Chemical evolution models: IMF and nucleosynthesis stellar yields

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Abstract

•Theoretical chemical evolution models may (?) reproduce the observed oxygen abundances with a variety of input parameters related with the star formation or infall rate histories.

•To fit simultaneously abundances of elements as C, N, and O, produced by stars in different mass ranges, we need the adequate combination of IMF + stellar yields.

•The Initial mass function and the nucleosynthesis stellar yields or production of new elements in stars, are two essential inputs for the chemical evolution models since they define the absolute elemental abundances provided by a single stellar population.

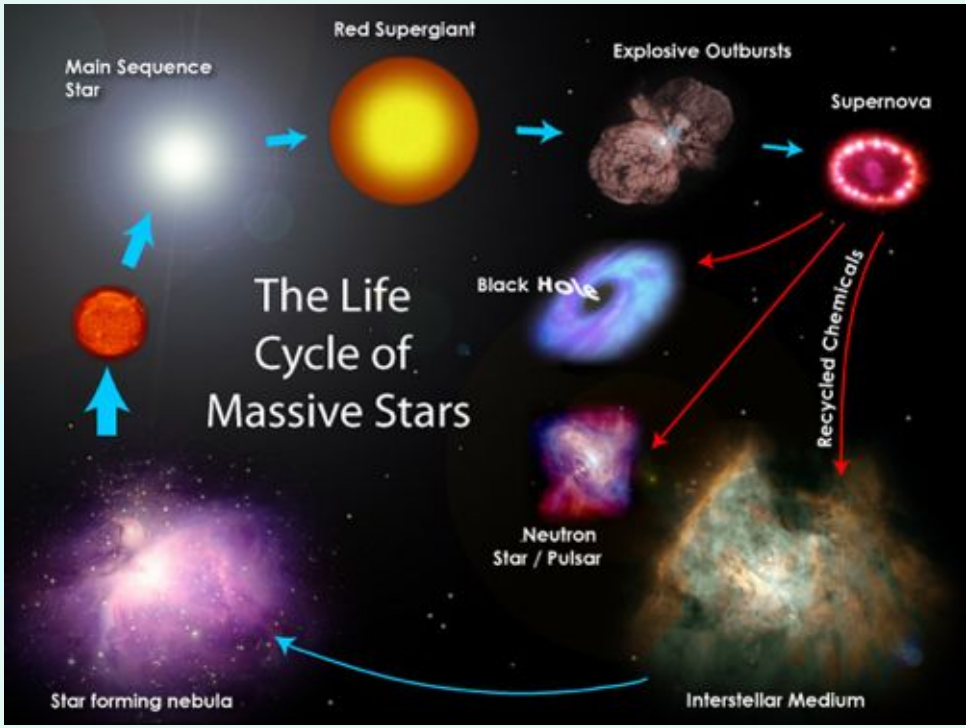
•We review the results of a chemical evolution model applied to the Milky Way Galaxy by using 100 different combinations of 5 possible IMFs plus 4 sets of low and intermediate mass stellar yields plus 5 massive star yields

•We compare them with the observational data of abundances within our Galaxy. From our analysis we may select the best combinations and also which would be inadequate to reproduce the observations.

Galaxies Chemical Evolution Models Aim

Chemical elements are created and then:

- Ejected and diluted in the interstellar medium
- Incorporated to the sucessive generations of stars

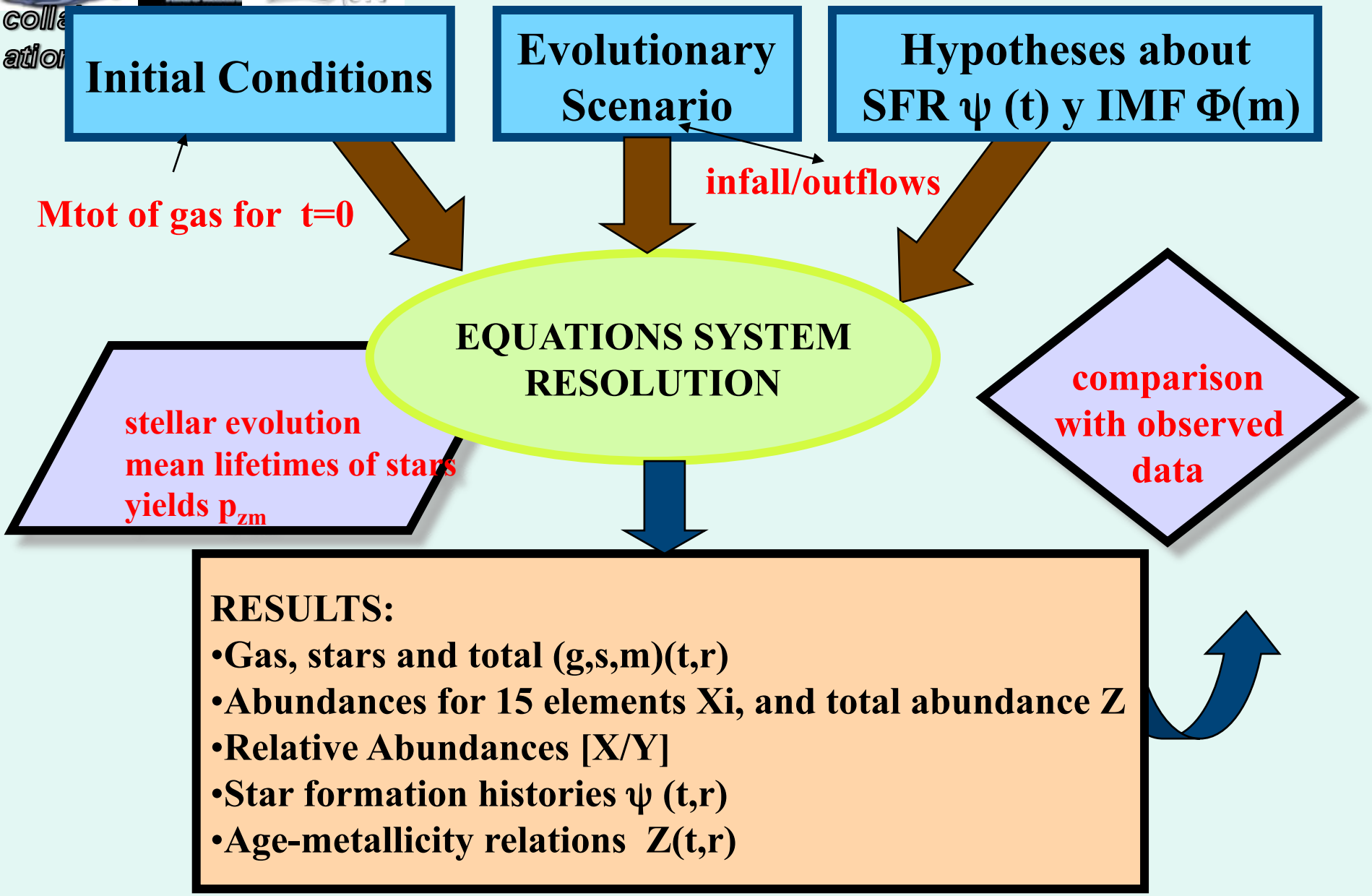


Elemental abundances give clues about star formation: when, how, with which rate stars form

- Phases:
  - –to understand processes,
  - –to predict elemental abundances,
  - –to compare with data

GCE tries to explain how and when the elements appear

From elemental abundances we may deduce the evolutionary histories of galaxies



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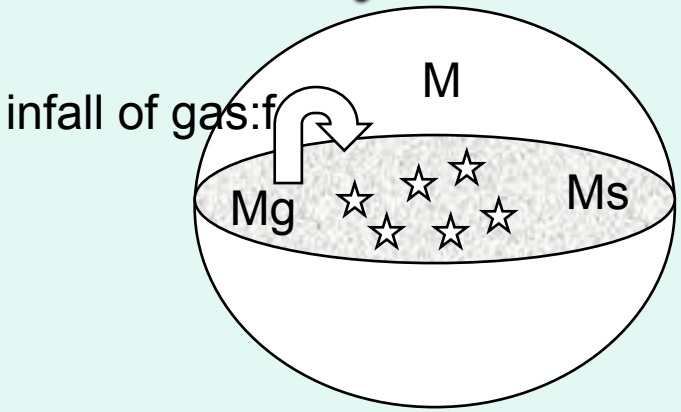
A chemical evolution model

The basic system of CEM



- f= flux of inflow gas (it may be 0)
- M= total mass of the system
- Ψ=SFR (star formation rate)
- E= mass ejection rate by the stars
- Ms=stellar mass
- Mg= gas mass

Each star loss mass after its stellar lifetime τm, after this there is a remnant ωm, and tehrefore the total ejection by all stars created in a region is:

$$E(t) = \int_{m_t}^{\infty} (m - \omega_m)\Psi(t - \tau_m)\Phi(m)dm$$

Initial mass function or number of stars in the range dm

Mass of stars created in the time (t-τm) which are now dying and ejecting mass after a time τm

Ejected mass by a star of mass m

Inputs of the multiphase chemical evolution model:

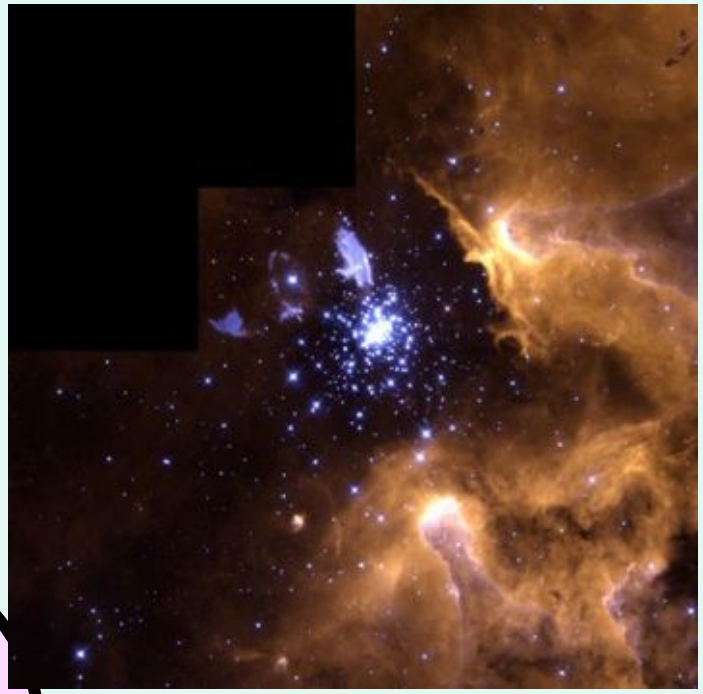
The star formation law

Star formation in the halo: SFR α K g $^{1.5}$

Stars form through cloud-cloud collisions: s α Hc ^{2}

In the disc molecular clouds form from the diffuse gas c α μg $^{1.5}$

Stars also form from the interaction between massive stars and molecular clouds: s α *a* c s $_{2}$



$$\Psi_D(t) = (H_1 + H_2)c_D^{\ 2}(t) + (a_1 + a_2)S_{2,D}(t)c_D(t)$$

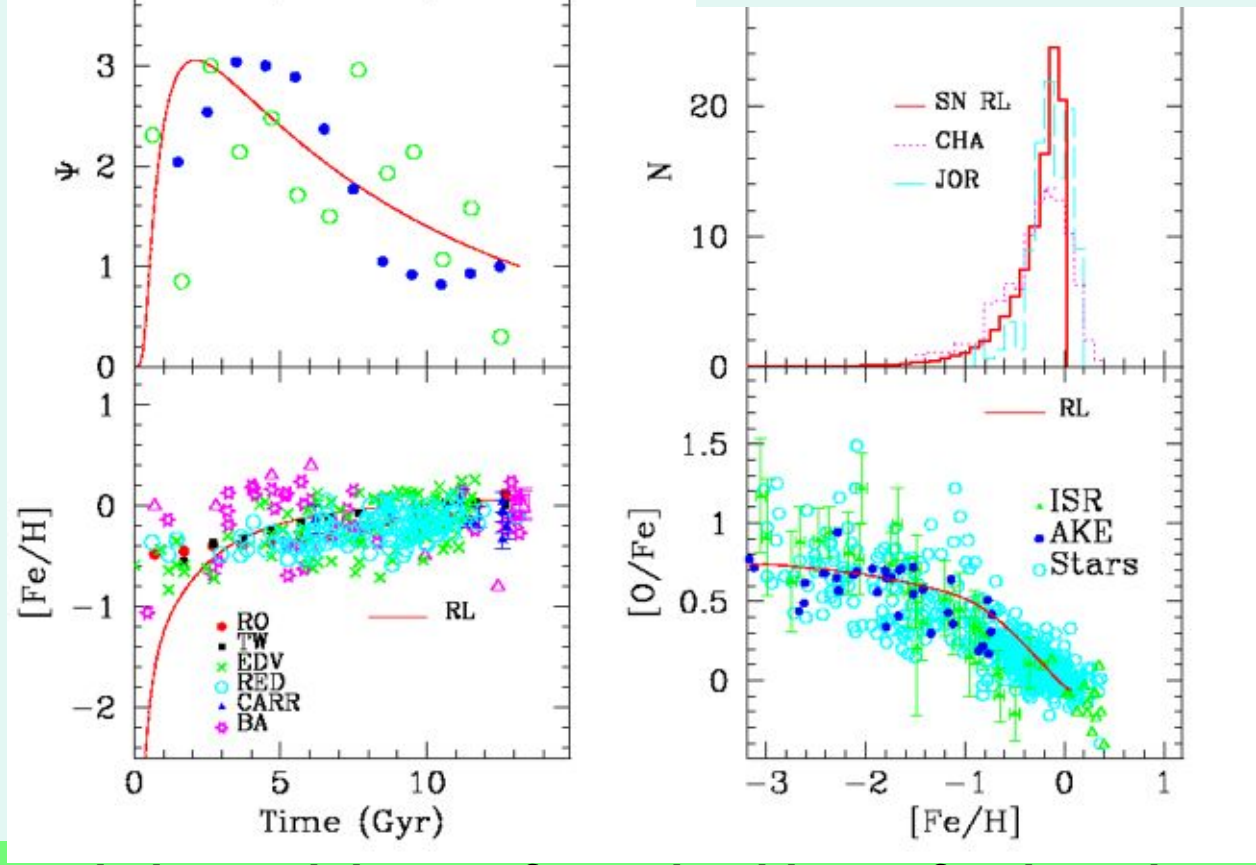
Calibration: the model against the Solar Vicinity data

Gavilán et al. 2005, 2006

IMF: Ferrini et al. 1998

Stellar yields: LIM-Gavilán et al 2005

MAS- Woosley & Waever 1996



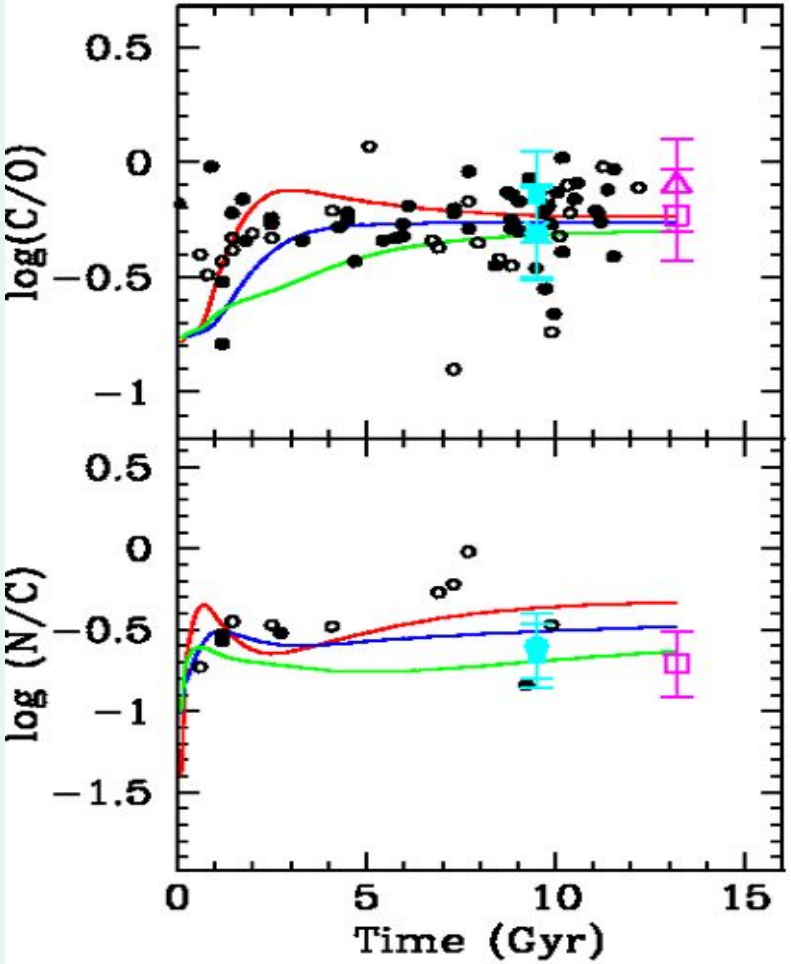
- **The age-metallicity relation and the star formation history for the solar region**
- **The metallicity distribution does not show the G-dwarf problem**

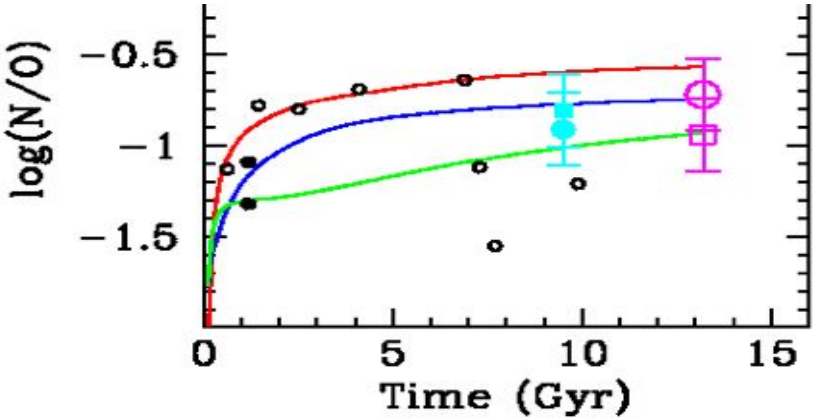
THE TIME EVOLUTION OF CNO ABUNDANCES

Red: Portinari et al 1998, PCB

Blue: Gavilan et al. 2005, GAV

Green: Van der Hoek & Groenewegen 1997 VHK



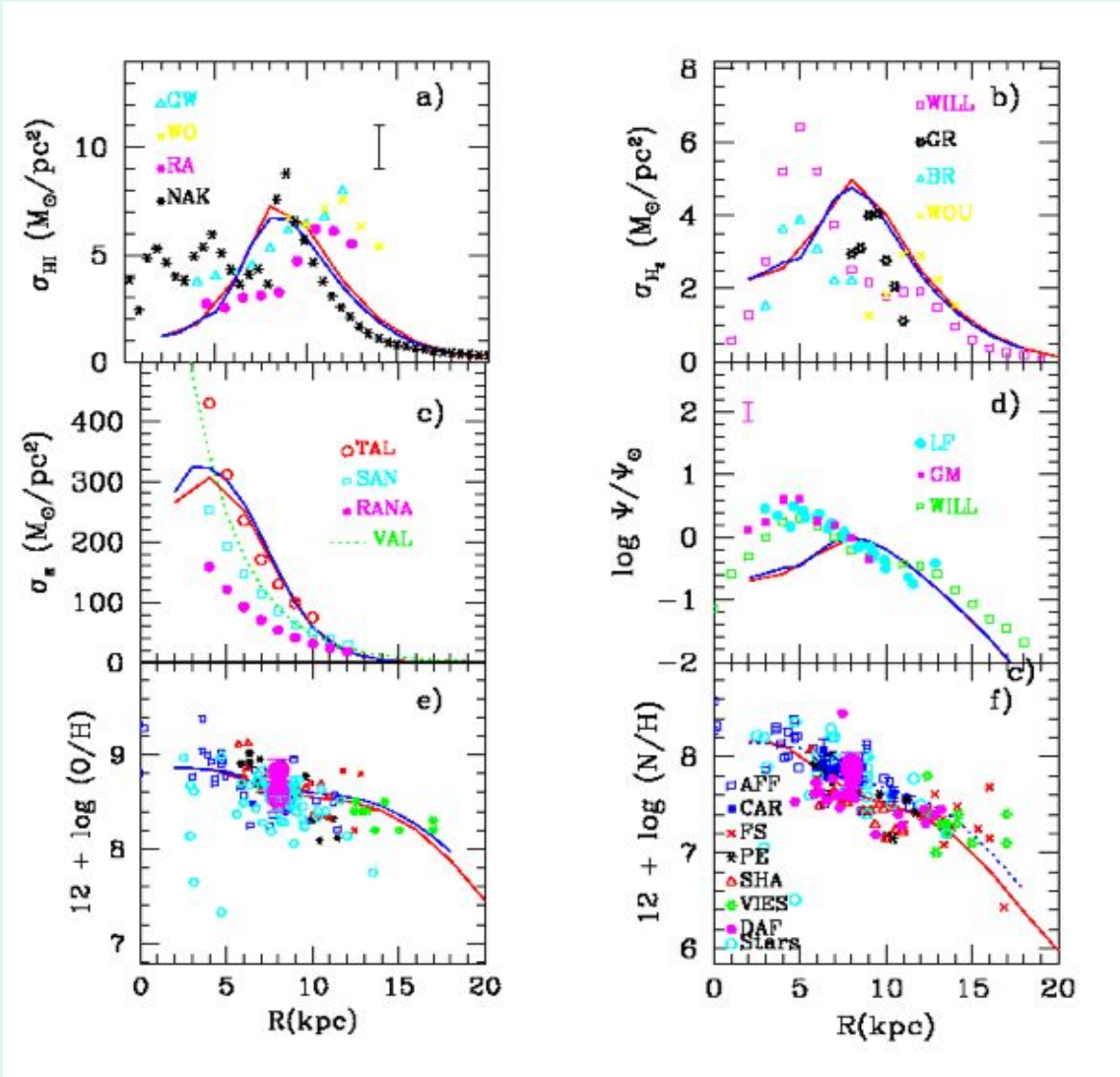


- **The elemental abundances reproduce well the observed data for the SN and also for other radial regions.**
- **The relative CNO abundances also are well fitted**

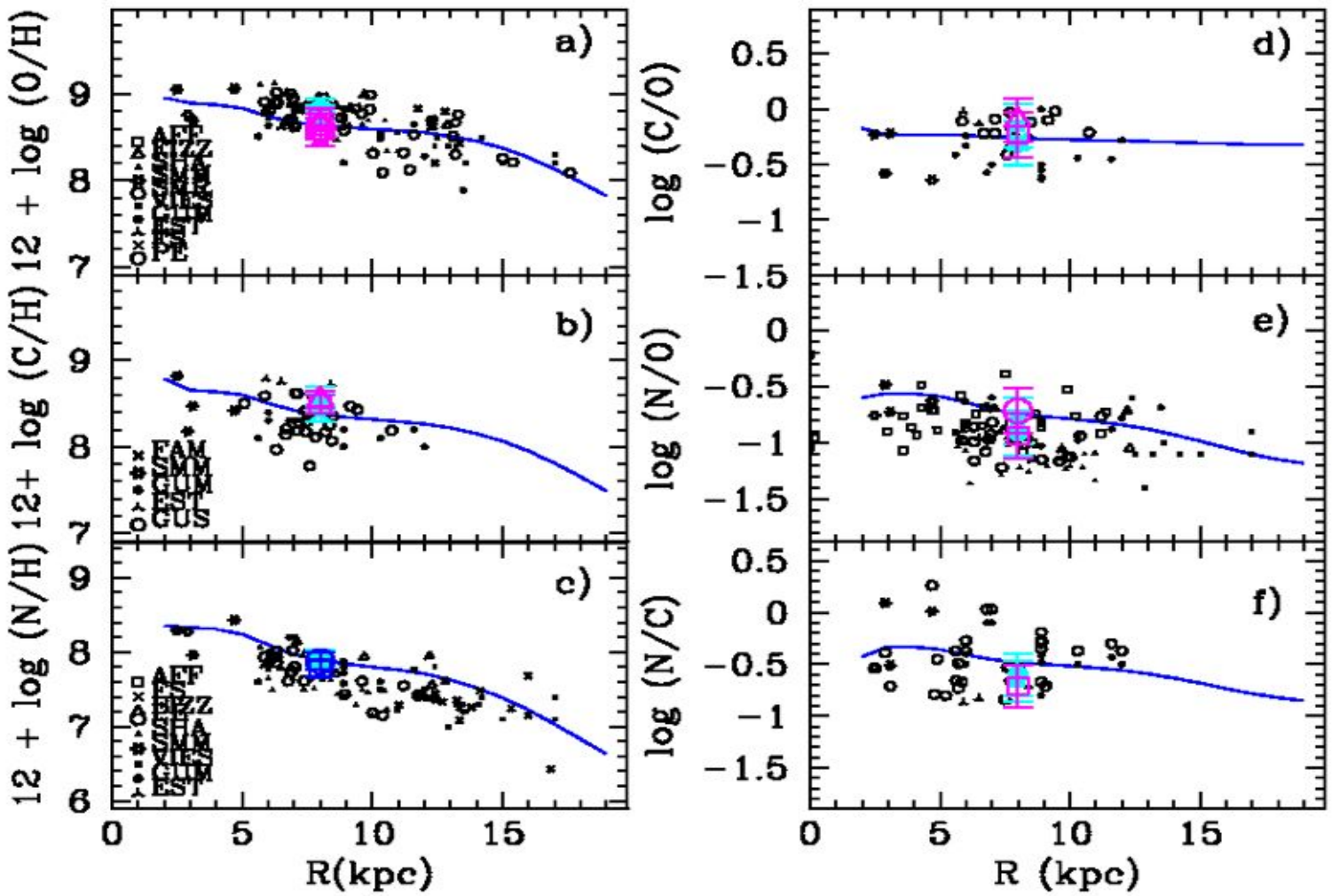
II. Calibration: the model: Vrot=200 km/s and N=4 against the Galactic disk data and model

(Gavilán et al. 2005, 2006)

- We can obtain separately the radial distributions of diffuse and molecular gas
- The radial gradients flattens in the inner disk in agreement with data (Smartt et al. 2001)
- The star formation rate surface density is underestimated in the inner radii



THE RADIAL GRADIENTS OF CNO ABUNDANCES



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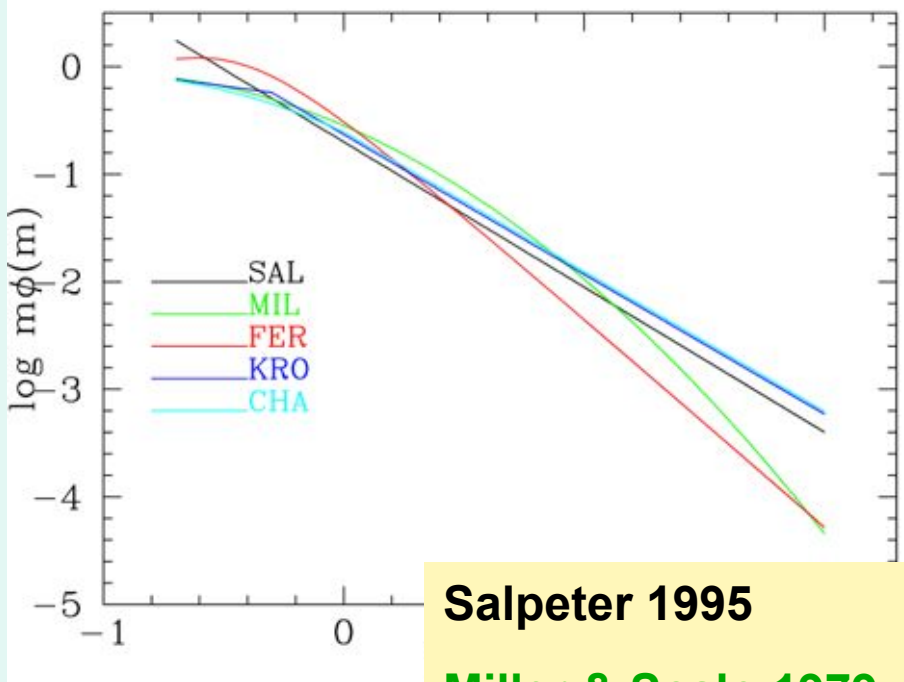
IMF + stellar yields

- Absolute abundances depend on **the yield of a generation of stars** (single stellar population): p_z + IMF

$$y = \frac{1}{1-R}\int_m^{\infty} m p_{z,m} \Phi(m) dm$$



Salpeter 1995

Miller & Scalo 1979

Ferrini et al. 1998

Kroupa 2002

Chabrier 2003

Cycle pp: low mass stars ***m<4Mo***

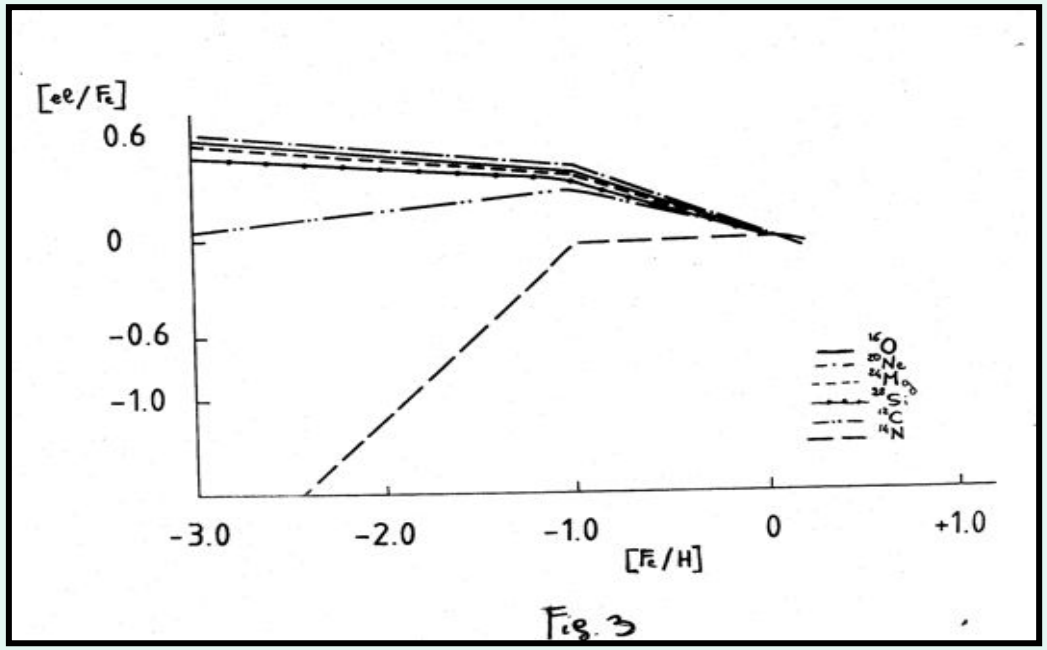
Cycle pp+CNO: intermediate mass stars ***4Mo< m < 8Mo***

Cycle CNO+ capture α: massive stars ***m > 8Mo***

Cycle pp: low mass stars ***m<4Mo***
Cycle pp+CNO: intermediate mass stars ***4Mo< m < 8Mo***
Cycle CNO+ capture α: massive stars ***m > 8Mo***

- **Low mass stars produce He and C**
- **Intermediate mass stars produce C,N and O**
- **Massive stars produce O,Ne,Mg,S..,N, and Fe**
- **Binary Systems, SNIa Fe**

The meanlifetimes of different stars explain the relative abundances of elements



- Massive star yields
  - ✓ **Woosley & Weaver (1995) WOW**
  - ✓ **Portinari et al. (1998) PCB**
  - ✓ **Chieffi & Limongi (2004) LIM**
  - ✓ **Kobayashi et al. (2007) KOB**
  - ✓ **Heger et al. (2008,1010) HEG**
  - ➢ Maeder & Meynet (1992)
  - ➢ Maeder, Meynet & Hischi (2005)
  - ➢ Frohlich et al. (2008)

- LIM yields
  - ✓ **Van der Hoek & Groenewegen (1997) VHK**
  - ✓ **Marigo (2001) MAR**
  - ✓ **Gavilán et al. (2005) GAV**
  - ✓ **Karakas & Lattanzio (2010) KAR**
  - ➢ Renzini & Voli (1991)
  - ➢ Ventura et al. (2002)
  - ➢ Dray et al (2003)

Extrapolated until 100 Msun

All stellar models calculated with Anders & Grevesse 1989

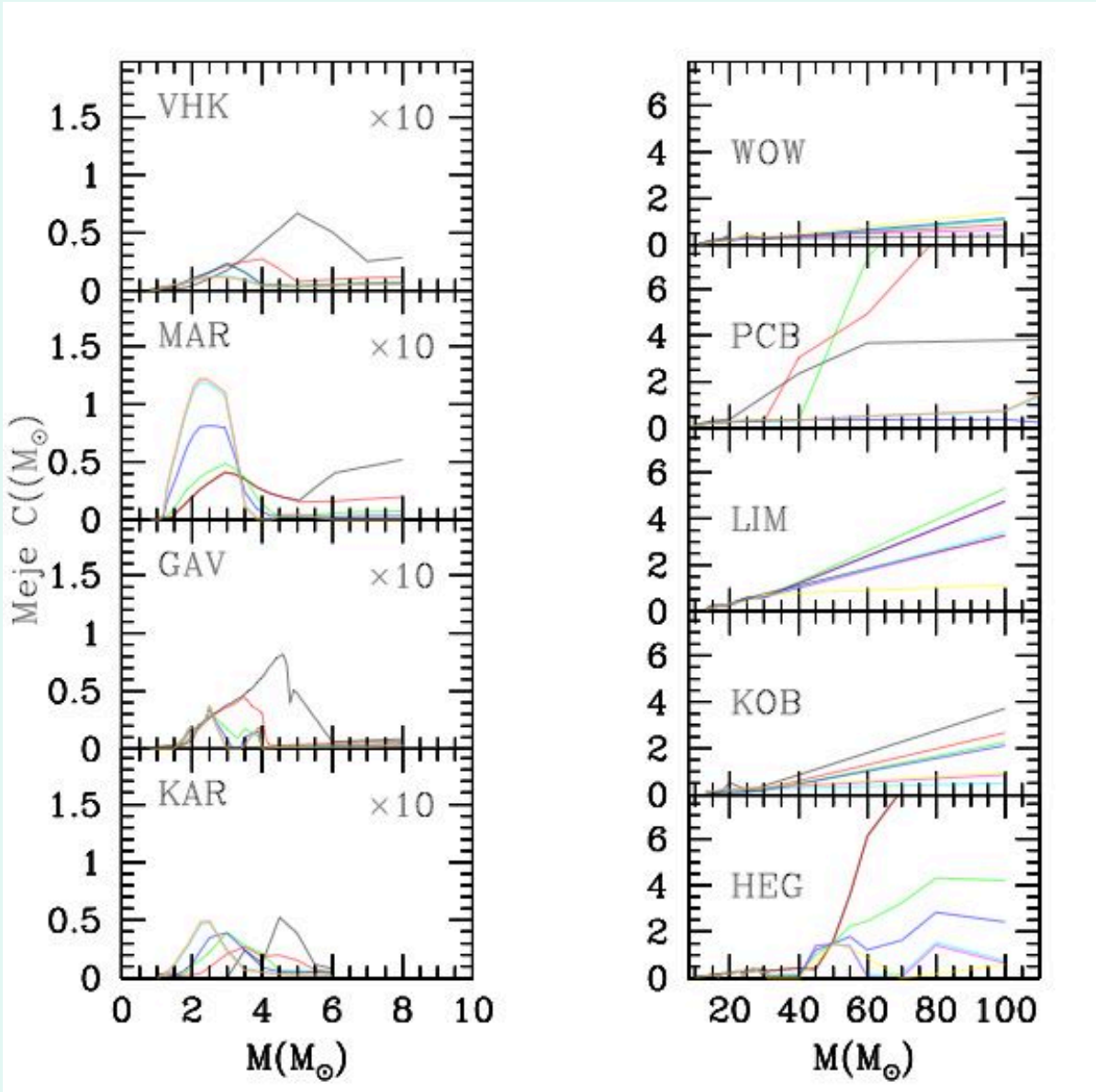
Stellar yields obtained from stellar masses

Ejected masses for ^{12}C

LIM stars: a maximum around 4-6 Msun

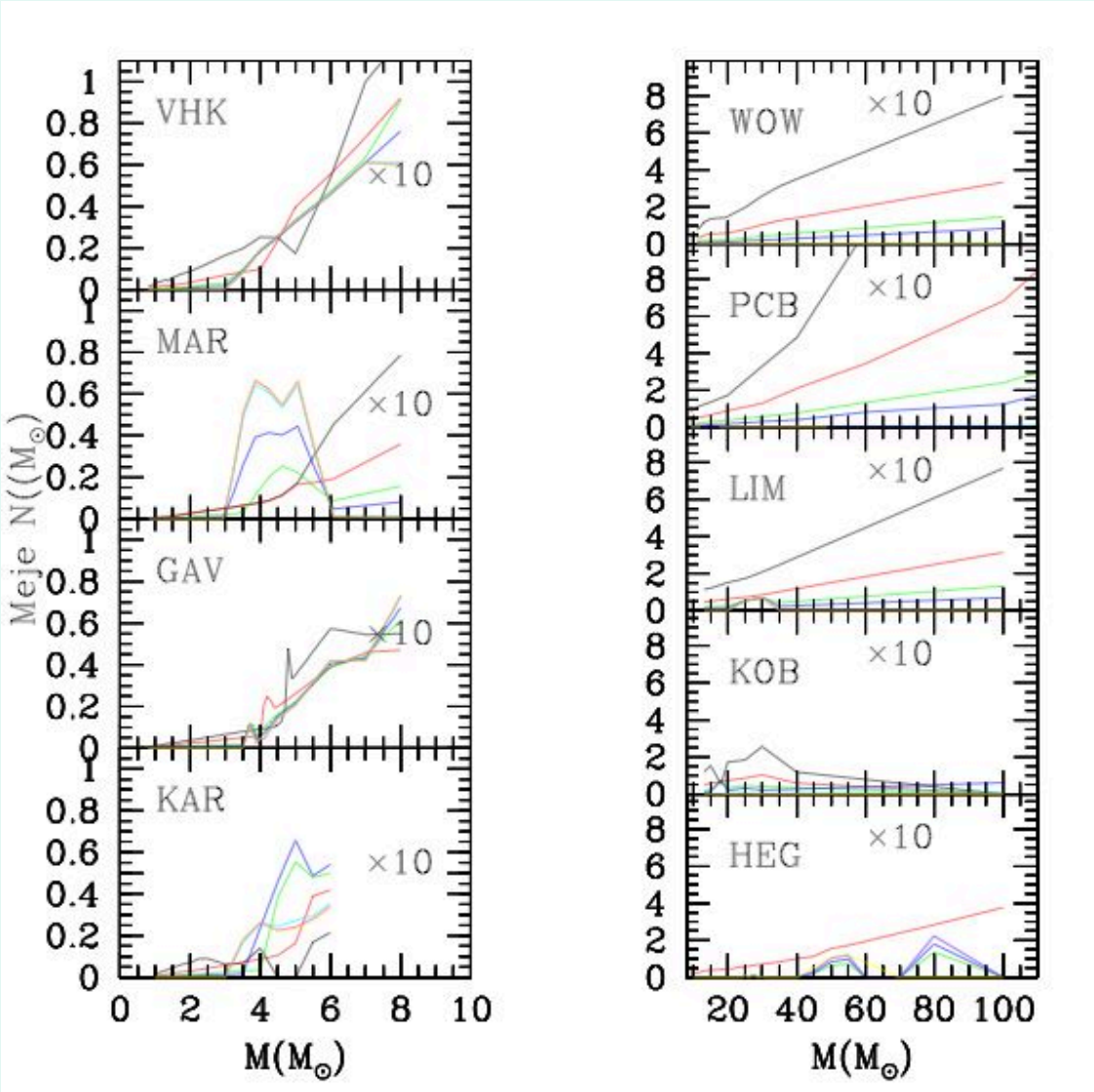
Massive stars: depend on the hypotheses about stellar winds

Different Zs with different colors



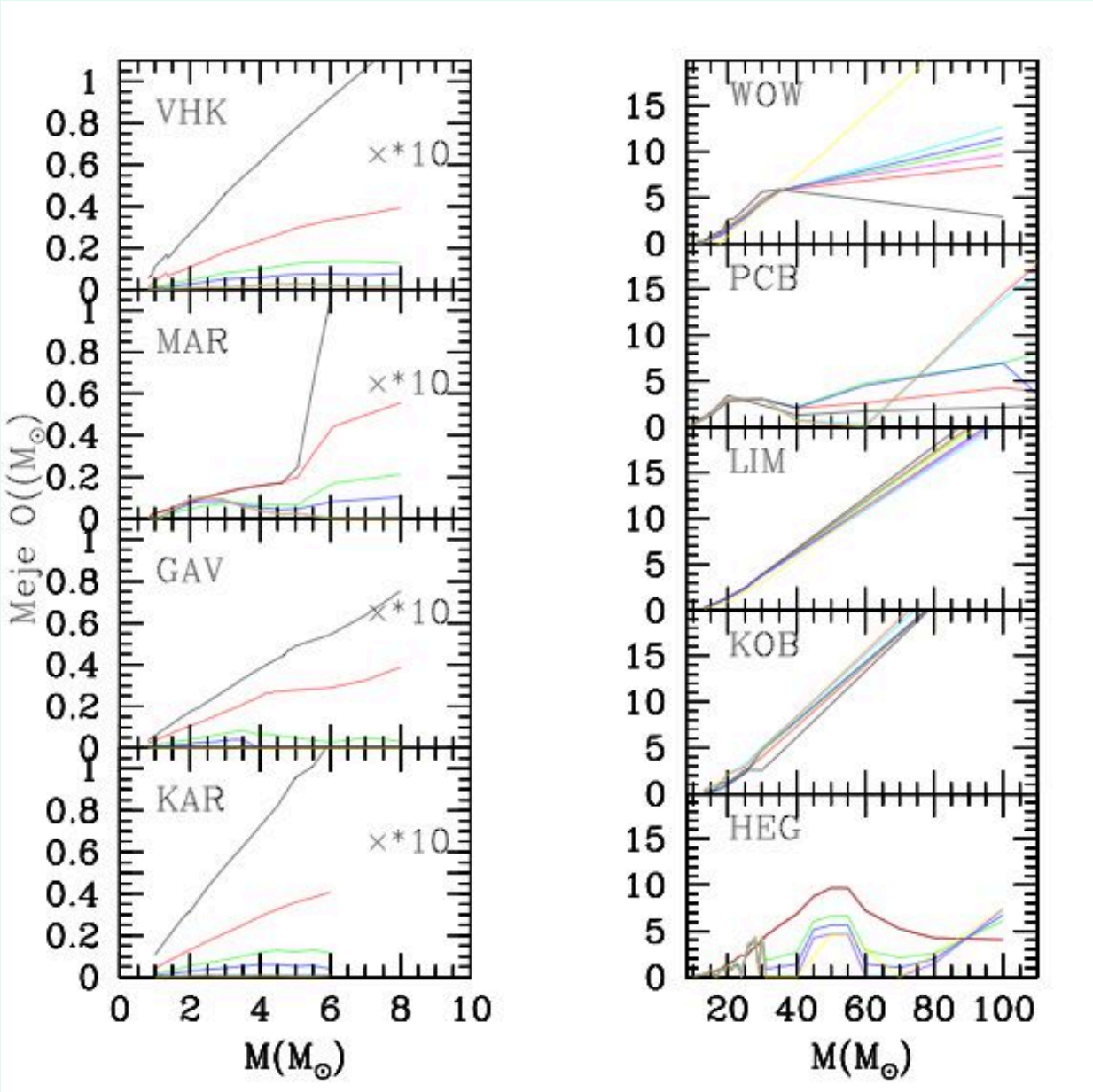
Ejected masses for ^{14}N

- LIM stars: increase with stellar mass
- Massive stars: smooth increase except Heger & Woosley 2008



Ejected masses for ^{16}O

- LIM stars: small quantities
- Massive stars: dependence on stellar winds



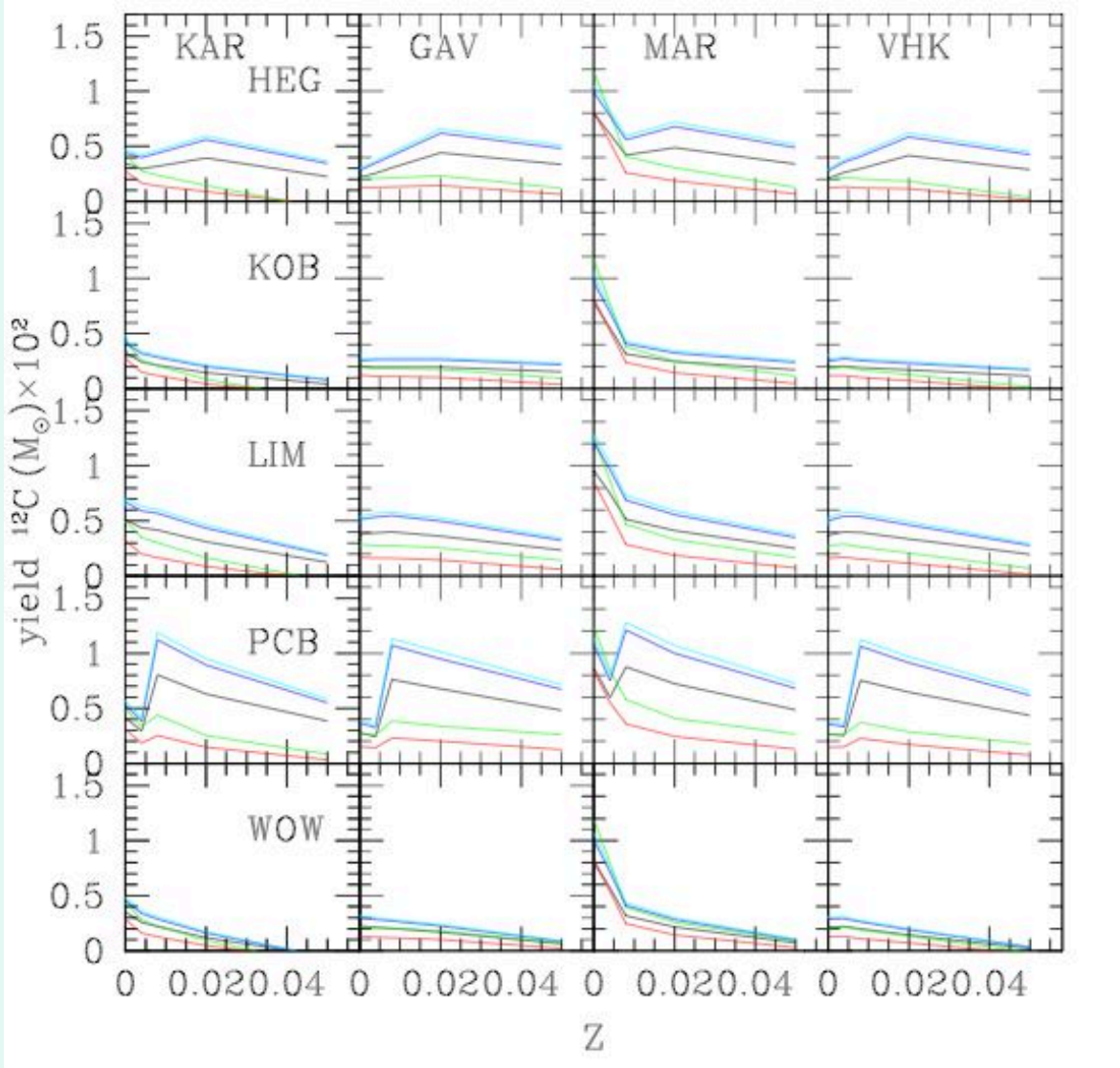
Integrated yields: dependence on Z

^{12}C

- Combination of LIM + MAS stellar yields for different IMFs

Black SAL
Green: MIL
Red: FER
Blue: KRO
Cyan: CHA

MAS ↓ LIM →



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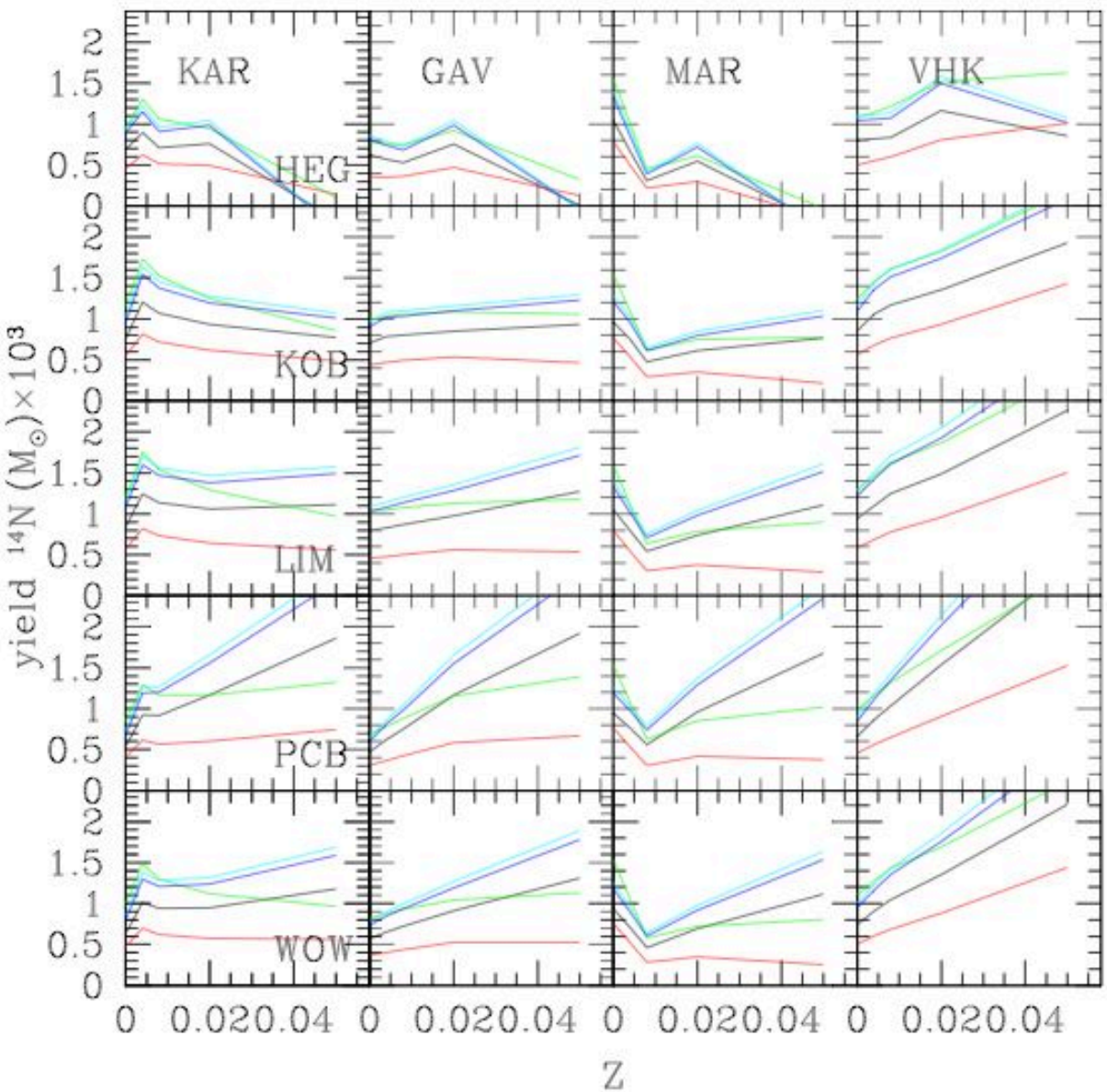
Integrated yields: dependence on Z

^{14}N



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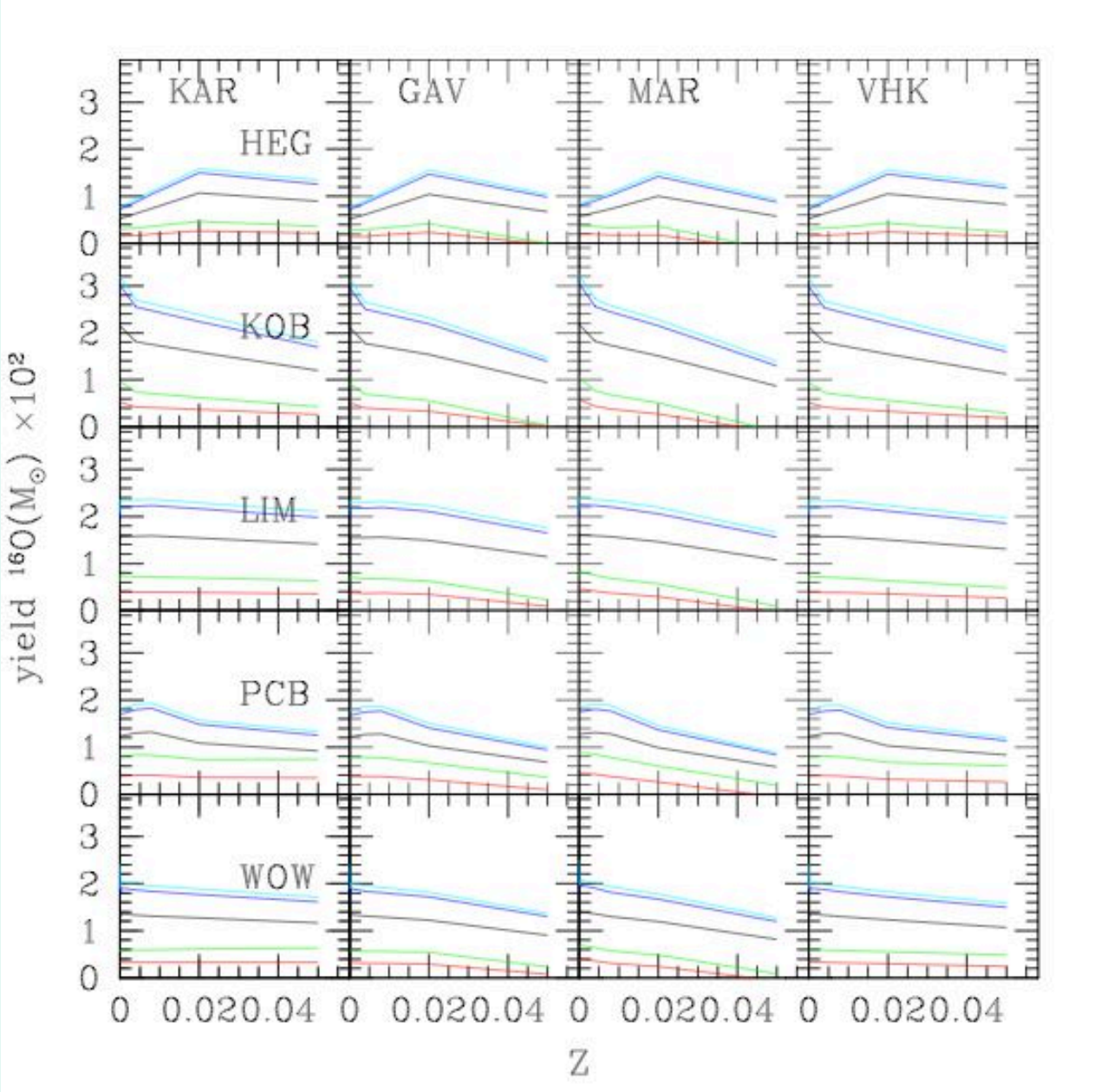
Integrated yields: dependence on Z

^{16}O



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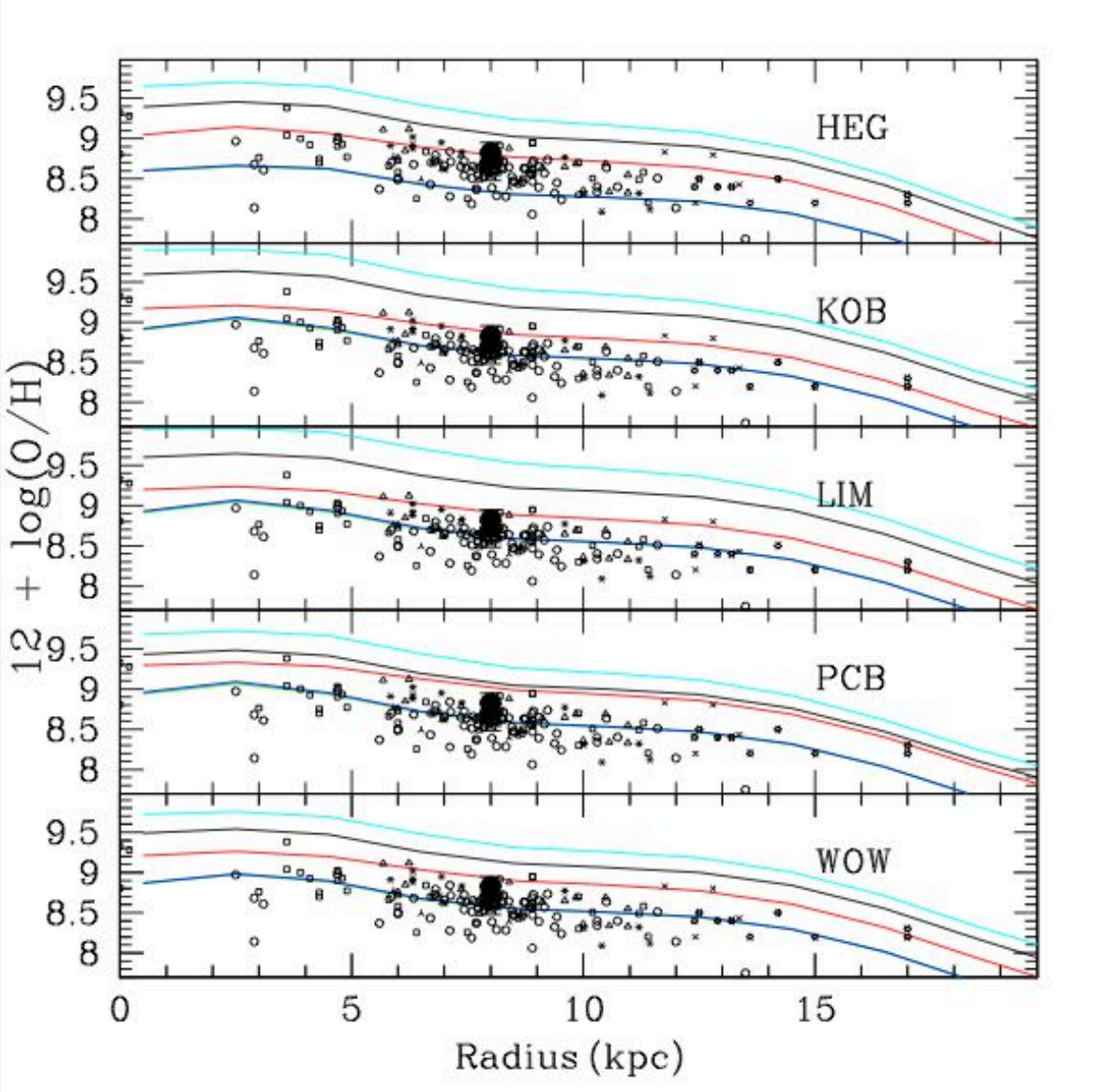
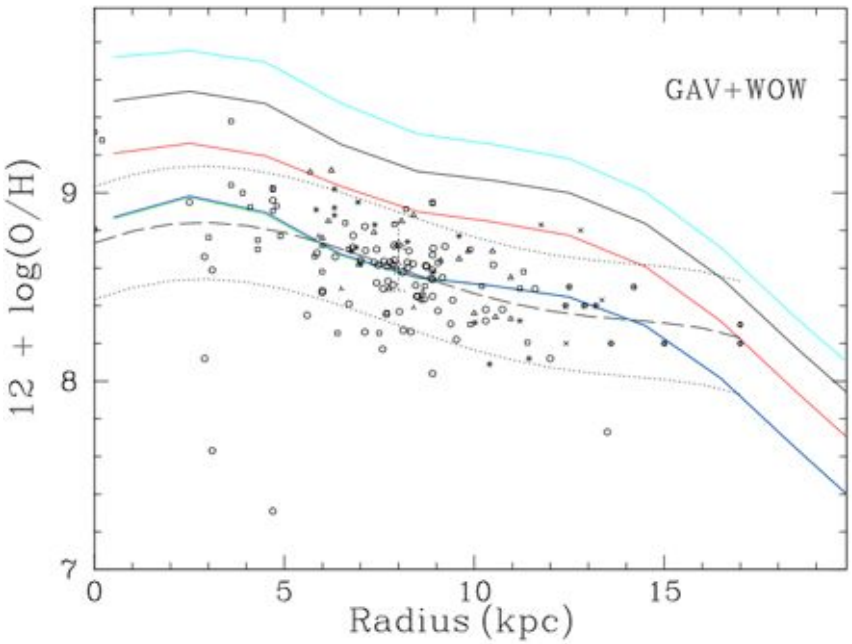
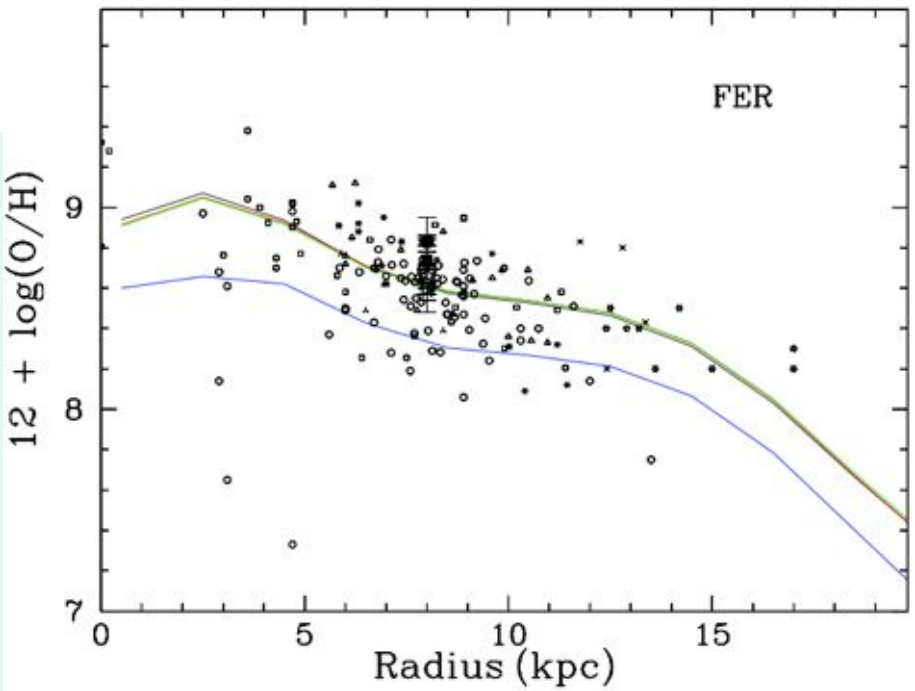
(Very preliminary) Results

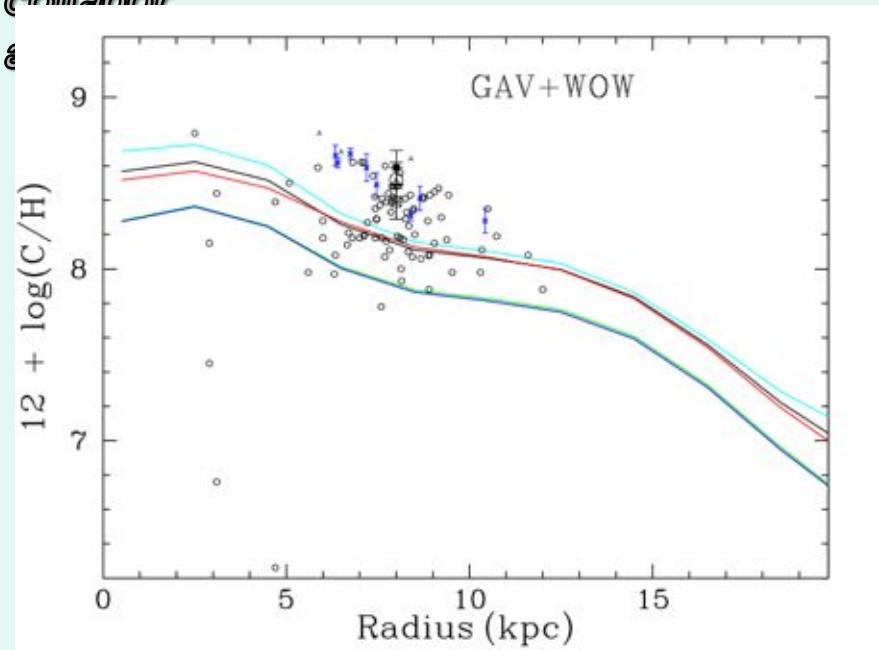
- Oxygen abundances very similar for all stellar yields sets
- Differences larger for dif. IMFs

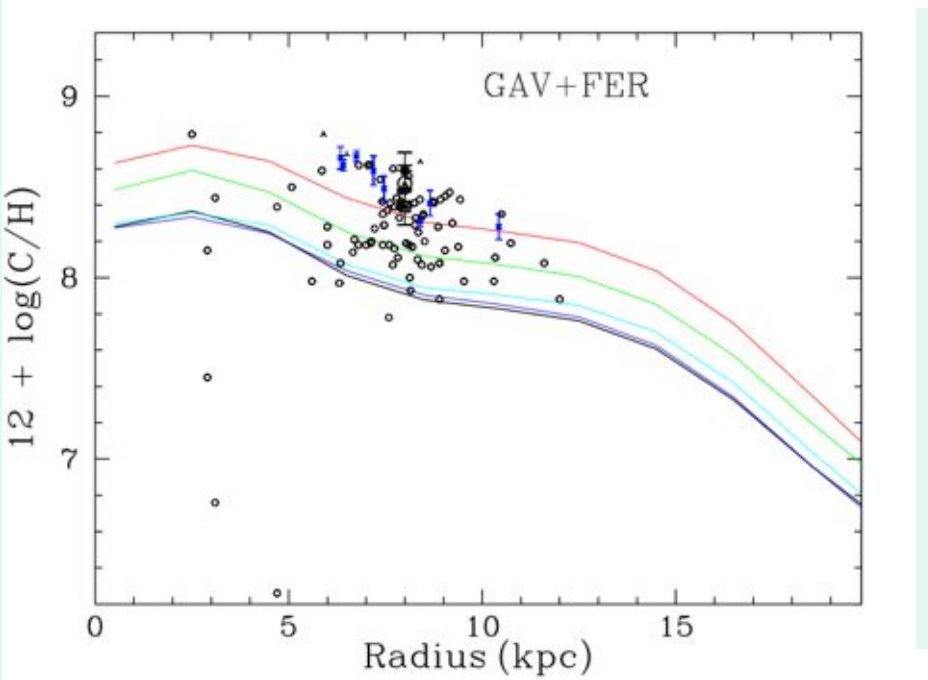


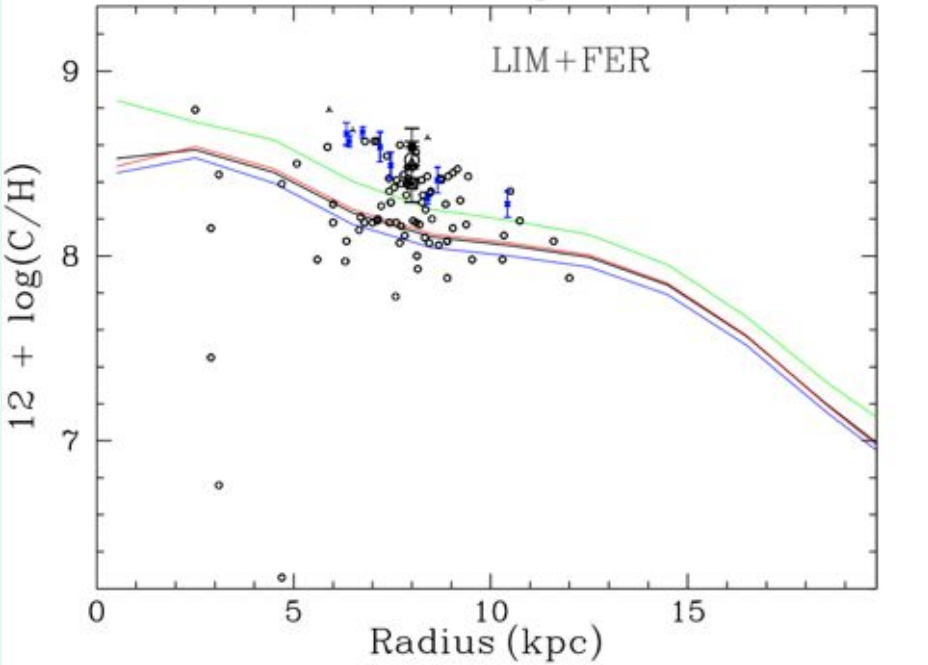


Effect of the IMF more important than the set of yields for Oxygen









The largest differences come from the use of different massive stellar yield sets

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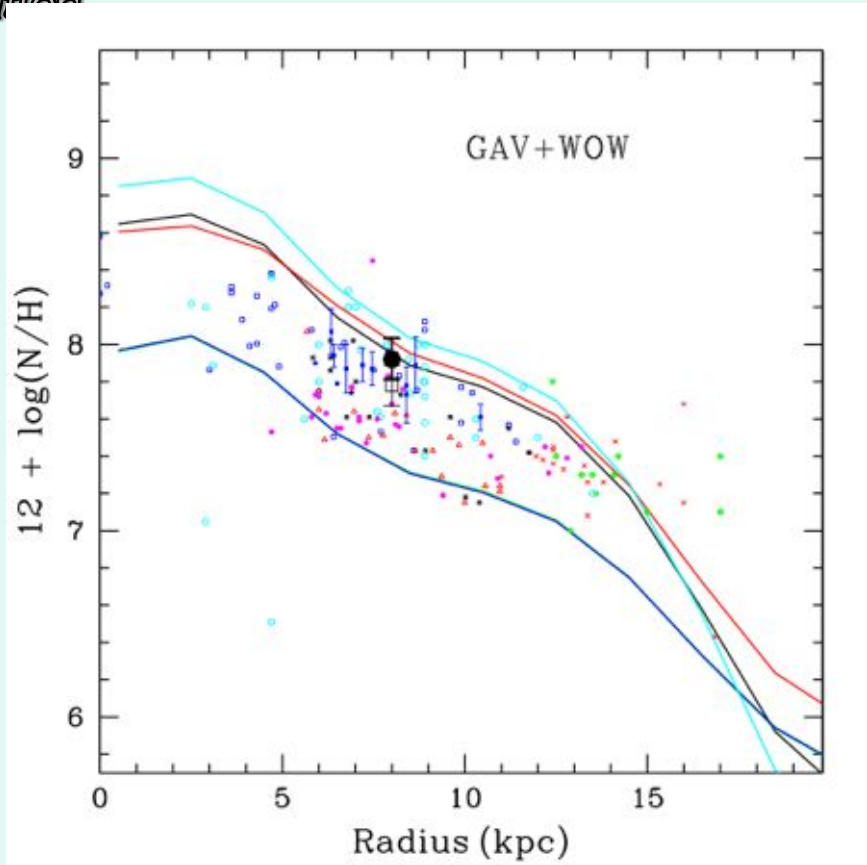

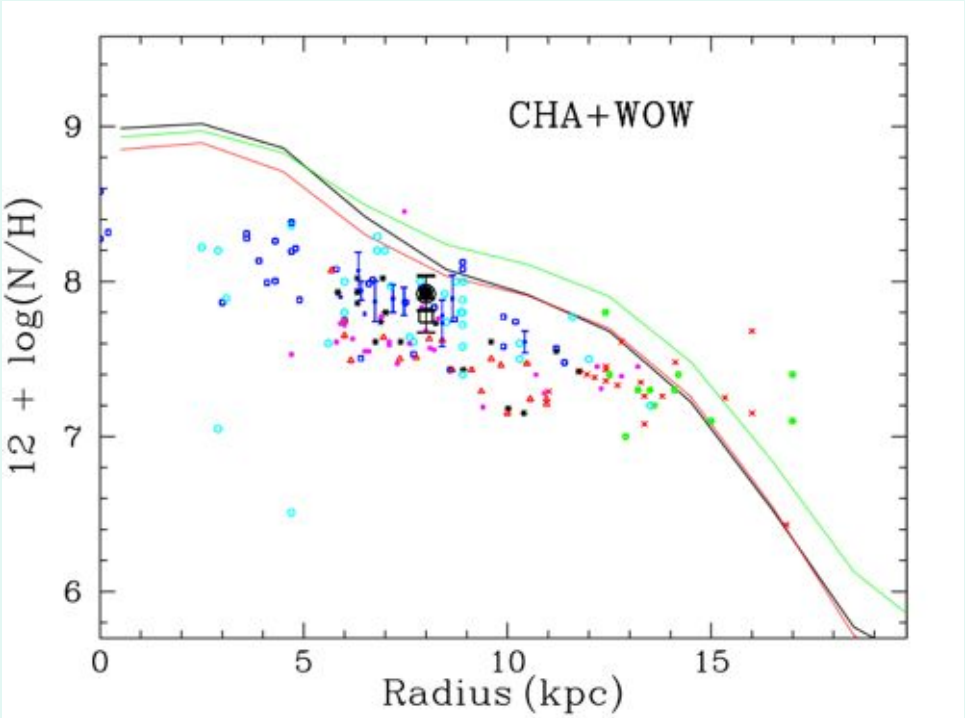

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Summary

- IMF+Stellar yields may change the absolute level of abundance
- Stellar yields of different masses stars must reproduce the relative abundances
- The stellar mean-lifetimes are important to explain when some elements as N or Fe appear in the ISM
- A fine tuning of IMF+yields is necessary to reproduce simultaneously the solar abundances and the relative abundances in galaxies
- The radial gradients depend on the ratio SFR/infall and its variation on the galactocentric distance
- It is essential to use the adequate ingredients (IMF+stellar yields +infall rate+ star formation efficiencies) to reproduce simultaneously all observational data sets