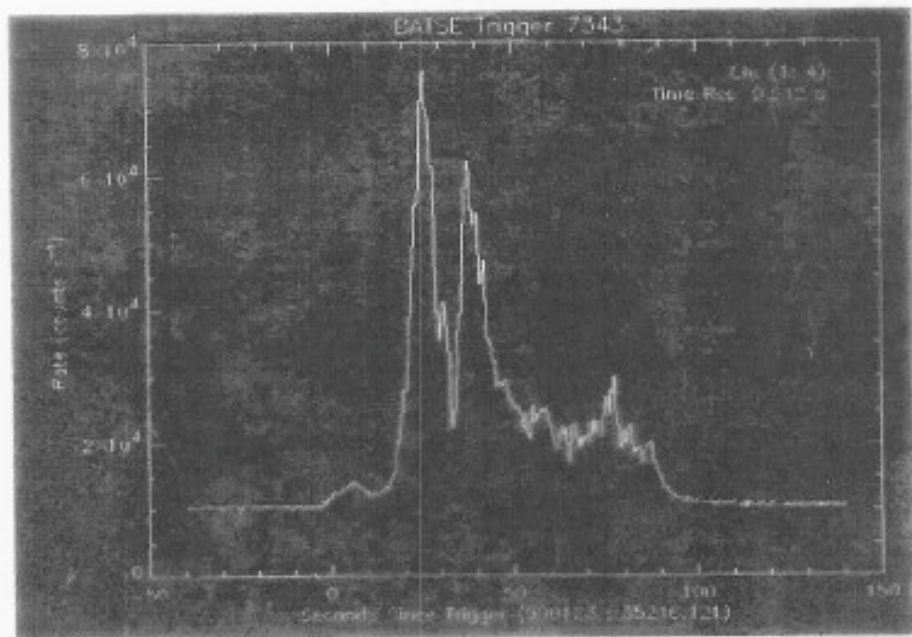


COSMIC

RAY

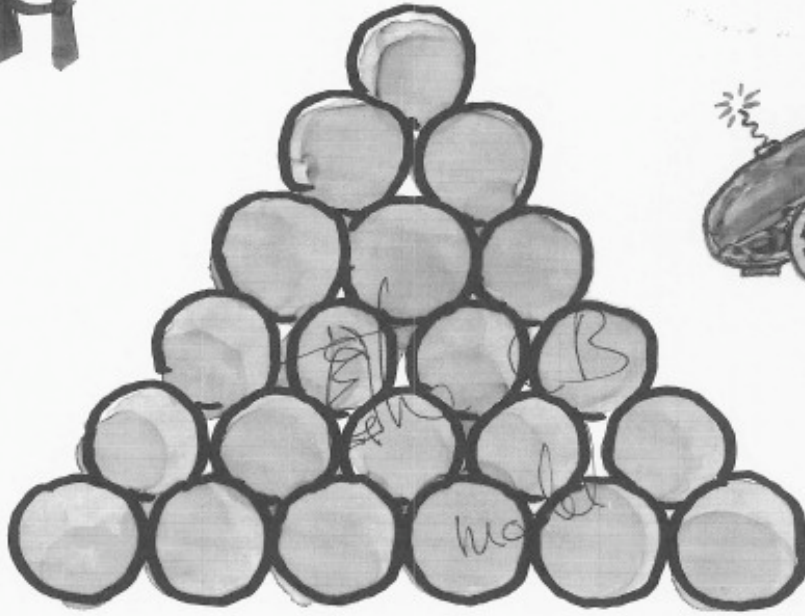
CONUNDRY

GRB 990123  $E_b > 20$  keV

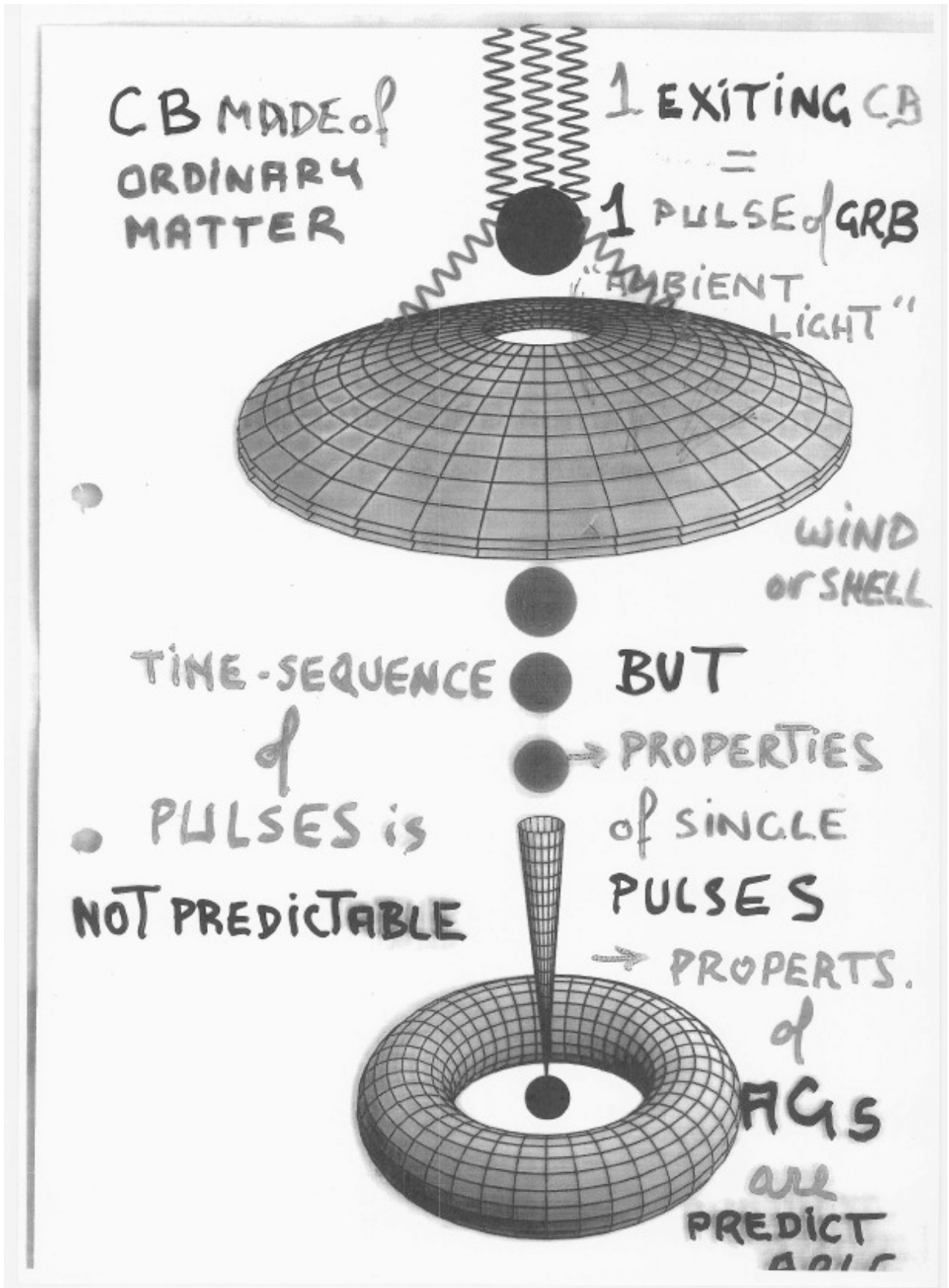


A

DAR  
ADR  
DADO



~~MODEL~~  
~~OF~~  
GRBS





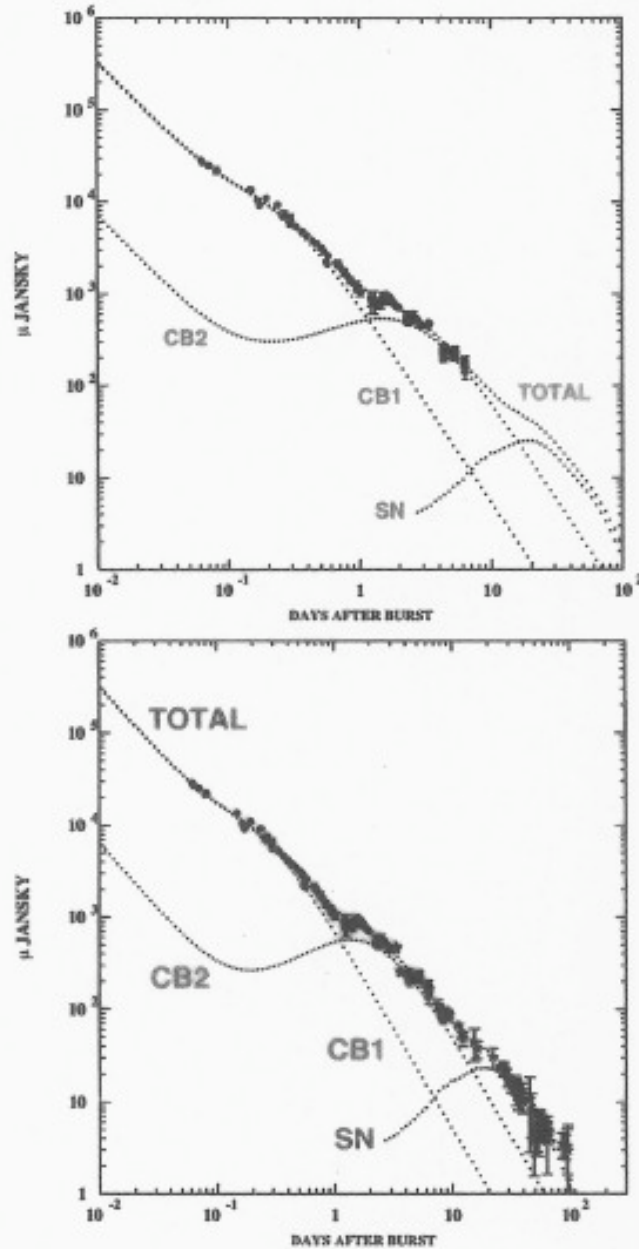
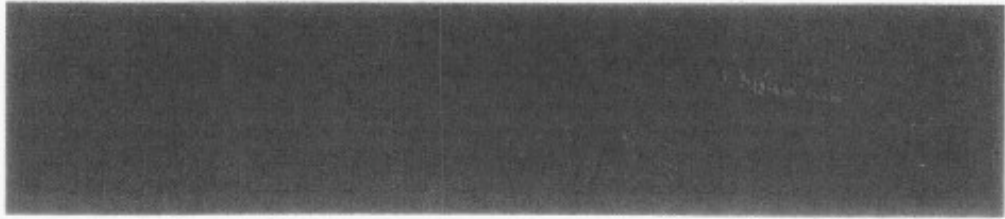


Fig. 19.— Upper panel: The R-band AG of GRB 030329, used along with other optical data to predict, in the CB model, the presence of a SN akin to SN1998bw (Dado, Dar & De Rújula 2003??). Lower panel: The subsequent data (the \* symbols) are added.



## **CBs are:**

- **Quasar emissions**  
 **$\mu$ -Quasar emissions**

## **CBs explain:**

- **Neutron-S natal kicks**
- **Cosmic Rays**
- **GBR:  $\gamma$  "Background" radiat.**
- **GRBs and XRFs**
- **Cluster "Cooling Flows"**

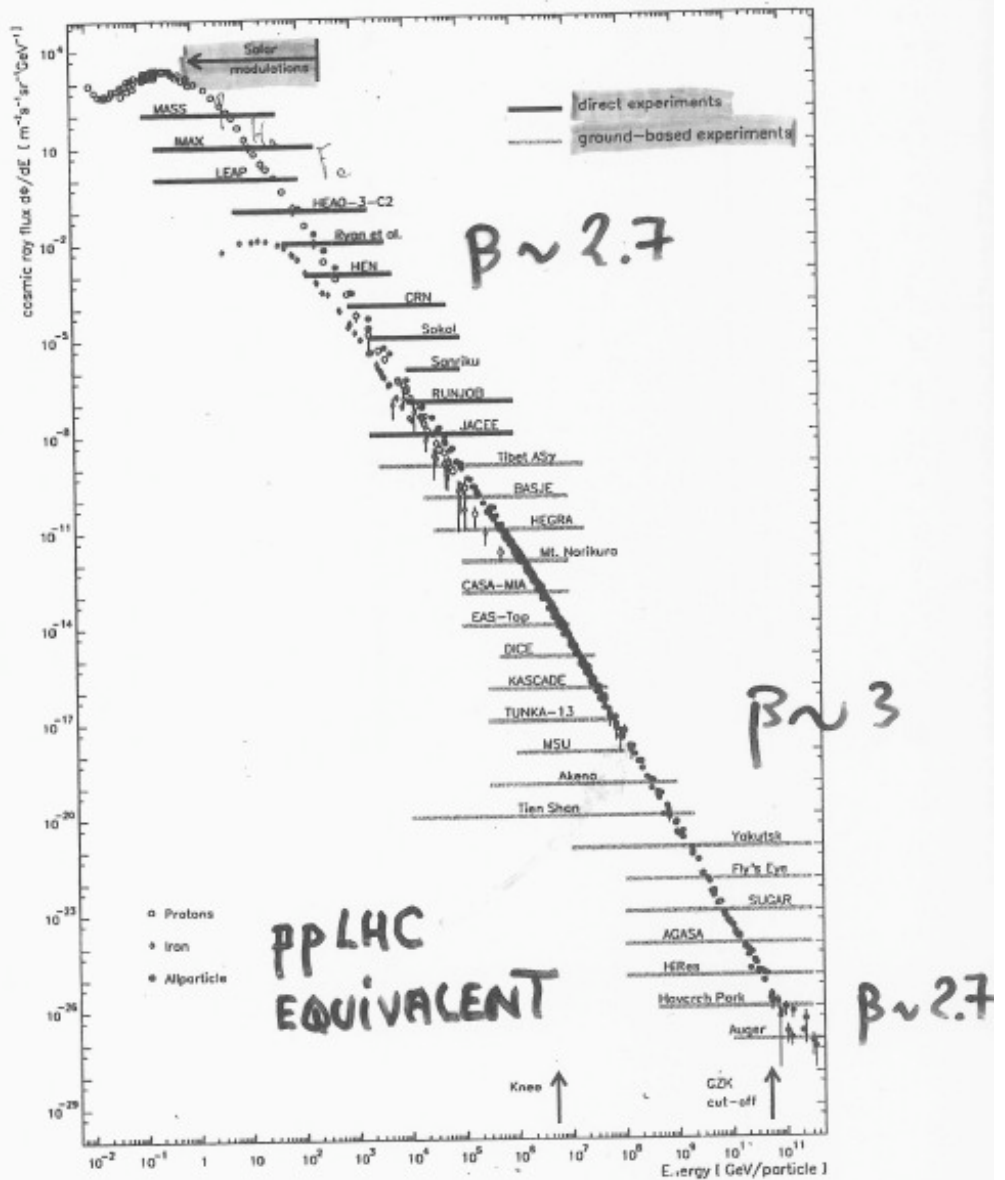
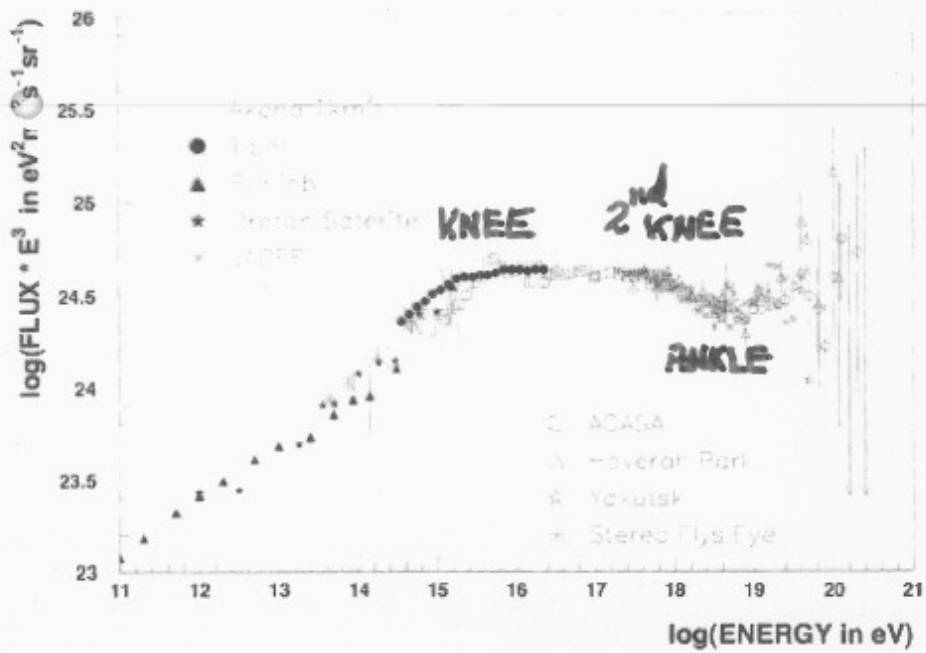


Figure 1: The energy ranges of several direct and indirect experiments, which provided data on the cosmic ray spectrum or will provide data in the near future.

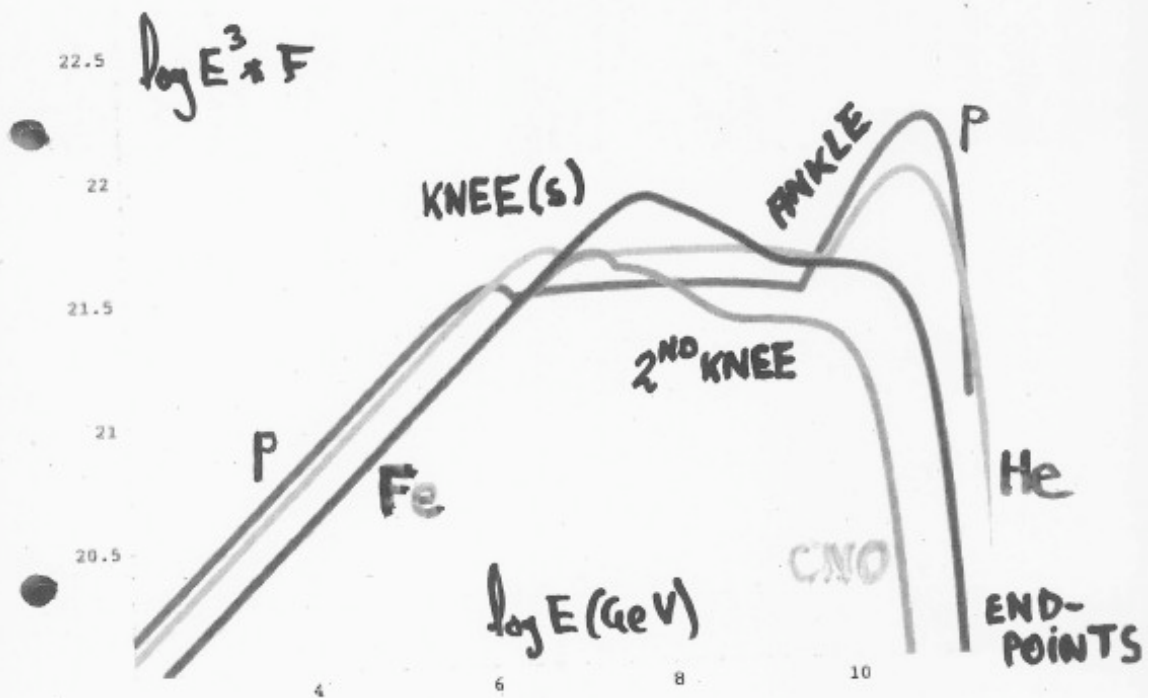
$$E^3 dN/dE$$



ALL-  
PARTICLE  
SPECTRUM

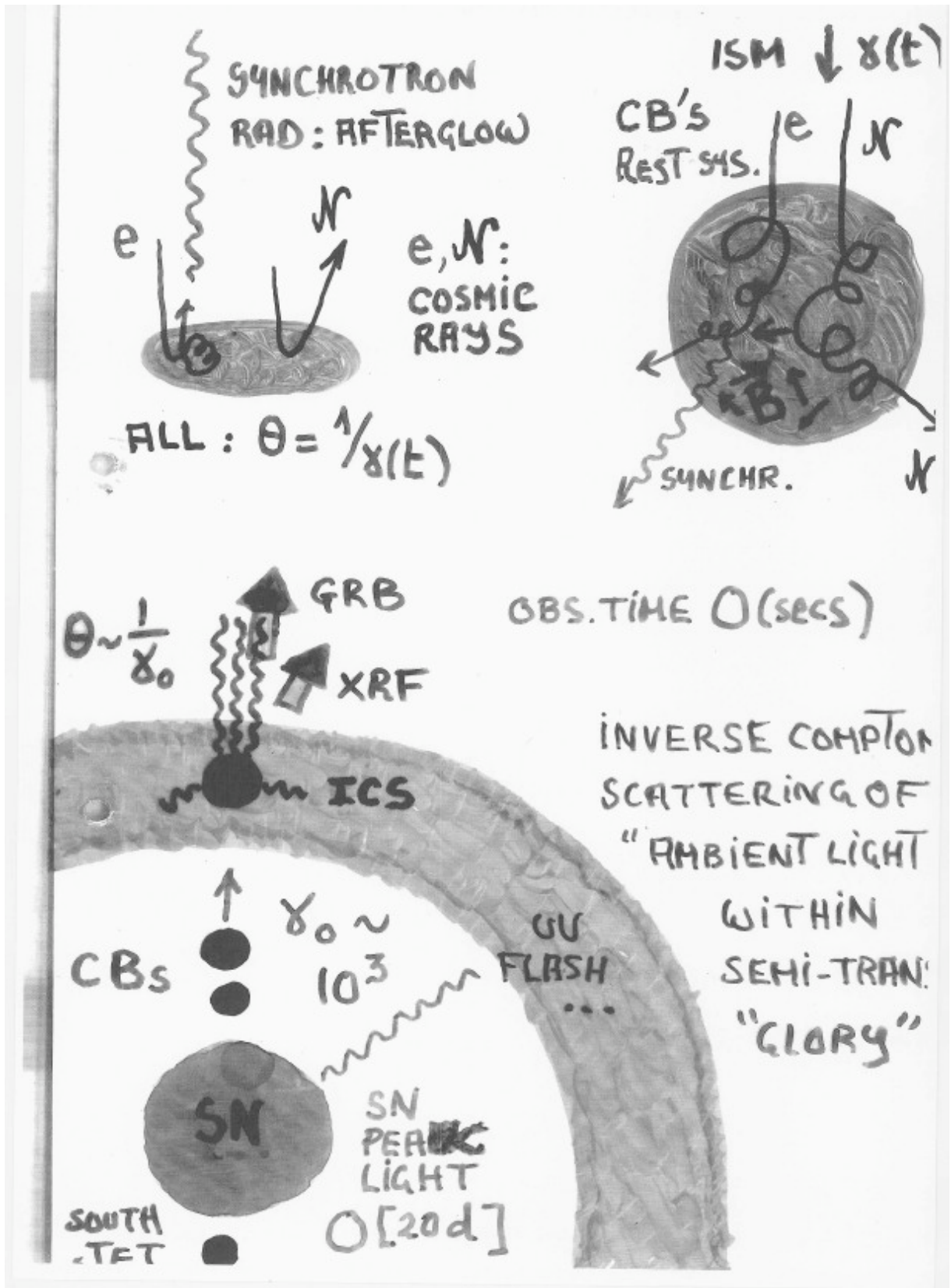


CHANGES OF SPECTRAL SLOPES,  
CHANGES OF COMPOSITION (E)  
POSITION OF 'FEATURES'



ALL PREDICTED,  
NOT TUNED, OR  
PUT IN BY





## CB MODEL OF GRBS

DESCRIPTION OF  
AFTERGLOWS SIMPLE, SUCCESSFUL

➔ PARAMETERS DETERMINED

e.g.  $\gamma_0, M_0$

- PREDS. VERIFIED e.g.  $\vec{B}$  [CB]

...

WITH NO NEW PARAMS

➔ ALL PROPERTIES OF GRB'S

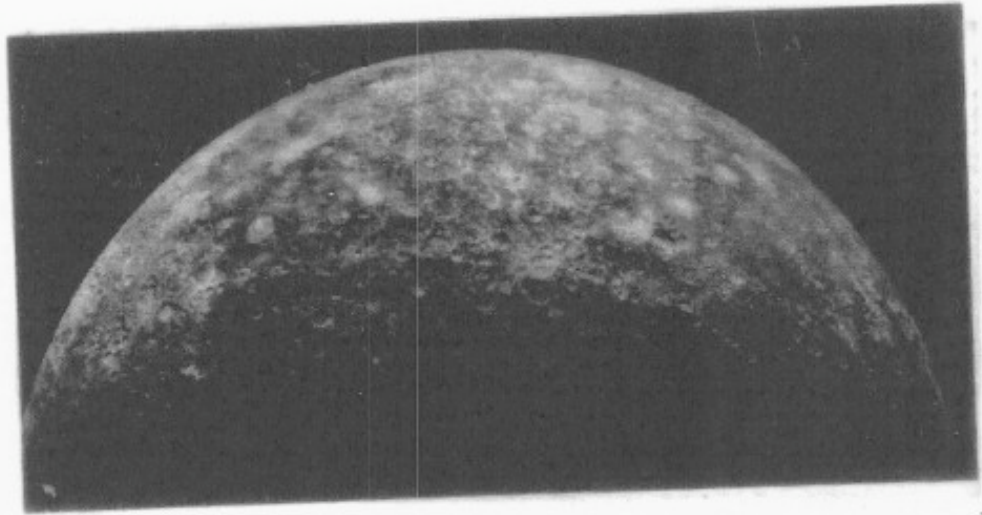
PROMPT'S (BUT 'CANNON'S' WORKING)

SUCCESSFULLY PREDICTED

➔ WE TRUST THE 'TYPICAL'  
CB PARAMETERS

$$\gamma_0 \approx 10^3$$

$$e_{pp} = p_{pp} \sim 10^{50}$$



$$v_{CB} \sim \beta_s \frac{c}{\sqrt{3}}, \quad \beta_s \sim 1$$

$$EFF \sim 10^{-2}$$



**Magnetic**

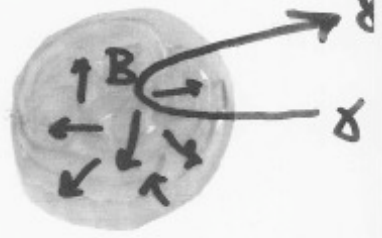
**Racket**

**ACCELE-**

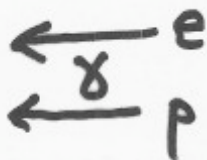
**RATORS**



[COLLISIONLESS]  
RELATIVISTIC  
MAGNETIC  
RACKET



ALSO INTERNAL CB ACCELERATION?



PLASMA + PLASMA  
AT HIGH  $\gamma$  ??  
DD GUESS

FIRST-PRINCIPLE NUMERICAL CALCULATION  
(MAXWELL EQS + LORENTZ FORCE)

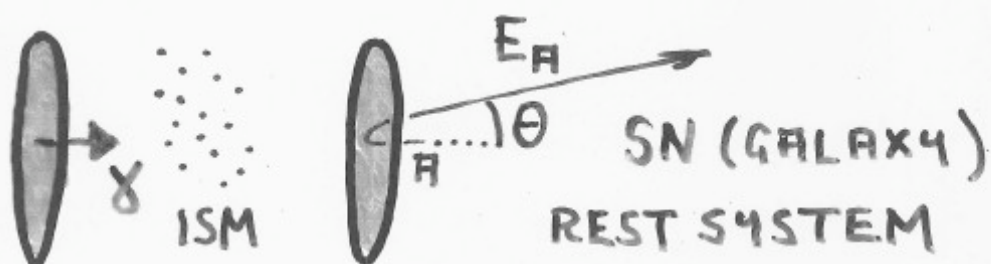
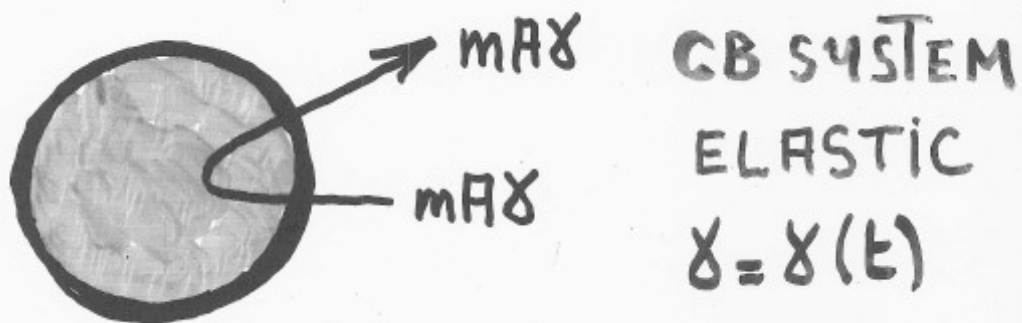
[FREDERIKSEN et al]

$\vec{B}$ ,  $\vec{J}_{e,p}$  TURBULENCE

GOOD OLD (RELATIVISTIC) FERMI ACCEL.

$\Rightarrow E^{-2.2}$ , NO SHOCKS

# POSITIONS OF THE $A$ - "FLAVOURED" KNEES



ANGULAR  
DISTRIBUTION

$$\theta \sim 1/\gamma$$

$$m_p A \lesssim E_A \lesssim 2 m_p A \gamma^2 \quad \text{ENERGY BRACKET}$$

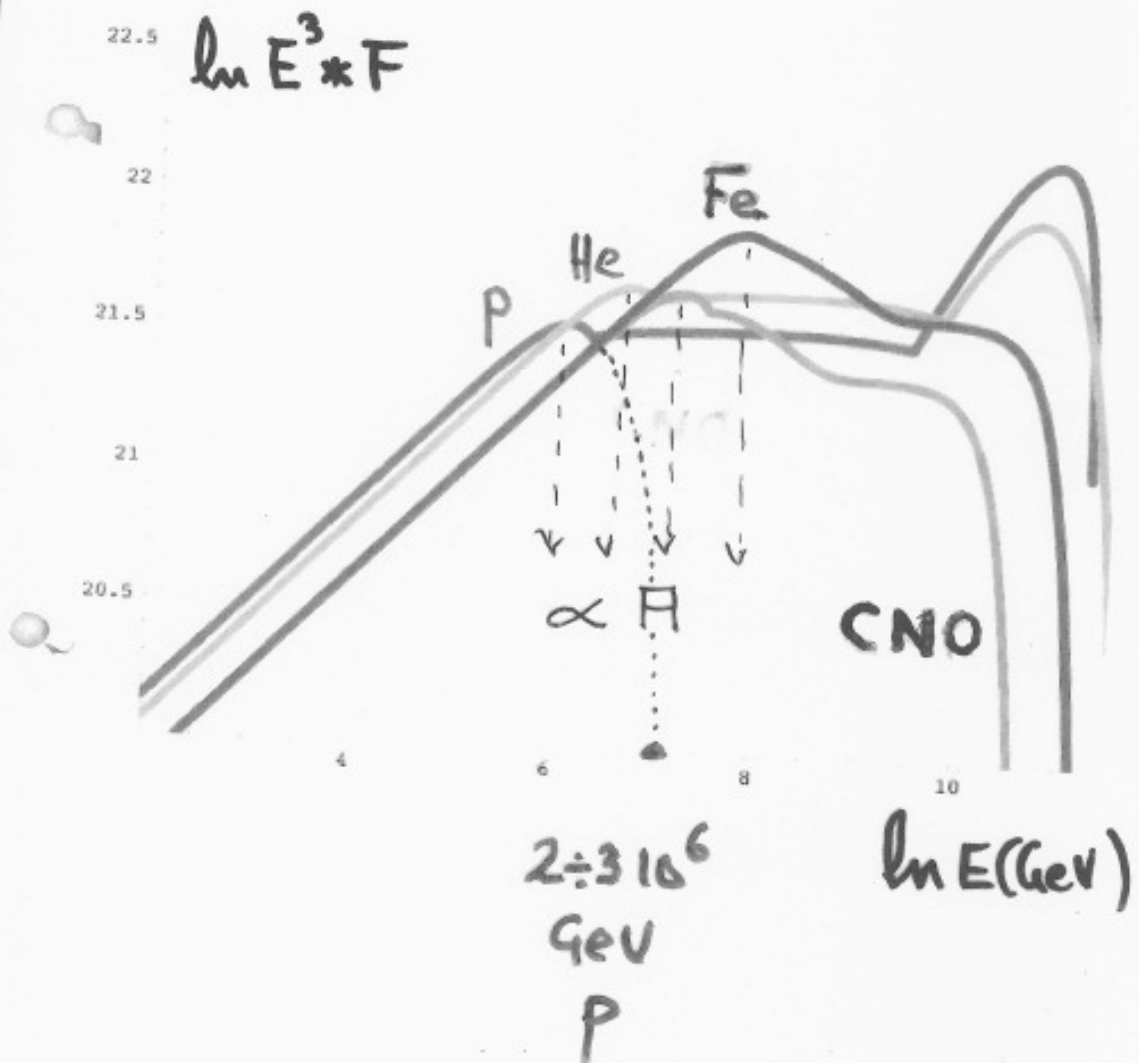
$$\gamma < \gamma_0 \simeq (1 \div 1.5) 10^3$$

$$E_A [\text{max}] \simeq (2 \div 3) 10^6 A \text{ GeV}$$

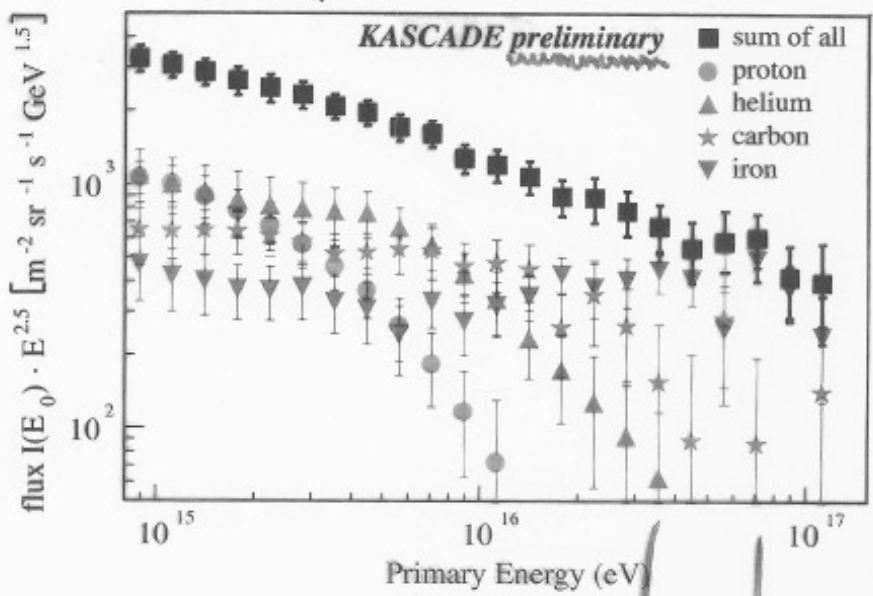
"FLAVOUR" ←

$$E_{\text{KNEES}} \sim 2 \div 3 \cdot 10^6 A \text{ GeV}$$

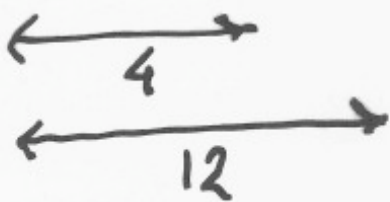
$$\propto A$$



PREDICTED p knee



P He C



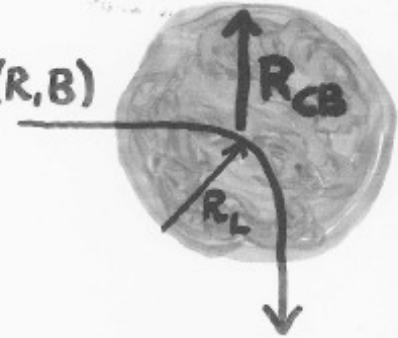
$\propto A$



## POSITIONS OF THE Z-FLAVOURED "TOE-NAILS"

$R_L > R_{CB}$  : ESCAPE

$E(R, B)$



NO ACCELERATION POSSIBLE

$$R_L(E, B) \rightarrow E(R, B)$$

①  $E_z(\text{max}) \approx 9 \cdot 10^{16} \text{ eV} \approx \frac{B}{3G} \frac{R_{CB}}{10^{14} \text{ cm}} \rightarrow \text{F.T.P.}$

$$B_{CB}[\gamma] = 3G (\gamma/10^3) (n_p/10^{-3} \text{ cm}^{-3})^{1/2} \leftarrow$$

②  $B_{CB}[\text{max}][\gamma_0 \sim 10^3] \rightarrow 3G$

●  $\textcircled{\text{I+II}}$  CB SYSTEM  $E_z(\text{max}) \sim 10^{17} \text{ eV} \approx$

SN SYSTEM  $E_z(\text{max}) = \downarrow * 2\gamma_0$

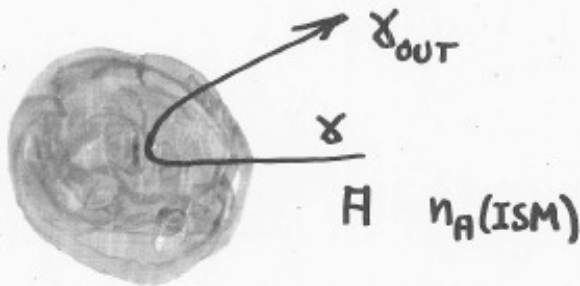
$$E_{\text{LARMOR}} = (2 \div 3) 10^{20} Z \text{ eV}$$

SPECTRE CUT-OFF AT "TOE-NAILS"



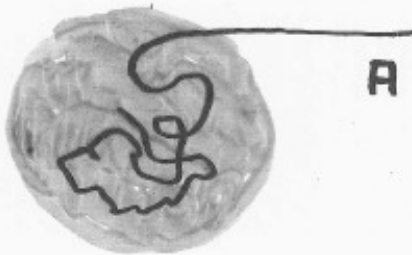
# ACB'S DECELERATION LAW

$$\langle \gamma_{out} \rangle \equiv a \gamma \quad M_0 \equiv \text{INITIAL CB MASS}$$



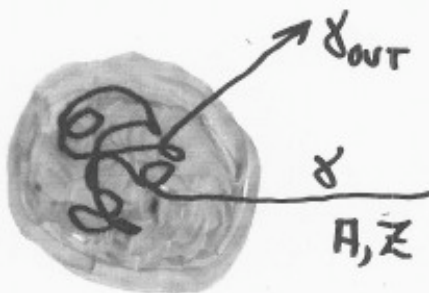
ELASTIC SCATTERING

$$a = 1$$



FACOCITATION

$$a = 0$$



ACCELERATION

$$a > 1$$

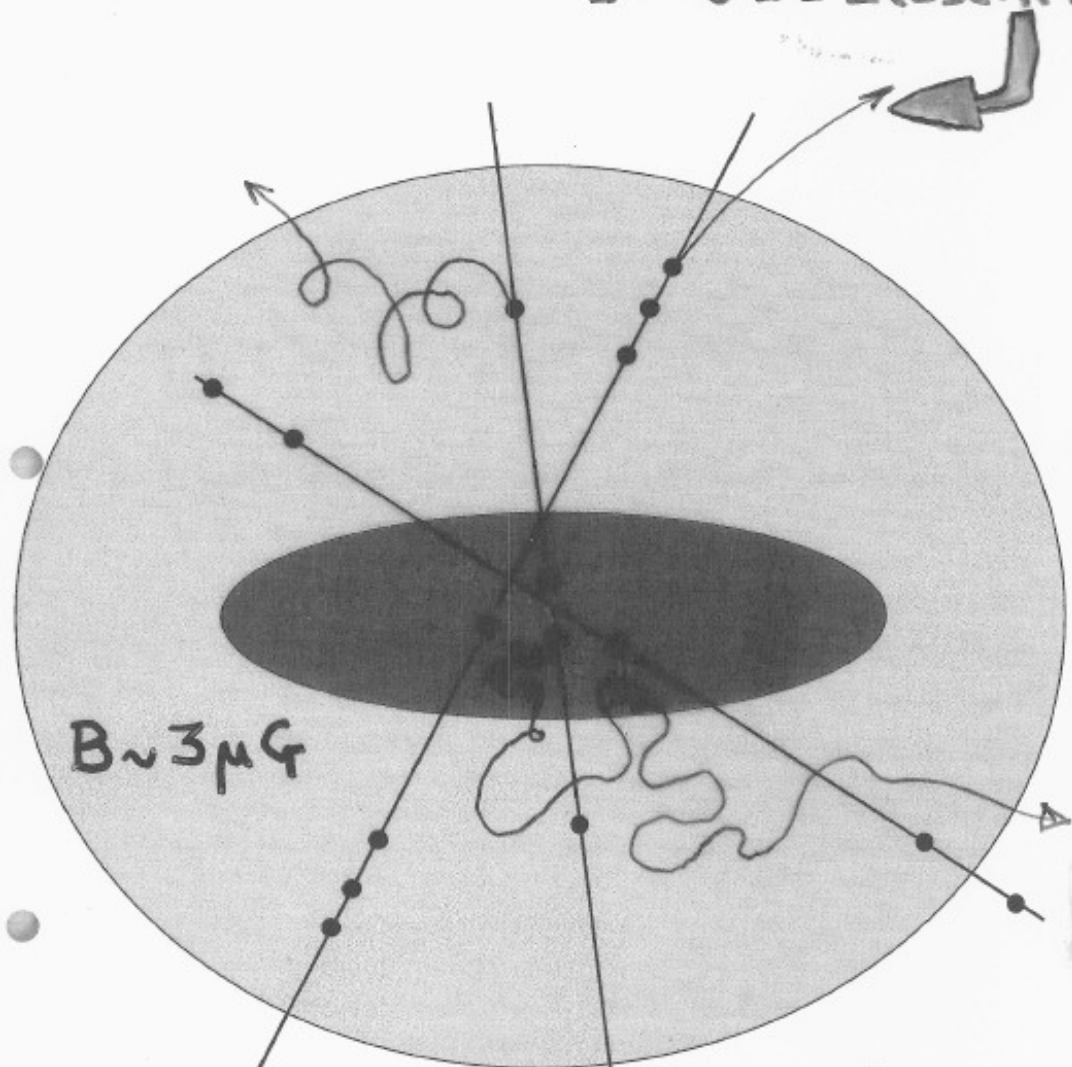
$$d\gamma / \gamma^{3-a} = - \frac{m_p}{M_0} \frac{1}{\gamma_0^{1-a}} \langle A \rangle dn_A$$

$$\frac{d\gamma}{\gamma^k} \propto dn_A \quad k \equiv 3-a \quad (\gamma^2 \gg 1)$$

k NOT WELL PRE-DETERMINED 😞!

**CONFINEMENT TIME**

$\tau(E) \sim E^{-c}$   $c \sim 0.5 \pm 0.1$   
UP TO  $E = E(\text{ESCAPE})$



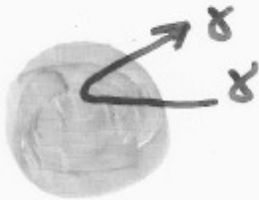
$B \sim 3 \mu G$

**OBSERVED FLUX : SOURCE(E) \*  $\tau(E)$**   
UP TO  $E = E(\text{ESCAPE})$   
**EQUILIBRIUM ESCAPING FLUX : SOURCE(E)**

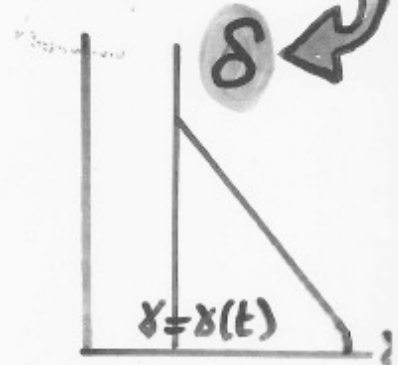
**ISOTROPIZATION** 1SN/50y

$\tau(E < E_{\text{ESCAPE}}) \gg 50y$

# NUCLEI ELASTICALLY SCATTERED



SAY  
 $\frac{dN}{d\alpha} \Big|_{CB} = \text{CONST.}$



$\delta^2 \gg 1$

•  $\frac{dN}{d\delta_N} \Big|_{SN} = \int_{-1}^1 \frac{d\cos\alpha}{2} \delta (\delta_N - \delta \delta (1 + \cos\alpha))$   
 $= \frac{1}{2\delta^2} \theta(1 < \delta_N < 2\delta^2) \quad \delta > \sqrt{\frac{\delta_N}{2}}$

•  $\int_{\text{TRAJ}} dn_A = \int_1^{\delta_0} \frac{d\delta}{\delta^k} \frac{dN}{d\delta_N} \Big|_{SN} \approx E_A = 2\delta_0^2 A m_1$   
 KNEES

$\left(\frac{1}{\delta_N}\right)^{\frac{k+1}{2}} \left[1 - \left[\frac{\delta_N}{2\delta_0^2}\right]^{\frac{k+1}{2}}\right] \theta[\delta_N < 2\delta_0^2]$

CONFINEMENT \*  
 IN GALAXY/HALO

$\left(\frac{1}{\delta_N}\right)^C$

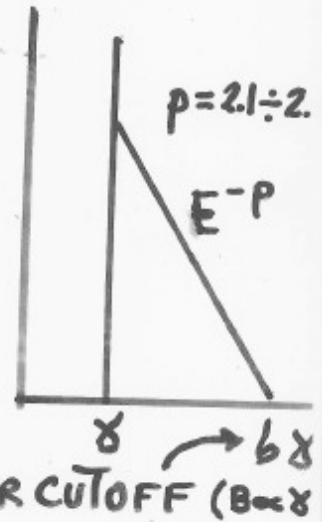
LIP TO GIVEN  
 ESCAPE ENERGY

DEGE-  $k=3$   $C=0.7$  CR SLOPE 2.7  
 NERA-  $k=3.4$   $C=0.5$  CR SLOPE 2.7  
 CY

# NUCLEI ACCELERATED WITHIN CB

$$\int_{\gamma}^{b\gamma} \frac{d\gamma_a}{\gamma_a^p} \int_{-1}^1 \frac{d\cos\theta}{2} (\gamma_N - \gamma\gamma_a (1 + \cos\theta)) \frac{dN}{d\gamma_a}$$

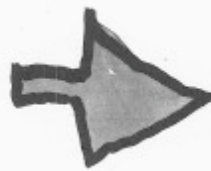
$\gamma_N$  / BOOST  
 $\gamma\gamma_a (1 + \cos\theta)$  /  $\gamma$ 's LORENTZ FACTOR



$$\propto \int_{\text{Max}[\gamma, \frac{\gamma_N}{2\gamma}]}^{b\gamma} d\gamma_a / \gamma_a^p \frac{1}{2\gamma\gamma_a}$$

↳ CHANGE OF SLOPE AT 'INSTANT' KNEE (FIXED  $\gamma$ )

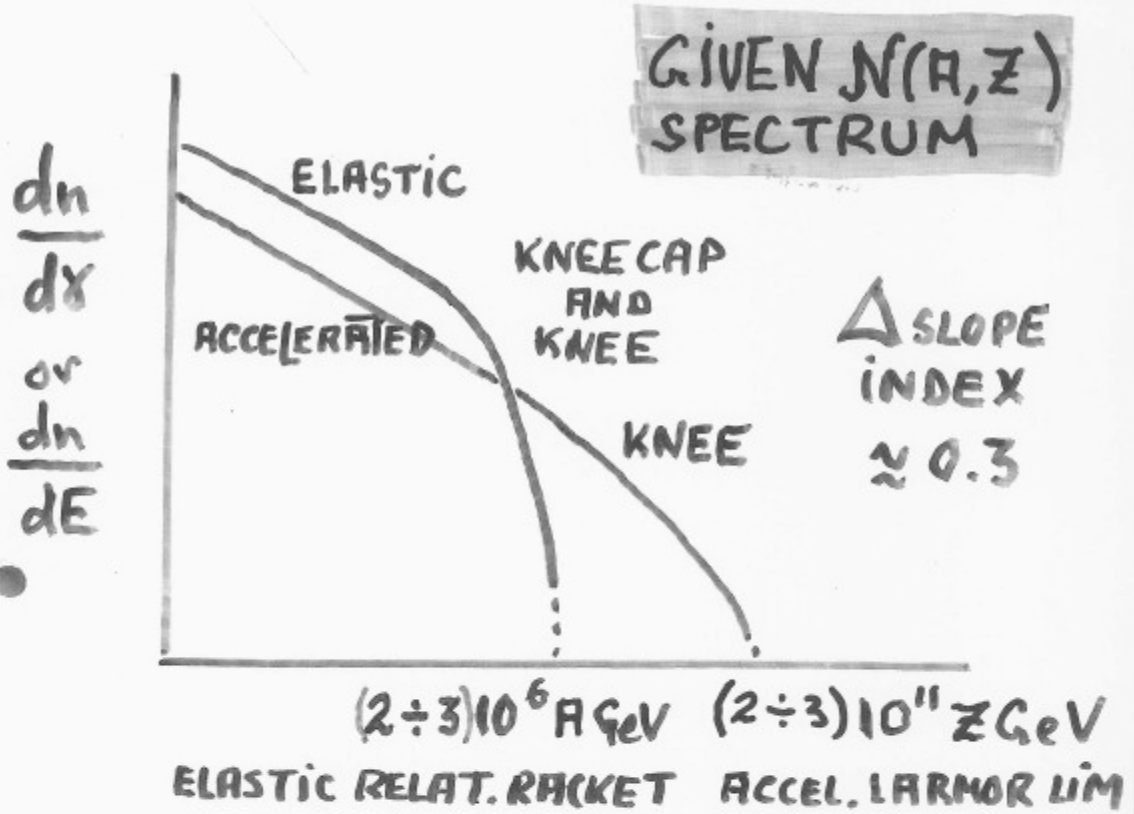
$$\int_1^{\gamma_0} \frac{d\gamma}{\gamma^k}$$



CHANGE OF SLOPE AT KNEE(S)

$$\gamma_N = 2\gamma_0^2$$





- ① KNEES NOT PUT IN BY HAND  $\leftarrow \gamma_0$   
(NATURAL KICKS OF N.S. ; GRBS, GRB AGCs)
- ② LARMOR CUTOFF NOT BY HAND  $\leftarrow \gamma_0, B(\gamma)$   
(GRB WIDE-BAND AG SPECTRA)
- ③  $\Delta$  SLOPE NOT BY HAND  $\leftarrow$  CB+K KINEMATICS
- ④ ONLY  $k_{eff}$  (DEC. LAW) TUNED  $k \approx 3.4$   
(FOR  $\epsilon \approx 0.5$ )



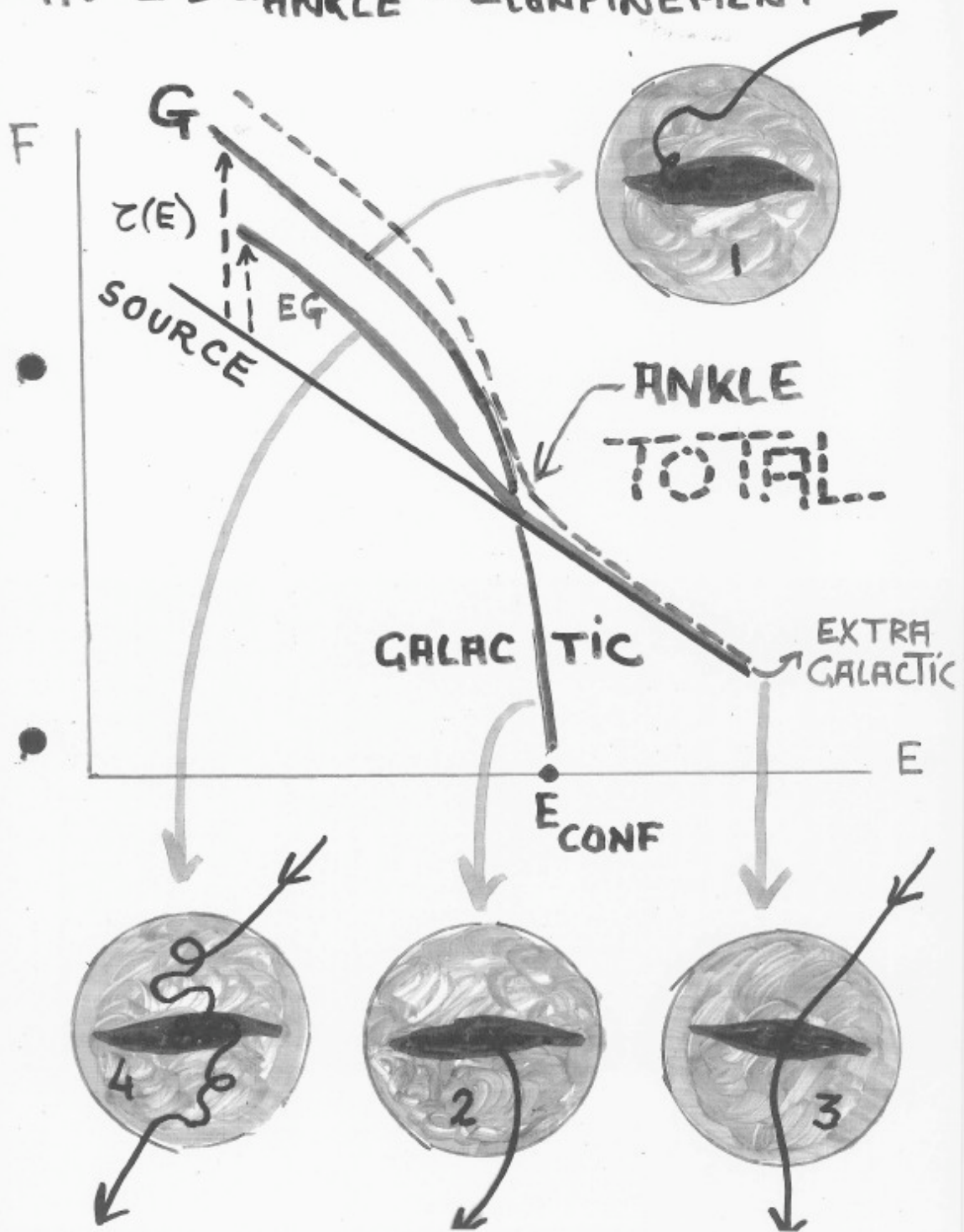
# GALACTIC vs EXTRAGALACTIC

## C.R.



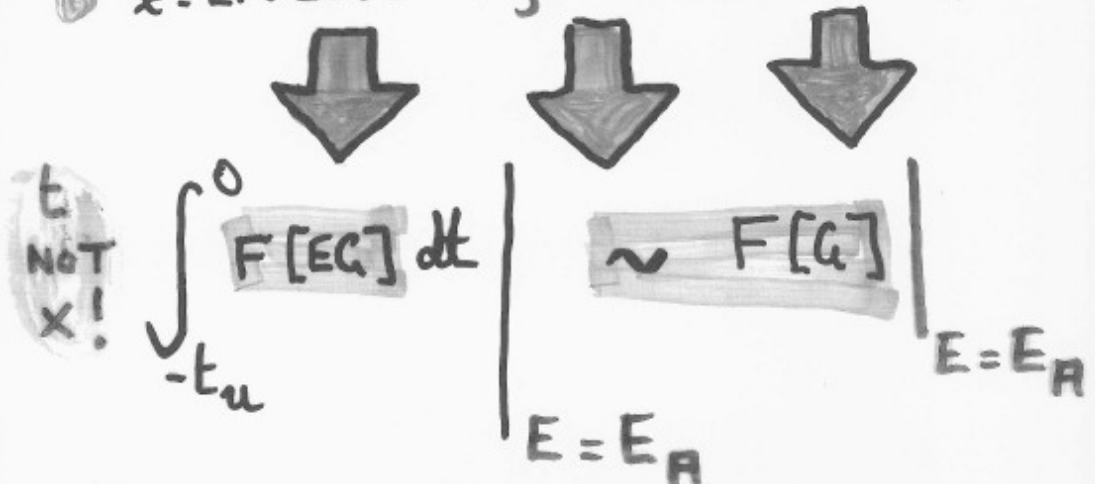
# STRUCTURE OF THE ANKLE

AT  $E = E_{\text{ANKLE}} = E_{\text{CONFINEMENT}}$

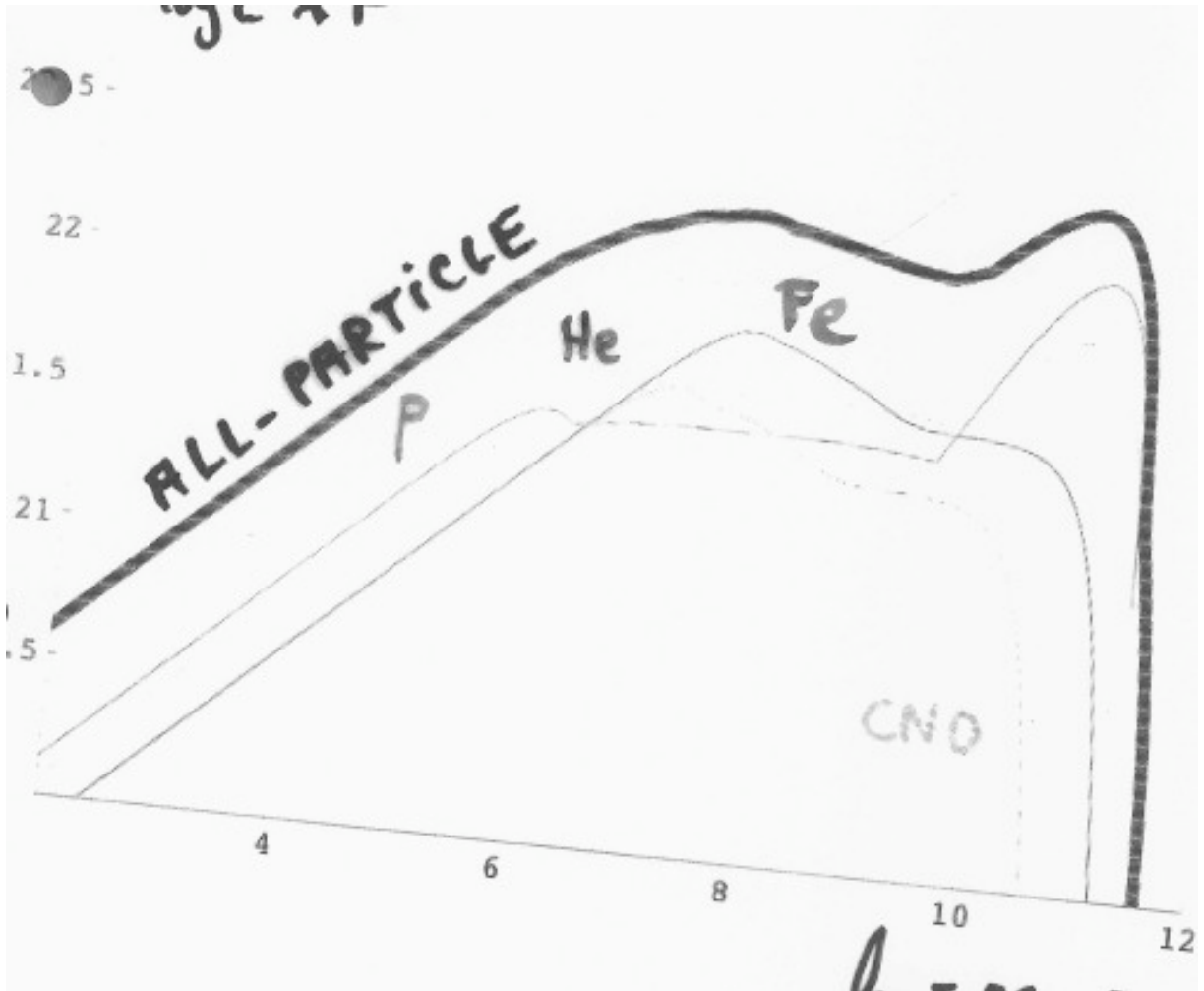


# G vs EG FLUX AT THE ANKLE

- $\langle N[\text{PULSES}] \rangle_{\text{GRB}} \cong 6$
- 2 JETS  $\rightarrow$  12 CBS / SN
- $\gamma_0 [\text{CB}] \sim 10^3$        $N_{\text{B}} [\text{CB}] \sim 10^{50}$
- MILKYWAY  $\rightarrow$  1 SN / 50 y  
 $\rightarrow 2.4 N[\star] * \text{AVERAGE GALAXY}$
- LOCALLY 1 GALAXY / (80 Mpc<sup>3</sup>)
- $dN/dE|_{\text{CR}} \sim E^{-2.7}$  UP TO ANKLE
- $t_u \sim 10^{10}$  y       $h \sim 0.65$
- z-EFFECTS e.g. S.F.R.  $\sim (1+z)^3$



FAR THE CR-MODEL CR LUMINOSITY



TWO PARAMETERS :

{ OVERALL NORMALIZATION

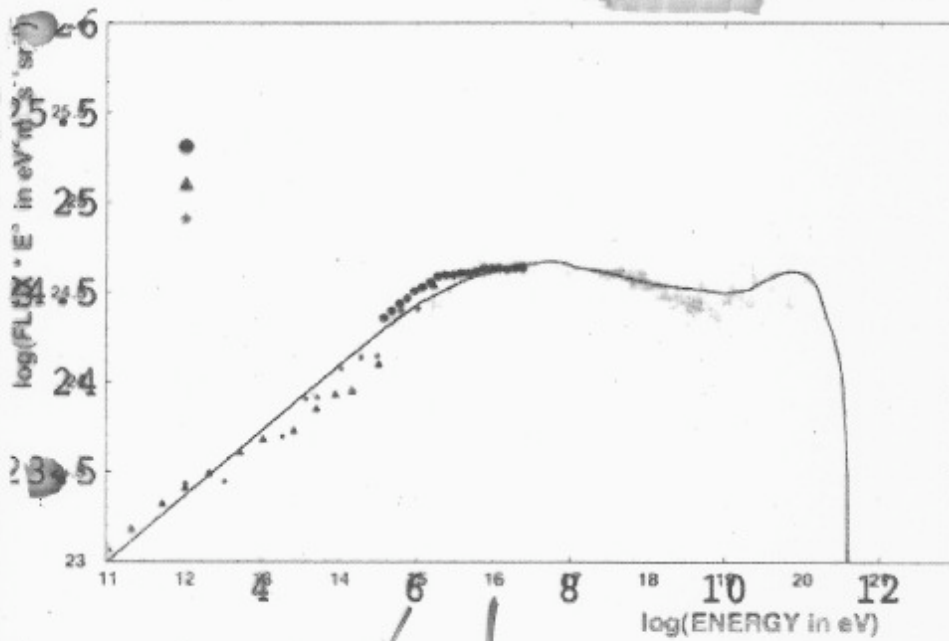
}  $k+c$

ALL OTHERS

PRE-ESTIMATED

$\log E^3 \times F(E)$

ONE MECHANISM

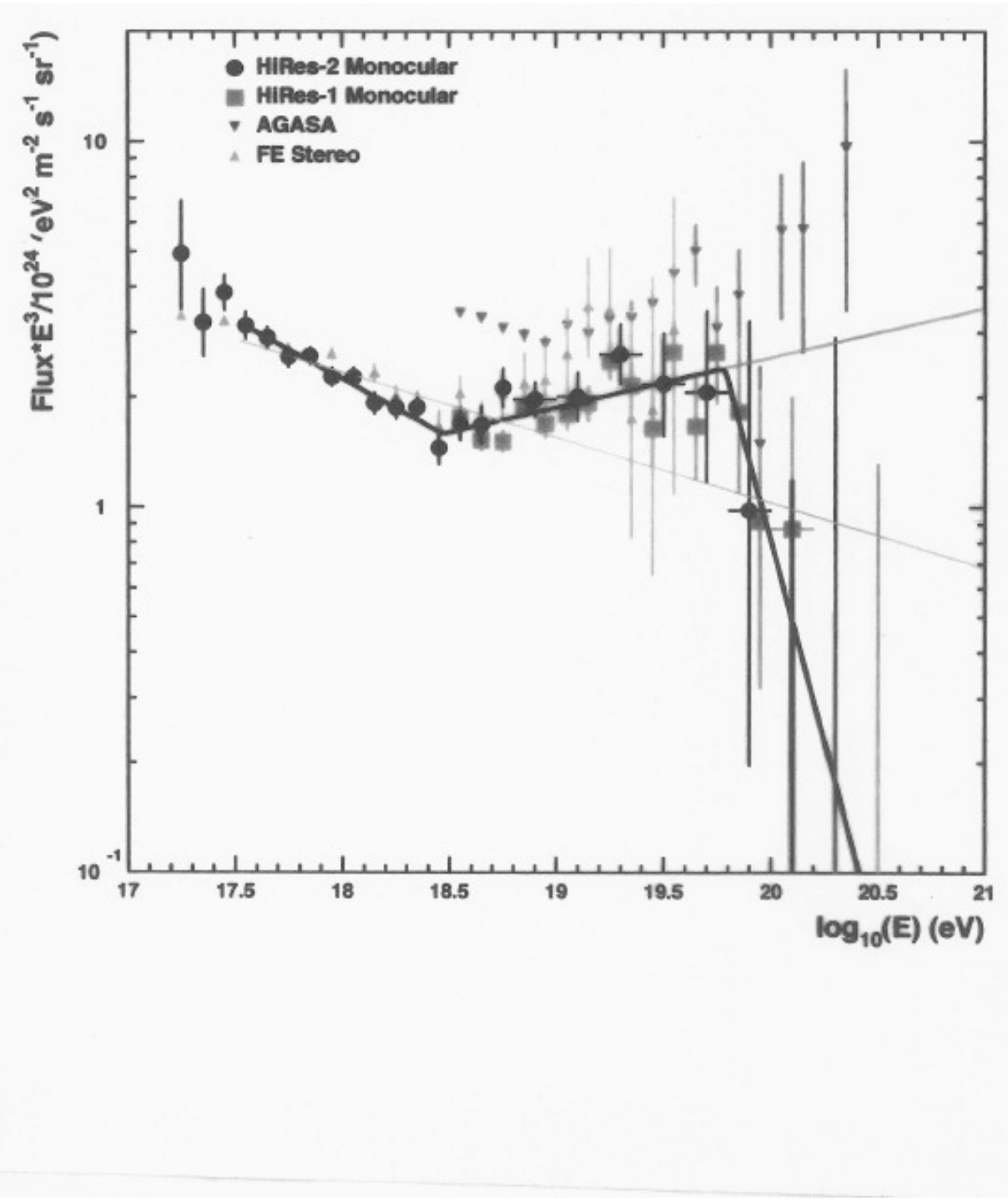


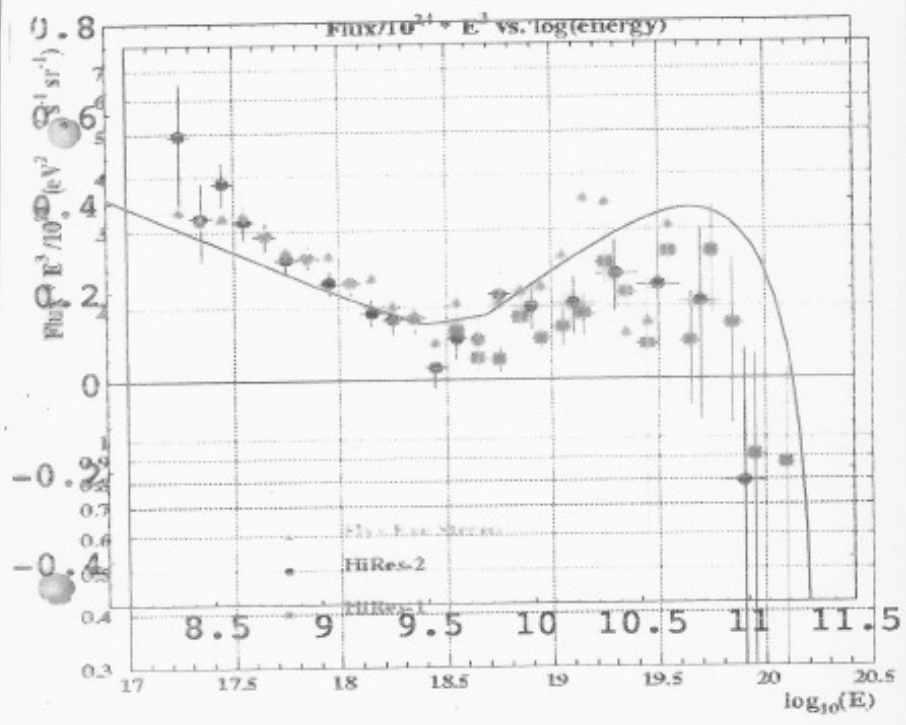
$\log E(\text{GeV})$

$\log E(\text{eV})$

WODAS!

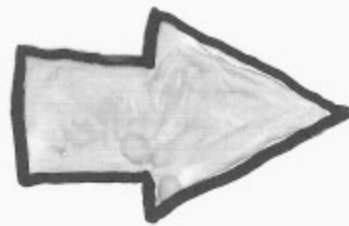






- HiRes-1
- HiRes-2
- Fly's Eye stereo

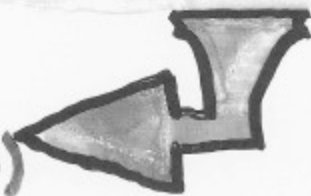
RELATIVISTIC  
MAGNETIC  
RACKETS are  
FLAVOR-BLIND



• IN CB-MODEL

$$\frac{dF(\gamma, A, Z)}{d\gamma} = n_{ISM}(A, Z) \mathcal{U}(\gamma)$$

UNIVERSAL (A, Z INDEP)



# ABUNDANCES

ISM abund.

$$\frac{dF_A}{dE_A} = \frac{1}{Amp} \frac{dF_A}{d\delta} \propto \frac{n_A}{Amp} \gamma^{-p}$$
$$\propto \frac{n_A}{A} \left(\frac{E_A}{A}\right)^{-p} = n_A A^{p-1} E_A^{-p}$$

BELOW ANKLE: \*  $\left(\frac{Z}{E_A}\right)^c$

$$\frac{dF_{AZ}}{dE_{AZ}} = K A^{p-1} Z^c n_A E_A^{-(p+c)}$$

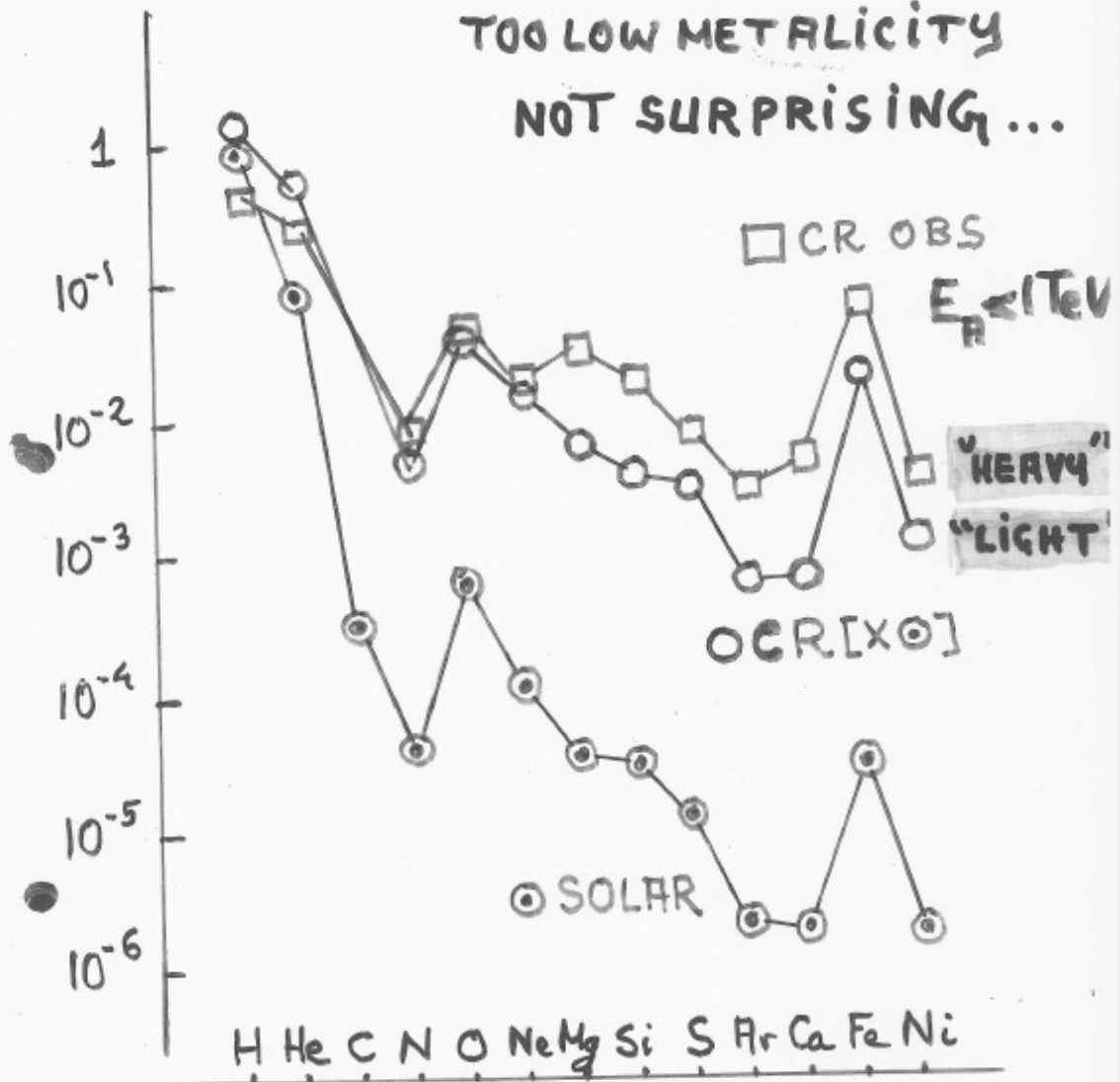
$n_A \propto X_A$  "TARGET"  
RELATIVE  
ABUNDANCES

BUT FOR H/He, RESULTS SIMILAR  
AT FIXED  $p+c \approx 2.7 < \text{KNEES}$   
 $\approx 3.0 > \text{KNEES}$

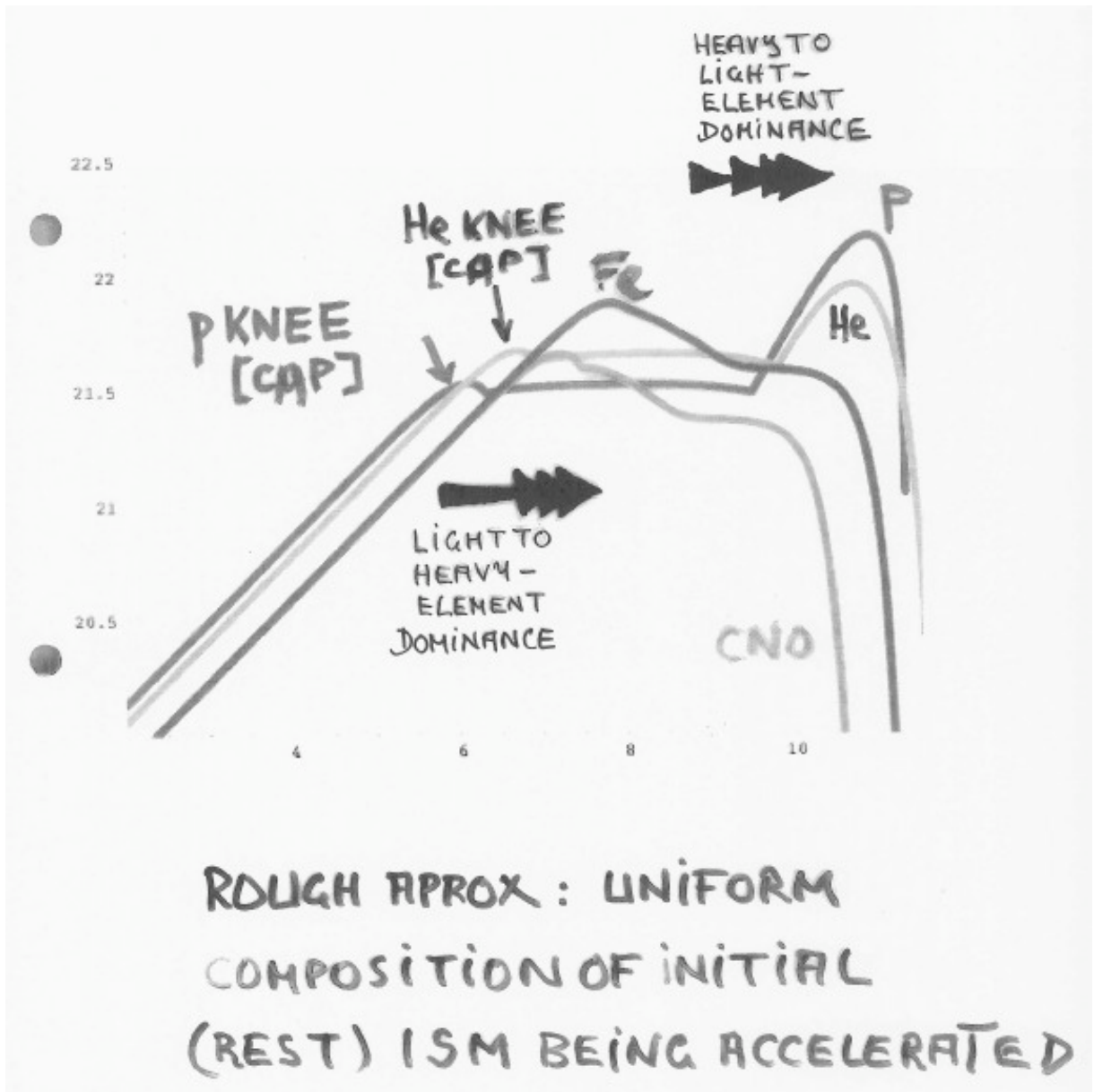


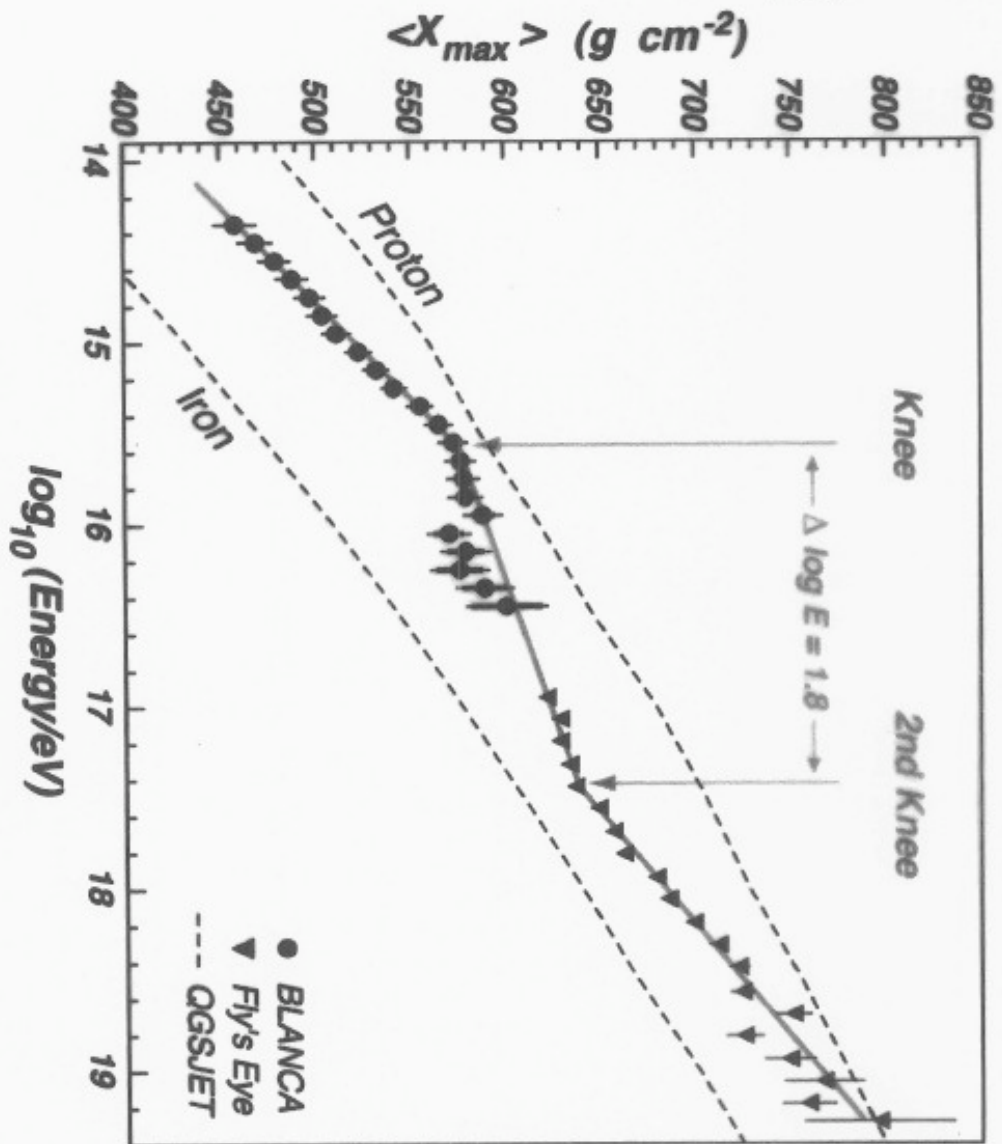
INPUT =  $X_A [⊙]$

TOO LOW METALICITY  
NOT SURPRISING...



... **CB** } STARBURST REGION { NOT WELL MEASURED  
 CROSSES } LOCAL SUPERBUBBLE {  $X_M > X_M [⊙]$   
 'NORMAL' ISM  $X_A \sim X_A [⊙]$





## UHE CR CUTOFFS

- GZK H:  $10^{20}$  eV  
He:  $4 \cdot 10^{20}$  eV

- PHOTODISSOCIATION

$$\text{He} \sim 10^{20} \text{ eV}$$

- CB MODEL ACCELERATOR ENDS AT

- H:  $2 \cdot 10^{20}$  eV

- He:  $4 \cdot 10^{20}$  eV

ALL IN THE SAME BALLPARK

+ COMPOSITION DETERMINATION  
AT VHE VERY ARDUOUS!



# WHAT DID I SAY?

- SUPERNOVAE EMIT CANNON BALLS OF KNOWN PROPERTIES  
(← GRBS, AFTERGLOWS...)

- CBS MOVE IN GALAXY KICKING THINGS OFF (ISM) MAGNETICALLY

→ COSMIC-RAY PROPERTIES EXPLAINED

## SOME CONCLUSIONS (of mine)

★ VVHE CRs INTERESTING  
← "NEARBY" POINT  
SOURCES

★ ALL FEATURES OF  
CR SPECTRA AND  
COMPOSITION AT  
ALL ENERGIES  
(SO FAR ... SEMIQUANTITATIVELY  
EXPLAINED IN CB MODEL

→ NO FANCIFUL  
"NEW PHYSICS"  
REQUIRED

How does the

**CEB**

**Accelerator**

**WORK ???**