

GW 170817 e GRB 170817

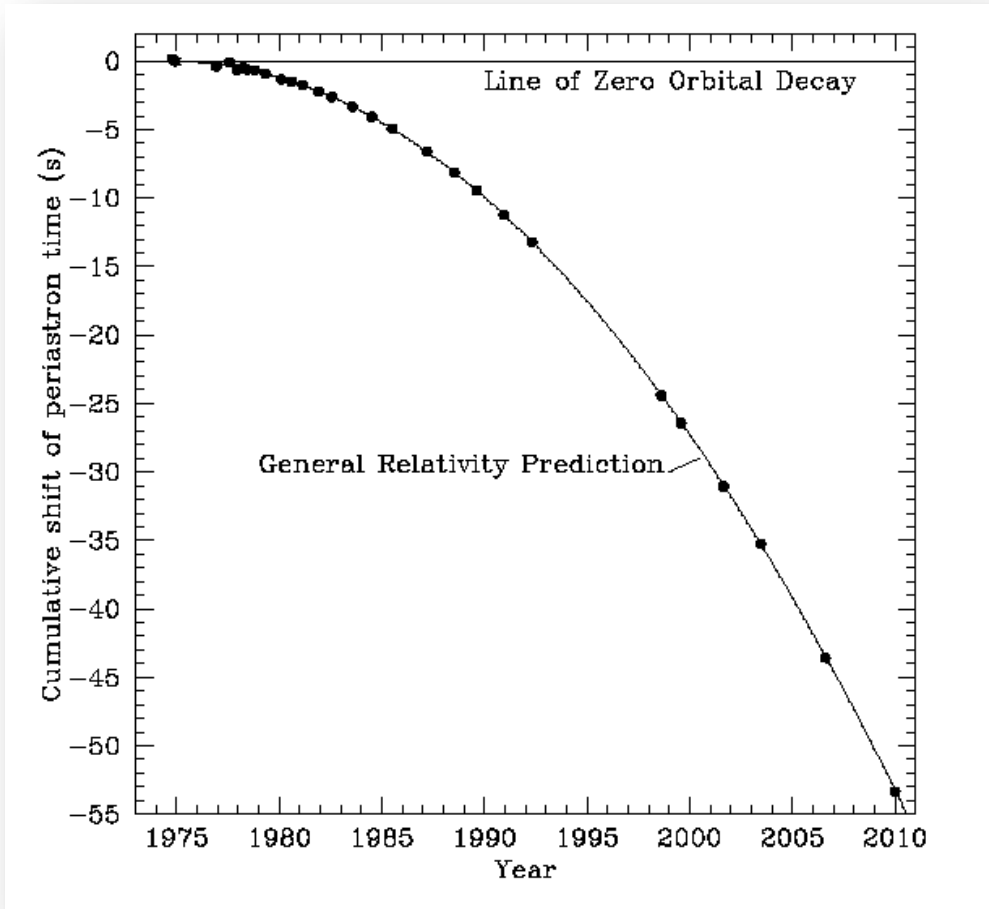
Inizia una nuova era

Sandro Mereghetti

Astrosiesta 26/10/2017

BINARY PSR 1913+16

$$P = 59 \text{ ms}, P_b = 7.75 \text{ hr}, e = 0.615$$



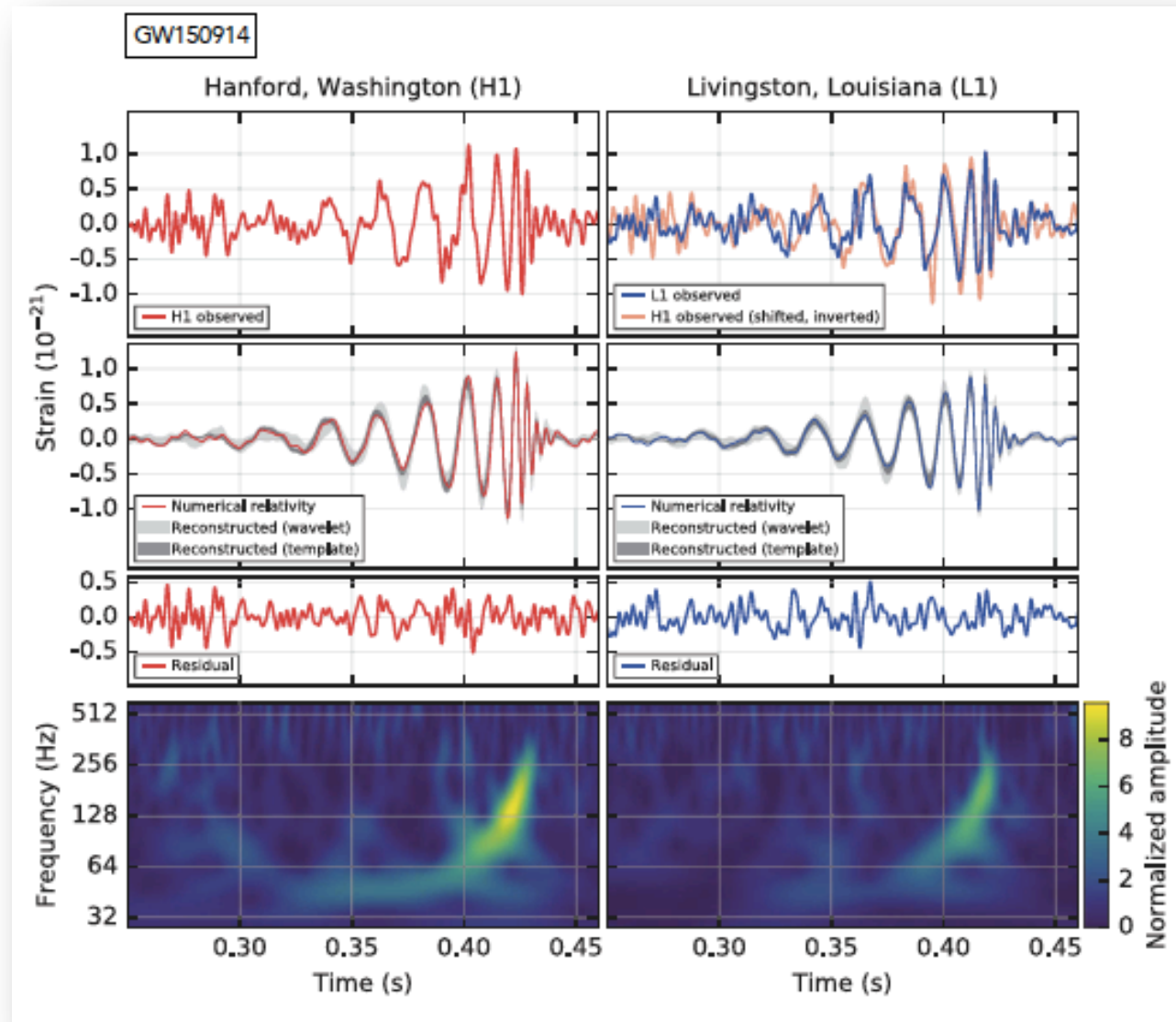
EVIDENZA INDIRETTA
DELL'ESISTENZA DELLE ONDE
GRAVITAZIONALI

PERFETTO ACCORDO CON
PREVISIONI RELATIVITA'
GENERALE

Nobel a Hulse e Taylor nel
1993

GW 150914

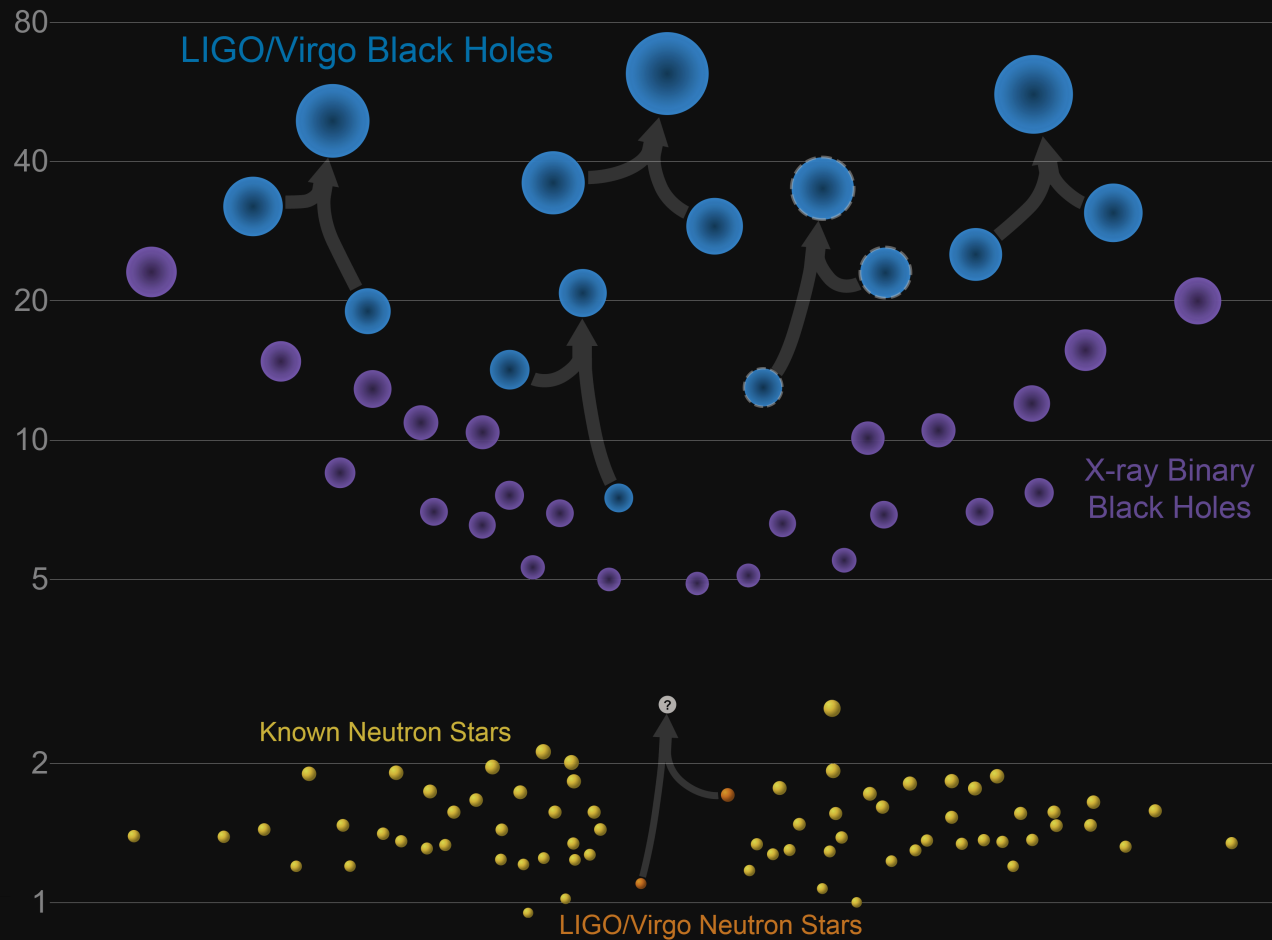
PRIMA EVIDENZA DIRETTA DELL'ESISTENZA DELLE ONDE GRAVITAZIONALI



Nobel a Weiss,
Barish e Thorne
nel 2017

Masses in the Stellar Graveyard

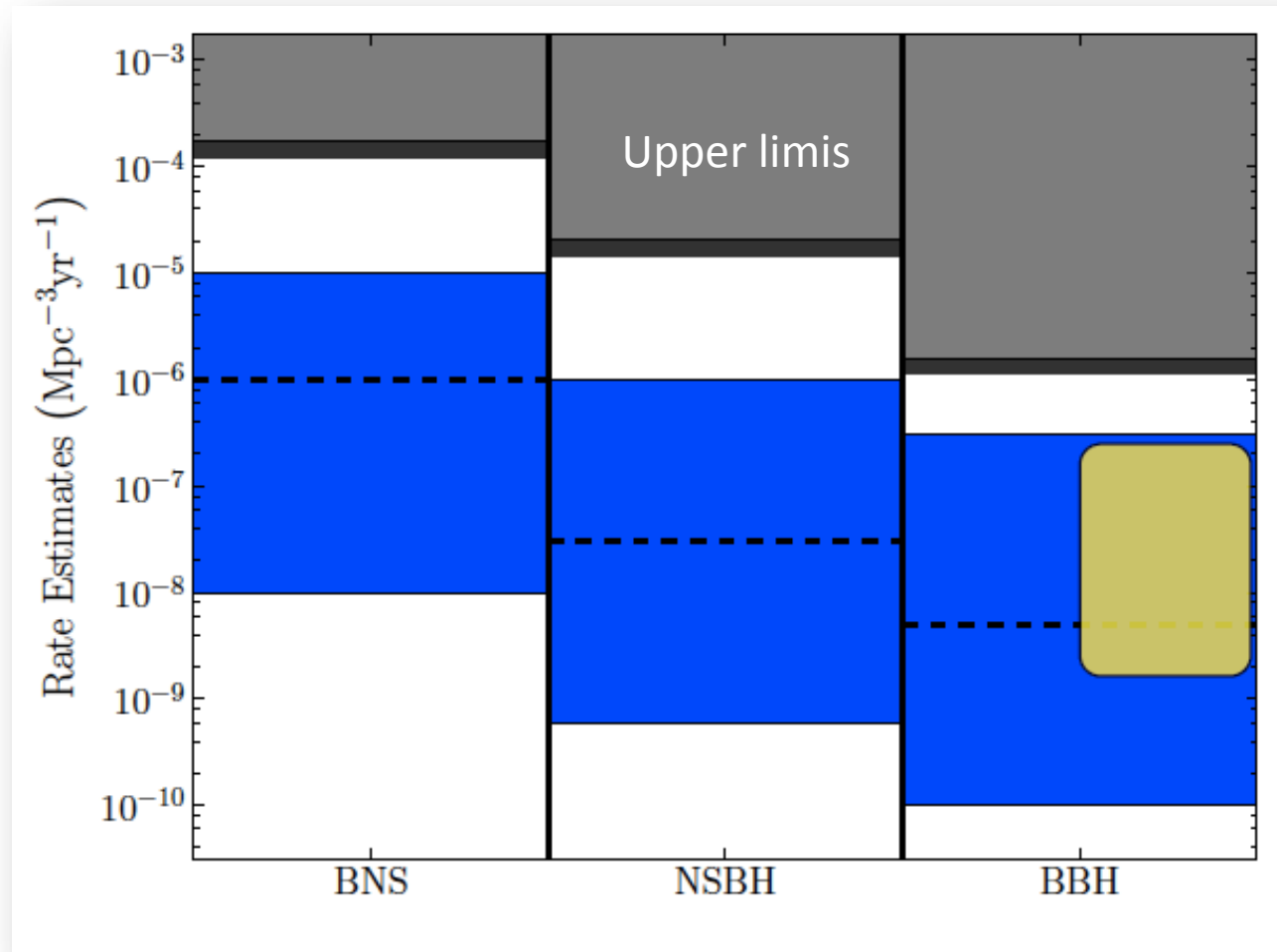
in Solar Masses



GW150914
e altri 4 segnali
rivelati da
LIGO/Virgo
erano
coalescenze di
2 black holes

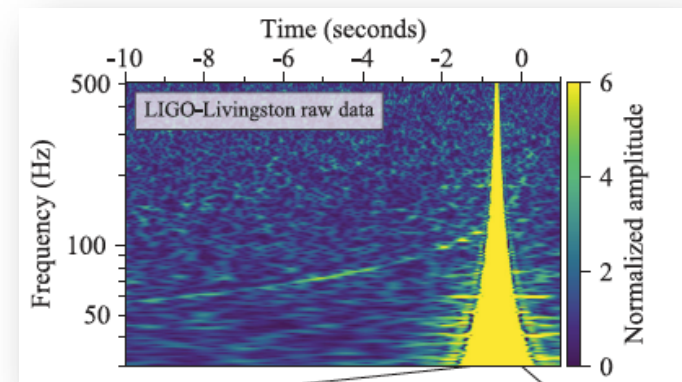
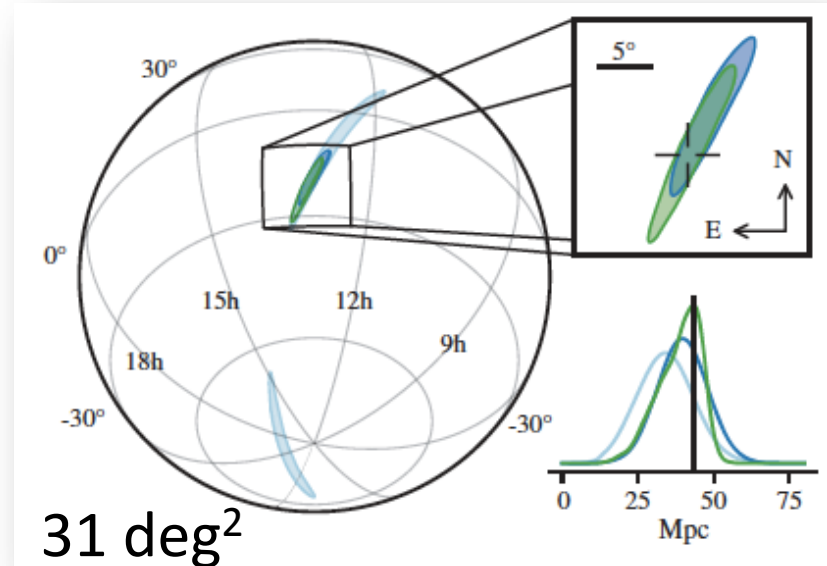
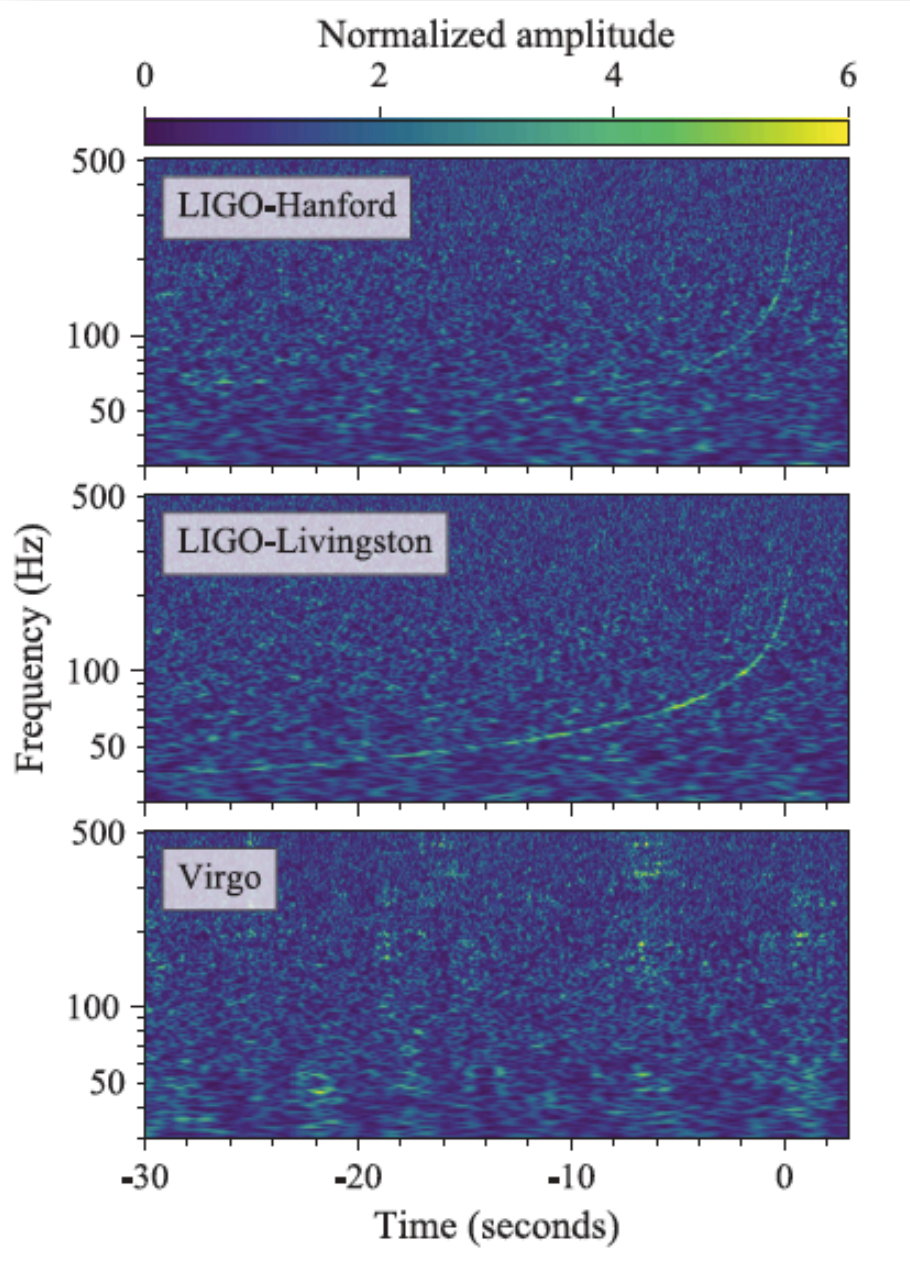
RATES DI COALESCENZE ATTESE (da Abadie+ 2012)

Colpi & Sesana 2016



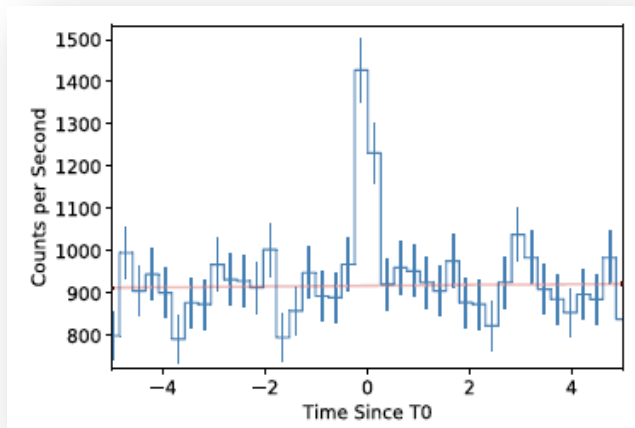
→ Da 1 BNS ogni qualche anno a centinaia per anno

GW 170817

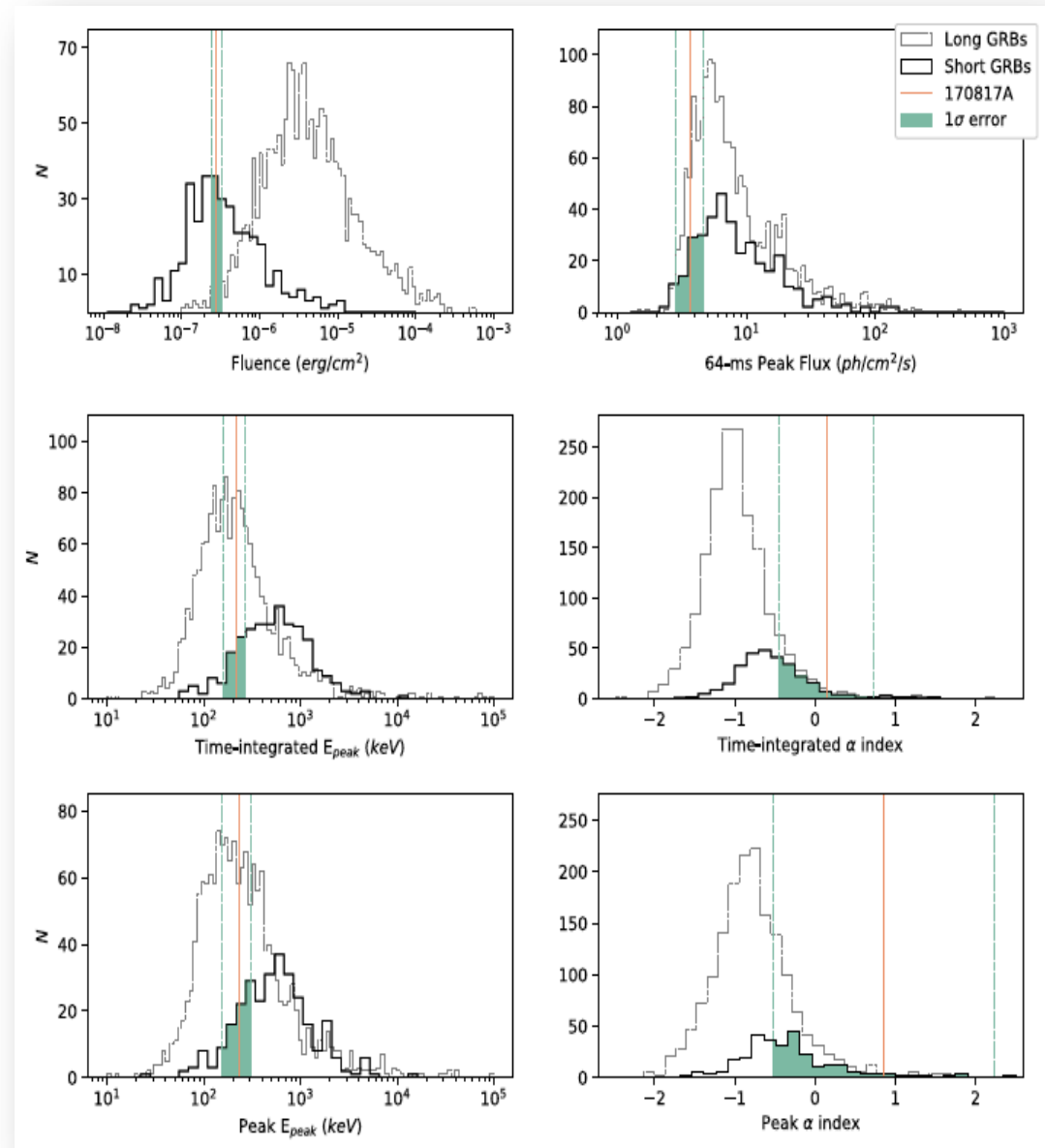


GRB 170817 short burst visto da Fermi/GBM e INTEGRAL

Goldstein_2017, ApJLett

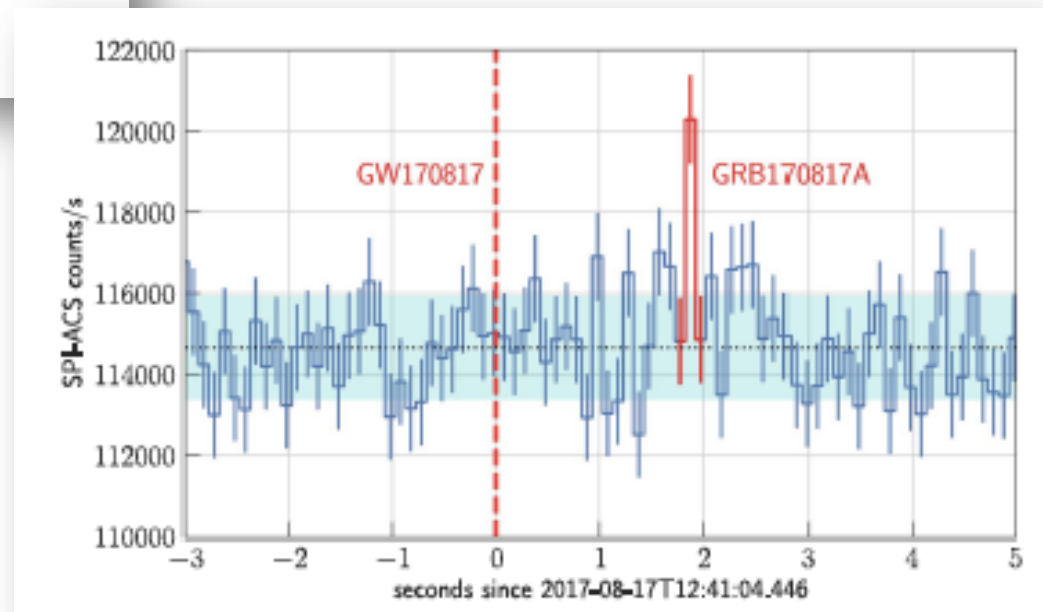
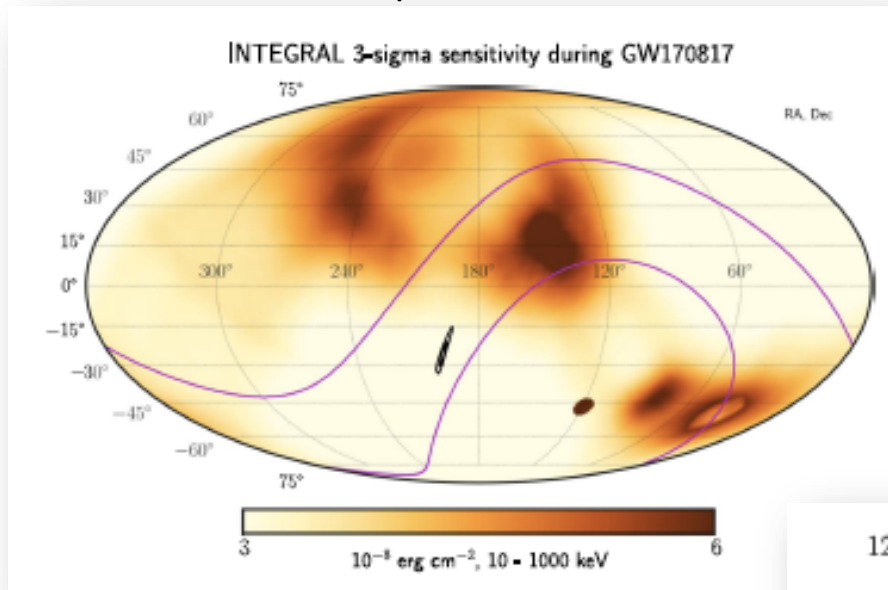


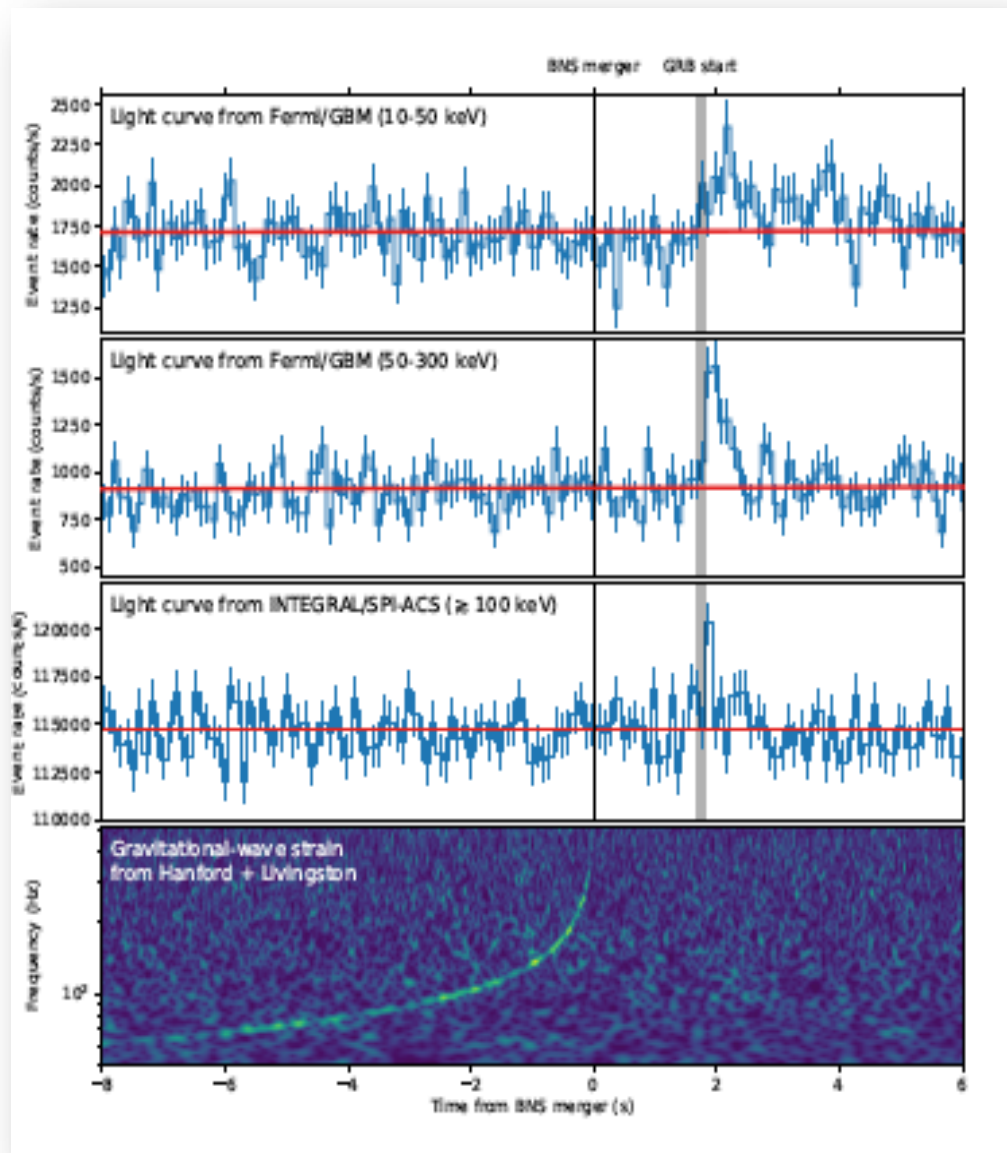
Fermi/GBM 50-300 keV



INTEGRAL

Savchenko+ 2017, ApJL





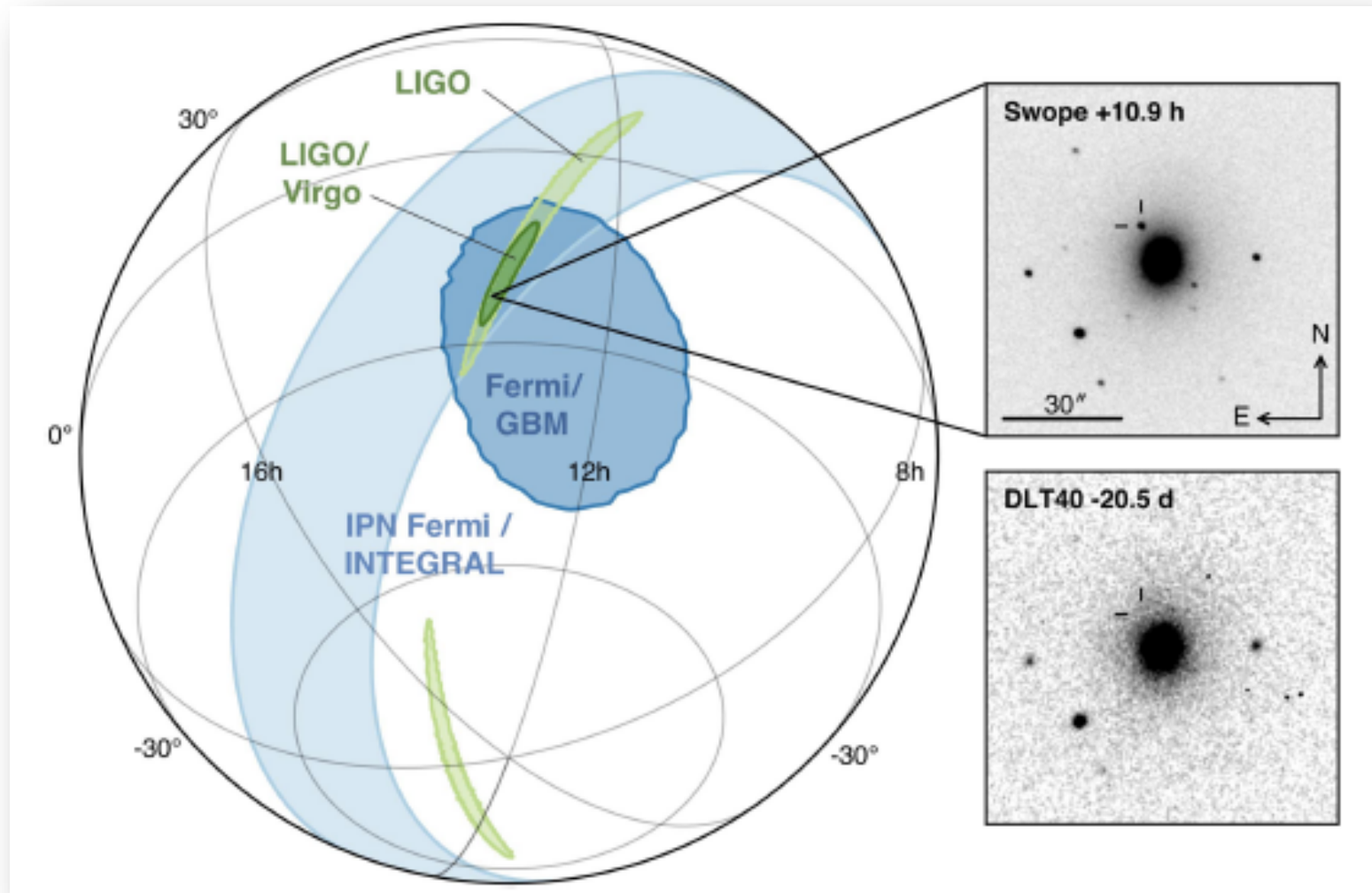
$$\Delta t = 1.74 \pm 0.05 \text{ sec}$$

← INTEGRAL

Conferma indipendente del GRB rivelato da Fermi

Riduzione della zona di errore, grazie alla "triangolazione" (differenza tempi di arrivo dei fotoni)

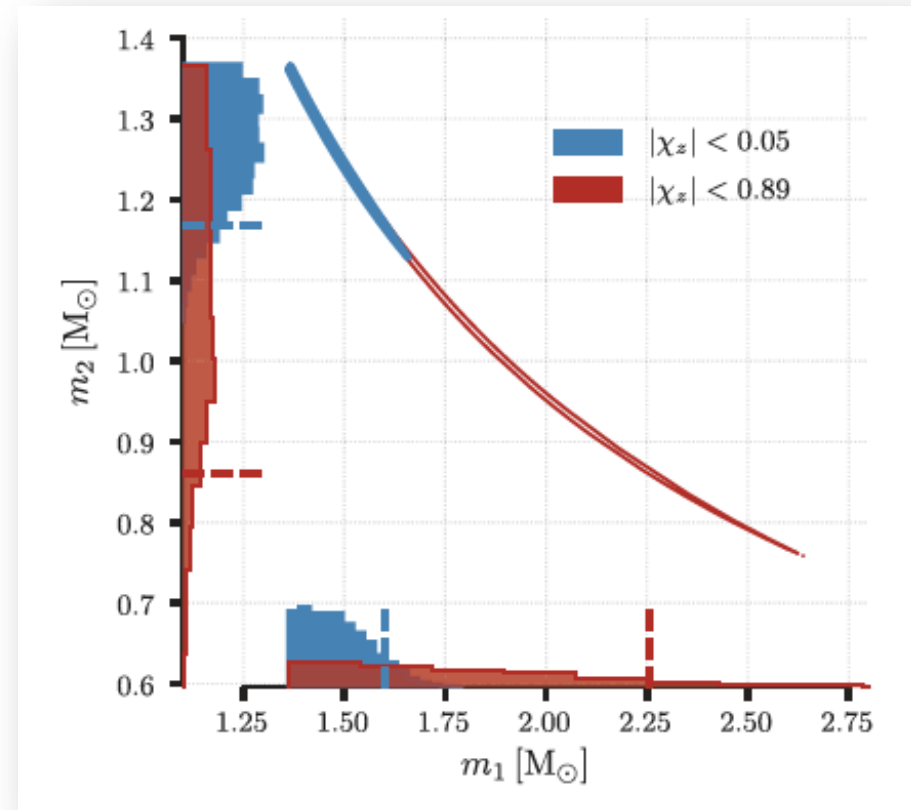
LIGO, VIRGO + ALL “Multi-Messenger paper” ApJLett



$$\text{Chirp mass} = M_c \equiv \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}} = 1.188^{+0.004}_{-0.002} M_\odot$$

$q = m_1/m_2$ e' degenerare con gli spin
 \rightarrow le masse delle due NS
 dipendono dalle assunzioni sulla
 loro rotazione

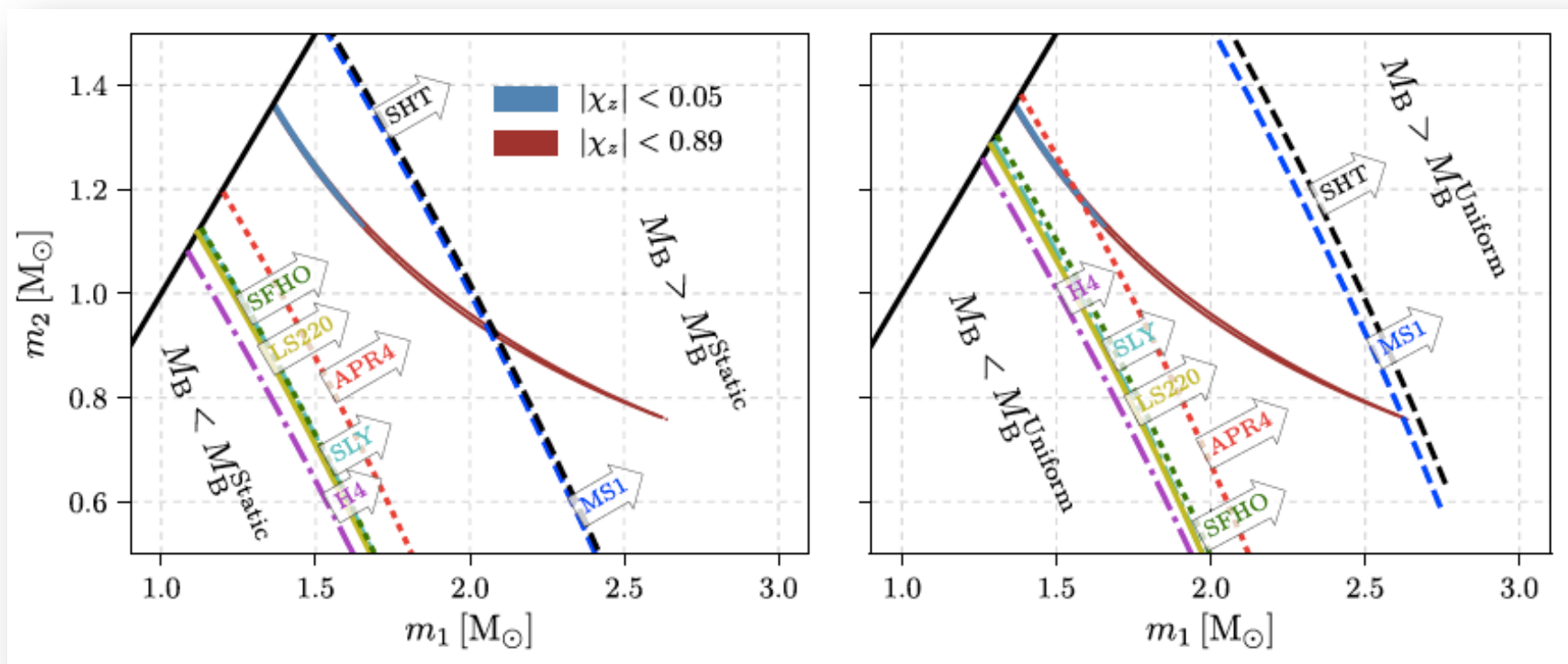
Blu = low spin scenario
 Rosso = high spin scenario



LVC 2017, Phys.Rev.Lett.

LIMITI SU EQUAZIONE DI STATO PER STELLE DI NEUTRONI

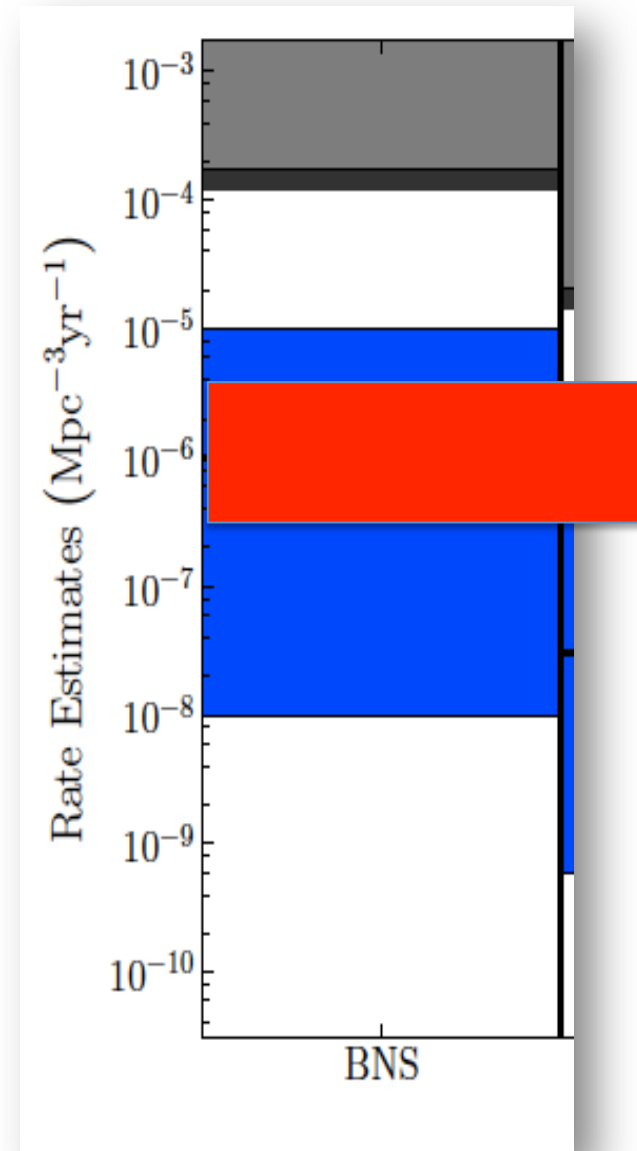
(l'osservazione di un GRB implica la formazione di un BH)



NB: No evidenza di \sim kHz post-merger (come atteso da NS) ma non e' esclusa del tutto la possibilita' di short- o long-lived post merger NS

NUOVA STIMA DI RATE DI COALESCENZA BNS

RATE BNS = 1540 (+3200, -1220) $\text{Gpc}^{-1} \text{yr}^{-1}$



IMPLICAZIONI DELLA COINCIDENZA TEMPORALE ONDE EM GW

$$\Delta t = 1.74 \pm 0.05 \text{ sec}$$

Limiti su differenza di velocità:

$$-3 \times 10^{-15} \leq \frac{\Delta v}{v_{EM}} \leq +7 \times 10^{-16}.$$

Limiti su violazione invarianza di Lorentz

Table 1
Constraints on the Dimensionless Minimal Gravity Sector Coefficients

| ℓ | Previous Lower | This Work Lower | Coefficient | This Work Upper | Previous Upper |
|--------|----------------------|----------------------|----------------------------------|---------------------|---------------------|
| 0 | -3×10^{-14} | -2×10^{-14} | $\bar{s}_{00}^{(4)}$ | 5×10^{-15} | 8×10^{-5} |
| 1 | -1×10^{-13} | -3×10^{-14} | $\bar{s}_{10}^{(4)}$ | 7×10^{-15} | 7×10^{-14} |
| | -8×10^{-14} | -1×10^{-14} | $-\text{Re } \bar{s}_{11}^{(4)}$ | 2×10^{-15} | 8×10^{-14} |
| | -7×10^{-14} | -3×10^{-14} | $\text{Im } \bar{s}_{11}^{(4)}$ | 7×10^{-15} | 9×10^{-14} |
| | | | | | |
| 2 | -1×10^{-13} | -4×10^{-14} | $-\bar{s}_{20}^{(4)}$ | 8×10^{-15} | 7×10^{-14} |
| | -7×10^{-14} | -1×10^{-14} | $-\text{Re } \bar{s}_{21}^{(4)}$ | 2×10^{-15} | 7×10^{-14} |
| | -5×10^{-14} | -4×10^{-14} | $\text{Im } \bar{s}_{21}^{(4)}$ | 8×10^{-15} | 8×10^{-14} |
| | -6×10^{-14} | -1×10^{-14} | $\text{Re } \bar{s}_{22}^{(4)}$ | 3×10^{-15} | 8×10^{-14} |
| | -7×10^{-14} | -2×10^{-14} | $-\text{Im } \bar{s}_{22}^{(4)}$ | 4×10^{-15} | 7×10^{-14} |

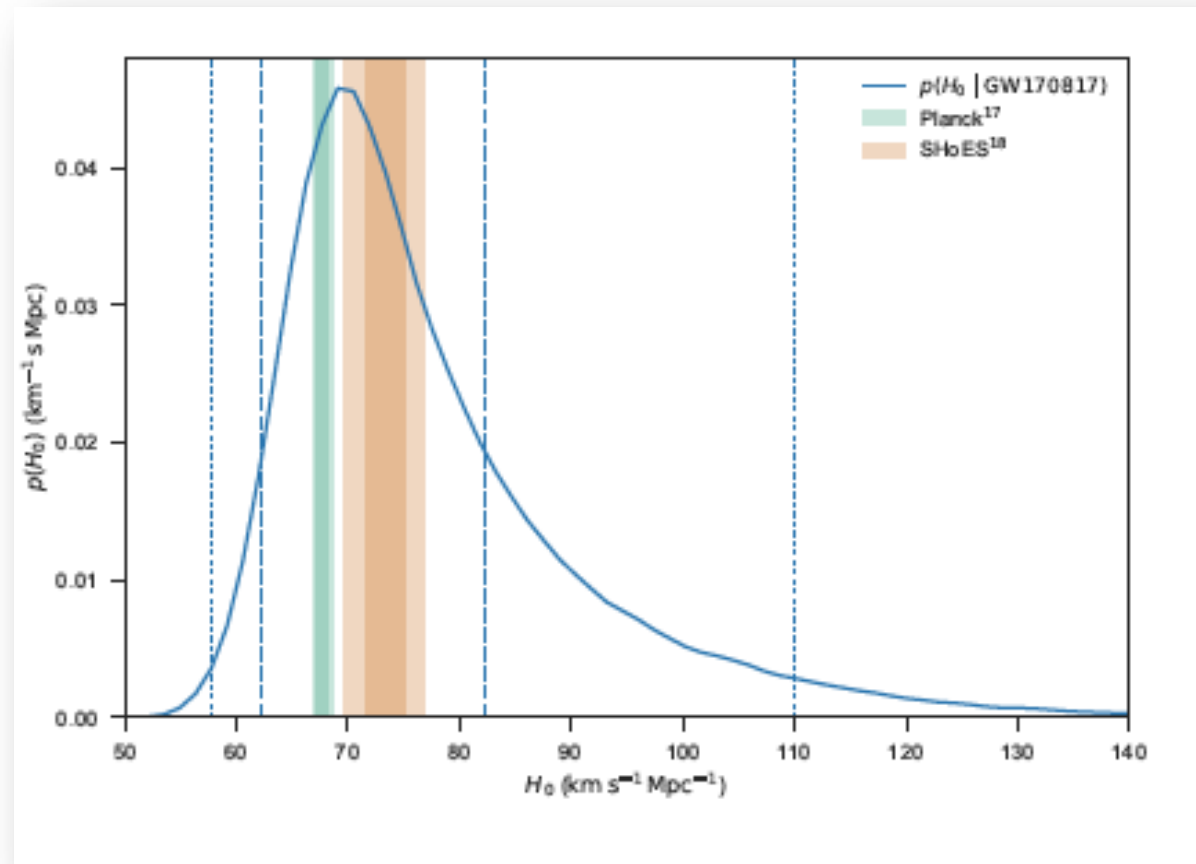
Test del principio di equivalenza
(basato su "Shapiro delay")

$$-2.6 \times 10^{-7} \leq \gamma_{GW} - \gamma_{EM} \leq 1.2 \times 10^{-6}.$$

COSMOLOGIA CON "STANDARD SIREN" -- Misura indipendente di H_0

redshift NGC 4993 + D_L da GW $\rightarrow H_0 = 70 [+12, -8]$

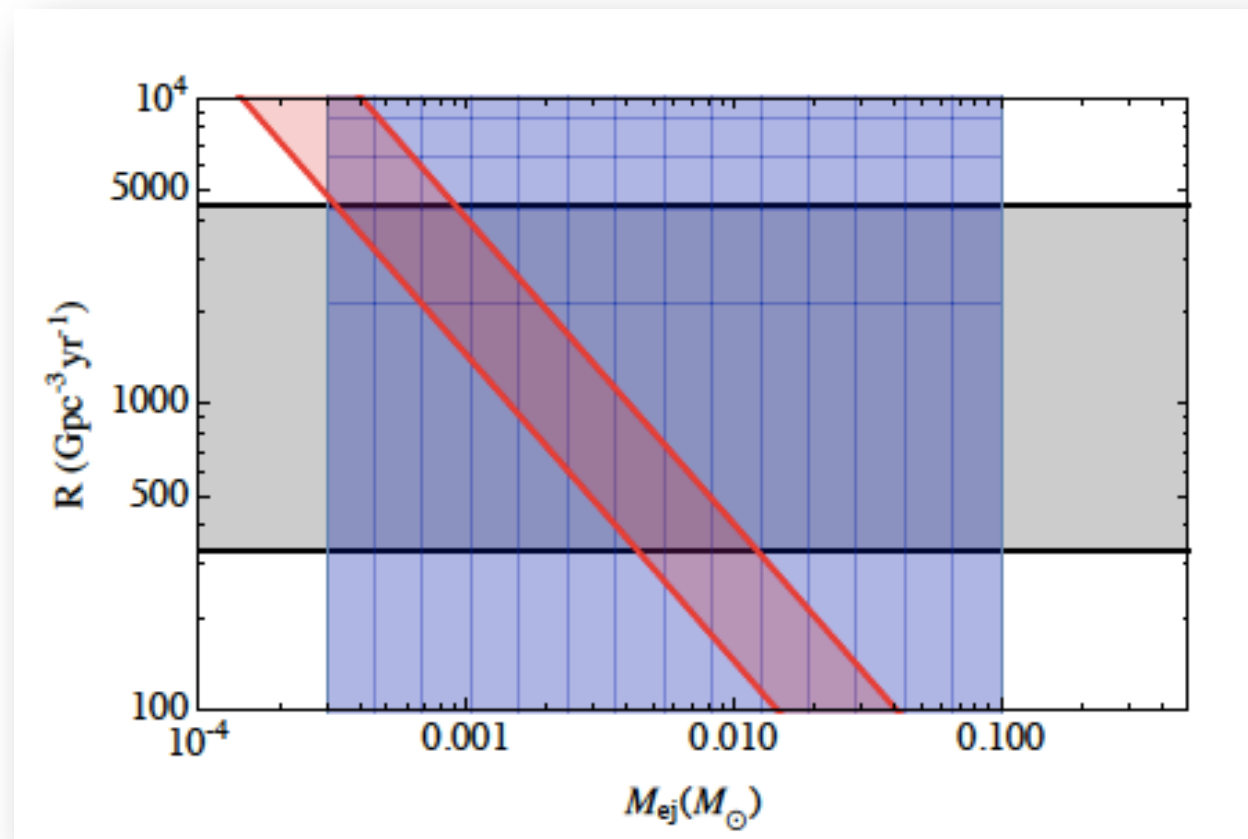
LVC 2017, Nature.



Se invece si assume $H_0 = 67.9 \rightarrow$ maggiori constraints sull'angolo di inclinazione $\rightarrow \Theta < 28^\circ$

MISURA DIRETTA (solo da segnale GW) DELLA MASSA ESPULSA

LVC 2017, ApJ Lett



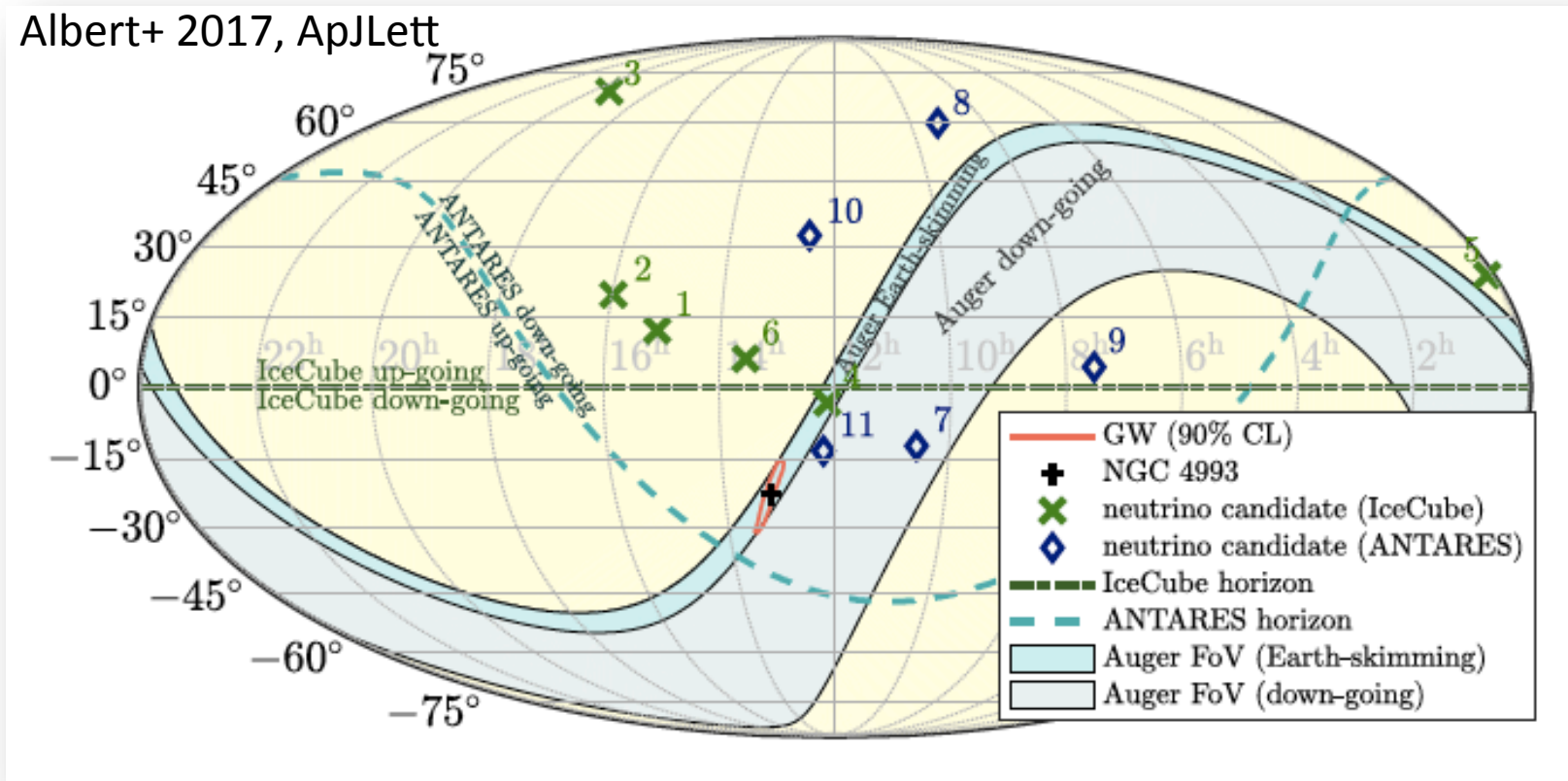
Red band is range of r-process elements based on Galactic observations

→ Mergers di NS+NS come GW170817 posson produrre le abbondanze di elementi r-process osservate nella Galassia

NIENTE NEUTRINI

come prevedibile, data l'energetica gamma ($E_{\text{iso}} \sim 4 \cdot 10^{46}$ erg)

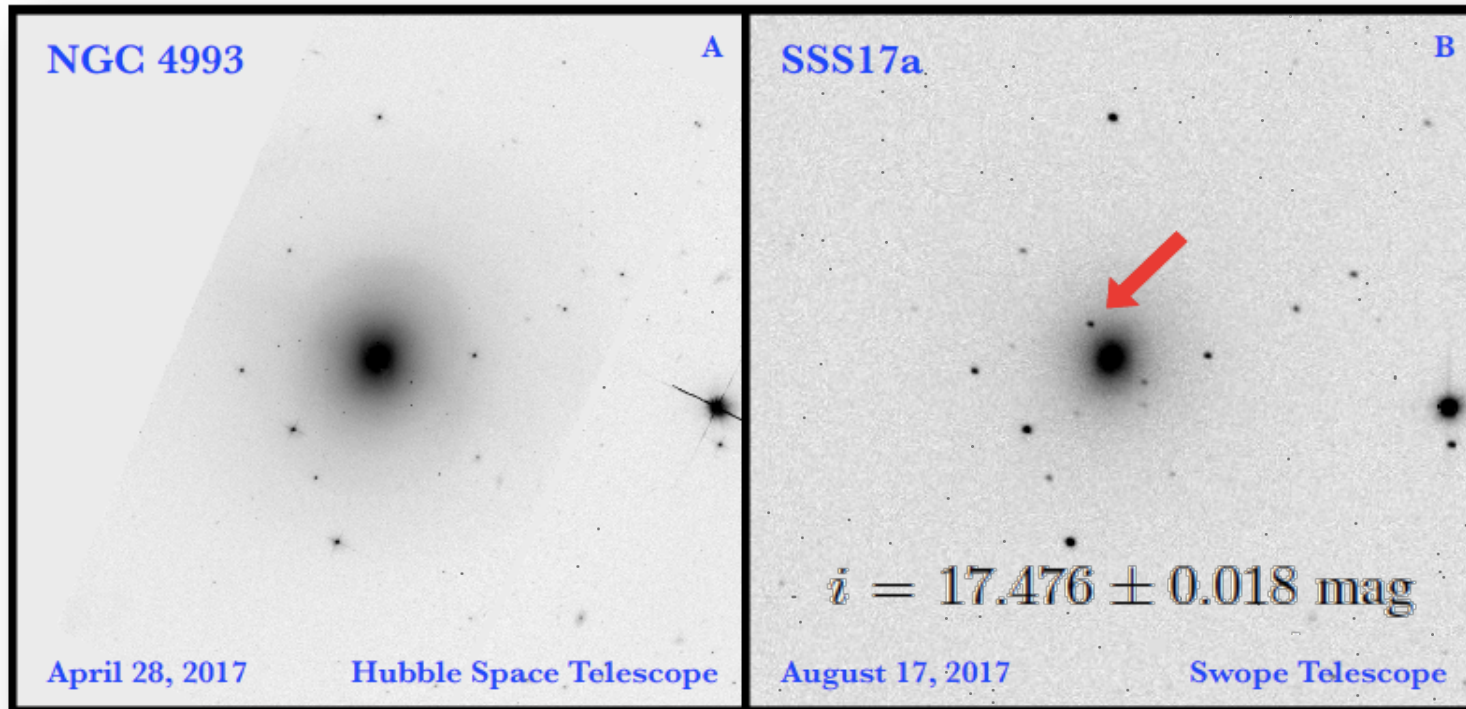
Albert+ 2017, ApJLett



SCOPERTA DELLA CONTROPARTE OTTICA in NGC4993

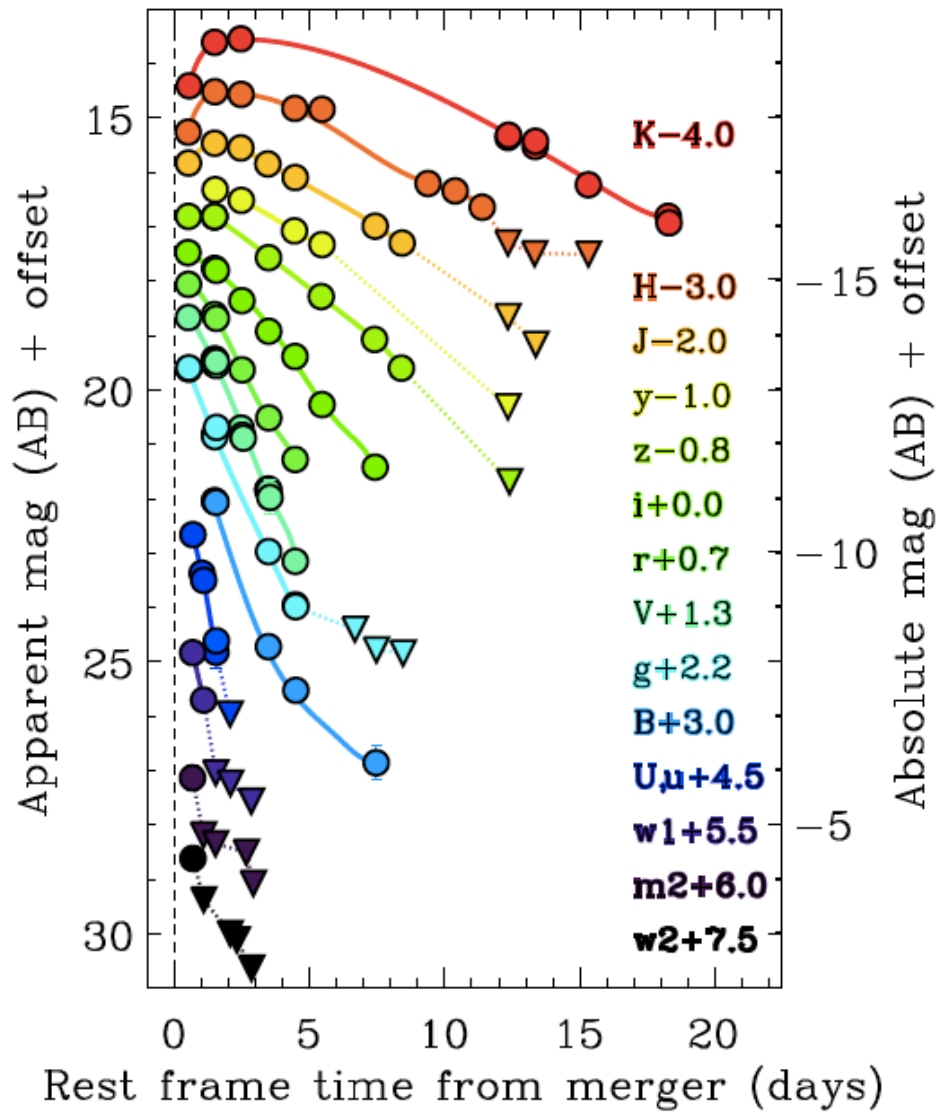
(S0 galaxy at 40 Mpc , $z=0.00968$)

Coulter+ 2017, Science

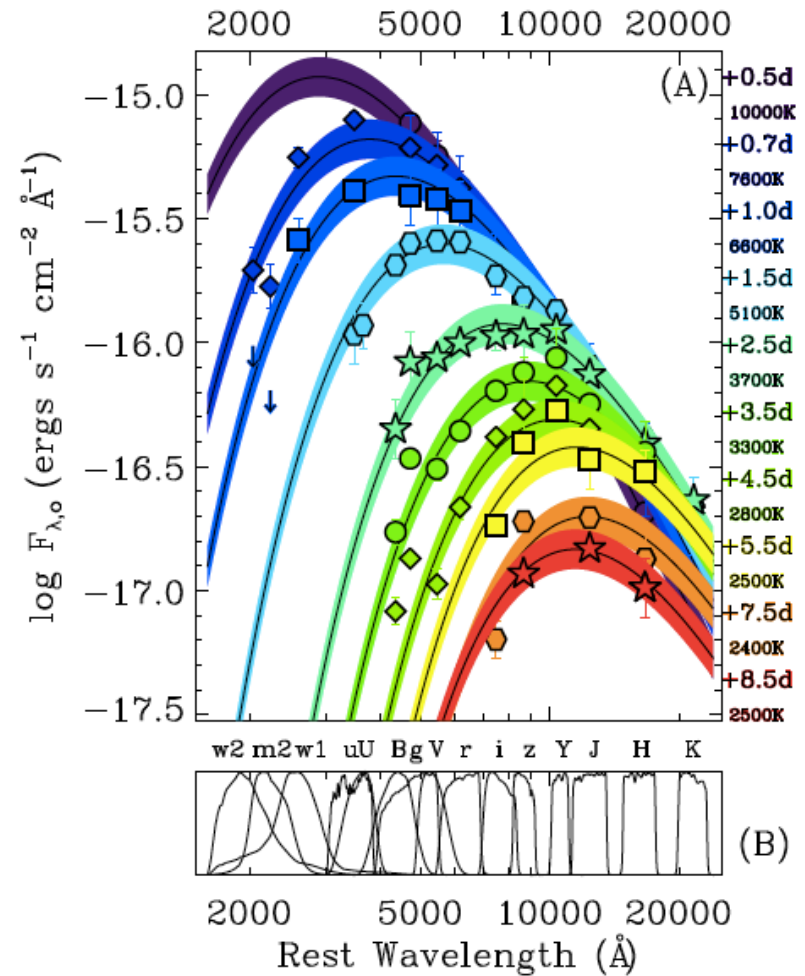


Offset 11''
(2 kpc)
from nucleus

Telescopio da 1m con FOV 30x30 arcmin²
Strategia ottimizzata per galassie piu' promettenti

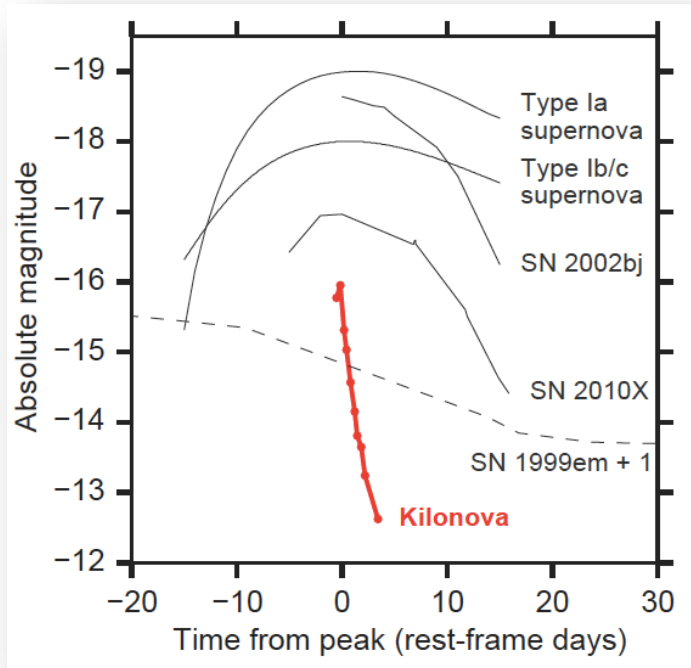


Drout+ 2017, Science

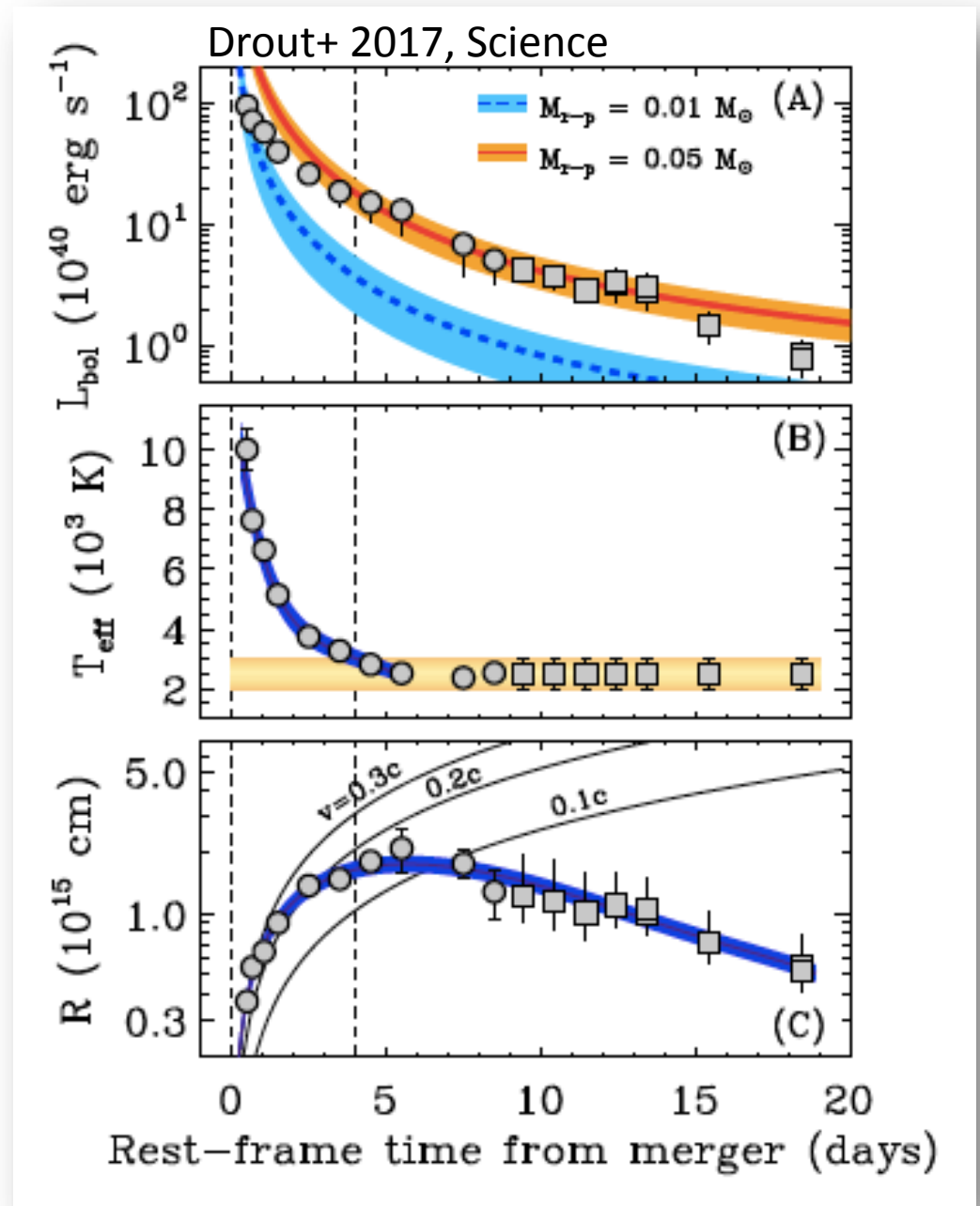


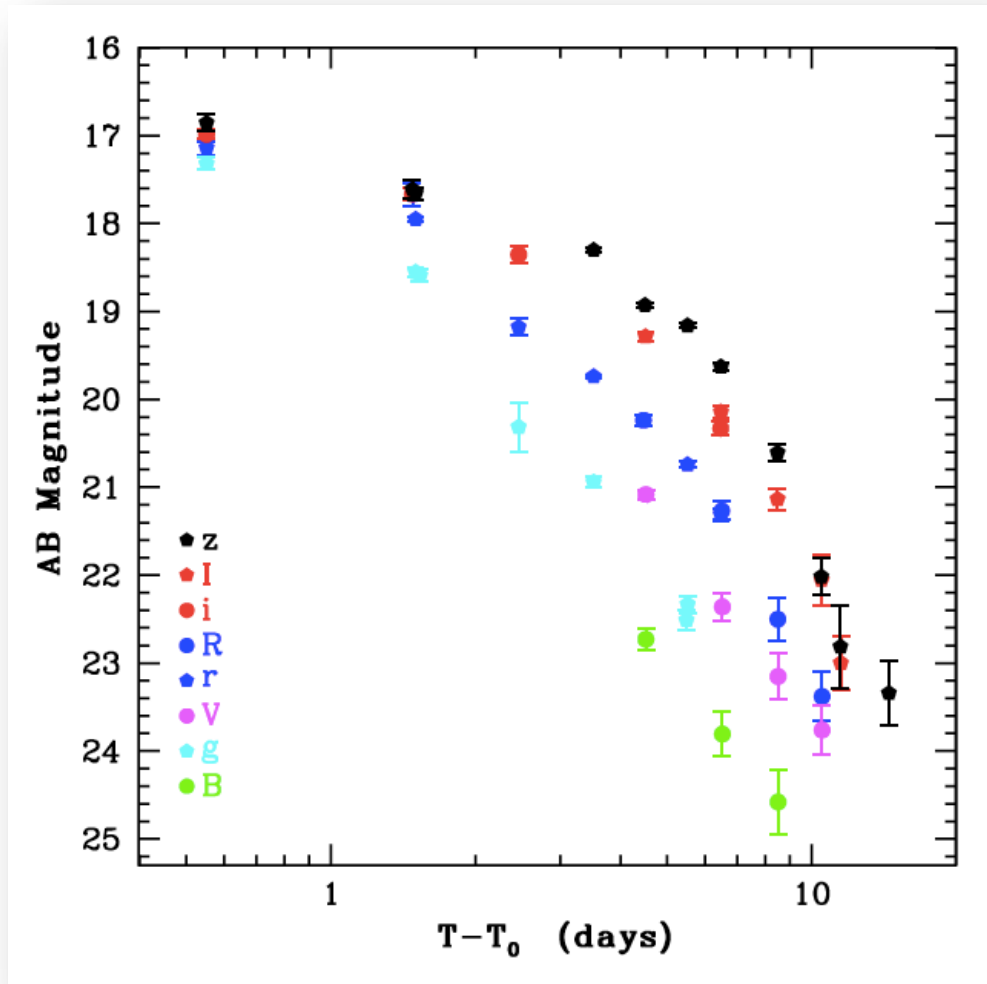
CONFRONTO CON MODELLI

Arcavi+ 2017, Nature



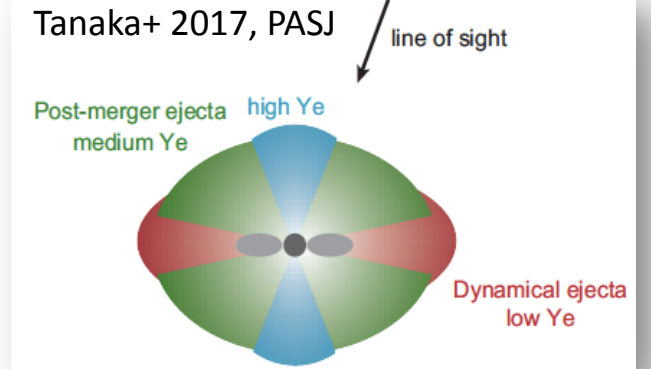
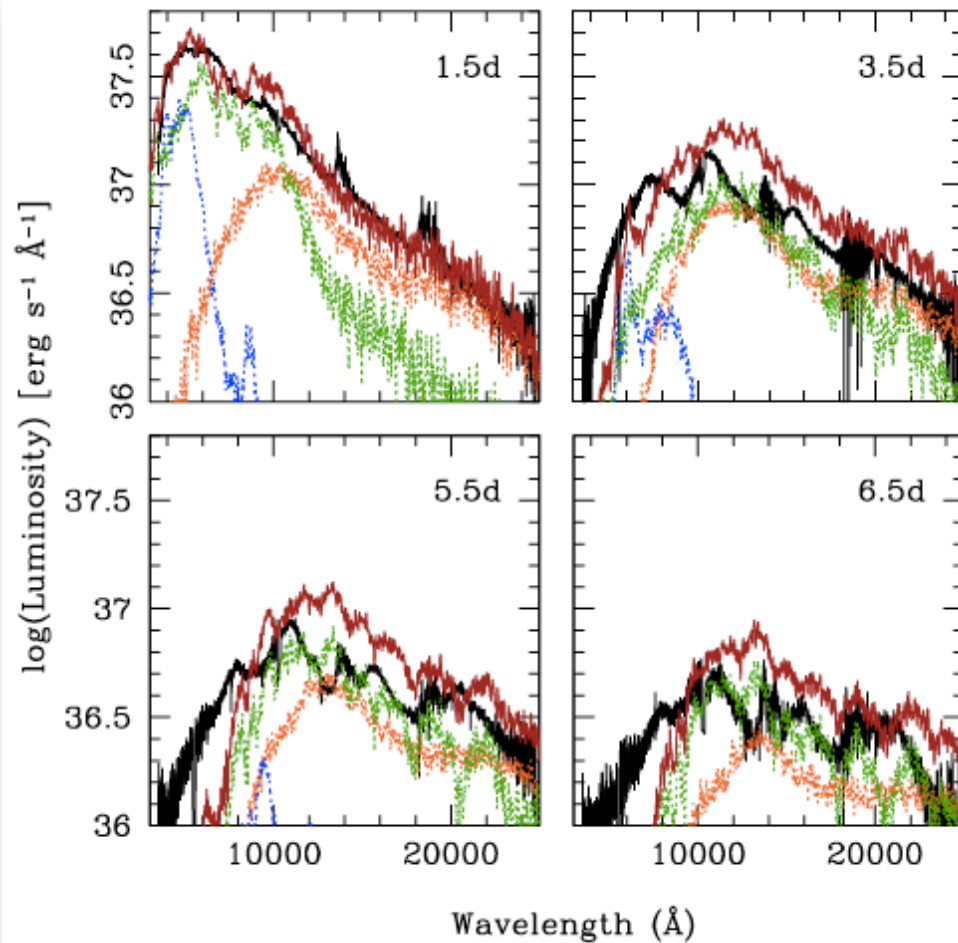
0.05 M_{\odot} di
elementi pesanti
prodotti per cattura
rapida di neutroni





CONFRONTO CON MODELLI

Pian, D'Avanzo et al 2017, Nature



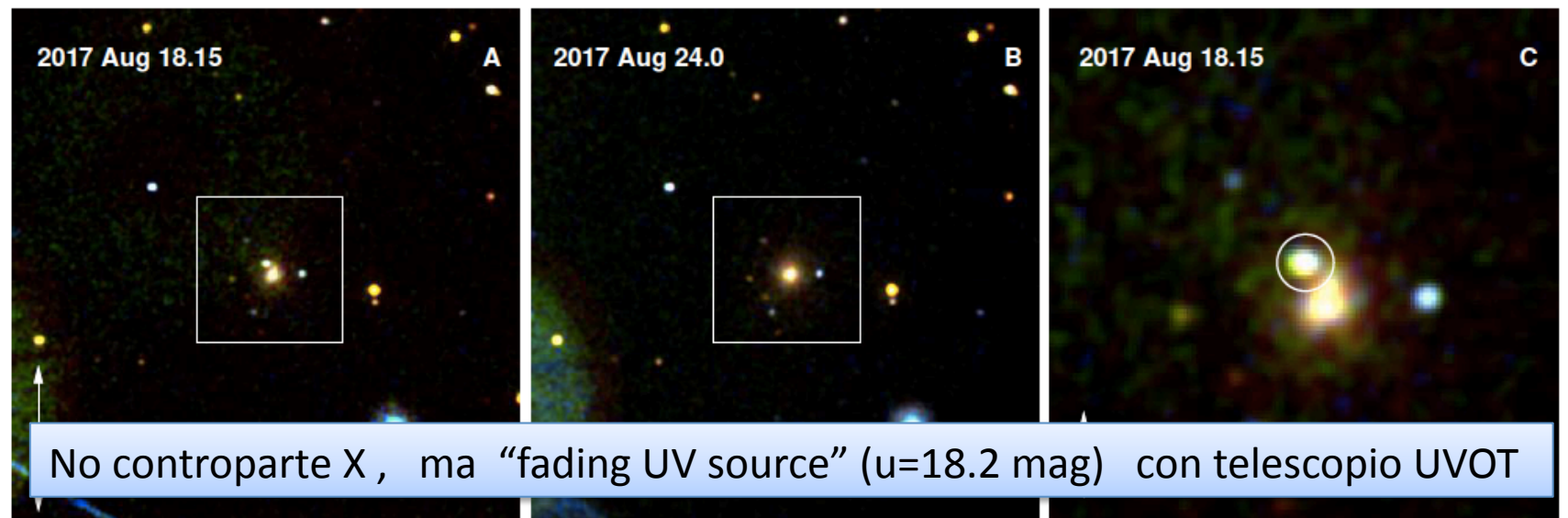
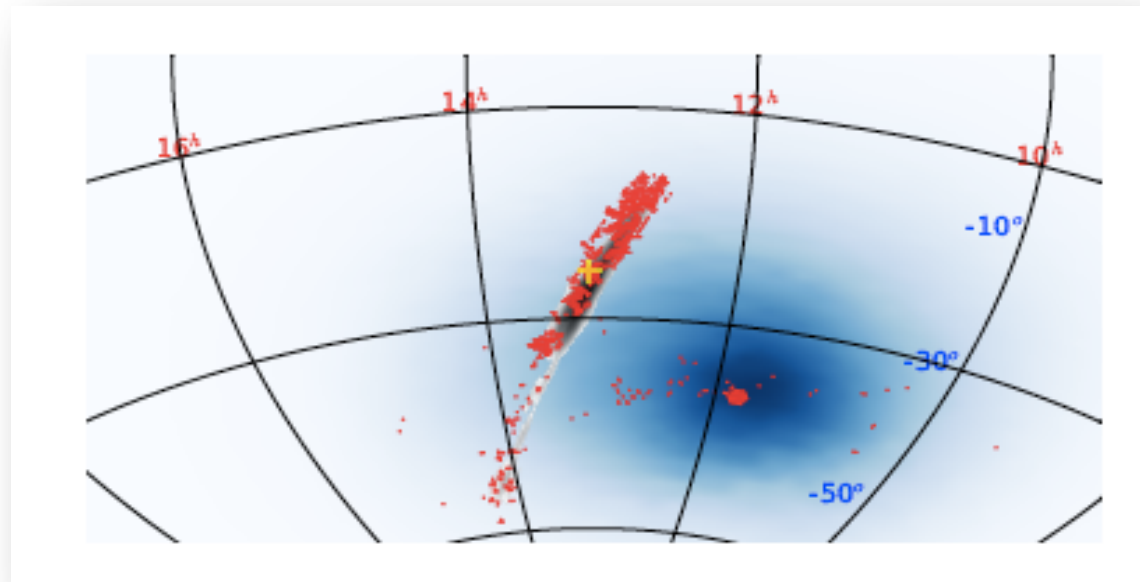
Tre componenti con diverse velocita', composizione, e frazione di protoni.

Opportunamente riscaldate e sommate (rosso) riproducono gli spettri (nero)

$\rightarrow 0.03-0.05 M_{\odot}$
Fast moving dynamical ejecta (0.2c) + slower wind (0.05c)

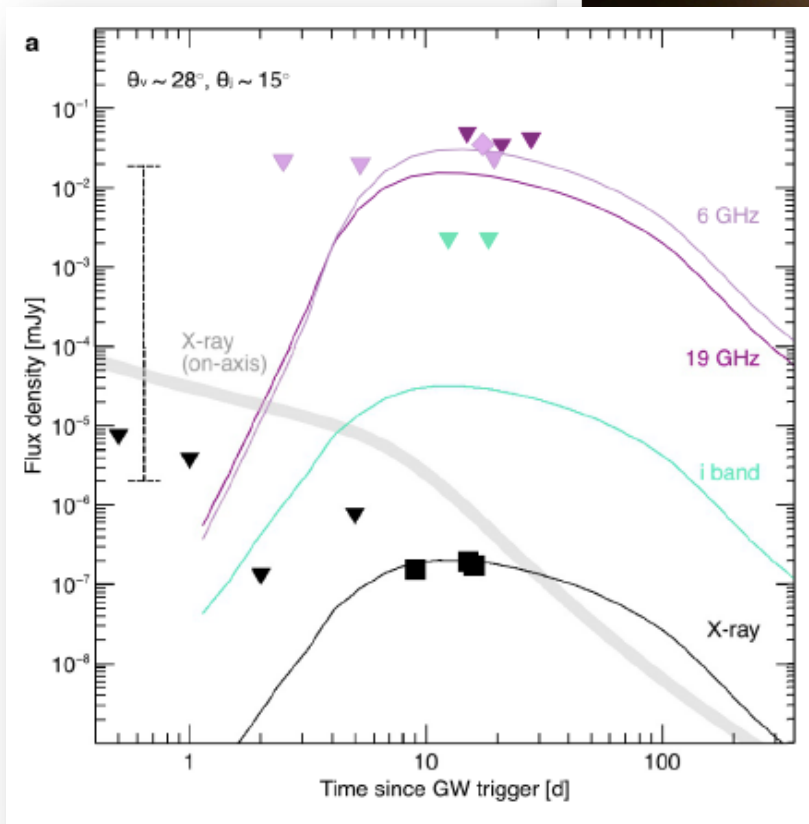
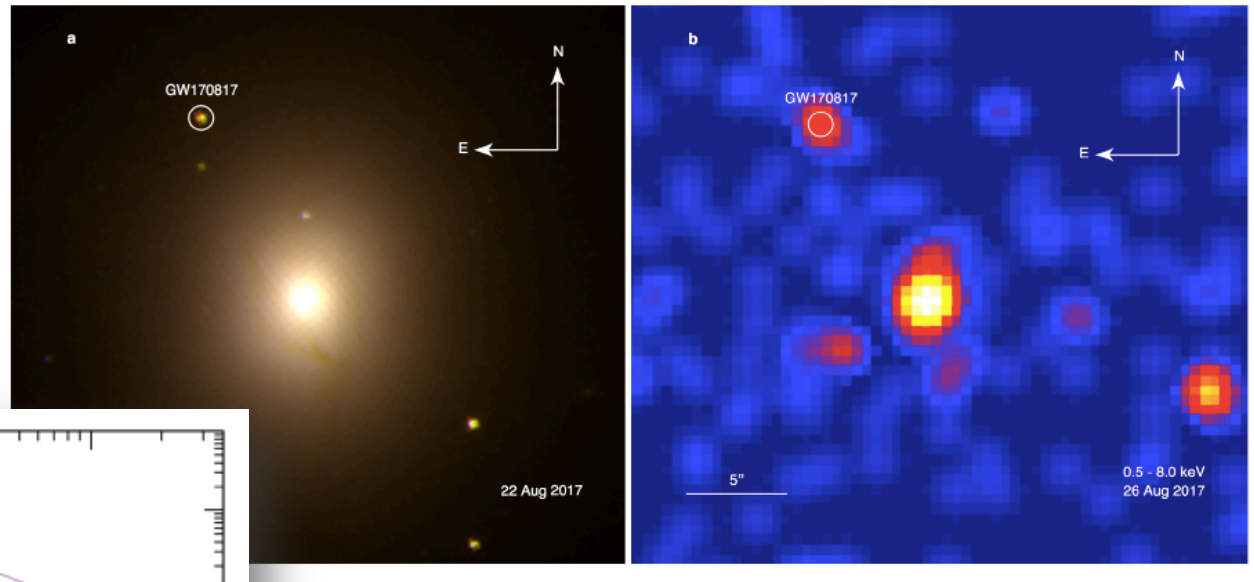
Evans+ 2017, Nature

Swift - inizia follow-up
un'ora dopo T_{GW} e punta
NGC4993 a $T_{GW} + 14.4$ hr

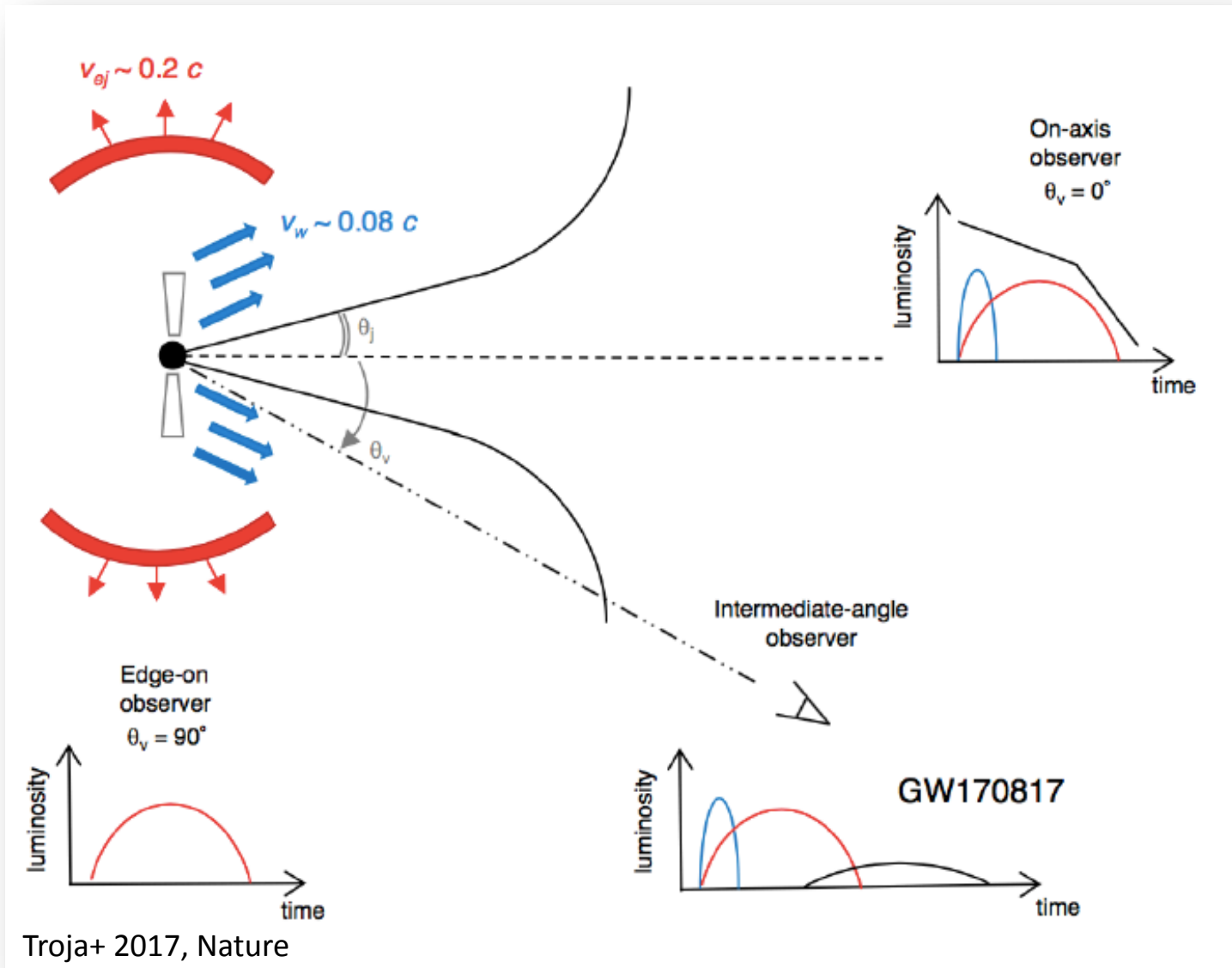


Chandra: EMISSIONE X a $T_{GW} + 9$ days

Troja+ 2017, Nature

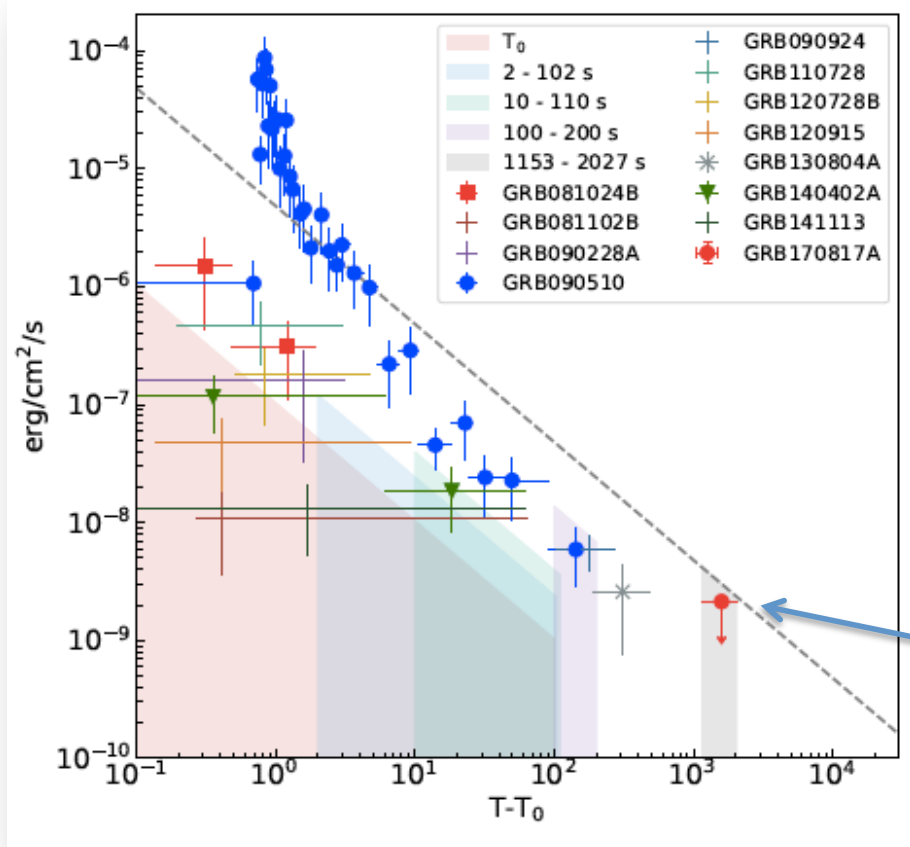
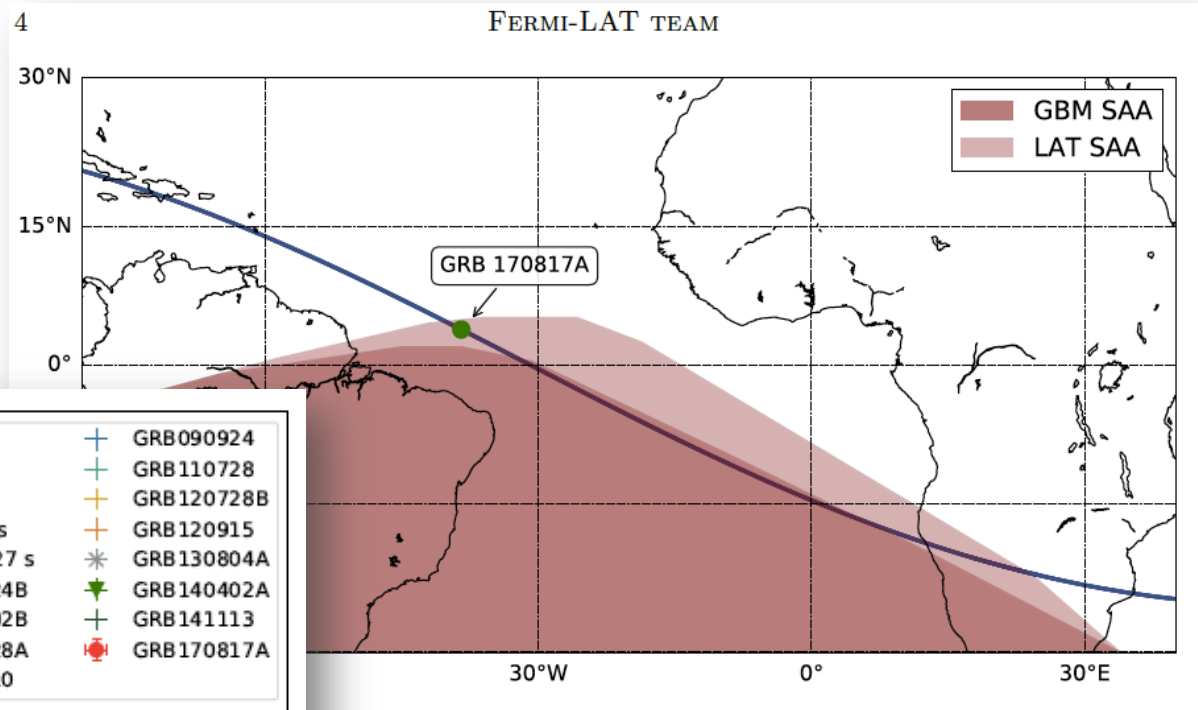


Consistente con afterglow di GRB visto ad angolo di $\sim 28^\circ$



Troja+ 2017, Nature

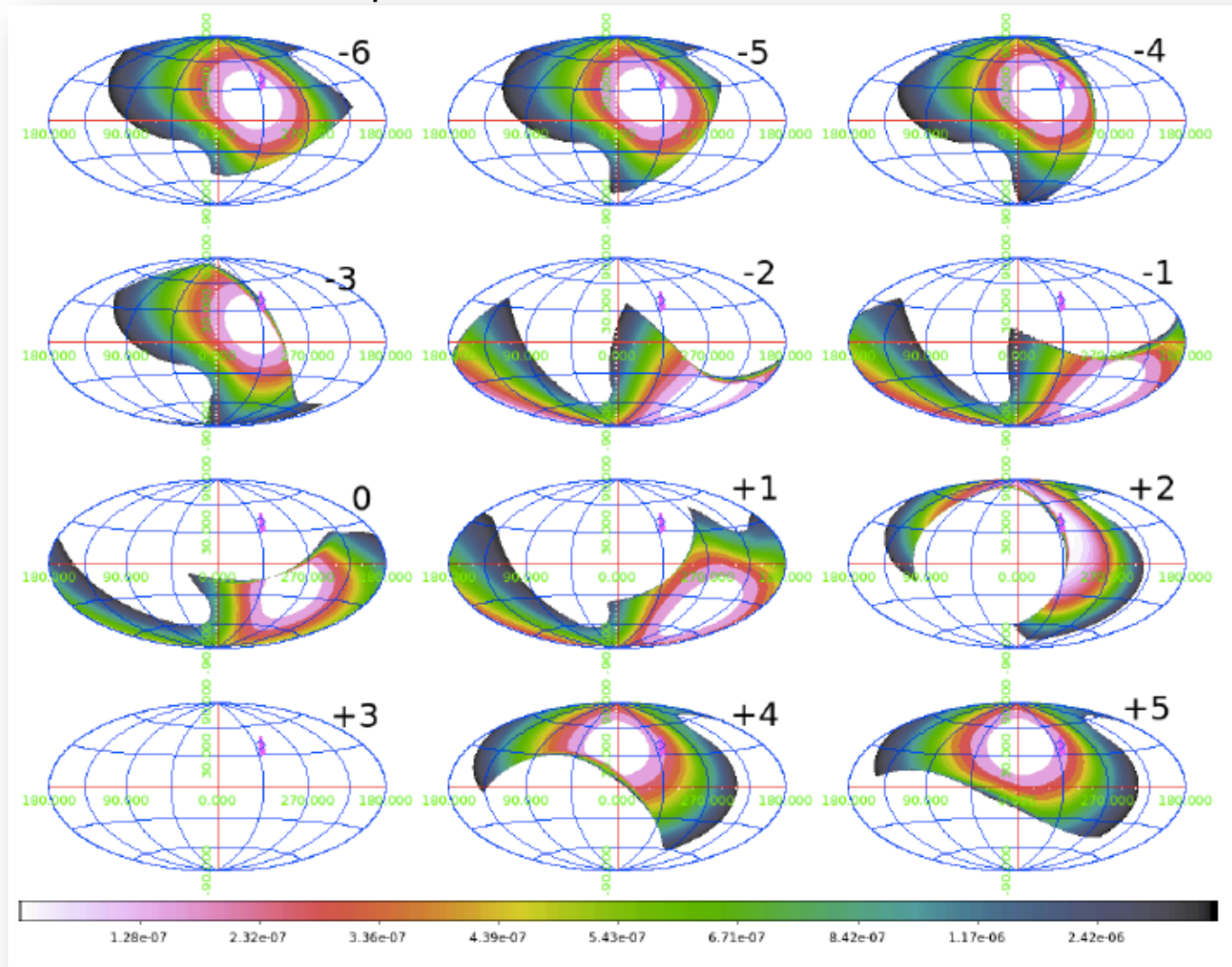
NO DATI Fermi-LAT (...e GBM per un pelo!!)



Upper limit per
emissione ritardata

AGILE no dati a T_{GW} (terra nel FOV) ma upper limits prima e dopo

Verrechia+ 2017, ApJLett

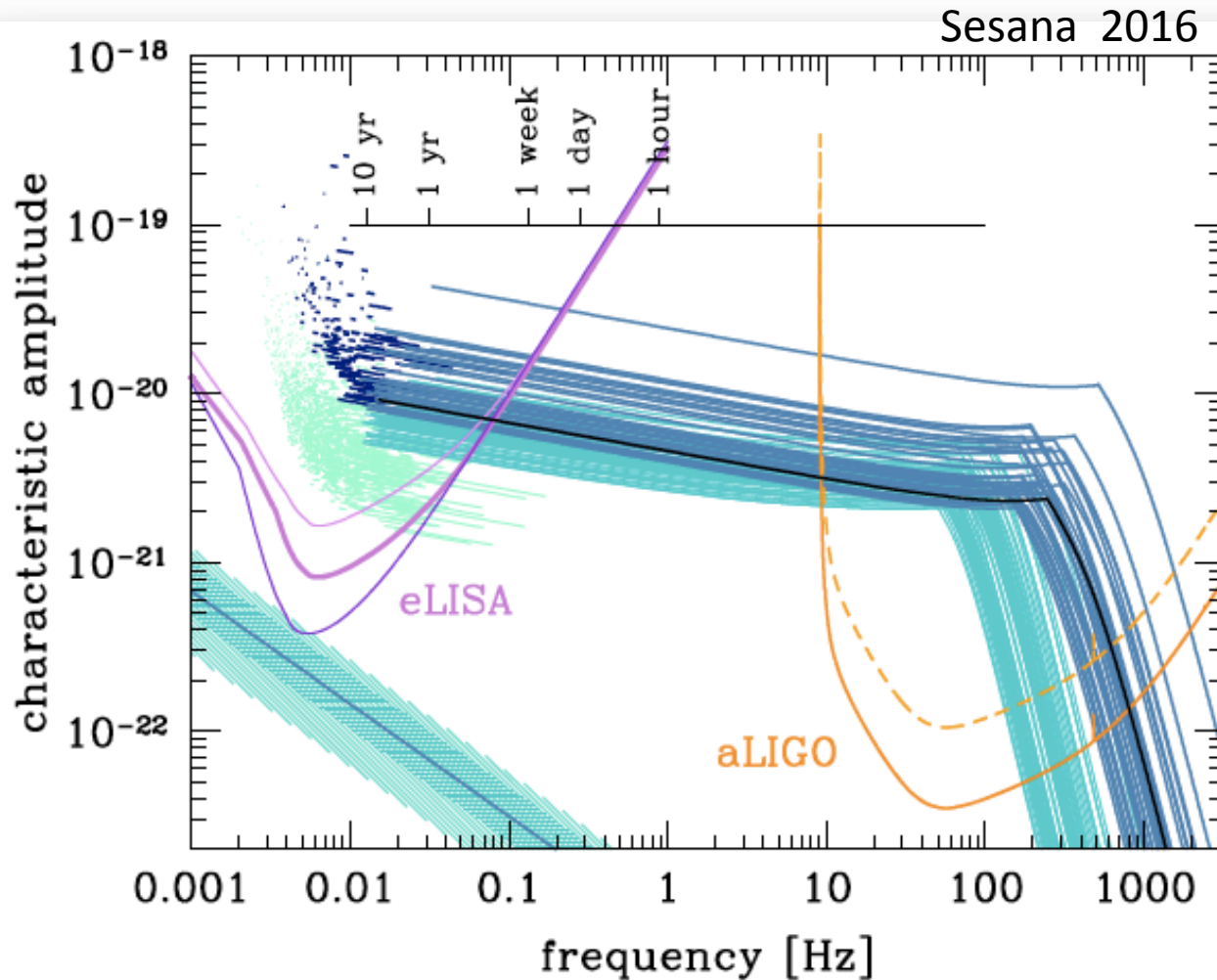


AGILE in
"spinning mode"

Copre 80% del cielo
ogni 7 min

UL $\sim 2 \cdot 10^{-8}$ -- few 10^{-7} erg/cm²/s (30 MeV-10 GeV)

Multi-band GW astronomy



GW150914 would have been seen by e-LISA for years before merger

→ Merger time (~seconds accuracy) and position (~ 1 sq deg) known in advance