How to Read a Physics Paper—The Four *i*'s +1

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Why read papers, and what kind?

- ***Peer-reviewed*** **papers are the primary means of communication in physics**
- **Three broad categories:**
  - **High profile (first time) results**
  - **Detailed methods & results**
  - **Review: synthesis by expert(s)**
- **There is also the arXiv (https://arxiv.org/)**
  - **Papers not peer reviewed yet**
  - **Most current research**

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How do you decide on what to read?

Learn about a new development in your area:

- **Focus on results in PRL or PRA (BCDE)- like journals**
- **New formalism or methods are in methods & formalisms (or in the supplement)**

Learn something new:

- **Start with review papers, books, and theses**
- **Focus on broad understanding of paper**
- **Need to pick up on details concerning the physics, methods and results!**

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A reading method

The four *i's (+1)*

Importance
Iteration
Interpretation
Integration

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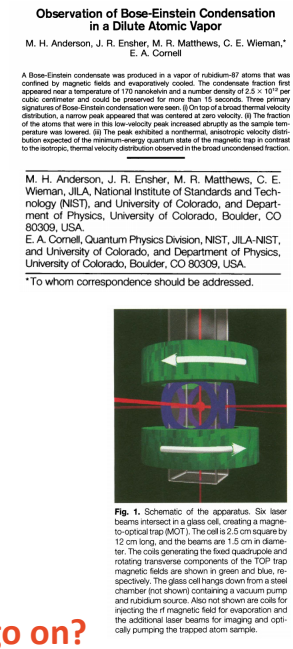
The first *i*: *importance*

Does the paper contain information (methods, results, conclusions) that has implications for your research?

- Read the title and the abstract
- Look at the author list and their affiliations
- Read the conclusions
- Look at the figures and captions
- Look at the references

Is the paper worth reading? Study or go on?



Observation of Bose-Einstein Condensation in a Dilute Atomic Vapor

M. H. Anderson, J. R. Ensher, M. R. Matthews, C. E. Wieman,* E. A. Cornell

A Bose-Einstein condensate was produced in a vapor of rubidium-87 atoms that was confined by magnetic fields and evaporatively cooled. The condensate fraction first appeared near a temperature of 170 nanokelvin and a number density of 2.5×10^{12} per cubic centimeter and could be preserved for more than 15 seconds. Three primary signatures of Bose-Einstein condensation were seen. (i) On top of a broad thermal velocity distribution, a narrow peak appeared that was centered at zero velocity. (ii) The fraction of the atoms that were in this low-velocity peak increased abruptly as the sample temperature was lowered. (iii) The peak exhibited a nonthermal, anisotropic velocity distribution expected of the minimum-energy quantum state of the magnetic trap in contrast to the isotropic, thermal velocity distribution observed in the broad uncondensed fraction.

M. H. Anderson, J. R. Ensher, M. R. Matthews, C. E. Wieman, JILA, National Institute of Standards and Technology (NIST), and University of Colorado, and Department of Physics, University of Colorado, Boulder, CO 80309, USA.
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Fig. 1. Schematic of the apparatus. Six laser beams intersect in a glass cell, creating a magneto-optical trap (MOT). The cell is 2.5 cm square by 12 cm long, and the beams are 1.5 cm in diameter. The coils generating the fixed quadrupole and rotating transverse components of the TOP trap magnetic fields are shown in green and blue, respectively. The glass cell hangs down from a steel chamber (not shown) containing a vacuum pump and rubidium source. Also not shown are coils for injecting the rf magnetic field for evaporation and the additional laser beams for imaging and optically pumping the trapped atom sample.

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Second *i*: *iteration*

1. Skim the article and identify its structure

   Many (not all) papers:

   Introduction, Methods and Results, Discussion, sometimes Methods (again)

2. Find main points of each section
3. Generate questions: active reading
4. Read to answer those questions
5. Iterate!

Turn on your skepticism filter and take notes as you read!

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Second *i*: *iteration* *(continued)*

Take the paper apart, section by section, and identify the key ideas

Highlight anything you don't understand

Cross-check the narrative with the figures and tables

Go back and re-read your highlighted sections; refer to the references or supplementary info

Repeat until you thoroughly understand the parts of interest to you

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The third *i*: *interpretation*

Put the paper aside and write down the key ideas in your own words

Check what you've written against the paper; have you correctly represented the information and emphasis of the original paper?

Are there parts that you still don't understand? (go back to *iteration*)

Do you agree with what the authors have said? Have they provided sufficient detail and supporting evidence? (Again: turn on your skepticism filter)

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The final *i*: *integration*

Evaluate how the information presented in the paper fits with what you already know

Does it contradict something that you believe?

Does it raise new questions that you should investigate?

Does it describe a method that you could use?

Is it something that you should refer to in the future? (If so, how are you going to keep track of it?)

The four *i's of mindful reading*

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+1 *i*: *investigation*

Devise a system to keep track of what you read

Many software solutions are available
(https://en.Wikipedia.org/wiki/Comparison_of_reference_management_software)

Several may be supported by your university's Library

Mendeley, Zotero, RefWorks, EndNote

Consult your adviser and senior students in your group and get their recommendations

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Now for the practical bits...

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Here's one way to deconstruct a paper

Read the abstract and write down the main ideas you think the paper will present

PRL 107, 117401 (2011) PHYSICAL REVIEW LETTERS week ending 9 SEPTEMBER 2011

Optical Response of Relativistic Electrons in the Polar BiTeI Semiconductor

J. S. Lee,[1,*] G. A. H. Schober,[2,3] M. S. Bahramy,[4] H. Murakawa,[5] Y. Onose,[2,5] R. Arita,[2,4] N. Nagaosa,[2,4] and Y. Tokura[1,2,4,5]

The transitions between the spin-split bands by spin-orbit interaction are relevant to many novel phenomena such as the resonant dynamical magnetoelectric effect and the spin Hall effect. We perform optical spectroscopy measurements combined with first-principles calculations to study these transitions in the recently discovered giant bulk Rashba spin-splitting system BiTeI. Several novel features are observed in the optical spectra of the material including a sharp edge singularity due to the reduced dimensionality of the joint density of states and a systematic doping dependence of the intraband transitions between the Rashba-split branches. These confirm the bulk nature of the Rashba-type splitting in BiTeI and manifest the relativistic nature of the electron dynamics in a solid.

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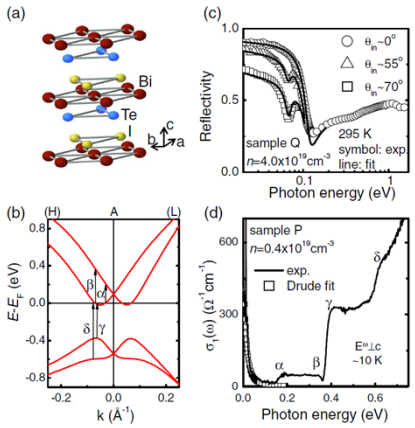
Next, look at the figures and tables

Write down a one-sentence description of each



J.S. Lee et al., Phys. Rev. Lett. **107**, 117401 (2011).

a) Crystal structure of BiTeI; red is Bi, blue is Te, and yellow is I.

b) Band dispersion points in the *H* and *L* directions; possible optical transitions indicated by arrows with an index of *α, β, γ,* and *δ.*

c) Reflectivity spectra were taken for one sample (*Q*) at different incident angles, as shown by variations in photon energy (eV).

d) Optical conductivity spectra were obtained by polarizing light directed normal to the *c* axis (solid line) and compared with a theoretical curve (open squares) based on the Drude model.

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Next, read the first sentence of each paragraph

Paraphrase each sentence in your own words

Highlight any sentences that you don't understand

Look at your sentences. Can you see a logical progression of ideas?

Summarize the logical argument in a short paragraph

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Go back to any sentences you highlighted

- Study the corresponding paragraph—does it answer your questions?
- If you still don't understand the sentence you highlighted, devise a strategy to figure out what it means
  - Look up key words
  - Find a review article on the topic
  - Check the references
  - Check for supplementary material
  - Google the author's name to see if she has a research website

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Read the conclusions section

- Have the authors supported their conclusions?
- How do their conclusions fit in with what you already know?
- Is there anything you don't agree with?
- Is there anything that you still don't understand?
- How can you resolve the issues?

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Figure out a way to keep track of this paper

- Enter the bibliographic information into your citation manager
- In your notes, clearly differentiate direct quotes from the paper and what you've paraphrased

Important: Develop your own method to deconstruct papers

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To recap:

- *Importance*—first determine if the paper is worth reading
- *Iteration*—go back over sections of the paper until you understand it; consult other sources if necessary
- *Interpretation*—summarize the main points in your own words
- *Integration*—synthesize the ideas with what you already know and believe
- Investigate a citation management system to keep track of what you read

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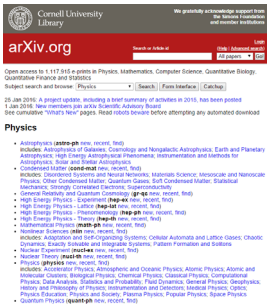
Final words:

Pro tip: Scan the arXiv each week via RSS feed!



Physics ideas are interconnected

Not a linear process, it will take a while

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