URAN: a Software System for the Analysis of Stellar Spectra

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Abstract. The main purpose of software system URAN is to help user in analyzing high dispersion stellar spectra. URAN include published high dispersion stellar and solar spectral atlases from UV to IR and all necessary components for processing spectral observations - from wavelengths scale setting and continuum placement to automatic fitting of observed spectra by synthetic one. The main features of URAN system are the using of synthetic spectra for all steps of spectra processing and the using of high dispersion published atlases of solar and stellar spectra for comparison. URAN include all Kurucz's atomic and molecular line data. Tools for processing the spectra of binary stars are part of the URAN system. Powerful graphic interface permit user to display observed and synthetic spectra of several stars simultaneously, in any desired scale. A brief review of results, obtained with this software is given.

Key words: Stars: atlases – Sun: atlases – stars: abundances – $r-, s-$process elements – data processing

1. Introduction

Spectral observations with highest resolving power and signal-to-noise ratio are available only for Sun and bright stars. The usual way of processing the observed spectra of faint stars is comparing with high dispersion spectral atlas obtained for a star of similar spectral type. The grid of homogeneous spectral atlases of stars of different spectral types, obtained with highest spectral resolution and signal-to-noise ratio will be very useful for stellar and laboratory spectroscopists. We made an attempt to create a data base of published atlases of stellar spectra. Here after we give a brief overview of this data base, used methods of spectra processing and last results, obtaines with this software.

2. Stellar data base

Now our stellar data base include the following atlases of stellar spectra:
Solar, visual and IR (Kurucz et al., 1984, Delbouille et al., 1973, Hinkle et al. 1995);
Arcturus, visual and IR (Griffin, 1968, Hinkle et al. 1995);
Procyon (Griffin & Griffin, 1979);
Aldebaran (Kipper & Klochkova, 1988);
Deneb, visual and UV (Leedjarv & Iliev, 1989 and Sapar & Sapar, 1990);
γ Tau (Appelquist et al., 1983, Gratton et al., 1975);
δ Tau, η Cep (Gratton et al., 1975);
Copernicus UV atlas of Sirius (Rogerson, 1987) and other Copernicus atlases.

Part of these atlases were obtained with photographic technique, the others atlases have high signal to noise. Other spectral atlases can be easily added to database. The atlases cover the range of spectral classes from B2 to K5 and wavelength region from 0.1 to 5.3 microns and can be used for comparison with program stars. In the nearest future we will include additional published atlases for infrared and ultraviolet wavelength regions.

3. Spectra processing

Various techniques have been developed to process high dispersion spectral observations. The main feature of our program is the using of synthetic spectra for all steps of spectra processing and the using of high dispersion published atlases of solar and stellar spectra for comparison. Calculations of synthetic spectra can be provided using Kurucz (1993) or Tsymbal (1996) programs. All Kurucz (1993) atomic and molecular

lines can be used for calculations. Kurucz (1993) and other grids of atmosphere models can be used. Hyperfine and isotopic splitting of spectral lines can be calculated. Some subprograms of Gadun & Sheminova (1988), and Pavlenko (1995) were used. URAN system work under Windows-NT operating system. Pentium processor, 2 Gb hard drive and 32 Mb RAM are minimal requirements. Our software permit:
To display on the screen of IBM PC the plots of above mentioned atlases, previously calculated synthetic spectra and any additional observed stellar spectra simultaneously, in any scale desired;
To provide all necessary operations with synthetic spectra (instrumental profile, macroturbulence, rotation), to select unblended and faintly blended lines of pointed chemical elements from synthetic spectra;
To provide all necessary operations with observed spectra (filtering, coaddition, decomposition of the spectrum in the sum of gaussian components, determination of equivalent widths, etc.);
To use convenient tools for processing the spectra of binary stars;
To fit the observed spectrum by calculated one in automatic and semiautomatic modes.

Automatic spectrum synthesis programs were developed by Cowley (1995, 1996), Valenty & Piskunov (1996). Our program URAN permit to adjust oscillator strengths of absorption lines to achieve the desired fit of the observed spectrum. A weighted mean of 30 points nearest to the lines centers is used for comparison. The used spacing of the spectrum must be not less than 300000. Linear extrapolation of oscillator strengths is made to bring the computed profiles into coincidence with observational data. All lines are corrected simultaneously, but the corrections of $log\ gf$ for blended lines are multiplified by some coefficient. The value of this coeffitient vary from 1.0 for clean lines to zero for weak lines in blends. Following Cowley (1996) we limit the changes in transition probabilities by 2 dex. From 5 to 50 iterations are required for fitting observed spectrum with desired level of accuracy.

4. Results

URAN system was created for identification of absorption lines of heavy and superheavy ($r-, s-$process) elements in stellar spectra, and calculations of abundances of these elements. We made an identification of erbium and disprosium lines in the solar spectrum (Gopka & Yushchenko, 1995, Yushchenko & Gopka 1994). The investigation of Procyon spectra permit us to find abundances of 10 heavy elements (Yushchenko & Gopka, 1996). At present time the abundances of 55 elements in the atmosphere of Procyon A are known and it is one of the highest level of completeness of stellar elemental abundance distributions, except Sun - 72 elements (Yushchenko & Gopka, 1998).

The investigations of cepheid V473 Lyr with OHP spectra permit to find abundances of 32 chemical elements (Andrievsky et al., 1998) The result of searching for heavy elements in the spectrum of SB2 star 66 Eri is the abundances of 26 chemical elements and the remarkable difference in chemical composition of the components of this binary star with the mass ratio of the components 0.97 (Yushchenko et al., 1998).

Now it is possible to produce the new generation of stellar spectral atlases with greater signal-to-noise ratio and resolving power. The modern computers, software and other facilities possibly can help us to reach the solar level of completeness of the chemical abundance pattern for some bright stars in the nearest decade.

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