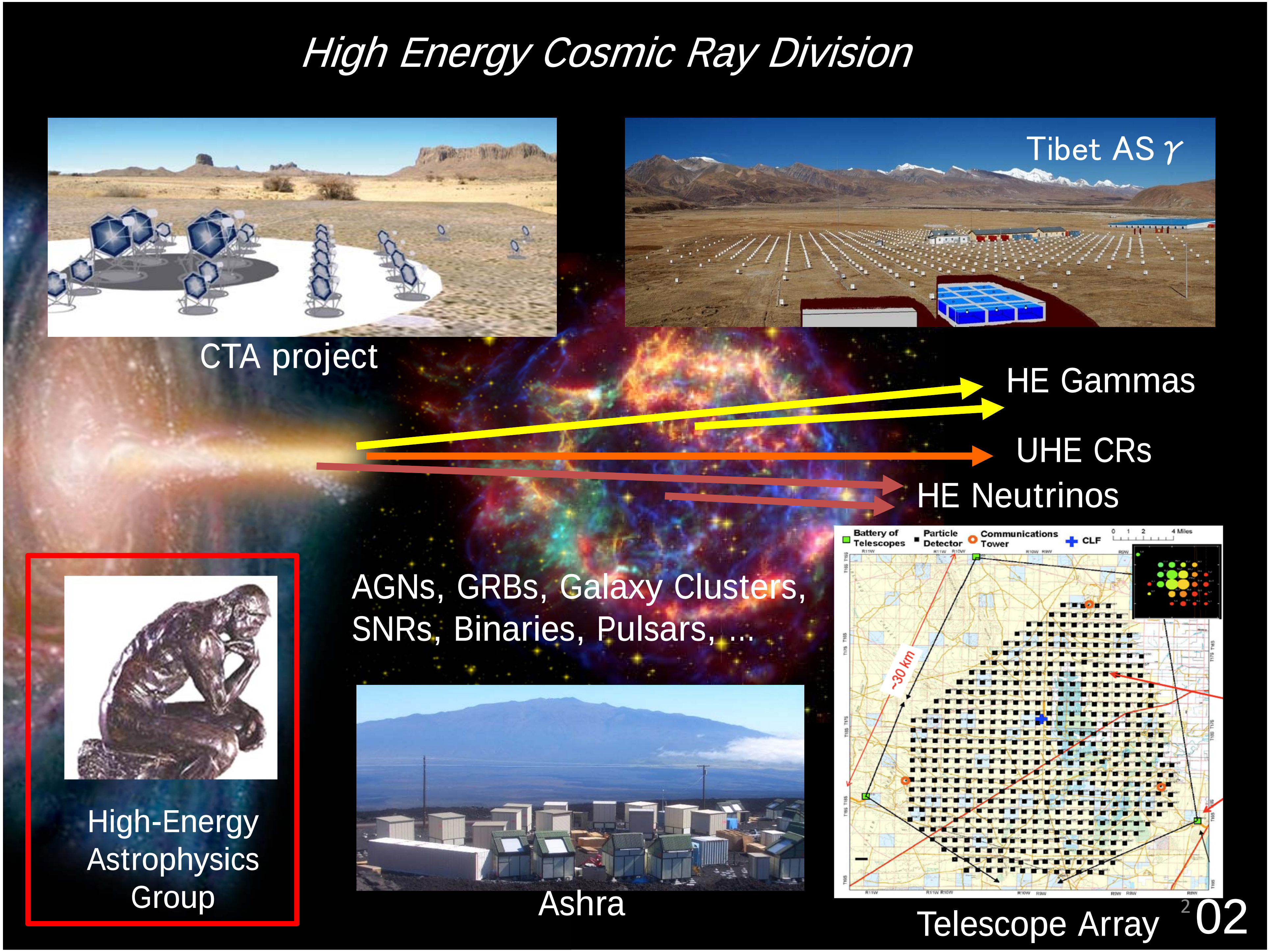
High-Energy Astrophysics (HEA) Group

Presenter: Toshio Terasawa

(c.f., p.88-95 of *Scientific Activities, ICRR*)


High Energy Cosmic Ray Division
CTA project
Tibet AS γ
HE Gammas
UHE CRs
HE Neutrinos
AGNs, GRBs, Galaxy Clusters,
SNRs, Binaries, Pulsars, ...
Battery of Telescopes
Particle Detector
Communications Tower
CLF
4 Miles
~30 km
High-Energy Astrophysics Group
Ashra
Telescope Array
02

High-Energy Astrophysics (HEA) Group in the *High Energy Cosmic Ray Division*

Scientific Targets:

Theoretical and Observational Studies of violent astrophysical phenomena, in which cosmic ray particles are being accelerated.

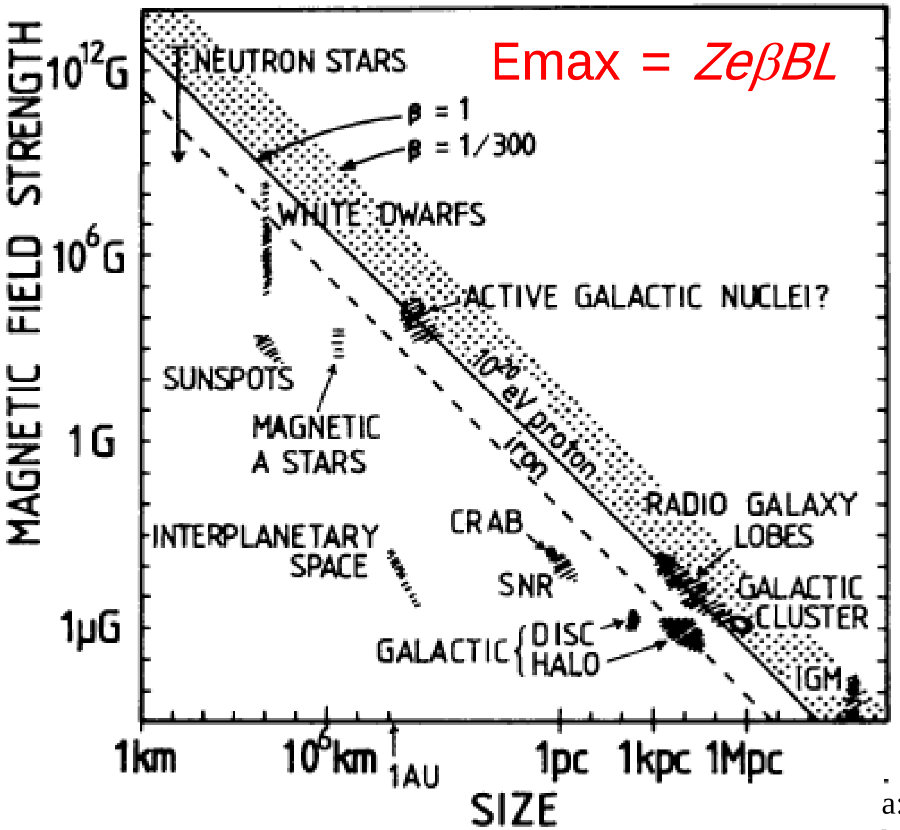
Created in December 2009 (T. Terasawa)

Since then - March 2012:	Preparation & start up phase
April 2012-Now:	Current activity with two PDs
April 2013-:	A new Research Associate (tenured) will join us.

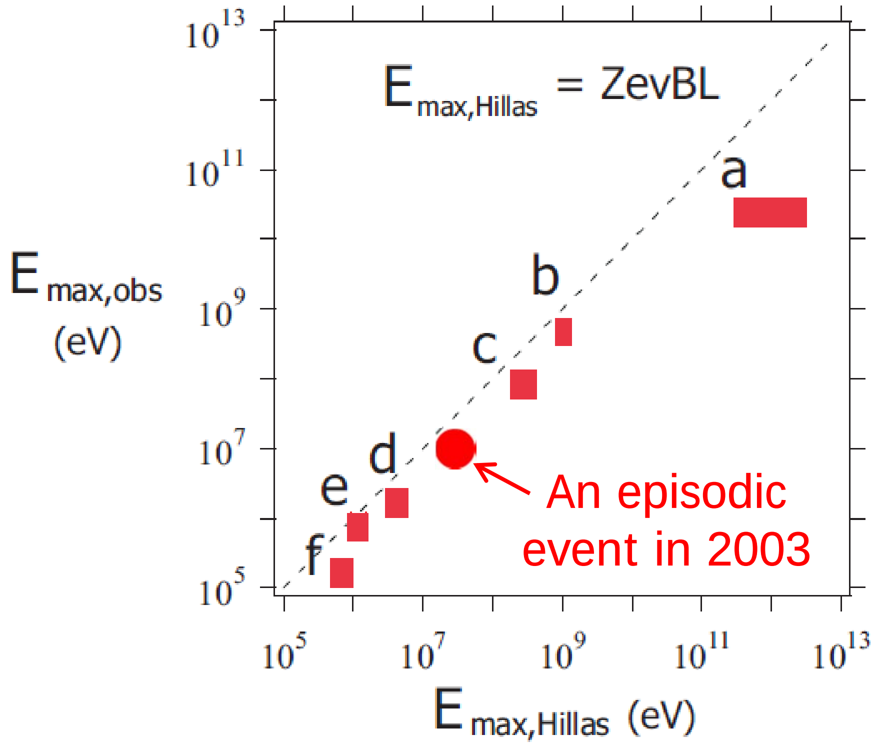
Number of graduate students: 4

Violent astrophysical phenomena as cosmic ray source candidates

Famous Hillas' plot (1984) for the acceleration region of UHECR

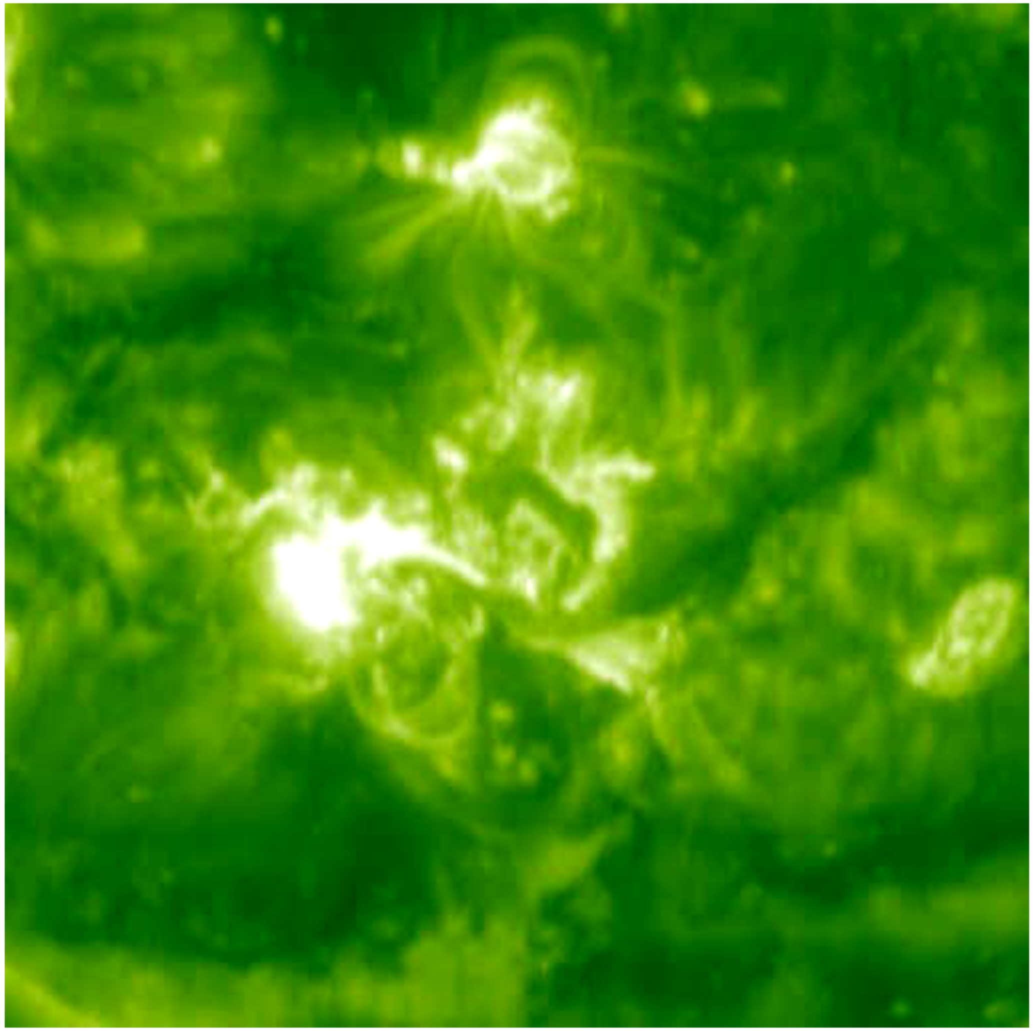


Heliospheric Hillas' plot (p. 88, Fig. 1)



a: solar flare,
b: the Van Allen belt of the earth,
c: heliospheric shocks,
d: the earth's bow shock and kinks of the interplanetary magnetic field,
e: the magnetotail of the earth,
f: the foreshock region of the earth's bow shock

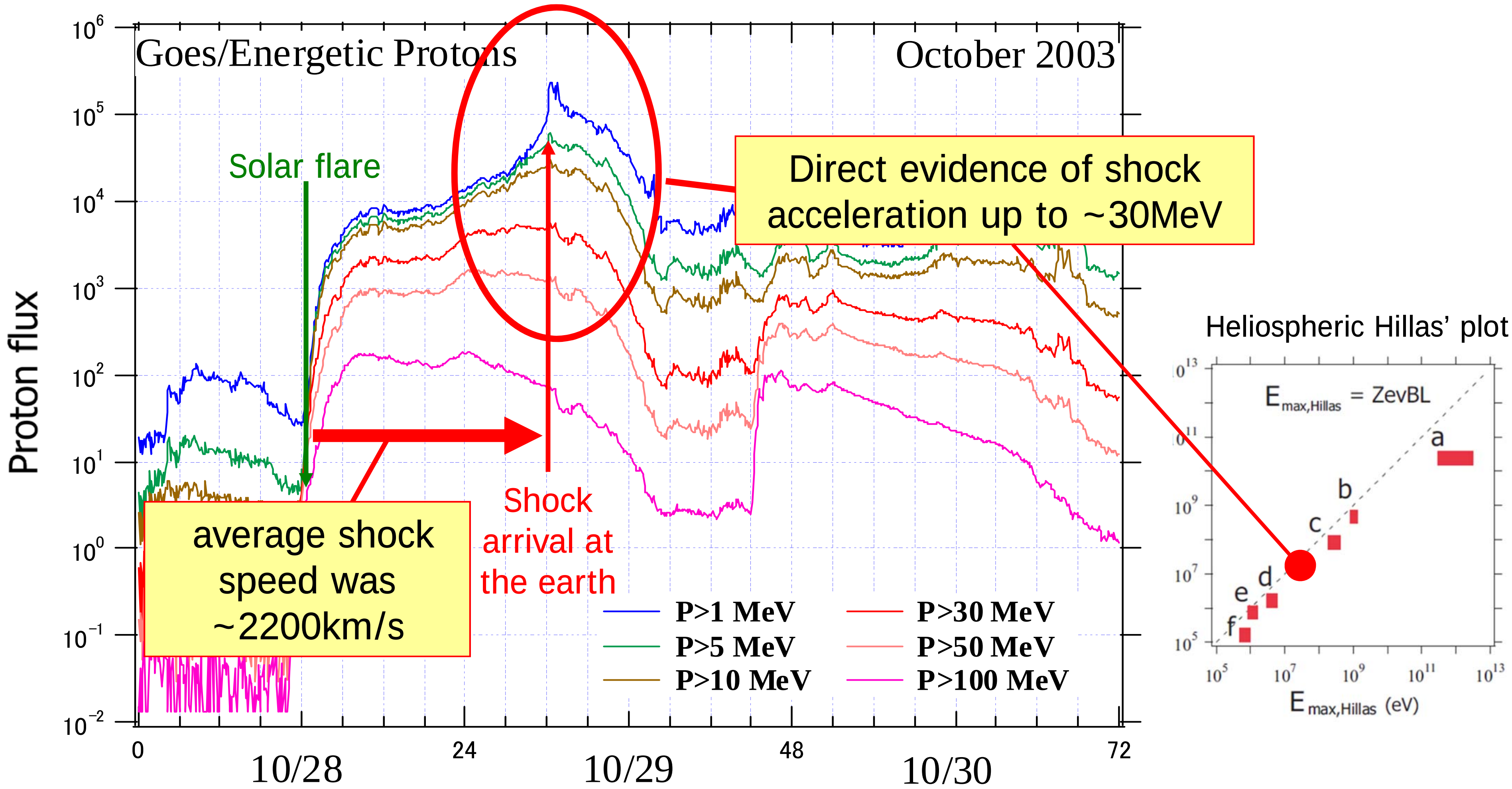
X-ray and optical images of a historical solar flare on 28 October, 2003



http://sohowww.nascom.nasa.gov/gallery/Movies/flares.html

Nearest cosmic explosions: Aftermath (example in 2003)

Sub-relativistic proton monitor on a geostationary satellite



Development of the Diffusive Shock Acceleration (DSA) theory has been based on these acceleration events within the heliosphere.

Current research topics / HEA group

1. Reevaluation of basic acceleration processes

(a) second order stochastic acceleration processes
in relativistic turbulence

(b) basic theory of cyclotron resonant interaction

(c) role of neutral particles in acceleration processes

2. Pulsars and Magnetars

(a) millisecond pulsars

(b) Crab pulsar

(c) magnetars

3. Solar system plasma physics

(a) solar wind interaction with the moon

4. R / D studies

(a) CALET project

(b) Radio detection of UHECRs and extraterrestrial grains

Current research topics / HEA group

1. Reevaluation of basic acceleration processes

(a) second order stochastic acceleration processes in relativistic turbulence

(b) basic theory of cyclotron resonant interaction

(c) role of neutral particles in acceleration processes

2. Pulsars and Magnetars

(a) millisecond pulsars

(b) Crab pulsar

(c) magnetars

3. Solar system plasma physics

(a) solar wind interaction with the moon

4. R / D studies

(a) CALET project

(b) Radio detection of UHECRs and extraterrestrial grains

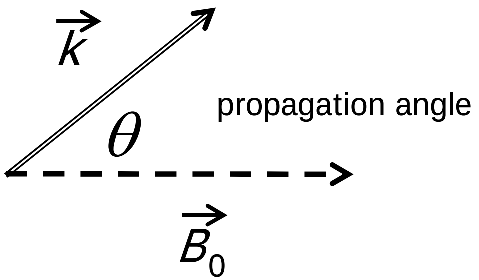
1. Reevaluation of basic acceleration processes

(b) basic theory of cyclotron resonant interaction

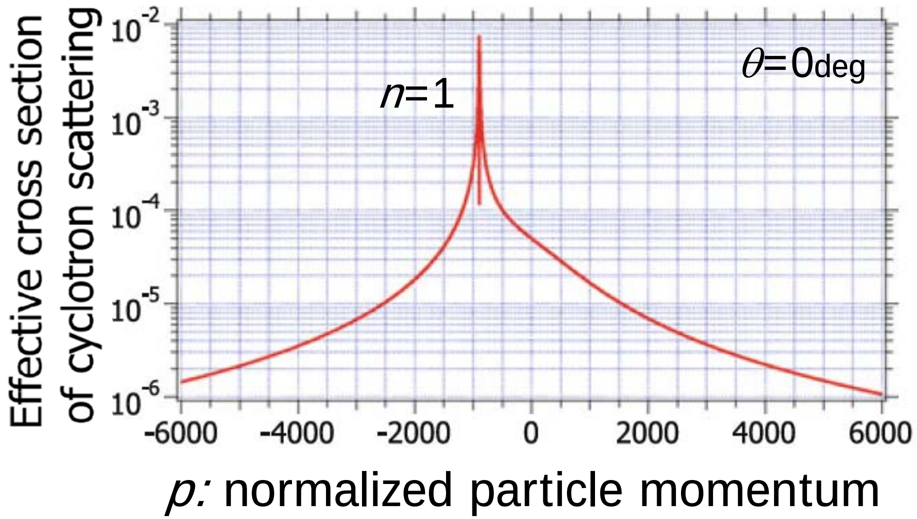
Both in diffusive shock acceleration and second-order acceleration processes, cyclotron resonant interaction between particles and turbulence plays the dominant role, whose condition is given by,

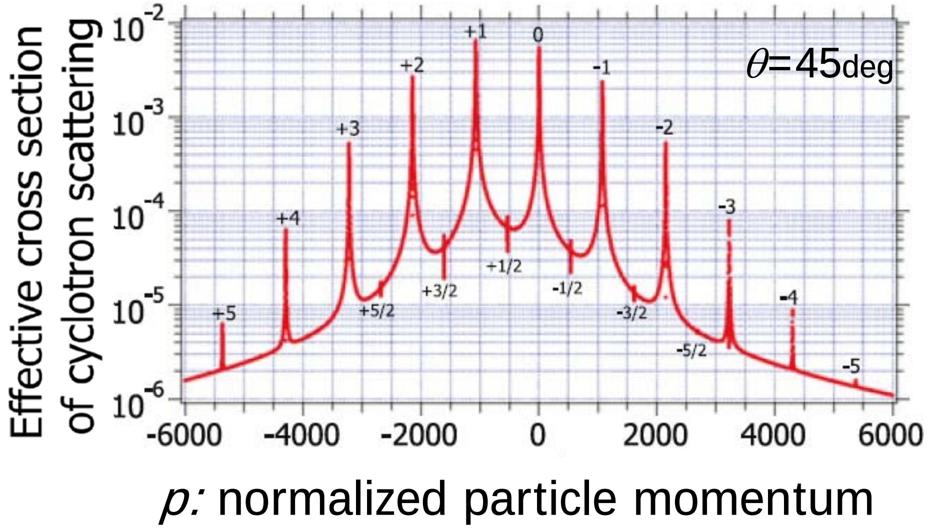
$$\omega - k_{\|} v_{\|} = n \frac{\Omega_c}{\gamma} \qquad (2)$$

where $(\omega, k_{\|})$ define the properties of turbulence, namely the frequency and wavenumber parallel to the background magnetic field $\vec{B}_0$. $v_{\|}$ is the particle velocity component parallel to $\vec{B}_0$, γ the Lorentz factor, and Ω_c the nonrelativistic cyclotron frequency. In eq.(2) the choice of n is named as follows: $n = +1$ the fundamental cyclotron resonance, $n = -1$ the anomalous cyclotron resonance, $n = 0$ the transit-time resonance (or Landau resonance), and $n = \pm 2, \pm 3, \ldots$ the cyclotron higher harmonic resonance. Since the middle 60's when the above definitions were made, there seem to have been some confusion and misunderstanding about their interpretation. By presenting a unified review of the cyclotron resonant interaction process [16], we have contributed to clarify the interpretation.



Scattering cross section: $\sigma(p)$





Current research topics/HEA group

1. Reevaluation of basic acceleration processes

(a) second order stochastic acceleration processes
in relativistic turbulence

(b) basic theory of cyclotron resonant interaction

(c) role of neutral particles in acceleration processes

2. Pulsars and Magnetars

(a) millisecond pulsars

(b) Crab pulsar

(c) magnetars

3. Solar system plasma physics

(a) solar wind interaction with the moon

4. R/D studies

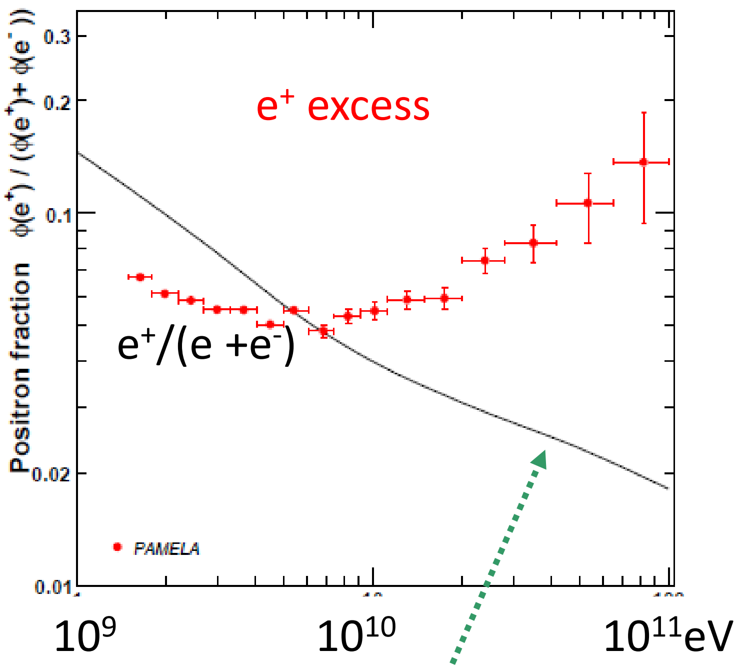
(a) CALET project

(b) Radio detection of UHECRs and extraterrestrial grains

2. Pulsars and Magnetars

(a) millisecond pulsars (MSP)

PAMELA



ATIC $e^+ + e^-$

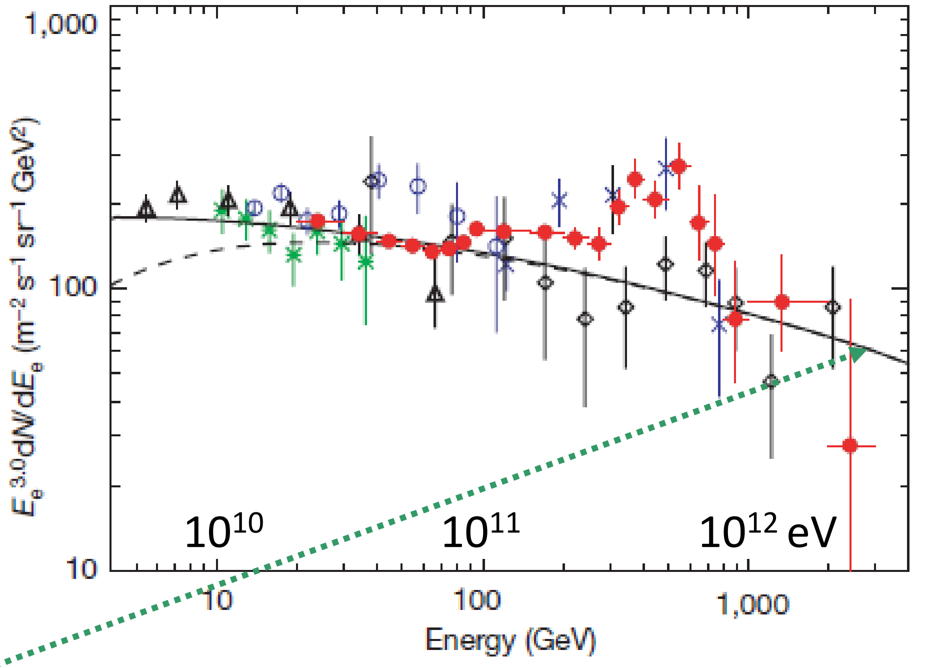


Figure 3 | ATIC results showing agreement with previous data at lower energy and with the imaging calorimeter PPB-BETS at higher energy.

Level of normal GCR e^+e^-

Origin of e+ excess above 10Gev?

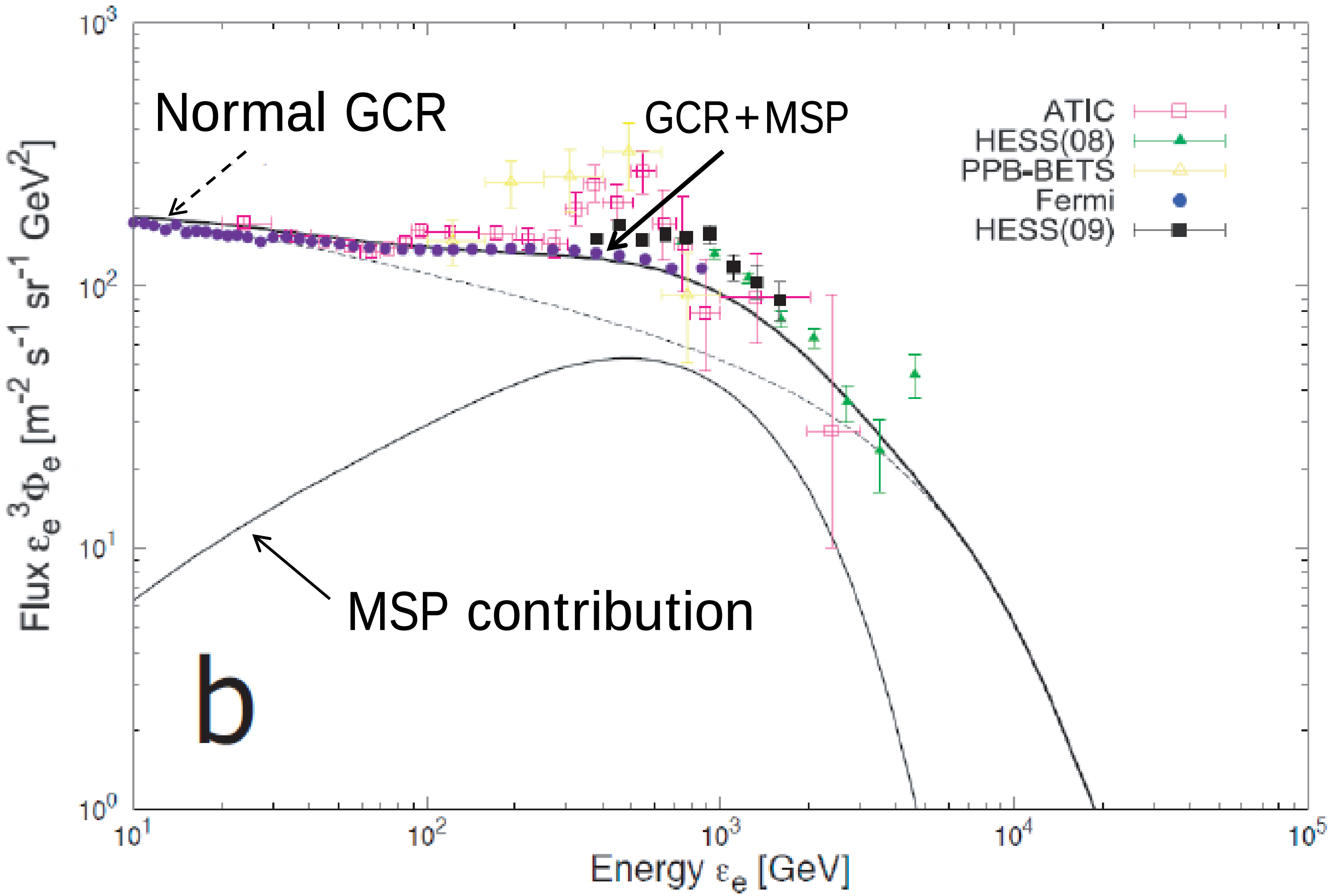
exotic model: Dark Matter Decay Products?

non-exotic models: ... neutron star origin

2. Pulsars and Magnetars

(a) millisecond pulsars (MSP)... contribution to e+ excess

(p. 90, Fig. 3b)



Current research topics / HEA group

1. Reevaluation of basic acceleration processes

(a) second order stochastic acceleration processes
in relativistic turbulence
(b) basic theory of cyclotron resonant interaction
(c) role of neutral particles in acceleration processes

2. Pulsars and Magnetars

(a) millisecond pulsars
(b) Crab pulsar
(c) magnetars

3. Solar system plasma physics

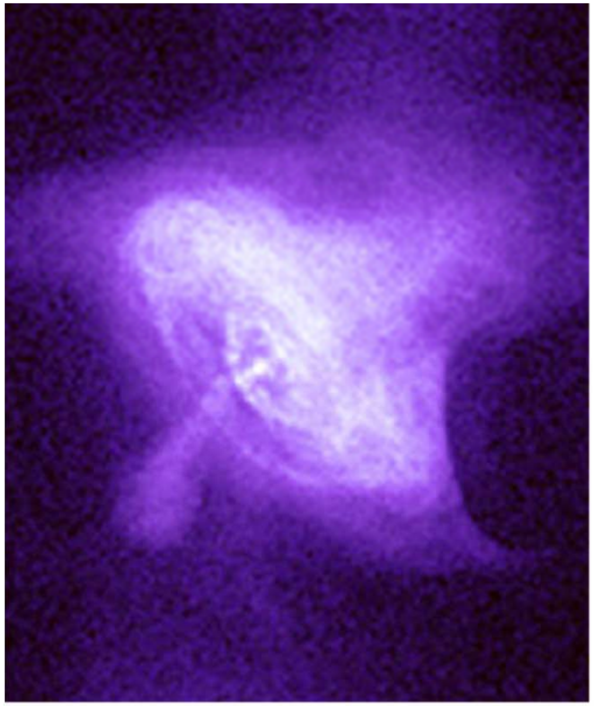
(a) solar wind interaction with the moon

4. R / D studies

(a) CALET project
(b) Radio detection of UHECRs and extraterrestrial grains

2. Pulsars and Magnetars

(b) Crab pulsar



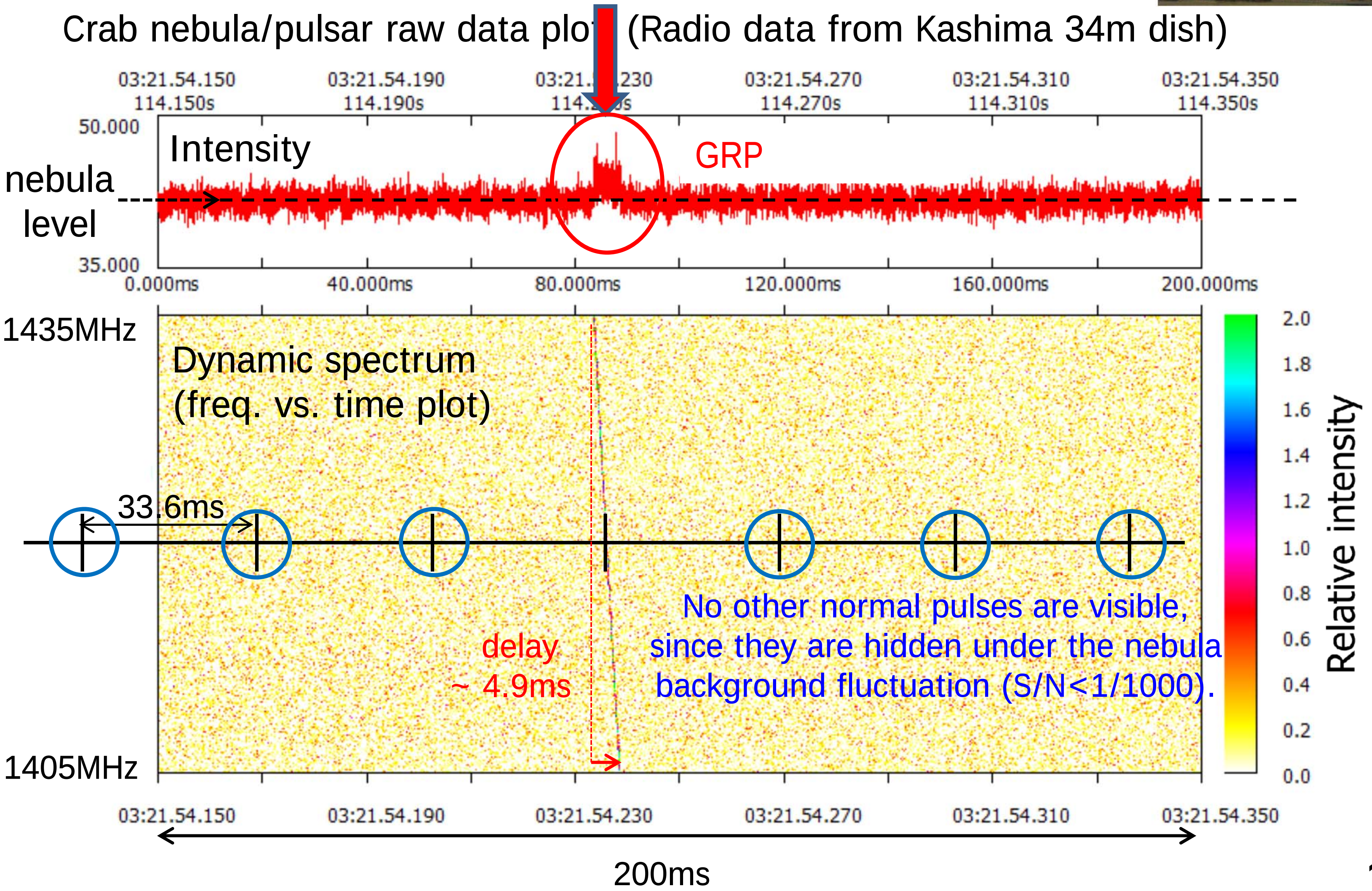
Crab nebula

Crab pulsar, the remnant of the supernova explosion in 1054 A.D., is one of the well-known radio pulsars. While the physical properties of this pulsar have been studied for more than 40 years since its discovery, there remains an enigma about the origin of giant radio pulses (GRPs).

2. Pulsars and Magnetars

(b) Crab pulsar Giant Radio Pulse: an example

Crab nebula/pulsar raw data plot (Radio data from Kashima 34m dish)



For a long time the GRPs had been regarded as a phenomenon limited to the radio frequency pulsar emission. However, a simultaneous 3% enhancement of the optical emission at the GRP timing was discovered in 2003, and it has stimulated related works in other frequency ranges.

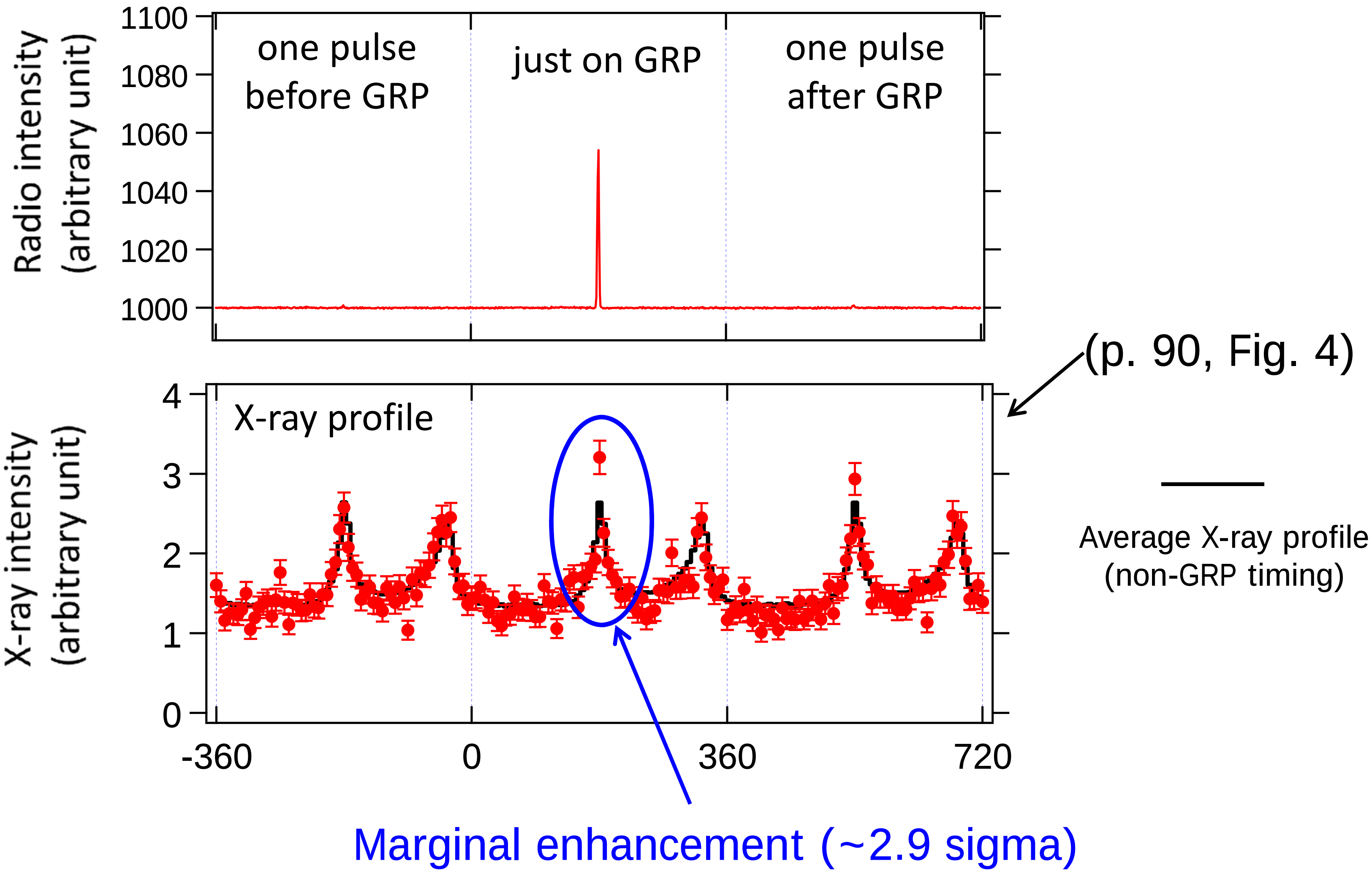
band	energy or wavelength	satellite/ telescope	Intensity variation (or upper limit) associated with GRPs	paper
Optical	600-750 nm	4.2m William Herschel Telescope	**3%** increase	Shearer et al., 2003
Soft X-ray	1-20 keV	Ginga	not significant	Kawai et al., 1992
	1-10 keV	RXTE	<7%	Patt et al., 1999
	1.5-4.5 keV	Chandra	<200%	Bilous et al., 2012
Hard X-ray	13.3-58.4 keV	RXTE	not significant	Vivekanand, 2001
	15-75 keV	Suzaku/HXD/PIN 2010 – 2011	marginal increase ($\sim 2.9\sigma$)	ours, in prep.
Soft γ-ray	50-220 keV	CGRO/OSSE	<250%	Lundgren et al., 1995
γ-ray	0.1-5 GeV	Fermi/LAT	<400%	Bilous et al., 2011
VHE γ-ray	>150 GeV	VERITAS	<500-1000 %	Aliu et al., 2012

Table: Attemps to detect the correlations between GRPs and pulses in other wavelengths of the Crab pulsar

We have started a correlational study between the radio and hard X-ray, and got some hint about the correlation.

Summary of observations for three seasons,
Apr. 2010, Mar. 2011, and Sept. 2011

Pulse profiles superposed over adjacent pulse intervals around GRPs



Current research topics/HEA group

1. Reevaluation of basic acceleration processes

(a) second order stochastic acceleration processes
in relativistic turbulence
(b) basic theory of cyclotron resonant interaction
(c) role of neutral particles in acceleration processes

2. Pulsars and Magnetars

(a) millisecond pulsars
(b) Crab pulsar
(c) magnetars

3. Solar system plasma physics

(a) solar wind interaction with the moon

4. R/D studies

(a) CALET project
(b) Radio detection of UHECRs and extraterrestrial grains

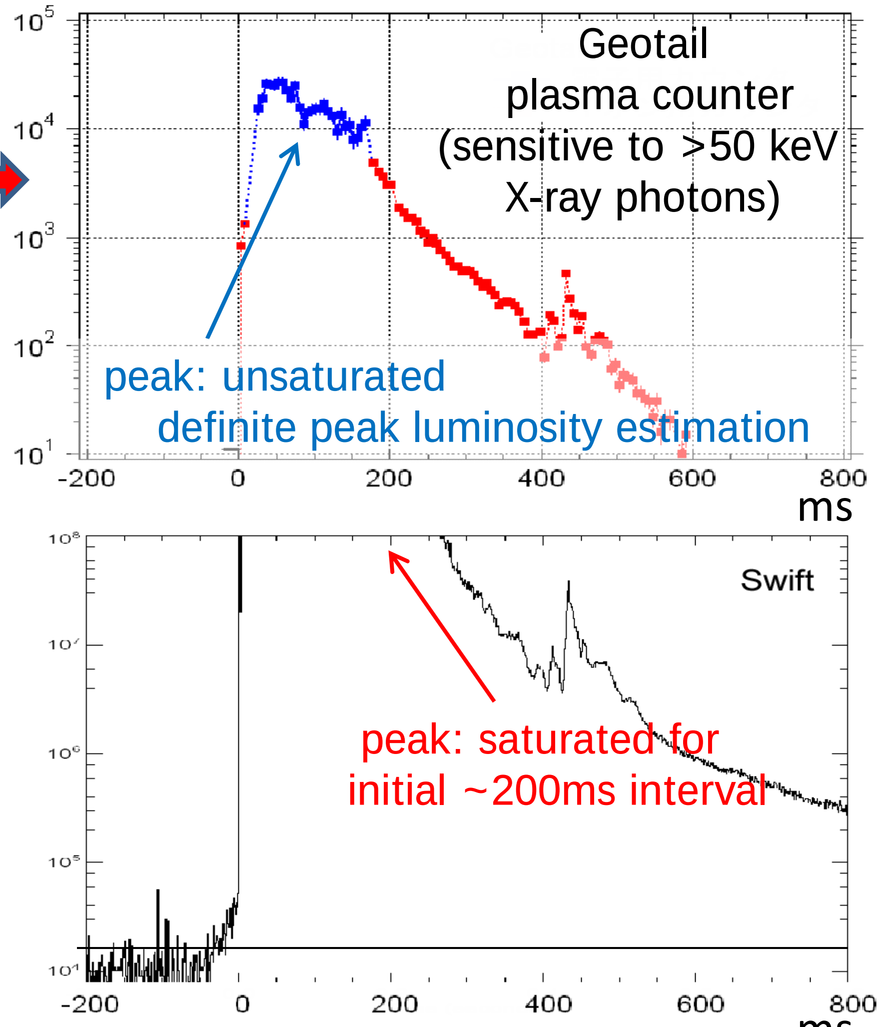
2. Pulsars and Magnetars

(c) magnetars

Magnetars, slowly-rotating neutron stars with strong magnetic field of 10^{13-15} G, occasionally show giant-flare (GF) activities with peak gamma-ray luminosities reaching to 10^{47} erg s^{-1}, which are as strong as the luminosities of AGNs. The detailed physics of magnetars have been under extensive investigations both theoretically and observationally. Our previous contribution to the magnetar study was the definite determination of the peak luminosities and fluences for two GFs in 1998 and 2004 based on the GEOTAIL measurements[4,5]. In addition we have reported the first clear detection of transient Extremely-Low-Frequency (ELF) radio waves caused by the largest-ever-known GF from the magnetar, SGR 1806-20, on 27 December 2004 (Figure 5 from [12]). Although the excitation mechanism of these ELF waves has not been uniquely identified, this provides a new monitoring method for magnetar GFs.

Nature (2005)

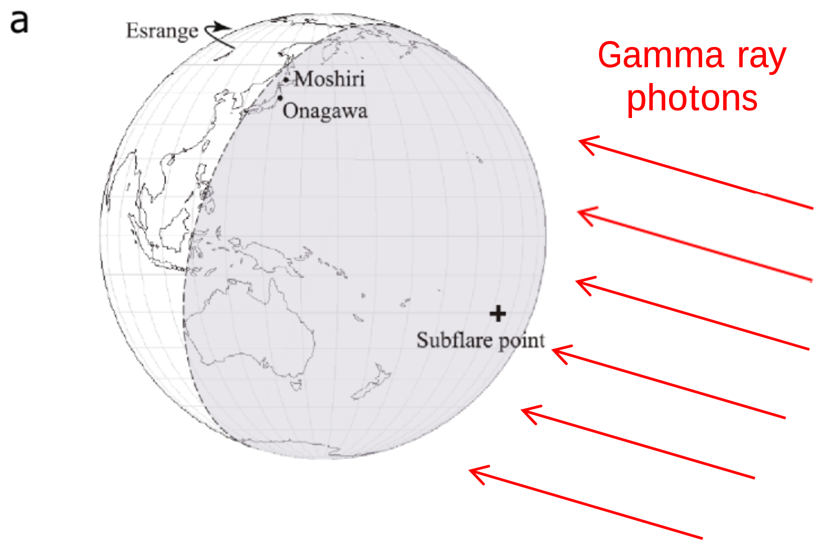
Repeated injections of energy in the first 600 ms of the giant flare of SGR 1806−20

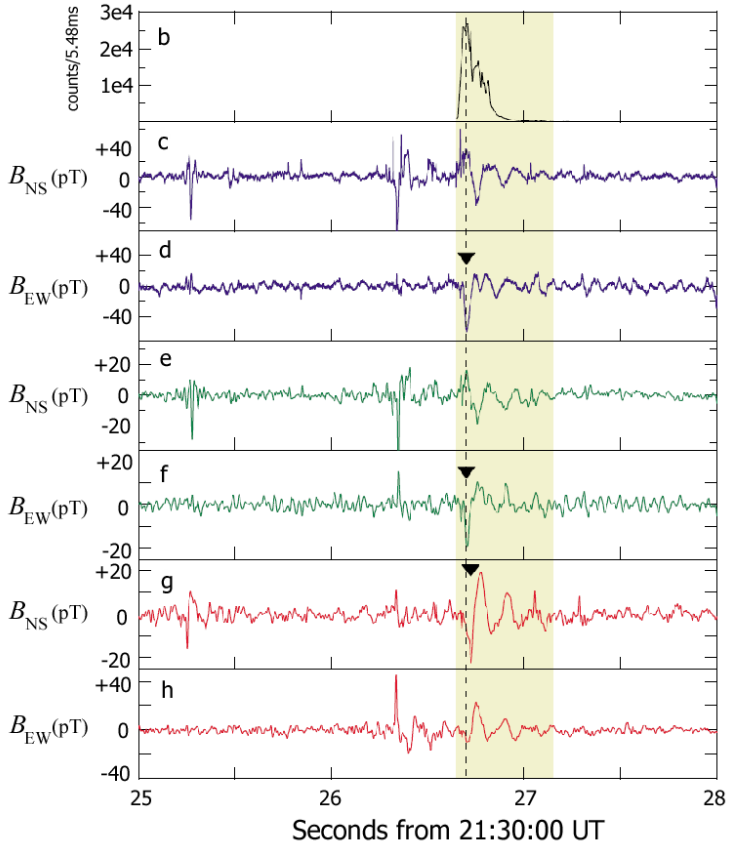


2. Pulsars and Magnetars
(c) magnetars

Magnetars, slowly-rotating neutron stars with strong magnetic field of 10^{13-15} G, occasionally show giant-flare (GF) activities with peak gamma-ray luminosities reaching to 10^{47} erg s^{-1}, which are as strong as the luminosities of AGNs. The detailed physics of magnetars have been under extensive investigations both theoretically and observationally. Our previous contribution to the magnetar study was the definite determination of the peak luminosities and fluences for two GFs in 1998 and 2004 based on the GEOTAIL measurements[4,5]. In addition we have reported the first clear detection of transient Extremely-Low-Frequency (ELF) radio waves caused by the largest-ever-known GF from the magnetar, SGR 1806-20, on 27 December 2004 (Figure 5 from [12]). Although the excitation mechanism of these ELF waves has not been uniquely identified, this provides a new monitoring method for magnetar GFs.

Gamma ray photons from this giant flare caused significant disturbances in the earth's ionosphere.





(p. 91, Fig. 5)

Current research topics / HEA group

1. Reevaluation of basic acceleration processes

(a) second order stochastic acceleration processes in relativistic turbulence

(b) basic theory of cyclotron resonant interaction

(c) role of neutral particles in acceleration processes

2. Pulsars and Magnetars

(a) millisecond pulsars

(b) Crab pulsar

(c) magnetars

3. Solar system plasma physics

(a) solar wind interaction with the moon

4. R / D studies

(a) CALET project

(b) Radio detection of UHECRs and extraterrestrial grains

p.94, Table 1. Topics of common interest: A few examples

Division in ICRR	Group/Project	Examples of topics
High Energy Cosmic Ray Division	Telescope Array Group	origin/propagation of UHECR radio detection of UHECR
	Cherenkov Cosmic Gamma Ray Group	high energy γ ray emission from SNR, pulsars, Galactic Center, GRB, AGN, ... origin of GCR origin of diffuse gamma rays
	Tibet ASγ Group	anisotropy/composition of GCR origin of diffuse gamma rays
Neutrino and Astroparticle Division	Hyper-Kamiokande Project	solar *flare* neutrino
Astrophysics and Gravity Division	Primary Cosmic Ray Group	solar modulation of GCR
	Observational Cosmology Group	origin of cosmic magnetic field source of reionization (GRB, AGN, ...)
	KAGRA[a] Project	merger events (NS-NS, NS-BH)

We want to play the role of 'theoretical engine' for experimental cosmic ray physics in ICRR.

Thank you for your attention.

Backup slides

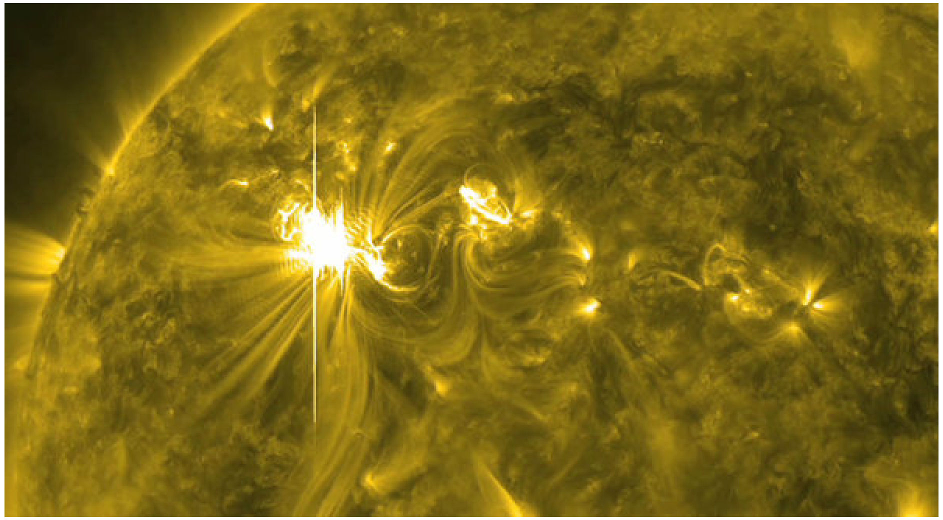
Nearest cosmic explosions: solar flares

HOME PAGE | TODAY'S PAPER | VIDEO | MOST POPULAR | U.S. Edition | Log In | Register Now | H

The New York Times **Space & Cosmos**

Search All NYTimes.com

Solar Bursts Spray Earth, With More to Come



-/Agence France-Presse — Getty Images

A NASA image shows a solar flare from Tuesday. Flares can affect satellites and power grids.

By KENNETH CHANG

Published: March 8, 2012

Solar storms like the one that buffeted the Earth's magnetic field on Thursday will soon become a common occurrence.

Related

The Lede Blog: Forecast Is Solar Stormy, With Slim Chance You'll Notice (March 8, 2012)

Magnetic eruptions on the Sun on Tuesday and Wednesday released two huge bursts of lights — two of the largest solar flares over the last five years — and accelerated a blob of high-speed particles headed toward us. As the charged particles slam the Earth's magnetic field at more than a million miles per hour and are funneled toward the north and south poles, they generate the

WORLD NEWS WITH DIANE SAWYER | NIGHTLINE | this with George

abc NEWS

HOT TOPICS: Os

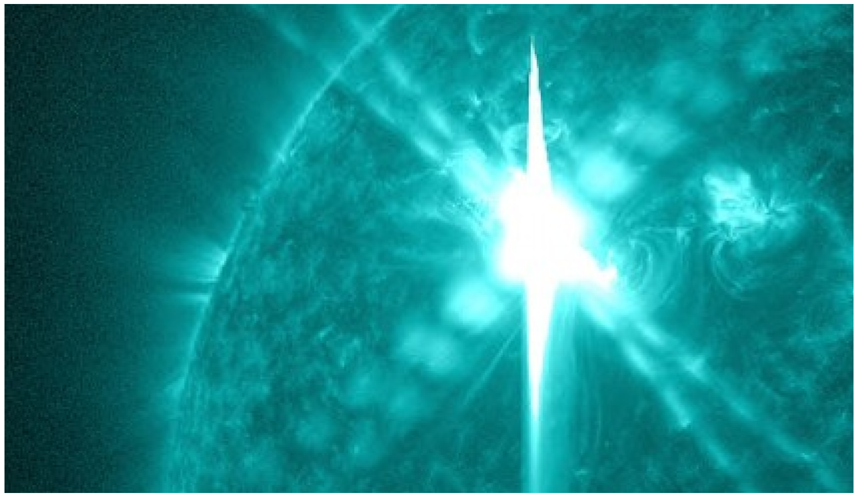
Home | U.S. | World | Politics | Video | Inve

Mar 7, 2012 12:30pm

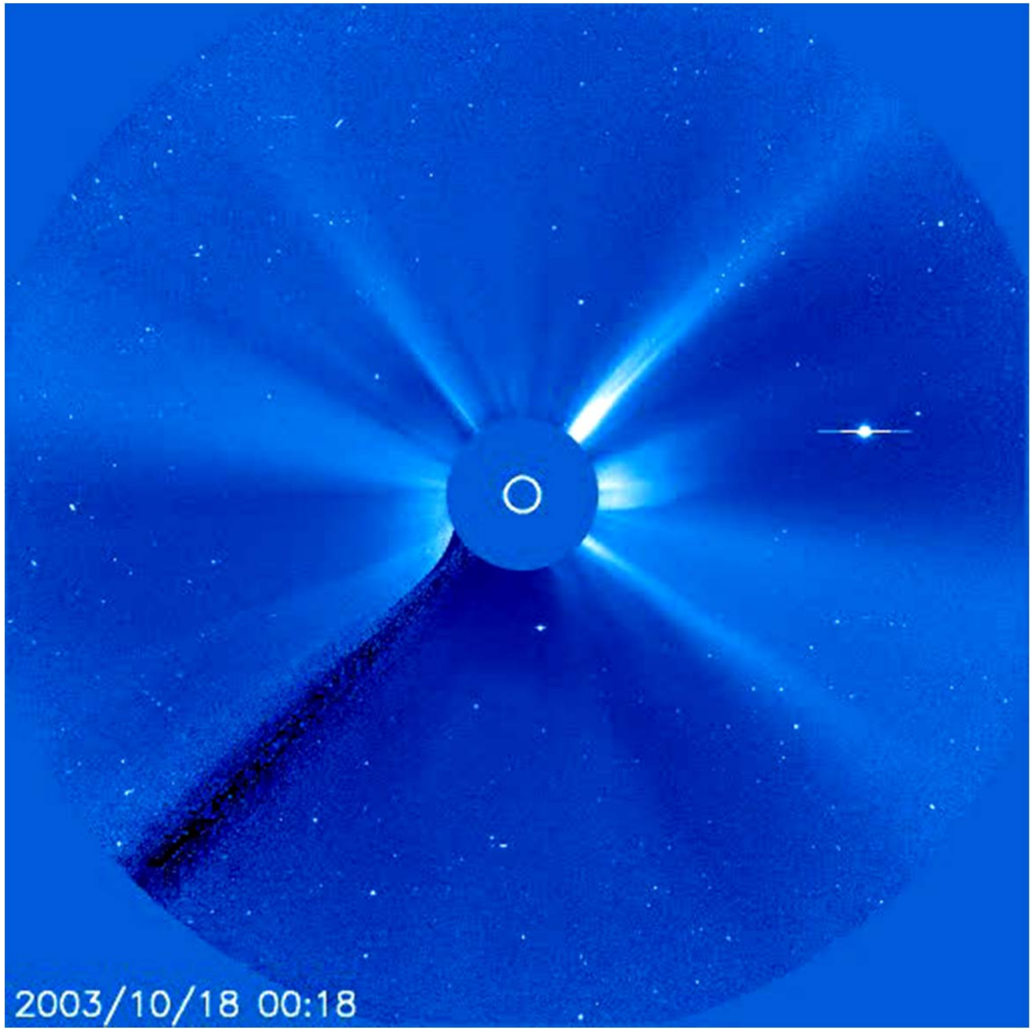
Largest Solar Flare May Create Sky Show

いいね！ 1,543 Tweet 237 8 Te

+1 52



Halloween storms LASCO C3 (Oct. 18 - Nov. 7 2003)



http://sohowww.nascom.nasa.gov/gallery/Movies/flares.html