

# External User Perspectives

1. Experimental Interests at NIF at a High Level
2. What I believe it will Take to Make NIF a Success as User Facility

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NIF-JUPITER User Group Meeting  
Sept. 6, 2009

Hotel InterContinental San Francisco, CA, USA

# Introduction

- **Exotic Laser Plasmas with PW**

- Electron Positron Plasma

- K. Nakajima and H. Takabe, *Numerical Study of “Positron Energy Spectrum Produced by Ultra-intense Lasers”*, Phys. Plasmas **9**, 1505-1512 (2002).

- Laser Nuclear & Particle Physics

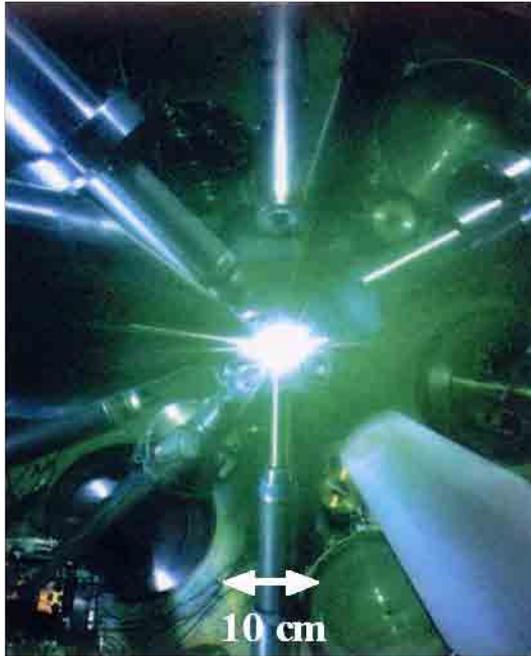
- A. I. Titov, B. Kämpfer and H. Takabe  
    *”Di-muon production by laser-wake-field accelerated electrons”*, submitted to Physical Review (2009)

- **Laboratory Astrophysics with MJ**

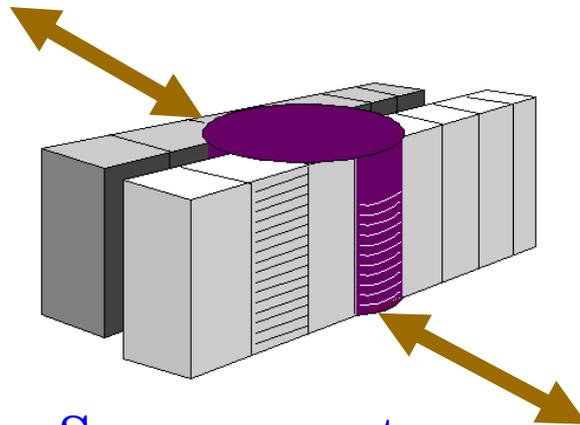
- I have many but propose two main subjects

# What is Laboratory Astrophysics ?

1. Test bed for Numerical Astrophysics
2. New Finding of Physics not Expected
3. Prediction of Astrophysical Phenomena
4. Provide Challenging Plasma Physics



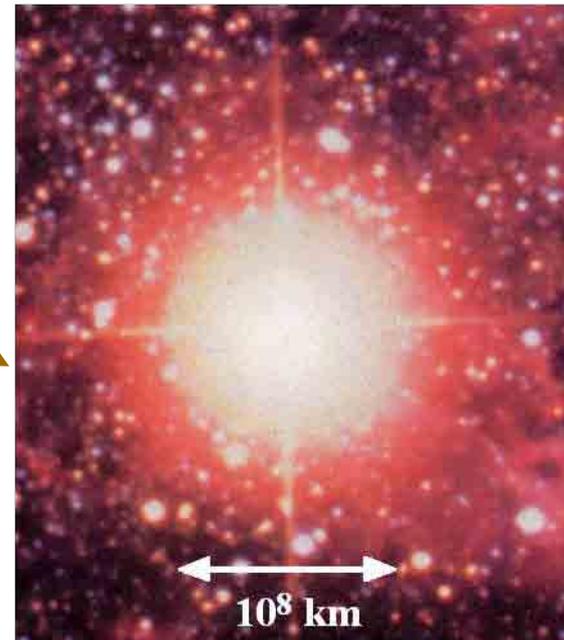
Model Experiment



Supercomputer

( $\times 10^{14}$ )

Space & Time



Supernova

# What is Laboratory Astrophysics ?



1. Test bed for Nuclear Astrophysics
2. New Findings: Physics not Expected
3. Probing Physical Phenomena
4. Impact on Physics

*Exciting discovery-driven research that has high scientific merit to fund (by F. Iorio, DOE)*

at time



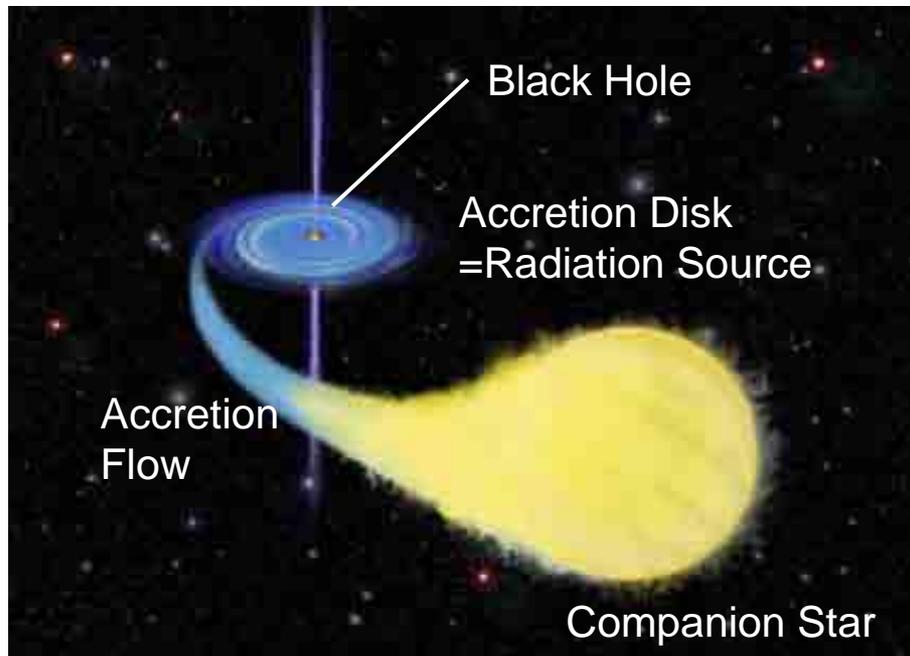
# *High Level Proposal - 1*

- Photo-ionized Non-LTE Plasma in Binary System with Compact Objects; WD, NS, and BH.
- Thermal Radiation Temperature is
  - One to two kilo-electron-Volt ( $T_r=1-2\text{keV}$ )
  - Chandra has wide range spectroscopic instrument
  - Highest in Universe as Planckian Radiation is about 5 keV from Black Hole with Halo.
- Only NIF can realize 5 keV Radiation Source

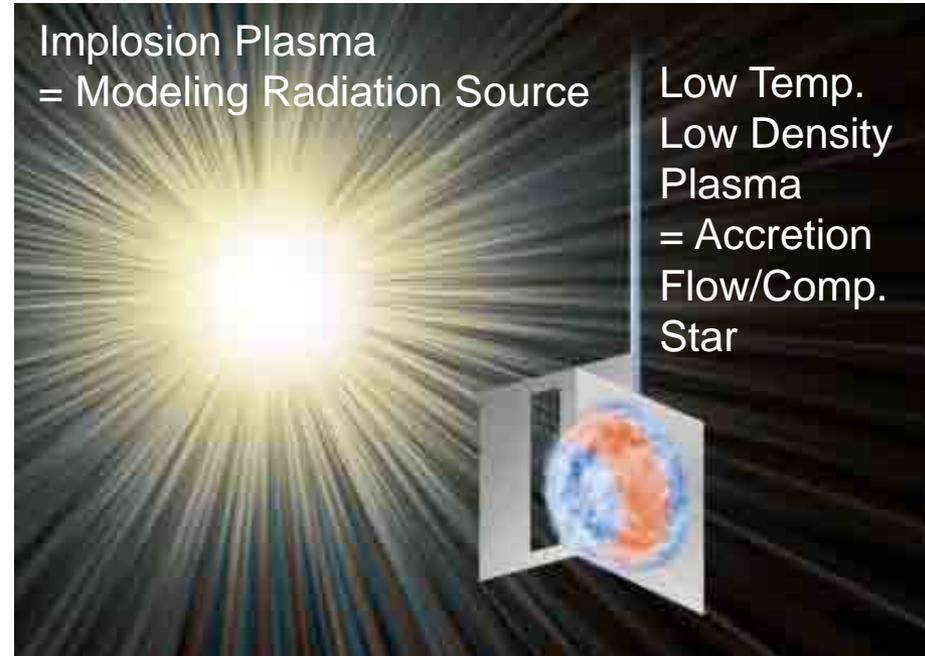


# We Could Realize Extremely High Radiation Temperature Source to Model Radiation Source of Compact Objects, NS, BH.

## Black Hole Binary

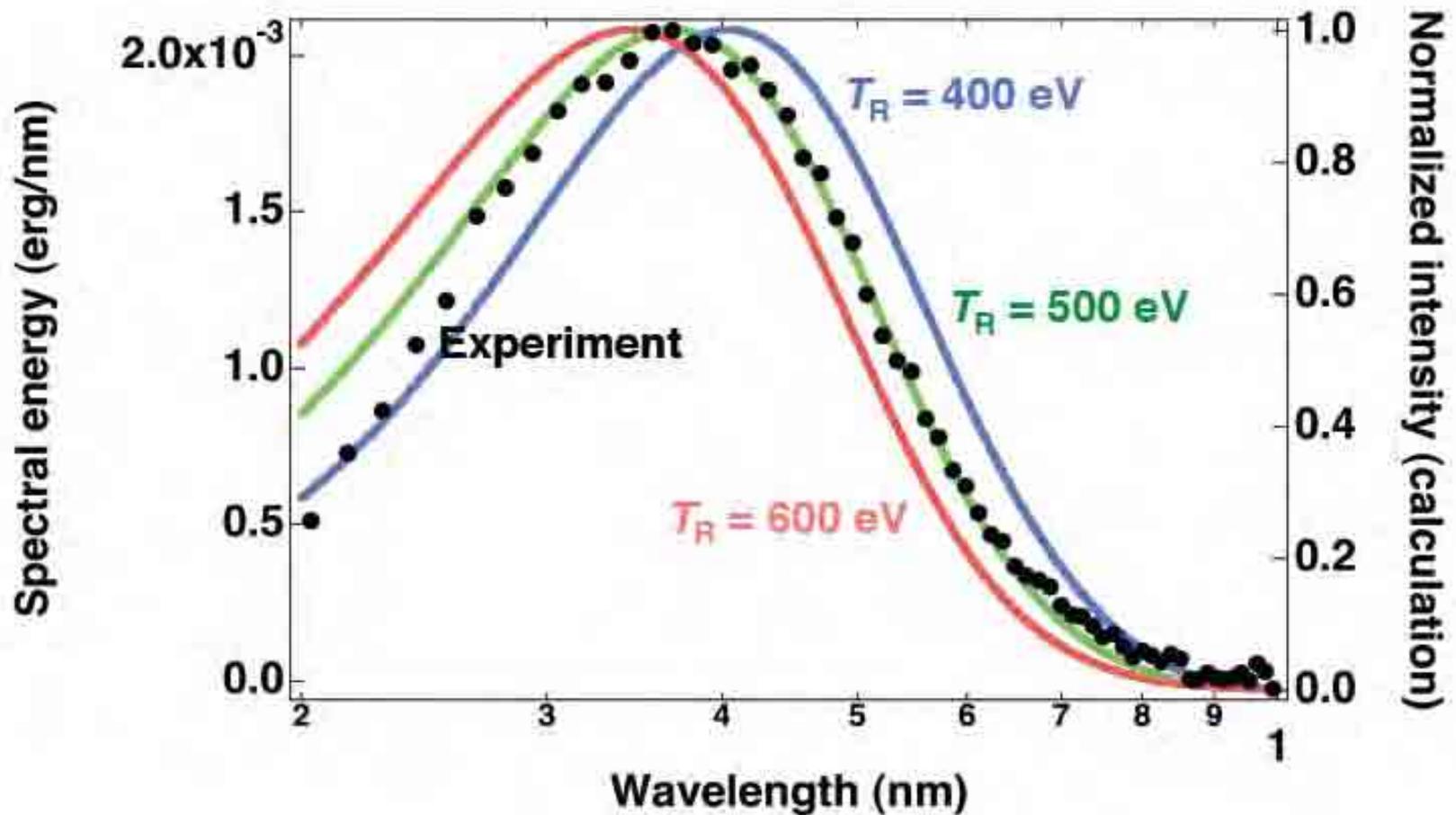


## Modeling BH Binary



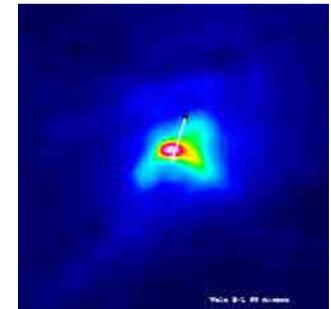
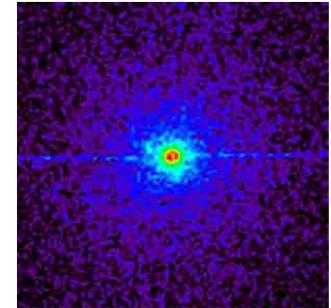
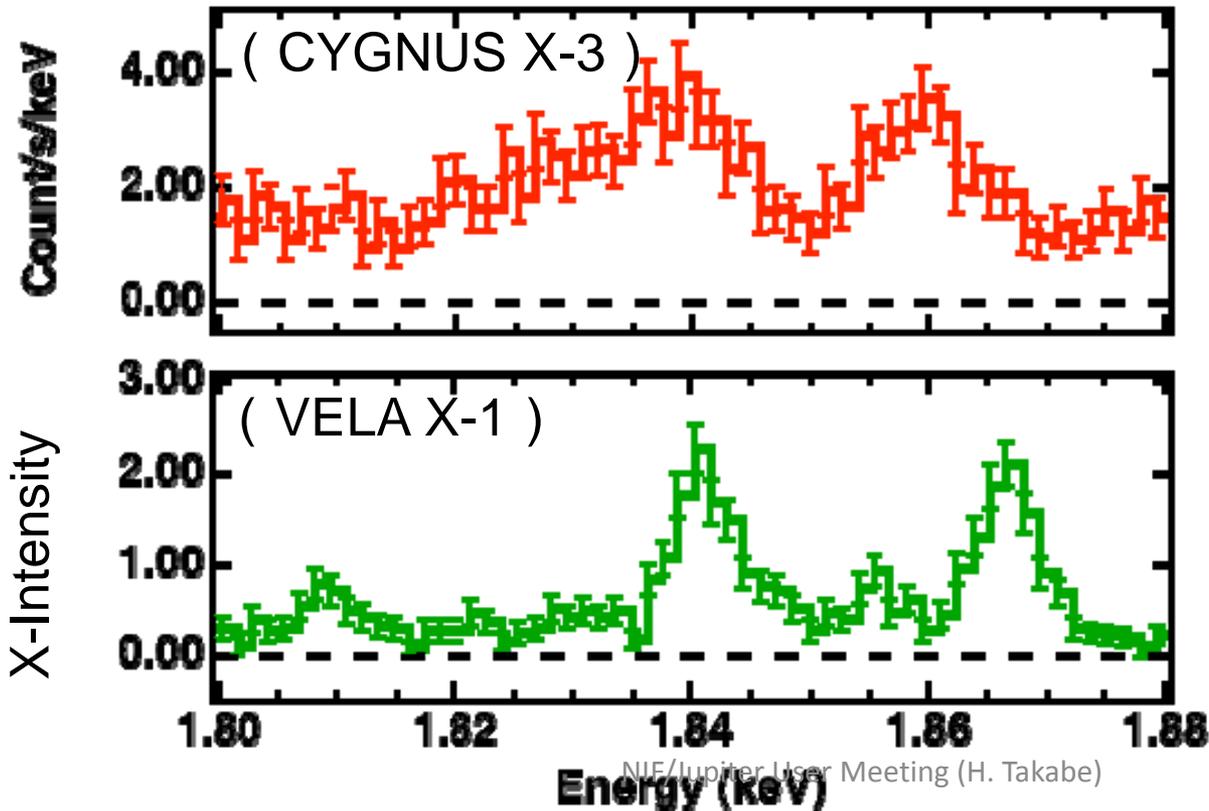
**Only NIF Can Achieve the Highest Radiation Temperature 5 keV, the Highest of BH**

# Spectrum from Imploded CH Core Plasma

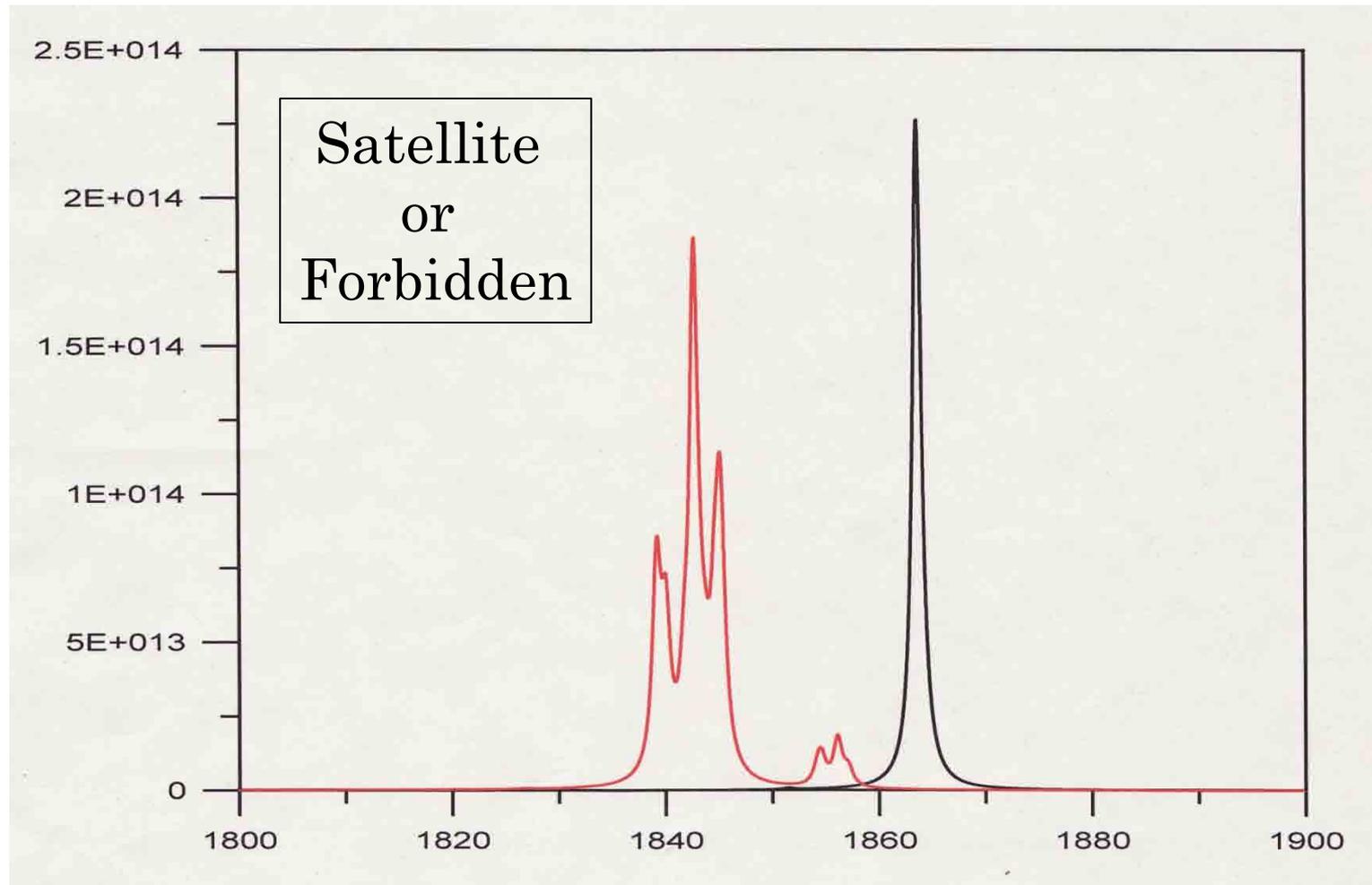


Gekko XII could achieve  $T_e = 0.5$  keV and we demonstrated that we can do model experiment to obtain the same spectrum of Silicon He-like line emission.

Experiment



# Details of Theoretical Spectrum



**We expect Inverse-population in X-ray region:  
Prediction of X-ray Laser Objects in Universe**

# *High Level Proposal - 2*

- Collisionless Shock Formation by Self-generated Magnetic Field
- Most of Shocks in Universe are Collisionless, not Hydrodynamic Shocks.
- Origin of Cosmic-Ray is 100-years-standing Big Question in Astrophysics.
- Charged Acceleration and Power Law Spectrum
- Only NIF can produce a large-scale, long-live plasma to observe whole physics scinarion.

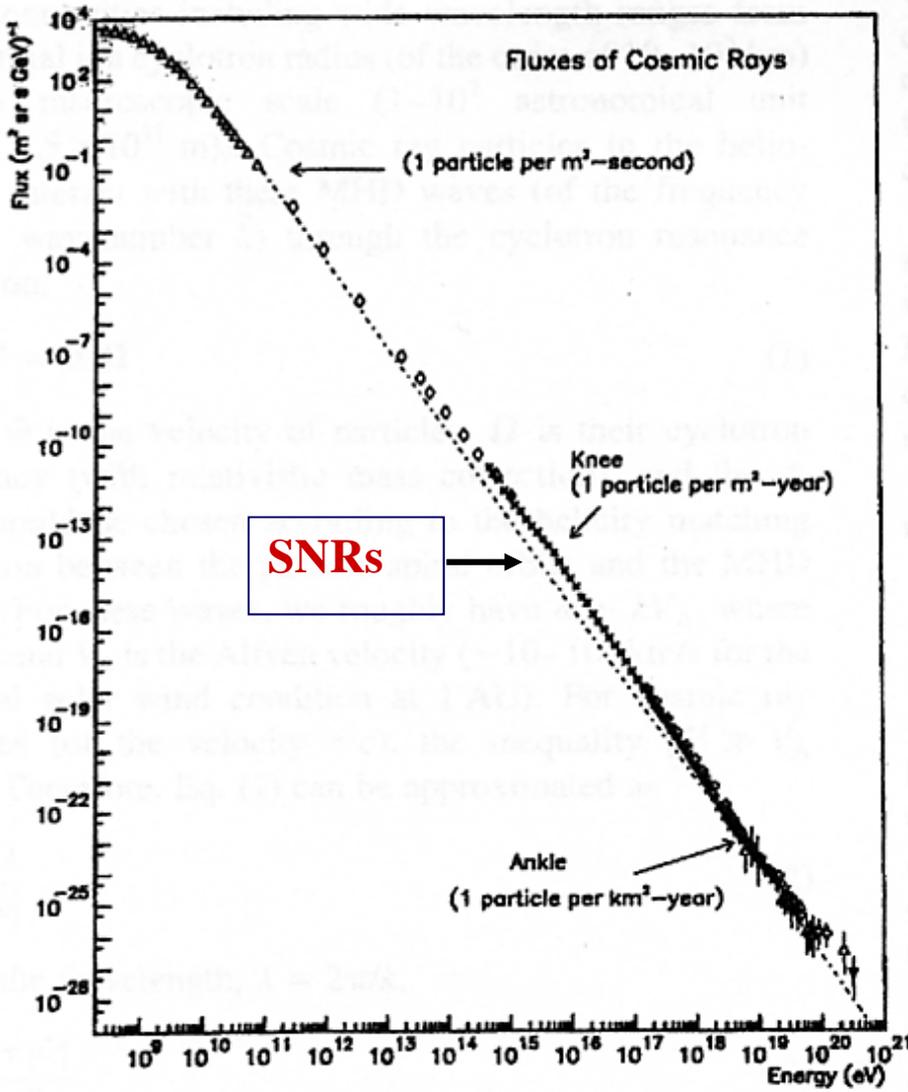
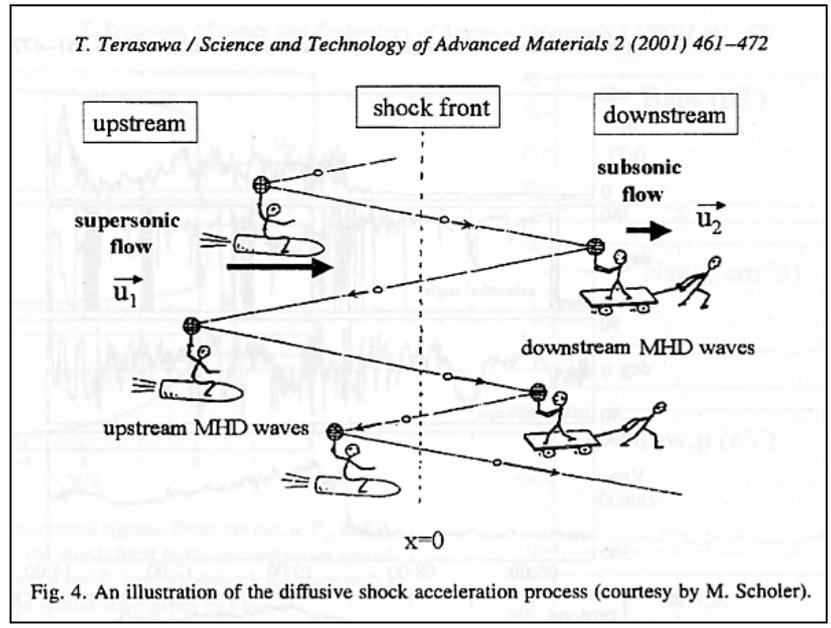
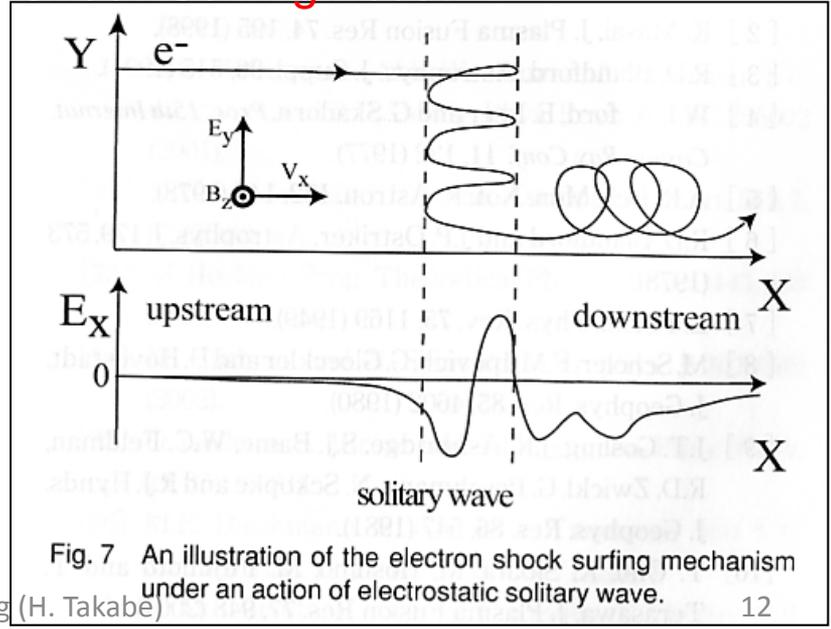


Fig. 2. Energy dependence of the flux of nonthermal particles, namely cosmic rays, in the cosmic plasma around us (by S. Swordy, cited from Cronin [9]).

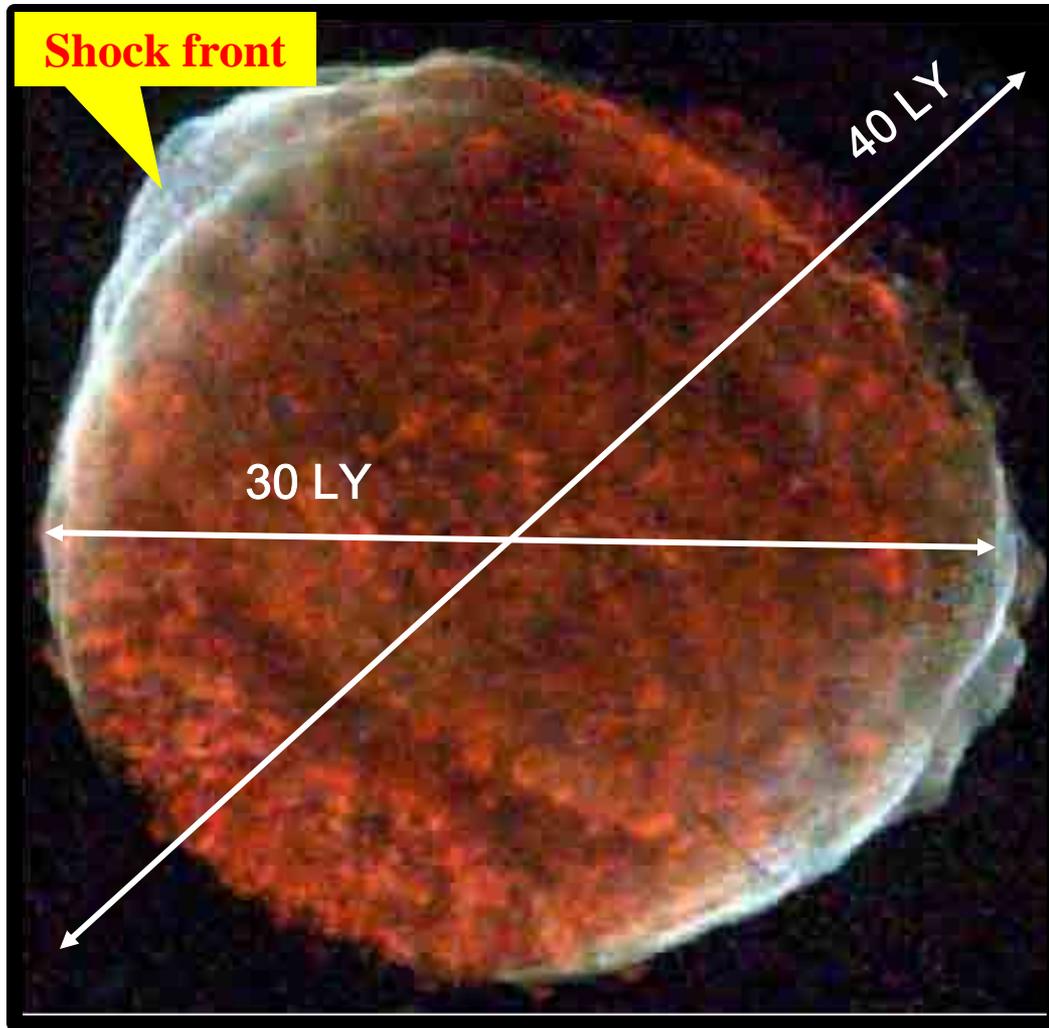
## Diffusive Shock Accel.



## Shock Surfing Accel.



# Typical Example of Collisionless Shocks (SNR)



X-ray Image of SN1006,  
exploded 1003 years ago

$$n = 1 \text{ cm}^{-3}$$

$$T = 15 \text{ keV}$$



**Mean-free-path: 40 ly**  
**Diameter of SNR: 30 ly**



□ Effect of EM wave ( ? )  
□ Accelerated electrons  
emitting X-ray

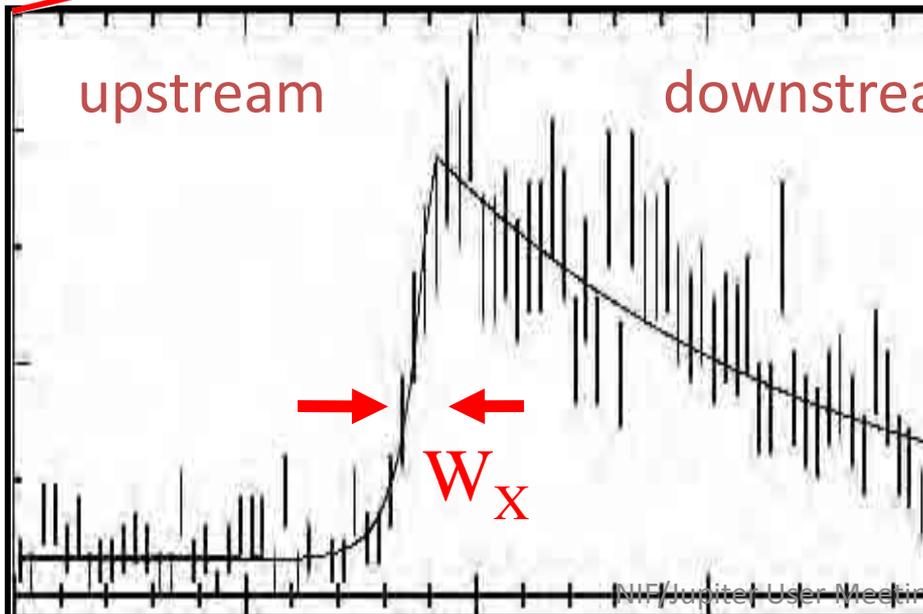
# SNR is Accelerator in Universe

## 1 . Relativistic Syclotron Emission

$$h\nu_{\text{rce}} = 2 \text{ keV} \left( \frac{B}{10\mu\text{G}} \right) \left( \frac{E_e}{10^{14} \text{ eV}} \right)^2$$

## 2 . Shock Thickness (Observation)

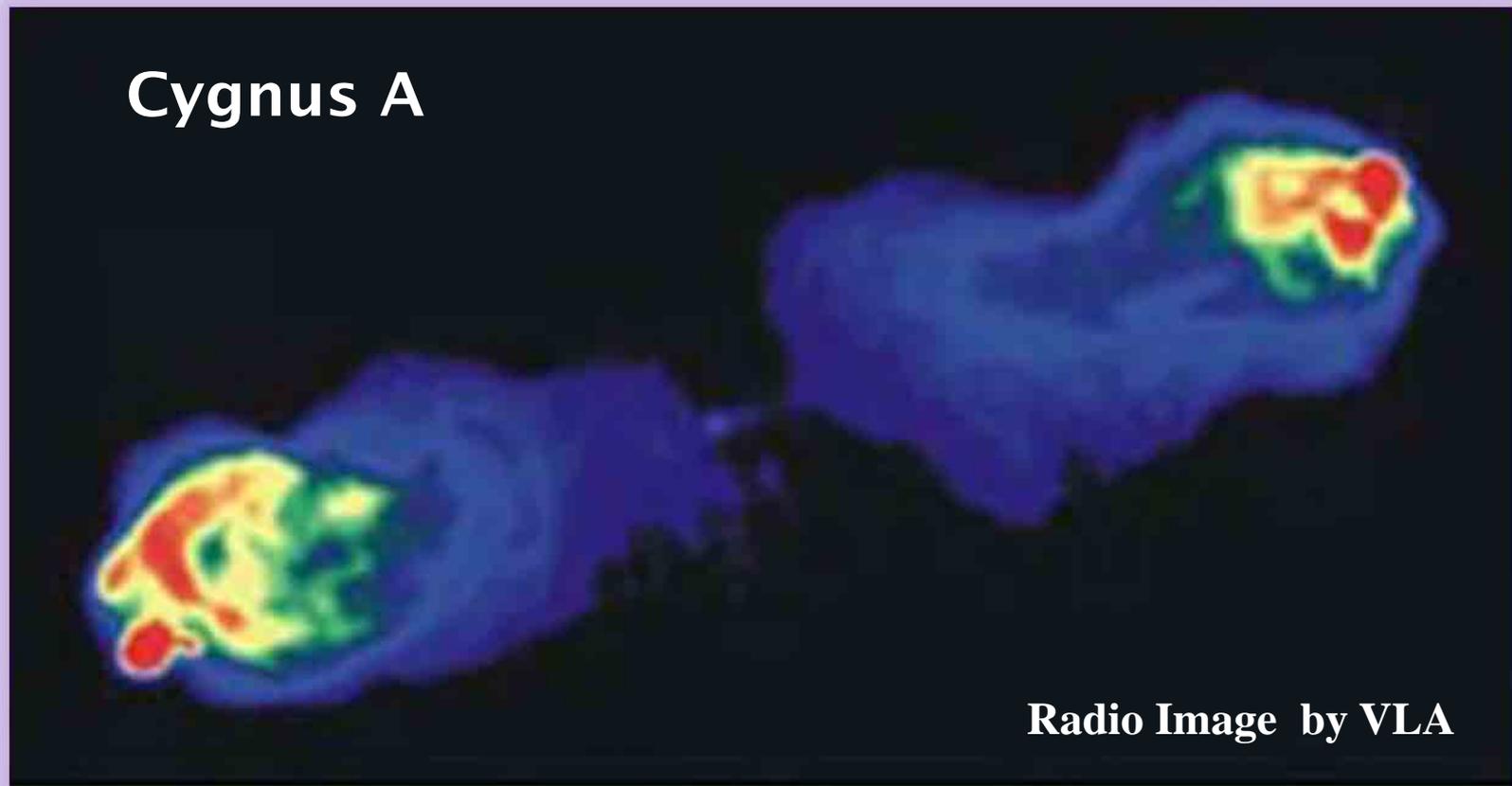
$$W_X = 1 \times 10^{17} \text{ cm} (=1/400 l_{\text{mfp}})$$



# Collisionless Bow Shocks by AGN Jet are Provable Candidate for Highest Energy Particle Accelerator

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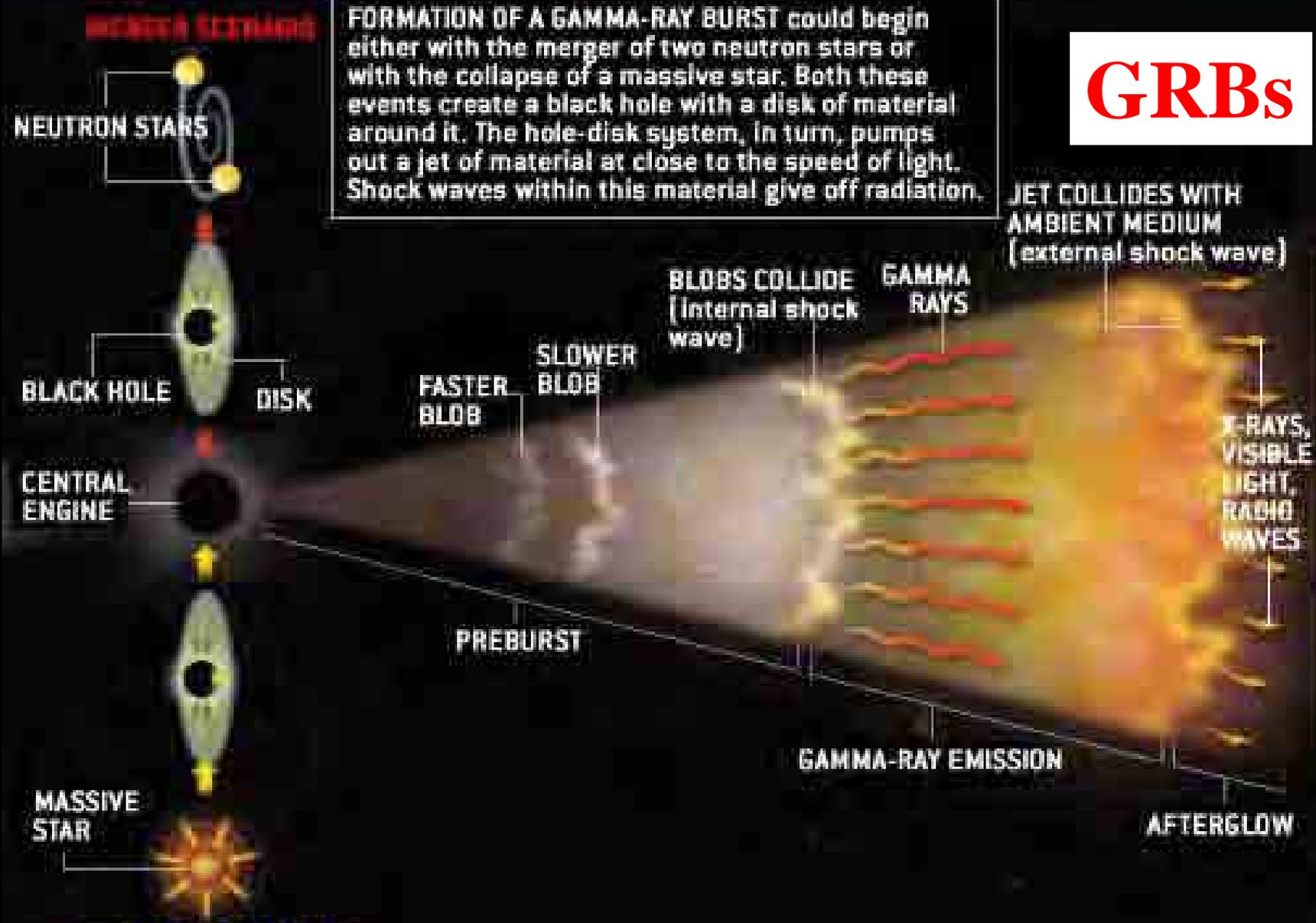
1. Pair Plasma Jet
2.  $\Gamma \sim 10$



# BURSTING OUT

## GRBs

FORMATION OF A GAMMA-RAY BURST could begin either with the merger of two neutron stars or with the collapse of a massive star. Both these events create a black hole with a disk of material around it. The hole-disk system, in turn, pumps out a jet of material at close to the speed of light. Shock waves within this material give off radiation.



HYPERNOVA SCENARIO

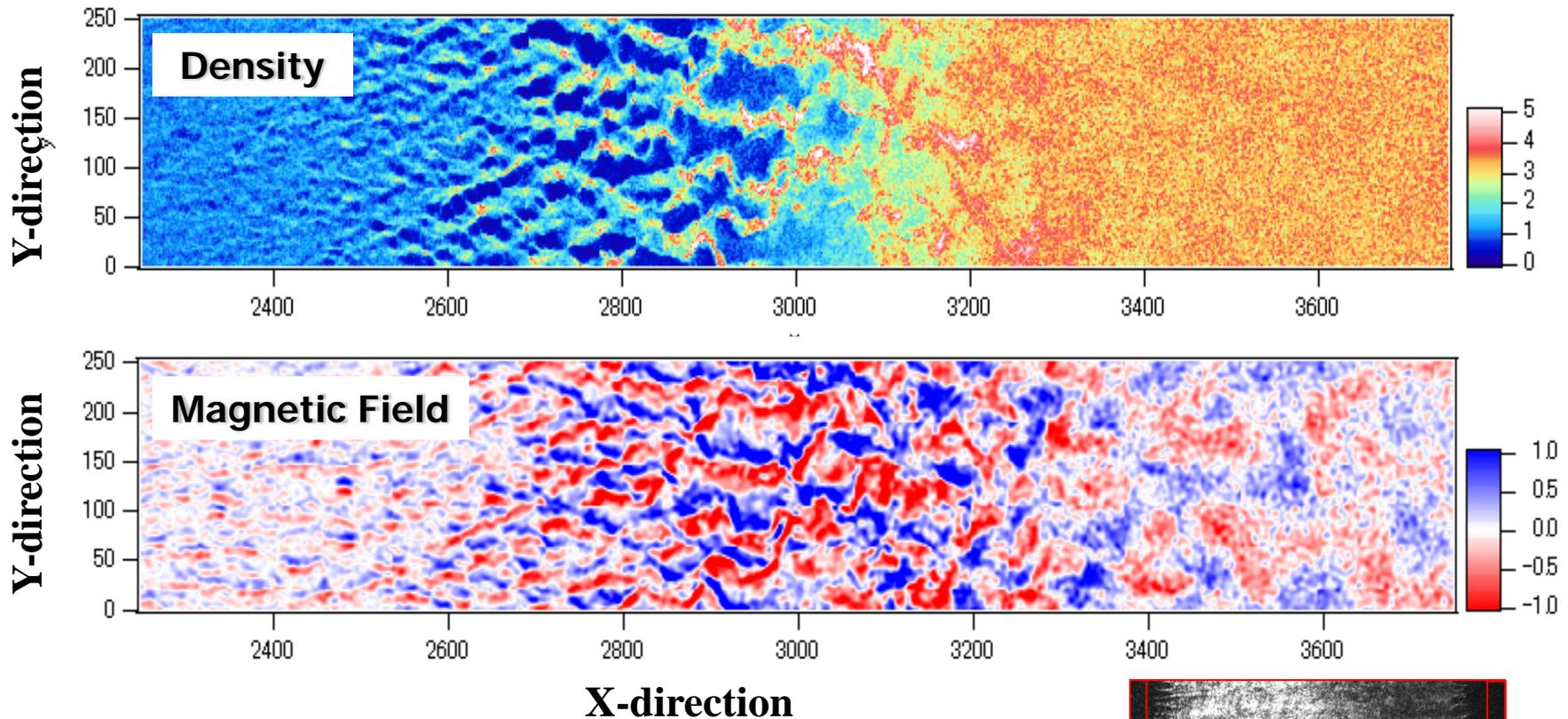
HYPERNOVA SCENARIO

JUAN VELASCO

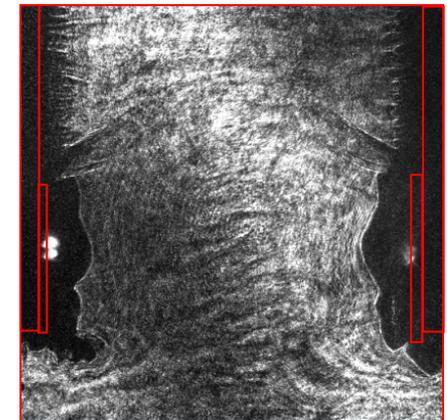
NIF/Jupiter User Meeting (H. Takabe)

N. Gehrels et al., Scientific American, December (2002)

# Collisionless Shock Formation by Weibel Instability

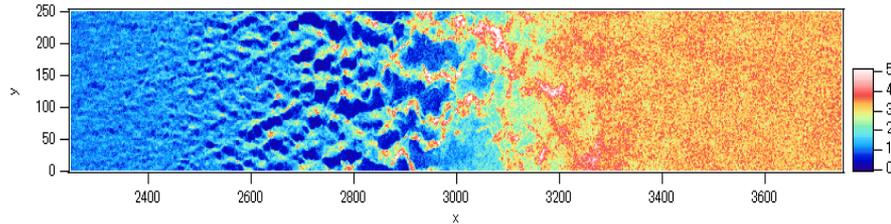


- 0 . No magnetic field and Flow from right
- 1 . Linear grow of Weibel Instability
- 2 . Filament coalisence by NL effect, **B** getting stronger
- 3 . **B** grows, Ion orbit is modified, finally self-organization occurs

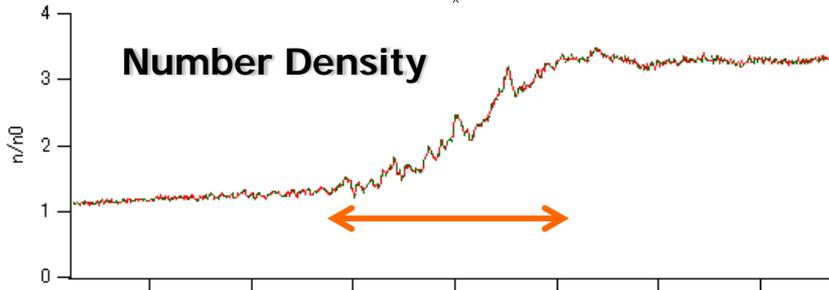


**Experimental Data**

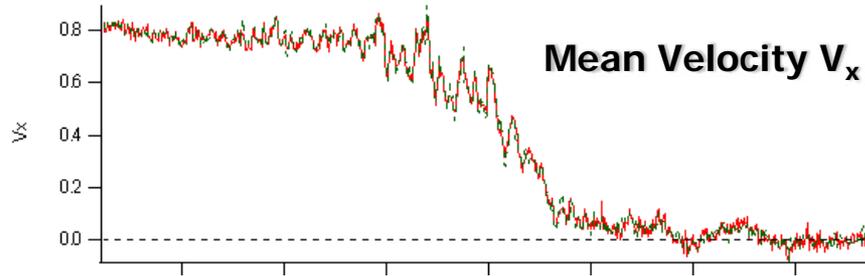
## Transition Region



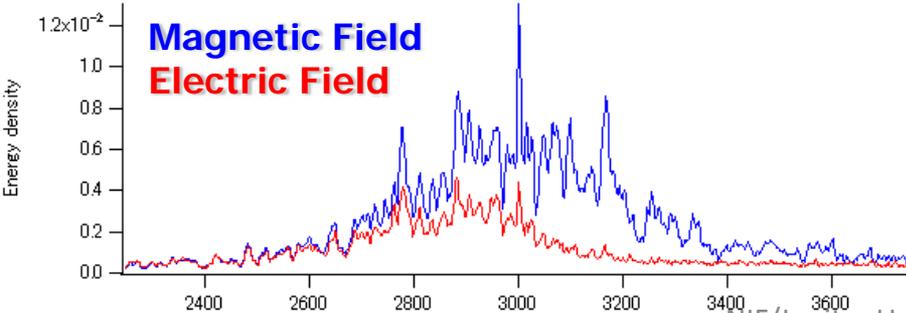
Number Density



Mean Velocity  $V_x$

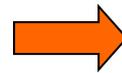


Magnetic Field  
Electric Field



# Shock Wave Formation and Profiles

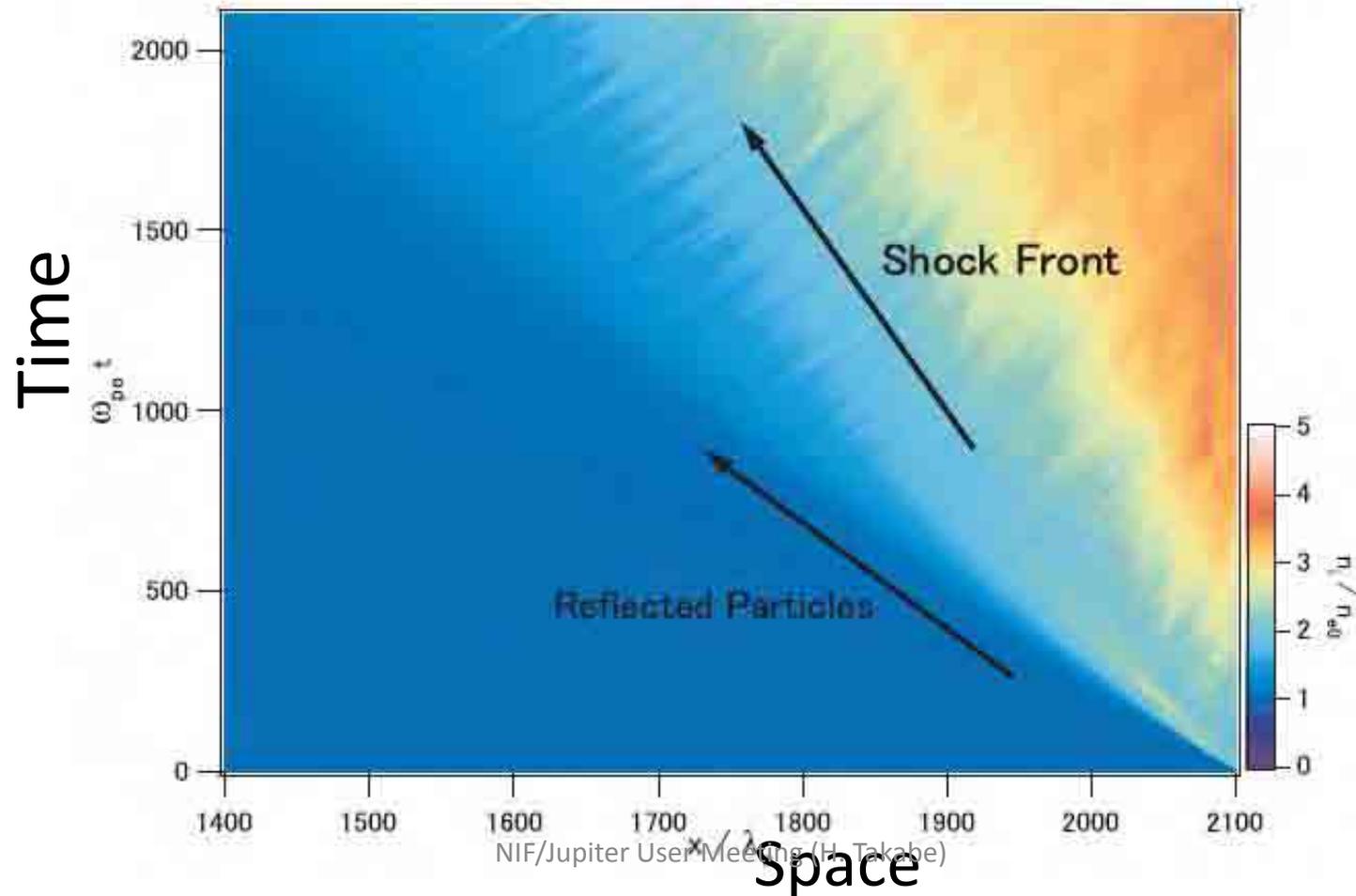
Strong magnetic field provides an **effective dissipation mechanism** for the upstream plasma



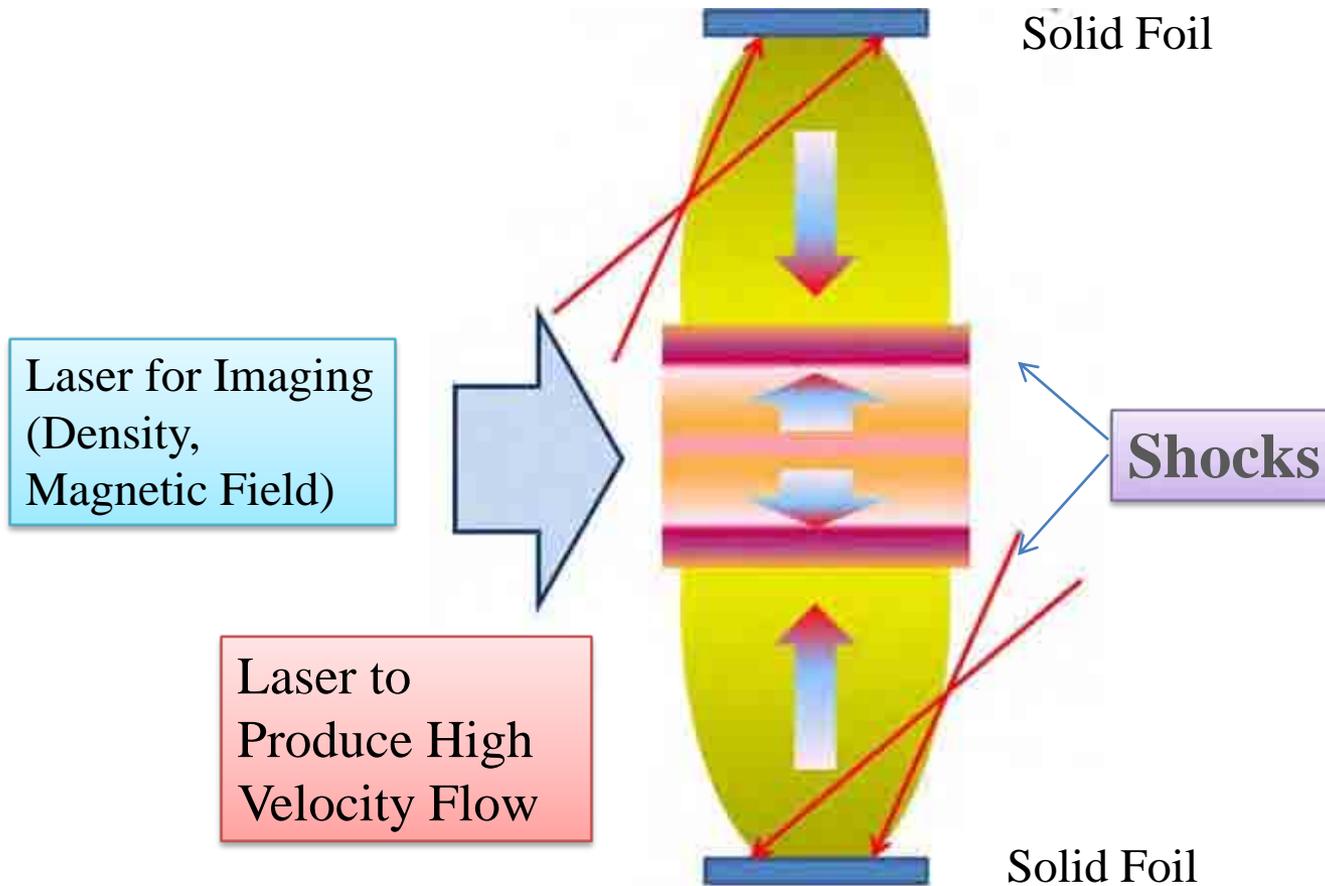
# NON-RELATIVISTIC COLLISIONLESS SHOCKS IN UNMAGNETIZED ELECTRON-ION PLASMAS

Tsunehiko N. Kato and Hideaki Takabe

*Astrophysical Journal* 681, L93 (2008)



# Model Experiments



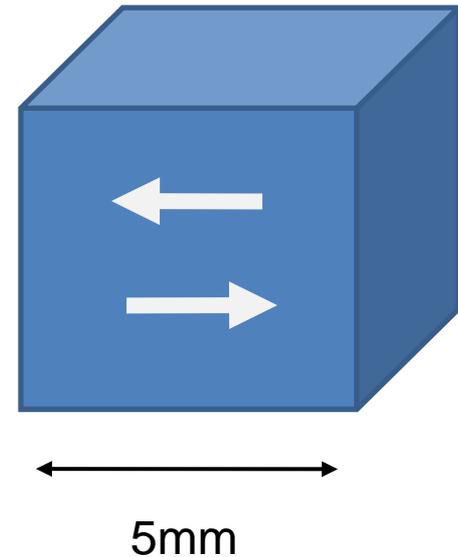
# We Need NIF to Demonstrate Universality

## 1. Shock width

$$\Delta X = 0.2 \text{ cm} \times \frac{1}{Z} \sqrt{\frac{A}{n_{20}}}$$

## 2. Coulomb mean-free-path

$$l = \frac{1}{n\sigma_0 \ln\Lambda} = 20 \text{ cm} \times \frac{A^2 V_8^4}{Z^4 n_{20}}$$



## 3. Energy of counter-streaming plasma

$$\begin{aligned} E &= 1/2 Z m_p n_i V^2 L^3 \\ &= 35 \text{ kJ} \end{aligned}$$

$$\begin{aligned} n_{20} &= n / 10^{20} \text{ cm}^{-3} \\ V_8 &= V / 10^8 \text{ cm/s} \end{aligned}$$

# UV 16frames×100 ps Shadow graph (Diagnostic System to be Developed)

Timing Signal from  
Main Lasers

Sync

Trigger Signal

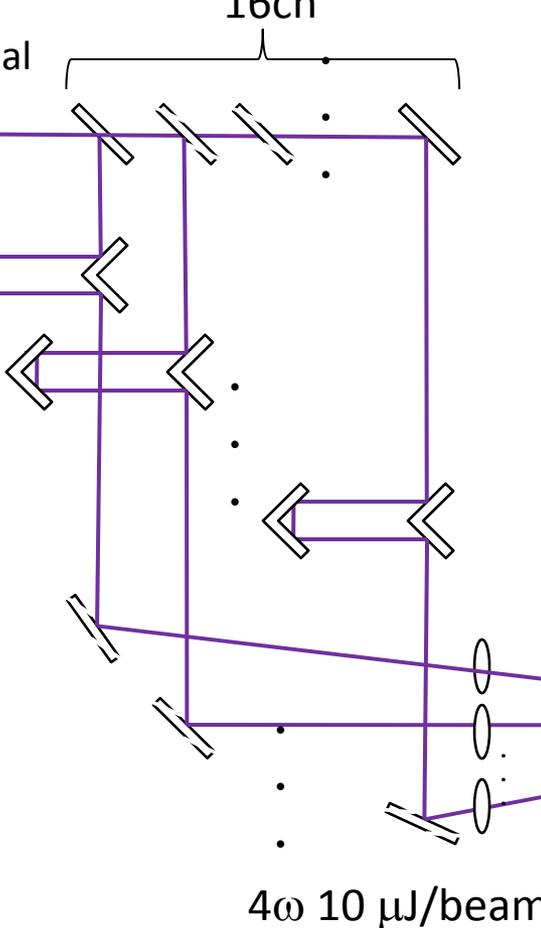
Nd3+:YAG  
RGA

4 $\omega$

16ch

1064 nm, 10 ps  
10 Hz, 1.2 mJ

delay arm  
0-10 ns



~KJ,  $\omega$ , 3 ns

4 $\omega$  10  $\mu$ J/beam

UV  
→Visible

CCD

*2. What I believe it will  
Take to Make NIF a  
Success as User  
Facilities*

# World Facilities for Laboratory Astrophysics Research



RAL, UK

Osaka, JP



UoR, US



Ecole.P, FR



Shanghai, CN

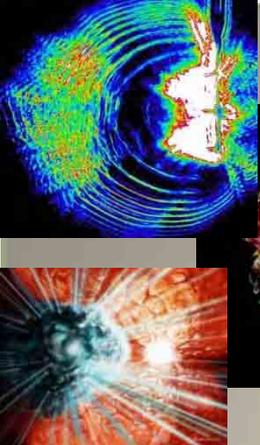


Livermore, US

Asia :  
2  
US : 2

# *Motta*

- A Collaborator should be a Good Competitor
- Scientists should always think of what we aim at and prepare for the next generation; for our sons and daughters.
- NIF should be the central facility of inter-disciplinary researches; HUB to create new disciplines.
- When you drink water, think of people who made the source of water.



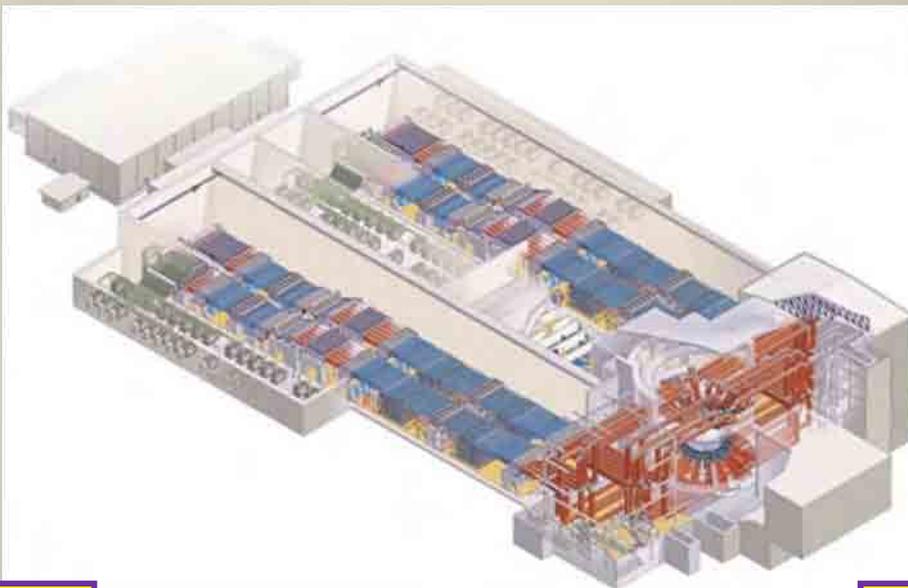
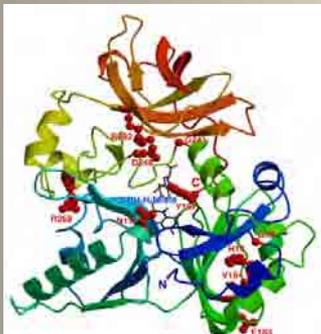
## Laser Astrophysics

# NIF Should Attract Many Academic Societies

## Laser Accelerator



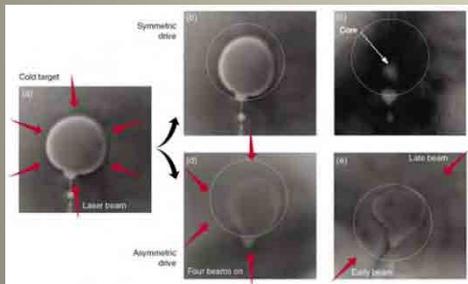
## Laser Biology



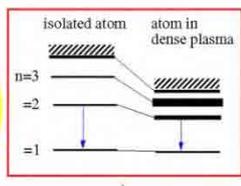
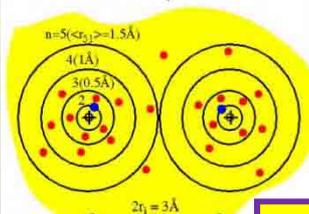
## Laser Nuclear Physics



## Advanced Diagnostics



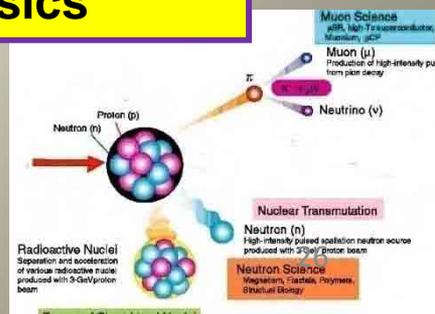
hydrogen-like Al at  $n_e = 7 \times 10^{23} \text{ cm}^{-3}$



for  $T_e = 500 \text{ eV}$ :  
 $E_{\text{coll}} = 10 \text{ eV}$   
 $E_{\text{coll}} = 4 \text{ eV}$   
 therm (strongly coupled)

## High-Pressure Physics

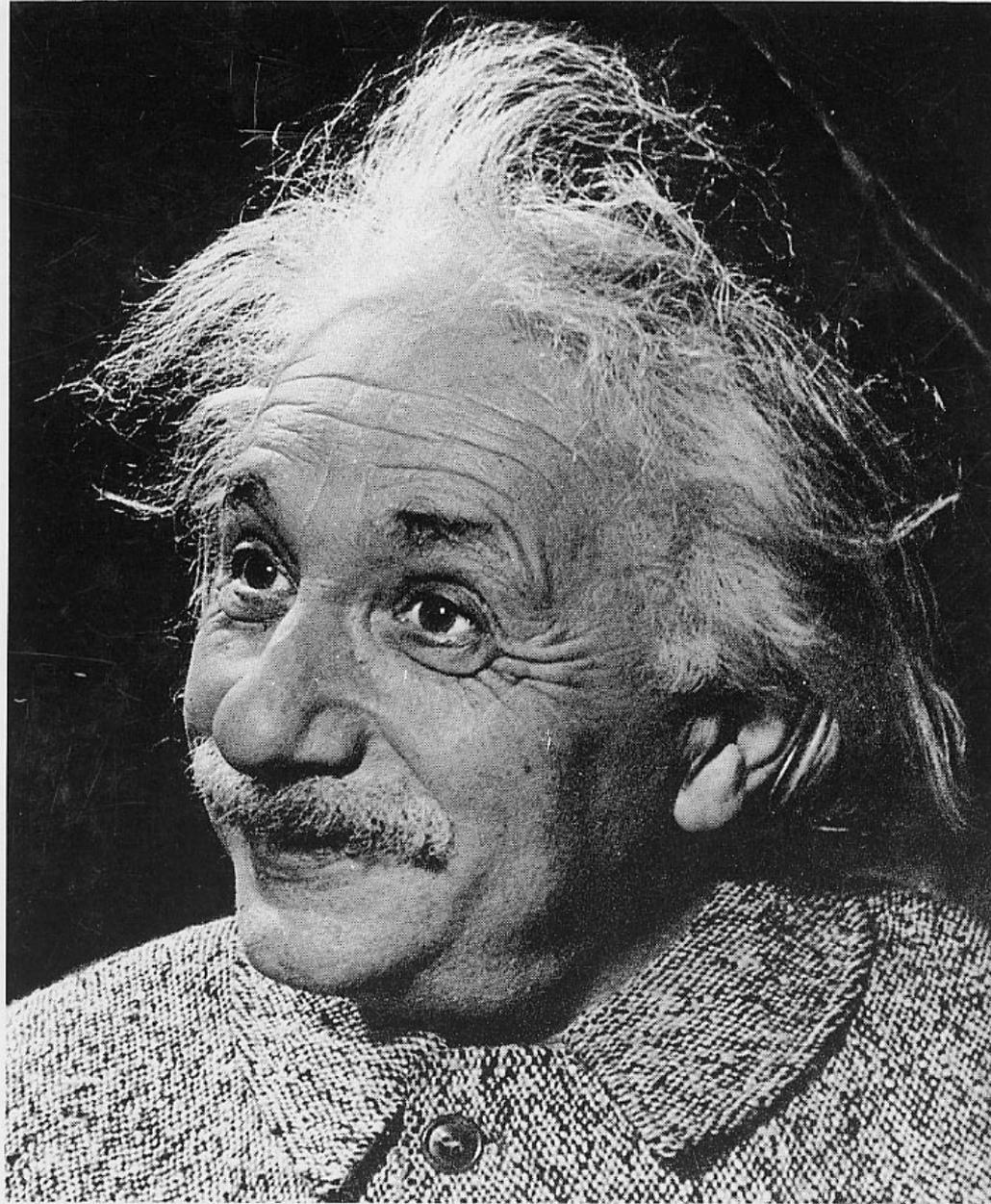
## Laser Particle Physics



# Increase of Users from Different Fields is very Important

*Key Word for Success of NIF  
as User Facility*

- 1. Inter-Society*
- 2. Inter-Disciplinary*
- 3. Inter-National*



*"Imagination is more important than knowledge"*

*Albert Einstein*

*Laboratory astrophysics calls for your imagination to make NIF a success as user facility*

*Hideaki Takabe*

# Announcement



## Asia-Europe Physics Summit (ASEPS)

March 24-26, 2010 Tsukuba (Japan)

*"Physics towards science innovations"*

The AAPPS (Association of the Asia-Pacific Physical Societies) and the EPS (European Physical Society) are happy to announce the first Asia-Europe Physics Summit (<http://aseps.kek.jp>):

**"Physics towards Science Innovations"**

to be held in Tsukuba (Japan) on March 24-26, 2010.

This Summit aims at strengthening the cooperation in physics research between European and Asian scientists, physics institutions and countries. A balanced partnership between Europe, Asia and America is a crucial aspect of any world-wide endeavor in the field of science and technology. The Summit will deal with programs addressing either issues in fundamental physics or physics research playing a significant role in other fields (i.e. biology, chemistry, earth, space sciences ...).