Benchmark Exercises for stellar X-ray Spectroscopy Testing (BEXST): Initial Results

A. Maggio

INAF - Osservatorio Astronomico di Palermo

Project proposed by

A. Maggio, J. Drake, F. Favata, M. Güdel, C. Jordan

implemented by the "hare team"

C. Jordan (Oxford Uni.), S. Orlando & A. Maggio (INAF-OAPa)

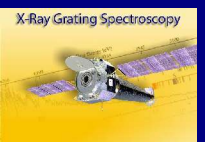
and executed by the "hounds team"

C. Argiroffi (UniPa), J. Sanz Forcada (LAEFF),

D. Huenemoeder (MIT), C. Liefke (Hamburger Sternwarte),

J.-U. Ness (ASU), R. Nordon (Technion),

T. Raassen (SRON), L. Scelsi (OAPa)



Why BEXST (1)

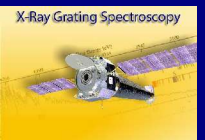
Scientific issue:

- Physics of hot, low-density plasmas in astrophysical environments, e.g. stellar coronae
  - Thermal structure ⇒ heating deposition, energy balance
  - Chemical composition ⇒ cosmic abundances, fractionation mechanisms
  - Densities ⇒ inhomogeneities, magnetic confinement

Methodology issue:

- Line-based analysis of high-resolution X-ray spectra from optically-thin plasmas
  - Plasma emission measure distribution vs. temperature

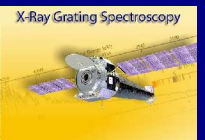
    (ill-posed mathematical problem)
  - Relative and absolute element abundances (continuum level)
  - Density-sensitive line ratios (e.g. He-like triplets)



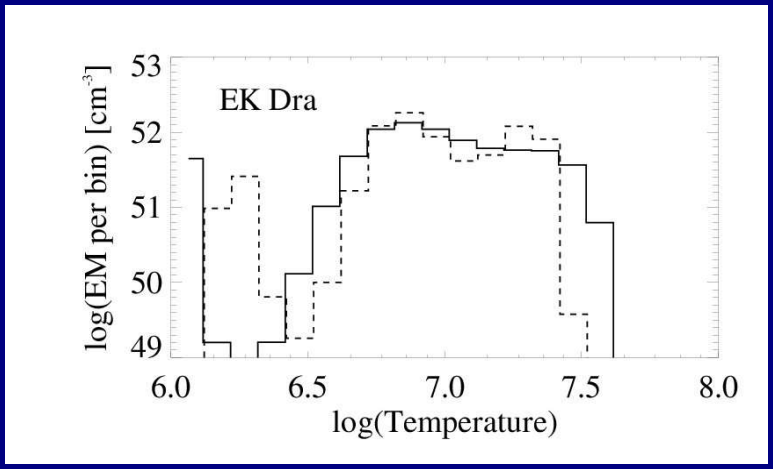
Why BEXST (2)

- Methods used for the analysis of Chandra and XMM-Newton grating spectra differ in
  - numerical inversion strategies or convergence techniques
  - sample of emission lines used
  - atomic physics databases
  - free parameters allowed in the underlying models

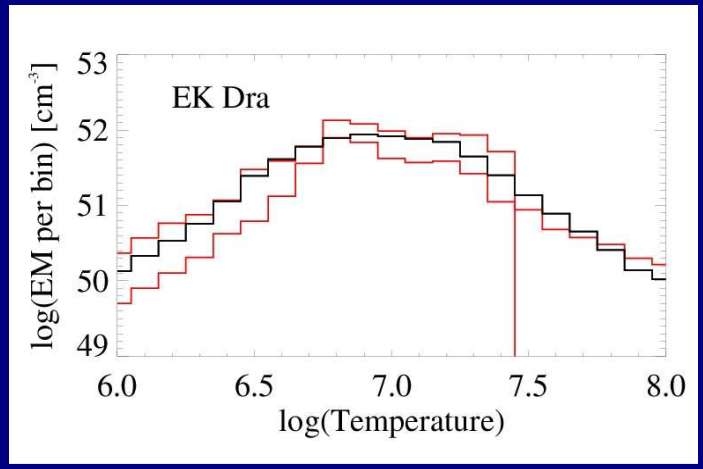
- Need to compare the results of all the different approaches in order to check whether these are compatible, and whether some (or all) of these lead to biases in the physical parameters derived.



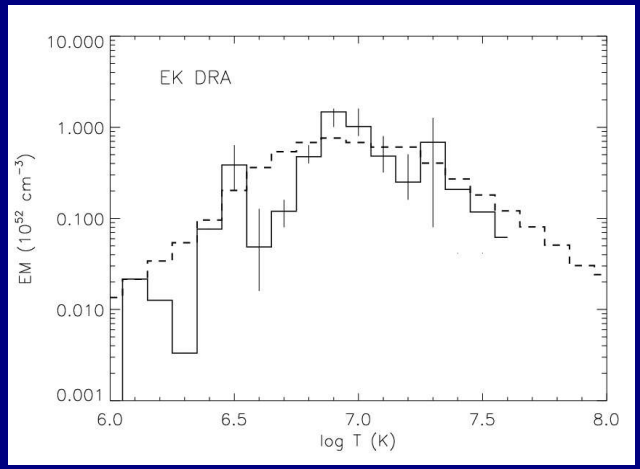
Current uncertainties: EMDs



Analytic EMD approximation (Chebychev polynomials, orders 6 and 8 Telleschi et al. 2004)



EMD based on selected line fluxes and ratios (Withbroe iteration algorithm Telleschi et al. 2004)

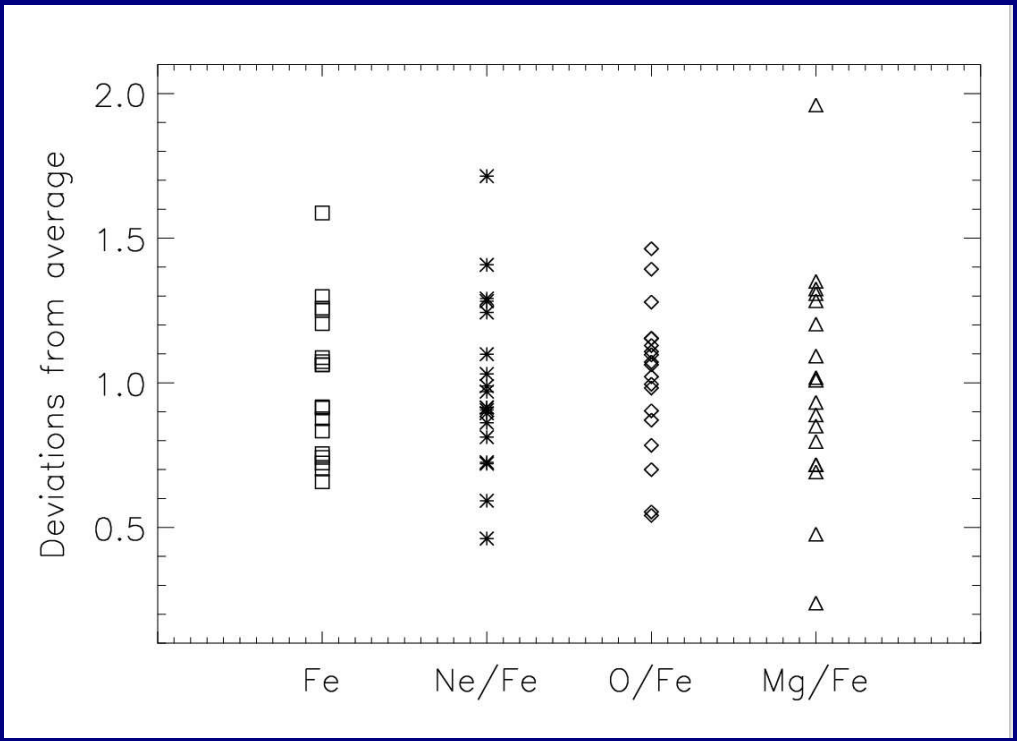


Line-based EMD with different methods (PINTofALE / MCMC Scelsi et al. 2004)

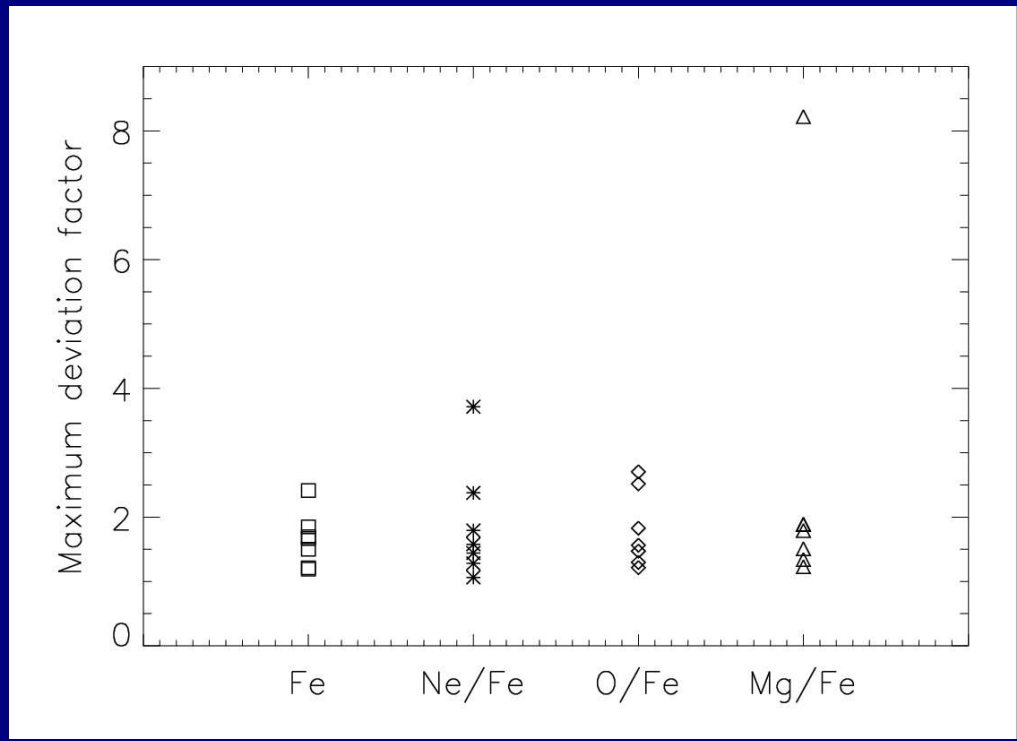
- Can we trust EMD shapes?
- Are error ranges correctly estimated?

Current uncertainties: abundances

Dispersion of different meaurements for 7 stars (Güdel 2004)



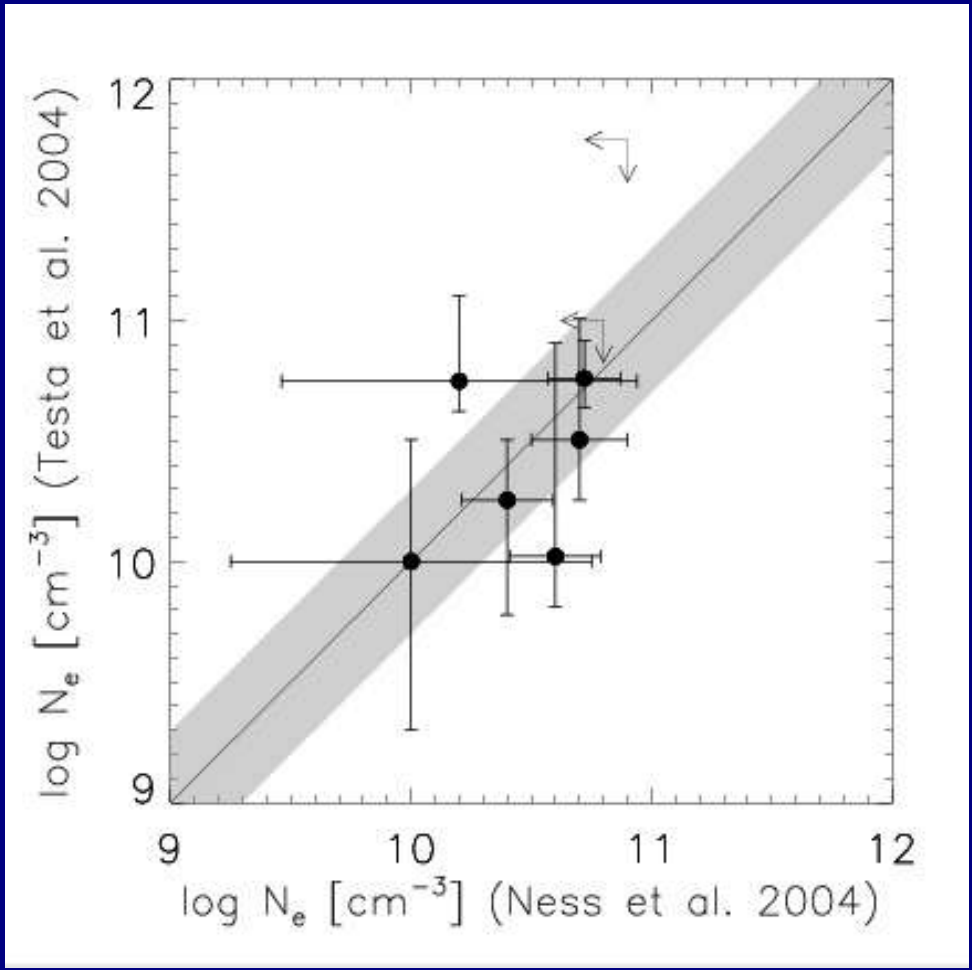
Ratios of individual measurements from average values for each star and quantity (Maggio et al. 2005)



Ratios of maximum to minimum values for each star and quantity (Maggio et al. 2005)

- Differences of a factor 2 are not uncommon, while nominal error ranges are 10% — 50%

Current uncertainties: densities

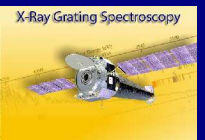


- Densities from O VII triplet line ratios in Chandra/MEG spectra
- 8 stars, same data, two different determinations (Testa et al. *vs.* Ness et al.)
- Results compatible within the (relatively large) uncertainties

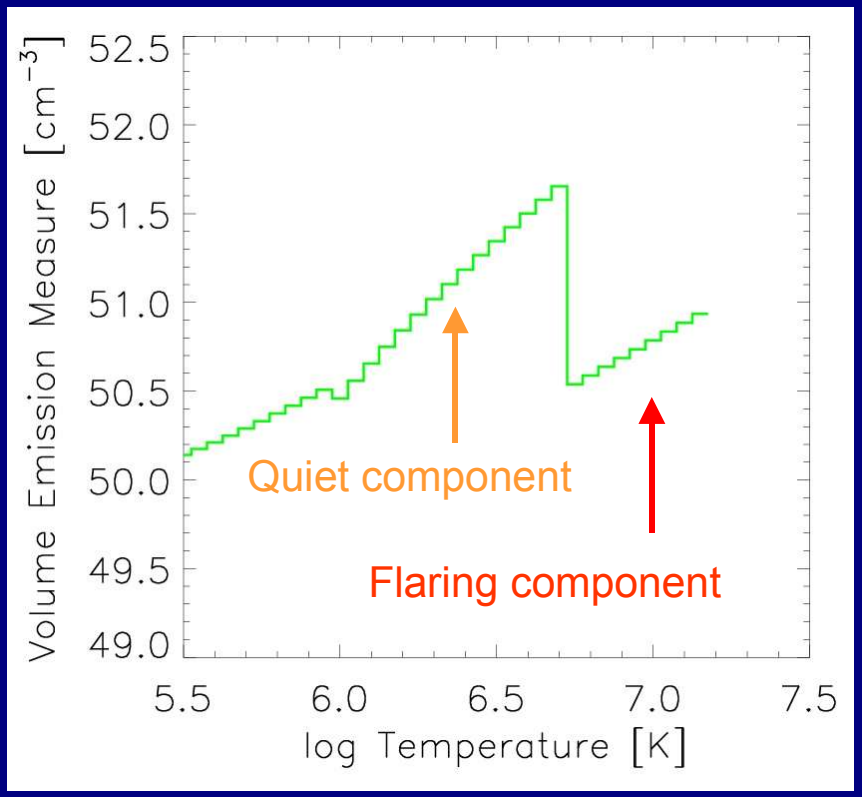
Maggio et al. 2005

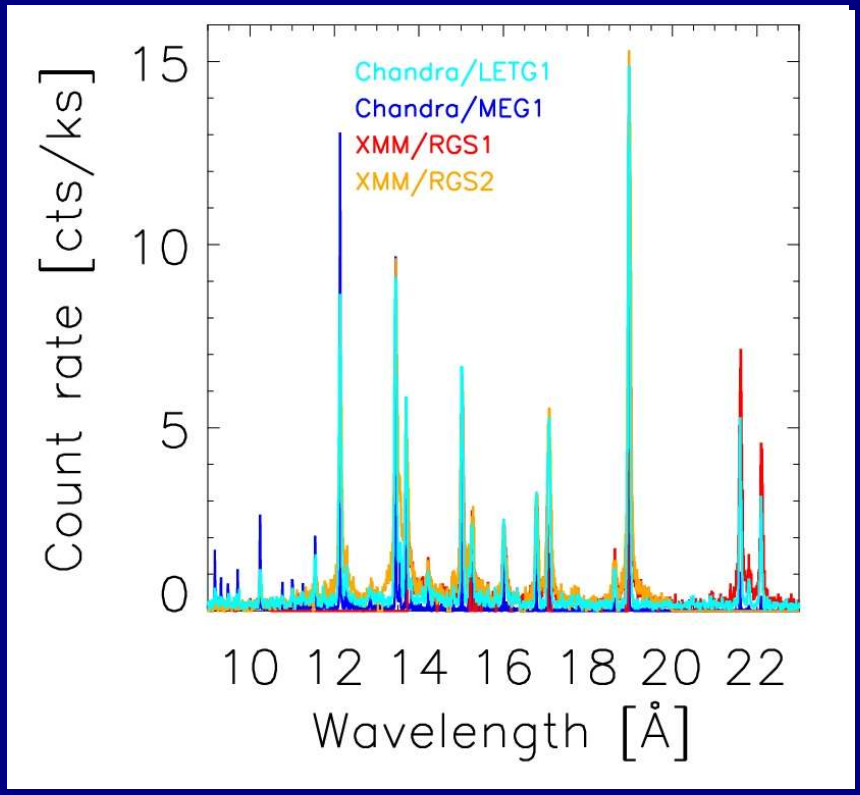
The BEXST project

- A *hare and hounds* approach
  - The “hare” team produces realistic high-res X-ray spectra based on an undisclosed source emission model
  - The “hounds” teams perform the analysis and try to infer the source characteristics
- The 1st BEXST challenge
  - Chandra and XMM-Newton X-ray spectra with high S/N ratio, based on a physically plausible plasma emission measure distribution (EMD) vs. temperature and element abundances
  - Plasma emissivity database (APED) known a priori
  - 6 teams provided detailed spectral analysis results



1st BEXST challenge

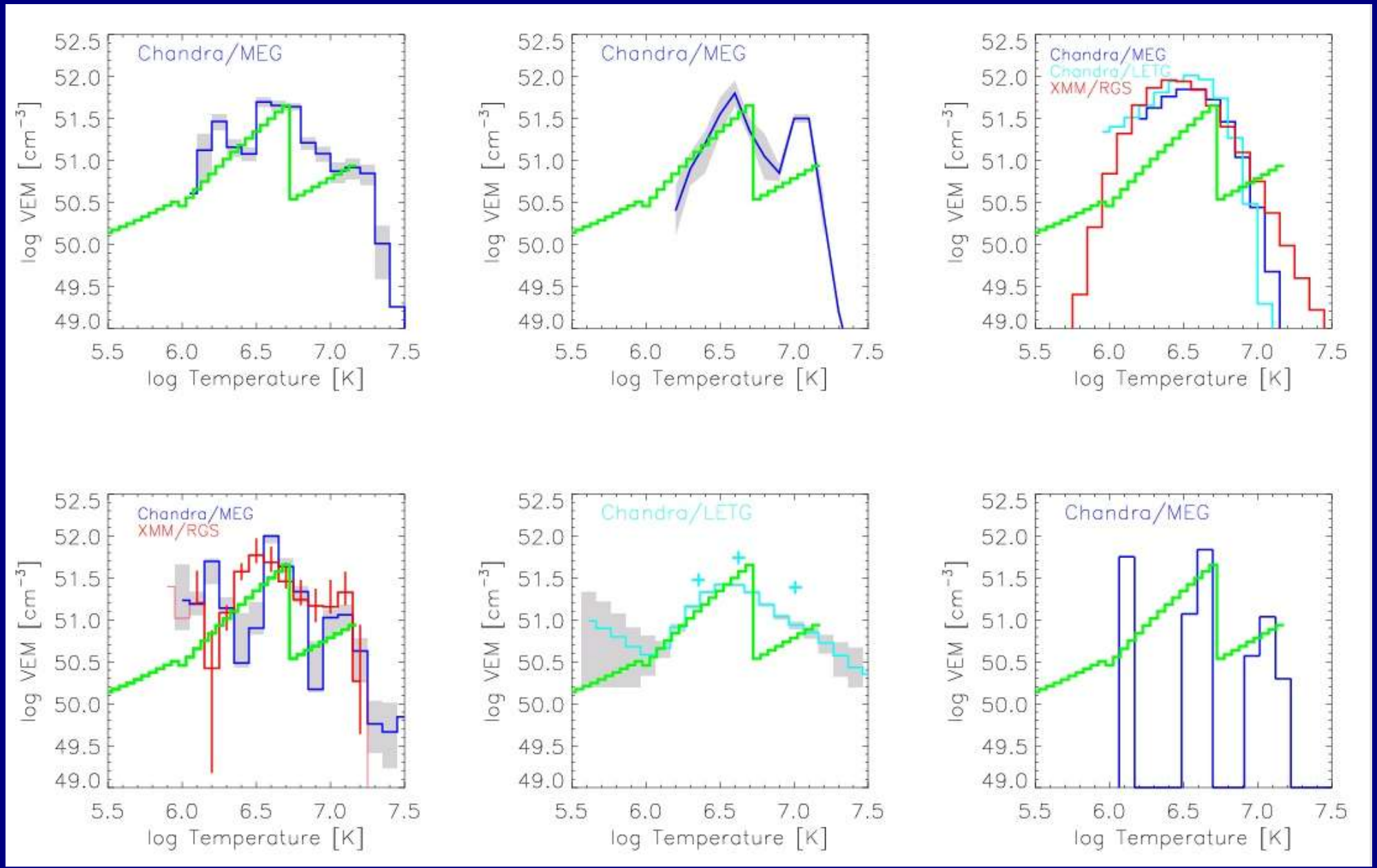




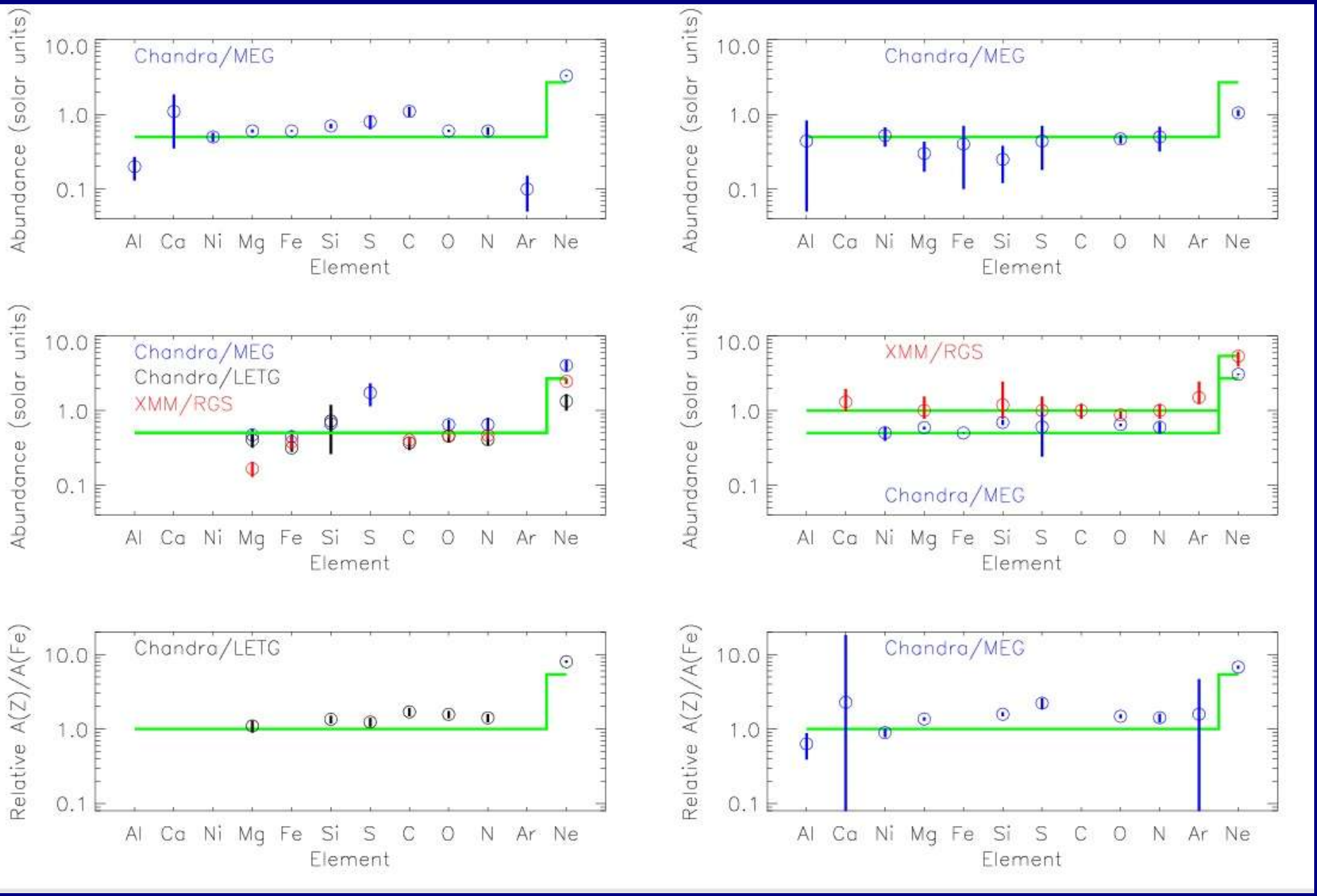
- Model EMD (C. Jordan)
  - Quiescent + flare corona of an active Sun-like star
  - Half solar abundances for all elements except Ne 2.7 solar

- Model spectrum (S. Orlando)
  - APED emissivities at low-density limit
  - Chandra HETG/MEG and LETG, XMM/RGS simulated spectra based on realistic instrument responses, including background
  - About 20,000 net counts

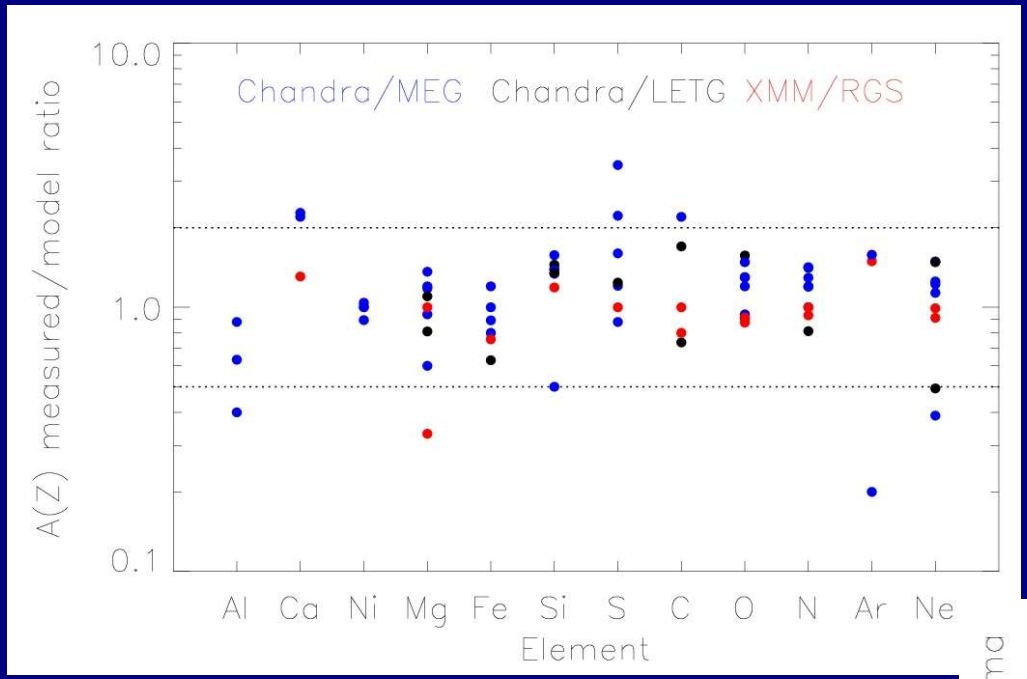
Results: EMDs

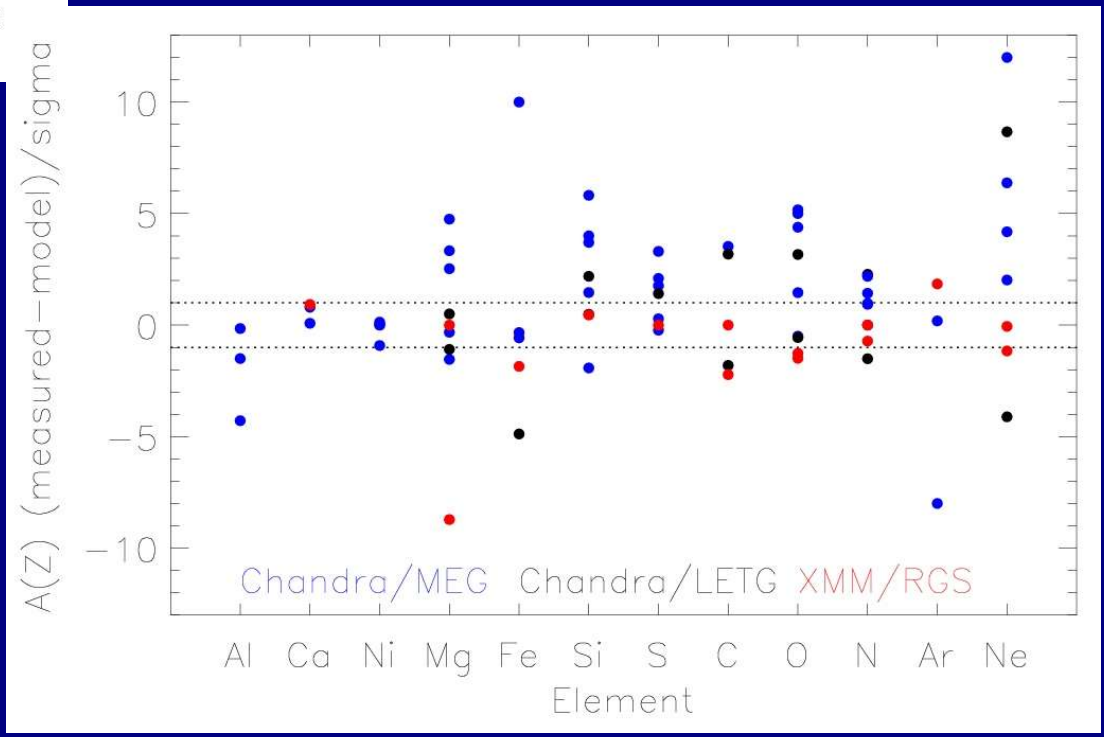


Results: abundances

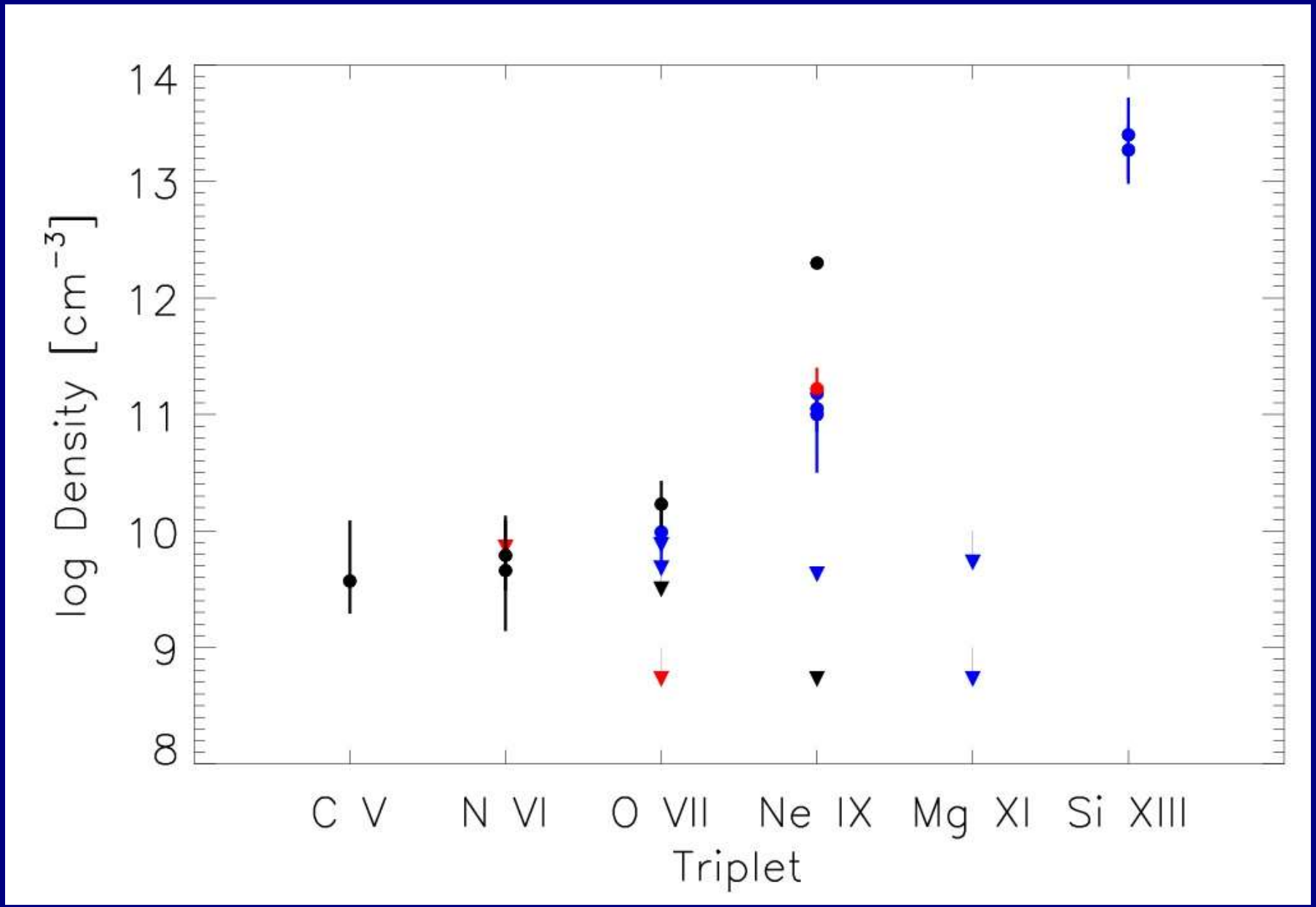


Results: abundances





Results: densities



Conclusions

- The bulk features of EMDs are well recovered, but the details are elusive
- Abundance patterns are robust (in spite of the EMD uncertainties), but formal errors are underestimated (measurements rest within a factor 2—3 from true values)
- Low densities are correctly found in most cases, but Ne IX and Si XIII triplets may lead to overestimated values
- We need to trace the error source(s), and we need to (and can) do BEXST!