External user perspective
Burning plasmas

S J Rose
Imperial College London

Overview

Potential for experimental measurement of microphysics processes in a burning plasma

- Kinetic processes
- Survival of bound electronic structure - spectroscopy

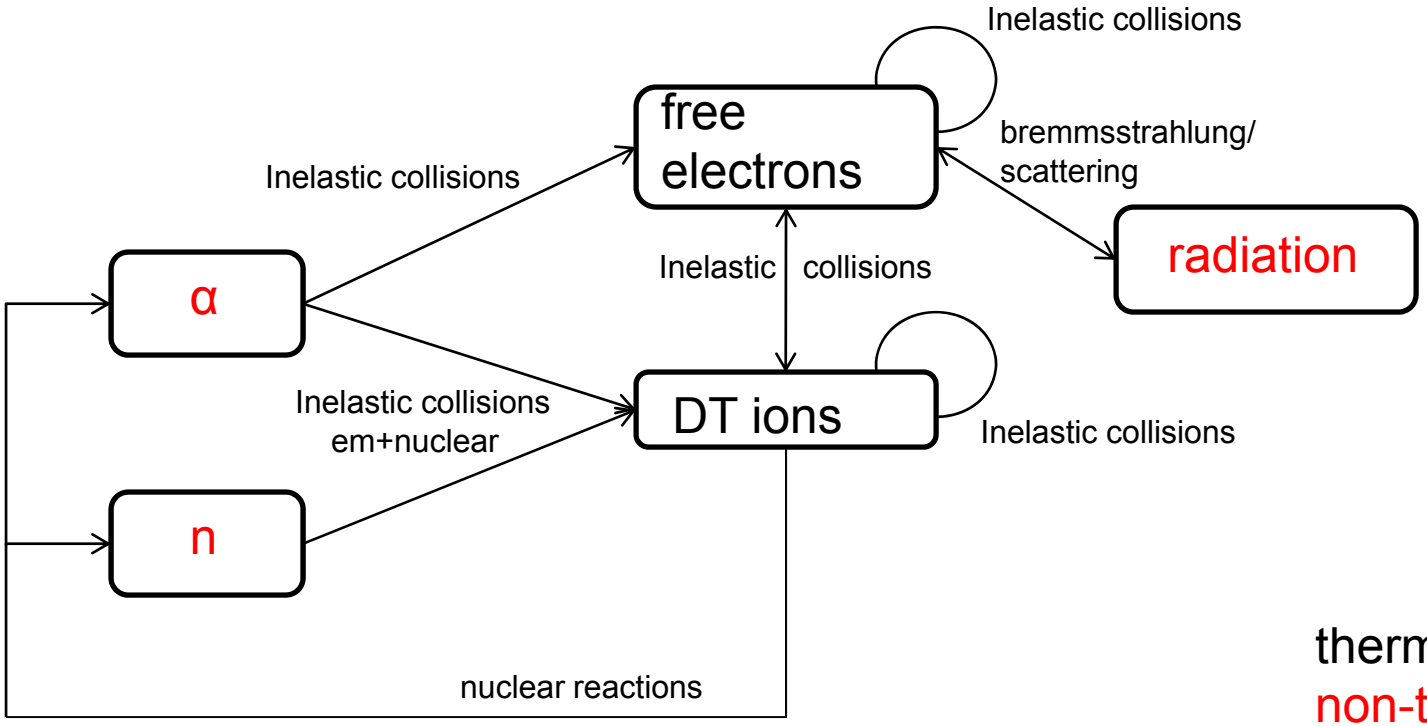
Applications of the output from a burning plasma

- Photoionised plasmas

Potential for experimental measurement of microphysics processes in a burning plasma

Kinetic processes

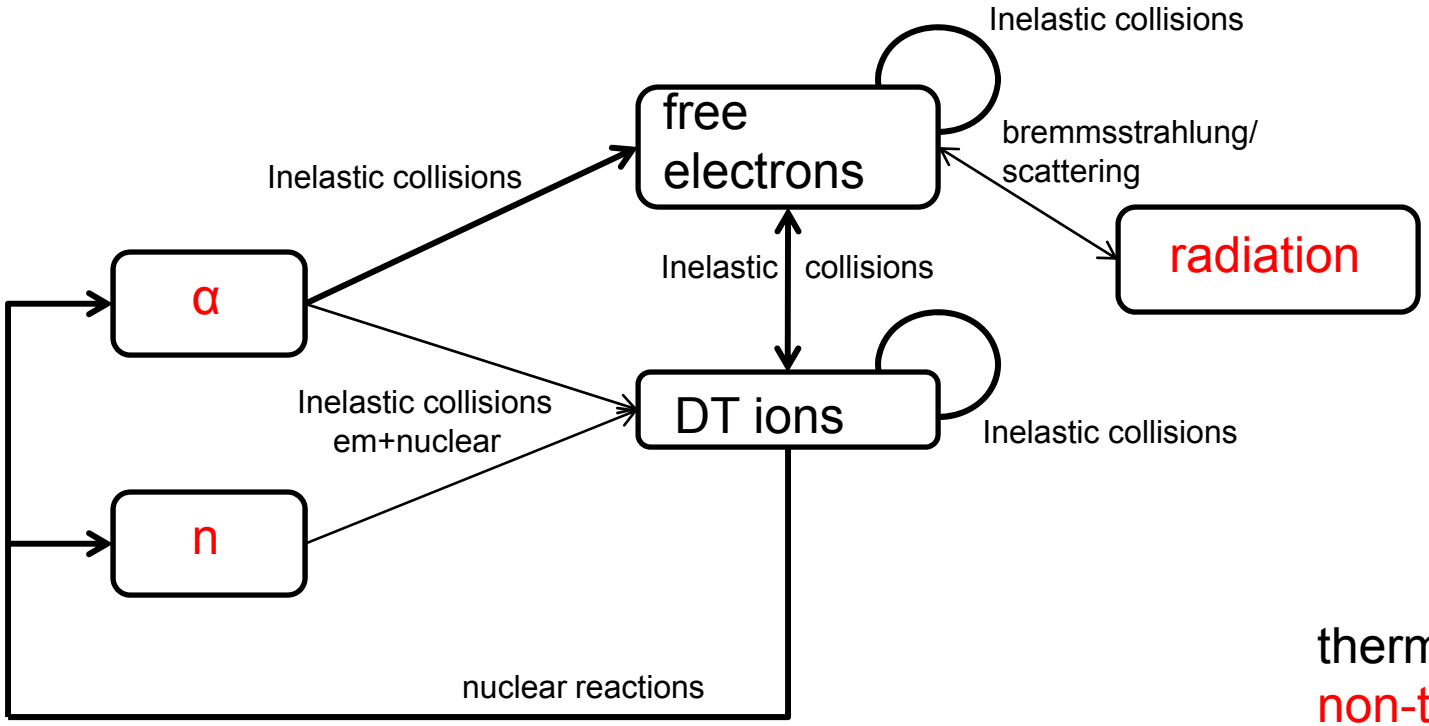
Many aspects of the microphysics of burning plasmas have not been tested experimentally



thermal
non-thermal

Many aspects of the microphysics of burning plasmas have not been tested experimentally

For T_e < 32keV

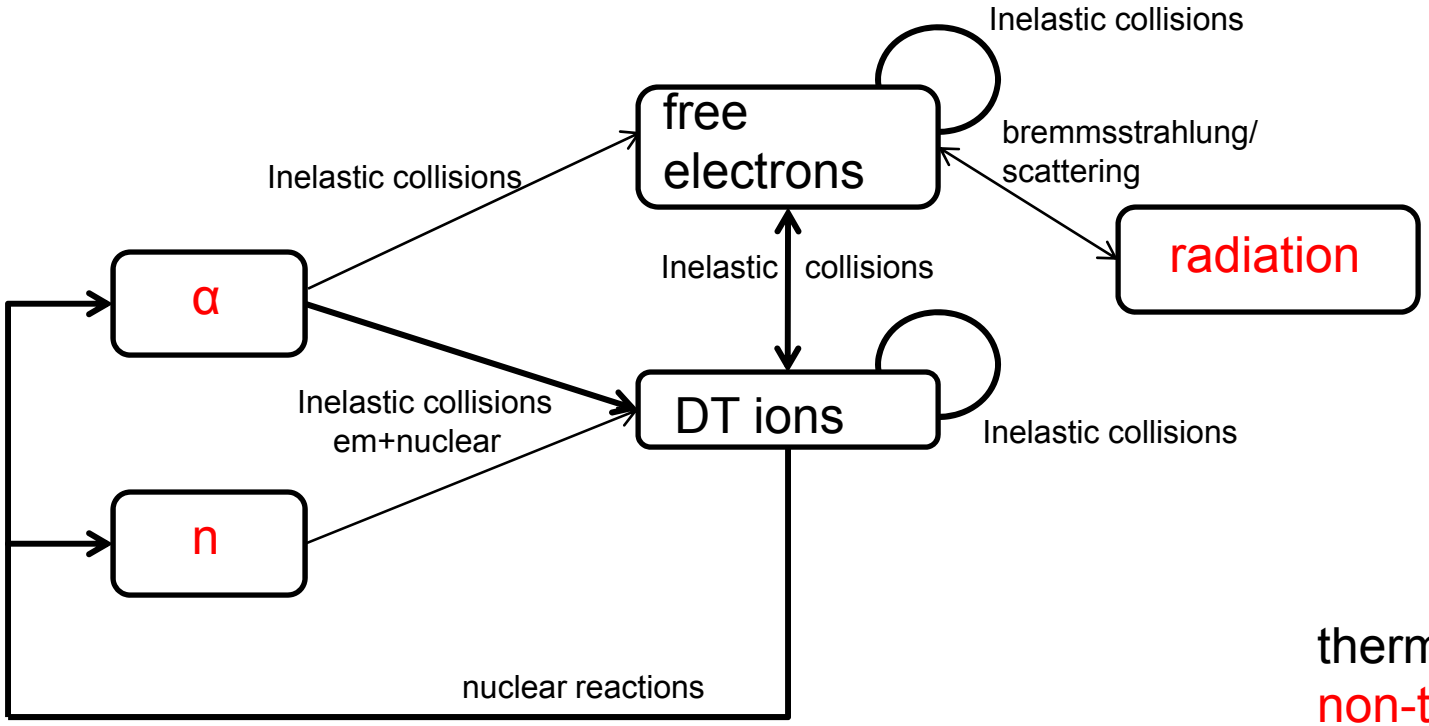


thermal

non-thermal

Many aspects of the microphysics of burning plasmas have not been tested experimentally

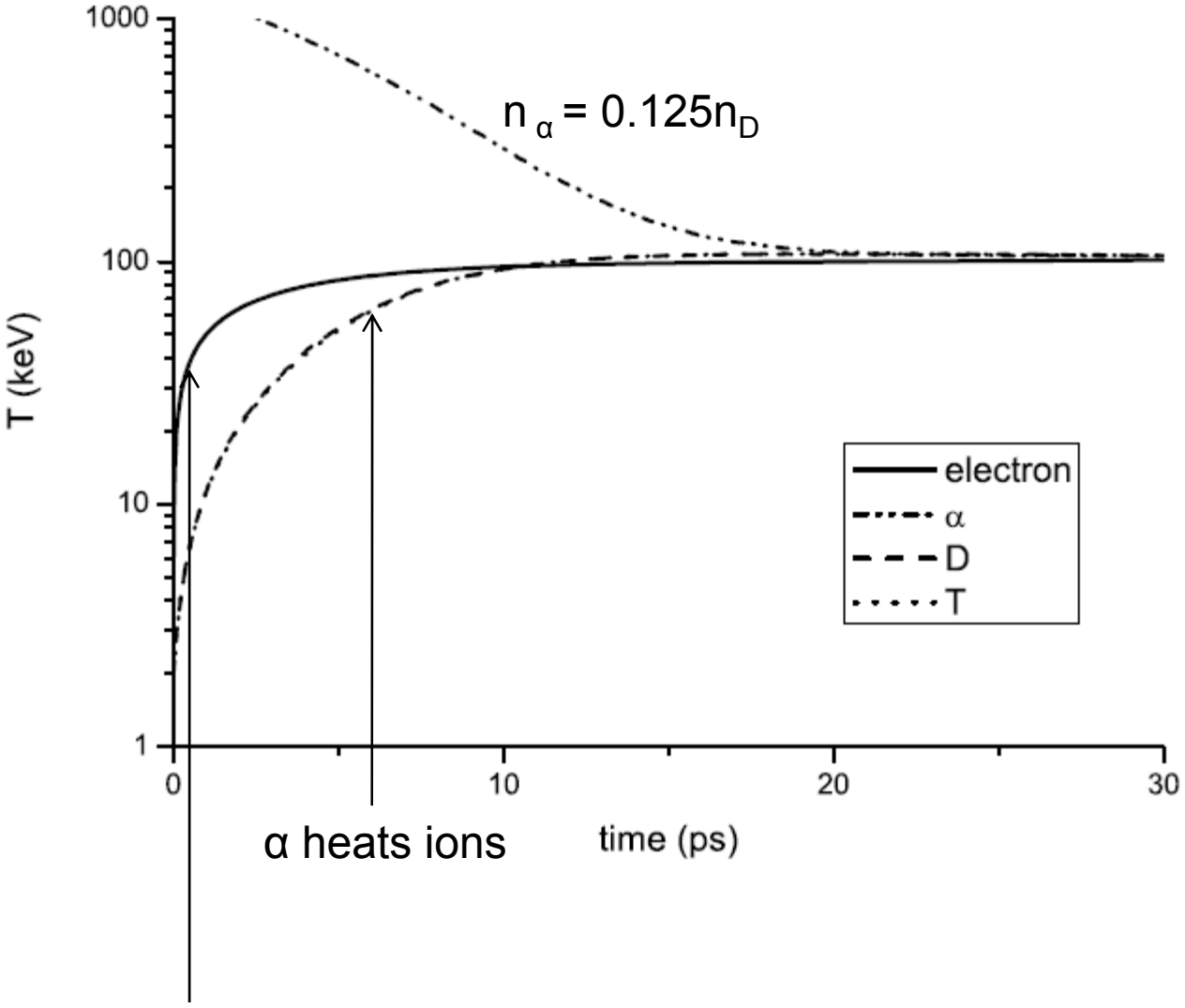
For T_e > 32keV



thermal

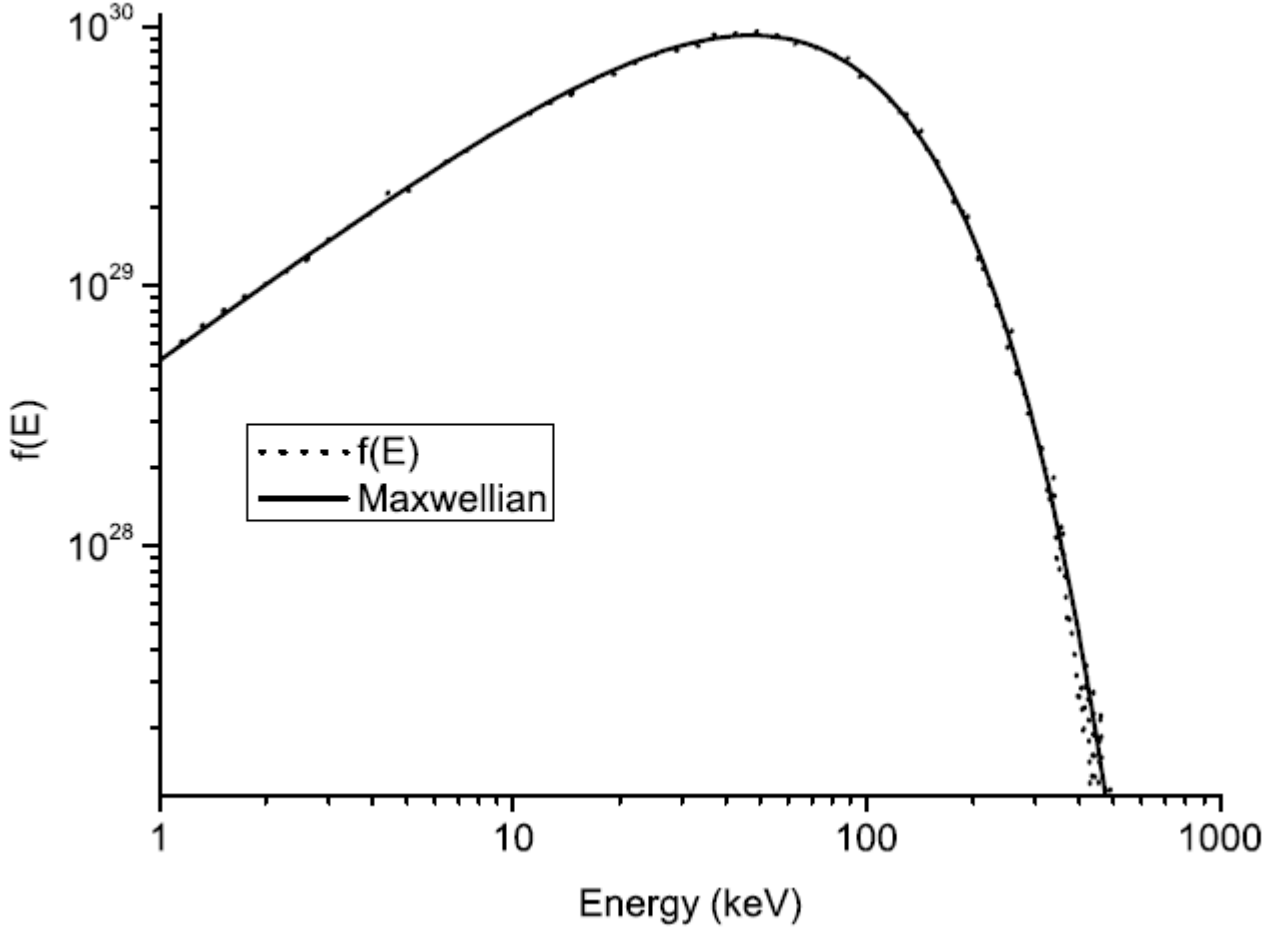
non-thermal

Heating of 2keV, 300gcm^{-3} plasma (D,T and electrons) with 3.6MeV alpha particles



Sherlock and Rose, HEDP (2008)

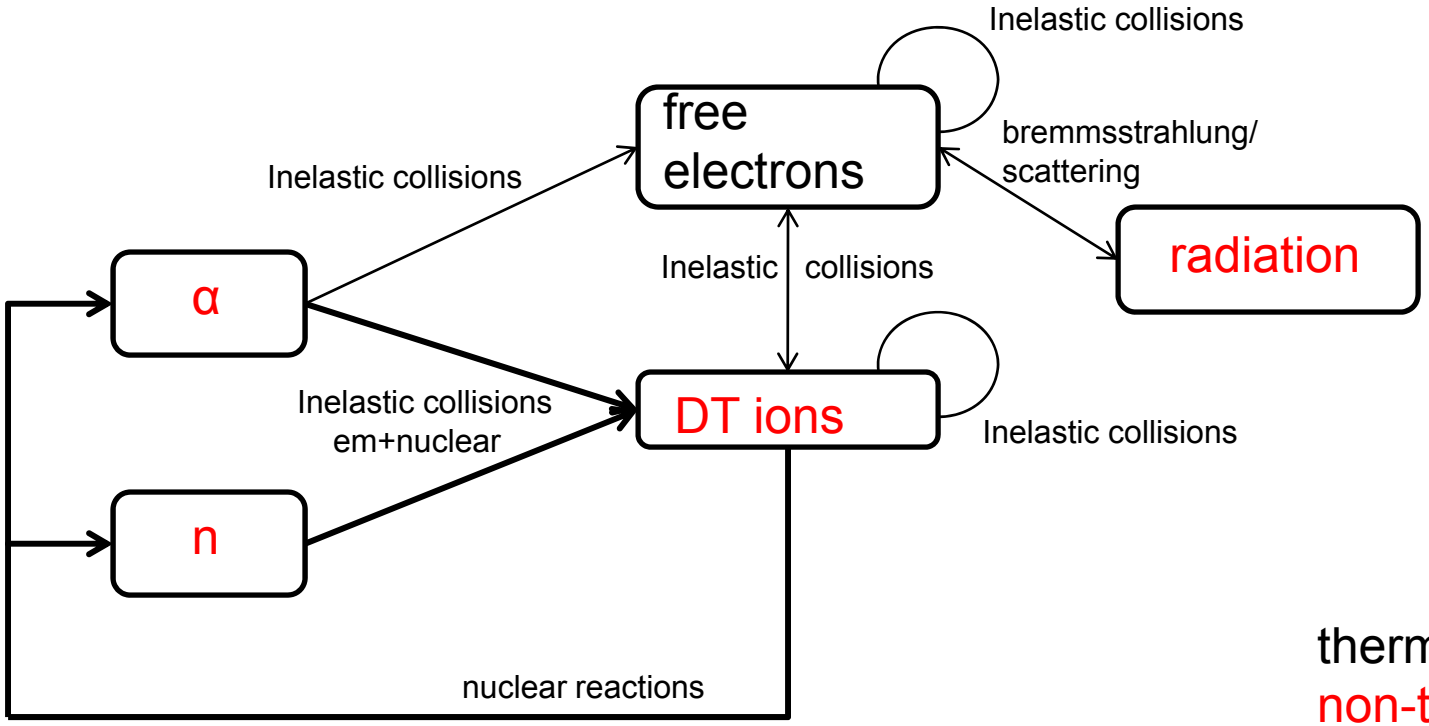
T energy distribution at 14psec



Sherlock and Rose, HEDP (2008)

Possibility exists of driving non-thermal aspect to fusion

Brueckner and Brysk, J Plasma Phys (1973)
Brueckner, Brysk and Janda J Plasma Phys (1974)

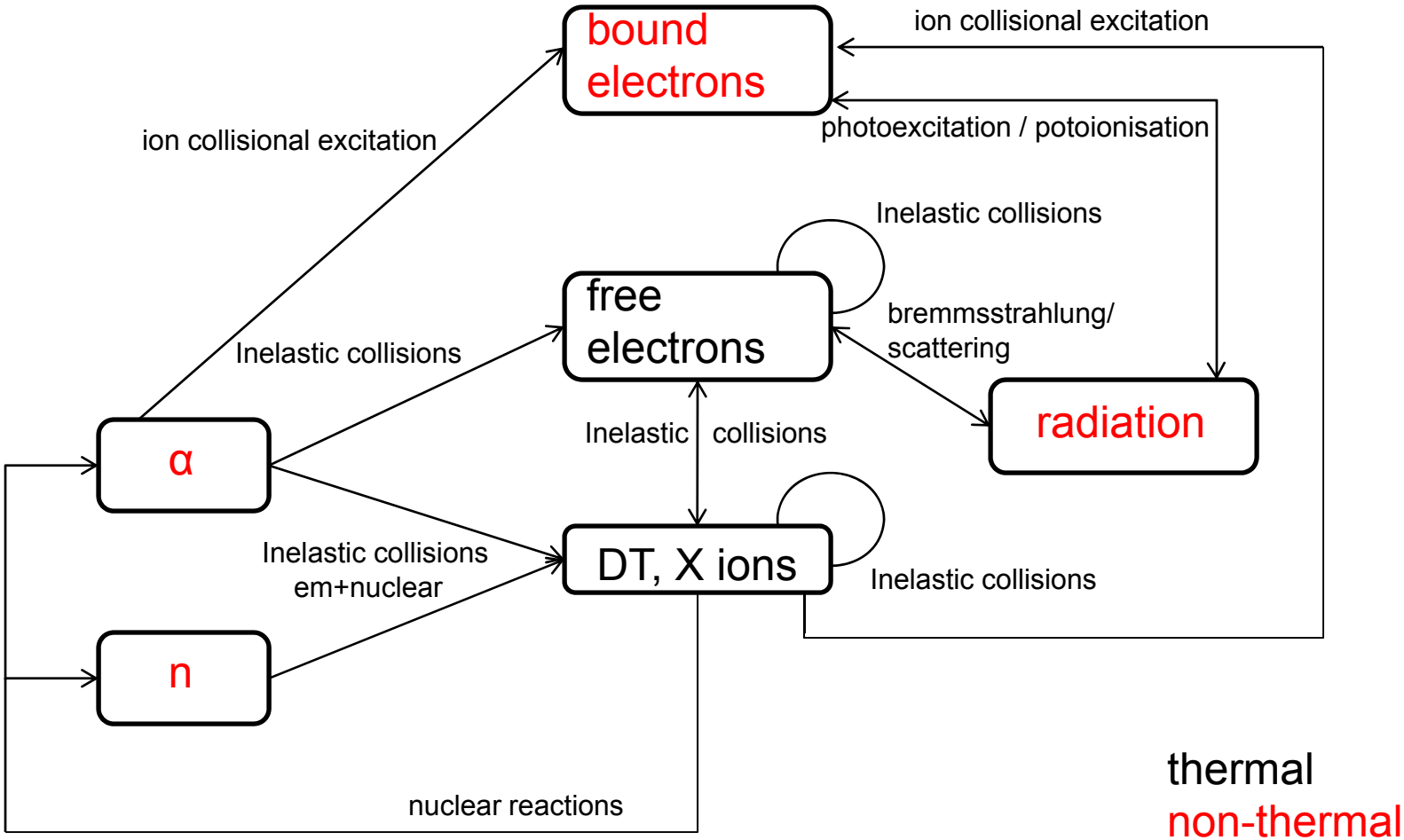


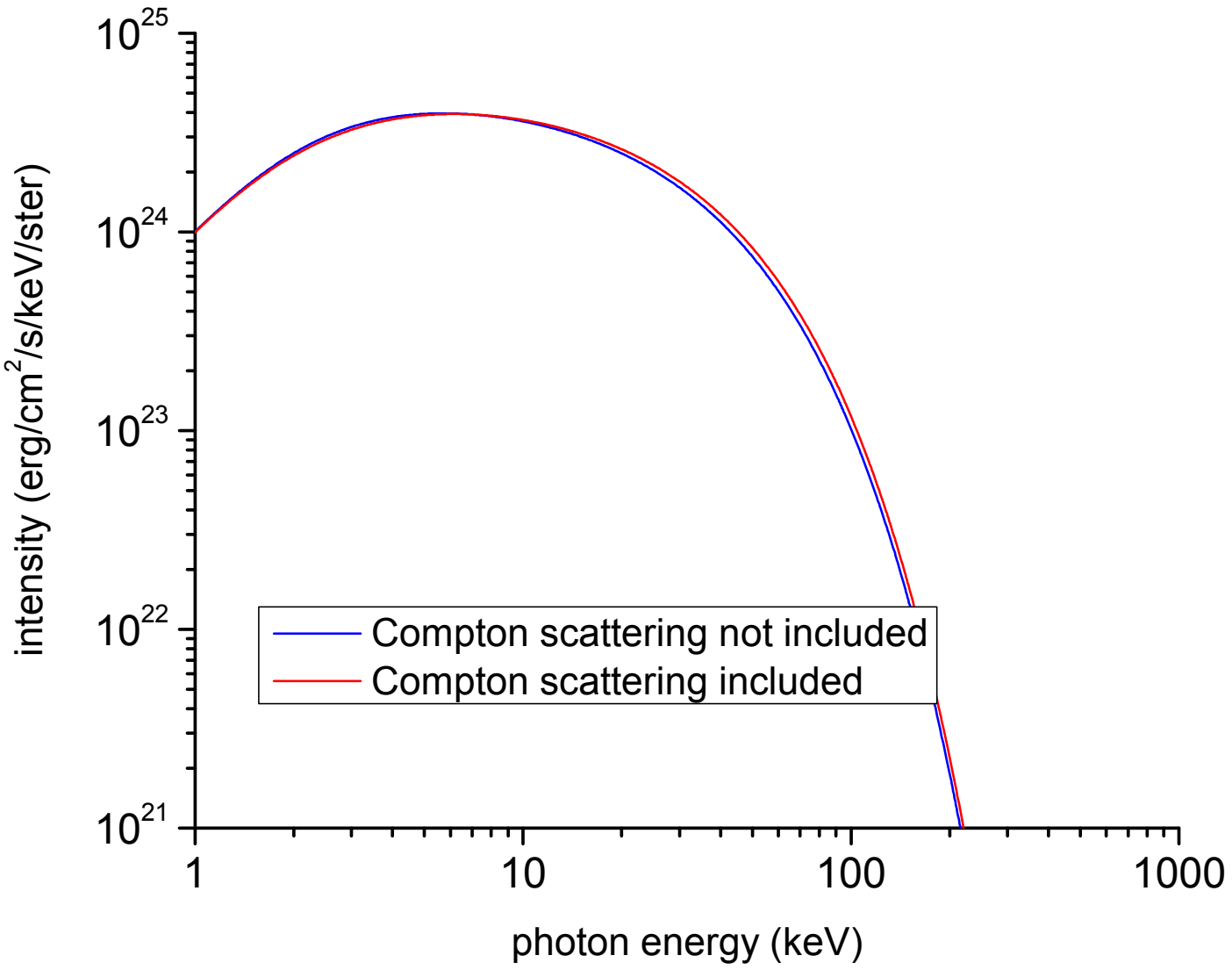
thermal
non-thermal

Potential for experimental measurement of microphysics processes in a burning plasma

Survival of bound electronic structure - spectroscopy

Introduction of bound electrons perturbs kinetics and allows spectroscopic diagnostic possibilities



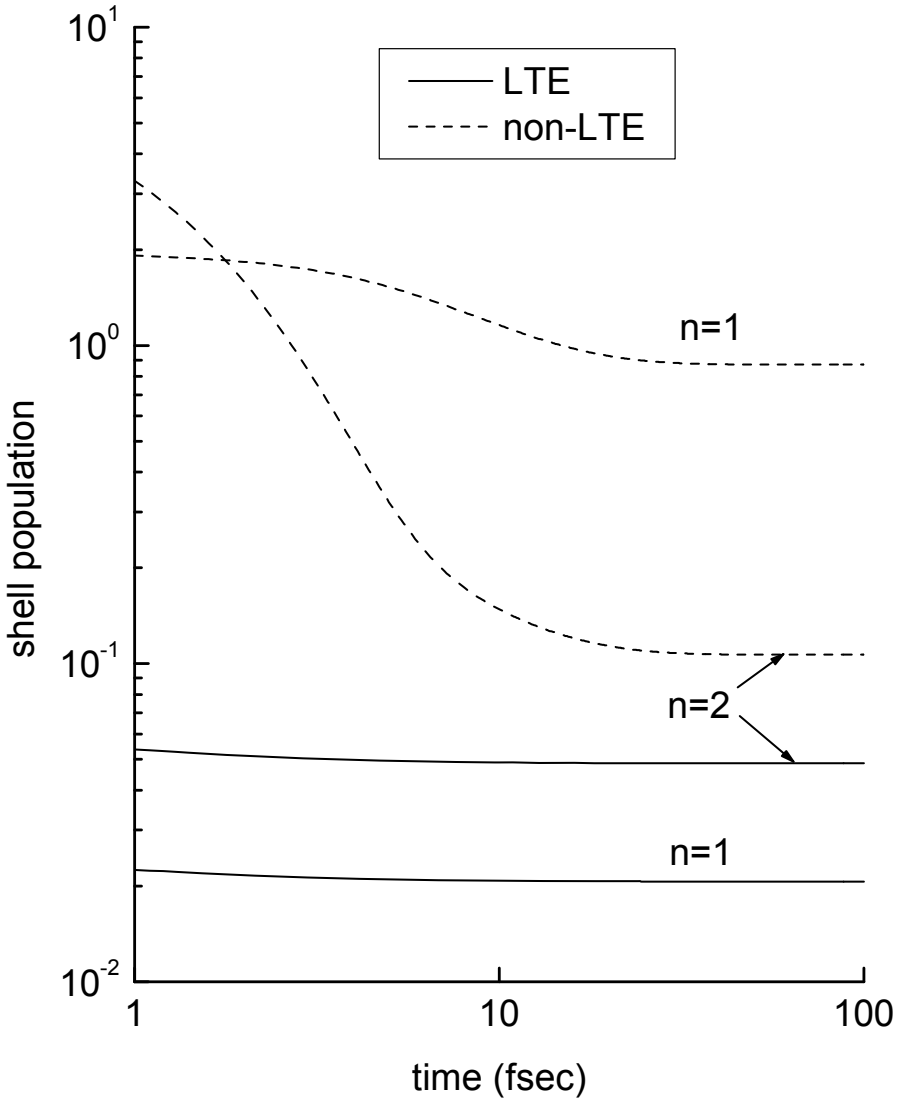

Radiation intensity for DT,
25keV, 500gcm-3, ρr=2.5gcm-2
intensity (erg/cm2/s/keV/ster)
10^25
10^24
10^23
10^22
10^21
1
10
100
1000
photon energy (keV)
Compton scattering not included
Compton scattering included

High-Z-doped DT implosion

- High-Z dopant (Kr) needed to retain bound electrons at high T_e
- High density gives a large depression of the continuum (only Kr n=1 and 2 survive).
- High temperature leads to non-LTE populations.
- Populations come into a steady-state in 100fsec.

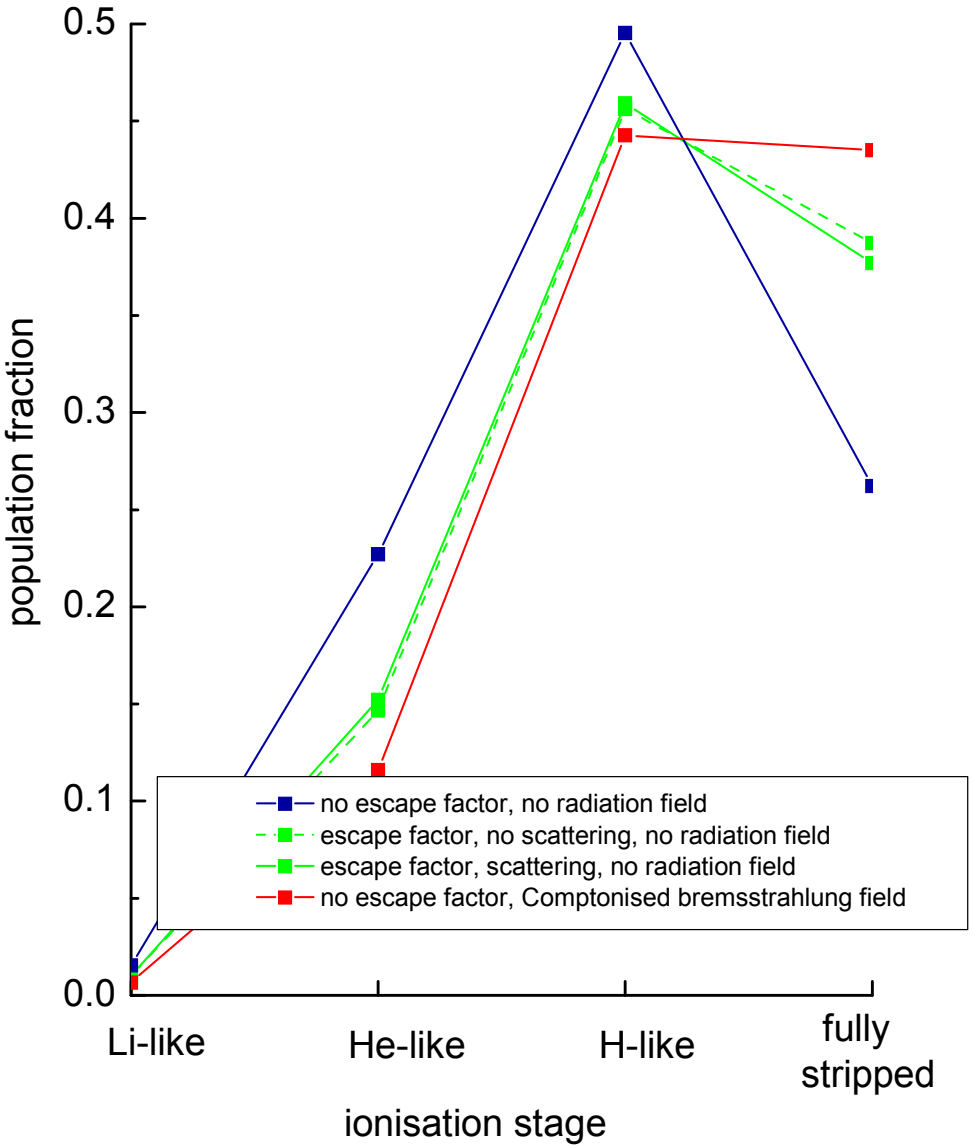
Time-dependence of ionisation of Kr in DT

T_e=25keV, ρ=500gcm^{-3}



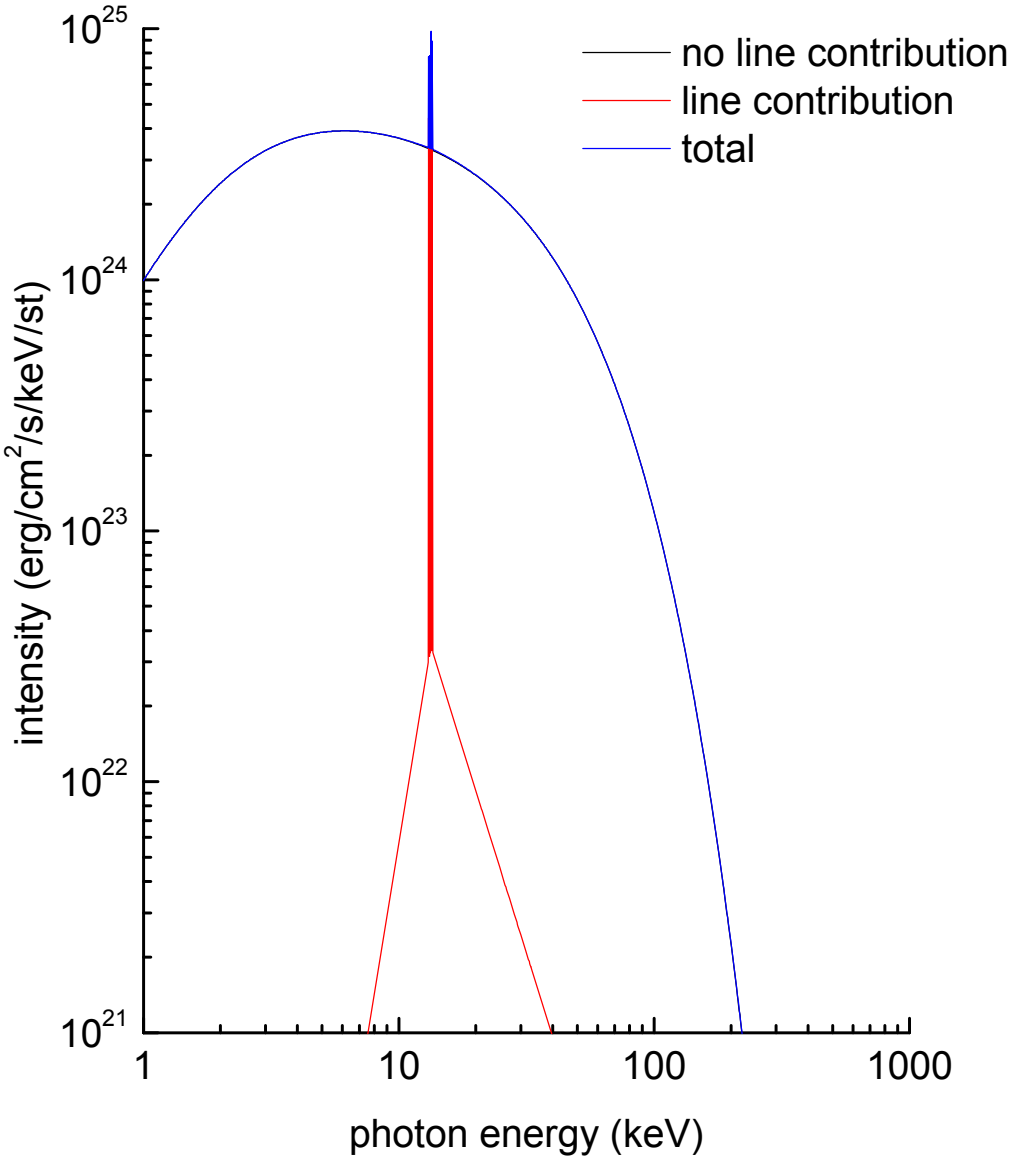
Distribution of ionisation of Kr in $D_{0.49995}T_{0.49995}Kr_{0.0001}$

T_e=25keV, ρ=500gcm^{-3}, ρr=2.5gcm^{-2}



Emission from $D_{0.49995}T_{0.49995}Kr_{0.0001}$

T_e=25keV, ρ=500gcm^{-3}, ρr=2.5gcm^{-2}



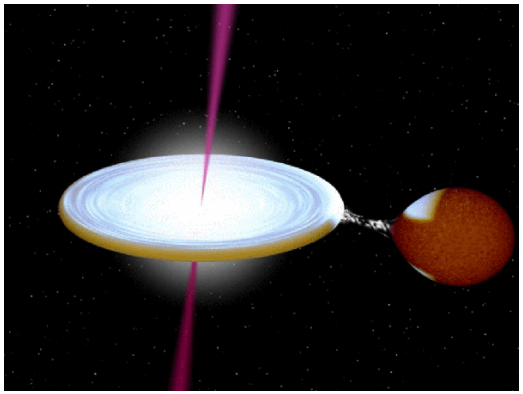
Applications of the output from a burning plasma

Photoionised plasmas

Accretion-powered objects

Photoionised plasmas (radiation-dominated plasmas) scale with the ionisation parameter $\xi=4\pi F/n_e$

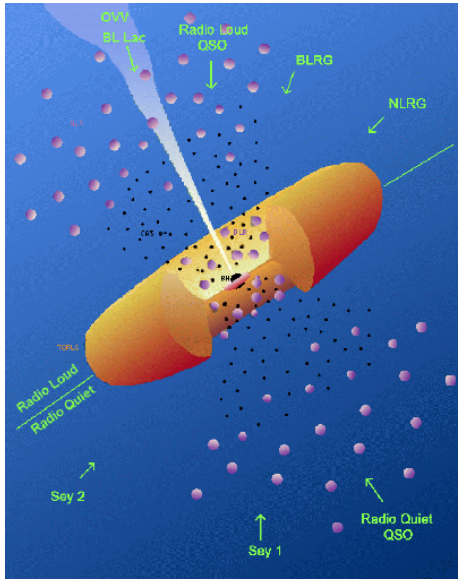
Tarter, Tucker and Salpeter, ApJ, **156**, 943,(1969)
Tarter and Salpeter, ApJ, **156**, 953 (1969)



EXO 0748-676

Low mass X-ray binary

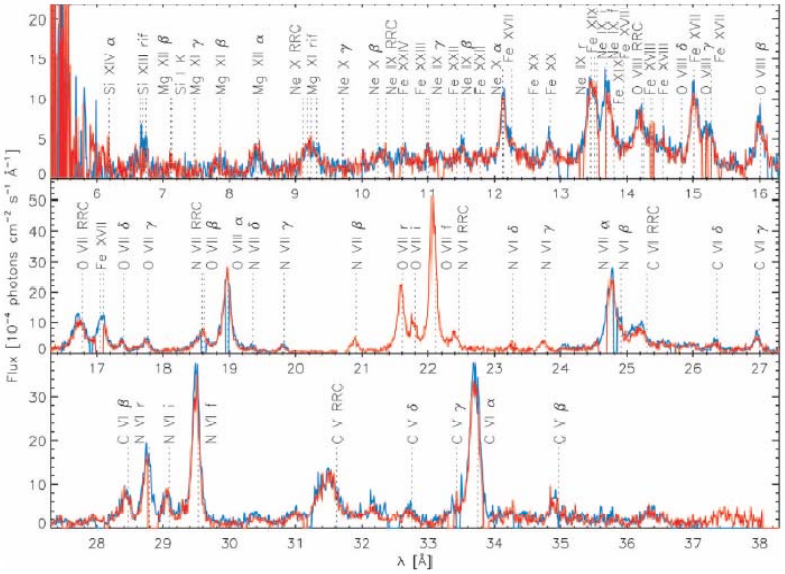
ξ=30 ergcms^{-1}



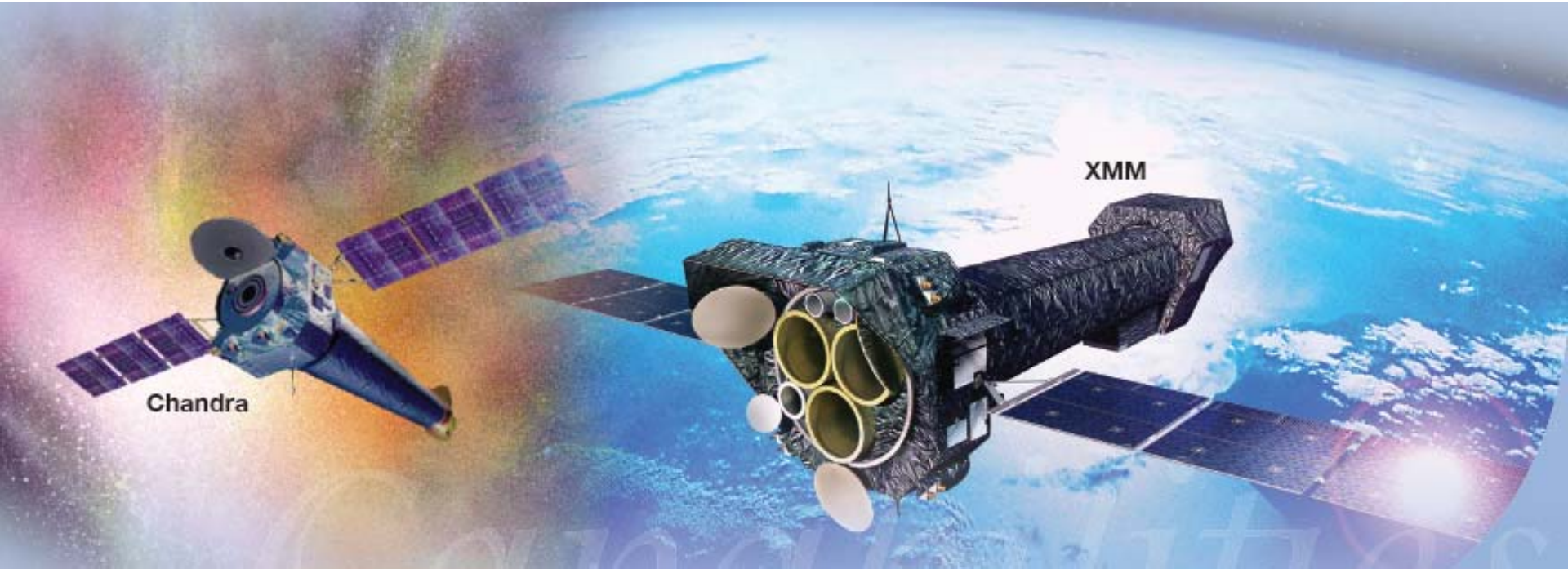
NGC 4593

Seyfert galaxy

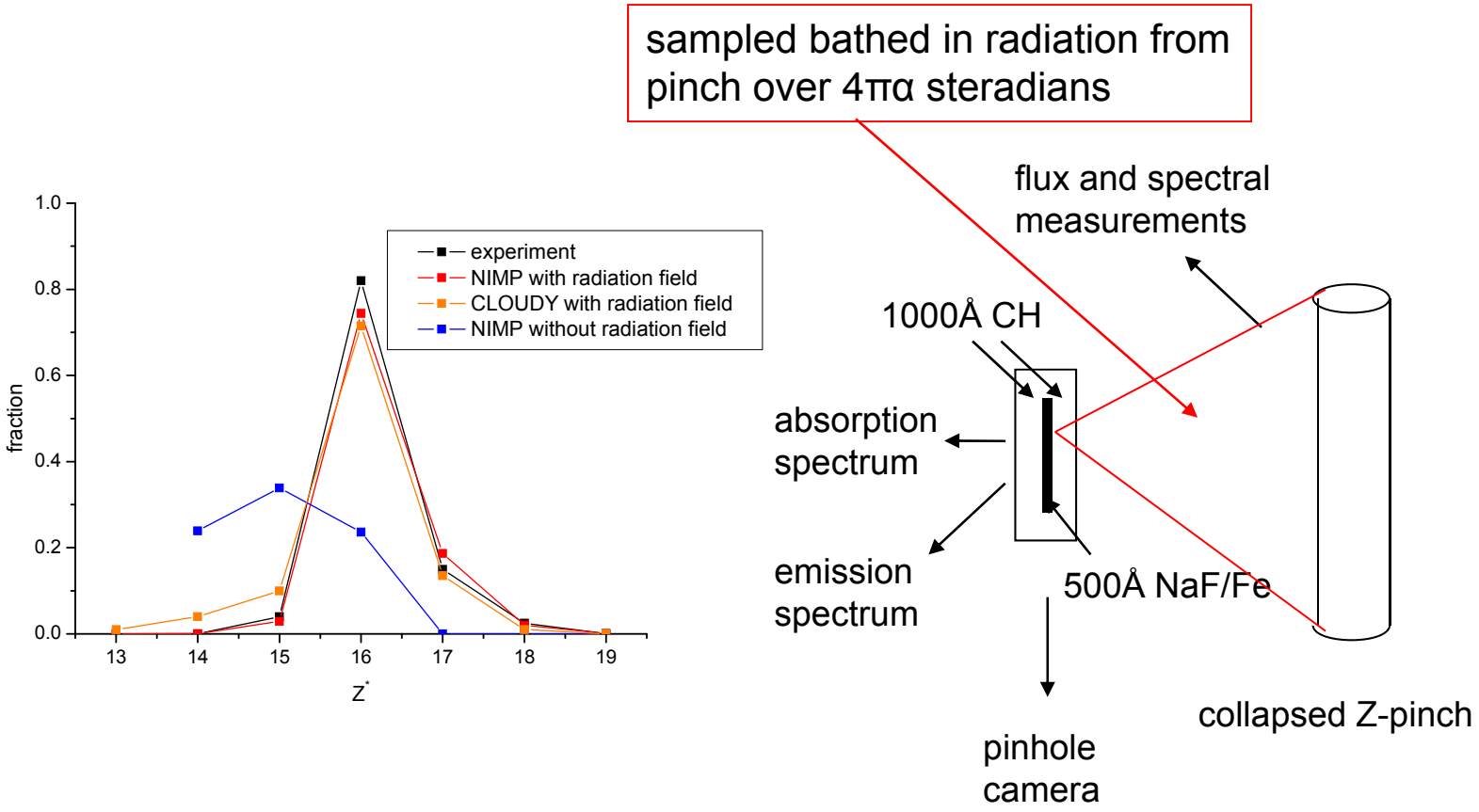
ξ=300 ergcms^{-1}



Spectral interpretation needs reliable models



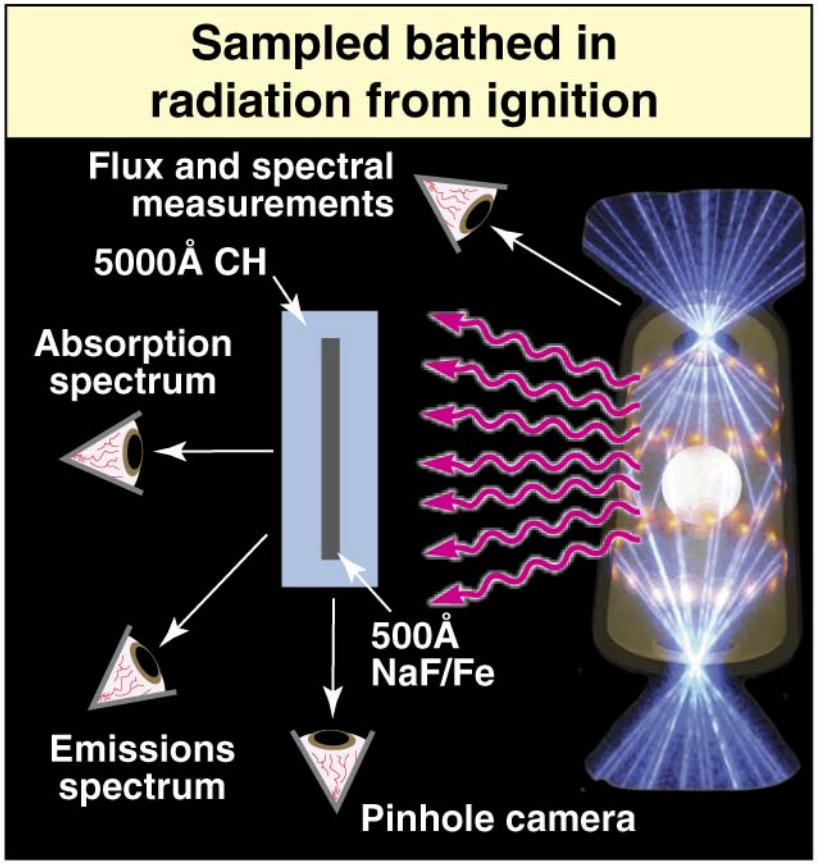
Photoionised plasma experiments have only reached ξ=20ergcms^{-1}



Much higher ξ values could be obtained by using radiation output from a burning capsule on NIF, allowing access to most extreme astrophysical photoionised plasma conditions.

Foord, Heeter, van Hoof, Thoe, Bailey, Cuneo, Chung, Liedahl, Fournier, Chandler, Jonauskas, Kisielius, Mix, Ramsbottom, Springer, Keenan, Rose and Goldstein, Phys Rev Letts, (2004)

Photoionised experiments using radiation output from NIF capsule



Much higher ξ values could be obtained by using radiation output from a burning capsule on NIF, allowing access to most extreme astrophysical photoionised plasma conditions.
(see: Fujioka et al, arXiv:0909.0315v1)

Conclusions

- Operation of the NIF target depends critically on microphysics of burn (connected to the transport properties). No experiments to measure kinetics in the burning phase, although some experiments have measured rates in cooler phase.

- Kinetic modelling of ion distributions shows no effect from fast alphas. However other studies show 10-20% effect which include large-angle scattering, nuclear interactions and neutron scattering kinetically. Possibility of measuring non-thermal aspect to burn?

- High-Z spectroscopy of doped plasma may be able to diagnose conditions through usual spectroscopic techniques.

- High photon output could be used to drive photoionised plasma experiment with $\xi \sim 100$ ergcms^{-1}.