Frères Mentouri Constantine 1 University
Faculty of Sciences Exact, Physics Departement
LPMPS Laboratoiry

The GRB Afterglows flowchart

By:
Dr. Esma ZOUAOUI
Pr. Nour elddin MEBARKI

2nd Electronic Conference on Universe
16 February – 03 March, 2023

Outline

- Introduction
- Hydrodynamic of the external shock and their flowchart
- Radiation of the GRB-Afterglows and their flowchart
- Conclusion

Introduction

Gamma ray bursts (GRB)

- Flashes rays of gamma rays

- **Energy**

From (keV) to (GeV)

[10^51 – 10^54] erg

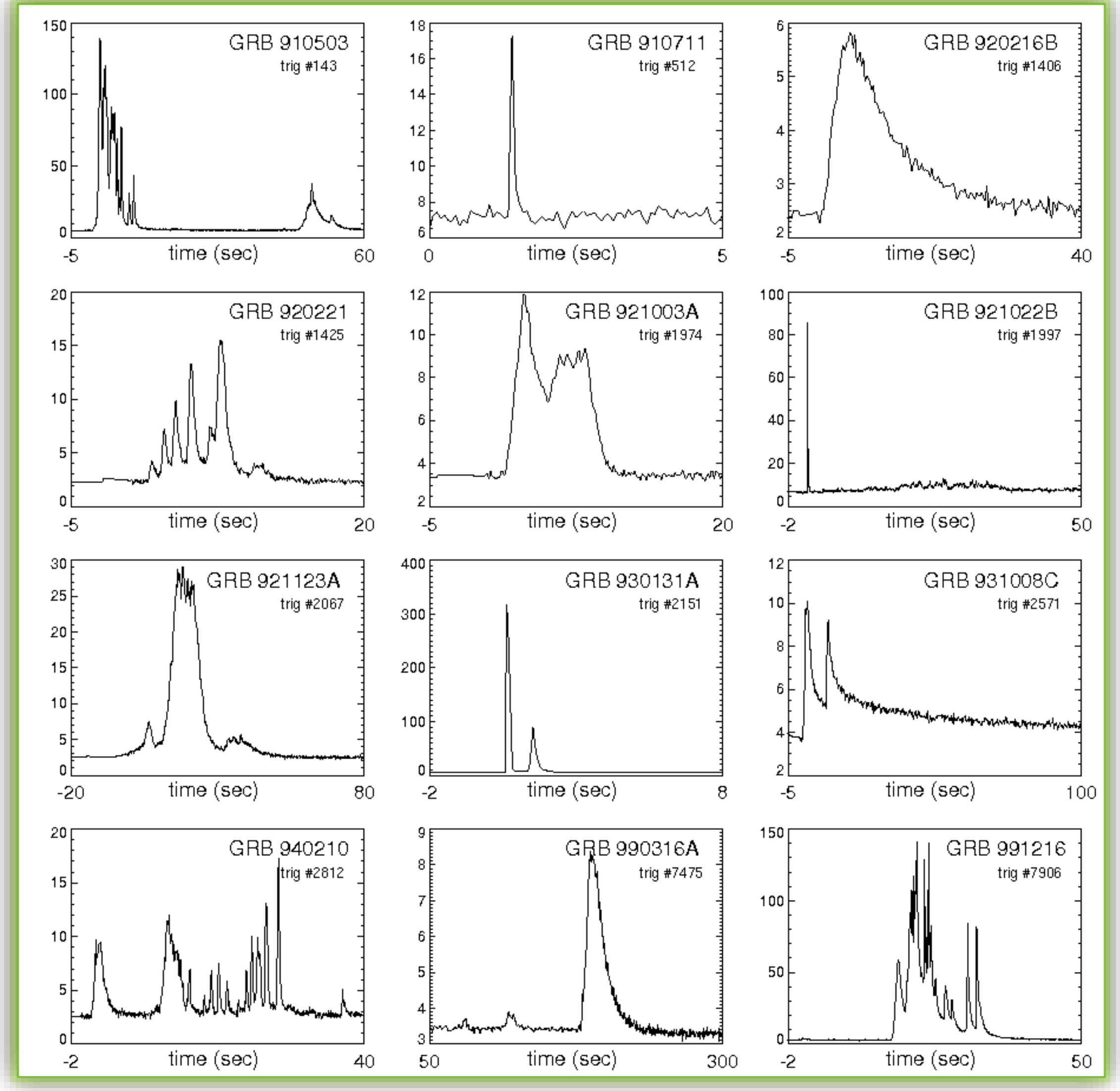
- **Duration**

[10-2 - 102] s

- **Flux**

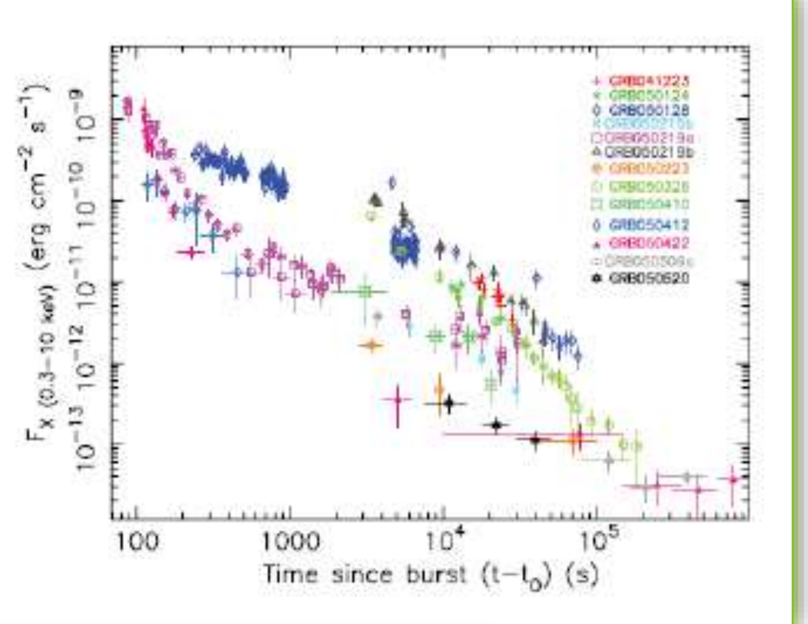
[10^(-7)-10^ (-4)]

erg.s^-1.cm^-2



- Internal shocks (Fireball model)

Afterglows of GRB

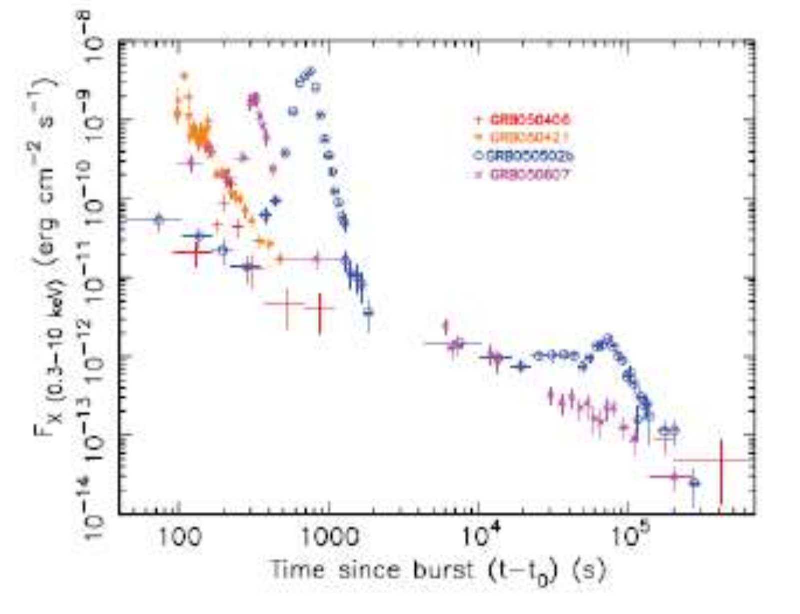


- Delayed emission of GRBs.

- **Duration**
Seconds to weeks

- **Energy band**
From hard gamma-ray, X-rays to radio waves.

- External shocks (Fireball model)



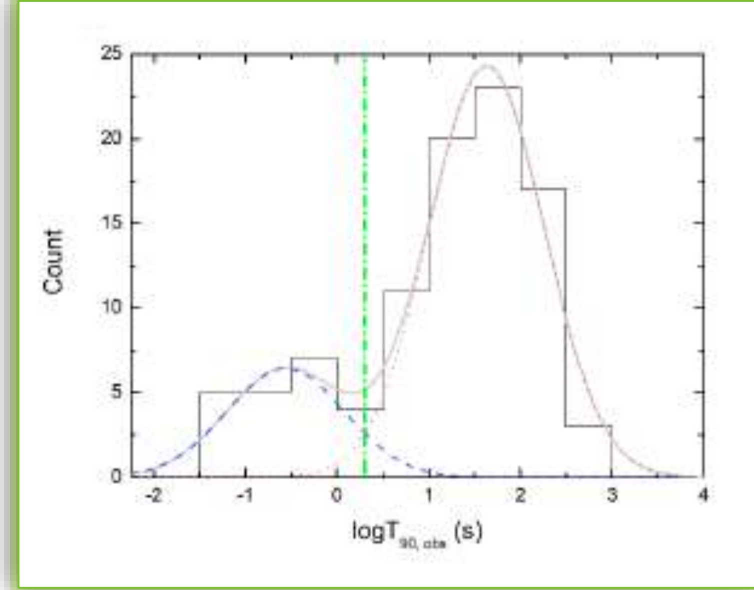
GRB the luminosity

Astronomical object, cosmic bodies	Luminosity $[ergs^{-1}]$
Sun	$\sim 10^{33}$
Milky Way Galaxy (Total star-light)	$\sim 10^{44}$
Active Galactic Nuclei	$\sim 10^{48}$
GRBs	$\sim 10^{53}$

Classification

- **Short gamma-ray burst**
  Duration< 2s

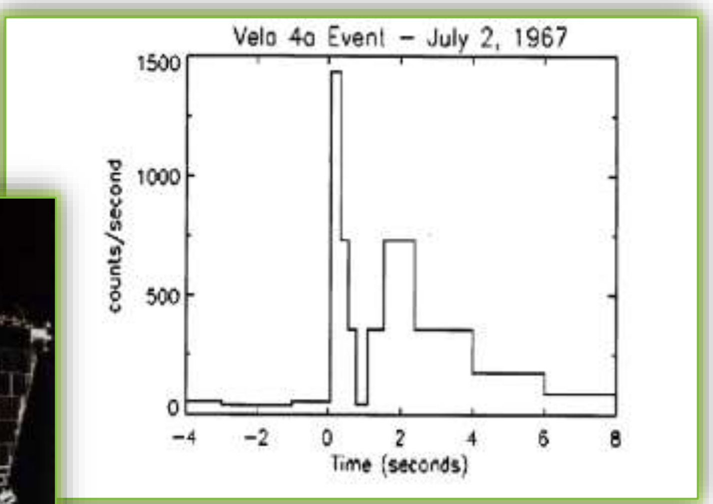
- **Long gamma-ray burst**
  Duration > 2s



BATSE

Discovered of GRBs

First discovered of GRBs, 1967 by VELA satellites missions.



First Publisher

THE ASTROPHYSICAL JOURNAL, 182:L85–L88, 1973 June 1

OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

RAY W. KLEBESADEL, IAN B. STRONG, AND ROY A. OLSON

University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico

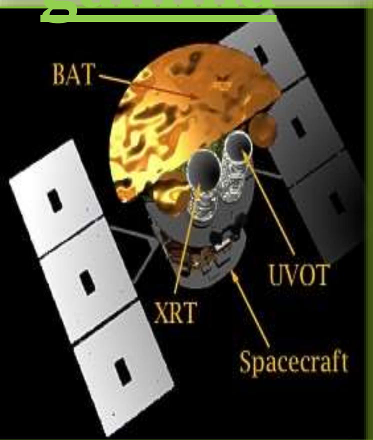
Received 1973 March 16; revised 1973 April 2

ABSTRACT

Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to ~30 s, and time-integrated flux densities from ~10^{-5} ergs cm^{-2} to ~2×10^{-4} ergs cm^{-2} in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.

Subject headings: gamma rays — X-rays — variable stars

Enigme des sursauts gamma

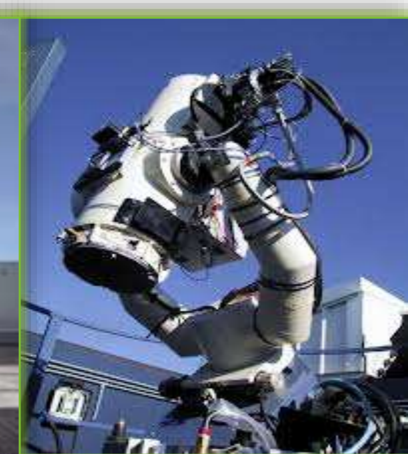


Swift
(2004)

Fermi-GLAST
(2008)

VLBI
(radio-1967)

VLT
(optique-1987)



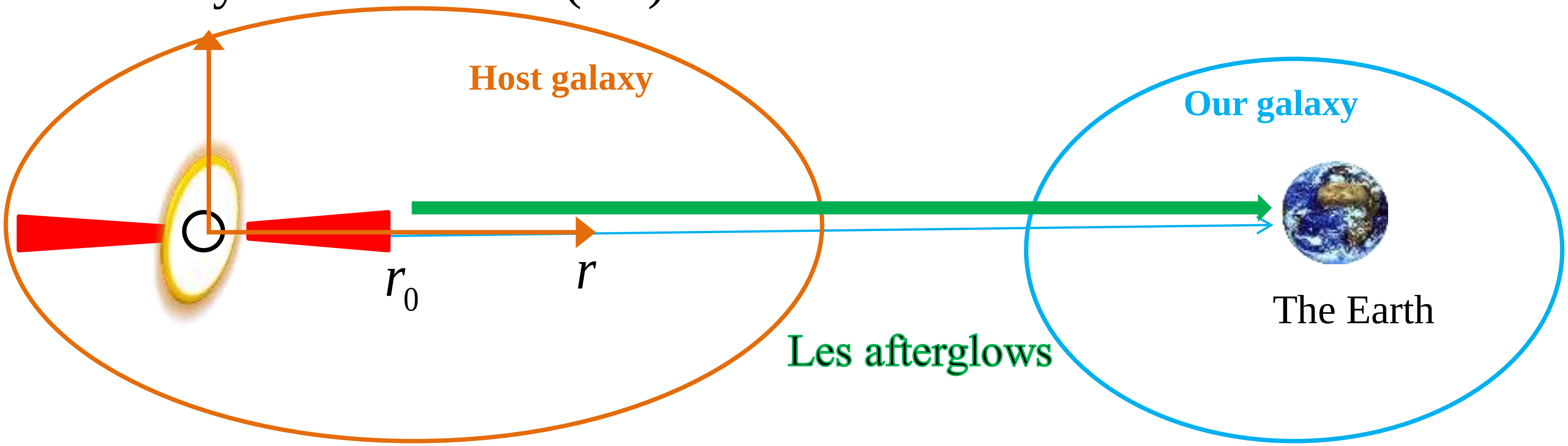
TAROT
(optique-1995)

- Galactic or extragalactic Origin ?
- The progenitor ?
- The radiation mechanisms and

Hydrodynamic study of external shock and their flowchart

Fireball model

Geometry of the fireball (FB):



The total kinetic energy of the fireball is:

$$E_c = (\Gamma - 1)(M_0 + m)c^2 + \Gamma U_{rest}$$

(Panaitescu, et al., 1998)

The radiated thermal kinetic energy is:

$$dE_r = \varepsilon \, \Gamma \left(\Gamma - 1\right) dm \, c^2$$

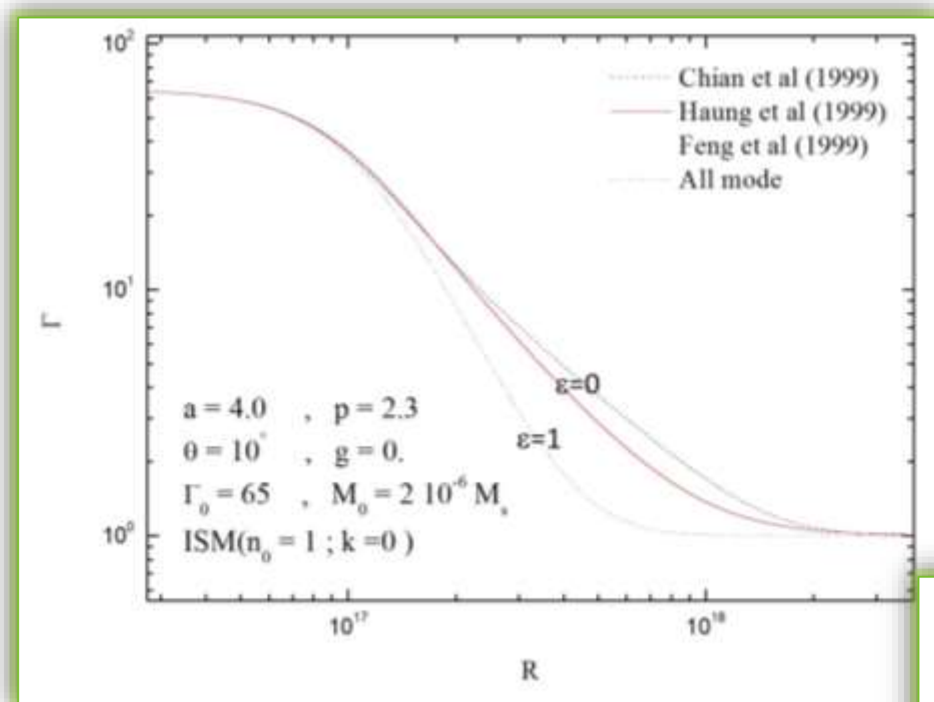
(Blandford, et al., 1976)

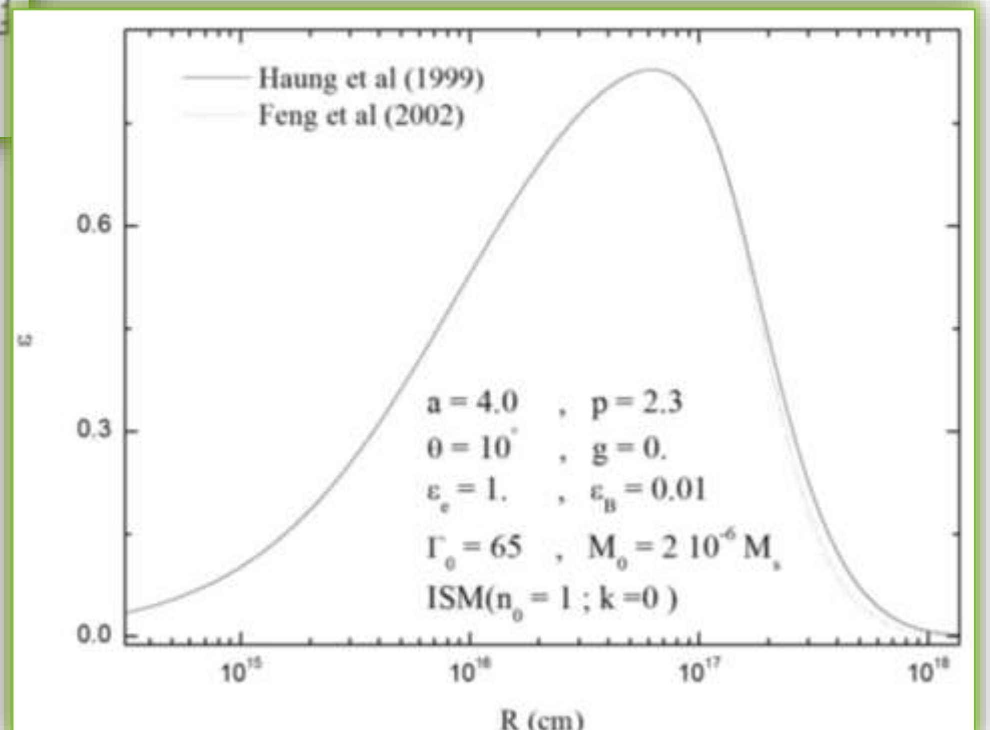
The global energy balance is:

$$dE_c = - \, dE_r$$

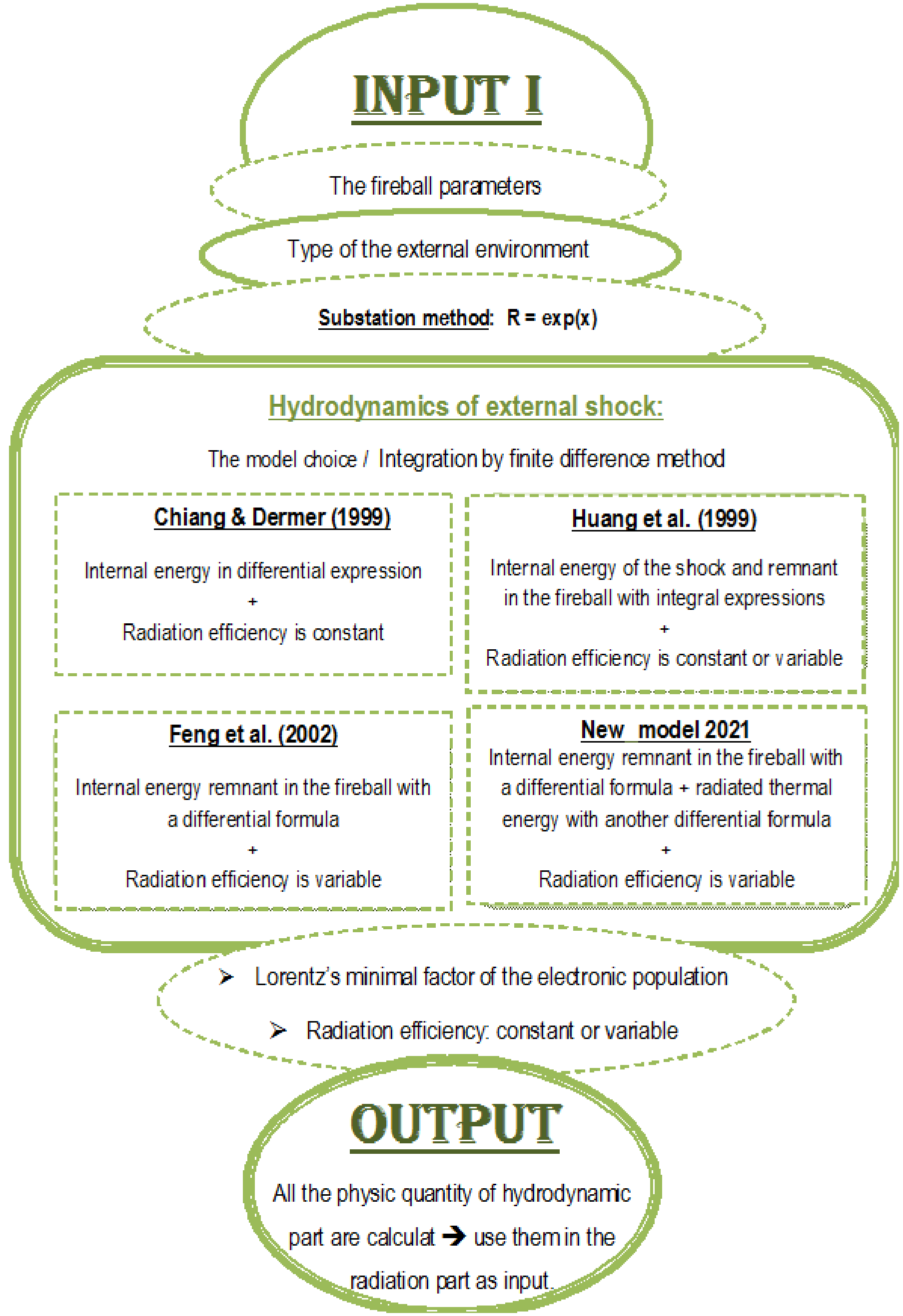
The proposed models

Feng (2002)	Huang (1999)	Chaing Dermer (1999)
$dU = (1-\varepsilon)dU_{ex}$	$U = (\Gamma - 1)mc^2$	$dU = (\Gamma - 1)dmc^2$
$dU_{ex} = (\Gamma - 1)dmc^2 + mc^2 d\Gamma$	$dU = (\Gamma - 1)dmc^2 + mc^2 d\Gamma$	$U = \int (\Gamma - 1)dmc^2$
$\frac{d\Gamma}{dm} = -\frac{\Gamma^2 - 1}{M_0 + m + U/c^2 + (1-\varepsilon)\Gamma m}$	$\frac{d\Gamma}{dm} = -\frac{\Gamma^2 - 1}{M_0 + \varepsilon m + 2(1-\varepsilon)\Gamma m}$	$\frac{d\Gamma}{dm} = -\frac{\Gamma^2 - 1}{M}$
$dE_r = \varepsilon\Gamma(\Gamma - 1)\, dm\, c^2$	$dE_r = \varepsilon\Gamma(\Gamma - 1)\, dm\, c^2$	$dE_r = \varepsilon\Gamma(\Gamma - 1)\, dm\, c^2$


Chian et al (1999)
Haung et al (1999)
Feng et al (1999)
All mode
ε=0
ε=1
a = 4.0 , p = 2.3
θ = 10° , g = 0.
Γ0 = 65 , M0 = 2 10^-6 Ms
ISM(n0 = 1 ; k =0)
Γ
R


Haung et al (1999)
Feng et al (2002)
a = 4.0 , p = 2.3
θ = 10° , g = 0.
εe = 1. , εB = 0.01
Γ0 = 65 , M0 = 2 10^-6 Ms
ISM(n0 = 1 ; k =0)
ε
R (cm)

The flowchart



Radiation of the fireball and their flowchart

Synchrotron radiation

Puissance spectral for 1 é: $$P_\nu = \frac{2\sqrt{3}e^2\nu_L}{c}F\left(\frac{\nu'}{\nu'_c}\right)\gamma_e$$ (Rybicki, et al., 1979)

Puissance spectral : $$P_\nu = \frac{2\sqrt{3}e^2\nu_L}{c}\int_{\gamma_{\min}}^{\gamma_{\max}} N'_e(\gamma_e)F\left(\frac{\nu'}{\nu'_c}\right)d\gamma_e,$$

with:

$$N_e(\gamma_e) = \frac{dN_e}{d\gamma_e} = C\gamma_e^{-p}$$

$2.2 < p < 2.3$

$$\nu'_c = \frac{3}{4\pi}\gamma_e^2\frac{eB_\perp}{mc}$$

$$\gamma_{\max} = a\times 10^7\left(B'/1G\right)^{-\frac{1}{2}}$$

$$\gamma_{\min} = \varepsilon_e\left(\frac{p-2}{p-1}\right)\frac{m_p}{m_e}(\Gamma-1)+1$$

Instantaneous intensity :

$$\frac{dP_\nu}{d\Omega} = (1+z)(1+\beta)^3\Gamma^3\frac{dP_{\nu'}}{d\Omega'}$$

The relativistic translation :

$$\begin{cases} \nu = \dfrac{(1+\beta)\Gamma}{1+z}\nu' \\ d\Omega = \dfrac{1}{(1+\beta)^2\Gamma^2}d\Omega' \\ t_{obs} = (1+z)t \end{cases}$$

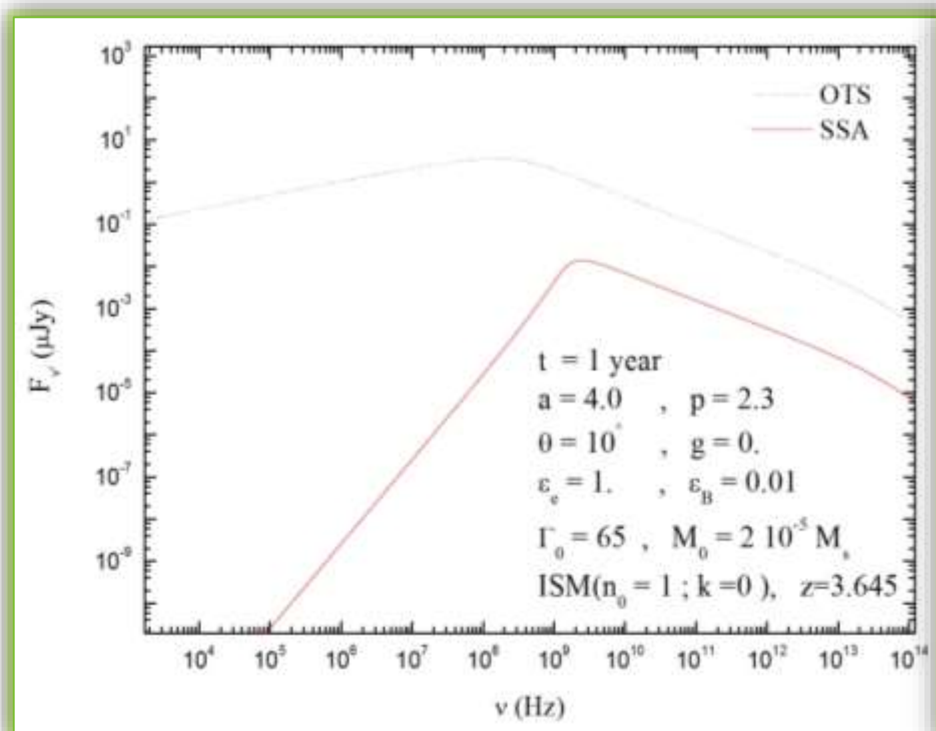
Synchrotron self-absorption (SSA)

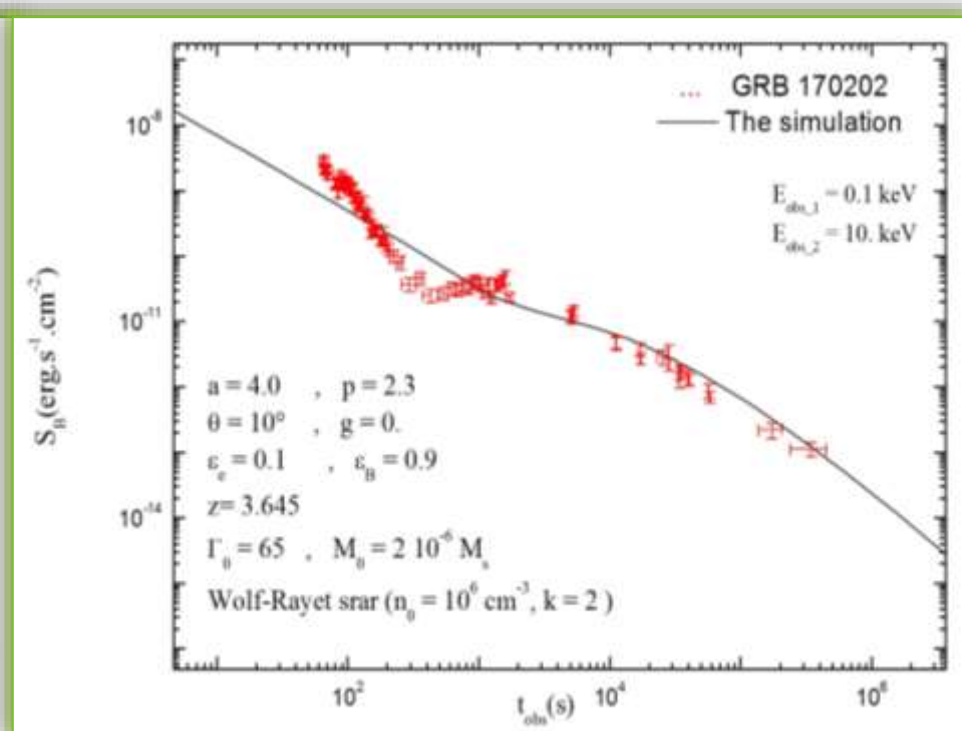
Absorption coefficient:

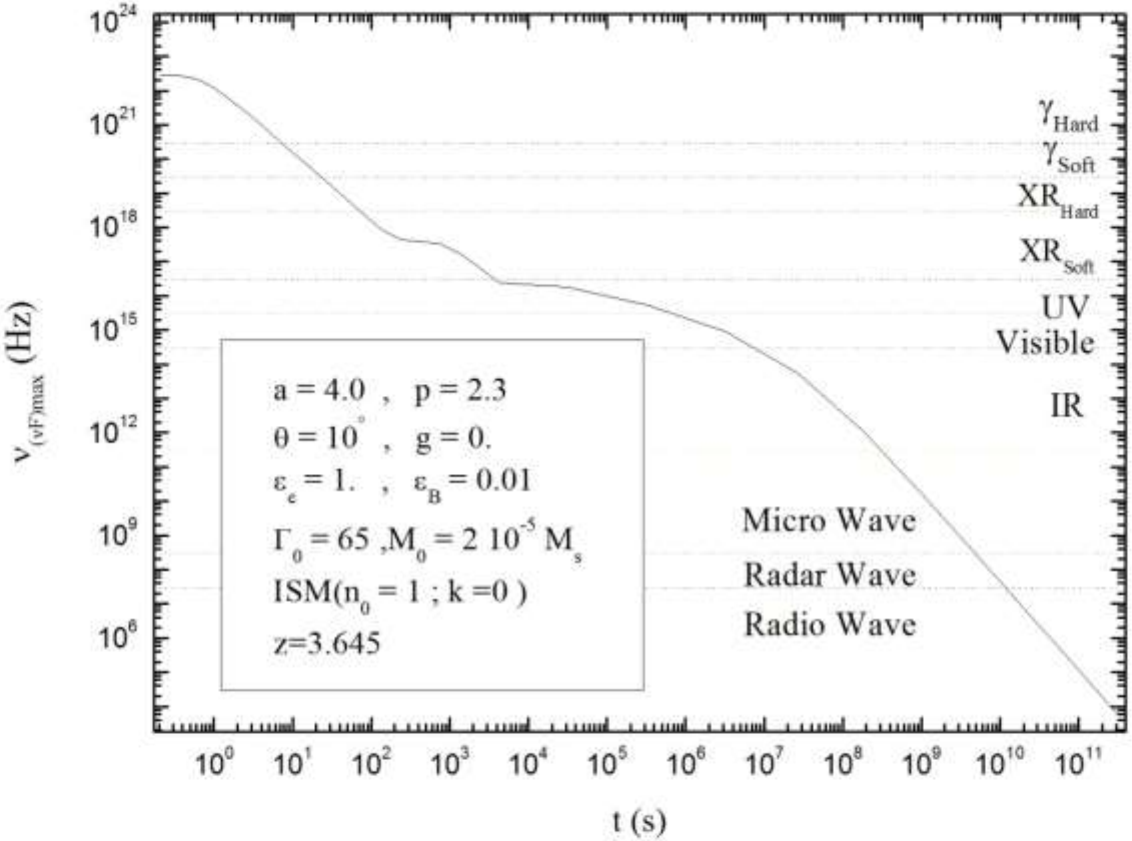
$$\alpha_{\nu'} = \frac{(p+2)}{8\pi m_e \nu_e'^{2}} \int_{\gamma_{min}}^{\gamma_{max}} P'_{\nu',e}(\gamma_e) \frac{N'_e(\gamma_e)}{(\gamma_e)} d(\gamma_e)$$

Instantaneous intensity :

$$\left(\frac{dP_{\nu'}}{d\Gamma'}\right)_{SSA} = \left(\frac{dP_{\nu'}}{d\Gamma'}\right)_{OTS} \frac{1}{\alpha'_\nu \Delta'} (1 - e^{\alpha'_\nu \Delta'})$$

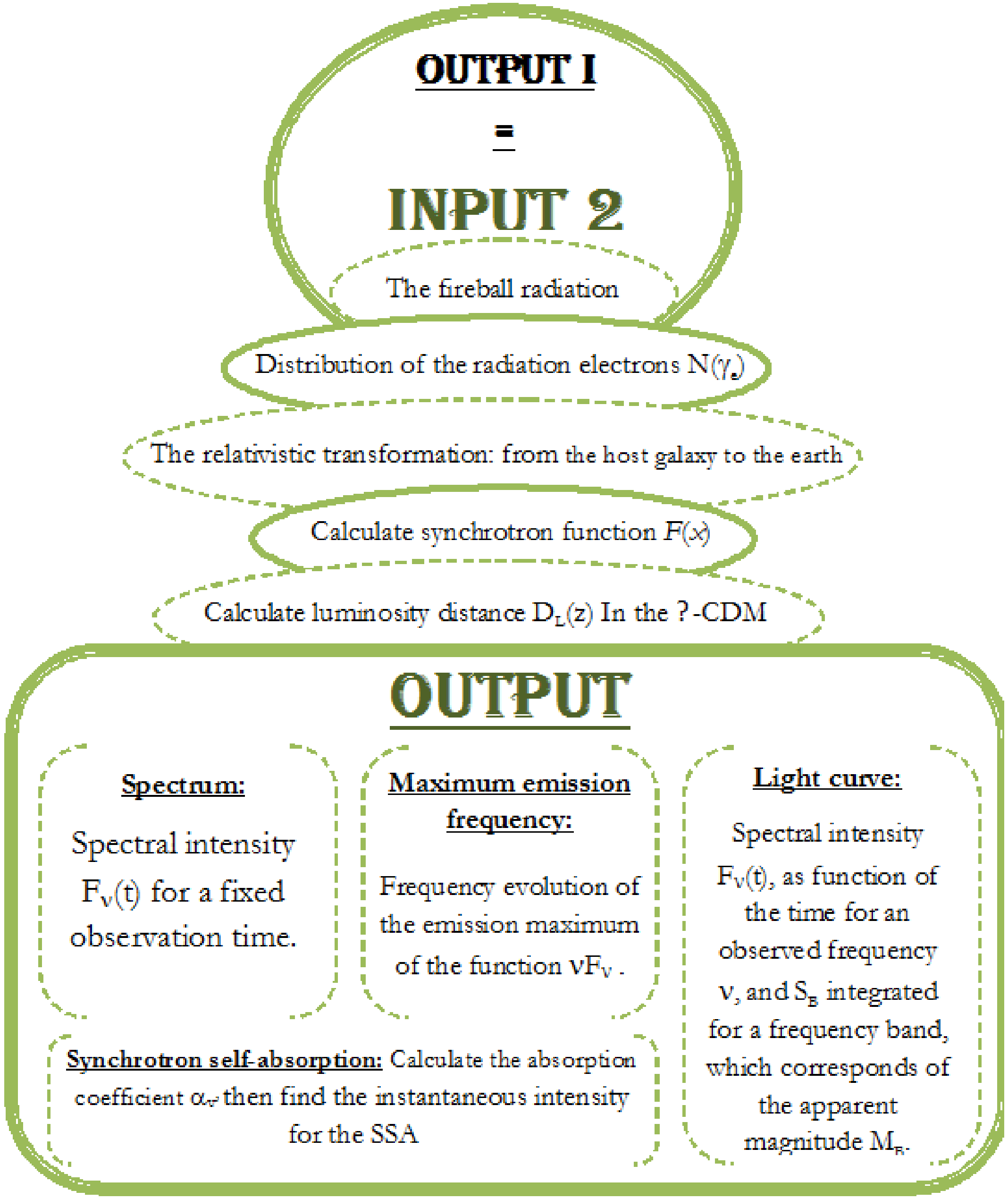






10^{24}
10^{21}
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
$\nu_{(\nu F)max}$ (Hz)
γ_{Hard}
γ_{Soft}
XR_{Hard}
XR_{Soft}
UV
Visible
IR
Micro Wave
Radar Wave
Radio Wave
a = 4.0 , p = 2.3
θ = 10° , g = 0.
ε_e = 1. , ε_B = 0.01
Γ_0 = 65 ,M_0 = 2 10^{-5} M_s
ISM(n_0 = 1 ; k =0)
z=3.645
10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11}
t (s)

The flowchart



Conclustion

- ✓ In the work we have studied the evolving hydrodynamics of the afterglow and its emission.

- ✓ we have seen that the Feng's model is the most interesting one. From the point of view of the efficiency, which it more realistic to describe the internal energy.

- ✓ It is worth to mention that the Feng models consistent with the Sedov solution both the non-relativistic phase and adiabatic regime.

- ✓ In the second part we have studied the basic radiation of the GRB afterglow by the synchrotron emission.

✓ The self synchrotron absorption plays important role in the low frequency range giving a fairly good approximation to the real data as in our case where the profile of the GRB 170202 afterglow was detected by Swift/XRT.

✓ The flowchart shows the great tool of the theoretical studies, which could give explanations of the phenomena.

✓ Finally, we can see that the importance of the modulisation studies when we can simulate the data observed.


THANK YOU
أسماء
Esma EsH2O