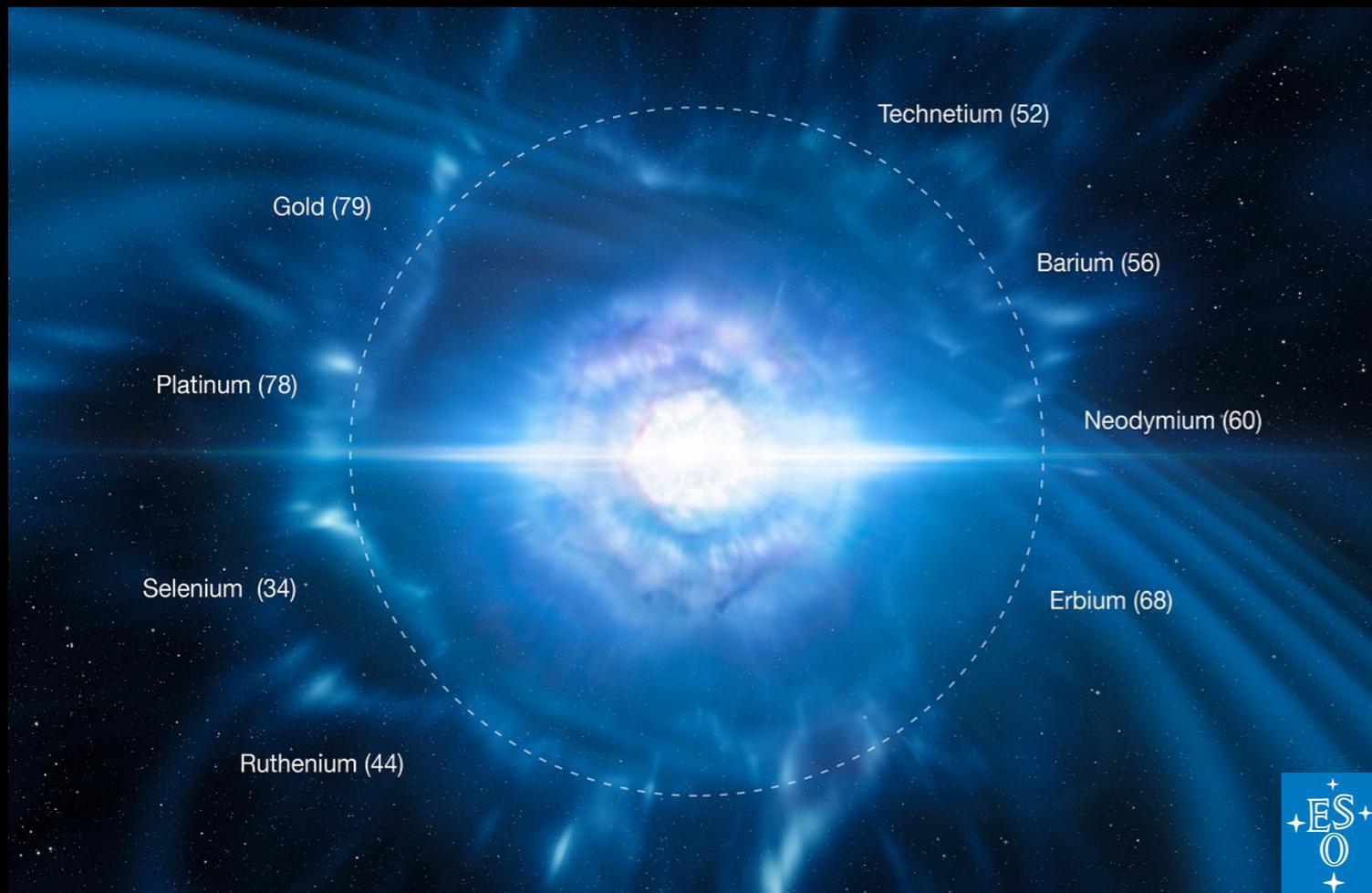
La prima controparte elettromagnetica di un'onda gravitazionale







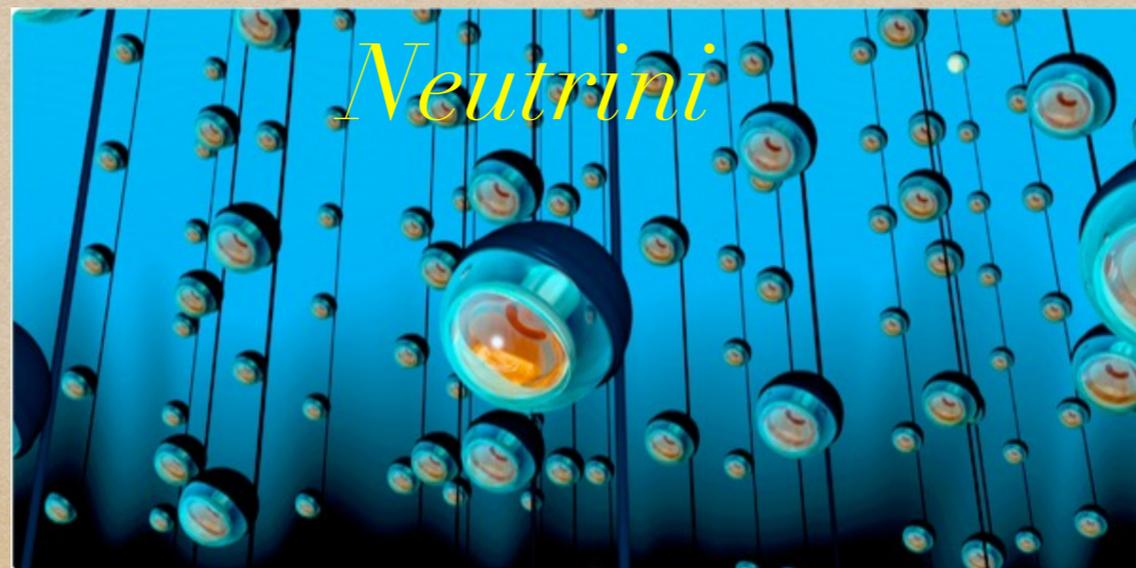
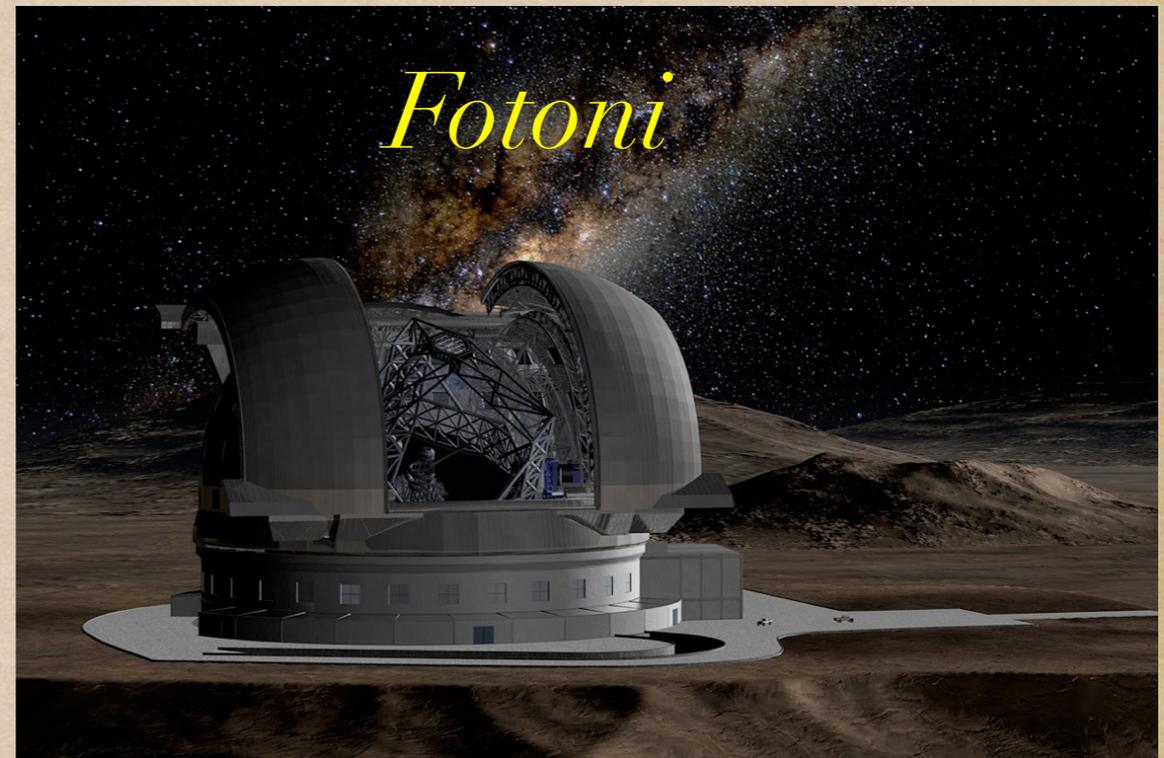
Kilonova & heavy elements nucleosynthesis



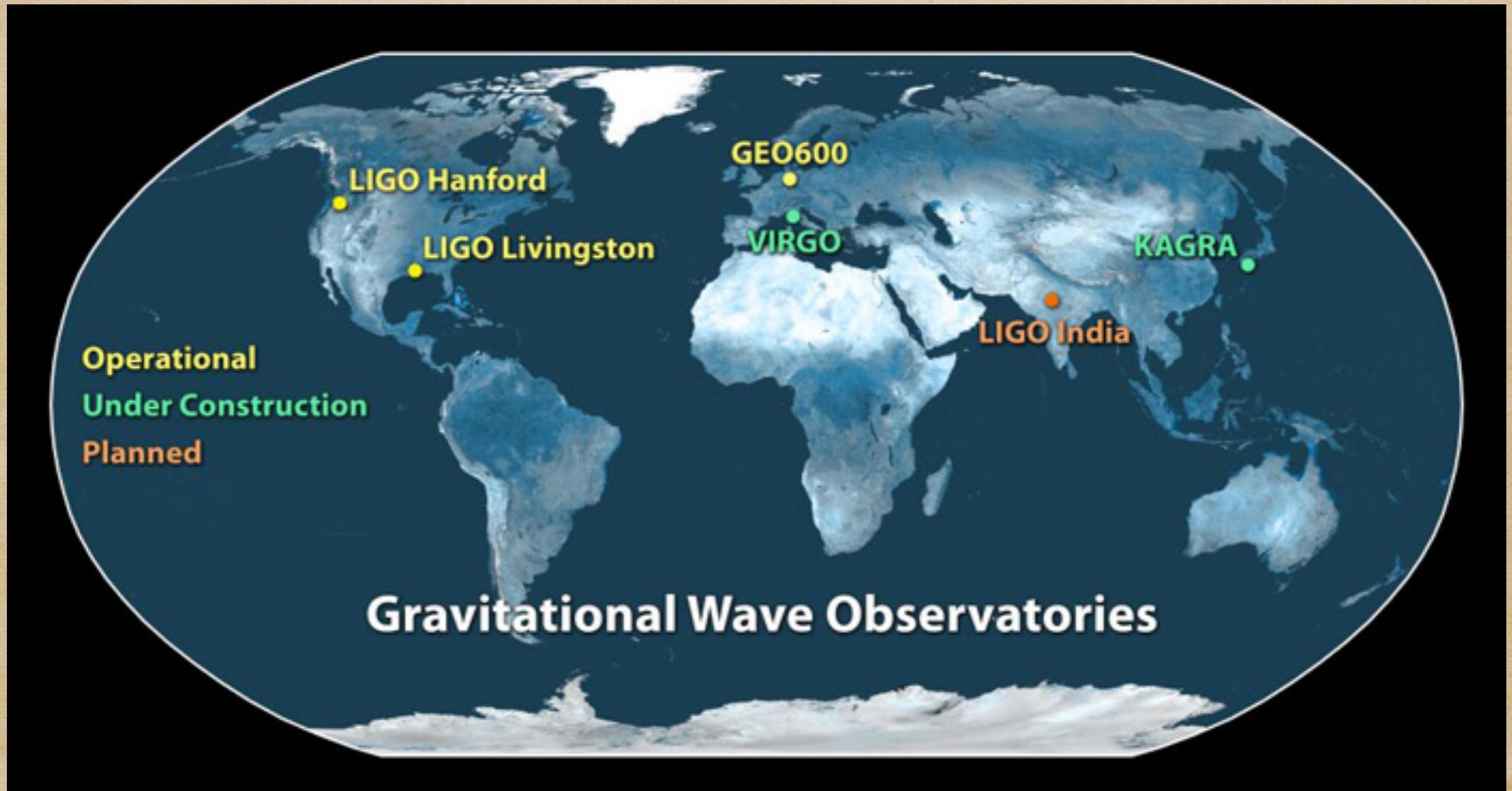
Periodo	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA	
1	1 H												5 B	6 C	7 N	8 O	9 F	10 Ne	
2	3 Li	4 Be											11 Na	12 Mg				18 Ar	
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	19 K	20 Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	29 Ga	30 Ge	31 As	32 Se	33 Br	34 Kr	
5	37 Rb	38 Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
6	55 Cs	56 Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
7	87 Fr	88 Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg								
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
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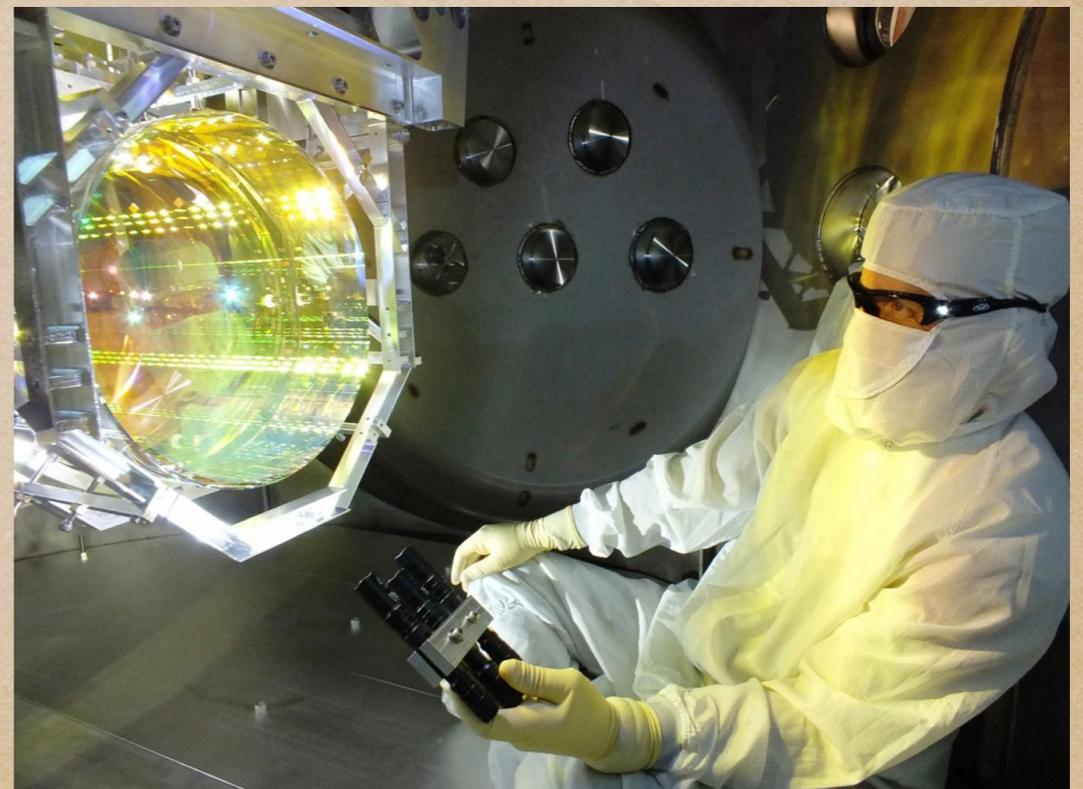
Numero Atomico	Peso Atomico	Numero di Ossidazione	Simbolo	Nome
1	1,0079	+1	H	Idrogeno
2	4,0026	+2	He	Elio
3	6,941	+1	Li	Litio
4	9,0122	+2	Be	Berillio
5	9,0122	+3	B	Boro
6	12,011	+4	C	Carbonio
7	14,0067	+3	N	Azoto
8	15,9994	+2	O	Ossigeno
9	18,9984	-1	F	Fluoro
10	20,179	0	Ne	Neon
11	22,9898	+1	Na	Sodio
12	24,305	+2	Mg	Magnesio
13	26,9815	+3	Al	Alluminio
14	28,0855	+4	Si	Silicio
15	30,9738	+3	P	Fosforo
16	32,06	+4	S	Zolfo
17	35,453	-1	Cl	Cloro
18	39,948	0	Ar	Argon
19	39,0983	+1	K	Potassio
20	40,08	+2	Ca	Calcio
21	44,9559	+3	Sc	Scandio
22	47,9	+4	Ti	Titanio
23	50,9415	+4	V	Vanadio
24	51,996	+4	Cr	Cromo
25	54,938	+4	Mn	Manganese
26	55,847	+2	Fe	Ferro
27	58,9332	+2	Co	Cobalto
28	58,7	+2	Ni	Nichel
29	63,546	+2	Cu	Rame
30	65,38	+2	Zn	Zinco
31	69,72	+3	Ga	Gallio
32	72,59	+4	Ge	Germanio
33	74,9216	+3	As	Arsenico
34	78,96	+4	Se	Selenio
35	79,904	-1	Br	Bromo
36	83,8	0	Kr	Kriptone
37	85,4678	+1	Rb	Rubidio
38	87,62	+2	Sr	Stronzio
39	88,9059	+3	Y	Ittrio
40	91,224	+4	Zr	Zirconio
41	92,9064	+4	Nb	Niobio
42	95,94	+4	Mo	Molibdeno
43	101,07	+4	Tc	Tecnecio
44	101,07	+4	Ru	Rutenio
45	102,9055	+4	Rh	Rodio
46	106,4	+4	Pd	Palladio
47	107,868	+4	Ag	Argento
48	112,41	+4	Cd	Cadmio
49	114,82	+3	In	Indio
50	118,69	+4	Sn	Stagno
51	121,75	+3	Sb	Antimonio
52	127,6	+4	Te	Tellurio
53	126,9045	-1	I	Iodio
54	131,3	0	Xe	Xenone
55	132,9054	+1	Rb	Rubidio
56	137,33	+2	Ba	Bario
57	138,9055	+3	La	Lantanio
58	140,12	+3	Ce	Cerio
59	140,9077	+3	Pr	Praseodimio
60	144,24	+3	Nd	Neodimio
61	145	+3	Pm	Promezio
62	150,4	+3	Sm	Samario
63	151,96	+3	Eu	Europio
64	157,25	+3	Gd	Gadolinio
65	158,9254	+3	Tb	Terbio
66	162,5	+3	Dy	Disprozio
67	164,9304	+3	Ho	Olmio
68	167,26	+3	Er	Erbio
69	168,9342	+3	Tm	Tulio
70	173,04	+3	Yb	Itterbio
71	174,967	+3	Lu	Lutezio
72	175,04	+3	Hf	Hafnio
73	180,9479	+4	Ta	Tantalio
74	183,85	+4	W	Tungsteno
75	186,207	+4	Re	Renio
76	190,2	+4	Os	Osmio
77	193,22	+4	Ir	Iridio
78	195,08	+4	Pt	Platino
79	196,9665	+4	Au	Oro
80	200,59	+2	Hg	Mercurio
81	204,37	+3	Tl	Tallio
82	207,2	+4	Pb	Piombo
83	208,9804	+3	Bi	Bismuto
84	209	+4	Po	Polonio
85	210	+4	At	Astato
86	222	0	Rn	Radone
87	223	+1	Fr	Francio
88	226,025	+2	Ra	Radio
89	227,028	+3	Ac	Attinio
90	232,0381	+4	Th	Torio
91	232,0381	+4	Pa	Protoattinio
92	238,0289	+4	U	Uranio
93	237,048	+4	Np	Nettunio
94	244	+4	Pu	Plutonio
95	243	+4	Am	Americio
96	247	+4	Cm	Curio
97	247	+4	Bk	Berchelio
98	251	+4	Cf	Californio
99	252	+4	Es	Einsteinio
100	257	+4	Fm	Fermio
101	258	+4	Md	Mendelevio
102	259	+4	No	Nobelio
103	260	+4	Lr	Laurenzio

Una nuova era:
l'astronomia multi-messaggio!



Rivelatori di onde gravitazionali





Ed O3 è cominciato il primo d'aprile!



14:33 Ven 10 mag gracedb.ligo.org

Superevent Log Messages

Sky Localization

event ID: G331903
50% area: 175 deg²
90% area: 3462 deg²

Mollweide projection of [bayestar.fits](#)
[bayestar.png](#). Submitted by LIGO/Virgo EM Follow-Up on May 10, 2019 04:03:43 UTC

event ID: G331903
distance: 269±108 Mpc

541 Mpc

270 Mpc

Volume rendering of [bayestar.fits](#)
[bayestar.volume.png](#). Submitted by LIGO/Virgo EM Follow-Up on May 10, 2019 04:04:32 UTC

50% area: 31 deg²
90% area: 1166 deg²

Mollweide projection of [LALInference.fits](#)
[LALInference.png](#). Submitted by LIGO/Virgo EM Follow-Up on May 10, 2019 10:06:59 UTC

distance: 227±92 Mpc

466 Mpc

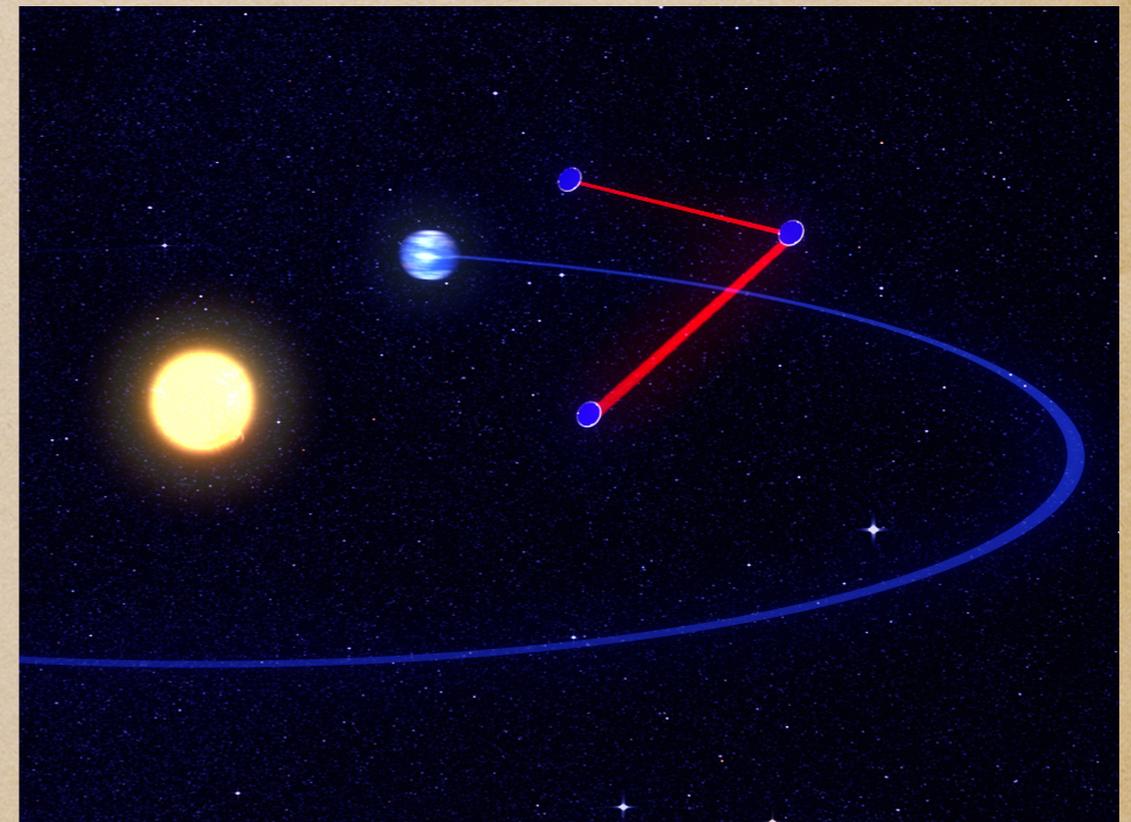
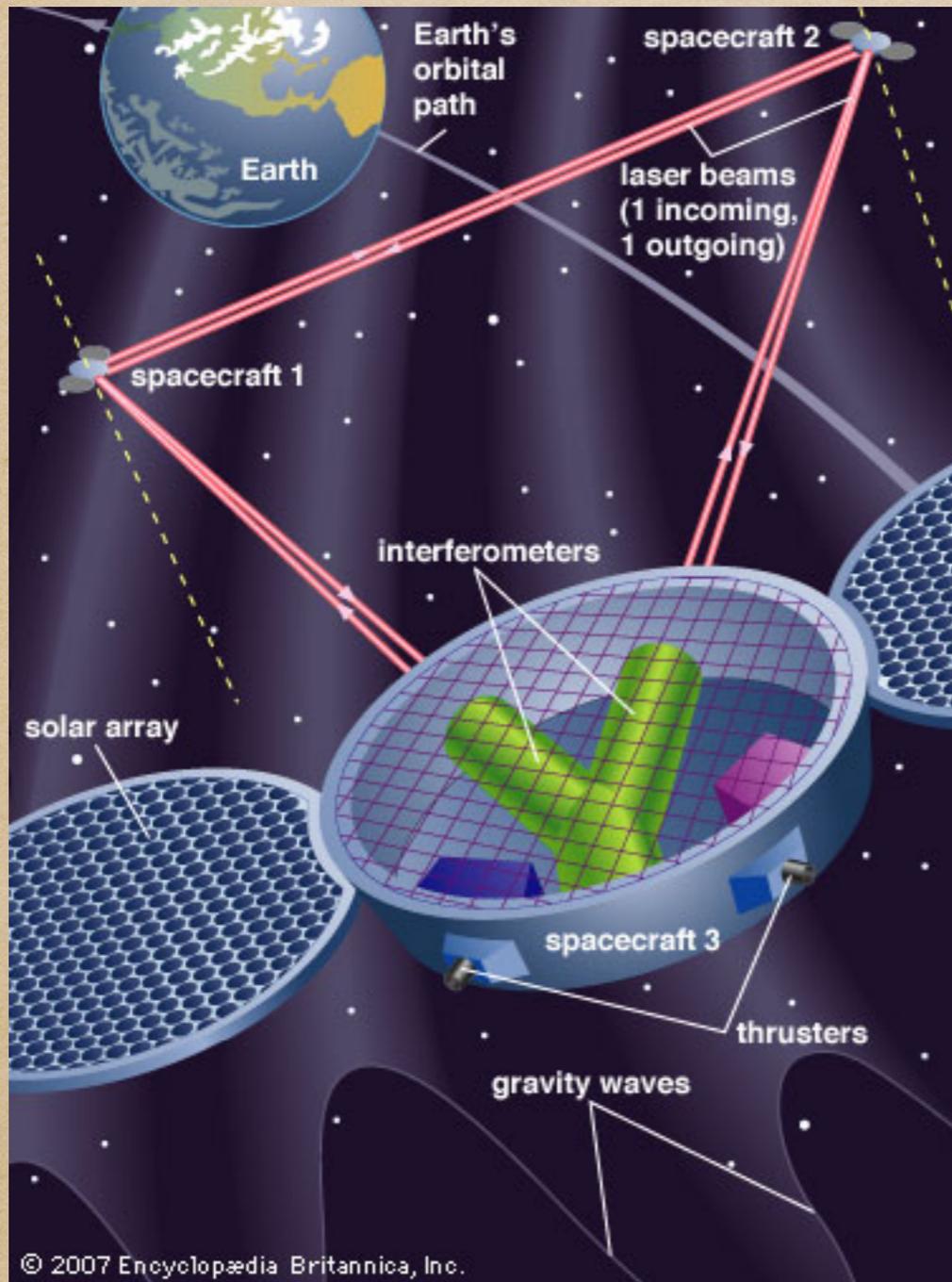
233 Mpc

Volume rendering of [LALInference.fits](#)
[LALInference.volume.png](#). Submitted by LIGO/Virgo EM Follow-Up on May 10, 2019 10:08:01 UTC

UTC	Log Entry Created	Submitter	Comment
UTC	May 10, 2019 10:08:19 UTC	LIGO/Virgo EM Follow-Up	Flattened from multiresolution file LALInference.fits

Segnale rilevato questa mattina all'alba!

E rivelatori in orbita: il progetto LISA

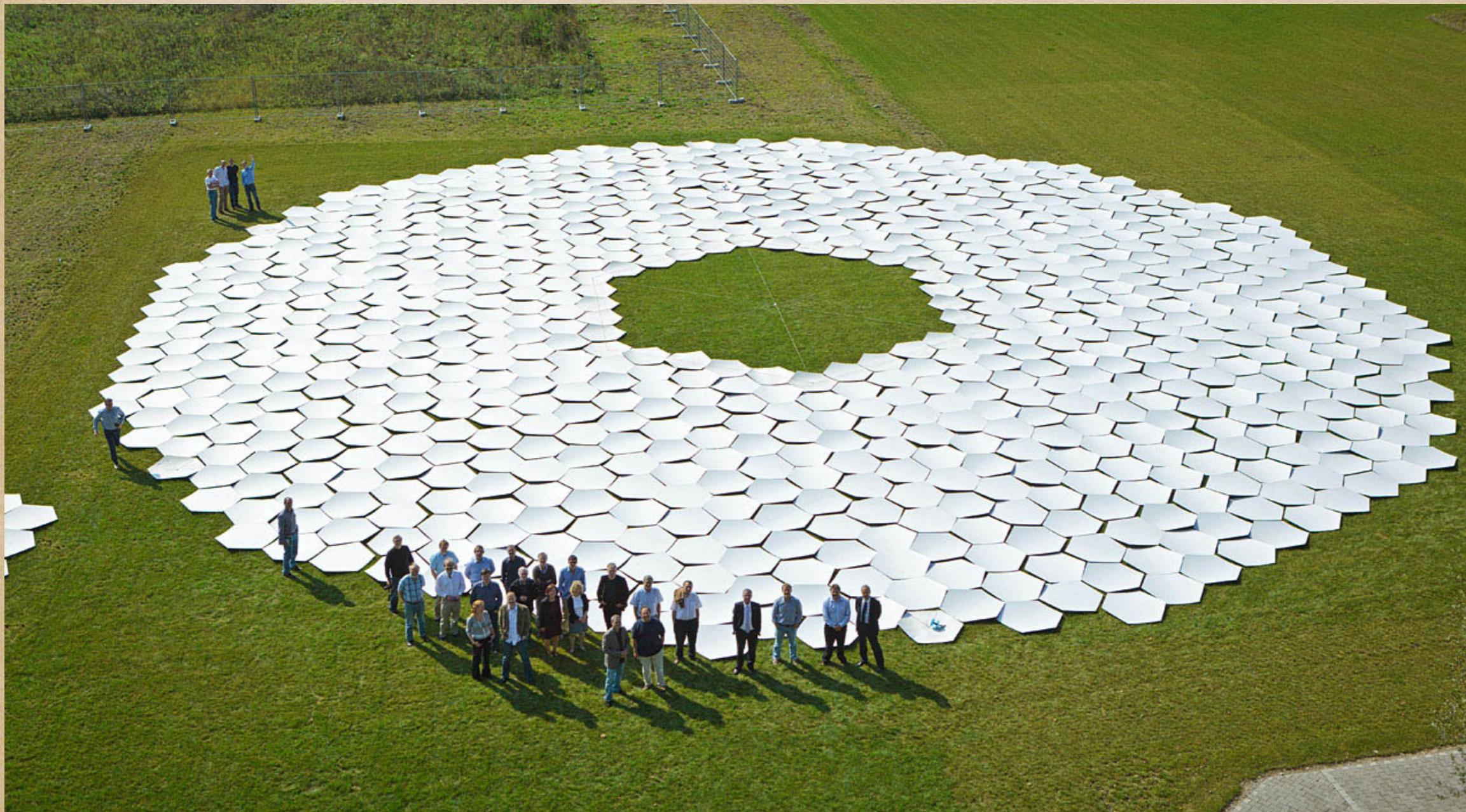


L'epoca dei telescopi giganti

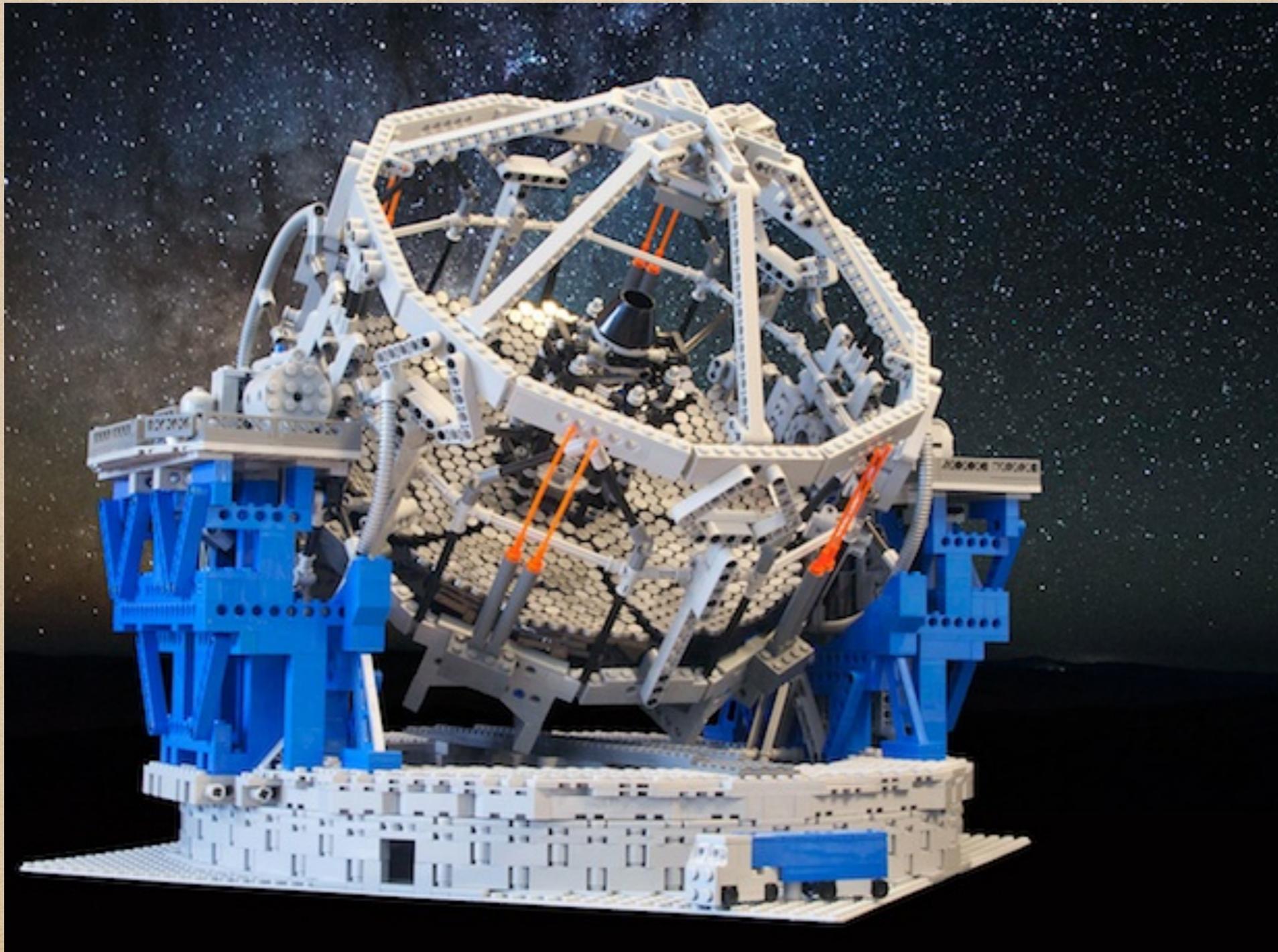
ELT: specchio di quasi 40m
di diametro!



ELT: specchio di quasi 40m di diametro!



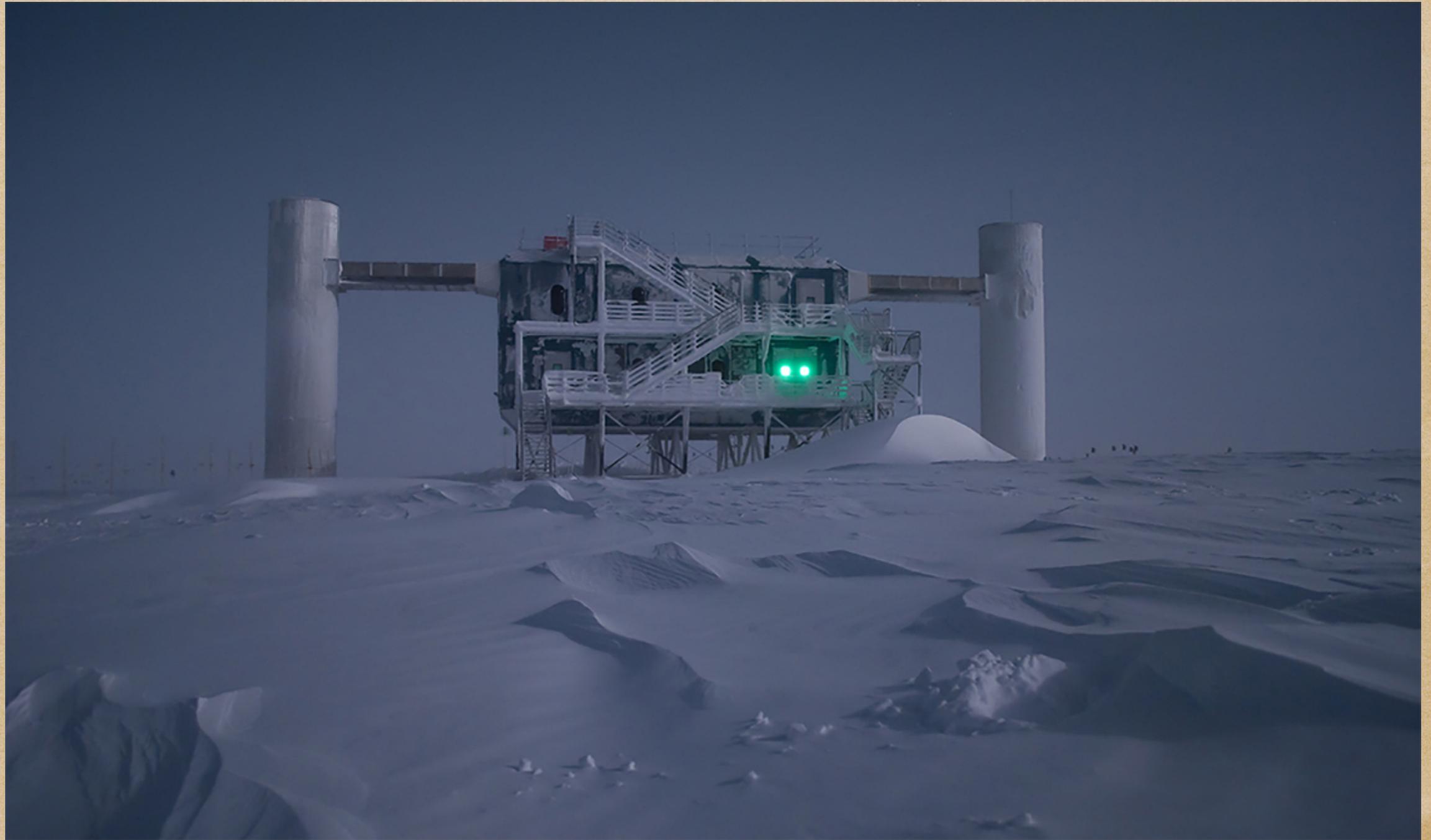
La versione “LEGO” per bambini anche cresciuti...

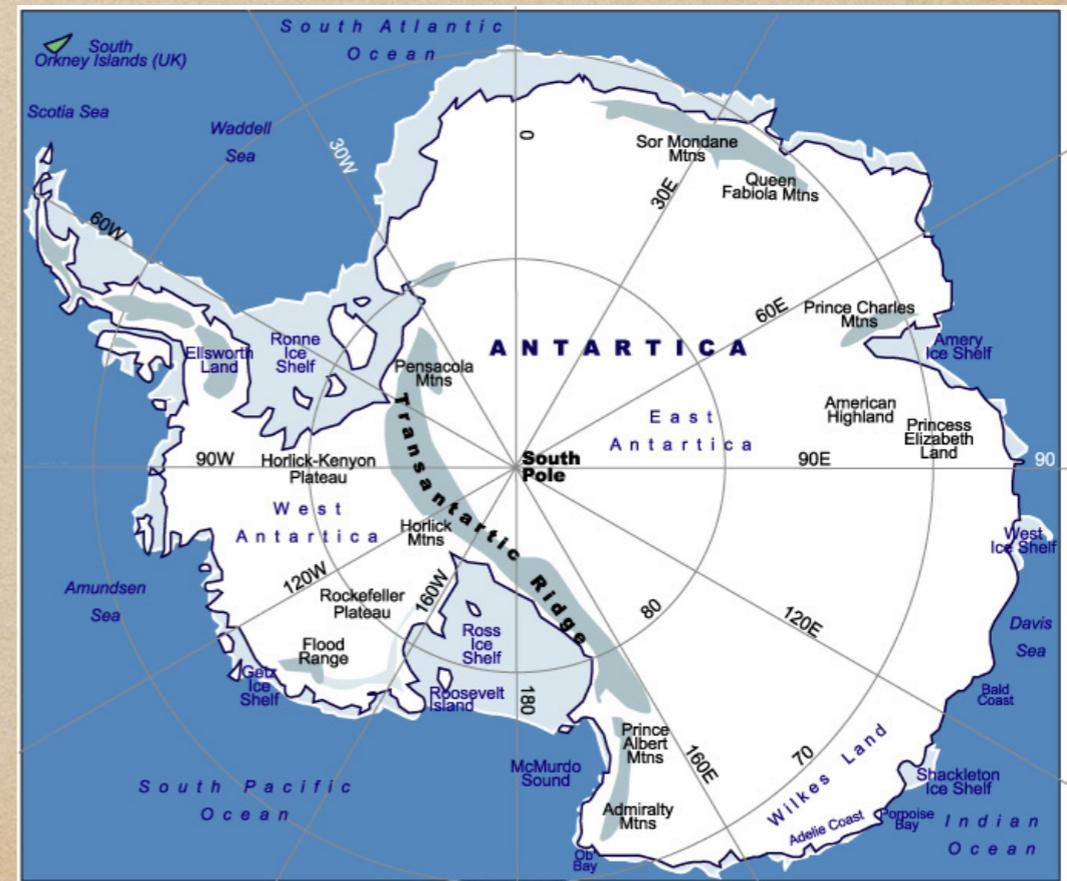
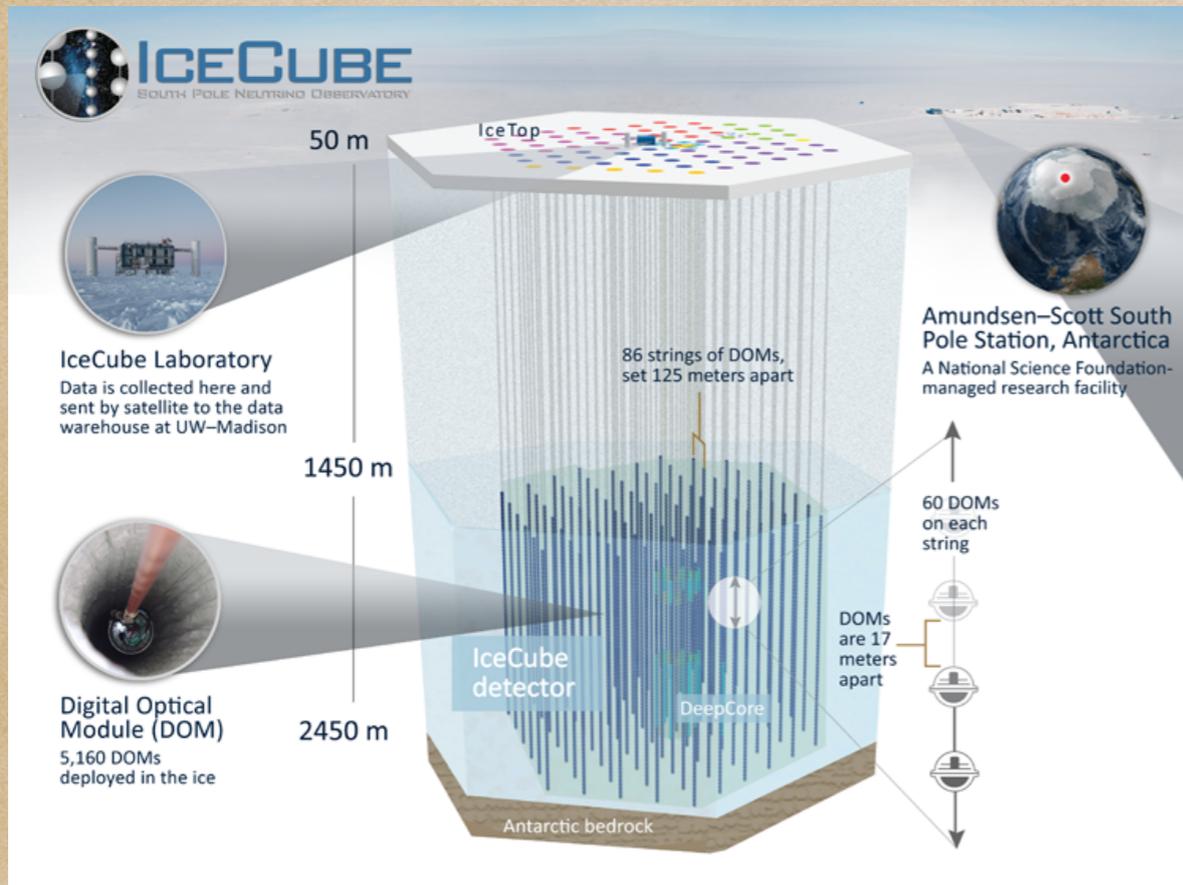
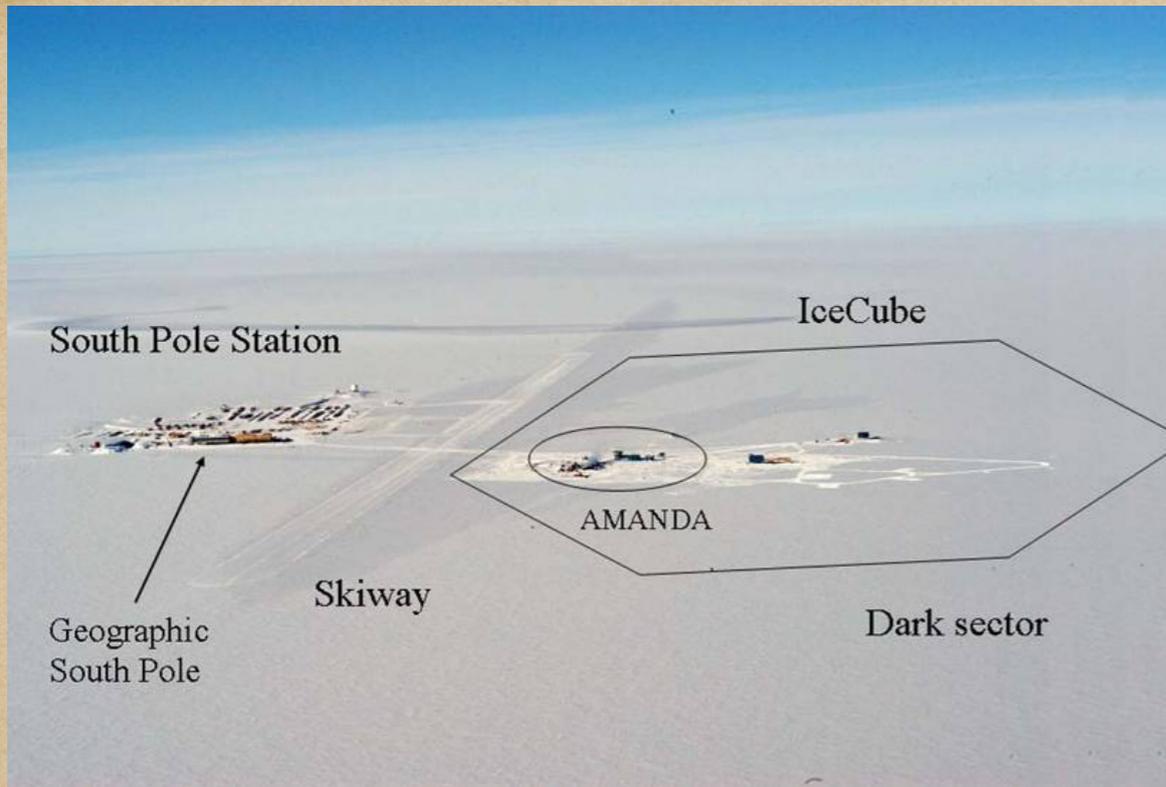




ELT: prima luce prevista
intorno al 2023-24!

I neutríni: Ice Cube

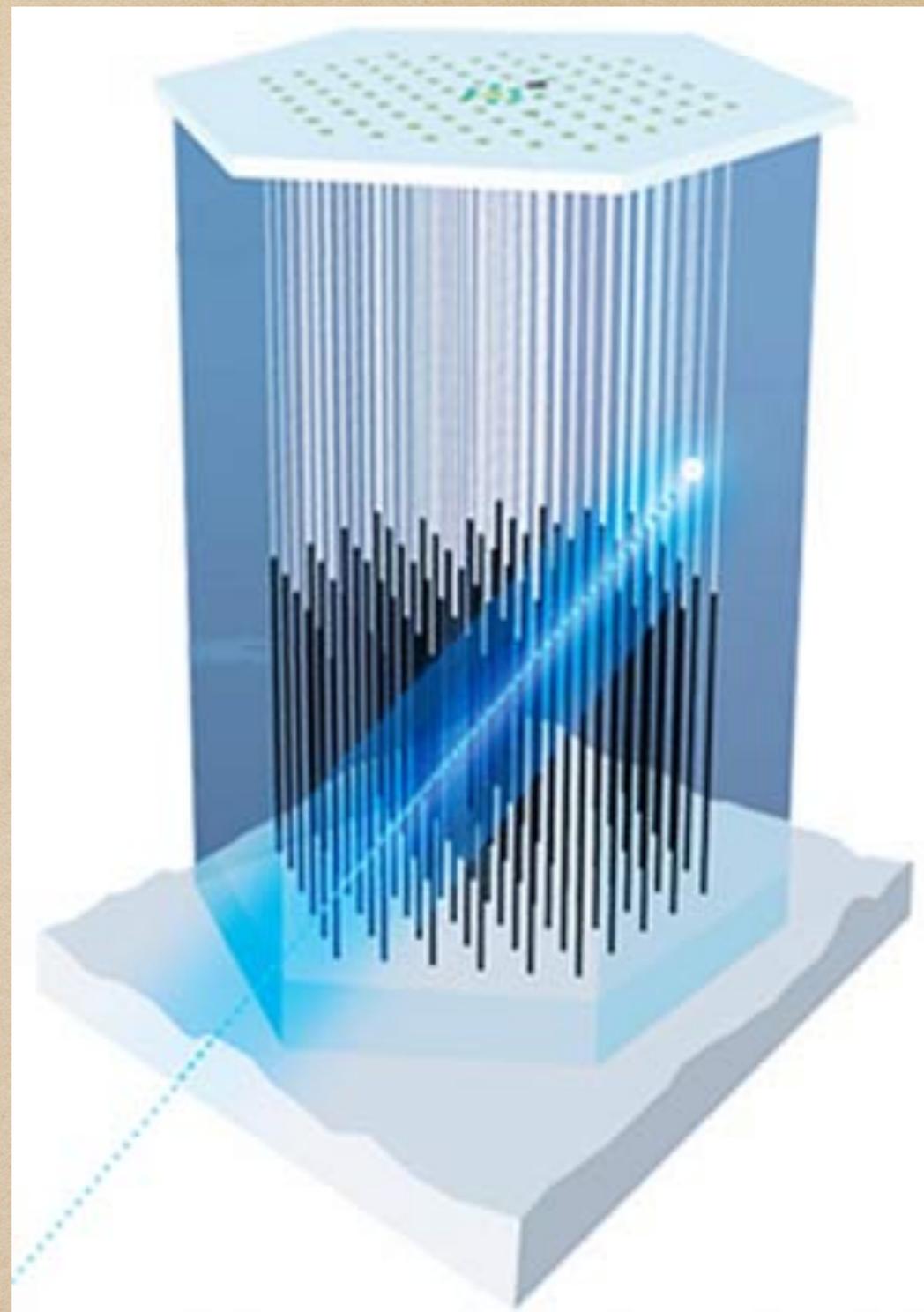






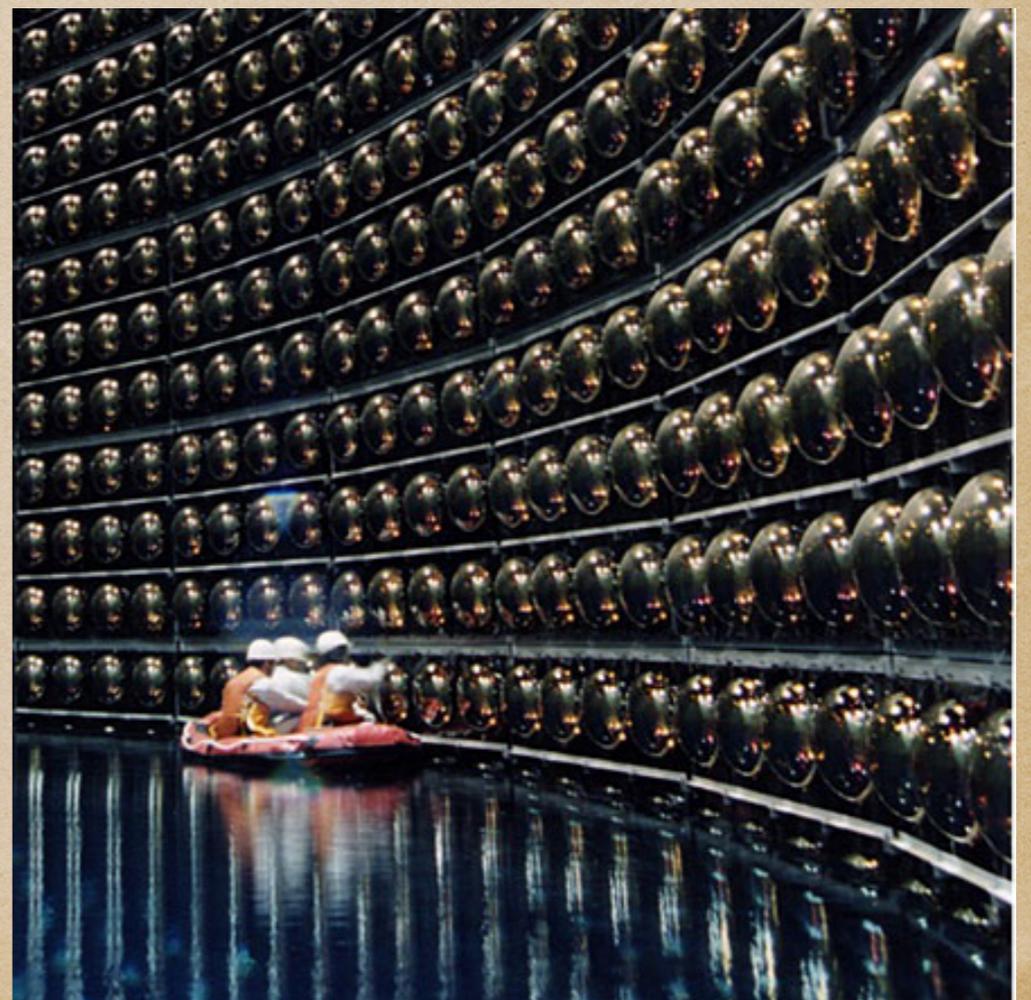
Più di 60 milioni di neutrini attraversano il nostro pollice ogni secondo!

I neutrini sono rivelati tramite la radiazione Cherenkov emessa attraversando i ghiacci antartici.





Rivelatori di neutrini



Una generazione fortunata di astronomi!



Grazie a tutti!



