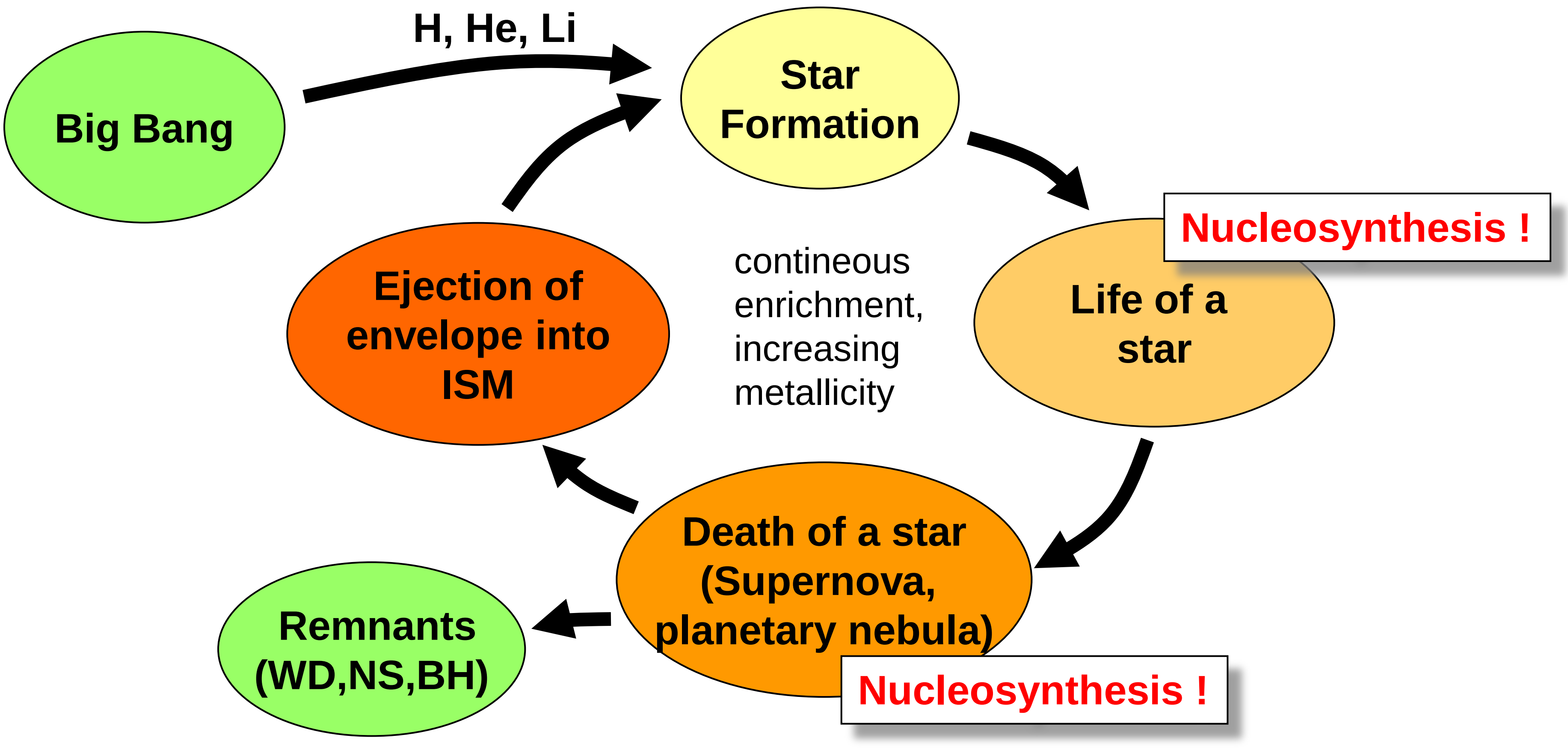
Abundances outside the solar neighborhood ?

Abundances outside the solar system can be determined through:

- Stellar absorption spectra of other stars than the sun
- Interstellar absorption spectra
- Emission lines from Nebulae (Supernova remnants, Planetary nebulae, …)
- γ-ray detection from the decay of radioactive nuclei
- Cosmic Rays
- Presolar grains in meteorites

What do we expect ?

Nucleosynthesis is a gradual, still ongoing process:

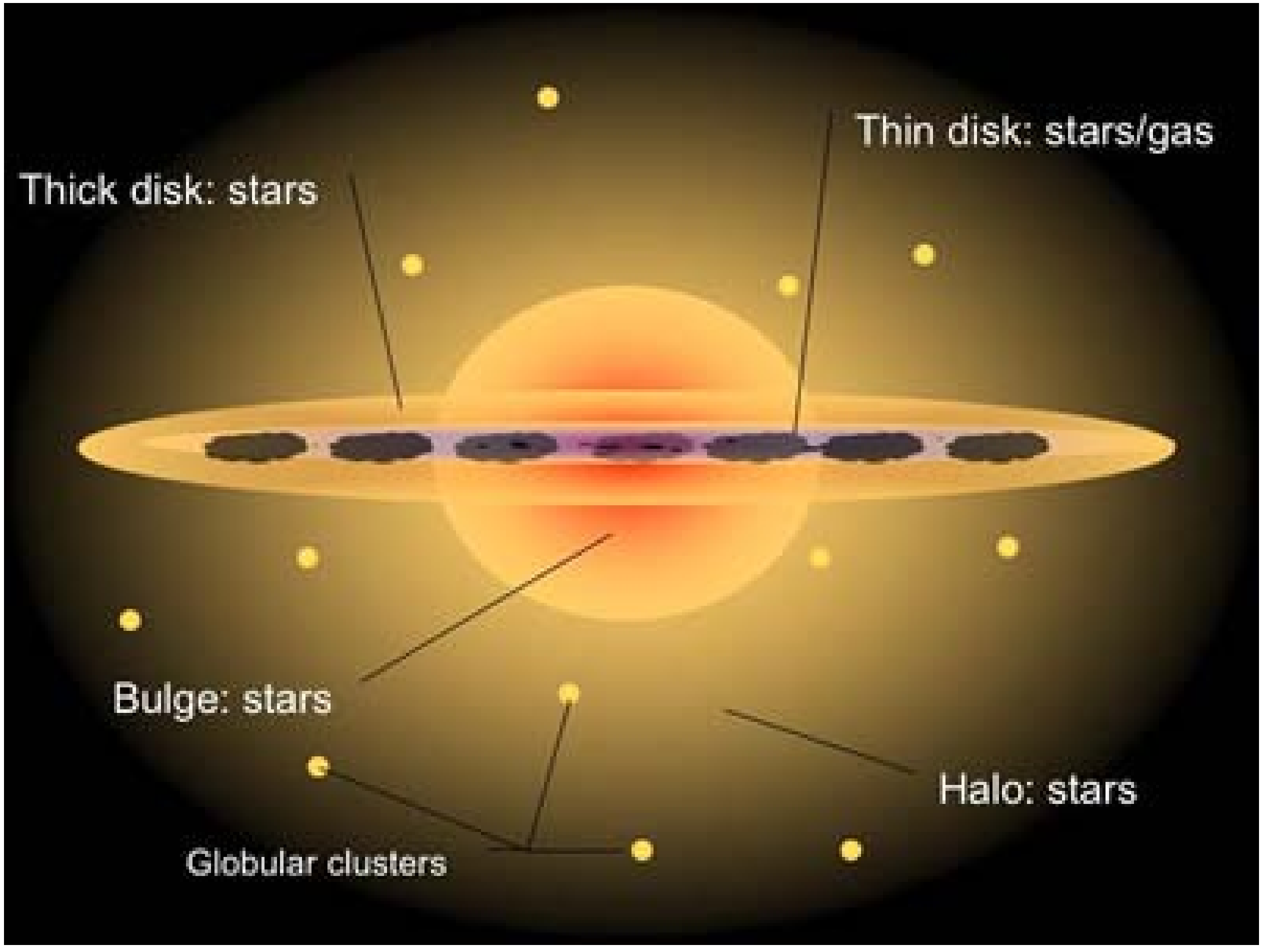


BH: Black Hole
NS: Neutron Star
WD: White Dwarf Star
ISM Interstellar Medium

Therefore the composition of the universe is NOT homogeneous !

- **Efficiency of nucleosynthesis cycle depends on local environment**

  For example star formation requires gas and dust - therefore extremely different metallicities in different parts of the Galaxy



- "**population effect" - enrichment contineous over time (see prev. slide) so metallicity of a star depends on when it was born**

$$[Fe/H] = \log \frac{(Fe/H)}{(Fe/H)_{solar}}$$

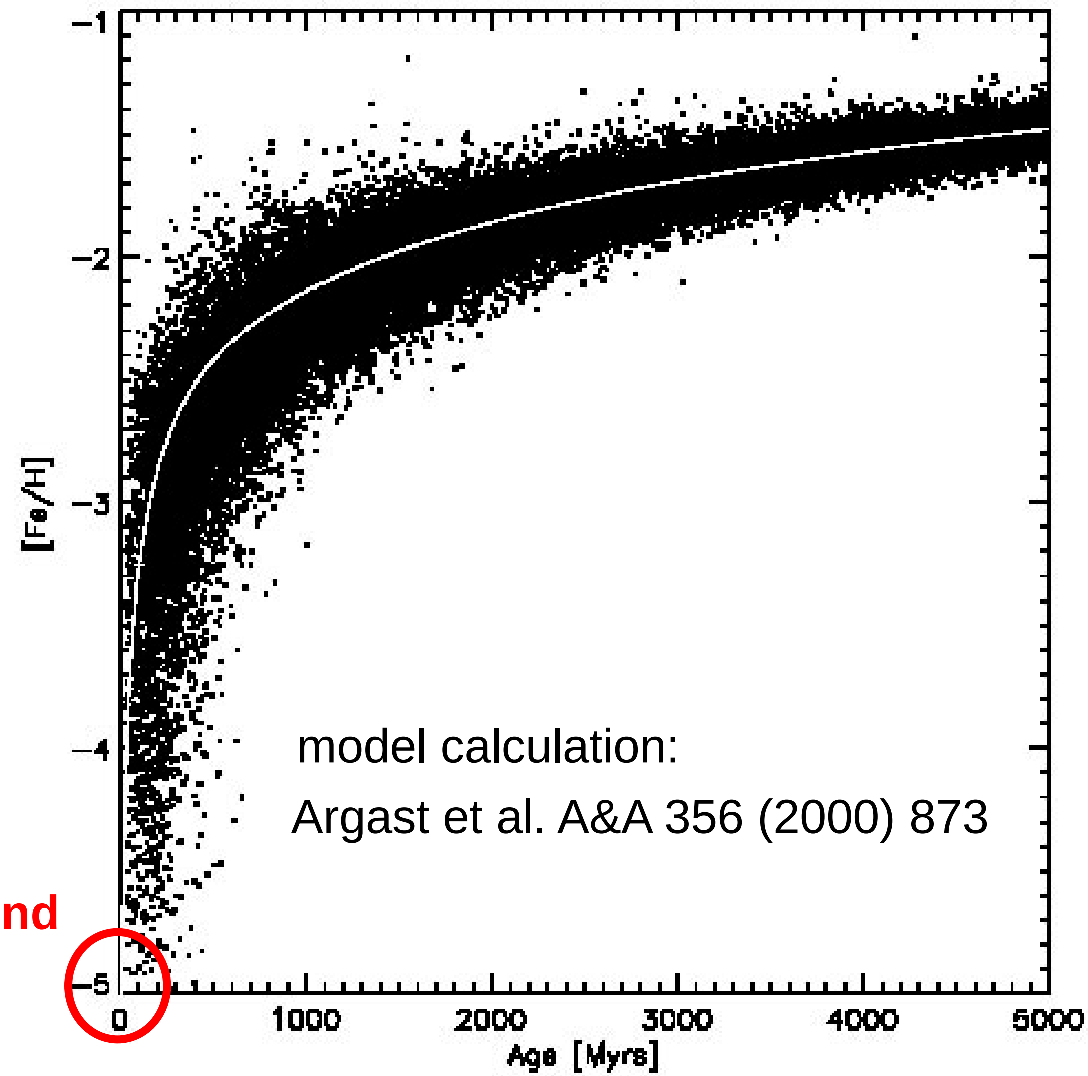
<u>Classical picture:</u>

Pop I: metal rich like sun

Pop II: metal poor [Fe/H]<-2

PopIII: first stars (not seen)

but today situation is much more complicated - many mixed case …



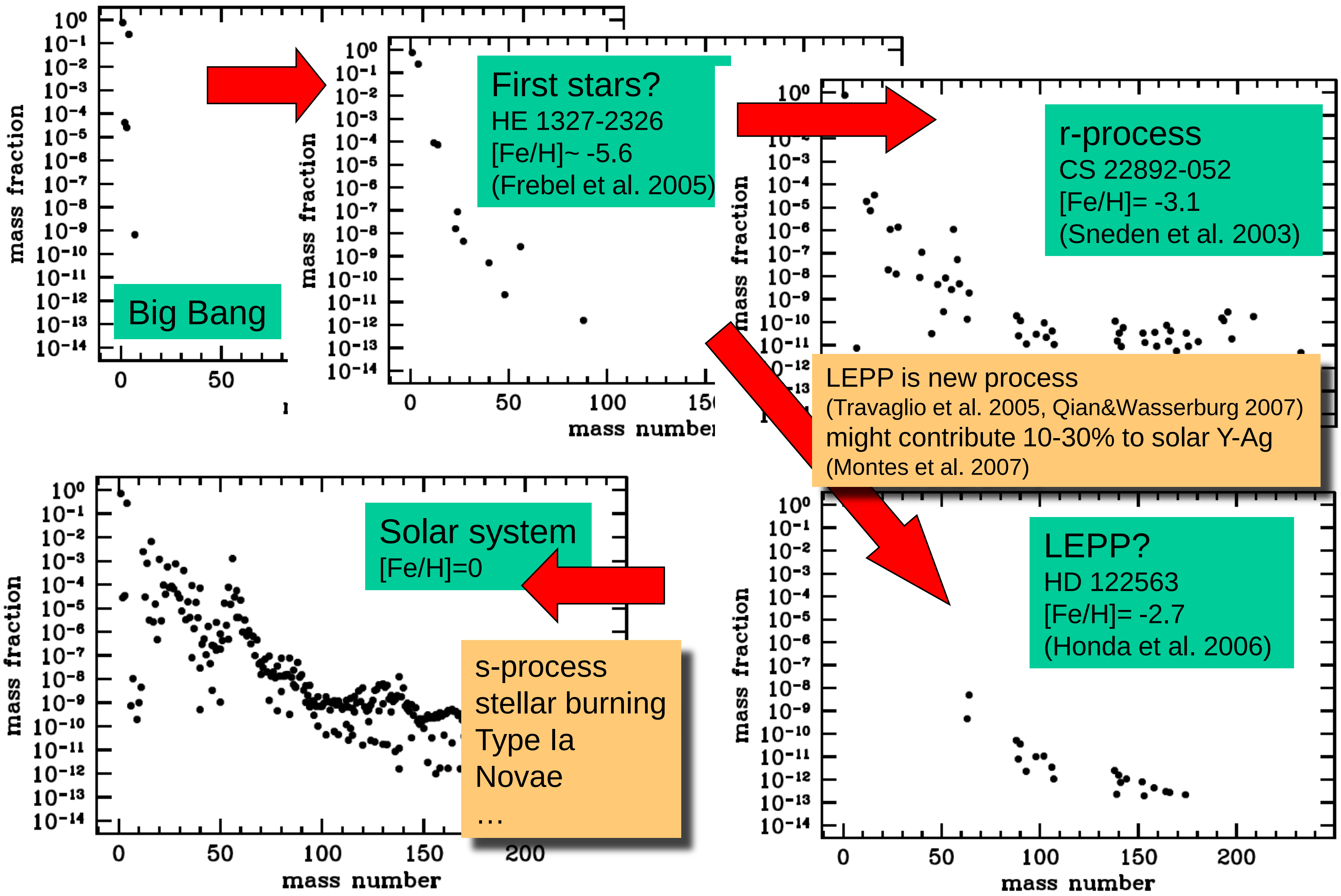
metallicity - age relation: old stars are metal poor BUT: large scatter !!!

From MSU Physics and Astronomy Department Website:

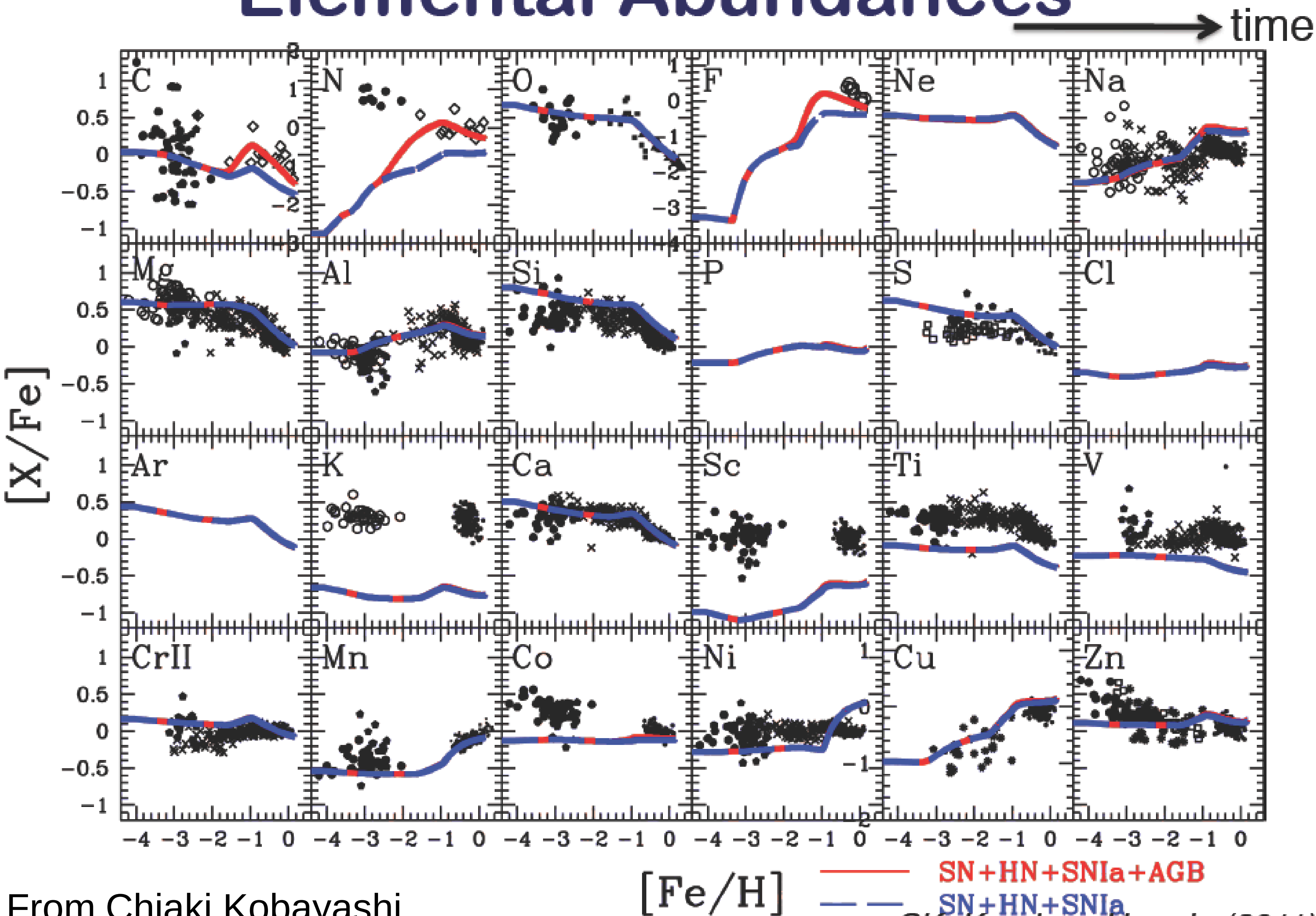
[Fe/H]=-5.1

found in halo (little star formation, lots of old, metal poor stars)

Piecing together the fossil record of chemical evolution



Elemental Abundances



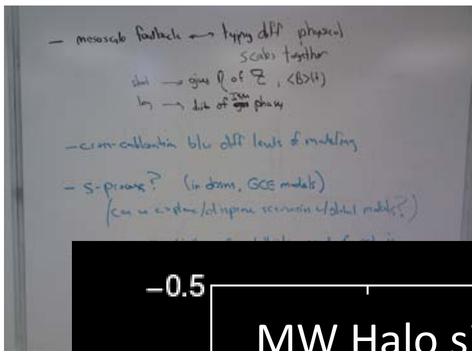
From Chiaki Kobayashi

CK, Karakas, Umeda (2011)

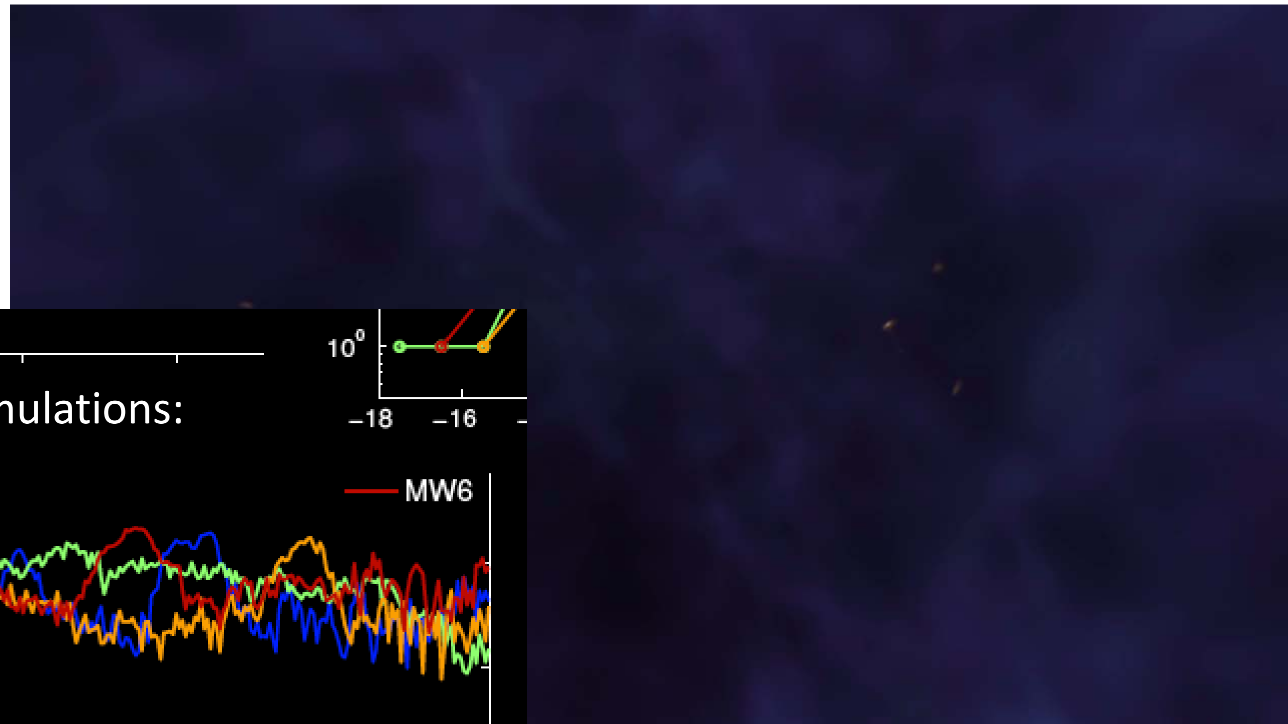
Bringing it all together: advanced GCE modeling

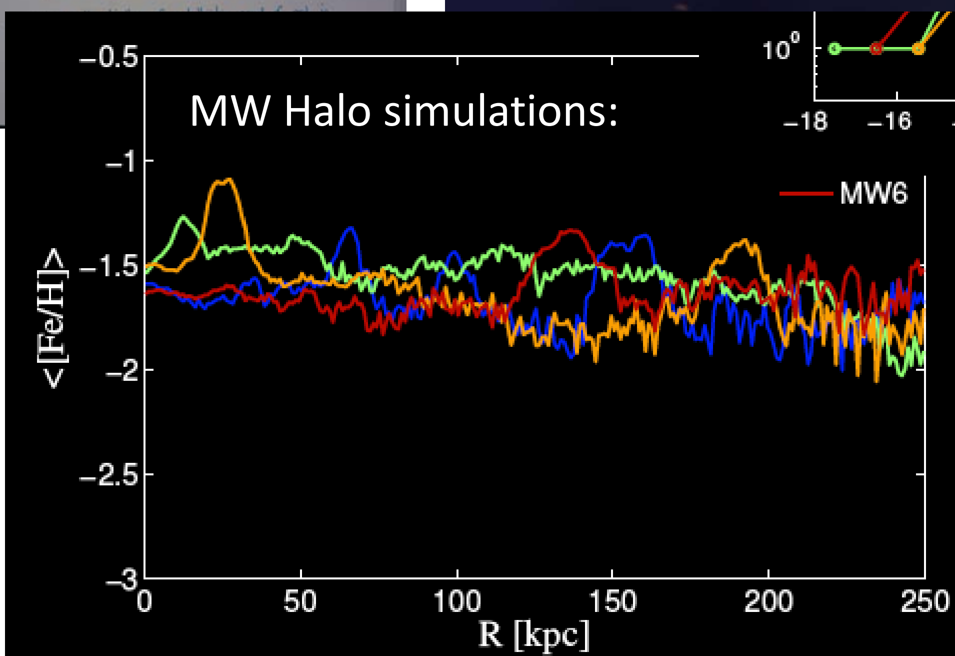
Input: NuGRID stellar yields incl s-process, r-process, SNIa, … plus energies
Validation: with SDSS data on stellar dynamics, abundances in Milky Way → Mock SEGUE Obs.

Virtual Galaxy Workshop
(MSU, April 2010, O'Shea/Beers)



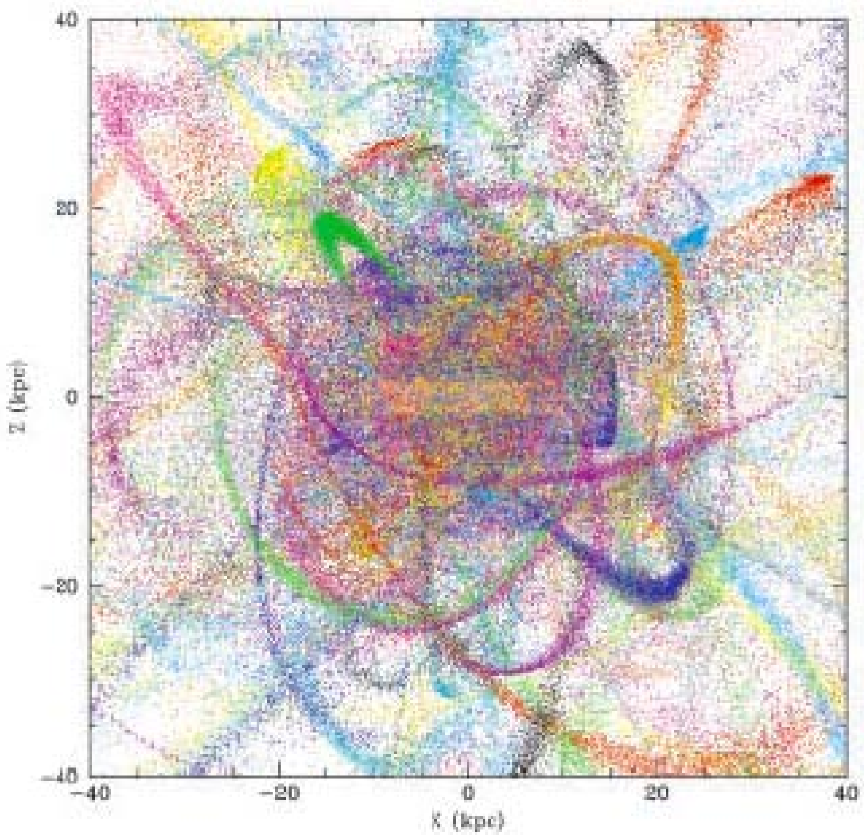
Population synthesis model (MSU)
Currently track: C, N, O, Mg, Ca, Ti, Fe, Co, Zn, Eu, Ba, Sr for stars and gas





Goal: constrain parameters of Galaxy formation
→ Near Field Cosmology

• **"population effect (3)" … and also where it was born:**



(Bland-Hawthorn & Freeman, Science 287, 2000)

• Galaxy (here halo) has formed over extended Periods of time by accretion and merging with other galaxies

• This process is still ongoing at low level

• Stellar composition is characteristic of original galaxy and can be used to disentangle components and merger history

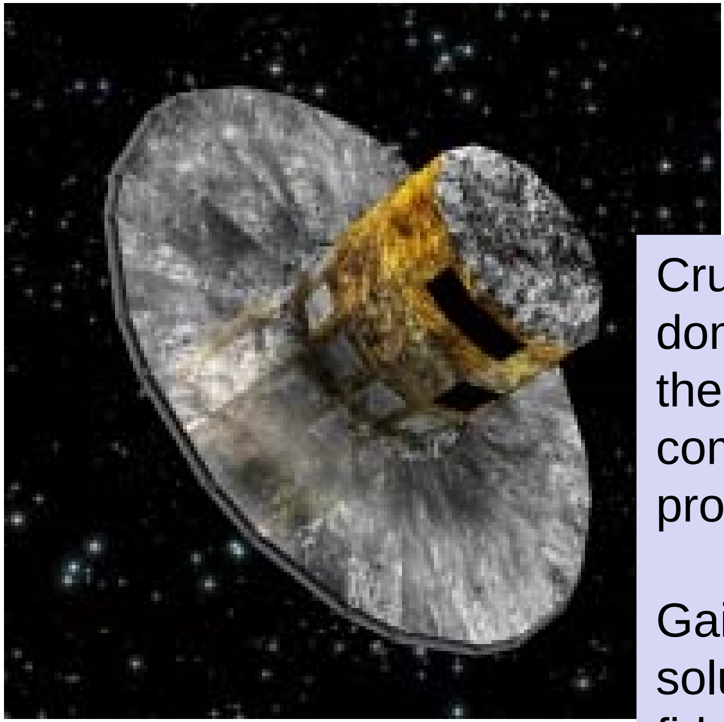
→ Can study Galaxy formation "at home" using nuclear astrophysics

"near field cosmology"

"Future satellite missions to derive 3D space motions and heavy element (metal) abundances for a billion stars will disentangle the existing web and elucidate how galaxies like our own came into existence."

Future: GAIA Mission

Data on about 1 Bio stars (1% of galactic population !!!)
Expected to be launched in August 2013 by ESA



Crucial information on which was the dominant mechanism for the formation of the thick disk and other Galactic components is encoded in the chemical properties of their stars.

Gaia shall bring a quantum leap to the solution of this problem, by providing fiducial samples of the different galactic components with both, chemical and full kinematic information

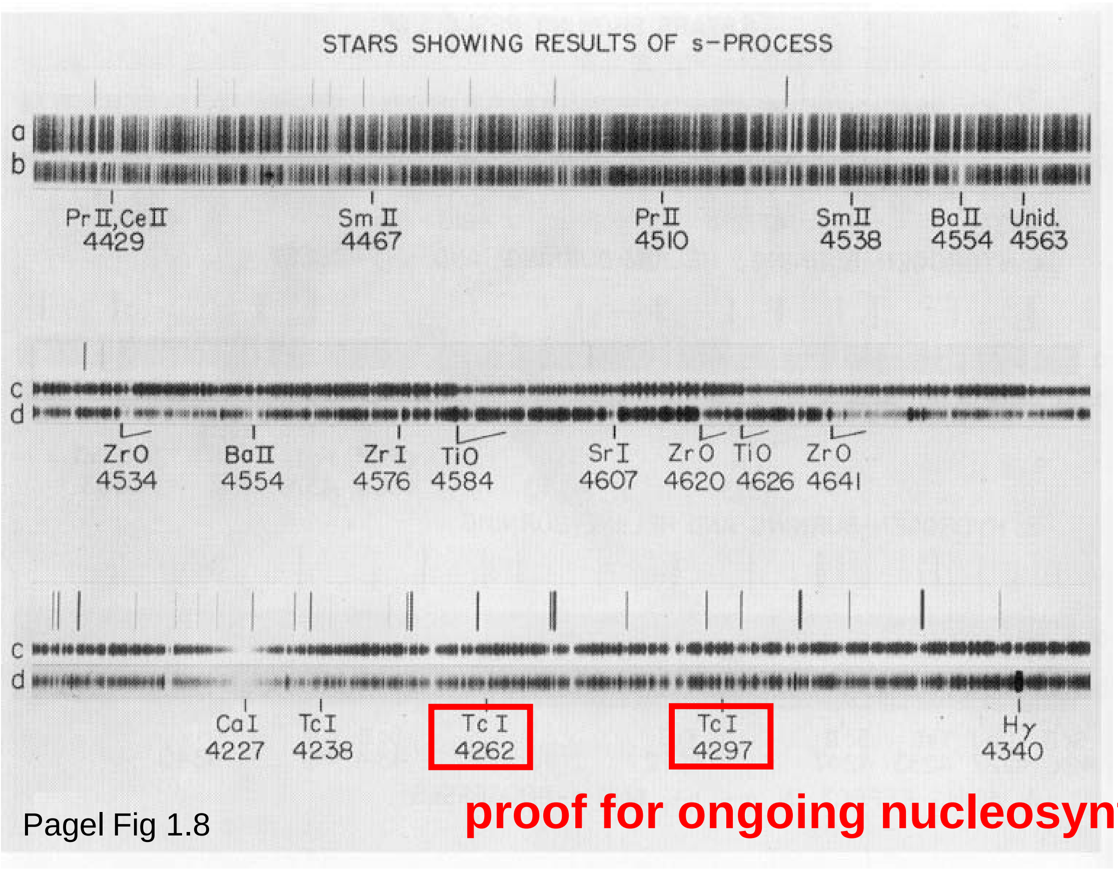
C. Chiappini

- **very different abundance distribution when one looks directly at or near nucleosynthesis sites (before mixing with ISM)**

Examples:

(a) Stars where, unlike in the sun, nucleosynthesis products from the interior are mixed into the photosphere

for example discovery of Tc in stars. Tc has no stable isotope and decays with a half-life of 4 Mio years (Merrill 1952)

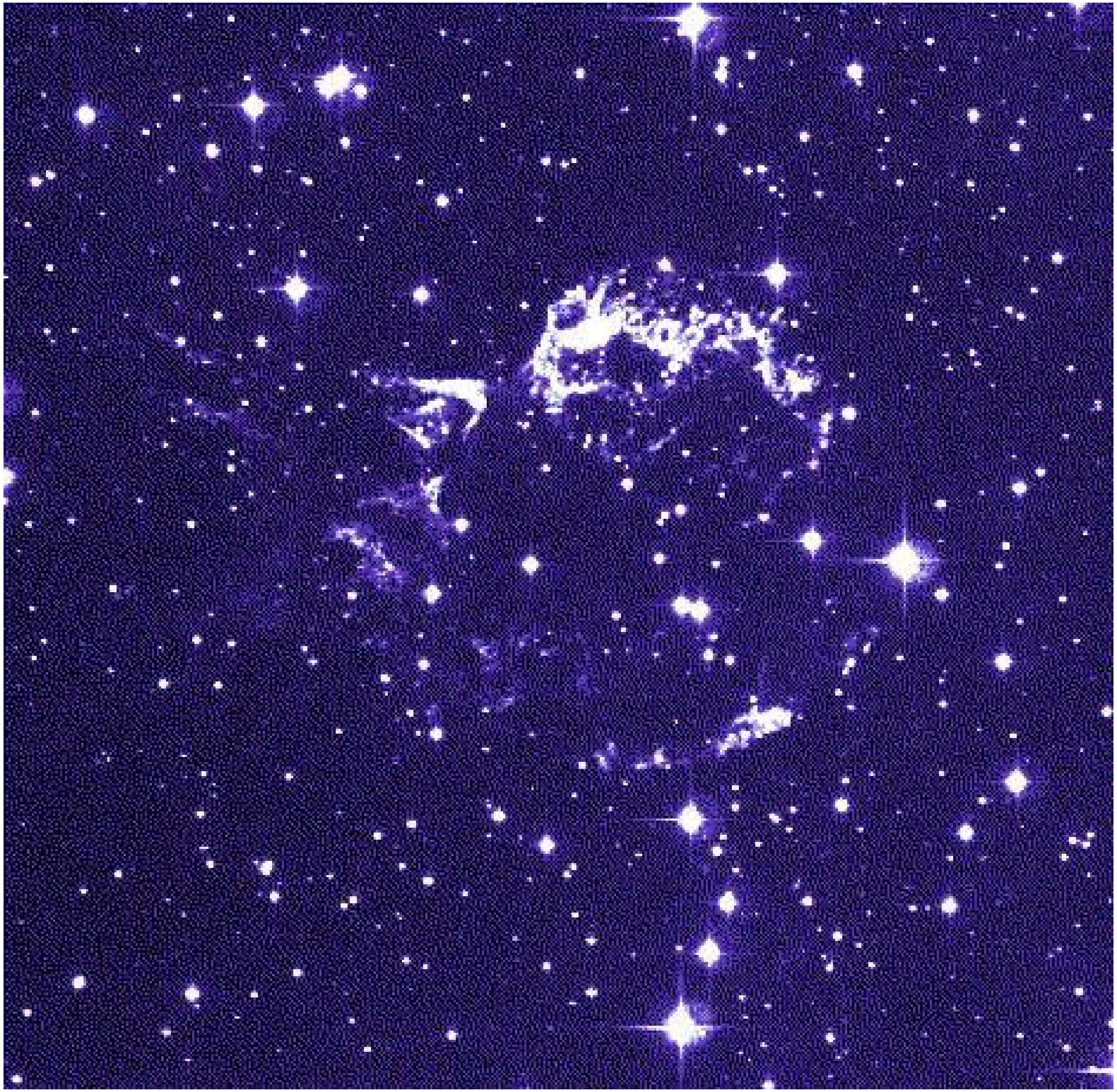


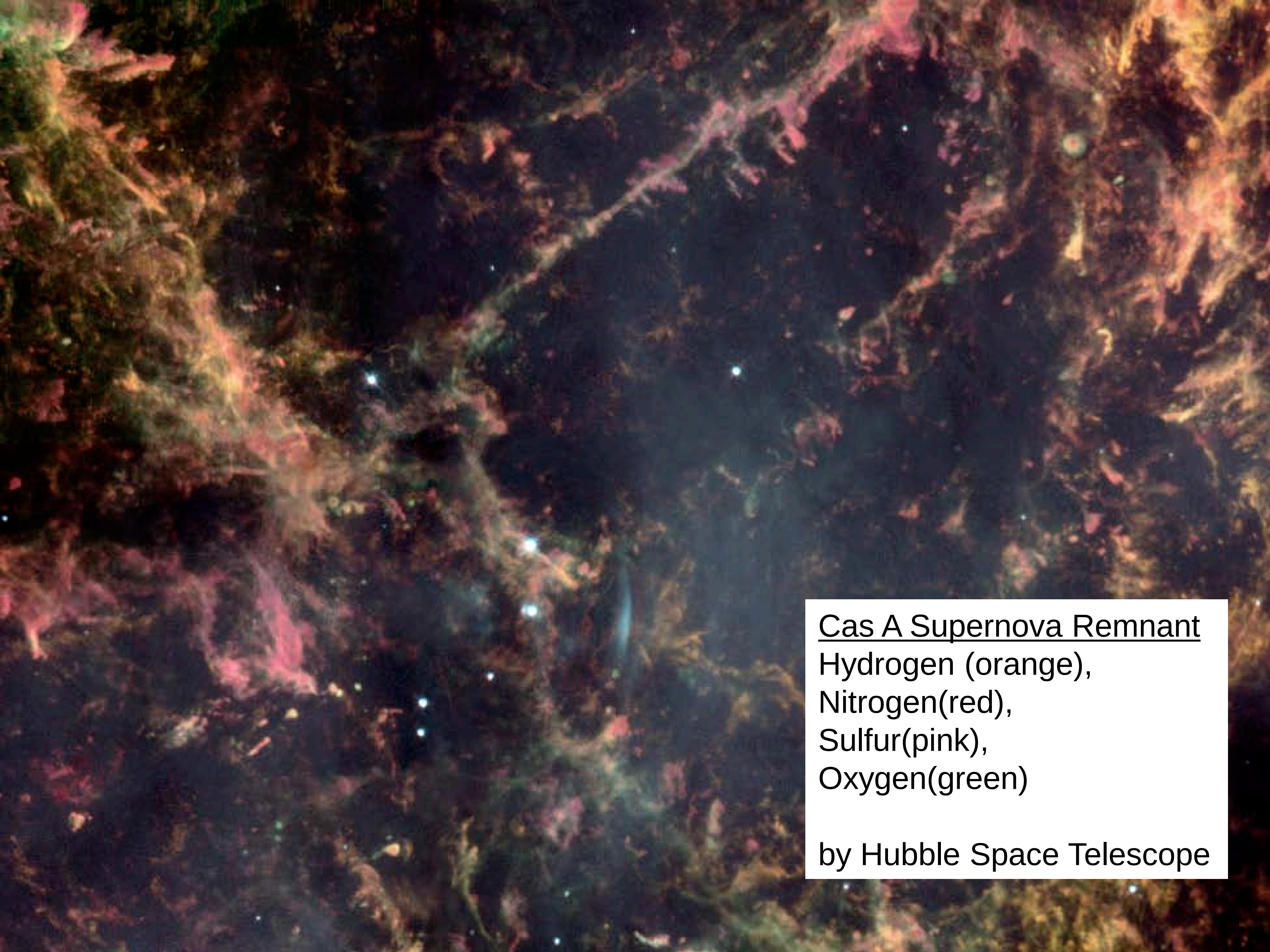
Pagel Fig 1.8

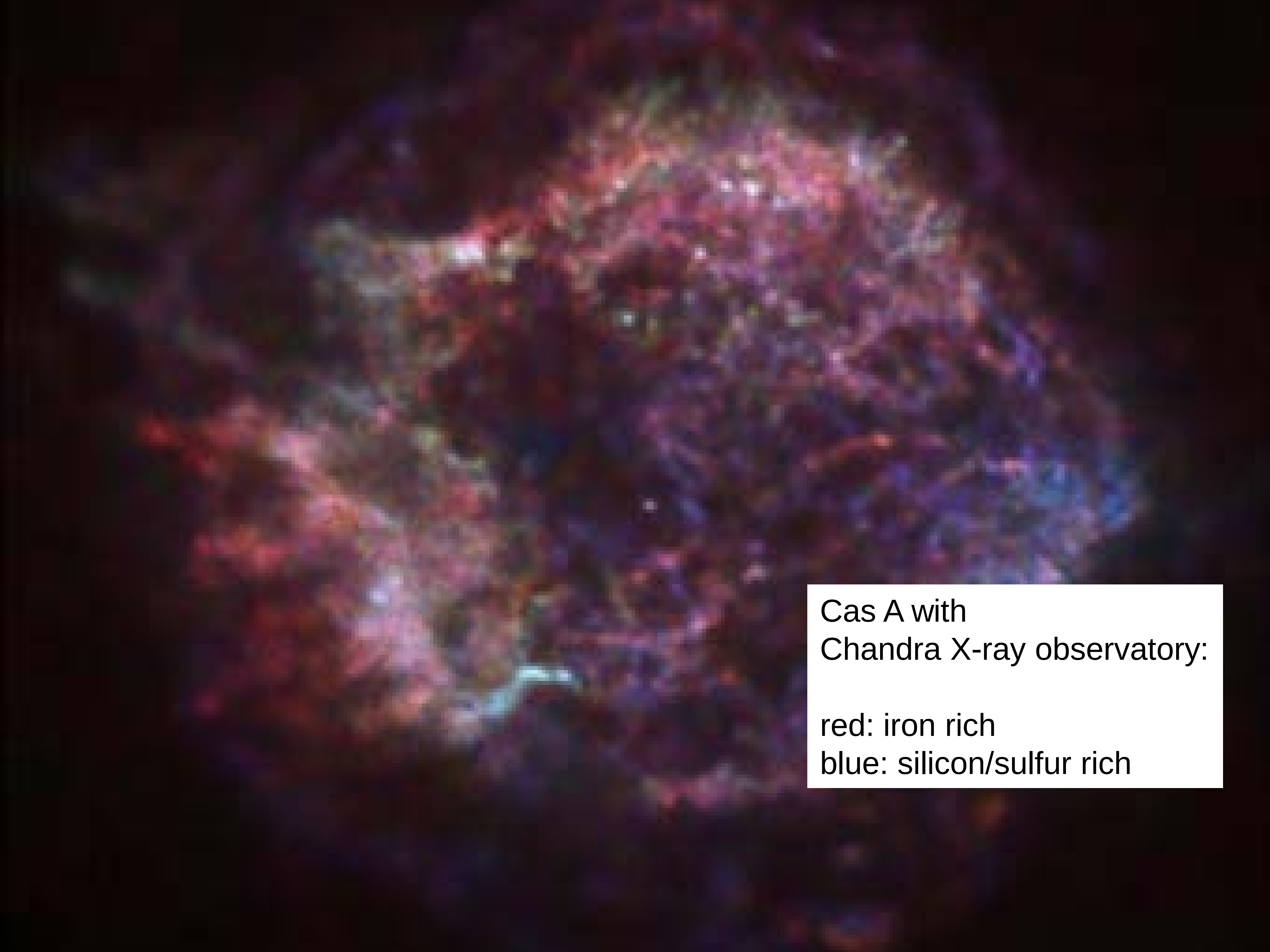
proof for ongoing nucleosynthesis in stars !

(b) Supernova remnants - where freshly synthesized elements got ejected

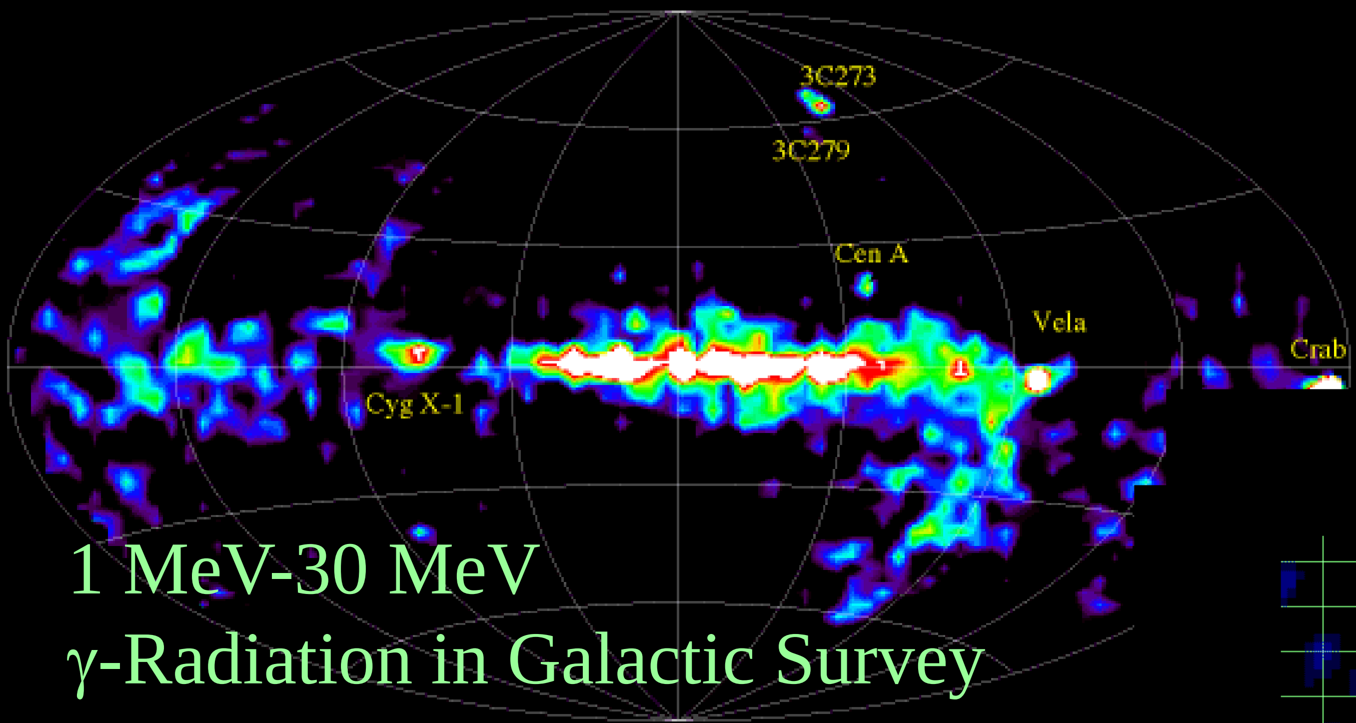
Cas A:




Cas A Supernova Remnant
Hydrogen (orange),
Nitrogen(red),
Sulfur(pink),
Oxygen(green)
by Hubble Space Telescope


Cas A with
Chandra X-ray observatory:
red: iron rich
blue: silicon/sulfur rich

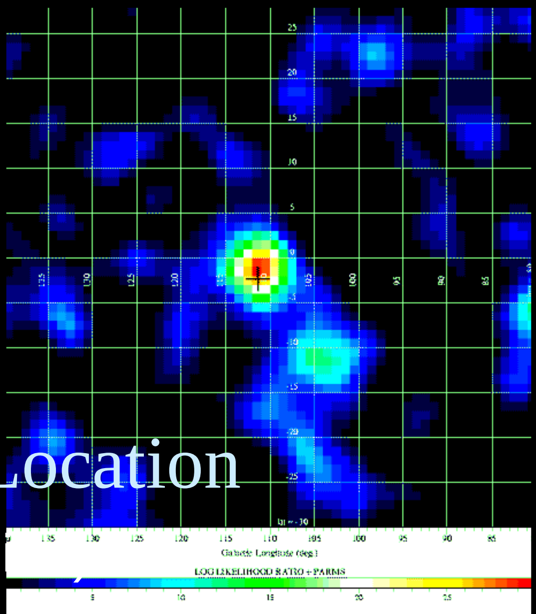
Galactic Radioactivity - detected by γ-radiation



1 MeV-30 MeV

γ-Radiation in Galactic Survey

(^{26}Al Half life: 700,0000 years, 1.809 MeV line)

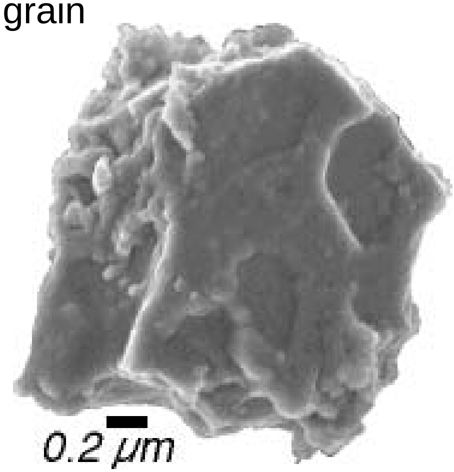


^{44}Ti in Supernova Cas-A Location

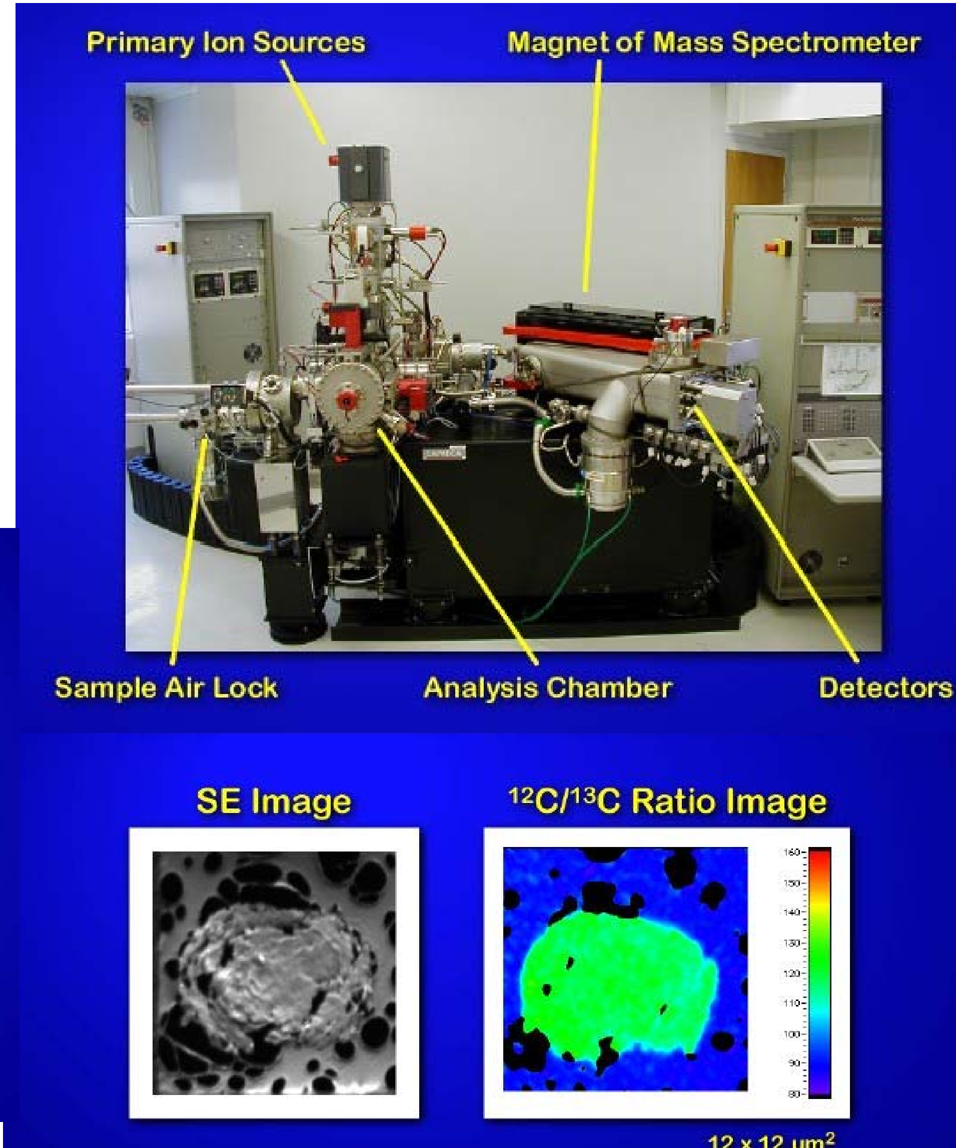
(Half life: 60 years, , 1.157 MeV li

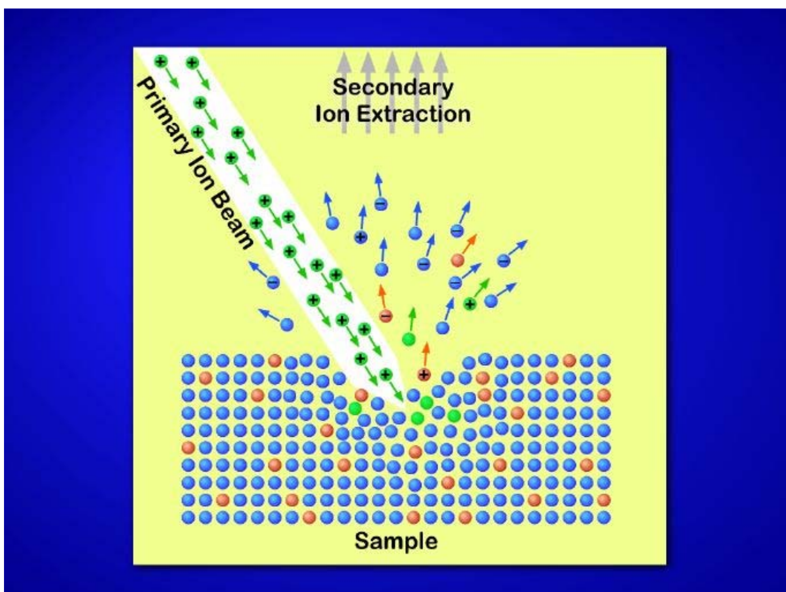
Analysis of presolar grains found in meteorites

SiC grain



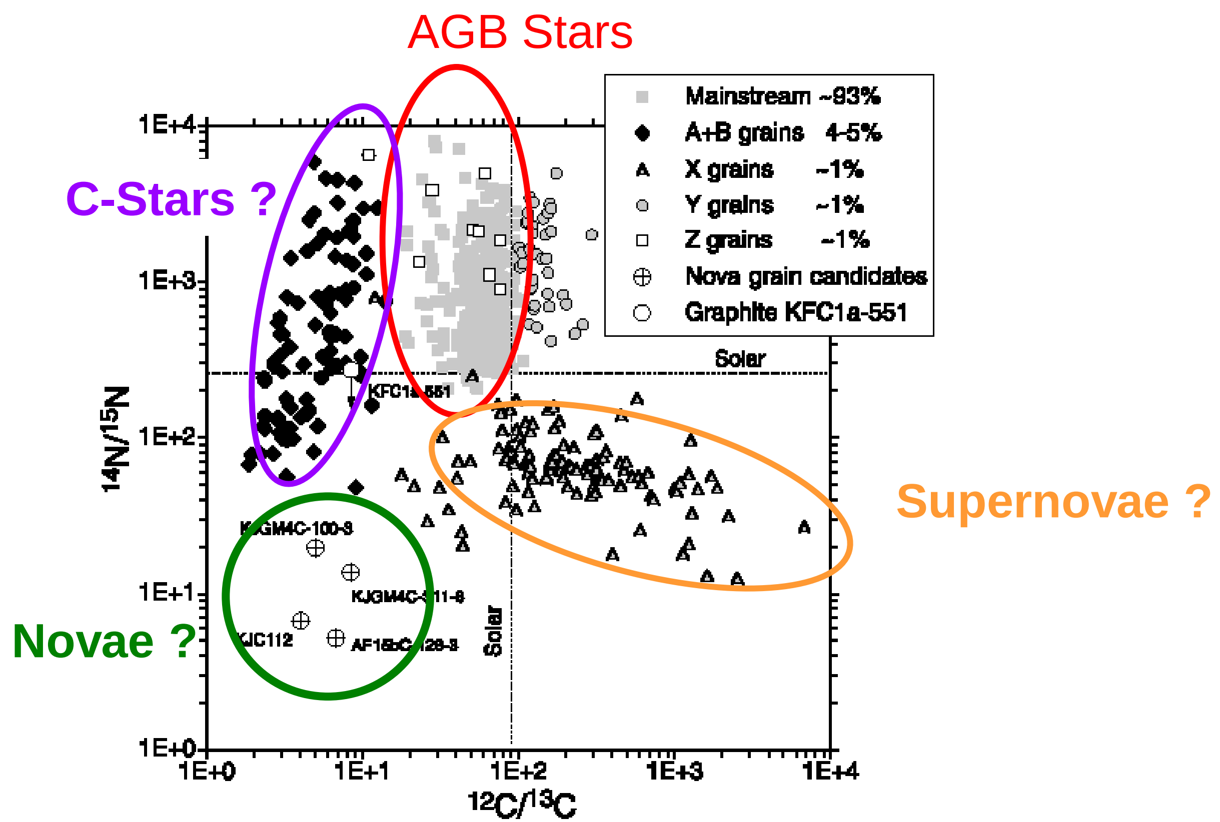
NanoSIMS at Washington University, St. Louis





F.J. Stadermann, http://presolar.wustl.edu/nanosims/wks2003/index.html

SiC grain analysis – and the origin of the grains



E. Zinner, Ann. Rev. Earth. Planet. Sci. 1998, 26; 147-188