Cosmic Ray
Conundra
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.
- $M_{pe}$ relics of BB
- Neutral particles
  - Light quinons
- Monopoles
- Knots in primordial strings
- Topological defects
- $\nu_{ihe} + \nu_{halo} \rightarrow WW, ZZ, \ldots$
- Breakdown of $L$-invar.
- Wimpzillas
JETS in ASTROPHYSICS
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
MODEL of GRBs
and
HEAPn.
WHAT MAKES GRBS?
(LONG-DURATION)
CORE-Collapse SUPERNOVAE
CB made of ordinary matter

1 exiting CB = 1 pulse/GRB

"Ambient light"

Wind of shell

Time-sequence of pulses is not predictable

But properties of single pulses are predictable

Properties of AGs are predictable
SCORE OF GRBs WITH KNOWN $z$

\[ V_{\text{cases}} \geq V_{\text{SN}} \quad \text{could be seen} \]
\[ \text{it was seen} \]
\[ \sim 1/2 \]

\[ V_{\text{cases}} < V_{\text{SN}} \quad \text{could not be seen} \]
\[ \text{it was not seen} \]
\[ \sim 1/2 \]
CB-Model of GRBs

Works very well

Trust CB parameters

Extracted from fits to GRB data

e.g.: $M_0$ : CB mass at $t = 0$

$x_0 = \frac{E}{M C^2}$ : CB LF at $t = 0$

Use these CB-parameter ranges as "priors"

In a theory of cosmic flows
\[ \gamma_0 \approx 10^3 \]
\[ e_{pp \pi} = {}_{p}^{p} p \pi \sim 10^{50} \]

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

\[ E_{Fe} \sim 10^2 \]
Consensus on origin
[or lack thereof]

\[ E^{2.35} \frac{d\phi}{dE} \]

Less efficient acceleration at given source?

Knee | SN shocks
---|---
3 \(10^{15}\) eV

Ankle | Extragalactic?
---|---
3 \(10^{18}\) eV

GZK
SYNCHROTRON RAD: AFTERGLOW

ALL: $\theta = \frac{1}{x(t)}$

CB's Rest Sys. $e \rightarrow e^+$

GRB

ICS

XRF

inverse Compton scattering of "ambient light" within semi-trans "glory"

CBs $\gamma_0 \sim 10^3$

SN Peak Light

SN

obs. time $O(secs)$
Magnetic Racket Accelerators
Collisionless Relativistic Magnetic Racket

\[ \frac{\partial}{\partial t} E_{\perp} \rightarrow \frac{2\mu}{e} \rightarrow 2x^2 \]

Also Internal CB Acceleration?

First principle numerical calculation (Maxwell eqs + Lorentz force)

[Frederiksen et al.]

\[ \mathbf{B}, \mathbf{J}_e, \mathbf{J}_p, \text{ turbulence} \]

Good old (relativistic) Fermi Acceleration

\[ E^{-2:2.2} \rightarrow \text{No Schocks} \]
Electron and ion current densities
$E_{\text{Knee}} [\text{GeV}] \sim 3 \times 10^6 \text{ GeV}$
FORWARD CONE OF $e, N$ CRS

ELASTICALLY SCATTERED
ACCELERATED WITHIN CB,
REEMITTED

CB's $x_0 \rightarrow x(t)$
MAGNETIC CONFINEMENT TO GALAXY + HALO

\[ E > E_{\text{conf}} \]

\[ B \sim 3 \mu G \]

\[ E_{\text{conf}} \sim 3 \times 10^{18} \text{ eV} \]

\[ E < E_{\text{conf}} \]

**Diagram:**
- Flux vs. Energy graph with:
  - Confined flux: \[ \text{source} \times \left( \frac{z}{E} \right)^c \]
  - Escape path
  - Steepening at the ankle

**Notes:**
- \( E_{\text{conf}} \): Energy of confinement
Positions of the \( A^- \) "flavoured" knees

CB system elastic \( \delta = \delta(t) \)

SN (galaxy) rest system

Angular distribution \( \theta \sim 1/\delta \)

\[
m_pA \leq E_A \leq 2m_p A \delta^2
\]

Energy bracket

\[
\delta < \delta_0 \leq (1 \div 1.5) \times 10^3
\]

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

"Flavour"
Flux $d\Phi / d E_0 L_{E_0}^{2.5}$ [m$^{-2}$ sr$^{-1}$ s$^{-1}$ GeV$^{-1.5}$]

Energy $E_0$ [GeV]

- Anand
- ATIC
- BESS
- CAPRICE
- HEAT
- Ichimura
- MAX
- JACEE
- Kawamura
- MASS
- Ormes
- Papini
- RICH
- Ryan
- Smith
- SOKOL
- Webber

△ KASCADE (QGSJET)
▽ KASCADE (SIBYLL)
How did we get the Abundances?
**Relative Abundances**

\[
\frac{dE_A}{dx_A} = n_A \kappa A^{(p+c)} C^c
\]

\[
\kappa_A = \frac{E_A}{A} \quad \text{in mp units}
\]

\[
\frac{dF}{dE_A} = \frac{n_A}{A} \left( \frac{A}{E_A} \right)^p C^c K
\]

\[
= KA^{p-1} C^c n_A E^{-B}
\]

- **A universal (A-Z) independent constant**
- **ISM 'Target'**
- **SBBLe**

**CR Relative Abundances**
- 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 cannon balls of known properties (GRBs, afterglows...)

- CBs move in galaxy kicking things off (ISM) magnetically

- Cosmic-ray properties explained
How does the CB Accelerator WORK???