Turbulence: Flow Analysis By Imaging Particles

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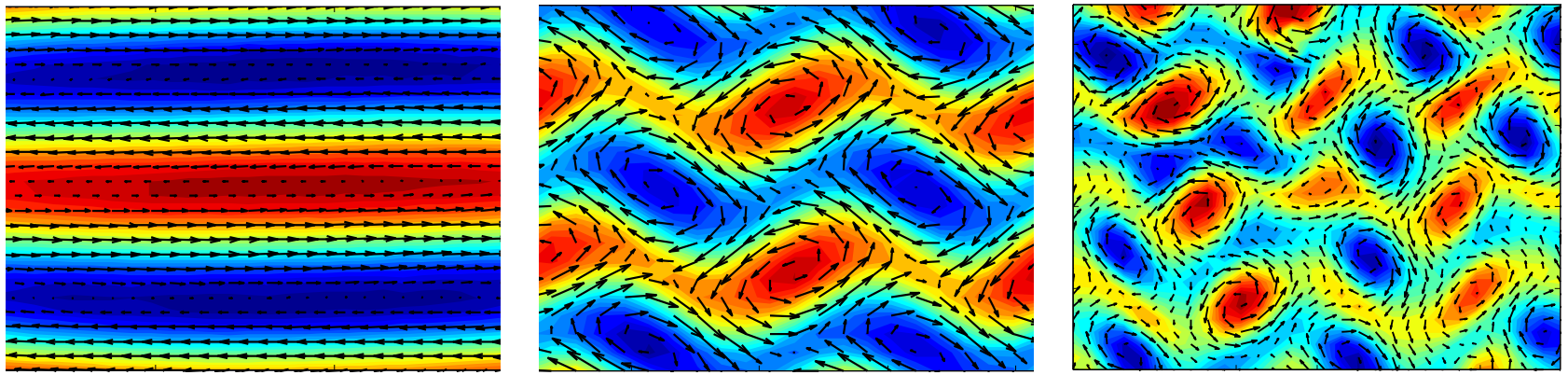


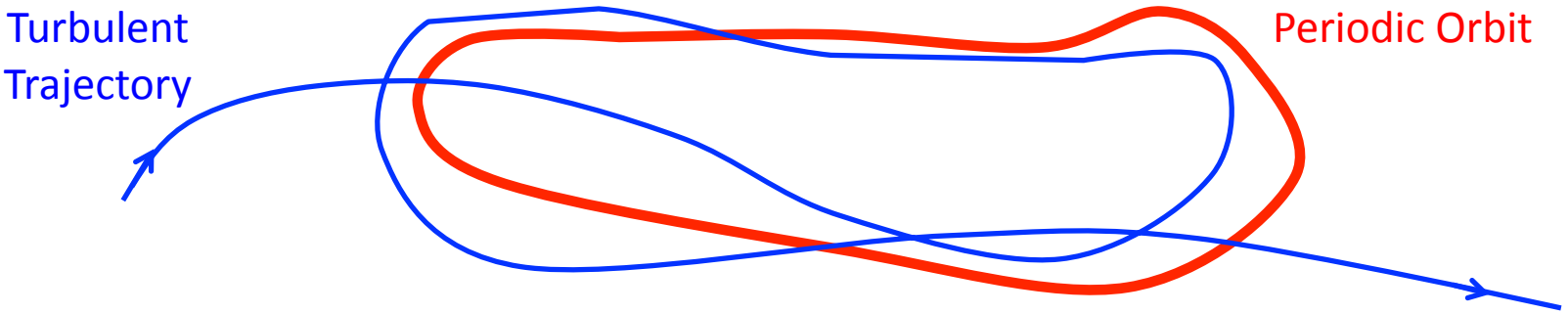
Today's Agenda

- Motivation
- Setting Up the Experiment
- Collecting Data
- Processing and Analyzing Data in Matlab

Motivation

- Statistical Treatment of Turbulence
- “Exact Coherent Structures” Guide Turbulence

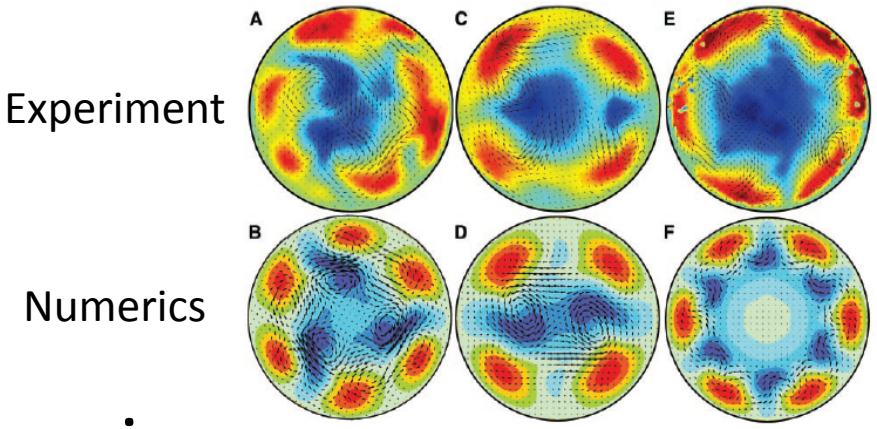
Phase Space
Visualization



- http://chaosbook.org/tutorials/

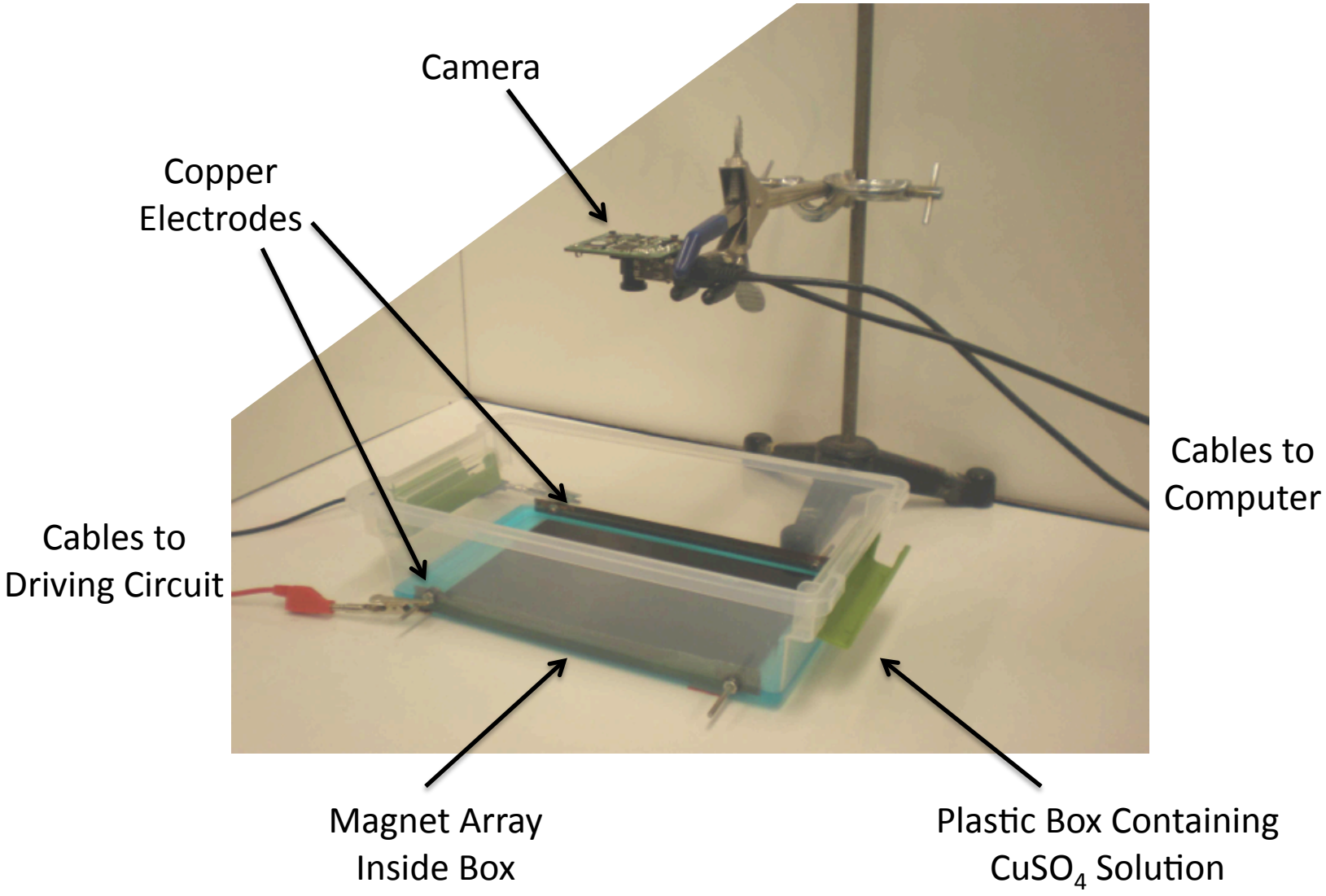
Motivation

- Previous work
  - Hof et al. (2004)



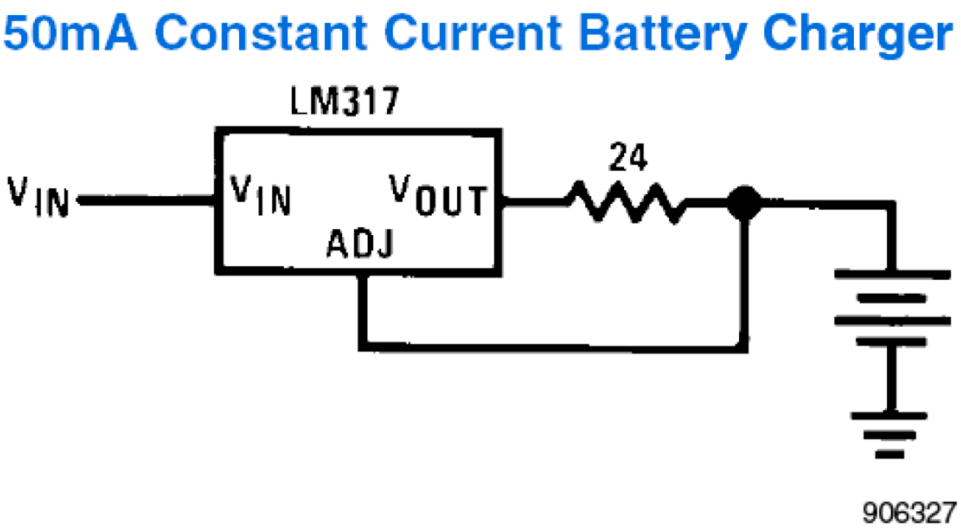
- Experimental evidence is scarce
- Learn computational modeling in Dr. Storey's session (Mathematical Modeling Session B)
- Unique opportunity to compare experiment and numerics
- Your work on 2D turbulence could provide new evidence!

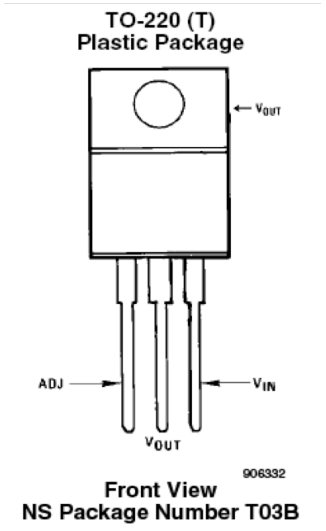
Setting Up the Experiment



Setting Up the Experiment

- Using a **Constant Current Source** is Ideal
  - Constant driving parameter
  - Prevent LEDs from flashing

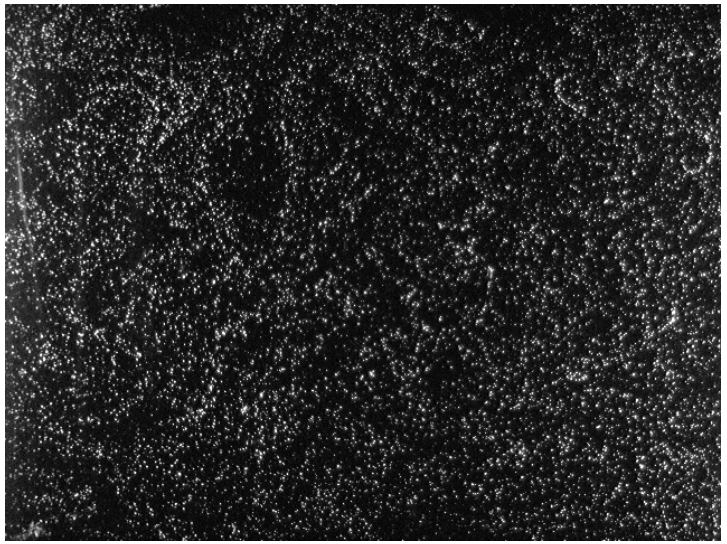




- More info in “ConstantCurrentSupply.pdf”

Setting Up the Experiment

- To visualize the flow
  - Sprinkle some tracer particles
  - Light up the flow with LEDs
  - Place a box over setup (to make it dark inside)
- Open "Fire-i" on the laptop
  - Start a "Preview"
  - Should look like this image:
- We will use a technique called "PIV" to extract velocities from these images



Collecting Data

- Adjust the variable resistor so that you see laminar flow (~2mA for Kolmogorov, ~10mA for Checkerboard)
- Make a new folder on the desktop
- In Fire-i:
  - Make sure the frame rate is set to 7.5
  - Go to Settings->Frame Capture Properties, then set the folder and number of frames to capture
  - To start taking data, check “Frame Capture” and click “Start”

Collecting Data

- To see interesting dynamics, collect data at the following current values:

Kolmogorov	Checkerboard
2mA	10mA
7mA	25mA
15mA	45mA

Processing and Analyzing Data in Matlab

- Open Matlab, change to the folder containing your images, and execute these scripts:

Matlab Scripts (Listed in Execution Order)	Purpose
image_process('startnum', 'stopnum', h_cm, fps);	Calls OSIV software to perform PIV.
taverage;	Time averages data to reduce noise.
vfield_cgs;	Converts velocities and lengths to cgs units.
vortex_cgs;	Calculates vorticity contour in cgs units.
remove_vortex_noise;	Removes noisy parts of vorticity to make data look smoother.
make_video(jump, video_fps);	Generates an AVI video of the flow.
recurrence;	Generates a recurrence plot of the velocity field time-series.

- Examples:

  image_process('002', '900', 4.8, 7.5);
  make_video(8, 15);

Additional Analysis

- Calculating Reynolds numbers

$$\mathrm{Re} = \frac{L_0 \cdot V_{rms}}{\nu} \quad \text{where} \quad \nu \approx 0.01\ cm^2/s$$

- Time averaging steady state data

- Calculating Rayleigh friction decay constant