Cosmic Ray

Gnumdra

Victor Hess before his 1912 balloon flight in Austria, during which he discovered cosmic rays

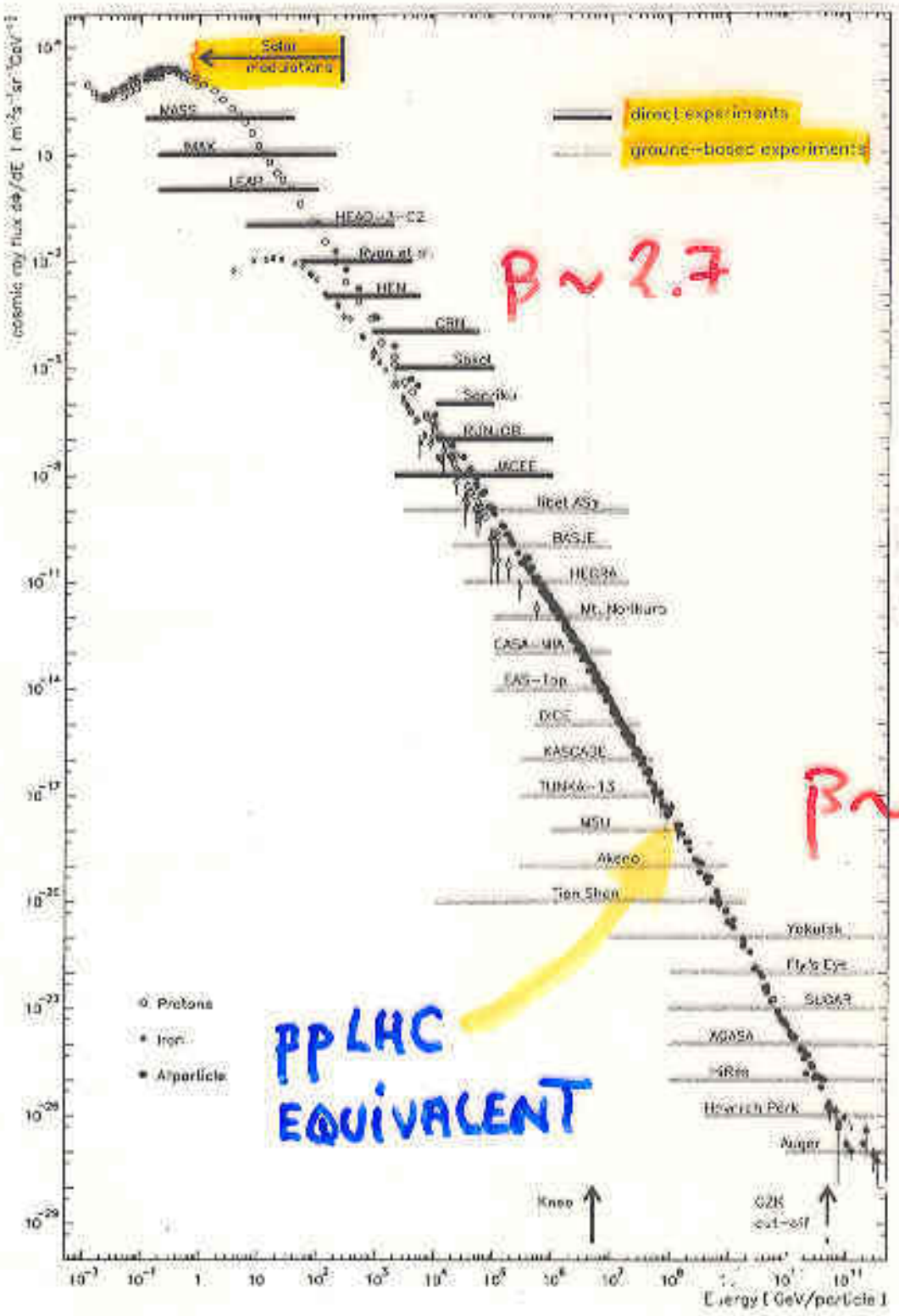
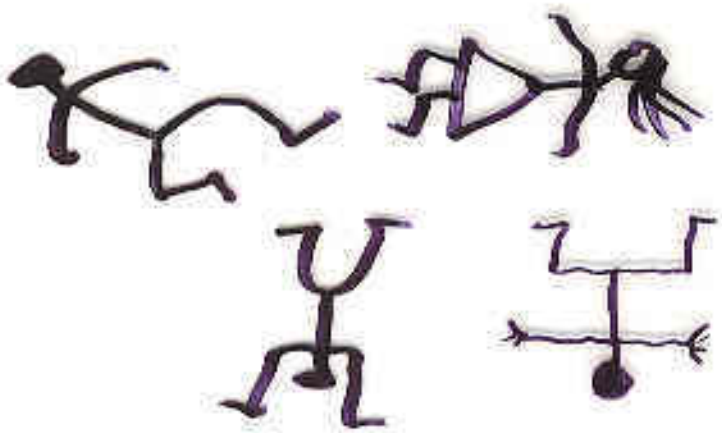
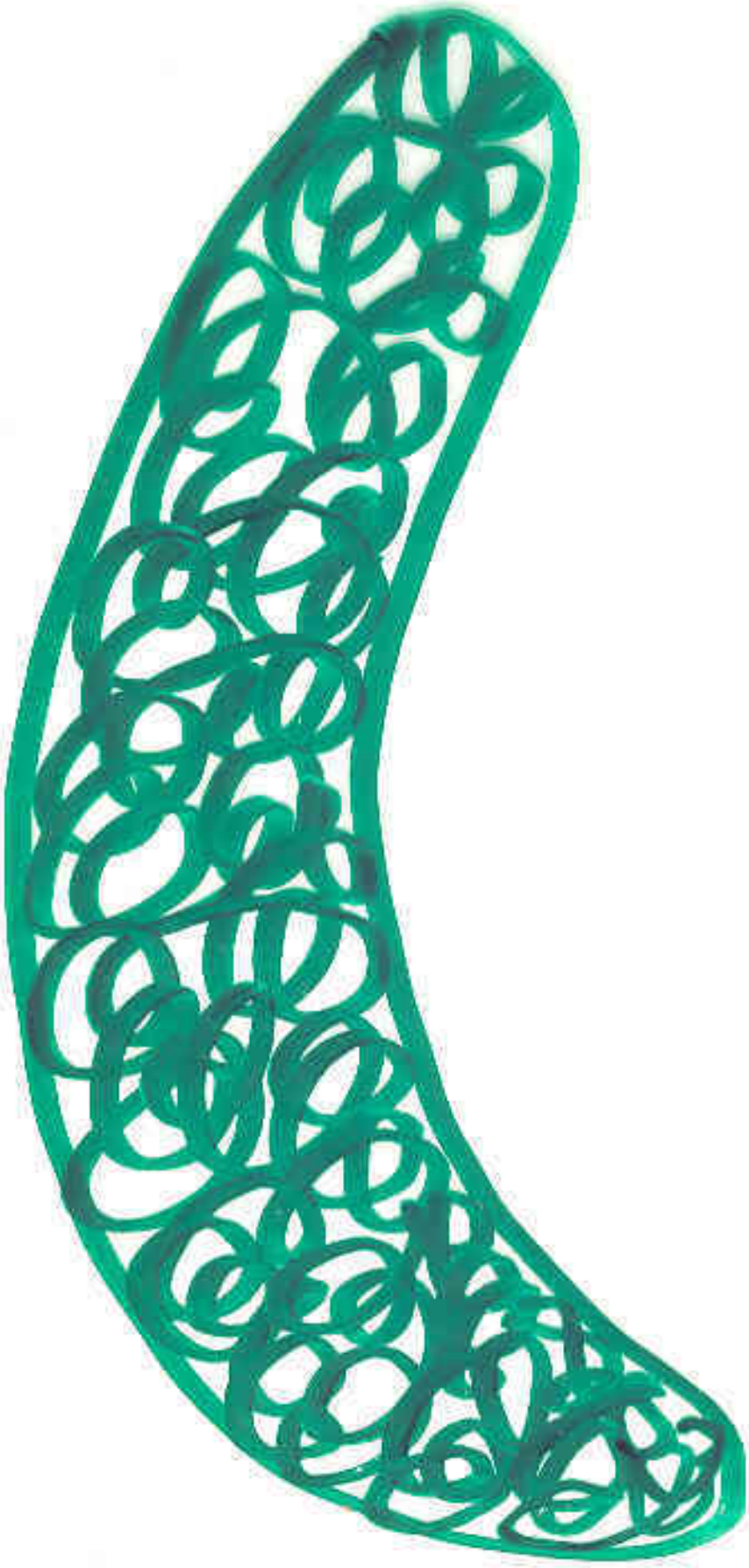


Figure 1: The energy ranges of several direct and indirect experiments, which provided data on the cosmic ray spectrum or will provide data in the near future.

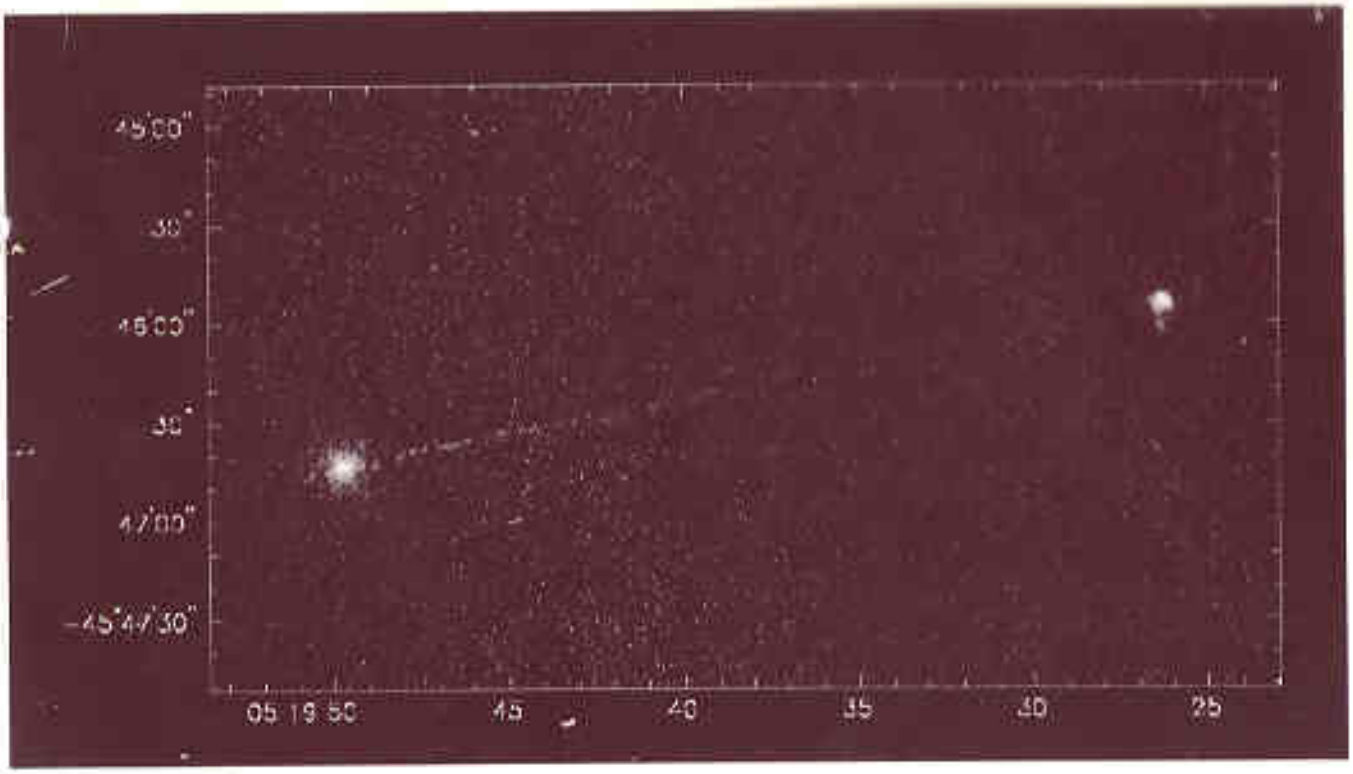


- M_{Pl} RELICS OF BB
- NEUTRAL PARTICLES
  ⊃ LIGHT GLUINOS
- MONOPOLES
- KNOTS IN PRIMORDIAL STRINGS
- TOPOLOGICAL DEFECTS
- $\nu_{UHE} + \nu_{HALO} \rightarrow WW, ZZ \ldots$
- BREKDOWN OF $\mathcal{L}$-INVAR.
- WIMPZILLAS

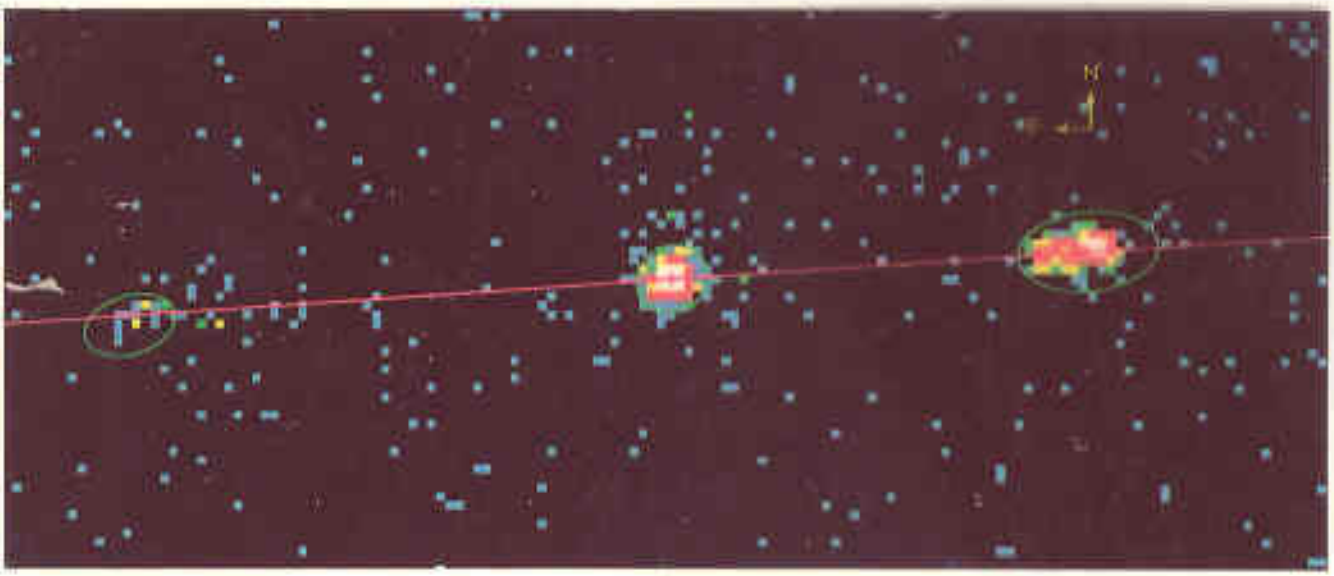


JETS in ASTRO-PHYSICS

X-RAY IMAGE of PICTOR-A QUASAR

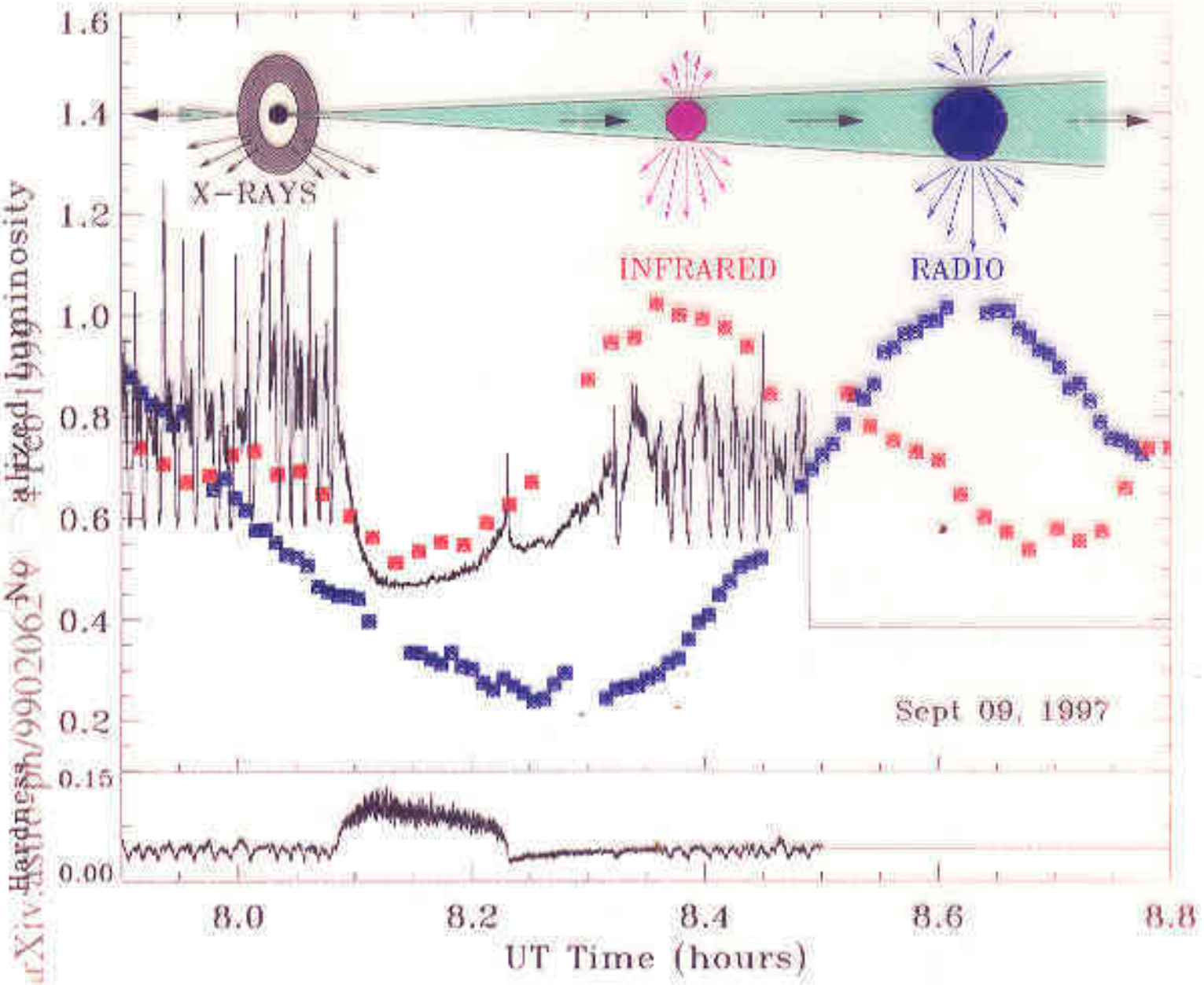


μ-QUASAR XRS J1550-564



X-RAY image

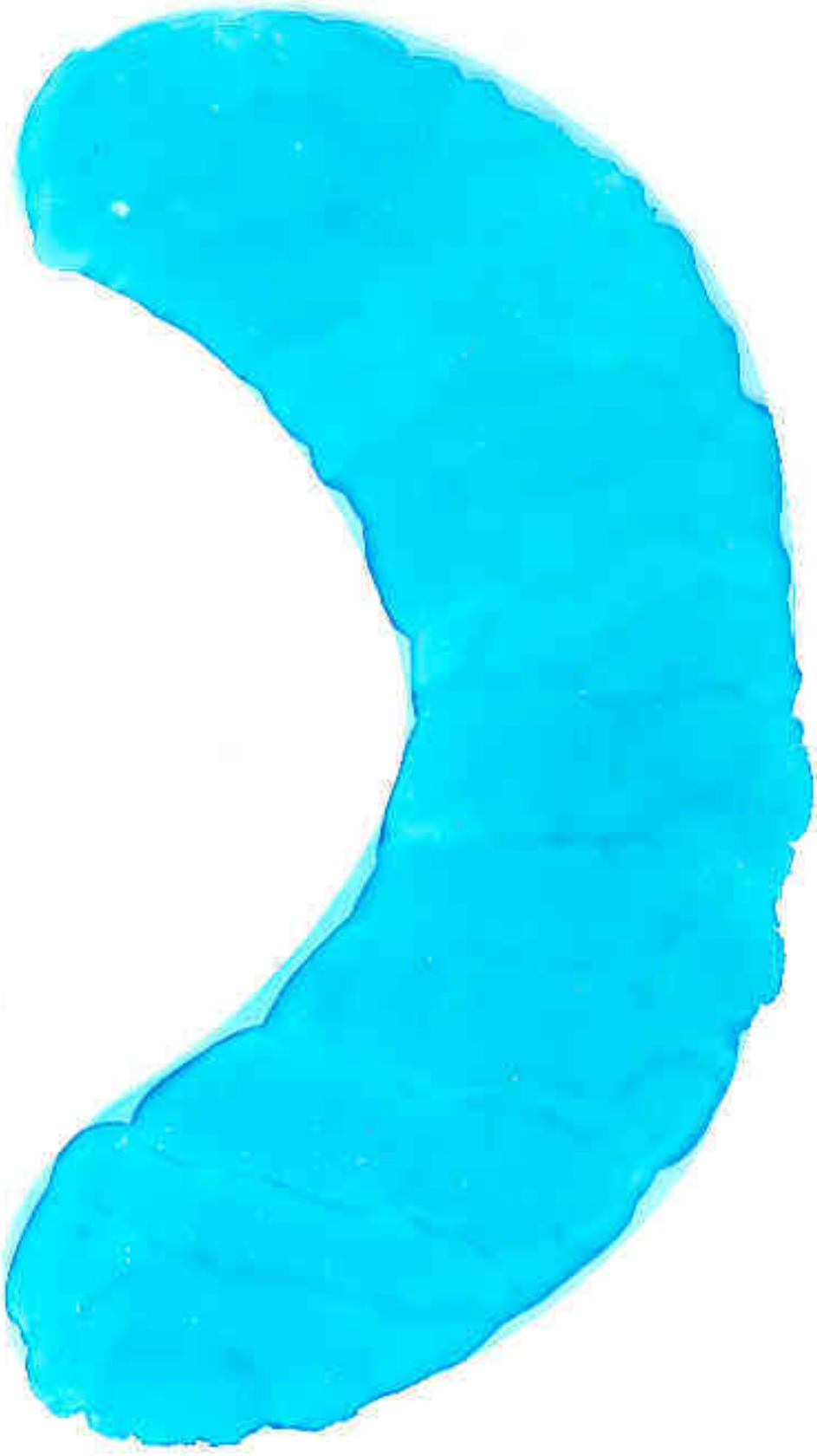
CORBEL et al. 2002



GRS 1915+105

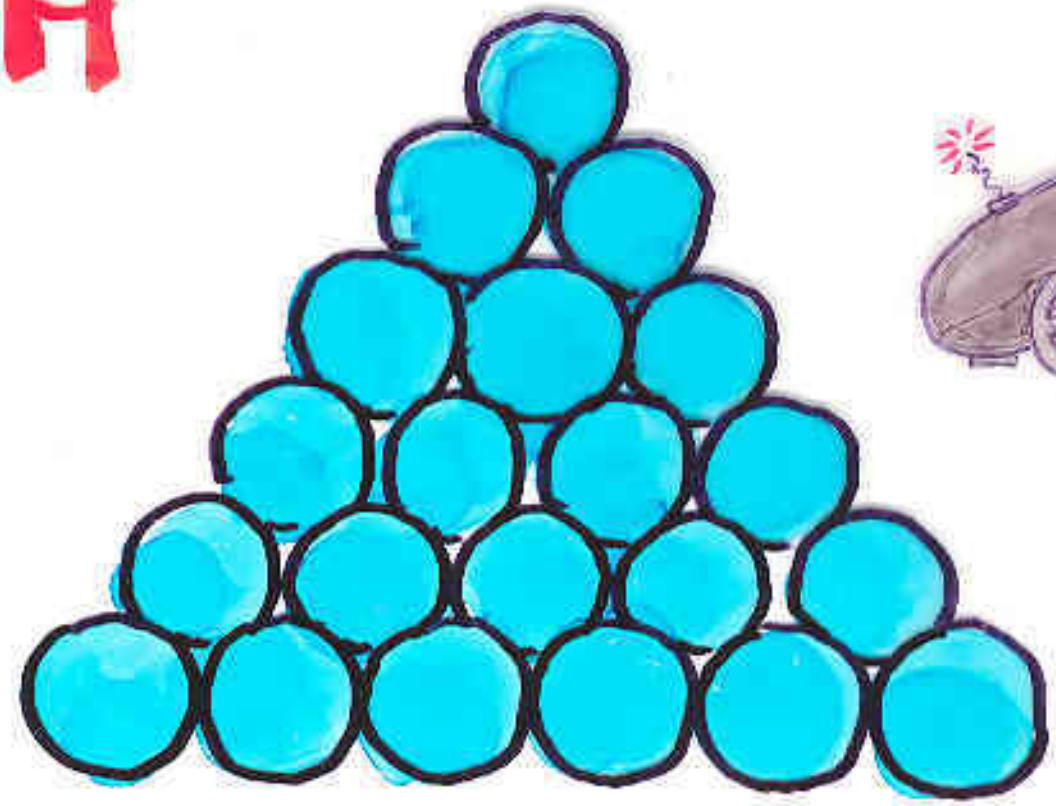
MERIBEL/RODRIGUEZ

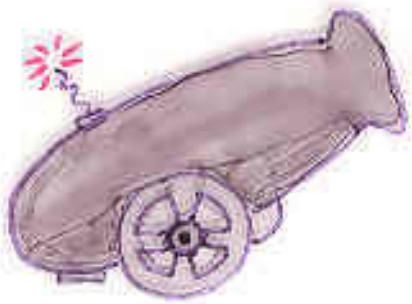
... MHD



DAR
ADR
DADO

A





MODEL of GRBs

and

H.E.A.R.

WHAT MAKES GRBs ¿?

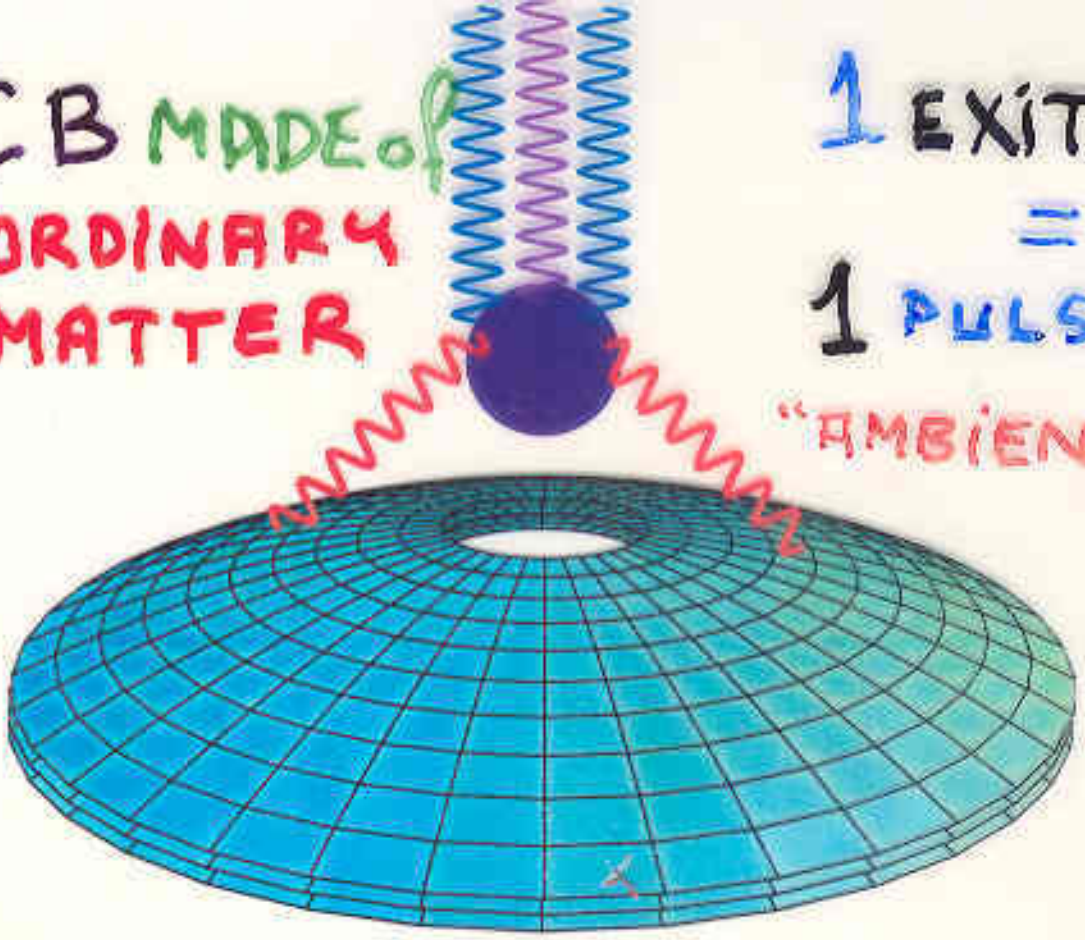
(LONG-DURATION)

CORE-COLLAPSE SUPERNOVAE

CB MADE of ORDINARY MATTER

1 EXITING CB = 1 PULSE of GRB

"AMBIENT LIGHT"



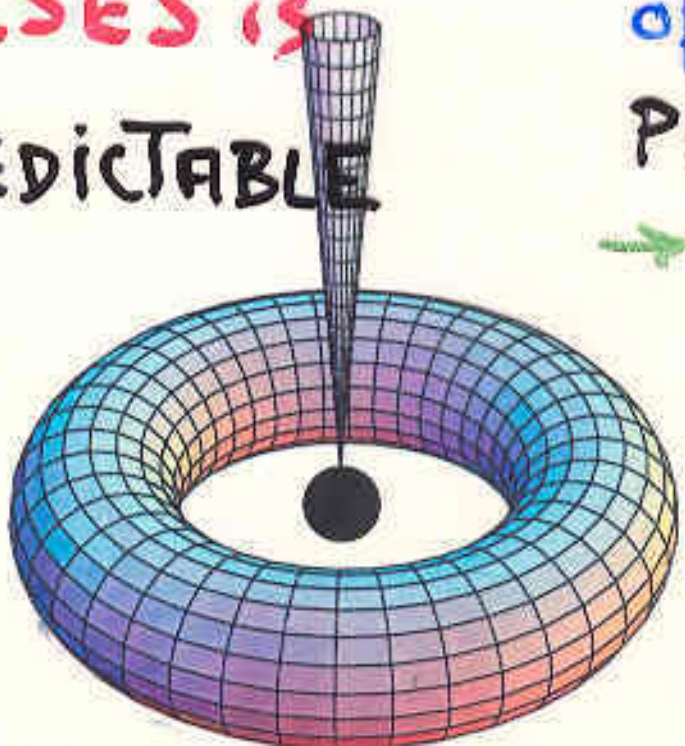
WIND or SHELL

TIME-SEQUENCE of PULSES is NOT PREDICTABLE

BUT

→ PROPERTIES of SINGLE PULSES

→ PROPERTS. of AGs are PREDICT



[redacted] DDD [redacted] 2002 (astro-ph/0107364)

SCORE OF GRBs WITH KNOWN z

∀ CASES ⊐ SN

COULD BE SEEN

IT WAS SEEN

~ 1/2

∀ CASES ⊐ SN

COULD NOT BE SEEN

IT WAS NOT SEEN

~ 1/2

CB-MODEL of GRBs

WORKS VERY WELL

TRUST CB PARAMETERS

EXTRACTED FROM FITS TO GRB DATA

e.g: M_0 : CB MASS AT $t=0$

$\gamma_0 = \frac{E}{Mc^2}$: CB LF AT $t=0$

USE THESE CB-PARAMETER RANGES AS "PRIORS"

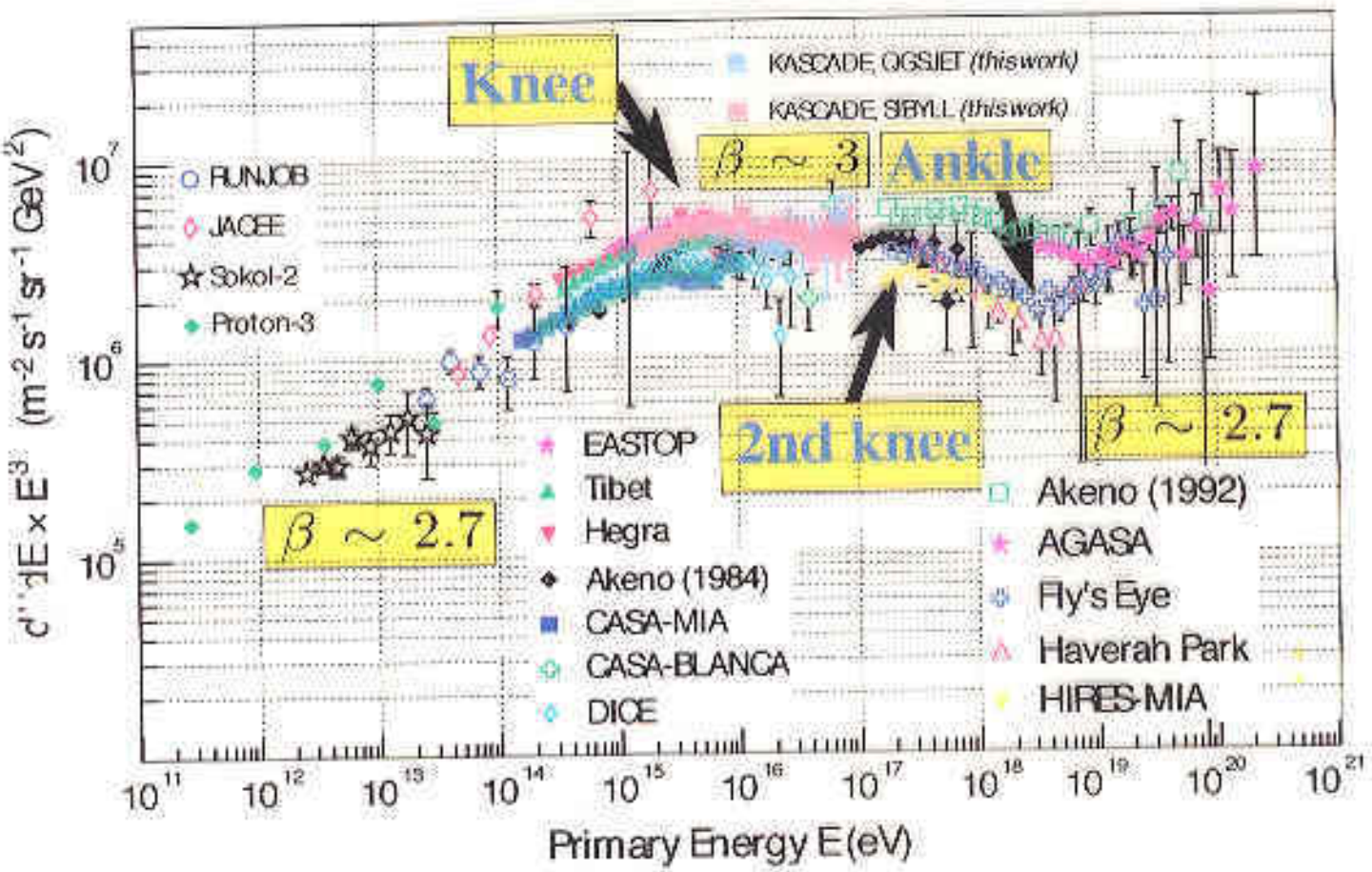
IN A THEORY OF COSMIC

$$\gamma_0 \approx 10^3$$

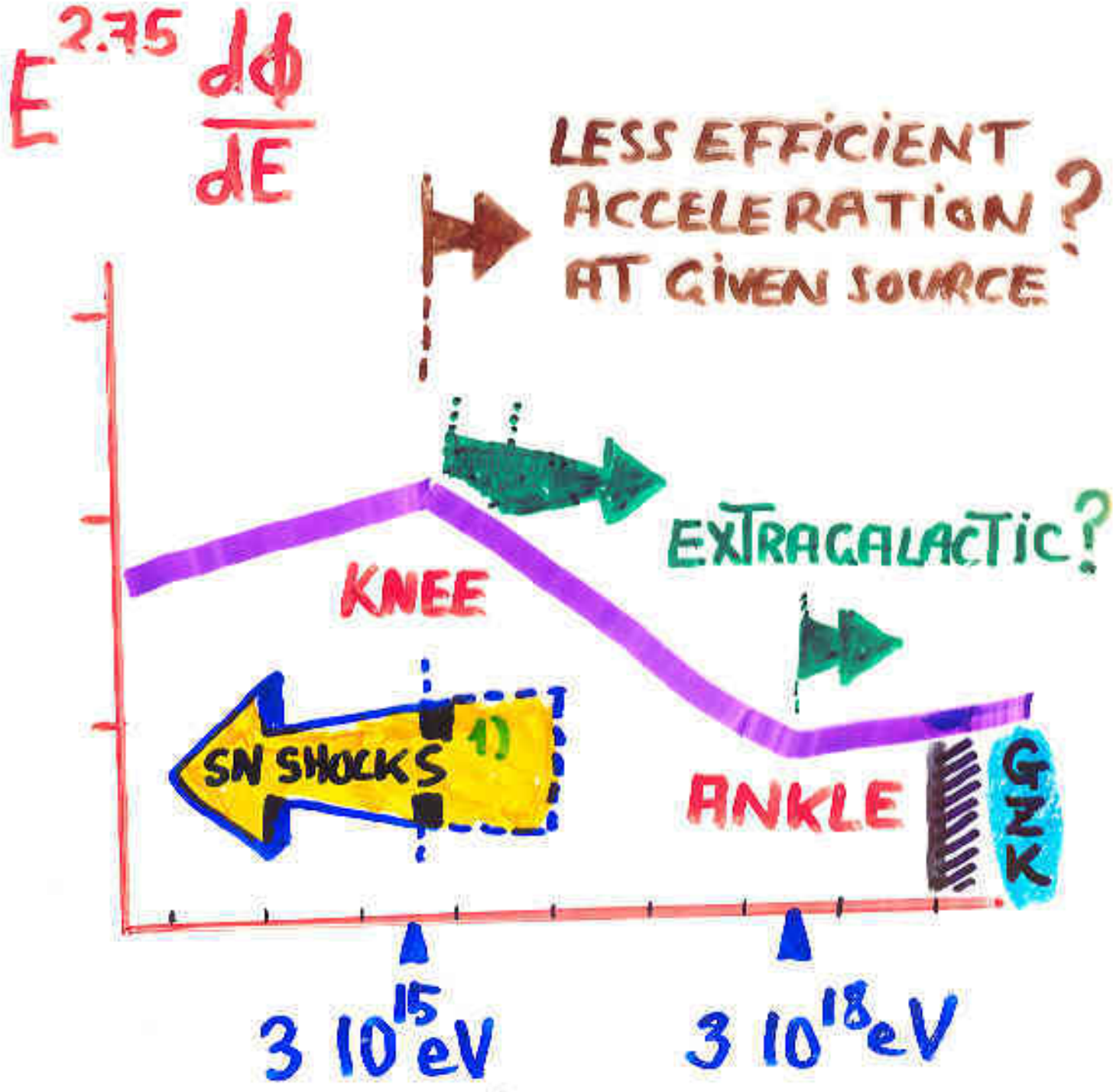
epp = ppp ~ 10^{50}

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

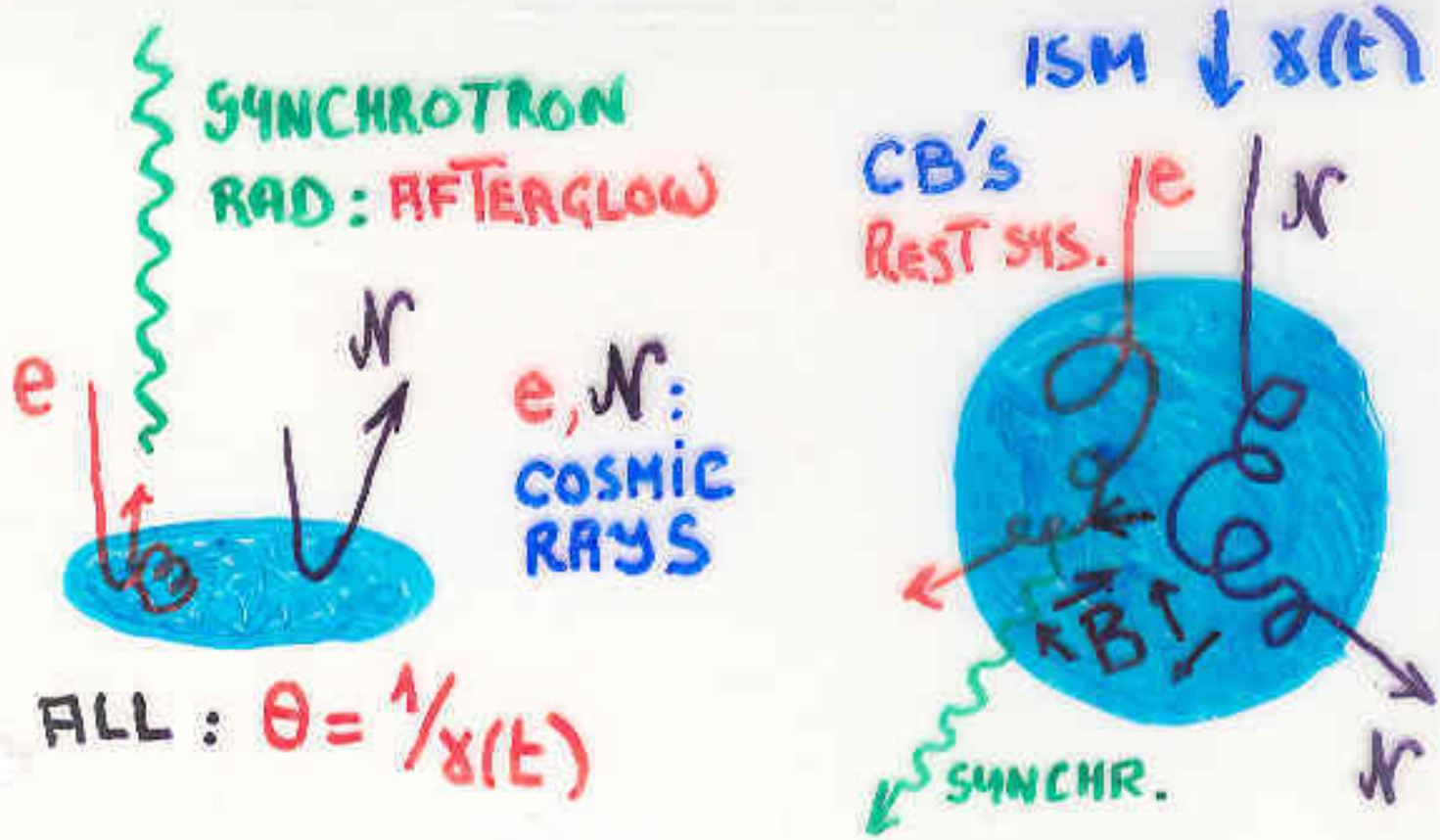
EFF ~ 10^{-2}

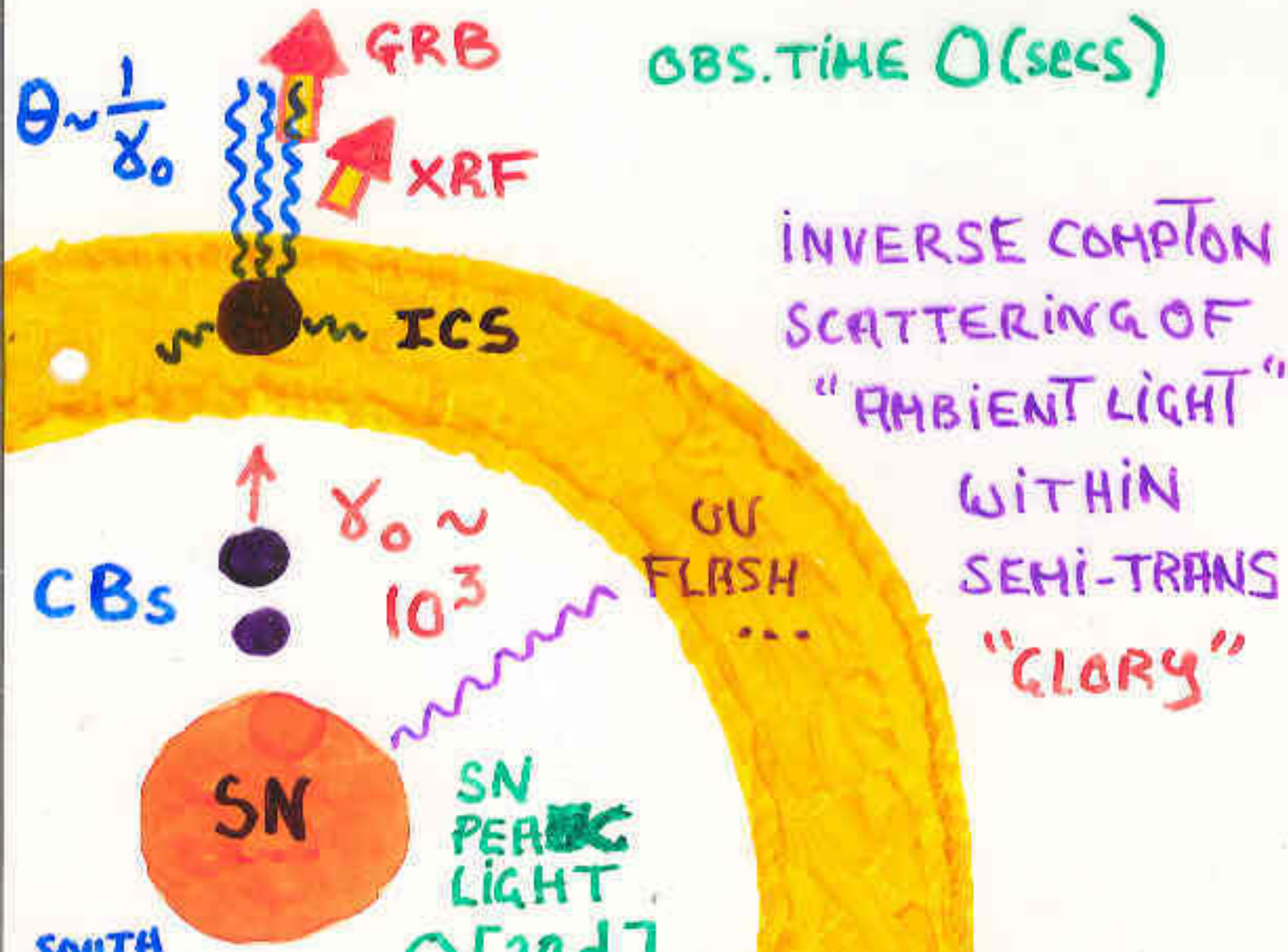

Knee
KASCADE, QGSJET (this work)
KASCADE, SIBYLL (this work)
β ~ 3
Ankle
RUNJOB
JACEE
Sokol-2
Proton-3
β ~ 2.7
2nd knee
β ~ 2.7
EASTOP
Tibet
Hegra
Akeno (1984)
CASA-MIA
CASA-BLANCA
DICE
Akeno (1992)
AGASA
Fly's Eye
Haverah Park
HIRES-MIA
dN/dE x E^3 (m^-2 s^-1 sr^-1 GeV^2)
Primary Energy E (eV)

CONSENSUS ON ORIGIN [OR LACK THEREOF] OF CRs



1) Baade, Zwicky 1934

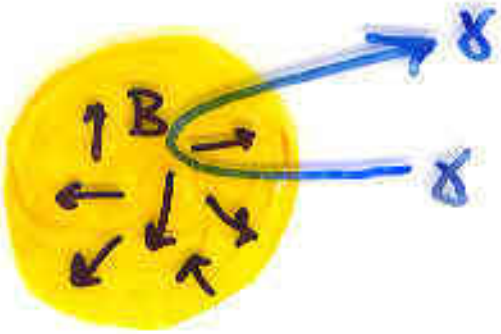

SYNCHROTRON
RAD: AFTERGLOW
e
γ
e, γ:
COSMIC
RAYS
ALL: θ = 1/γ(t)
ISM γ(t)
CB's
REST SYS.
e
γ
SYNCHR.
γ


GRB
XRF
θ ~ 1/γ₀
OBS. TIME O(SECS)
ICS
INVERSE COMPTON
SCATTERING OF
"AMBIENT LIGHT"
WITHIN
SEMI-TRANS
"GLORY"
CBs
γ₀ ~ 10³
GU
FLASH
...
SN
SN
PEAK
LIGHT

Magnetic Racket

ACCELE-RATORS

[COLLISIONLESS] RELATIVISTIC MAGNETIC RACKET



ALSO INTERNAL CB ACCELERT ?

PLASMA + PLASMA AT HIGH γ ??

DD GUESS

FIRST-PRINCIPLE NUMERICAL CALCULATION

(MAXWELL EQS + LORENTZ FORCE)

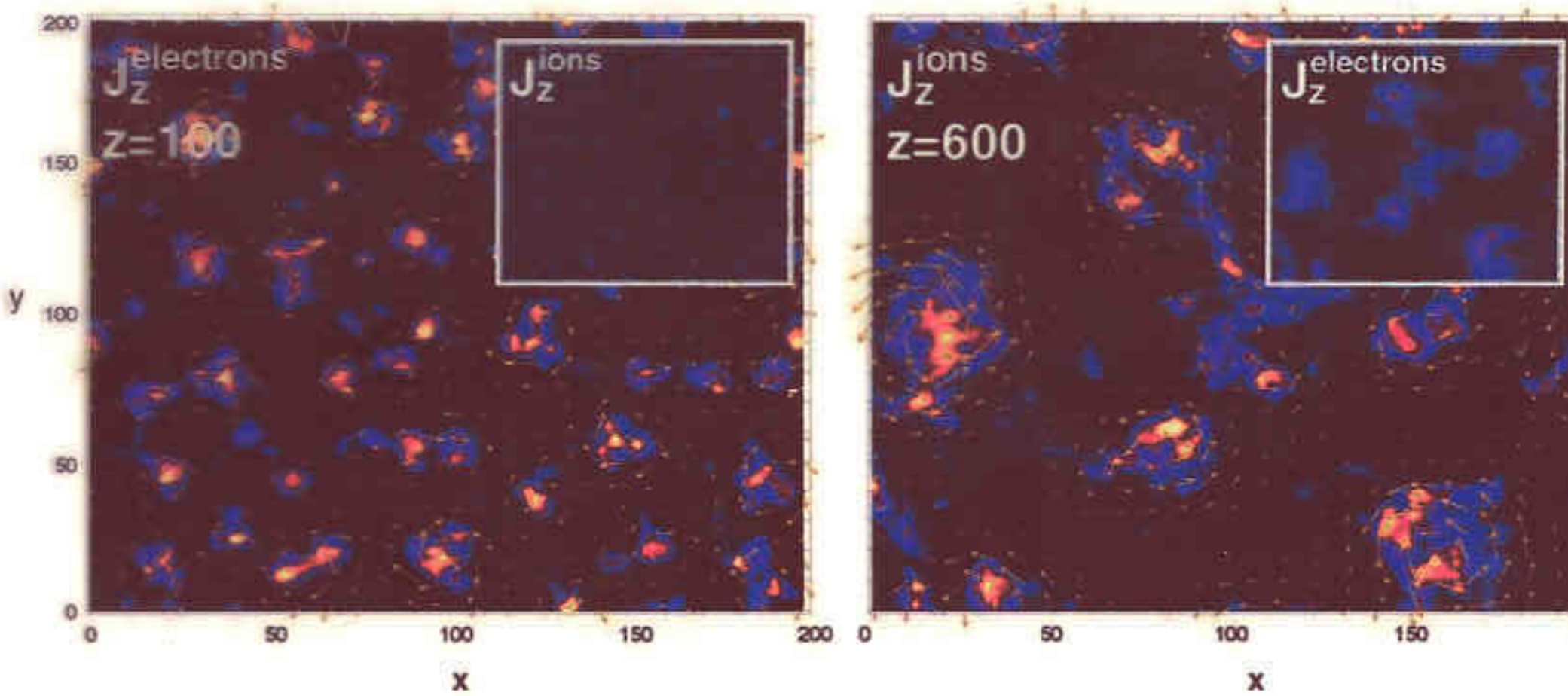
[FREDERIKSEN et al]

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

GOOD OLD (RELATIVISTIC) FERMI ACCEL.

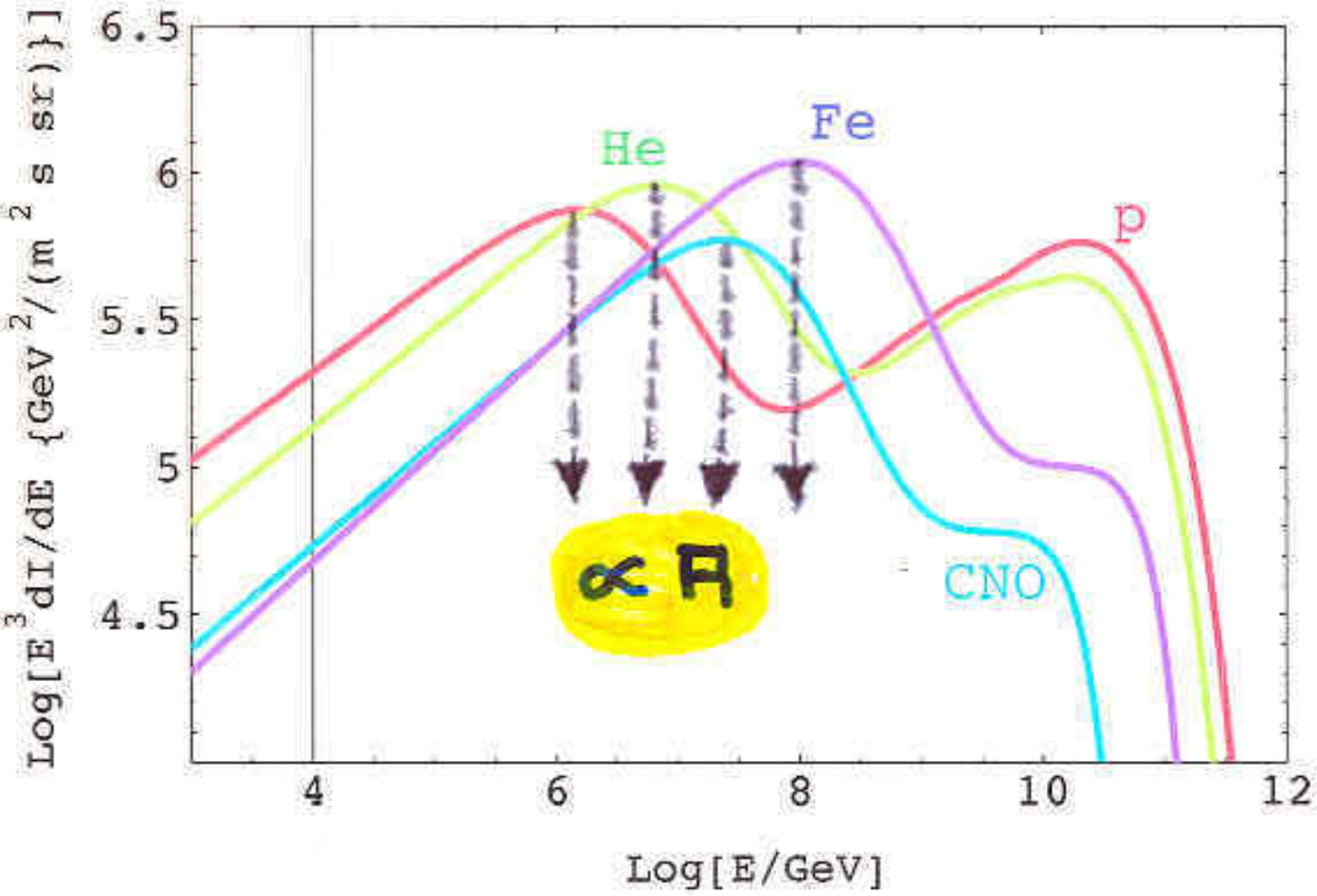
$E^{-(2:2.2)}$ NO SCHOCKS

Frederiksen et al.



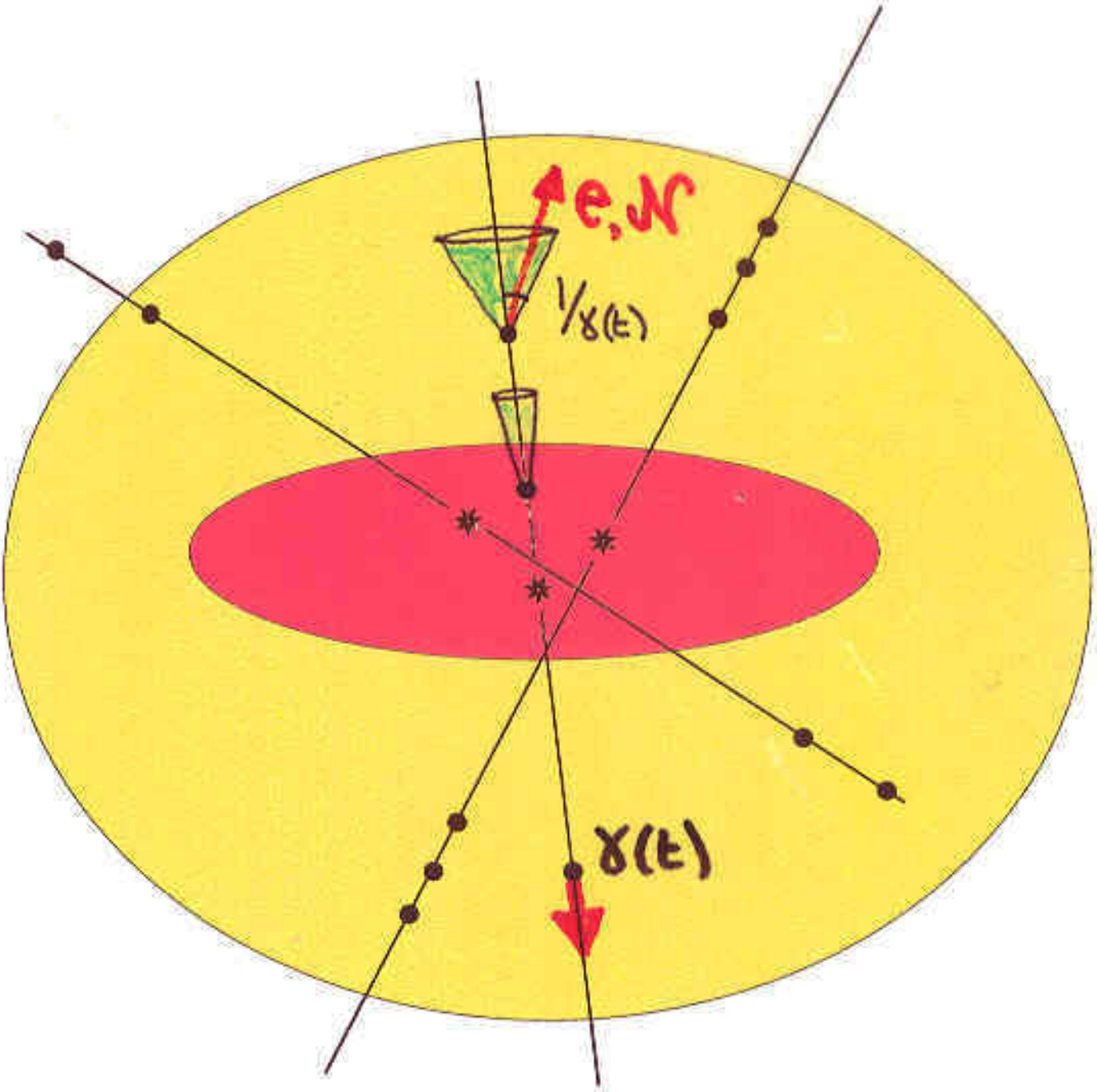
Electron and Ion current densities

$E_{KNEES}[A] \sim 3\ 10^6\ A\ GeV$



FORWARD CONE OF e, $\mathcal{N}$ CRs

{ ELASTICALLY SCATTERED
ACCELERATED WITHIN CB,
REEMITTED



CB's $\gamma_0 \rightarrow \gamma(t)$

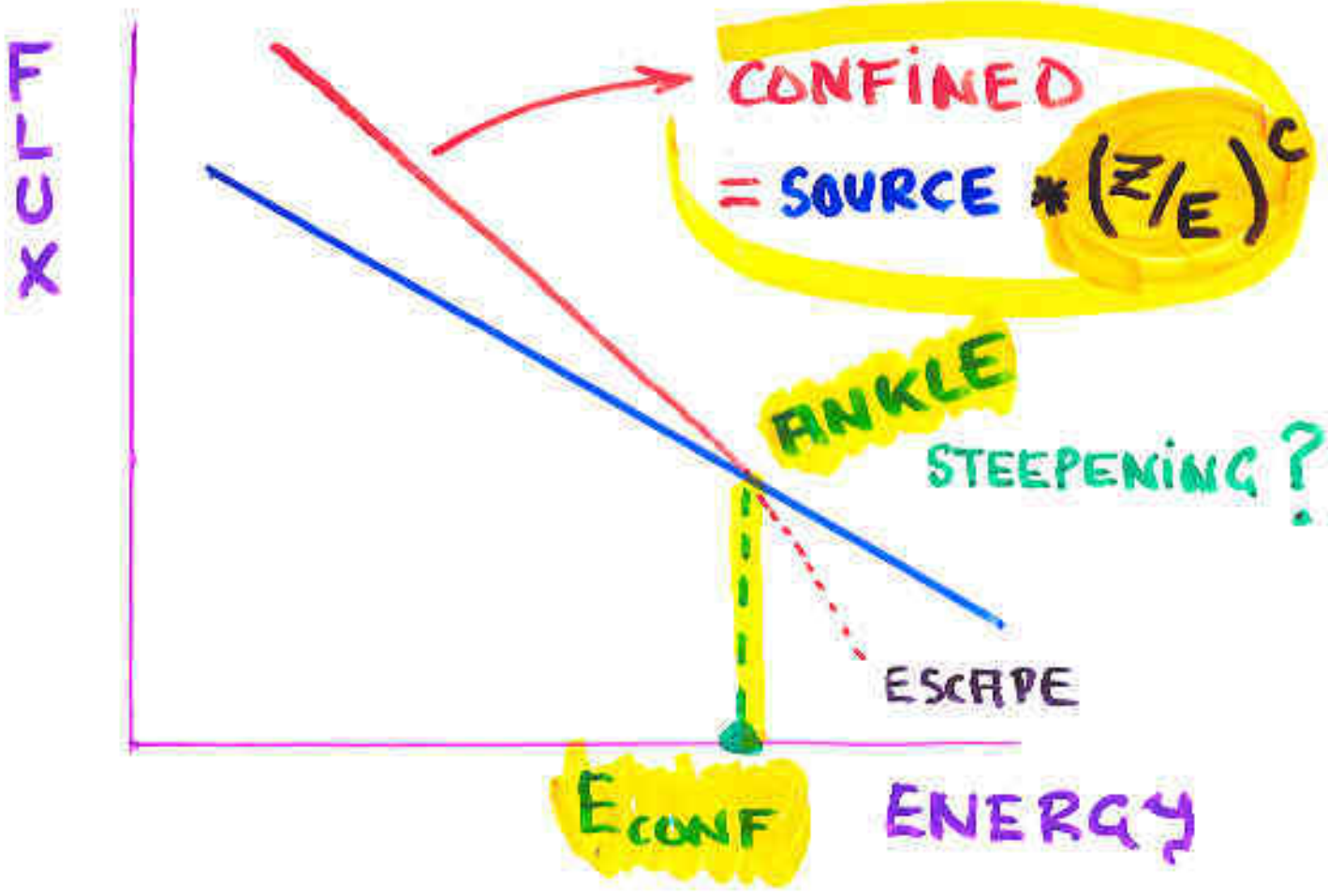
MAGNETIC CONFINEMENT to GALAXY + HALO

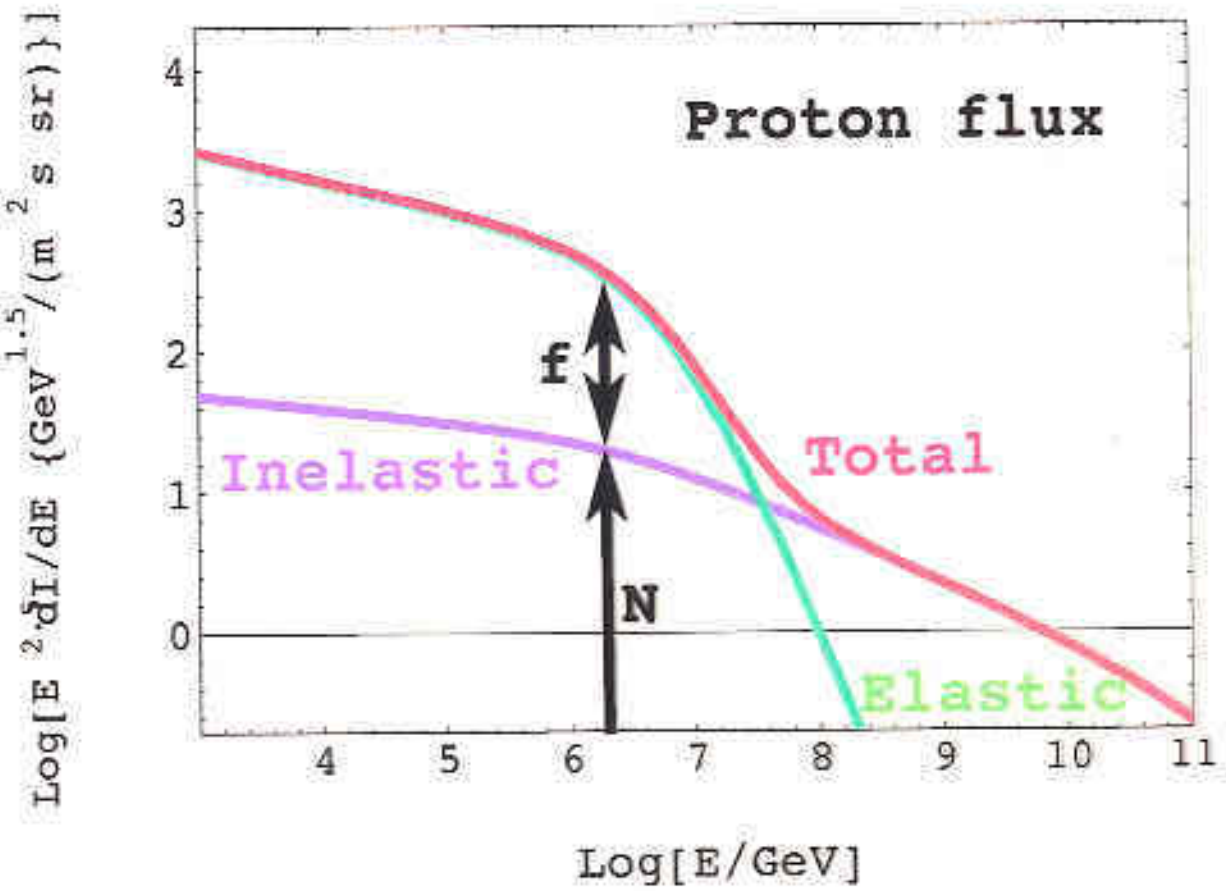
$E > E_{CONF}$

$B \sim 3\,\mu G$

$E_{CONF} \sim 3\,10^{18} Z \;\; eV$

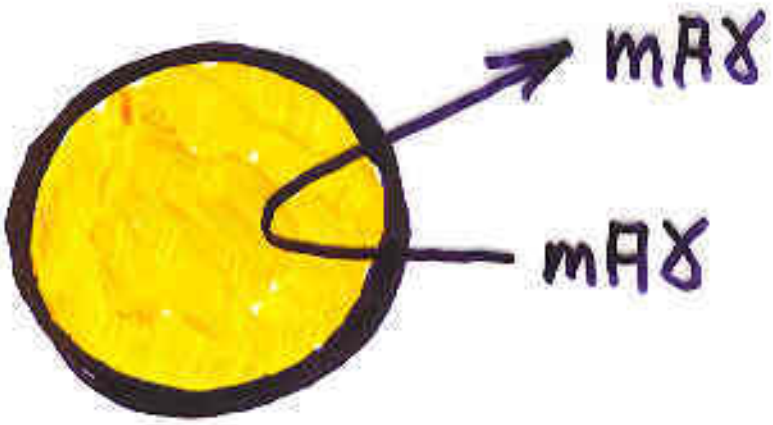
$E < E_{CONF}$



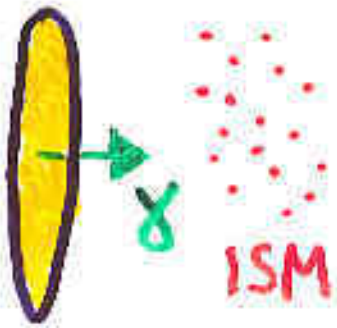


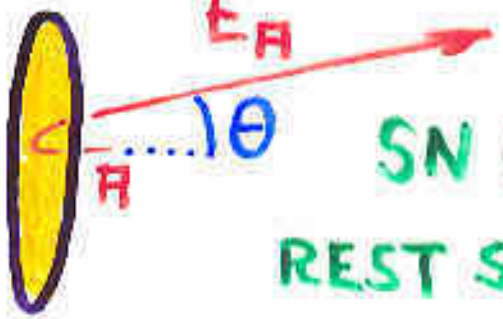
f, N UNIVERSAL $\neq f(A,Z)$

POSITIONS OF THE A — "FLAVOURED" KNEES



CB SYSTEM
ELASTIC
$\gamma = \gamma(t)$





SN (GALAXY)
REST SYSTEM

ANGULAR DISTRIBUTION $\theta \sim 1/\gamma$

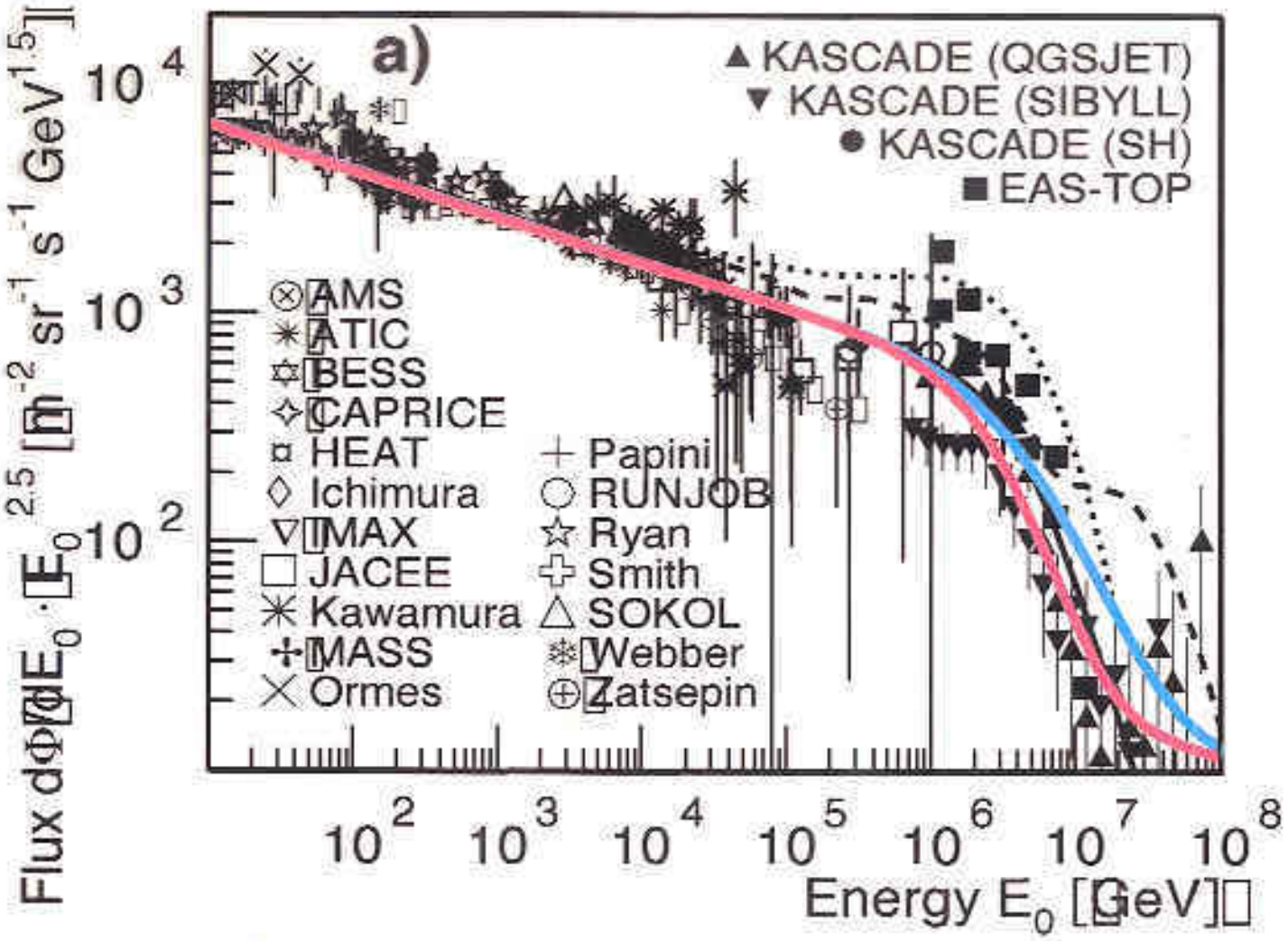
$$m_p A \leq E_A \leq 2 m_p A \gamma^2$$

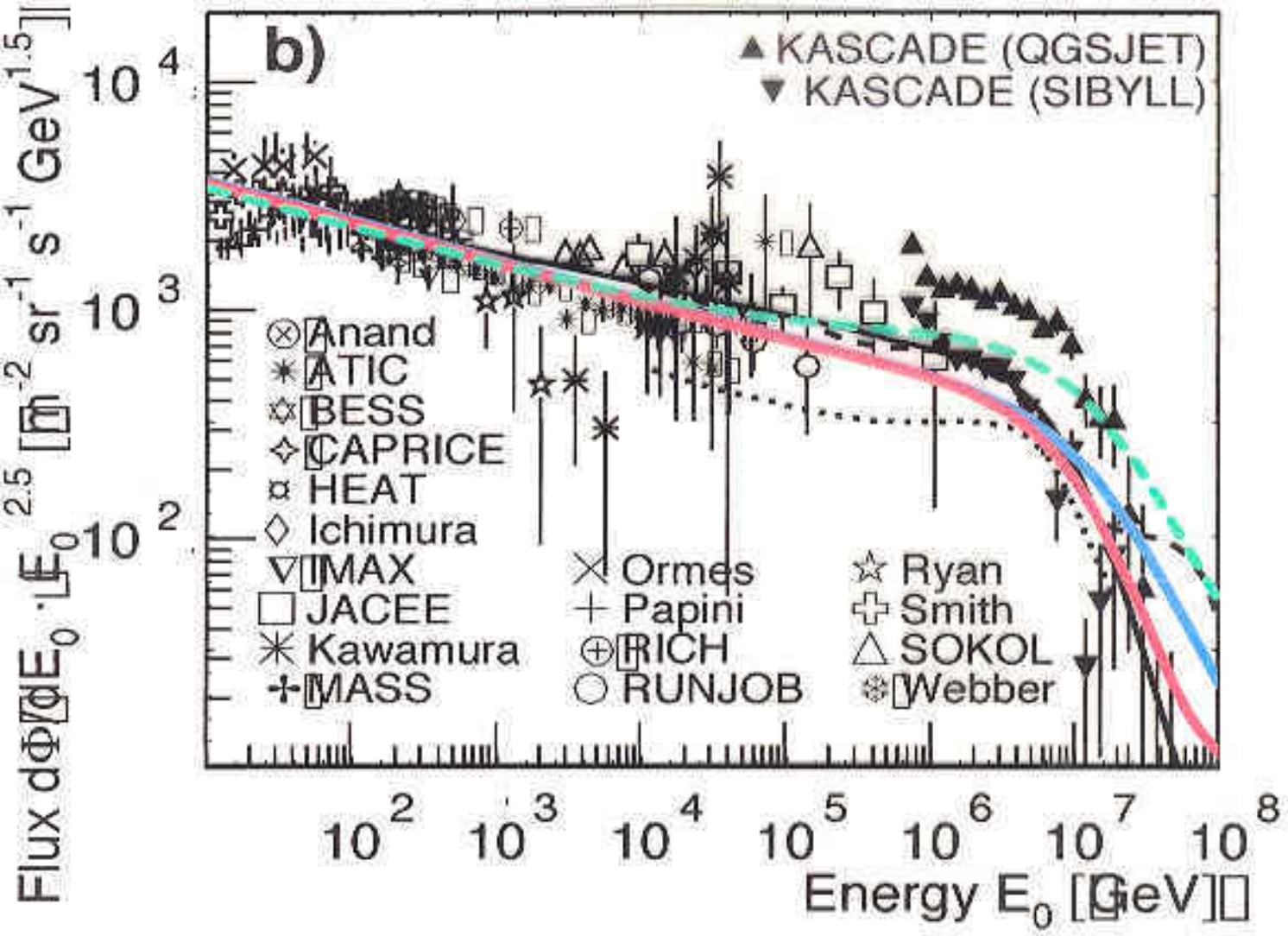
ENERGY BRACKET

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

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

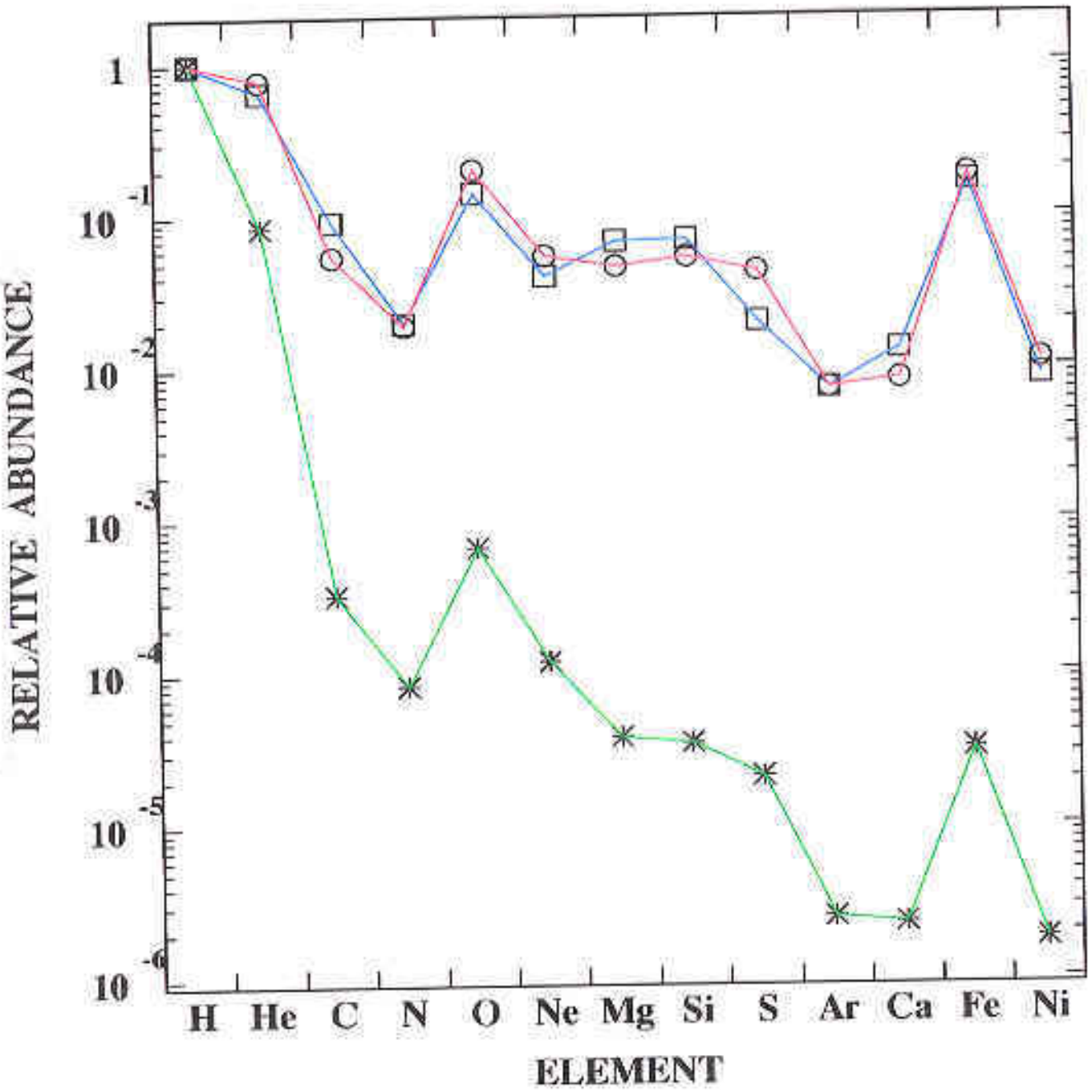
"FLAVOUR"


a)
▲ KASCADE (QGSJET)
▼ KASCADE (SIBYLL)
● KASCADE (SH)
■ EAS-TOP
AMS
ATIC
BESS
CAPRICE
HEAT
Ichimura
IMAX
JACEE
Kawamura
MASS
Ormes
Papini
RUNJOB
Ryan
Smith
SOKOL
Webber
Zatsepin
Flux dΦ/dE$_0$ · E$_0$$^{2.5}$ [m^{-2} sr^{-1} s^{-1} GeV$^{1.5}$]
Energy E$_0$ [GeV]
10^2
10^3
10^4
10^5
10^6
10^7
10^8


b)
KASCADE (QGSJET)
KASCADE (SIBYLL)
Anand
ATIC
BESS
CAPRICE
HEAT
Ichimura
IMAX
JACEE
Kawamura
MASS
Ormes
Papini
RICH
RUNJOB
Ryan
Smith
SOKOL
Webber
Flux dΦ/dE$_0$ · E$_0^{2.5}$ [m^{-2} sr^{-1} s^{-1} GeV$^{1.5}$]
Energy E$_0$ [GeV]
10^2
10^3
10^4
10^5
10^6
10^7
10^8

How did we get the *ABUN-DANCES*

¿ ¿ ? ?


RELATIVE ABUNDANCE
1
10 -1
10 -2
10 -3
10 -4
10 -5
10 -6
H He C N O Ne Mg Si S Ar Ca Fe Ni
ELEMENT

RELATIVE ABUNDANCES

$$\frac{dF_A}{d\gamma_A} \propto n_A \gamma_A^{\overbrace{-(p+c)}^{\beta}} Z^c$$

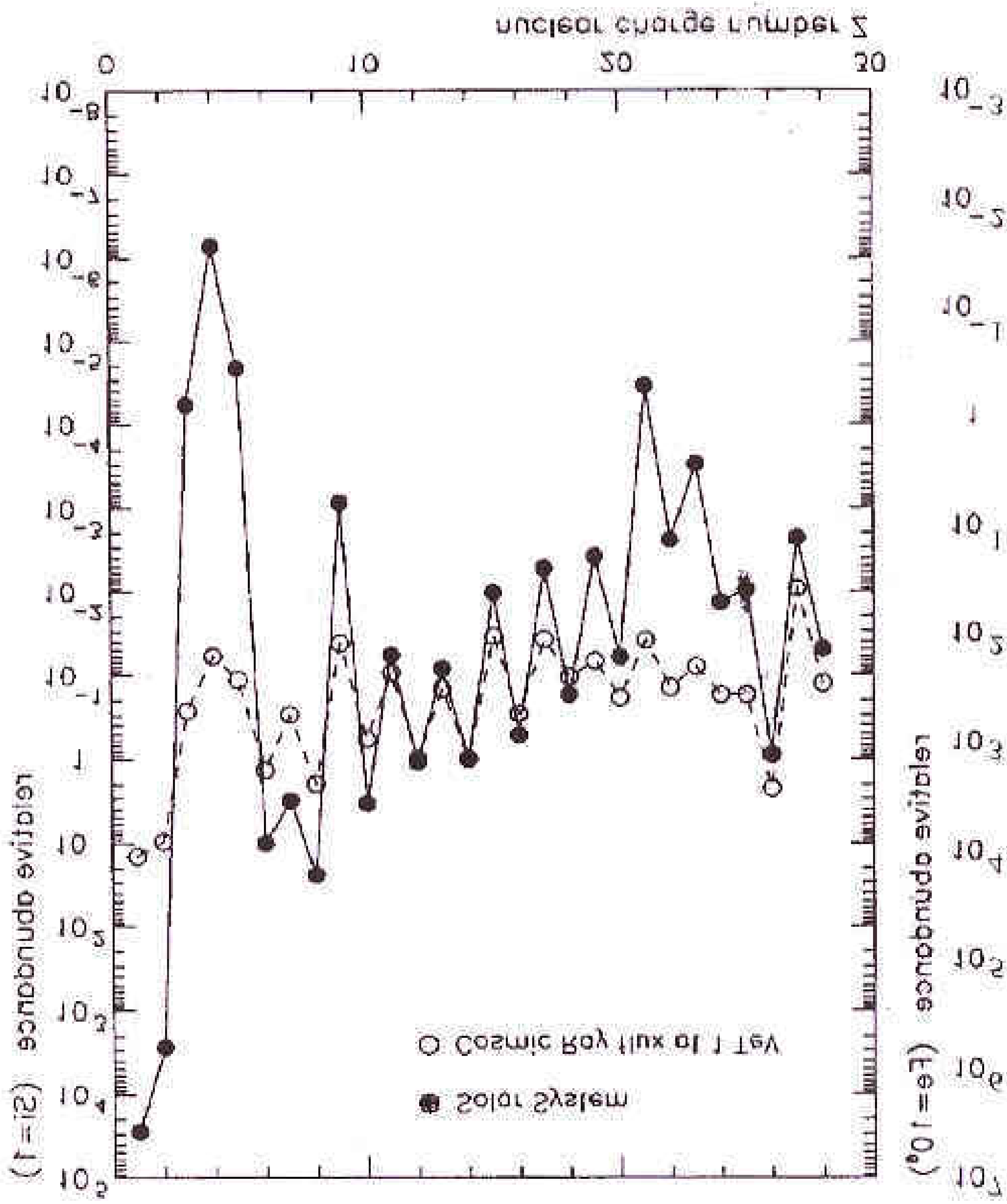
$$\gamma_A = \frac{E_A}{A} \quad \text{in } m_p \text{ units}$$

$$\frac{dF}{dE_A} = \frac{n_A}{A}\left(\frac{A}{E_A}\right)^{\beta} Z^c \quad K \leftarrow \text{A UNIVERSAL } (A-Z) \text{ INDEP. CONSTANT}$$

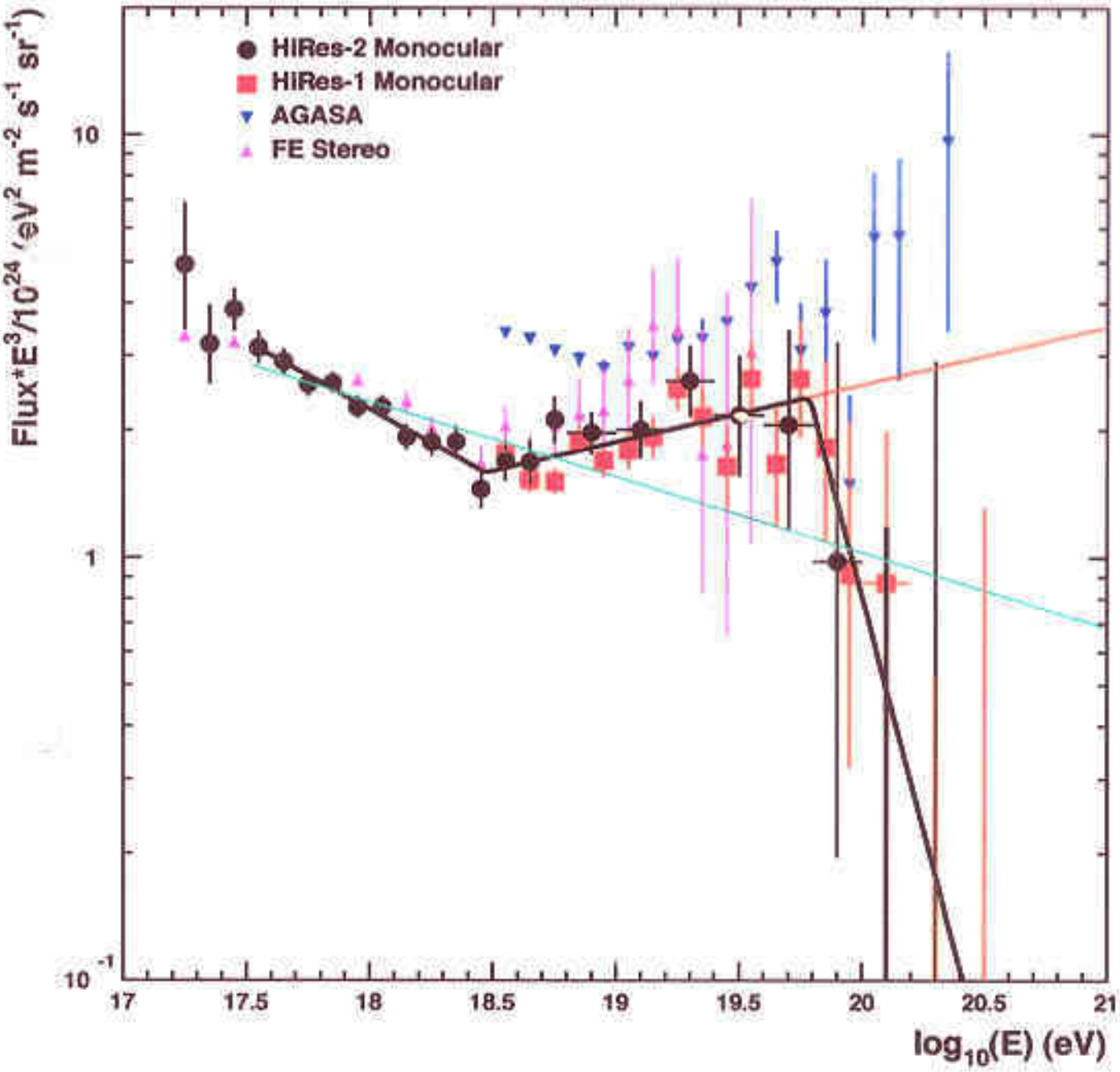
$$= K A^{\beta-1} Z^c n_A E_A^{-\beta}$$

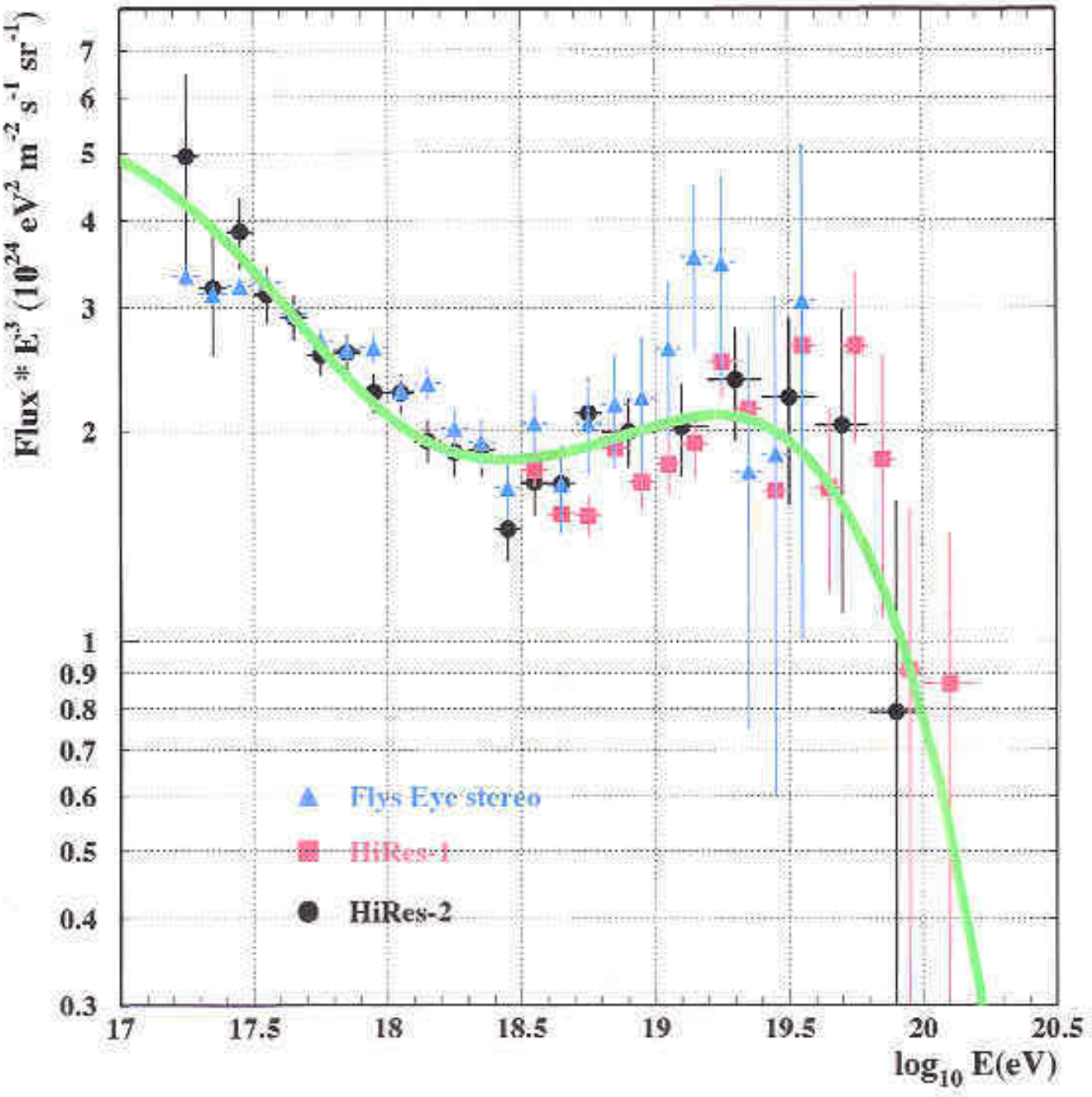
n_A ↓ ISM 'TARGET' — SBBle

CR RELATIVE ABUNDANCES



nuclear charge number Z
relative abundance (Si=1)
relative abundance (Fe=10^6)
● Solar System
○ Cosmic Ray flux at 1 TeV


HIRes-2 Monocular
HIRes-1 Monocular
AGASA
FE Stereo
Flux*E^3/10^{24} (eV^2 m^{-2} s^{-1} sr^{-1})
10
1
10^{-1}
17
17.5
18
18.5
19
19.5
20
20.5
21
log$_{10}$(E) (eV)


Flux * E^3 (10^24 eV^2 m^-2 s^-1 sr^-1)
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
17
17.5
18
18.5
19
19.5
20
20.5
log10 E(eV)
Flys Eye stereo
HiRes-1
HiRes-2

- **Spectral Features**
  (knees, ankle, endpoint)
- **Spectral Slopes**
- **UHECR Flux: norm, shape**
- **"Chemical" Abundances**
  (and their E-evolution)

All Predicted

Two - Parameter

fit to CR data , other inputs: only PRIORS)

ONE Mechanism

at ALL relativistic energies

WHAT DID I SAY?

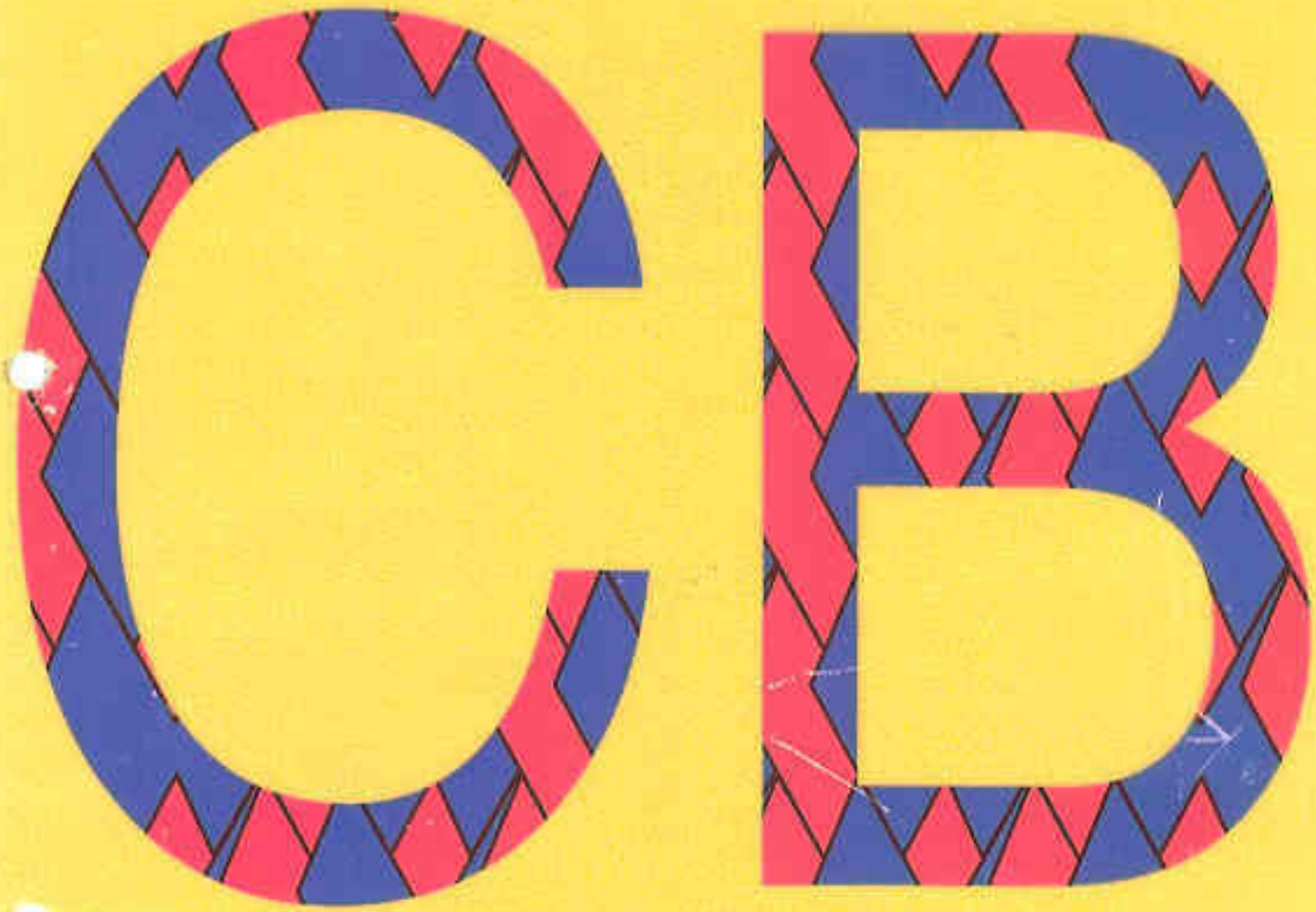
- SUPERNOVAE EMIT CANNONBALLS OF KNOWN PROPERTIES

(⬅ GRBs, AFTERGLOWS...)

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

➡ COSMIC-RAY PROPERTIES EXPLAINED

How does the



Accelerator

WORK???