Peculiar Interstellar Spectra

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The space between stars in the Galaxy is not a vacuum. It is filled with the interstellar medium in the form of clouds, several light years across, each. The average density of this medium is close to one hydrogen atom per ccm; in the clouds it may be several tens of atoms while in between of the clouds – just 0.01 atom per ccm. The relatively dense clouds are built out of neutral gas while the intercloud gas is usually ionized. This is because in a very low density and unfrequent collisions of every particle, once the ionization took place, another collision between the ion and free electron is very unlikely. The neutral clouds are usually revealed by several phenomena which can be observed in spectra of the stars shining through these clouds. The latter are thus called translucent interstellar clouds and the observed phenomena are:

- continuous attenuation (extinction) of the starlight. The phenomenon is selective, i.e. the blue light beam is more efficiently blocked by a cloud that the red one. The function, describing the relations between the amount of attenuation and the wavelength is called the interstellar extinction curve or extinction law. It is commonly believed that the extinction is caused by dust grains, smaller than the light wavelength
- spectral lines (very local absorptions) of interstellar elements. The practical lack of collisions between the atoms makes possible only transitions from the ground energetic level, the resonance lines. A vast majority of such lines can be observed only from space-born instruments. Their analysis leads to the conclusion that heavy elements in interstellar clouds are depleted, i.e. their abundances, relative to hydrogen, are much lower than those in e.g. our Sun. The fact is interpreted as the result of the fact that dust grains are composed mostly out of heavy elements
- bands (sets of lines originated in molecules) of simple molecules (free radicals) such as CH, CN, CH+, OH, NH, C2 or C3. These molecules are very reactive and exist in interstellar clouds only due to the lack of collisions with anything else. My recent works, completed with the cooperation with colleagues from the Sackler Laboratory in Leiden (The Netherlands), led to the discovery of SH and OH+. This required very high quality spectra; in this case from Very Large Telescope at Paranal (Chile) – the largest facility of optical astronomy on the Earth
- diffuse interstellar bands – the relatively broad interstellar spectral features, discovered in 1922 but not identified until now. It is thus the longest standing unsolved problem in all of spectroscopy. It is commonly believed that the rich (over 400 features) spectrum of diffuse bands is being carried by a set of complex, likely carbon-bearing, molecules. None of the proposed identifications was however, commonly accepted.

Interstellar clouds form also the raw material for newly born stars together with planetary systems, which are common as we currently know. A proper interpretation of the chemistry of translucent clouds means thus a very first step to understanding star forming processes together with planetary systems and the possible creation of life because a majority of observed molecules are carbon-bearing species, i.e. the organic ones. Abundance ratios of the above mentioned molecules constrain the possible models of translucent interstellar clouds. It is worth of being emphasized that models of stellar atmospheres and interiors exist already for a long time – mostly because astronomers had in their disposal huge sets of data concerning individual objects. Once a star is formed its further evolution and current state do not depend on any environmental parameters. Our Sun evolves not paying any attention to whatever happens in its vicinity. The situation of interstellar clouds is quite different. Physical parameters of any cloud, depend strongly on e.g. the irradiation by neighbour stars and the irradiating object does not have to be the one we observe but something aside. Moreover, in a vast majority of cases we observe stars not shining through a single cloud but through several clouds situated along the sightline. As a result what we observe is an ill-defined average and one must not separate its components. Such the average cannot be physically interpreted. However, the observed averages are reasonably similar and thus considered as „typical". Much more interesting are „peculiar" cases because they are most likely single cloud cases, i.e. reveal quite homogeneous environments, and may be interpreted in terms of the laws of physics.

The aim of this project is to concentrate observations on such „peculiar" objects, individual clouds which can be modelled using known laws of physics. The main observational constraint should be the set of abundance ratios of the above mentioned molecules. These abundances are seemingly related to the shape of the extinction curve. Thus my observations are to be focused on the objects for which peculiar extinction curves have already een reported by Fitzpatrick and Massa in their extensive atlas of extinction curves. The Northern Hemisphere observations would be done at the Terskol Observatory (Northern Caucasus) and, very likely, at the Shamakhy Observatory (Southern Caucasus). Southern Hemisphere would be covered from the European Southern Observatory; Poland joined this institution this year. The expected peculiar cases should reveal the reaction of diffuse band profiles to the varying physical parameters of the interveing clouds. This should make a good basement to solve the famous puzzle – what are the diffuse band carriers?

However, the identification of diffuse band carriers requires not only observations. Chemistry knows many thousands of molecules. Only the organic chemistry lists nearly 11,000 species. Naturally far not all their spectra are known. Thus the identification requires proper laboratory experiments. Several years ago I started a cooperation with the Sackler Laboratory at the Leiden University, headed by Harold Linnartz – the successor of Mayo Greenberg – the founder of laboratory astrophysics. This cooperation resulted in the most precise description of the interstellar C3 and the discovery of SH and OH+. In the laboratory the unique setup was recently built for 6,000,000.- €. This should allow to investigate molecular spectra in a very broad wavelength range in gas phase. Until now the molecular spectra in gas phase could be investigated only using the cavity ring down method which allows to record only very narrow wavelength ranges and is thus very time-consuming. I sincerely believe that the synergic efforts of observers using the world's best instruments and experimentalists, equipped with the world's best apparatus will allow to identify during a few coming years at least the carriers of some of the diffuse interstellar bands.