Milky Way twins

L. S. Pilyugin[1,2], G. Tautvaišienė[1]

[1]Institute of Theoretical Physics and Astronomy, Vilnius University, Sauletekio av. 3, 10257, Vilnius, Lithuania
[2]Main Astronomical Observatory, National Academy of Sciences of Ukraine, 27 Akademika Zabolotnoho St, 03680, Kiev, Ukraine

pil620a@gmail.com, grazina.tautvaisiene@tfai.vu.lt

The position of the Milky Way (MW) in the context of the general galaxy population is an important question. Is the Milky Way a typical spiral galaxy, and if not, in what way(s) it differs? Milky Way-like galaxies are usually named as Milky Way analogues (MWA) [1]. There is no single and commonly accepted definition of a Milky Way analogue. Different caracteristics of the MW can be used when comparing to other galaxies [1,2,3,4].

The characteristics of a galaxy can be conditionally divided into two types. The parameters of the first type (e.g., morphology, luminosity, stellar mass, rotation velocity) describe the structure and global characteristics of a galaxy at the present-day epoch and can be called as structural parameters. The oxygen abundance at a given radius is defined by the evolution of this region of a galaxy (fraction of gas converted into stars, i.e. astration level, and matter exchange with the surroundings). Then the oxygen abundance can be considered as an indicator of the galactic evolution and can be considered as the evolutionary parameter (the parameter of the second type). A galaxy located close to the MW in the field(s) of the first type of parameters can be referred as the structure analogue to the MW (sMWA). A galaxy located close to the MW in the field of the second type of parameters can be referred to as the evolutionary analogue to the MW (eMWA). If a galaxy is simultaneously both sMWA and eMWA then this galaxy can be considered as a twin of the MW.

In fact, the sMWAs were selected and examined in the previous papers [1,2,3,4]. The oxygen abundance at the optical radius of the Milky Way is appreciably lower in comparison to other galaxies of similar central oxygen abundance. This feature of the Milky Way evidences that its chemical evolution is not typical. Therefore it is highly useful to study the evolutionary analogs of the Milky Way. We search for and examine the galaxies which are simultaneously both, sMWAs and eMWAs. We analyse three structural parameters (the optical radius, stellar mass, and rotation velocity). The rotation curve is not available for some galaxies or the rotation velocity is measured with a large uncertainty (e.g. in face-on galaxies with low inclination angles). Therefore, the stellar mass – optical radius diagram has be used to select the sMWAs. The central abundance – abundance at the optical radius diagram serves to search for eMWAs. We compare the Milky Way with a sample of ~500 spiral galaxies for which radial abundance distributions, optical radii, stellar masses, and rotation curves are derived by us or compiled from the literature. The obtained candidates to Milky Way twins are examined in more detail.

We found that the eMWAs are quite rare, while the sMWAs are more numerous. The majority of the evolutionary analogues of the Milky Way are not structural analogues. Either the optical radii of the eMWAs are significantly larger in comparison to the MW, or the eMWAs have appreciable lower values of stellar mass and rotation velocity than the Milky Way.

We found four galaxies (NGC 3521, NGC 4651, NGC 2903, and MaNGA galaxy M-8341-09101) being simultaneously both sMWA and eMWA, thus they can be considered as MW twins. The galaxy NGC 3521 can be the closest MW twin. All the characteristics considered (the stellar mass, optical radius, rotation velocity, central oxygen abundance, and abundance at the optical radius) of NGC 3521 are close to those for the Milky Way. The masses of black holes in those galaxies are also similar. However, in order to make a solid conclusion that the galaxy NGC 3521 is the closest twin to the Milky Way, a more accurate radial distribution of abundances in NGC 3521 should be established. Spectral investigations including all the emission lines necessary for reliable abundance determinations (through the R calibration) should be carried out. The distance to NGC 3521 and its optical radius should also be more precise.

Key words: Milky Way, spiral galaxies, fundamental parameters, abundances

References

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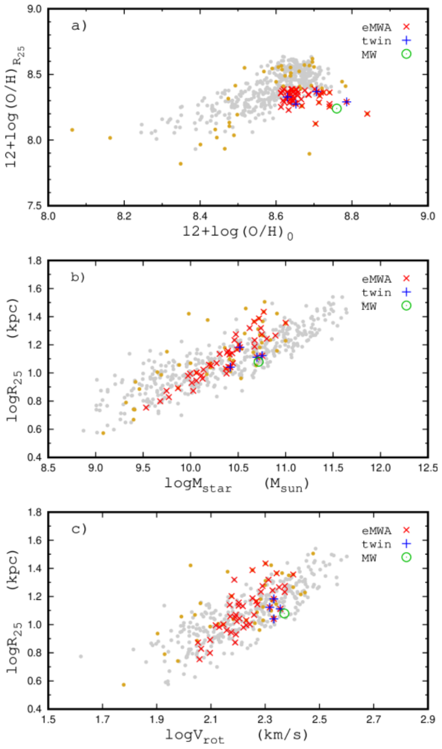

Oscillations are found in stars of most masses and essentially all stages of evolution.The amplitudes and phases are controlled by the energetics and dynamics of the near-surface layers and the frequencies are determined by the internal sound-speed and density structure of the star. Observationally, the frequencies can be determined with exceedingly high accuracy compared to any other quantity relevant to the internal properties of the stars. Analysis of the observed frequencies, including comparison with computed stellar models, allows determination of the properties of the stellar interiors as well as global stellar properties. Typically one can determination of stellar mean densities to an accuracy of 1%, radii to 2–3%, masses to 5%, and ages to 5–10% of the main-sequence lifetime. For rotating stars, the angle of inclination can also be determined.

Figure 1. The power spectrum of oscillations in the the stars α Cen A, The Sun and α Cen B. The fiure shows the details of the p-mode structure, and we indicate the so-called large frequency separations for each star, which contain information on the basic properties (density).

Planetary transits (when an exoplanet will cross the disc of the host star) and the occultations (when the exoplanet passes behind the disc of the star) is a geometrical effect that in general will scale with the absolute size of star (the stellar radius). The transit depth in the light curve is determined as the relative dip in the light curve during transit (see figure 2). The transit depth is a direct measure of the relative size of the exoplanet. Apart from the transit depth one can also measure the accurate orbital period for the exoplanet as the time difference between the centre of two transits in the light curve.

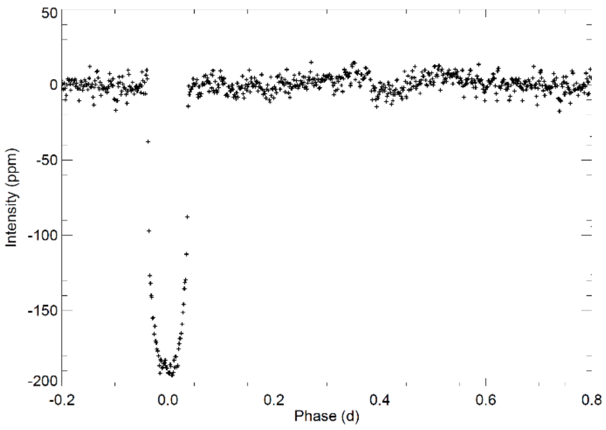

Figure 2. An example of an exoplanet transit in the star Kepler-10. The relative depth of the transit can be used to determine the relative size of the exoplanet (R(planet)/R(star) = 0.01254 ± 0.00013).

If we combine asteroseismology with planetary transit measurements one is able to obtain very acurate absolute values for the properties of both the host star as well as the exoplanet in orbit around a given star. Those meaurements can be used to test structure and evolution of stars and exoplanets in a large number of specific cases. In this talk I will discuss detailed measurements of stars and exoplanets and present some of the results which are obtained by use of high quality time seires data from space combined with ground-based spectroscopy. I will also discuss and deminstrate why and how interational reserach collaborations are essential for the success of those reserach activities.

Key words: stars, exoplanets, space missions, asteroseismology

References (example)

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