Basics of technical writing for astronomy graduate students

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ABSTRACT

This document is intended to help astronomy graduate students who are in the process of, or will soon be, writing their first paper. It covers both the overall basic principles of good writing as well as various style conventions that are commonly used in the astronomy literature.

Contents

1. Introduction

Many beginning graduate students maintain their high school attitude, of "I am good at math and science and all this humanities stuff is boring and I'd like to spend as little time and effort on it as possible". However, the reality is that you cannot be a successful scientist today if you are unable to write. Because poor writing obscures your meaning, you can have the best science result or project idea, but if you cannot write a good paper or proposal, your readers will not be able to grasp your result or idea. Therefore, with poor writing, you will not get your colleagues' acclaim and citations, you will not get the telescope time, and you will not get the funding.

Even more fundamentally, most students think writing is something that happens after you finish your research project – as in "write-up your results". However, writing is far from being only about the end product that gets published. Writing is how you organize your thoughts, and thus helps you clarify in your own mind what are the key conclusions from your work. After all, a paper is not just a collection of figures and statements like "I did this, and this and this and this....". Throughout the paper there needs to be a story that is being told. First and foremost you need to work out what that story is: what are the big open questions that are being addressed, how does your work build upon earlier work in the field, and what exactly your new data or analyses tell you. If, in the process of writing, you find that you are not able to address these questions, then you have to go back and do more analysis, or generate new figures. You iterate on this process until you are able to more directly address the questions you are trying to answer. You may also find that your results lead to new questions or phenomena that you were not aware of at the beginning of the project. Thus, writing is an integral part of the research process itself.

Ultimately, for your future readers to know what you mean, you must first know what you mean yourself. As you write, you should think about *every single sentence* and ensure that you know what it is you are trying to convey. You also need to bear in mind that everybody, from novices to experienced writers, goes through many drafts in order to achieve the desired clarity of thought and expression. You should never expect that you can sit down, write something, give it to your advisor and have them not cover it in red. They would not expect that of their own writing! This guide is intended to help you follow some basic principles that will lead to more clear, concise, and professional looking writing. Wouldn't it be more rewarding when discussing a draft with your advisor if you spend less time discussing the need for better grammar and shorter sentences, and more time on the science?

2.   A "how-to" guide

2.1.   Where to begin

Beginning a new paper draft can be challenging for students, especially if it is their first one. Before you do any writing you need to have at least tentative answers to the following questions:

- What are the conclusions of the paper (qualitative and/or quantitative)?

- What is the evidence for those conclusions?

- How do these results relate to prior work?

- What are the implications of this work – i.e. what theories are being tested/questions are being answered etc?

It is helpful if you actually write down your answers to the above questions. It is typical to think that you know these answers, but when forced to articulate them, you may find that you do not understand these as well as you thought you did. Once you have written those down, or if you are completely stuck, you should go to your advisor.

Once you have a reasonable answer to each of the above questions, make a paper outline. I tend to do this either on the blackboard or on a piece of paper. The outline includes the names of sections and subsection (even ones where I have no results yet). It also includes sketches of figures that may go in each section/sub-section. This may also include side notes on what exactly I will try to convey in each section. In other words, the outline sketches the story I think I am going to be able to tell (in somewhat more depth that the above questions alone).

Once you're done your outline, begin your draft. The easiest sections for you will be the ones where you describe your analysis, so might as well begin there. Place any figures you have already made into their relative sections, and write some words that go with them. Many people leave the introduction to the very end. However, to give you context for your "Results" and "Conclusions" sections, you should write at least a basic introduction including the questions your project is trying to answer as well as present some key literature results. You would have been pointed to relevant papers by your advisor at the start of your project. As you polish your paper, over time, the introductions of these and related papers will give you a good idea of what your introduction should include.

2.2.   Basic principles

It may seem that with the above described steps you are almost done. Actually, that is just the beginning. You should expect and do lots and lots of revisions of your draft. This is not due to your inexperience! Indeed, the more seasoned a writer you become, the more editing you'll find yourself doing. Below I list some basic principles of good writing (with some examples specific to astronomy papers). As you revise your draft, you should try to follow these principles as much as possible. They will help you tell your story in a more clear and concise manner. This will not only benefit your future readers, but most importantly will benefit you. Forcing yourself away from vagueness and ambiguity and toward clarity and concreteness, you will come to a better understanding of your own project's results.

- Use correct English – This point is often an issue for both native and non-native English speakers (though the pitfalls differ). I suggest everybody go over the contents of one of the many online grammar guides so that at least you know what's there and can go to it for reference as needed. Some useful starting points are included in the "Further Reading" section [1,2].

- Omit unnecessary words – By far the most common thing that a professor does when editing student writing is to go through and remove "fluff", which are unnecessary words or even whole sentences. As you write, you should always consider: "Can I say this with fewer words?". Think of it as decluttering.

- Break-up long sentences – This is part of the effort to maintain clarity (see below). Students tend to have long, involved sentences, which typically lose the plot about halfways through. Short, declarative sentences are always better.

- Maintain a logic flow – This is related to the idea that your paper should convey a story. More specifically, there should be a clear logic flow not only from section to section, but also from paragraph to paragraph and within paragraphs.

- Be mindful of emphasis – If you want to emphasize a particular idea, or result, in your readers' minds, you should consider where it appears. Generally, the last sentence in a paragraph has the most emphasis. Within a given sentence, the thing you want to emphasize should be the subject. For example, notice the difference between: "The infrared-derived star-formation rates are higher than those derived from the UV" vs. "We look at UV- and IR-based star-formation rates and find the later to be higher".

- Convey professionalism – Papers should convey professionalism, which, apart from the content, means more formal language than typical spoken English. This means avoiding colloquialisms and expressions of emotional reaction (e.g. *awesome, fascinating,*

exciting). On the other hand, you'll see in papers words typically not used in common speech – e.g. *salient, elucidate, paradigm.* If you are unfamiliar with these (or any other words you come across in a paper) you should look them up. In time, you will be able to use a wider range of vocabulary in your own writing which, *used sparingly and appropriately*, makes a good impression.

- Be clear – *This is the most important of all basic principles of writing.* Following on the previous point, while the language in papers is more formal than you may be used to, it should not be unnecessarily heavy. A piece of writing that is nothing but jargon and multi-syllable words will be hard to digest. You should never let your desire for a more formal language come at the expense of clarity. The next two points, are also directly related to the "Be clear" principle.

- Define terms – You should always make clear exactly how you define a particular parameter, unless it is unambiguous. For example, a magnitude is very different if it is in the Vega or AB system. Any term or parameter than is subject to confusion, should have an explicit definition in your paper.

- Be consistent – Once you decide on a particular definition or terminology, stick with it throughout the paper. If you start using S_ν for flux density, do not suddenly switch to F_ν.

2.3. Title

This, and the following subsections, deal with various other aspects of writing a good astronomy paper. They range in importance from crucial (the paper's title) to minutiae (conventions for names of telescopes). However, all are issues to be considered as you edit your paper, since they do make a difference in making your final paper look "polished".

The title is likely the single most important aspect of writing a paper, since people typically decide whether or not to read a given paper on astro-ph based on its title. Therefore the title has to be relatively brief, understandable outside a narrow specialist field, and it has to give a sense of the key results in it (otherwise why would people bother to read it!). In addition, a title that contains grammatical errors or attempts to be funny, will not be taken seriously. Indeed, it has been shown that papers with humorous titles receive fewer citations, than papers with standard titles [3].

A quick look at today's astro-ph listings (January 10, 2014) yields examples of both good and bad titles. As you read them, think about what makes them good or bad.

Bad titles

- E(B-V), N(H I) and N(H_2)

- Synthetic hydrogen spectra of prominence oscillations

- A Mid-IR comparative analysis of the Seyfert galaxies NGC 7213 and NGC 1386

Good titles

- The low or retrograde spin of the first extragalactic microquasar: implications for Blandford-Znajek powering of jets

- Stellar populations in central cluster galaxies: the influence of cooling flows

- Metallicity inhomogeneities in local star-forming galaxies as sign of recent metal-poor gas accretion

2.4.   Figures

Besides the title, the figures are the most looked at aspect of any paper. Because of this, you should ensure that the figures alone convey the story you are trying to tell. Your paper should contain a figure where a reader can clearly see the most important result of your paper. A good such figure can go a long way toward garnering more recognition and citations for your paper.

Before you can generate that perfect figure, you should of course always remember what you were taught in your undergraduate physics labs: figures should always have axis labels; the axis ranges should be consistent with the data range; you should consider the form of display (e.g. linear, log) that makes the most sense for your data; you should use large enough character and symbol sizes for easy readability of your figure. The style of your figures (including line thickness, character font, and character size, as well as meaning of symbols and colors) should be as consistent as possible throughout your paper.

All figures, tables (Section 2.5) and references (Section 2.6) must be explicitly referred to in the text. If they are not, you should remove them. In addition, figures and tables should be referred to in the text in the order in which they appear. If you find that you mention Figure 4 before Figure 3 then you should switch their order.

Always use the `\label` and `\ref` structure to avoid having to hardwire the numbering of the figures and tables (same applies to sections). It is good practice to make your labels as

explicit as possible to avoid confusion. For example, I use labels such as `\label{fig:seds}`, `\label{table:photometry}`, or `\label{sec:data}`. These structures are based on the LaTeX document preparation system, which is the norm in the scientific literature. If you are unfamiliar with it, there are numerous online resources to help you get started[1].

2.5. Tables and astronomical objects designation

As you all know, any new data (e.g. photometry, redshifts) or analysis results (e.g. derived values such as molecular gas masses, star-formation rates and so on) for your sample of objects will be presented in table. Other common tables include, but are not limited to, an observations summary and parameter settings for a a given code. As in the case of figures, consistency in the look of all tables in your paper is key. The best table environment is `\deluxetable`. You should look at a range of papers in the literature to ensure the style of your figures and tables is up to par.

The most common mistakes that students make in their tables are to give too many digits (think significant figures), and to not specify the units of their numbers. However, the crucial aspect of tables is that they convey the quantitative results of your paper. You should always double and triple check that the values included in your tables are correct.

Specifying your objects (through their names and coordinates) is a key information in astronomy papers. Being mindful of how you designate your sources will increase your results' usefulness to other researchers. It will also facilitate your results being included in existing and widely used databases (such as the NASA Extragalactic Database; NED[2]) and therefore lead to more citations for your paper. For more information on the subject, you should read the *Best Practices for Data Publication to Facilitate Integration into NED: A Reference Guide for Authors (Schmitz, M. et al. 2013)* put together by the NED team (see "Further Reading" [4]).

2.6. References

For your references, use the `\natbib` package and maintain a *.bib file. You will re-use and add-to this file over time so maintaining a good .bib file will make your life easier in the

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[1]For example see http://latex-project.org/guides/

[2]http://ned.ipac.caltech.edu

future. In the case of an ApJ paper, your paper directory should also have the file **apj.bst** and the pre-amble of your document should include the lines:

```
\usepackage{natbib}
\bibliographystyle{apj}
```

The easiest means of adding references to your .bib file is through the NASA/ADS website. Once you find the paper you are interested in, click on "Bibtex entry for this abstract" and cut and paste the result into your .bib file. The only change you'll need to make is to change their generic reference, which is something like `2012ApJ...757...13S`, to something more meaningful such as **smith2012**. Then you include the citation in your paper with `\citet{smith2012}` or `\citep{smith2012}`.

2.7. Other style issues

Here I point out some rules and conventions that appear very trivial, but do make the difference between writing that looks professional and writing that looks unpolished. As pointed out under "Basic principles", whatever style you adopt, you should be consistent throughout your paper.

- **Value and units** – While the names of quantities such as flux, mass, luminosity are often in italics, the units are not in italics. For example: $S_\nu = 5\,\mathrm{mJy}$. Subscripts should be roman (using `\rm`) as in $L_{\mathrm{IR}} = 10^{12}\,\mathrm{L}_\odot$.

- **Spacing** – You should always leave a small space, `\,`, between the numerical value and the units. For example: $S_\nu = 5\,\mathrm{mJy}$ not $S_\nu{=}5\mathrm{mJy}$. You should also leave a small space between "Figure" and "Table" and its number. In practice, this means using something like: `Table\,\ref{table:photometry}`.

- **Quotes** – These should say "example" not "example".

- **Names of telescopes** – Space-based telescopes are in italics (e.g. *HST, Planck, Herschel*), whereas ground-based telescopes are not (e.g. Keck, Gemini, VLA).

- **Singular vs. plural** – The word "data" is always plural (as in "Our data indicate ..." not "Our data indicates").

- **Single sentence paragraphs** – You should never have a paragraph that consists of a single sentence.

- **Spelling out acronyms** – Astronomy is full of acronyms. The first time you mention an acronym it must be spelled out. This is also the time to add a citation to the relevant paper. A good structure is something like: ....Wide-field Infrared Survey Explorer `\citep[{\slWISE };][]{wright2010}`.....

- **Names of software packages and routines** – You need to specify what software package you use to reduce your data, as well as what specific routines you use to make fits. Although it is not obligatory, these are commonly written out in small capital letters (using `\sc`). For example, IDL, MPFIT, CASA.

3. Conclusions

The basic principles outlined here may sound obvious, but are not easy to master. It takes a lot of practice. It also takes an attitude that writing is important to you as a scientist, and that you should aim to improve at it during your PhD. In the words of George Orwell [5] – *A scrupulous writer, in every sentence that he writes, will ask himself at least four questions thus: What am I trying to say? What words will express it? Could I put it more shortly? Have I said anything that is avoidably ugly?*

Scientific writing, in particular, is integral to the research process itself – it is the means by which you organize your thoughts and even potentially discover new directions for your research. But this process is particularly challenging for beginning students. The best way to improve here is by reading many, many papers in your field. When reading them try to make the connections between a paper's results (for example as expressed in their figures) and their conclusions. Do not merely think "the authors conclude X,Y,Z". What is their basis for these conclusions? Do you believe them? Why or why not? By seeing multiple example of how a story is being told in these papers from introduction to conclusions, you will be better equipped to tackling your own first paper. As in all forms of writing, the more you read, the better writer you'll become.

4. Further reading

1. Useful grammar resources can be found via: `http://writing-program.uchicago.edu/resources/grammar.htm`.

2. The writing resources website by Tufts Computer Science professor Norman Ramsey: `http://www.cs.tufts.edu/~nr/students/writing.html`.

3. Sagi and Yechiam "Amusing titles in scientific journals and article citation", 2008, Journal of Information Science, 34, 5

4. Best Practices for Data Publication to Facilitate Integration into NED: A Reference Guide for Authors (Schmitz, M. et al. 2013): `http://ned.ipac.caltech.edu/`

5. George Orwell, *Politics and the English Language* `https://www.mtholyoke.edu/acad/intrel/orwell46.htm`