Satio Hayakawa and dawn of high-energy astrophysics in Japan

- Dawn of High-Energy AstroPhysics -

Jun Nishimura ISAS/JAXA

Fifth International Fermi Symposium @ Nagoya University

Oct. 20th, 2014

Contents

1. Early History of Cosmic-ray works in Nishina laboratory

   ~1930:

   Theoretical Work, Muon Discovery, Deep Underground.....

2 Prediction of Gamma-ray Astronomy (~1950s)

   by Hayakawa and P. Morrison.

3. X-ray Astronomy and Direct Observation of Cosmic rays.

4. Pioneering works and an Outstanding leadership.

Prof. S. Hayakawa (1932- 1992)

- Depth Intensity of Muons
  1949
- Gamma Ray Astronomy
  1952
- SN Origin / Cosmic Rays
  1956
- Be^{10} CR Confinement time
  1958
- Other Prediction, Analysis

Prof. Y. Nishina Devoting to promote the Modern Physics

Klein Nishina Formula(1929)

1928: Came back from Niels Bohr Institute

Y. Nishina

1929: Member of Riken (H. Nagaoka)

1929: Invite Dirac and Heisenberg

Stimulate Young Scientists

Yukawa, Tomonaga・・

1931: Nishina Laboratory, Riken

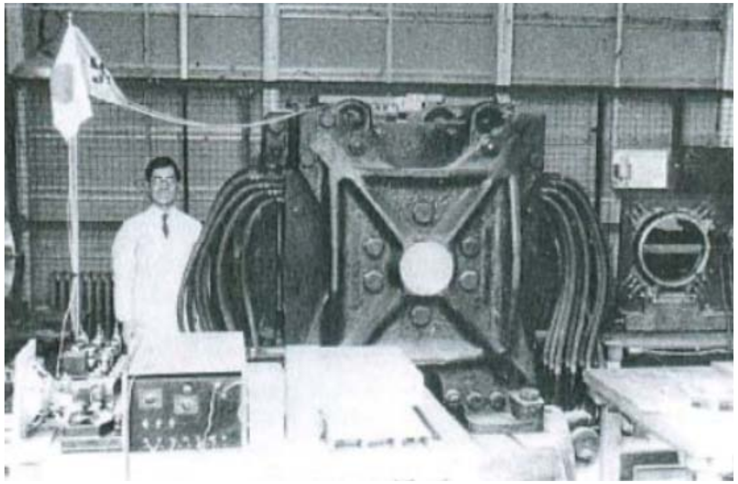
- Cosmic Ray Group
- Theoretical Group
- Nuclear Physics Group

● CR Research in Nishina Lab.

1931 Start Cosmic Ray Study, One year before Positron Discovery.

1937 Magnetic Cloud Chamber : MUON.

1937 Latitude Effect.



1939 Deep Underground.

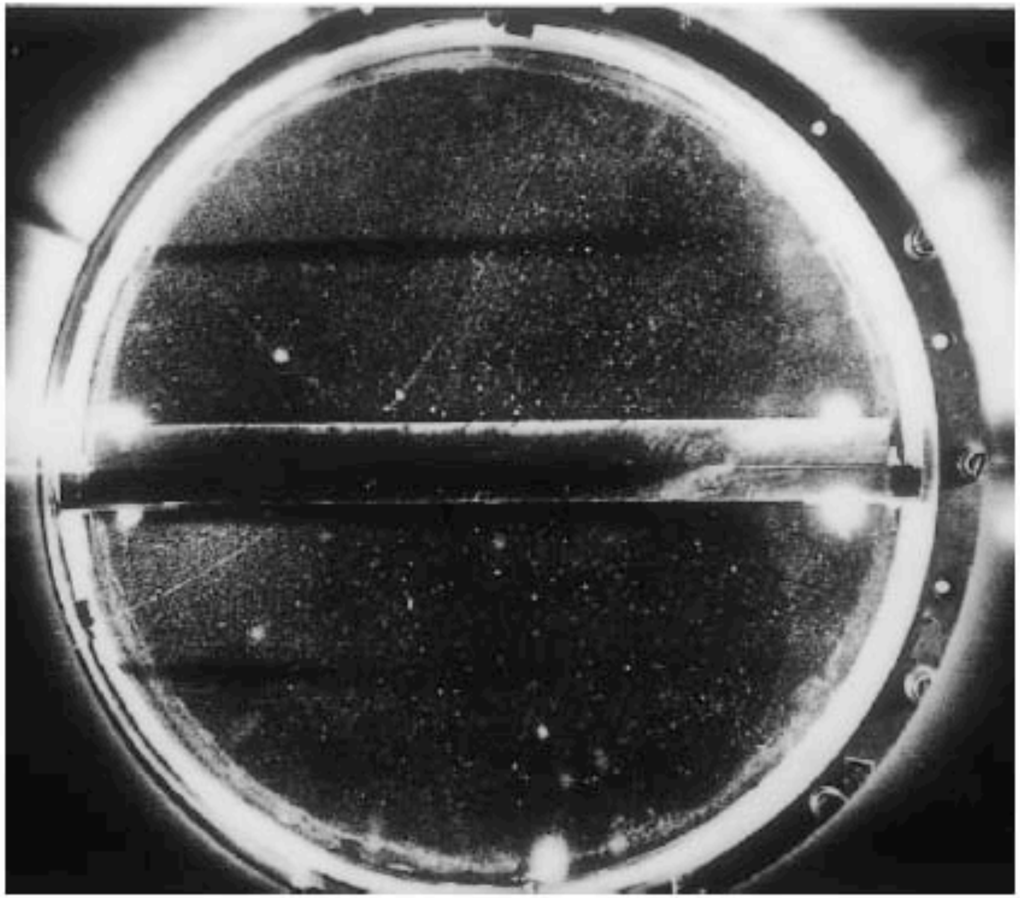
(1400, 3000m.w.e)

1941 Continuous Observation.

1942 Balloon Observations .

● Strong Theoretical Group in Japan

- H. Yukawa (Guest member) : Meson (1935-).
- S. Tomonaga: QED, Pair Creation ······(1933,······).
- S. Sakata: Two mesons······ (1943······).
- H. Tamaki: Cosmic Rays ······
- M. Kobayashi: Cosmic Rays······
- M.Taketani: $\pi^o \to 2\gamma$ Source of Soft Comp (1943).

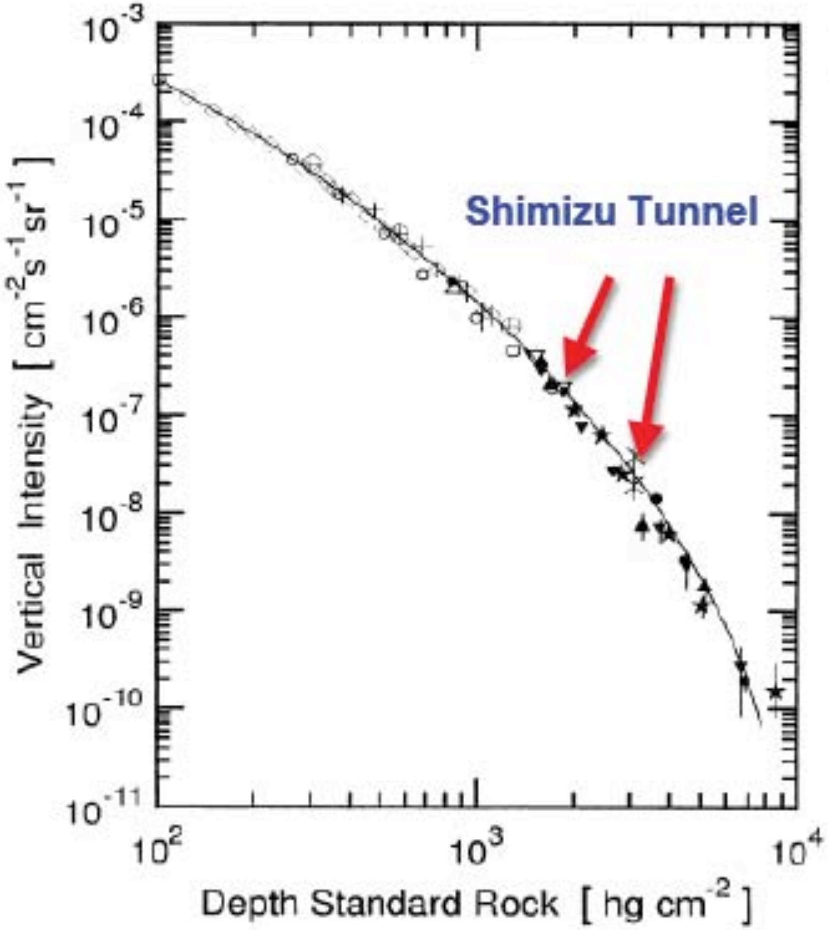


Dia. =40cmφ,
H= 1.7 Tesla.

Mass =223±39me
(Momentum *vs.*
Momentum Loss)

Y.Nishina, M. Takeuchi & T.Ichimiya; Phys Rev. 52(1937)1198.

Deep Under Ground (1400m.w.e., 3000m.w.e) (1939-1944)



The Deepest Observation point till 1951

(Bollinger)

Y.Miyazaki, Phys Rev. 76(1949)173

Hayakawa : A Student of Tomonaga (1944 -)

Start Cosmic Ray Works as a particle Physics.

- **Intensity vs Depth relation of Muon.**

  (Analysis of Obs. Data @ Shimizu Tunnel)

Effects of Pion,Kaon , Muon Decay Life Time and Direct Pair

S. Hayakawa & S.Tomonaga : Prog. Theor. Phys. 4 (1949) 287

Photo ~ 1946

Tomonaga Hayakawa

MInakawa

Baba

Sakata

Koba,

Miyajima,

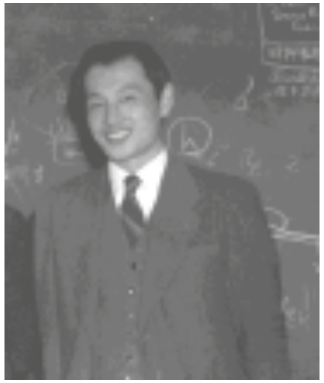
Taketani,

●Gamma rays From the Space (1952)

Propagation of the Cosmic Radiation through the interstellar Space

S. Hayakawa: Prog. Theor. Phys. 8 (1952) 571.

In the passage through this thickness secondary particles are scarcely produced except photons which are due to the decay of neutral pions. The intensity of the secondary photons are estimated as about 0.1% of the total intensity at the geomagnetic latitude 55^0, but as nearly 1.5% at the equator. In the latter case this effect would be detectable.



Flux of Gamma rays : ~10^{-4} /cm^2 sec sr.

● Prediction by P. Morrison (1958)

On Gamma ray Astronomy.

- Diffuse and Point Source-

P.Morrison Il Nuovo Ciment Vol. 7 (1958) 958.

Process: Synchrotron, Brems, π^{o}, Nuclear gamma,

e^+e^- Anni. IC was not mentioned.

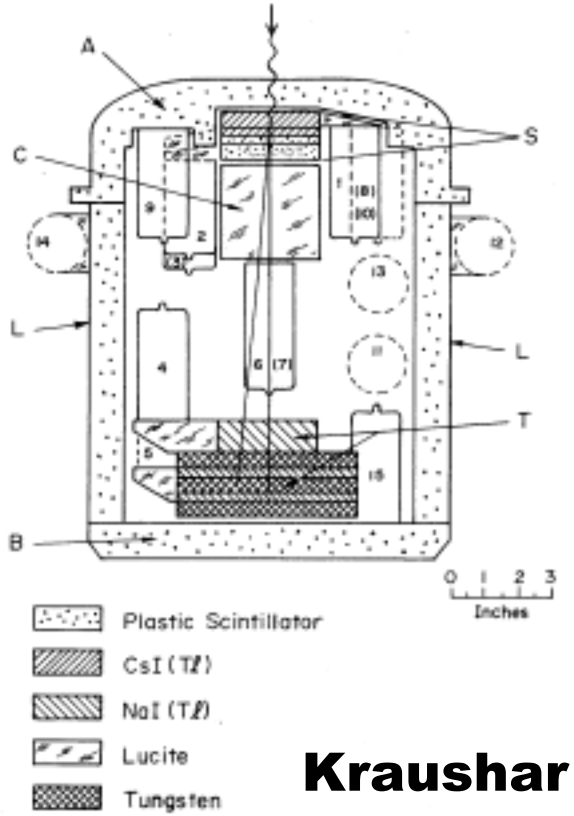
Flux of Gamma : ~10^{-2} - 10^{2} /cm^2sec.

10^2 - 10^4 Times of Hayakawa's Prediction.

Flights of several hours' duration are adequate, and the altitudes required are not extreme. Telemetering of data, or even recovery

Flights of Several Hours are adequate !!

● Gamma Ray Satellites (1972~)



SAS-II (1975),

COS-B (1979),

CGRO (1991),

Integral (2002),

Fermi (2008).

Kraushar , Clark et.al. ApJ 177(1972),341.

OSO 3 found the indication of Galactic Diffuse Gamma Rays,

Observing 600 gammas which agree well with Hayakawa's Prediction.

● Short Summary

Authors **Prediction** **Results in**

●1952: Hayakawa: Accurate and Faint Flux.

Hesitate to carry pout the Experiment.

●1958: Morrison: Too Optimistic Estimate.

Encourage to Start the Experiments,

But Physicists Disappointed for more than 10 yrs.

● 1972: OSO 3 : *600 gamma rays :*

indication of Gamma Flux from the Disc:

Well agree with Hayakawa !!

- **Lessons Learned :**

Irony is that

Accurate Expectation does not always help to

Open the Door of New Field

But

Optimistic and somewhat Erroneous Expectation

Boosted the Gamma- Ray Astronomy !!

Prof. S. Hayakawa (1932- 1992)

- Depth Intensity of Muons
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  1958
- Other Prediction, Analysis

Super nova origin of Cosmic rays.

S.Hayakawa.

Prog.Their. Phys Vol 15 (1956) 111

- **SN origin: Based on Energetics by Zwiky, Ginzburg….**
- **Hayakawa noticed in this paper:**

Fe Component is dominant in Cosmic rays mentioning:

The supernova origin of cosmic rays is proposed in connection with the stellar evolution and the building up of heavy elements in the core of stars as they evolve. Nearly equal abundances of heavy and medium nuclei in primary cosmic rays suggest that the sources may be such stars, in which the thermonuclear reactions of building up heavy elements take place and which eventually explode as super-

This argument was appreciated as a strong support of the SN origin of cosmic rays,

Although, Later found, the relation is more complicate between the Composition of the sources and Cosmic Rays.

The Age of the cosmic Rays Derived from the Abundance of 10Be

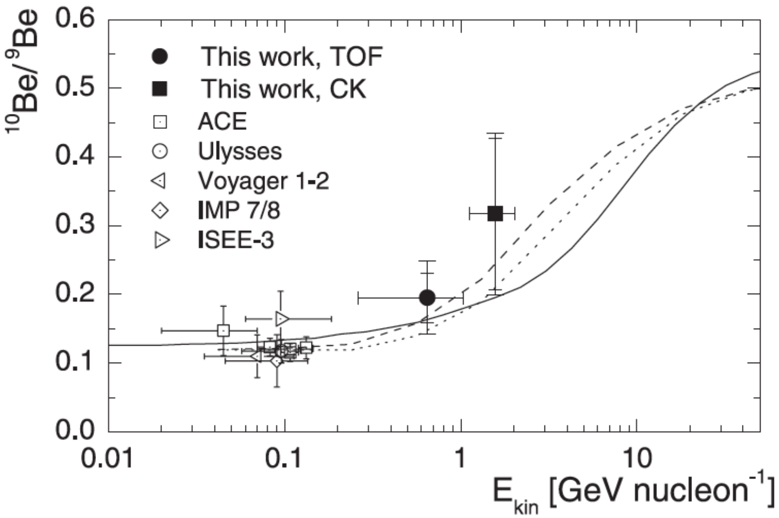
Garcia Munos, G. M Mason, J.A. Simpson

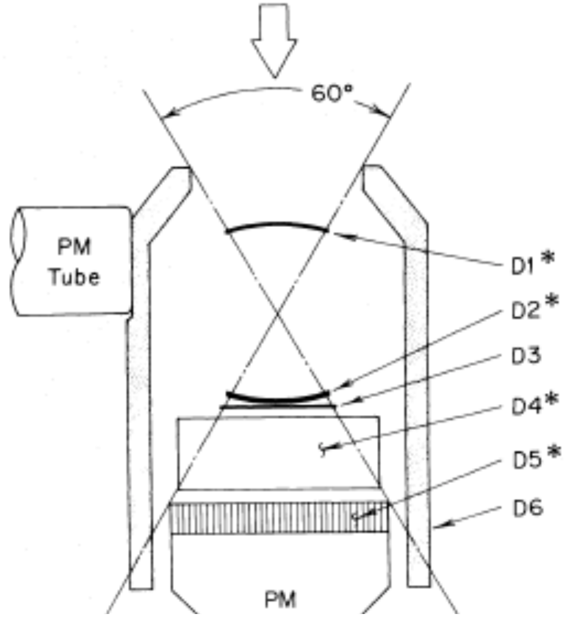
ApJ, 217 (1977) 859

The first successful observations of 10Be.

The author noted in their paper:

……, and the abundance of ^{10}Be, with a half-life of 1.5×10^6 years, has long been recognized as an attractive candidate for this test (e.g., Hayakawa, Ito, and Terashima 1958).



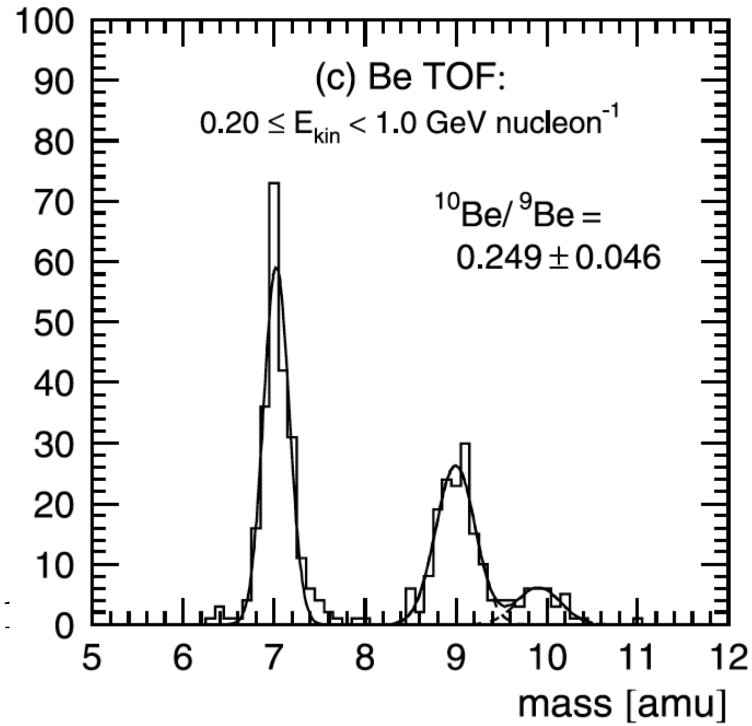


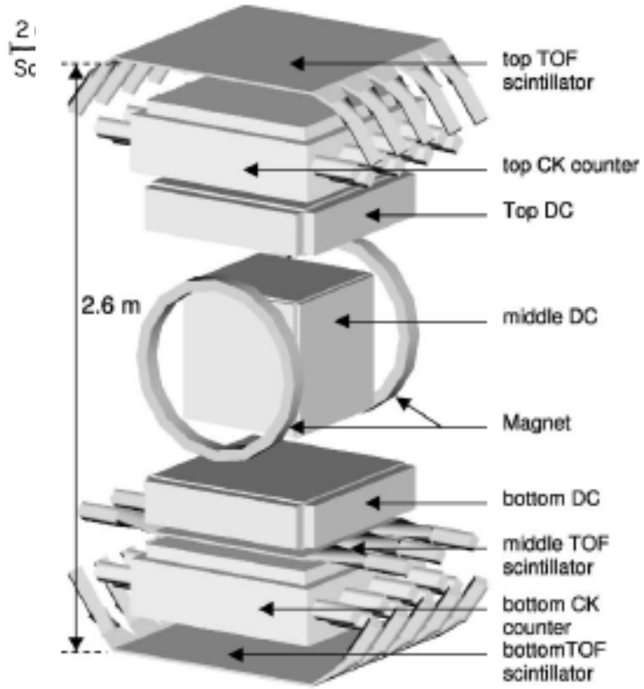
IMP 7-8.

Garcia-Munos etal

ApJ.**217**(1977) 859

ApJ.6





Isomax.

T.Hams etal

●1961

In his speech at the Dinner party of the ICRR in Kyoto , Prof. Powell Talked

C.F. Powell

In Near Future, Shall We Cosmic Ray Physicists Tell to the Astronomers !!

" How much Interstellar matters !
and How they are distributing !
in our Galaxy".

●**1962 (Ten year before gamma rays were observed)**

Contrary to Gamma ray Astronomy, No Efficient Process for X-ray production from the space were predicted:

▲**Faint Florescent X rays from the Moon by hitting cosmic rays,**

▲**Others? ,.....**

However: Rossi mentioned :

Nature is more imaginative in many case than we suspect !!

He Launched the Sounding Rocket:

Found Extremely Strong X-ray Flux From the direction of Scorpio.

B. Rossi

R. Giacconi

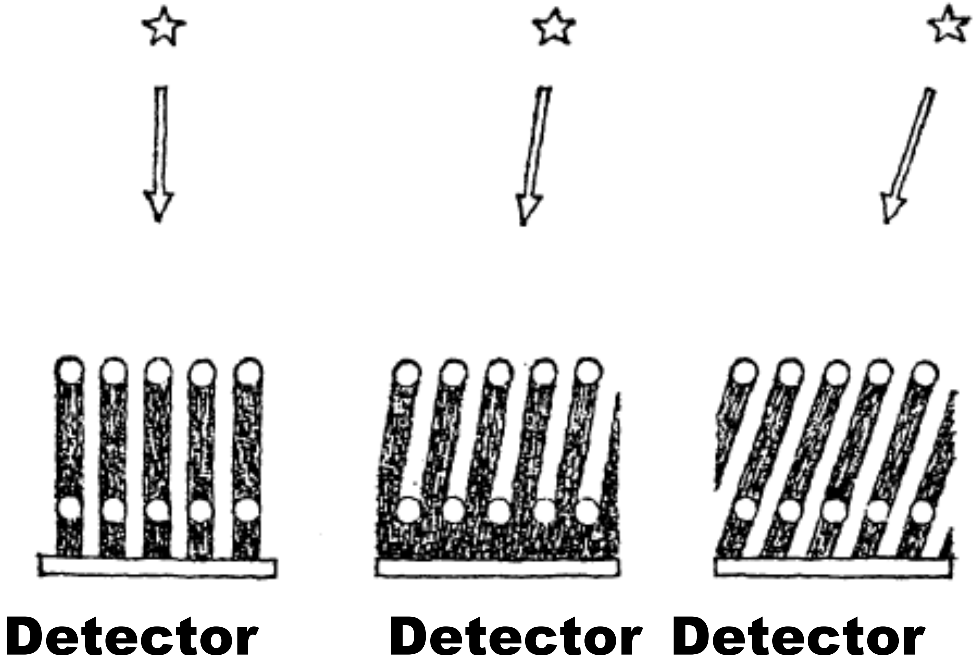
●Invention of Modulation Collimator by M.Oda

X ray Source of Scorpio: Identified by this device (1965)

Rossi asked Oda to come to MIT for the X-ray Astronomy,

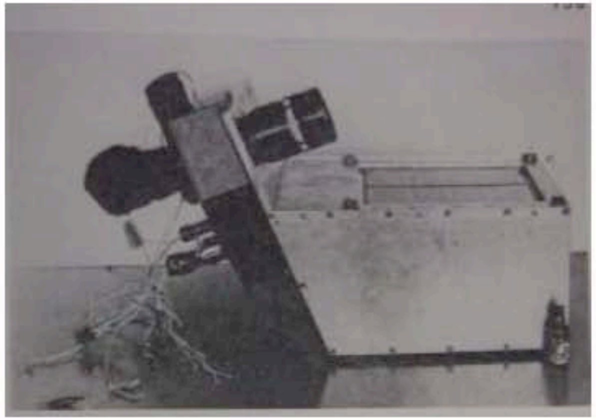
Since Oda was in his laboratory early in 1950's for EAS studies.

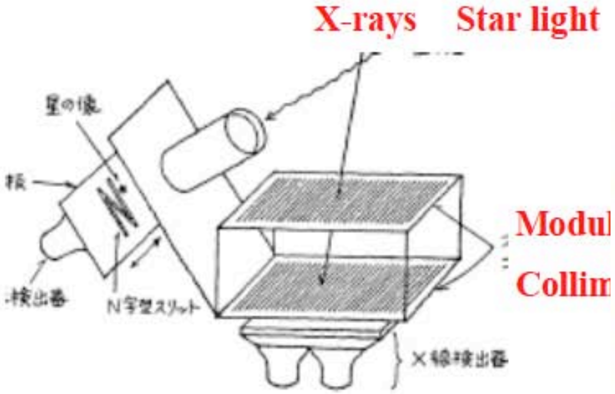
M. Oda



Modulation Collimator

Determination of Location of Cygnus X1 (1967-70)





Location was determined within

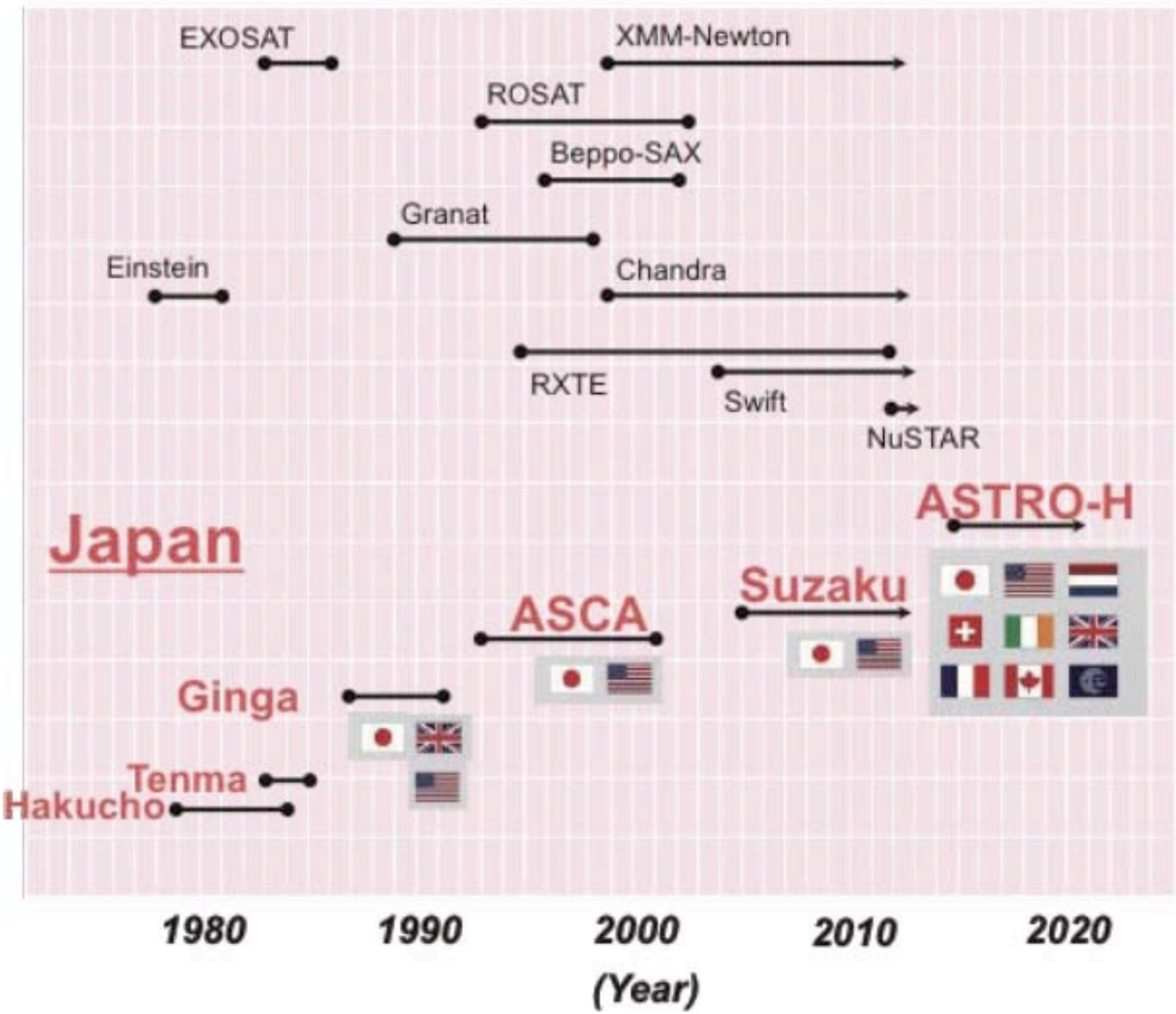
10 arc min.

Then found the first candidate of Black Hole !

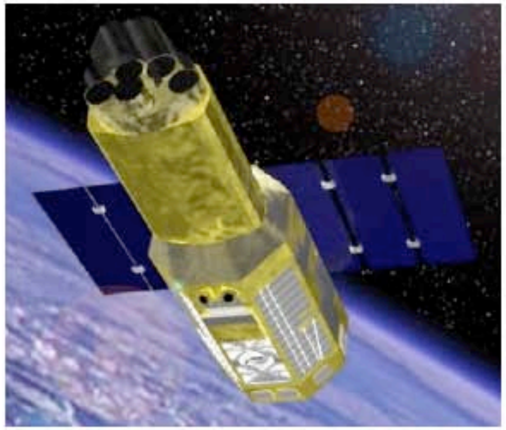
S. M iyamoto et.al. ApJ.168(1971) L11.

H Tananbaum et. Al. ApJ.165(1971) L37.

X-ray Astronomy Missions for 4 decades



From Suzaku to ASTRO-H



High-sensitivity, soft X-ray imaging spectroscopy, and Wide-band soft to hard X-ray spectroscopy

~1.7 tons
In orbit since 2005

High-resolution soft X-ray spectroscopy, and High-sensitivity hard X-ray imaging spectroscopy

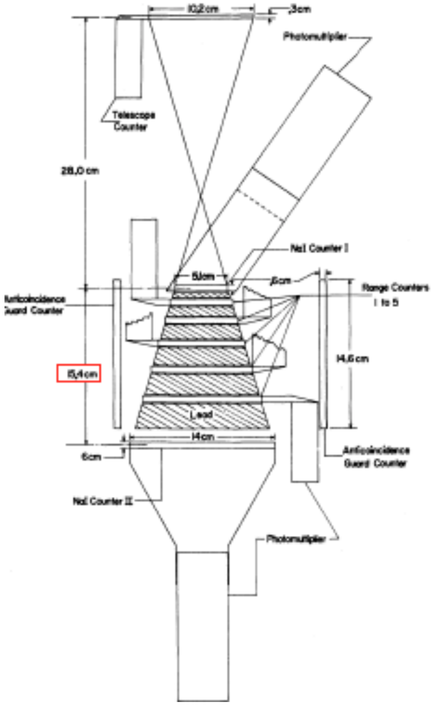
~2.7 tons
will be inserted in orbit in 2015 to early 2016

Primary Electrons

Synchrotron and Inverse Compton Loss:

Specific feature for Propagation in the Galaxy

Electron Flux small : e/P ~ 1% - 0.1% ; Difficult to Observe

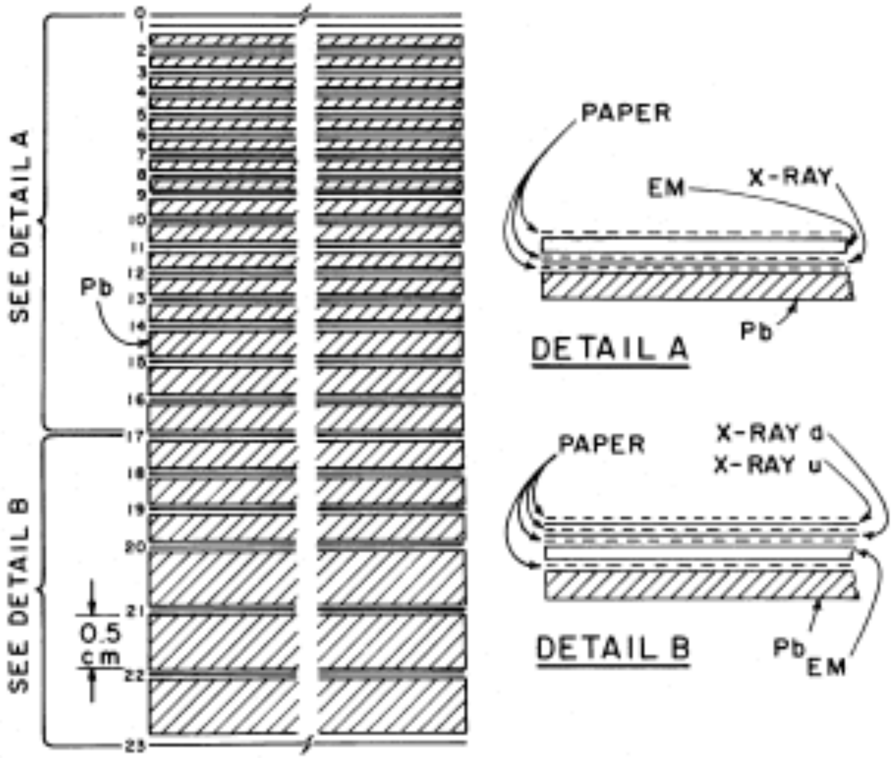


P.Meyer & R. Vogt (1961), Phys. Rev. Lett 6 (1961) 193.

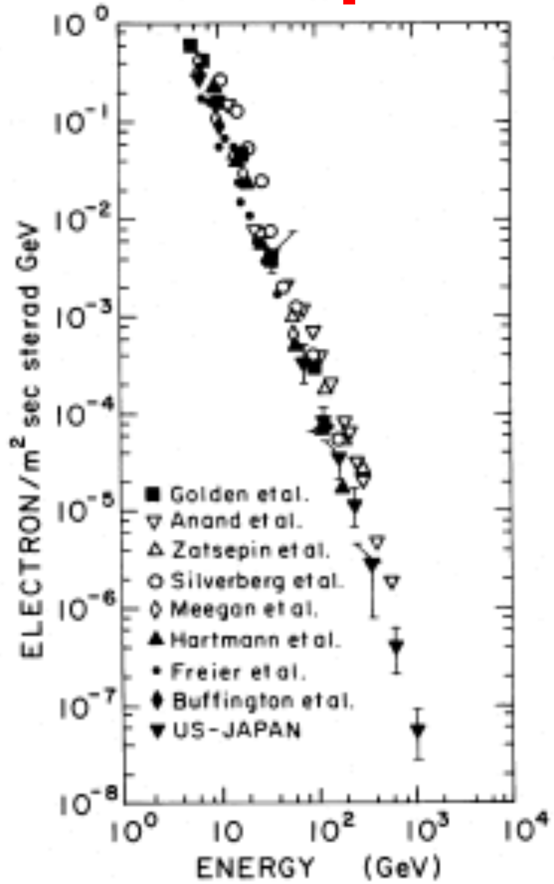
J.A. Earl (1965), Phys. Rev. 138 (1965) 300B.

● Observations During (1961- 2000).

No Particular structure was observed in the spectrum.



Emulsion Chamber



Observed Electron

An Example : J. Nishimura et.al. : 238(1980)394.

● Contribution of Nearby Sources (1970 -).

Electron Loss the energy by Syn. & Inverse Compton ~ b E^2 ,

Then Life of electron: E ~ 1/b

For E>1TeV : R < 1kpc, Life T < 10^5 yr.

Cannot Travel far distance from the Source.

C.S. Shen: ApJL 162 (1970)L 181

J.Nishimura, J. et al : 1979 16th ICRC (Kyoto) 1, p488

R.Cowsik, R. & Lee, M.A. 228 (1979)297

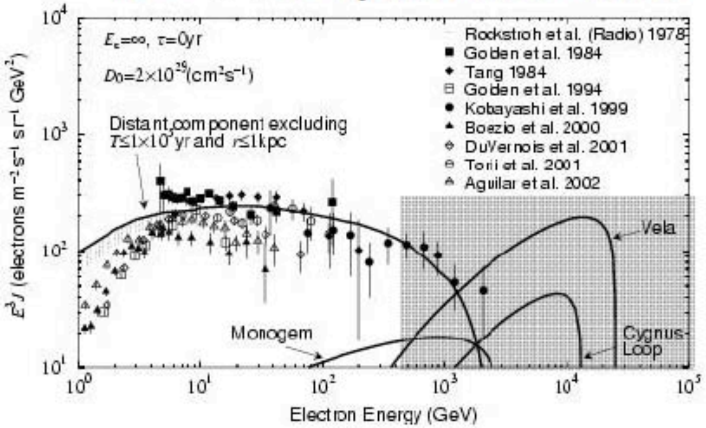
F.A.Aharonian, Atoyan,A.M, & Volk, H.J. A&A 295 (1995) L41

T.Kobayashi, et. Al. : ApJ 601 (2004) 340/

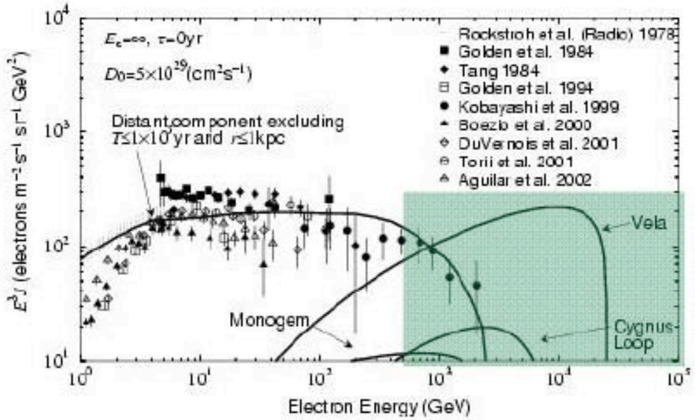
....

Model Dependence of Nearby Source Effect

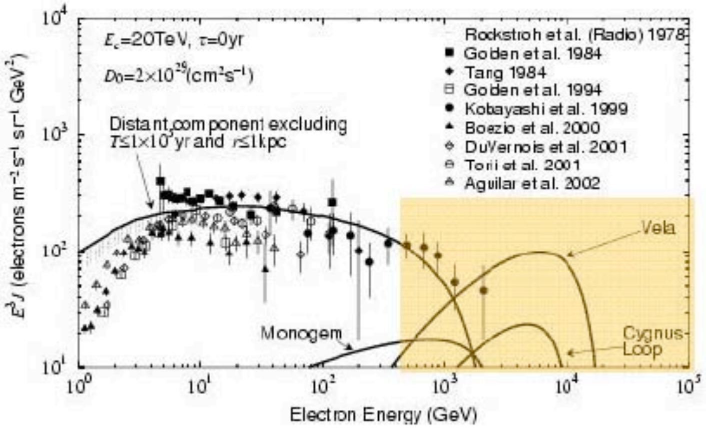
Ec=∞、ΔT=0 yr, Do=2x10^{29} cm^2/s



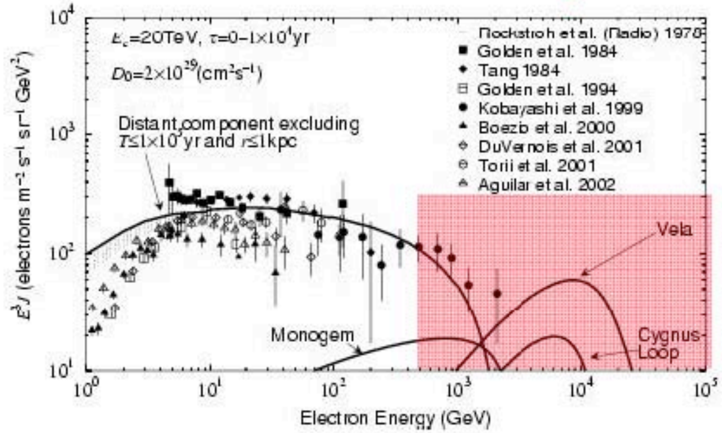
Do=5 x 10^{29} cm^2/s



Ec= 20 TeV

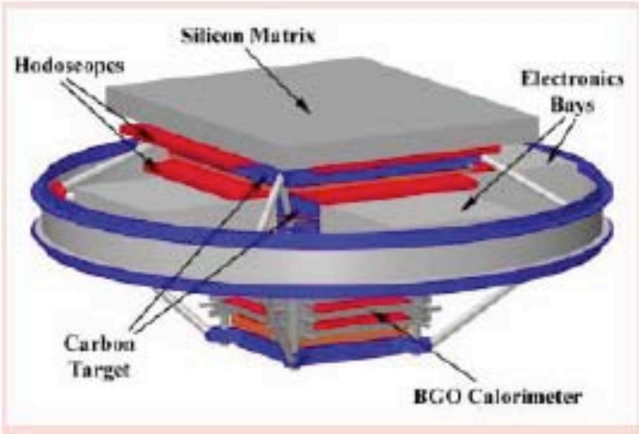


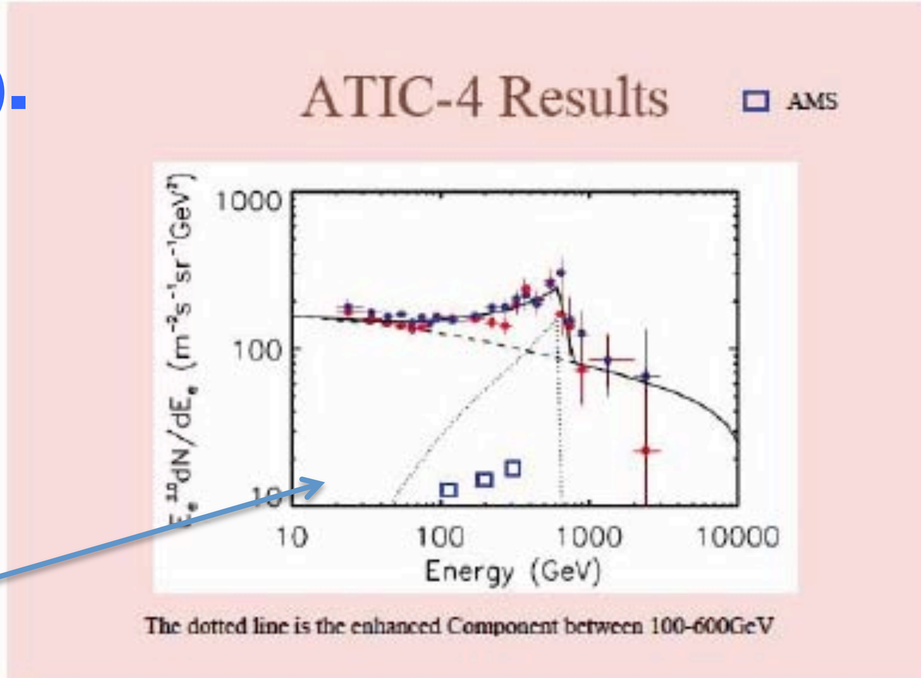
Ec=20 TeV、ΔT=1-10^4 yr



T.Kobayashi et .al. : ApJ 601 (2004) 340.

- **Structure in the Spectrum was first observed in ATIC Experiments (2008).**

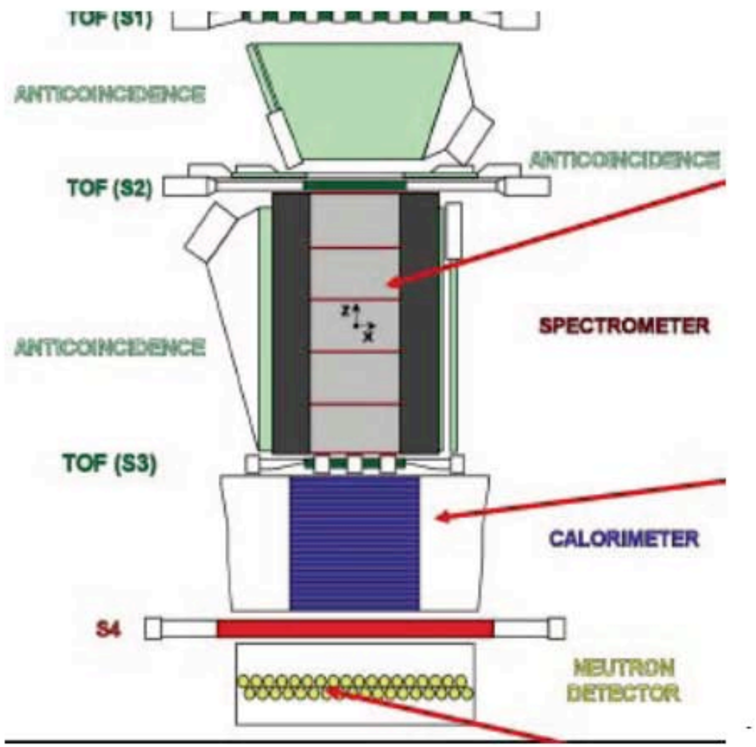


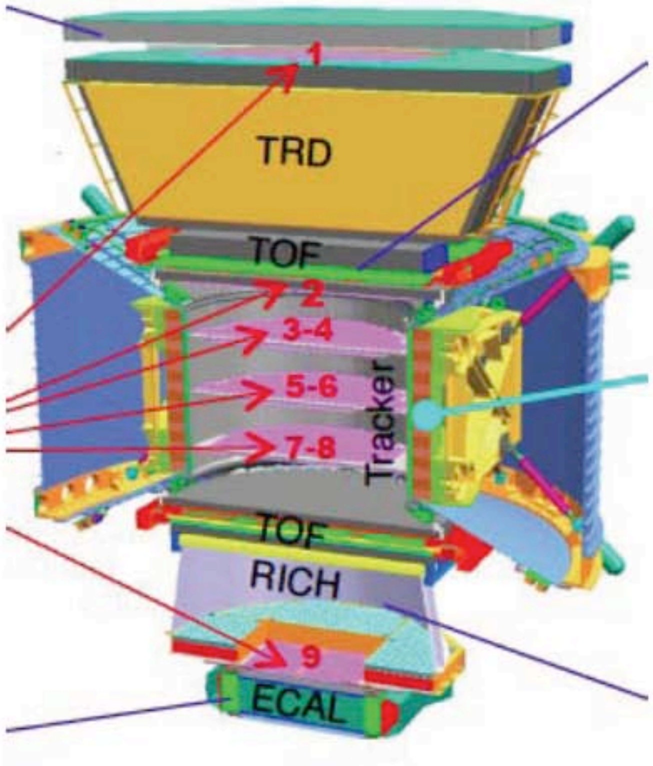


Expected Spectrum after propagation from the line spectrum of electron pairs from the annihilations of Kulza-Klein Dark matter of mass of ~600GeV. **B1B1→e+e- .**

J. Chang et al: Nature 456(2008) 362.

● Magnet Spectrometer (2006-).





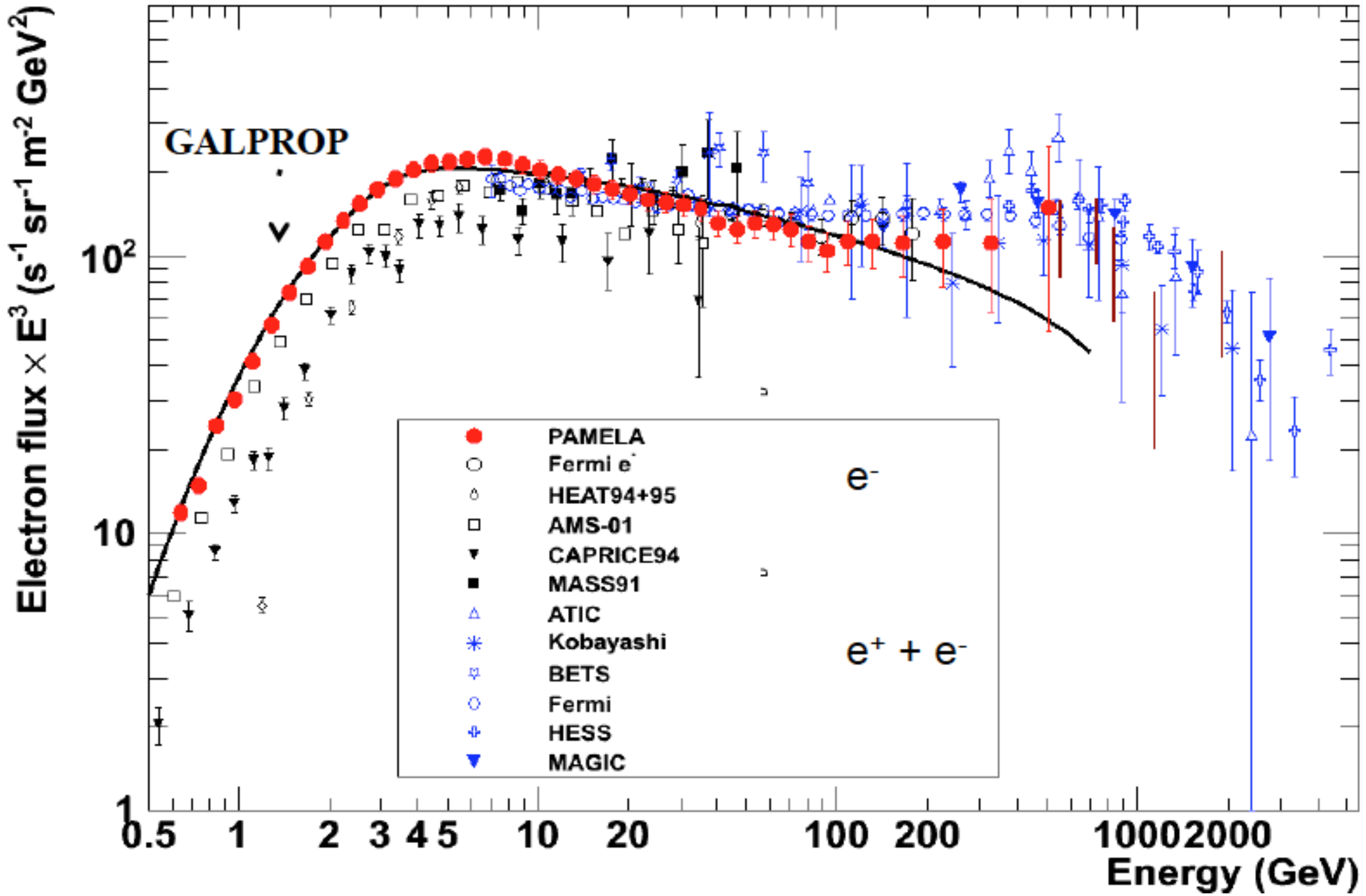
Pamela (2006-) **AMS (2010-)**

O. Adriani et al: Phys Rev. Lett.11 (2013) 081102,

M. Agrial etal : Phys Rev. Lett. 13 (2014) 121102.

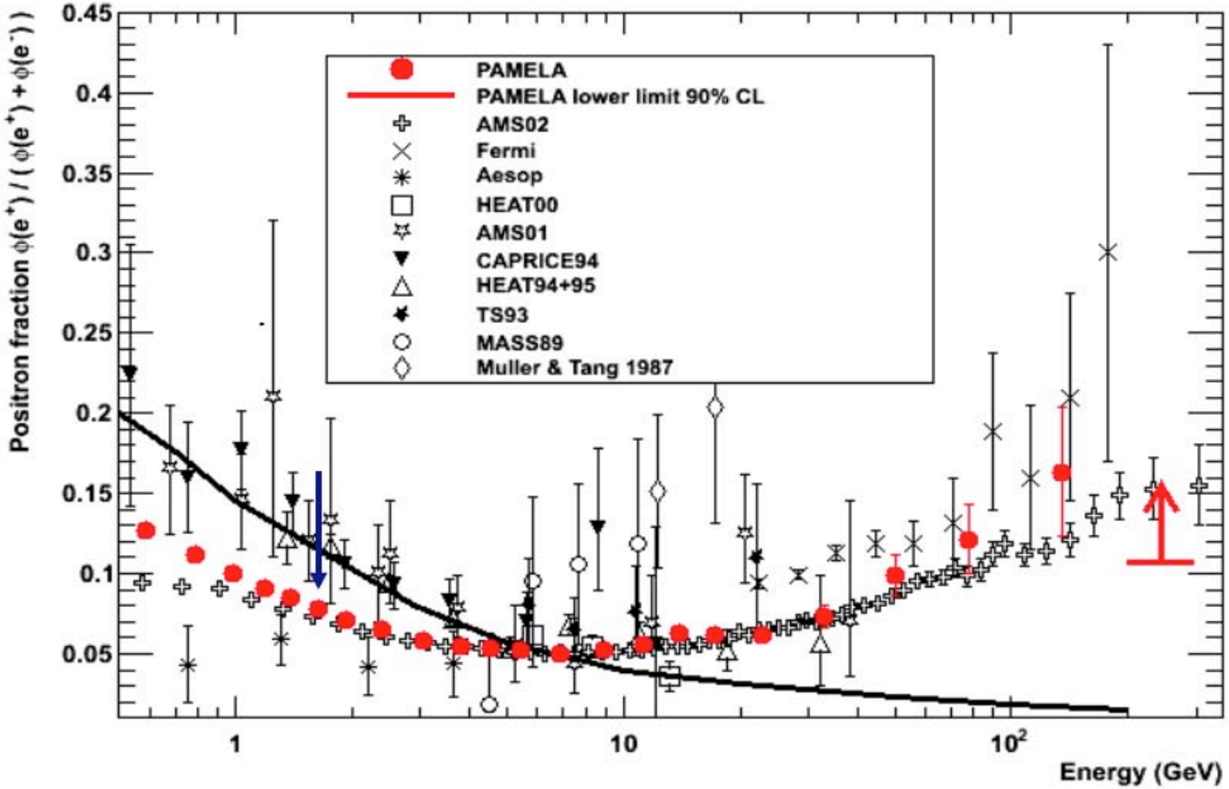
●Summary of the Electron Spectrum by Various Experiments

ICRC, Rio, (2013) Rapporteur Talk by J.W.Mitchell.

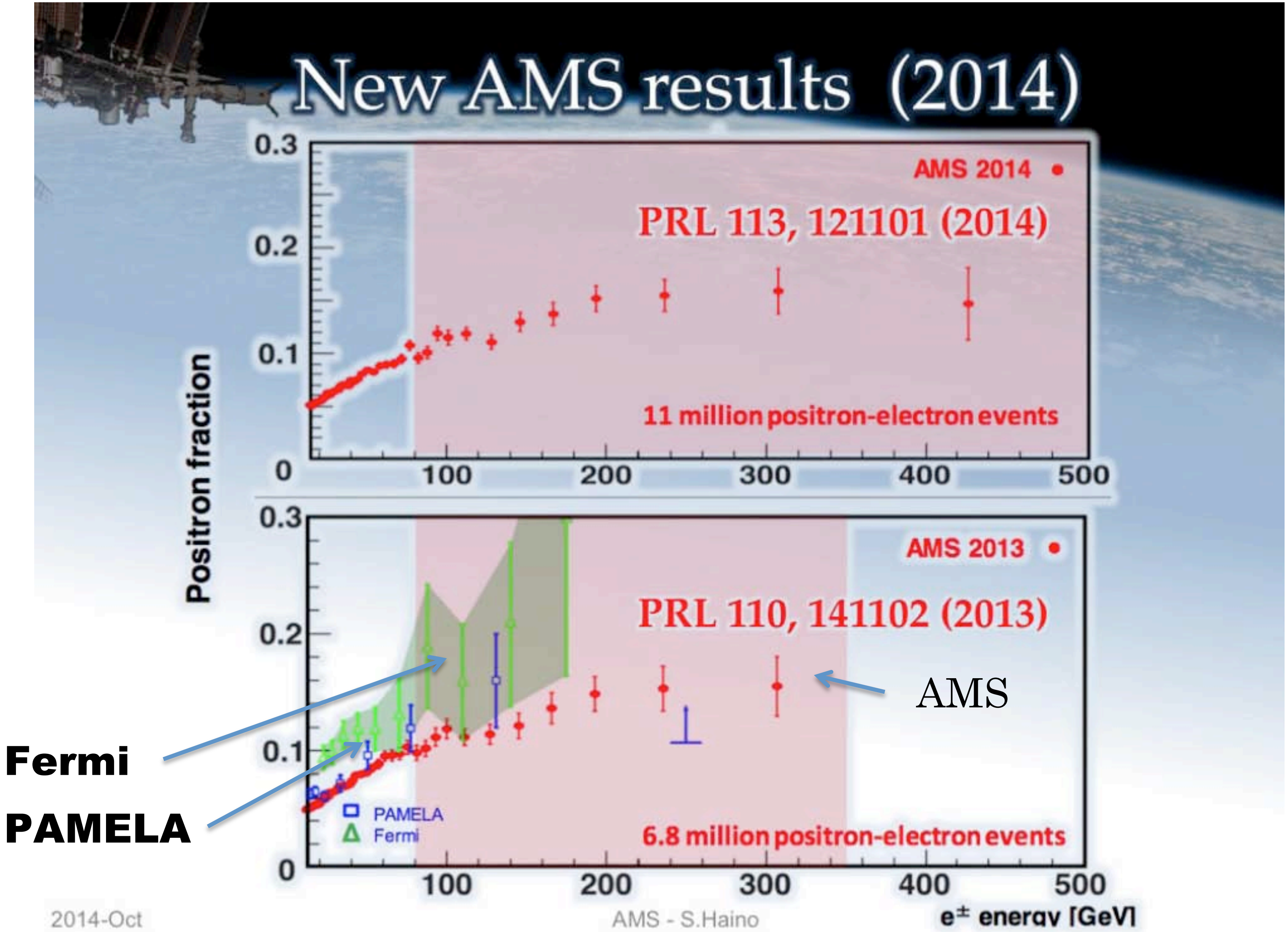


● Positron Excess is Observed

PAMELA, AMS and FERMI Positron Fraction
Compared to Expectation



The Most Recent Data by AMS , Pamela and Fermi



● **What is the sources of Positron Components??.**

Other sources of Positrons different from secondary's

Produced by the collisions of

Cosmic Rays + Inter stellar gas.

Source ? : Dark matter,

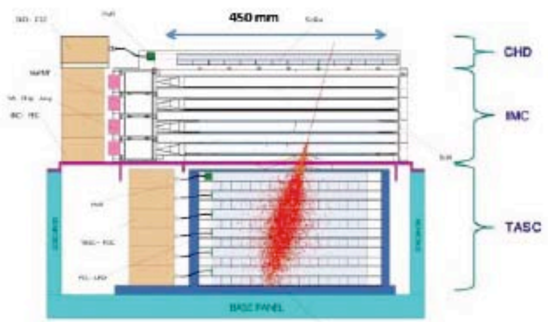
Nearby Pulsars,

Nearby Super nova.

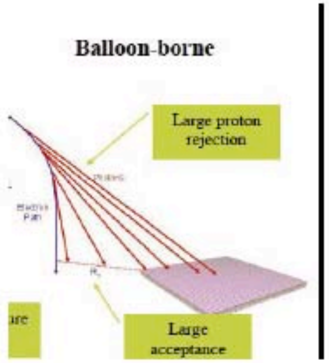
Many papers and conjectures.

To be discussed in this meeting.

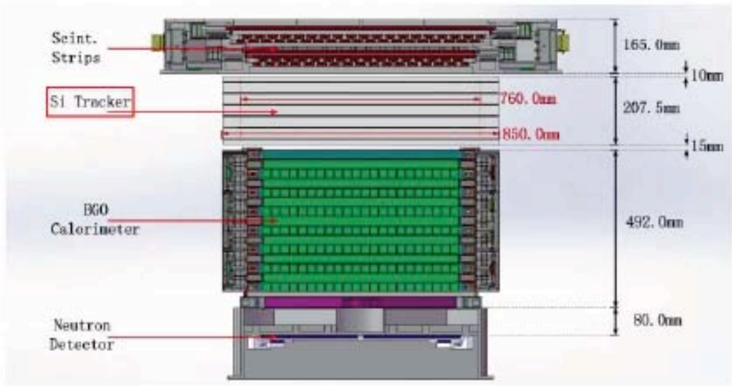
● Upcoming Programs to Explore the Electron Spectrum from GeV to beyond TeV.



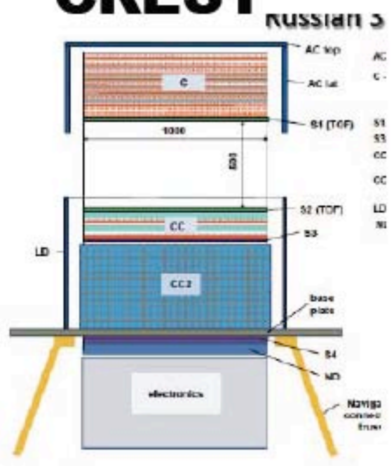
ECC→ Calet (2015)



CREST



ATIC→DAMPE(2016?)



GAMMA 400 (2020)

Deep Appreciations to Prof. Hayakawa !!.

For his tremendous efforts to develop the high-energy astrophysics in our country, with his pioneering works, stimulations and outstanding leadership for many years from his young days of the late 1940's.

Hoping a Good Success of

the 5th Fermi Symposium

In Nagoya.

End

Addendum

Who Found the MUONS

Nedermeyer-Anderson; Street-Stevenson; Nishina-Takeuchi-Ichimiya

E.R.Bagge→	P.Kunze	(1933)
....	←H.Yukawa	(1935)
J.Wheeler →	A-N	(1936)
B.Rossi →	N-A + S-S	(1937)
J.C.Street →	J.F.Carson & J.R.Oppenheimer	(1937)
P.M.S.Blackett →	N-A + S-S + N-T-I	(1937)
A.Pais →	C.F.Powell (π—μ)	(1947)

- N-A: S.H. Neddermeyer and C.D.Anderson

  S-S : J.C.Street and A.C. Stevenson

  N-T-I: Y.Nishina ,M.Takeuchi and T. Ichimiya

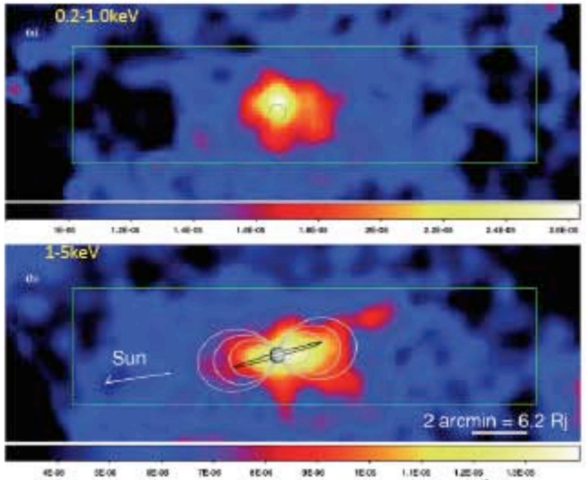
Accepted and Publication Date of Muon Finding.

	Accepted date	Publication Date
Kunze:	Mar.24 (1933)	Z.Phys. (1933)
Neddermeyer, Anderson:	Mar. 30 (1937)	Phys. Rev.May.15
Street, Stevenson.1:	Meeting (April 29, 1937)	Phys. Rev.June.1
Street, Stevenson *.2:	Oct.6 (1937)	Phys. Rev.L.Nov.1
Nishina, Takeuchi, Ichimiya* :	Aug.28 (1937)	Phys. Rev .Dec.1

* The paper of Nishina accepted one month earlier than Street's, but was published one month later, since it was too long as a letter paper.

Suzaku highlights: from the solar system to clusters of galaxies

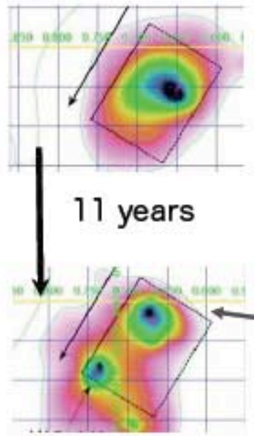
Discovery of hard X-ray (1-5keV) emission from the torus of Jupiter Io



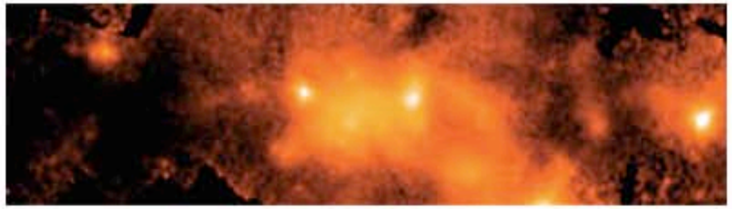
Ezoe et al. 2010

Activities of the center of our Galaxy

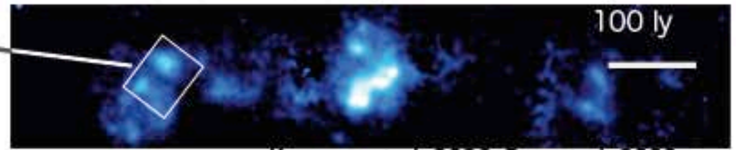
ASCA



Continuum spectrum (hot plasma)

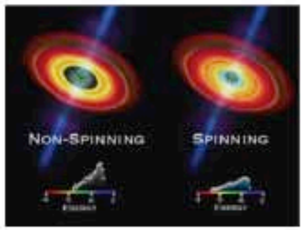


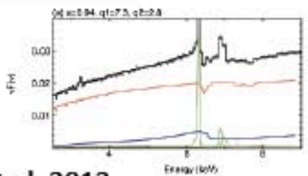
Neutral Iron emission line (molecular cloud)



Koyama et al. 2006, Ryu et al. 2009

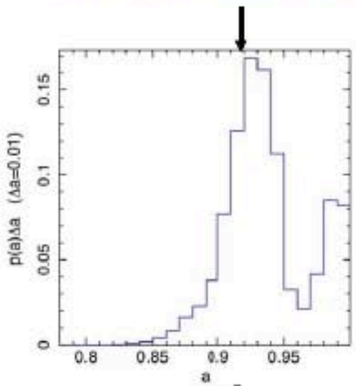
Constraints on black-hole spin of active galactic nuclei from iron emission line





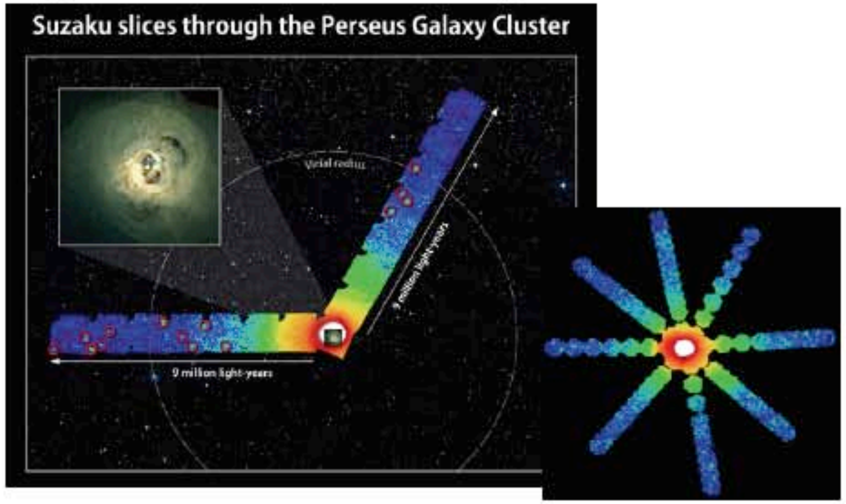
Reynolds et al. 2012

90% of the relativistic limit



$$a = \frac{cJ}{GM^2}$$

Probing outer limb of clusters of galaxies



Simionescu et al. 2011, Allen 2012

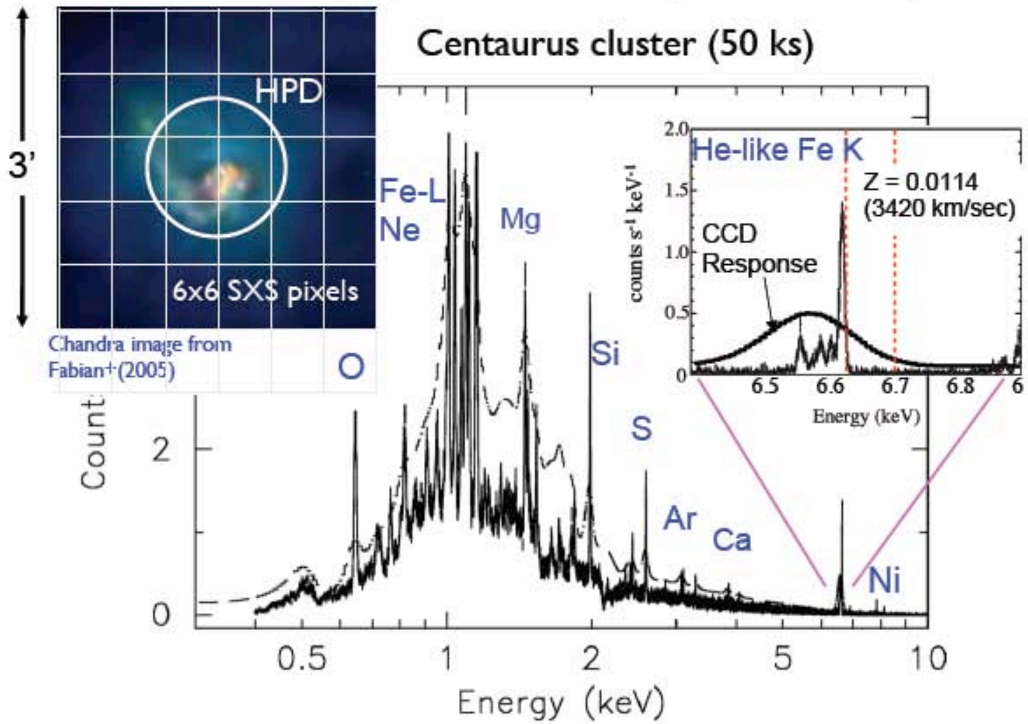
Launch: JFY 2015 (planned)

ASTRO-H

Main objectives:

- To uncover entire picture of galaxy-cluster energy budget; thermal, kinetic, and non-thermal energies, and to directly trace the dynamic evolutions of galaxy clusters.
- Measure the motion of matter governed by gravitational distortion at extreme proximity of black holes, and reveal the structure of relativistic space-time.

Soft X-ray Spectrometer (simulation)



Hard X-ray Telescope + imager (simulation)