SAND2006-6468C

Basic science measurements at Z

Z Users Workshop

Santa Fe, New Mexico

October 16, 2006

J. E. Bailey (jebaile@sandia.gov)

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Sandia National Laboratories

Z offers many opportunities for basic science investigations

"you guys are sitting on a gold mine"
--Bruce Remington, LLNL

Why is Z so interesting for basic science?

-- The large energy available can create extreme conditions in relatively large volumes, for relatively long times.

A useful reference:
R.W. Lee, R. Petrasso, and R. Falcone
"The possibilities for scientific use of high energy density lasers: From now to the NIF"
www.llnl.gov/science_on_lasers

Sandia National Laboratories

Basic science benefits NNSA missions

- **Basic science collaborations stimulate new ideas and sharpen our thinking**

- **Information transfer is a two way street**
(e.g., Chandra & XMM are Billion $ investments)

- **We need to recruit next-generation NNSA scientists**

- **A broader pool of proposal idea will intensify competition and help ensure the very best quality science gets done**

Sandia National Laboratories

Successful user groups will share common elements

- **Committed participation by someone on site is a pre-requisite to success**

- **Diagnostic implementation is a multi-year process**
  - **Year 1: fabricate and field protoype, obtain proof of principle data**
  - **Year 2: refine and exploit**

Question: How can we improve our agility *and* maintain quality?

- **Ride-alongs are invaluable for developing techniques:**
  - **target fab**
  - **diagnostics**
  - **experiment design**

- **High quality results must be obtained with relatively few shots**

- **Basic science user groups may require funding commitment duration that is compatible with student participation**

There are many topics that provide “grand-challenge” level basic science opportunities

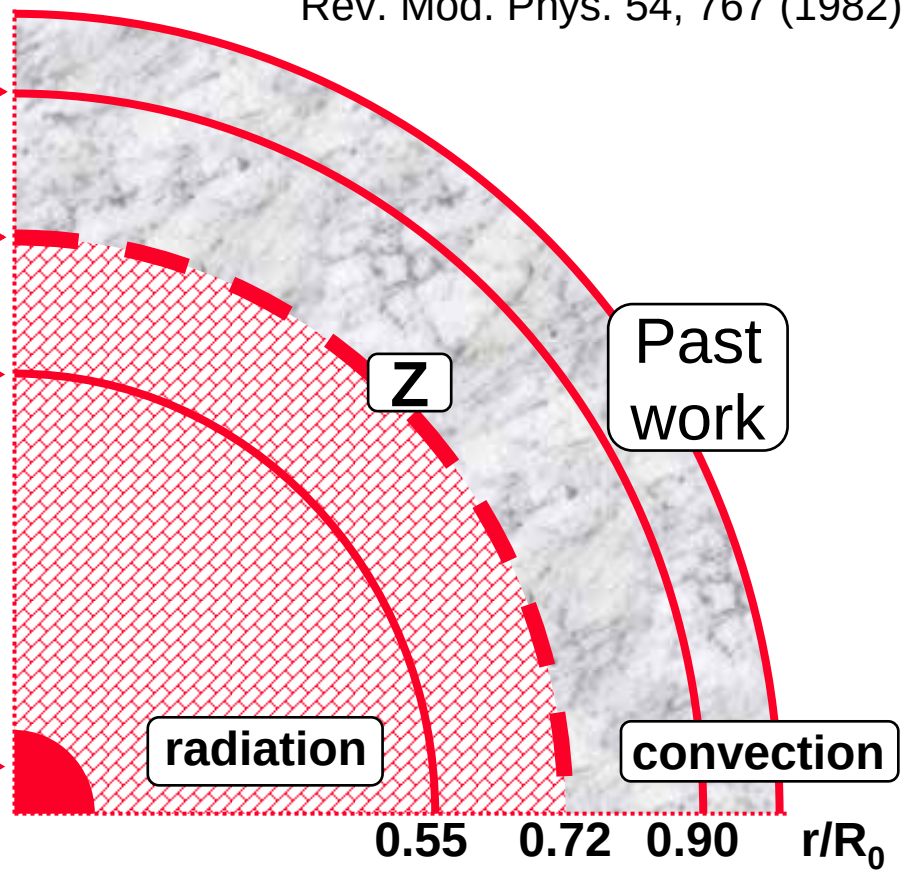
Grand-Challenge extensions of past work:
Stellar opacity
Photoionized plasma kinetics
Jets
Radiative shocks

Possible new Grand Challenges (more speculative!):
Atoms in strong fields
Electron-ion equilibration
Ionization of shocked solid density matter
Plasma physics of photoionized nebula
Properties of solid density plasmas
Conversion of magnetic energy into thermal energy
Lattice dynamics of shocked materials
Equation of state for the earth’s interior

Laboratory opacity measurements at stellar interior conditions are possible for the first time

T(eV)	n_e (cm^{-3})	ρ (g/cc)
54	$1x10^{22}$	0.025
182	$9x10^{22}$	0.18
293	$4x10^{23}$	0.77
1360	$6x10^{25}$	157

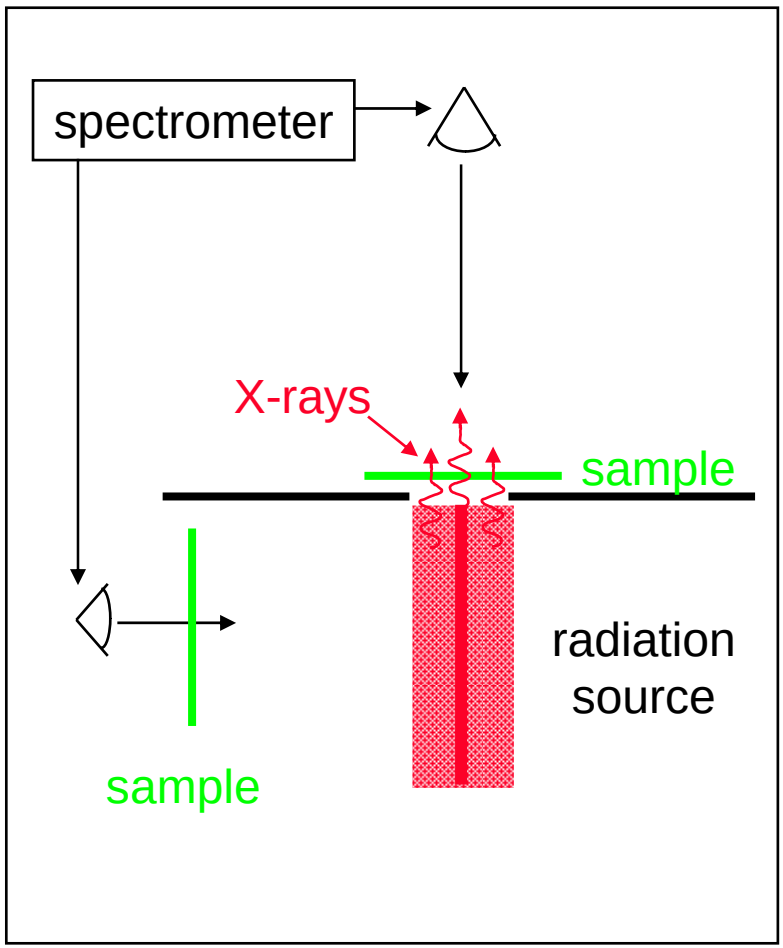
Solar model : J.N. Bahcall et al, Rev. Mod. Phys. 54, 767 (1982)

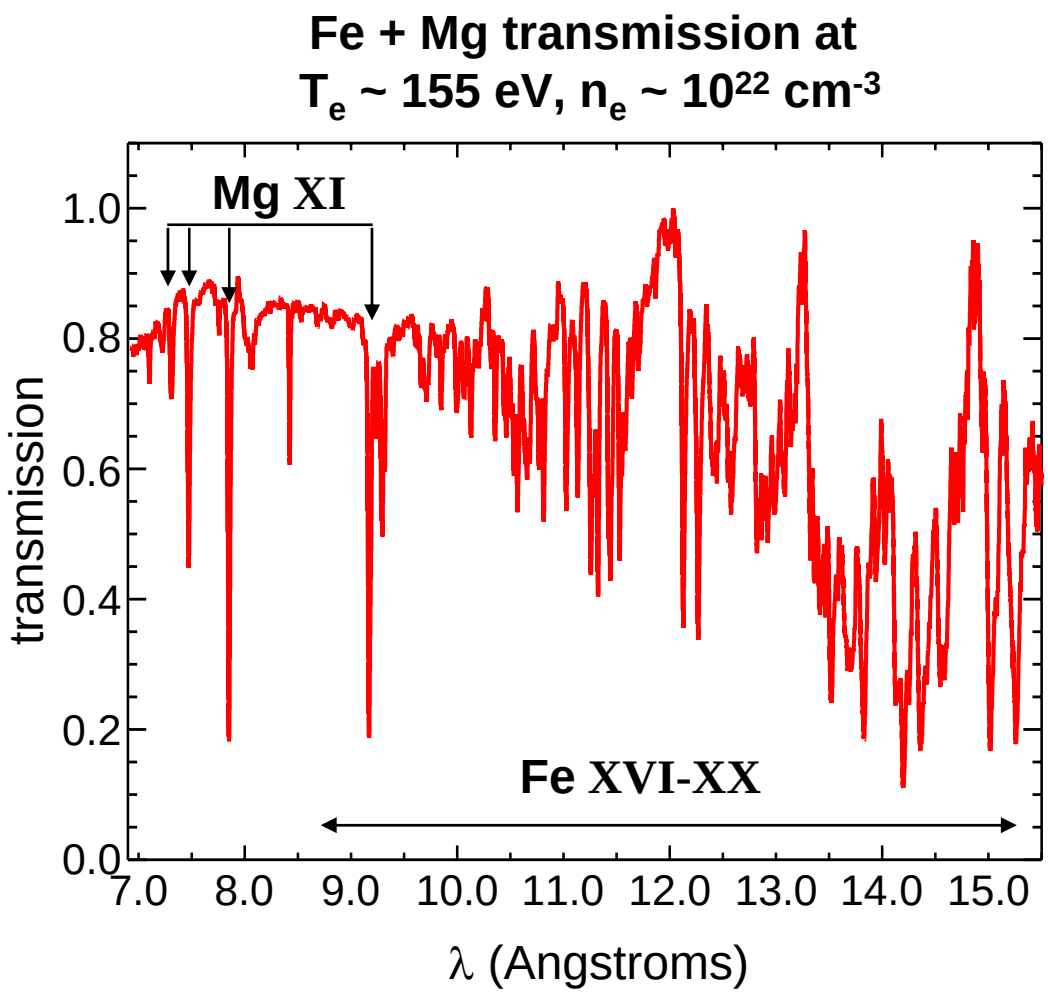


This is just one of many situations requiring quality opacity data

Sandia National Laboratories

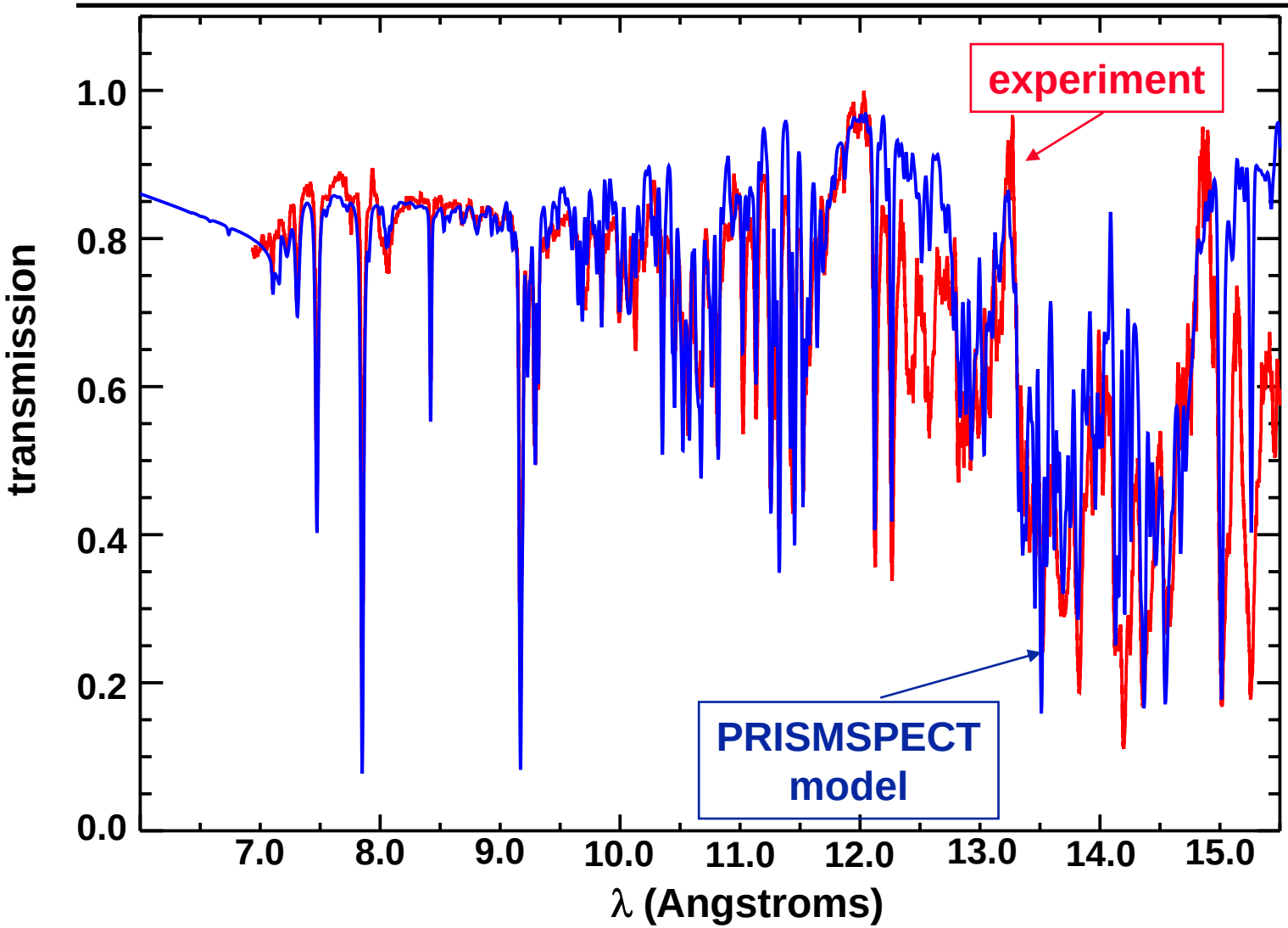
Z opacity experiments extend measurements beyond T ~ 150 eV





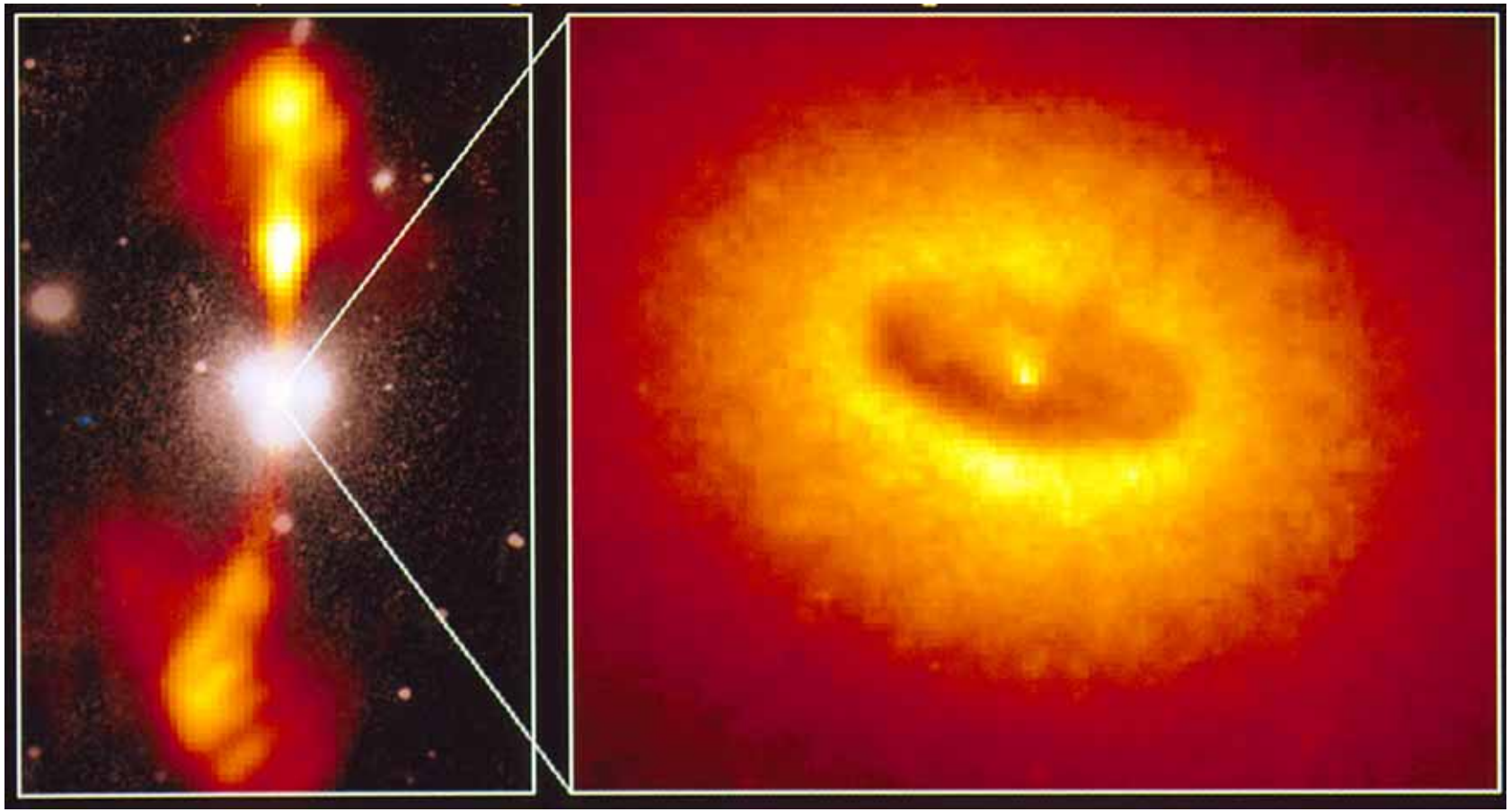
Sandia National Laboratories

Comparisons with opacity models can identify the level of physics complexity required



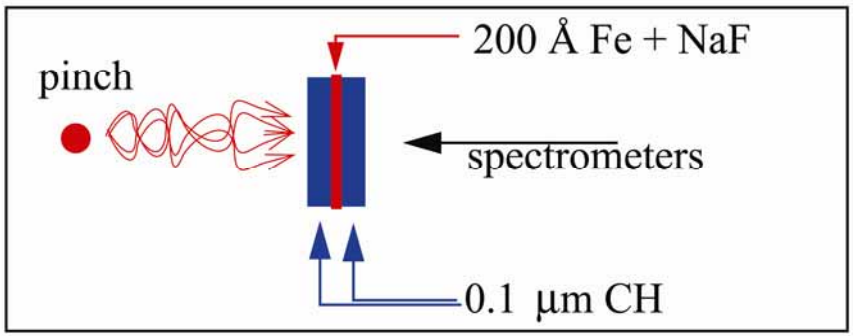
Sandia National Laboratories

Plasma kinetics are controlled by photo-ionization in many astrophysical objects

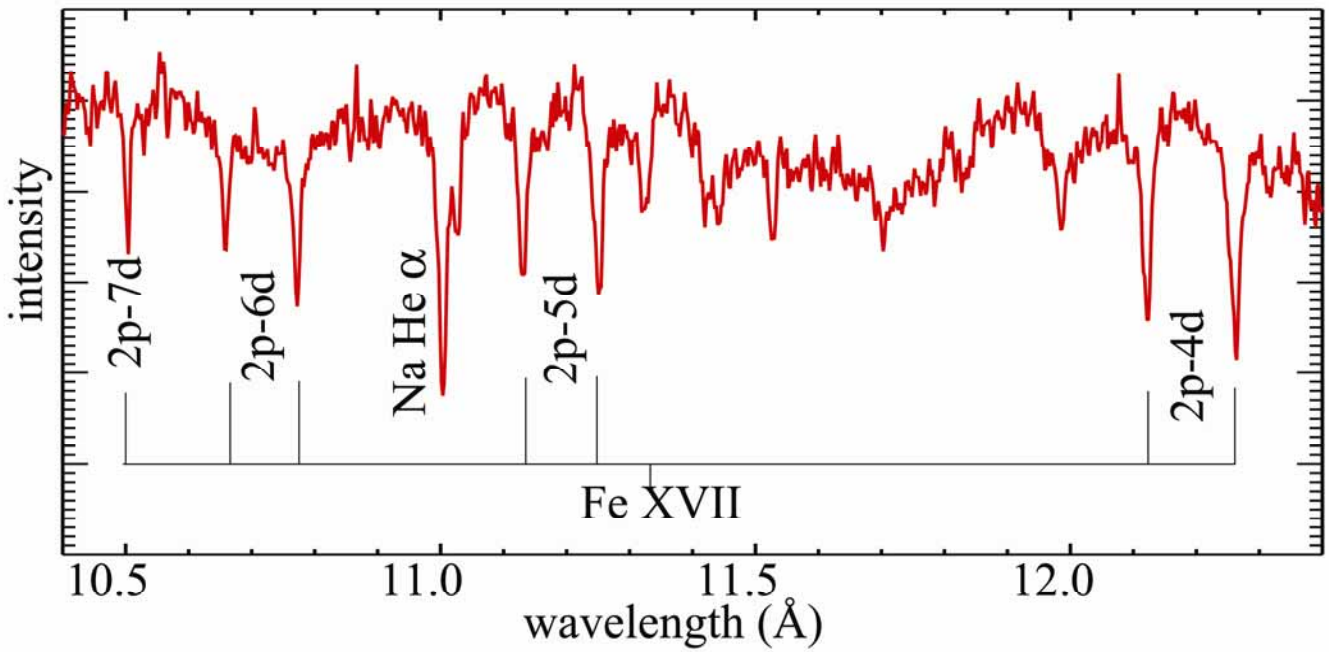


Hubble Space Telescope image of glowing acretion disk

LLNL–led collaboration acquired first photo-ionized plasma data using Z experriments



M.E. Foord *et al*.
PRL 93, 055002 (2004)

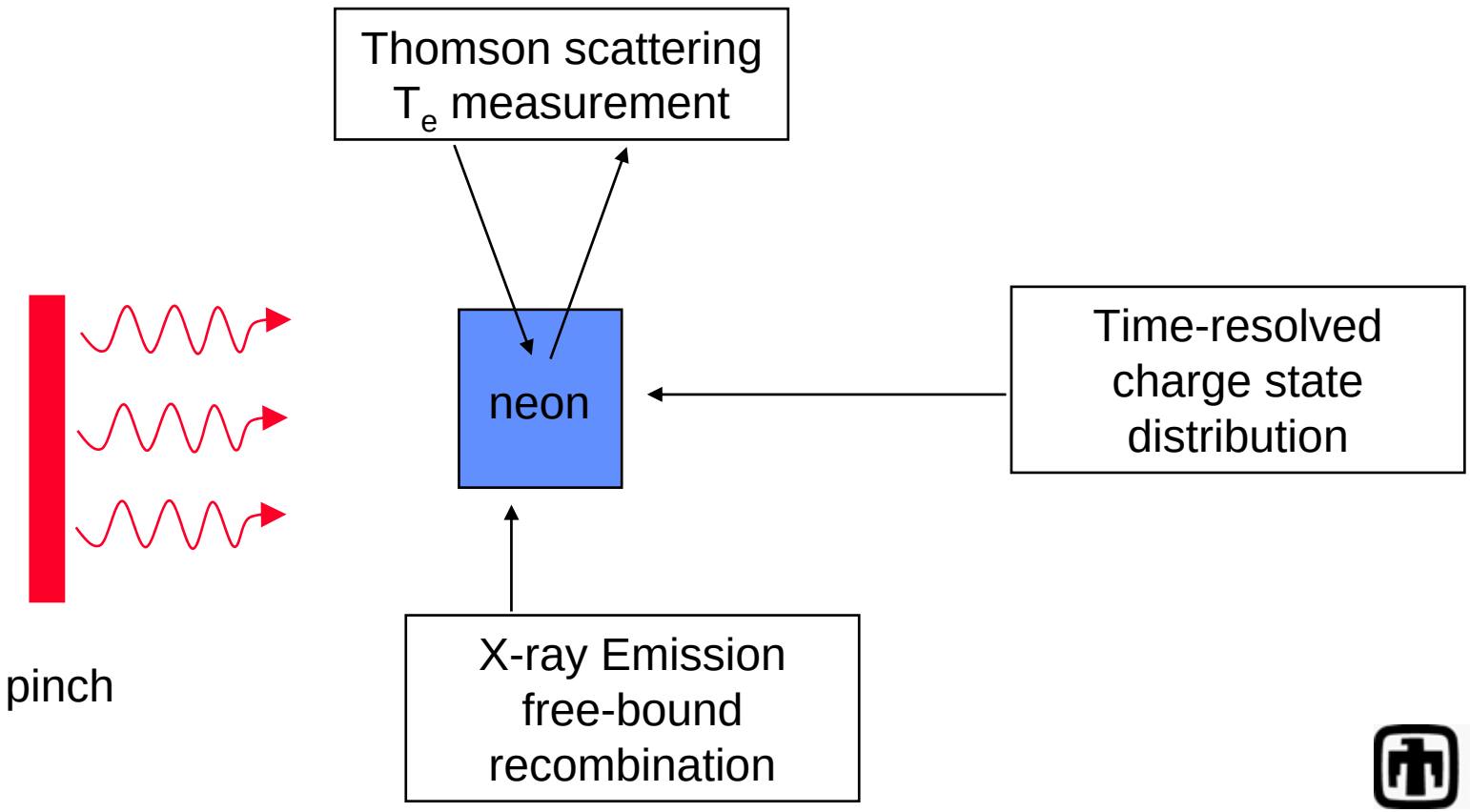


Sandia National Laboratories

An NNSA academic alliance grant will enable refined photoionized plasma experiments on Z

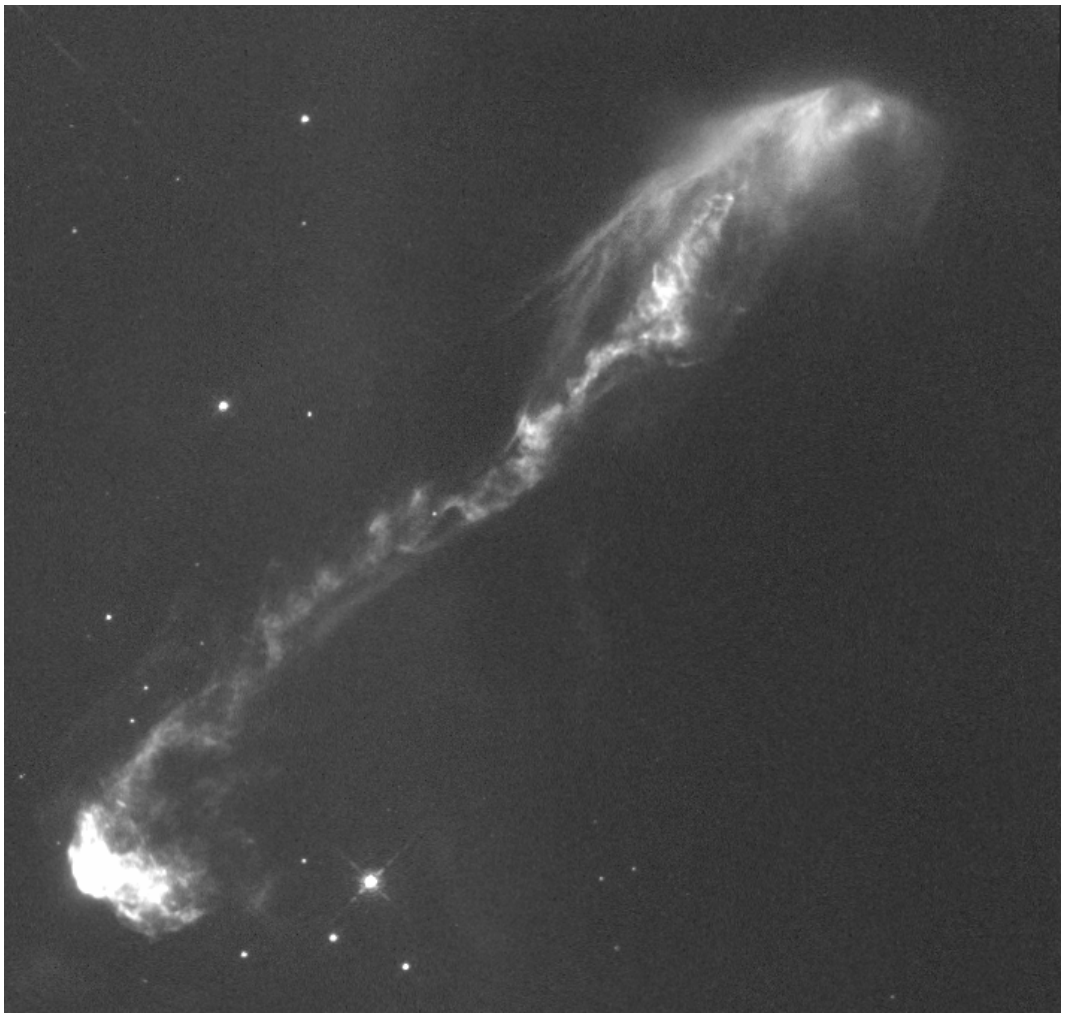
Team led by Roberto Mancini (U. Nevada Reno) with LLNL, Swarthmore College, Prism, and SNL participants

This three year project could serve as pilot for basic science user groups



Sandia National Laboratories

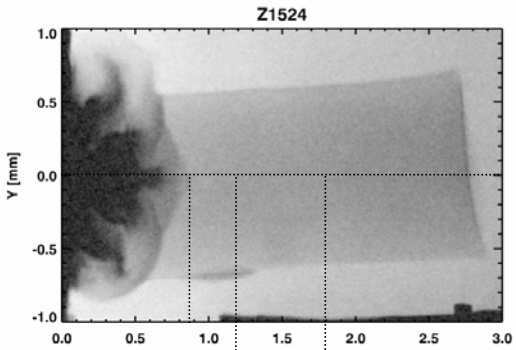
Astrophysical jet behavior can be studied with scaled laboratory experiments



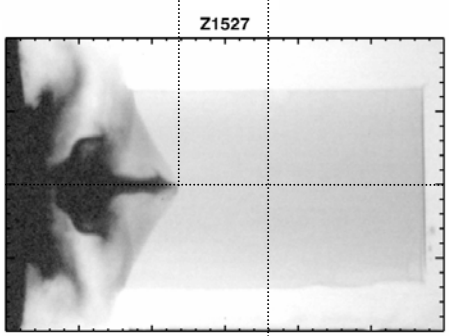
Hubble Space Telescope
Image of HH 47

Sandia National Laboratories

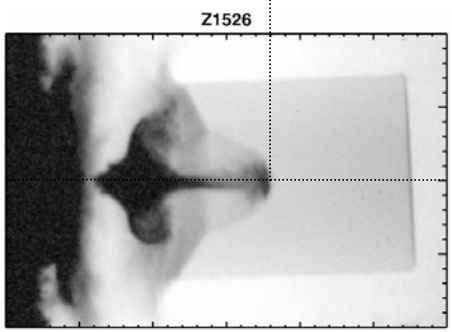
A sequence of Z experiments measured jet evolution using spherical crystal backlighting



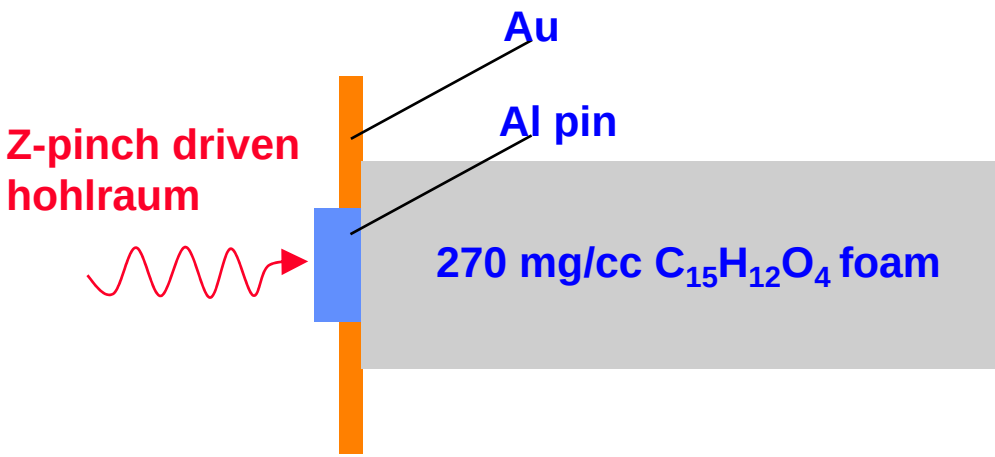
t=31 ns
328.1 mg/cc



t=40 ns
285.2 mg/cc



t=73 ns
270.1 mg/cc



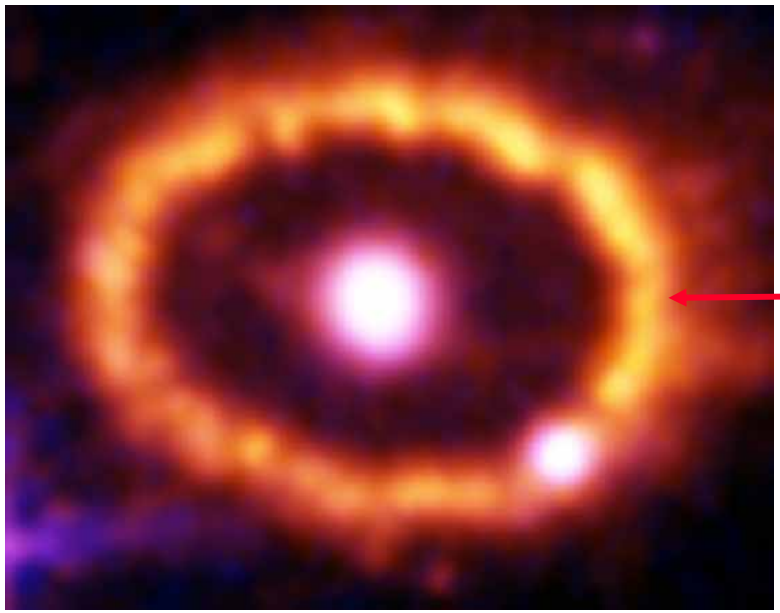
Data provided by GR Bennett and collaborators.

Future Z experiments can exploit multi-frame backlighting and more energetic conditions.

Sandia National Laboratories

Radiating shocks in supernova 1987a and in Z dynamic hohlraums occupy similar parameter space

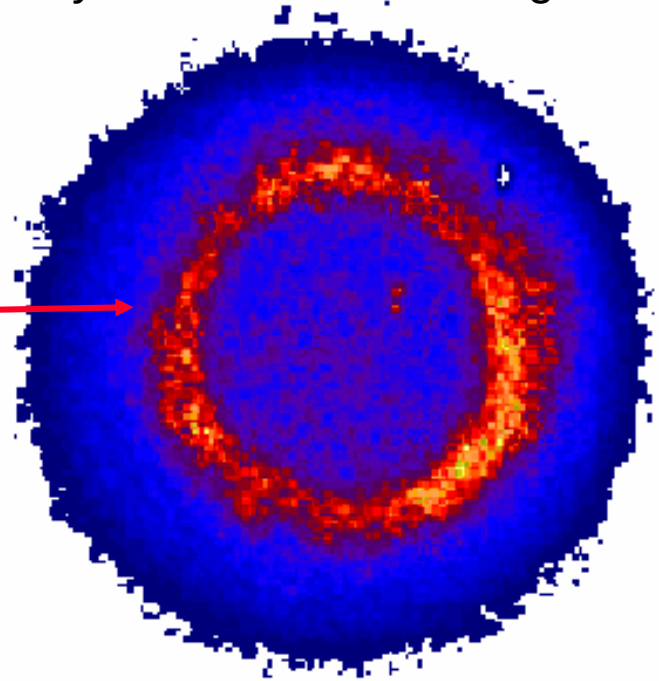
HST image SNR1987a



1 light year

radiating shock

Z dynamic hohlraum image

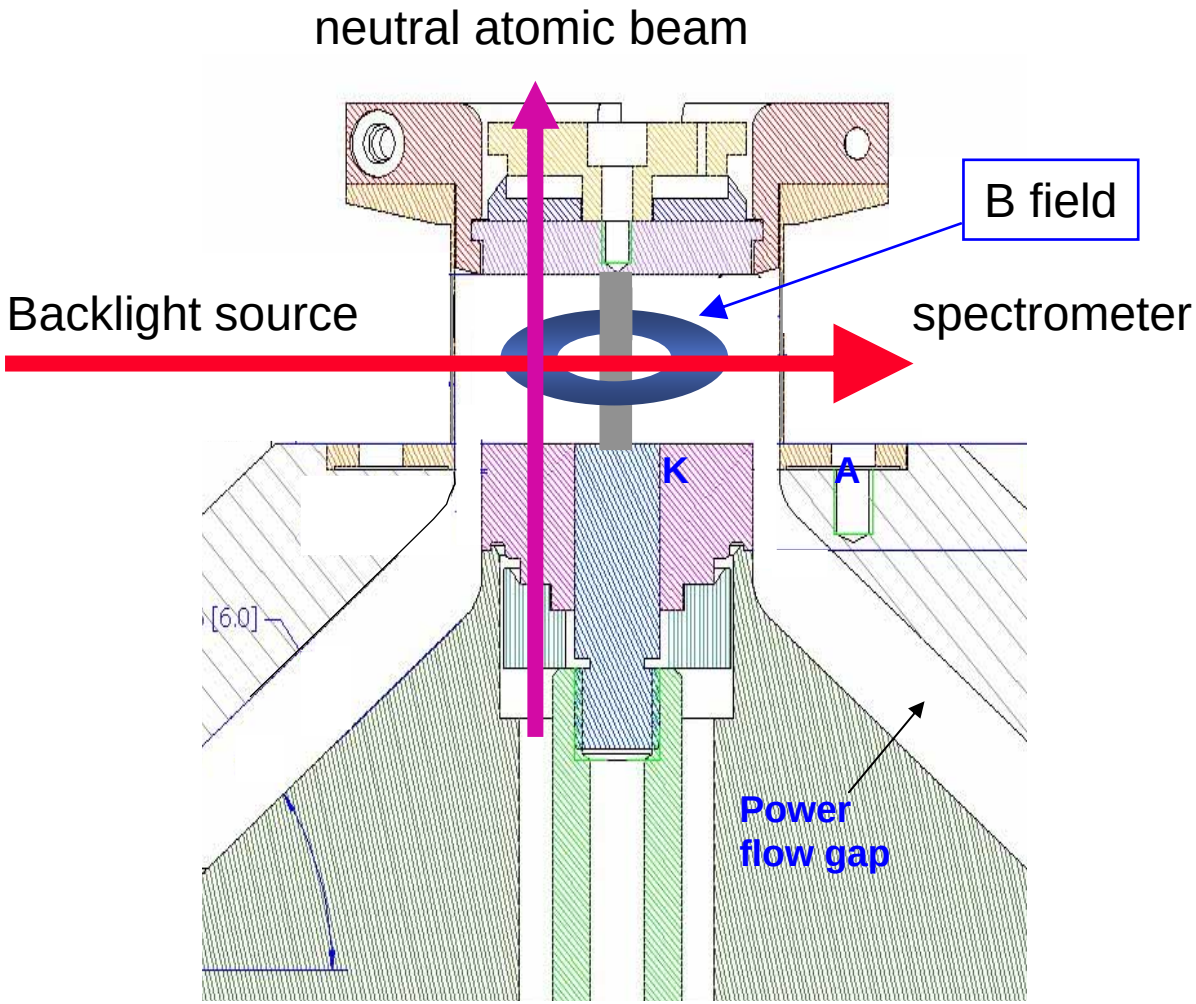


5 mm

Both shocks have $v_s/v_c >> 1$ and radiation cooling time short compared to hydro time $t_{rad} << 1$

Sandia National Laboratories

Short circuit Z experiments could enable atomic physics studies under high B fields



Sandia National Laboratories

Thinking big could enable creation of meter-scale radiation heated plasmas

Sandia National Laboratories