STELLE DI NEUTRONI, KILONOVAE E FABBRICHE DELL'ORO

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What is a kilonova?

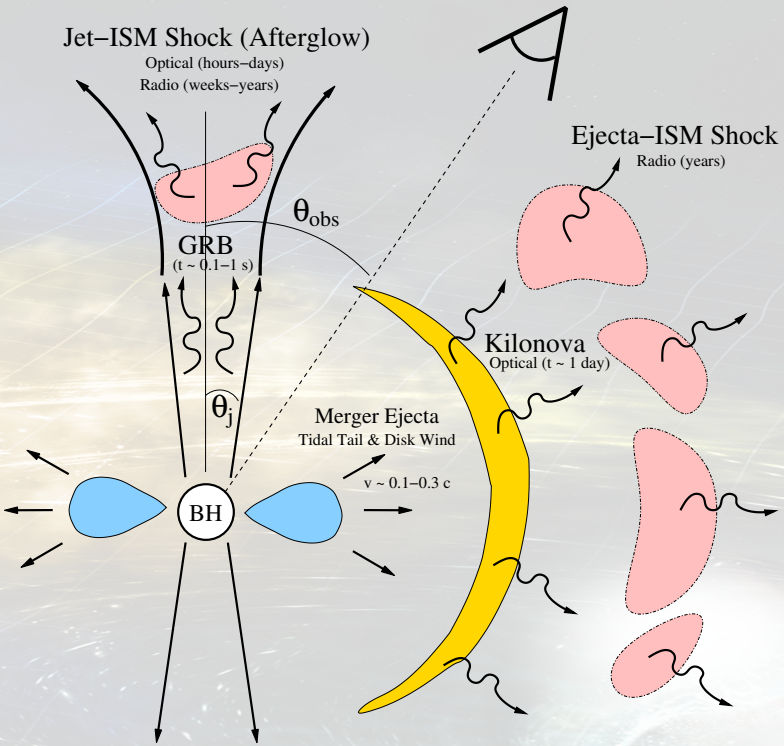


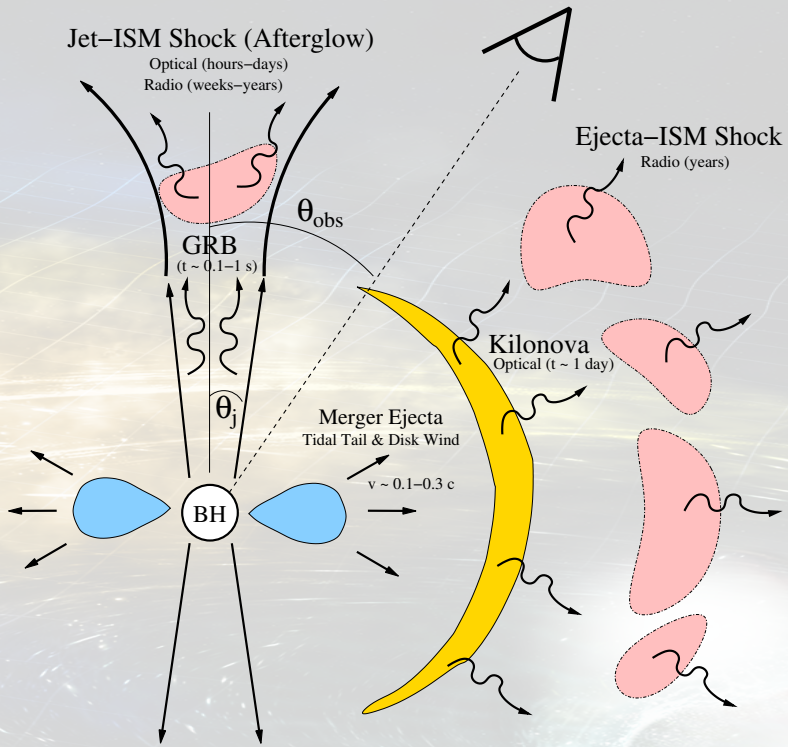
Image credit: Metzger & Berger 2012

- *Significant mass (0.01-0.1 $M_\odot$) is ejected during NS-NS NS-BH mergers at sub-relativistic velocity (0.1- 0.3 c)*
- *The neutron-rich ejecta undergoes rapid neutron capture (r-process) nucleosynthesis*
- *The radioactive decay of unstable nuclei powers a rapidly evolving, supernova-like transient: the* **"kilonova"**.

r-process: neutron capture much faster than beta decay; this requires special conditions:

$T > 10^9$ K, high neutron density 10^{22} cm^{-3}

What is a kilonova?



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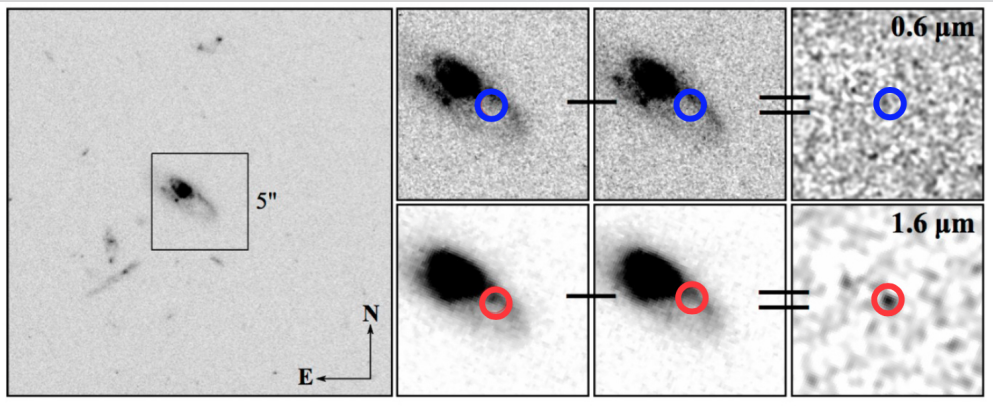
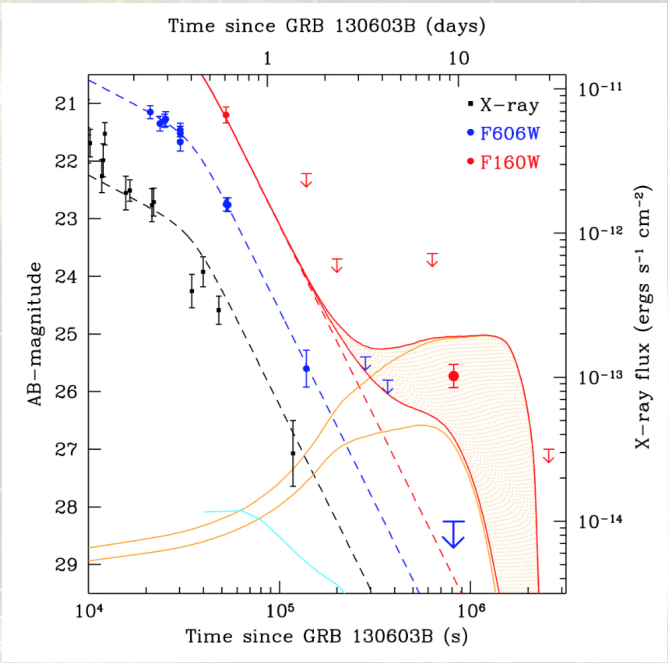
- *The interaction of the sub-relativistic outflow with the surrounding matter produces long lasting radio signals (years)*

A kilonova detection for GRB 130603B?



F606W/optical

NIR/F160W



- blue curve: optical afterglow
- orange curves: kilonova NIR model

  ejected masses:
  10^{-2} $M_\odot$ and 10^{-1} $M_\odot$
- cyan curve: kilonova optical model
- solid red curves:
  afterglow+kilonova

Tanvir et al, Nature, 500, 547 (2013)

AT 2017gfo:

the first spectroscopic identification of a kilonova associated with a GW signal and a short GRB

The optical transient AT 2017gfo

During the electromagnetic follow-up of GW170817, an **optical transient** (SSS17a/AT 2017gfo) has been discovered; the transient is located at $\sim 10''$ from the center of the galaxy NGC 4993, at a distance of 40 Mpc.

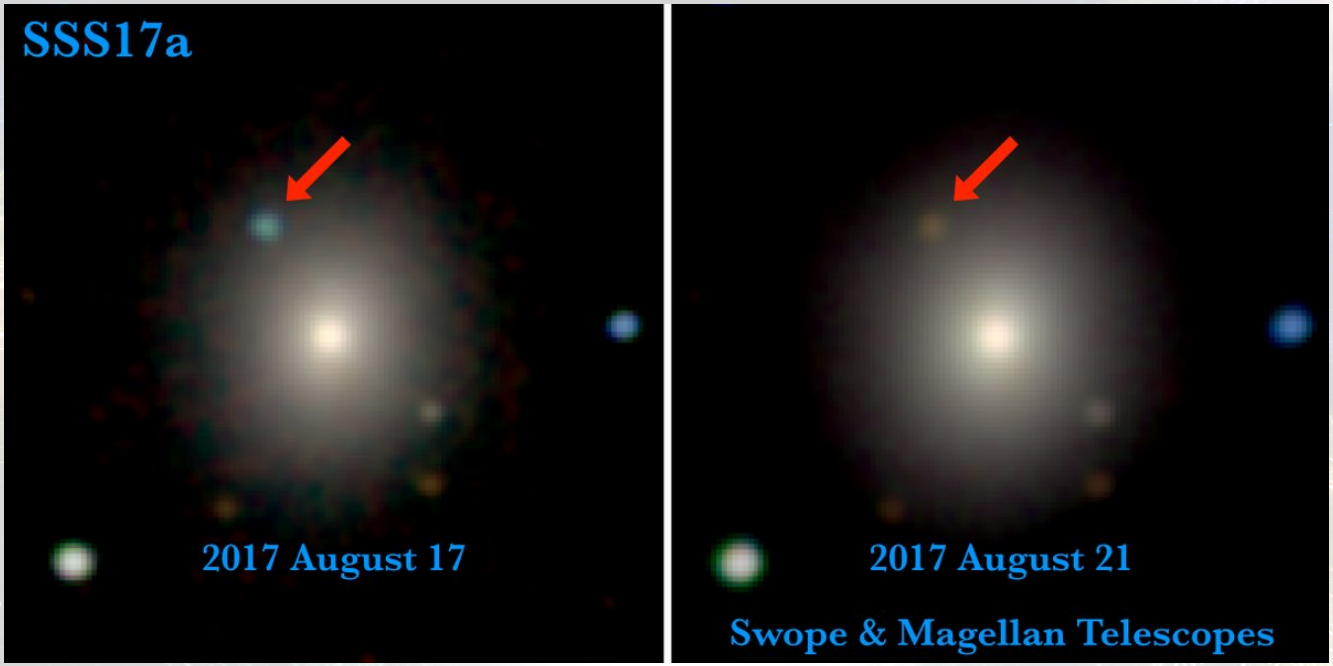
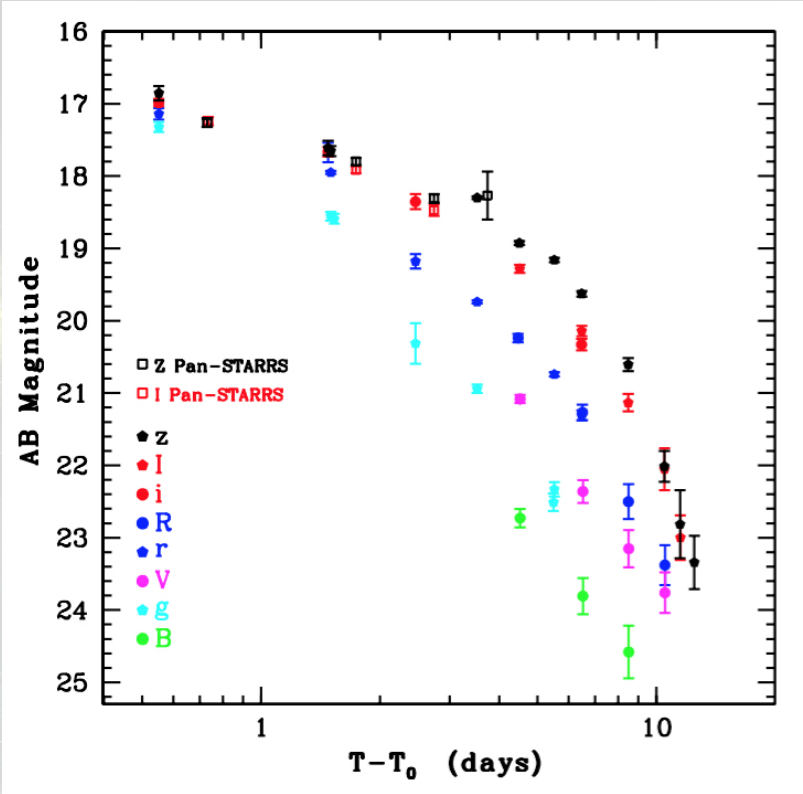


Image credit: 1M2H/UC Santa Cruz and Carnegie Observatories/Ryan Foley

The optical transient AT 2017gfo

The optical transient was later observed with different instruments

(REM, ESO-VST, ESO-VLT...)



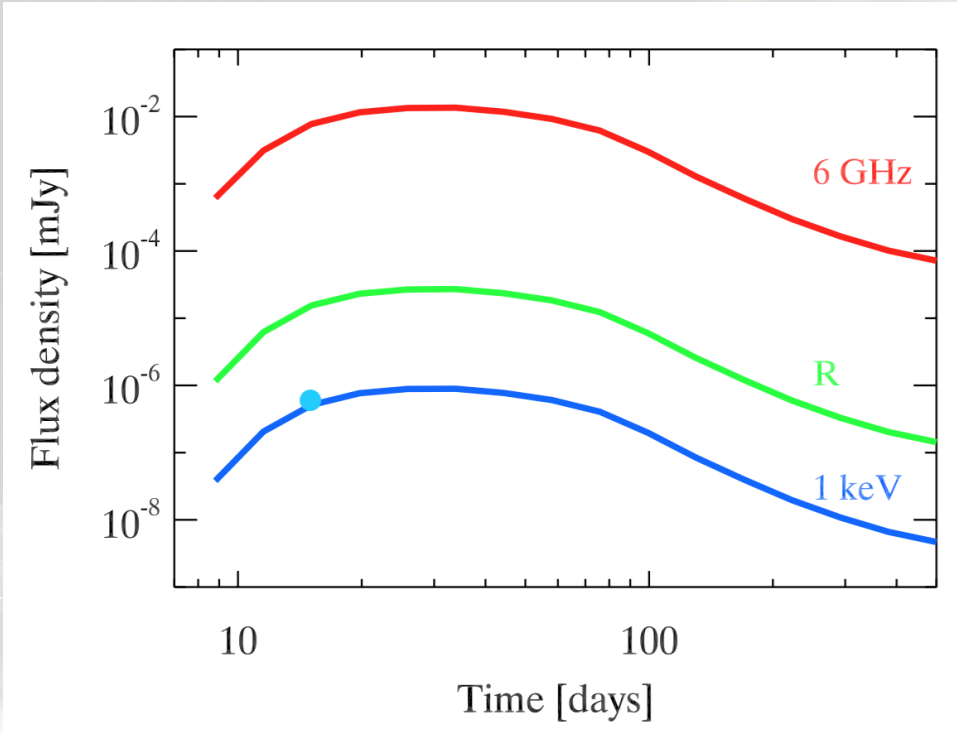
Pian et al., Nature, 2017

Could it be the optical afterglow emission?

- Chandra X-ray observation
  - X-ray source discovered 9 days after GW170817
  - consistent with afterglow emission seen off-axis

    Troja et al., Nature, 2017

Data have been used to evaluate the expected contribution in other energy bands ⇒



The predicted optical afterglow is much fainter than the observed optical emission

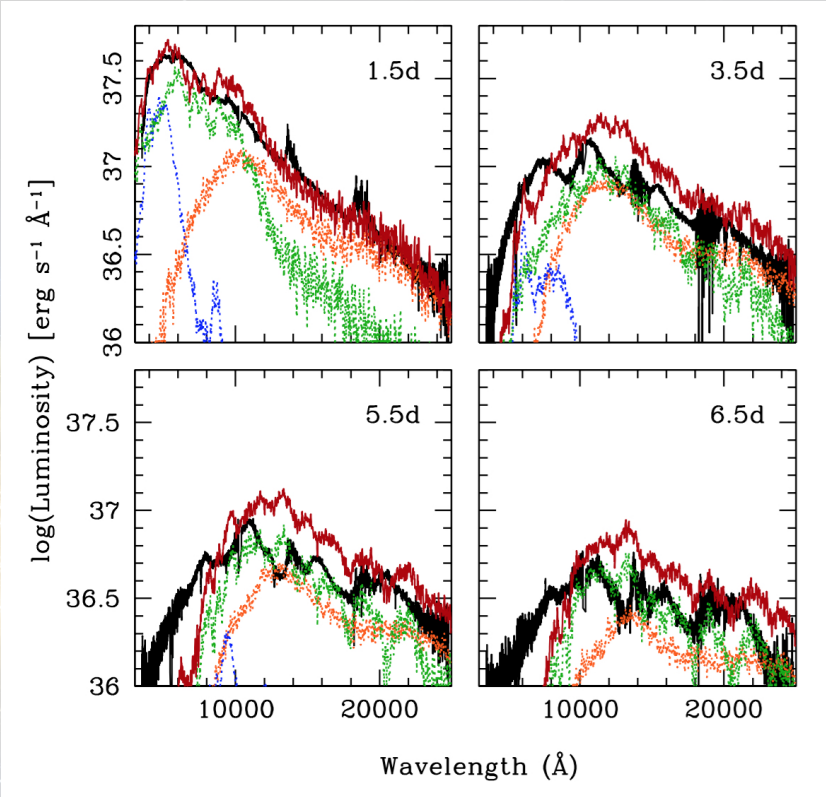
Pian et al., Nature, 2017

The spectroscopic identification of the kilonova

(Loading Video...)

Credit: ESO/E. Pian et al./S. Smartt & ePESSTO

The spectroscopic identification of the kilonova



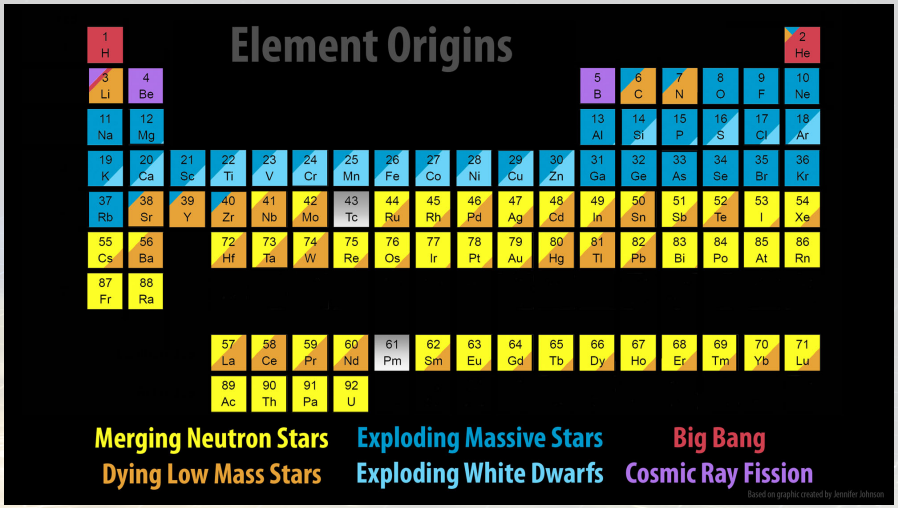
- observational data
- lanthanide-rich dynamical ejecta region
- wind region with mixed (lanthanide-free and lanthanide-rich) composition
- wind region with lanthanide-free composition
- sum of the three model components

(Models from Tanaka et al. 2017)

The evolution of the observed spectrum with time is in a good match with the expectations for kilonovae $\Rightarrow$ this is the first spectroscopic identification of a kilonova!

Pian et al., Nature, 2017

Kilonovae as cosmic gold mines



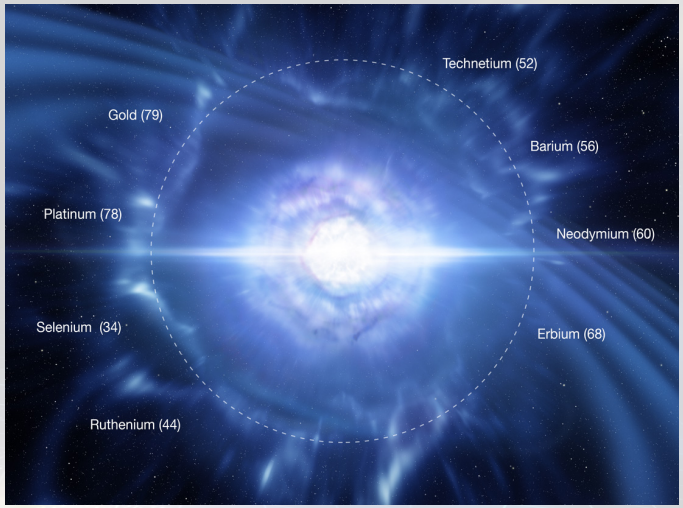


Image Credits:
Jennifer Johnson/SDSS/CC BY 2.0

Eso/L. Calçada/M. Kornmesser

Observations confirmed that kilonovae can build up the heaviest elements,

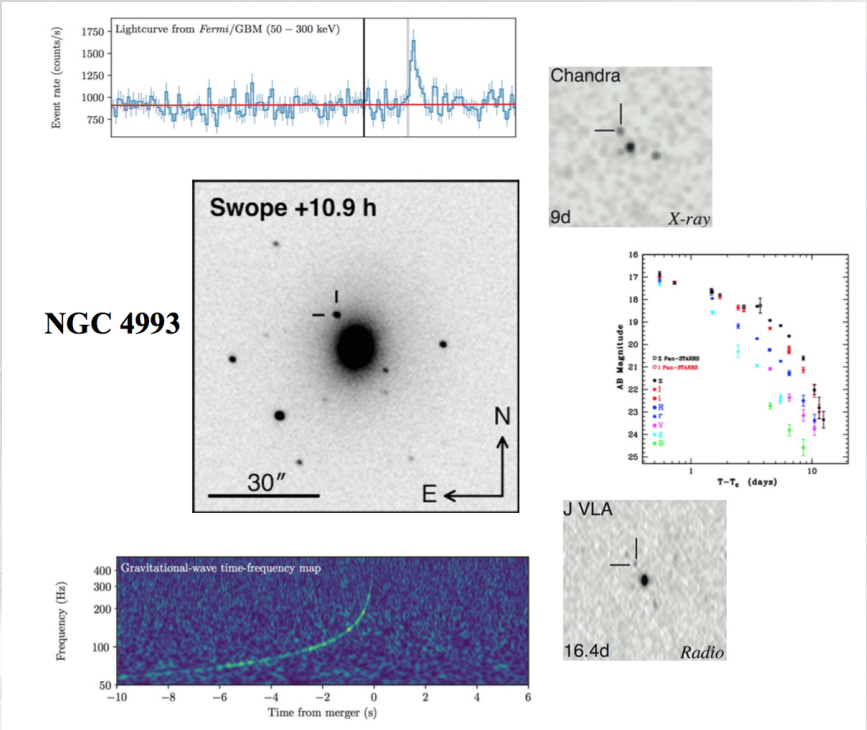
including gold and platinum!

Conclusions

The EM follow-up campaign led to many discoveries!

Among them, the kilonova:

- AT 2017gfo is the first spectroscopically identified kilonova
- AT 2017gfo is the first observation of a kilonova associated to both a short GRB and a GW event
- kilonovae produce heavy elements (gold, platinum...)



Multi-messenger astronomy has just begun,

many discoveries are expected in the near future!