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High resolution spectroscopy with a 10-m class telescope

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Observing facilities such as the 10m class telescope are mandatory for the elucidation of stellar popular characteristics in our galaxy and possibly the local group of galaxies. Accessibility to relatively fainter magnitude objects could allow us to study the spectroscopy of distant star clusters and nearby galaxies as well as very low luminosity stars in our neighbourhood (some of them might turn out to be brown dwarfs). It will also allow us to deal with other important programs like spectroscopy of QSOs, SN remnants, interstellar and intergalactic matter on which the studies so far have been made only with low resolution spectra. Existing high resolution programs like measurement of isotopic ratios, Doppler imaging etc could also be carried out for farther and fainter objects. The present contribution describes briefly, some of the important programs that require high-resolution spectroscopy.

Table 1. Comparative performance of telescopes of different sizes for 1hr integration time

Telescope size and Instrument	Resolution	S/N	Mag. limit approx
2.1 m McDonald Sandiford spectrograph	45,000	40	11.5
2.7 m McDonald 2dcoude spectrograph	60,000	40	12.5
2.8 m Lick Hamilton spectrograph	45,000	50	12.5
4.0 m KPNO echelle spectrograph	22,000	50	14.0
10.0 m Keck HIRES spectrograph	45,000	20	16.5

Study of ISM : Hot ionised gas found near HII regions, PNe and in SN ejecta provide important information on mass-loss, dynamical structure and physical conditions of ISM. To accomplish this, two dimensional spectroscopy with a resolution of 20,000 will be required. The cold tenuous gas of diffuse clouds produces very narrow absorption line (seen on the spectrum of background stars) that are used for determining the abundances of trace atomic and molecular species in diffuse clouds. For this a resolution R of > 100,000 is required.

Quasar absorption-line system: The narrow absorption lines from HI and other elements in galactic gas can be measured on the spectra of background quasars or AGNs. Wolfe et al. (1994) used Keck 10m telescope and HIRES spectra of a quasar PHL 957 to study abundances of Zn, Cr and Ni in a probable foreground galaxy with redshift z = 2.309. They found the galaxy to be more metal-deficient than the oldest disk stars in the Galaxy. The observed line profile of metallic lines arising in damped Lyα system indicatearotationally supported disk system for PHL 957.

Low luminosity stars: For low mass objects ($M_* < 0.06\ M_\odot$) the core temperatures are not high enough for Li fusion reaction and hence original Li is retained. The detection of this feature in low-luminosity cool objects is considered an important approach to identify brown dwarfs. Recently, DENIS-PJ1228.2-1547 has been identified by Martin et al. (1997) using the above mentioned criterion.

Globular cluster studies: Being old members of the galactic halo, they provide opportunity to study the early history of the Galaxy. The studies made earlier using moderate size telescopes covered mostly the objects on the red-gaint branch of their H-R diagrams since they are the brightest members of the cluster. However, hydrogen burning and deep convective mixing over the red-gaint evolution modifies the abundances of many (lighter) elements like C, O, Na, A1 and Mg. The observations of the stars on the main sequence or at the turnoff in H-R diagram can help in getting initial abundances of the ISM out of which the cluster was formed. The main-sequence stars and subgiants have an additional advantage. It is well known that most of the model atmospheres used currently assume LTE, plane-parallel atmosphere and hydrostatic equilibrium. For the atmospheres of main sequence stars and subgiants these assumptions hold good and hence reasonably good abundances can be derived for the stars using these models. Red gaints on the other hand, having extended geometries, are known to have convection, chromospheric structures and turbulence. Hence the derived abundances for these are relatively less accurate.

Moreover, the abundance determination for the stars belonging to different parts of H-R diagram in a given cluster permits the to study of the chemical evolution of cluster in real time. One can differentiate between compositional changes occurred due to the evolution of cluster members from the primordial mechanisms (like SN enrichment) that operated in different parts of ISM by extending the studies to fainter members of the cluster. Recent studies with larger telescopes have paid rich dividends. Reported CN and Na variations among main sequence stars for 47 Tuc by Briley et al. (1994, 1995), Ba and Eu variation found for M15 by Sneden et al. (1997), and very low [O/Fe] observed near the base of red gaint for M13 by Pilachowski et al. (1996) point to the presence of primordial mechanism affecting the abundances of ISM. The use of larger telescopes to make more complete studies have brought in additional results. While studying the globular cluster M92, the use of Keck 10m telescope enabled King et al. (1998) to do detailed spectroscopic investigations of six subgaint stars located at the turnoff and at the base of the red giant branch. Their derived abundances and the temperature for these turnoff objects point to a downward revision in age and larger distance to M92.

Metal-poor field stars: Beers, et. al (1992) have done an objective prism survey to identify metal-poor stars among field stars. They reported that among metal-poor stars, there is high incidence of stars with enhanced carbon. Considering the fact that the mixing process in the course of evolution causes depletion of carbon, their initial carbon abundances must have been much larger than normally encountered. Galactic chemical enrichment models do not produce enough carbon to explain the existence of these objects. The finding of C-rich stars have thereby led to development of new models that include the effect of carbon producing zero heavy elements supernovae presented in Woosley & Weaver (1982, 1995) and others. Supernova simulations of this kind for 18-13 $M_\odot$ zero heavy element objects produce little or no Fe and O but large amount of carbon.

Surveys of high proper-motion objects have also led to discovery of several ultra metal-poor objects. Detailed chemical composition studies made at high resolution have reported very unusual abundance pattern for some of them. LP625-44 and LP 706-7 are metal-poor stars showing enrichment of carbon and heavier s-process elements as reported by Norris et al. (1997). These authors find LP 625-44 a possible CH giant star but LP 706-7 does not show Li abundances nor does it show radial velocity variations to link it with halo CH gaints that are known to be binaries. On the other hand, there is another metal-poor star CS 22892-052 that is carbon-rich but is overabundant in r-process elements. Sneden et al. (1996) derived abundances of 20 n-capture elements for it. These authors have compared scaled solar system r-process curve, with their derived abundances for n-capture elements in Z range 56-76 and get excellent agreement and no indication of s-processing. The observed Th/Eu ratio give an age estimate of 15.2±3.7 Gyr for CS 22892-052 which has the [Fe/H] of −3.1. The unusually large overabundance of r-process elements indicates massive progenitors early in the history of the Galaxy. Metal-poor stars also show [α/Fe] ~ + 0.3. Since O and other α elements are more efficiently produced in the high mass type II SNe the nucleosynthesis in these massive stars is believed to have dominated the early galactic element production. Most of these metal-poor candidates are fainter than the 13th magnitude and a comprehensive study of a large sample of such stars can be done effectively only with 10m class telescopes.

Distant clusters in galactic anticenter direction: The outer fringe of the Galaxy is the place were star formation might take place at subsolar metallicity. The age and metallicity of old disk clusters lies between young open cluster and globular cluster and hence could be used as additional observational data in stellar evolutionary calculations. Brown et al. (1996) found low [O/Fe] in outer disk clusters Tom 2, Mel 171, and NGC 2112. Either these systems were formed from materials containing ejecta of SN Ia alone, or these systems migh have been captured from a companion galaxy.

Evolved stars with extended envelopes: At AGB state of evolution, a star ejects considerable amount of mass that surrounds it, making it optically faint though it emits considerable flux in IR, mm wavelengths. Mostly, optically bright post-AGB stars have been studied so far and among them, a very small number unambiguously show the effect of a third dredge-up (a high C/O ratio, enhanced He and enhancement of s-process elements). With a larger telescope, optically faint members can be studied and one can hope to find with the help of optical and IR spectroscopy, very interesting objects that are undergoing fast evolutionary changes. Using high resolution spectra, molecular C_2, CN lines formed in AGB remnant have been detected in the optical spectra of a few post-AGB stars (Bakker 1995). These features are used in deriving outflow velocities, rotational temperatures and column densities in the AGB remnant. These molecules are new tracers of AGB remnants and are formed in the regions relatively nearer to the star than those detected from CO and IR observations. By comparing the results from different molecules with different excitation conditions one can study the AGB ejected material as a function of distance and make inferences on the evolutionary status of the star on AGB.

Search for planets and stellar seismology : The search for planets around stars not only requires high accuracy in radial velocity measurement ($\sim 1 ms^{-1}$) but also short integration time like 30s since orbital periods are generally short. High spectral resolution and large telescopes are necessary to carry out this program. The similar resolution (10^5) and speed are required for seismology where time series of stellar line profiles are required. Using radial velocity variations for θ^2 Tau, Kennelly and Walker (1996) have detected oscillation frequency of 13.8 cycles day^{-1} consistent with p-modes of radial order n=2 or 3. A higher frequency of 16.1 cycles day^{-1} is also detected by them using variations within the absorption profiles.

Spectroscopy of Magellanic clouds and other neighbours : Sneden et al. (1995) have shown beautifully the distance modulii that can be reached by representative types of stars like M2 Ia, Cepheids of periods 8 and 40 days, K giants, B8 stars etc for M3, Be 17, MCs, Carina and M31. These authors have demonstrated the capability of a 8m class telescope with a resolution of 30,000. The figure 1 of their paper shows four cases, optical with S/N of 10 and 100, IR spectroscopy (in J-K band) with S/N ratio of 10 and 100. The sample of stellar groups considered by them span a distance modulus range 10 to 25 mag.

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