Radio and X-rays from GW170817: the show is still on

NORTHWESTERN UNIVERSITY

Raffaella Margutti

CIERA

Sources of X-rays/Radio

Credit: NASA's Goddard Space Flight Center/CI Lab

Sources of X-rays/Radio

Relativistic Jets
Radio-to-Xrays

Cocoon

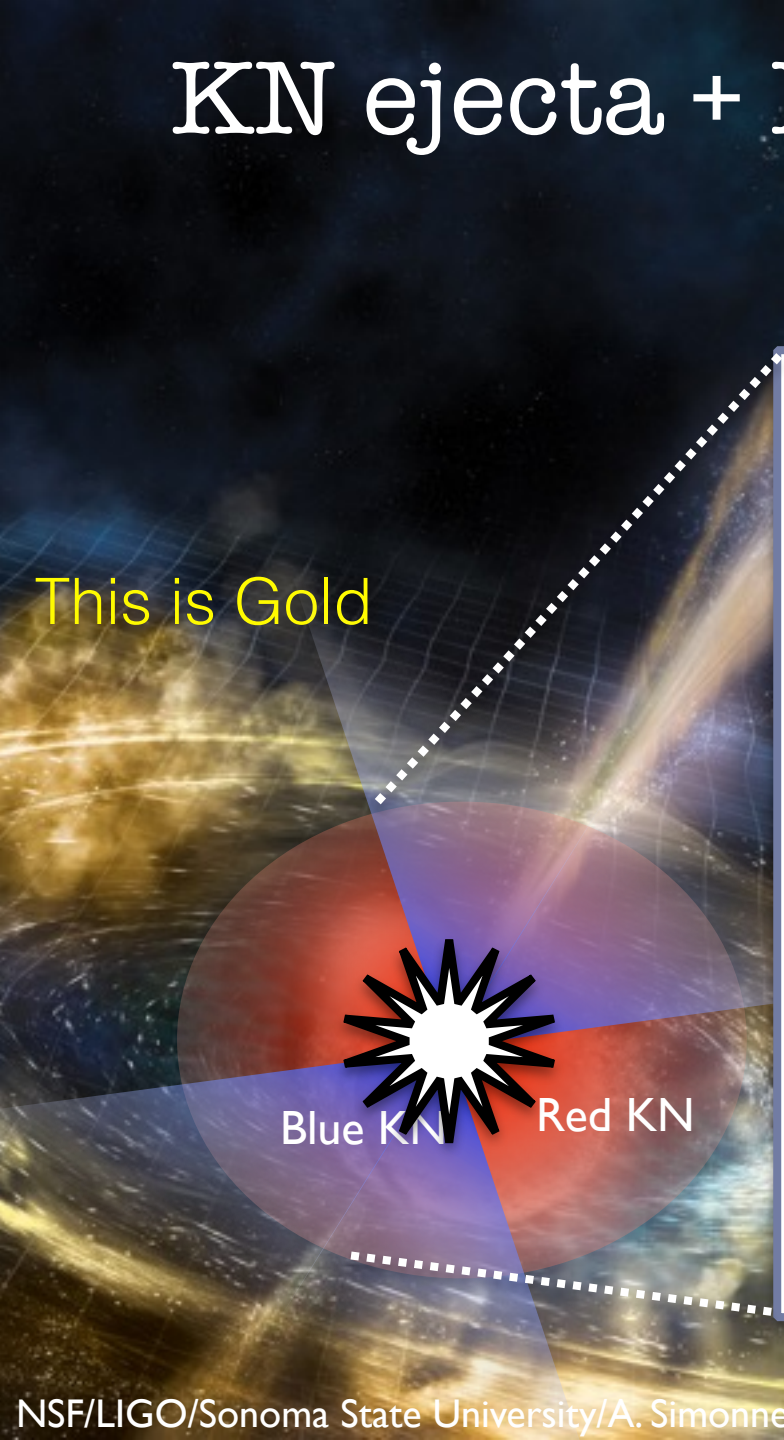
Central Engine

Credit: NASA's Goddard Space Flight Center/CI Lab

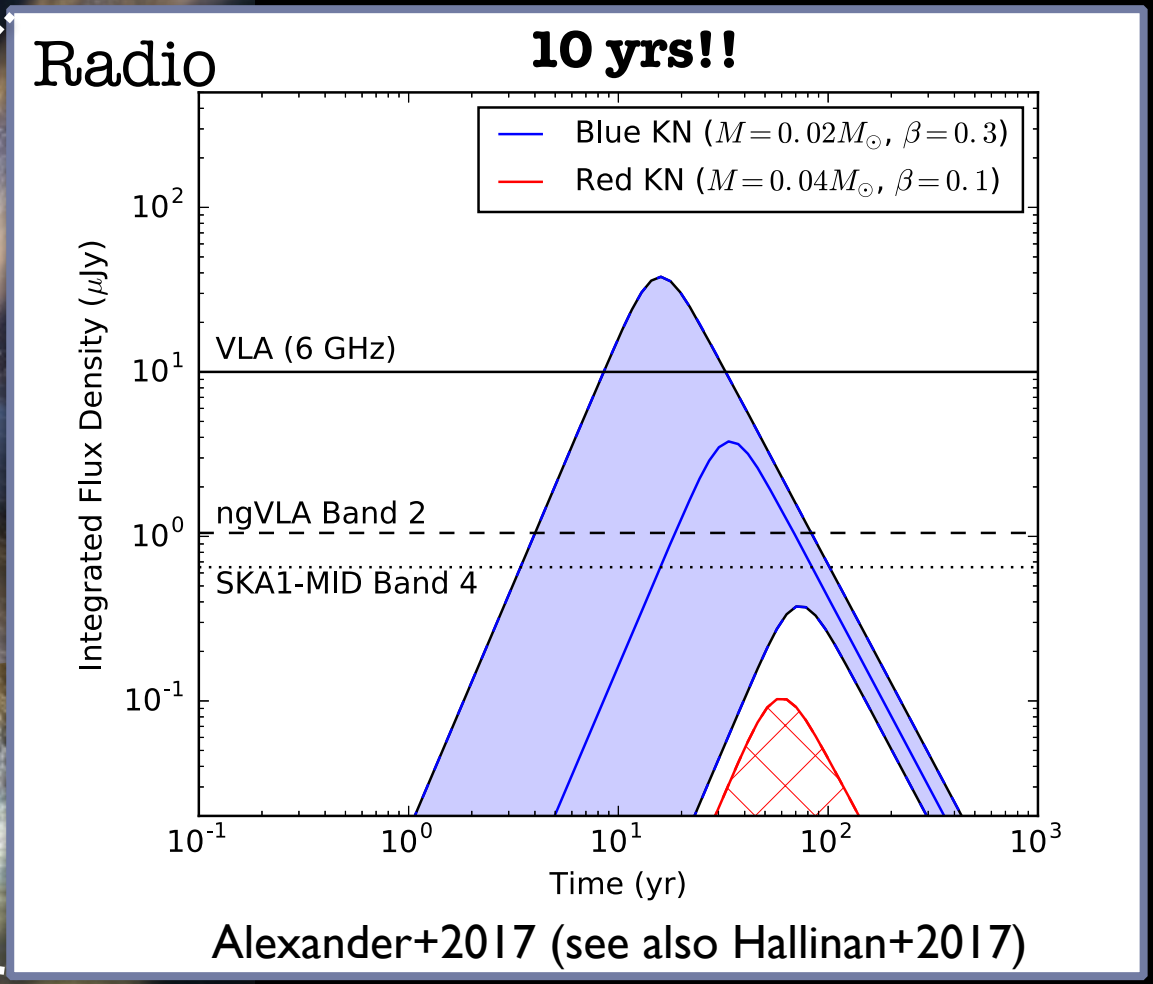
Merger + Environment

KN ejecta + Engine @ t<40 days

This is Gold



NSF/LIGO/Sonoma State University/A. Simonnet



Alexander+2017 (see also Hallinan+2017)

Sources of X-rays/Radio

Relativistic Jets
Radio-to-Xrays

Credit W. Fong

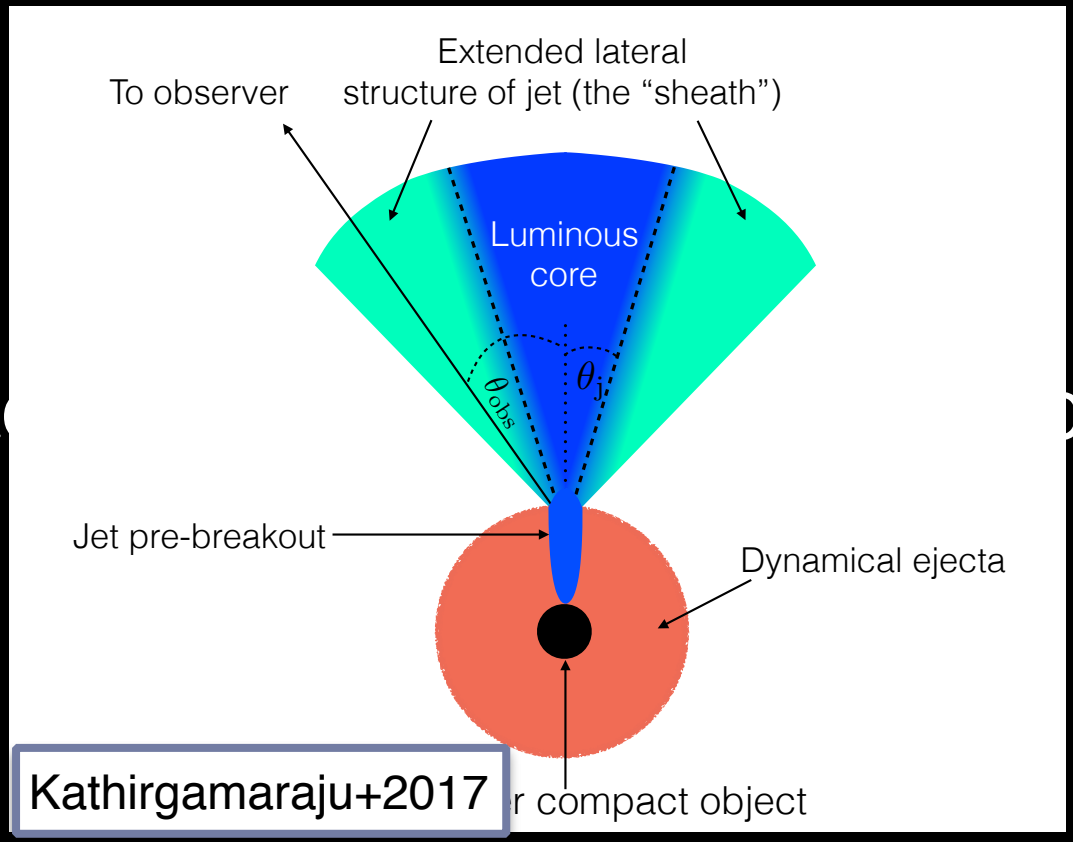
Cocoon
(mildy relativistic,
not strongly collimated)

Credit W. Fong

Credit: NASA's Goddard Space Flight Center/CI Lab

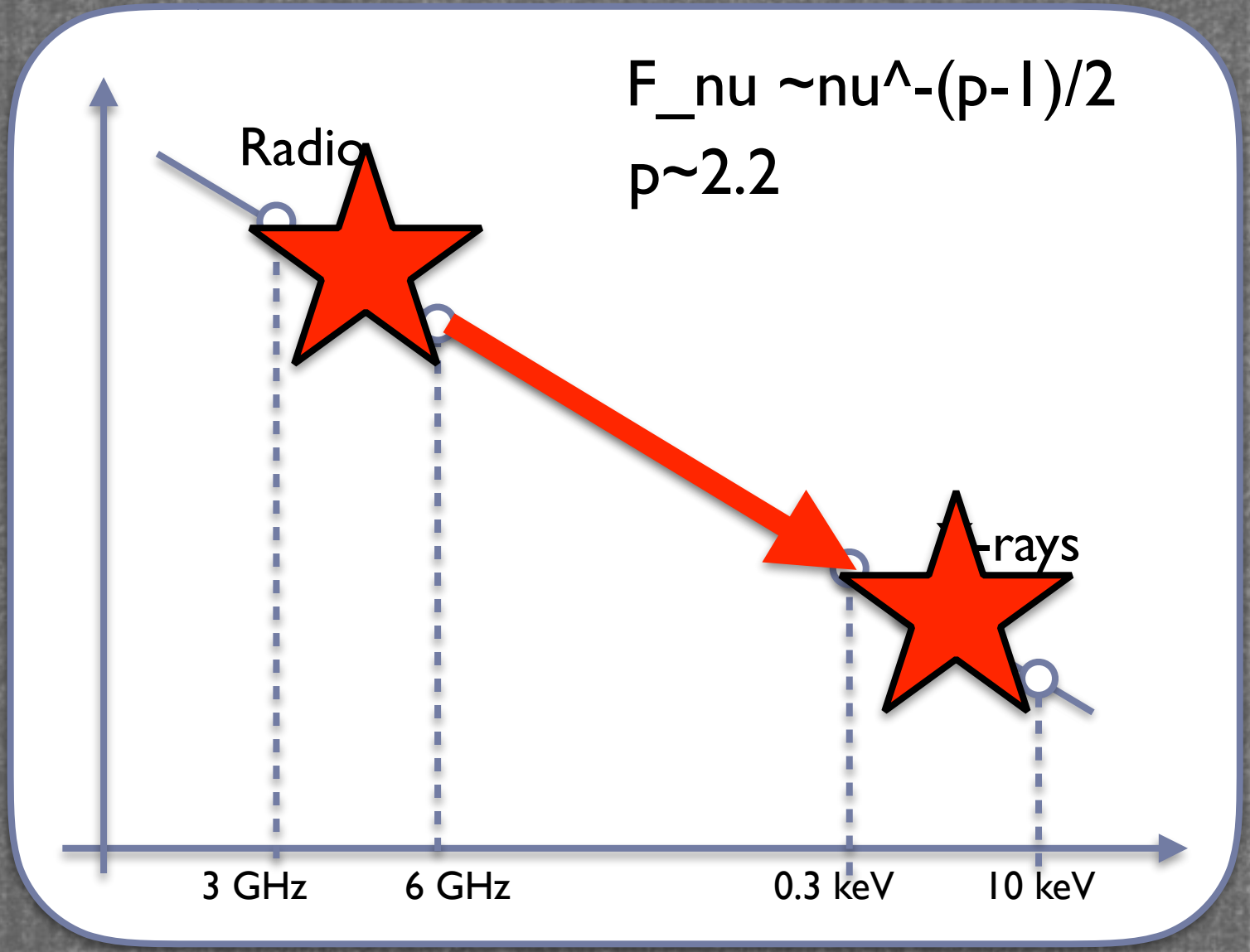
Structured jets models need to be given a chance

The n o settle



Kathirgamaraju+2017

Radio-to-Xrays SED



This is NOT unique to a particular model

Science with ZERO photons

Timeline of our EM follow-up: The first 72 hours

12 hr: Optical discovery

GW trigger

1

2

3

13.7 hr: First radio observations

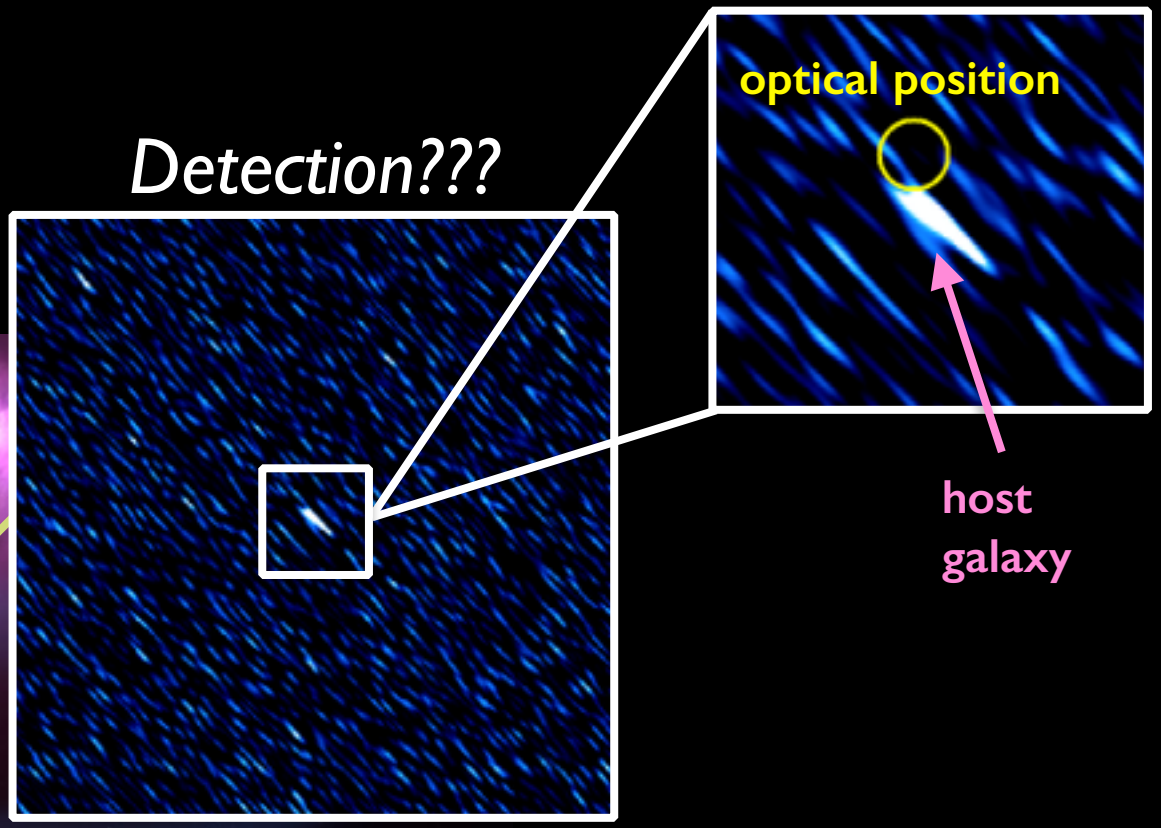
Slide courtesy W. Fong

What we did **NOT** see:

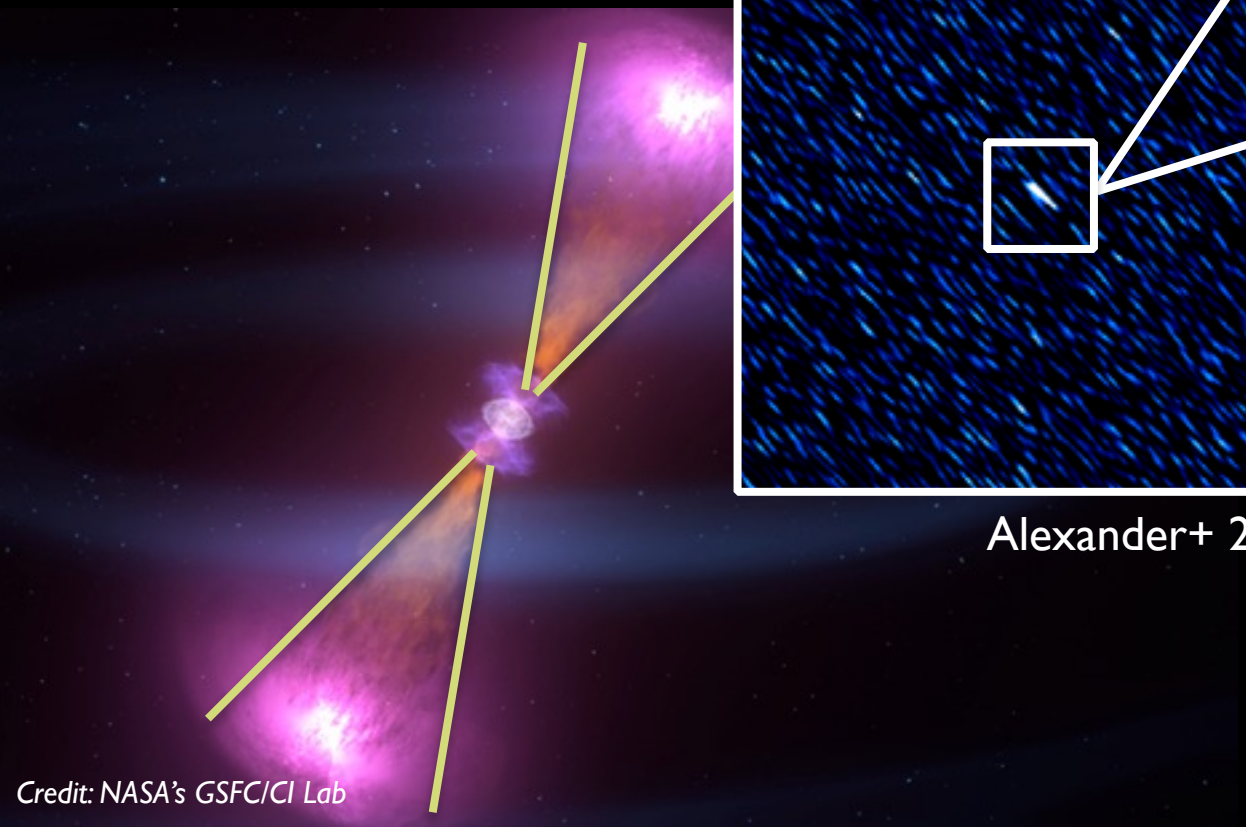
Radio

Look closer…

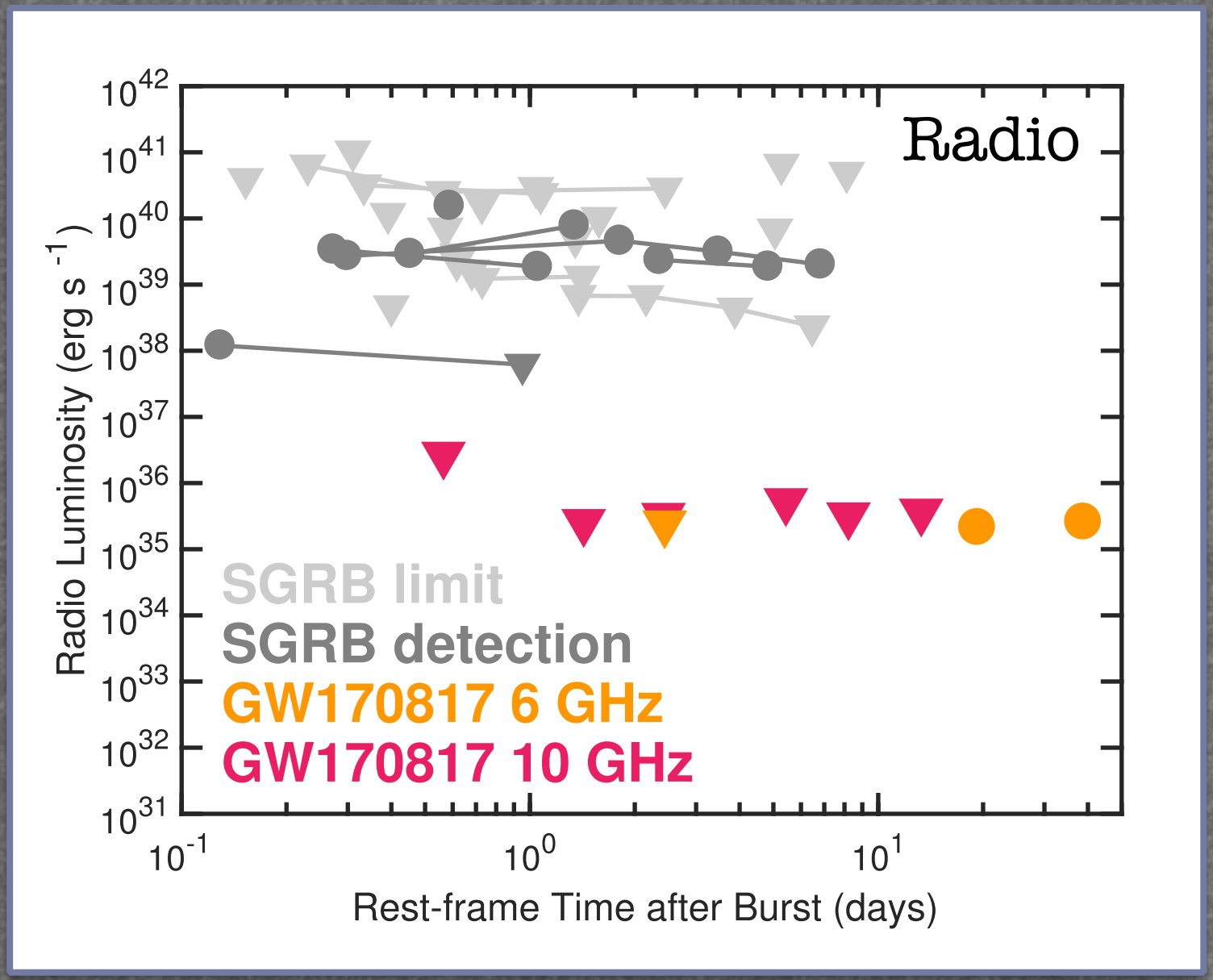
Detection???



Alexander+ 2017



Credit: NASA's GSFC/CI Lab



Fong, .. Margutti+ 2017

Timeline of our EM follow-up: The first 72 hours

12 hr: Optical discovery

1.5 days: First optical and near-infrared spectra

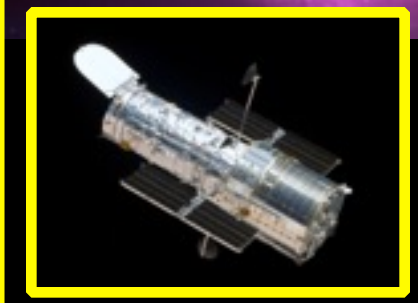
GW trigger

1

2

3

13.7 hr: First radio observations



Slide courtesy W. Fong

Timeline of our EM follow-up: The first 72 hours

12 hr: Optical discovery

1.5 days: First optical and near-infrared spectra

GW trigger

1

2

3

13.7 hr: First radio observations

2.4 days: First, deep X-ray observations

Slide courtesy W. Fong

Chandra X-ray Observatory

0.5-8 keV

T=2.4 days

1.5 arcsec

PI: Fong

Margutti, ..Fong et al., 2017

Extremely important non-detection

Timeline of our EM follow-up: The first few weeks

GW trigger

9 days

20 days

30 days

9-15 days: X-rays come into view!

Margutti, ..Fong et al., 2017
Haggard, et al., 2017
Troja et al., 2017

T=15 days

Chandra

0.5-8 keV

1.5 arcsec

GW170817

Margutti, ..Fong et al., 2017

Timeline of our EM follow-up: The first two weeks

SUN block!

GW trigger

9 days

15 days

20 days

30 days

9-15 days: X-rays com into view!

Margutti, ..Fong et al., 2017
Haggard, ..Kalogera, et al., 2017
Troja et al., 2017

16 days:
Radio comes into view!

Alexander, ...Fong, Margutti +2017
Hallinan+2017

GW trigger

9 days

15 day

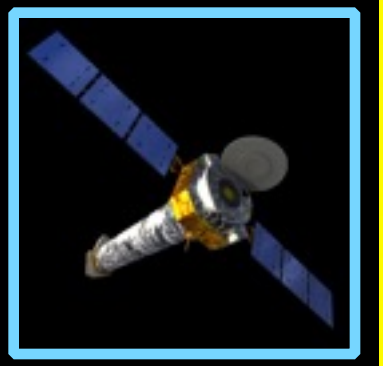
days

30 days

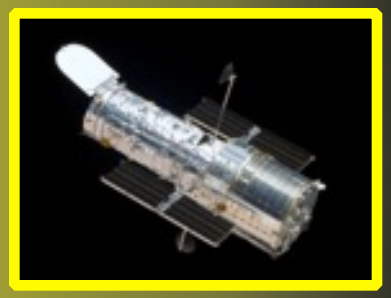
9-15 days:
X-rays come into view!

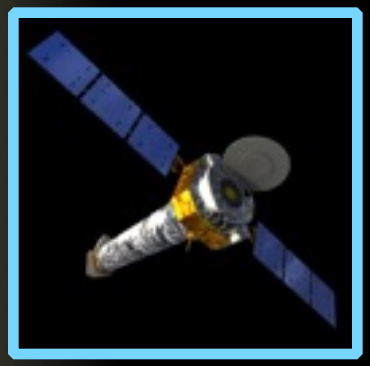
Margutti, ..Fong et al., 2017
Haggard, ..Kalogera, et al., 2017
Troja et al., 2017

The FUTURE of our EM follow-up:



SUN block!





GW trigger

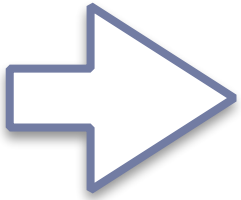
9 days

15 days

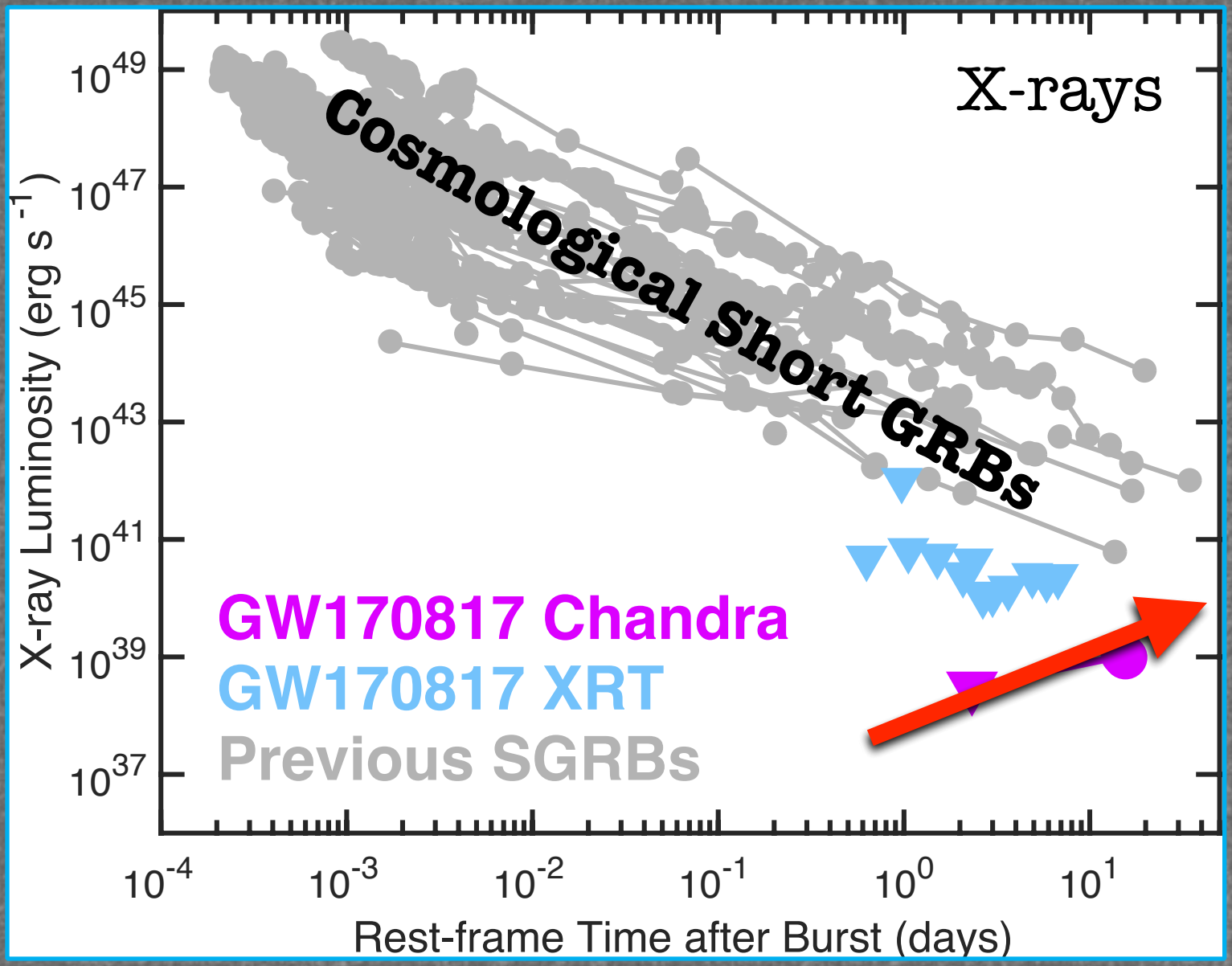
100days

GW170817 is still ON in X-rays and radio!

Deep non-detection followed by a detection on t~10 days

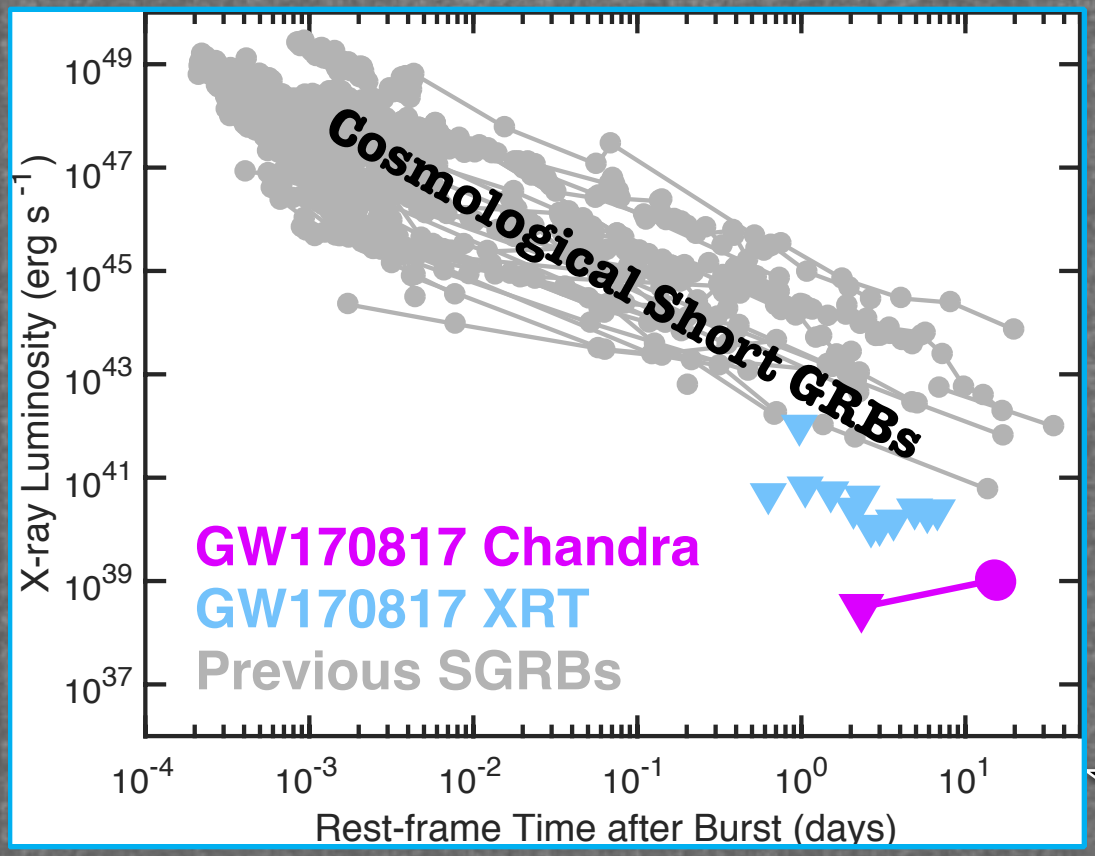


Radio and X-rays **RISING** with time!



Fong, .. Margutti+ 2017

Properties to explain (X-rays):



★ Rising X-ray emission (importance of zero-photon science!)

★ Mild rise,

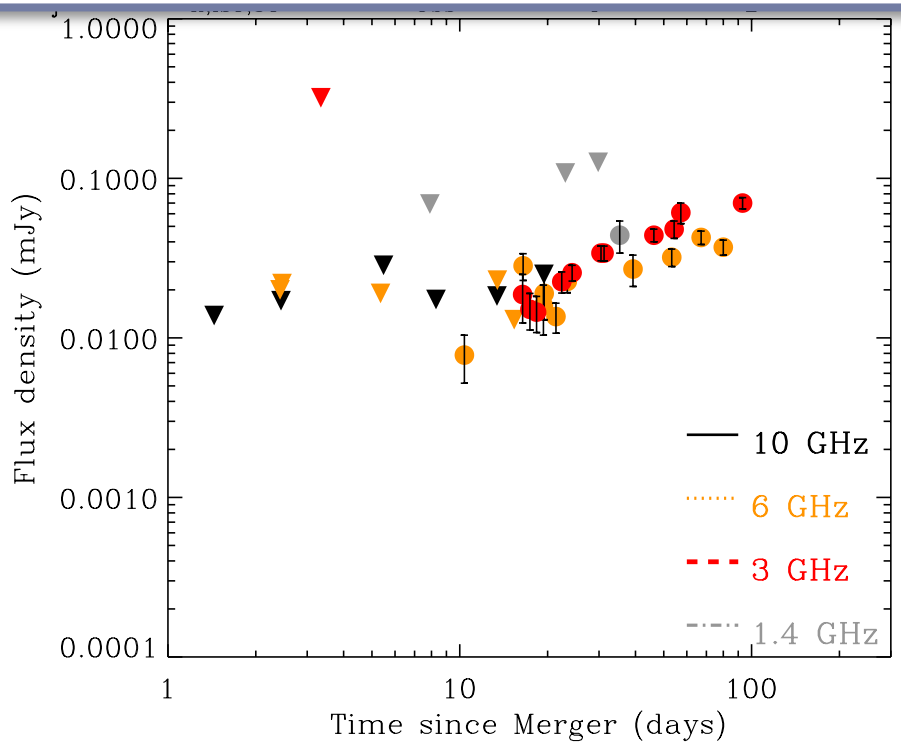
★ Lx~10^39 erg/s

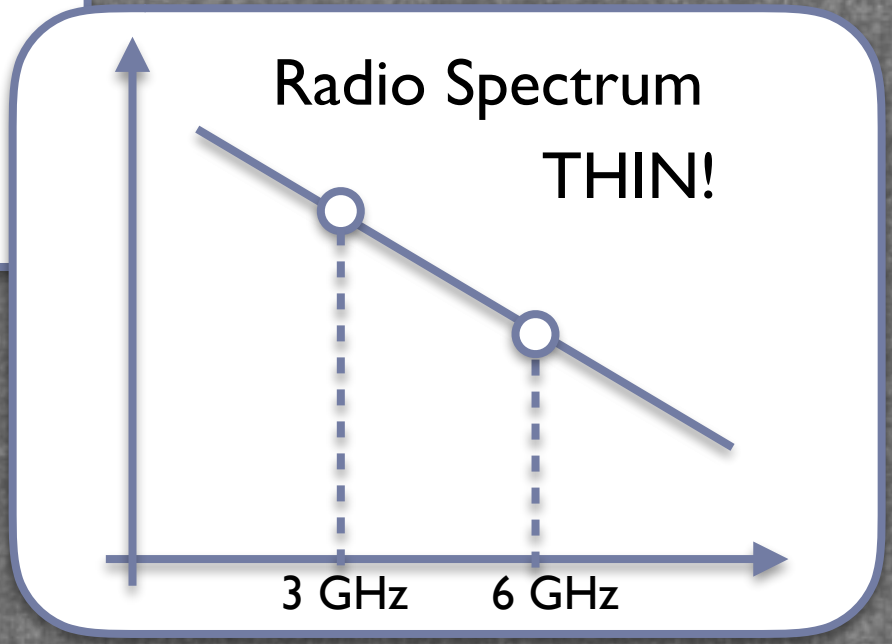
★ Hard spectrum with Gamma~1.5 (beta~0.5)

★ Radio-to-Xray SED also implies beta~0.5

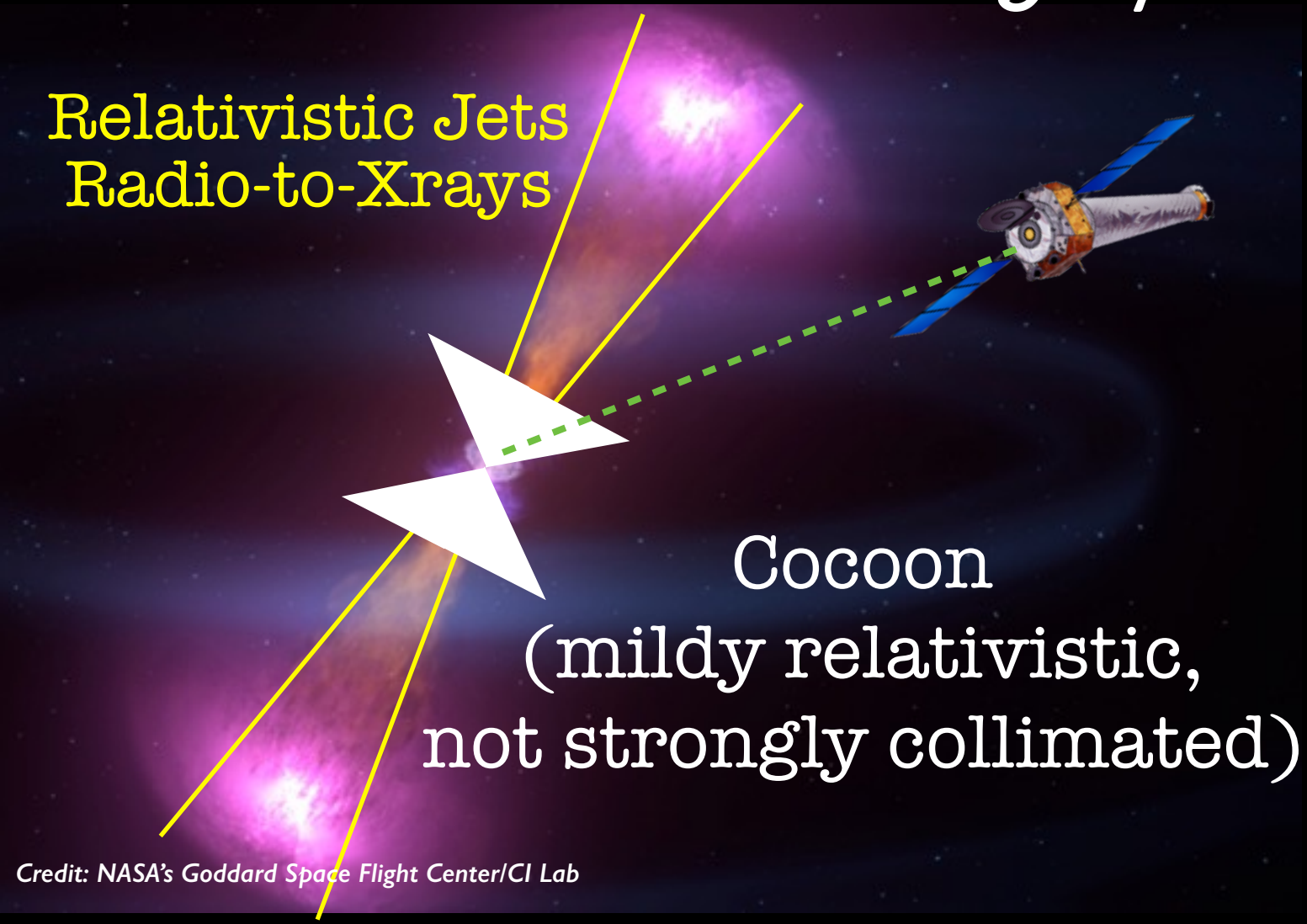
Properties to explain (Radio):

data from Alexander+2017; Hallinan+2017; Mooley+2017





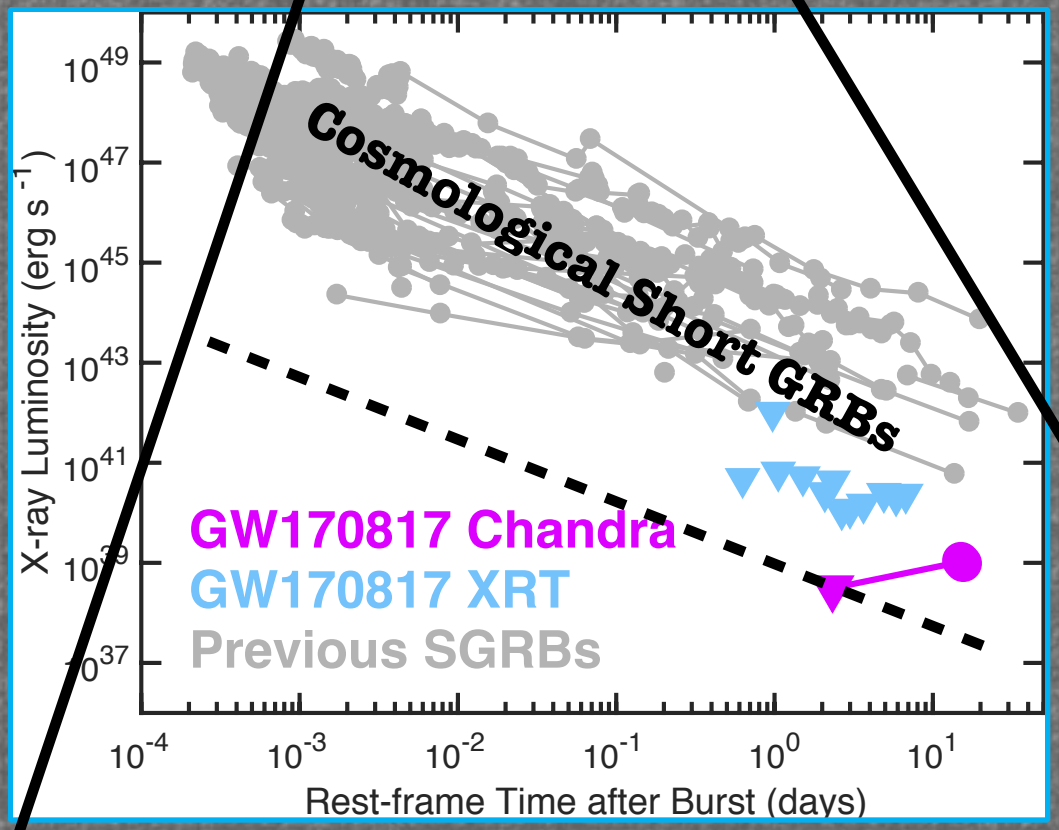
Sources of X-rays/Radio



Keyword: DECELERATION

Rising

X-ray/Radio emission



Onset of the (cocoon?) afterglow (on-axis /spherical)

Off-axis Afterglow (beamed)

Onset of the afterglow (on-axis /spherical)

$$\Gamma_0 \sim 8.0 E_{k,iso,52}^{1/8} n_0^{-1/8} t_{pk,day}^{-3/8}$$

~2

$F \sim 2.4 \times 10^{-7}\,\mathrm{erg\,cm^{-2}}$ (Goldstein et al. 2017),

$E_{k,iso} \sim 5 \times 10^{47}$ erg for a fiducial γ-ray efficiency $\eta_\gamma = 0.1$,

Ek,iso~10^50 erg

~(3-15) 10^-3 cm-3

10^-4 cm-3

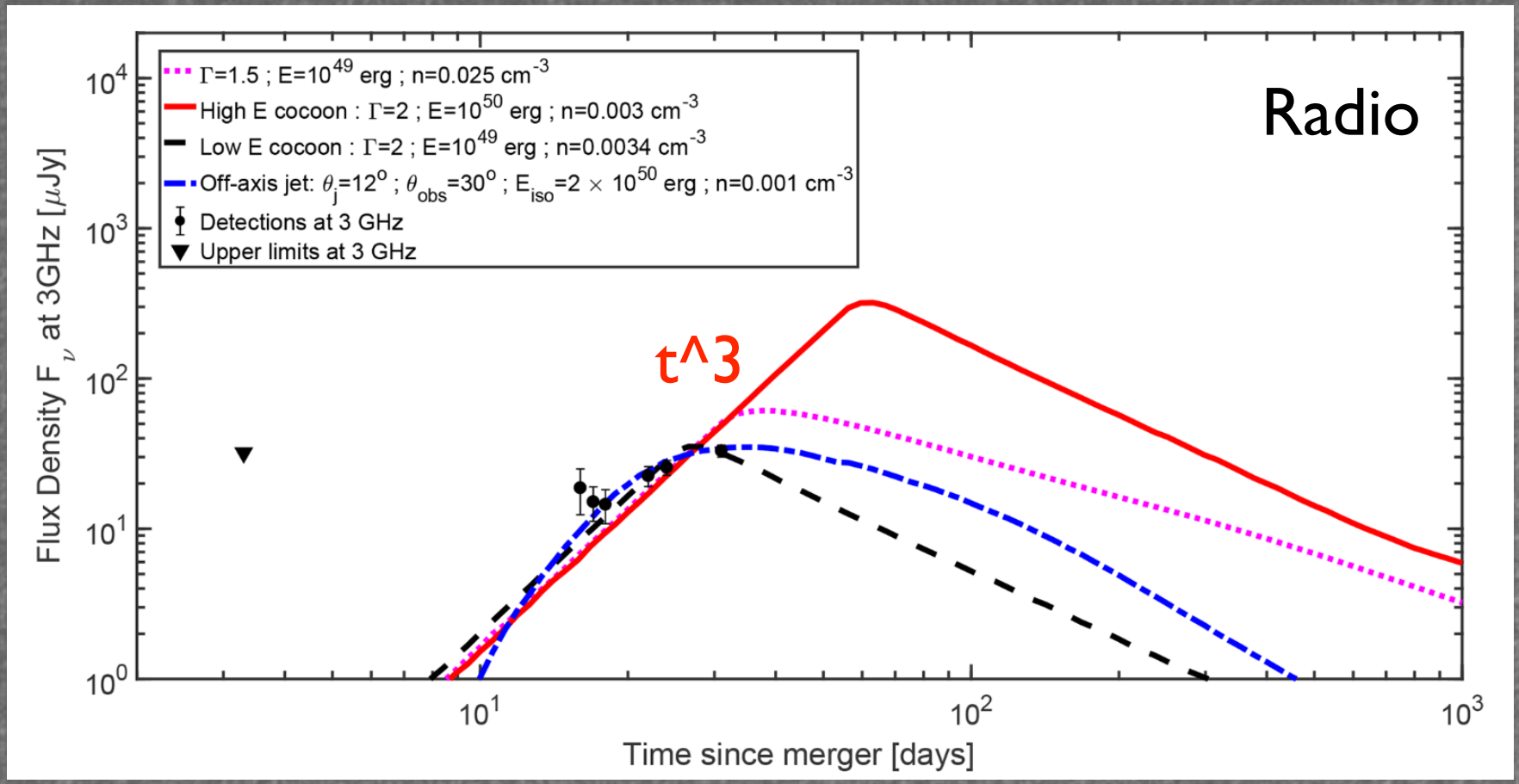
~15-30 days

~200 days

Mildly Relativistic shock —-> Cocoon afterglow emission?

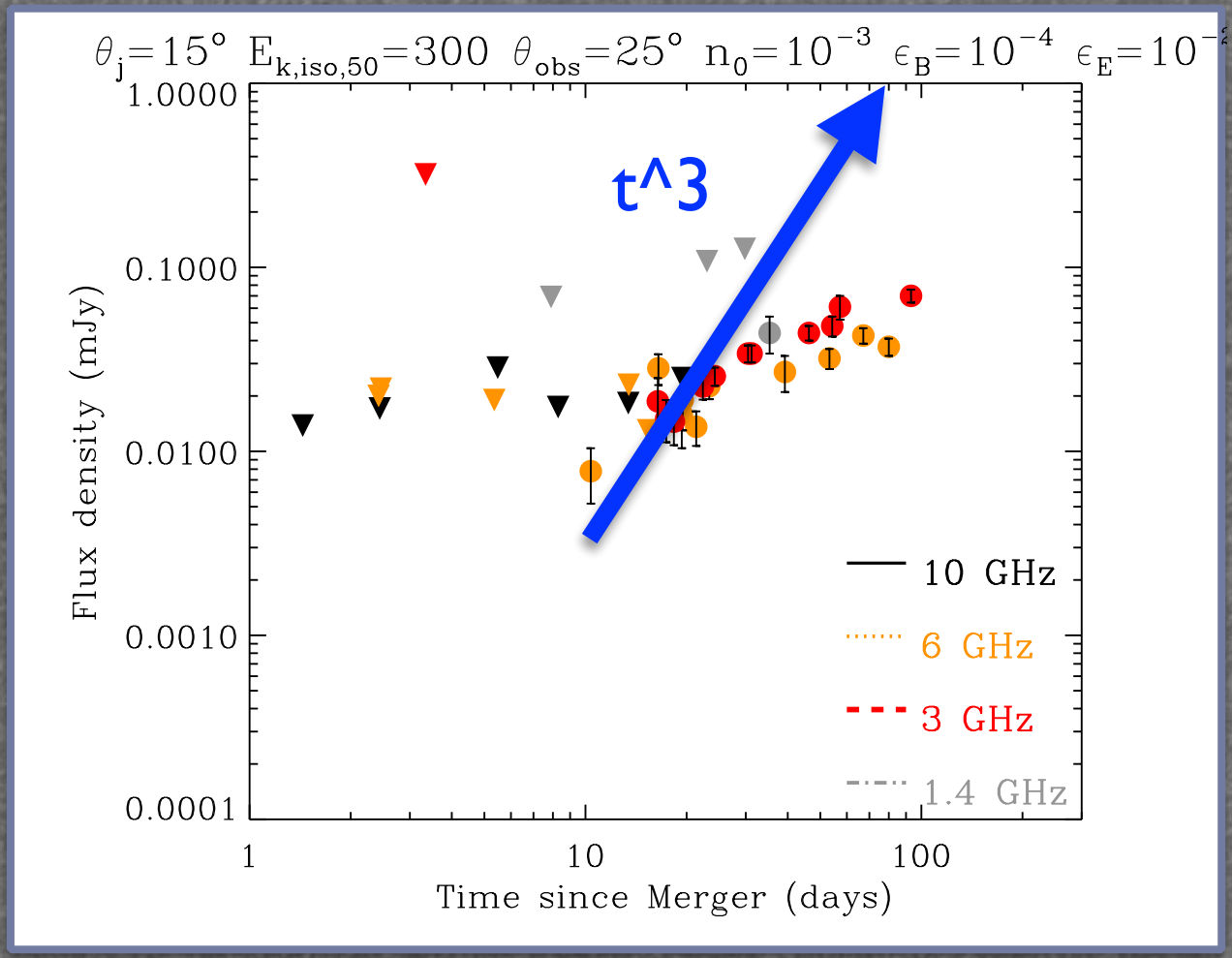
Nakar+2016; Lazzati+2016; Lazzati+2017a; 2017b; Margutti+2017; Hallinan+2017

Onset of the afterglow (on-axis /spherical)



Hallinan+2017

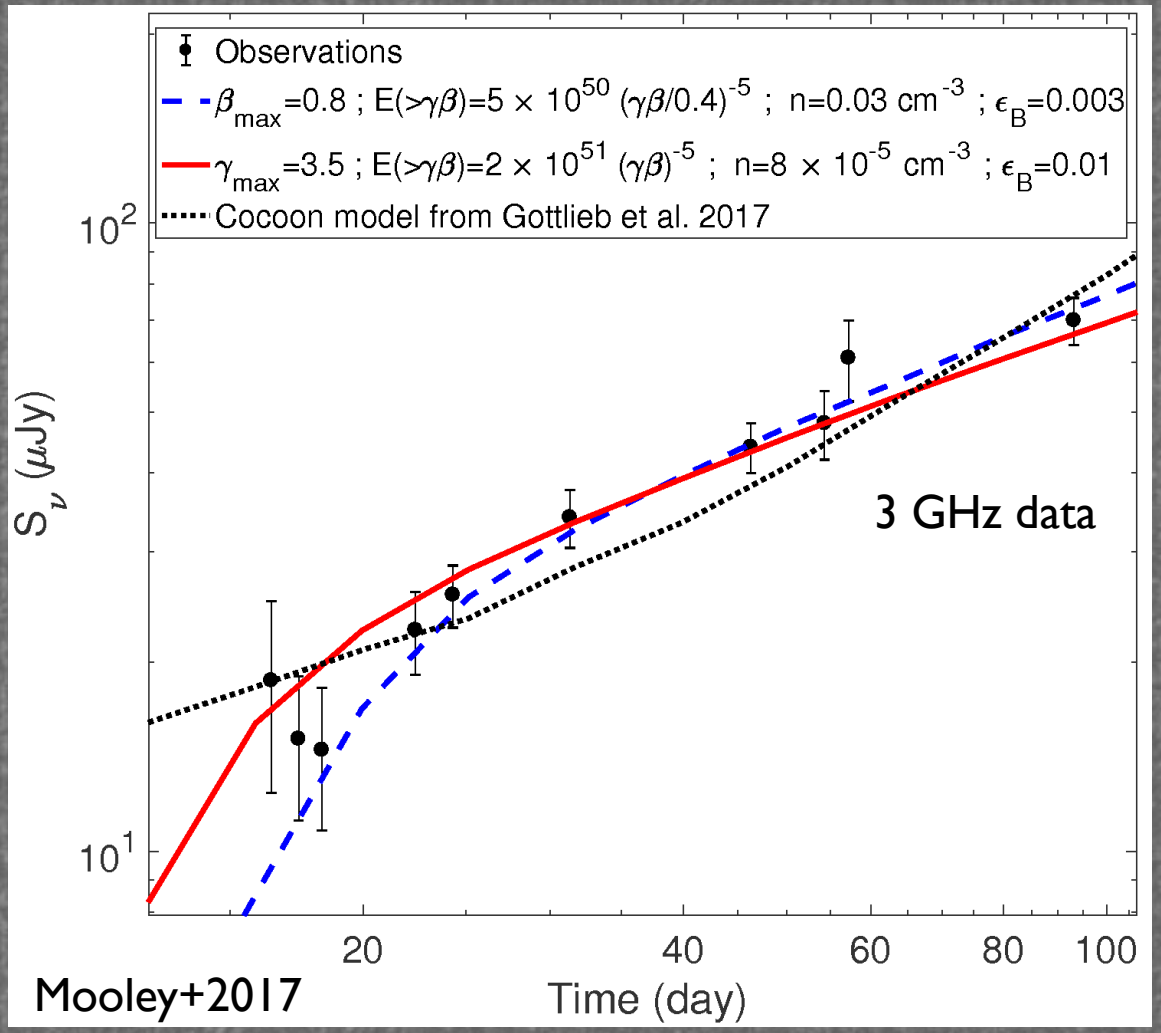
With NEW DATA does not work



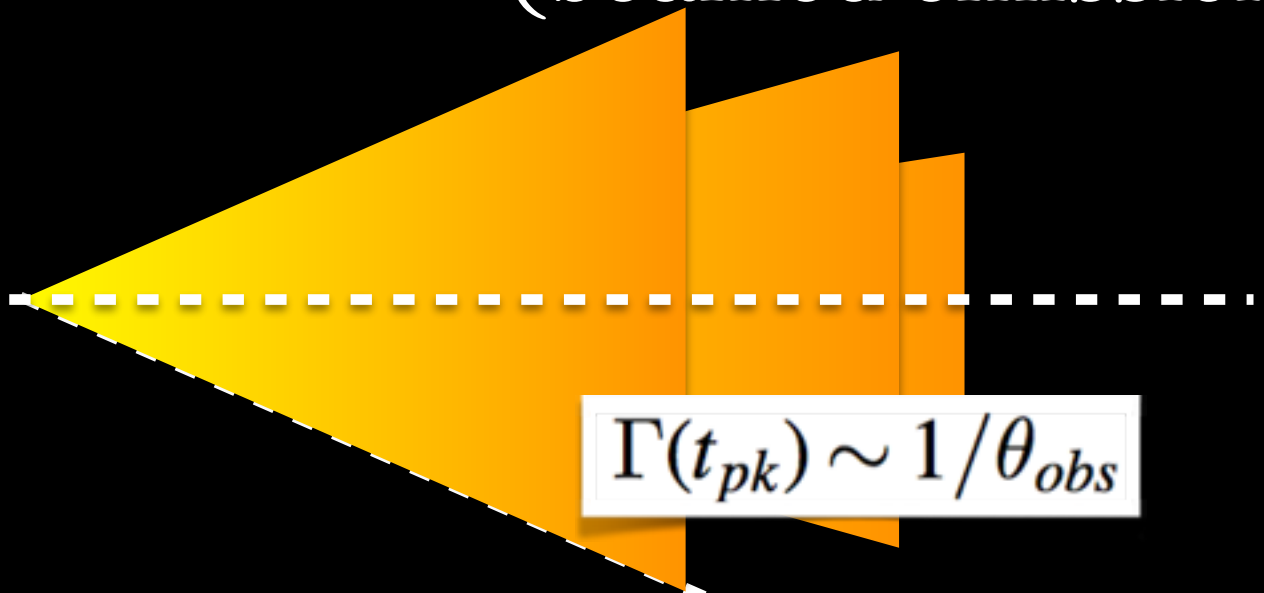
Single Gamma fireball does NOT work

Introduce STRUCTURE in the ejecta

E(GammaBeta)~(GammaBeta)^-alpha



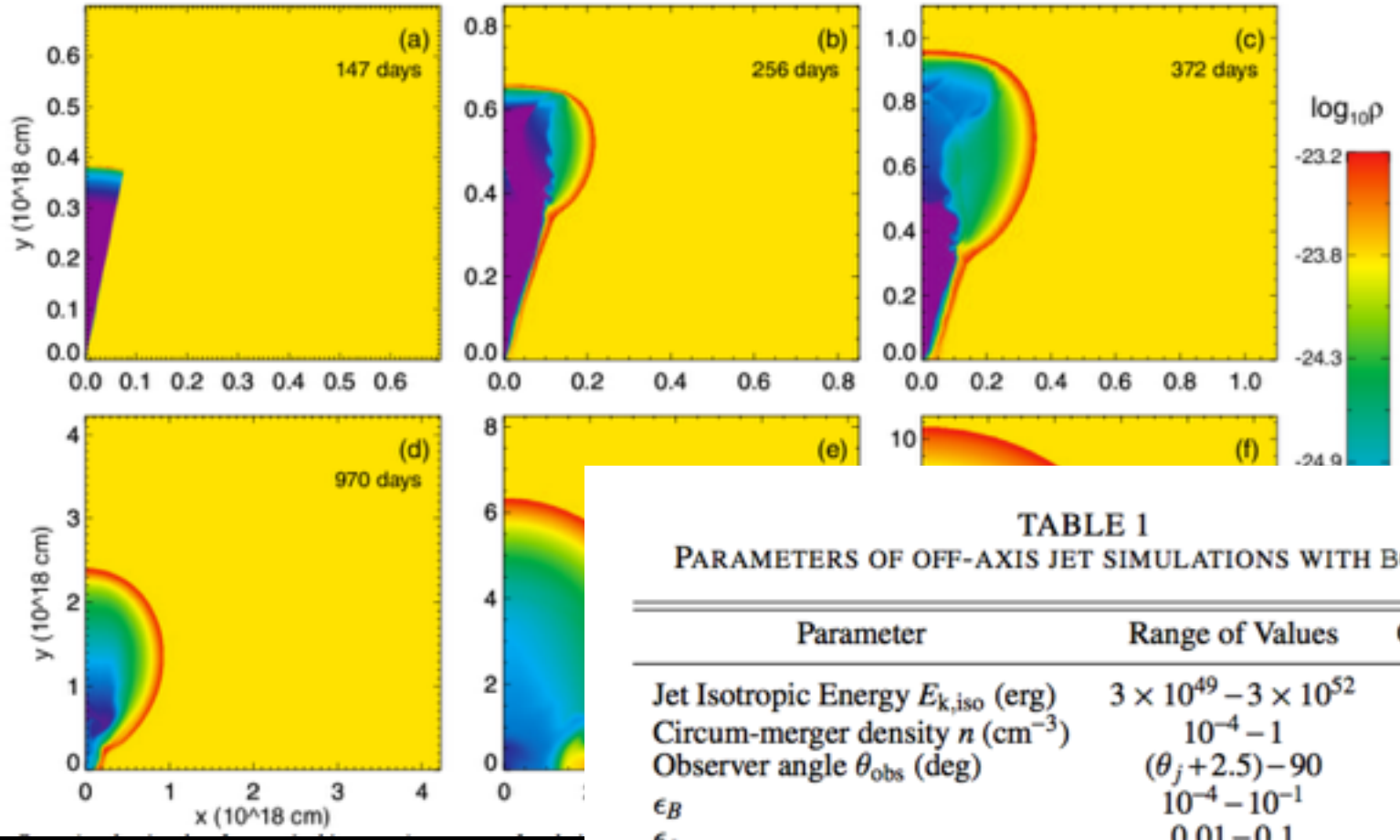
Off-Axis *top-hat* Jet (beamed emission)



$$\Gamma(t_{pk}) \sim 1/\theta_{obs}$$

DECELERATION

Numerical jet simulations



Zhang & MacFadyen (2009).

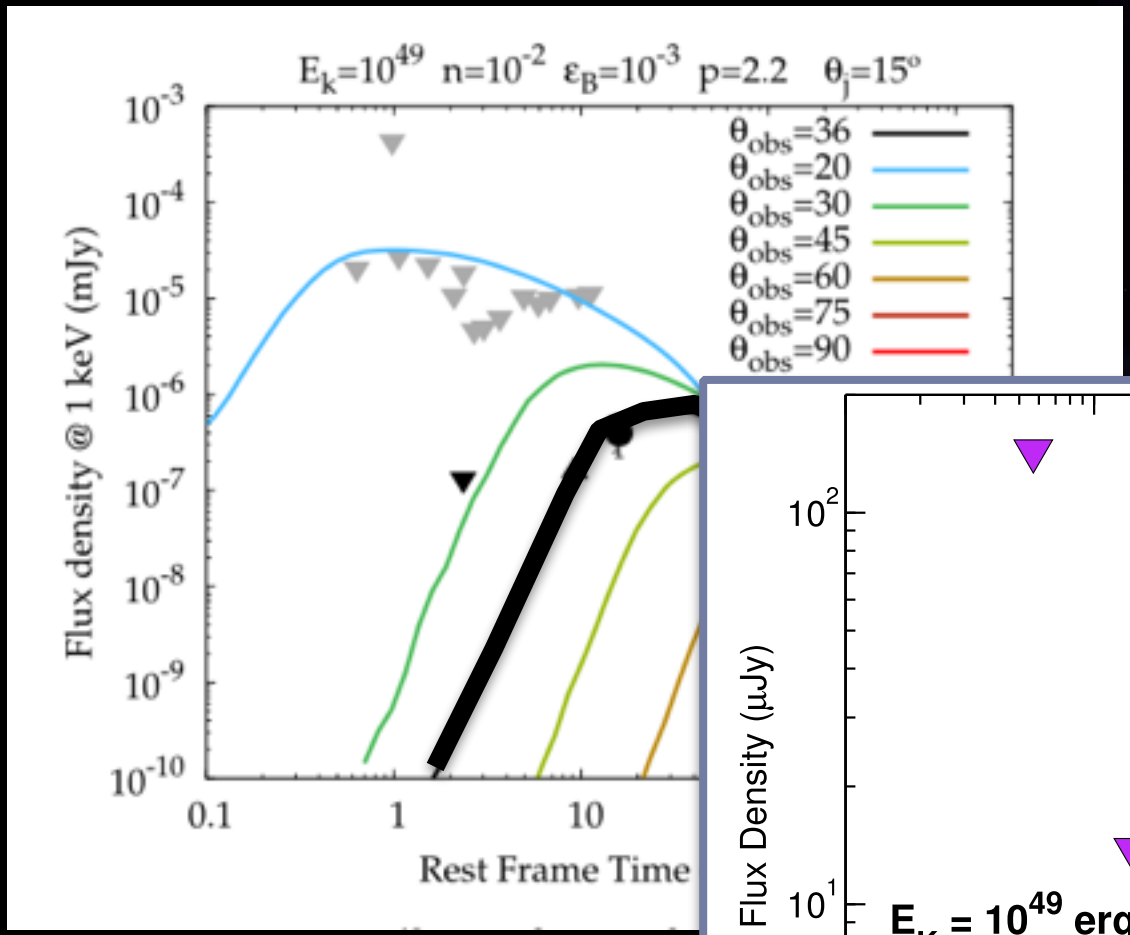
TABLE 1
PARAMETERS OF OFF-AXIS JET SIMULATIONS WITH BOXFIT

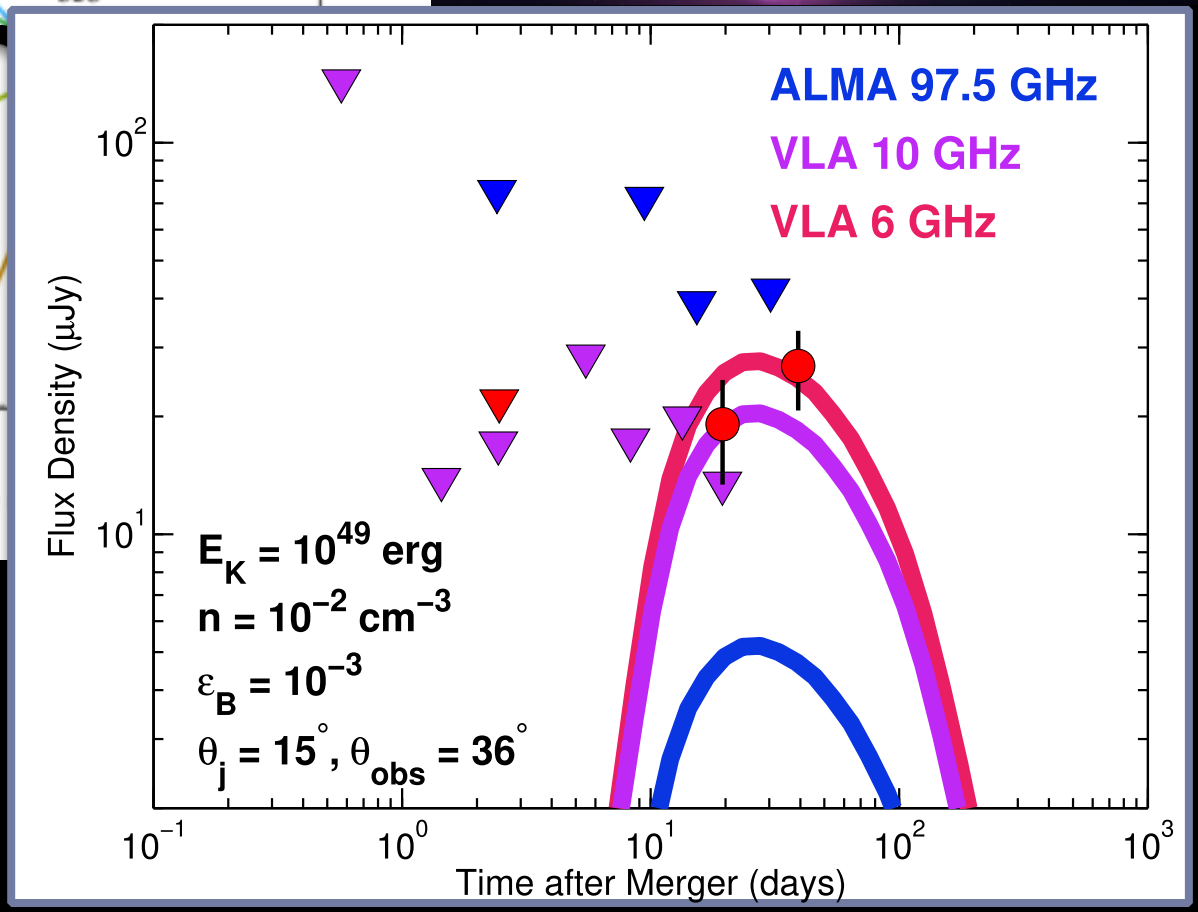
Parameter	Range of Values	Grid Pace
Jet Isotropic Energy $E_{k,iso}$ (erg)	$3 \times 10^{49} - 3 \times 10^{52}$	0.5 dec
Circum-merger density n (cm^{-3})	$10^{-4} - 1$	0.5 dec
Observer angle θ_{obs} (deg)	$(\theta_j + 2.5) - 90$	2.5
ϵ_B	$10^{-4} - 10^{-1}$	1 dec
ϵ_e	$0.01 - 0.1$	1 dec
p	$2.1 - 2.2$	0.1

NOTE. — Simulations were run at two fixed values of jet opening angles $\theta_j = 5°$ and $\theta_j = 15°$, propagating in a constant density medium.

Margutti, et al., 2017; Alexander et al., 2017
Guidorzi, Margutti et al., 2017

X-rays





Margutti+2017;
Guidorzi, Margutti+2017;
Alexander+ 2017.

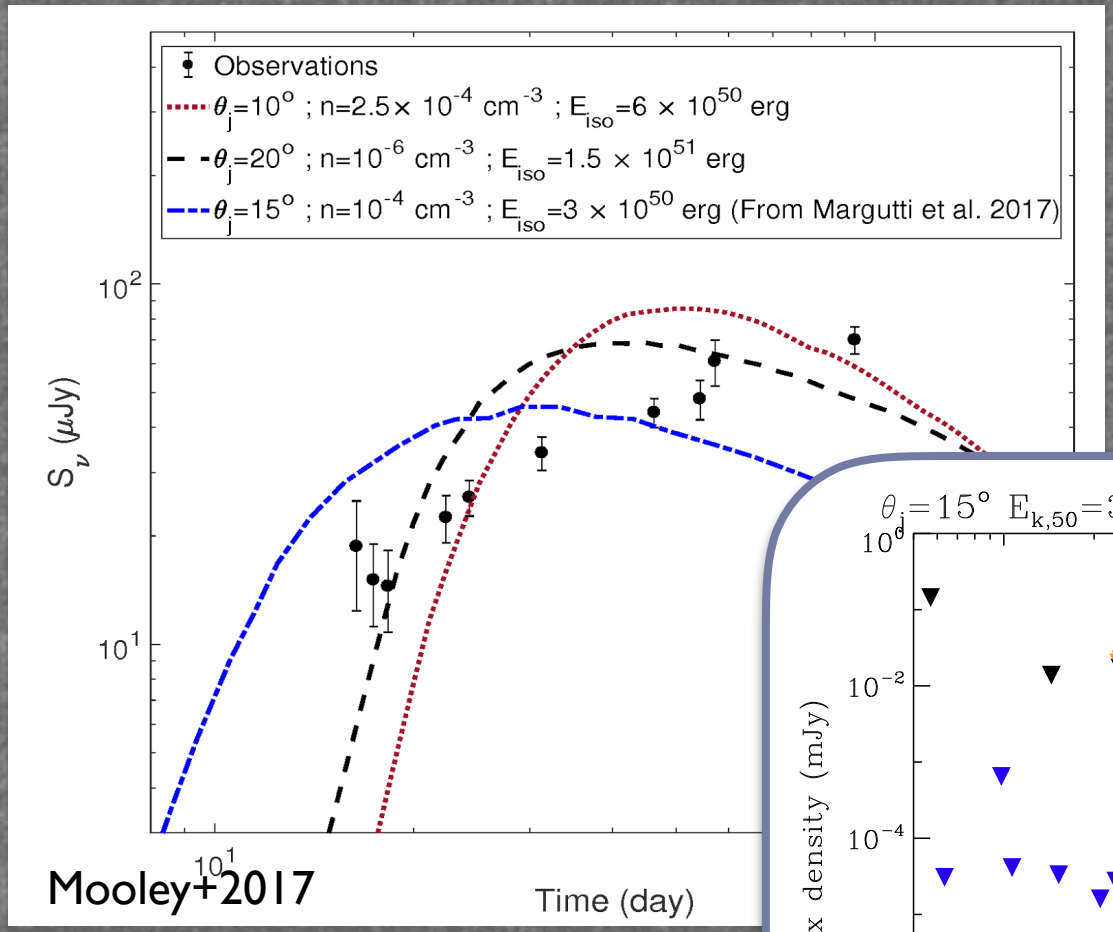
We identified a **FAMILY** of solutions
Ek~10^49-10^50 erg
n~0.0001-0.01
theta_obs~20-40 deg
(+micro-physics)

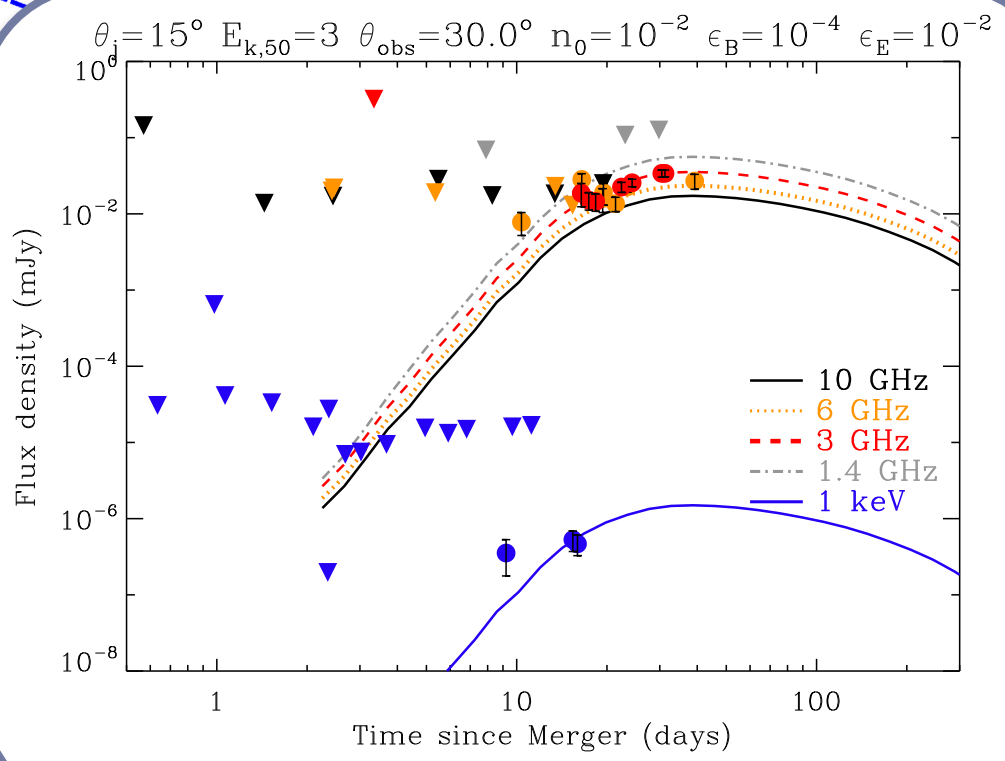
This is the **SIMPLEST** version of a relativistic jet

This is a fit limited to the **EARLY** t<40 days data

One out of a **FAMILY** of solutions for **EARLY** data

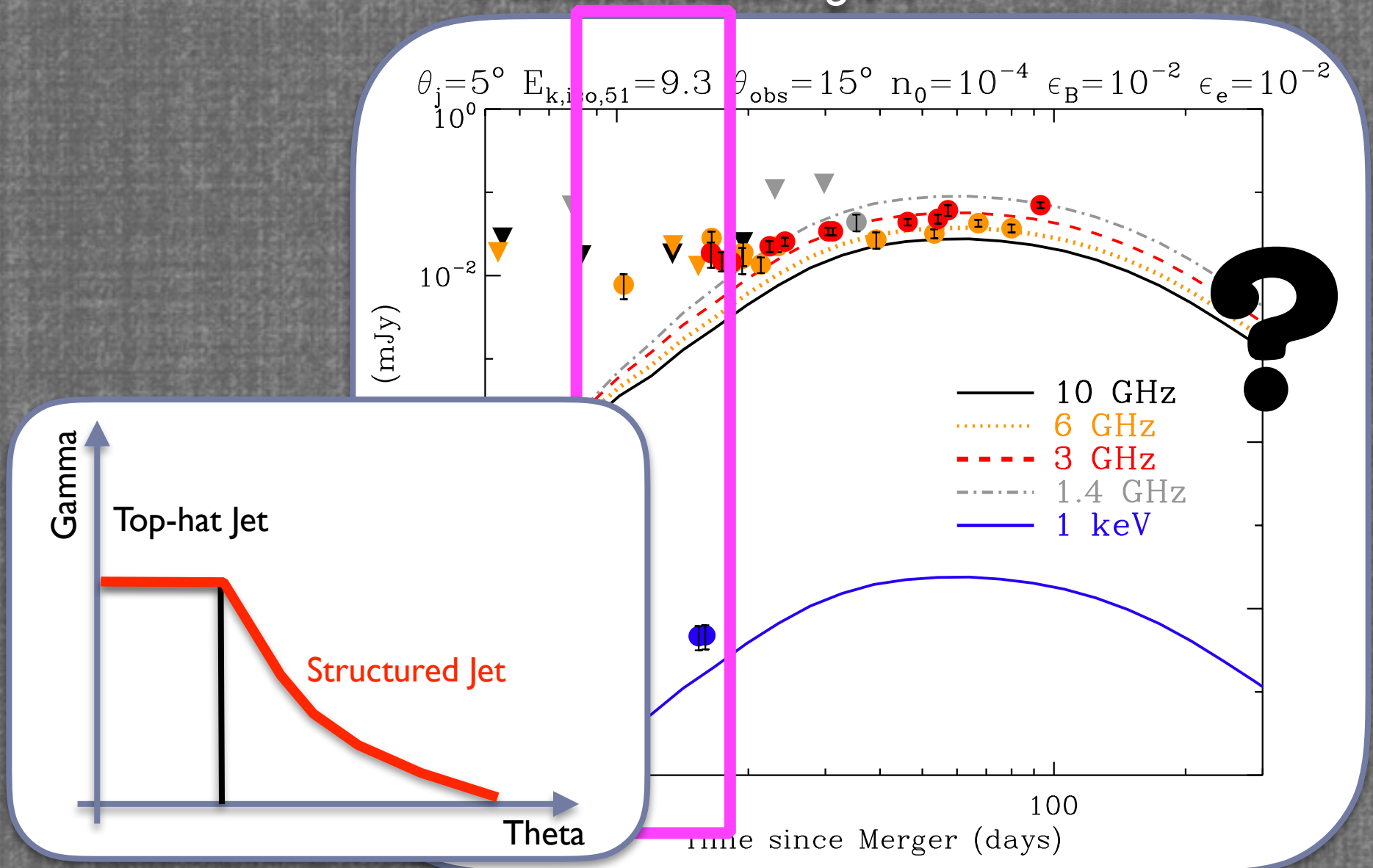
Ek~10^49-10^50 erg
n~0.0001-0.01
theta_obs~20-40 deg
(+micro-physics)



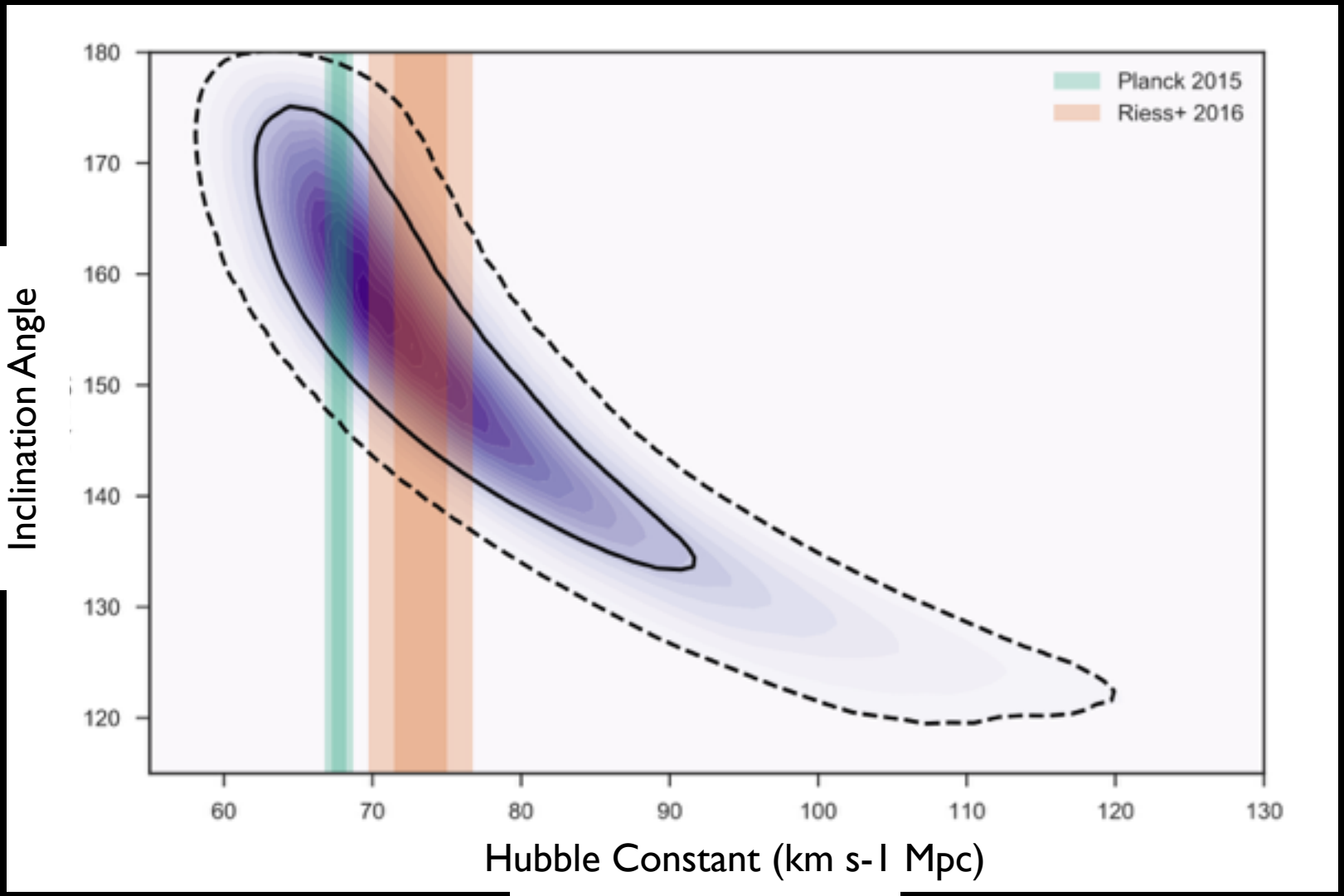


n~10^-2 - 10^-4 cm-3
Ek=10^48-3x10^50 erg
Theta_obs=15-50 deg

This is the **SIMPLEST** version of a relativistic jet

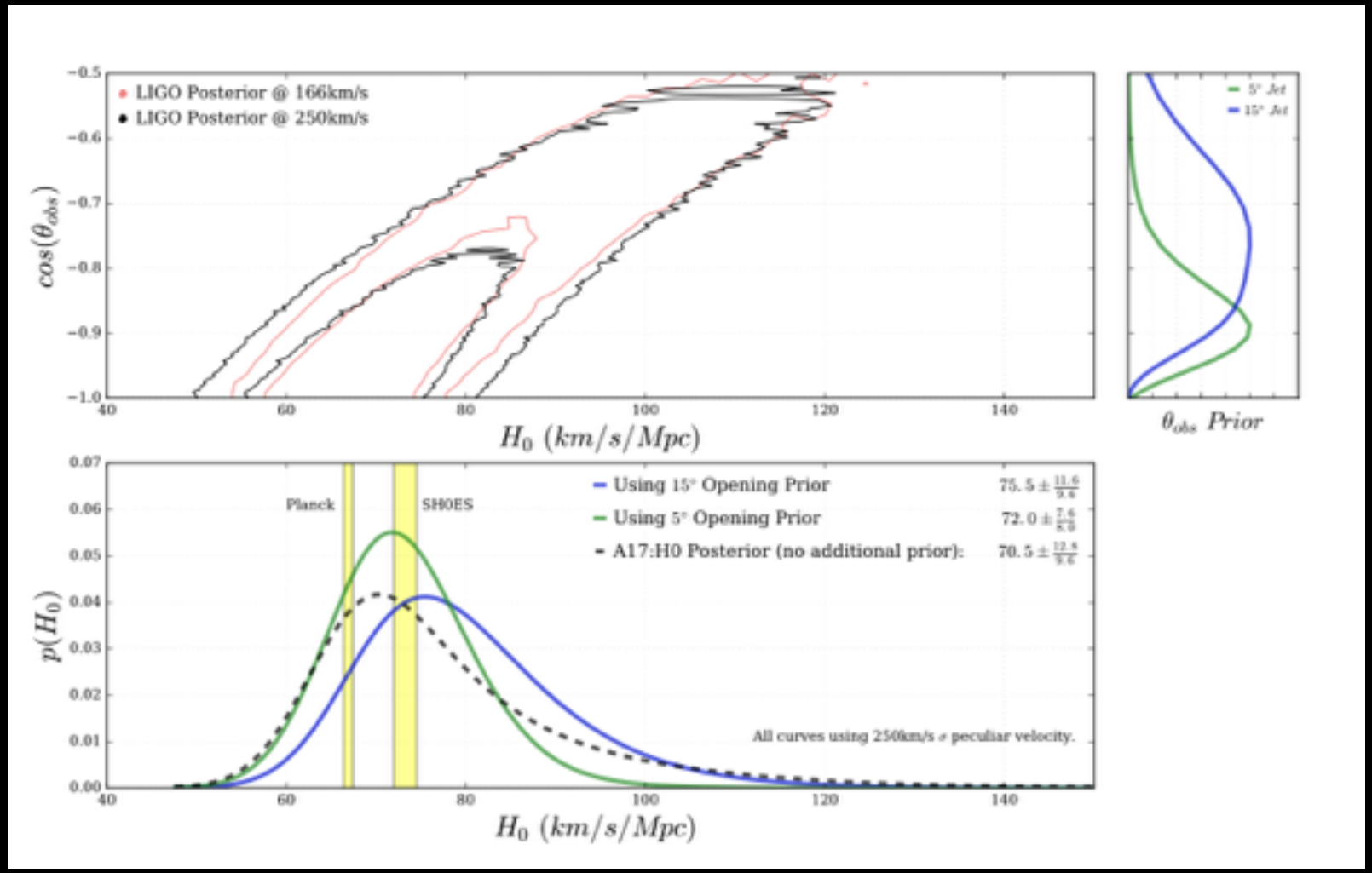


New Method for Hubble Constant Measurement (Schutz 1986)



H0 paper, LVC + 6 EM host-galaxy co-discovery teams, Nature, 2017

Improving the constraints on H0 with GW + EM



Guidorzi, Margutti.. Fong et al., 2017

Structured jets models need to be given a chance to fail

The new X-rays are unlikely to solve the debate (models predict similar spectrum)

Episode 2

Is there some possible future evolution of GW170817 that the no-jet models would NOT be able to explain?

The End

"We always find something, eh Didi, to give us the impression we exist?"