Chapter 4

Writing and Editing Papers

Introduction

Few people, including students, amateur astronomers, and the general public, learn about writing genres beyond high school and college English courses. Most of these classes focus their writing on narrative essays, persuasive arguments, and poetry. Technical writing in science has special principles that are largely foreign to those working outside the field. For example, a science abstract (the first and most often read piece of text in a paper) states the findings, interpretations, and implications of a research project. Imagine if the opening paragraph of your favorite novel told you the final twist! In this chapter, we will briefly review the contents of a typical research paper; offer some guidance about the qualities of a good science paper; and describe the writing, editing, and review process.

Content and Style of a Research Paper

The scientific community has developed a standard set of sections for a research paper, each with distinct content. The scientific community also has expectations about the style of a research paper.

Regarding style, science papers are very cut and dry, and there is little room for embellishing or flowery language. The goal of the writing is clarity and objectivity. Research papers are evidence-oriented—everything that is said should be justified by evidence. For instance, in the case of double star astrometry, one cannot insert frivolous opinions regarding the aesthetics of a particular system. Rather, what gets researchers excited about a study is what it contributes to the field.

It is a widespread expectation that activities will be described in the passive voice (e.g. “measurements were made...”), although in recent years active voice is being increasingly accepted (e.g. “we measured...”), particularly if active voice results in clearer and shorter sentences. However, it is strongly suggested that students use the traditional passive voice, as it is a style of writing that helps them take the objective, neutral stance appropriate in science.

Regarding contents, each of the following segments should be included in a scientific publication:

Title

Naturally, the first thing anyone is going to read of a paper is its title. The title should be interesting and capture the purpose of the research. Strive for a phrase that captures the “one big idea” or “significant new result” of the research being reported.

An astronomical research project often focuses on a particular target and uses a specific observing technique. As such, the title could highlight the key points of the paper: the name of the target object, the type of measurements done, and, occasionally, the materials or institutions involved.

It is acceptable to phrase the title as a question. A title such as “Are there variations in the transit times of the exoplanet WASP 1b?” may entice researchers to discover something new about a particular system.

Authors and Institutions

The authors are the individuals who contributed significantly to the research project, including instructors. Their contribution may range from making observations, doing some statistical or other analysis, leading a team, or writing the paper. If someone only contributed a small amount, such as reviewing the paper or giving general guidance, their names should appear in the acknowledgments, not as authors.

The order of the authors is by far the most politically sensitive aspect of a research paper. It is generally assumed that the first author (called the lead author) did the most work and carries the most

responsibility for the research. It is not unusual for an instructor or advisor who significantly contributed to the paper to ask to be purposefully placed as the last author. Some instructors require that student teams work through the political process of deciding who should be the first author as part of introducing students to the realities of scientific research. It usually becomes clear to everyone, fairly soon, who the first author should be. Less realistically, some instructors may wish to avoid this and either assign the first author or place the authors in alphabetical order. This is likely to be perceived as unfair. The instructor should, realistically, require that the first author (a student) be responsible for making sure the project is completed, even if this requires considerable work on their part past the end of the seminar. This special responsibility can be extended to the first several authors.

The corresponding author is often the first author, although this does not have to be the case. The corresponding author is responsible for interfacing with the journal and carrying the paper through the last steps of publication. The corresponding author might be an instructor. If the corresponding author is other than the first author, this fact should be noted as a footnote on the first page.

The primary institution of each author should be given. These affiliations may be schools, corporations, branches of government, non-profits, etc. An individual may have more than one affiliation on rare occasions. A student's affiliation would be their school, while a professional researcher deeply involved in their project may be affiliated with an observatory or university or both.

Abstract

The abstract answers the critical questions a reader may ask. What was being studied? Why is this research important? What methods were used? What were the results?

Some students may be surprised that in science, the major "plot points" are given away before the body of the paper even begins. The abstract is there to save researchers time so they will not have to skim-read an entire paper to see if it is relevant to their interests. The title may intrigue them, but the abstract ensures that the paper will be of use to them. The abstract should be brief; typically, a journal will limit the abstract to 250 words, and abstracts much shorter than this are usually appropriate.

If the key result of the research amounts to just one or two parameters, it is often expected that the numerical value (and uncertainty) will be placed in the abstract. For example, if a paper is reporting the rotational light curve of an asteroid, the abstract should include "... measured synodic rotation period is P = XX ± yy hr."

Introduction

The introduction tells the reader the scientific reason that the project was done, enumerating the specific scientific goals. It should put the current research in an historical and theoretical context and tell the reader how this project contributes to the field, fills a gap in knowledge, extends a data set, probes more deeply into an unexplained phenomenon, resolves a previously-confusing observation, or tests a specific hypothesis. There should be references to work others have done in the past that set the stage for the present study.

Equipment and Procedures (Materials and Methods)

The equipment and procedures (in some areas of science called "materials and methods") portion of the paper describes the instruments used, observations made, data reduction, and analysis methods used.

The instruments used in observational projects should be described, such as a telescope, cameras, etc. The location and dates that any observations were made should be reported. The software used to control the telescope, camera, and reduce data should be credited here as well. Anything that does not contribute to understanding and replicating the procedure can be left out (such as red LED lights and warm clothing).

The methods of data collection should be outlined in enough detail that someone with a knowledge of observational astronomy could replicate the observations. For example, if a CCD camera was used to make astrometric measurements of double stars, the procedures could skip the steps of camera installation but need to describe the measurement procedures.

Professional papers usually just name standard techniques and give a citation. In contrast, student papers may want to describe some basic principles. Subtracting darks and rotating eyepieces could, for instance, be explained. Giving reasons why a particular technique is used can increase the value of this section.

It is sometimes appropriate to describe the statistical analyses used.

Data and/or Results

The results are typically shown as tables, images, or graphic curves. They should *always* be accompanied by an assessment of the uncertainty in the numerical values (e.g. standard deviations, or standard errors of the mean in tabulated results; "error bars" for data points on a graph; measures of significance in hypothesis tests).

In terms of text, the results section is often the shortest segment of a scientific paper. It may be tempting to begin interpreting the results in this section, but this section should only contain the measurements themselves and some accounting of their accuracy and/or precision. Raw data is generally not included.

Discussion

In the discussion section, comparisons are often made between the present study and past observations. Here the authors attempt to establish trends in the data or identify deviations. Ultimately, the content of the discussion section depends entirely on the research question at hand. A team studying exoplanets may look for cases in which the transit timings do not match their ephemerides. A project to measure double stars may find that the relative motion of two stars is linear rather than elliptical. In most research papers the Discussion section tends to be the most technically involved section, as it relates the results to the theoretical framework described in the introduction.

Conclusion

The conclusion relates the results and discussion back to the goals stated in the introduction. The conclusions must not go beyond what is justified by the data—if the data could justify more than one conclusion, acknowledge that. One trick for reviewing a paper is to read the introduction and conclusion and see if they mirror each other or not. If the conclusions do not address the issues brought up in the introduction, and vice versa, then one or the other part of the paper should be amended.

This is not the place for introducing any new information or reasoning, but it is appropriate to identify recommended future directions and questions that remain unresolved. Any potential areas of research should be specific. Do not say, "X needs more follow-up studies." Instead, say, for example, "Observations of this object in the B- and R-bands, over the next five years, at a monthly cadence, will help to resolve it characteristics."

Acknowledgments

While the rest of the paper is very straightforward, facts-only material, the acknowledgments offer the opportunity to be slightly less formal in style. It is appropriate to thank anyone who contributed to the project but is not an author. Anyone who reviewed the paper should be thanked along with any advisers. Most importantly, any person or organization that contributed data funding, materials, or facilities should be recognized.

References

Any source material regarding background, methodology, or analyses should receive a proper citation (author, date, title of article/chapter, title of book/journal, volume number, page numbers). All references should be cited in the paper. References are normally listed alphabetically by the first author's last name. Suggested further reading and helpful resources should be placed in a separate section with an appropriate title, or simply omitted.

Qualities of a Good Science Paper

A good science paper follows the standard outline as previously described. Some modifications are permissible in topical publications such as the Journal of Double Star Observations, but at the very least, there must be an introduction, equipment and procedures (methods), results, and conclusion. Most often the discussion section may be titled "System Analysis" or something that is specific to your unique project. Other parts of the paper such as acknowledgements and references may vary depending on the publication.

Sometimes novice writers, be they students or otherwise, embellish their manuscript with "fluffy" language. This includes clichés such as "on the other hand" or "at the end of the day." Such phrases push readers to tune out as though they have read this before. Using extra words to make a point increases a paper's word count which is broadly viewed as unprofessional. In fact, many journals (including some that are exclusively online) have a printing fee associated with the number of pages in a paper. Limiting literary devices and annotations can help trim a paper down.

Another trick that authors may use to improve their writing is to incorporate a combination of active and passive voice. An author may write, "the two stars seem to be orbiting one another." However, excessive use of "to be" and its derivatives can become monotonous to read, even for a cut and dried science paper. It can also unnecessarily add to the word count of your paper. Instead, write the sentence like this: "the two stars seem to orbit one another." Throwing in action verbs may not always be appropriate either. An author may write, "the two stars find themselves 20 arc seconds apart." Are the stars sentient beings capable of pondering their relative positions in the sky from an Earthling's perspective? This sentence implies that this is the case (and adds to the word count). Rather, simply write, "the two stars are 20 arc seconds apart."

A final aspect of technical writing that may not be strictly adhered to in topical journals but improves the professionality of a paper is writing in third-person. Instead of saying "I used a ten-inch Meade LX200," write "the authors used a ten inch Meade LX200." Science papers should especially avoid using the word "I" when there are multiple authors. In rare cases, one might say "[author last name] made observations at…on the night of…" which is still a third-person reference to a specific contribution of one of the authors.

Helpful Hints for Writing a Science Paper

Writing your paper is part of the work of your research, so while you're doing your work, don't forget that you are going to write a paper about it. It is highly recommended that you start writing your first draft as you go along, even before the observations have been made. After all, the goals and procedures are known (and their description can be modified if needed). That way, the introduction, materials, and methods are drafted early on.

The abstract is often written last because it will address the key points of the paper including abbreviated results and conclusions.

Dividing Sections among Team Members

Most researchers work in teams, and, naturally, some team members will be more gifted in writing than others. Leaders recognize the skill sets of their team-mates. While the many portions of a paper may appear rather daunting to an individual student, especially in a one-semester seminar, a group of students can divide the work such that each team member only writes one or two sections. Alternatively, some team members may concentrate on observations or analysis, while others concentrate on writing.

Once all the sections have been written, the sections can be pieced together to create a unified paper. The team should then work through the paper, ensuring a logical flow, cutting superfluous information, adding important material, and setting the appropriate tone. Once the paper is set in a logical order, the group can then go over the paper at the granular levels, ensuring proper English, creating a consistent phraseology, parallel structures, and consolidating or expanding sentences.

Graphics and Tables

Graphics may include light curves, orbital plots, photos, and, on occasion, artistic renderings. Each graphic and table must be referenced in the text and their content summarized in the paper such that they add to the reader's understanding. Pictures and tables must have captions stating what they are, and their significance.

Graphs should have legible axes and scales. Photographs should be un-retouched; or, if some sort of image enhancement was done, it must be clearly disclosed and explained.

External Review

With all of the figures and their captions in place, the text's wording as precise as possible, and a final check has been made for spelling or grammatical errors, the team should send their paper to an external reviewer. These are often experienced astronomers who are friends of the research seminar.

The reviewer may suggest that additional data be collected, alternate analysis techniques be implemented, or that conclusions appear insufficiently supported (or go beyond) the evidence.

Any suggestions the external reviewer makes should be addressed. This includes anything from major questions about procedure or analysis to grammar and spelling. It is standard scientific practice that any and all reviewer comments receive a response. If a suggestion is not adopted, the author should be prepared to respond with an explanation. Typically, in small telescope science, the revisions are simple, but, occasionally, reviewers may make suggestions so critical that they should be invited to be co-authors of the paper if they were willing to make the contribution themselves. All reviewers should be thanked in the acknowledgement section.

Submission

Once all of the changes and suggestions have been incorporated from reviewers and the paper has been checked one last time for proper English, the paper is ready to be submitted to a journal.

To increase the odds of acceptance, authors should select an appropriate journal. The prestigious science journals such as *Nature* would likely reject a project offering a new data point on a well-studied double star. Likewise, topical journals such as the *Journal of Double Star Observations* may not accept some theoretical relativistic treatise on binary black holes.

Some journals, such as the *Journal of Double Star Observations,* do not charge for publishing a paper. Many journals, however, charge a per page fee or a flat fee per paper (which can run $1000 or more). Some journals, such as the *Journal of the American Association of Variable Star Observers,* charge a page fee for non-members of their parent organization. These charges may impact where the authors choose to publish (or even what projects they undertake to begin with).

The cover letter (email) should address the editor(s) of the journal formally and introduce the team and their overall project. The cover letter does not need to be lengthy—in fact it should be no more than a paragraph or two. The letter should state why the paper is appropriate for the Journal. Always tell the editor(s) that "while the paper is considered by the authors to be final, any suggestions or comments from the journal's editor or additional referees will be addressed."

While all higher level scientific journals are refereed, some of the lower level journals are not refereed; papers are published as they are submitted without any further review. For papers submitted to non-refereed journals, it is strongly recommended (especially for novice researchers) that, prior to submission for publication, papers be sent out for external review by one or more experts.

Even for papers sent to a refereed journal, it is good practice to send papers out for external expert review prior to journal submission. The journal editor and referee(s) will appreciate the care the authors took in obtaining any external reviews. Such external reviewers should be mentioned in the Acknowledgements, adding to the gravitas of the paper.

Some papers will receive more suggestions from referees than others. This does not necessarily reflect on the quality of the paper. However, each suggestion should be addressed, and the final round of edits should incorporate any further changes requested by the journal. This often includes formatting preferences. With these edits complete, the team (or more likely the corresponding author) can resubmit their paper in its new version.

Prior to publication, most journals send a proof-copy back to the first (or corresponding) author to check for errors made during preparation (formatting, sizing pictures, etc.) of the manuscript. The first author must be sure to check as large errors can be made. Even whole paragraphs can accidently be deleted or pictures placed out of order.

With this final check of the paper completed, the paper will await publication in the next available issue. A journal may have several full issues with the team's paper waiting in a queue. This is not a problem for citing the publication anyway. Once a paper has been accepted for publication by the journal, it may be cited in other papers (with the words "in press" for the date), in school applications, in scholarships, and incorporated within CV's.

Astronomy Research Publication Guide

We recommend that you refer to Appendix C of this book for formatting and style instructions that were specifically developed for papers resulting from Astronomical Research Seminars. Care was taken to be sure that formatting and style parameters could be set up in other venues, such as Google Docs or Mac Pages, and then easily transferred into a Microsoft Word document for final submission. They provide a simplified yet professionally correct structuring of astronomical research papers, both for journal and book publication.

It is, however, highly recommended that this Publication Guide be used early in the research process, starting with the development of the Project Proposal and subsequently when beginning the writing of research papers. There are several benefits to early use of the Guide which include:

- Introducing novice researchers to the need to meet publishing requirements for their papers.
- Providing a structural guide for the Project Proposal to help researchers to understand what needs to be done.
- Envisioning the final paper and format it as it is written, ultimately saving time and frustration in the end.
- Creating a clean, professional paper that can be sent out for review with confidence.
- Producing a final version that, once accepted for publication, can be used by researchers on their resumes and applications until the final version is actually published.
- Produce research papers formatted so that they can be easily transformed into a differing specification of a journal or publisher, whether these specifications are met by the researcher or journal/publisher.

The Guide is organized to present the most immediately necessary and important information first, including "quick-guide" charts that provide easy access to formatting and style specifics. These are followed by a style template for research papers that can also be found on the InStAR website as a Word document, and further recommendations and technical specifications drawn primarily from the *Astronomical Journal* (AJ) and the *Astrophysical Journal* (ApJ) guidelines.

Conclusion

The motto of the Astronomy Research Seminar has always been: "learn science by doing science." Publication is the very heart of science. The outline and hints above will guide students, mentors, and instructors in the fundamentals of science writing.