ABUNDANCE ANALYSES : METHODS, RESULTS AND IMPLICATIONS

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ABSTRACT. The methods by which abundance analyses can be undertaken, especially with the growing use of high quantum efficiency digital detectors, are reviewed. The importance of the differential curve of growth technique is discussed, followed by a review of some recent results involving both late-type dwarf and giant stars. These include (1) the F and G dwarf abundance analyses of the elements sodium through nickel, which show an important differentiation between stars belonging to the young and old disk populations, (2) the possibility that departures from local thermodynamic equilibrium can effect sodium and aluminium abundances in late-type giants and supergiants and (3) that significant differences exist between the abundances of carbon, nitrogen and oxygen in old disk and young disk giant stars. Finally, the implications of these abundances in terms of stellar and galactic evolution are briefly addressed.

1. INTRODUCTION

Sometimes as astronomers we narrow our visions into a specific area, whereas we should be broadening our horizons. We hope that this symposium has a breadth which will/and has helped.

In spectroscopic abundance analyses we often get involved in very specific analyses in which we overlook the broader picture. We need to take a (large) step back and look at:

- more than an individual star;
- more than a group of stars of a given spectral type and luminosity class;
- and even more than the solar neighbourhood (although this is a useful region);
- and one should at least be aware of the implications of abundances to the Galaxy as a whole and consequently to extra-galactic systems.

One person who possibly applied the latter approaches better than anyone else was Beatrice (Hill) Tinsley (a graduate of the University of Canterbury), and reading her published works and various other

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articles about her has been a refreshing experience. I'll return (briefly) to some aspects of her work and others in relation to the *implications* of abundance analyses, when I've talked a little about the *methods* and some new abundance *results*.

And so to begin my talk after the preaching and publicity, I'll deal with some of the more "specific" aspects which relate to the use of stellar abundances in understanding stellar nucleosynthesis, stellar evolution and galactic evolution using samples of "normal" late-type dwarf and giant stars. I must also bring my talk within the auspices of this symposium on small telescopes. I will take a little "LOC licence" and discuss observations from "slightly" larger telescopes but as has been/and will be shown at this symposium, the size of the telescope is not as important as the *nature* and *quality* of the *dispersing* and *detecting* elements. In particular here at Canterbury, a post-graduate student (Phillip MacQueen) has designed, built and commissioned a diode array system for our échelle spectrograph (which many of you would have seen at Mount John University Observatory yesterday), with which we will be able to address similar astrophysical problems to those which I will talk about here today. Charge-coupled devices have/and will continue to revolutionize data taking and therefore smaller telescopes will be able to undertake programmes to determine abundances that 20 years ago would have only been possible with *large* allocations of *large* telescope time.

2. METHODS

Historically, the curve of growth (COG) technique is the method used to deduce stellar atmospheric and abundance parameters from high resolution ($\Delta\lambda \leqslant 0.2$Å or $\lambda/\Delta\lambda \geqslant 30000$) data. It is still used extensively today although in slightly different forms.

The most useful is the differential COG technique developed in the 1940s by Wright (1947) and Greenstein (1948), and emphasised by Gustafsson (1981) especially in relation to the use of model stellar atmospheres. The differential aspect enables the astronomer to eliminate the need for many absolute parameters (e.g. oscillator strengths) and also to minimize the problems of departures from sphericity and local thermodynamic equilibrium when one is working differentially between objects of similar effective temperature (T_{eff}) and luminosity class. These and many other aspects of model atmosphere techniques have been excellently reviewed by Gustafsson (1981, 1983).

Gustafsson (1983) and Cayrel de Strobel (1983) both concluded that the primary method for abundance analyses must be for high resolution, high signal to noise data which can be used to calibrate low resolution spectroscopic (e.g. Laird 1985a,b; Zinn 1985; Langer, Kraft and Friel 1985) or photometric (e.g. Twarog 1980a,b; Hartwick and McClure 1980) data. Although the basic abundance analyses for this began with Wright (1947) and Greenstein (1948) they have been continued by a large body of people on a variety of objects (e.g. Wallerstein 1962; Spite 1968; Hearnshaw 1972; Lambert and Ries 1977, 1981; Peterson 1981; Clegg, Lambert and Tomkin 1981; Kjaergaard et al 1982; Edvardsson, Gustafsson and Nissen 1984; Tomkin, Lambert and Balachandran 1985). One feature of the analyses listed above is that they were/are for large (> 10 stars) samples which enable other workers in the field to calibrate their derived properties and hence make significantly better use (in a statistical sense) of an even larger sample of data. However a list of standards (similar to those in the discussion of the paper by Cayrel de Strobel 1976), but including a few more stars (e.g. ϕ^2Ori) accessible from southern latitudes, especially New Zealand, would be useful.

Now I would like to outline the procedure which has been undertaken to improve the number of large samples for which stellar abundances are available. This will involve the recent work of Edvardsson et al (1984) [EGN], Tomkin et al (1985) [TLB] and Cottrell and Sneden (1986) [CS]. EGN and TLB described analyses of F and G dwarfs which relate directly to some of the problems involved in *galactic* evolution, whereas the third paper deals with G and K giants and involves implications in terms of *stellar* evolution. (These analyses involve "normal" stars, varying only in their principal parameters, T_{eff}, log g and metallicity, [M/H]. The peculiar giant stars (e.g. see Scalo 1981) also have to be fitted into the overall picture of stellar and galactic evolution.)

This procedure requires one to combine together the observational system(s) available to the user with the types of stars involved (e.g. a restricted spectral type and luminosity class). The system must be capable of a resolution of 30,000 and a signal to noise ratio of ~ 100 : 1 which will enable the all important weak spectral lines to be measured (see Gustafsson 1981). The wavelength regions required to proceed with the analysis should be carefully chosen to give you just the correct amount of data for the problem posed, and not a severe case of data poisoning. One also needs to look at the distribution of spectral lines for the species under investigation.

For example in our analysis (CS) we were endeavouring to extract atmospheric parameters and abundances with reasonable uncertainties (e.g. ± 100 K in T_{eff} and <0.2 dex in the abundances) using spectral data from a restricted number of wavelength intervals (Table I).

TABLE I

Wavelength regions, principle features and atmospheric parameters.

Central Wavelength (λ_c in Å)	Wavelength Range (Å)	Principle Features	Principal Atmospheric Parameters
5110	5060 - 5160	C_2	C abundance
5380	5330 - 5430	TiI/II, FeI/II	T_{eff}, log g, [M/H]
5950	5900 - 6000	TiI, FeI	T_{eff}, [M/H]
6325	6275 - 6375	[OI]	O abundance
8030	7980 - 8080	^{12}CN, ^{13}CN	N abundnace, ^{12}C/^{13}C ratio

This has been extended at Mount John University Observatory by Begley (1985) initially with image tube plates, but in the near future with the diode array to determine Na ($\lambda_c \sim 5680$Å and ~ 6160Å) and Aℓ ($\lambda_c \sim 6700$Å) abundances in a large sample of young and old disk giant stars.

Having gathered ones' data your problems have only just begun, especially if you don't have access to a computer on which you have the ability to massage your data (Fourier filtering, continuum placement and a wavelength dispersion solution) into a suitable format from which the strengths of your chosen spectral features can be measured. Chris Sneden and I chose to use an automatic measuring programme (by adopting a gaussian approximation to the line profile) to determine the equivalent widths of the 150 lines in the ~ 40 stars (that is more than 6,000 lines) in our giant star sample. As in EGN and TLB strict selection criteria were placed on the lines. We chose lines for which there was no known blend within 0.5Å and only used lines in the subsequent abundance analysis with log $({}^{W\lambda}/_{\lambda}) \leqslant -4.8$.

Our differential analysis was conducted relative to β Gem and ε Vir, which have similar T_{eff} and gravities to our programme star sample. Our analysis required us to initially deduce atmospheric parameters from our observations followed by a detailed abundance study of, in particular, CNO. By working differentially with respect to stars of similar spectral type and luminosity class we hoped to minimise any non-LTE effects since one would expect stars with similar atmospheric properties to exhibit similar departures from equilibrium conditions. (The consequence of the differential technique is another reason why a more extensive grid of standard stars in the T_{eff}, log g *and* [M/H] domain should be compiled.)

Although the differential COG method is used to determine the abundances, its use requires the construction of stellar model atmospheres and implicit or explicit calculation of curves of growth. These can be undertaken using a number of analysis programmes (see Gustafsson et al 1975; WIDTH6 and ATLAS6 : see Kurucz 1970, 1979; LINES : Sneden 1973). Although many comparisons have been made between the derived abundances from various computer codes, I know of no complete comparison that has been made between the programmes themselves using a standard set of data and a standard grid of model atmospheres in the T_{eff}, log g and [M/H] domain. A similar comparison should also be made between the various spectrum synthesis codes (e.g. Bell 1970 and Sneden 1973), with the input dataset available in the literature. The use of the synthesis technique reflects the growing interest in not only the analysis of stars (see Gustafsson 1981) but of the total light output of galaxies (e.g. population synthesis calculations, see Pickles 1985).

3. RESULTS

The first set of results which I would like to discuss are the CNO abundances of CS, in which I will compare the old disk (OD) giants with previous analyses of principally young disk (YD) giants (Lambert and Ries

1981 [LR81]; Kjaergaard et al 1981 [KGWH]) and dwarfs (Clegg et al) 1981 [CLT].

When analysing the abundances of giant stars one is not necessarily obtaining information about the formation abundances for these objects but abundances which may have been altered by mixing of nuclear processed material (see Lambert 1981). The F and G dwarf sample of CLT (and references therein) should indicate the formation CNO abundances for our comparison between old and disk giant stars. These are listed in Table II along with the relevant abundances from LR81 and CS. LR81 explained their results by the mixing of CN-processed material into the surface layers. Our old disk giant analysis provides quite a contrast. (See Figure 1)

TABLE II

Mean CNO abundances for F & G dwarf and G & K giant stars

	Young disk (YD)			Old disk (OD)	(OD-YD)	
Mean differential abundance[a]	dwarf CLT	giant LR81	giant CS	giant CS	dwarf CLT	giant CS
[C/X]	0.0	-0.24	-0.33	-0.08	0.0	+0.25
[N/X]	0.0	+0.37	+0.37	-0.05	0.0	-0.42
[O/X]	0.0	0.0	-0.09	+0.11	+0.2	+0.20
[X/H]	0.0	0.0	-0.13	-0.50	-0.4	-0.37

[a] X corresponds to either Fe (CLT and LR81) or Ti and Fe (CS)

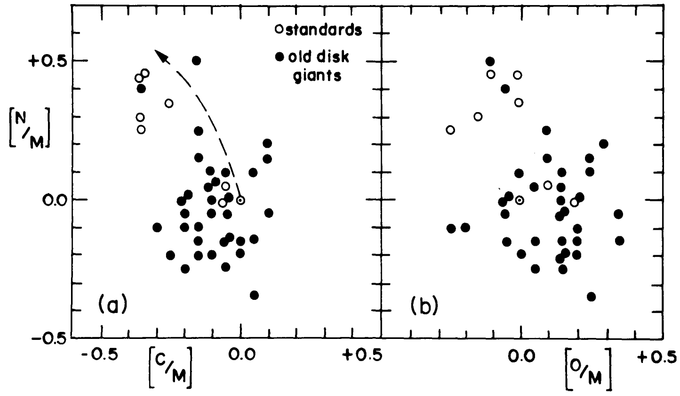

Figure 1. Carbon, nitrogen and oxygen abundances for old disk and young disk (standards) giant stars from CS. The solar abundances are shown by the usual solar symbol. The dashed line in (a) leading from the solar abundances to depleted carbon and enhanced nitrogen corresponds to the conversion of carbon to nitrogen by CN-processing with the conservation of the total amount of (C+N). The mean values of [^{C}/M], [^{N}/M] and [^{O}/M] are given in Table II. M is the average metal abundance determined from Ti and Fe lines.

In particular our differential abundances (OD-YD) are shown in the final column of Table II, where they are compared with the abundances from CLT for a similar mean metallicity. One is able to see that the OD giants appear not to exhibit any of the effects of interior nuclear processing. [There was some indication of this effect in both LR81 and KGWH, in particular see Figures 13, 14 and 15 in the latter.] Some mixing of processed material may occur in the OD stars as some have low $^{12}C/^{13}C$ ratios (~10-20), which is well below the value (50-100) one would expect of the interstellar medium from which these objects formed.

One other domain in which we can illustrate our results is in terms of the kinematics of the stars, a point also emphasized by EGN. Figure 2 shows the difference between metal rich, $[Fe/H] > -0.3$ and metal poor $[Fe/H] < -0.3$ objects. A clear separation exists between the solar ($^{C}/N$) ratio, high velocities, for the metal poor objects and low (typical of the YD stars) $^{C}/N$ ratio, low velocities, for the metal rich objects.

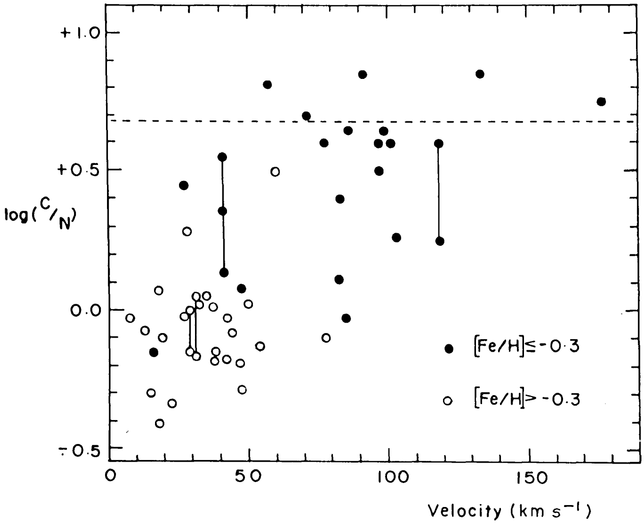

Figure 2. log ($^{C}/N$) ratio versus total space velocity for a merged sample (from LR81, KGWH and CS) of giant stars. The dashed line corresponds to the solar value of C/N. The lines connecting some points correspond to observations of the same object by two or three of the groups mentioned above.

This quantitative abundance analysis adds another dimension to the photometric results of Hartwick and McClure (1980) where they compared the DDO CN index (41-42) for OD and YD objects, and illustrates the interplay between photometric and spectroscopic techniques.

So one can see that there is much to offer in this area (CNO abundance analyses) in terms of how stars in the different populations evolve.

I would now like to pass onto the next group of light elements (sodium to silicon). (Fluorine and neon have been bypassed since adequate stellar spectral information can not be obtained.) The dwarfs hold important keys to our understanding of galactic evolution, since for these stars their surface abundances are indicative of those they had at the time of their formation.

Begley (1985) has conducted a differential analysis between old and young disk giants. He found enhancement of both Na and Aℓ. (Open and filled circles respectively in Figure 3.)

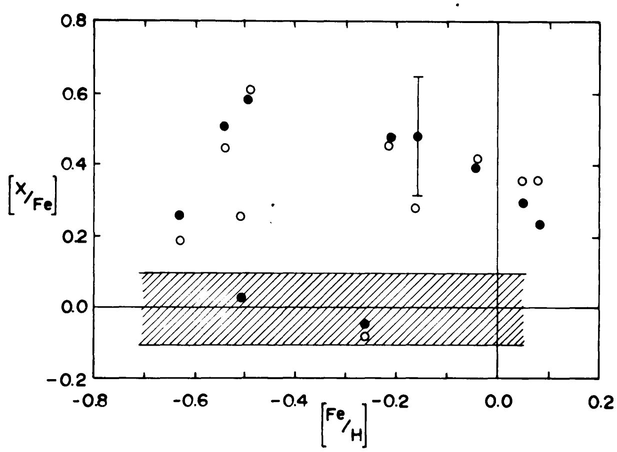

Figure 3. Sodium (open circles) and aluminium (filled circles) abundances, relative to iron for G and K *giant* stars belonging to the old and young disk populations (Begley 1985). The hatched region corresponds to the *spread* in sodium and aluminium abundances for F and G dwarf stars (EGN and TLB).

Begley discussed an interesting effect when one compared Na to Si abundances in G and K giants with their progenitors, the F and G dwarfs (EGN, TLB). Many analyses of late-type giants (see Begley 1985) also show enhancements of Na and Aℓ with respect to Fe whereas the dwarfs, from which they would be expected to have evolved, show no such enhancement (see Figure 3). (Similar enhancements of sodium in K giants were noted by Helfer and Wallerstein (1968).) Some departure from LTE in either the excitation or ionisation equilibria of Na and Aℓ is a possible explanation of this effect. Much more work in this area is required to follow up both the observational work (e.g. Ruland et al 1980 and Brown et al 1983) and theoretical non-LTE analyses (e.g. Kelch 1975 and Kelch and Milkey 1976). In particular these latter two papers predict that different energy levels (and hence different transitions) are affected in different ways by departures from LTE. The final solution for abundance analyses may require full non-LTE analyses for *all* species. Thus unless our understanding of stellar evolution is drastically incomplete, the enhancement of Na and Aℓ in the giants and supergiants relative to the dwarfs must be viewed with some caution and an atmospheric explanation (e.g. departures from LTE) may be more likely.

And so to the abundances of the α-rich elements Mg, Si and Ca (see EGN and TLB). I have combined their data (Figure 4) to give the schematic distribution of these abundances as a function of metallicity, [Fe/H]. This shows that for abundances [Fe/H] < -0.5, there is an enhancement, relative to iron, of these elements. This shows that there has been a change in the production of these α-rich elements relative to iron over the lifetime of the disk, based on the age-metallicity distribution of Twarog (1980b).

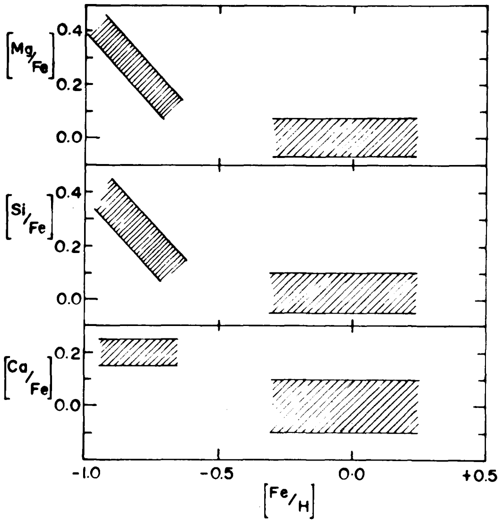

Figure 4. The spread of [Mg/Fe], [Si/Fe] and [Ca/Fe] abundances (from the data of EGN and TLB) as a function of overall metallicity.

It would now seem appropriate to discuss some of the implications of these results.

4. IMPLICATIONS

As alluded to at the beginning of this talk the abundance analyses discussed here are referring to two different areas of evolution, namely stellar and galactic. I'll take each in turn.

The results for the OD giant stars (and for that matter those of the YD) indicate that there are different processes (or the same process to different extents) in action in the stars of different populations. Stars with different metallicity and yet at a similar position in the HR diagram should be expected to differ in their average mass and age. In such a way the OD stars are of lower average mass and have evolved much more slowly (than the YD stars) to now be at the same position in the HR diagram. In particular, it appears that the less massive, metal poor stars show little (or no) CNO-processed material in their outer layers. This raises a number of questions, the solutions to which I feel are beyond the scope of the current review and will require further theoretical modelling. For example, does the convective envelope in these less massive, metal poor stars not involve as much of the outer mass of the star (*cf* the more massive stars) so that the nuclear processed material is not reached by this envelope? Or, does shell burning occur closer to the centre of the star and hence the convective envelope doesn't reach the processed layers? (The $^{12}C/^{13}C$ results seem to indicate that there may be a little processed material mixed into the outer layers.) Anyway it appears that there is certainly some more work that can be done, both observationally and theoretically, on these types of objects. In addition, there may be some important consequences in terms of the origin of the CN anomalies (which are correlated with Na abundances) observed in the giant stars of many globular clusters (see Freeman and Norris 1981). The lack of any correlation between CN and Na (or Aℓ) in the disk (at least between the old and young disk stars) indicates that the environment in which the globular clusters evolved may have been dramatically different.

And so to the galactic evolution implications. EGN and TLB have both shown that the yields of the various α-rich elements can be explained by the predictions of explosive C nucleosynthesis (Arnett 1971) and massive star ($25M_\odot$) nucleosynthesis (Woosley and Weaver 1982). The Na and Aℓ results of EGN and TLB can also be explained by the work of Arnett (1971) and Pardo, Couch and Arnett (1974). The odd numbered nuclei species (i.e. Na and Aℓ) are produced less than the even numbered species (e.g. Mg) in the more metal poor stars. This is because the production of Na and Aℓ in explosive nucleosynthesis depends upon a source of neutrons, from ^{14}N, ^{18}O or ^{22}Ne, so that as more of these elements are produced (in the more metal rich objects) so more Na and Aℓ will be produced relative to adjacent species in the periodic table. This explains the flattening of the [Aℓ/Mg] versus $[C{+}N{+}O/_H]$ for $[C{+}N{+}O/_H] \geqslant 0.5$ (see Figure 4 of TLB).

Once again, continued observational work needs to be undertaken (as outlined by EGN) on large samples of F and G dwards. This should fill the [X/Fe] versus [Fe/H] diagrams between -1.0 dex and +0.3 dex in metallicity such that the extent of the enrichment of some species can be clearly seen and the transition from halo to disk abundances can be quantified. Kinematic information on *all* these objects is also essential.

All this data can then be fitted into a model for galactic evolution as has been shown by Twarog and Wheeler (1982) based on the data of Clegg, Lambert and Tomkin (1981). Twarog and Wheeler carefully considered which types of stars produced which elements (such that certain species are not under or over-produced), as well as the nature and type of the material falling into the disk, the star formation rate and the initial mass function at different epochs.

However, analyses should not be confined just to those elements considered here nor just to the "normal" stars, as some of the less abundant elements *and* more peculiar objects hold important keys linking various phases of stellar and galactic evolution. In particular, the use of small telescope time on these types of projects is an extremely useful task to increase the pool of abundance data.

Finally I would like to conclude my talk by once again drawing your attention to the work of Beatrice Tinsley (e.g. see Dearborn, Tinsley and Schramm 1978; Tinsley 1979), and in particular Figure 1 of Tinsley (1980) which illustrates the importance of fitting one's own place of research into the overall galactic picture. As Beatrice said, Tinsley (1980), one must treat 'different aspects of galactic evolution as pieces of a jigsaw puzzle that may someday be put together."

REFERENCES

Arnett, W.D. 1971, *Astrophys. J.*, 166, 153.

Begley, M.J. 1985, M.Sc. thesis, University of Canterbury, Christchurch, New Zealand.

Bell, R.A. 1970, *Monthly Notices Roy. Astron. Soc.*, 148, 25.

Brown, J.A., Tomkin, J., and Lambert, D.L. 1983, *Astrophys. J.* (Letters), 265, L93.

Cayrel de Strobel, G. 1976, in 'Abundance Effects in Classification' IAU Symposium No. 72, eds B. Hauck and P.C. Keenan (Dordrecht : Reidel), p29.

Cayrel de Strobel, G. 1983, *Pub. Astron. Soc. Pacific*, 95, 111.

Clegg, R.E.S., Lambert, D.L., and Tomkin, J. 1981, *Astrophys. J.*, 250, 262, [CLT].

Cottrell, P.L., and Sneden, C. 1986, *Astron. Astrophys.*, in press,[CS].

Dearborn, D., Tinsley, B.M., and Schramm, D.N. 1978, *Astrophys. J.*, 223, 557.

Edvardsson, B., Gustafsson, B., and Nissen, P.E. 1984, *The Messenger*, 38, 33, [EGN].

Freeman, K.C., and Norris, J. 1981, *Ann. Rev. Astron. Astrophys.*, 19, 319.

Greenstein, J.L. 1948, *Astrophys. J.*, 107, 151.

Gustafsson, B. 1981, *Astrophys. Space Science Library*, 88, 25.

Gustafsson, B. 1983, *Pub. Astron. Soc. Pacific*, 95, 101.

Gustafsson, B., Bell, R.A., Eriksson, K., and Nordlund, A. 1975, *Astron. Astrophys.*, 42, 407.

Hartwick, F.D.A., and McClure, R.D. 1980, *Astrophys. J.*, 235, 470.

Hearnshaw, J.B. 1972, *Mem. Roy. Astron. Soc.*, 77, 55.

Helfer, H.L., and Wallerstein, G. 1968, *Astrophys. J. Suppl.*, 16, 1.

Kelch, W.L. 1975, *Astrophys. J.*, 195, 679.

Kelch, W.L., and Milkey, R.W. 1976, *Astrophys. J.*, 208, 428.

Kjaergaard, P., Gustafsson, B., Walker, G.A.H., and Hultqvist, L. 1982, *Astron. Astrophys.*, 115, 145, [KGWH].

Kurucz, R.L. 1970, SAO Special Report No. 309.

Kurucz, R.L. 1979, *Astrophys. J. Suppl.*, 40, 1.

Laird, J.B. 1985a, *Astrophys. J.*, 289, 556.

Laird, J.B. 1985b, *Astrophys. J. Suppl.*, 57, 387.

Lambert, D.L. 1981, *Astrophys. Space Science Library*, 88, 115.

Lambert, D.L., and Ries, L.M. 1977, *Astrophys. J.*, 217, 508.

Lambert, D.L., and Ries, L.M. 1981, *Astrophys. J.*, 248, 228, [LR81].

Langer, G.E., Kraft, R.P., and Friel, E.D. 1985, *Pub. Astron. Soc. Pacific*, 97, 373.

Pardo, R.C., Couch, R.G., and Arnett, W.D. 1974, *Astrophys. J.*, 191, 711.
Peterson, R. 1981, *Astrophys. J.*, 244, 989.
Pickles, A.J. 1985, *Astrophys. J.*, 296, 340.
Ruland, F., Holweger, H., Griffin, R., Griffin, R., and Biehl, D. 1980, *Astron. Astrophys.* 92, 70.
Scalo, J.M. 1981, *Astrophys. Space Science Library*, 88, 77.
Sneden, C. 1973, Ph.D. thesis, The University of Texas at Austin.
Spite, M. 1965, *Ann. d'Astrophys.*, 31, 269.
Tinsley, B.M. 1979, *Astrophys. J.*, 229, 1046.
Tinsley, B.M. 1980, *Fundamentals Cosmic Physics*, 5, 287.
Tomkin, J., Lambert, D.L., and Balachandran, S. 1985, *Astrophys. J.*, 290, 289 [TLB].
Twarog, B.A. 1980a, *Astrophys. J. Suppl.*, 44, 1.
Twarog, B.A. 1980b, *Astrophys. J.*, 242, 242.
Twarog, B.A., and Wheeler, J.C. 1982, *Astrophys. J.*, 261, 636.
Wallerstein, G. 1962, *Astrophys. J. Suppl.*, 6, 407.
Woosley, S.E., and Weaver, T.A. 1982, in 'Essays in Nuclear Astrophys.', eds C.A. Barnes, D.D. Clayton, and D.N. Schramm (Cambridge : Cambridge University Press),p377.
Wright, K.O. 1947, *Pub. Dominion Astrophys. Obs.*, 8, 1.
Zinn, R. 1985, *Astrophys. J.*, 293, 424.

DISCUSSION

Garrison: I always worry a bit about comparisons of absolute observations derived using different techniques. How sensitive are the results for old and young disk stars to analysis methods? Are there comparisons for the same star between the Texan, Swedish and Australian groups?

Cottrell: Sneden's programme (LINES) has been used by many research workers (e.g. CS, TLB, SR81) so good absolute comparison should be possible. I don't know whether a direct comparison has been made between the Texan and Swedish programmes. However, I think the important thing one needs is a standard set of data (lines and equivalent widths) on some standard stars available to all users of analysis programmes.

Kumar: Have $^{12}C/^{13}C$ ratios been obtained with the échelle spectrograph and diode array detector which we saw at Mt John University Observatory?

Cottrell: No, but we expect to be able to obtain $^{12}C/^{13}C$ results similar to those which have been obtained at McDonald Observatory.

Hearnshaw: The main reason why different analyses of the same star give different results is that different observers have adopted different temperatures. The latter generally come from broad-band photometric observations, and so I would urge better calibration of the photometric data.

Mochnacki: There is a new temperature calibration in the uvby system by John Lester, Richard Gray and Bob Kurucz which will be out soon.