Galaxy Clusters as Plasma Physics Laboratories and Cosmological Probes

Elena Rasia

Physics Department,

University of Michigan,

Ann Arbor

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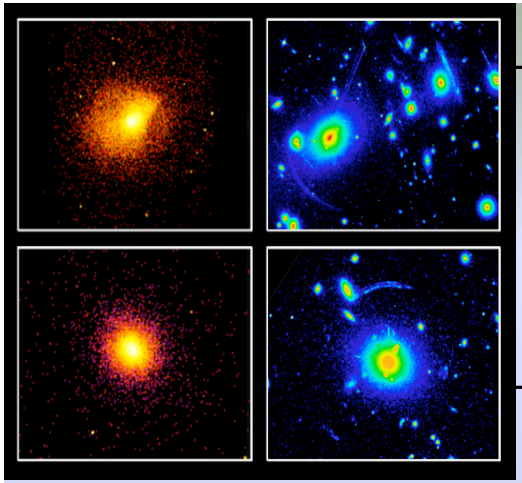
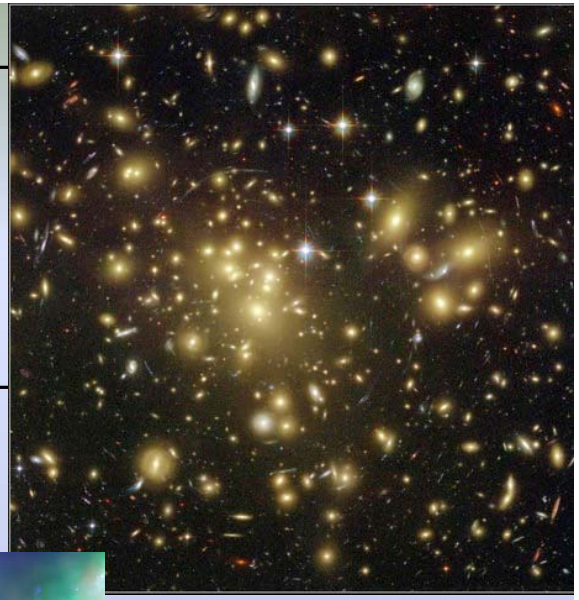
CLUSTERS OF GALAXIES



Abell 2390 & MS2137.3-2353

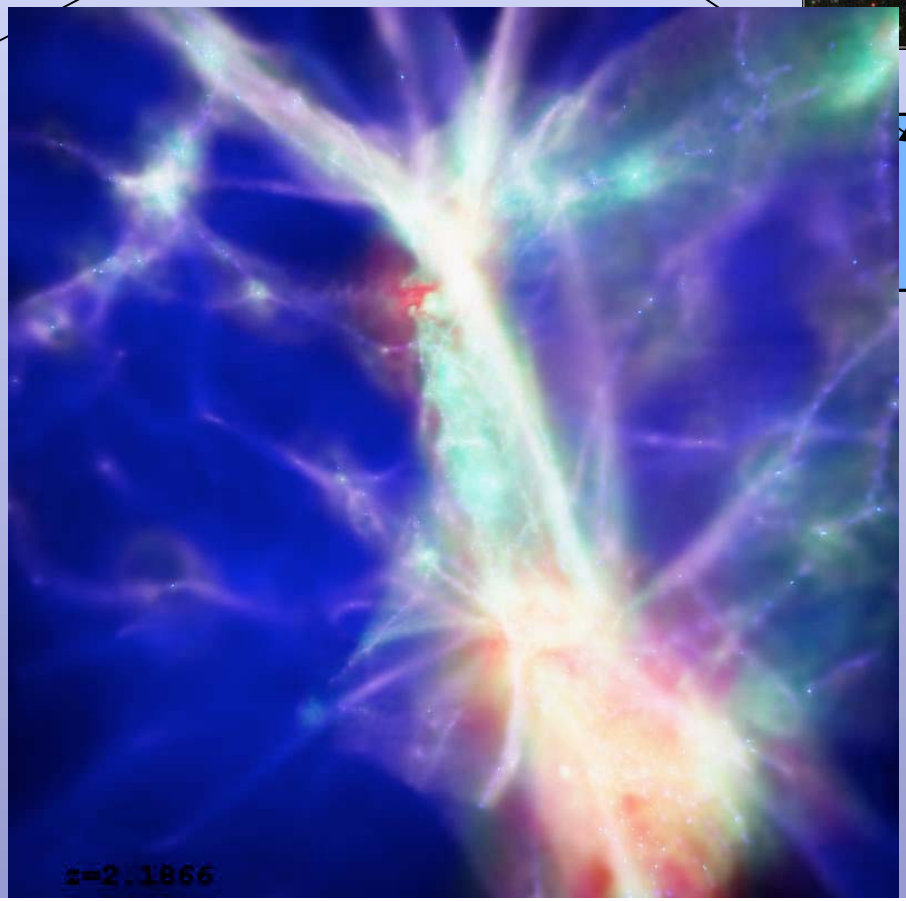


Abell 1689

LABORATORY OF THE ICM PHYSICS

Key quantities:
Hydro-properties
Gas density
Temperature
Pressure
Metals

Dolag, Meneghetti, Moscardini, Rasia, Bonaldi, 06



VIEWPOINT O COSMIC WEB

Key quantity:
MASS

Movie: thanks to Klaus Dolag

http:
//www.astro.unipd.it/~cosmo/

CLUSTERS AS LABORATORIES...

OF THE ICM MEDIUM

… OF THE STELLAR EVOLUTION AND HISTORY

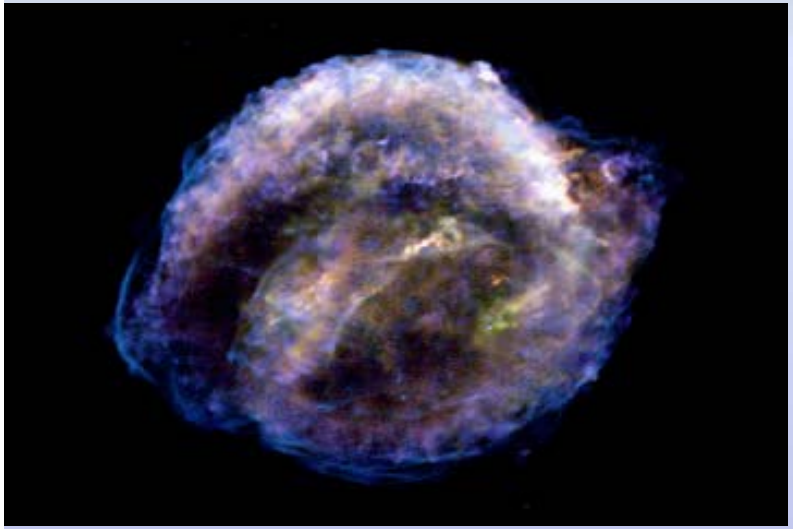
“X-MAS2: STUDY SYSTEMATICS ON THE ICM METALLICITY MEASUREMENTS”

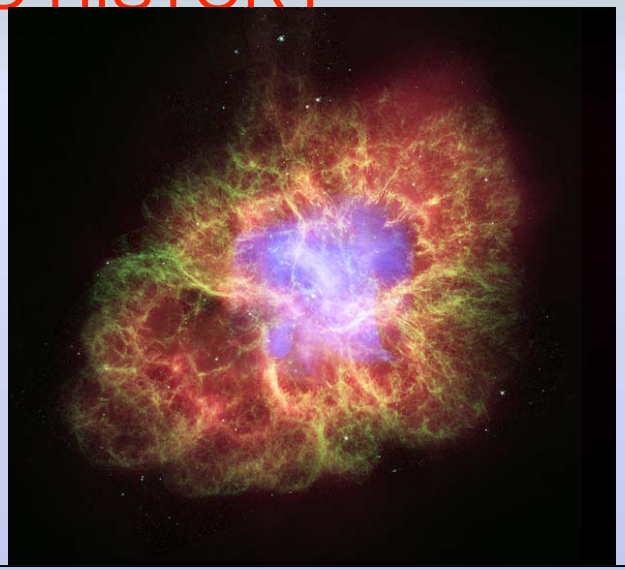
In collaboration with

Mazzotta P., Bourdin H., Borgani S.,Tornatore L., Ettori S., Dolag K., Moscardini L.

(accepted ApJ, astro-ph/0707:2614)

CLUSTERS AS LABORATORIES FOR THE STELLAR EVOLUTION AND HISTORY





SNe IA PROGENITORS:
white dwarf accreting matter from a nearby companion star

Iron (major contributor), Silicon

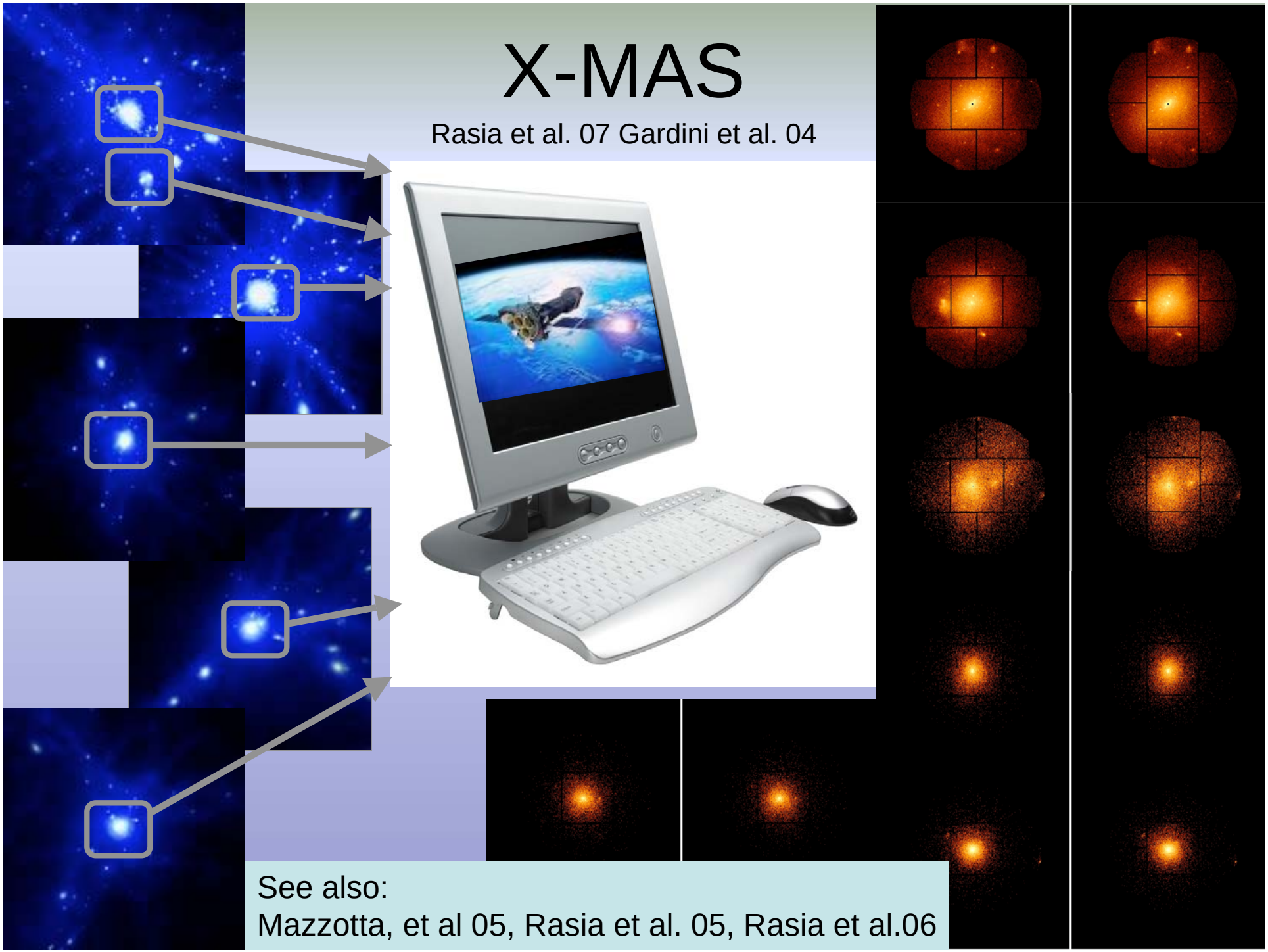
SNe II PROGENITORS:
massive stars (with mass greater than 8 M_{sun})

α-elements,as Oxygen, Magnesium, Silicon

$\Rightarrow$[α/Fe] gives indication of (SN Ia/ SN II)
$\Rightarrow$[Si/Fe] gives indication of yields of SN Ia

X-MAS

Rasia et al. 07 Gardini et al. 04



See also:
Mazzotta, et al 05, Rasia et al. 05, Rasia et al.06

Procedure of X-ray Analysis

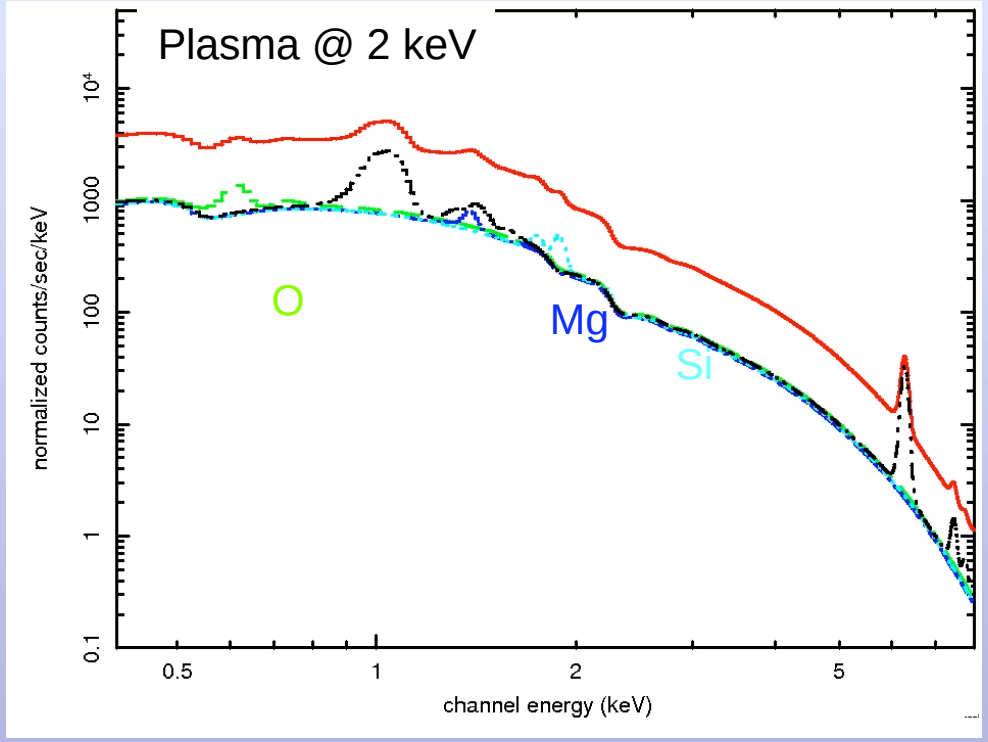
- Procedure 1:

Fitting VMEKAL model on [0.4 8] keV band with T, O, Mg, Si, Fe and normalization as free parameters

-> green crosses

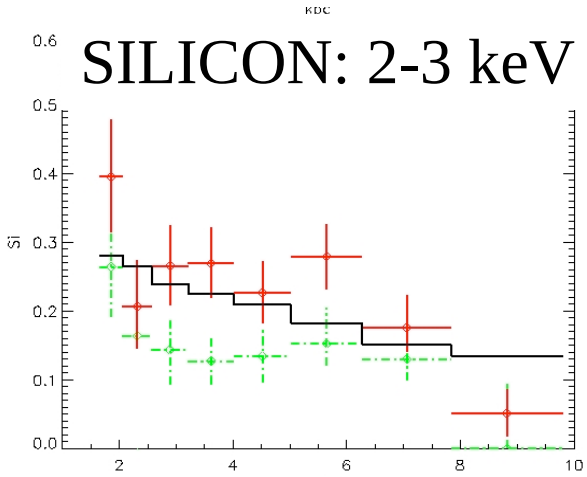
- Procedure 2:
  - Measure T and Fe from [0.4 8]keV band
  - Fix T and Fe and calculate O in [0.4 1.5] keV band and Mg and Si in [1.2 3.2] keV band.

-> red crosses

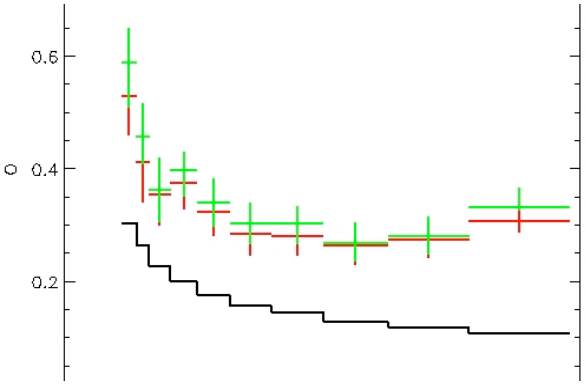


Alpha-Elements Profiles

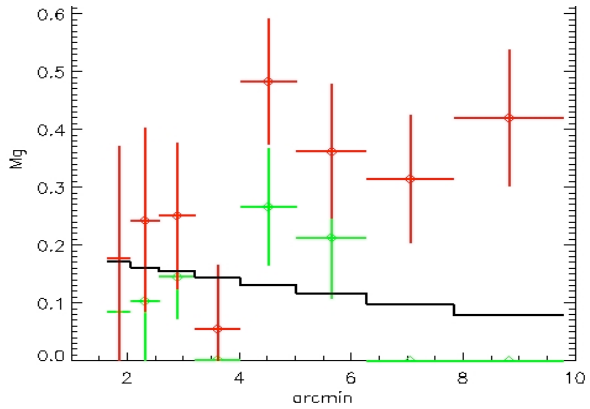
SILICON: 2-3 keV



OXYGEN: 8-12 keV



MAGNESIUM: 6-9 keV



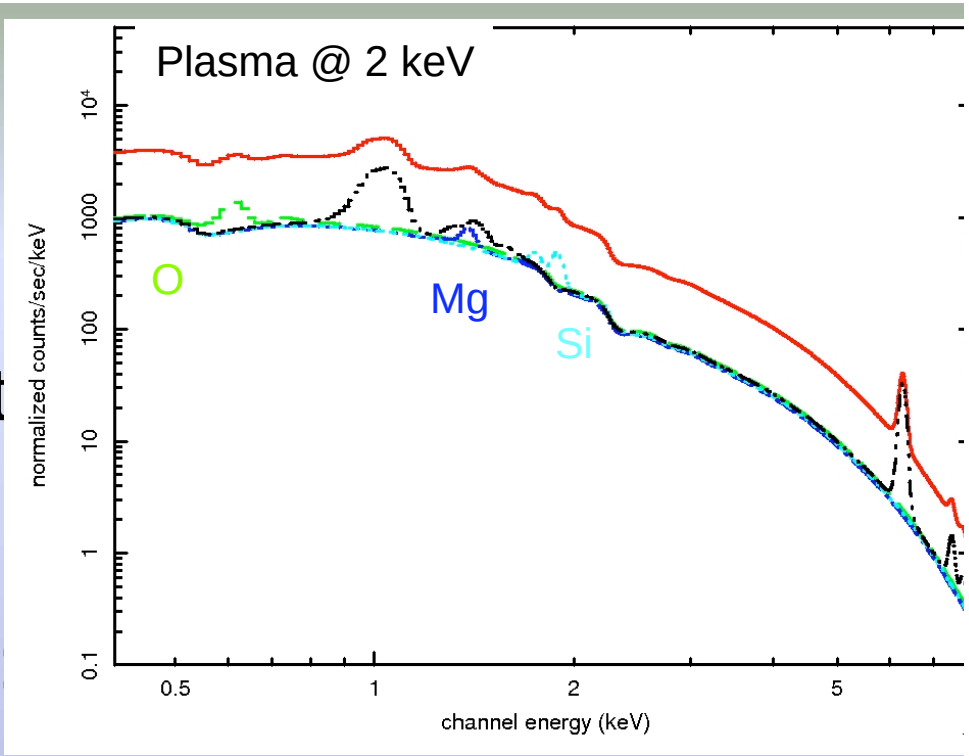
Silicon profiles are well recovered for all the clusters in the sample

For systems with T < 5 keV, we perfectly recover Oxygen.
Magnesium is difficult to detect at all temperatures.
Large and hot systems show a systematic overestimate of Oxygen and Magnesium lines.

free
frozen

Interpretation: O and Mg

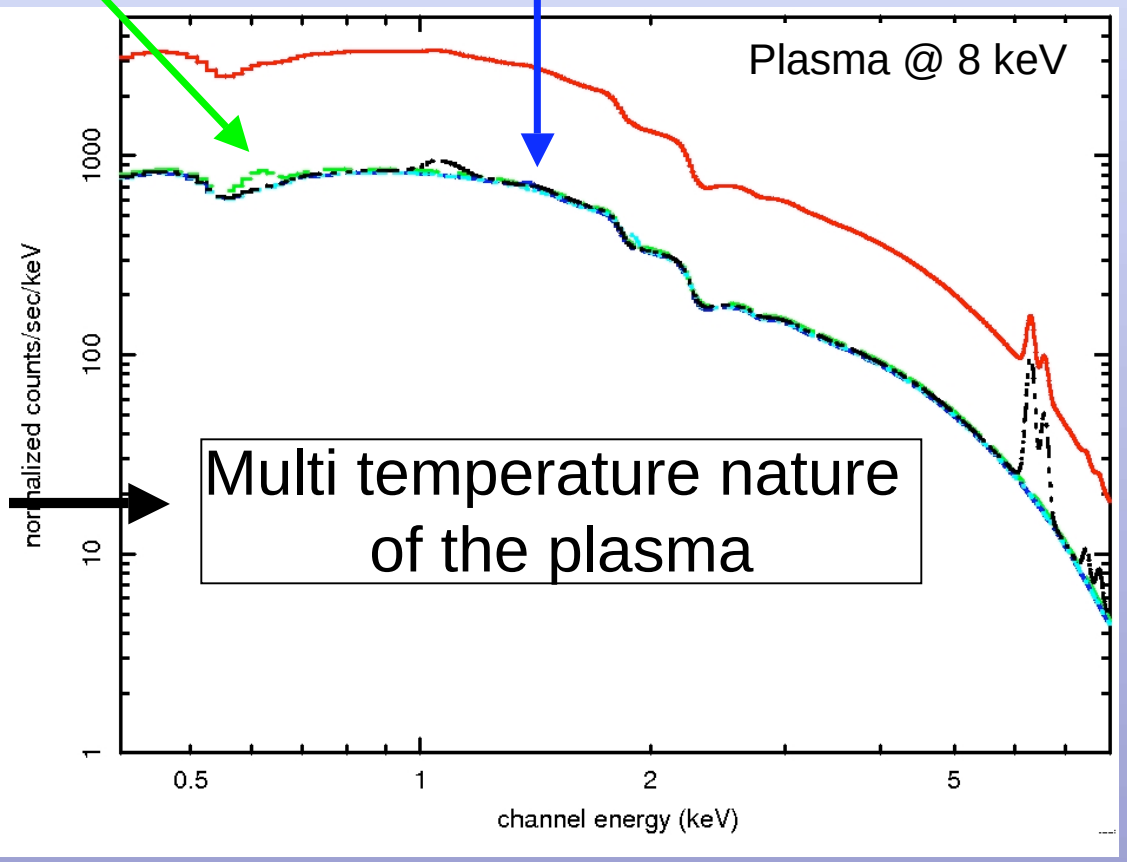
Those elements are the best alpha-elements indicators.
It necessary to understand the origin of the discrepancy



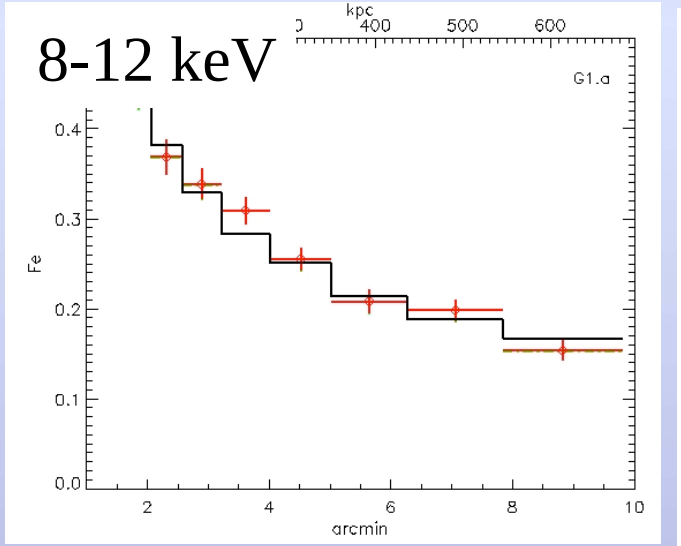
- Presence of cold blobs
- Dynamical state of the cluster
- Fe-L - Fe-K ratio (the analyzed spectra contains contribution from different plasma present on the line of sight: Fe-L/Fe-K ratio change. For G51 Fe-L < Fe-K)
- Continuum determination: Oxygen

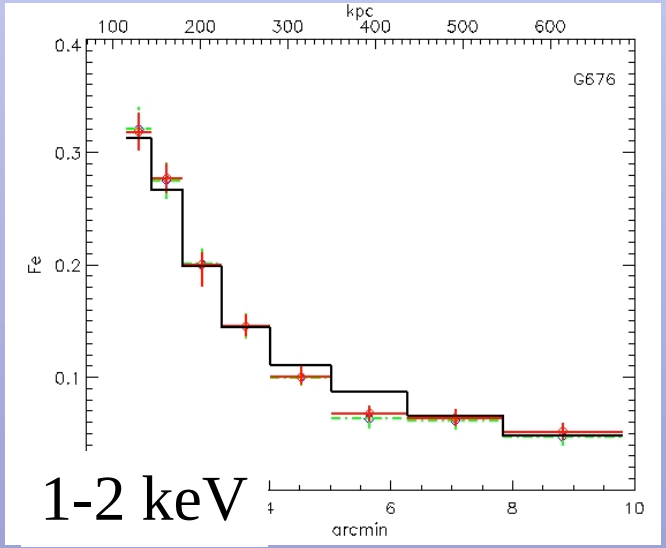
Interpretation: Oxygen and Magnesium

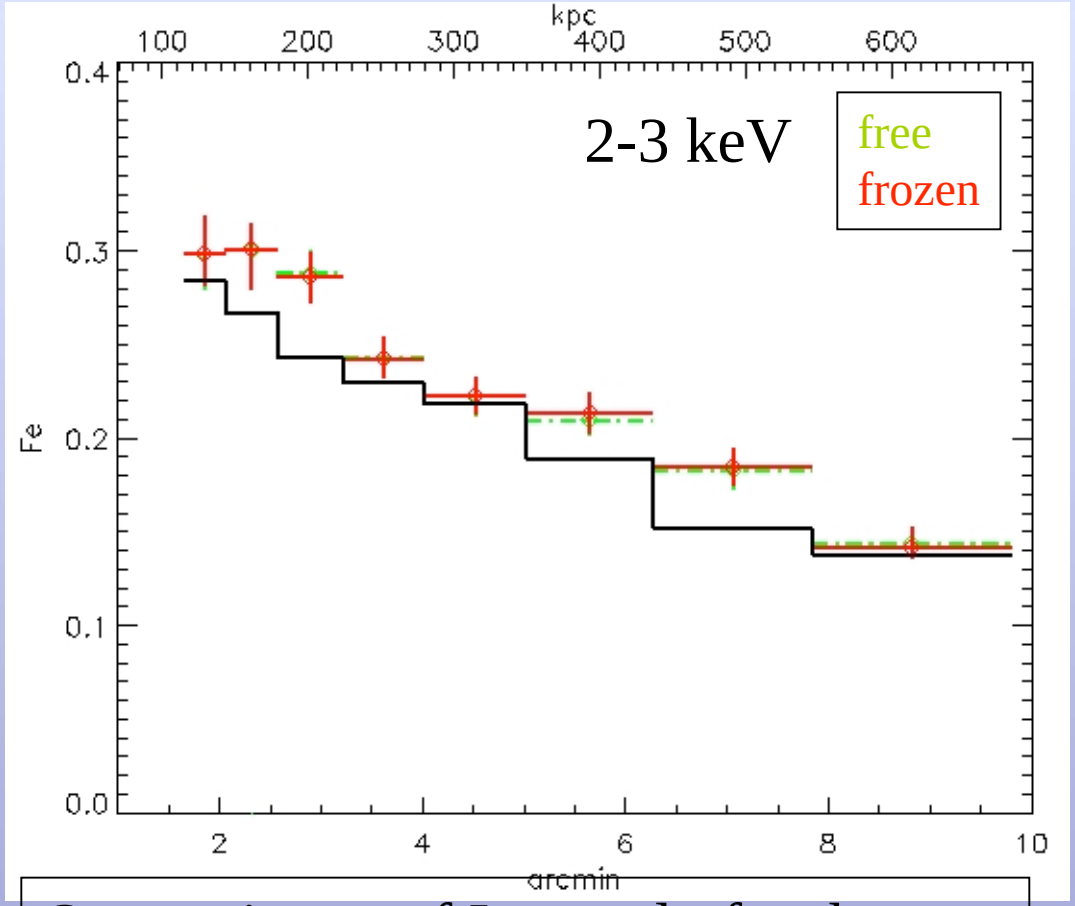
At high temperatures, Oxygen and Magnesium are very weak. For both elements, slight changes in the continuum produce large deviation on the lines' emissivity measurements.



Iron profile

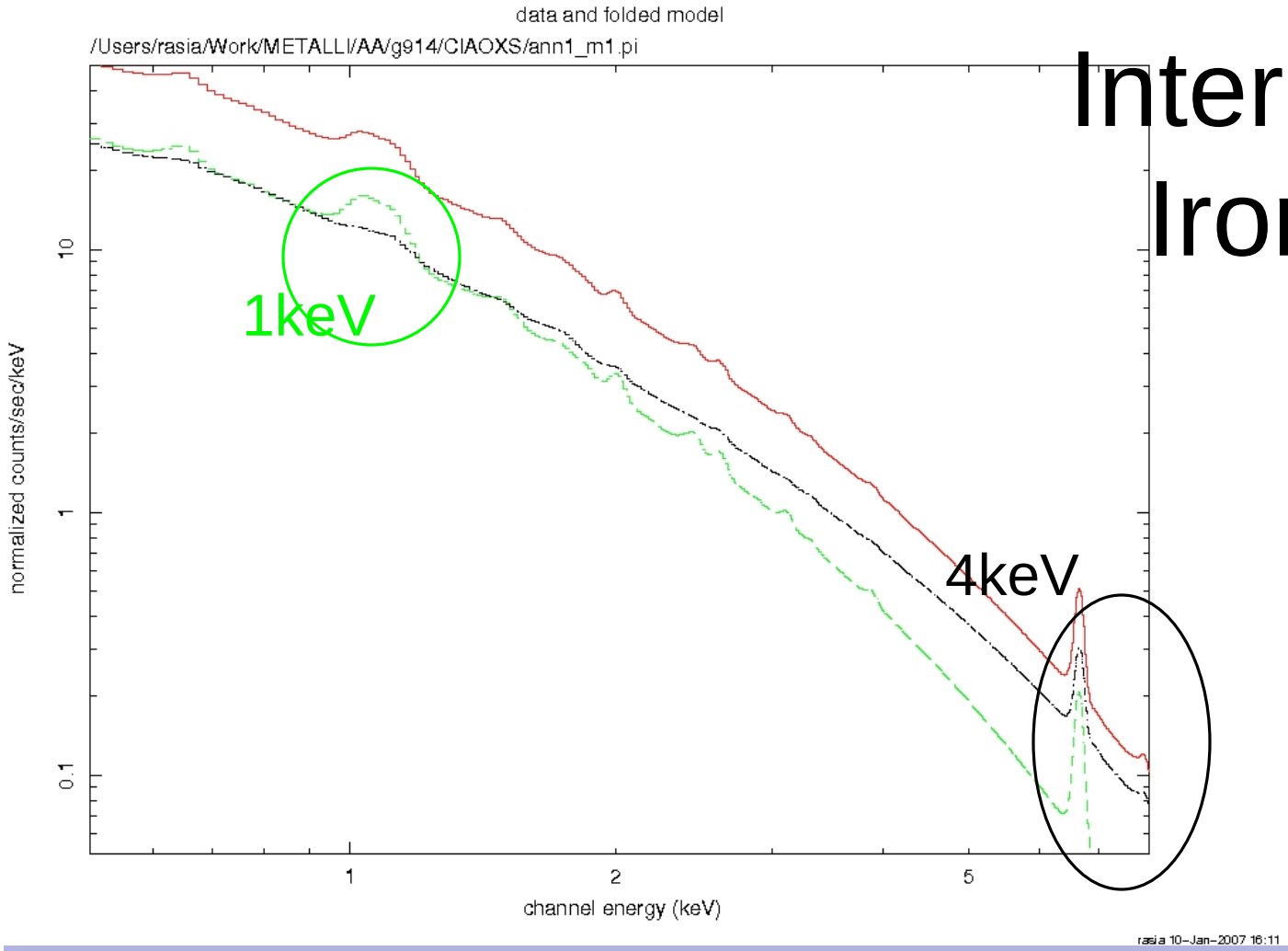






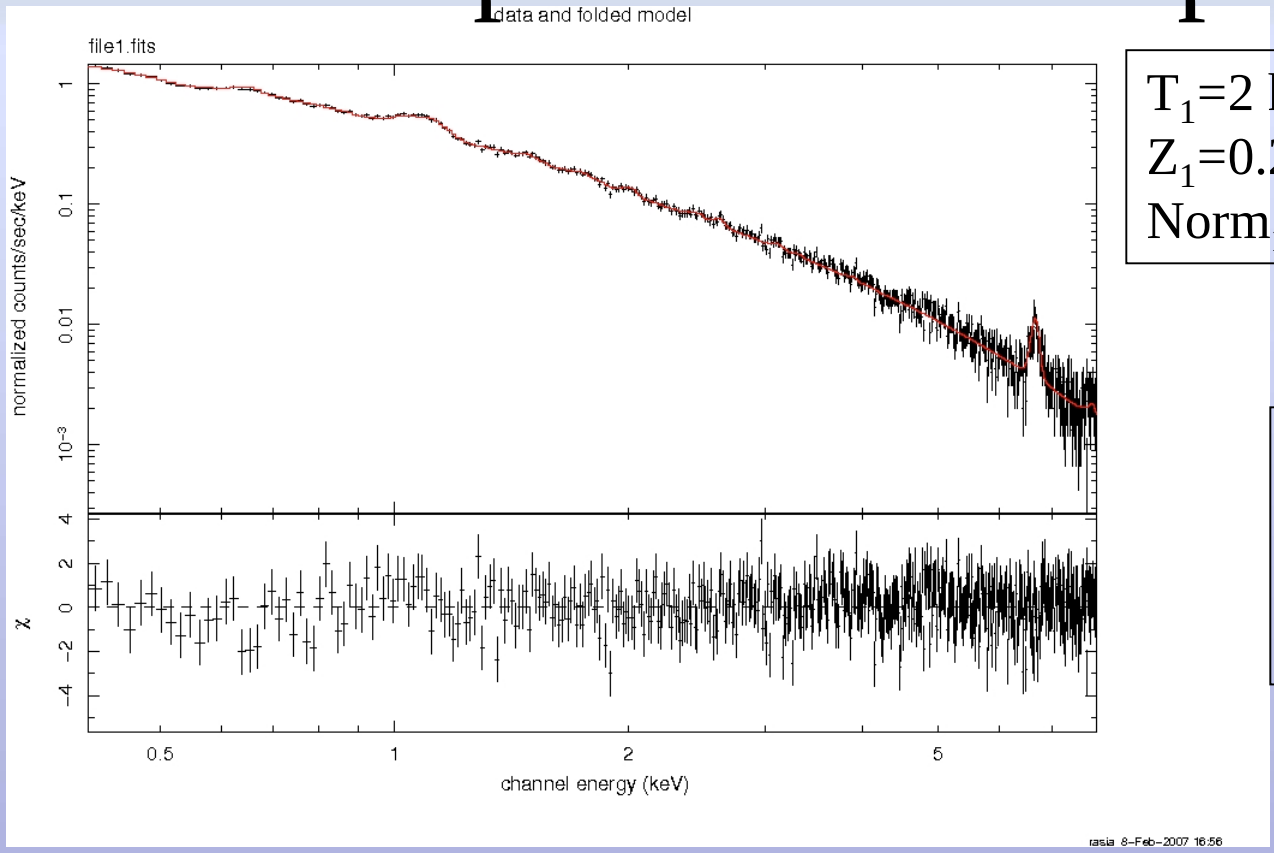
Overestimate of Iron only for the cluster at temperature of 2-3 keV. Good agreement for hotter and colder systems.

Interpretation: Iron profile



A 2-3 keV object is a combination of temperature: those larger than 2.5/3 give a large contribution to the Fe-K lines; those smaller, to the Fe-L lines => both groups of lines are pumped up by different-temperature plasmas

Interpretation: Iron profile



T_1=2 keV
Z_1=0.2
$Norm_1$=1

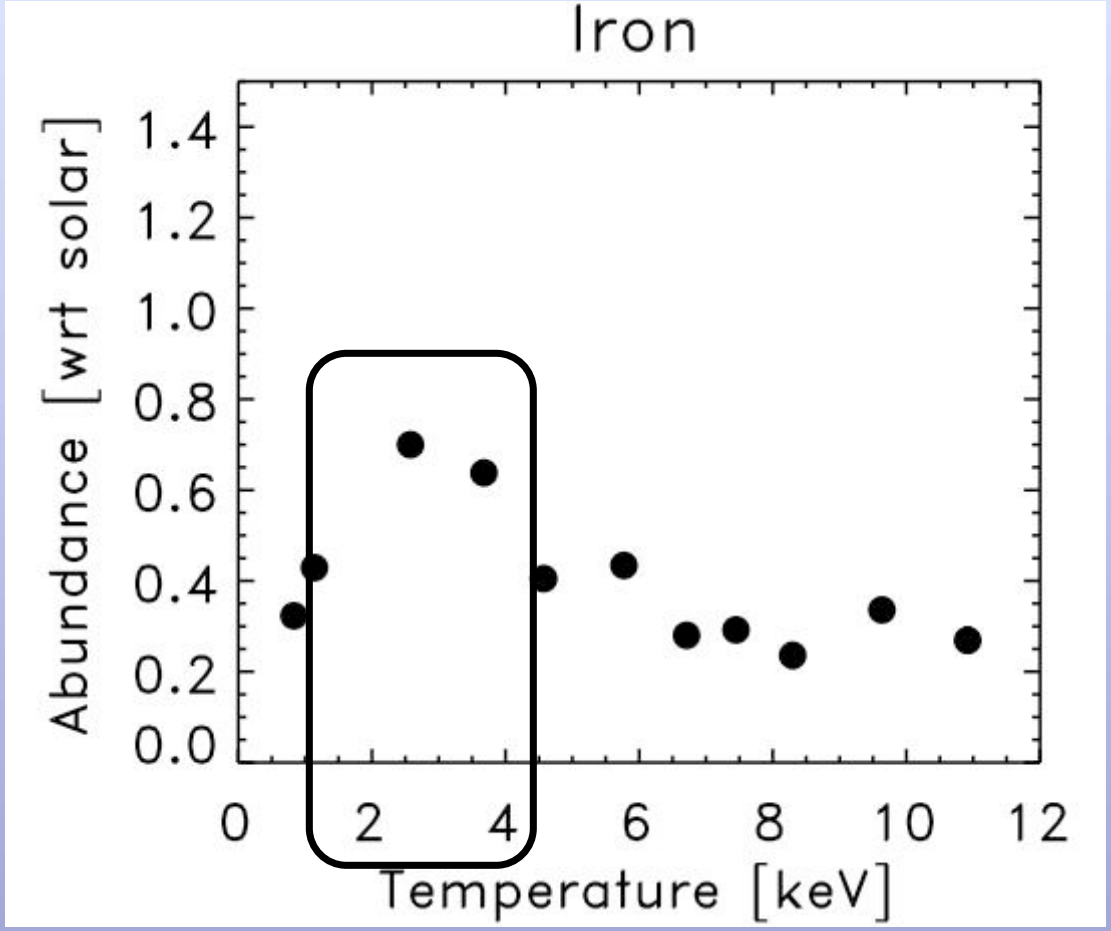
+

T_2=3keV
Z_2=0.1
$Norm_2$=1

EXPECTED:
T = 2.420
Z = 0.144
N = 2.000

# counts	4.5 1e3	9.0 1e3	4.5 1e4	9.0 1e4	4.5 1e5	9.0 1e5
T	2.439	2.434	2.51	2.44	2.27	2.45
FE	0.199 (38%)	0.186 (29%)	0.185 (27%)	0.183 (27%)	0.174 (21%)	0.165 (16%)

Consequences



Baumgartner et al. 05

- The systematic overestimate of Fe for systems of 2-3 keV can reduce the significance of the bump of Baumgartner et al. plot

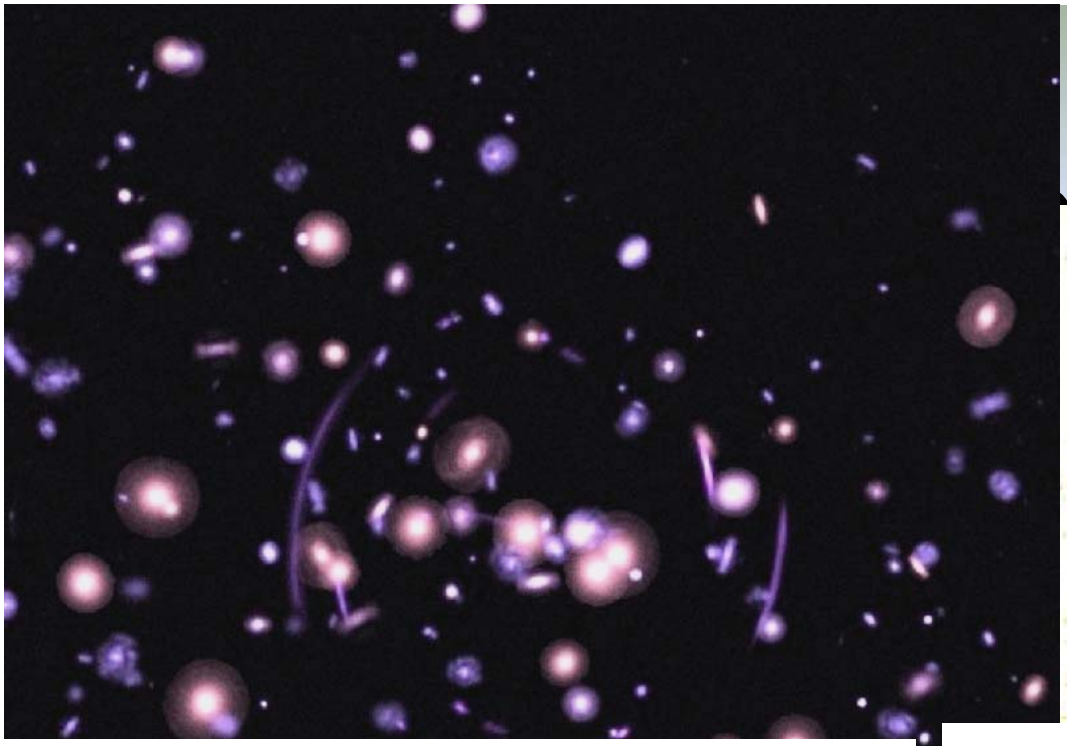
- Attention has to be paid to different [α/Fe] ratios…
- and to their interpretation

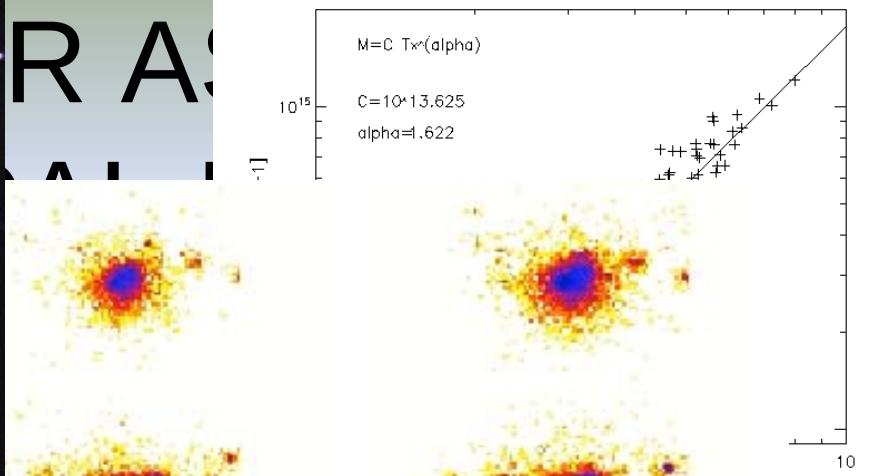
Conclusion

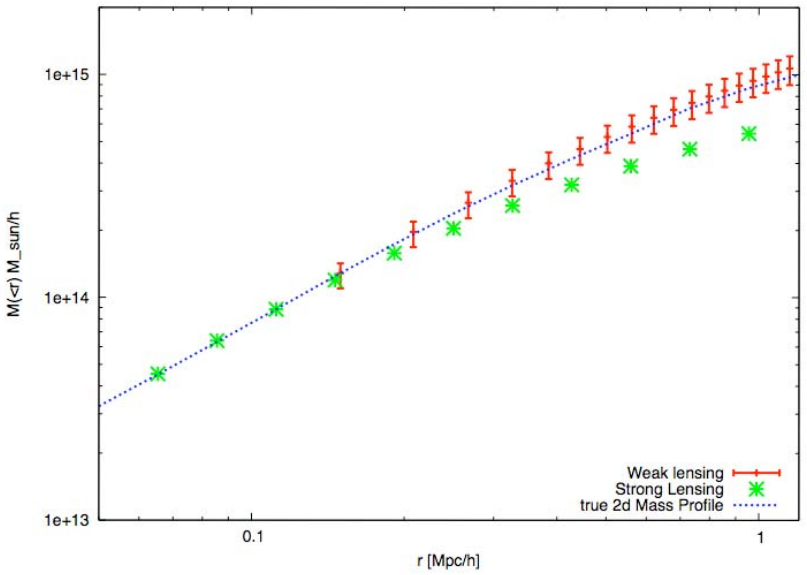
For the multi-temperature nature of plasma in clusters the measurement of elements which have a weak emission in respect to the continuum IS NOT A SOLID AND ROBUST ESTIMATE

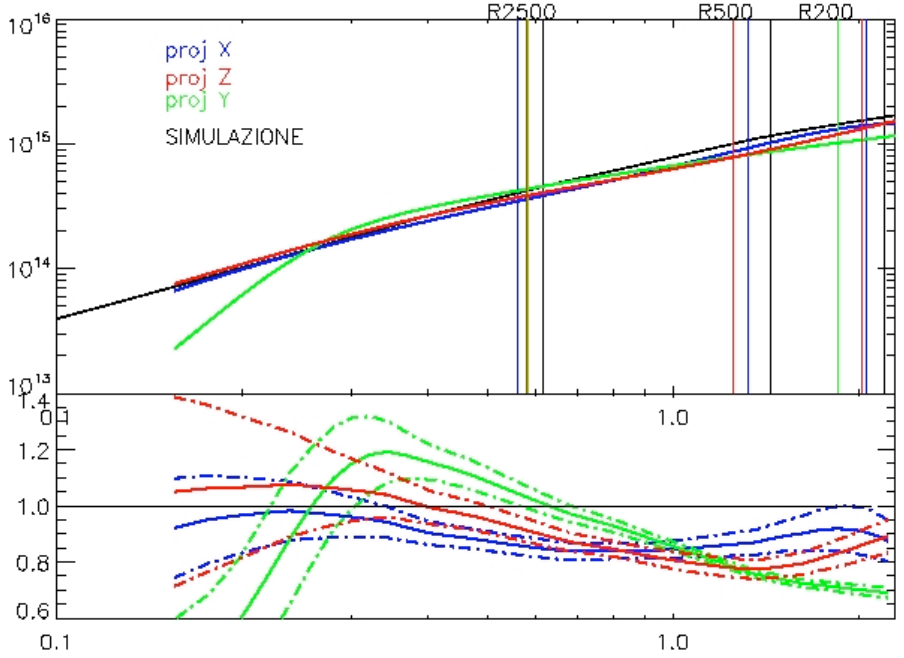
Iron estimate for systems of 2-3 keV can likely be biased towards higher values since this is a critical temperature range where we mix together plasma presenting either strong Fe-L or strong Fe-K

Measuring O, Mg and Si in a narrow band leads to a result closer to the input value




M=C Tx^(alpha)
C=10^13.625
alpha=1.622
10^{15}
10


1e+15
1e+14
1e+13
M(<r) M_sun/h
0.1
1
r [Mpc/h]
Weak lensing
Strong Lensing
true 2d Mass Profile


R2500
R500
R200
10^{16}
10^{15}
10^{14}
10^{13}
proj X
proj Z
proj Y
SIMULAZIONE
1.4
1.2
1.0
0.8
0.6
0.1
1.0