# Experimental Schedule

| Sample | Availability |
|---|---|
| LSMO | Ready |
| FeS/FeTe (altermagnets?) | Completed/Ready |
| Fe thin film | Ready |
| Topological insulator | Shipping label sent, waiting on Oak Ridge |

Groups (experiments will run for ~24-72 hours, but you don't have to be on call, will text if need anything from you)

- Oct. 5, Monday 4pm: Ryan, Gavin, Alp **Completed**
- Oct. **27**, Tues. 10:15am: Evan, Jeffrey, Austin (part broke)
- Oct. 16, Friday 5pm: Melissa, Shelby, Leeam
- Oct. 20, Tuesday 4pm: Bryce and Tyler
- Oct. 23, Friday 1:30pm: Nickolai and Durham

**Last day before late penalty**: proposals/papers

Good/Bad Graphs
Bring in examples of good and bad graphs from a paper. I don't need the whole paper. Discuss why you think they are good or bad. DO NOT just google looking for good and bad graphs. I want YOU to practice recognizing what makes a graph good or bad-- not someone else. It's ok if we disagree on what is good or bad.

Why Important Papers and Proposal deadlines? Because the Lab Notebook is *supposed to be* a second try on the same questions. And a second round of feedback.

| Date | 293 Topic | Homework (with goals color) |
|---|---|---|
| 18-Aug | Pre-Surveys; What is this Class About? | Partner/Scheduling Info |
| 20-Aug | Distinguishing Types of Magnetism | Reading 1 on Perusall |
| 25-Aug | Holcomb Group Discovery | Reading 2 on Perusall |
| 27-Aug | MOKE versus Other Magnetometry | Watch Video on Perusall |
| 1-Sep | Project Planning: What Kinds of Magnetic Measurements | Syllabus Read/Agree |
| 3-Sep | Finding Published Papers Relevant to Your Project | Bring a Related Paper to Class |
| 8-Sep | Reading and Evaluating Papers | |
| 10-Sep | Best Practices with Lab Notebooks | University Safety Requirement |
| 15-Sep | MOKE Hands-On Demonstration | |
| 17-Sep | VSM Hands-On Demonstration **50% after Oct 13** | Important Papers. Why? (2-5) |
| 22-Sep | How to Give Peer Feedback and Group Project Planning | |
| 24-Sep | Planning Group Oral Reports and Peer Grading | Mini Reports (in class) |
| 29-Sep | Group Project Planning and Refinement | Quality Reading on Perusall |
| 1-Oct | Assessing the Quality of Materials **50% after Oct 13** | Project Proposal |
| 6-Oct | Best Practices with Graphing | Good/Bad Graphs |
| 8-Oct | Fall Break (No Class) | |
| 13-Oct | Introduction to Excel: Spreadsheets, Graphing and Fitting | Thursday! |
| 15-Oct | Understanding and Processing Your Data | Lab Notebook Check-In |
| 20-Oct | Building a Story with Your Data When It Isn't Obvious | **5% on time bonus** |
| 22-Oct | Check-In and How Are Materials Grown | |
| 27-Oct | How to Give a Good Talk | |
| 29-Oct | Peer Evaluation of Lab Notebooks (Bring Notebooks) | **Can submit early for feedback** |
| 3-Nov | Election Day (Vote If You Can) | |
| 5-Nov | Project Speed Dating: Share Your Project with Others | Graphs of Your Data **5% Bonus** |
| 10-Nov | Time for groups to Discuss Presentation/Data Planning | |
| 12-Nov | 10-15 Min Group Presentations **FeS/LSMO** | Presentations |
| 17-Nov | **Rest** | Presentations **No Bonus** |
| 19-Nov | How to Write a Good Abstract | |
| 1-Dec | Ask Your Final Questions of Instructor, Partners or Class | **5% on time bonus** |
| 3-Dec | Discussion of Research and Scholarship Opportunities | Abstract & Notebook |

# What is Graded for Early Check-In (Oct 15)

25% of total lab notebook score

Will probably check for in class journaling (2 so far, Sept 1&29)

**Lab Notebook Rubric (Early lab noteobook focuses on experiment planning/motivation.)**

| Category | Far below threshold (1) | Below the threshold (2) | Meets the threshold (3) | Exceeds the threshold (4) | Score |
|---|---|---|---|---|---|
| Communicate / Define Topic<br>Introduction/ Motivation/ Goals | Does not include background or previous work. Does not identify the purpose, the project, the main question(s) or issue being addressed. | Gives very little background or information. May include the main question(s) or issue but does not identify the purpose for addressing them. Unrelated background | Gives a listing of the background information and previous work but does not tie them together well to show how they lead to the purpose of the present work and the questions being addressed. | Effectively ties background to the research question(s) and purpose that directly leads into the question(s) being addressed and the purpose of the research. | This is a step up from Why Important. ¾ here is still good! |
| Define Topic / Gather Sources / Analyze<br>Figures explaining the background | Only one figure is provided that relates to the background of the experiment or material. The relevance of the figure is unclear or not explained. | One or more figures related to explaining the key concepts of the experiments are included. Only one is well discussed and related to the project. | Two or more figures related to explaining the key concepts of the project are included. One may not be explained well or relation clear. | At least two figures clearly illustrate and reinforce the key background concepts and are well integrated into the narrative. | |
| Gather Sources / Communicate<br>Description of material uniqueness | The uniqueness of the material selected is not addressed, or is very general, **such as saying "it hasn't been studied before."** Why might we expect it to be interesting? | Attempts to explain the uniqueness of the material, but the rationale for its interest or value is unclear. | It is communicated what is unique about the material that was selected by the group and at least one application of the material is discussed. | It is well communicated what is unique about the material that was selected and potential material applications (and their importance) are discussed. | |
| Gather Sources<br>References | Referenced information is insufficient to verify where the information was found. | While a reference list exists within the lab notebook, it's not always clear what information was taken from the sources. Formatting poor. | While references are in a nice list and near where the information is mentioned, it could be more clear exactly what information is taken from the reference. | References are cited inline with short names (such as "NIST"), enabling the reader to easily trace information and a full reference list occurs elsewhere. | You must have references to not score a zero here! |

At least 2 references

Define Topic ↔ Gather Sources ↔ Experiment ↔ Analyze ↔ Communicate

You don’t have to do MOKE! But if you want to, please let me know so that we can find good times. It’s literally impossible to find a time that works for everyone, but not everyone is interested in MOKE.

| Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|
| 9:00 am 11 | 9:00 am 10 | 9:00 am 12 | 9:00 am 11 | 9:00 am 11 | 9:00 am 12 | 9:00 am 12 |
| 9:30 am 11 | 9:30 am 10 | 9:30 am 12 | 9:30 am 11 | 9:30 am 11 | 9:30 am 12 | 9:30 am 12 |
| 10:00 am 12 | 10:00 am 11 | 10:00 am 13 | 10:00 am 12 | 10:00 am 12 | 10:00 am 10 | 10:00 am 11 |
| 10:30 am 12 | 10:30 am 10 | 10:30 am 13 | 10:30 am 12 | 10:30 am 12 | 10:30 am 10 | 10:30 am 11 |
| 11:00 am 13 | 11:00 am 10 | 11:00 am 13 | 11:00 am 12 | 11:00 am 12 | 11:00 am 10 | 11:00 am 11 |
| 11:30 am 14 | 11:30 am 9 | 11:30 am 14 | 11:30 am 10 | 11:30 am 13 | 11:30 am 10 | 11:30 am 11 |
| 12:00 pm 14 | 12:00 pm 10 | 12:00 pm 13 | 12:00 pm 11 | 12:00 pm 14 | 12:00 pm 9 | 12:00 pm 10 |
| 12:30 pm 14 | 12:30 pm 11 | 12:30 pm 13 | 12:30 pm 11 | 12:30 pm 14 | 12:30 pm 9 | 12:30 pm 10 |
| 1:00 pm 14 | 1:00 pm 13 | 1:00 pm 13 | 1:00 pm 12 | 1:00 pm 14 | 1:00 pm 9 | 1:00 pm 9 |
| 1:30 pm 11 | 1:30 pm 13 | 1:30 pm 13 | 1:30 pm 12 | 1:30 pm 13 | 1:30 pm 9 | 1:30 pm 8 |
| 2:00 pm 7 | 2:00 pm 12 | 2:00 pm 14 | 2:00 pm 12 | 2:00 pm 9 | 2:00 pm 9 | 2:00 pm 7 |
| 2:30 pm 7 | 2:30 pm 13 | 2:30 pm 13 | 2:30 pm 13 | 2:30 pm 9 | 2:30 pm 9 | 2:30 pm 7 |
| 3:00 pm 5 | 3:00 pm 13 | 3:00 pm 10 | 3:00 pm 14 | 3:00 pm 7 | 3:00 pm 8 | 3:00 pm 7 |
| 3:30 pm 5 | 3:30 pm 13 | 3:30 pm 10 | 3:30 pm 14 | 3:30 pm 8 | 3:30 pm 8 | 3:30 pm 7 |
| 4:00 pm 5 | 4:00 pm 8 | 4:00 pm 8 | 4:00 pm 10 | 4:00 pm 7 | 4:00 pm 7 | 4:00 pm 8 |
| 4:30 pm 5 | 4:30 pm 7 | 4:30 pm 9 | 4:30 pm 9 | 4:30 pm 7 | 4:30 pm 7 | 4:30 pm 8 |
| 5:00 pm 6 | 5:00 pm 5 | 5:00 pm 8 | 5:00 pm 9 | 5:00 pm 5 | 5:00 pm 7 | 5:00 pm 8 |
| 5:30 pm 6 | 5:30 pm 6 | 5:30 pm 8 | 5:30 pm 10 | 5:30 pm 6 | 5:30 pm 7 | 5:30 pm 8 |
| 6:00 pm 5 | 6:00 pm 6 | 6:00 pm 8 | 6:00 pm 10 | 6:00 pm 7 | 6:00 pm 9 | 6:00 pm 8 |
| 6:30 pm 5 | 6:30 pm 6 | 6:30 pm 8 | 6:30 pm 10 | 6:30 pm 7 | 6:30 pm 9 | 6:30 pm 8 |
| 7:00 pm 5 | 7:00 pm 6 | 7:00 pm 8 | 7:00 pm 10 | 7:00 pm 7 | 7:00 pm 9 | 7:00 pm 8 |
| 7:30 pm 6 | 7:30 pm 7 | 7:30 pm 9 | 7:30 pm 10 | 7:30 pm 7 | 7:30 pm 9 | 7:30 pm 8 |
| 8:00 pm 8 | 8:00 pm 9 | 8:00 pm 10 | 8:00 pm 10 | 8:00 pm 8 | 8:00 pm 9 | 8:00 pm 9 |
| 8:30 pm 10 | 8:30 pm 10 | 8:30 pm 11 | 8:30 pm 11 | 8:30 pm 9 | 8:30 pm 10 | 8:30 pm 10 |

Your schedules input into a scheduling program

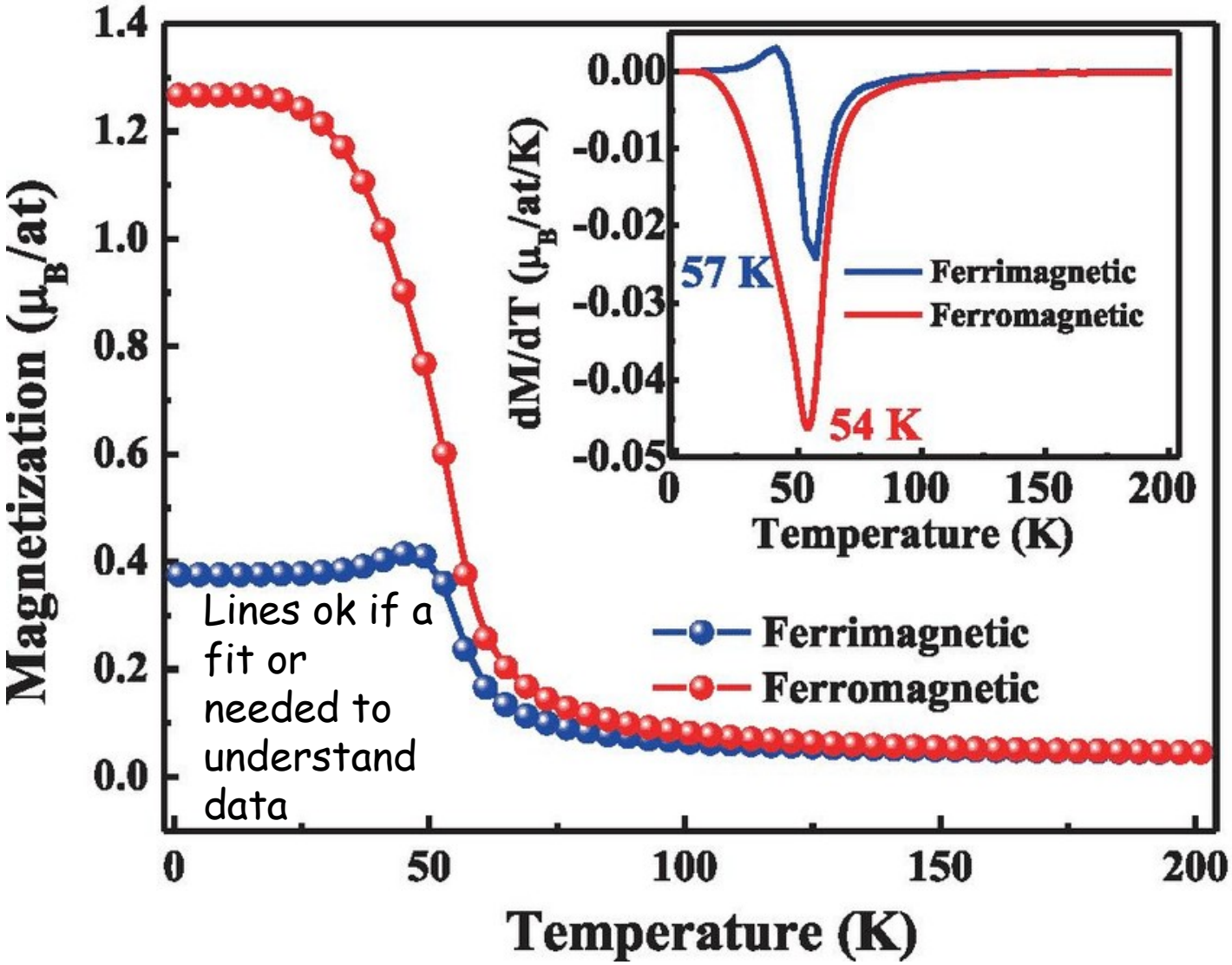
No need to come every time! Just when you want to!

It’s merely an opportunity that you may or may not take advantage of.

Jeremy and Ivan can best do weekends, but if enough people want to and aren’t available, we can consider others.

They found a signal! It’s small. Improving stage.

# Insets can be helpful sometimes if it's related data

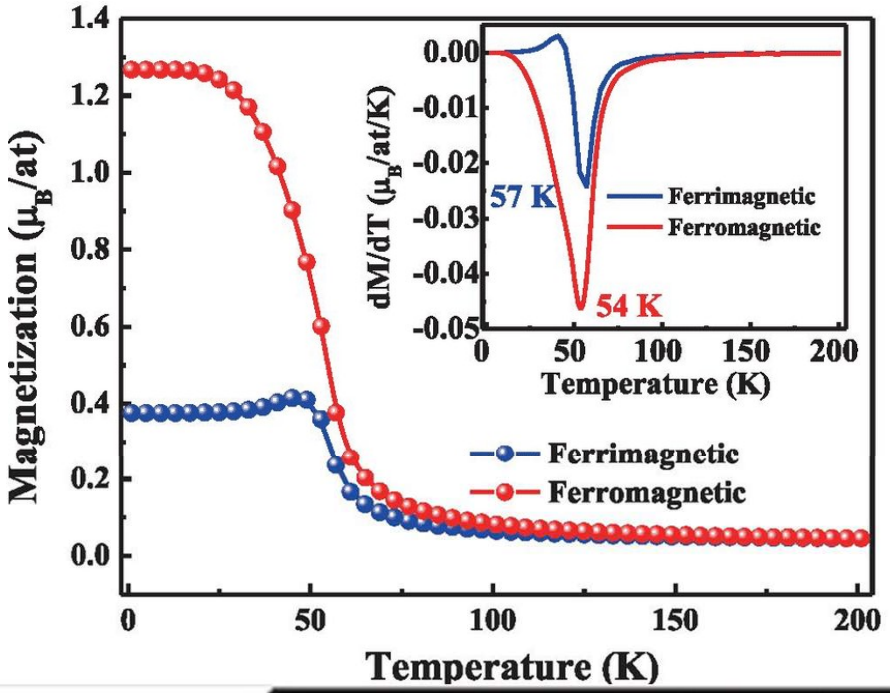


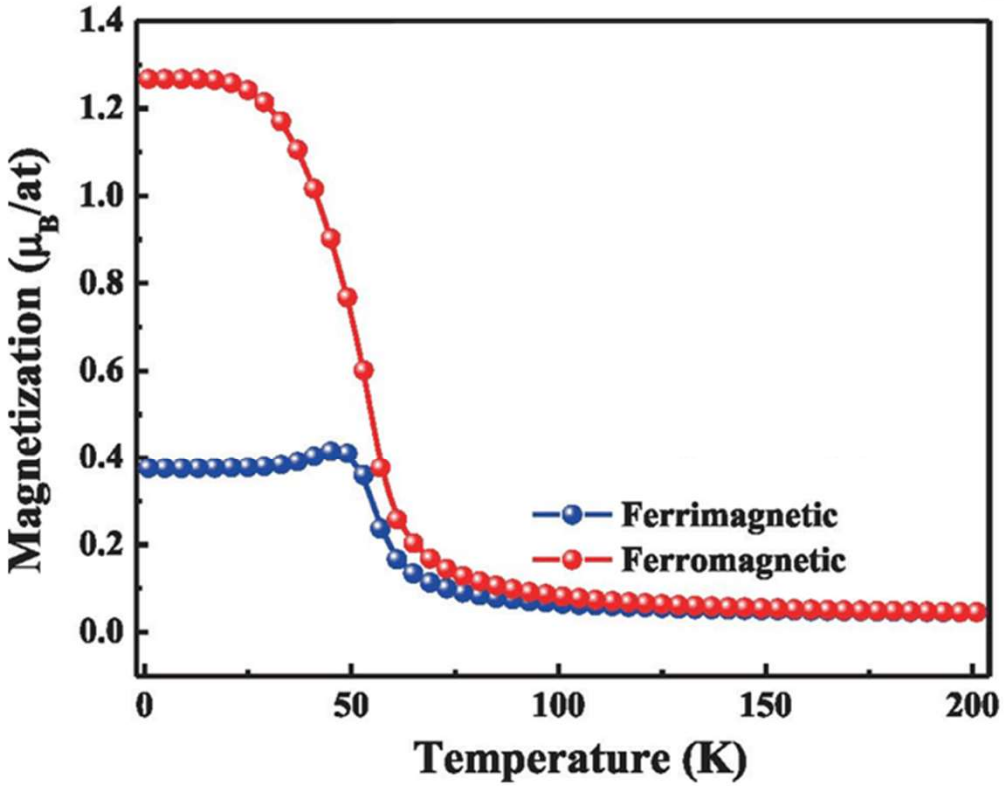

This inset took the derivative of the Magnetization as a function of temperature. They used to dip to better approximate the transition temperature. While not the best way to do it, it is probably the fastest IF you know how to take a derivative of your data. You don't have to. What were other ways we discussed?

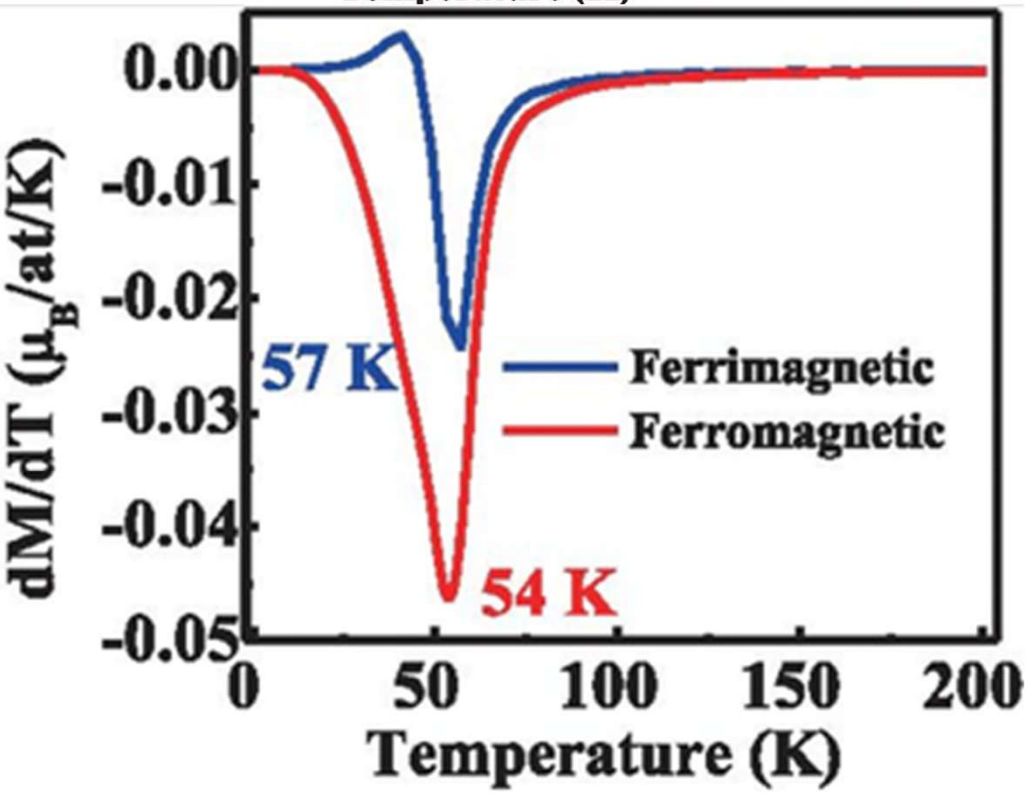
How do you make an inset?

You just shrink it down. What do you notice when I have both the same size?

**The numbers and the line thicknesses have to be bigger to match**



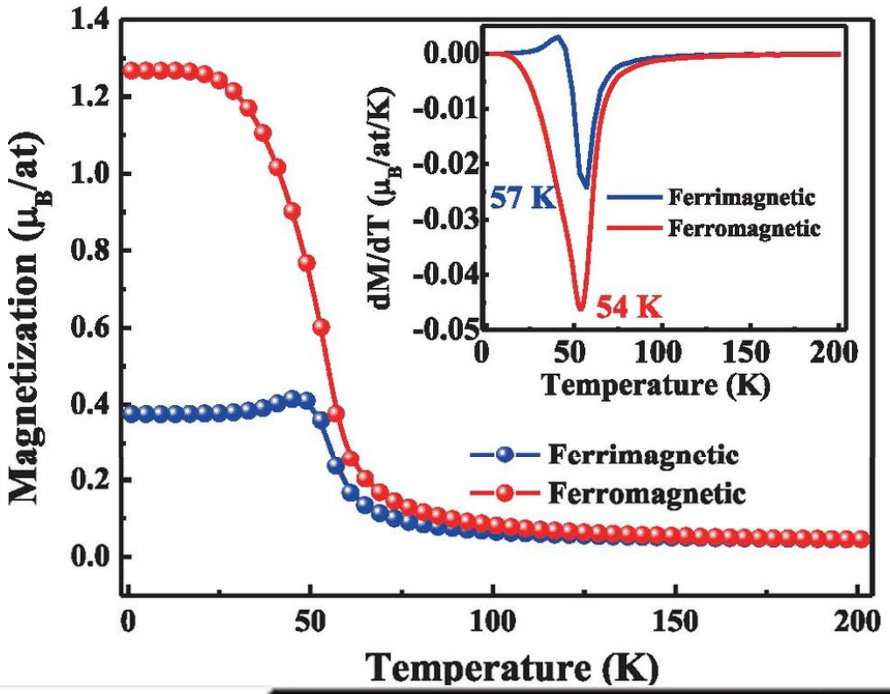



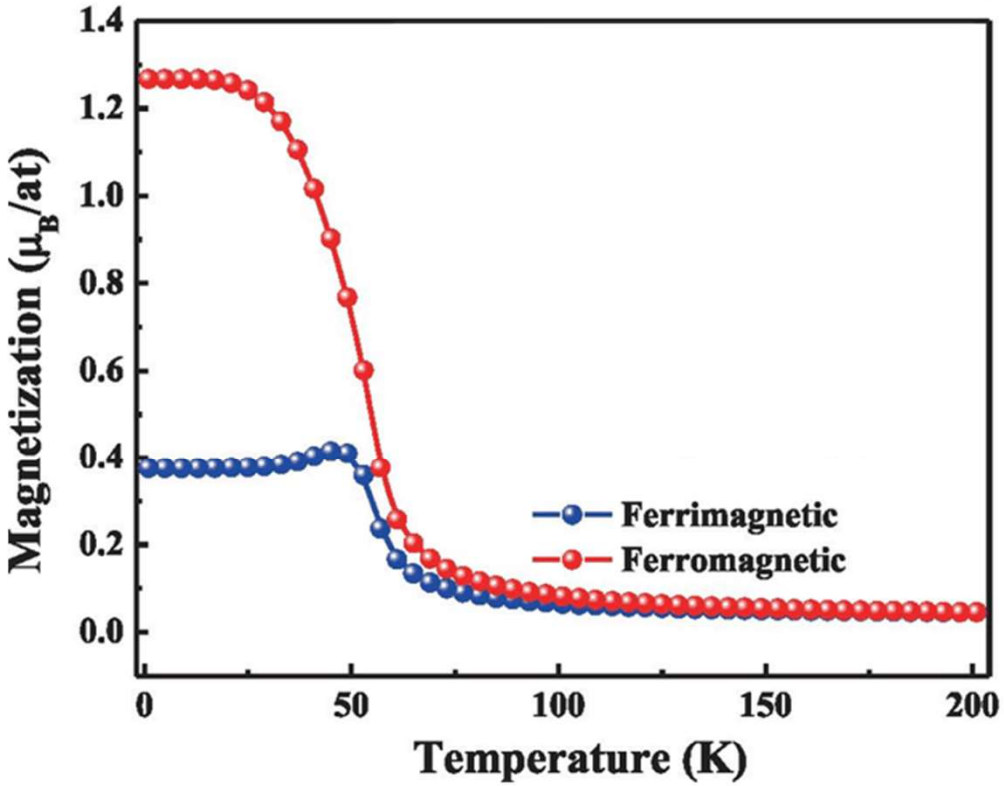



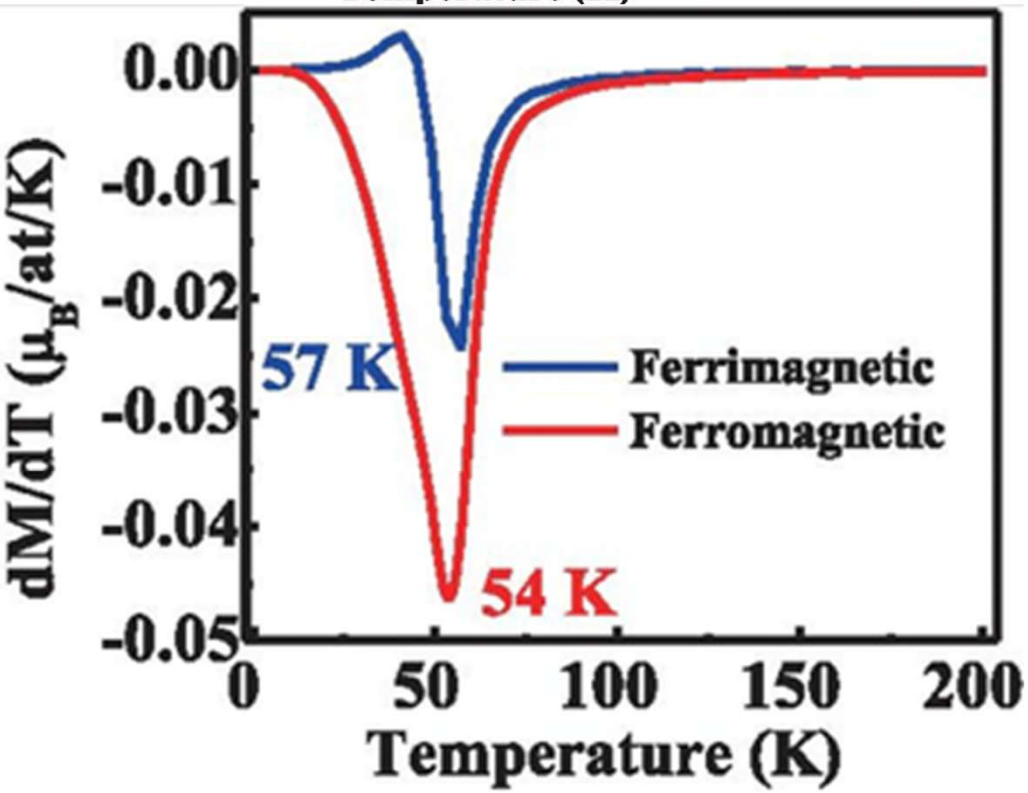
Would I go to all this trouble for a lab notebook? No.

Would I for a paper? Yes, and we are trying to practice that for the Graphing Your Data HW.

**The numbers and the line thicknesses have to be bigger to match**



Last time we talked about many visual aspects to graphs

Let me get into one more conceptual part before we get into the details of how to make graphs

## 1. FIGURING OUT HOW TO DO IT

**The nuts and bolts of making graphs**

- ✓ Choose data
- ✓ Choose axes
- ✓ Scale the axes
- ✓ Plot the points
- ✓ Add labels
- ✓ Add a legend



**A TECHNICAL SKILLSET**

*Important. Necessary.*
*But it's not the whole story.*

*Both are important.*



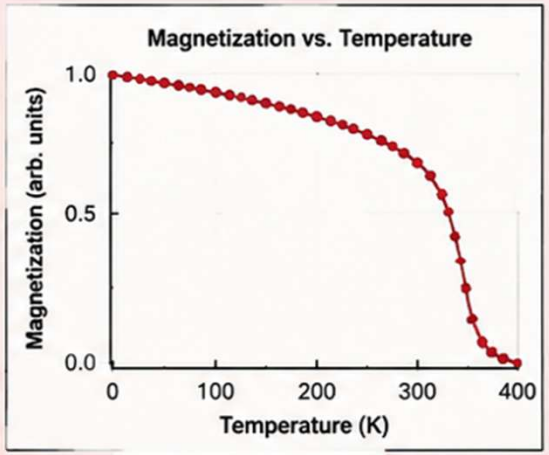

Great graphs need **both** skills!

## 2. DESIGNING IT TO COMMUNICATE YOUR MESSAGE

**The visual part of graphing**



- Clarity
- Focus
- Balance
- Audience




**A DESIGN SKILLSET**

*It turns data into insight.*
*It helps others see what matters.*

# Graphing Your Data Rubric  Material:  Author:

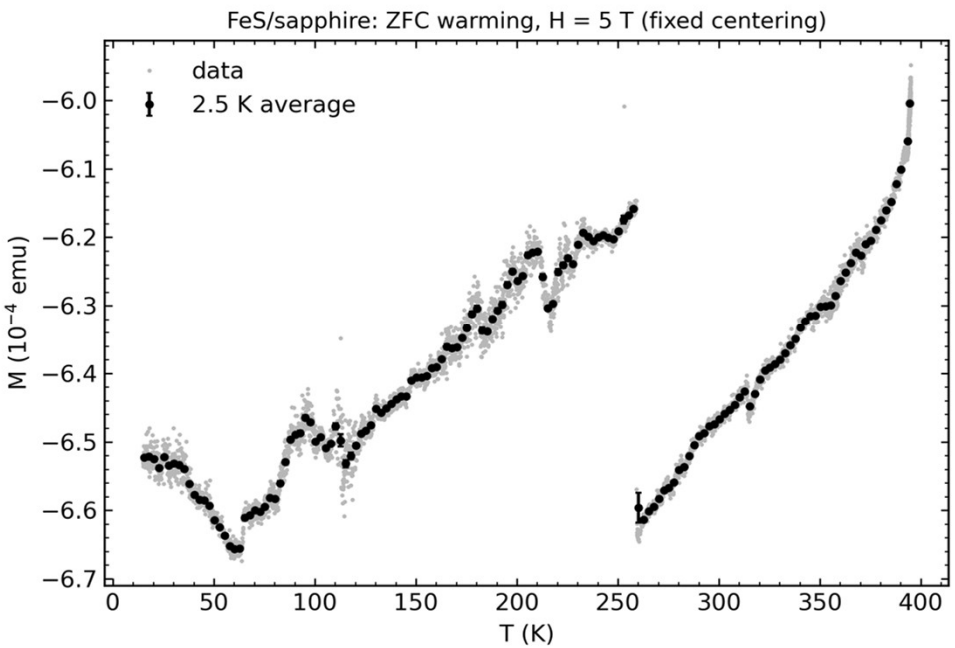
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| Make It Big! | Graph is too small to read comfortably. Axis labels and data are hard to see. | Graph is generally readable, but some elements (e.g., axis numbers or labels) are too small. | Graph and all elements are large enough to read easily, without wasting space. Fits well on a page. | Graph is highly readable and well-sized. All components are well-proportioned and aesthetically clear. | |
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| Axes Labels With Units | One or both axes are missing labels. | Labels are present but units are missing, incorrect, or in nonstandard form.y | Both axes have correct labels and standard units. | Axes are clearly labeled with accurate and standard units. Labels are well-placed and unambiguous. | |
| Normalizing and Correcting Data | No attempt is made to subtract background or normalize data, or the method used is clearly incorrect and distorts the results. | One or both processes are attempted but done inconsistently or with insufficient justification. Methods may be unclear or poorly documented. | Data is correctly background-subtracted and normalized using standard and appropriate methods (e.g., subtracting a baseline, normalizing to max/min). The process is briefly explained. | Both background subtraction and normalization are done clearly and skillfully. The result is clean, interpretable data that maintains physical meaning and supports meaningful comparison. | |
| A Full Box Around Your Graph | No border around the graph area; axes are floating or incomplete. | Only partial borders are present, or framing is inconsistent. | A full box surrounds the data area, improving clarity and presentation. | Box is present and enhances visual appeal. It helps define the data space without distraction. | |
| Legend/Labels for When More than One Set of Data | Multiple data sets are plotted separately or without identification. | Labels/legend are present but unclear or hard to distinguish (e.g., similar colors/symbols). | Each data set is clearly labeled with a distinct legend or direct labels. Comparisons are easy. | Labeling is exemplary—distinct, clear, and enhances comparative understanding of multiple data sets. | |
| No Gridlines and Don't Connect the Dots | Gridlines are present and distracting. Data points are connected by default lines. | Either gridlines or line connections remain, though effort is made to follow instructions. | No gridlines. Data points are not connected. A fit line is only added when appropriate. | Excellent attention to detail. Gridlines and inappropriate connections are avoided. Fit lines or reference lines are clearly marked and relevant. | |

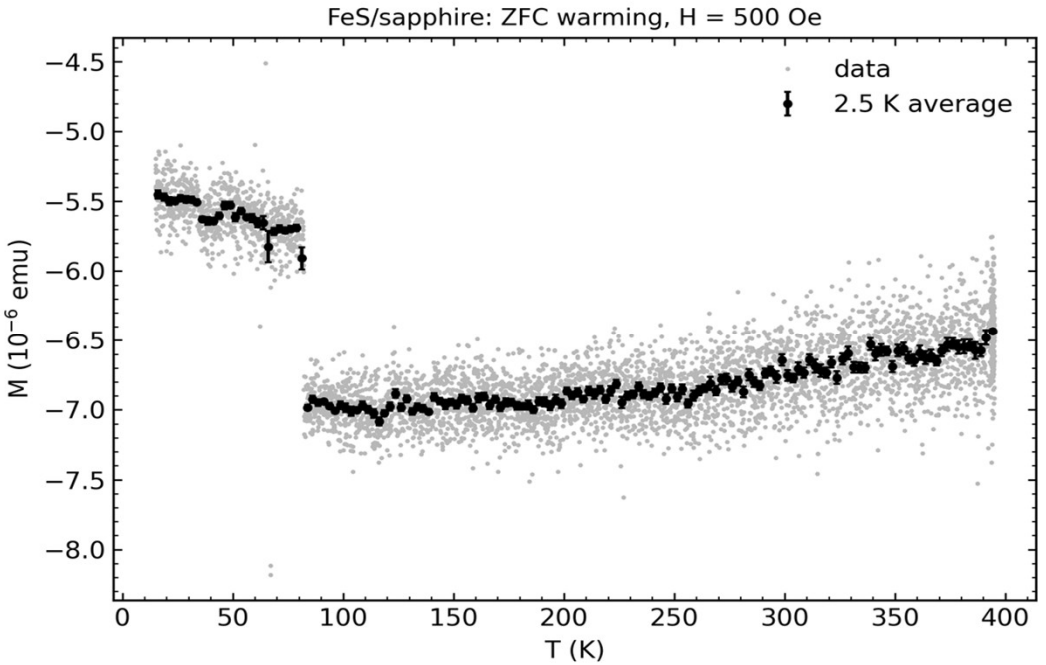
Background subtraction, dealing with any jumps or artifacts

# Normalizing/“Correcting” Data

- If you don’t know the thickness of your films, you won’t be able to normalize the magnetic moment into the magnetization axis. Most of you don’t, so maybe let’s not focus on that part. (I can discuss it later if time and requested, but let’s get through the other stuff first.)
- There are two other types of “corrections” that you might want to do. You’ll need to do some form of correction to get a 100% on your Graphing Your Data Homework (Nov. 5)

# The data will sometimes be wrong
# Two examples from Group 1




**First**: These are not perfect graphs for papers. If there weren't still issues with the data, they'd get an A on my rubric, but not 100%. Besides the data itself, what do you notice that doesn't seem to jive with what we talked about last time. No graphing program gives perfect graphs unless you program it perfectly.

Graphing Your Data Rubric  Material:  Author:

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In the Graph Your Data HW, you practice improving

Due Nov 5

# Graphing Your Data Rubric

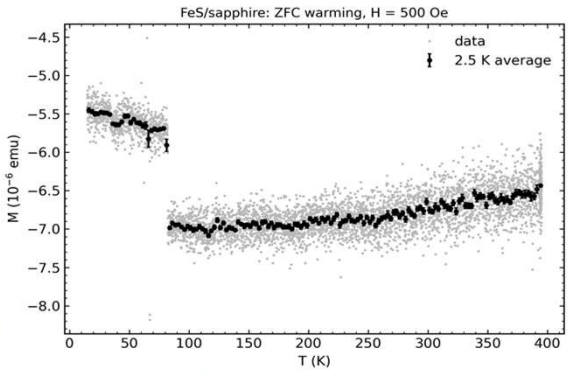
Grade = B, mostly pretty but raw data with no figure caption, axes small

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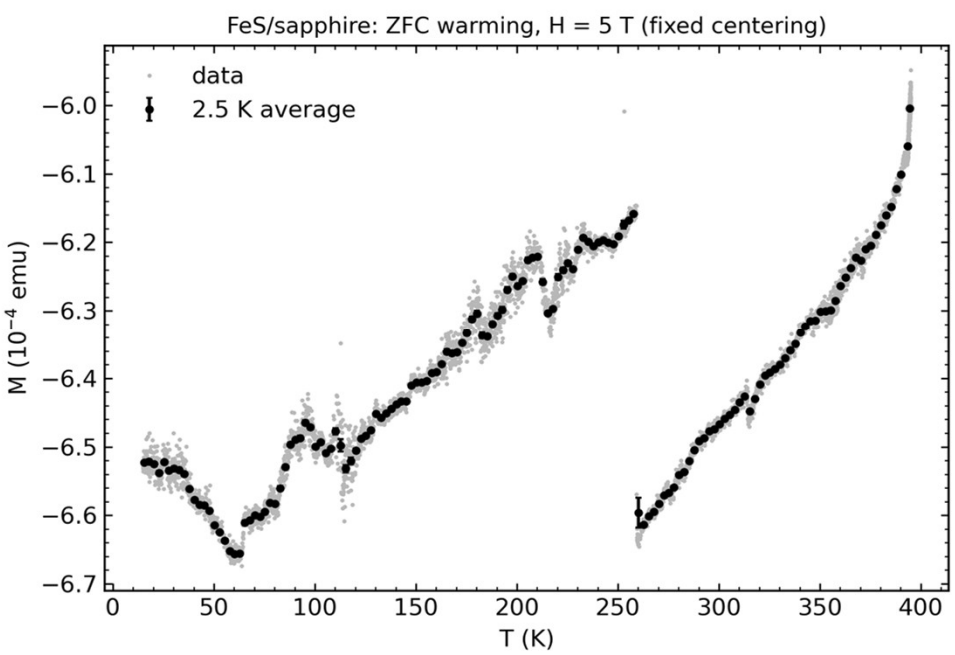
But I'd prefer you spell out temperature and magnetic moment

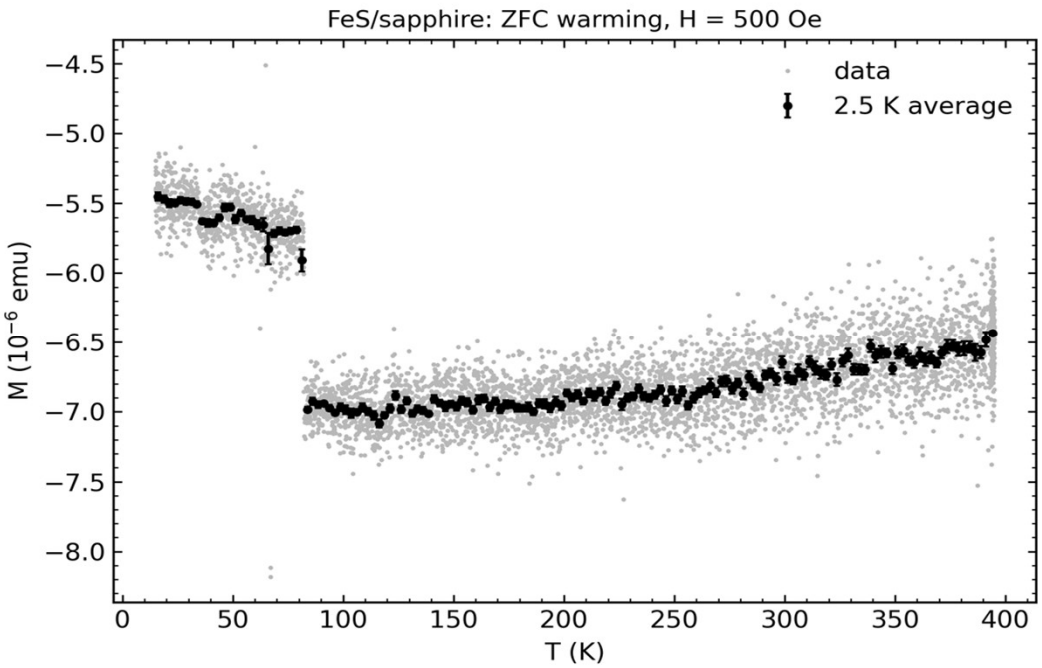
Rubrics are designed to

1. Make it more clear where you need improvement
2. Make expectations clear



# The data will sometimes be wrong
# What looks fishy about this data?

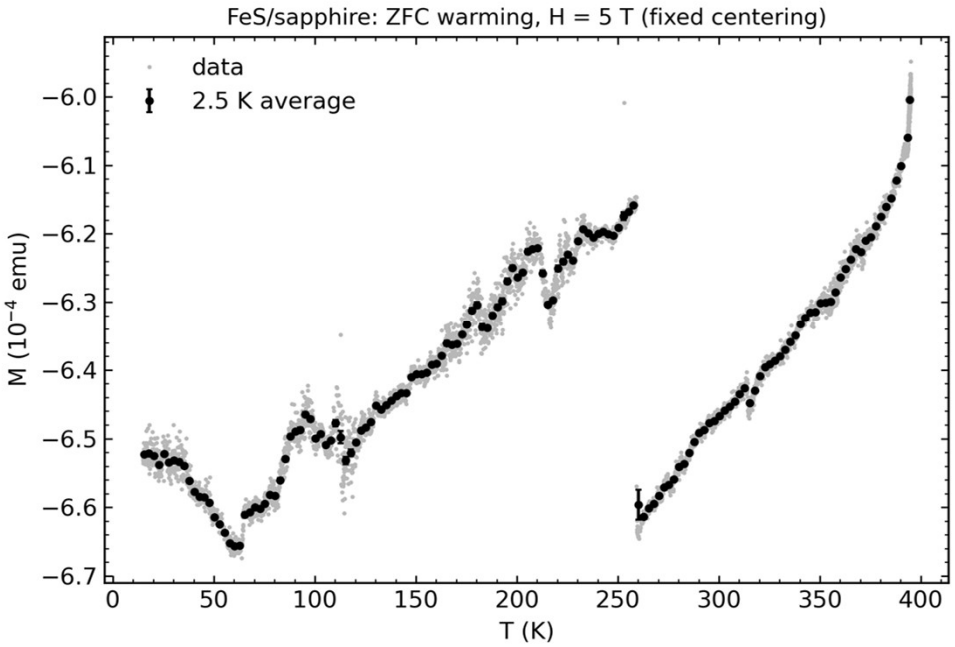


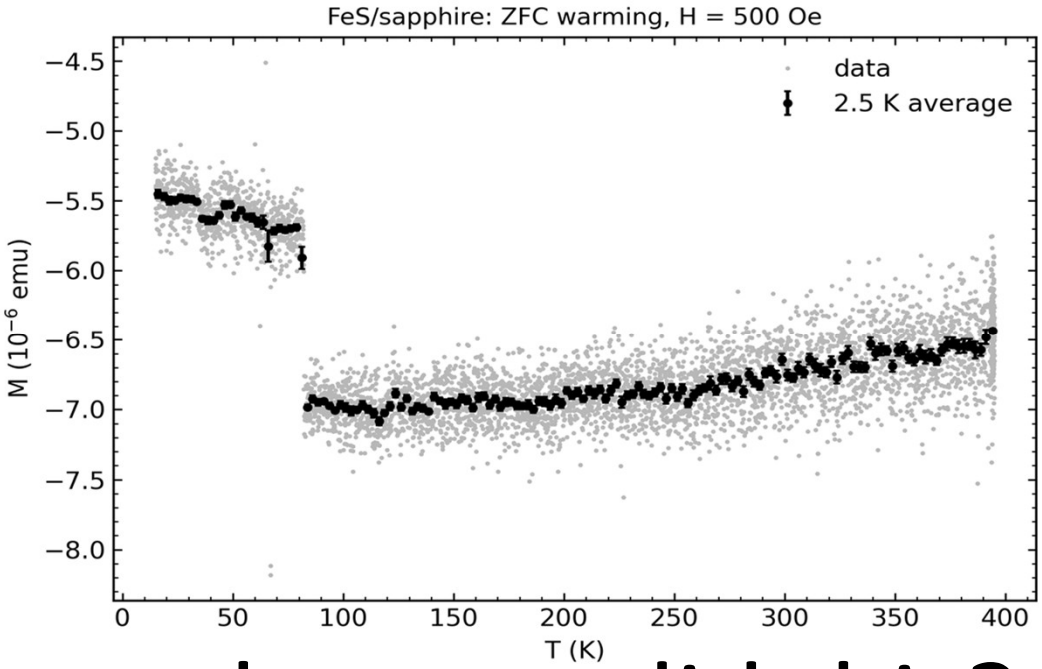




Any ideas what might cause it?

Any ideas how we might check whether or not it is real?

# If you had enough data to be certain this were a machine artifact and no time to repeat, what might you do?




How should you disclose that you did this?

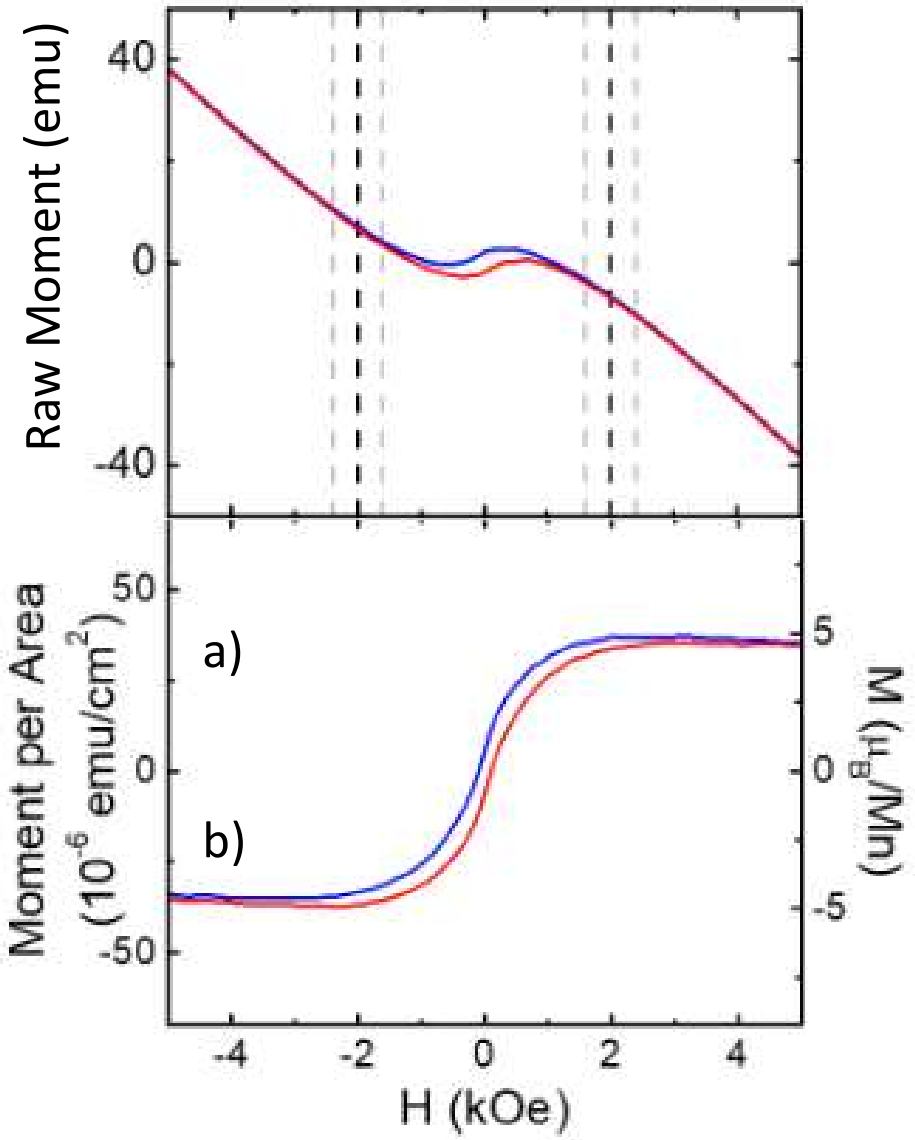
With words but also the scale. How do you know which one is right?

Could use a normalized scale. Set something =1.

# Careful

- If it were a paper, you'd want to repeat the data. But for brainstorming, some form of correction would be fine.

# Why do we need to process it at all?

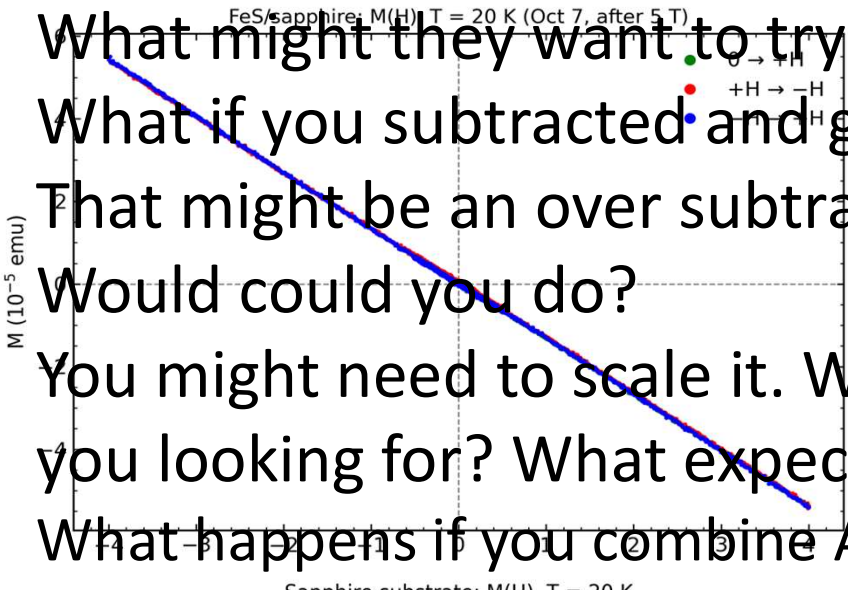


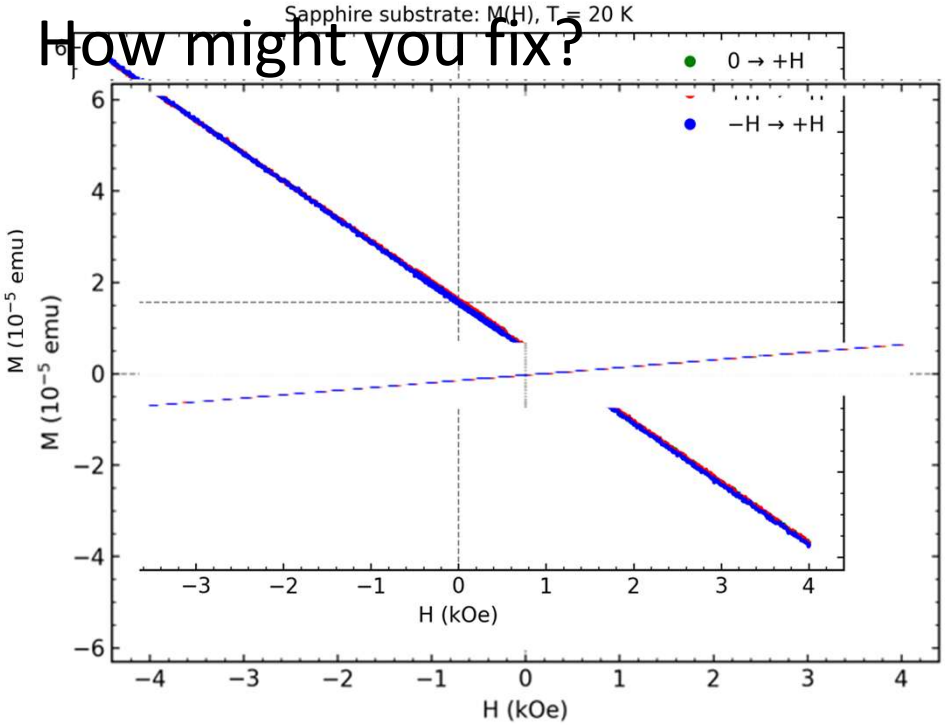

- Remember that the vibrating sample magnetometer (VSM) system gives total magnetization.
- This includes the substrate, which will have some type of magnetism. What kind here?
- It is also not normalized for volume.
- First, we subtract the substrate signal.

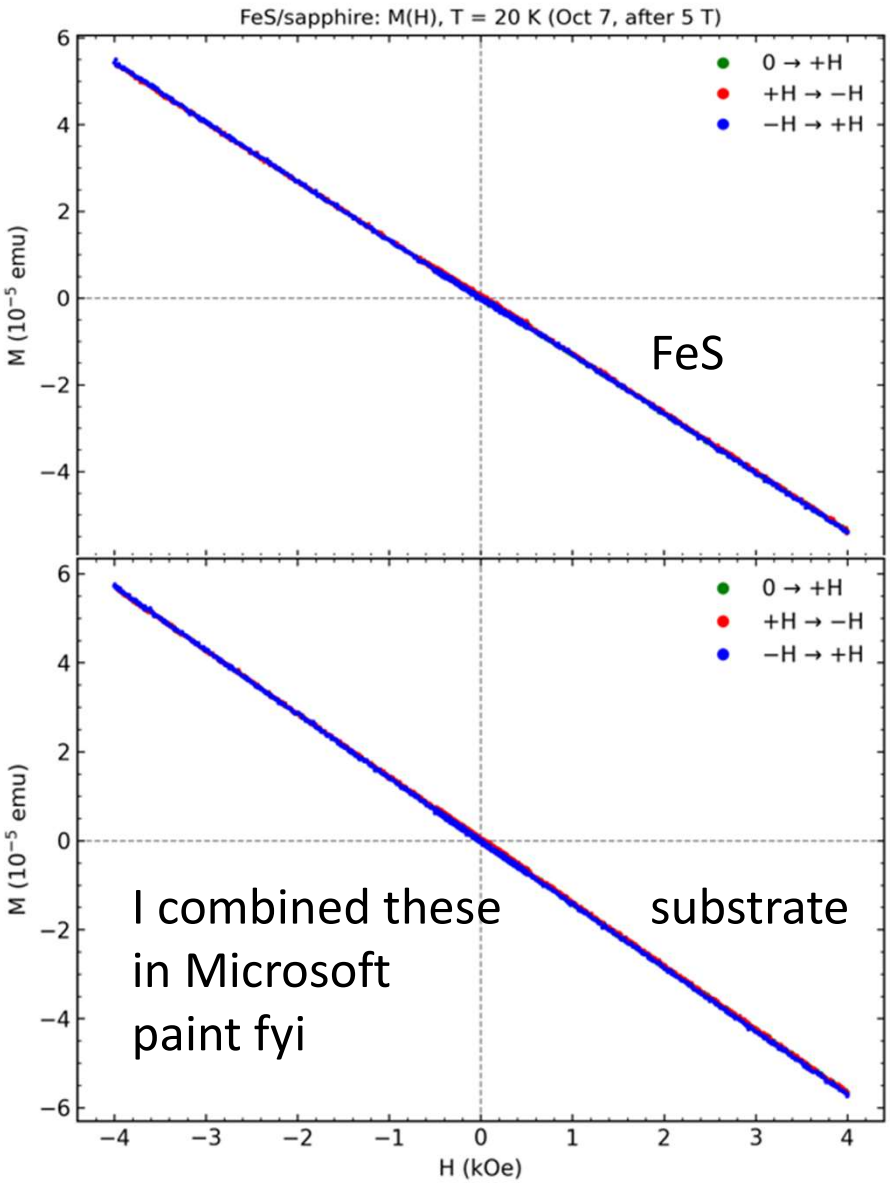
https://arxiv.org/ftp/arxiv/papers/1807/1807.01348.pdf

# Extreme case: FeS/sapphire

What might they want to try next?
What if you subtracted and got this?
That might be an over subtraction.
Would could you do?
You might need to scale it. What are you looking for? What expecting?
What happens if you combine AFM&DM?
How might you fix?



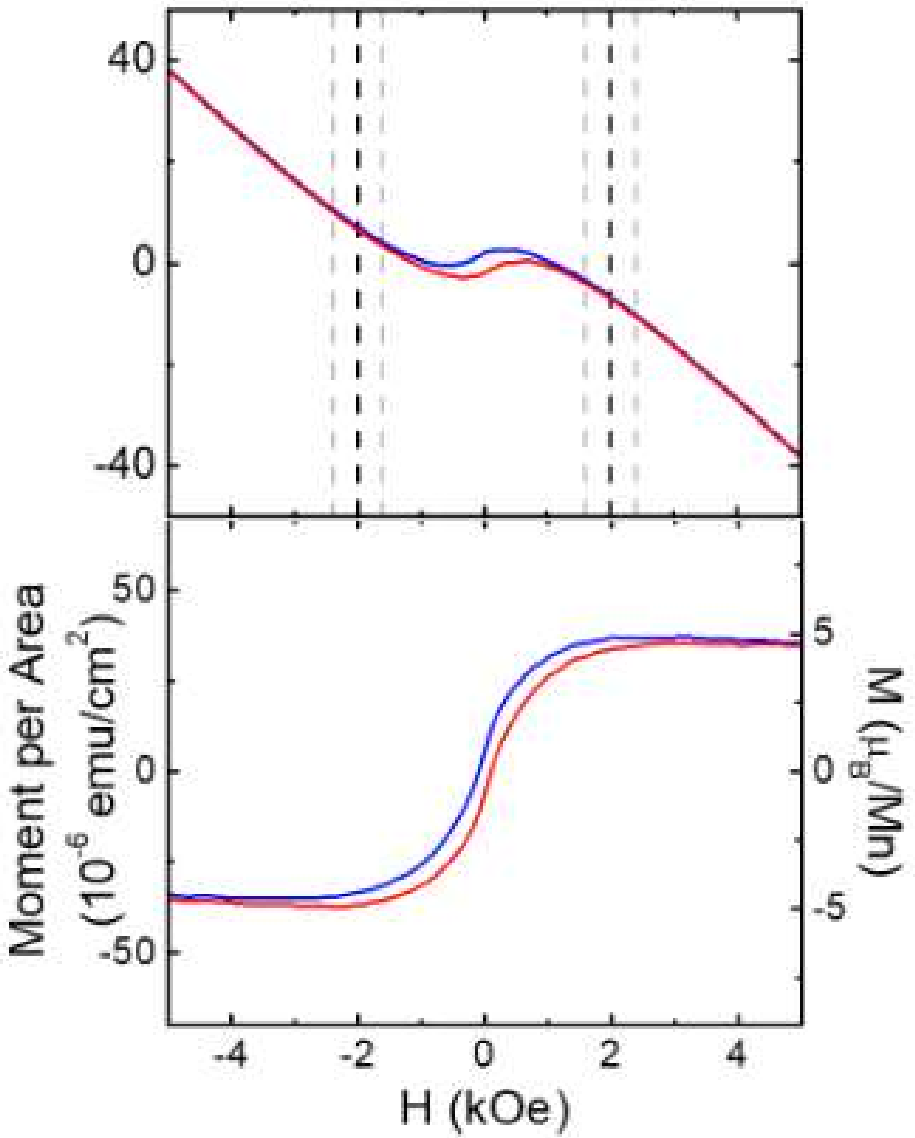
# Substrate subtraction doesn't always work for two main reasons




It's not uncommon for scientists to cut our substrates in half. Gives us twice as many substrates, but cutting will lead to small variations.

Even if the substrate is exactly the same (looks to be the case for FeS/FeTe examples), the growth process itself COULD change the sample. Heat can add vacancies, for example.

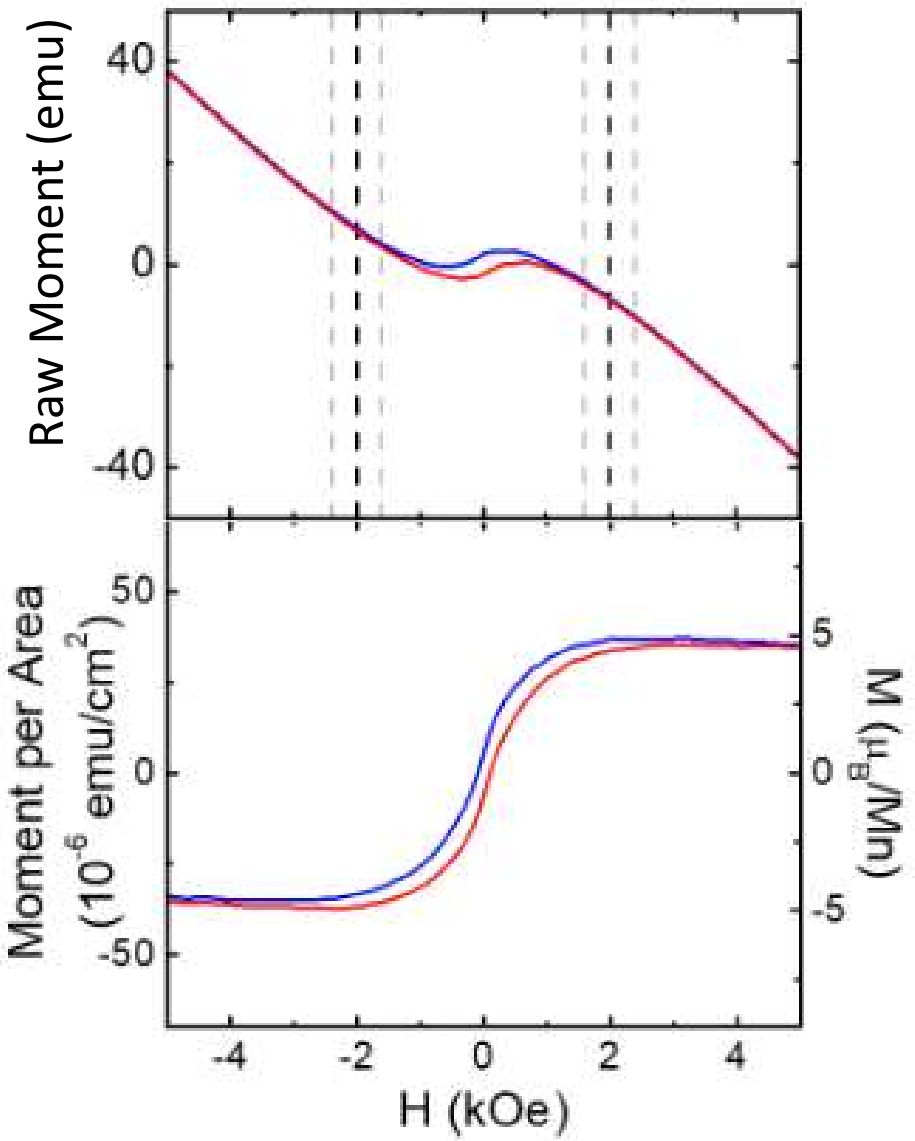
# Altermagnet groups have substrate data, but others don't. What then?




We did a substrate for them because we saw the magnetic signal was small and potentially dominated by the substrate. I don't expect that for the rest.

This figure is a hint.

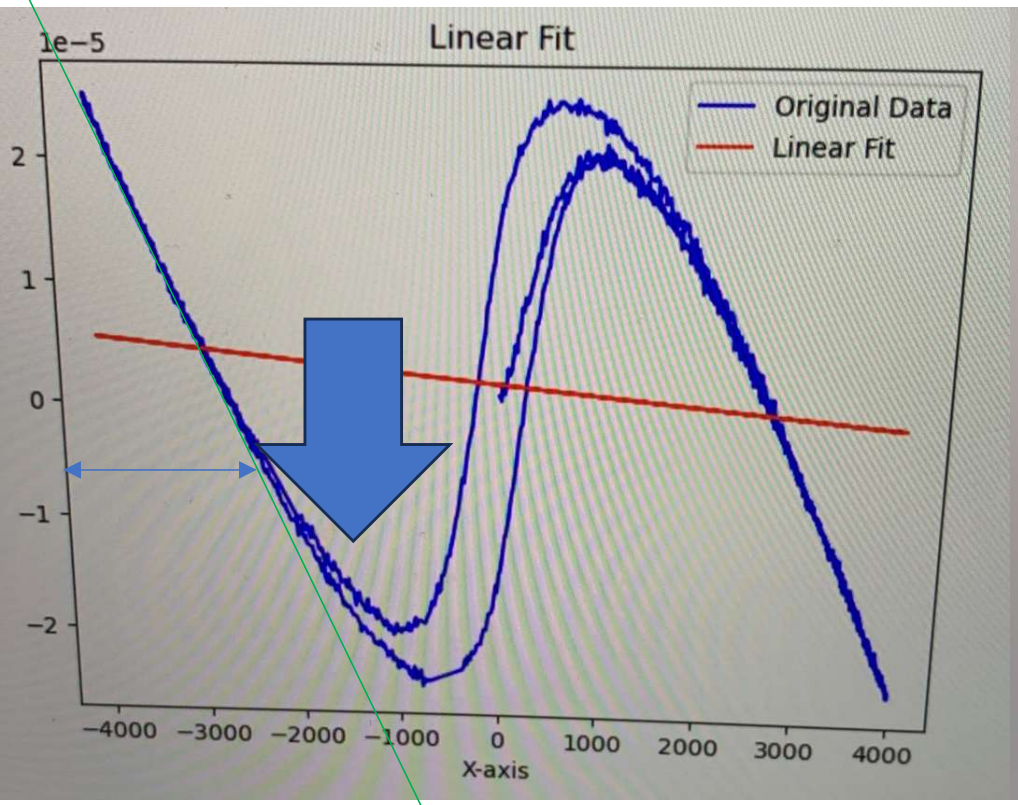
# How exactly do you subtract?



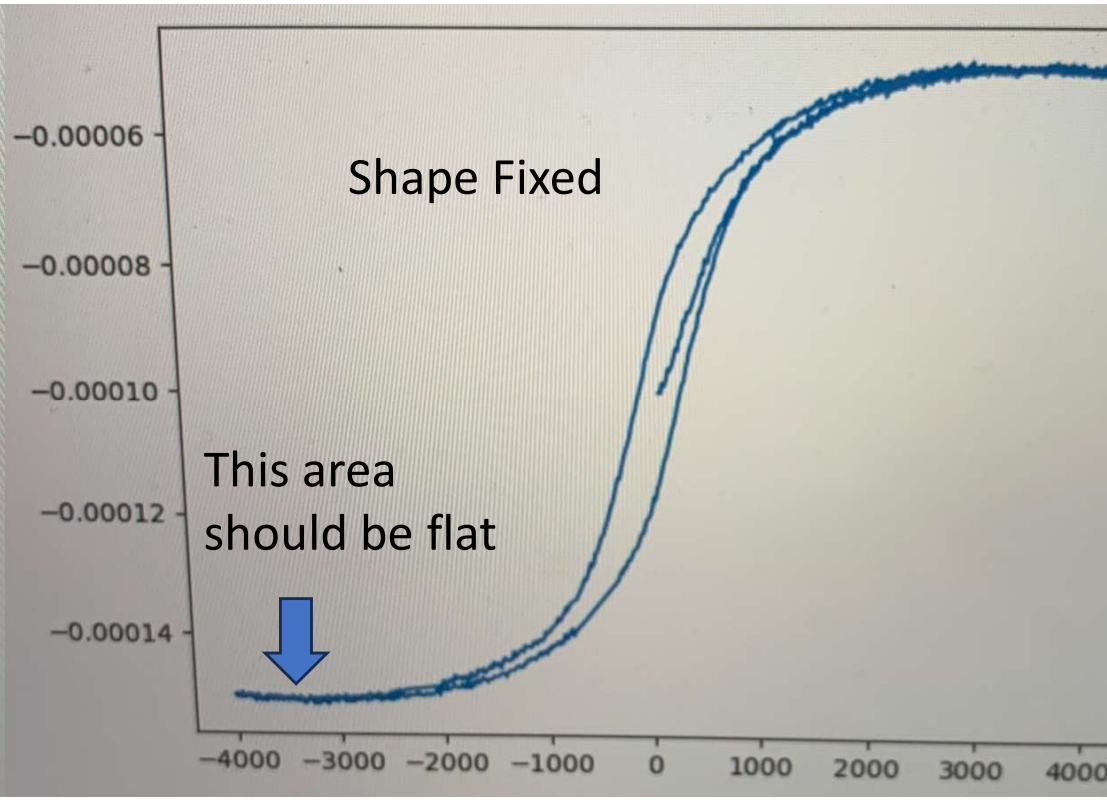

- We have two lines. Would it be better to use just one?
- Should they have the same slope?
- Where should we cut out the data? Do we even need to?
- (See next slide for why)

https://arxiv.org/ftp/arxiv/papers/1807/1807.01348.pdf

# Linear fit if you don't subtract the middle. Fit the tails!




Applied Magnetic Field (Oe)




Applied Magnetic Field (Oe)

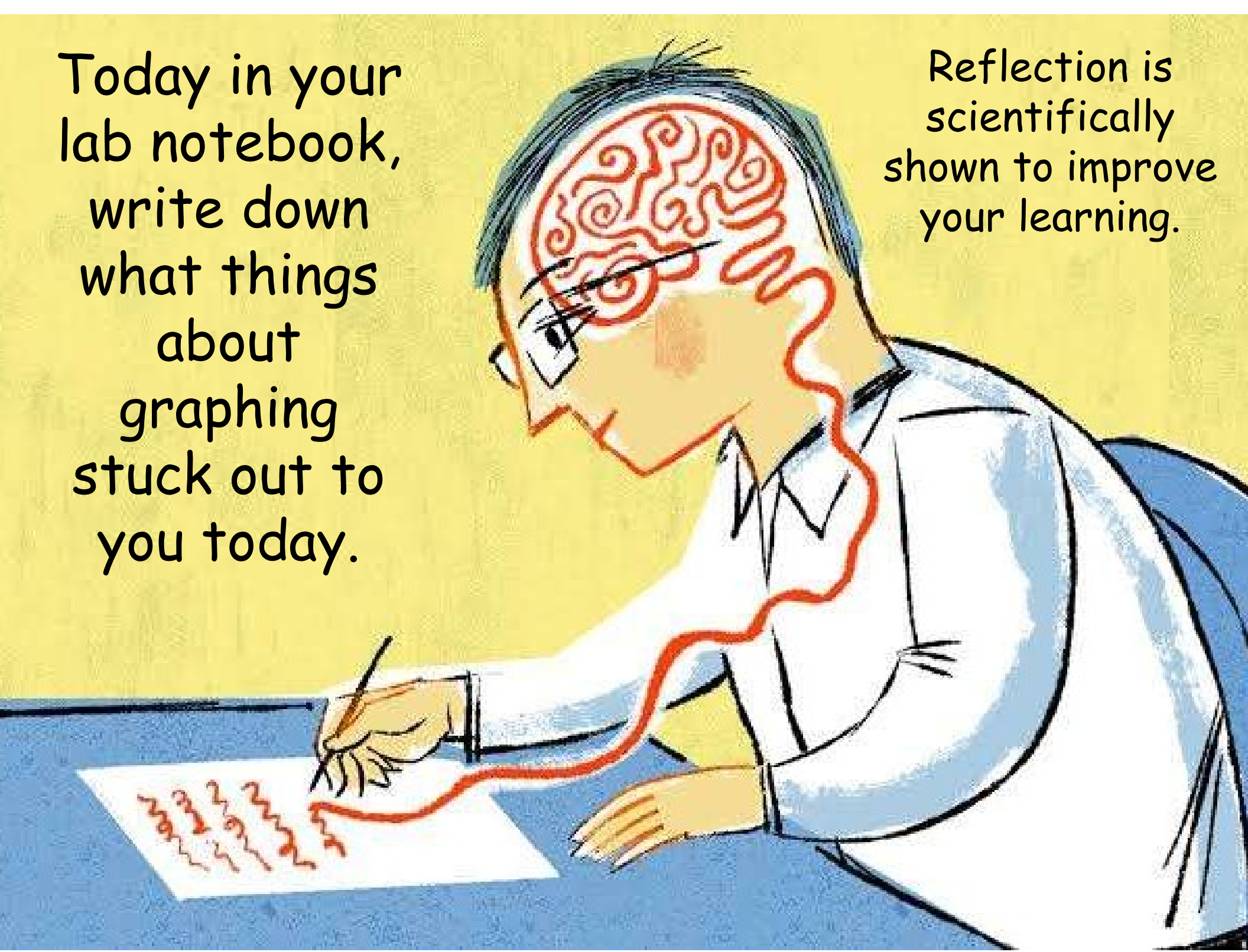
Anything else seem weird?

Should be centered around zero.

If you take data too close to loop, it will also affect your fit. I recommend plotting the fit to make sure it looks like this line!

Today in your lab notebook, write down what things about graphing stuck out to you today.

Reflection is scientifically shown to improve your learning.



# Any Questions Before We Shift Gears to HOW TO PLOT GRAPHS?

## 1. FIGURING OUT HOW TO DO IT

**The nuts and bolts of making graphs**

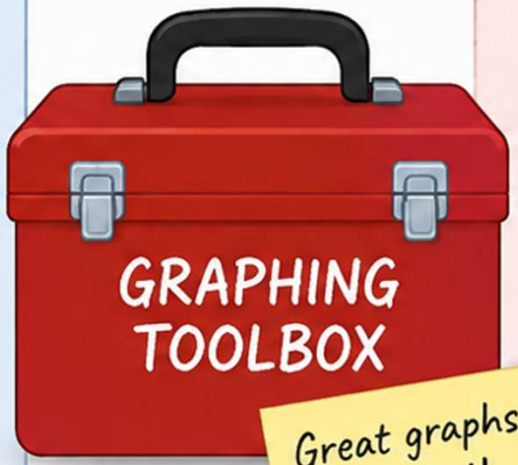
- ✓ Choose data
- ✓ Choose axes
- ✓ Scale the axes
- ✓ Plot the points
- ✓ Add labels
- ✓ Add a legend



**A TECHNICAL SKILLSET**

*Important. Necessary.*
*But it's not the whole story.*

*Both are important.*



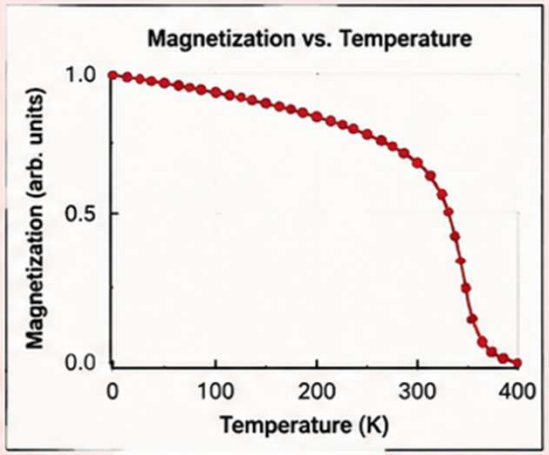

Great graphs need **both** skills!

## 2. DESIGNING IT TO COMMUNICATE YOUR MESSAGE

**The visual part of graphing**



- Clarity
- Focus
- Balance
- Audience




**A DESIGN SKILLSET**

*It turns data into insight.*
*It helps others see what matters.*

How many of you have graphed data points before?

What program(s) have you used?