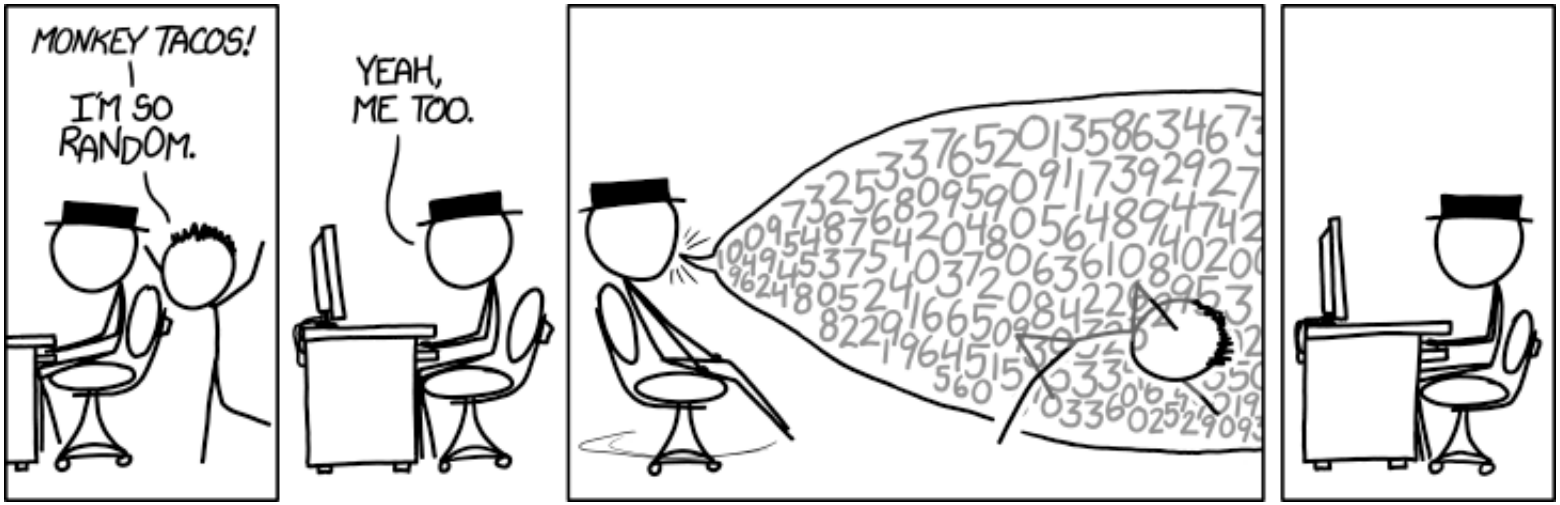
Monte Carlo techniques

Meg Estapa

Ocean Optics class, 2023

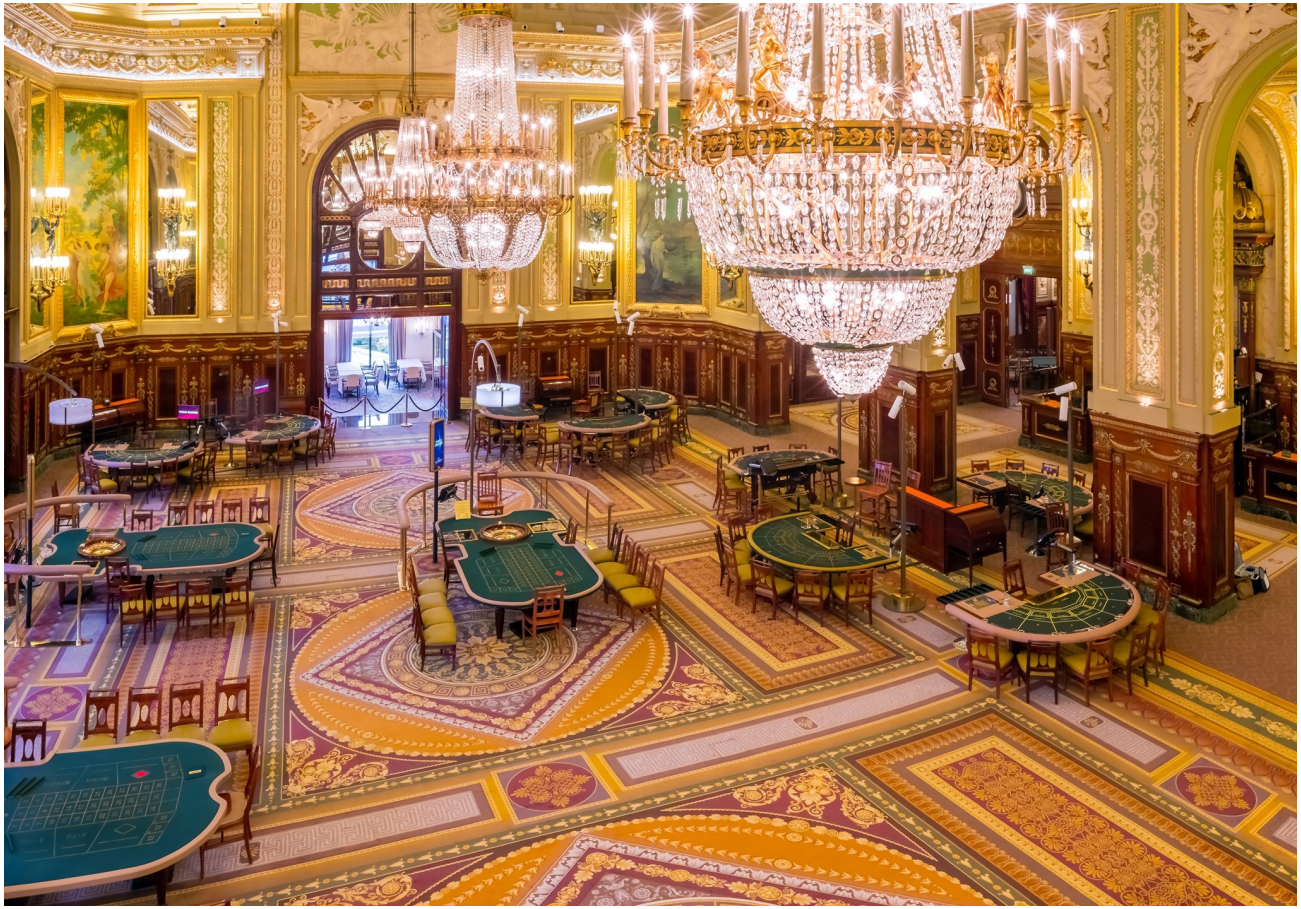


https://xkcd.com/1210

Code for class today (in student Google share drive → "Code_for_Lect30_MonteCarlo")
https://drive.google.com/drive/folders/16N9ECwZzzQ06JYaK9NoxQQTcMGyX41DR?usp=drive_link

- Overview
- Examples
  - Error propagation
  - Modeling photons in a beaker
  - Modeling photons in a 1-D optically deep ocean[1]

- Also check out: https://towardsdatascience.com/how-to-create-a-monte-carlo-simulation-using-python-c24634a0978a

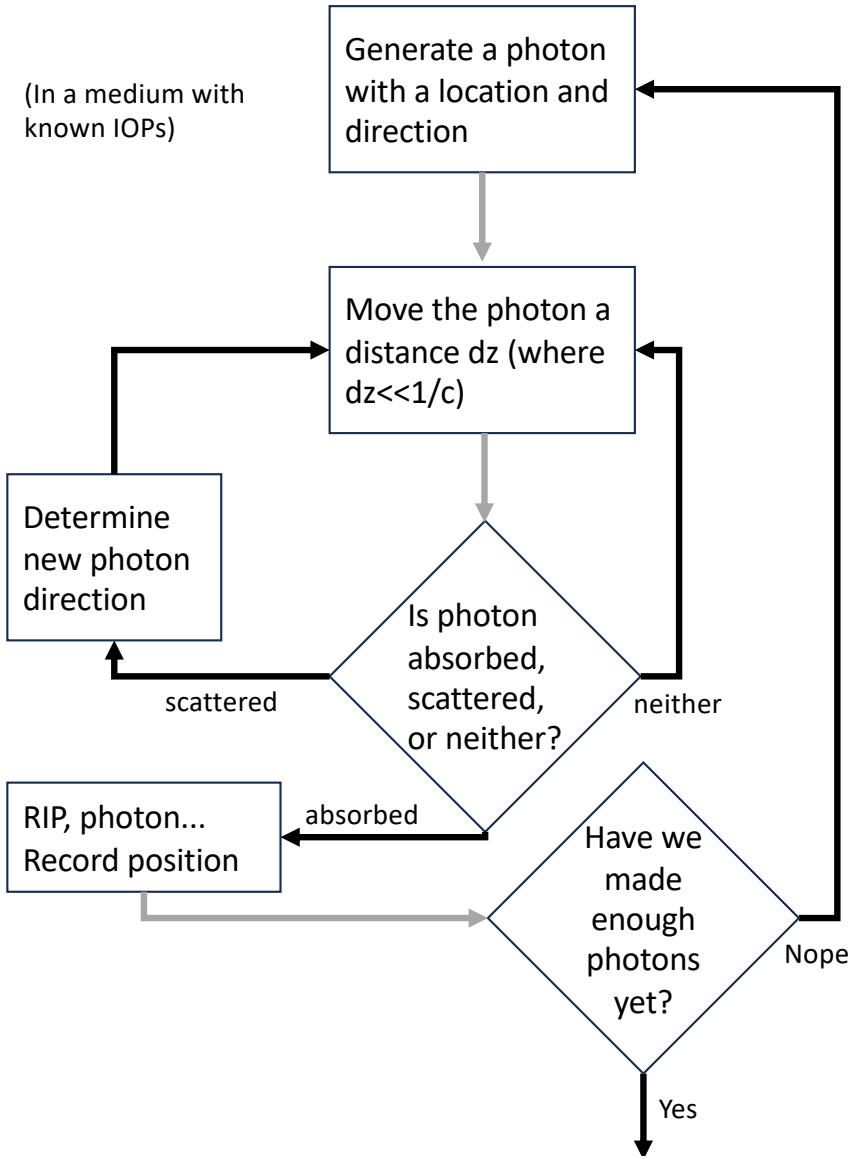


[1] based on Leathers et al. 2004 and Kirk, 1981.
https://apps.dtic.mil/sti/pdfs/ADA426624.pdf
https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:7baf44de-cf0b-48cb-855b-5aab024cee19

General premise

- Map the probability distribution of an event's occurrence onto the interval [0...1]
- In the model, generate a random number between 0 and 1 to determine whether the event occurs
- Repeat many times until stable distribution of results is achieved

In this hypothetical model, what probability distributions do we need to know or estimate?



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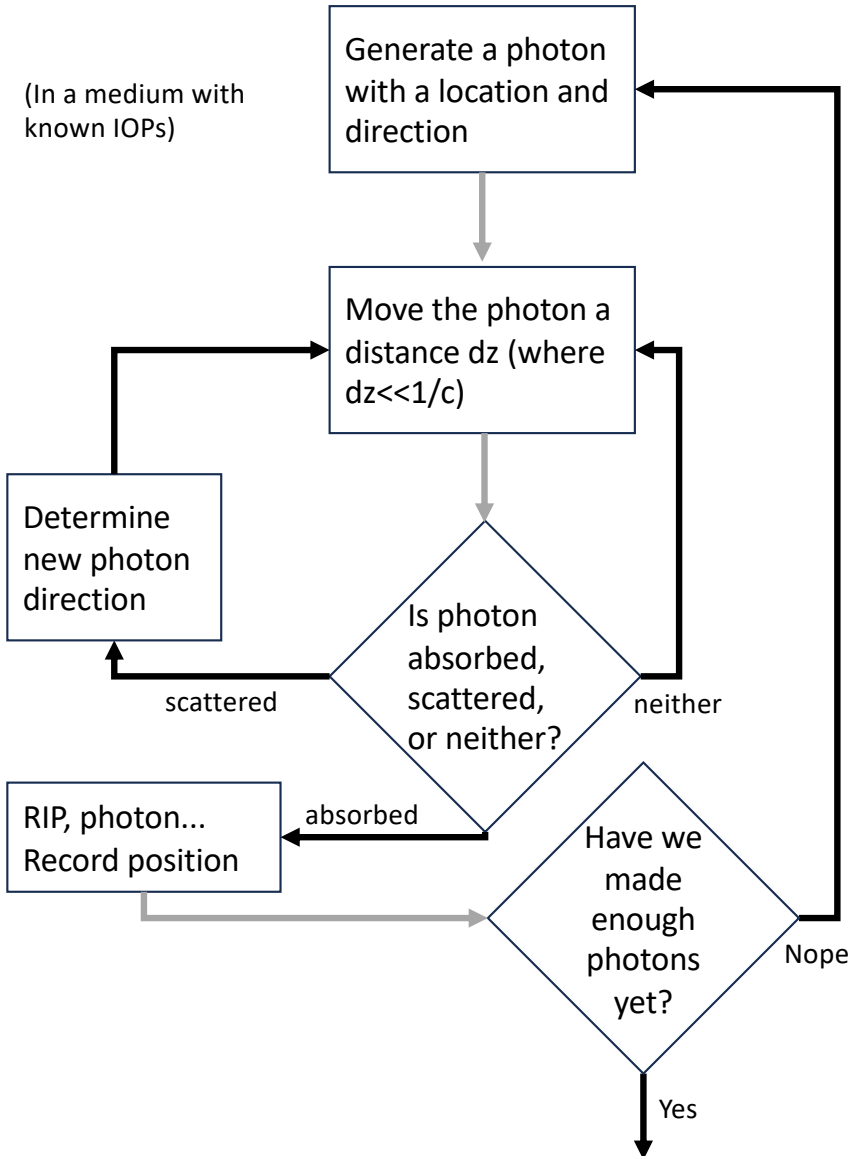
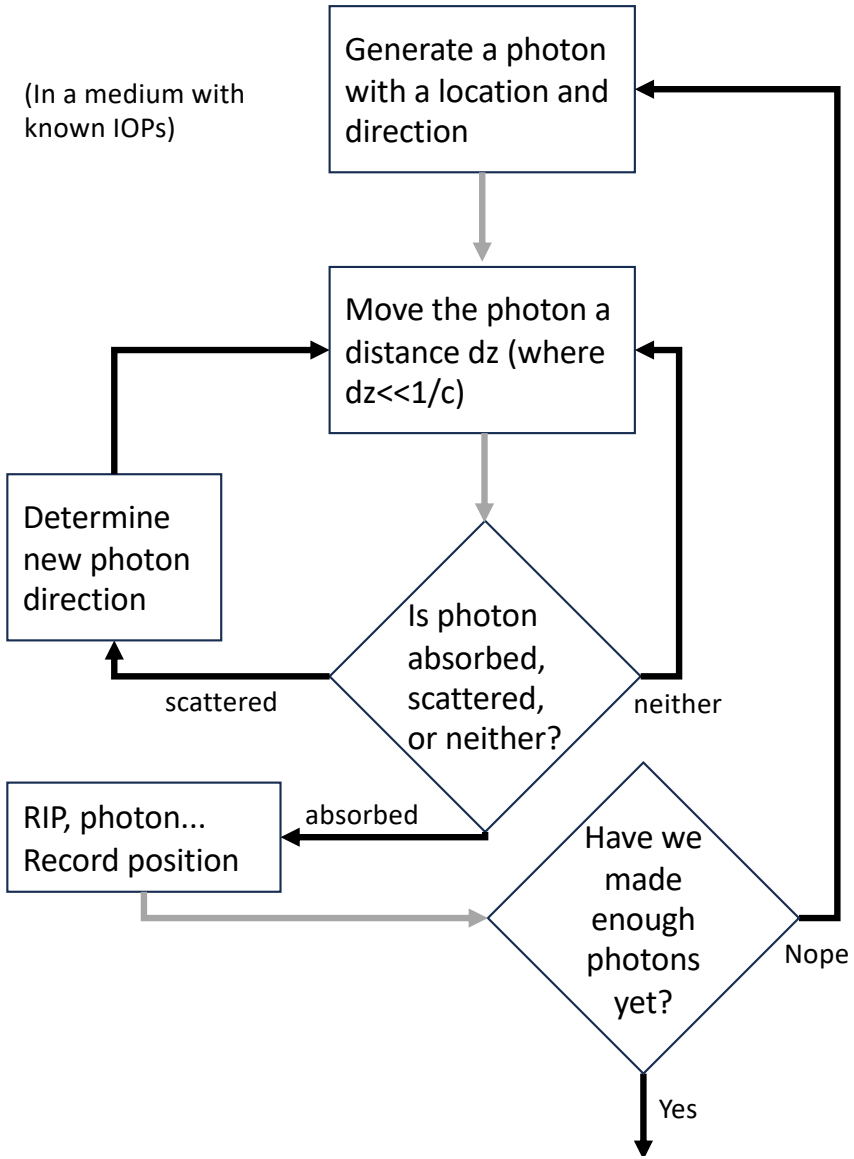


In this hypothetical model, what probability distributions do we need to know or estimate?

- Initial direction of photon
- Initial location of photon
- How far photon goes between attenuation events
  - Model “distance between attenuation events” as –log(n)/c (where n is random # [0-1])
- When an attenuation event occurs, whether the photon is absorbed/lost or scattered
- Direction of scattering



When are Monte Carlo models useful?

- Estimating uncertainty when sources are difficult (or impossible) to propagate analytically
- Radiative transfer modeling in non-plane parallel systems (e.g. light interacting with a sensor, asymmetric bodies of water, shading of sensors by platforms)
- Sensitivity testing
- Many other things!

Examples: Build intuition on how Monte Carlo models work and show some examples (some more elegant than others).

- Overview
- **Examples (and *.mlx filenames)**
  - **Error propagation**
    - **process_IFCB_PSD_MCexamp**
  - **Modeling photons in a beaker**
    - **montecarlo2D**
    - **montecarlo2Dbounded**
    - **montecarlo3D**
  - **Modeling photons in a 1-D optically deep ocean[1]**
    - **Leathers04_Ex10p5_Estapa_updates**

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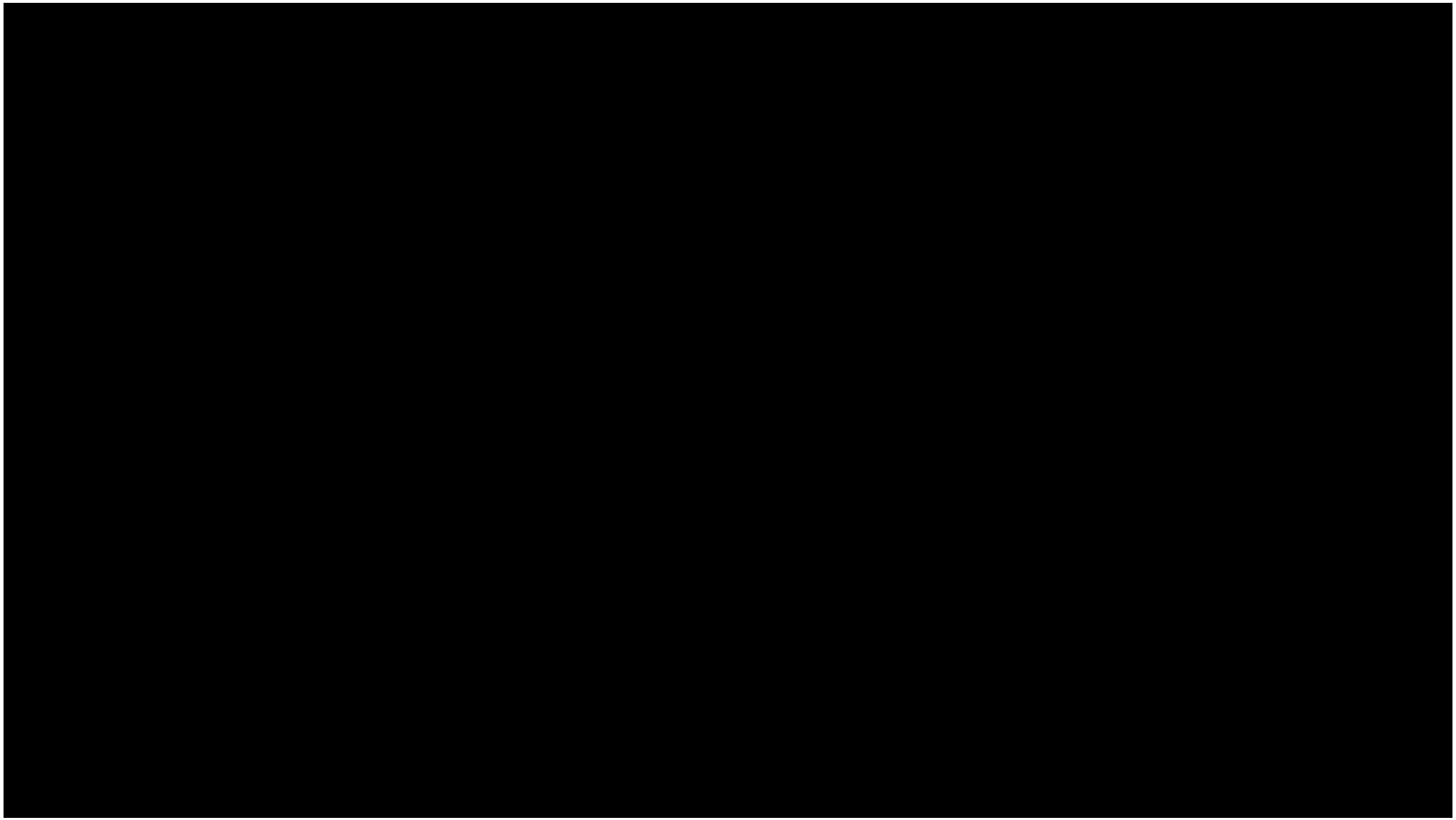
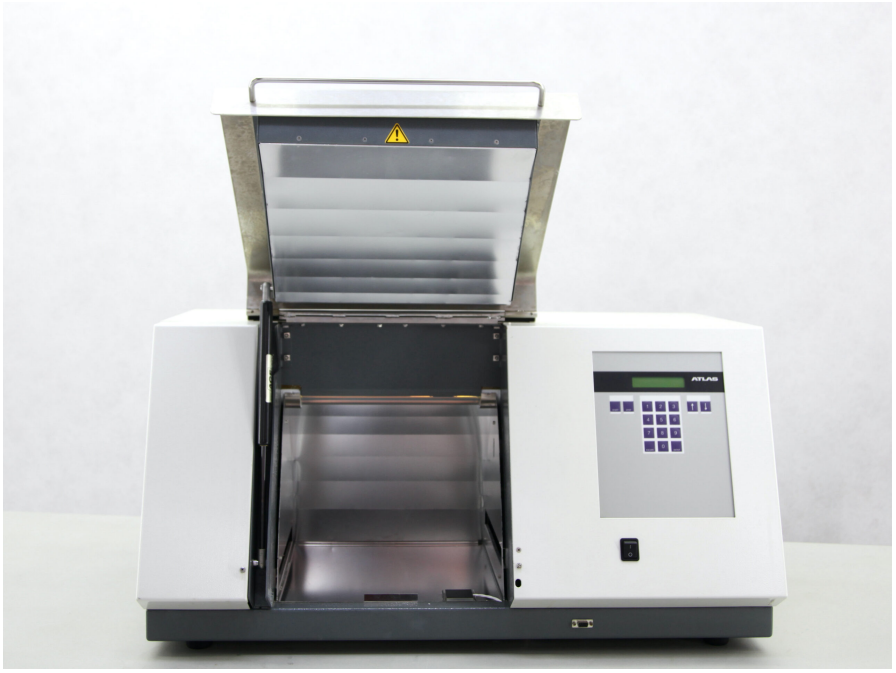


Modeling photons in a beaker of muddy water

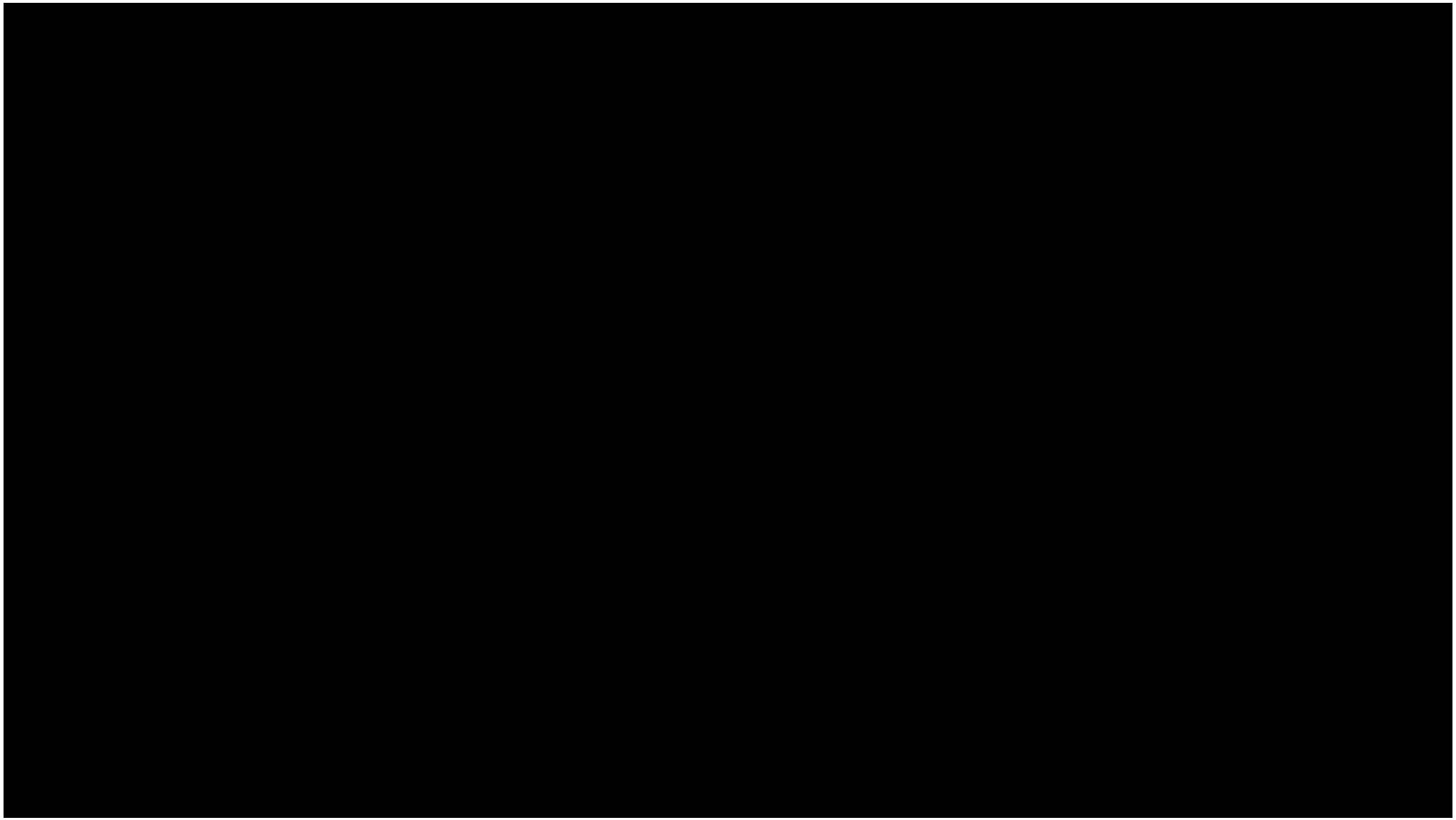
- Not plane-parallel
- Multiply scattering, but interested mainly in particulate absorption...
- Optical depth ~1-2 cm

Stirred beaker approx. 5 cm diameter and 10 cm in height

Suspended particulate mass = 0.5 g m^{-3}



Representative images are arbitrary & sourced from Google. (note to future instructors: don't forget to photograph your experimental apparatus...)



Improving the computational efficiency

- Model populations of photons (e.g. weighting, in the Kirk/Leathers example) instead of individual ones
- Only model photons that reach the detector (i.e. model “backwards” aka, inverse Monte Carlo)
- Use lookup tables to map random numbers to probability distribution functions
- Computers continue to get faster...