

How to Read Scientific Papers

Advice from Prof. Julie Comerford, ASTR-6000, Fall 2015

When astronomers sit down to read a paper, they almost never read every word, in order, cover to cover. The way you read a paper depends on your level of expertise with the subject; if you are very familiar with the subject then you skim through the Introduction and read the Methods and Results sections in detail. If you are new to the subject, then it is important to read the Introduction closely.

Here, I will assume that you are relatively new to the subjects of these papers. I suggest taking the following approach to reading these papers:

1. Read the Abstract. This will give you an idea of the main points in the paper that you should look out for.
2. Read the Introduction. In many ways, this will be the most useful part of the paper to you. If you come across terms that are unfamiliar, look them up and teach yourself what they mean.
3. Skim through the Methods and Analysis sections. Look for the major points: how did the authors choose their sample of objects to study? What telescope/simulation/set of physics equations did they use? How did they perform their analysis? For the purposes of this seminar you don't need to get caught up in the nitty gritty details of, e.g., how they reduced their data.
4. As you work through the paper, look at every figure and table and read their captions.
5. Read the Results/Discussion/Conclusion sections. This is the meat of the paper where the authors discuss what they found and what it means.
6. Reread the abstract. Did you read in the paper about each point raised in the abstract, or did you miss a few things?
7. As a test of your comprehension of the paper and its major points, you should be able to describe:
 - (a) What is the question that the authors aim to answer?
 - (b) Why is it important?
 - (c) What did they do?
 - (d) What did they find?
 - (e) Why does it matter?

Advice from “How to Succeed in Graduate School: A Guide for Students and Advisors,” by Marie desJardins

Before bothering to read any paper, make sure it’s worth it. Scan the title, then the abstract, then—if you haven’t completely lost interest already—glance at the introduction and conclusions. (Of course, if your advisor tells you that this is an important paper, skip this preliminary step and jump right in!) Before you try to get all of the nitty-gritty details of the paper, skim the whole thing, and try to get a feel for the most important points. If it still seems worthwhile and relevant, go back and read the whole thing. Many people find it useful to take notes while they read. Even if you don’t go back later and reread them, it helps to focus your attention and forces you to summarize as you read. And if you do need to refresh your memory later, rereading your notes is much easier and faster than reading the whole paper.

A few other points to keep in mind as you read and evaluate papers:

- Make sure the ideas described really worked (as opposed to just being theoretically valid, or tested on a few toy examples).
- Try to get past buzzwords: they may sound good, but not mean much. Is there substance and an interesting idea underneath the jargon?
- To really understand a paper, you have to understand the motivations for the problem posed, the choices made in finding a solution, the assumptions behind the solution, whether the assumptions are realistic and whether they can be removed without invalidating the approach, future directions for research, what was actually accomplished or implemented, the validity (or lack thereof) of the theoretical justifications or empirical demonstrations, and the potential for extending and scaling the algorithm up.

Others:

- Michael Fosmire created a nice infographic-rich presentation called “How to Read a Scientific Paper” ([PDF here](#)).
- In 2017, Astrobites posted a [three-part series](#) of articles titled “Tools for Reading Papers,” but these have more to do with finding them (e.g., ADS, arXiv) and talking about them (e.g., journal clubs) than about actually reading them.
- Additional advice about reading papers and participating in seminars was given by Cooke et al. (2020), [arXiv:2006.12566](#).
- See also S. Keshav’s short paper on “How to Read a Paper” included on the next two pages.

How to Read a Paper

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ABSTRACT

Researchers spend a great deal of time reading research papers. However, this skill is rarely taught, leading to much wasted effort. This article outlines a practical and efficient *three-pass method* for reading research papers. I also describe how to use this method to do a literature survey.

Categories and Subject Descriptors: A.1 [Introductory and Survey]

General Terms: Documentation.

Keywords: Paper, Reading, Hints.

1. INTRODUCTION

Researchers must read papers for several reasons: to review them for a conference or a class, to keep current in their field, or for a literature survey of a new field. A typical researcher will likely spend hundreds of hours every year reading papers.

Learning to efficiently read a paper is a critical but rarely taught skill. Beginning graduate students, therefore, must learn on their own using trial and error. Students waste much effort in the process and are frequently driven to frustration.

For many years I have used a simple approach to efficiently read papers. This paper describes the ‘three-pass’ approach and its use in doing a literature survey.

2. THE THREE-PASS APPROACH

The key idea is that you should read the paper in up to three passes, instead of starting at the beginning and plowing your way to the end. Each pass accomplishes specific goals and builds upon the previous pass: The *first* pass gives you a general idea about the paper. The *second* pass lets you grasp the paper’s content, but not its details. The *third* pass helps you understand the paper in depth.

2.1 The first pass

The first pass is a quick scan to get a bird’s-eye view of the paper. You can also decide whether you need to do any more passes. This pass should take about five to ten minutes and consists of the following steps:

1. Carefully read the title, abstract, and introduction
2. Read the section and sub-section headings, but ignore everything else
3. Read the conclusions

4. Glance over the references, mentally ticking off the ones you’ve already read

At the end of the first pass, you should be able to answer the *five Cs*:

1. *Category*: What type of paper is this? A measurement paper? An analysis of an existing system? A description of a research prototype?
2. *Context*: Which other papers is it related to? Which theoretical bases were used to analyze the problem?
3. *Correctness*: Do the assumptions appear to be valid?
4. *Contributions*: What are the paper’s main contributions?
5. *Clarity*: Is the paper well written?

Using this information, you may choose not to read further. This could be because the paper doesn’t interest you, or you don’t know enough about the area to understand the paper, or that the authors make invalid assumptions. The first pass is adequate for papers that aren’t in your research area, but may someday prove relevant.

Incidentally, when you write a paper, you can expect most reviewers (and readers) to make only one pass over it. Take care to choose coherent section and sub-section titles and to write concise and comprehensive abstracts. If a reviewer cannot understand the gist after one pass, the paper will likely be rejected; if a reader cannot understand the highlights of the paper after five minutes, the paper will likely never be read.

2.2 The second pass

In the second pass, read the paper with greater care, but ignore details such as proofs. It helps to jot down the key points, or to make comments in the margins, as you read.

1. Look carefully at the figures, diagrams and other illustrations in the paper. Pay special attention to graphs. Are the axes properly labeled? Are results shown with error bars, so that conclusions are statistically significant? Common mistakes like these will separate rushed, shoddy work from the truly excellent.
2. Remember to mark relevant unread references for further reading (this is a good way to learn more about the background of the paper).

The second pass should take up to an hour. After this pass, you should be able to grasp the content of the paper. You should be able to summarize the main thrust of the paper, with supporting evidence, to someone else. This level of detail is appropriate for a paper in which you are interested, but does not lie in your research speciality.

Sometimes you won't understand a paper even at the end of the second pass. This may be because the subject matter is new to you, with unfamiliar terminology and acronyms. Or the authors may use a proof or experimental technique that you don't understand, so that the bulk of the paper is incomprehensible. The paper may be poorly written with unsubstantiated assertions and numerous forward references. Or it could just be that it's late at night and you're tired. You can now choose to: (a) set the paper aside, hoping you don't need to understand the material to be successful in your career, (b) return to the paper later, perhaps after reading background material or (c) persevere and go on to the third pass.

2.3 The third pass

To fully understand a paper, particularly if you are reviewer, requires a third pass. The key to the third pass is to attempt to *virtually re-implement* the paper: that is, making the same assumptions as the authors, re-create the work. By comparing this re-creation with the actual paper, you can easily identify not only a paper's innovations, but also its hidden failings and assumptions.

This pass requires great attention to detail. You should identify and challenge every assumption in every statement. Moreover, you should think about how you yourself would present a particular idea. This comparison of the actual with the virtual lends a sharp insight into the proof and presentation techniques in the paper and you can very likely add this to your repertoire of tools. During this pass, you should also jot down ideas for future work.

This pass can take about four or five hours for beginners, and about an hour for an experienced reader. At the end of this pass, you should be able to reconstruct the entire structure of the paper from memory, as well as be able to identify its strong and weak points. In particular, you should be able to pinpoint implicit assumptions, missing citations to relevant work, and potential issues with experimental or analytical techniques.

3. DOING A LITERATURE SURVEY

Paper reading skills are put to the test in doing a literature survey. This will require you to read tens of papers, perhaps in an unfamiliar field. What papers should you read? Here is how you can use the three-pass approach to help.

First, use an academic search engine such as Google Scholar or CiteSeer and some well-chosen keywords to find three to five *recent* papers in the area. Do one pass on each paper to get a sense of the work, then read their related work sections. You will find a thumbnail summary of the recent work, and perhaps, if you are lucky, a pointer to a recent survey paper. If you can find such a survey, you are done. Read the survey, congratulating yourself on your good luck.

Otherwise, in the second step, find shared citations and repeated author names in the bibliography. These are the key papers and researchers in that area. Download the key papers and set them aside. Then go to the websites of the key researchers and see where they've published recently.

That will help you identify the top conferences in that field because the best researchers usually publish in the top conferences.

The third step is to go to the website for these top conferences and look through their recent proceedings. A quick scan will usually identify recent high-quality related work. These papers, along with the ones you set aside earlier, constitute the first version of your survey. Make two passes through these papers. If they all cite a key paper that you did not find earlier, obtain and read it, iterating as necessary.

4. EXPERIENCE

I've used this approach for the last 15 years to read conference proceedings, write reviews, do background research, and to quickly review papers before a discussion. This disciplined approach prevents me from drowning in the details before getting a bird's-eye-view. It allows me to estimate the amount of time required to review a set of papers. Moreover, I can adjust the depth of paper evaluation depending on my needs and how much time I have.

5. RELATED WORK

If you are reading a paper to do a review, you should also read Timothy Roscoe's paper on "Writing reviews for systems conferences" [1]. If you're planning to write a technical paper, you should refer both to Henning Schulzrinne's comprehensive web site [2] and George Whitesides's excellent overview of the process [3].

6. A REQUEST

I would like to make this a living document, updating it as I receive comments. Please take a moment to email me any comments or suggestions for improvement. You can also add comments at CCRo, the online edition of CCR [4].

7. ACKNOWLEDGMENTS

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8. REFERENCES

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