Report on the GREAT-ESF Workshop

Asteroseismology of large time-resolved astronomical surveys

organized from 19 to 21 September 2012 in Leuven, Belgium.

Scientific Organizing Committee

The SOC consisted of the following persons:

1. *Joris De Ridder* (KU Leuven, main organizer)
2. Gisella Clementini (Bologna Observatory)
3. Marc-Antoine Dupret (Liège University)
4. Laurent Eyer (Geneva Observatory)
5. Don Kurtz (University of Central Lancashire)
6. Eric Michel (Paris Observatory)
7. Andre Moitinho de Almeida (Lisbon University)
8. Andrzej Pigulski (Wroclaw University)
9. Anne Thoul (Liège University)

The website is located at: http://fys.kuleuven.be/ster/conferences/GREATworkshop

Financial expenditure summary

The following expenses for the workshop were made:

1. Workshop venue + lunches + coffee breaks:	6,984.00 euro
2. Travel expenses:	3,581.95 euro
3. Workshop material:	149.48 euro
4. Local administrative costs:	250.00 euro
Total:	**10,965.43 euro**

The travel expenses include both the expenses of the invited speakers as well as the travel expenses of the PhD students and young postdocs that applied for financial support.

Scientific Summary

We organized a 3-day international workshop on “Asteroseismology with large time-resolved surveys”, which was the first GREAT-ESF meeting that focused on stellar variability. This meeting was not only relevant for the many existing and ongoing large time-resolved surveys, but also for the several upcoming ones, including Gaia. Gaia promises hundred thousands of variable stars so that we can talk about the advent of a new era in stellar variability. This workshop therefore focused on how stellar variability in large time-resolved surveys can be exploited to learn about stellar evolution and the structure of our Milky Way, what lessons were learned from previous and existing time-resolved surveys, and the future outlook of time-resolved combined surveys.

Scientific Content and Impact

The workshop had three main scientific themes:

1. Lessons learned from existing time-resolved surveys
2. The most important upcoming mega-surveys
3. Exploiting time-resolved surveys: what can variability teach us?

The highlights of the first theme were the talk of Igor Soszynski (Poland) on the OGLE survey, the talk of Philip Lucas (UK) on the VISTA survey, and the talk of Barry Smalley (UK) on the Superwasp survey. Dr. Soszynski gave an overview of the history of the OGLE survey, the technical specifications of the instruments and how they evolved in time, the fields of view on the sky that were covered, both in the bulge of our Milky Way as in the Magellanic clouds. He reviewed the principles behind the OGLE Catalog of Variable Stars, and gave the current state of achievements, in total almost 400,000 variable stars discovered. He also highlighted the OGLE results on classical Cepheids, in particular cepheids in eclipsing binary systems and cepheids in the Magellanic Bridge. The talk of Dr. Lucas was particularly instructive as the VVV survey is less well known than e.g. the OGLE survey. He described the technical properties of the VVV survey, and highlighted the different aspects of its main scientific goal: to derive the 3-D structure of our Galaxy. Also very useful was his list of problems and difficulties they had encountered. He presented the first results on RR Lyr variables, globular clusters, open clusters, and young stellar objects. The overview talk of Dr. Smalley was not invited, but we were nevertheless very lucky that he was able to attend the meeting. Also he started with the technical specifications of the Superwasp survey, and explained its observing strategy and goals. He continued with giving an overview of Superwasp’s achievements related to main-sequence pulsators (like delta Scuti, gamma Dor, and roAp stars), highlighting some of the weirdest objects. Besides the talks mentioned above, we should also mention the talks presented by Paul Groot (Netherlands) on fast variability with the Palomar Transient Factory, and by Konstanze Zwintz (Austria) on the BRITE space mission survey. The former talk was particularly useful as not many time-resolved surveys are able to tackle the problem of variability on very short time-scales. Dr. Groot

highlighted some exciting results on ultra-compact binaries, white dwarfs, and sdB stars.

The highlights on the second theme were the talk of Zeljko Ivezic (USA) on the LSST survey, and the talk of Laurent Eyer (Switzerland) on the ESA mission Gaia. The talk of Ivezic showed some impressive results that can be obtained with time-resolved photometry of asteroids, Kuiper belt objects, and comets. Next he showed a remarkable and recent result using kinematics of halo stars that proved that the dark matter halo is in fact oblate. Next, the technical capabilities of the upcoming LSST survey were highlighted, together with its data pipeline and its data products. He then focused on the four main themes of the LSST science case: 1) dark matter, dark energy and cosmology, 2) time domain astronomy (e.g. cosmic explosions, variable stars), 3) Solar system structure (e.g. asteroids), and 4) the Milky Way structure, giving several examples where LSST is expected to provide a breakthrough. The talk of Eyer first went into great detail about the main technical specifications of the upcoming Gaia mission, because these largely determine the (time-resolved) data product. He then continued with the number of expected variable stars that will be detected by this mission, and went over the different steps of the Gaia variability analysis pipeline.

The majority of the time slots of the workshop were (of course) spent on talks presenting highly interesting applications of time-resolved surveys for astrophysical and galactic purposes. These include talks such as the ones of Chris Engelbrecht (South-Africa), Lovro Palaversa (Switzerland), Martin Groenewegen (Belgium), Branimir Sesar (USA), Conny Aerts (Belgium), Daniel Holdsworth (UK), Gordon Ramsey (UK), Konstanze Zwintz (Austria), and Marc Moniez (France). It is beyond the scope of this report to discuss each one of them separately, but we would like to highlight two of them. The first one is the talk of Sesar on “Finding and characterizing distant halo substructure using RR Lyr stars as tracers” who used the SDSS and LINEAR surveys to prove that RR Lyr variables are the most practical solution to find streams and ultra-faint dwarf spheroidal galaxies. He offered an explicit roadmap to find halo substructures, and gave impressive results on the Cancer groups, and his first results on the Hercules groups. The talk of Moniez taught us to think out-of-the-box, and showed why seemingly unlikely events like stellar scintillations are actually worthwhile to pursue. He discussed their likelihood, their expected properties, and the best conditions to observe them. It’s probably fair to say that for most of the audience it was the first time to hear about this possibility.

We invited two speakers on a theoretical topic: synthetic populations of variable stars. We felt this was extremely useful because before we can actually compare observational populations with theoretical populations, progress needs to be made on the latter field. Leo Girardi (Italy) and Maurizio Salaris (UK) gave excellent overview talks on the status and challenges in this research field. These presentations served as good discussion starting points.

A fourth type of talks consisted of methodological talks which were for the larger part presented on the third day of the workshop. These include “*How to convert a large*

amount of data into understanding" of Robert Szabo (Hungary), "*Automated variability characterization of (combined) large time-resolved astronomical surveys*" of Jan Cuypers (Belgium), "*The art of variable star data mining*" of Jonas Debosscher (Belgium), "*Evaluating the content of large time-resolved surveys: bias estimation*" of Luis Sarro (Spain), and "*Photometric mode-identification using combined time-resolved surveys*" of Pieter Degroote (Belgium). These talks brought the topic of exploiting time-resolved astronomical surveys to the meta-level, offering an helicopter view and, although giving many concrete examples, presented their methods in a survey-independent way. Again, it would take us too far to discuss all and each of the presentations, but one stood out which was the talk presented by Dr. Sarro. The main question he posed was "Suppose we have gathered an impressive time-resolved astronomical survey, like Gaia or LSST. How do we discover its limitations, its flaws, or its biases?" Throughout the talk he argued that examining individual targets is not the most efficient way to handle this, and showed how hierarchical bayesian model can be extremely useful to compare observed and expected samples of targets.

Three large slots were reserved for discussions, which were particularly fruitful and interesting. Because of the fairly small size of the group, there was a high participation level, and it is therefore here that the workshop made a significant impact. The most important discussion topics were the following:

1. In the talks the successes of the different existing surveys were often highlighted. However, usually we learn most from our mistakes. We therefore asked to the different survey representatives what they would do differently if they had to organize/ set up the survey again. The common problems where then discussed afterwards.
2. Although it is very common to make the data public after a certain proprietary period, it is far less common to release the software to the public. As a consequence, almost every surveys has to re-invent the wheel when developing data processing software. We set up a discussion on possible causes. Why are people often reluctant to share software? What can be done to mitigate this?
3. We also explored what data product(s) should be released to the scientific community. Some surveys apply a correction procedure for instrumental artifacts before releasing the data. Others say that this is impossible because the instrumental corrections may depend on the science signals that you are looking for, so that only the raw data should be distributed. We discussed the different approaches of the existing surveys, together with their pros and cons.
4. Organizing massive surveys requires a lot of manpower working on the infrastructure of surveys (hardware, software, survey planning and operations, database/data distribution), sometimes called "builders" or "architects". We discussed how the different surveys find a way to recognize the intellectual contributions of those people, and how one could offer these people career paths that allow them to thrive.
5. We talked about what approach the different surveys have to search for variable (pulsating) stars. How do they manage the huge number of targets? How do they separate variables from non-variables and how do they keep the number of false

positives under control? Related to this, we also briefly discussed what approach the different surveys take to classify their variable targets.

6. A very interesting topic we also discussed was how to combine different time-resolved surveys (e.g. MACHO + OGLE + GAIA + LSST + ...). The benefits are a lower detection-threshold, much higher precision of the oscillation periods, larger periods detectable, period changes, mode identification using multiple passbands, ... The questions we asked ourselves is whether it's technically and/or political feasible. What would be needed to pull this off? A remarkable quote came from the LSST representative who mentioned that adding all Gaia time series to the LSST database, would in fact only be a rather minor increment. So, technically this seems not much of a problem.
7. Before the advent of large time-resolved surveys, the data came to the astronomer. With the huge (and not easily downloadable) databases, the astronomer needs to go to the data. What if you want to search for variability with your own super-algorithm, which requires processing the entire database? During the discussion it was revealed that the LSST solution is to write a proposal and if accepted, run your code on the LSST computer farm. The Gaia-CU9 community currently discusses a similar solution. This way of doing science turns out to require a new way of thinking.
8. The last topic we discussed was how to actually exploit the period values of variable stars. During the talks many examples were given that used variable stars as population tracers, halo tracers, HR-diagram locators, or mass tracers. But no (or very few) examples of using variable stars for their period values (except simply listing them). Surveys like Gaia will detect only 1 or 2 periods per variable star, but will deliver them with much greater precision than e.g. CoRoT, because the timespan of the observations is significantly longer (150 d vs 5 yrs).

Final Workshop Program

From	To	Speaker	Topic
Wednesday - 19 September 2012			
10h00	10h15	J. De Ridder	Welcome + goals of this workshop
10h15	11h00	I. Soszynski	Stellar variability with the OGLE survey: achievements and lessons learned
11h00	11h30	C. Engelbrecht	OGLE Survey follow-up of pulsators in the LMC
11h30	12h00	L. Palaversa	Exploring the variable sky with LINEAR
12h00	13h15		Lunch
13h15	13h45	M. Groenewegen	Exploiting long period variables: the past and the future
13h45	14h30	Z. Ivezic	Time-resolved astronomy with SDSS and LSST: achievements and the future
14h30	15h00	B. Sesar	Mapping the Galactic Halo with SDSS, LINEAR and PTF RR Lyr

From	To	Speaker	Topic
15h00	15h30		Coffee Break
15h30	16h15	Ph. Lucas	The VISTA variables in the Via Lactea survey
16h15	16h45	C. Aerts	Asteroseismology: from single targets to large ensembles
16h45	17h30		Panel Discussion
Thursday - 20 September 2012			
09h00	09h45	L. Eyer	Gaia: a billion-target time-resolved survey
09h45	10h15	J. Debosscher	The art of variable star data mining
10h15	10h45		Coffee Break
10h45	11h30	B. Smalley	Asteroseismology with SuperWASP
11h30	12h00	D. Holdsworth	Characterisation of SuperWASP detection limits
12h00	13h15		Lunch Break
13h15	13h45	P. Groot	Fast variability with the Palomar Transient Factory
13h45	14h15	G. Ramsey	Identifying short-period compact pulsators in the RATS survey
14h15	14h45	K. Zwintz	Ensemble asteroseismology using multiple space missions and ground-based campaigns
14h45	15h15	M. Steslicki	Kepler observations of solar-like oscillations in red giants
15h15	15h45		Coffee Break
15h45	16h30	L. Girardi	TRILEGAL: the art of stellar population synthesis
16h30	17h15	M. Salaris	How can populations of variable stars help us improve our knowledge on stellar structure and evolution?
17h15	18h00		Panel Discussion
Friday - 21 September 2012			
09h00	09h30	E. Niemczura	Spectroscopic observations of large sample of the Kepler target
09h30	10h00	M. Moniez	The search for interstellar scintillation
10h00	10h30		Coffee Break
10h30	11h00	R. Szabo	How to convert quantity into understanding
11h00	11h30	J. Cuypers	Automated variability characterization of large time-resolved surveys.
11h30	12h00	P. Degroote	Photometric mode-identification using combined time-resolved surveys
12h00	13h15		Lunch Break
13h15	13h45	L. Sarro	Bias estimation in large time-resolved surveys
13h45	14h00	K. Zwintz	The BRITE space mission
14h00	14h45		Panel Discussion
14h45	15h00	J. De Ridder	End of meeting