Physics 3306

Provides an introduction to a wide variety of topics in classical (pre-quantum) physics as a bridge to prepare students for subsequent upper-level courses in physics. The topics covered include thermodynamics, fluid mechanics, mechanical waves, optics, radiation, electromagnetic phenomena, atoms, and laboratory techniques. Prerequisites: C- or better in PHYS 1106; and in PHYS 1304 or PHYS 1308.

Saptaparna Bhattacharya

February 5th, 2025

A few announcements

- I have lab reports from five of you
- Could the rest of you send them to me as soon as you can?
  - What deadline would you like? Friday of every week by midnight?
- We should use canvas for lab submission
- Let's try with assignments on canvas
- Emailing is fine but the subject line needs to be a bit more descriptive
  - Please rename the file with your first-name_last-name_Lab_1.ipynb (Lab 1 is for lab 1!)
- Award for the funniest email subject goes to "that's my lab, bro"!

A few announcements

- Which brings me to:
  - My name is Saptaparna Bhattacharya
  - Please feel free to refer to me as: Dr. Bhattacharya, Prof. Bhattacharya or even Sapta — they are all OK

A few announcements

- Please check that the jupyter notebook is filled
- I have received at least one unfilled notebook

A few announcements

- Mishaps can happen to any of us, so I will grant each of you a makeup class
- Typically, the Lab 60 classroom is free one hour before and after the lecture
- It is *your* responsibility to find a classmate who can help you out or a member of your lab group to come and assist you in the hour before and after class
- If these two time slots don't work or you cannot do the experiment in two parts (you can always keep your apparatus in the back room), you should let me know and I will find out when the classroom is free — I will come and open the door for you and do my work at the desk, while you finish the lab

Finally…

- I have placed bandaids here at the desk — use them as you see fit
- If you are injured or a classmate is injured, immediately call SMU emergency: 214-768-3333
  - This number is for a life threatening situation
  - For non-life threatening situations, call 214-768-2277
- In general, the SMU webpage on emergencies is very thorough: https://www.smu.edu/studentaffairs/drbobsmithhealthcenter/counseling-services/emergencies

Undergraduate research

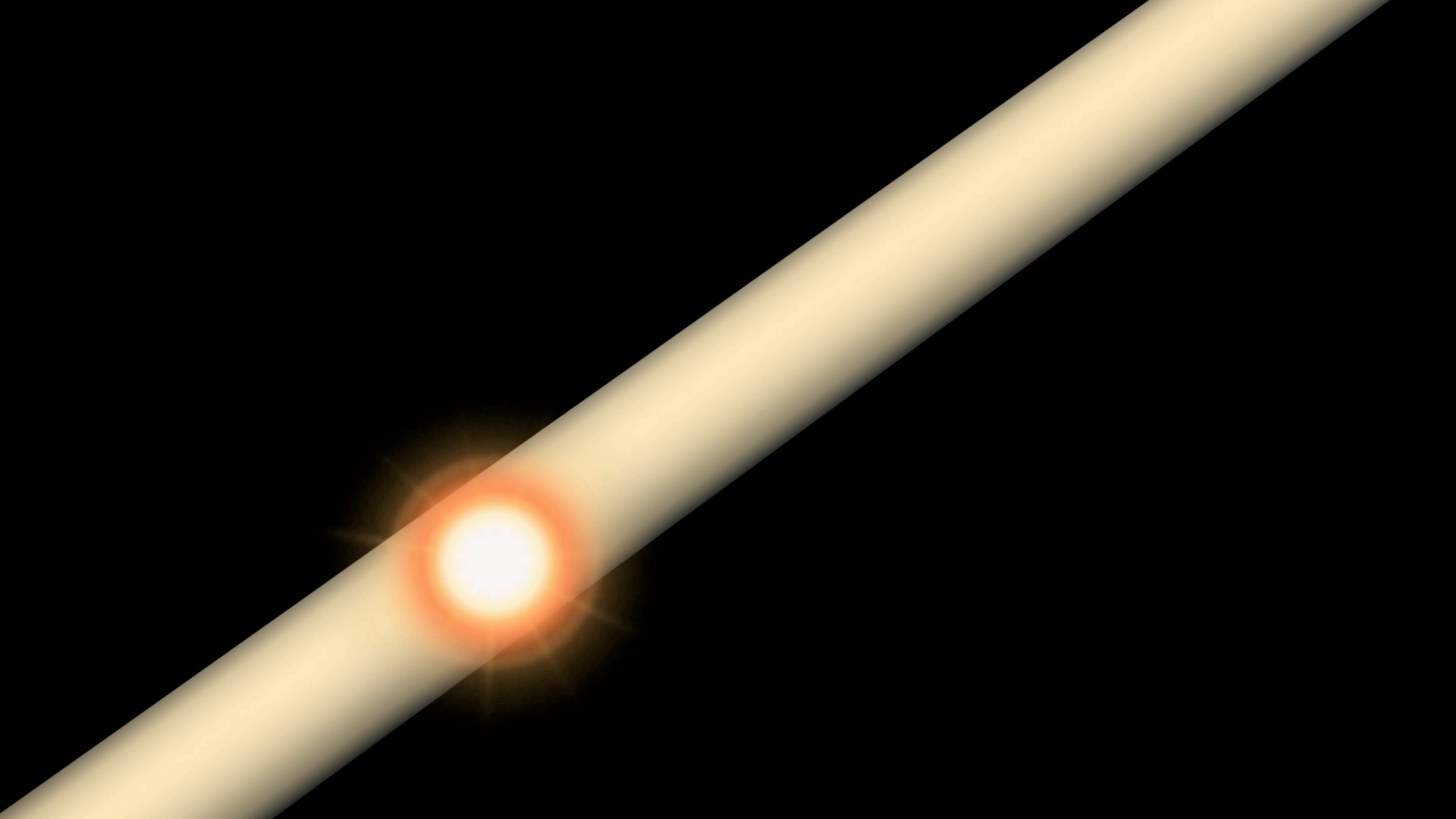
- Some of you expressed interest in doing research with me
- I found that the department supports undergraduate research
- In my conversation with Prof. David. Son, I have found out that undergraduates can be paid $12-15/hour for research
- Those of you who are interested, please let me know your availability via email and we will fix a time
- I think I had suggested Monday earlier, but we can start on Friday — will probably have to be afternoon at this point

Back to regular programming now!

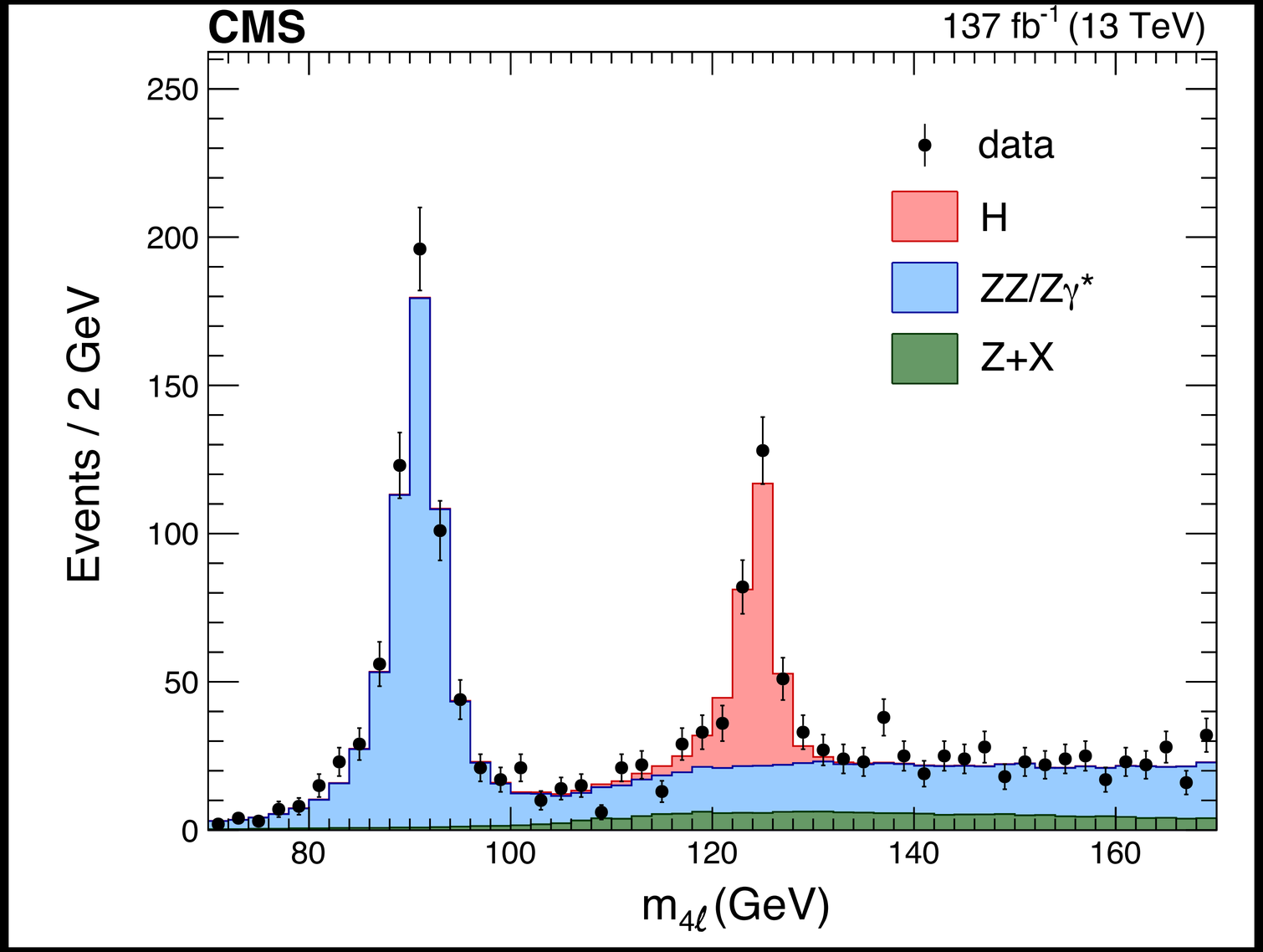
Lab reports

What is a data point?

- It is one instance of any measurement
- Google AI tells me: “A data point is **a discrete unit of information**. In a general sense, any single fact is a data point. The term data point is roughly equivalent to datum, the singular form of data.”



Each black dot is a data point: shown here with a statistical uncertainty



What data have we collected here?

- Examples?

What kind of data could we collect?

- Examples?
- Let’s look at the spreadsheet here: https://www.weather.gov/fwd/dmotemp

Let’s see if we can reproduce the results

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January			Jan. 1 High: 53°F Low: 38°F	Jan. 2 High: 59°F Low: 38°F	Jan. 3 High: 64°F Low: 41°F	Jan. 4 High: 68°F Low: 55°F	Jan. 5 High: 68°F Low: 25°F
	Jan. 6 High: 40°F Low: 21°F	Jan. 7 High: 41°F Low: 24°F	Jan. 8 High: 40°F Low: 27°F	Jan. 9 High: 37°F Low: 31°F	Jan. 10 High: 38°F Low: 30°F	Jan. 11 High: 55°F Low: 25°F	Jan. 12 High: 52°F Low: 35°F
	Jan. 13 High: 52°F Low: 28°F	Jan. 14 High: 56°F Low: 29°F	Jan. 15 High: 61°F Low: 32°F	Jan. 16 High: 64°F Low: 33°F	Jan. 17 High: 63°F Low: 47°F	Jan. 18 High: 58°F Low: 29°F	Jan. 19 High: 35°F Low: 22°F
	Jan. 20 High: 34°F Low: 22°F	Jan. 21 High: 33°F Low: 22°F	Jan. 22 High: 51°F Low: 24°F	Jan. 23 High: 51°F Low: 26°F	Jan. 24 High: 57°F Low: 26°F	Jan. 25 High: 56°F Low: 37°F	Jan. 26 High: 51°F Low: 42°F
	Jan. 27 High: 54°F Low: 31°F	Jan. 28 High: 59°F Low: 47°F	Jan. 29 High: 61°F Low: 52°F	Jan. 30 High: 68°F Low: 56°F	Jan. 31 High: 66°F Low: 46°F		

Source: https://www.accuweather.com/en/us/north-dallas/75230/january-weather/3591134?year=2025

Let’s select a different month: based on your personal experience is there a month where the temptation variation is not quite as severe

July 2024 DAILY →

S	M	T	W	T	F	S
30	1	2	3	4	5	6
100° 82°	100° 84°	101° 82°	100° 83°	100° 82°	91° 74°	95° 72°
7	8	9	10	11	12	13
97° 80°	85° 74°	95° 71°	99° 77°	98° 78°	97° 79°	95° 77°
14	15	16	17	18	19	20
99° 77°	100° 79°	101° 83°	90° 79°	91° 76°	93° 75°	95° 73°

21	22	23	24	25	26	27
87° 73°	89° 75°	87° 74°	93° 74°	92° 76°	88° 74°	92° 75°
28	29	30	31	1	2	3
95° 75°	97° 79°	98° 79°	99° 81°	102° 78°	104° 81°	101° 74°

Data analysis is powerful

- You can debunk claims

Small sample sizes

Smaller sample sizes mean less power and a lower probability of a true research finding.

Flexibility in design

Greater flexibility in designs, definitions, outcomes, and analytical modes can lead to less likely research findings.

Financial and other interests

Greater financial and other interests and prejudices can lead to less likely research findings.

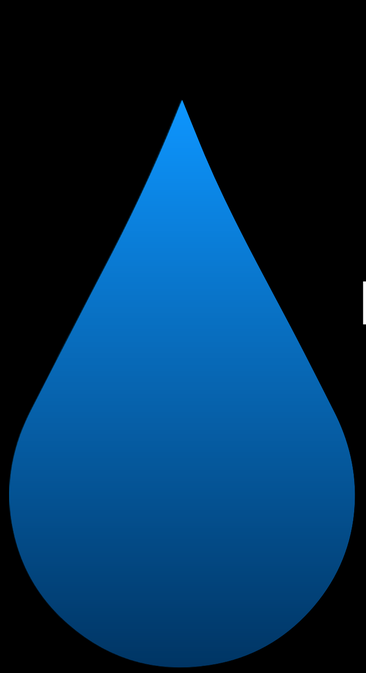
Solutions

- **Fraud checkers**: Technology startups can help publishers, researchers, and institutions spot potential fraud.
- **Open access journals**: Open access journals can be less rigorous than they claim.

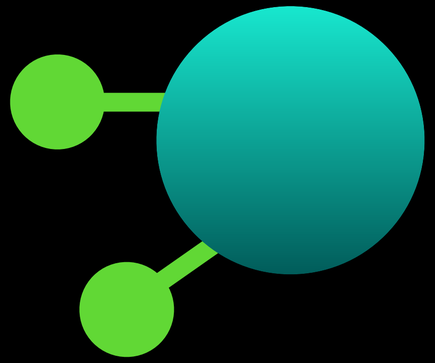
Measurement uncertainty

- Most of you have quoted the uncertainty associated with the instrument
- This is where it is key that you pick that correct instrument or setting
- Where have we already encountered this?

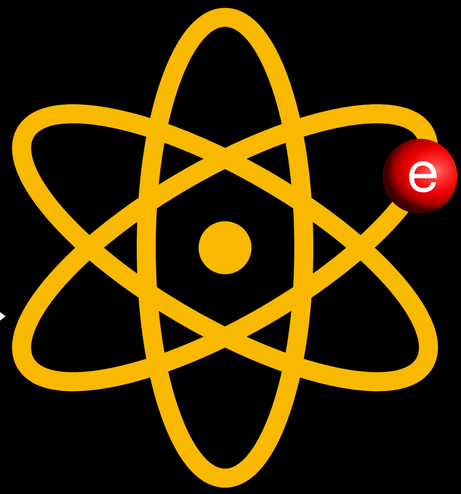
Size: 1 m



Drop of water (H_2O)!



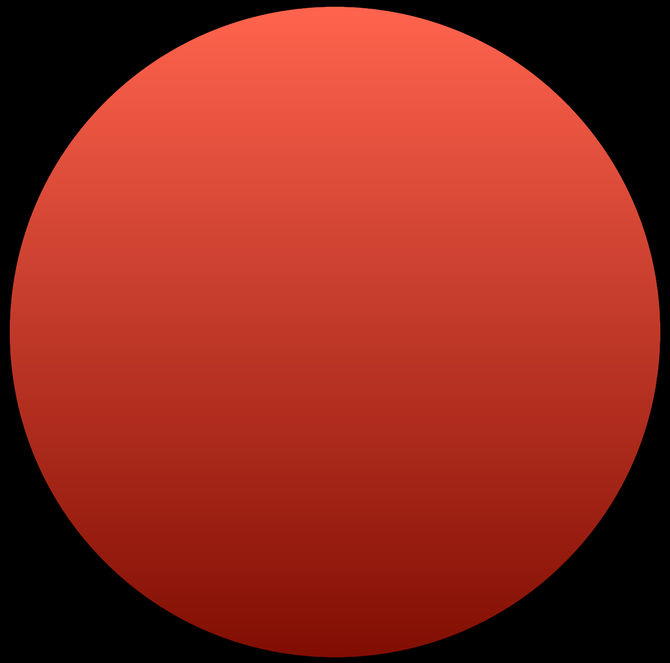
Two molecules of Hydrogen and one molecule of Oxygen



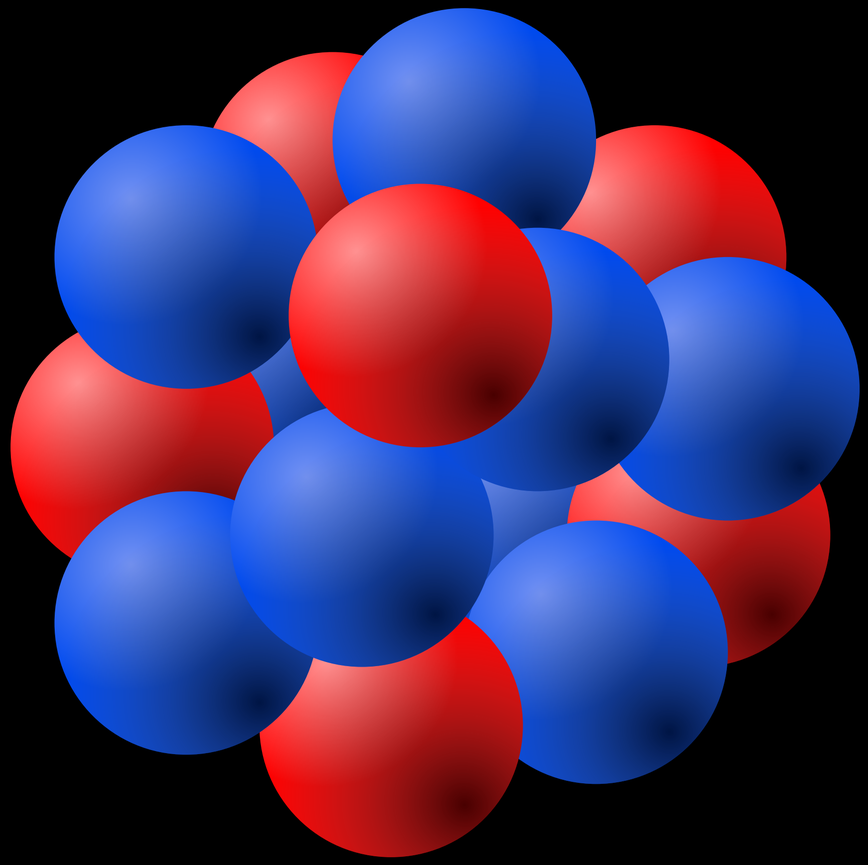
An atom

The nucleus

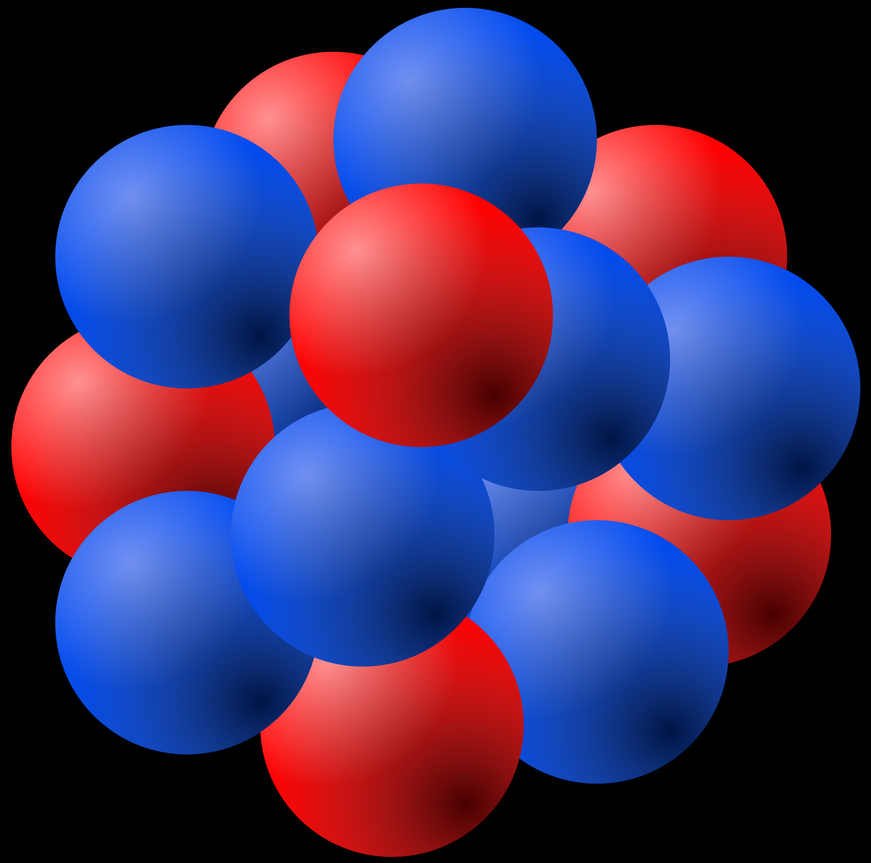
Size: 10^{-3} m	Size: 10^{-9} m	Size: 10^{-10} m	Size: 10^{-15} m



The nucleus



Finer structure of the nucleus made up of protons and neutrons



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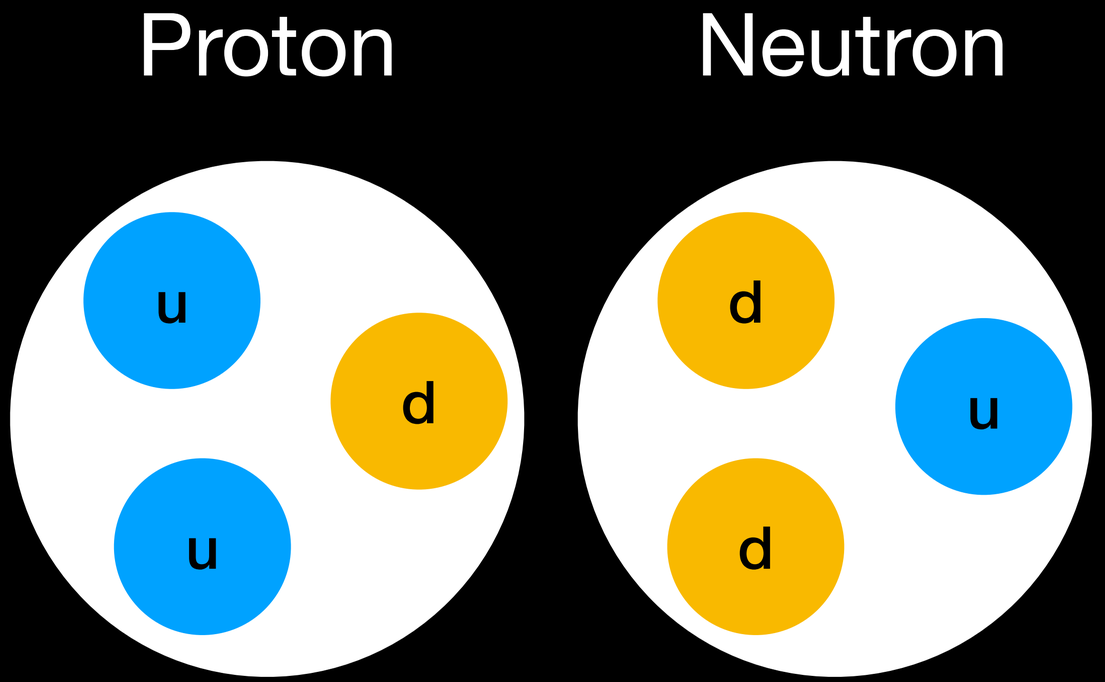
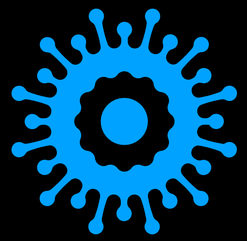
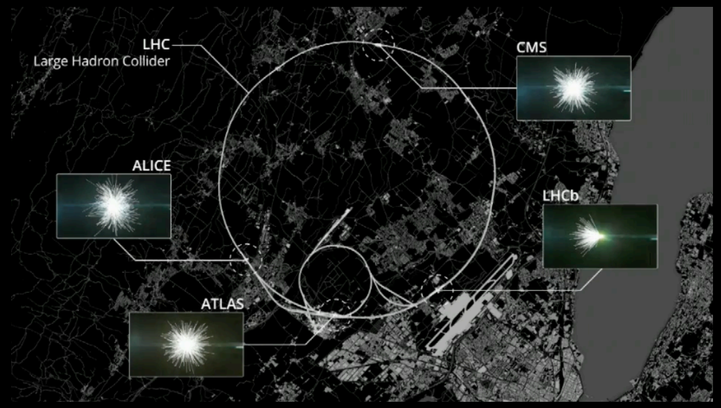


Protons and neutrons are made of quarks

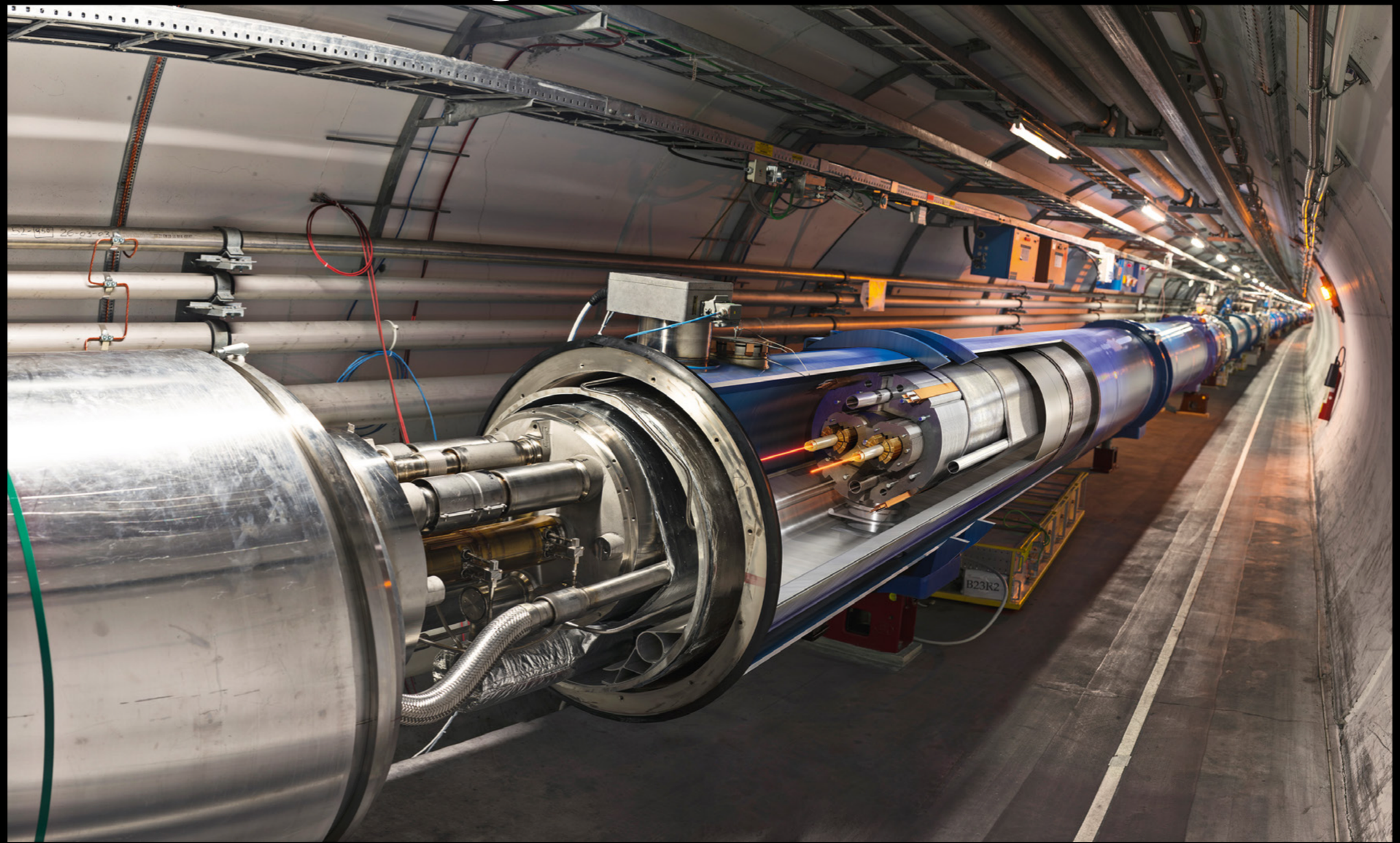
Observables



Instruments



The Large Hadron Collider




LHCb
ATLAS
CERN Meyrin
PS 628 m
CERN Prévessin
SPS 7 km
ALICE
CMS
LHC 27 km

The Large Hadron *Collider*

- Collider?
  - Particles from two beams traveling in opposite directions are made to collide at four different points

The Large *Hadron* Collider

- Hadron?
  - It accelerates protons or ions → called a hadron
  - From the Greek “adros” meaning bulky

The *Large* Hadron Collider

- Large?
  - Approximately 27 km in circumference

The Large Hadron Collider

- Two particle beams travel at the speed of light in opposite directions in beam pipes that are kept at ultrahigh vacuum
- Guided around the accelerator ring by strong magnetic fields generated by super conducting elecromagnets
- Super conducting state or zero resistance state achieved at -271.3°C 🥶 — this is colder than outer space!
- Achieved with vast distribution system of liquid helium

Coming back to our lab again…

One more thing…

- I appreciate insights in lab reports
- Last week you measured a distance with 3 different rulers
  - Why did you get different values?

Today’s lab - I

- Record your analysis of the weather data in January in a Jupyter-notebook or any other data collection device you can think of

Today’s lab - II

- Switch to a jupyter-notebook and draw a circuit to calculate the internal resistance of a battery
- Once you do this, come and take the materials you need
- This is open ended and different people will come up with different circuits
- A good resource is here: https://learn.sparkfun.com/tutorials/measuring-internal-resistance-of-batteries/internal-resistance

Today’s lab - III

- Get the function generator to show various waveforms for you
- Take pictures and paste them in the notebook
- Explain what each little setting of the oscilloscope does: feel free to look for the exact model of the oscilloscope and get it’s manual and test out the various features

Propagation of uncertainties

- I am measuring the density, which is a function of mass m and volume V and is given by:
  - $\rho(m, V) = m/V$
  - For a functional dependence of one measured quantity x, $f(x)$ with an uncertainty Δx in x, the uncertainty in $f(x)$ can be computed as:
    - $\Delta f_x = |f(x + \Delta x) - f(x)|$
  - For multiple variables, as is the case here, we add the uncertainties in quadrature:
    - $\Delta\rho = \sqrt{(\Delta\rho_m)^2 + (\Delta\rho_v)^2} \equiv \sqrt{|\rho(m + \Delta m, V) - \rho(m, V)|^2 + |\rho(m, V + \Delta V) - \rho(m, V)|^2}$

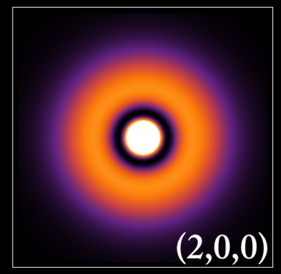
Propagation of uncertainties

- Since you have measured dimensions and mass, compute the density and make sure you propagate the uncertainty
- Make a new cell in the jupyter-notebook and write down your calculation
- Show your work!

Hydrogen Wave Function

Probability density plots.

$$\psi_{nlm}(r,\vartheta,\varphi)=\sqrt{\left(\frac{2}{na_0}\right)^3\frac{(n-l-1)!}{2n[(n+l)!]}}e^{-\rho/2}\rho^l L_{n-l-1}^{2l+1}(\rho)\cdot Y_{lm}(\vartheta,\varphi)$$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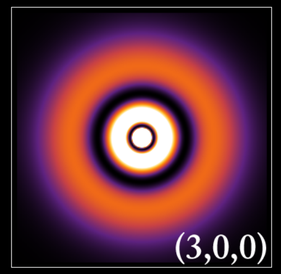
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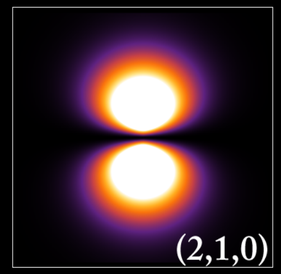
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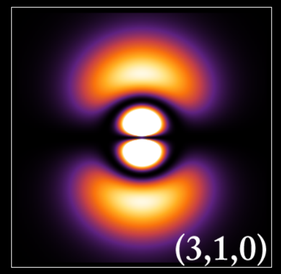
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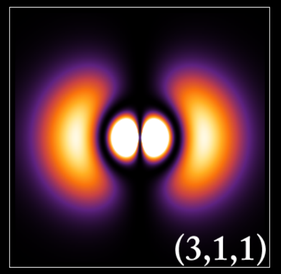
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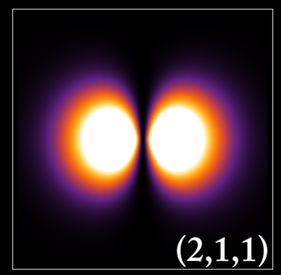
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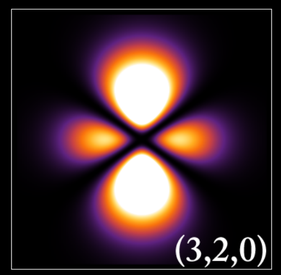
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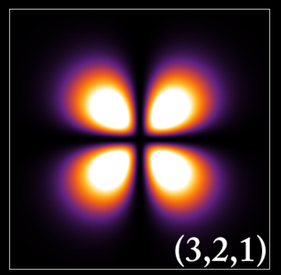
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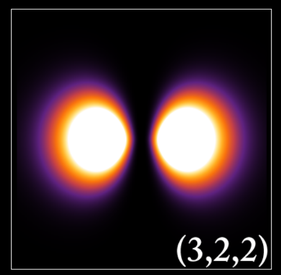
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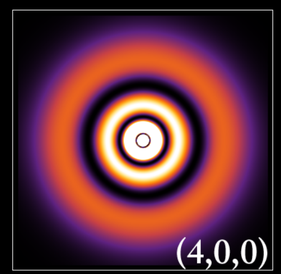
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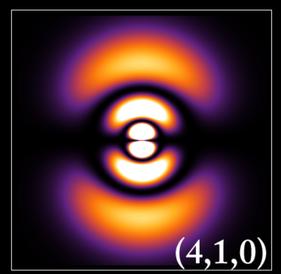
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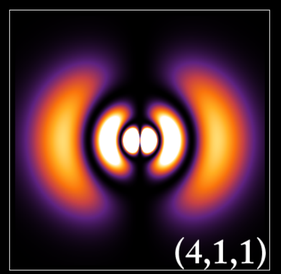
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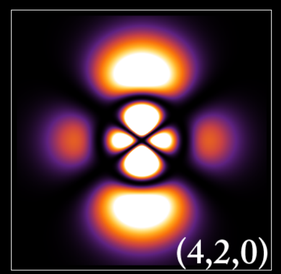
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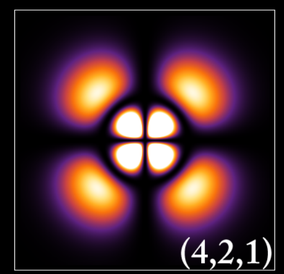
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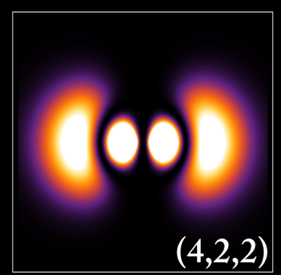
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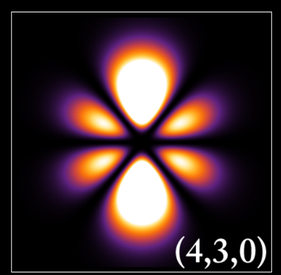
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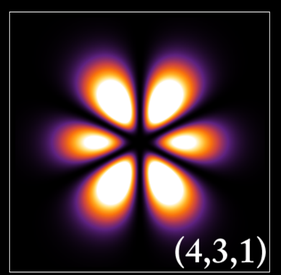
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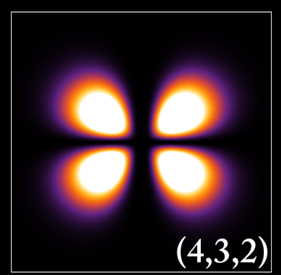
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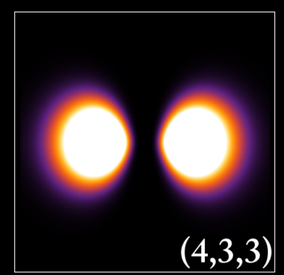
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