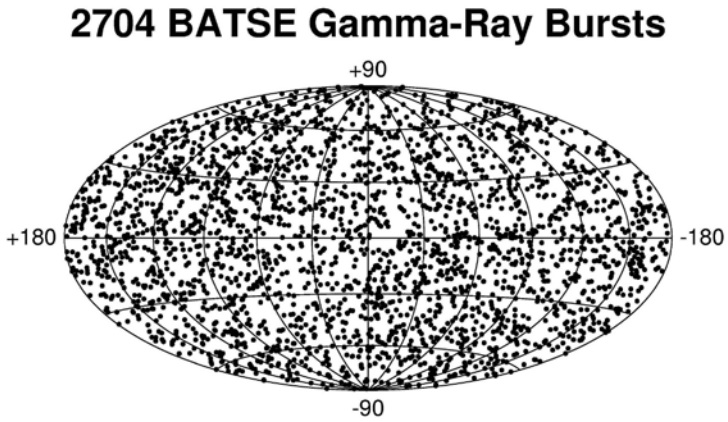
1992 - 2017: 25 years of GRB Physics

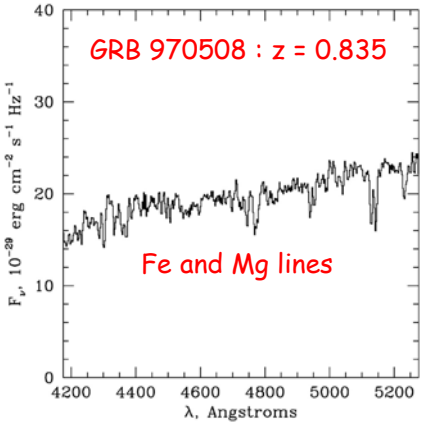
Robert Mochkovitch (IAP)

The situation in 1992: one year after Compton GRO was launched



Isotropic distribution on the sky ☐extended galactic halo or…

cosmological distance scale



Confirmed by Beppo-SAX and the first redshifts

(now about 500 redshifts from 0.01 to 8.2/9.4)

First models of cosmological GRBs

Problem: sources must be compact (short time scale variability of light curves)

the luminosity is huge: $L > 10^{51}$ erg.s^{-1} (hyper-Eddington)

- should drive an optically thick wind ("baryonic pollution" problem)
- thermal spectrum contrary to observations (broken power-law)

Possible solution: *Nature* **361**, 236-238 and The New York Times

January 26, 1993

Near or Far? Mystery Grows Over Blasts of Gamma Ray

…. Most extragalactic theories draw on ideas advanced earlier by Dr. Bohdan Paczynski of Princeton University. They posit an event triggered by neutron stars colliding or merging with each other or with a black hole.

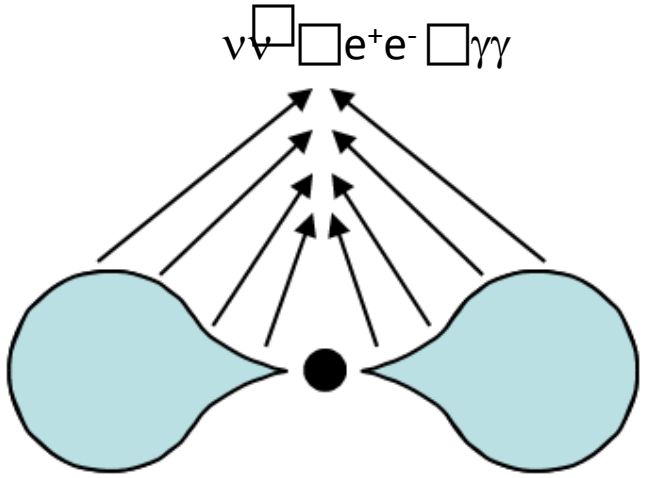
Then there is the problem of how such catastrophes might generate gamma rays and how the radiation could escape the very maelstrom of its creation.

In what Dr. Rees said is the "most credible mechanism," the energy would initially be in the form of neutrinos and anti-neutrinos, subatomic particles with little or no mass. When neutrinos and anti-neutrinos collide, they annihilate each other and emit a barrage of gamma rays. But this radiation is usually absorbed by clouds of material surrounding the neutron star or black hole.

Escape Route Theorized

There may, however, be a way out for the gamma rays. Two similar proposals have been offered, first by Dr. Rees and Dr. Peter Meszaros of Pennsylvania State University last year and now by a scientific team at the Institute of Astrophysics in Paris (IAP).

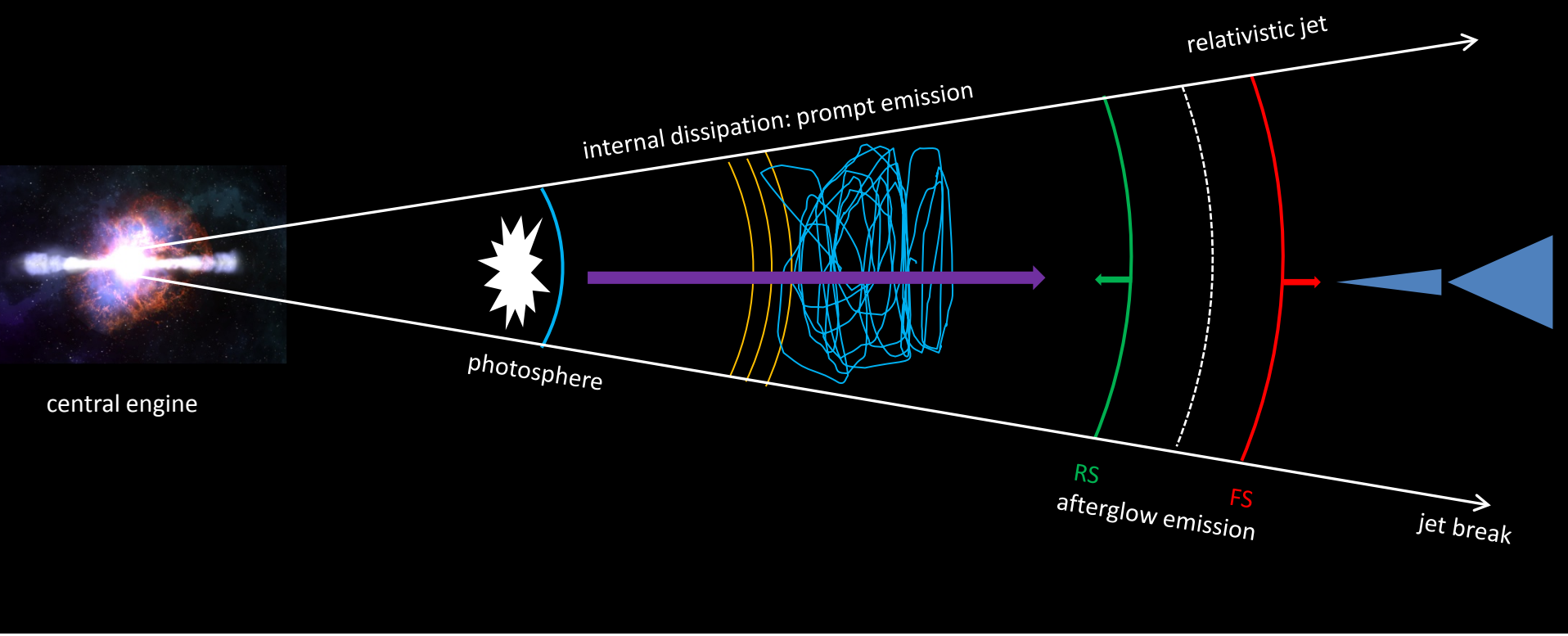
Writing in the current Nature, the IAP team noted that in violent encounters between a neutron star and a black hole, the cloud of obscuring material would be concentrated around the "equator" of the system. This could leave a kind of funnel along the system's axis of rotation through which the gamma rays could escape in a highly directional column of energy.



The “IAP team” :

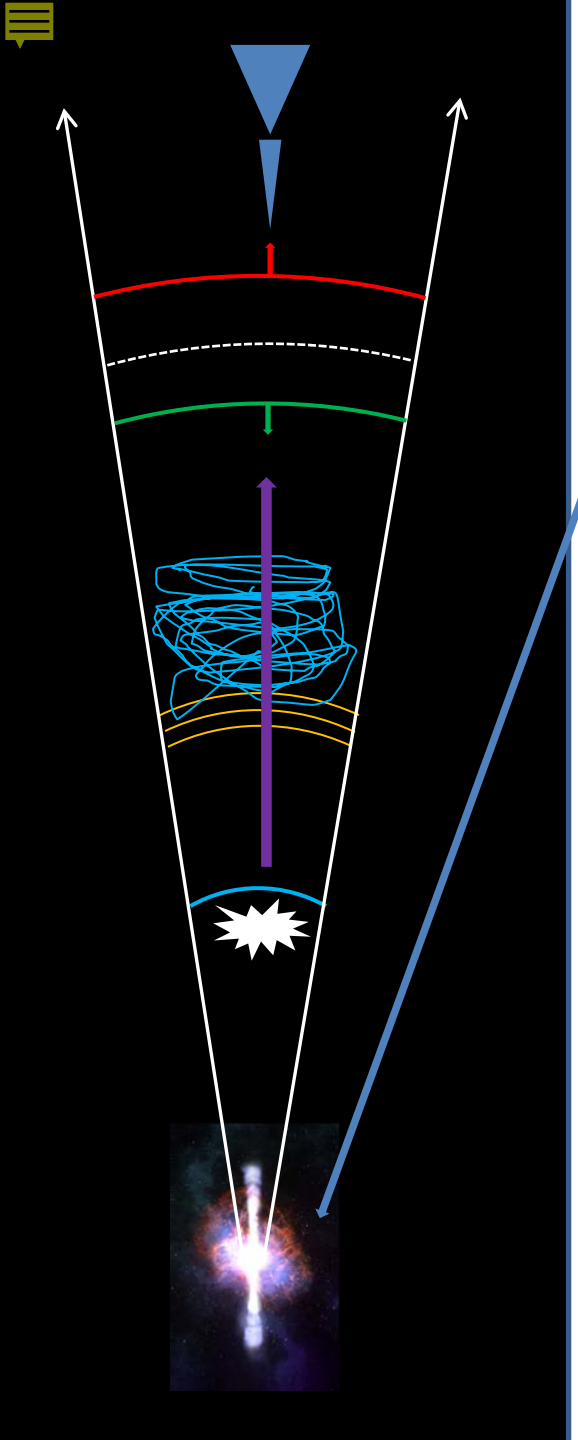
Hernanz, Isern, Martin, Mochkovitch

The present picture



Some unsettled issues

- source of energy
- acceleration/energy content of the jet: thermal/magnetic?
- where is the energy dissipated?
- dissipation mechanism at work?

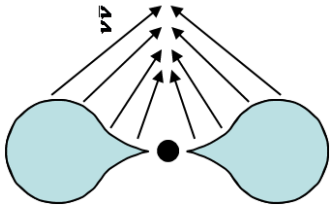


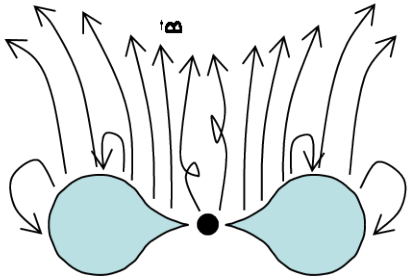
Central object:

- Collapsar or merger ? Black hole or magnetar?
- What is the ultimate source of energy ? accretion, rotation of the BH/magnetar ?

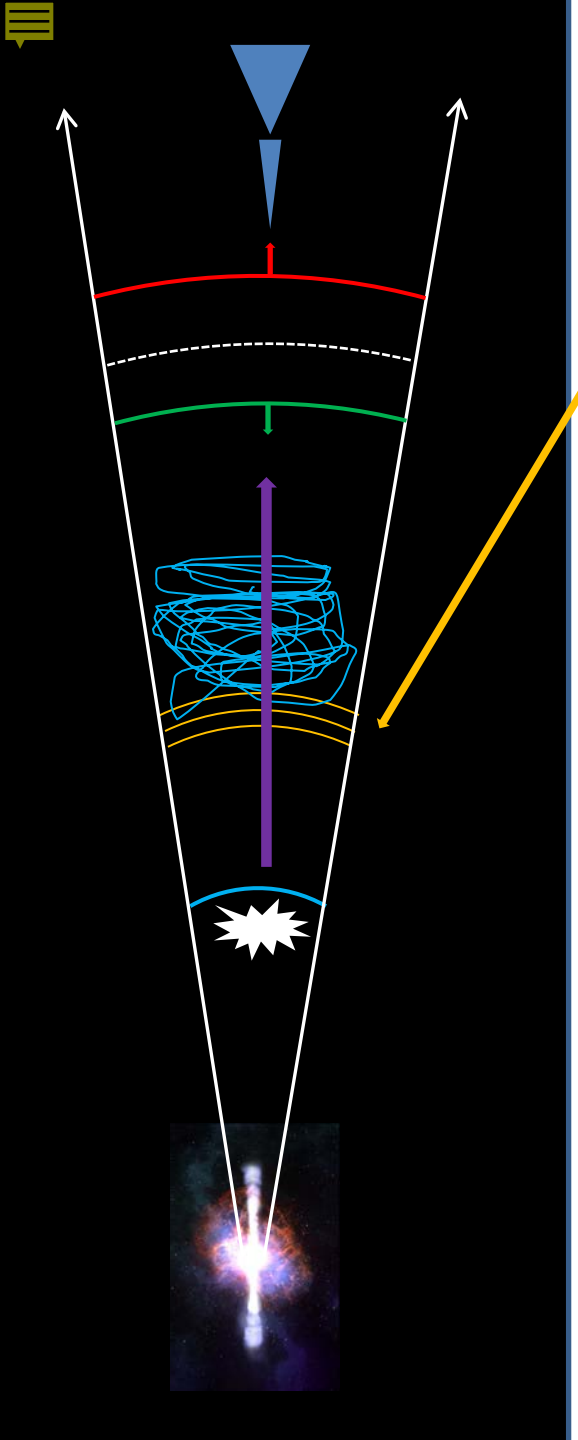
Extraction of energy and acceleration mechanism:

- $\nu\bar{\nu}$ annihilation, thermal acceleration → hot wind
- Magnetic extraction and acceleration → cold wind





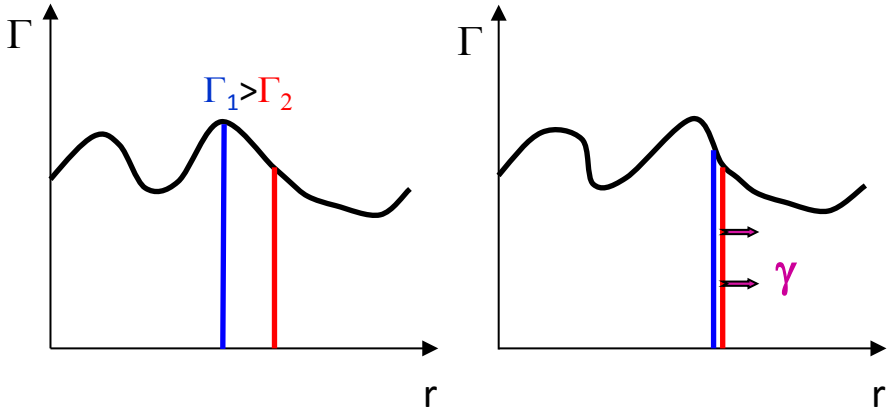
Energy content of the jet: thermal/magnetic → kinetic
→ residual thermal/magnetic energy far from the source?

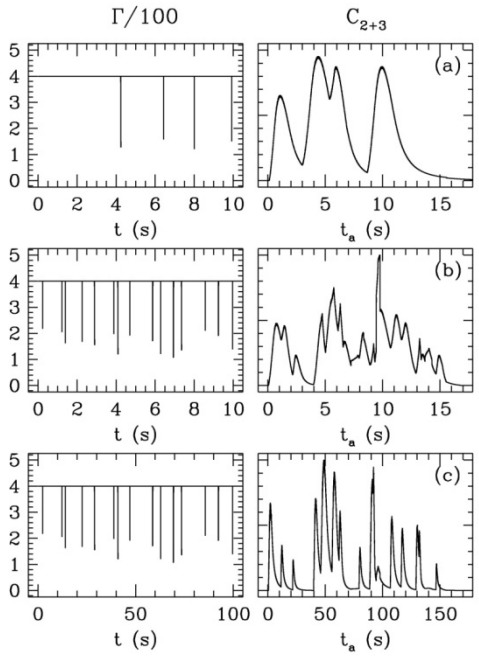


- **Dissipation processes**

above the photosphere: *internal shocks*

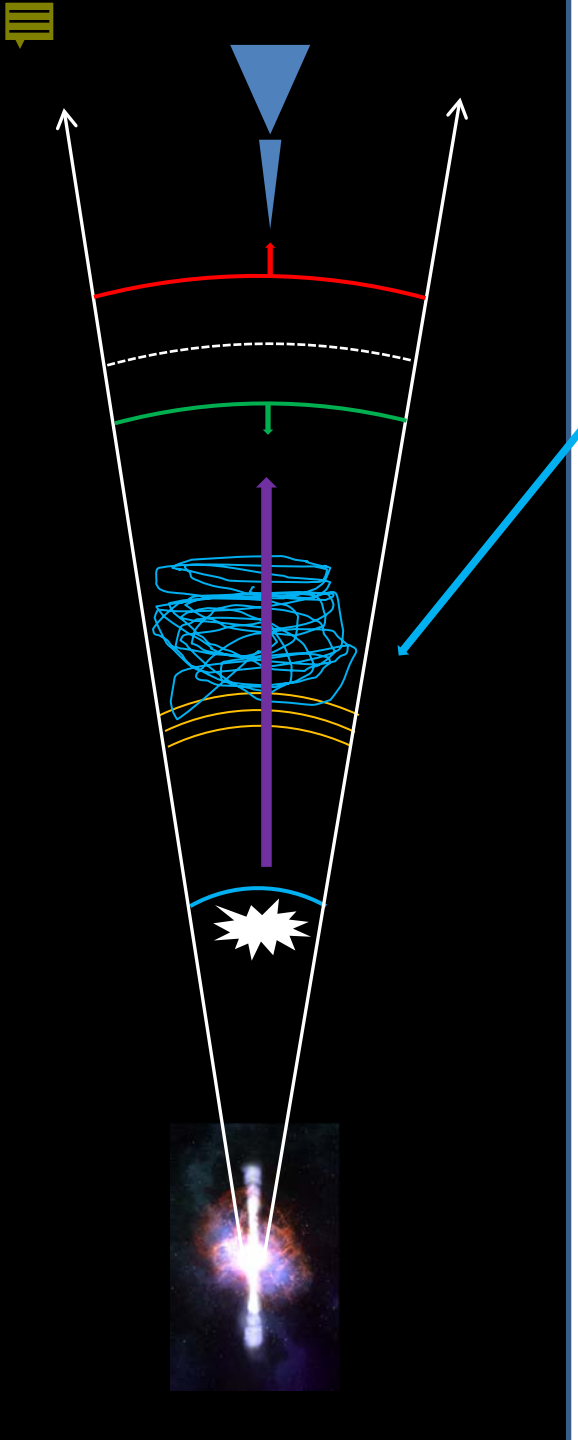
variable Lorentz factor in the outflow





Shock accelerated electrons emit γ–rays by synchrotron radiation

(Daigne & Mochkovitch, 1998)

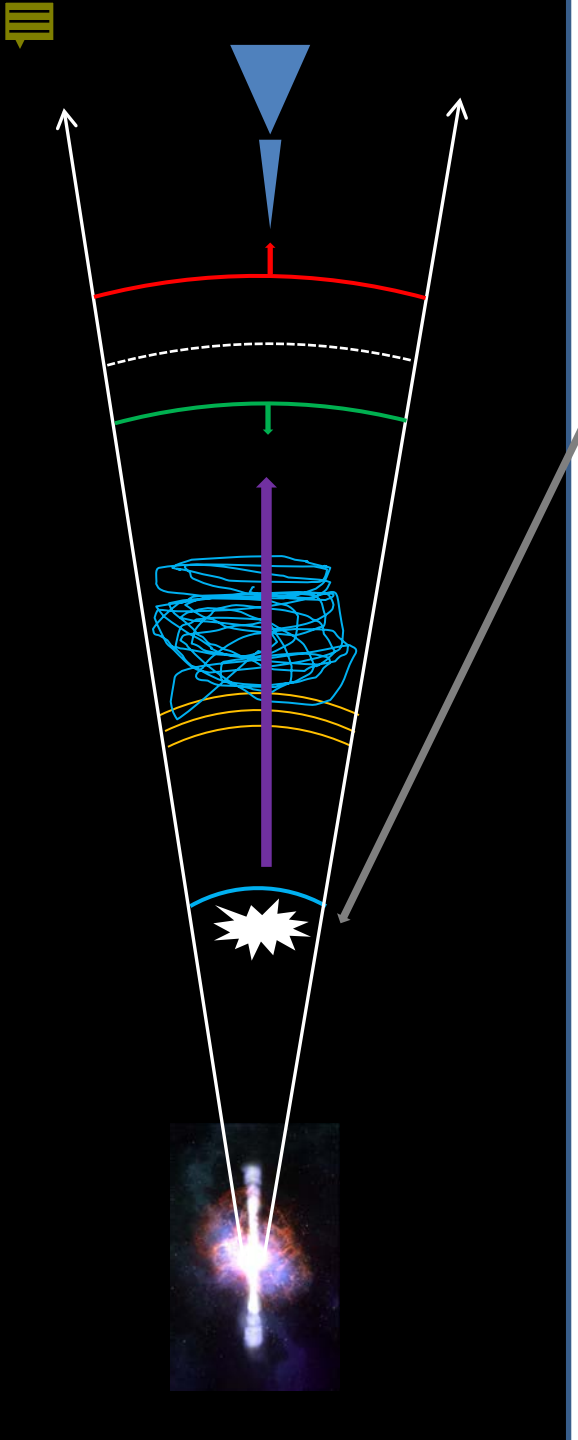


- **<u>Dissipation processes</u>**

  <u>above the photosphere</u>: *reconnection*

Magnetic field lines get reorganized in a new configuration carrying less energy

→ the difference is used to accelerate particles which then emit synchrotron radiation

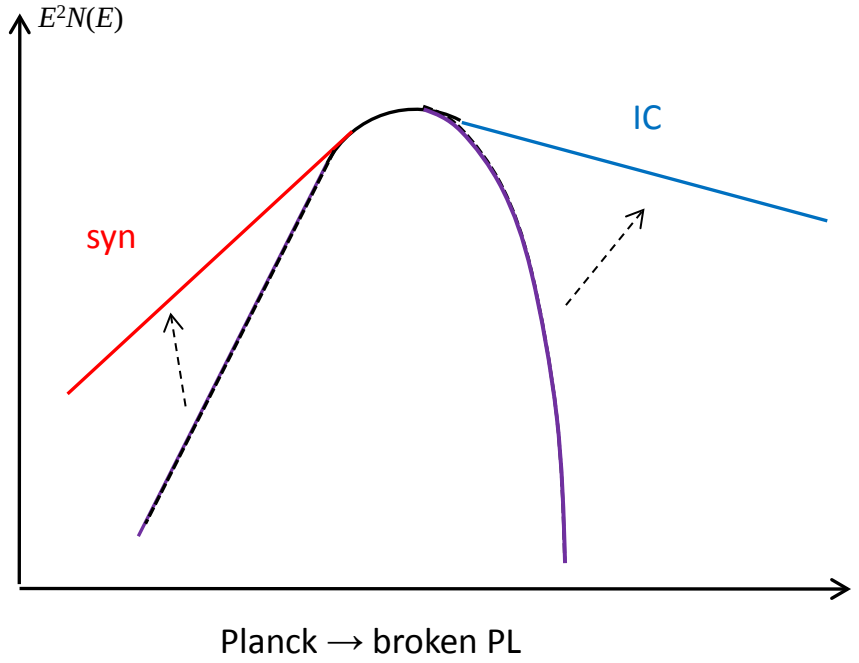


- **Dissipation processes**

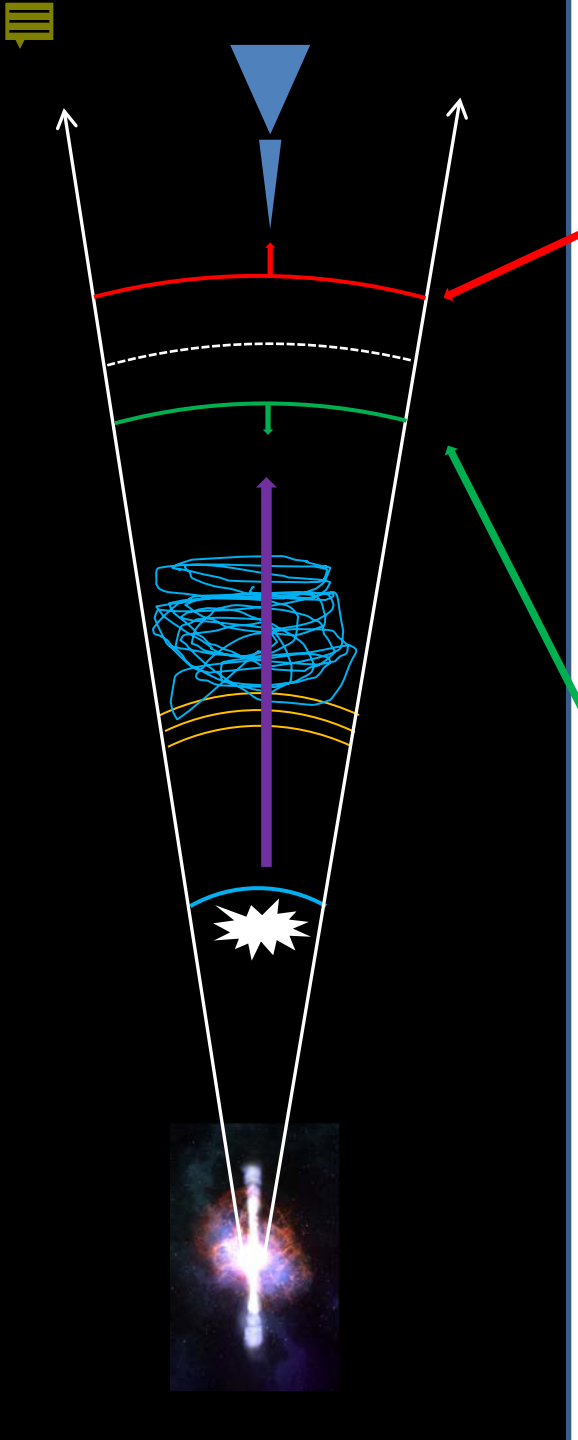
  below the photosphere: starting from a thermal spectrum

  "comptonization" photon energy boosted by collision with e^-

  + synchrotron contribution



Planck ⟶ broken PL



- **Is the afterglow simpler ?**

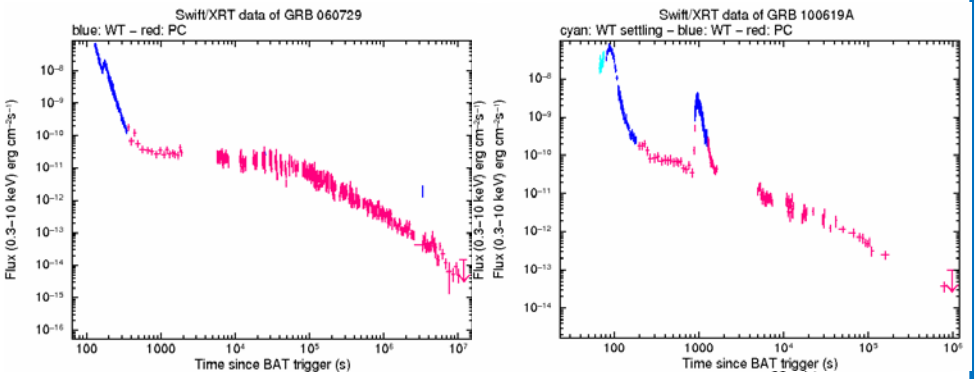
It seemed so before Swift…

relativistic generalization of the Sedov-Taylor (blast wave) problem:

→ self-similar solution, power-law behavior

But how to explain the early afterglow ?

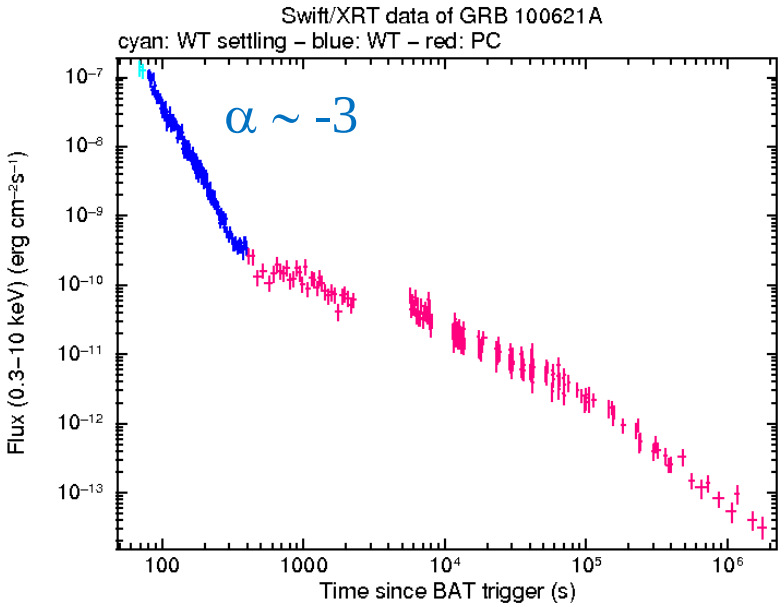
plateau and flares do not fit in the picture

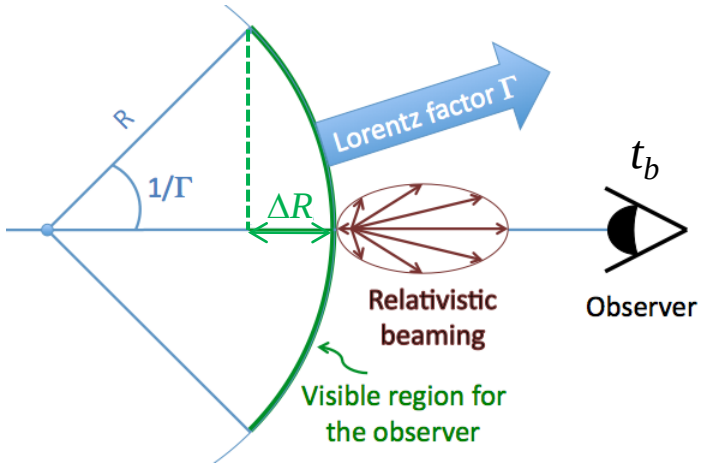


- late activity of the central engine ?
- contribution of the reverse shock ?

Looking for tests to select among the models

Test of the emission radius: the “early steep decay”





$$\alpha(t_b) = \left.\frac{d\mathrm{Log}L}{d\mathrm{Log}t}\right|_{t_b} = -3\frac{t_b}{\Delta t_{geo}} \;;\; \Delta t_{geo} = \frac{\Delta R}{c}$$

IS, reconnection : $\Delta t_{geo} \sim t_b \;\rightarrow\; \alpha \sim -3$

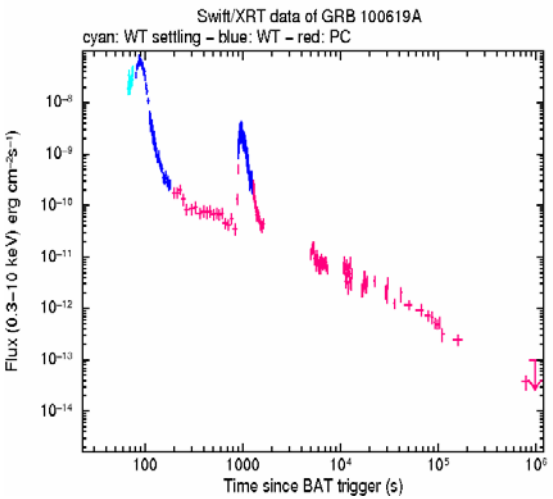
Photospheric models : $\Delta t_{geo} << t_b$

In photopheric models the initial decay must correspond to an effective behavior of the central engine

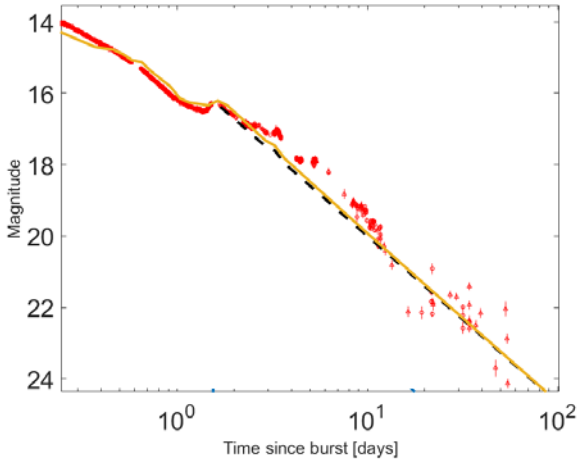
(Hascoët, Daigne & Mochkovitch, 2012)

Test of the magnetization from the presence of shocks

Flares in the early X-ray afterglow



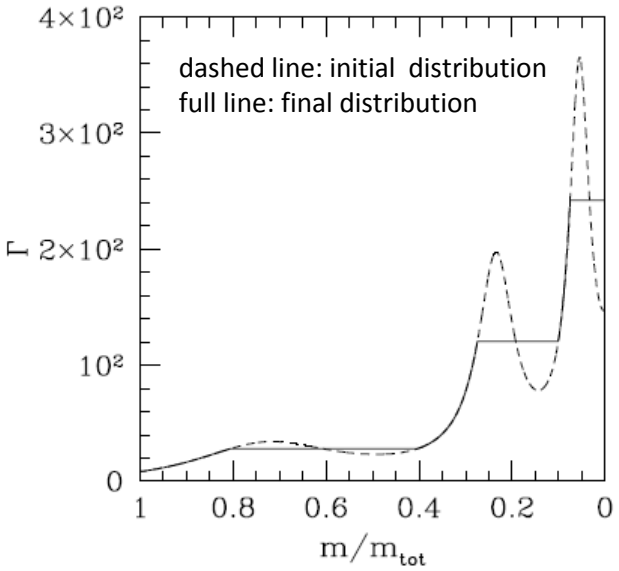
Bumps in optical light curve: GRB 030329

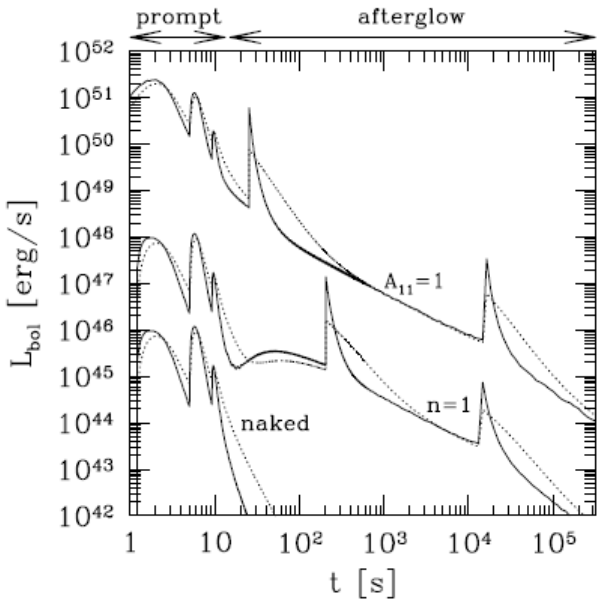


(Beniamini & RM)
(in prep.)

FS

RS





(Hascoët et al, 2017)

Conclusion

Since 1992:

We have learned a lot about GRBs

- Distance scale (from z = 0.01 (sub-luminous) to z = 8.2)
- Progenitors (collapsars/mergers for long/short GRBs)
- Emission from a high Γ jet of opening angle 5 – 20°
- Afterglow from the deceleration of the jet by the external medium
  X-rays to radio (minutes to years)

French baccalaureat Philosophie 2017: "suffit-il d'observer pour connaitre"

" To know, is it enough to observe?"

So, do we understand them?

- Prompt: shocks, reconnection, comptonization at the photosphere
  problems with synchrotron spectra
- Afterglow: going beyond the simple models (plateaus, flares)

The future

- The GW era: GRB + GW signal in coincidence ?
- SVOM mission (to be launched in 2021)
  broad coverage of the prompt emission
  + localization capabilities

Felipe V : born in Versailles

December 19, 1683 : just 273 years before Margarita !

OBSERVATIONS ASTRONOMIQUES ET PHYSIQUES

FAITES PAR ORDRE

DU ROI D'ESPAGNE

POUR DETERMINER LA FIGURE ET LA GRANDEUR DE LA TERRE, RELATIVEMENT A LA NAVIGATION.

Par DON GEORGE JUAN,

COMMANDEUR D'ALIAGA DANS L'ORDRE DE MALTHE, ET COMMANDANT DE LA COMPAGNIE DES GENTILS-HOMMES GARDES DE LA MARINE,

ET

Par DON ANTOINE DE ULLOA,

LIEUTENANT DE LA MEME COMPAGNIE,

TOUS DEUX CAPITAINES DE HAUT-BORD DE L'ARME'E NAVALE DU ROI D'ESPAGNE, MEMBRES DES SOCIE'TE'S ROYALES DE LONDRES ET DE BERLIN, ET CORRESPONDANS DE L'ACADEMIE DES SCIENCES DE PARIS.

Tome II. Partie II.

PREFACE.

UNe des plus grandes marques que le Roi PHILIPE V. *de Glorieuſe Mémoire ait donnée de ſon zéle pour l'avancement des Sciences en* Eſpagne, *a été ſans-doute d'avoir non ſeulement permis que des* Académiciens François *paſſaſſent dans ſes Etats d'*Amérique, *pour y meſurer le degré terreſtre ſous l'Equateur; mais encore de les avoir fait accompagner par quelques-uns de ſes propres Sujets, pour faire les obſervations qu'ils jugeroient néceſſaires. Le choix de ce Monarque tomba ſur* Don Antonio de Ulloa *& ſur moi, & nous en fûmes d'autant plus flattés qu'il nous parut être un gage de l'eſtime d'un ſi grand Prince.*

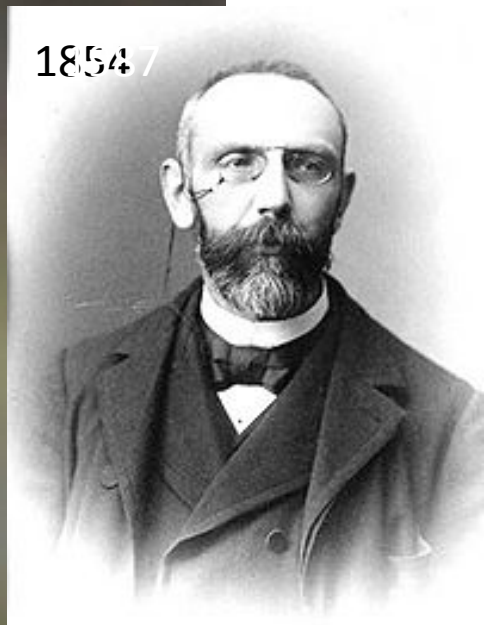
*Nous partîmes d'*Europe *au mois de* Mai 1735, *& nous ne fûmes de retour qu'en* 1746. *Une ſi longue abſence accompagnée de tant de peines, de travaux & de fatigues, auroit été inutile, du-moins à nos Compatriotes, par la mort du Monarque qui nous avoit envoyés, ſi nous n'avions eu la conſolation de voir ſur le Trône un digne Héritier de ſes vertus autant que de ſon ſceptre & de ſon ſang, lequel a bien voulu nous accorder la méme protection que ſon Prédéceſſeur. En effet, à peine l'illuſtre Marquis de* la Enſenade *eut informé Sa Majeſté de notre retour à* Madrid, *& combien il ſeroit utile à l'avancement des Sciences & au bien général des Nations de l'*Europe *que cet Ouvrage fût publié, qu'Elle donna non ſeulement ordre qu'il fût imprimé à ſes dépens, mais le daigna méme prendre ſous ſa protection Royale.*

Conformément aux intentions de ce Monarque nous avons arrangé nos matériaux le plus briévement qu'il nous a été poſſible, & pour plus de clarté nous avons diviſé notre Ouvrage en deux Parties. L'une, dont D. Antonio de Ulloa *s'eſt chargé, contient la rélation du Voyage, les Cartes, les Deſcriptions des Pays, & les Remarques que nous avons faites ſur tout ce qu'il y a de ſingulier dans les Royaumes du* Pérou *par où nous avons paſſé. L'autre qui eſt contenue dans ce Volume-ci, m'eſt tombée en partage, & renferme toutes les* Obſervations Aſtronomiques & Phyſiques *que nous avons faites tant par rapport au but principal de notre Voyage, que pour exécuter les inſtructions particulieres dont il avoit plû à Sa Majeſté de nous charger.*

Le principal but de notre Voyage, étoit de vérifier la valeur du degré terreſtre ſous l'Equateur, afin que comparé avec celui

AND…

LAST BUT NOT LEAST…



1999

A star… from the Galácticos !

Cheers !

Margarita

Specified ingredients	•3.5 cL (7 parts) Tequila •2 cL (4 parts) Triple Sec •1.5 cL (3 parts) Lime juice
Preparation	Rub the rim of the glass with the lime slice to make the salt stick to it. Take care to moisten only the outer rim and sprinkle the salt on it. The salt should present to the lips of the imbiber and never mix into the cocktail. Shake the other ingredients with ice, then carefully pour into the glass.