Observational Astrophysics

Rodolfo Smiljanic

Autumn/Winter 2021/2022

Nicolaus Copernicus Astronomical Center
Polish Academy of Sciences
ul. Bartycka 18
00-716 Warsaw, PL

E-mail: rsmiljanic@camk.edu.pl
Office: 115

`http://users.camk.edu.pl/rsmiljanic`

What is observational astrophysics? It is the part of astrophysics concerned with making measurements of properties from astronomical sources, understanding the errors of those measurements, and using the measurements to estimate parameters and test theories. Most of such measurements are from information that arrives to us in the form of electromagnetic radiation. But not only. Other possibilities include: cosmic rays, neutrinos, meteorites, gravitational waves, solar wind particles, and samples returned from solar system objects.

What to expect from this course? The goal is to provide an overview of things that one needs to know in order to plan, propose, prepare, carry out, and analyse observations. The course will also help you to understand the limitations of the observational data that has been obtained by someone else, but that you want to use for your calculations, to compare with your models, or to test your theories. Unfortunately, there is no time to cover all possible topics in detail. There will be an obvious focus on the range that includes near-ultraviolet, optical, and near-infrared wavelengths because: i) this is what I know best and ii) most of the observational facilities in the world cover this wavelength range.

Who can benefit from this course? The immediate benefit is perhaps more clear to those working with observations. If that is your case, you will get an overview of observing techniques, of modern instrumentation, telescopes, and missions, and some tips for writing observing proposals. Nevertheless, there should be something of interest for those working with theoretical astrophysics as well. If that is your case, I believe you would eventually like to compare models to or test theories against observational data. At some point, you might want to motivate your colleagues working with observations to obtain the right data that you need to test your models. Alternatively, you might be invited to join an observing proposal, as the person providing the models or theoretical background; a team preparing the science case for a new instrument or mission; or panels judging observational proposals or research grant projects dealing with observations. Some of the things you will hear in this course might come in handy when those times arrive.

When: Tuesdays, at 11:15am (Warsaw time), unless otherwise noted. We will try a hybrid format. You can join in person or on-line. **Please, only join in person if you are fully vaccinated against covid-19. No one will be checking, we rely on your common sense.** The room where we will meet and the instructions to connect on-line will be provided in advance by e-mail. There will be 12 meetings of 1h 30min each. **We start on October 19th, 2021**.

Texts: I am trying to make most of the reading material available in advance. From time to time, I will share a link where you can download the material. I tried to write some of the notes myself but, most of the time, I rely on material extracted from a few textbooks and/or papers that you

can access from ADS. In such cases, the notes will tell you where to find the relevant material. Ideally, you should read the relevant material before the meeting where the topic will be discussed.

Slides: the slides will NOT be available in advance. I will make them available after the end of each lecture.

Topics that will be covered:

- The electromagnetic spectrum
- The effects of the Earth's atmosphere
- Telescopes and image formation
- Adaptive and active optics
- Measurements, signal-to-noise, and errors
- Astronomical coordinate systems and time
- Detectors
- Photometry and magnitudes
- Spectroscopy
- Astrometry
- Interferometry
- Polarimetry
- Asteroseismology
- Observing in the infrared
- Preparing and evaluating observing proposals

If and only if time allows, I might add some information about the topics below. In any case, I plan to (eventually, i.e. before the end of the lectures) provide reading material for these topics as well, even if we do not manage to discuss them during the meetings:

- Radio and sub-mm telescopes
- X-ray and gamma-ray telescopes
- Neutrino detection
- Cosmic rays
- Gravitational waves

Plan of the lectures:

The way that I plan to cover the topics is not going to linearly follow the order of topics given above. I am going to motivate and introduce the topics by looking at some of the current and future observing facilities. The choice might seem somewhat arbitrary, as it reflects my own personal biases, but I tried to include major facilities to which we have access in Poland, plus some important on-going space missions, and a few of the facilities and missions that will be transformational in the future.

During most of the time, we will be discussing the telescopes and instruments of the Cerro Paranal Observatory operated by the European Organisation for Astronomical Research in the Southern Hemisphere (usually referred to as the European Southern Observatory, ESO). In the course of such discussions, I will try to add information about the instrumentation available at the South African Large Telescope (SALT).

We will move to space-based facilities when discussing astrometry, to look at the Gaia mission, and asteroseismology, to look at least at the Transiting Exoplanet Survey Satellite (TESS) and the Planetary Transits and Oscillations of Stars missions (PLATO).

Finally, there are some future ground- and space-based telescopes that we need to cover because of their importance in the coming years: the European Extremely Large Telescope (E-ELT), the Vera Rubin Observatory (formelly known as the Large Synoptic Survey Telescope, LSST), and the James Webb Space Telescope (JWST).

The 12 meetings are planned to look more or less like this:

1. (October 19, 2021) Introduction to the course; overview of the Cerro Paranal Observatory;
2. (October 26, 2021) Measurements, electromagnetic spectrum and the Earth's atmosphere;
3. (November 9, 2021) Optical telescopes;
4. (November 16, 2021) Photometry and magnitude systems;
5. (November 23, 2021) Spectroscopy (slit, fiber, multi-object, integral-field);
6. (November 30, 2022) Infrared (atmosphere, spectroscopy, photometry, detectors, observing techniques);
7. (December 7, 2021) Coordinate systems, time, writing and evaluating observing proposals;
8. (December 14, 2021) Detectors and data processing;
9. (January 18, 2022) Polarimetry and interferometry;
10. (January 25, 2022) Vera Rubin Observatory and giant telescopes (E-ELT, GMT, TMT);
11. (February 1, 2022) Astrometry (Gaia) and asteroseismology (TESS and PLATO);
12. (February 8, 2022) Mock panel for proposal evaluation.

Grades: There are up to 100 points to be made out of the activities that will be evaluated, distributed in the following way:

- 0-10 for active participation during the lectures,
- 0-20 for the presentation of a short seminar (5 minutes, 2-3 slides),
- 0-20 for one practical data analysis activity,
- 0-25 for the preparation of one observing proposal,
- 0-25 for the performance as a member of the proposal evaluation panel.

The equivalence table between evaluation points and grades for the doctoral school is the following:

- 00-49 points = grade 2 (no pass)
- 50-59 points = grade 3 (pass)
- 60-69 points = grade 3.5 (pass plus)
- 70-79 points = grade 4 (satisfactory)
- 80-89 points = grade 4.5 (satisfactory plus)
- 90-100 points = grade 5 (very good)

Short presentation: Everyone will be asked to give a short seminar during the course. These seminars will take place on three different dates, **most likely November 16, December 7, and January 25**. On each date, 1/3 of the students will present. I will assign the dates randomly after I get the list of students. You will know the topic of your presentation one week in advance. You are all encouraged to ask questions to your colleague that is presenting. This will count for your participation grade.

Practical data reduction: Each person will be given raw data and calibration files of either one long-slit stellar spectrum or the image of an open cluster field in one band (data can be different for each person). The data will have to be corrected from bias, dark (if applicable), and flat field.

I will ask that you deliver a FITS file with the final reduced data product, where information of all the reduction procedures have been registered in the header. Tutorials will be provided for performing this tasks using IRAF. Yes, I know IRAF is pre-historic and not even supported anymore. But it is available in CAMK desktops (ask ADM in case it is missing from your computer), it is well tested and it works for the tasks and data that I will provide. It can also be installed in your laptop or home computer, using Anaconda for example. You are of course not obliged to use IRAF and can choose any other software of your liking (IDL routines, Astropy, etc.). Just make sure that the data processing information is saved to the FITS header.

The data, tutorials, and further instructions **will be made available around December 14**, when we will talk about data processing. Deadline to deliver the reduced data will be the day of the last lecture, **February 8th, 2022.**

Proposal preparation: On December 7th, 2021, after the lecture on proposal writing and evaluation, I will send by e-mail a fake alert of an astronomical transient event. Your individual

task will be to prepare a proposal for follow-up observation(s) of that event. Each student should prepare their own proposal. We will use the ESO Phase 1 proposal template for that. You can choose to use any instrument/telescope available at the Cerro Paranal Observatory (i.e., the VLT, VLTI, or survey telescopes).

Do deliver your proposal by **the deadline, January 14th, 2022**. Proposals delivered after the deadline will not be graded and will not be included in the evaluation panel. **This is a deadline that I will not be able to change.** Proposal deadlines in real life are also strict. But more importantly, there is very little time between the proposal deadline and the deadline for your colleagues to read and evaluate your proposal. So the deadline must be strict also out of consideration for the time that your colleagues need to review the proposals.

For the purpose of evaluation points, I will not judge if the science case that you proposed is interesting. I will check the technical parts of your proposal. Things like: did you choose the correct telescope and instrument for the observations? Did you correctly estimate and justify the exposure time(s)? Did you correctly choose and justify the required observing conditions? Did you check if your requested data already exist? Will the data that you propose to obtain address the scientific question that you want to answer?

Proposal evaluation: We are going to perform a mock proposal evaluation panel, more or less following the procedure used for the ESO panels. **Each student that submits a proposal** will be assigned to referee 3 proposals; for one of them you will be the primary referee. For the other two, you will act as secondary referee. You will be asked to submit, in advance of the panel, your comments and pre-evaluation grades of the 3 proposals (the so-called evaluation cards, **deadline January 28th, 2022**).

A few days before the panel (**by February 4th, 2022**), I will circulate all comments and pre-evaluation grades to the other panel members (but you will NOT receive the comments and pre-evaluation grades of your own proposal).

During the panel, when it is time for your own proposal to be discussed, you will be asked to leave the panel and wait for the duration of the discussion. You will be admitted back after the panel members submit their final grades. You can not judge your own proposal, neither influence the discussion. You can not explain better what you meant. Proposals are evaluated solely on the basis of what you wrote. The primary referee will present the proposal science case, its strong and weak points. The secondary referees can give their opinions. Ideally, everybody should read all proposals, and check pre-evaluation comments and grades, to be able to join the discussion if needed. After the discussion, we will vote (voting is secret, only I will have access to all grades). Primary and secondary referees can change their opinion and give a final grade that is different from the pre-evaluation grade. We will need to discuss and vote on all proposals in 1h30min, so things will need to go fast. In a real proposal panel, we would have more time per proposal, but the total time is still limited, so discussions indeed need to be focused and short. After the panel, I will renormalize the grades from each panel member and combine them. Proposals are then ranked. You will get an e-mail saying in which quartile of the grade distribution your proposal was ranked. But you will not know the final grade, just like in real life.

The proposal ranking by itself does not count for your evaluation points. For your performance evaluating a proposal, I will judge if your comments are relevant, if you noticed or not obvious mistakes in the proposal, if you clearly presented and summarized the science case, if you actively

participated in the discussions, etc.

Ethics: I will strive to make our meetings inclusive and stimulating, creating an environment where we all feel free to discuss ideas without the fear of being intimidated, ridiculed, or humiliated. And I ask all of you to actively contribute to that. If you think that I am failing in that, either by my own actions, or by not preventing actions of a third party, do let me know. Contact me either in person, by e-mail, or anonymously, as you prefer (see Feedback below).

Please, when you have doubts, do ask a question. Do not keep the doubts to yourself. Do not concern yourself with whether your doubt is too simple or naive. It is better to finish the courses having cleared out all of your questions. If you feel your background has not prepared you well for the lectures, I can try to give you additional things to read. Just bring the matter to my attention.

If you have a preferred way to be called which is perhaps not obvious at the first moment (e.g., second name, surname, nickname, other name, different pronoun, etc), just let me know.

I encourage all of you to have a look at the "Conduct towards others" section of the Ethics Statement of the European Astronomical Society and the corresponding section in the Guidelines for good practice (in the same pdf document). A few other topics that might be relevant include recommendations about language, conflict of interest, authorship, attribution of work, and peer review.

Feedback: I appreciate feedback about the lectures during or after the course. A link for a Google form where you can send your feedback anonymously will be provided by e-mail. Eventually, I would like to give this course again, and your feedback will help me to improve it (the reading material, format of the lectures, contents, activities, the way things were presented, etc).

If there is any feedback that you prefer to not give to me directly, feel free to contact instead the PhD studies coordinator or maybe any member of my team with whom you are friends with and feel comfortable talking to.