GRB 170817A: some lessons and new questions from an historical event

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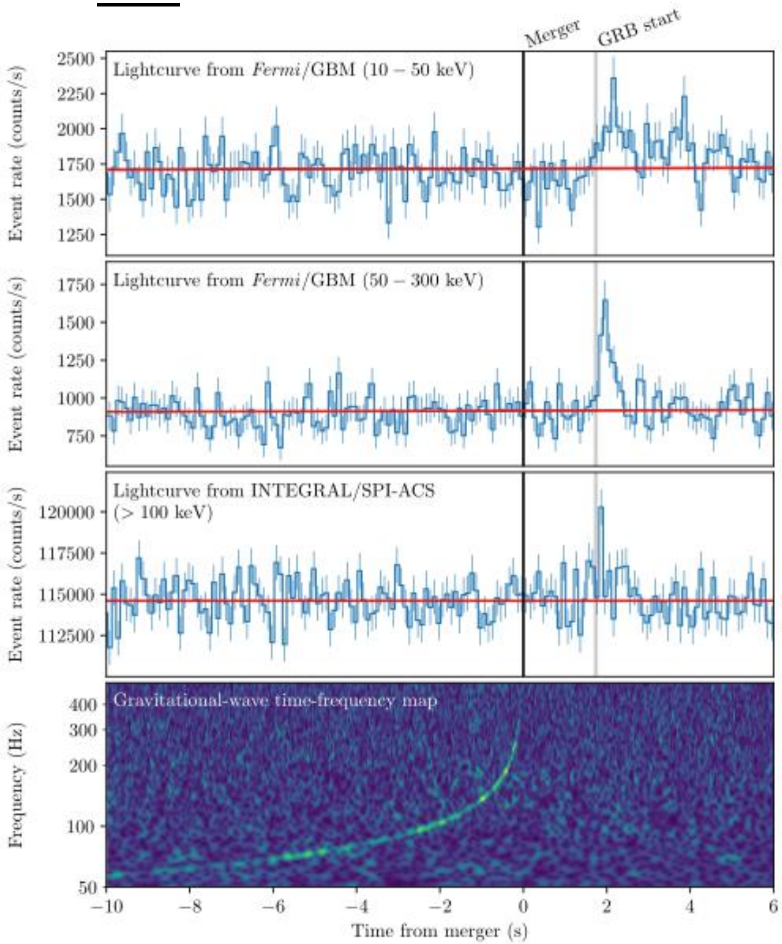
- **A (very) brief summary of the electromagnetic observations: GRB, KN, AG**

GRB



Starts 1.7 s after GW signal ; 1.5 s duration

Seen off-axis: $\theta_v < 28°$

GRB: photons above 100 keV
from 0 – 0.7 s : non thermal spectrum
followed by a thermal tail

Very underluminous: $L_p \sim 10^{47}$ erg/s
$E_{\gamma,iso} \sim 4\times10^{46}$ erg

→ outlier of $E_p - E_{iso}$ and $E_p - L_{iso}$ correlations

Kilonova

Very detailed set of observations:
rapid blue to red/infrared evolution
Global confirmation of theoretical scenario
(Bauswein and Goriely talks)

→ ejected material from the two merging NS

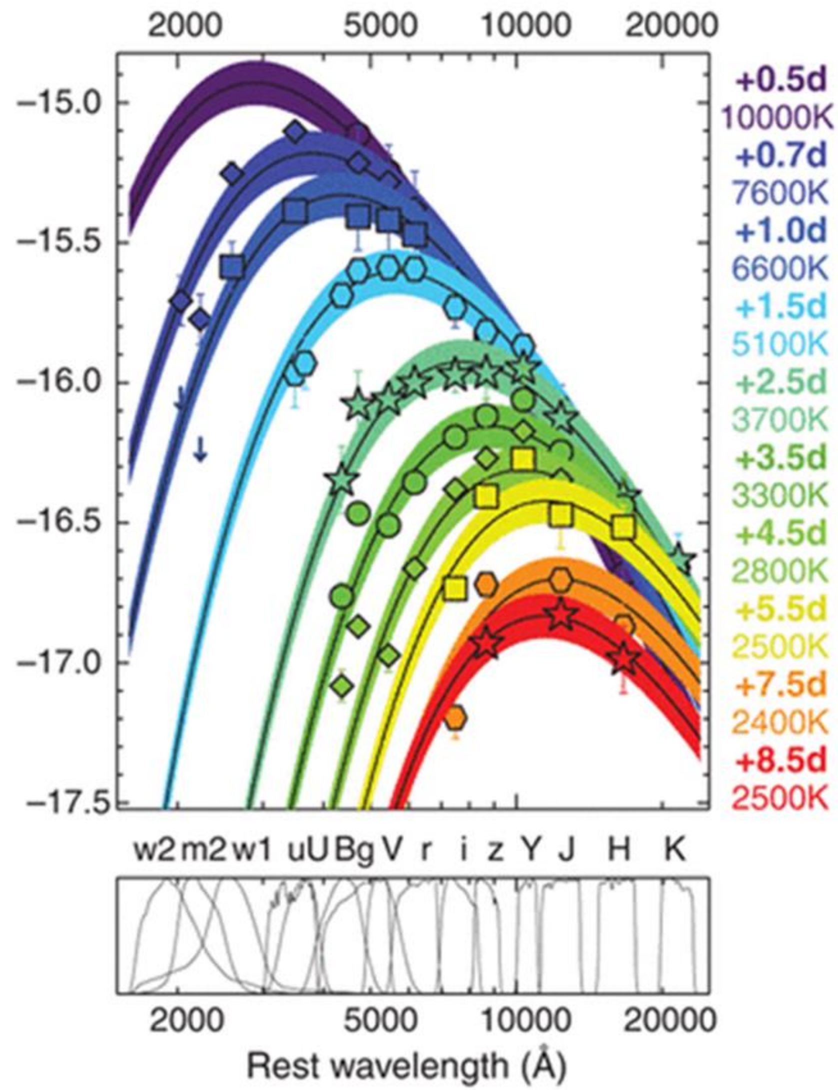
dynamical/wind components

r process elements

radioactive heating

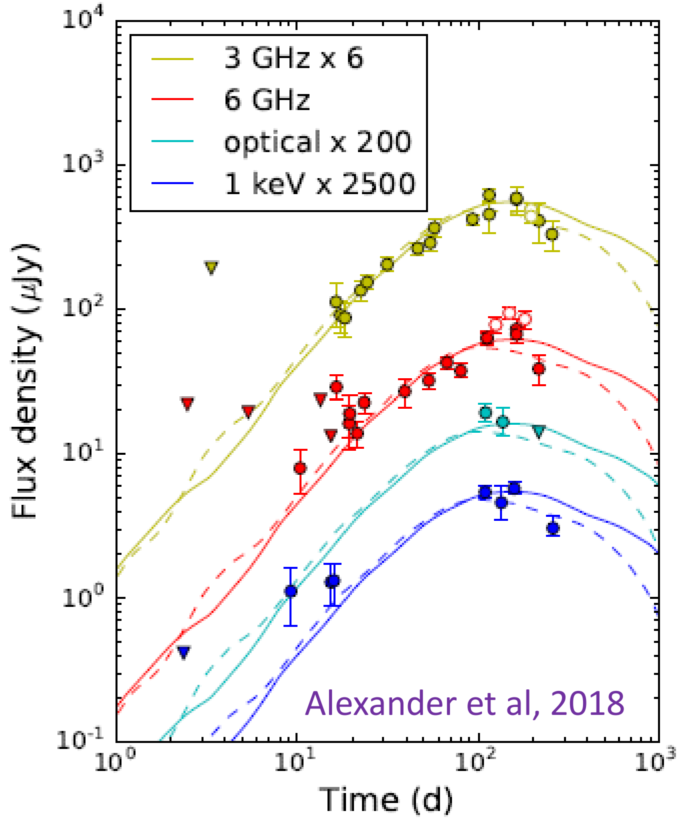
lanthanide opacity

$M_{KN} \sim 0.03 – 0.05\ M_{\odot}$; $v_{exp} \sim 0.1 - 0.2\ c$



Drout et al., Science, 2017

Afterglow



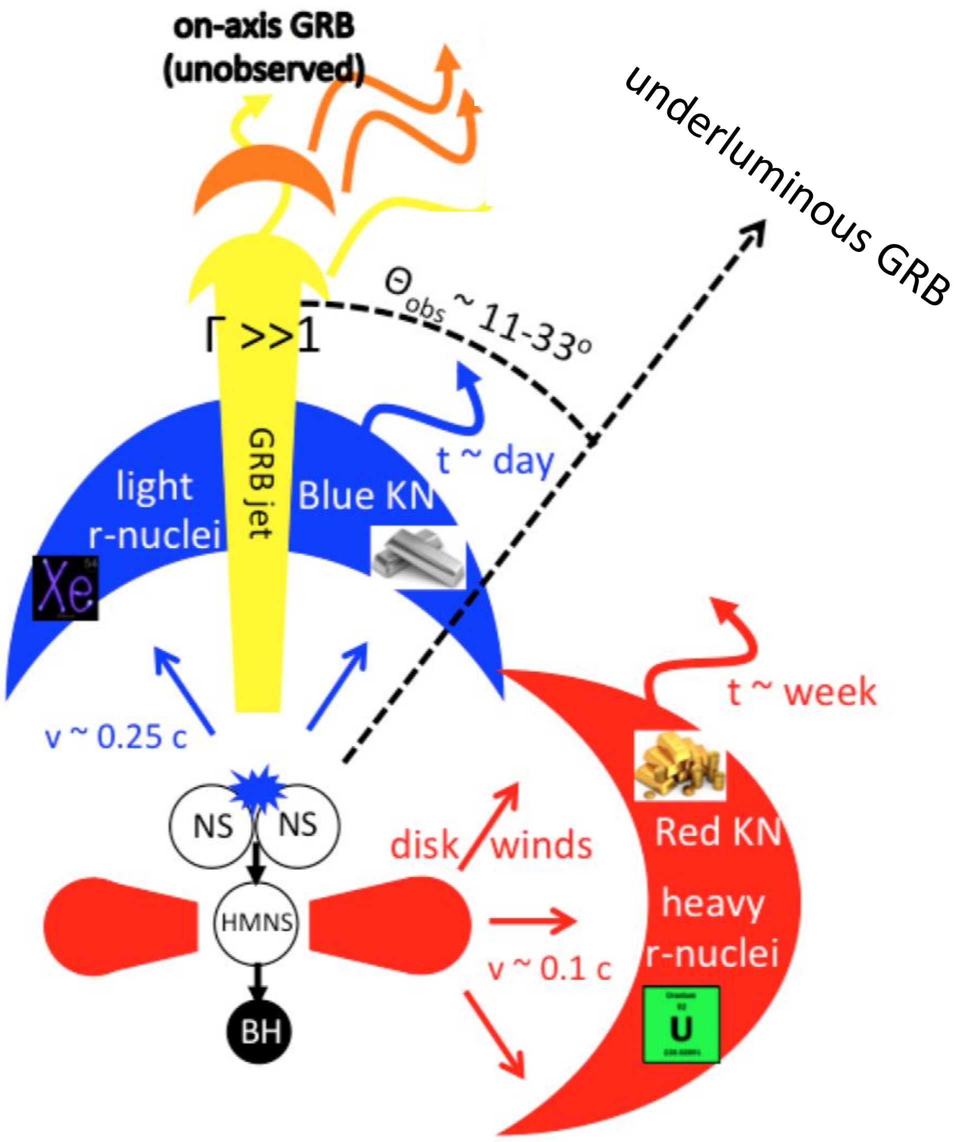
Homothetic light curves from radio to X-rays

→ same spectral regime: $\nu_m < \nu_{obs} < \nu_c$

Rise to maximum as ~ $t^{1.5}$

Decline confirmed at 250 days

General picture (adapted from Metzger)



- **A few questions**

➢ Nature of the central remnant: black hole or massive neutron star ?

GW data not conclusive → clues from electromagnetic observations ?

➢ Was there a central (along system axis) luminous GRB ? ($L_\gamma \gtrsim 10^{51}$ erg/s) ?

or was the jet chocked ?

➢ Which scenario for the underluminous GRB ?

What it cannot be: a regular GRB, simply seen off-axis .

Then, is it:

- just a special case of an usual scenario (IS, reconnection, photospheric) with different input parameters (energy, Lorentz factor) or should one invoke
- a different scenario: shock breakout from the cocoon (Nakar, Piran et al.)
  diffusion of photons from the central GRB ? (Kisaka et al. 2018)

➢ Origin of the kilonova components ?

➢ Was the afterglow dominated by emission from material along the line of sight ?

Or was the whole cocoon contributing ?

- **Addressing (some of) the questions**

➢ Which scenario for the underluminous GRB ?

- A special case of an usual scenario: the example of internal shocks

$$E_p \propto \frac{\dot{E}^{1/2}\,\varphi(\kappa)}{\tau\Gamma^2}$$

$\dot{E}$: injected power in the flow ; τ: duration

Γ : Lorentz factor ; κ: contrast in the distribution of Γ

→ it is possible (i) to produce gamma-rays and (ii) to stay transparent
if the Lorentz factor is decreased from ~ 100 to 10
while the injected power is reduced by 4 orders of magnitude
(cf. DM 2002 model for GRB 980425)

- ICMART, photospheric models (see Meng et al., 2018)

- A specific scenario for underluminous GRB: energy released at shock breakout (Bromberg et al., 2018; Nakar et al., 2018)

Initially out of equilibrium: → non thermal to quasi-thermal spectrum

- The afterglow: disentangling radial and/or angular structure of the outflow

What it cannot be:

- the afterglow from the central jet: essentially no flux as long as $1/\Gamma > (\theta_v - \theta_j)$
  then rise much steeper than observed
- the afterglow from a single (mono Γ), spherical shell

Then, two limiting cases:

(i) afterglow dominated by the emission of material along the line of sight (quasi sph. appr.)
$\rightarrow$ ejecta should be radially structured (slower material progressively catching up)

(ii) afterglow resulting from contributions from the whole cocoon
as the angle with the line of sight increases, the contribution is delayed
and more power should be injected
$\rightarrow$ ejecta should be laterally structured

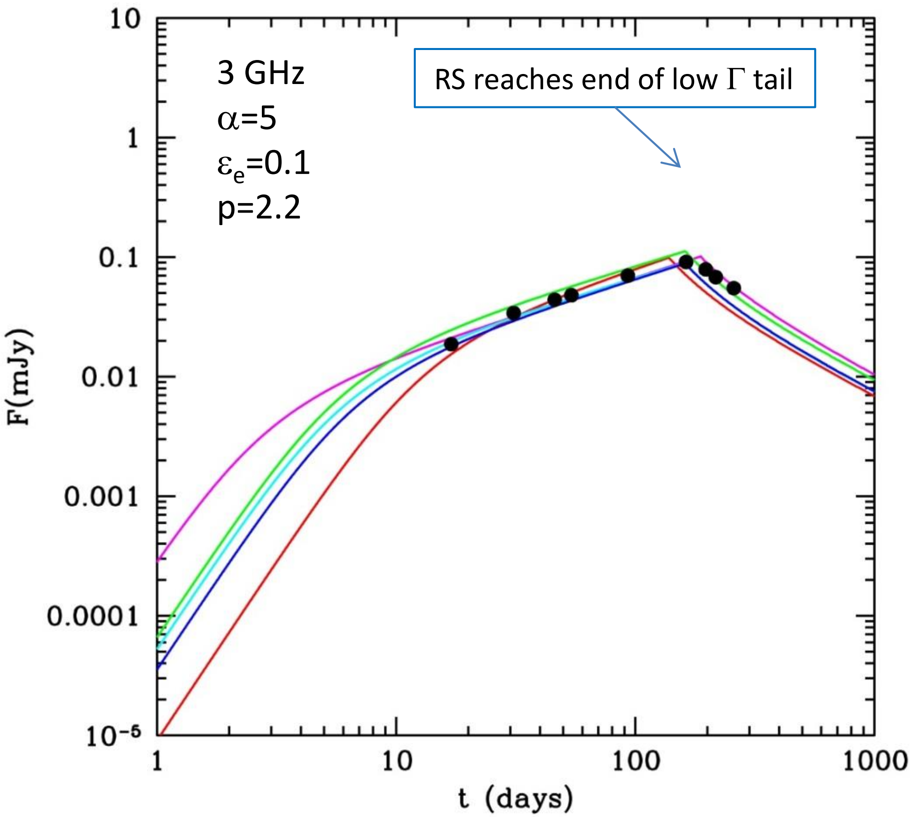
Both radial and angular structure are probably present !

(i) afterglow dominated by the emission of material along the line of sight

- ejecta characterized by: E, $(\beta\Gamma)$min, $(\beta\Gamma)$max, α
- shock physics, radiative processes: ε_e, ε_B, p
- external medium: n

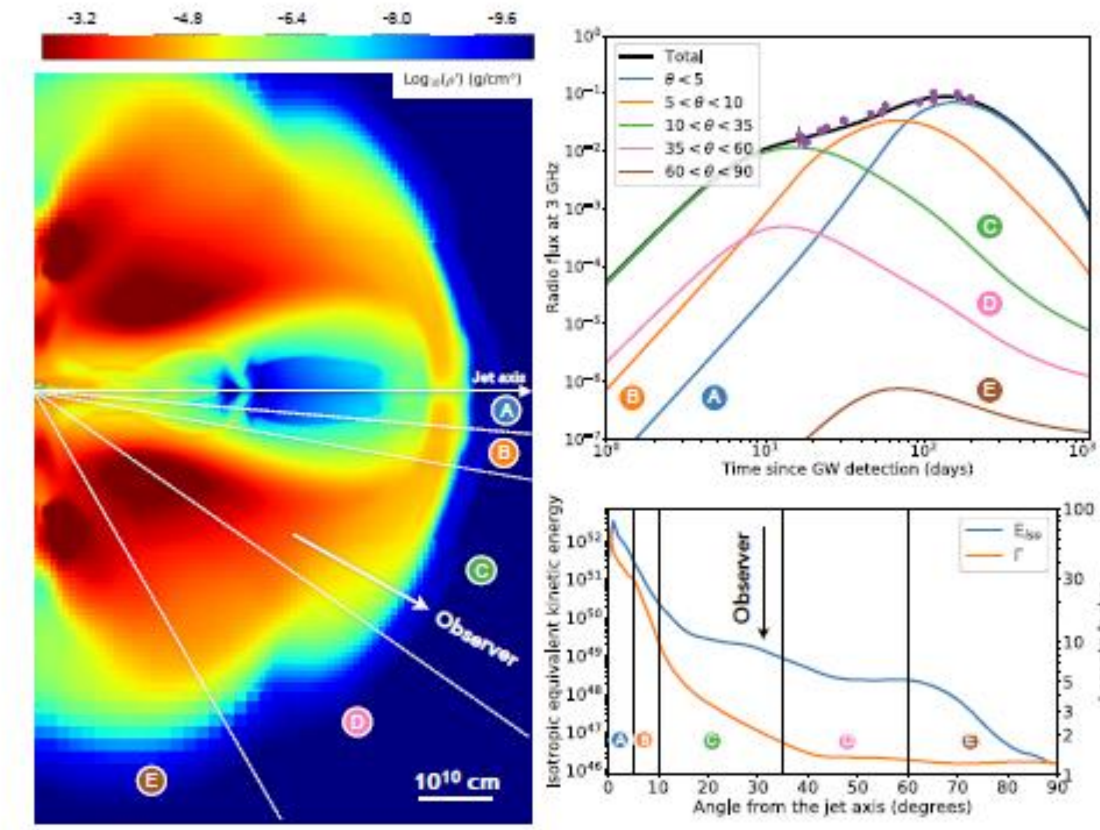
Fitting the data: many possible solutions (multi-λ does not help, except for p)

Multi-λ does not help, except for p: $\nu_m<\nu_{obs}<\nu_c$ from radio to X-rays



E_{50}	$(\beta\Gamma)_m$	$(\beta\Gamma)_M$	n	ε_B	
0.56	1.0	2.0	$3\ 10^{-3}$	10^{-2}	red
1.0	0.79	2.5	10^{-2}	$3\ 10^{-3}$	magenta
1.78	1.26	3.2	10^{-3}	$3\ 10^{-3}$	cyan
3.16	1.0	2.5	10^{-2}	$3\ 10^{-4}$	blue
5.62	1.26	3.2	$3\ 10^{-3}$	$3\ 10^{-4}$	green

(ii) afterglow resulting from contributions from the whole cocoon



(Lazzati et al., 2018)

As $(\theta-\theta_v)$ increases
the contribution from θ is delayed
and more energy is needed.

The central jet contributes at
at 100+ days

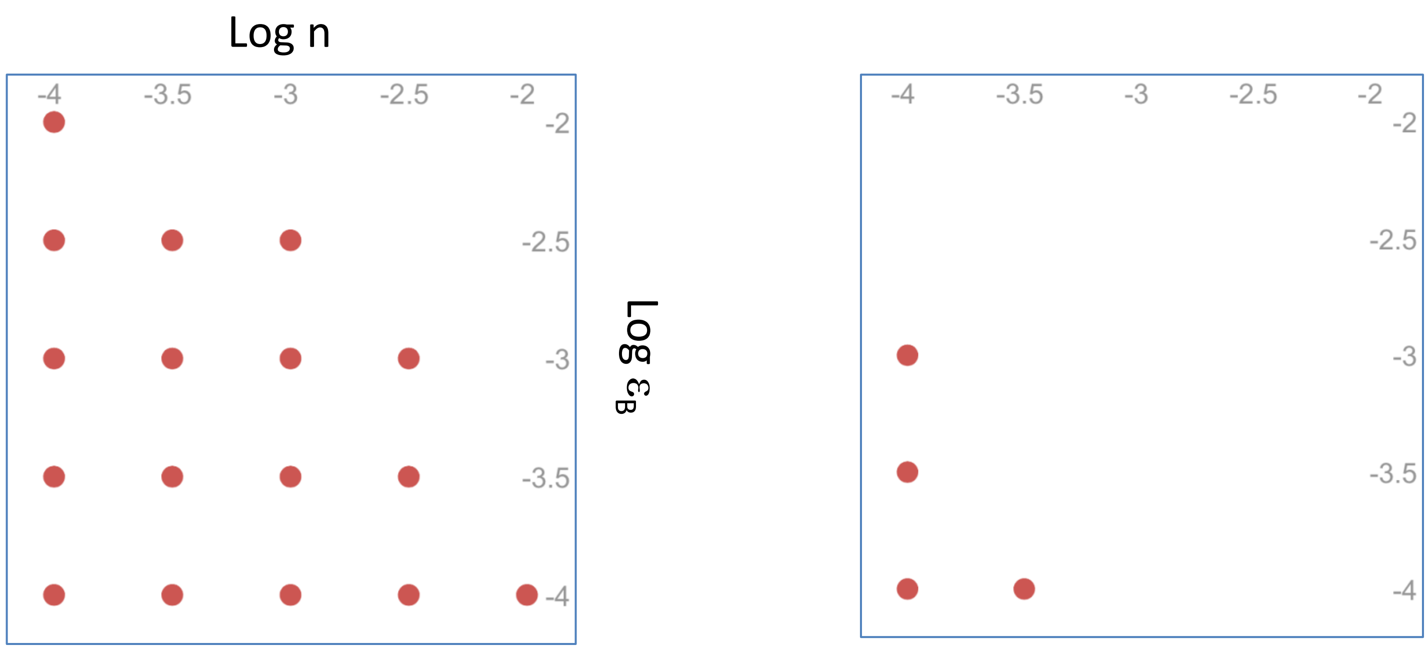
$\rightarrow$ $E_{iso} \gtrsim 10^{52}$ erg on axis

Large polarization expected
at one year (Gill & Granot, 2017)

(iii) Hiding the central jet ?

Suppose that the afterglow is dominated by the emission of material along the line of sight

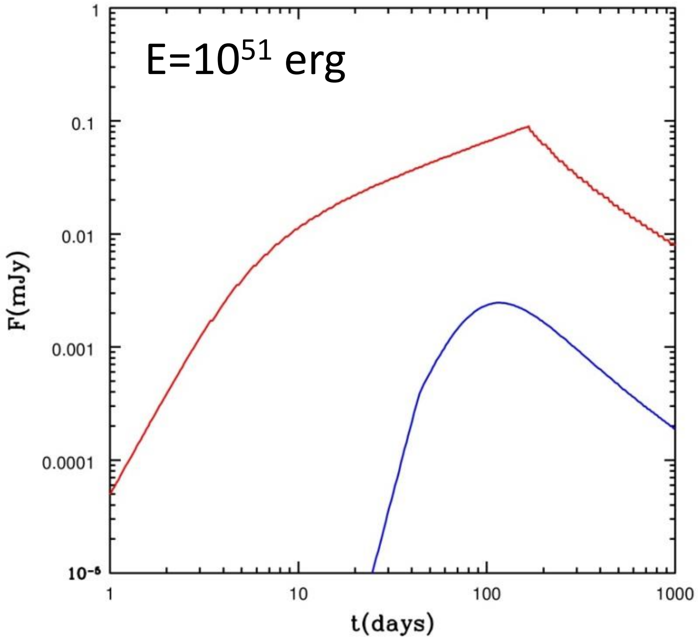
Constraints for the central jet to be hidden (θ_j=5°, θ_v=25°, ε_e=0.1)

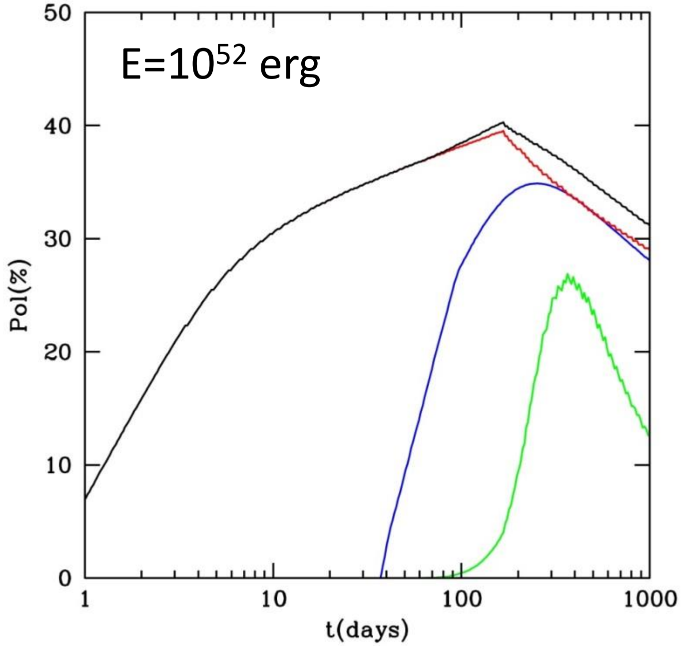


$E_j=10^{51}$ erg $E_j=10^{52}$ erg

The smaller the viewing angle, the harder it is to hide the jet

Examples





Maximum polarization: 28% at ~ one year

Quasi spherical afterglow + jet

θ_v=25°, n=10^{-3} cm^{-3}, ε_B=10^{-3}

- **Conclusion and perspectives**

What can we expect from future events? Intrinsic/viewing angle diversity

- intrinsic diversity: a BH + NS event? Different dynamical or/and radiative parameters (moderate for NS + NS events?)
- environment diversity: n
- viewing angle diversity: P(0-30°) ~ 0.23 ; P(30-60°) ~ 0.42 ; P(60-90°) ~ 0.25

We were lucky with the first event at 40 Mpc with a full display: GW – KN – GRB – AG !

→ 3D view after many events !

GRB and afterglow brightness as a function of viewing angle depends on cocoon extension and energy distribution

→ probably no GRB at all (or no detectable GRB) and afterglow beyond a certain viewing angle

Wait 2019 for the next episode !