Art of Reading a Scientific Paper

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What are some challenges you’ve faced while reading scientific papers?
Before reading, identify your goal

• **Overview Level**: I want to understand a topic
  – E.g. What is the current state of research for graphene plasmonics?

• **Main ideas Level**: I want to understand the results of a paper
  – E.g. How does the propagation length of a graphene plasmon depend on carrier density?

• **Details Level**: I want to understand how to replicate/use some method
  – E.g. How did they measure the propagation length and verify their results?
Find the appropriate paper type

• Literature Reviews

These papers summarize a topic, and can be in tutorial/textbook form, a summary of recent papers, or just a list of citations and references.

These are great starting points whenever learning about a new topic.
Find the appropriate paper type

- Literature Reviews
- Articles/Reports/Letters

These are your typical scientific papers. They will usually spend most of the paper on methods and results.

Letters are usually constrained in length (4-6 pages), so detailed information (methods, derivations, additional measurements, etc.) will be in supplementary information (SI).

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Experimental Evidence of Backward Raman Scattering Driven Cooperatively by Two Picosecond Laser Pulses Propagating Side by Side

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This Letter investigates experimentally the backward stimulated Raman scattering (SRS) of two copropagating, 1-μm wavelength, 1.5-ps duration laser pulses focused side by side, but not simultaneously, in a dispersed ultra-pure plasma. When the two lasers do not interact, one of the pulses (so-called strong) yields a large SRS efficiency, while the other weak pulse is essentially ineffective as regards SRS. By contrast, the weak pulse shows significant SRS activity if it is launched in the plasma slightly after the strong one, and for time delays as large as 10 ps. For crossed polarizations and a lateral distance of 80–90 μm, the time delay has to be larger than 5 ps for the weak pulse to be active, while it has just to be positive when the polarizations are parallel. The experimental results are discussed with the help of large-scale particle-in-cell simulations.

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The control of laser parameter instabilities such as backward stimulated Raman (SRS) or Brillouin (SBS) scattering [1–3] is of crucial importance for the inertial confinement fusion programs of the National Ignition Facility (NIF) [4] and of the Laser Megajoule [5]. Besides significant cross-over energy transfers, altering the implosion symmetry, unexpected high SRS reflectivities—up to 80%—have been observed in the inner beam of the NIF laser, the megajoule energy range, propagates through millimeter-scale, hot, highly ionized plasmas [6,7]. The quantitative interpretation of Raman and Brillouin reflectivities has always been a major challenge in plasmas physics, due to many interrelated saturation mechanisms, which compete over very short space and time scales. Through particle-in-cell (PIC) simulations [8,9], advanced nonlinear models [10] and high-resolution experiments [11,12], significant progress has been achieved in the understanding of monopolar laser pulses interacting with well-characterized plasmas. In a multipole configuration, the overall reflectivity is usually estimated by averaging over the statistical laser intensity patterns produced by a random phase plate [13,14], thereby neglecting coupling effects between neighboring specie. Using this independent hot spot model, realistic 3D paraxial-wave simulations performed with different laser smoothing techniques provided reliable quantitative predictions for both the thresholds and reflective of SBS [15]. However, these encouraging benchmarks did not predict any significant SBS, unlike what has been measured on the NIF.

Besides intrinsic wave coupling processes, kinetic physics plays a key role in the triggering and saturation of parametric instabilities. For example, reduced PIC simulations have demonstrated the significant role, in NIF conditions, of kinetically heated ions and electrons on SBS [16] and SRS [17]. The modified ion velocity distribution has also been found to have a stabilizing effect on SRS [18]. As regards SRS, which we focus on in this Letter, it strongly modifies the electron distribution function, either through electrostatic trapping or through quasilinearlike diffusion if a strong spectrum of sidebands has developed [12,19]. Because of the large electron mean free path, the locally perturbed distribution function should quickly spread around an SRS-active region. Consequently, depending on the characteristic collisionless damping rate of the electron plasma waves (E PWs), the remaining laser pulse, or neighboring hot spots, encounter a non-Maxwellian plasma. In such a perturbed medium, SRS can no longer be modeled using linear theory. For example, the SRS threshold is found to be lower than the linear one (inflection threshold), and SRS reflectivity matches those exceeding the predictions of models based on fixed damping [17].

The study of kinetic effects in SRS has been recently revived with the help of analytical developments [19,20], together with massive PIC simulations, notably those performed at the Los Alamos National Laboratory [21]. These simulations calculate how a laser beam smoothed by a random phase plate becomes Raman unstable as it propagates in hot, NIF-like plasmas. Two important features have been identified in this collective regime: (i) the multipole SRS threshold is lower than for an isolated hot spot and (ii) the saturated reflectivity is significantly higher than that of the isolated hot spot. Hence, the importance of multiplexion effect is to be addressed in any laser-plasma interaction scenario with smooth laser beams, such as those involved in NIF experiments.
Find the appropriate paper type

- Literature Reviews
- Articles/Reports/Letters
- News & Views

These are summaries of a research paper by an expert in the field, meant to summarize and put the research in context for a broad scientific audience.

Not all papers have these, but they are good to read if available.

Do not confuse this with a press release! Those are usually written by journalists/PR people.
Reading Review Articles

Review articles are written for all different levels, from those starting out in the field, to experts who want an overarching view

1. Find a review that is at an appropriate level for you
   - Is the scope too large? Too narrow?
   - Is there too much jargon right away? Find a review article that is more introductory

2. Identify the relevant sections
   - Reviews can be quite long – figure out which sections are worth reading

3. Browse through figures and captions first
   - Get a general idea of what the review will cover and the research it considers most relevant

4. Read through the review like a textbook
Workshop Activity: Find a Review Paper

Open Google Scholar and find a review article of your research field.

– Is the abstract understandable? If not, find another one that is appropriate for your level of knowledge

– Some reviews are just an organized compilation of recently published papers – avoid those for now, and look for ones that are meant to be more pedagogical

– Can’t find a review paper on your topic? You may have to broaden the scope – it’s possible that your topic is a subsection of a review paper
Finding Research Papers – Searching Smart

• Start with a review paper, and find the relevant papers they cite.
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- Start with a review paper, and find the relevant papers they cite
- Start with a relevant paper, and find papers that cite it
- Start with a relevant paper, and look up papers also published by the first author or the last author
  - First author will be the lead researcher, last author will be the lead principal investigator (PI)
Reading a Scientific Paper: Summarize the Main Ideas and Results

1. Identify your goal
2. This is not a novel: know the ending before you start reading
   – Abstract should outline motivation and results of the paper
   – If the main idea is still unclear after the abstract and introduction, read the conclusion
   – Look over the figures before reading the details
3. You don’t have to read in order (or the entire paper)
   – Sometimes skipping from the abstract to the conclusions and going back and forth in the paper will help
4. At this level, you are trusting the authors and their conclusions
Don’t fall into the rabbit hole!

Scientific papers can contain a lot of jargon, and one can easily fall in the rabbit hole of old papers and trying to understand everything.

You don’t need to fully understand every paper you find
- Some parts of a paper will be more important than others

Identify which terms are worth figuring out
- Sometimes extra concepts are thrown in as semi-related examples, or to appease a reviewer

There are more papers than physically possible to read – a key skill is being able to quickly skim a paper and determine which ones are worth close reading.
Workshop Activity: Quickly Read a Scientific Paper

1. Find a paper related to your current research project (but not from your group)

2. Read the abstract and introduction
   - Keep track of unfamiliar terms
     • Are these necessary to understand, or just an example the authors threw in?
   - What’s the goal of this paper? What is its main result?

3. Look at the figures and captions
   - If the figures make sense, skim the results, and make sure your interpretation agrees with the authors’
   - If they don’t, read through the results section to find the part that references the figure, and try to get a main idea from each figure.

4. Read the conclusions. Does this align with your takeaway points?

5. Write a 1-3 sentence summary of the paper.
   - You can type the notes on an electronic copy of the paper
   - Alternatively, can keep track in Word/Powerpoint, or on paper
Close Reading: Some Advice

Everyone has their own way of close reading a paper. Some advice specific to scientific papers:

• **Start with the same principles of summarizing a paper**
  - Figure out the main conclusions before reading the whole paper

• **Don’t get sidetracked by jargon**
  - Google or ask your mentor for definitions. Don’t feel like you need to fully understand every cited work
  - Finish one paper before starting the next

• **Highlight/underline acronyms for easy reference later**
  - Some are common acronyms, while others can be specific to a paper

• **Summarize sections of papers as you read**
Help! This paper still doesn’t make sense!

Prepare to reread a paper 2, 3, or 4 times before fully understanding it. Still, things might be confusing when

- You do not have enough background
- The paper was badly written
- They don’t make sense. Just because something is published doesn’t mean that you have to believe everything they say

When having trouble,

- **Look up the references, a textbook, or relevant reviews.** Older papers will generally have more detailed derivations and explanations, though be careful – they may be out of date
- **Come back to it later.** It may not make sense during the $1^{st}$ or $2^{nd}$ read, but it might make more sense after reading other papers in the field
- **Propose a journal club.** It can be helpful to get perspectives and analysis from multiple people.
Critically reading a paper

Critically analyzing a paper is probably the most difficult part of reading a paper. This gets easier, though, with more background of the field, and practice.

Some questions to consider:
- What assumptions did the authors make?
- Why is this problem important? What makes this particular contribution of interest?
- Why did they choose certain methods over others? What are the advantages/disadvantages?
- Are the results plausible? Are there alternative explanations that would be consistent with the results?
- Are the conclusions consistent with the experiment and results?
- Given these results, what other experiments can we try? What would be the next logical follow-up experiment?
- What other systems can we apply these methods to?