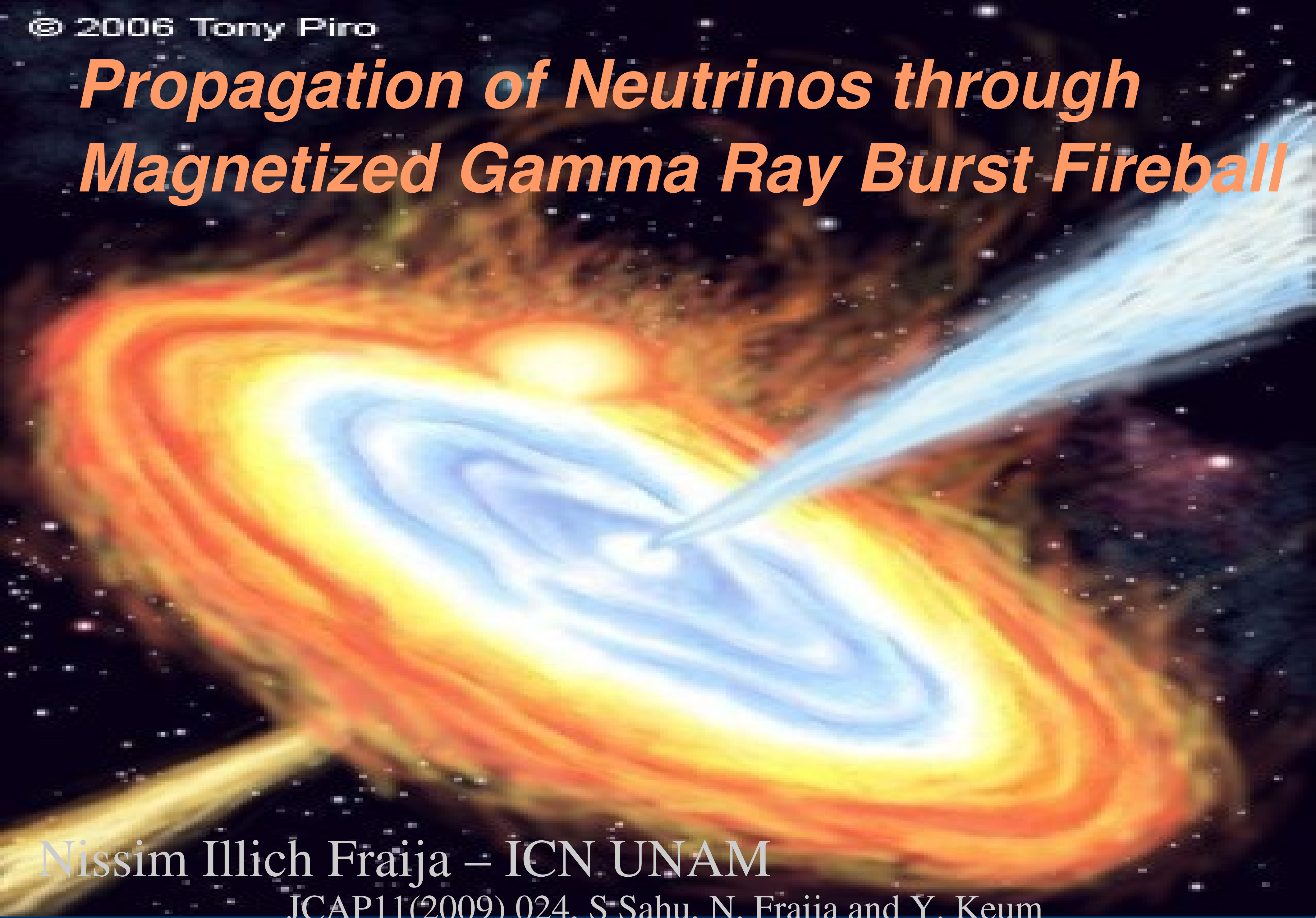


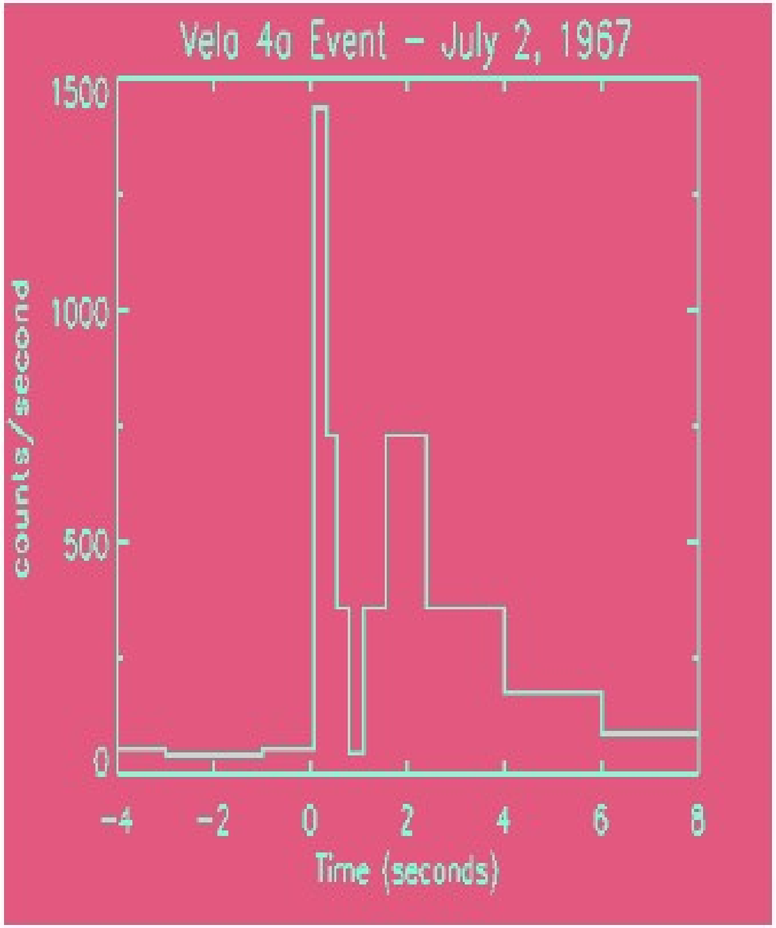
Propagation of Neutrinos through Magnetized Gamma Ray Burst Fireball

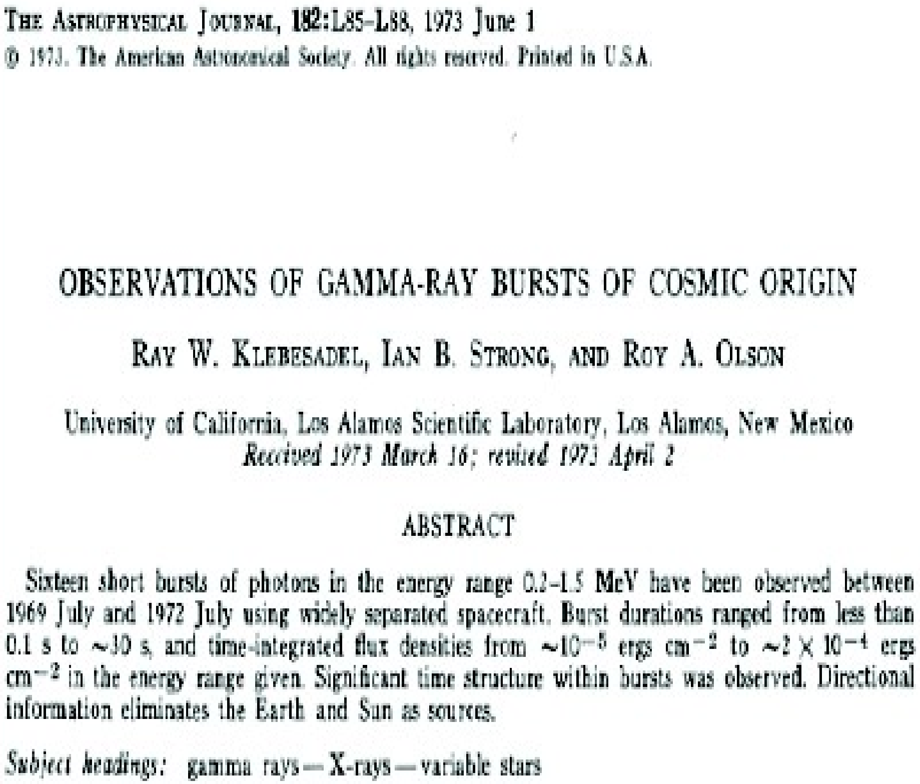
Nissim Illich Fraija – ICN UNAM

JCAP11(2009) 024, S Sahu, N. Fraija and Y. Keum

Gamma-Ray Bursts: are the most luminous objects after the Big Bang !

Discovered by VELAs Satelite




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
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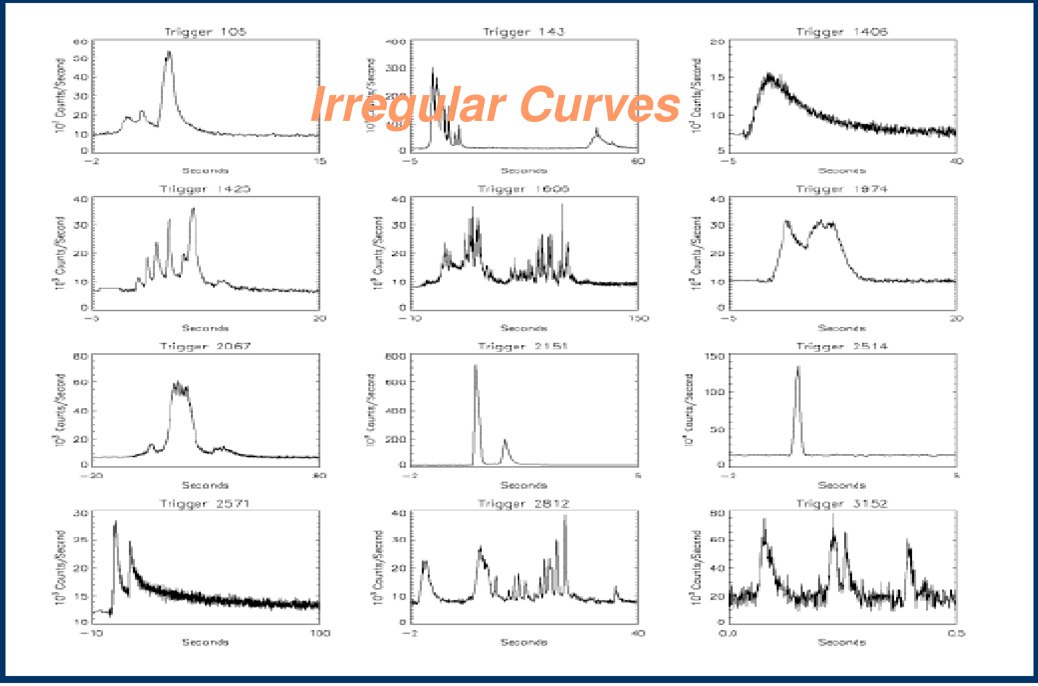
ABSTRACT

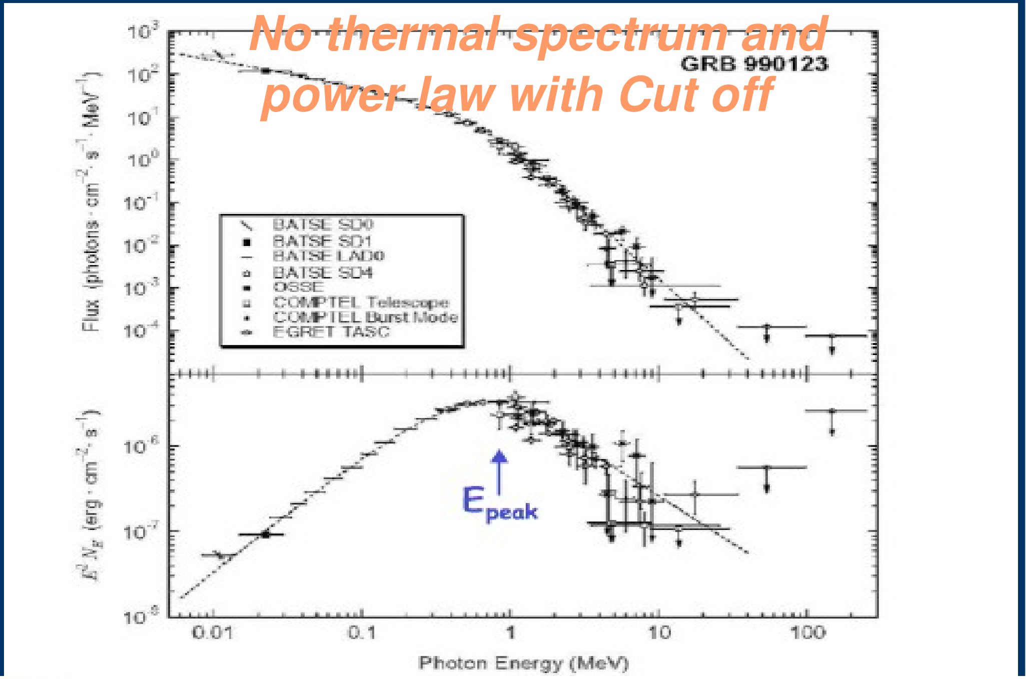
Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to ~30 s, and time-integrated flux densities from ~10^{-5} ergs cm^{-2} to ~2×10^{-4} ergs cm^{-2} in the energy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

The first Characteristics



Irregular Curves



No thermal spectrum and power law with Cut off

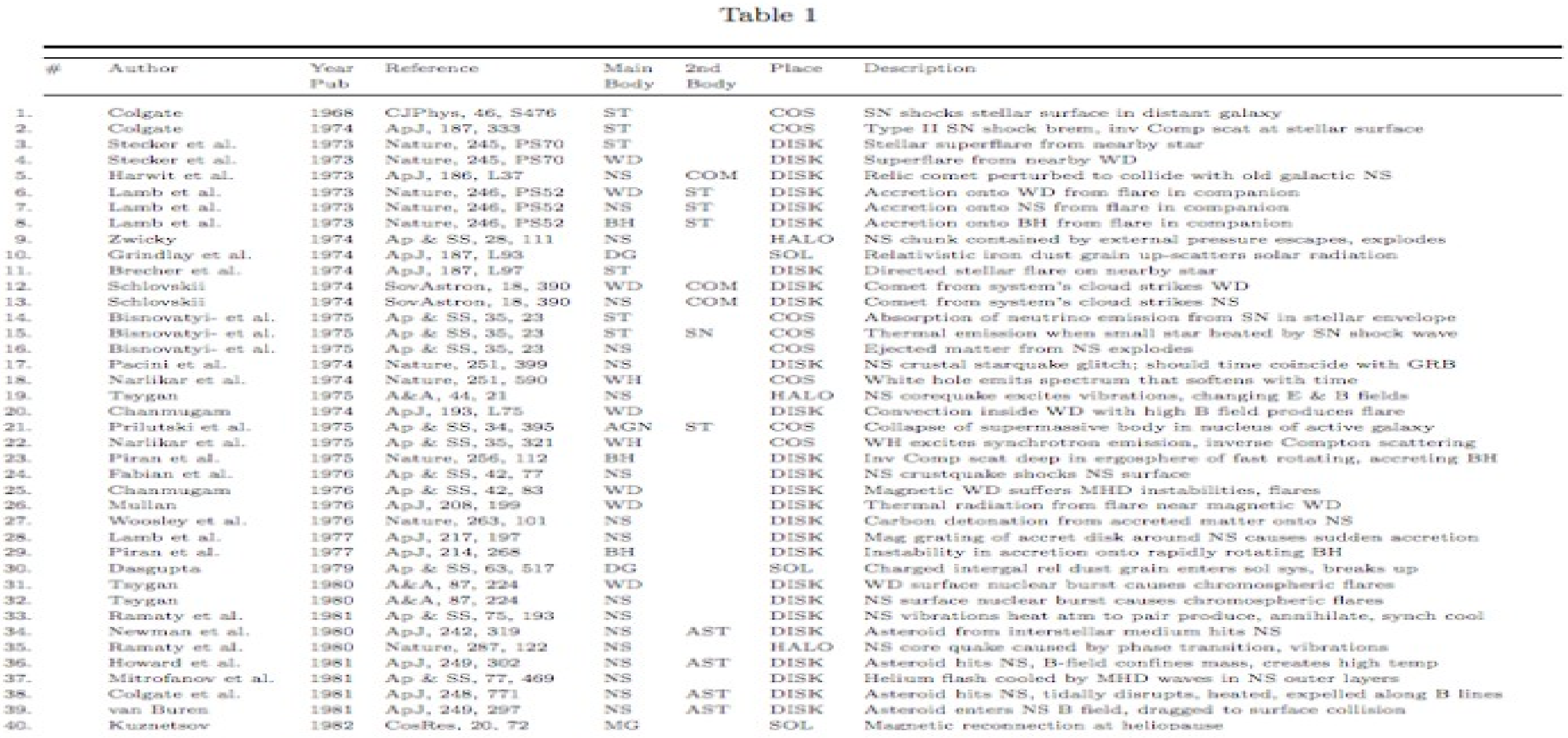
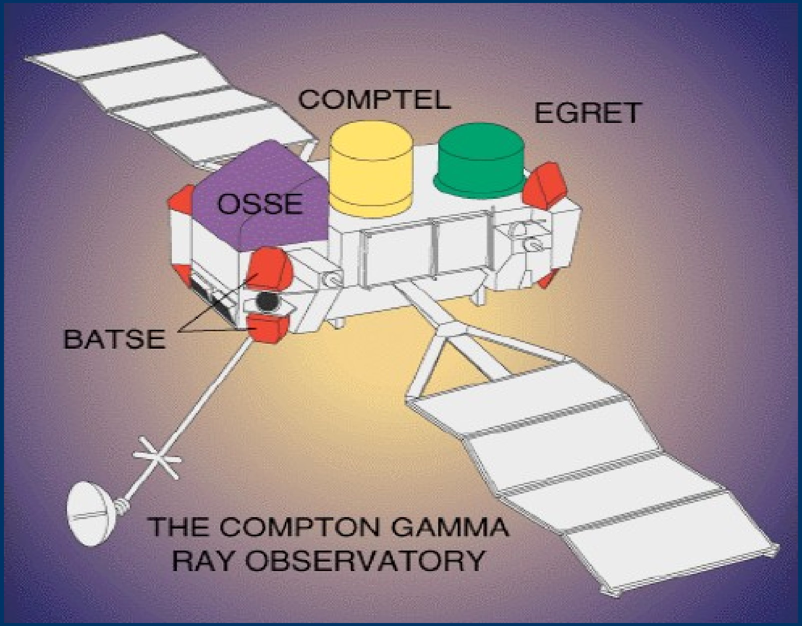


Table 1

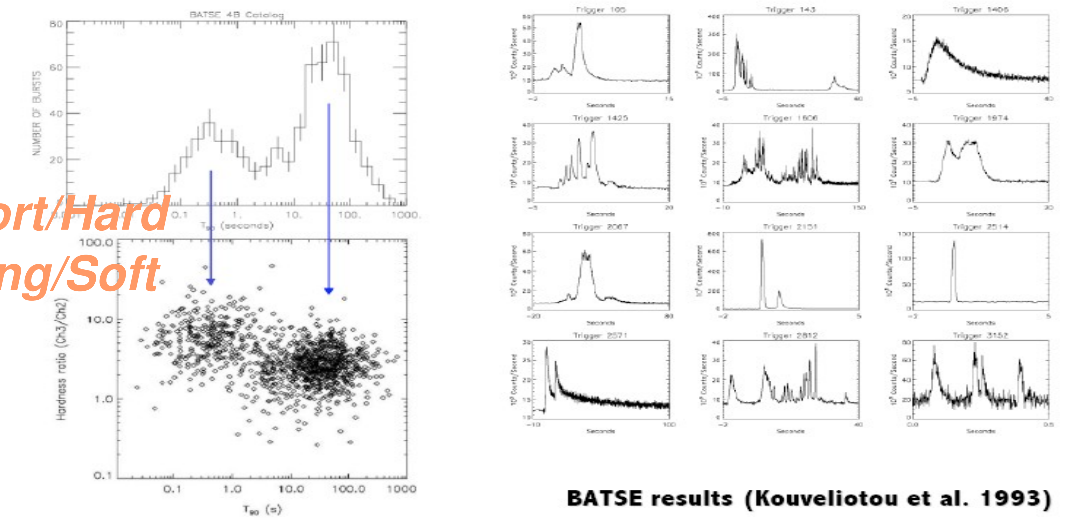
#	Author	Year Pub	Reference	Main Body	2nd Body	Place	Description
1.	Colgate	1968	CJPhys, 46, S476	ST		COS	SN shocks stellar surface in distant galaxy
2.	Colgate	1974	ApJ, 187, 333	ST		COS	Type II SN shock brem, inv Comp scat at stellar surface
3.	Stecker et al.	1973	Nature, 245, PS70	ST		DISK	Stellar superflare from nearby star
4.	Stecker et al.	1973	Nature, 245, PS70	WD		DISK	Superflare from nearby WD
5.	Harwit et al.	1973	ApJ, 186, L37	NS	COM	DISK	Relic comet perturbed to collide with old galactic NS
6.	Lamb et al.	1973	Nature, 246, PS52	WD	ST	DISK	Accretion onto WD from flare in companion
7.	Lamb et al.	1973	Nature, 246, PS52	NS	ST	DISK	Accretion onto NS from flare in companion
8.	Lamb et al.	1973	Nature, 246, PS52	BH	ST	DISK	Accretion onto BH from flare in companion
9.	Zwicky	1974	Ap & SS, 28, 111	NS		HALO	NS chunk contained by external pressure escapes, explodes
10.	Grindlay et al.	1974	ApJ, 187, L93	DG		SOL	Relativistic iron dust grain up-scatters solar radiation
11.	Brecher et al.	1974	ApJ, 187, L97	ST		DISK	Directed stellar flare on nearby star
12.	Schlovskii	1974	SovAstron, 18, 390	WD	COM	DISK	Comet from system's cloud strikes WD
13.	Schlovskii	1974	SovAstron, 18, 390	NS	COM	DISK	Comet from system's cloud strikes NS
14.	Bisnovatyi- et al.	1975	Ap & SS, 35, 23	ST		COS	Absorption of neutrino emission from SN in stellar envelope
15.	Bisnovatyi- et al.	1975	Ap & SS, 35, 23	ST	SN	COS	Thermal emission when small star heated by SN shock wave
16.	Bisnovatyi- et al.	1975	Ap & SS, 35, 23	NS		COS	Ejected matter from NS explodes
17.	Pacini et al.	1974	Nature, 251, 399	NS		DISK	NS crustal starquake glitch; should time coincide with GRB
18.	Narlikar et al.	1974	Nature, 251, 590	WH		COS	White hole emits spectrum that softens with time
19.	Tsygan	1975	A&A, 44, 21	NS		HALO	NS corequake excites vibrations, changing E & B fields
20.	Chanmugam	1974	ApJ, 193, L75	WD		DISK	Convection inside WD with high B field produces flare
21.	Prilutski et al.	1975	Ap & SS, 34, 395	AGN	ST	COS	Collapse of supermassive body in nucleus of active galaxy
22.	Narlikar et al.	1975	Ap & SS, 35, 321	WH		COS	WH excites synchrotron emission, inverse Compton scattering
23.	Piran et al.	1975	Nature, 256, 112	BH		DISK	Inv Comp scat deep in ergosphere of fast rotating, accreting BH
24.	Fabian et al.	1976	Ap & SS, 42, 77	NS		DISK	NS crustquake shocks NS surface
25.	Chanmugam	1976	Ap & SS, 42, 83	WD		DISK	Magnetic WD suffers MHD instabilities, flares
26.	Mullan	1976	ApJ, 208, 199	WD		DISK	Thermal radiation from flare near magnetic WD
27.	Woosley et al.	1976	Nature, 263, 101	NS		DISK	Carbon detonation from accreted matter onto NS
28.	Lamb et al.	1977	ApJ, 217, 197	NS		DISK	Mag grating of accret disk around NS causes sudden accretion
29.	Piran et al.	1977	ApJ, 214, 268	BH		DISK	Instability in accretion onto rapidly rotating BH
30.	Dasgupta	1979	Ap & SS, 63, 517	DG		SOL	Charged intergal rel dust grain enters sol sys, breaks up
31.	Tsygan	1980	A&A, 87, 224	WD		DISK	WD surface nuclear burst causes chromospheric flares
32.	Tsygan	1980	A&A, 87, 224	NS		DISK	NS surface nuclear burst causes chromospheric flares
33.	Ramaty et al.	1981	Ap & SS, 75, 193	NS		DISK	NS vibrations heat atm to pair produce, annihilate, synch cool
34.	Newman et al.	1980	ApJ, 242, 319	NS	AST	DISK	Asteroid from interstellar medium hits NS
35.	Ramaty et al.	1980	Nature, 287, 122	NS		HALO	NS core quake caused by phase transition, vibrations
36.	Howard et al.	1981	ApJ, 249, 302	NS	AST	DISK	Asteroid hits NS, B-field confines mass, creates high temp
37.	Mitrofanov et al.	1981	Ap & SS, 77, 469	NS		DISK	Helium flash cooled by MHD waves in NS outer layers
38.	Colgate et al.	1981	ApJ, 248, 771	NS	AST	DISK	Asteroid hits NS, tidally disrupts, heated, expelled along B lines
39.	van Buren	1981	ApJ, 249, 297	NS	AST	DISK	Asteroid enters NS B field, dragged to surface collision
40.	Kuznetsov	1982	CosRes, 20, 72	MG		SOL	Magnetic reconnection at heliopause

Nemiroff,
1993

CGRO



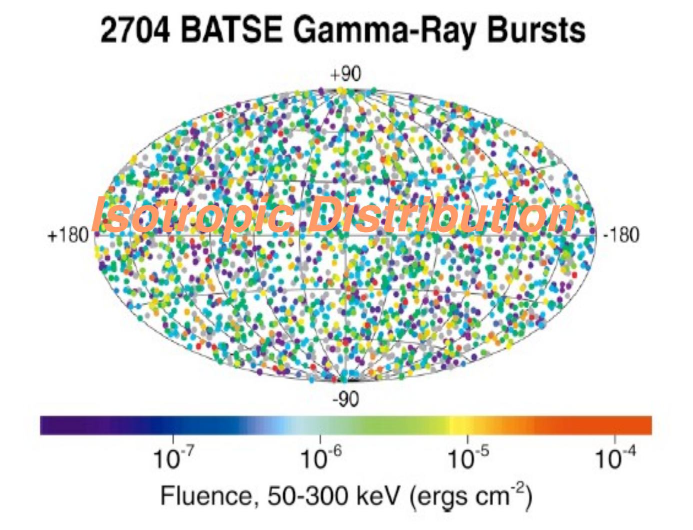
- *Established two kind of GRB.*
- *Proposed an Isotropic distrib.*



Short/Hard

Long/Soft

BATSE results (Kouveliotou et al. 1993)


2704 BATSE Gamma-Ray Bursts

Isotropic Distribution

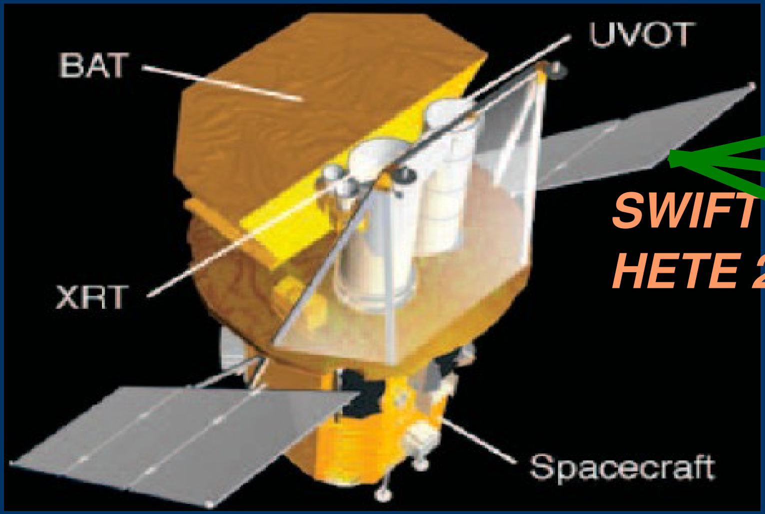
Others Detectors

BEPPOSAX

Predicted the Fireball Model

Long GRB are asociated wit final estate of hypernova their redshifts were found

Jet colimation



SWIFT
HETE 2

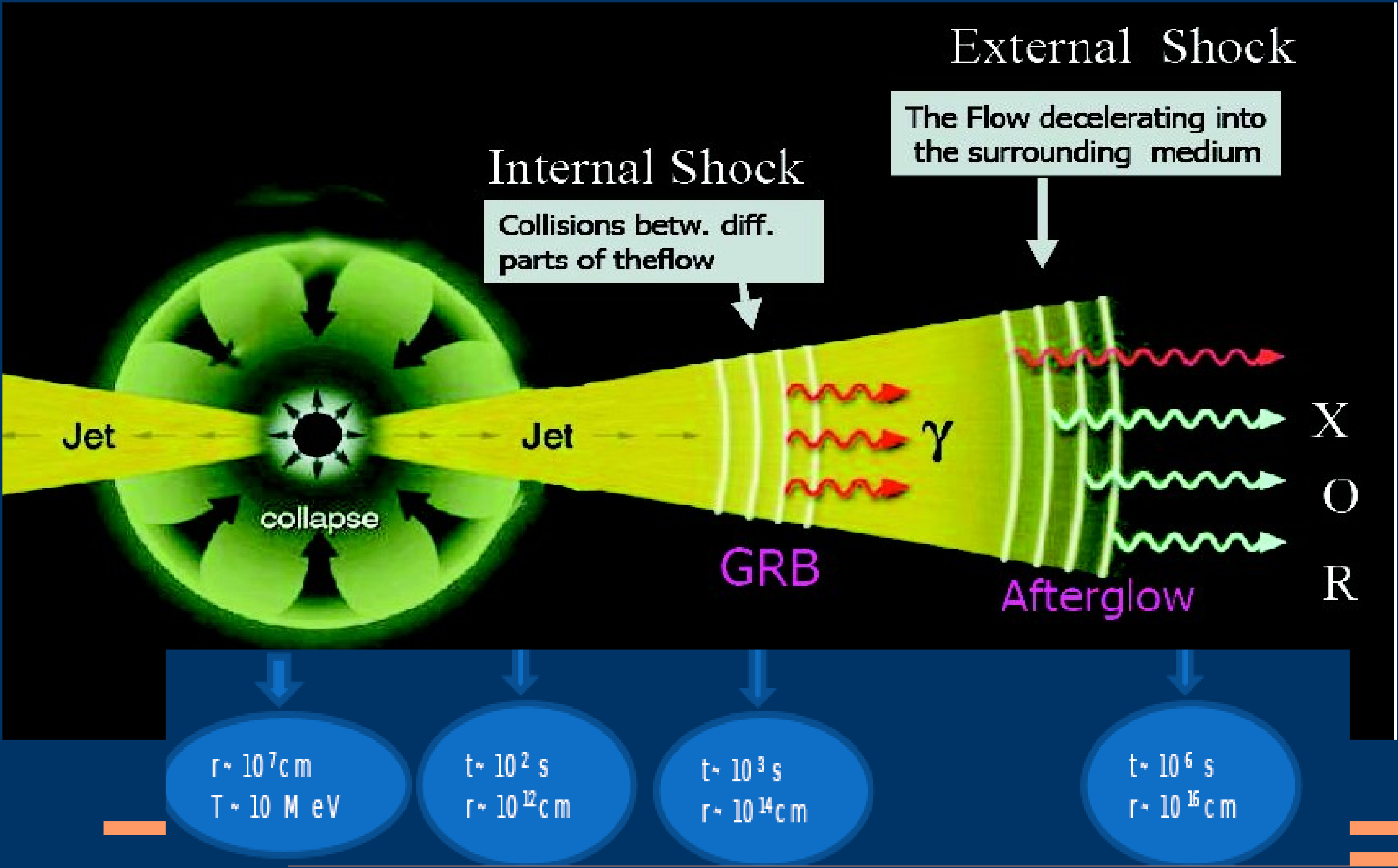
Short GRBs are asociated with NS-black hole and NS-NS

The Afterglows of the short GRBs are observated

Diversity of GRBs

Irrespective of the nature of the progenitor huge energies within a very small volume imply the formation of e± and γ fireball which would expand relativistically.

Fireball Model



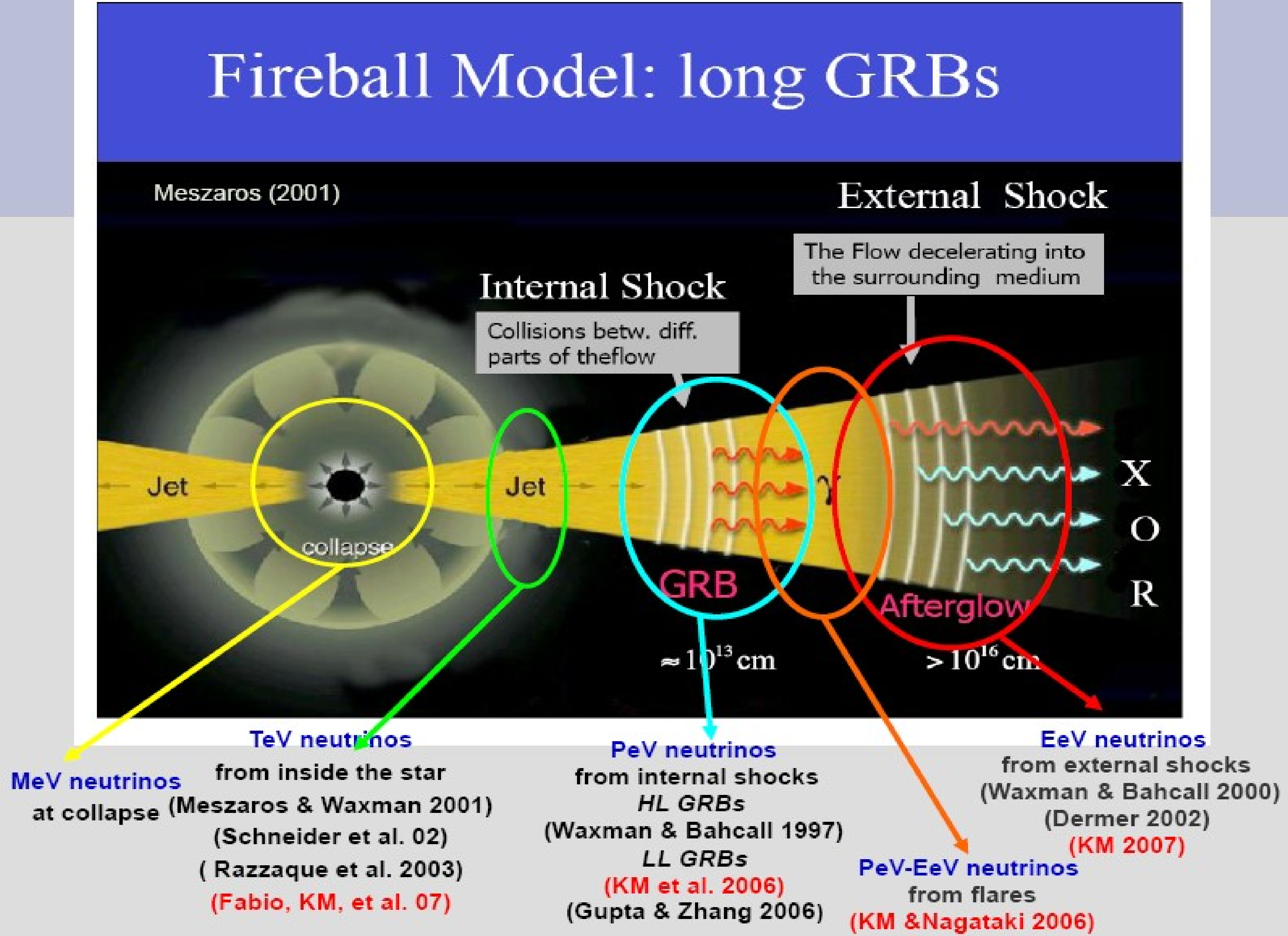
$r \sim 10^7$ cm
$T \sim 10$ MeV

$t \sim 10^2$ s
$r \sim 10^{12}$ cm

$t \sim 10^3$ s
$r \sim 10^{14}$ cm

$t \sim 10^6$ s
$r \sim 10^{16}$ cm

Fireball Model: long GRBs



Meszaros (2001)

External Shock

The Flow decelerating into the surrounding medium

Internal Shock

Collisions betw. diff. parts of theflow

MeV neutrinos
at collapse

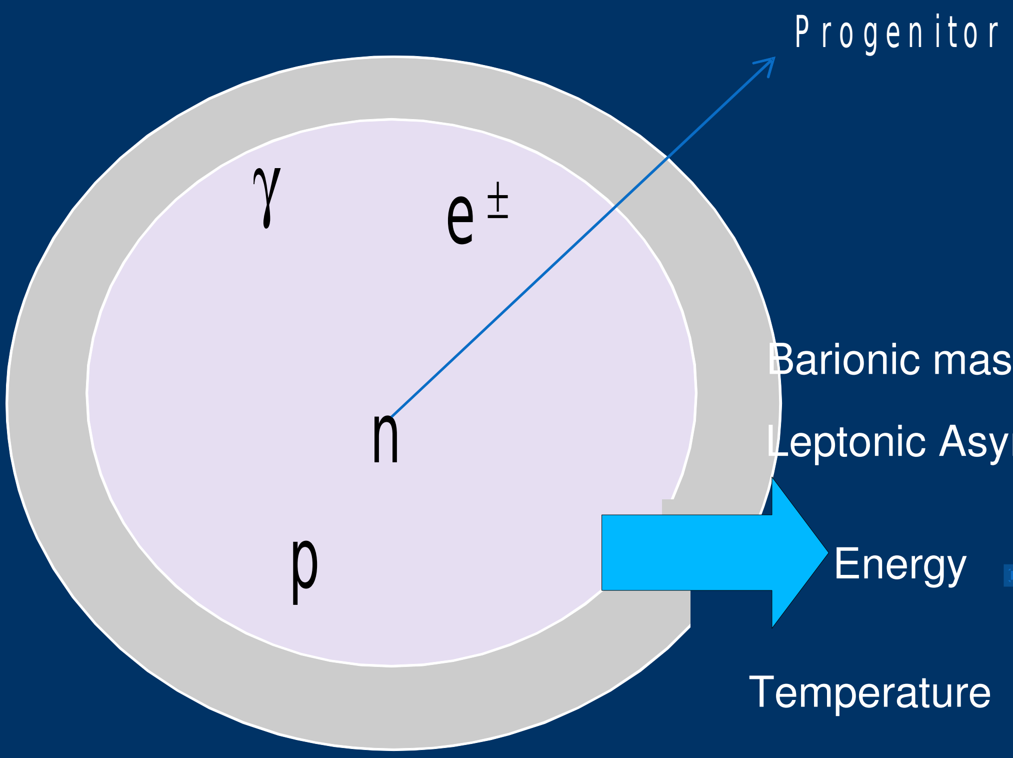
TeV neutrinos
from inside the star
(Meszaros & Waxman 2001)
(Schneider et al. 02)
(Razzaque et al. 2003)
(Fabio, KM, et al. 07)

PeV neutrinos
from internal shocks
HL GRBs
(Waxman & Bahcall 1997)
LL GRBs
(KM et al. 2006)
(Gupta & Zhang 2006)

PeV-EeV neutrinos
from flares
(KM &Nagataki 2006)

EeV neutrinos
from external shocks
(Waxman & Bahcall 2000)
(Dermer 2002)
(KM 2007)

At the first aproximate state



$\nu \rightarrow$

$e^- + p \rightarrow n + \nu_e$

$e^+ + e^- \rightarrow \nu + \bar{\nu}$

$N + N \rightarrow N + N + \nu + \bar{\nu}$

Barionic mass $10^{-8} M_\odot - 10^{-5} M_\odot$.

Leptonic Asym. $8.1 \times 10^{-4} R_7^{-3} \leq L_e \leq 8.1 \times 10^{-1} R_7^{-3}$.

Energy $E \approx 10^{51} erg \left(\frac{D}{3\,Gpc}\right)^2 \left(\frac{F}{10^{-6}\,erg\,cm^{-2}}\right)$

Temperature $T_i \approx 10\, E_{52}^{1/4} R_{i7}^{-3/4}\, MeV$

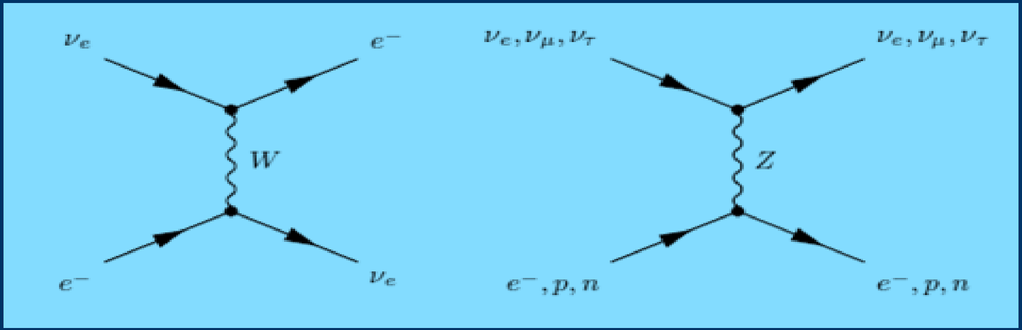
Inicial Radium $R_i \approx c\,\delta T \approx 3 \times 10^7 \left(\frac{\delta T}{1\,ms}\right) cm$

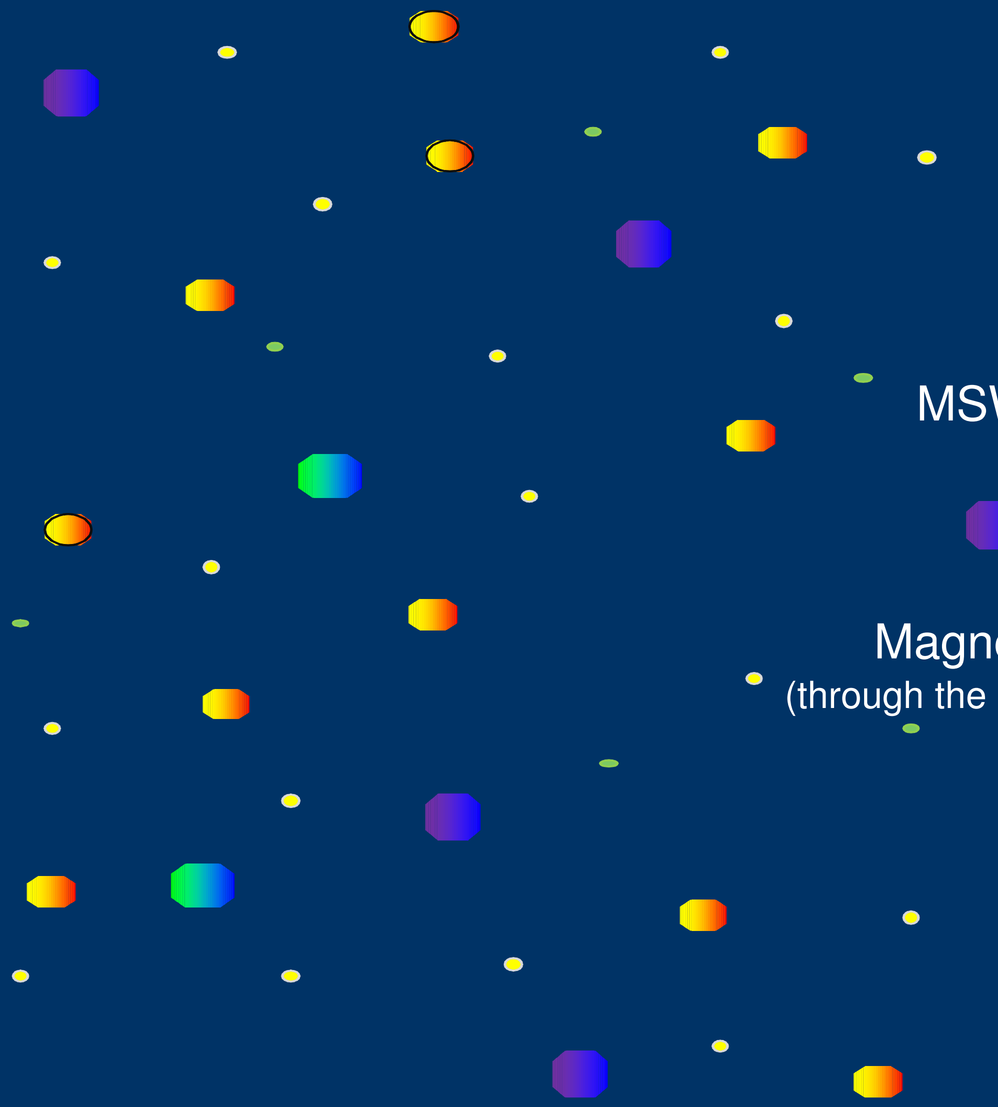
Optical Depth $\tau_{\gamma\gamma} \approx \frac{f_p \gamma^{\beta_B} \sigma_T F D^2}{R_e^2 m_e c^2} \approx \frac{10^{13}}{\gamma^{(4-\beta_B)}} f_p \left(\frac{F}{10^{-7}\,ergs\,cm^2}\right) \left(\frac{D}{3\,Gpc}\right)^2 \left(\frac{\delta T}{10\,ms}\right)^{-2}$

$B < B_c$

It Produces MeV Neutrinos → Supernovae 1987

Propagation Neutrino through the background





MSW Efect

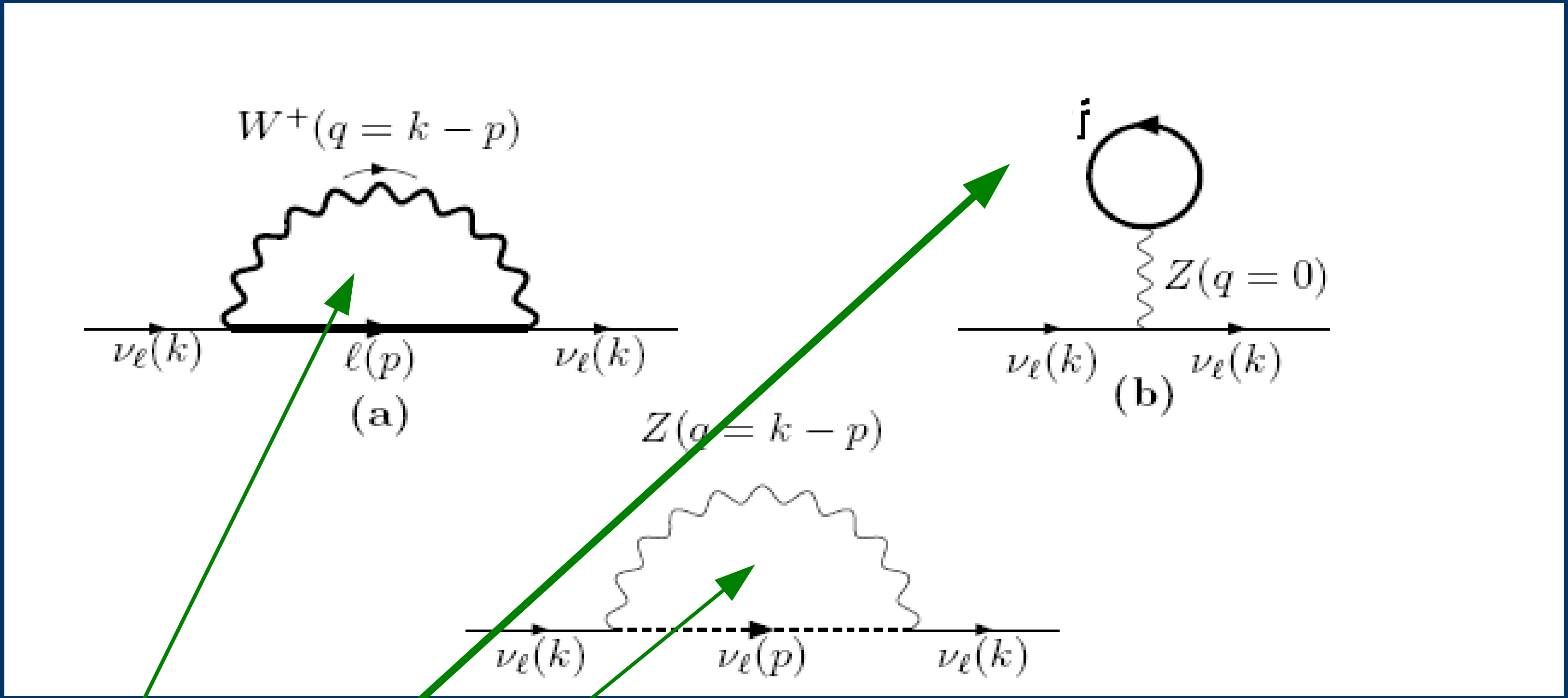
neutrino test

Magnetic Field
(through the charge particles)

particles

- ν_e
- $\nu_{\mu,\tau}$
- e^-
- e^+
- n
- p

Neutrino Self Energy



$$\Sigma(k) = \Sigma_W(k) + \Sigma_Z(k) + \Sigma_t(k).$$

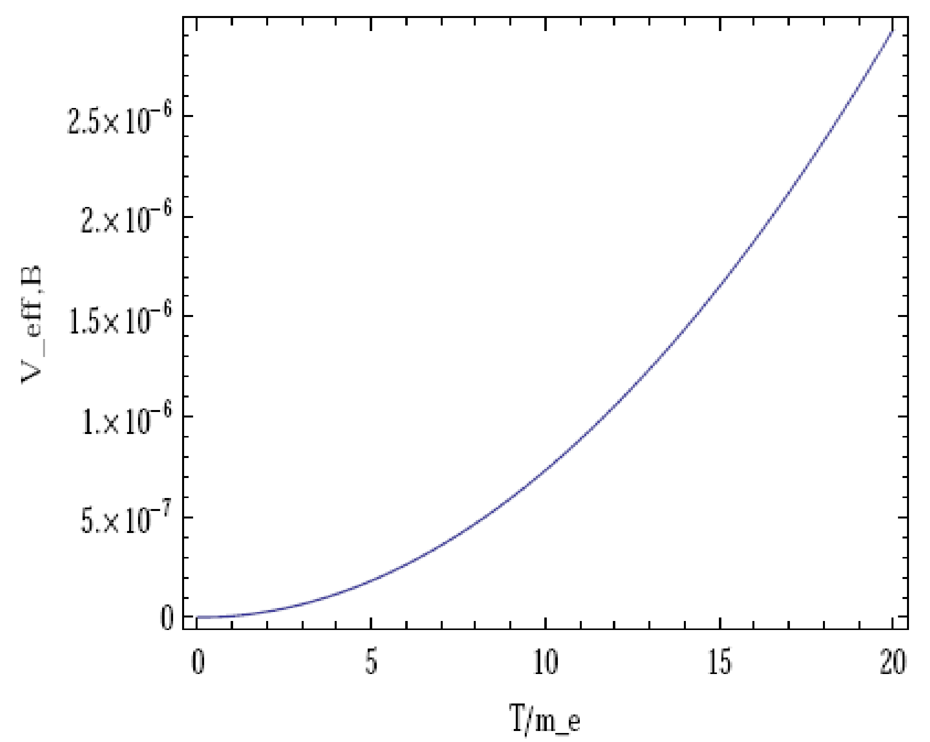
$$-i\Sigma_t(k) = -\left(\frac{g}{2\cos\theta_W}\right)^2 R\,\gamma_\mu\, iZ^{\mu\nu}(0)\int\frac{d^4p}{(2\pi)^4}\mathrm{Tr}\left[\gamma_\nu\left(C_V + C_A\gamma_5\right) iS_\ell(p)\right]$$

$$-i\Sigma_W(k) = \int\frac{d^4p}{(2\pi)^4}\left(\frac{-ig}{\sqrt{2}}\right)\gamma_\mu\, L\, iS_\ell(p)\left(\frac{-ig}{\sqrt{2}}\right)\gamma_\nu\, L\, iW^{\mu\nu}(q)$$

$$-i\Sigma_Z(k) = \int\frac{d^4p}{(2\pi)^4}\left(\frac{-ig}{\sqrt{2}\cos\theta_W}\right)\gamma_\mu\, L\, iS_{\nu_\ell}(p)\left(\frac{-ig}{\sqrt{2}\cos\theta_W}\right)\gamma_\nu\, L\, iZ^{\mu\nu}(q)$$

Neutrino Efective Potential with $B<B_c$ (weak limit)

$$
\begin{aligned}
V_{eff,B} \; = \; & \sqrt{2}G_F\Bigg[\frac{m_e^3}{\pi^2}\sum_{l=0}^{\infty}(-1)^l \sinh\alpha\Bigg\{\left(1+\frac{3}{2}\frac{m_e^2}{M_W^2}-\frac{eB}{M_W^2}\right)\left(\frac{2}{\sigma}K_2(\sigma)-\frac{B}{B_c}K_1(\sigma)\right) \\
& -\frac{B}{B_c}\left(1+\frac{m_e^2}{2M_W^2}-\frac{eB}{M_W^2}\right)K_1(\sigma)\Bigg\} \\
& -\frac{2}{\pi^2}\left(\frac{m_e^2}{M_W}\right)^2 E_{\nu_e}\sum_{l=0}^{\infty}(-1)^l \cosh\alpha\Bigg\{\left(\frac{8}{\sigma^2}-\frac{5}{2}\frac{B}{B_c}\right)K_0(\sigma)+\left(2-4\frac{B}{B_c}+\frac{16}{\sigma^2}\right)\frac{K_1(\sigma)}{\sigma}\Bigg\}\Bigg]
\end{aligned}
$$

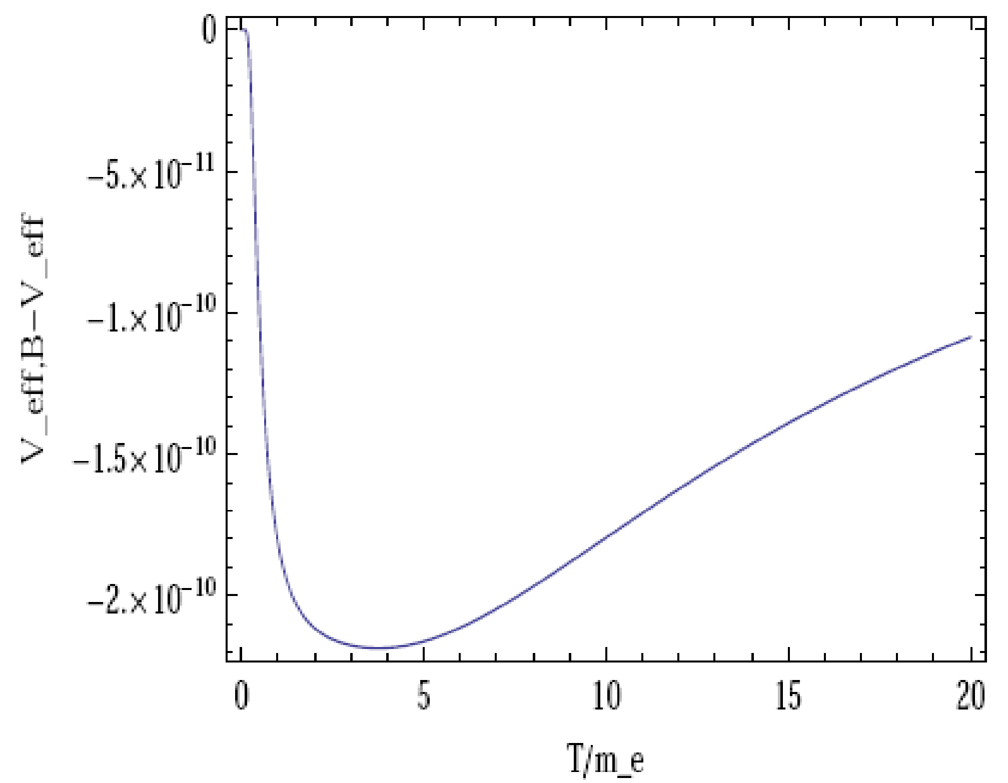


$$\alpha = \beta\mu(l+1)$$

$$\sigma = \beta m_e(l+1)$$

Neutrino Efective Potential without B

$$\begin{aligned} V_{eff} &= \sqrt{2}G_F\Bigg[\left(1+\frac{3}{2}\frac{m_e^2}{M_W^2}\right)\frac{m_e^3}{\pi^2}\sum_{l=0}^{\infty}(-1)^l\sinh\alpha\,\frac{2}{\sigma}K_2(\sigma) \\ &\quad -\frac{4}{\pi^2}\left(\frac{m_e^2}{M_W}\right)^2 E_{\nu_e}\sum_{l=0}^{\infty}(-1)^l\cosh\,\alpha\left\{\frac{4K_0(\sigma)}{\sigma^2}+\left(1+\frac{8}{\sigma^2}\right)\frac{K_1(\sigma)}{\sigma}\right\}\Bigg]. \end{aligned}$$



Neutrino Oscillation

Rev. of Mod. Phys., Vol 75, Abr. 2003, Neutrinos masses and Mixing: evidence and implications M.C. Gonzalez-Garcia

$$i\frac{d\vec{\nu}}{dt} = H\vec{\nu},$$

$$\vec{\nu} \equiv (\nu_e, \nu_\mu, \nu_\tau)^T .$$

$$H = U \cdot H_0^d \cdot U^\dagger + diag(V_e, 0, 0),$$

$$H_0^d = \frac{1}{2E_\nu} diag(\Delta m_{12}^2, 0, \Delta m_{32}^2)$$

$$U = \begin{pmatrix} c_{13}c_{12} & s_{12}c_{13} & s_{13} \\ -s_{12}c_{23} - s_{23}s_{13}c_{12} & c_{23}c_{12} - s_{23}s_{13}s_{12} & s_{23}c_{13} \\ s_{23}s_{12} - s_{13}c_{23}c_{12} & -s_{23}c_{12} - s_{13}s_{12}c_{23} & c_{23}c_{13} \end{pmatrix}$$

$$s_{ij} = \sin\theta_{ij} \qquad c_{ij} = \cos\theta_{ij}$$

Probabilities :

$$\begin{aligned}
P_{ee} &= 1-4s^2_{13,m}c^2_{13,m}S_{31}, \\
P_{\mu\mu} &= 1-4s^2_{13,m}c^2_{13,m}s^4_{23}S_{31}-4s^2_{13,m}s^2_{23}c^2_{23}S_{21}-4c^2_{13,m}s^2_{23}c^2_{23}S_{32}, \\
P_{\tau\tau} &= 1-4s^2_{13,m}c^2_{13,m}c^4_{23}S_{31}-4s^2_{13,m}s^2_{23}c^2_{23}S_{21}-4c^2_{13,m}s^2_{23}c^2_{23}S_{32}, \\
P_{e\mu} &= 4s^2_{13,m}c^2_{13,m}s^2_{23}S_{31}, \\
P_{e\tau} &= 4s^2_{13,m}c^2_{13,m}c^2_{23}S_{31} \\
P_{\mu\tau} &= -4s^2_{13,m}c^2_{13,m}s^2_{23}c^2_{23}S_{31}+4s^2_{13,m}s^2_{23}c^2_{23}S_{21}+4c^2_{13,m}s^2_{23}c^2_{23}S_{32},
\end{aligned}$$

$$S_{ij}=\sin^2\left(\frac{\Delta\mu^2_{ij}}{4E_\nu}L\right).$$

$$\begin{aligned}
\Delta\mu^2_{21} &= \frac{\Delta m^2_{32}}{2}\left(\frac{\sin 2\theta_{13}}{\sin 2\theta_{13,m}}-1\right)-E_\nu V_e \\
\Delta\mu^2_{32} &= \frac{\Delta m^2_{32}}{2}\left(\frac{\sin 2\theta_{13}}{\sin 2\theta_{13,m}}+1\right)+E_\nu V_e \\
\Delta\mu^2_{31} &= \Delta m^2_{32}\frac{\sin 2\theta_{13}}{\sin 2\theta_{13,m}}
\end{aligned}$$

$$\sin 2\theta_{13,m}=\frac{\sin 2\theta_{13}}{\sqrt{(\cos 2\theta_{13}-2E_\nu V_e/\Delta m^2_{32})^2+(\sin 2\theta_{13})^2}},$$

Resonance Lenght:

$$L_{osc}=\frac{L_v}{\sqrt{\cos^2 2\theta_{13}(1-\frac{2E_\nu V_e}{\Delta m^2_{32}\cos 2\theta_{13}})^2+\sin^2 2\theta_{13}}},$$

$$L_v=4\pi E_\nu/\Delta m^2_{32}$$

Resonance condition :

$$\cos 2\theta_{13}=\frac{2E_\nu V_e}{\Delta m^2_{32}}.$$

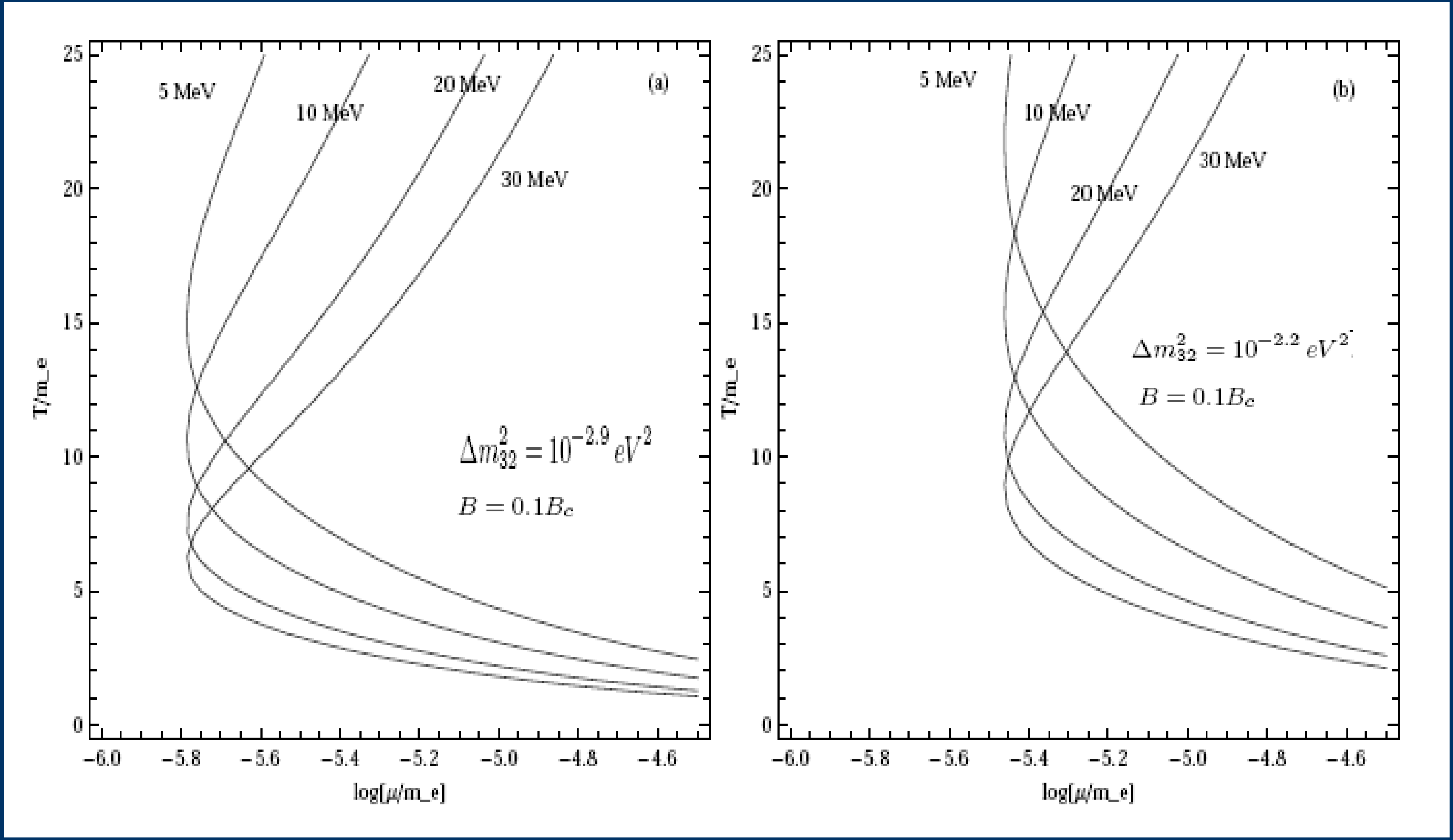
RESULTS

$$1.4 \times 10^{-3} < \Delta m^2_{32}/eV^2 < 6.0 \times 10^{-3}$$

$$\theta_{13} \simeq 6^\circ$$

$$\theta_{23} = 45^\circ$$

Resonance condition



- For one or two temperatures are related with one chemical potential, so we can calculted the following fireball observables

Barionic load

$$\begin{aligned} M_b &\simeq \frac{16}{3\pi}\xi(3)L_pT^3R^3m_p \\ &\simeq 2.23\times10^{-4}L_pT_{MeV}^3R_7^3M_\odot \end{aligned}$$

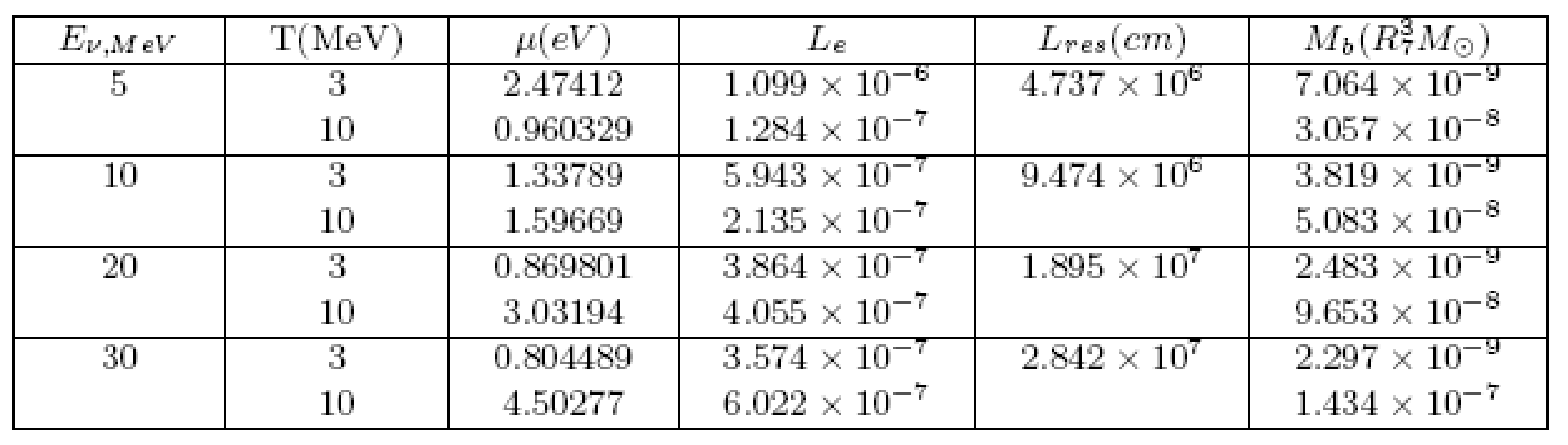
Leptonic Asimet.

$$L_a = \frac{N_a - \bar{N}_a}{N_\gamma}, \quad \Rightarrow \quad N_\gamma = \tfrac{2}{\pi^2}\zeta(3)T^3.$$

$$N_p = \frac{m^3}{2\pi^2}\sum_{l=0}^{\infty}(-1)^l e^{\alpha}\left[\frac{2}{\sigma}K_2(\sigma) - \frac{B}{B_c}K_1(\sigma)\right]$$

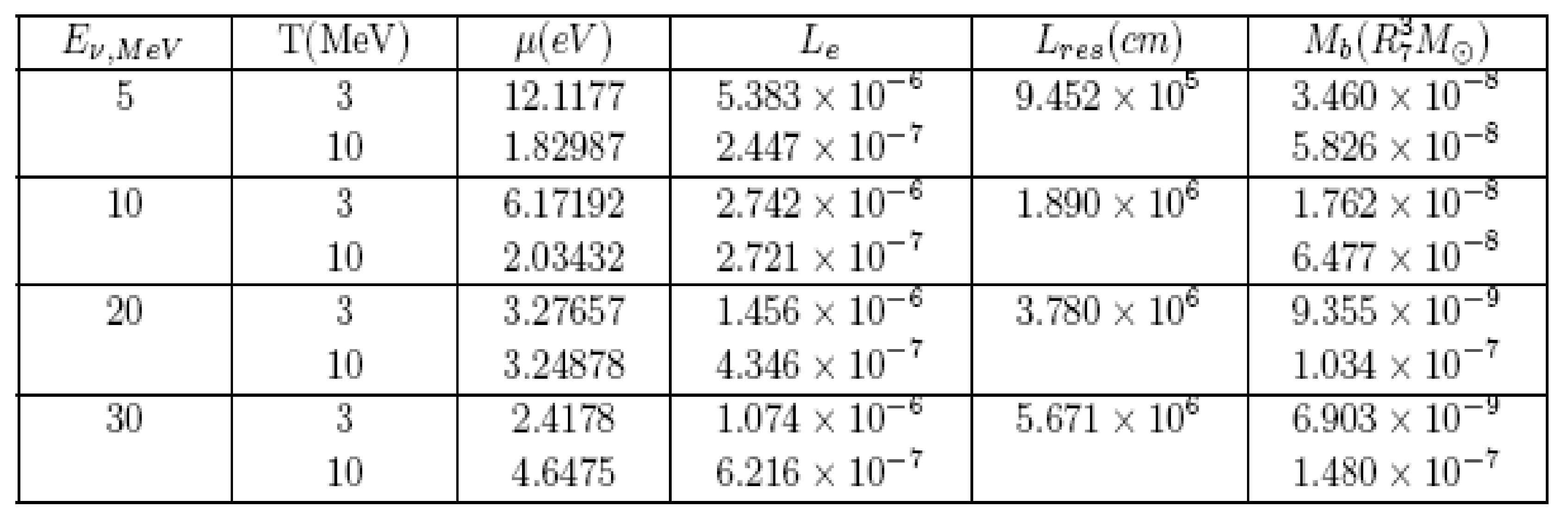
And we calculate,

$\Delta m^2_{32} = 10^{-2.9}\, eV^2$



$E_{\nu,MeV}$	T(MeV)	$\mu(eV)$	L_e	$L_{res}(cm)$	$M_b(R_7^3 M_\odot)$
5	3	2.47412	1.099×10^{-6}	4.737×10^{6}	7.064×10^{-9}
	10	0.960329	1.284×10^{-7}		3.057×10^{-8}
10	3	1.33789	5.943×10^{-7}	9.474×10^{6}	3.819×10^{-9}
	10	1.59669	2.135×10^{-7}		5.083×10^{-8}
20	3	0.869801	3.864×10^{-7}	1.895×10^{7}	2.483×10^{-9}
	10	3.03194	4.055×10^{-7}		9.653×10^{-8}
30	3	0.804489	3.574×10^{-7}	2.842×10^{7}	2.297×10^{-9}
	10	4.50277	6.022×10^{-7}		1.434×10^{-7}

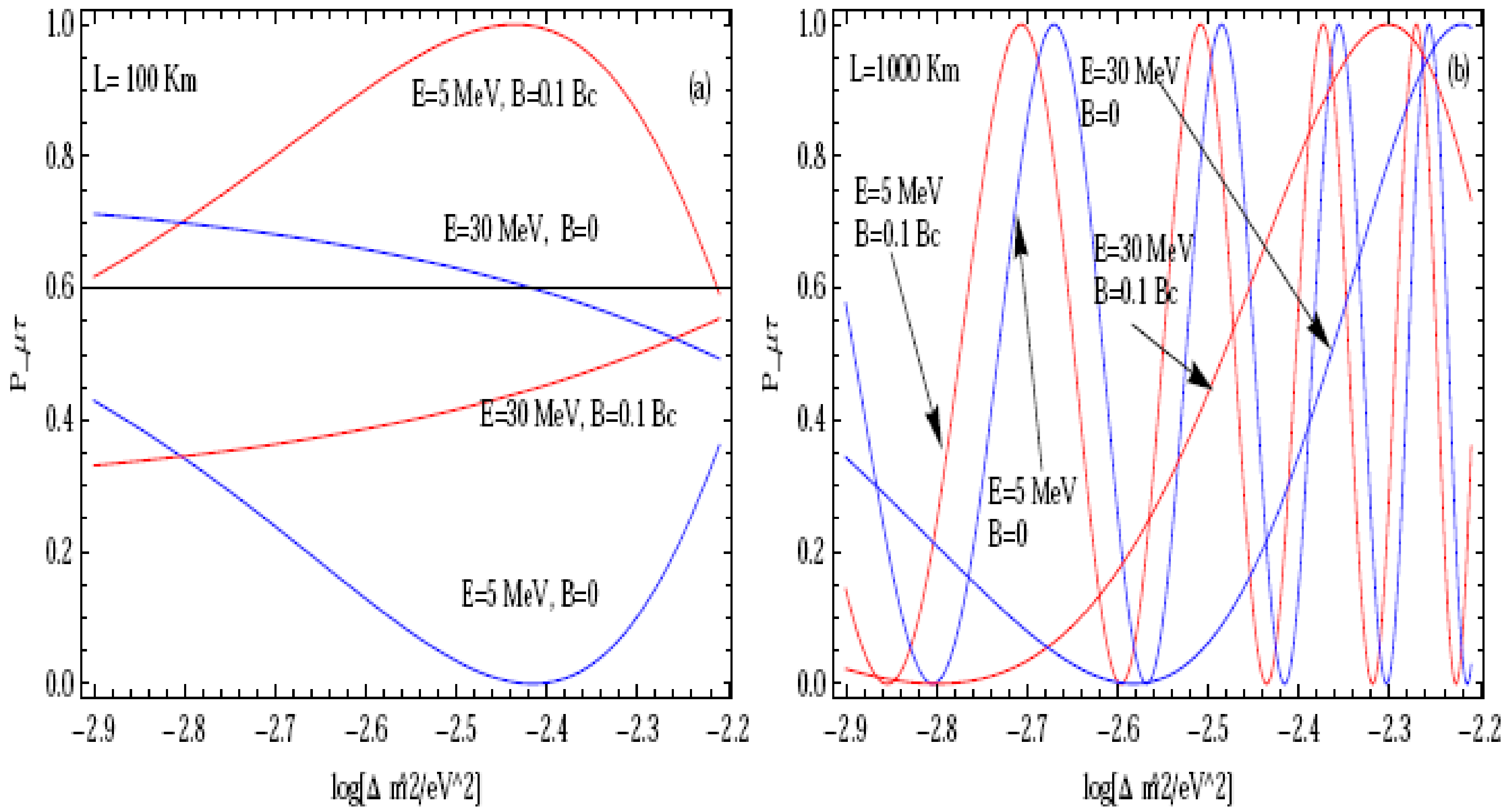
$\Delta m^2_{32} = 10^{-2.2}\, eV^2$



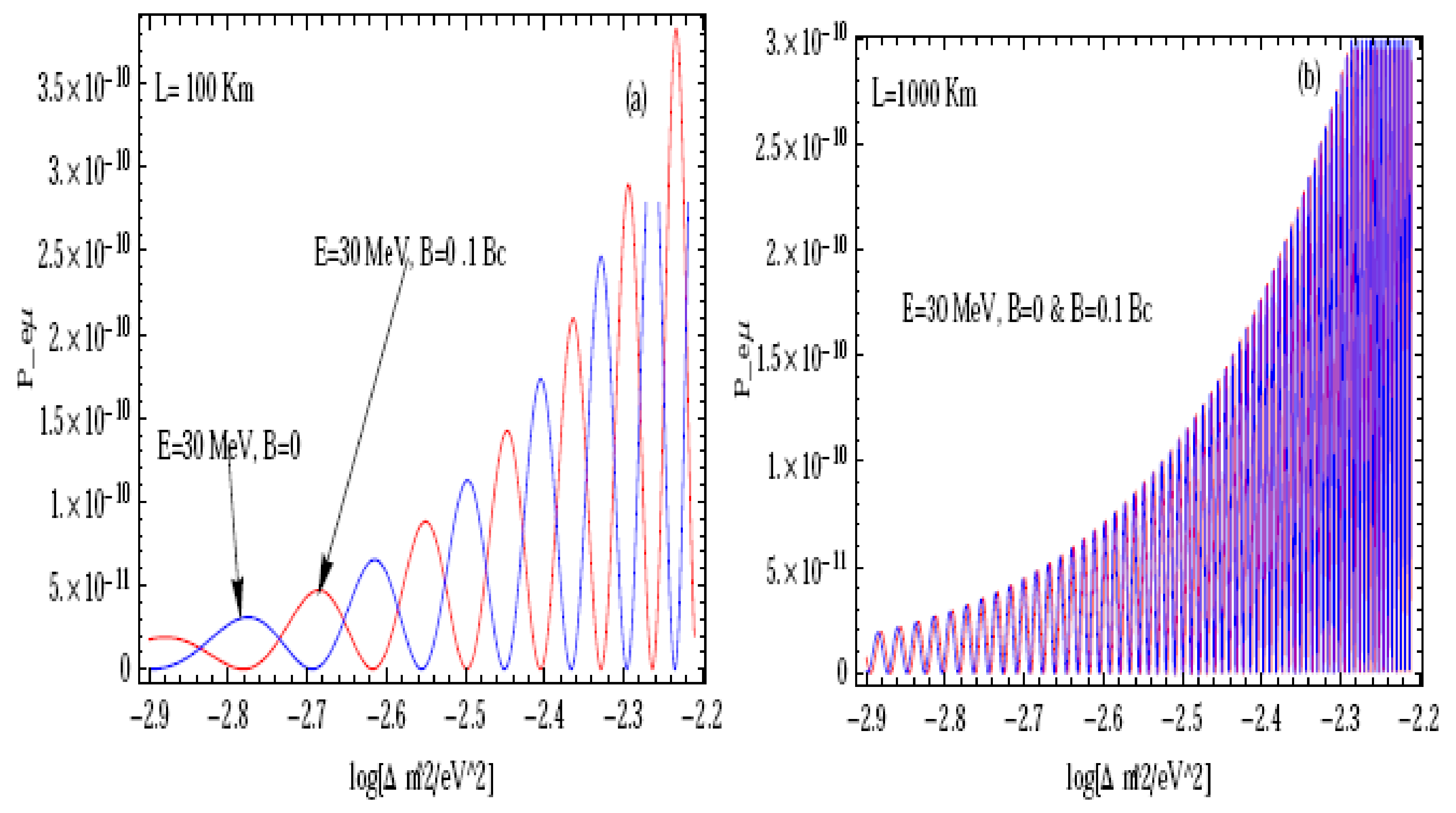
$E_{\nu,MeV}$	T(MeV)	$\mu(eV)$	L_e	$L_{res}(cm)$	$M_b(R_7^3 M_\odot)$
5	3	12.1177	5.383×10^{-6}	9.452×10^{5}	3.460×10^{-8}
	10	1.82987	2.447×10^{-7}		5.826×10^{-8}
10	3	6.17192	2.742×10^{-6}	1.890×10^{6}	1.762×10^{-8}
	10	2.03432	2.721×10^{-7}		6.477×10^{-8}
20	3	3.27657	1.456×10^{-6}	3.780×10^{6}	9.355×10^{-9}
	10	3.24878	4.346×10^{-7}		1.034×10^{-7}
30	3	2.4178	1.074×10^{-6}	5.671×10^{6}	6.903×10^{-9}
	10	4.6475	6.216×10^{-7}		1.480×10^{-7}

And the Probabilities !!!

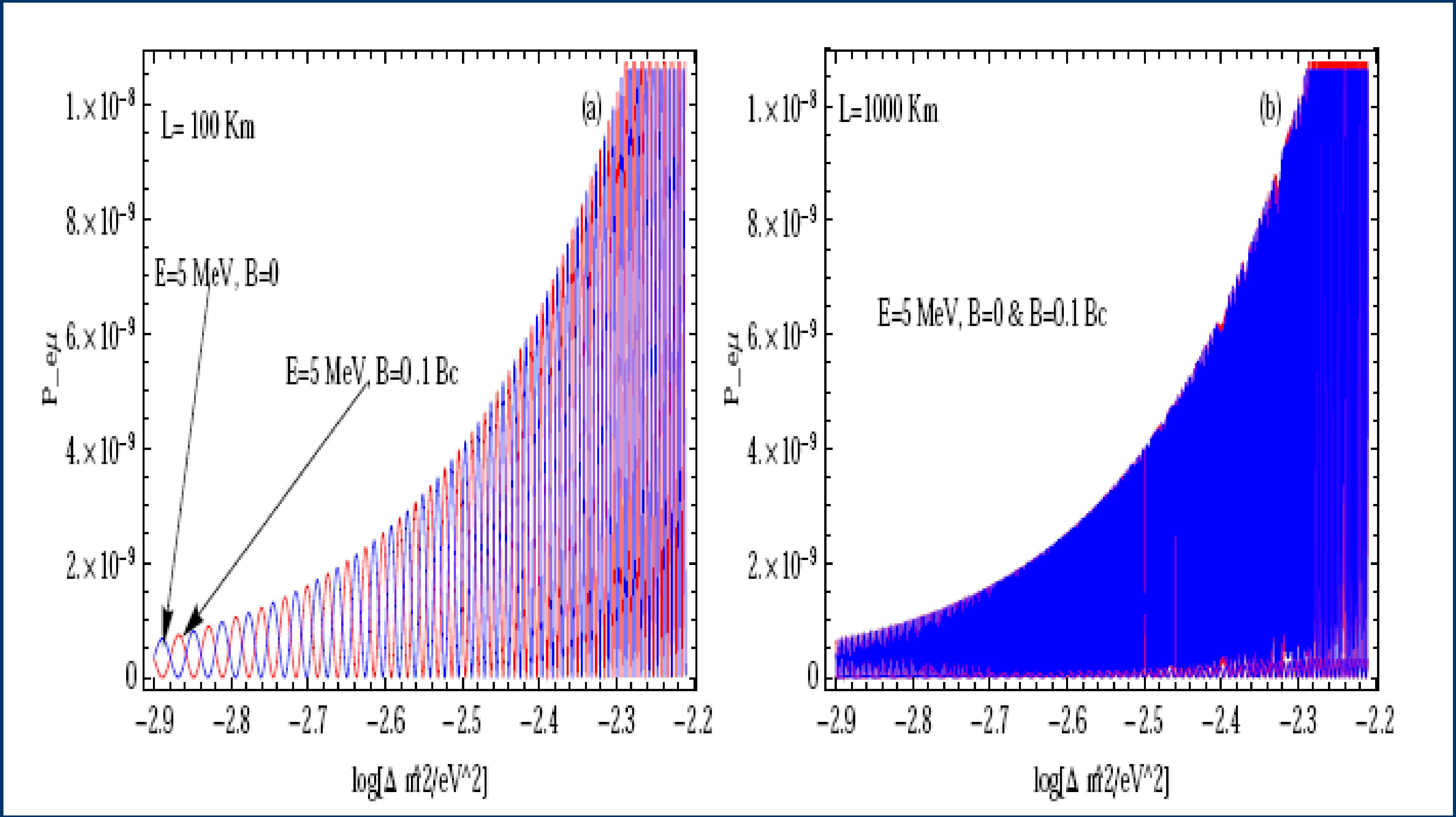
Probability: $\nu_\mu \rightarrow \nu_\tau$



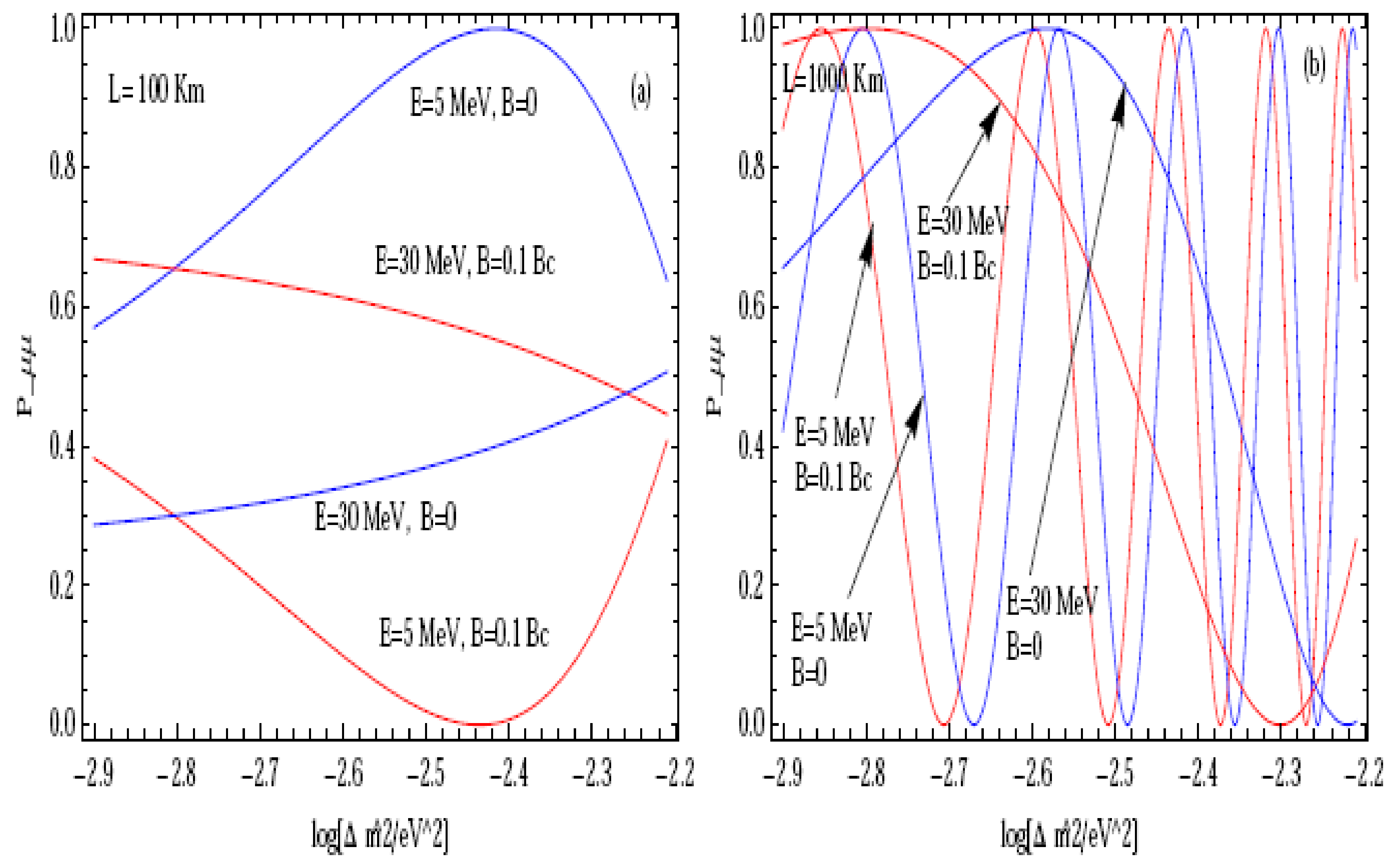
Probability: $\nu_e \rightarrow \nu_\mu$



Probability: $\nu_e \rightarrow \nu_\mu$



Probability: $\nu_\mu \rightarrow \nu_\mu$



Conclusions

- We calculated the efective potencial for a weak magnetized astrophysic plasma which content $e^{\pm}$, protons, neutrons and neutrinos.
- We have taken the three flavors mixing and we have studied the neutrino oscillation active – active with background.
- In our analysis, we observed the probabilities $P_{ee} \sim 1$, y $P_{e\mu} \sim P_{e\tau} \sim 0$ (ν_e does not oscillate). While ν_μ and ν_τ oscillate between them by depending on magnetic field, the size of the fireball and its energy.

- We analized the resonance condition for several neutrino energies 5-30 MeV and temperatures 3- 10 MeV and we observed that to satisfy this condition, the chemical potential should lie between 1-12 eV, and the resonance length lies between 9.4 and 284 Km. In the same way , the baryon load calculated by using the resonance condition lies in the range $10^{-9}\,M_{\odot} < M_b < 10^{-7}\,M_{\odot}$.