The GRB-GW Past, Present and Future

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Neil Gehrels Memorial Meeting
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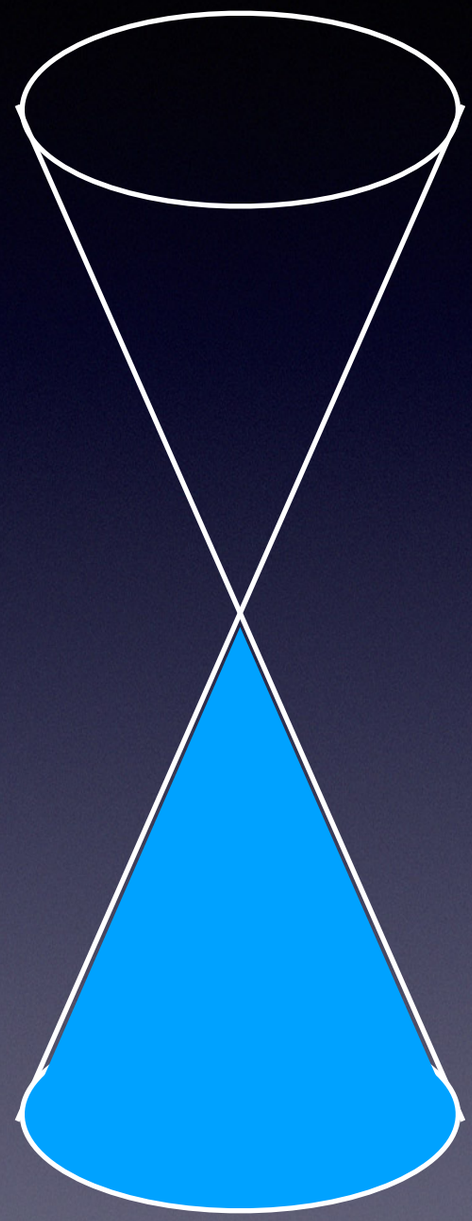
Subject: Lorentz factor of GRB 060218

Dear Tsvi,

I noticed that in the initial astro-ph versions of the attached paper [on GRB060218] an initial Lorentz factor of ~15 was given in the abstract. In the current version, I don't see a definite number anywhere in the paper (maybe I missed it). What changed in your thinking on the Lorentz factor for this burst?

Best Regards,
Neil

The Past

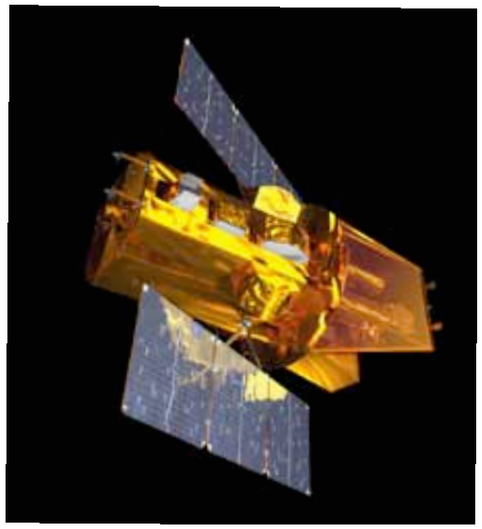


- 1974 - r-process Nucleosynthesis from DNS mergers: *Lattimer & Schramm*
- 1975 - PSR1913+16: *Hules & Taylor*
- 1975 - GW from DNS: (*Smarr and Blandford …..*)
- 1982 - 1990 Shift in GW search from focus on SNe to focus on mergers *(Thorne)*
- 1989 - GW+GRB+r-process: *Eichler et al.*
- 1993 - sGRB vs LGRBs: *Kovelioutou et al.*
- 1997 - Radioactive remnant (mini-supernova later called macronova and then kilonova): *Li & Paczynski*
- 2005 - GRB 090509B First evidence for sGRB-BNS association. ***Gehrels et al.,*** *Bloom et al*.
- 2011 - Radio flare following DNS mergers: *Nakar and Piran*
- 2013 -130603B first macronova candidate: *Tanvir et al., Berger et al.*

June 6th 2017

למה אנו מצפים עכשיו?

- ארוע "קרוב" (פחות ממיליארד שנות אור מאיתנו) של מיזוג כוכבי נויטרונים
- מארוע כזה נראה -
  - ✳ גלי כבידה
  - ✳ הבזק קרינת גאמה
  - ✳ מקרונובה ו"יצור זהב"
  - ✳ אות רדיו מאוחר יותר



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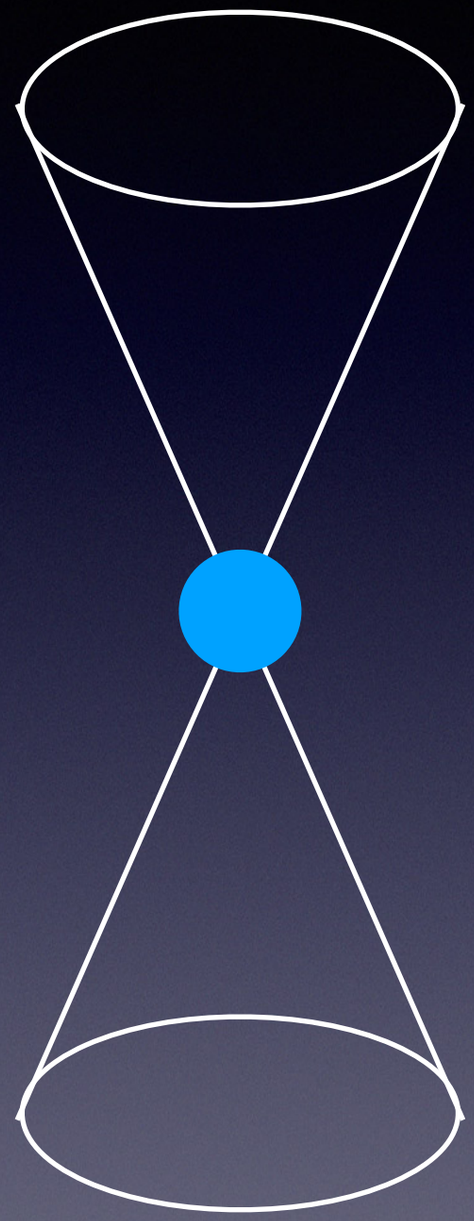
What are we expecting now?

- A nearby (< 1 Gly) binary neutron star mergers
- From such an event we will see in addition to the gravitational waves:
  - A short gamma-ray burst
  - A macronova and nucleosynthesis of “gold”
  - A radio flare

The Present

GW 170817 +
GRB170817A



GW 170817 and its EM counterparts

- A double NS merger + a sGRB
- An unusual low-luminosity GRB
- A macronova/kilonova => r-process nucleosynthesis

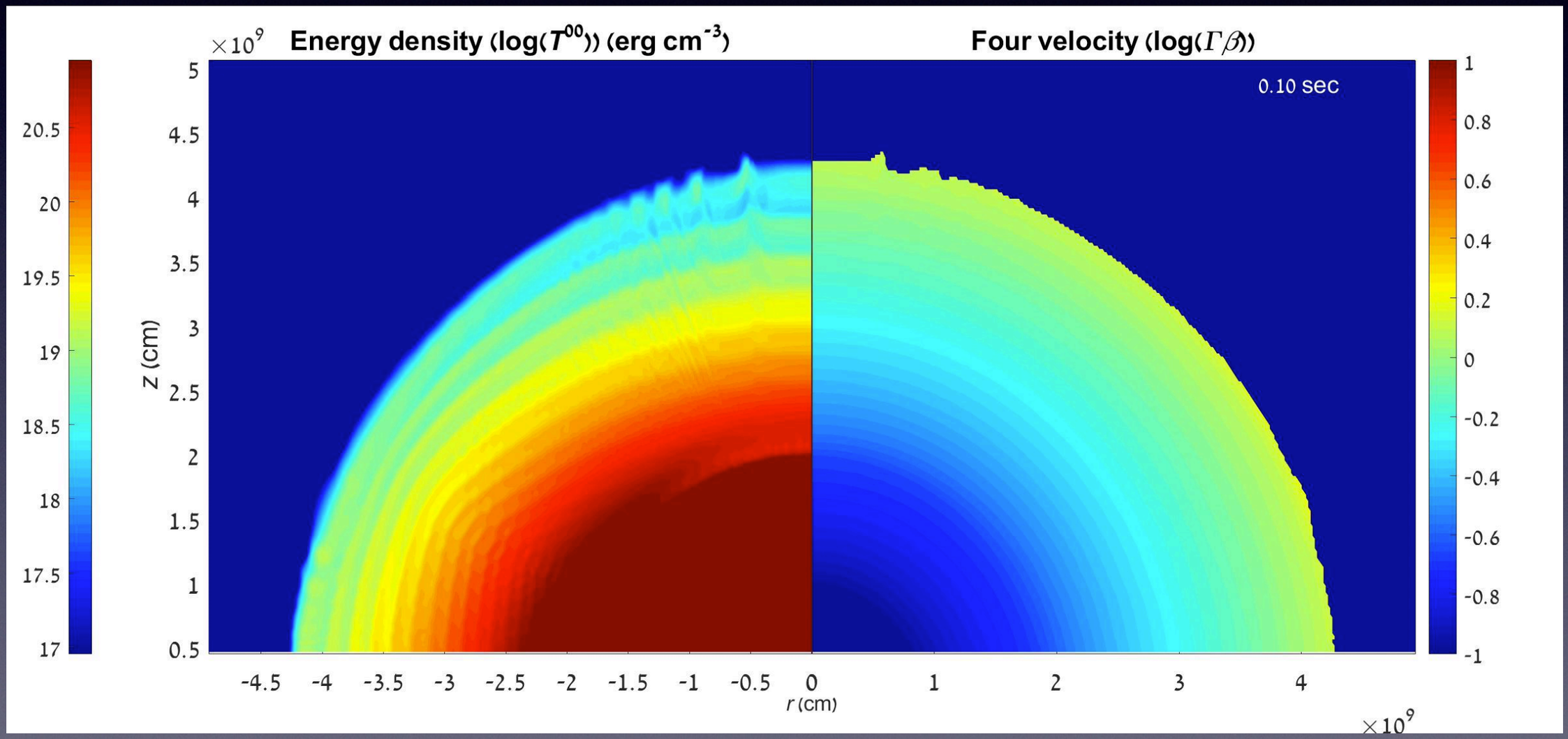
- X-ray and Radio at a relatively late time (9,16 days) inconsistent with off-axis emission of a regular sGRB
- X-ray and Radio rising as $t^{0.8}$ over 150 days than decay.
- *Is there a single picture that explains all the observations?*
- The key is in the $\boldsymbol{\gamma}$, the confirmation from the radio

A Low Luminosity sGRB

- Regular short GRBs:
- E_{iso}~10^{50}-10^{52} ergs
- **Variable**
- **Hard** (E_{peak} > 400 keV)

- GRB 170817A
- E_{iso}~10^{46} ergs
- **Smooth**
- **Soft** (E_{peak} 180 keV)

The cocoon and the shock breakout

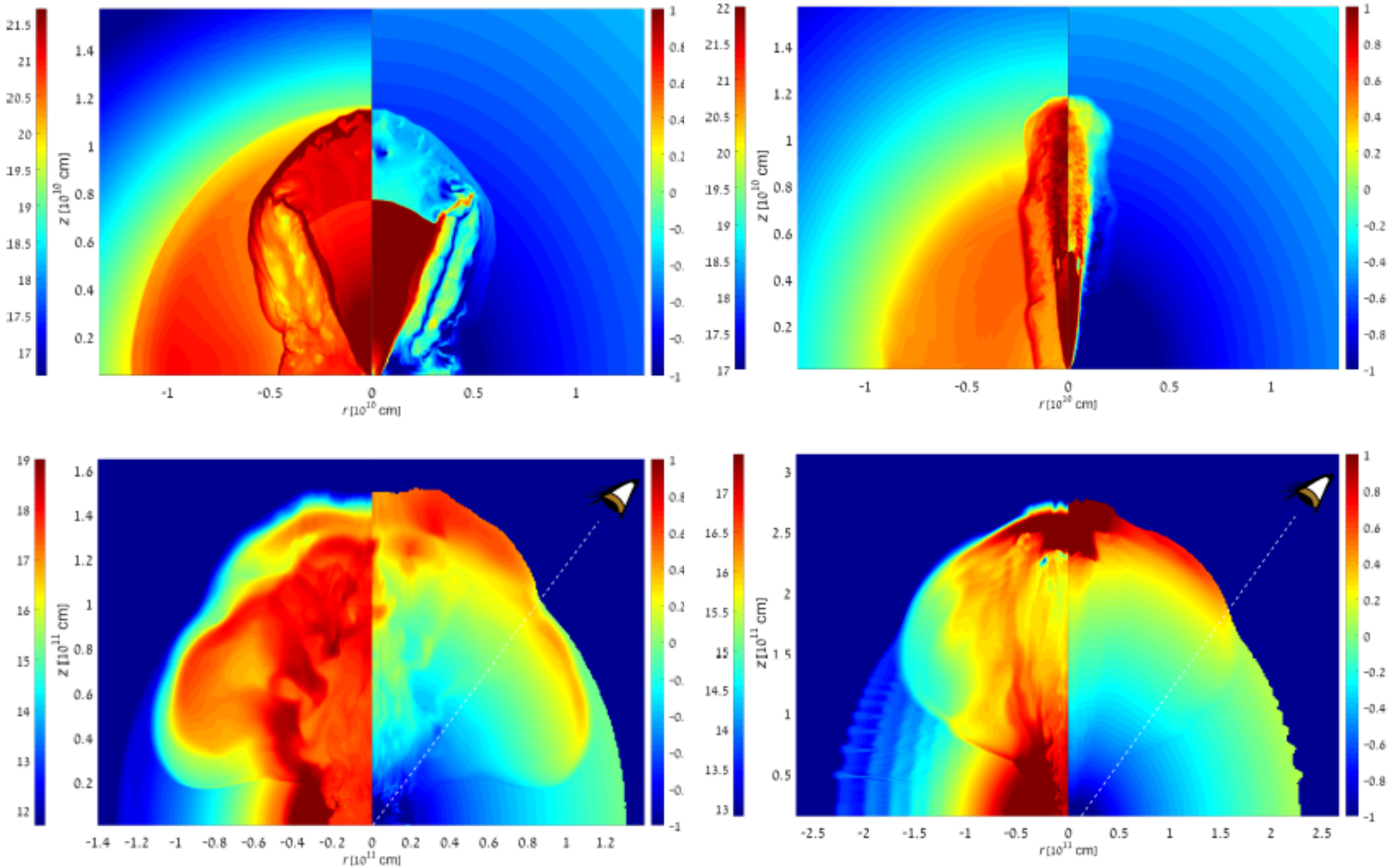


Credit: Ore Gottlieb

A Choked Jet

Gottlieb et al. Oct 17

A Successful Jet



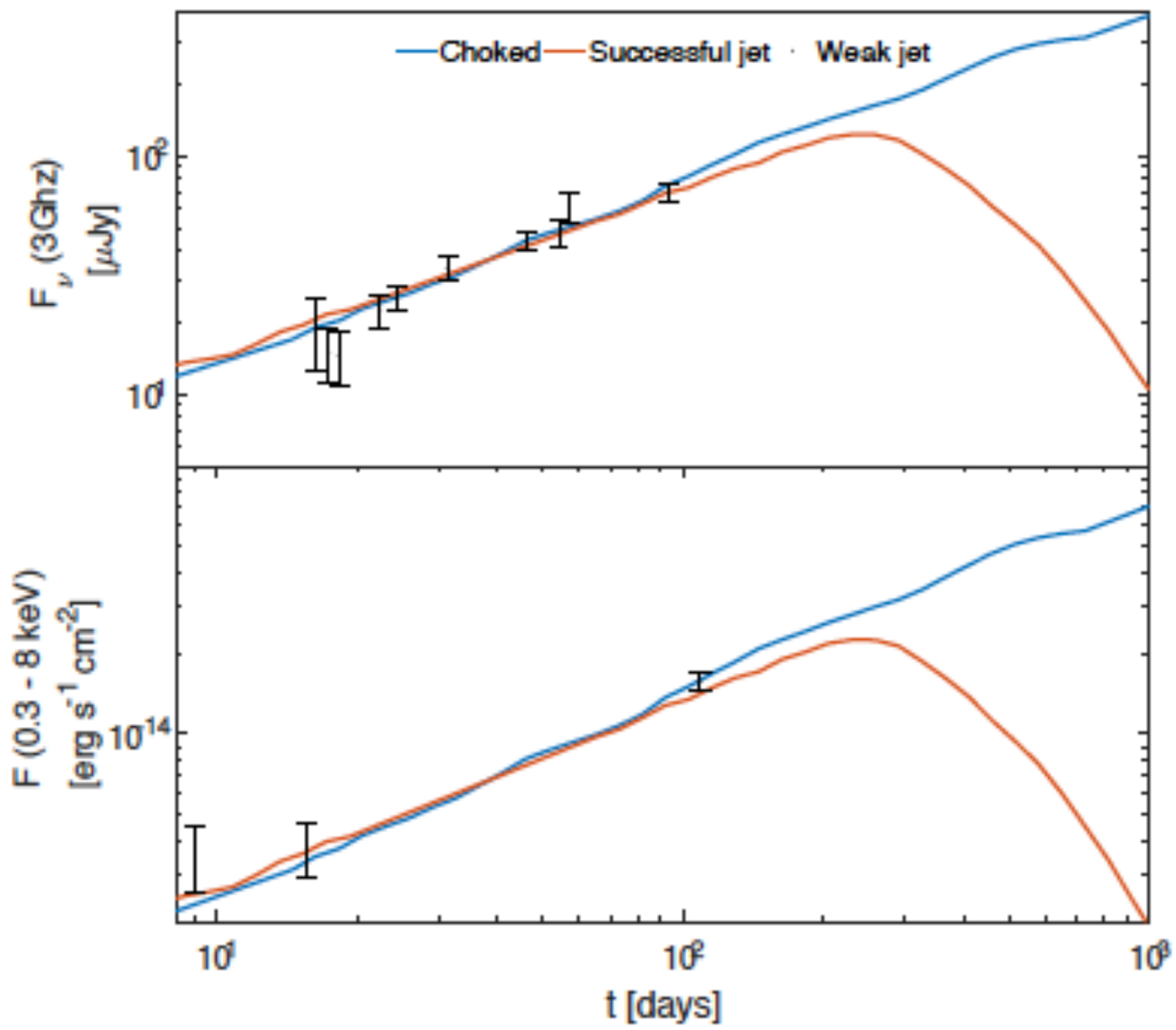
Cocoon - Blandford and Begelman introduced to GRBs by Meszaros and Rees

See also: Pozanenko 17; Lazzati et a., 17 for GRB 170817A

Physical Process

Progenitor	Regular	Low luminosity
Long Collapsar	Non-thermal	Shock Breakout
Short Merger	Non-thermal	Shock Breakout

The radio & X-rays



See also:
Margutti et al., 18;
Ruan et al, 18;
A'Avanzo et al., 18 ;
Lamb et al., 18;
Troja et al., 18;
Granot et al., 18 and others for related modeling of the radio and the x-rays.

This radio signal that is produced from the same cocoons that produced the gamma-rays (From Mooley et al., 18)

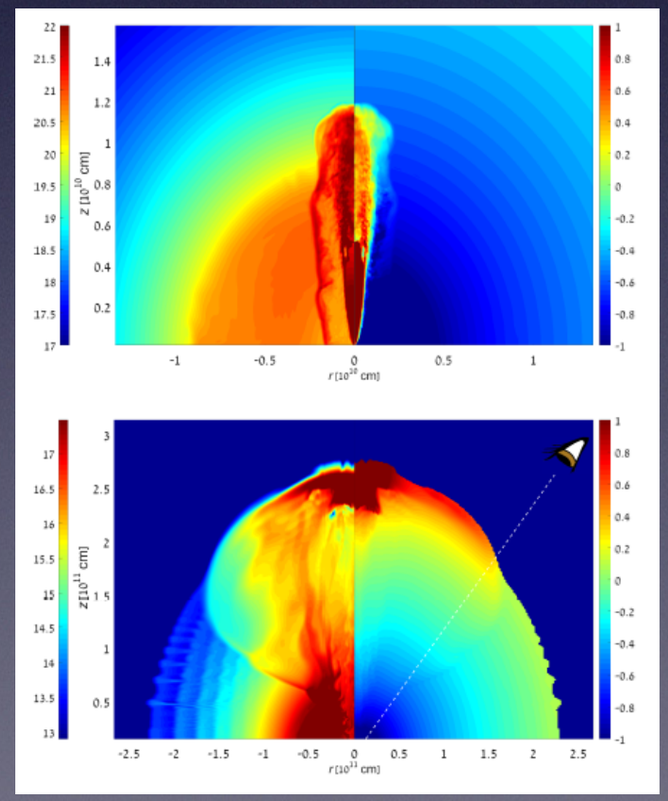
A few words about words - confusion about terminology

- A Structured jet - an outflow with E(r,$\boldsymbol{\theta}$).

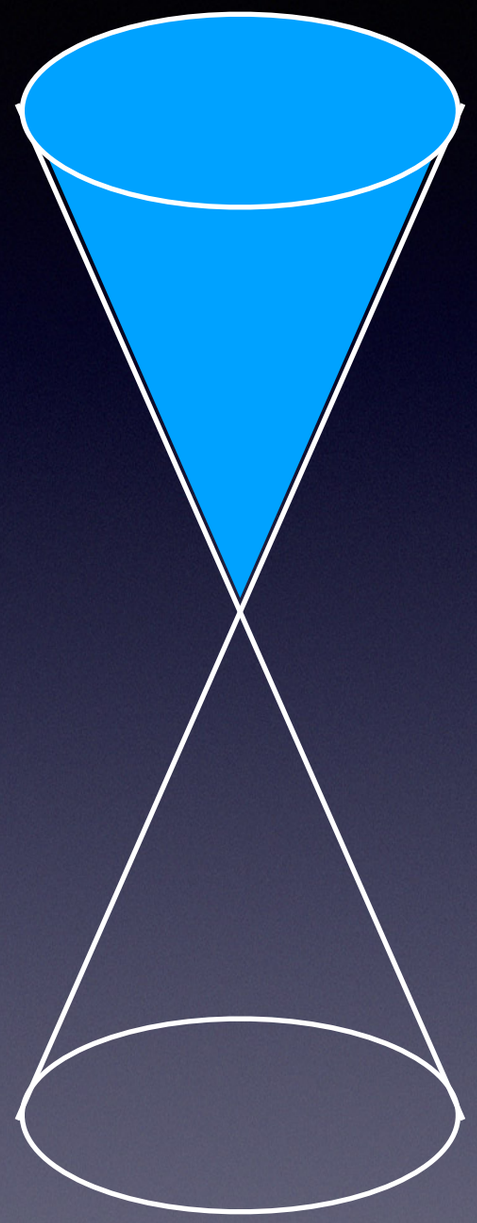
  By itself this is not a physical model. A physically motivated model for a "structured jet" is a cocoon.

- A Cocoon*: The structure that arises from a propagation of a relativistic jet within external matter (also called "cloud" by some).

★ Coined by Blandford and Begeleman. Intoroduced to GRBs by Meszaros and Rees.



The Future



What are the questions?

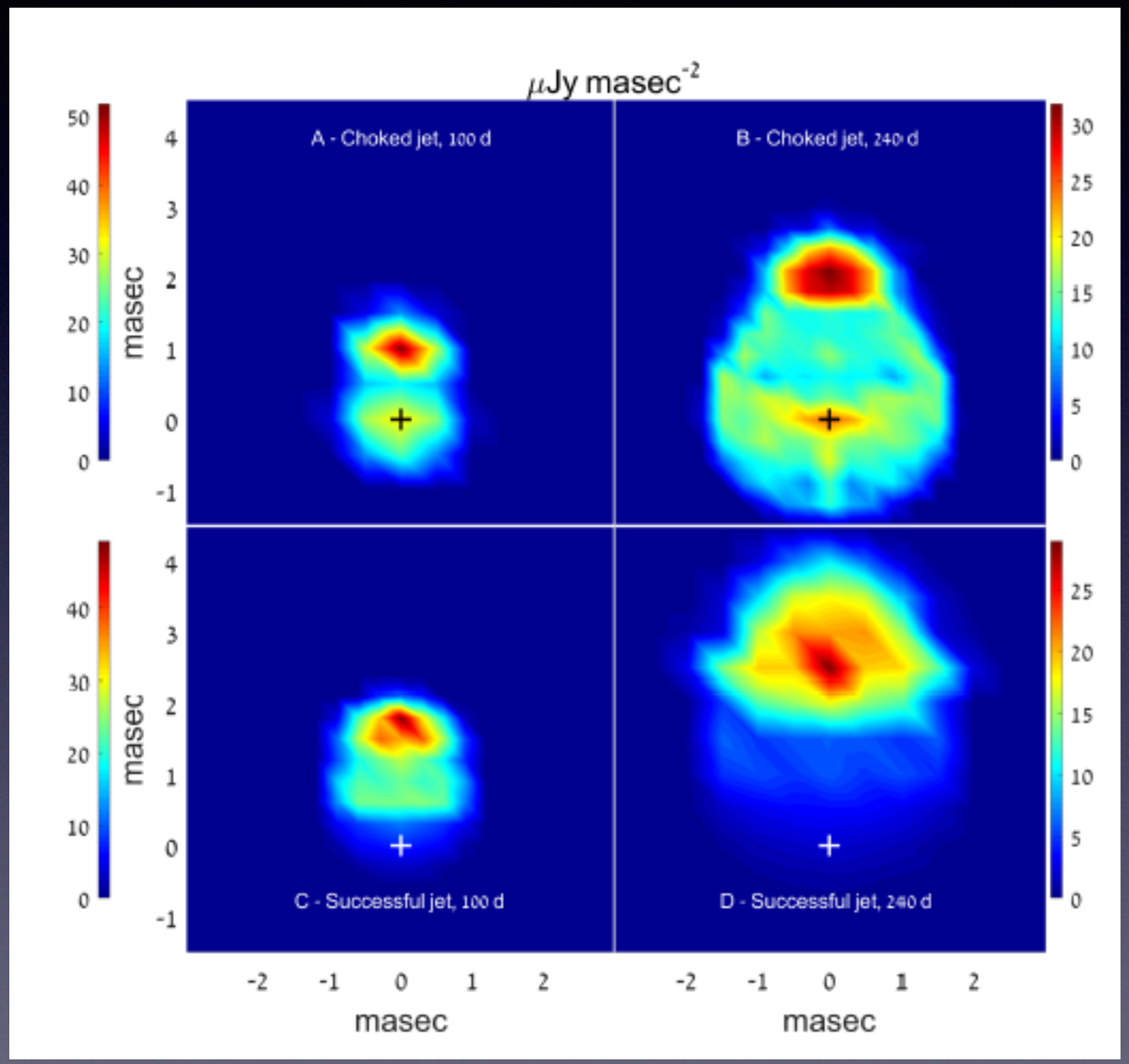
- The question is <u>not</u> “structured jet” vs. “cocoon” but:

1. Is the structure, $E(r,\theta)$, mostly angular or mostly radial (both arise in a “cocoon” scenario)?

2. What caused the structure (a “cocoon” is one option - any other?).

3. Did the jet emerge and produce a sGRB in another direction observed by some aliens?

Was there a regular sGRB?



VLBI predictions (Gottlieb + 18)

The GW - sGRB Connection

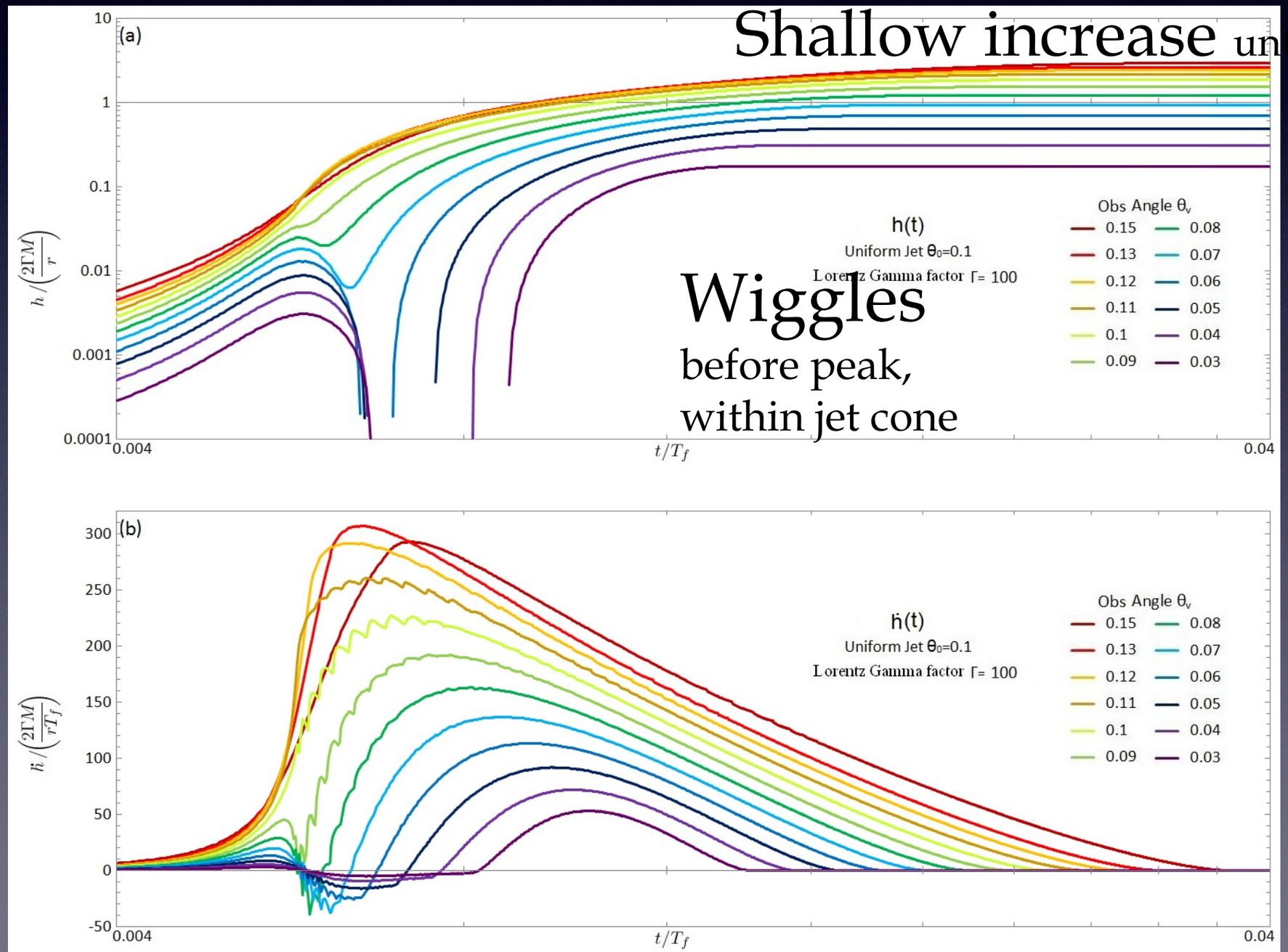
- Numerous events, including "on axis" regular sGRBs
- Most will look very different from GW 170817 (viewing angle!). The Macronova component will be most similar.

➡ Statistics, nature of the remnant…

But there is more to come. With GW we will be able to observe the jet evolution.

GW from the jet

(Birnholtz & TP, 14; Leidershnier & TP 18)



Summary

- GW 170817 and sGRB 170817A confirmed the association of GW with sGRB 29 years after its prediction.
- The macronova/kilonova signal confirmed r-process nucleosynthesis in mergers 43 years after its prediction.
- *A single model (Kasliwal et al., 17; Gotlieb et al. 17,…) explains the observed EM emission from the weak/soft γ-rays to the unique radio and x-rays.*
- Future observations with Adv LIGO could detect GW from the accelerating (and decelerating) jet and reveal the inner working of sGRB engines!