Automated parametrization of stellar spectra by MDM

Caroline Soubiran, Observatoire de Bordeaux

Introduction

The problem of the parametrization of stellar spectra by a minimum distance method can be set as follows. We have a target spectrum, i.e. measured fluxes at a discrete number of wavelengths (λ_i, F_i), and we would like to estimate its effective temperature, gravity, metallicity, (T, G, M) having at disposal a set of reference spectra k with known atmospheric parameters (T^k, G^k, M^k). The problem is to find among the reference spectra the one which has the minimum distance to the target, adopting for exemple a weighted euclidian metric :

$$\sum_i w_i (F_i - \Phi_i^k)^2$$

A more sophisticated approach is to interpolate the closest neighbours. This method was introduced and applied by Cayrel et al (1991, A&A 247,108) and they showed that reliable parameters could be retrieved even at low resolution. The priciple is very simple, but to put it in practice requires several steps which constitute the most difficult part of the work. First, we must have a library of templates (observed or synthetic) which is representative of the atmospheric parameters we may find among the targets. Then the spectra have to be cleaned of defects like cosmic impacts, defective pixels or scattered light. Finally, all the spectra must be put on a common horizontal and vertical scale to be compared. This implies to ajust the resolutions, the wavelengths (radial velocity correction), the sampling and the flux levels (and estimate the position of the continuum). The accuracy of the results will depend on how the library describes the parameter space. The extent, density, and the accuracy of the atmospheric parameters are the properties which define the quality of an observed library. The final results will also depend on the signal to noise ratio of the target spectrum and the resolution and spectral range we are woking with.

Softwares

The software TGMET was developed by Katz et al. (1998, A&A 338, 151) for a fast analysis of the HR echelle spectra provided by ELODIE (R=42000, $\lambda\lambda$= 440 nm - 680 nm). We have obtained typical standard deviations on test stars of $\sim 100K$ in T, lower than 0.3 in G and than 0.2 in F. The limits were given by a library of observed spectra of 211 FGK reference stars (Soubiran et al, 1998) with T $\in$ [4000 K , 6300 K], G $\in$ [0 , 5.6], M $\in$ [-3 , +1]., But TGMET is restricted to ELODIE spectra, to FGK stars, and we have also noticed that the solution was very sensitive to local irregularities of the library due to the non-uniform distribution of the reference stars in the parameter space, or to wrong parameters among the reference stars. Due to these limitations TGMET has evolved into TGM which uses an interpolator of an observed library (Prugniel & Soubiran, in preparation).

The first of TGM is to generate by interpolation a model spectrum of any T,G,M or a grid of model spectra (in the limits defined by an empirical library). The interpolator is defined by estimating at each wavelength λ_i a 4th order polynomial $P_i(T, G, M)$ from the fluxes F_i^k of the whole library. The advantage of the interpolation is to smooth the irregularities of the library and the cosmic scatter due to physical properties of the stars which are not taken into account (Vsini, $[\alpha/Fe]$, binarity...). Another advantage is that the solution of the minimum distance problem, or best match algorithms, can be optimised when using the model spectra as a reference system.

Some tests in the RVS range

The near-IR Ca II triplet stellar library (astro-ph/0109157 and astro-ph/0109158) provides spectra in the range $\lambda\lambda$ 8348-9020 Åat a resolution similar to what is forseen for RVS (R(FWHM) = 1.5Å). It provides 706 spectra parametrized in TGM, calibrated in relative flux, corrected of radial velocities. The coverage of the parameter space is very good. The library was interpolated, in the restricted wavelength range $\lambda\lambda$ 849-480 Å. Then each spectrum of the library was considered as a target spectrum with unknown atmospheric parameters to be determined with TGM with respect to the model spectra. The following figures show the distribution of the parameters determined by TGM versus those taken in the library. At the nominal S/N (Fig. 1) the standard deviation is about 200 K in T, ($\sim$ 160 K without the hot stars). In G and M the results are not so far from what was obtained at high resolution on a larger spectral range with TGMET. We have looked at the degradation of the results at lower S/N. The standard deviations are presented in Fig. 2 for S/N=20. At S/N=10 (Fig. 3) it begins to be difficult to retrieve the atmospheric parameters properly but there is still sufficient information to distinguish dwarfs from giants and metal poor stars from solar metallicity stars.

Conclusion

The resolution and spectral range of RVS seem to be sufficient to estimate the atmospheric parameters, even at low S/N, with a MDM method. Future improvements of the software TGM are related to the improvement of current libraries which implies their extend and the compilation of atmospheric parameters from the litterature to improve the atmospheric parameters of the reference spectra, especially of hot stars. This will improve the model spectra. Some other methods have to be tested to optimise the search of minimum distance between target and model spectra. We can think also to take into account other parameters (Vsini, [α/Fe]...) in the model library (this adds another dimension to the problem).

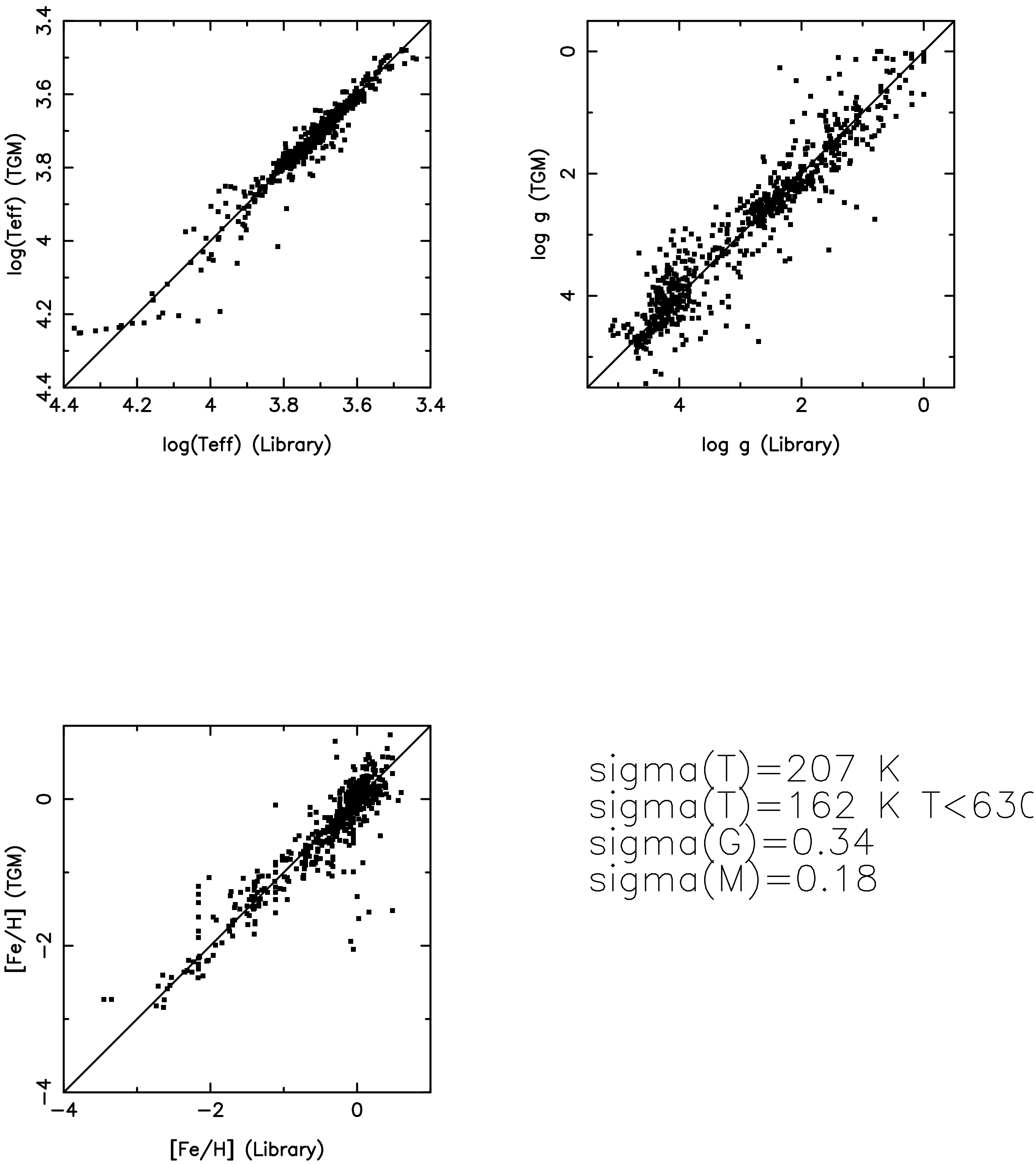

Figure 1: TGM parameters versus library parameters and standard deviation at nominal S/N.

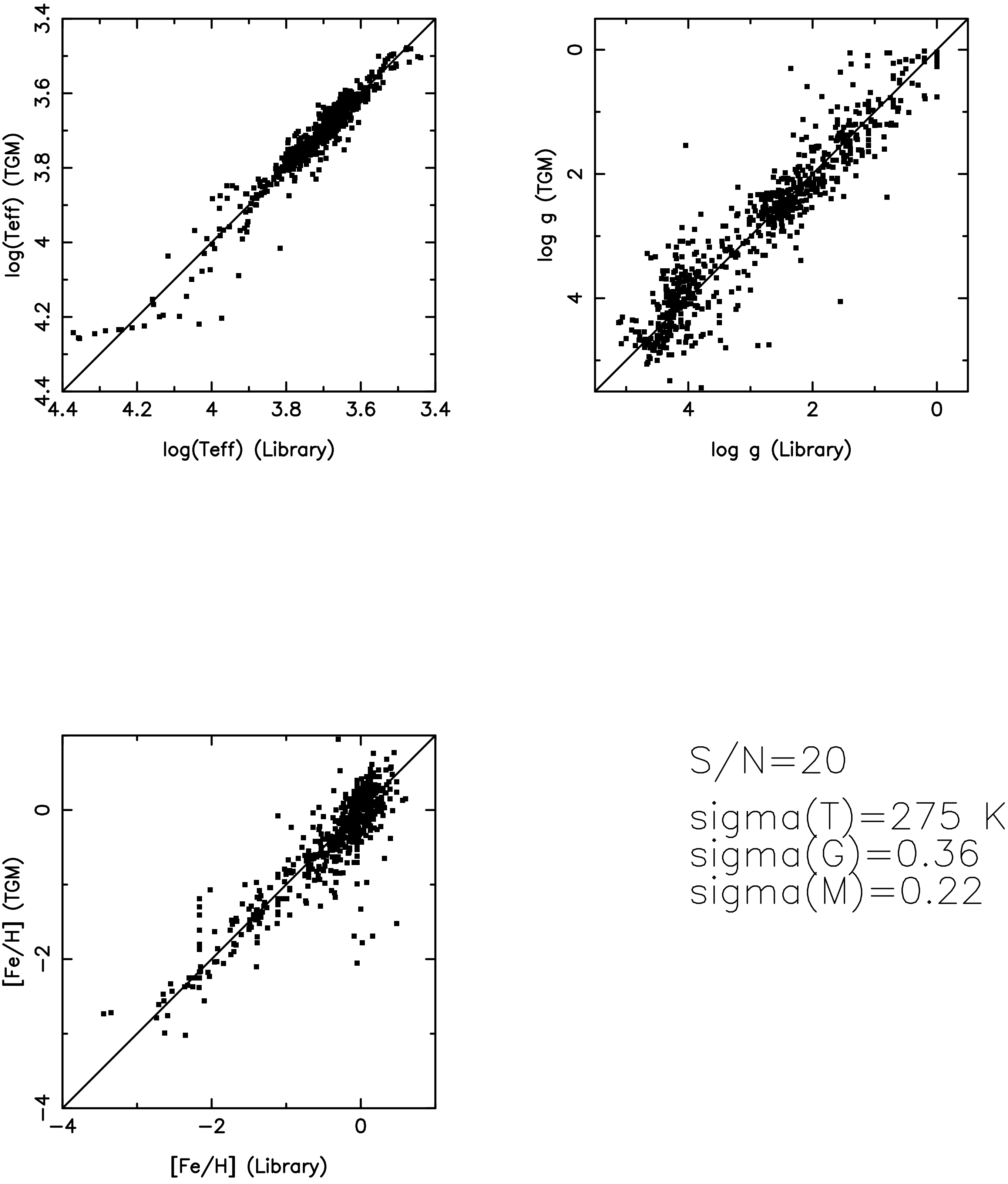

Figure 2: Same as Fig. 1 at S/N=20.

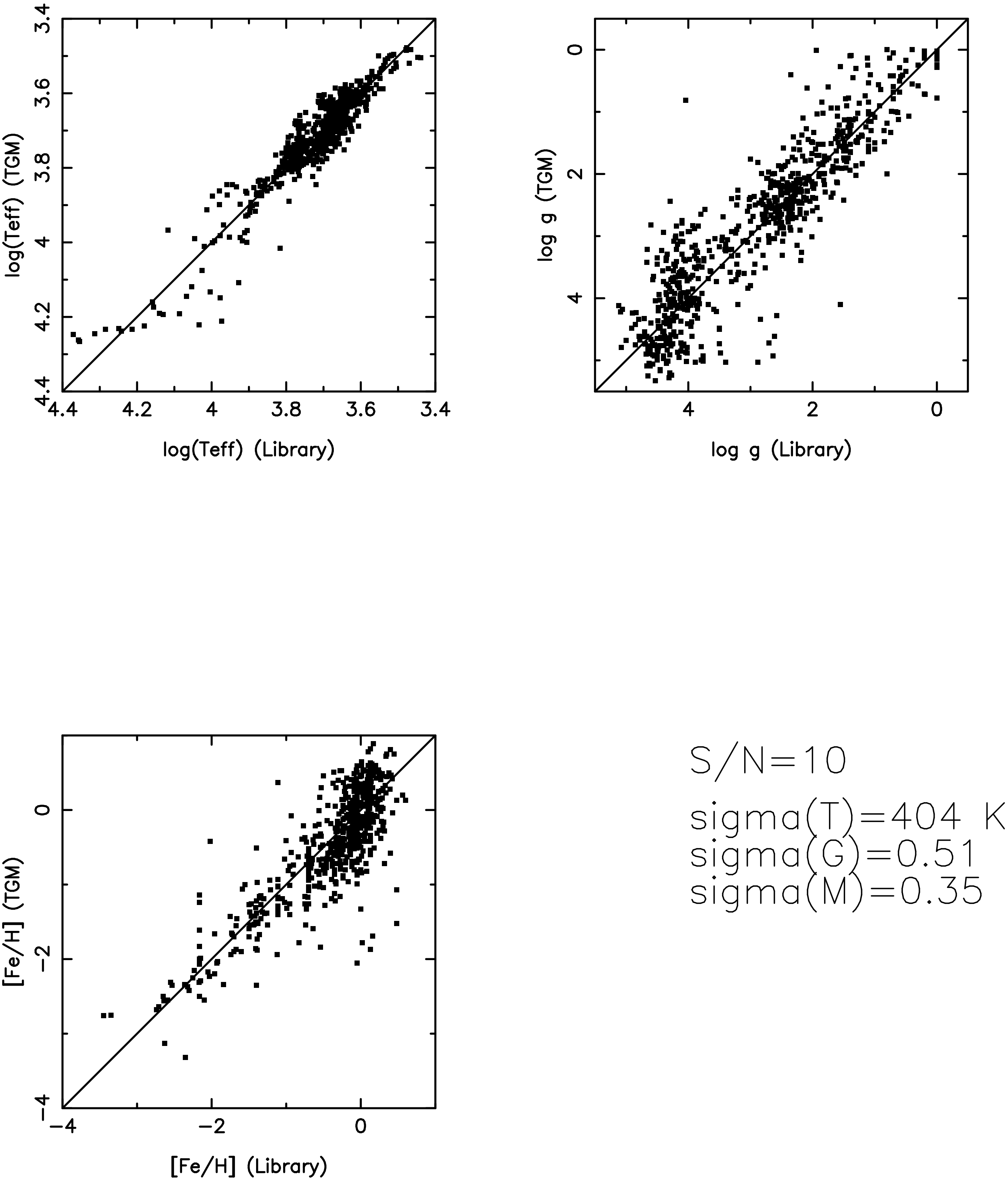

Figure 3: Same as Fig. 1 at S/N=1p0.