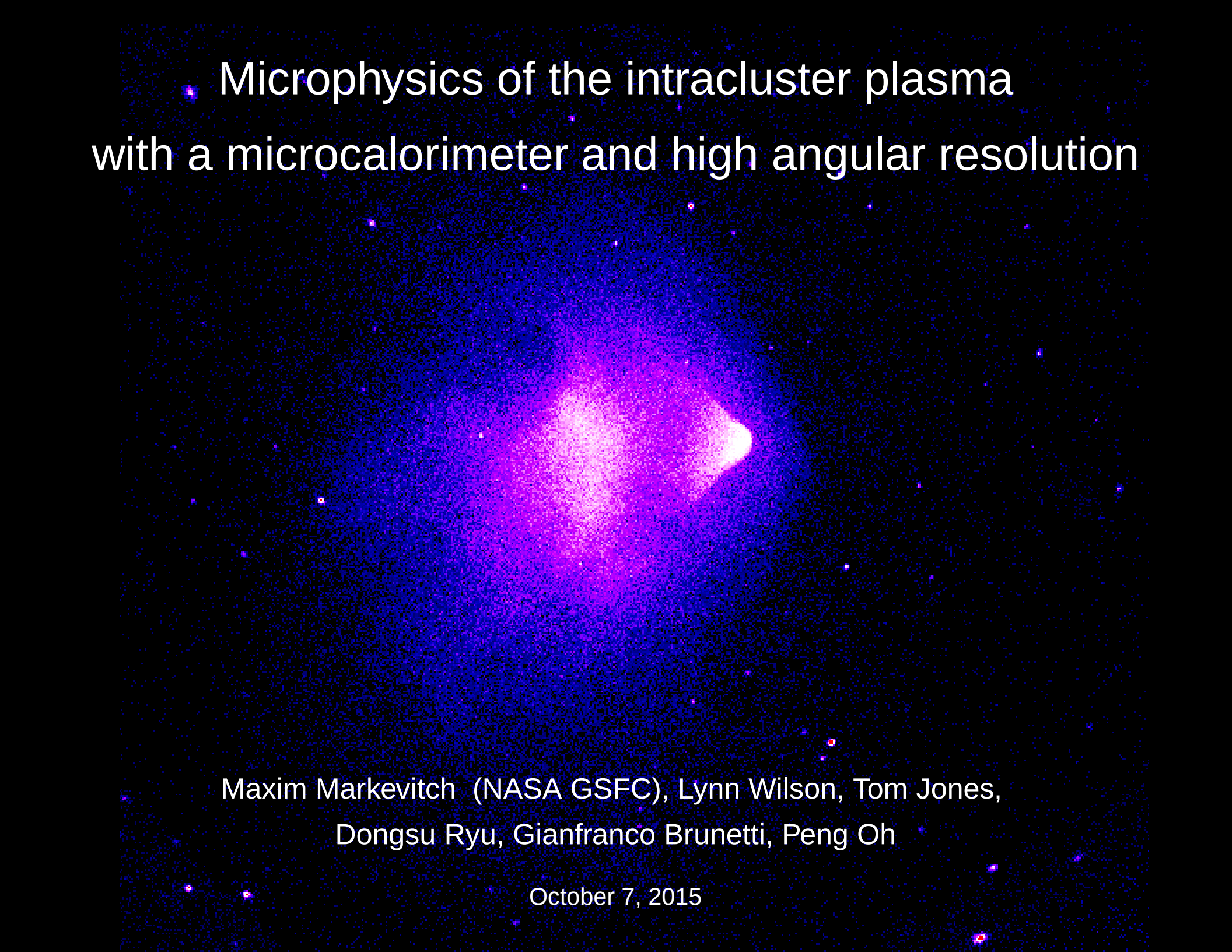
Microphysics of the intracluster plasma with a microcalorimeter and high angular resolution



Maxim Markevitch (NASA GSFC), Lynn Wilson, Tom Jones,
Dongsu Ryu, Gianfranco Brunetti, Peng Oh

October 7, 2015

Maxwellian distribution of electron velocities in plasma

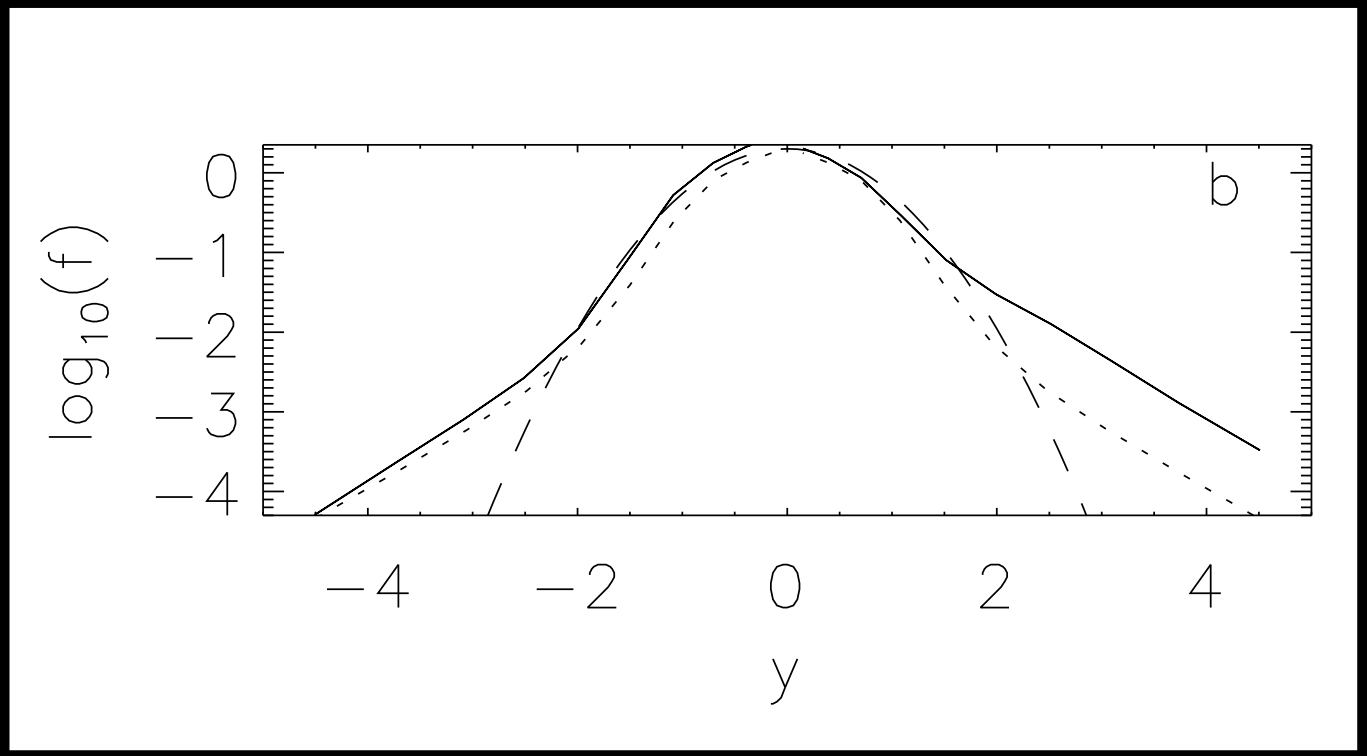
Basic assumption of local thermal equilibrium and the resulting Maxwellian distribution:

- ICM transport properties: heat conductivity
- X-ray bremsstrahlung, ionization equilibrium
- Sunyaev-Zeldovich effect
- Cosmic ray acceleration (from thermal pool)

. . .

... but what's actually observed?

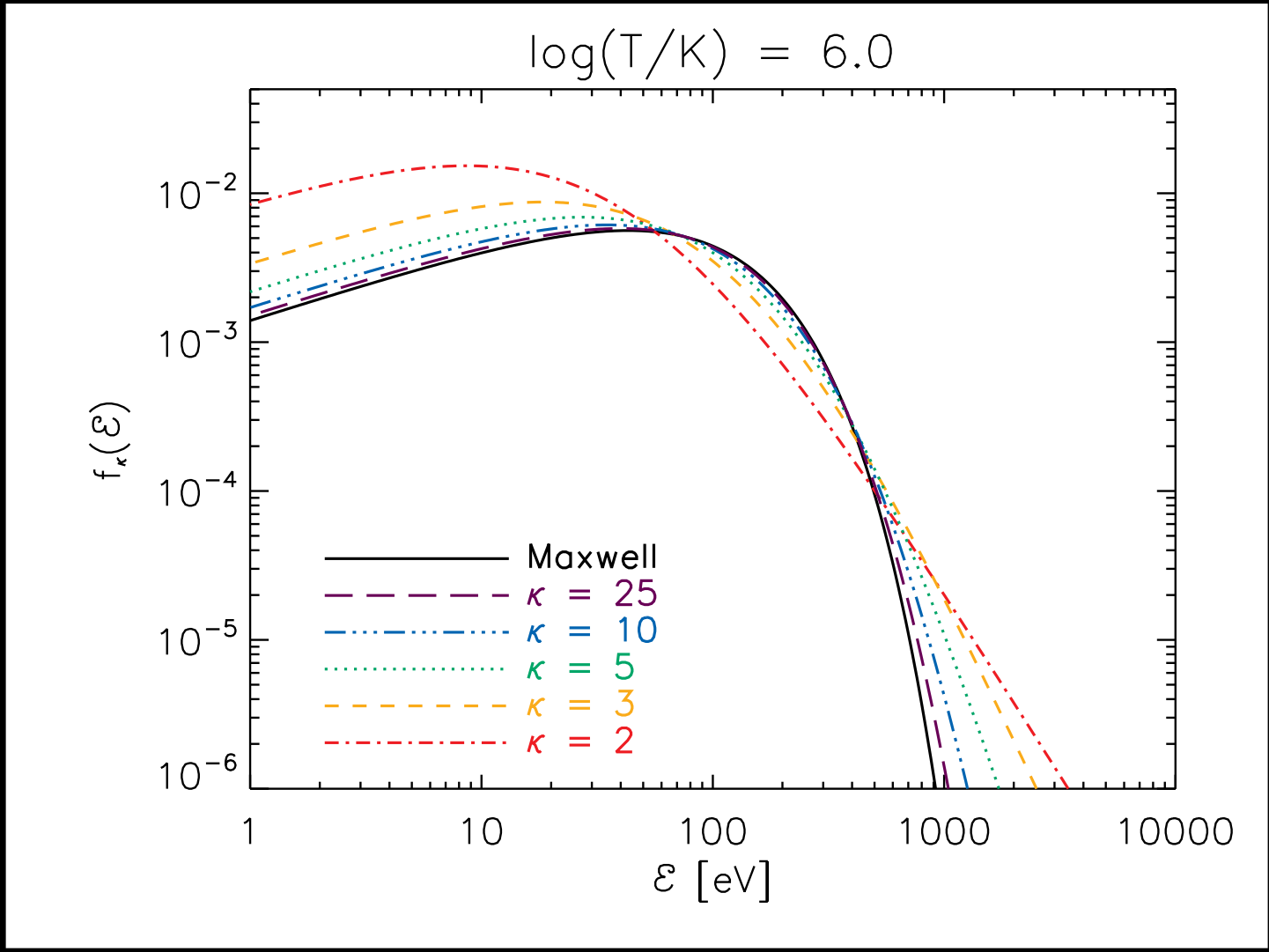
Electron velocity distribution function in the solar wind



WIND spacecraft (Pierrard 99; Pierrard 10)

- κ distribution

κ distribution



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T for non-Maxwellian distributions defined as mean kinetic energy

- $\kappa \sim$ 1.5 – 5 observed in solar and planetary plasmas

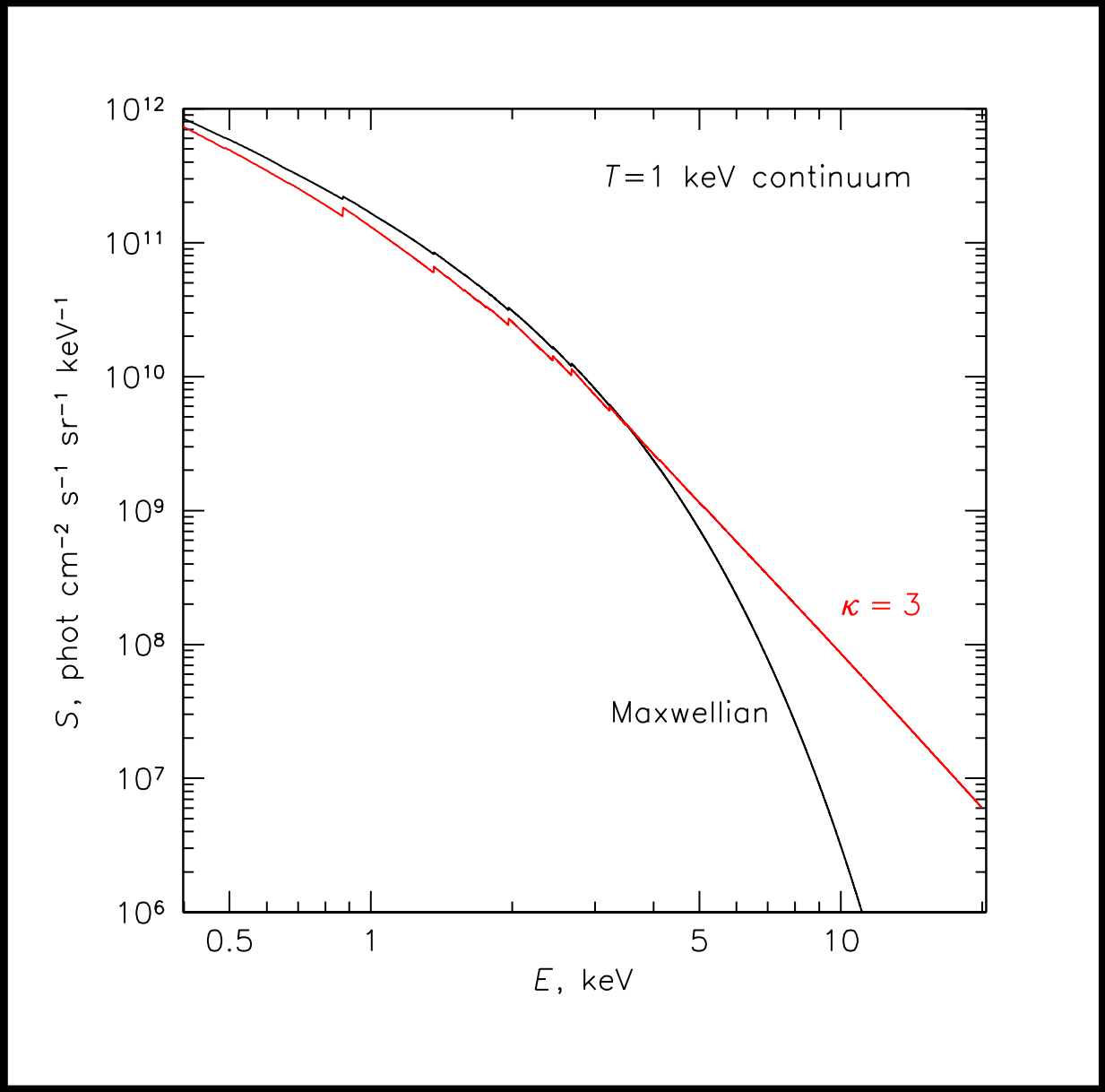
κ distribution

- stationary distribution for collisionless plasmas (Livadiotis 15)
- arises when plasma is rapidly heated, or particles accelerated, or from wave-particle interaction, ...

- anomalous viscosity, resistivity; more efficient particle acceleration; heat flux can change direction!

what if ICM is non-Maxwellian?

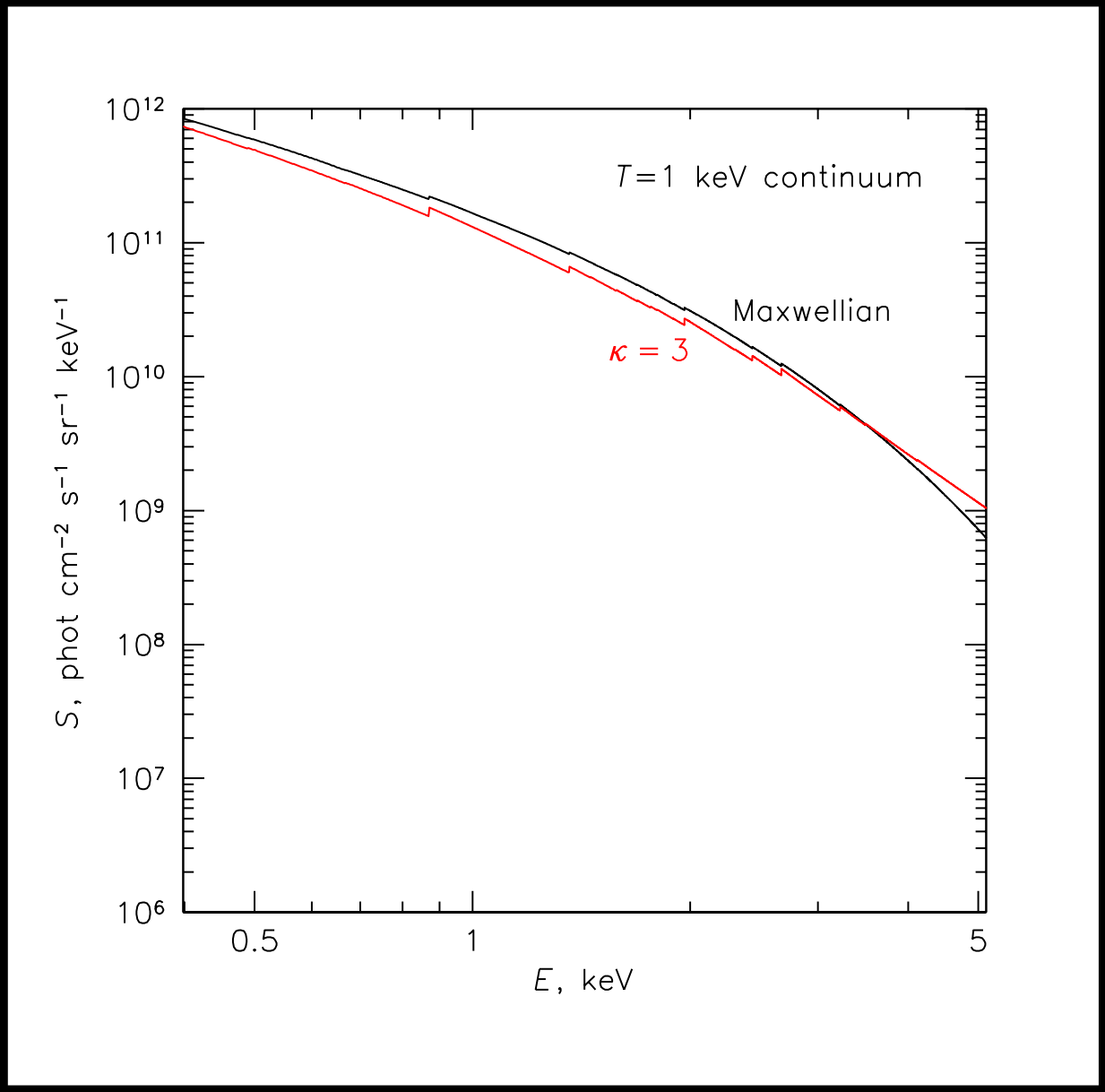
X-ray continuum for κ and Maxwellian distributions



using Dzifčáková 15 software

- no exponential cutoff!

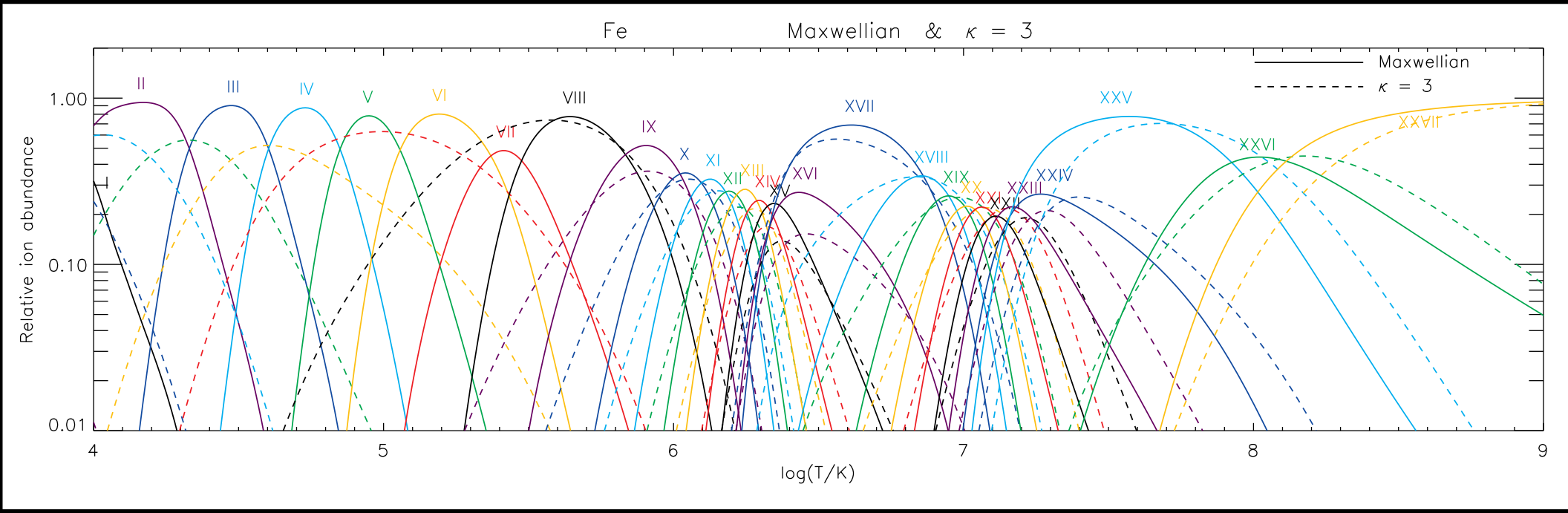
X-ray continuum for κ and Maxwellian distributions



using Dzifčáková 15 software

- normalization differs by factor ~ 1.25

κ distribution: ionization equilibrium



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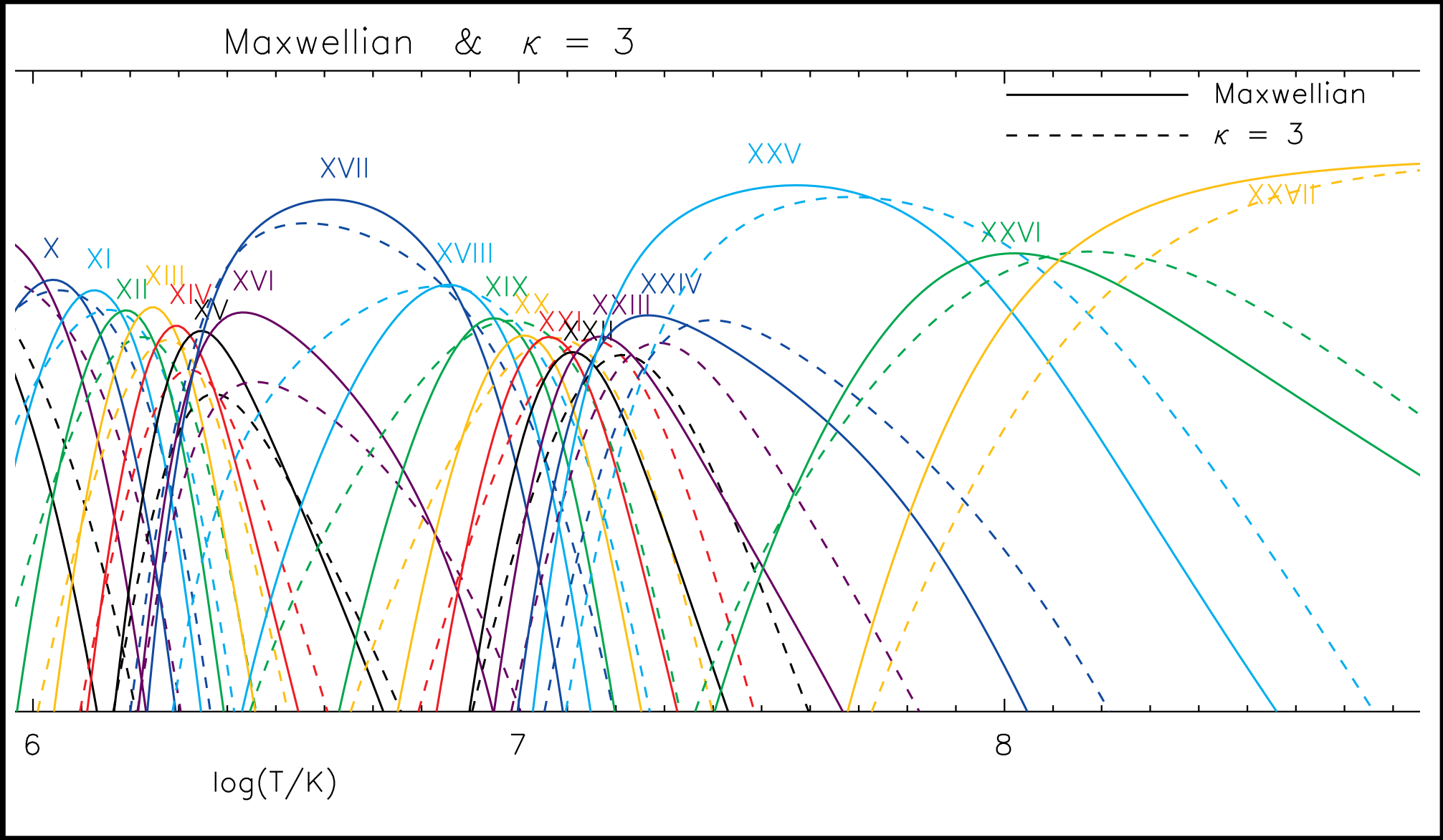
κ distribution: ionization equilibrium



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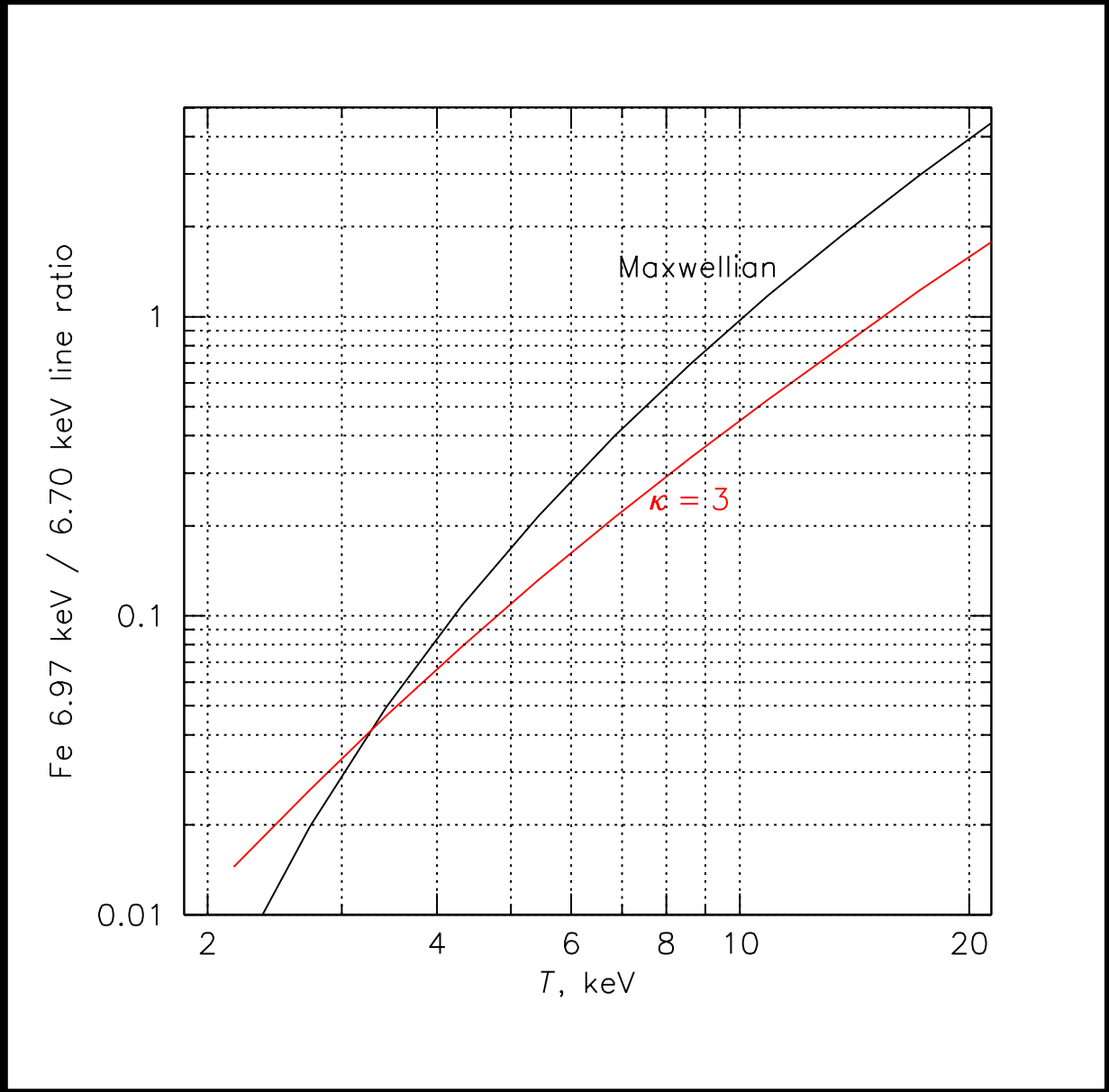
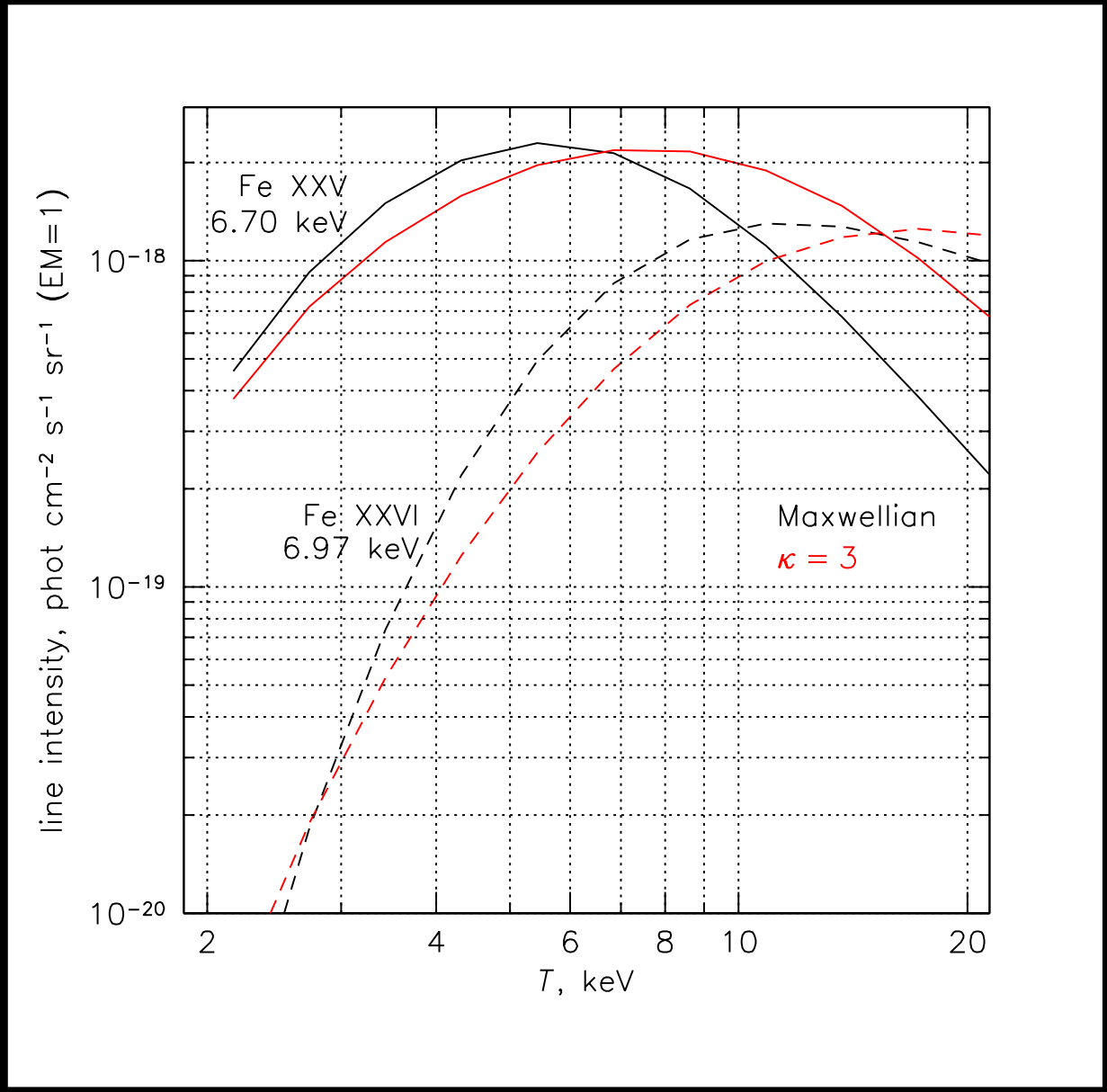
Fe line ratios for κ and Maxwellian distributions



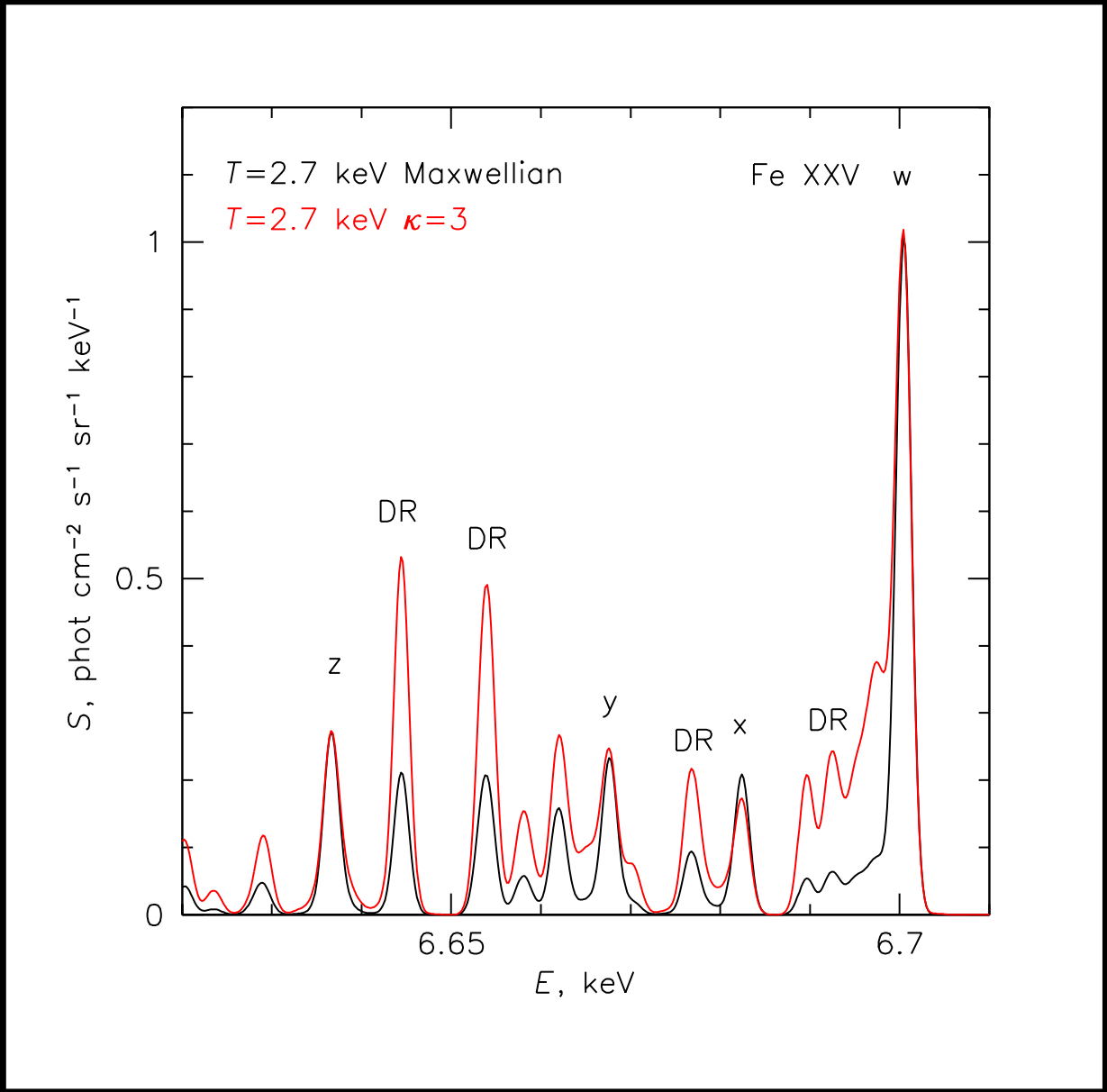
- different T from resonant lines and from continuum

Fe line fluxes for κ and Maxwellian distributions



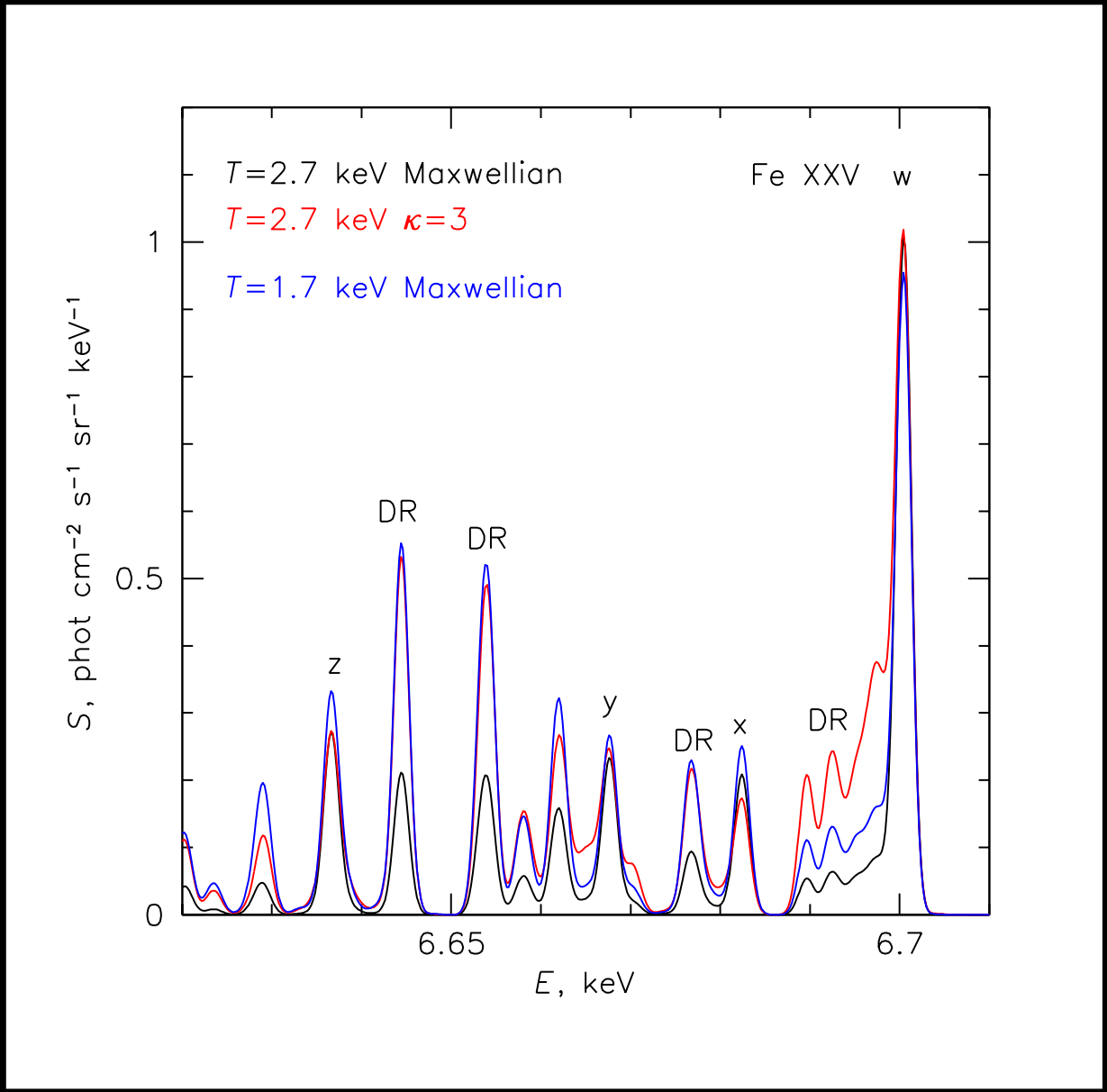
- peak resonant line fluxes not too different

Anomalous satellite lines



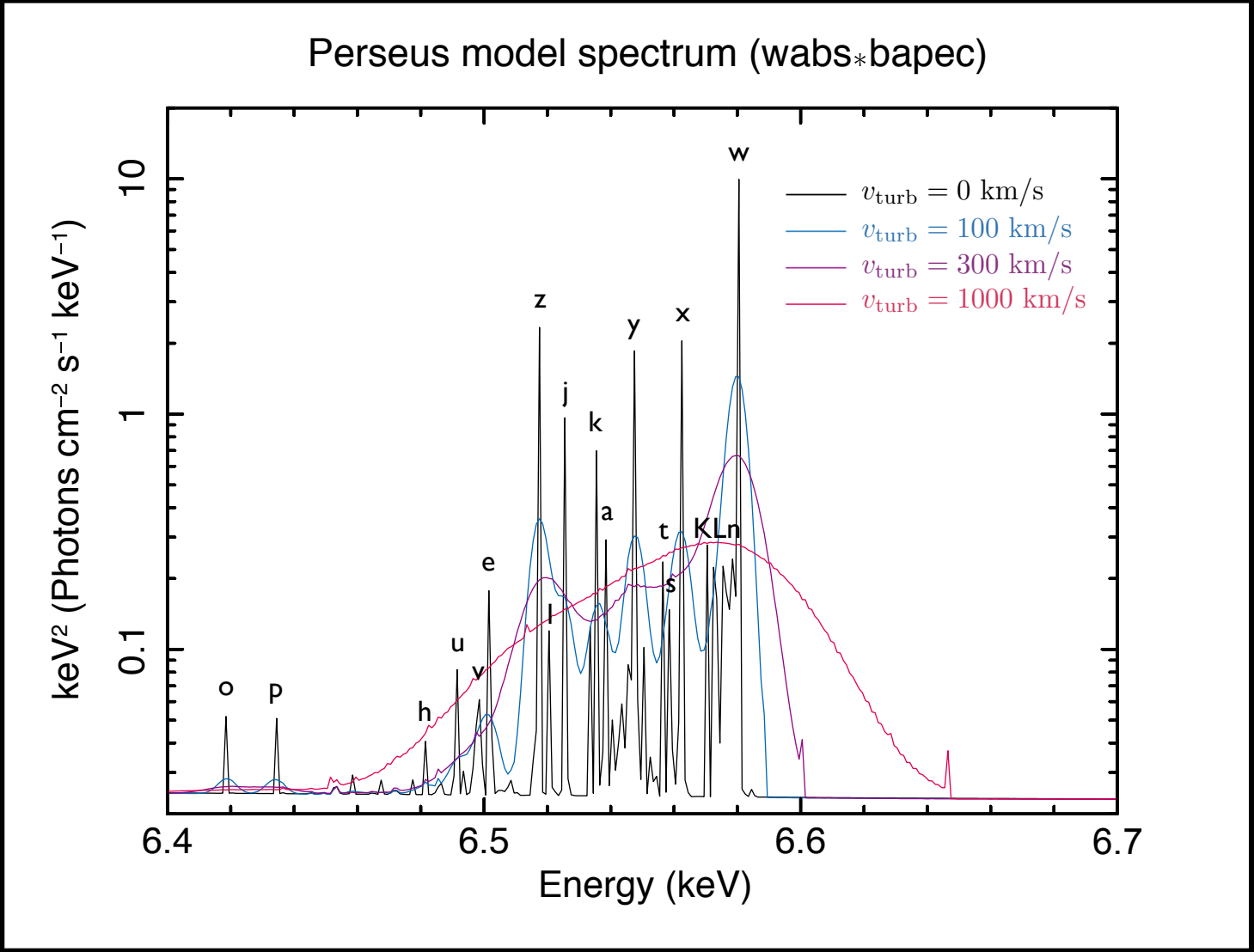
using Dzifčáková 15 software

Anomalous satellite lines



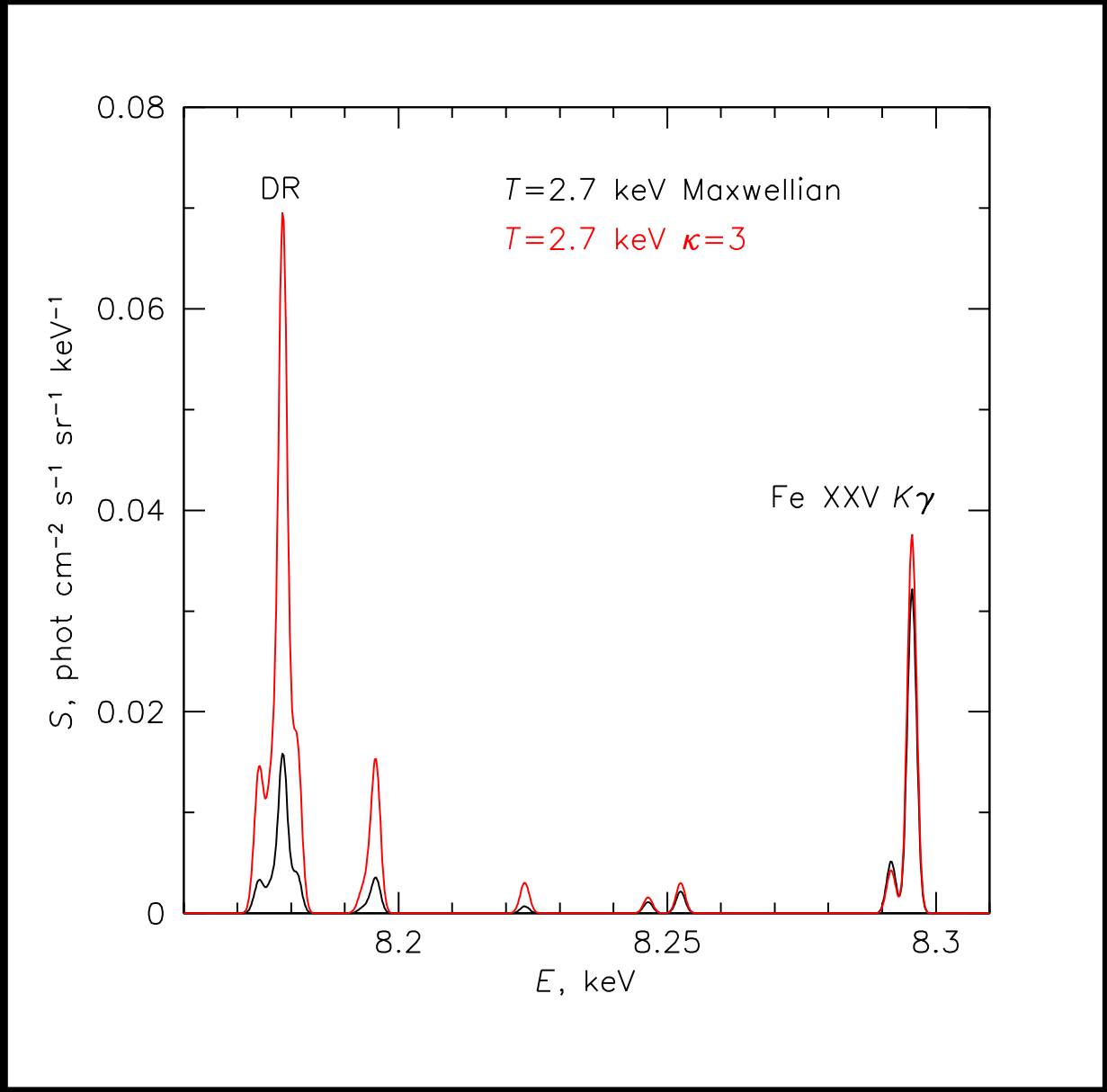
- some DR lines can be mimicked by lower-T components, but not all

... but there will be turbulent broadening

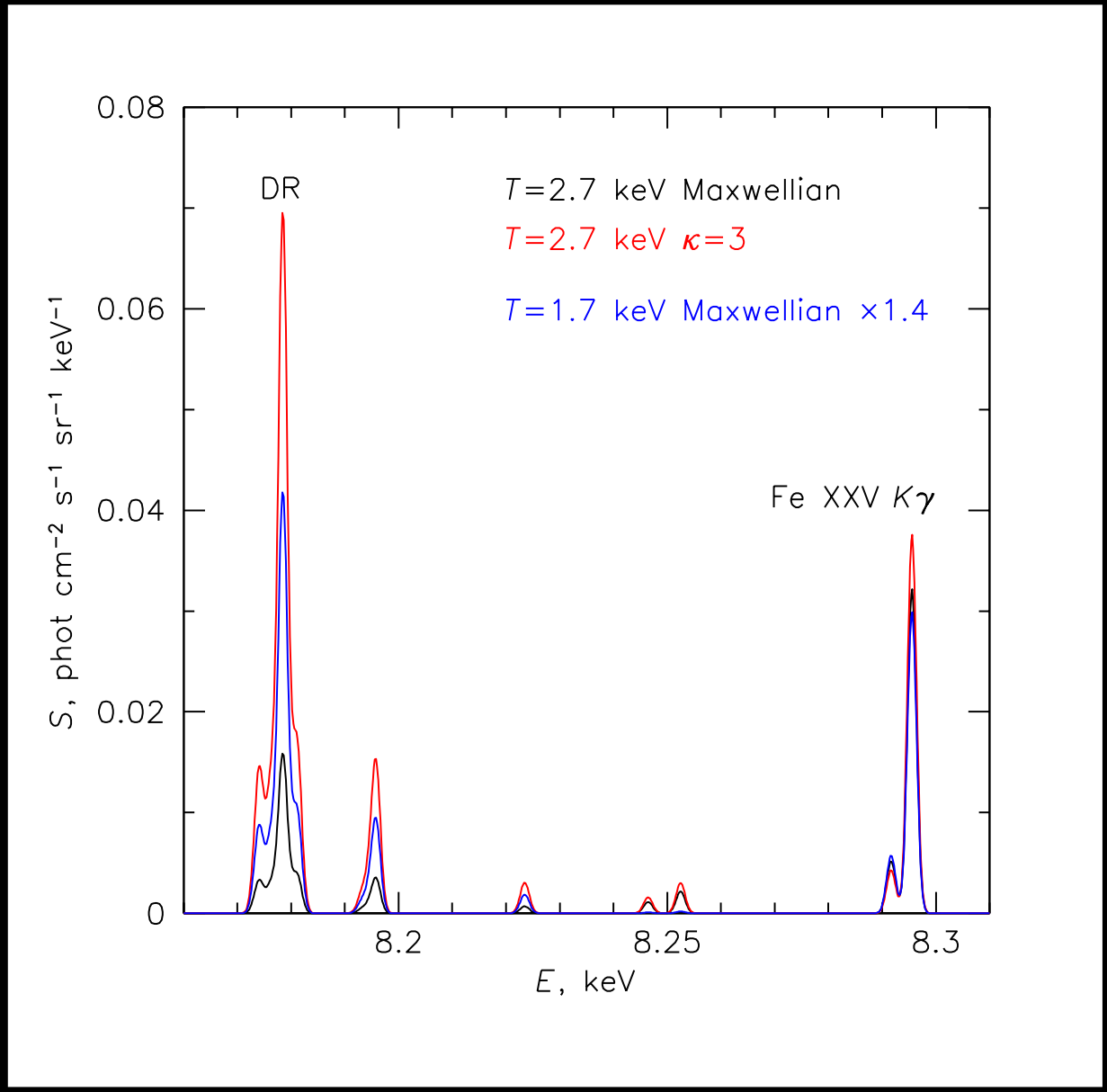


Astro-H White Paper, Kitayama 14

Anomalous satellite lines



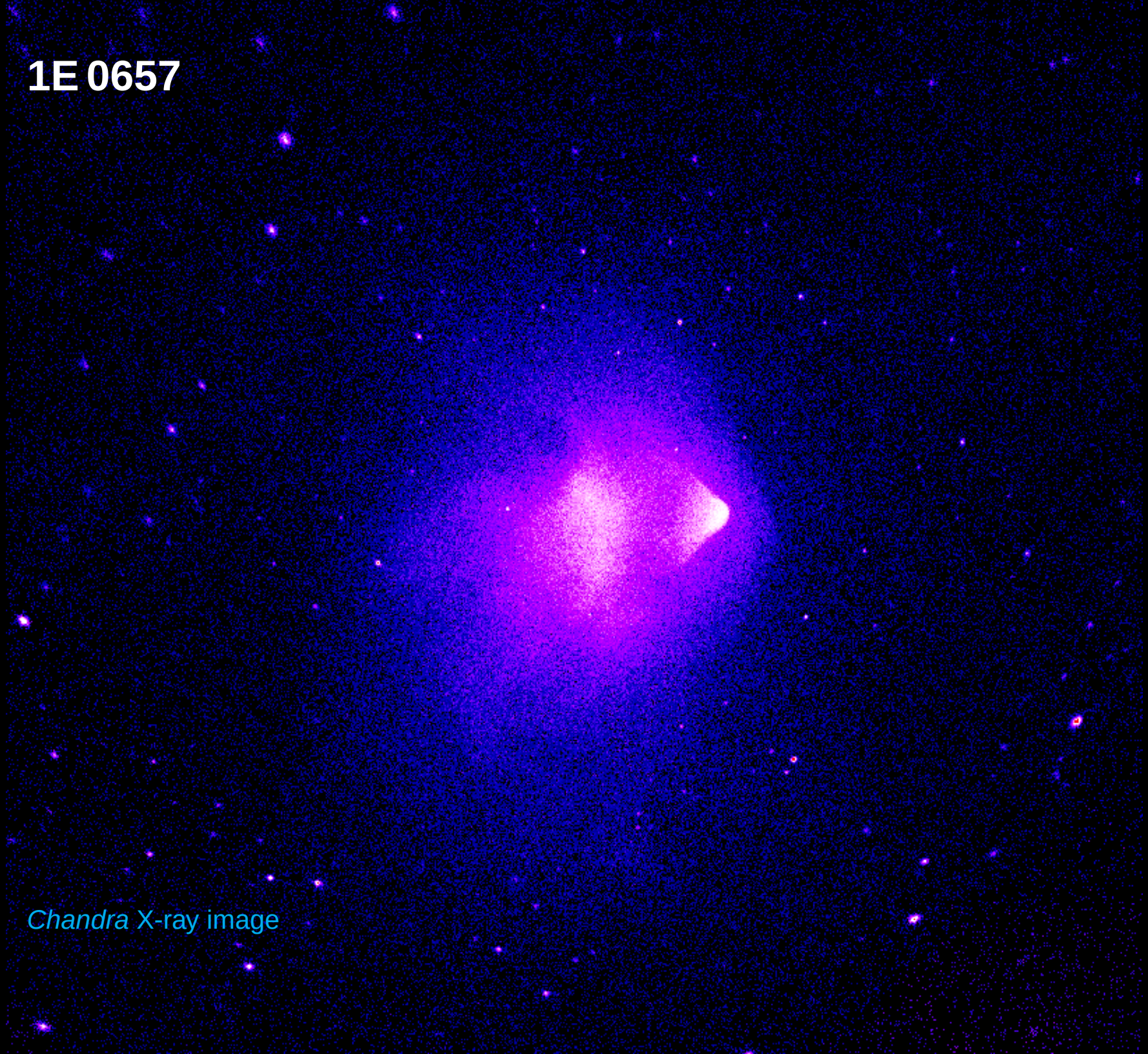
Anomalous satellite lines

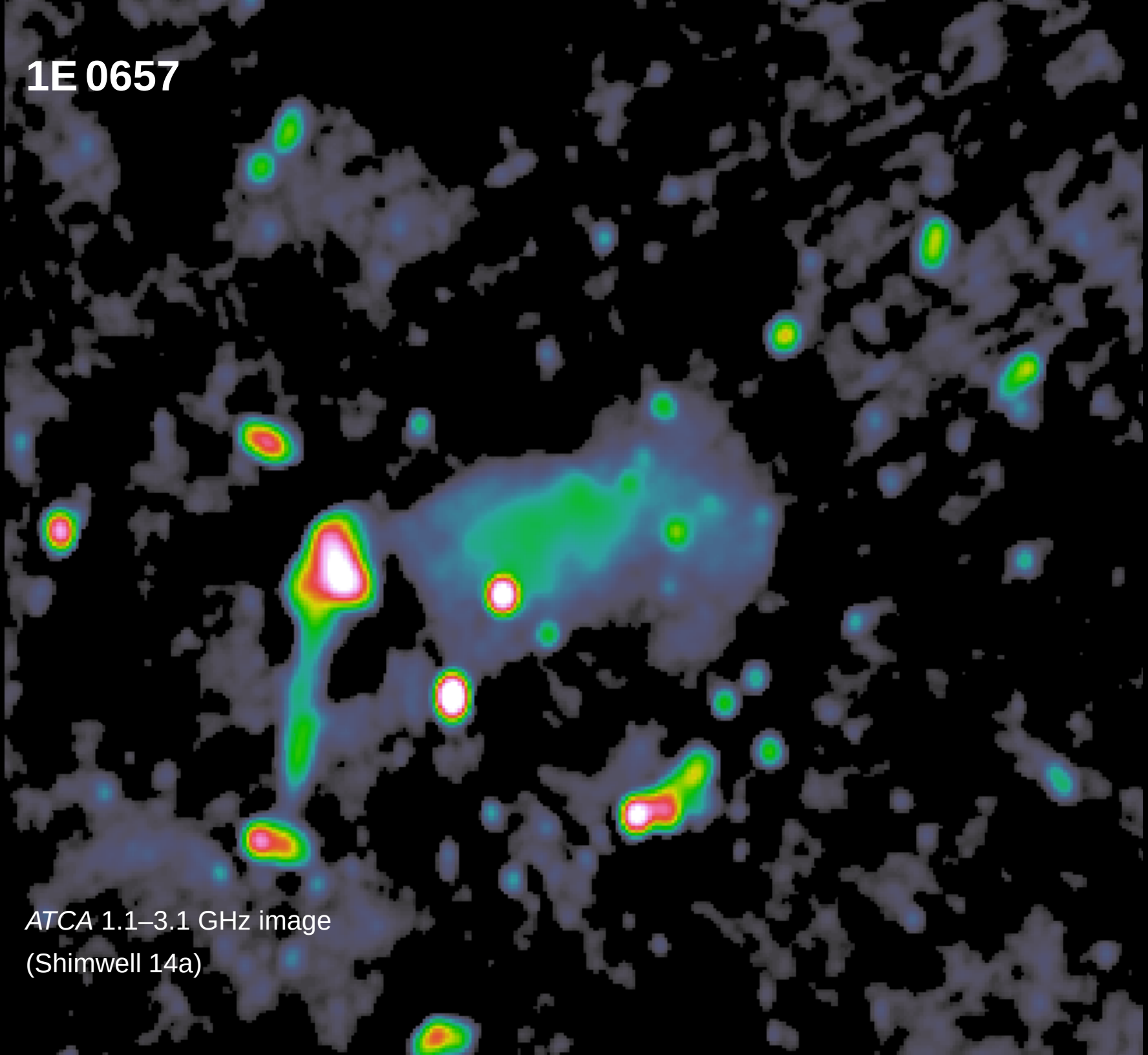


- these DR lines cannot be mimicked by a cooler component and are unaffected by turbulence

Can test for non-Maxwellian distribution in clusters
using satellite spectral lines.

- Obviously need a calorimeter, but why 1″ resolution?


1E 0657
Chandra X-ray image



ATCA 1.1–3.1 GHz image
(Shimwell 14a)

Although it may be widespread, most likely to detect non-Maxwellian plasma

- at shock fronts (rapid heating and particle acceleration)
- cold fronts (possible magnetic reconnection)
- radio relics, AGN bubbles (thermal plasma interacting with cosmic rays)

— all of these require 1″ resolution