

The Stagnation of Contemporary Stellar Astronomy

Petr Škoda*

Astronomical Institute, Academy of Sciences of the Czech Republic

E-mail: skoda@sunstel.asu.cas.cz

The stellar astronomy has always been considered the fundamental source of knowledge about the basic building blocks of the universe — the stars. It has proved correctness of many physical theories — like e.g. the idea of nuclear fusion in stellar cores, the exchange of mass in interacting binaries or models of stellar evolution towards white dwarfs or neutron stars. Despite its well acknowledged importance it seems to be loosing its interestingness for students, for telescope allocation committees at large observatories, as well as for granting agencies. In the domain of big telescopes it has been gradually overtaken by the extra-galactic research and cosmology, surviving however at smaller observatories and among most advanced amateur astronomers.

We try to analyse the main obstacles lowering the efficiency of research in contemporary stellar astronomy. We will shortly tackle several problems induced by paradigmatic changes in handling the extraordinary amount of data provided by current instruments as well as by introduction of economical criteria and factory-like management into the modern astronomy.

Finally we speculate the reasons of a marginal role of Virtual observatory in contemporary stellar research and give some ideas of possible improvements.

Accelerating the Rate of Astronomical Discovery, sps5

August 11-14, 2009

Rio de Janeiro, Brazil

*Speaker.

1. Introduction

The technological potential of the current astronomical research is enormous. The opening of almost all windows of electromagnetic spectrum facilitated by advances in detector technology together with specialized astronomical satellites as well as 8 to 10m class telescopes harnessed by extremely sensitive instrumentation provides the astronomical community with overwhelmingly massive amount of data about the very deep structure of our universe as well as detailed multi-wavelength information about the billions of even very distant objects. The most powerful GRIDs of computers as well as clever infrastructure of Virtual Observatory are supposed to easily handle the data avalanche and so amount of principal astronomical discoveries should follow the technological Moore's law. But is it really so ?

Unfortunately, there is a danger of loosing the important dimension — the time — from observations of the most powerful telescopes and their archives. The astronomy of past was based on long-term monitoring of selected objects and most physical analysis was concerning their time-dependent nature (e.g. the search of periods, phase dependent changes of line profiles or changes of intensity or spectra during the outbursts of novae or cataclysmic variables). The largest amount of data coming from large facilities is currently only some kind of snapshots of the Universe, being forced by the way the telescope time is allocated and by pressure on rapid publication of results. All of this may lead to the paradoxical situation when the next generation of astronomers will have from the then available data the feeling of the universe like something static and unchangeable as it was in the ancient times before the Galileo's invention of telescope.

2. The Historical Importance of Stellar Astronomy

2.1 Breaking of Medieval Dogmas

The principal break in a philosophical concepts of Middle Age started by observations of stellar astronomy. Before then the Universe was considered to be static (Aristotle) and there was a generally accepted dogma postulating the Sphere of Immutable Heavens is far away than the Sublunary spheres (filled with fire, air, water and earth) where everything changing happens [1].

The observation of Tycho's Supernova in 1572 was a nice opportunity to prove or disprove this concept. The observations of Tycho Brahe and Tadeas Hajek from Hajek tried to estimate the distance of the Supernova. As no parallax was observed, the results clearly proved the supernova is much further away than Moon thus breaking the idea of Immutable Heavens [2].

2.2 Physical Estimates from Variable Stars

For enabling the first estimates of stellar physical quantities there were very important discoveries of variable stars like Miras (omicron Ceti by Fabricius 1596), Cepheids (delta Cephei by Goodricke in 1784) as well as justification of nature of eclipsing binaries (the Algol by J. Goodricke in 1783) [3]. Together with first confirmation of physical binaries (by W. Herschel in 1803) [4] the astronomers were given methods of measuring the masses and radii of stars.

2.3 The Role of Stellar Spectroscopy

The important role in stellar research has played the spectroscopy. The discovery of spectral lines in solar spectrum (by Wollaston in 1802) and their high resolution mapping (by Fraunhofer in 1814) [5] together with the development of laboratory spectroscopy (by Bunsen and Kirchhoff in 1859) [6] started the boom of stellar spectroscopy after the first installation of spectroscope at the telescope (by Huggins around 1860) [7].

The fundamental quantitative methodology for study of stellar dynamics was laid after the first measurement of radial velocity of Sirius (by Huggins in 1868) using the theory of Doppler principle (postulated in 1842) [7] [8].

An important moment for understanding the physical nature of stars presented the method of stellar classification. The first trials of Sechi in 1863 [9] and advanced scheme introduced by Pickering (in 1885) followed the huge and tedious work of H. Draper and mainly A. Cannon [10] were finally acknowledged by astronomical community in 1922 as an official spectral classification standards.

Another important step towards the understanding of the Universe was the discovery of relation Period—Luminosity of Cepheids in SMC by H. Leavitt (in 1912) [11], which gave the astronomers the tool allowing the measurement of large astronomical distances.

The first important extragalactic measurements were obtained by Hubble (1923) using the Cepheids to measure the distance of M31 and thus finishing the Great Debate about its galactic nature [12]. In fact the currently most frequently cited variable in extragalactic research — the Red Shift — is just the logical combination of the techniques described earlier and thus a result of stellar astronomy research.

3. The Time Domain of Stellar Astronomy

It is sometimes said that the astronomy is entering the time domain using the network of robotic telescopes to react properly at the alerts from satellites — mainly for hunting of gamma ray bursts events.

But the stellar astronomy, in fact, had already entered the time domain at its early origins. Many physical ideas (e.g. the Roche lobe overflow scenario, or theory of accretion disks, non radial pulsation modes, the chemically peculiar spots at surface of some stars) came from the systematic spectroscopic observations of variable stars on different time scales. Deep knowledge about the interior of stars (and justification of theories) was obtained from observation of stellar pulsations (Cepheids, RR Lyr, Miras)

And current asteroseismology is even promising the detailed mapping of internal chemical composition of stellar cores. Although some of such a research has been done by photometry, the crucial role here still plays the time-resolved high resolution spectroscopy allowing the investigation of tiny changes in spectral line profiles.

There are huge surveys, like VST, VISTA or LSST, planned gathering the time series of observations [13]. But all of them will give only the photometric information. The sophisticated colour indices are expected to yield the potential candidates for interesting classes of objects. But the problem is that there will be only candidates. The only proof of their real physical nature will give

only detailed spectroscopy. Unfortunately, there are no huge all-sky spectroscopic surveys planned with sufficient spectral coverage and reasonably high resolution for stellar studies [14].

There are, however projects focused on time series observations of stellar objects, however most of them are focused on the suspected extrasolar planet and not on the star and its behaviour itself. Thus the selection of stars is biased, because the formation of planets is expected mostly around later-type solar analogues.

Many interesting aspects of physics occurring in the hot early-type stars like e.g. strong winds at O stars or disks and circumstellar envelopes of Be and B[e] stars are thus not getting a proper interest as they deserve — mainly their time evolution.

4. Boom of Extragalactic Research

As the sizes of telescopes and sensitivity of instrumentation became large enough the interest of many astronomers switched naturally towards the objects in distant Universe. The fascination by AGNs and their X-ray production or the achievements of cosmology studying the most distant quasars and large-scale structure and especially the hunt for dark matter have changed not only the image of contemporary astronomy among general public, but had strongly influenced the goals and priorities of the astronomical research at all.

The long-run observing programs of many large telescopes allocates most of time to extragalactic studies as well (typically to redshift surveys with integral field units and multi-object spectrographs). Most of the stellar projects just get few nights and the telescope allocation committee's priority is put on programs where one exposure will justify or rule-out some hypothesis.

So we have only a snapshots of the Universe enforced by large telescope time allocation rules and general interests. The extragalactic bias is seen in literature as well.

The publishers of main journals (and their peer reviewers) are accepting for publication almost every description of observation of an exotic distant object, while they often require the publication of observation in stellar astronomy to be accompanied by physical estimates and a model. But as the gathering of proper material allowing the construction of a reasonable model takes a long time and the theory of certain phenomena is still lacking behind the observations, the amount of published articles in stellar astronomy has decreasing in comparison to the extragalactic ones.

All these issues are responsible for the further fostering of a role of extragalactic research in future astronomical society as the interest of majority of PhD. students is now focused mainly on extragalactic research and cosmology and the stellar astronomers are becoming the astronomical minority.

Similar concerns were expressed by A.Tokovinin at the conference about binary stars in Brno in June 2009 [15] as the concept of a Data Gap. He had warned against the noticeable gap in observations of binary stars (especially missing time series of stellar spectra) occurring at the beginning of 21st century to future astronomers.

5. The Importance of Stellar Astronomy for Contemporary Extragalactic Research

The stellar research is, however, crucial for understanding of the galactic evolution as well as the structure of the whole universe.

G. Bruzual has emphasized the key role of knowledge of stellar evolution in understanding galaxies at the IAU General Assembly symposium S262 in Rio De Janeiro:

"There has been collected more photons from distant galaxies than from nearby stars but the answers to distant galaxy problems will come from understanding nearby stars !"

The main issue is the construction of the stellar synthesis models used to disentangle spectra of galaxies. The problem of current models is connected mainly with evolution of binary stars. During the post-AGB evolution the thermally pulsating asymptotic giant branch stars contribute about 60% of K-band light [16], but about 30% of them are binaries at Roche lobe overflow phase [17]. This is, however, usually ignored in most models of stellar population synthesis.

For precise modelling we need to understand the detailed principles of many phenomena observed on stars. Despite the progress in solution of many principal questions of modern physics (e.g. the CNO and p-p cycles, structure of neutron stars, sources of energy in black holes etc.) there are still open questions of stellar astronomy, which have not yet been solved. Let's name some of them:

- Nature of binary star formation
- The proper scenario of Post-AGB evolution in binaries
- Proper physical explanation of origin and structure of disks around Be and B[e] stars
- The precise contents of primordial Lithium in different structures of Universe — it is a cosmological question which may be answered by stellar spectroscopy
- The nature of stellar non-radial pulsations — are they really multi-periodic or is it just a chaotic behaviour?

6. Stellar Astronomy in Virtual Observatory

The hope of astronomy facing enormous amount of data is focused to the Virtual observatory allowing new types of pan-spectral research (e.g. easy building of spectra energy distributions) and application of data mining methods on huge surveys and databases of theoretical simulations. But why the VO is not widely used by the majority of stellar astronomers ?

The one of the main obstacles is the technological conservatism of leading stellar astronomers, who were accustomed to process every spectrum individually from scratch and are very afraid of automatic processing of huge amount of data. They do not trust the idea of VO and simply ignore it. But, what is worse, they do not speak about the VO with young students, who might be interested but are not informed.

Thus most of the work in well-renowned stellar research groups at smaller observatories and many universities has been still done using the legacy applications (IRAF, MIDAS, IDL) and custom (mostly FORTRAN-coded) programs and scripts calling the different inhomogeneous data converters from/to ASCII tables and simple plotting tools.

But not only the conservatism plays its role here. There are people eager to use the VO technology in stellar research, but they are paradoxically facing the lack of stellar data not only in VO but in publicly available archives at all.

Critical situation is with stellar spectra archives. The data often play the role of some kind of currency on the data exchange market and many astronomers consider it to be their private property. So they are very reluctant in the willingness of the release of data even very long time after the publication.

But the so called "data jealousy" is not the only reason. The most common reason of lack of data archives of small observatories is connected with availability of software engineers and data administrators capable of preparation and maintenance of proper (VO-compatible) data archives.

There are even plans of artificial degradation of published raw data in order to prevent some kind of research by non-involved team — especially for planet hunting (e.g. high-pass filters are considered for KEPLER mission to prevent the discovery of transiting extrasolar planet but allowing still the asteroseismology studies [18], or the ELODIE archive of spectra is missing exact time information for targets with a suspected extrasolar planets [19]).

7. The Role of Amateurs in Astronomy

While the professional astronomers are attracted by extragalactic topics under the pressure of rapid publication of results (and partly to justify the building of extremely large telescopes), there is a lot of very knowledgeable amateurs understanding the role of their astronomical observations as a voluntary work done for joy of knowledge.

They are indispensable for continuation of stellar research. They are able to concentrate on long-time monitoring of a large sample of stars as well as prepare ingenious projects exploiting fully the capabilities of their modest instrumentation [20] (e.g. the Whole Earth Telescope, projects for monitoring potential supernovae or transiting extrasolar planets and namely large networks of monitoring eclipsing binaries and variable stars in general — mostly by CCD photometry). The most advanced of them started building small spectrographs and observe with them [21].

However the limits of amateur observations are imposed by their typical instrumentation — the Peltier-cooled CCD photometry at 60cm telescopes or their networks. Some of them are using commercial photo (still) cameras or even cameras with a film. Despite their modest instrumentation they are the primary source of long-term monitoring data about most variable stars and many are regularly discovering new galactic novae or even supernovae in distant galaxies.

In contrast to this a lot of the stellar spectroscopy has been often accomplished at smaller and moderately large (1–3m) telescopes by students of astronomy with their supervisors or smaller institutional teams focused on certain projects.

The great potential of amateurs in their involvement in Virtual observatory is still not fully appreciated. They do not suffer of such a high level of conservatism as professionals, are very eager to learn new technology and some of them are prepared to offer their data in the VO — just they have to be informed about such a possibility. The level of knowledge of VO among general astronomical public is, unfortunately, still very low.

8. Conclusions

Stellar astronomy seems to be now in stagnation period. The interest of professional astronomers is turned towards very distant extragalactic objects. The still existing professional stellar

astronomy has been driven towards producing only snapshots than systematic monitoring. The stars are interesting for many astronomers only thanks to their planets, whereas most of the physical problems of the stellar structure and stellar evolution as well as nature of some phenomena remain still unsolved. Unfortunately, the stellar research seems not to be very appealing for students either, despite the great importance of stellar astronomy for understanding of galactic structure and evolution.

On the other hand there is a lot of enthusiastic people among amateur astronomers, who continue to monitor the stellar variability on the long time scales and report outburst of cataclysmic variables, but they can hardly take spectra of most interesting stars, mainly due to their limited capabilities.

The solution of the problems described might be the Virtual observatory, allowing the integration of dispersed observations from different (even small) teams. The VO principles might attract the number of young people fascinated by new software technologies. Unfortunately, there is a lack of stellar spectra in VO archives as well as little support of specific techniques important in stellar astronomy in VO tools with respect to existing legacy applications. There is also very little VO awareness among stellar astronomers and their students. Thus the possible solution of the current stellar crisis could be expressed by several goals:

- Convince people to put more stellar spectra into VO archives
- Circumvent the data jealousy by convincing people about advantage of openness
- Get resources needed for development of new more versatile analysis tools with VO interface (or for adding the VO interface to legacy applications)
- Rise the level of VO awareness by systematic VO education or rather "VO evangelization"

We can hopefully still preserve the image of the dynamic eternally changing universe for our grandsons instead of hinting them the idea of the Immutable Heavens again.

References

- [1] Fowler, T. 1995, *Aristotle's Astronomy*, <http://old.perseus.tufts.edu/GreekScience/Students/Tom/AristotleAstro.html>
- [2] Hujer, K. 1966, *Thaddeus Hajek and Early Attempts to measure Stellar Parallax*, Publications of the Astronomical Society of the Pacific, **78**, 427
- [3] Joy, A. H. 1937, *Some Early Variable Star Observers*, Leaflet of the Astronomical Society of the Pacific, **2**, 193
- [4] Niemela, V. 2001, *A Short History and Other Stories of Binary Stars*, Revista Mexicana de Astronomia y Astrofisica Conference Series, **11**, 23
- [5] *Fraunhofer lines*, Wikipedia, http://en.wikipedia.org/wiki/Fraunhofer_lines
- [6] *Spectroscopy and the Birth of Astrophysics*, <http://www.aip.org/history/cosmology/tools/tools-spectroscopy.htm>

- [7] Becker, B. J. 1993, *Eclecticism, Opportunism, and the Evolution of a New Research Agenda: William and Margaret Huggins and the Origins of Astrophysics*, PhD. thesis, John Hopkins University, <https://eee.uci.edu/clients/bjbecker/huggins>
- [8] Huggins, William, Encyclopedia.com, <http://www.encyclopedia.com/doc/1G2-2830902082.html>
- [9] *Secchi's Four Classes of Stellar Spectra* <http://www.aip.org/history/cosmology/tools/pic-spectroscopy-lithograph.htm>
- [10] Annie Jump Cannon, Encyclopedia.com, <http://www.encyclopedia.com/doc/1G2-3404701102.html>
- [11] Leavitt, H. S., & Pickering, E. C. 1912, *Periods of 25 Variable Stars in the Small Magellanic Cloud*, Harvard College Observatory Circular, **173**, 1
- [12] Hubble, E. P. 1925, *Cepheids in Spiral Nebulae* The Observatory, **48**, 139
- [13] *The LSST Science Requirements Document* <http://www.lsst.org/Science/docs/SRD.pdf>
- [14] Myers, A. 2009, *The Death of Spectroscopy* <http://www.astro.caltech.edu/AIworkshop/Myers.pdf>
- [15] Tokovinin, A. 2009, *Instrumentation and Missions in the 21st Century*, video of the contribution presented at Brno conference *Binaries - Key to Comprehension of the Universe*, http://astro.physics.muni.cz/binkey/download/video/20090608_05_Tokovinin.avi
- [16] Bruzual, G. A. 2009 *Star clusters as simple stellar populations*, arXiv:0911.0791, <http://arxiv.org/pdf/0911.0791>
- [17] Vanbeveren, D. 2009 *Close pairs: keys to comprehension of the evolution of star clusters*, arXiv:0909.3431, <http://arxiv.org/pdf/0909.3431v1>
- [18] Christensen-Dalsgaard, J. *Kepler Asteroseismic Investigation (KAI)* http://astro.phys.au.dk/KASC/JCD_KAI.pdf
- [19] Prugniel P. 2008, *private communication*
- [20] *Amateur Astronomy Projects*, <http://www.hobbyspace.com/Astronomy/astronomy2.html#AstProjects>
- [21] *Spectroscopy, CCD & Astronomy*, <http://www.astrosurf.com/buil>