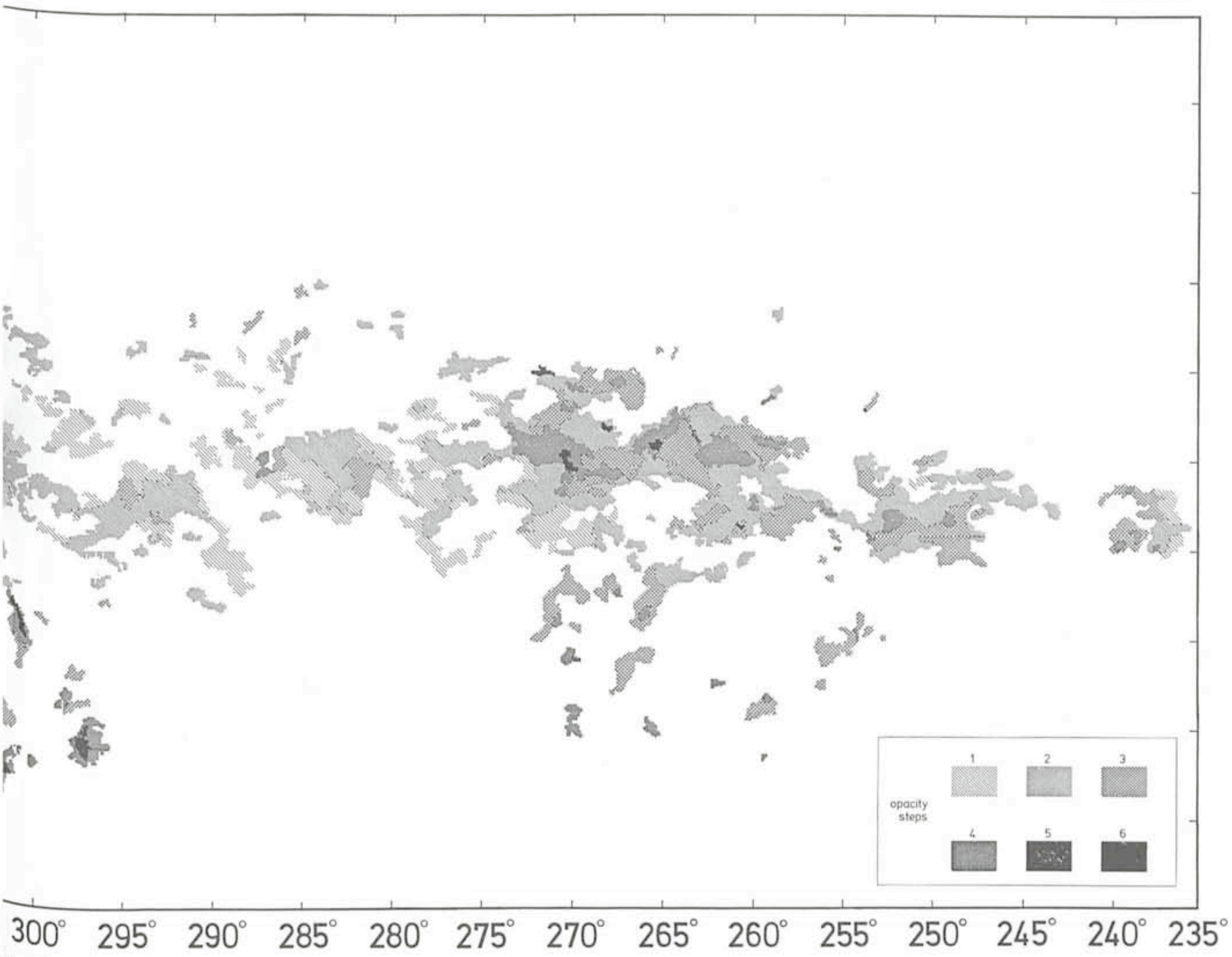

l = 0°.1).

Besides their different opacities interstellar clouds show a bewildering variety of shapes and sizes. To take this fact into account, we supplemented the catalogue by descriptive categories: tail of a cometary globule, worm track, dark filament, etc., and the classification scheme of van Bergh (1972). The four categories: amorphous cloud (α) . . . sharp-edged absorption (δ) may be understood in terms of a simple physical picture of the evolution of interstellar clouds. These classifications should reflect the evolutionary history of the dynamical or thermal processes that once provoked the formation of the dark clouds and globules.

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The Chemical Enrichment of Galaxies

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Galaxies are thought to have formed out of a primordial gas consisting of ~77 % Hydrogen, ~23 % Helium and traces of Deuterium and Lithium without heavier elements. At the present time the chemical composition of the interstellar medium (ISM) in the solar neighbourhood shows a composition of ~70 % Hydrogen, ~28 % Helium and ~2 % heavier elements. This progressive enhancement of Helium and heavier elements at the expense of Hydrogen in the interstellar gas is referred to as galactic chemical evolution.

The chemical evolution of galaxies is governed by many factors such as the rate at which stars form, their mass spectrum, their evolution through successive thermonuclear cycles and the dynamics of the gas-star system. Each generation of stars contributes to the chemical enrichment of a galaxy by processing new material in the stellar interiors and restoring to the interstellar medium (ISM) a fraction of its total mass in the form of both processed and unprocessed matter, during various mass loss events (stellar winds, planetary nebula ejection and supernova explosion). The next stellar generation then forms out of this enriched gas and evolves, giving rise to an ongoing process which terminates when all the available gas has been consumed.

In order to describe in detail this process of enrichment, it is necessary to know how much gas is turned into stars per unit time, the initial mass function (IMF), and how much and when nuclearly processed material is restored to the ISM by each star (stellar yields).

Since in recent years the chemical evolution of galaxies has been the subject of a great deal of theoretical work, I will not describe here the many details and intricacies of this topic, but I will present only some results:

(i) the determination of the yields per stellar generation of several chemical elements (He^4, C^{12}, C^{13}, O^{16}, N^{14} and Fe^{56}) as a function of two important stellar evolution parameters,

(ii) the effect of the iron production from intermediate mass stars on the chemical evolution of the solar neighbourhood.

(i) The Determination of Yields per Stellar Generation

The importance of determining the yields of the chemical elements per stellar generation is that, from them, many important conclusions regarding the chemical evolution of galaxies can be drawn without considering detailed evolutionary models. In fact, under simple assumptions, the ratio between the yields of two elements gives direct predictions concerning the ratio of the corresponding abundances.

The net yield per stellar generation of a given element (He and heavier) is defined as the fraction of matter restored to the ISM by a generation of evolving stars in the form of newly created element i, divided by the total fraction of matter locked up in low mass stars and remnants.

In order to compute the yields per stellar generation we need to specify only the stellar yields and the initial mass function. The initial mass function, defined as the mass of stars contained in the mass interval m, m+dm, is generally expressed as a power law (ψ (m) α m^{-x}) and, for the sake of simplicity, is assumed to be constant in time.

The most important factor governing the nucleosynthesis production is the stellar mass, even if the chemical composition can be very important in affecting the yields as I will show in the following.

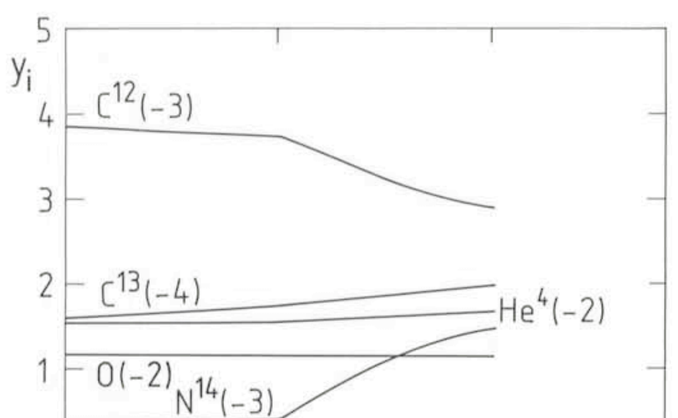

Fig. 1: *Yields per stellar generation of He^4, C^{12}, C^{13}, N^{14} and O^{16} as a function of the mixing-length to pressure scale height ratio α. The value of the mass loss efficiency parameter η is fixed and equal to 0.33.*

Star masses contributing to the galactic chemical enrichment can be divided into three main categories:

(a) low mass stars ($0.8 \lesssim m/m_\odot \lesssim 2.3$) which develop an electron degenerate core after the Main Sequence phase,

(b) intermediate mass stars ($2.3 \lesssim m/m_\odot \lesssim 9$) which ignite He non-degenerately but develop an electron degenerate Carbon-Oxygen core after the exhaustion of the Helium at the centre,

(c) massive stars ($10-15 \lesssim m/m_\odot \lesssim 100-120$) which are able to synthesize, during the course of their evolution, all the elements from Carbon to Iron.

Low mass stars evolve through a core H-burning, a shell H-burning, a core He-burning and a double shell phase (Asymptotic Giant Branch). They essentially contribute to the enrichment of He^3, He^4, C^{13}, N^{14} and s-process (slow neutron capture) elements through stellar winds and planetary nebula ejection, ending their lives as white dwarfs.

Intermediate mass stars evolve through the same phases as low mass stars but can also ignite Carbon in their cores. However, if the mass loss process reduces the mass of the star below 1.4 $M_\odot$ (Chandrasekhar mass), Carbon will never be ignited and the star will eventually become a white dwarf. On the other hand, if Carbon is ignited in an electron degenerate C-O core (which is the case for intermediate mass stars), hydrodynamical and nucleosynthesis computations suggest that a thermal runaway (Carbon-deflagration) should occur, resulting in the complete destruction of the star. During the C-deflagration some nucleosynthesis would occur and at least one half of the core mass of 1.4 $M_\odot$ would be transformed into Iron peak elements, with the composition of the remaining mass showing the presence of all the elements between Carbon and Iron (Nomoto, 1983). As a consequence, inter-

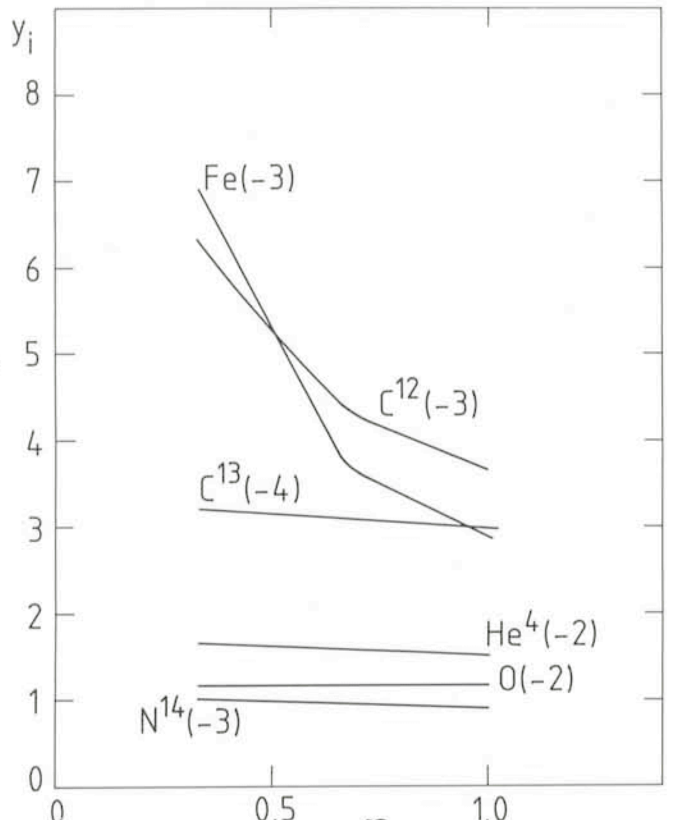

Fig. 2: *Yields per stellar generation of He^4, C^{12}, C^{13}, N^{14}, O^{16} and Fe^{56} as a function of the parameter η and for α = 1.5.*

mediate mass stars could be responsible for the production of a substantial amount of heavy elements in addition to the same elements produced by low mass stars. Unfortunately, the maximum limiting mass for which the final product is a C-O white dwarf is very uncertain, since it is a strong function of the mass loss efficiency, a quantity which is, in turn, very poorly known.

Massive stars are generally believed to be the major contributors to the heavy element production. In fact they can develop all the nuclear burnings up to the formation of a central Nickel-Iron core, followed by successive shells containing products of O- C- He- and H-burning. Massive stars contribute to the galactic enrichment through stellar winds and supernova explosions. The mass loss during the H- and He-burning phases essentially affects the Helium production; the contribution of the stellar wind to the yields of heavy elements can become important only after a certain mass limit i.e. 40–50 $M_\odot$ (Maeder, 1981, 1983).

Fig. 1 und 2 show the yields per stellar generation of several elements (He^4, C^{12}, C^{13}, O^{16}, N^{14} and Fe^{56}), which I computed for a given IMF (x = 1.35, Salpeter, 1955) and different choices of two important parameters influencing the evolution and nucleosynthesis of low and intermediate mass stars: the mixing length to pressure scale height ratio α, and the Reimers (1975) mass loss parameter η (the nucleosynthesis results concerning low and intermediate mass stars are taken from Renzini and Voli, 1981). The data concerning the chemical enrichment by massive stars are a miscellany of Arnett (1978), Woosley and Weaver (1983) and Maeder (1981), with the exception of the Iron production which I assumed to be one half of the quantity computed by Arnett (1978) as Silicon + Iron. With increasing α, the total yield of C^{12} decreases in favour of those of He^4, C^{13} and N^{14} as a consequence of the intermediate mass stars which convert the primary C^{12} (primary elements are those synthesized directly from H and He^4), dredged-up after each He-shell flash, into primary N^{14} and C^{13}. In fact, the parameter α affects the efficiency of the burning at the base of the convective envelope (hot-bottom burning), where the fresh Carbon is converted into N^{14} and C^{13} via CNO-cycle. By varying the parameter η from 0.33 to 1 the maximum limiting mass of a star becoming a white dwarf ranges from 4.7 to 6.8 $M_\odot$, owing to the functional relationship between this limiting mass and the parameter η (Iben and Renzini 1983, case b = 1). I have assumed that each SN produces 0.7 $M_\odot$ of Iron, 0.35 $M_\odot$ of Carbon and 0.35 $M_\odot$ of Oxygen after the destruction of its core of 1.4 $M_\odot$. With increasing η the number of intermediate mass stars suffering degenerate core carbon ignition decreases, affecting the yields of Fe and C^{12}. On the other hand, the yield of Oxygen is not very sensitive to the efficiency of mass loss from intermediate mass stars, because the bulk of this element is produced by massive stars. The yields of the other elements produced before the SN explosion (SNe) (He^4, C^{13}, N^{14}), are not substantially affected by mass loss by stellar winds.

I want to stress the point that chemical yields are very useful for testing the stellar evolution theory: in fact, we can select among the various yields, computed under different assumptions about the stellar evolution parameters, the ones which better reproduce the observed chemical abundance ratios, as I will show in the next section.

(ii) The Iron Production in the Solar Neighbourhood

More recent results (Tornambé 1984) suggest that the rate of SNe by Carbon-deflagration can be a function of the initial stellar metal content. It has been found, in fact, that stars in the mass range 5–10 $M_\odot$ can suffer degenerate core carbon ignition when their metal content Z ranges from 0 to 10^{-5} (first stellar generations), whereas for larger metallicities the mass range shrinks and at the present time (solar chemical composition) only stars between 8 and 9 $M_\odot$ are candidates to explode. This is due to the efficiency of mass loss which has been considered a function of the stellar metal content, increasing with increasing metallicity, as suggested by many observational and theoretical studies. Fig. 3 shows the yields per stellar generation of C^{12}, O^{16} and Fe which I have computed as a function of the metal content Z by taking into account the Tornambé (1984) results. The nucleosynthesis prescriptions are the same as described before with α = 1.5 and η = 1, which I found to be the better choice for these parameters in order to reproduce the presently observed abundance ratios.

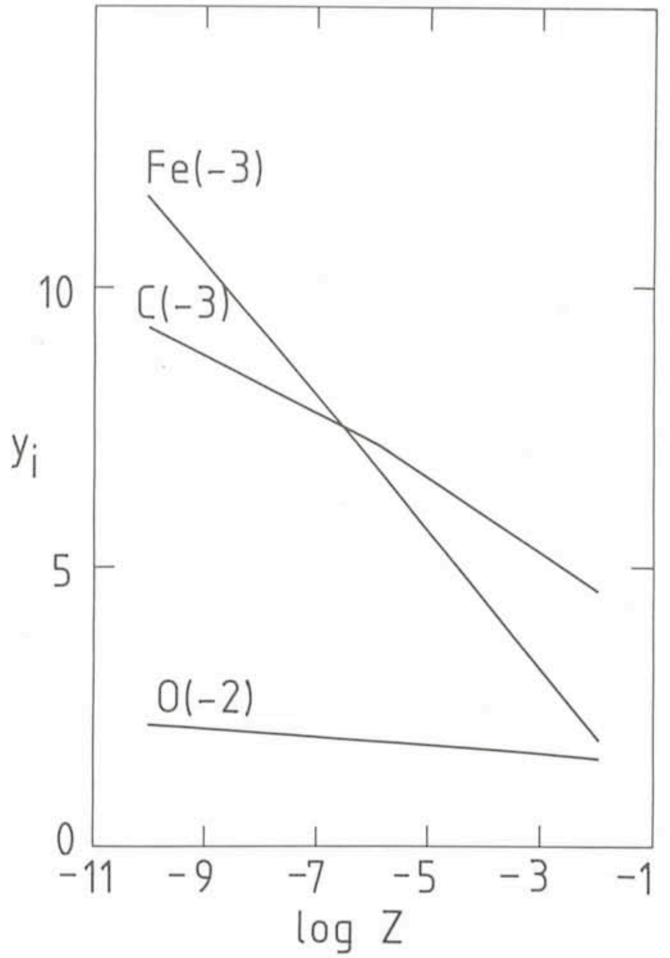

Fig. 3: *Yields per stellar generation of C^{12}, O^{16} and Fe^{56}, computed following Tornambé's (1984) results, as a function of the logarithm of the metal content Z, for α = 1.5 and η = 1.*

The predicted yields are decreasing with the increasing metal content, indicating that the first stellar generations produced more than the later ones. This result is due only to the influence of the stellar chemical composition on the yields, and can be very important in the study of galactic chemical evolution. For this reason I have computed the temporal variation of the Iron abundance in the solar neighbourhood. The chemical evolution model which I have used follows the evolution of the fractionary mass of a given element due to stellar nucleosynthesis, stellar mass ejection and infall of gas of primordial chemical composition; it also takes into account the temporal delay in the chemical enrichment due to stellar lifetimes, which is essential to account correctly for the contribution of long living stars. The predicted iron abundance

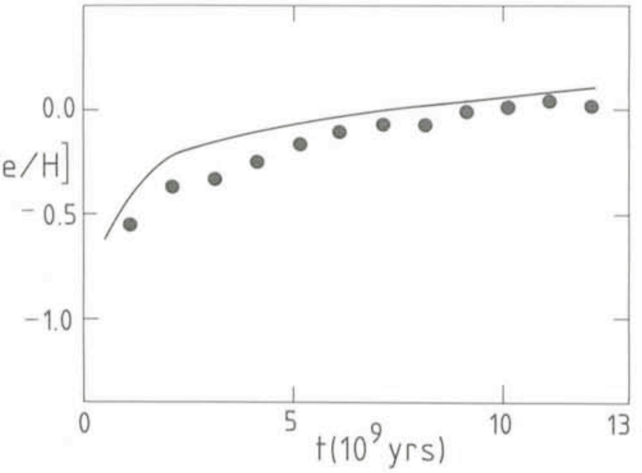

Fig. 4: *The theoretical age-metallicity ([Fe/H] is a logarithmic measure of the Iron abundance relative to the sun) relationship compared with the observational data of Twarog (1980) for solar neighbourhood stars (full dots). The time is in units of 10^9 years. The mean metallicity in the solar vicinity increased by about a factor of 5 between 12 and 5 billion years ago, and has increased only slightly since then.*

as a function of time is found to be in good agreement with the age-metallicity relationship for solar neighbourhood stars (Twarog 1980), as shown in Fig. 4. This indicates that the Iron produced by intermediate mass stars, in addition to the massive ones, does not lead to an overproduction of this element when the corresponding yield is a decreasing function of time.

Finally, I want to mention that, from an observational point of view, the possibility that low and intermediate mass stars can produce Iron peak and other heavy nuclei is suggested by the spectra of type I SNe (Branch, 1980), which are believed to originate from this stellar mass range. However, the progenitors of these SNe are still uncertain and two classes of them can be envisaged: single intermediate mass stars and white dwarfs in binary systems (Iben and Tutukov, 1983). In both cases the nucleosynthesis products would be the same because they come from the destruction of a C-O core of 1.4 $M_\odot$ exploding by carbon deflagration.

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Stellar Seismology: Five-Minute P Modes Detected on Alpha Centauri

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A short note in a recent issue of the *Messenger* (Fossat et al., 1983) described the first test of a new spectrophotometer specially designed for extending to a few bright stars the results already obtained in solar seismology. Since the late seventies, we know that the sun is pulsating within a certain range of eigenmodes, the most famous having periods around five minutes. The most striking results in this field have been obtained by the observation of integrated sunlight. Indeed in this case, the angular filtering is so severe that only radial and weakly non radial (degree $l \leqslant 3$) eigenmodes can be observed. Their number is limited enough to make the identification possible despite the absence of any angular resolution in the observation. More than 80 of such eigenmodes, attributed to the pression acting as a restoring force, have been thus identified in the five-minute range in the case of the sun (Grec et al., 1983). Once identified in angular degree, radial order and temporal frequency, these eigenmodes make possible a real seismological investigation of the internal solar structure (Gough, 1984).

Because important results have been obtained in integrated sunlight, observing the sun "as a star", it was tempting to try to achieve similar results on other stars. Evidently, the 10^{11} flux reduction factor for the brightest stars makes the task highly difficult, because the oscillation amplitudes to be detected are below 1 ms^{-1} in Doppler shift measurements. It is for this special goal that we have designed a special spectrophotometer, using again the principle of optical resonance spectroscopy. The conclusion of the first test of this new instrument was that if the observation can be photon noise limited (i.e. in total absence of any instrumental source of noise), the five-minute solar oscillation could still be detected by removing the sun far enough for its magnitude to reach about zero.

Such a situation is very closely represented by the observation of Alpha Centauri A, because it is a G2 V star, very similar to the sun, with a mass of 1.1 $M_\odot$. Six nights were granted to this programme on the ESO 3.6 m telescope, 22–28 May 1983. Two and a half nights provided over 20 hours of data of photometric quality good enough for analysis. In fact these data consist of two signals:

- The monochromatic intensity (about 0.08 Å bandwidth) in the red wings of the Na D1 and D2 lines.