OBSERVATIONS and CHEMICAL EVOLUTION

With help from L. MASHONKINA, F.MATTEUCCI , B. WEHMEYER,

J. COWAN, T. MISHENINA, M. PIGNATARI, N. PRATZOS, R. DIEHL, C. FROHLICH, A. ARCONES and F. K. THIELEMANN

Brainstorming and Fun II: September 29-30, 2014

IMPORTANT POINTS: OBSERVATIONS

- Can get observational constraints to models of heavy element production in the early Galaxy
- Observations of Ba/Eu vs. Eu/Fe in r-process stars seems consistent with SS r-process value
- R-process models like waiting point and HEW give similar results for Ba/Eu
- f_odd is high in r-enhanced star and low in Eu-poor stars like HD 122563
- Can observe differences in light vs. heavy n-capture elements in very metal poor stars: excess s-process in some stars
- It is possible to reproduce the n-capture elements in both r-proces and r-proces poor stars by employing a combination of two model fits (heavy appropriate for stars such as CS 22892-052) and light (appropriate for stars such as HD 122563
- Iron peak elements show a rise at low metallicity along with scatter
- Sne models and gce models must be able to reproduce these newly determined and more precise abundance values in metal-poor halo stars

IMPORTANT POINTS: OBSERVATIONS

- For a large number of open clusters a large scatter of Ba and Ba overabundances, compared to solar, were observed in the last ten years
- At present it is matter of debate the origin of such anomalous abundances (see Mischenina et al. 2014, Jacobson&Friel 2013, Yong et al, D'Orazi et al)
- Observations are difficult to reconcile with the present understanding of neutron-capture nucleosynthesis and may require an additional process, i.e., the i(ntermediate)-process (‘Cowan and Rose 1977).
- One of the peculiar signatures of the i-process is to predict a [Ba/La] ratio much larger than the s-process or the r-process, within the observed spread of [Eu/La].

Further Studies

- What is needed:
- multi-dimensional hydrodynamical simulations for the H ingestion in stellar He-rich material
- uniform observations, spectra processing, parameter determinations, methods and abundance calculation for a large sample of Ocs

Further Studies (continued)

- For the i process overall:
- uniform analysis of all the available observations (OCs, presolar grains, CEMP stars,) to constrain stellar simulations. This is needed to produce robust i process yields.

Discovering the nature of the i-process and is it relevant for GCE?

Herwig+2011, first observational evidenceof the i process. But post-AGB stars,likely not relevant from the GCE point of view.

Liu+ et al. 2014, mainstream SiCwith i process signature;Jadhav + 2013, Fujiya+2013 AB grains ~ solar like metallicity sources.

Solar metalicity sources but difficult to find constraints if relevant for gce?

Part of the CEMP-rs stars Are CEMP-i stars: Bertolli+ 2013 arXiv Herwig+2014, in prep.: Warning: the i process can contribute up to Pb..

OCs: Mischenina+ 2014 submittedGCE of young objects seem to need i process. Anomalous observtions of Ba abundance in open clusters are not consistent with s + r-process. So may need an additonal process, so s- + r- + i-process may be required.

In the future we need better nuclear data for the iprocess.

MORE TO BE DONE IN OBSERVATIONS AND THEORY

- More Ba/Eu observations in low metallicity stars
- Light trans iron (heavier than Zr) observations
- Determination of fractional isotopic abundances (already done Ba and Eu)
- Where possible
- Determine more precisely stellar parameters (Teff, log g, etc.)
- How to explain rising values of Fe-peak elements at low metallicity in Sne models and gce models

Need more observations of light n-capture elements such as Mo, up to Ag.

GALACTIC CHEMICAL EVOLUTION MODELS

A HOMOGENEOUS (same stellar physics – convection, nuclear rates etc)
and COMPLETE (in stellar mass and metallicity)
GRID OF STELLLAR YIELDS
M: 1.5 2 3 5 7 10 12 15 20 25 35 50 70 100 130 Msun
Z/Zsun = 0, 10^{-4} 10^{-3}, 10^{-2}, 10^{-1}, 3 10^{-1}, 1, 2
(to cover evolution of halo, thin and thick disks and bulge)

Models accounting for ALL available – and relevant – data sets
for a given galactic system
Ex 1: For MW halo: NOT only X/Fe vs Fe/H but ALSO *Metallicity distributions*
(requires OUTFLOW, and this changes timescales of met. evolution,
important if interested in sources with *different timescales*,
like NS mergers or AGBs)

Ex 2: *Dispersion* (if real), may point to physical ingredients
that should not be neglected
e.g. in local age-metallicity relation, it points to radial migration
In Eu/Fe vs Fe/H of halo stars, it points to ???

IMPORTANT POINTS: MODELS

•The chemical evolution of galaxies: massive stars occur in groups and co-evolve –
•> feedback and ejecta
> return into the cycle of matter occurs in superbubbles
> - modeling and studying the evolution of superbubbles from creation
> through fragmentation/dissolution until formation of dense cores /
> SFRregions:
>   this may be interesting by itself, shed light on abundance scatter
> expectations, and scale dependent aspects of chemical evolution at the
> sub-kpc scale
> - disk-halo connections could be important for the >10^8 year
•evolution
> of abundances, also shed light on infall and Galactic winds and the IGM
>
•- exploiting new measurements: sub-mm molecular lines of isotopes, GAIA,
> 26Al gamma-rays, QSO and GRB absorption lines.

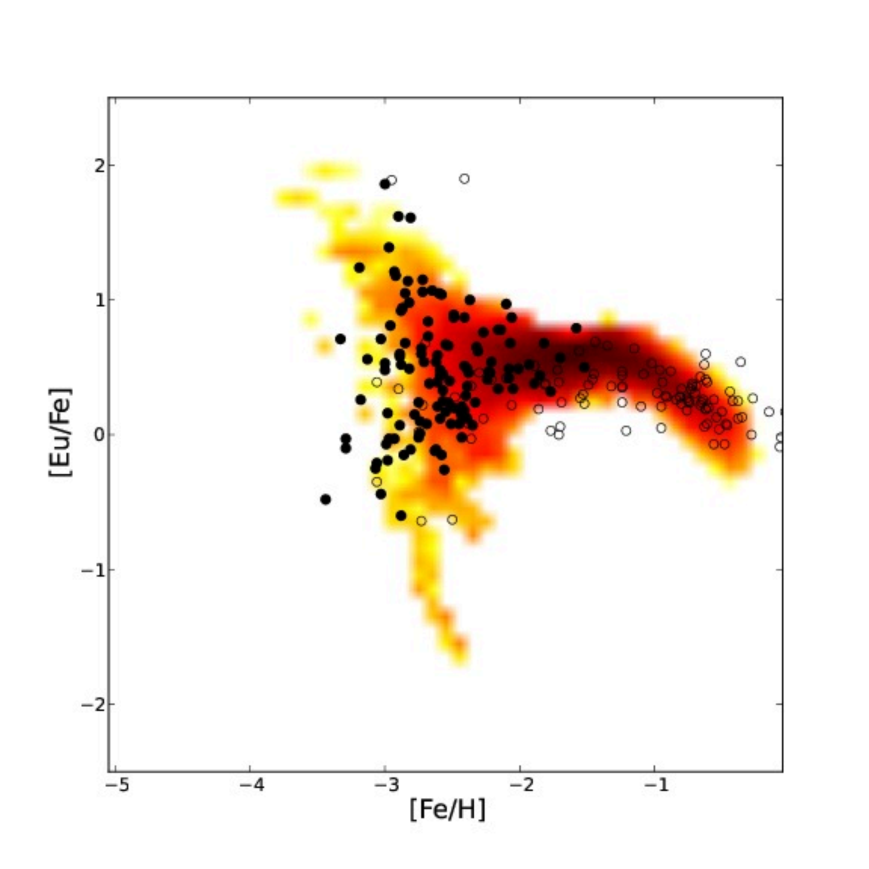
IMPORTANT POINTS: MERGER MODELS

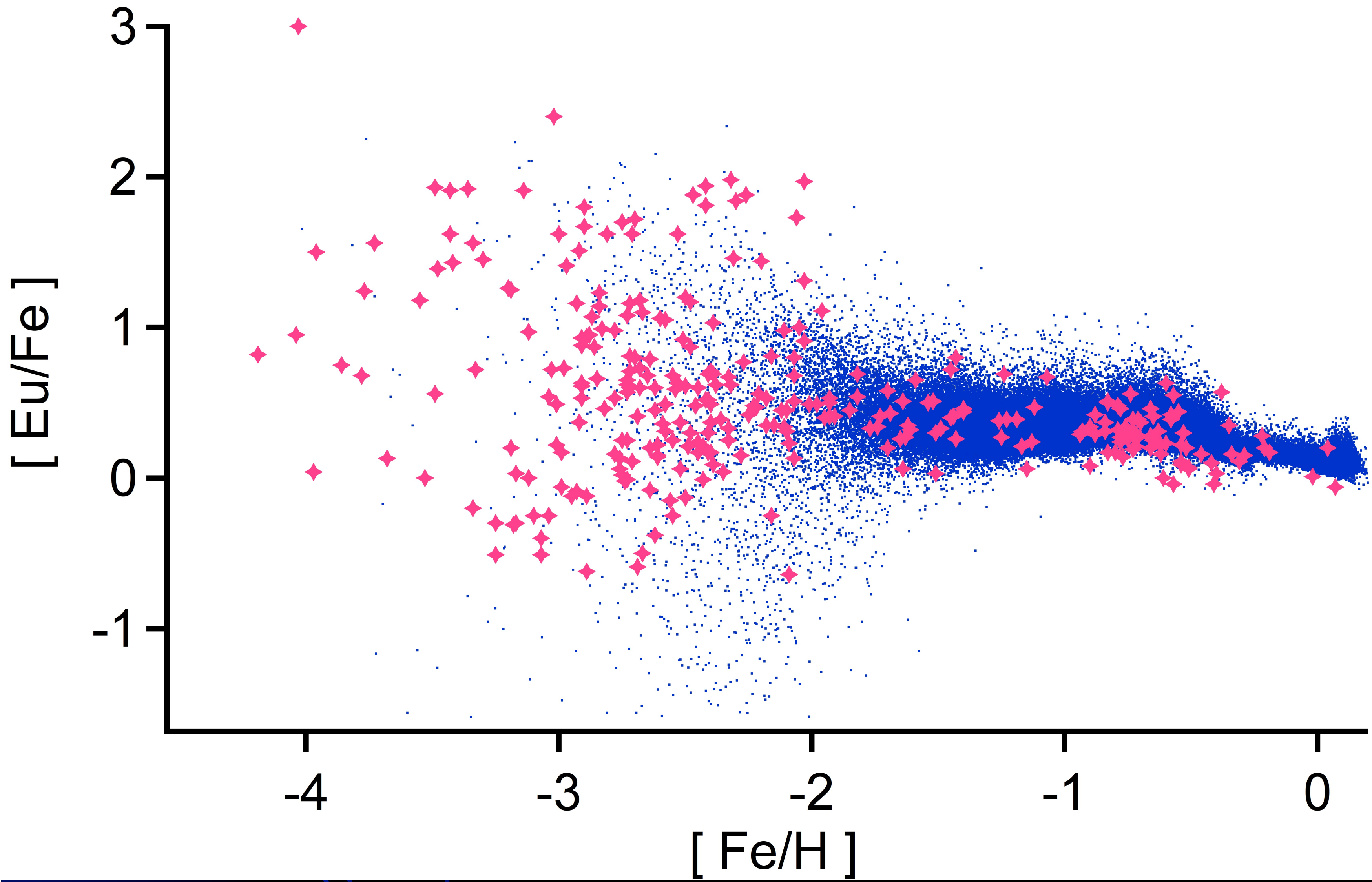
An alternative situation suggests that both SNeII and NSM can produce Eu. The best model in this case assumes that in NSM is produced M_{eu}= 2x 10^{-6} $M_{sun,}$ the delay times can be various. The SNe II should produce Eu in a range 20-50 Msun
It is very important to have Eu sources acting at early times to reproduce observations at low [Fe/H]

Europium can be produced only from NSM if: the NS systems explode with a delay of 1 Myr and each event produces M_{eu}= 3x 10^{-6} M_{sun} and all stars withprogenitor masses in the range 9-50 Msun leave a NS as a remnant

Results:NSM+MRD SNe

- Here Europium originates from NSM plus magneto rotational (MRD) SNe
- The merging events have a fixed delay of 100Myr
- The MRD SNe are assumed to be 10% of the total number of SNe II but only for $z<10^{-3}$





Pink crosses are observed stars and the blue dots are simulations.
-Both NSM and jet Sne are employed to try to reproduce the observed
-Scatter in Eu/Fe.

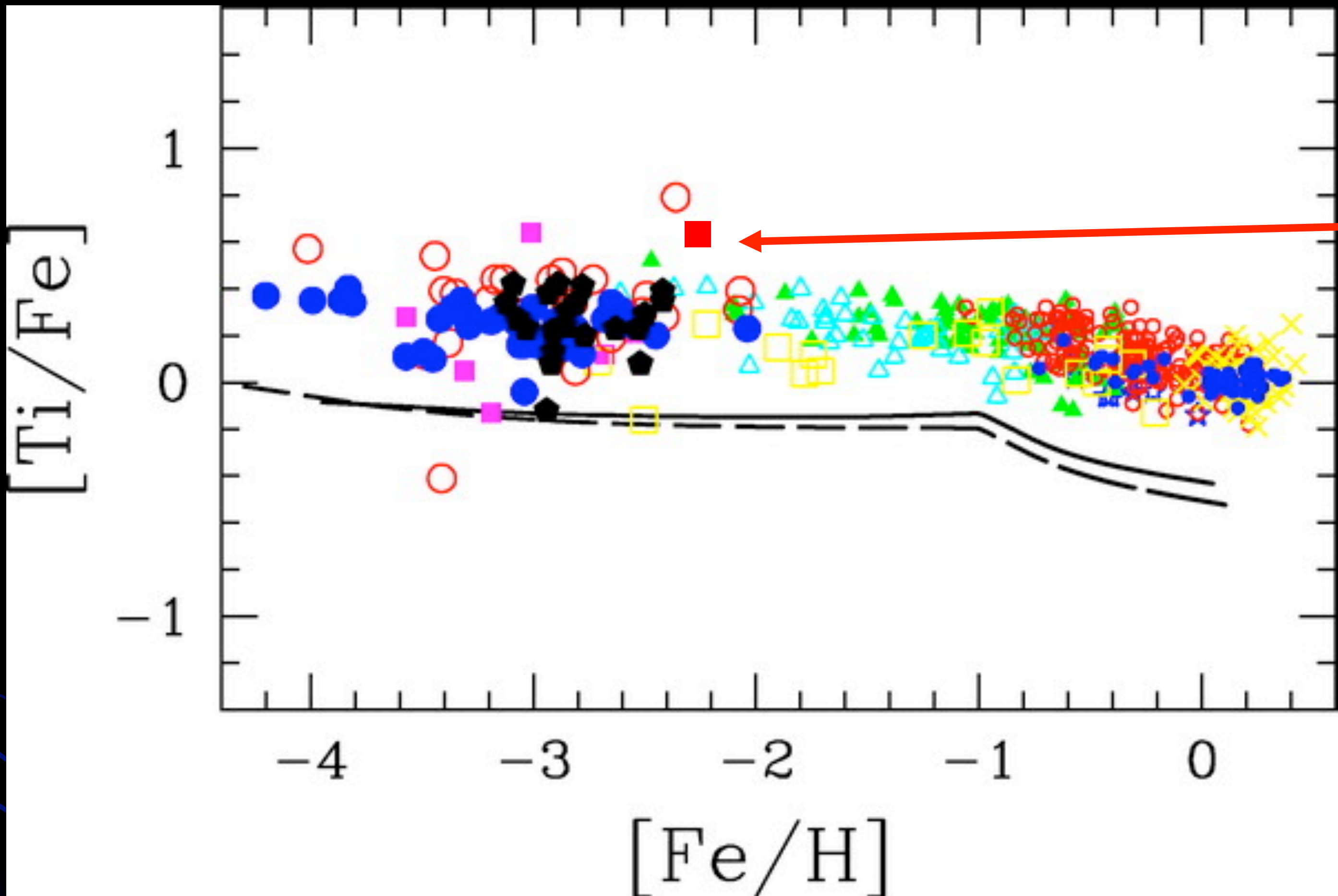
What is needed to improve NS Merger Models

- In the future the model could be improved by assuming a delay time function
- And also the results of Cescutti and assuming some inhomogenous mixing in the early phases of Galaxy evolution will be utilized
- A better more secure rate of merging of ns will also be required many uncertainities now

More Questions for Merger Models

- Question of black hole formation in early Galaxy- if 50 Msol stars are needed to make the r-process
- Do we need both core collapse SNe and NS Mergers to explain observed Eu/Fe

A new initiative on Fe-group abundances



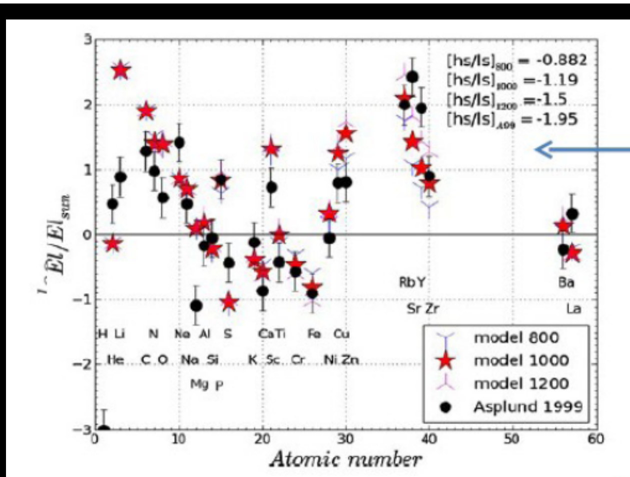
Observed in HD 84937 Wood et al. (2013)

Problems with SN models

Kobyashi et al. (2006)

this work concentrates on increasing accuracy of Fe-group elements
the big point: must have better transition probabilities
groups at Wisconsin, London, Belgium lead the way
HST data at low metallicity end explores more species

The i-process and GCE



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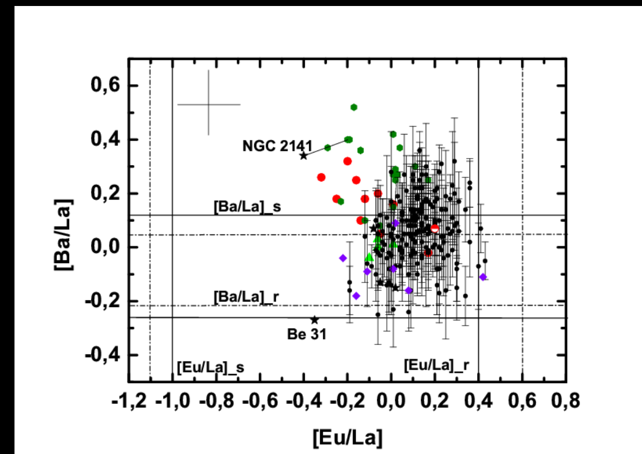

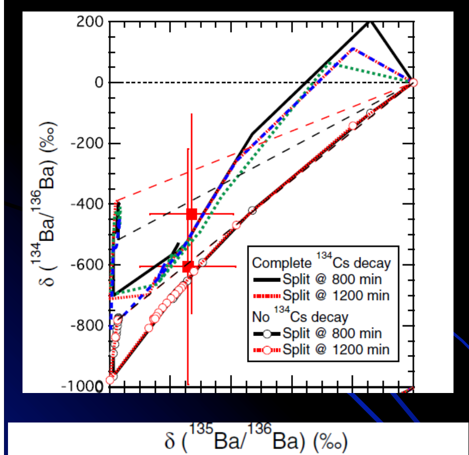

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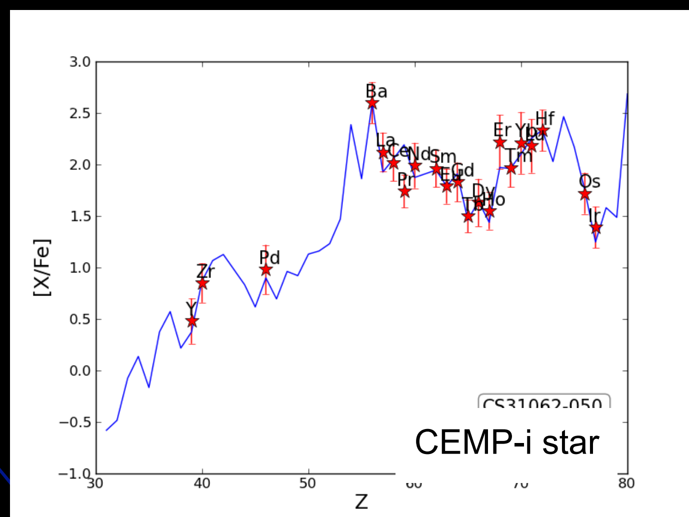

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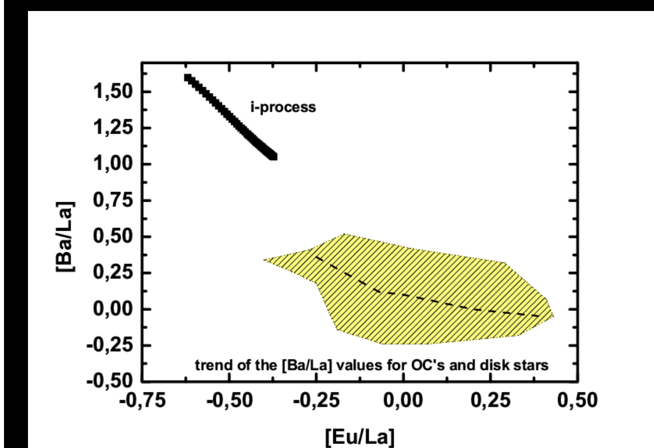

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