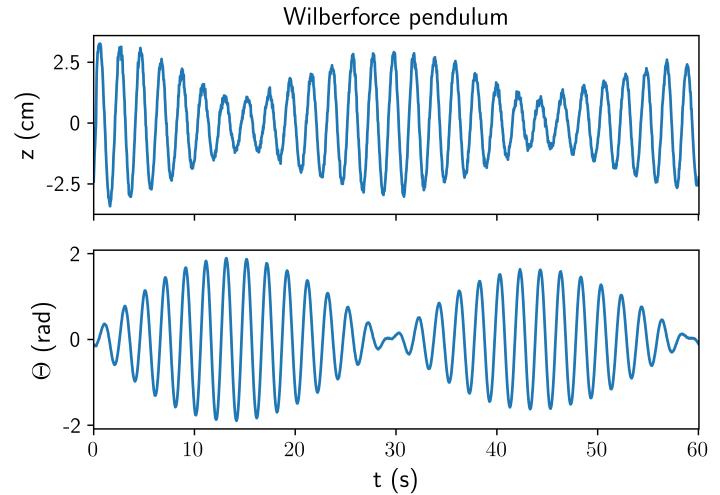
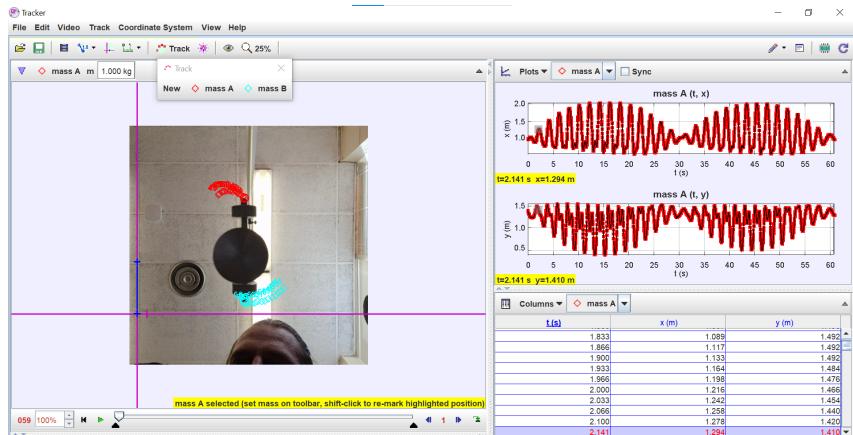


# From image to insight: Getting more out of video analysis



Dr. David Kordahl  
Department of Physics and Engineering  
Centenary College of Louisiana  
Full STEAM Ahead – 2025 Meeting

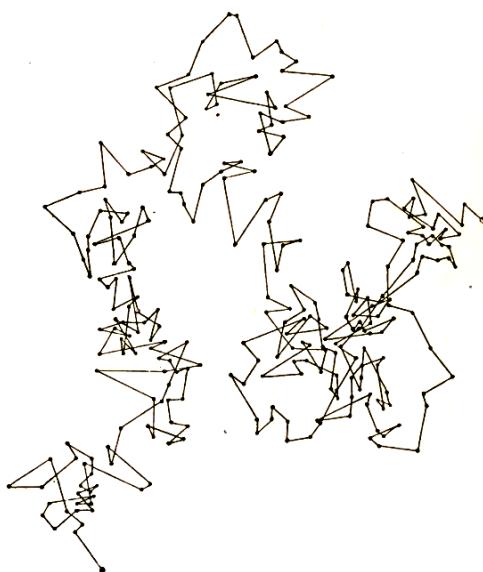


# Outline

- “Activist realism,” with video analysis as a model
- Standard educational applications of video analysis
  - Toy car, simple harmonic oscillator, dropped/thrown projectile
- Can video analysis accommodate 3D videos?
  - Car receding, Wilberforce pendulum, recoiling projectile
- Conclusion and project suggestions

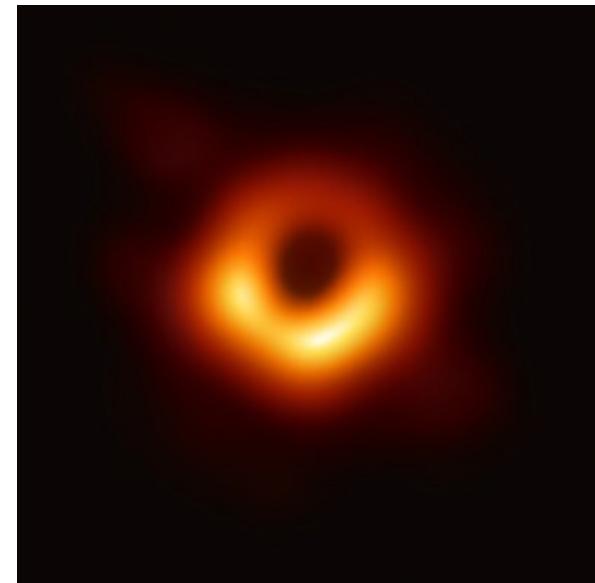
# Why do we believe in science?

- Philosophers of science are often critical of “realism” in science – how do we know that the objects that we’re talking about actually exist?



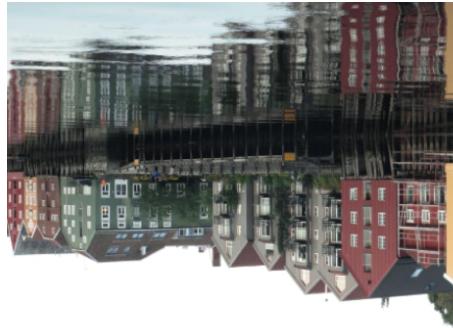
← Evidence of atomic  
Theory in *Les Atomes*  
by Jean Perrin, 1913

“The first picture of a  
black hole opens a  
new era of astrophysics”  
Science News, 2019



# What is “activist realism”?

- Hasok Chang provides a helpful perspective



## Realism for Realistic People

A New Pragmatist Philosophy of Science

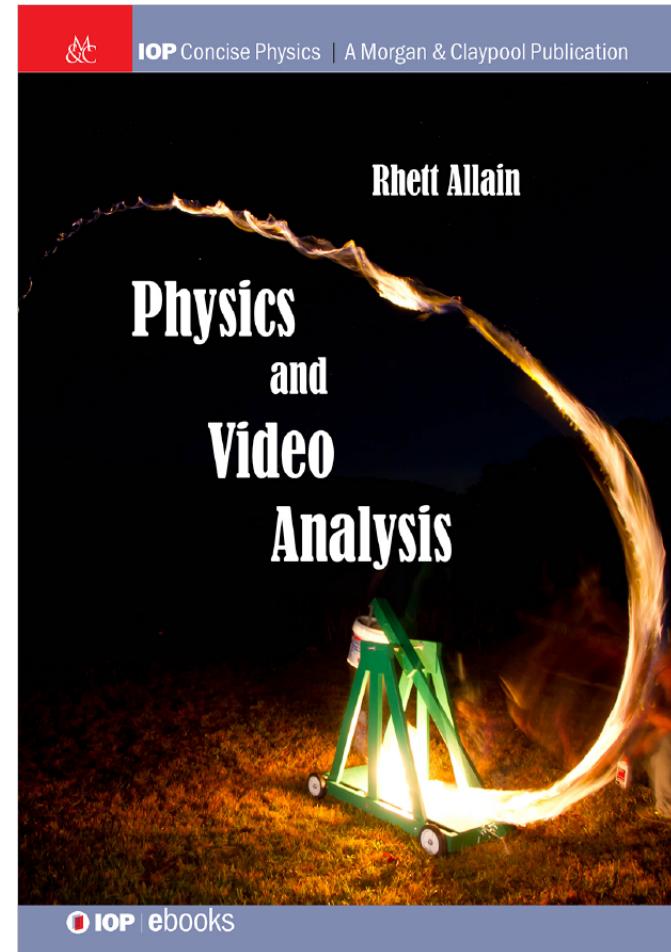
Hasok Chang

Scientific realism is usually taken as a thesis that science states the truth about the world. In contrast, I conceive realism in and about science as a commitment to maximize our learning about realities. [...] While my conception of realism is modest in some clear ways, it is also ambitious, in that it follows an imperative of progress: always seek to increase and improve knowledge maximally. For this reason I designate my position as ‘activist realism’.



# Video analysis and activist realism

- Video analysis puts the tools of science in students' hands
- Provides an active prototype of scientific inquiry and extends the possibility of genuine scientific discovery



# Available packages

- Vernier Video Analysis is slick, but isn't free
- Tracker and Kinovea are functional and free



[Open Tracker Online](#)

Over 2 million users in 31 languages. Completely free and open source.

Latest Tracker 6 installers: [Windows](#) | [Recent MacOS](#) | [Older MacOS](#) | [Linux](#)

Upgrade installers (requires earlier Tracker 6): [Windows](#) | [Recent MacOS](#) | [Linux](#)

A screenshot of the Kinovea website. At the top, there is a navigation bar with the Kinovea logo, "FEATURES", and "DOWNLOAD". The main heading is "A MICROSCOPE FOR YOUR VIDEOS". Below this, a text block describes Kinovea as a video annotation tool for sport analysis, featuring utilities for capture, slow down, compare, annotate, and measure motion in videos. It is noted as completely free and open source. At the bottom, there is a "DOWNLOAD" button and a "2023.1" button, along with a "OTHER DOWNLOADS" link.

# Toy car video analysis

Tracker

File Edit Video Track Coordinate System View Help

axes Grid origin pixel position x 412.0 y 712.0 angle from horizontal -2.0°

43%

axes selected (set angle to change tilt)

flipped\_toy\_car.mp4

Plots mass A Sync

mass A (t, x)

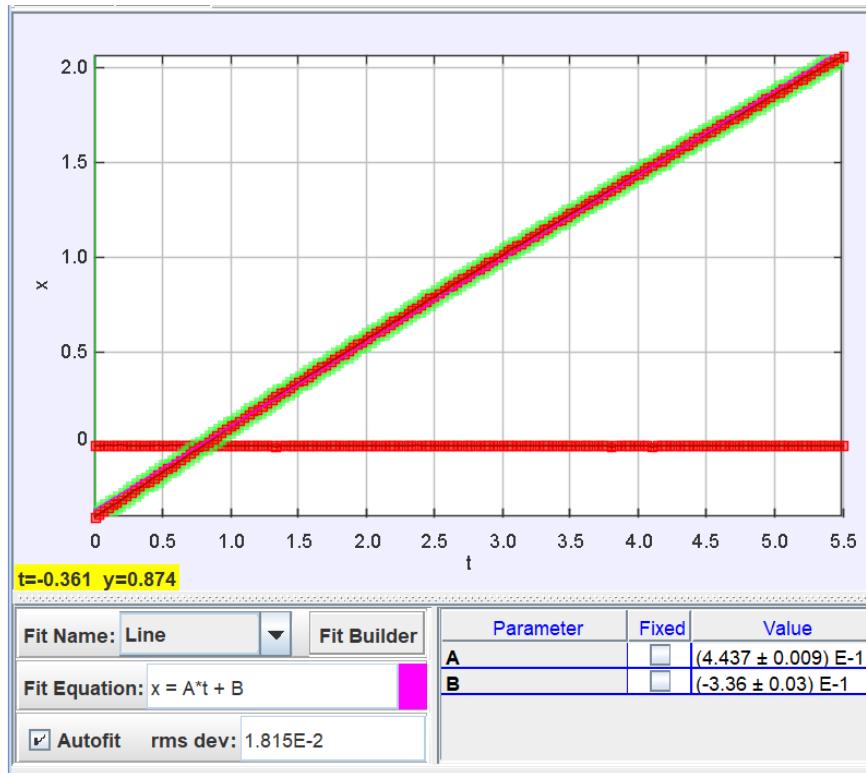
mass A (t, y)

Columns mass A

t (s)	x (m)	y (m)
2.867	0.958	3.984E-3
2.900	0.972	4.819E-3
2.933	0.987	3.780E-3
2.967	1.001	4.690E-3
3.000	1.015	3.788E-3
3.033	1.031	3.723E-3
3.067	1.045	3.283E-3
3.100	1.059	3.748E-3
3.133	1.073	2.938E-3
3.167	1.087	3.462E-3

# Toy car video: Constant velocity motion

- **Physics:** constant velocity yields constant slope



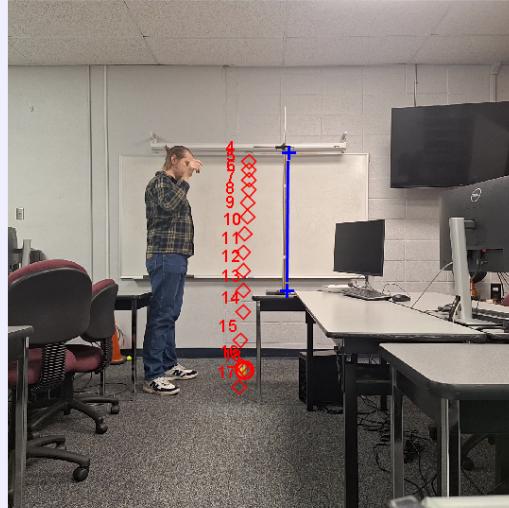
# Dropped ball video analysis

Tracker

File Edit Video Track Coordinate System View Help

Track 25%

mass A m 1.000 kg



mass A selected (set mass on toolbar, shift-click to re-mark highlighted position)

191 100% ▶ 1 ▶

Plots mass A Sync

mass A (t, x)

x (m)

t (s)

t=0.600 s x=-0.137 m

mass A (t, y)

y (m)

t (s)

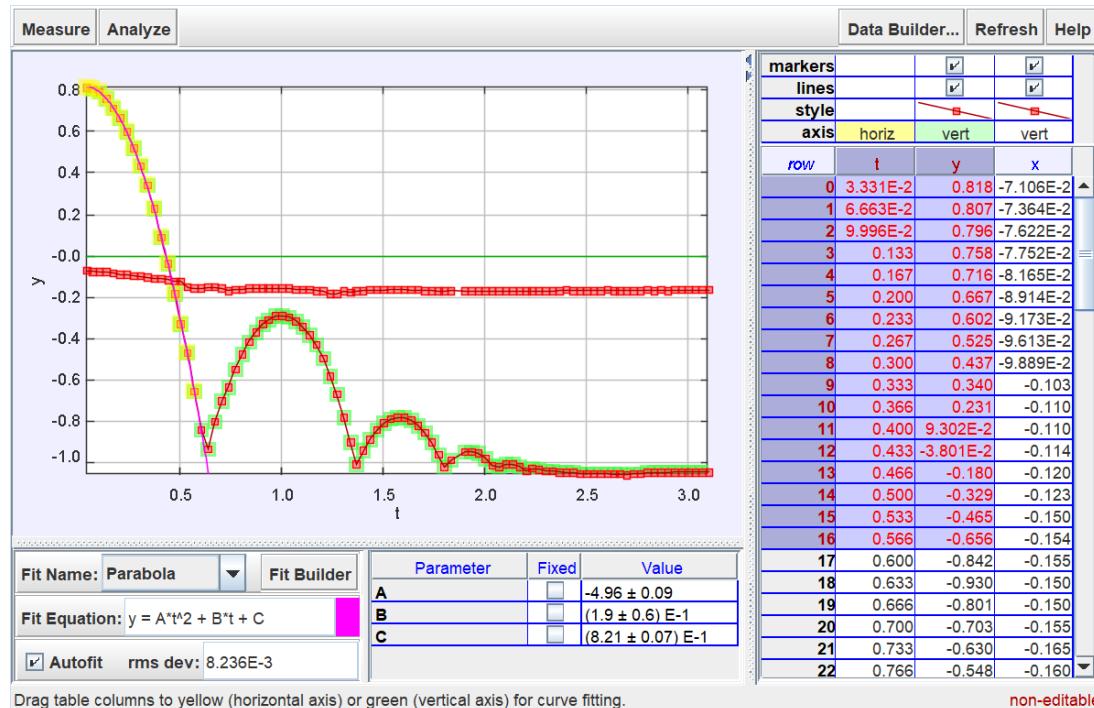
t=0.600 s y=-0.832 m

Columns mass A

t (s)	x (m)	y (m)
0.267	-0.110	0.389
0.300	-0.114	0.286
0.333	-0.137	0.156
0.367	-0.141	2.726E-2
0.400	-0.144	-0.113
0.433	-0.147	-0.257
0.466	-0.144	-0.414
0.500	-0.167	-0.619
0.533	-0.152	-0.802
0.566	-0.175	-0.961
0.600	-0.137	-0.832

# Dropped ball: Accelerated motion

- **Physics:** accelerated motion looks parabolic



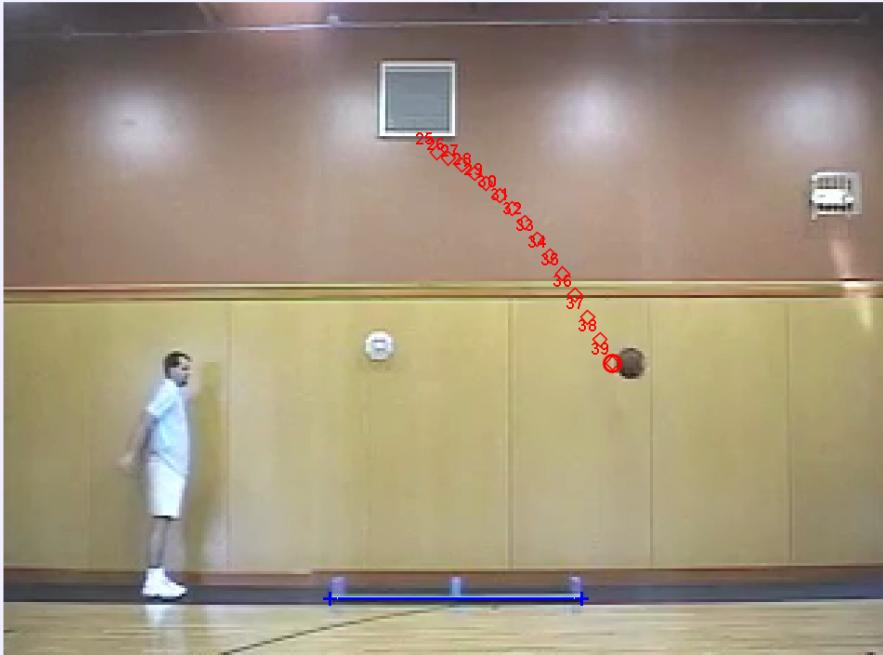
# Projectile motion video analysis

Tracker

File Edit Video Track Coordinate System View Help

25 26 27 28 29 30 31 32 33 34 35 36 37 38 39

mass A m 1.000 kg

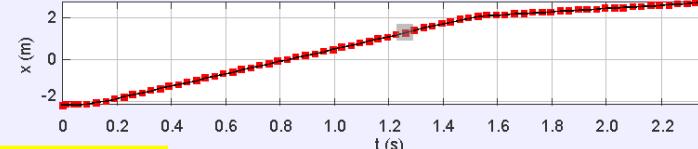


mass A selected (set mass on toolbar, shift-click to re-mark highlighted position)

039 100% ▶ 1 ▶

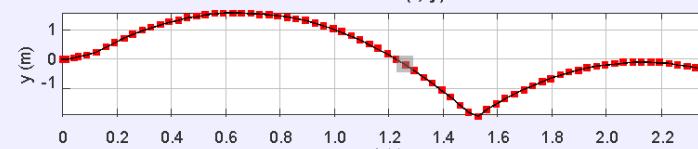
Plots mass A Sync

mass A (t, x)



$t=1.260 \text{ s}$   $x=1.297 \text{ m}$

mass A (t, y)



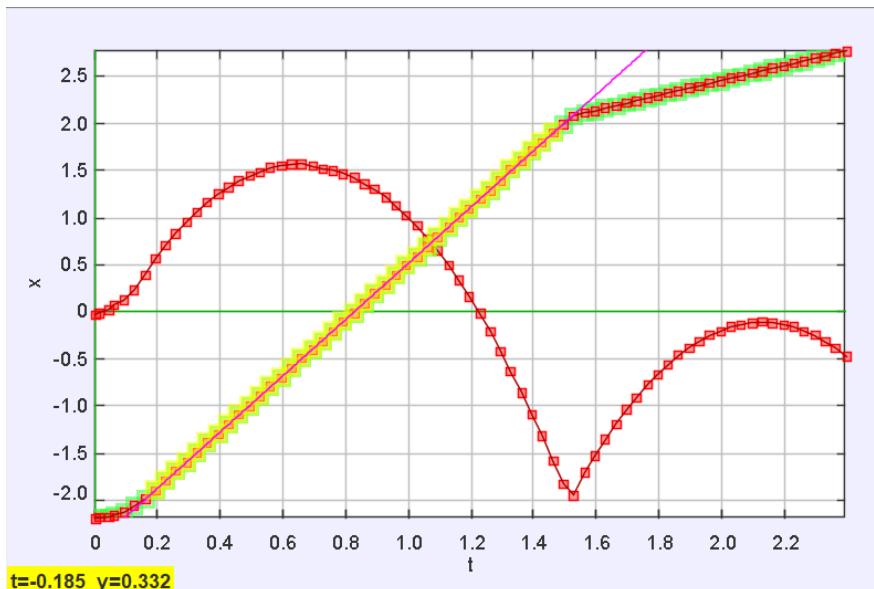
$t=1.260 \text{ s}$   $y=-0.204 \text{ m}$

Columns mass A

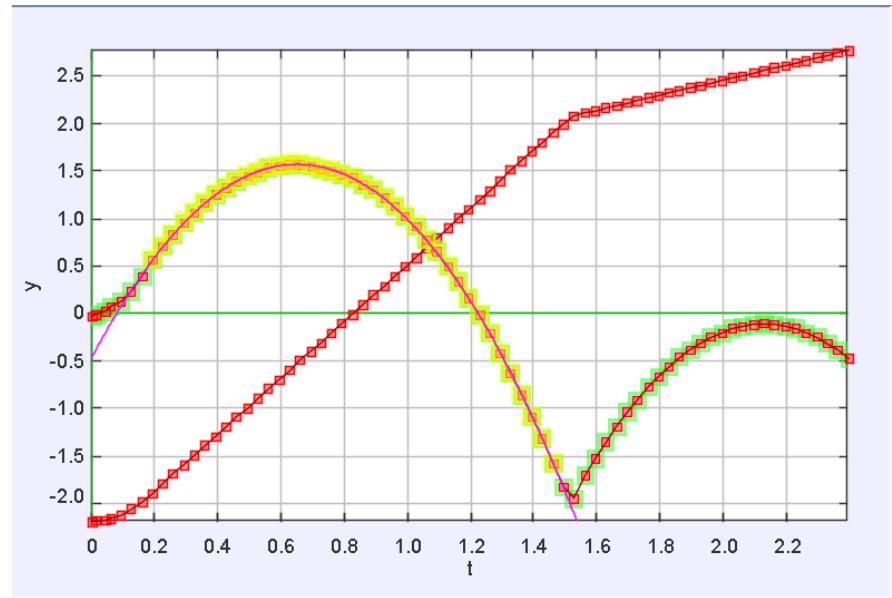
t (s)	x (m)	y (m)
1.260	1.297	-0.204
1.293	1.404	-0.408
1.327	1.516	-0.631
1.360	1.615	-0.848
1.393	1.710	-1.081
1.427	1.808	-1.319
1.460	1.910	-1.574
1.493	2.003	-1.820
1.527	2.086	-1.942
1.560	2.124	-1.710
1.593	2.136	-1.527

# Thrown ball: Projectile motion

- **Physics:** ball is accelerated in vertical direction, but is unaccelerated in horizontal direction



Fit Name	Line	Fit Builder
Fit Equation	$x = A*t + B$	
Parameter	A: $2.990 \pm 0.003$ B: $-2.466 \pm 0.003$	
Autofit	<input checked="" type="checkbox"/>	
rms dev	7.716E-3	



Fit Name	Parabola	Fit Builder
Fit Equation	$y = A*t^2 + B*t + C$	
Parameter	A: $-4.81 \pm 0.01$ B: $6.26 \pm 0.02$ C: $(-4.61 \pm 0.07) \cdot 10^{-3}$	
Autofit	<input checked="" type="checkbox"/>	
rms dev	8.953E-3	

# Mass on spring video analysis

Tracker

File Edit Video Track Coordinate System View Help

490 100% ▶ 1

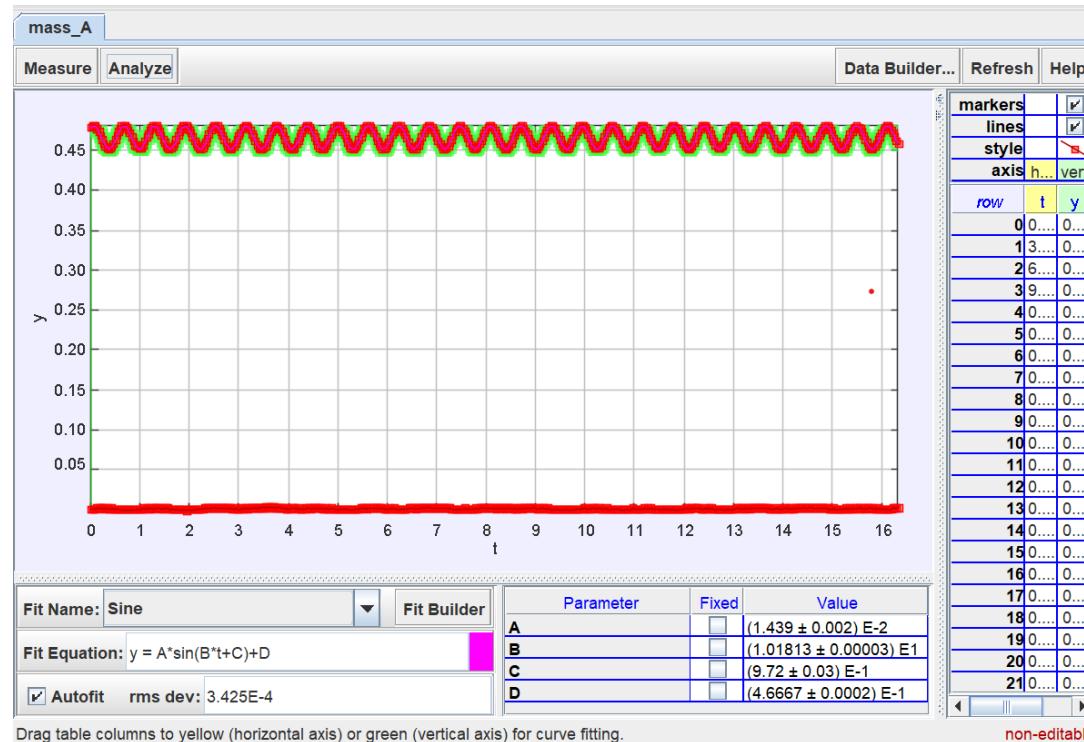
oscillator.mp4

The image shows the Tracker software interface. On the left, a video frame of a mass-spring system is displayed. A red marker labeled '490' is attached to a mass, and a blue vertical line indicates the displacement of the mass from its equilibrium position. The software's toolbar and menu bar are visible at the top. The bottom of the interface shows playback controls and the file name 'oscillator.mp4'. On the right, there are two plots: 'mass A (t, x)' showing position x (m) vs. time t (s), and 'mass A (t, y)' showing position y (m) vs. time t (s). Both plots show a periodic oscillation. Below the plots is a data table with columns for time t (s), position x (m), and position y (m). The data table lists 12 data points corresponding to the oscillations shown in the plots.

t (s)	x (m)	y (m)
16.026	4.451E-4	0.480
16.059	4.439E-4	0.483
16.093	4.016E-4	0.484
16.126	3.107E-4	0.484
16.159	1.016E-4	0.482
16.193	3.754E-4	0.479
16.226	1.937E-3	0.476
16.259	1.736E-3	0.470
16.292	1.756E-3	0.465
16.326	1.819E-3	0.462

# Mass on spring: Oscillatory motion

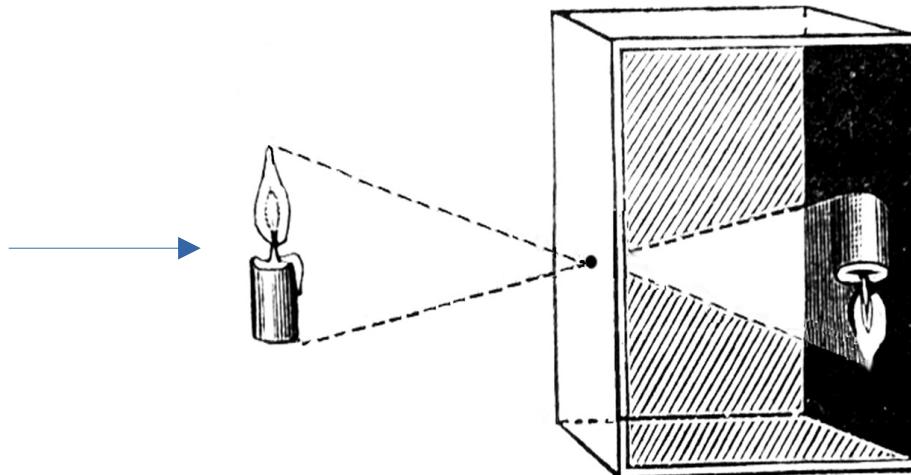
- **Physics:** oscillations look like sinusoids



# Video analysis at face value: When does that work?

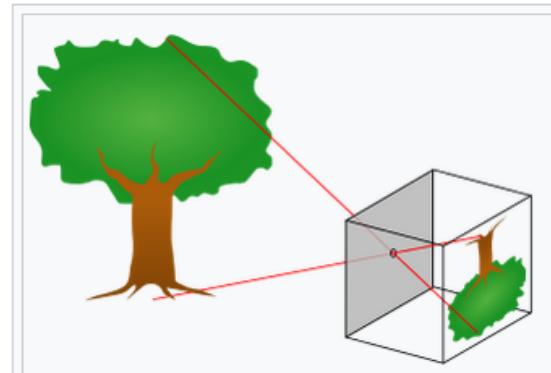
- Usually, video analysis maps points in one vertical plane to points in the image plane

Simplest possible model  
for a functional camera:  
the *pinhole* camera

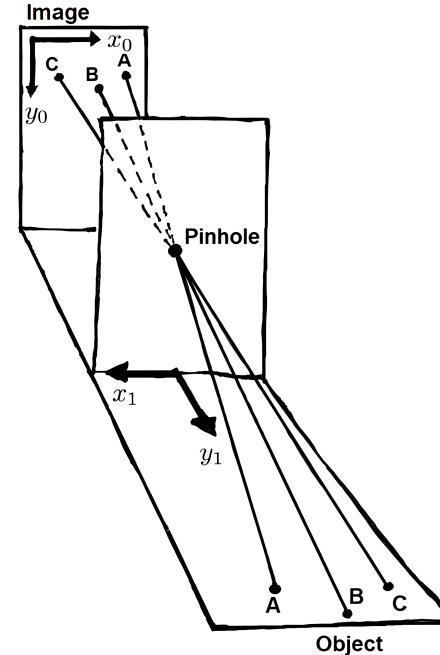


# Video analysis *not* at face value: Motion outside a single plane

- Points on ground map to points in the image, but the path on the ground is not the path in the image!

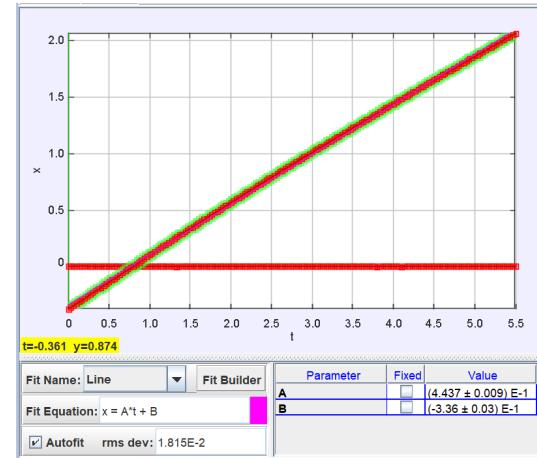
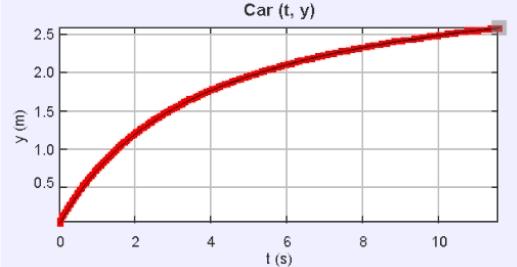
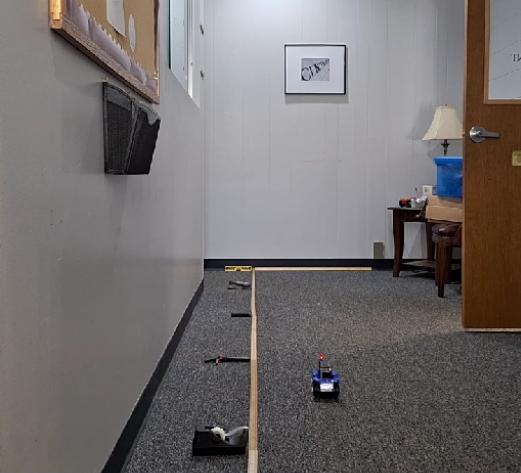
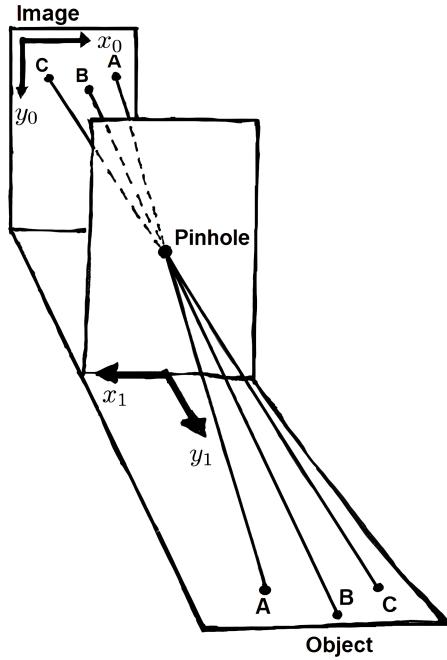


Early pinhole camera. Light enters a dark box through a small hole and creates an inverted image on the wall opposite the hole.<sup>[8]</sup>



# Receding toy car: Still constant velocity, but needs correction

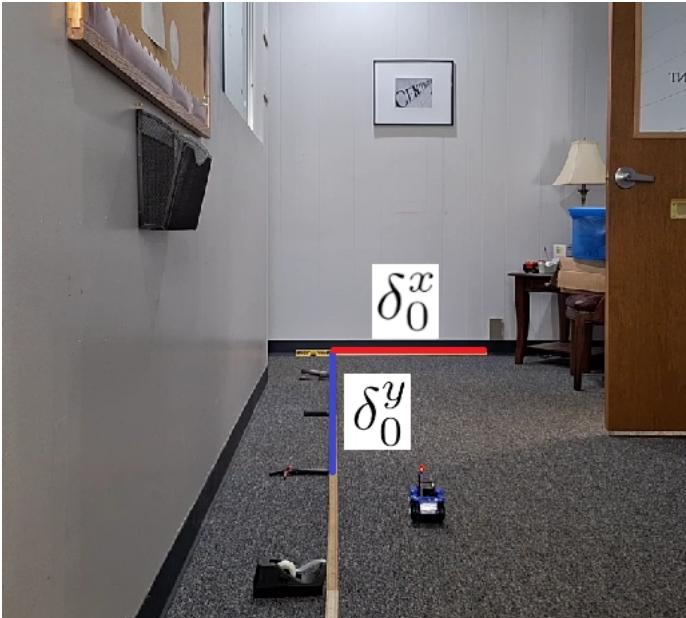
- Apparent velocity is not the physical velocity!



This graph represents the same motion as the graph above, but the apparent velocity (slope) decreases!

# Corrected motion for receding car is possible, but somewhat involved

- We can correct if we know the distance  $\delta_1$  from our camera to our length references



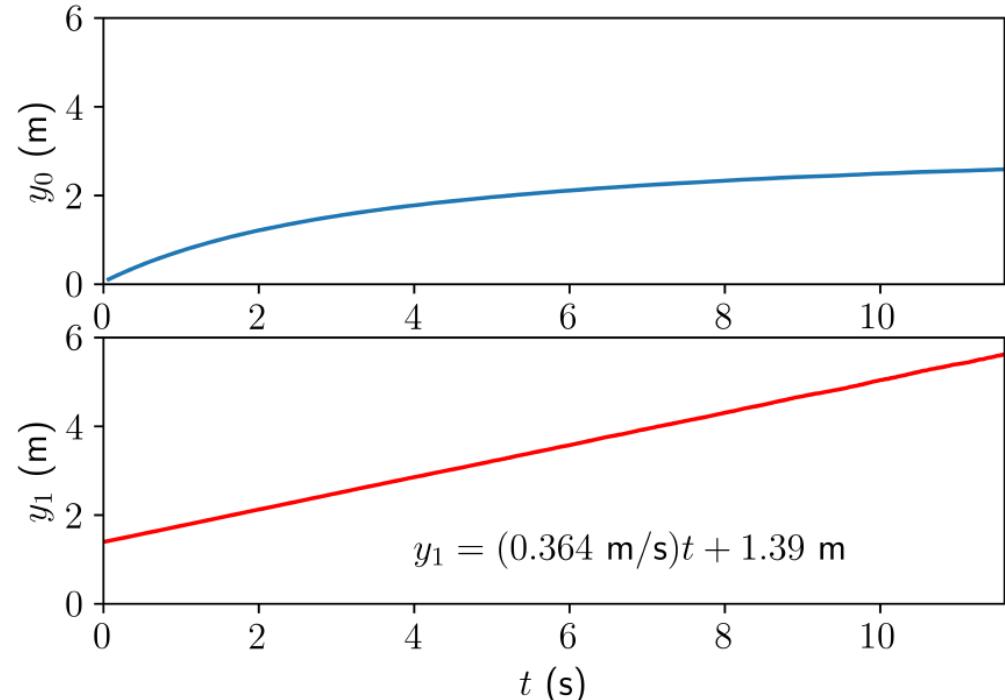
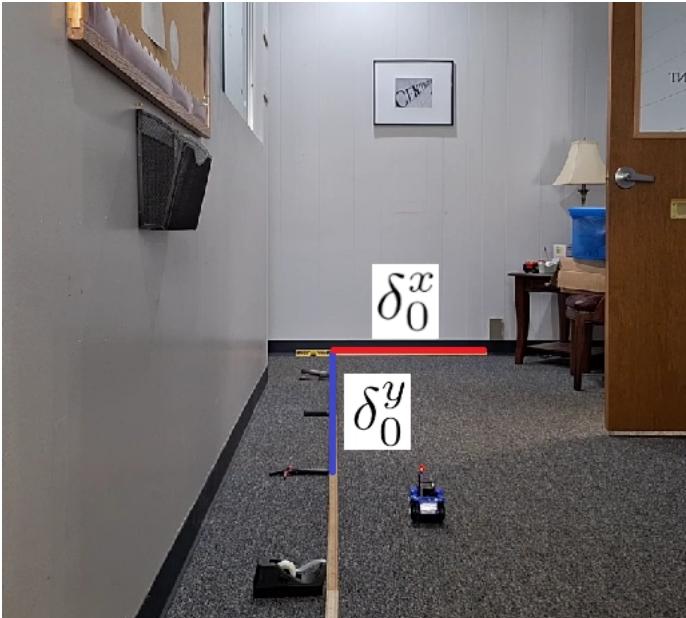
Extract apparent position  $(x_0, y_0)$  vs. time from video using software (e.g., [Tracker](#) or [LoggerPro](#)), with the horizontal length standard  $\delta_1^x$  setting the scale. Note the apparent video coordinates  $(x_0^A, y_0^A)$  of the end of the “vertical” length standard  $\delta_1^y$  that is farthest from the camera (i.e., the end whose distance from the camera base is  $\delta_1$ ).

$$x_1 = \frac{\delta_0^y(\delta_1 - \delta_1^y)(x_0 - x_0^A)}{\delta_0^y(\delta_1 - \delta_1^y) - \delta_1^y(y_0 - y_0^A)},$$

$$y_1 = \frac{\delta_1\delta_0^y(\delta_1 - \delta_1^y)}{\delta_0^y(\delta_1 - \delta_1^y) - \delta_1^y(y_0 - y_0^A)}.$$

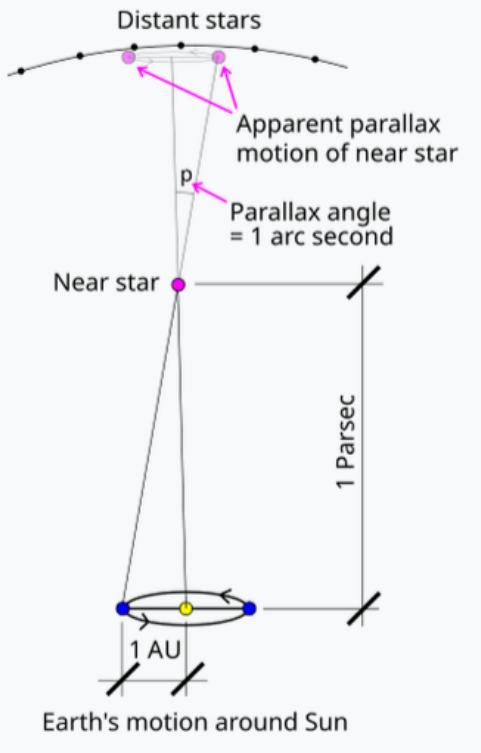
# Corrected motion for receding car is possible, but somewhat involved

- We can correct if we know the distance  $\delta_1$  from our camera to our length references



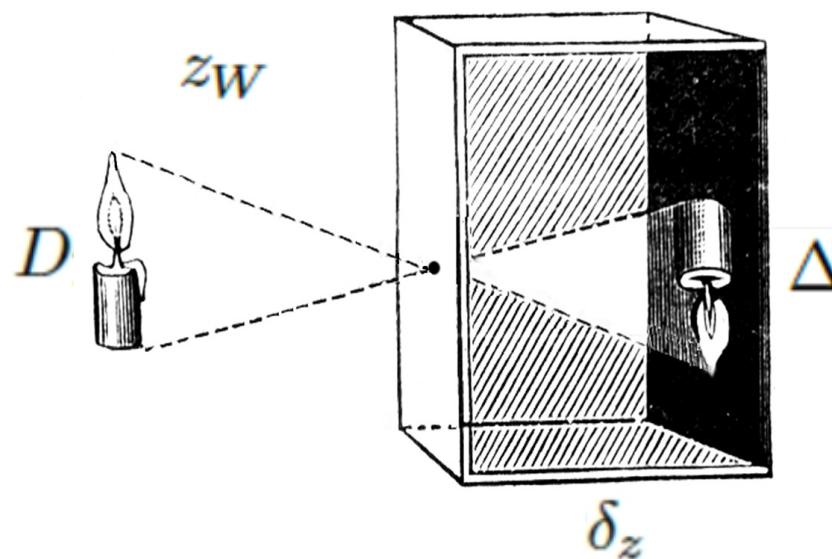
# Simpler analysis: Use parallax

- If we can track points that are equally spaced, we can get relative distances!

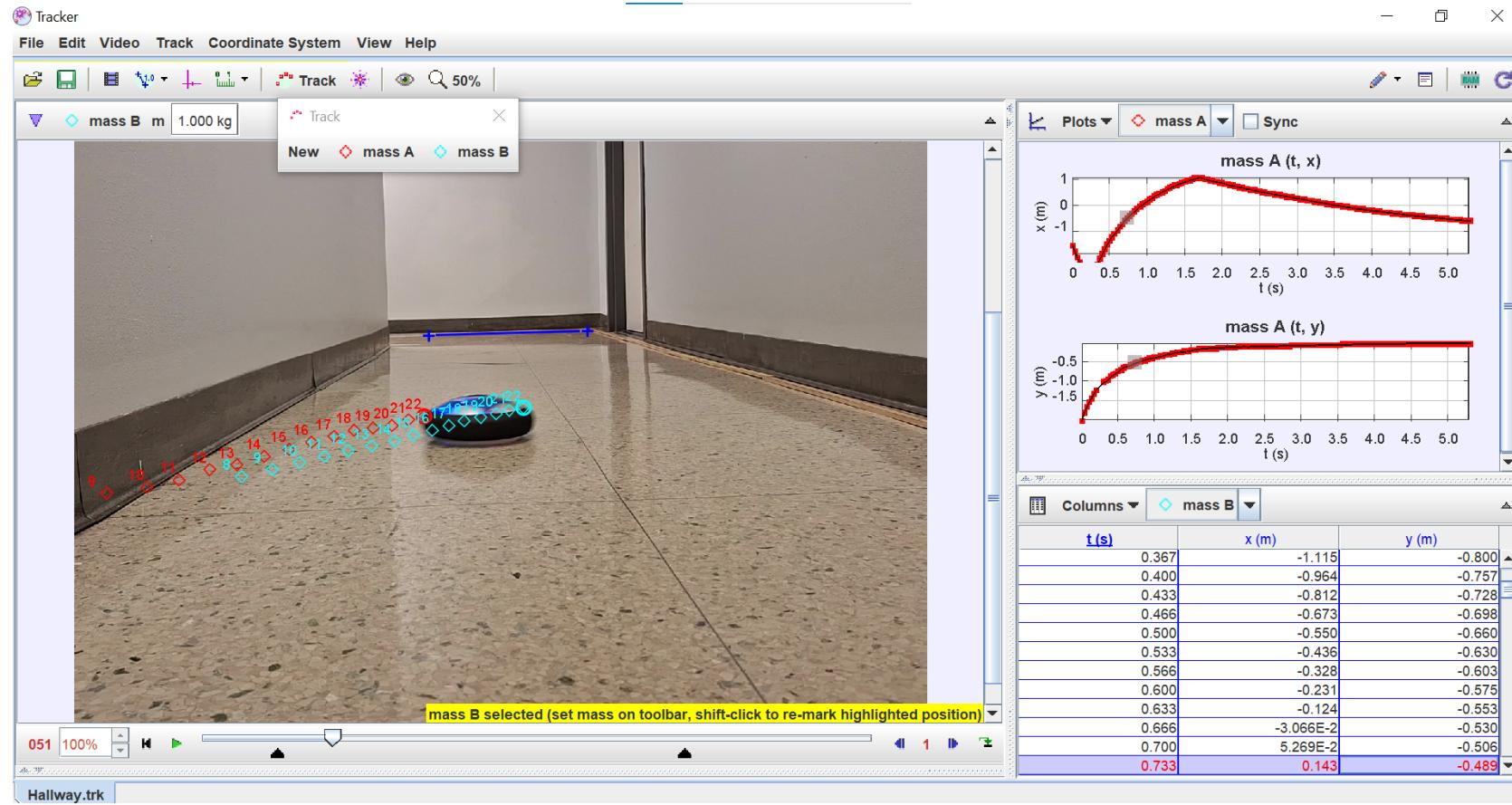


Stellar parallax is the basis for the [parsec](#), which is the distance from the Sun to an [astronomical object](#) that has a [parallax](#) angle of one [arcsecond](#). (1 AU and 1 parsec are not to scale, 1 parsec = ~206265 AU)

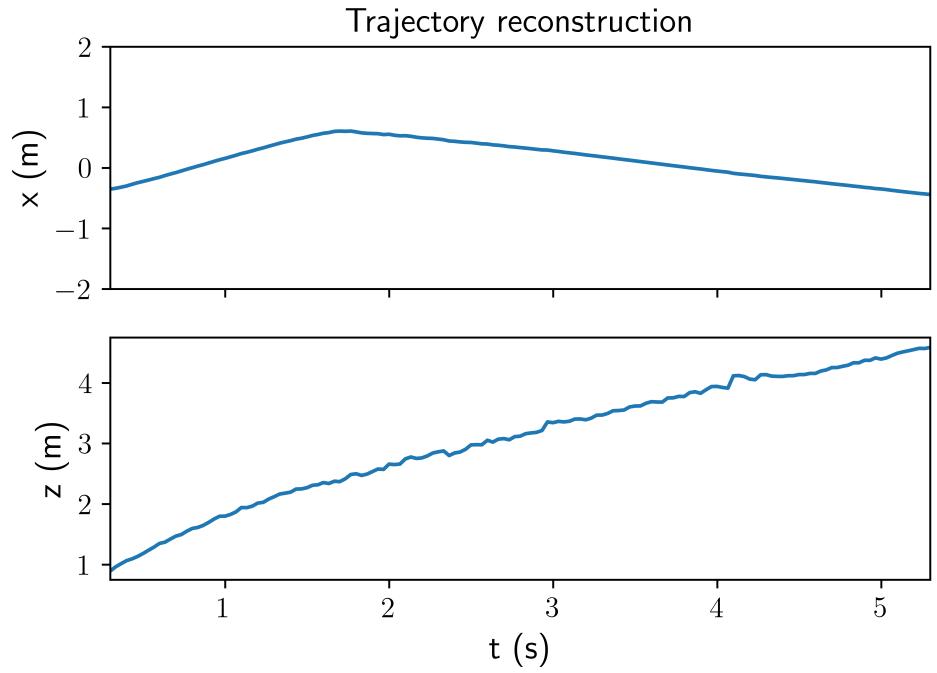
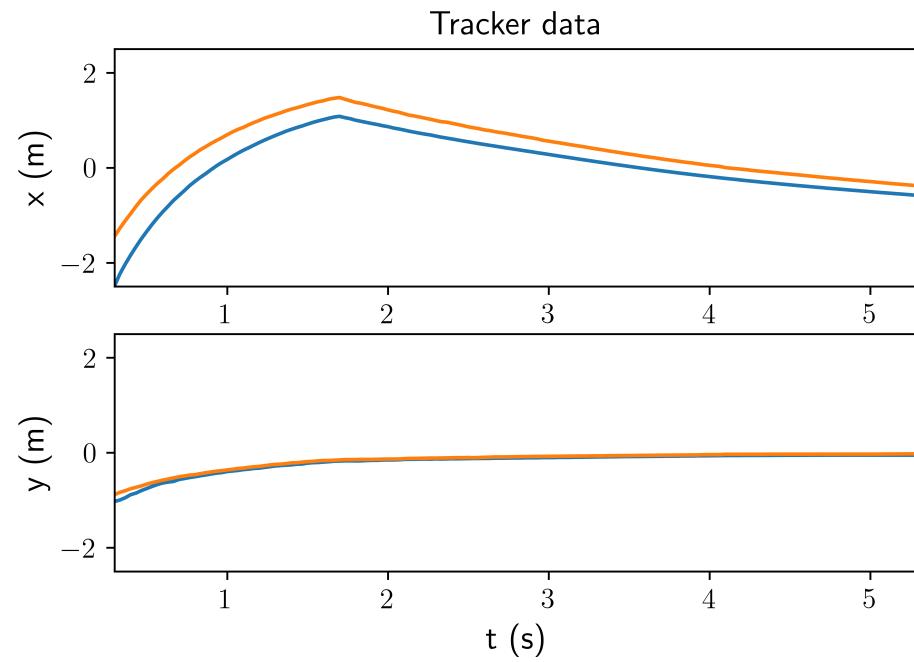
$$x_W = \frac{Dx_C}{\Delta}$$
$$y_W = \frac{Dy_C}{\Delta}$$
$$z_W = \frac{D\delta_z}{\Delta}.$$



# Receding hover puck video analysis



# Receding hover puck: parallax-corrected motion



# Recoiling projectile video analysis

Tracker

File Edit Video Track Coordinate System View Help

mass B m 1.000 kg

mass B selected (set mass on toolbar, shift-click to mark)

074 100% ▶ 1 ▶

Plots mass B Sync

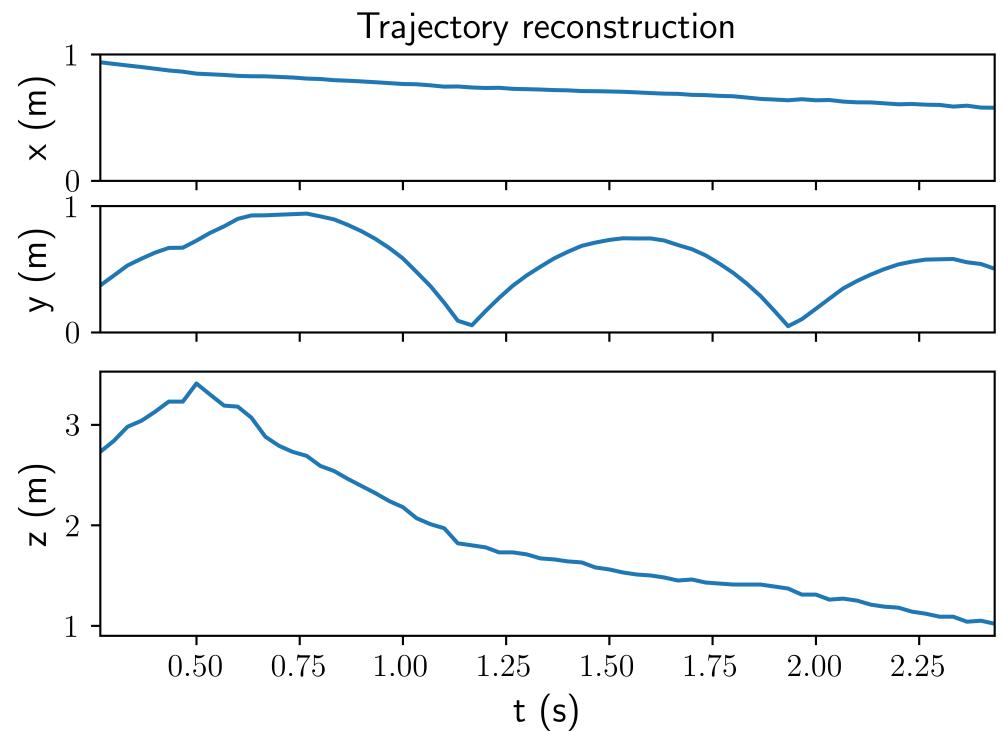
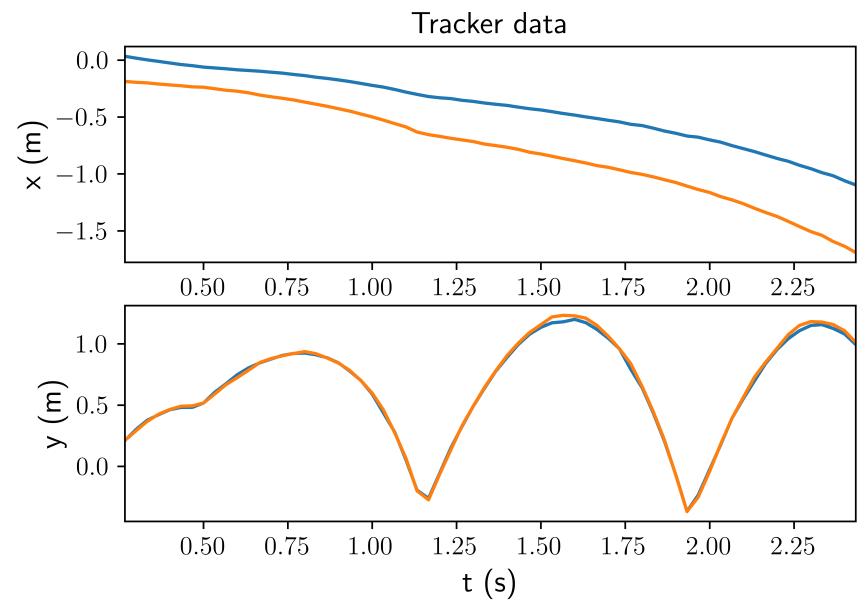
mass B (t, x)

mass B (t, y)

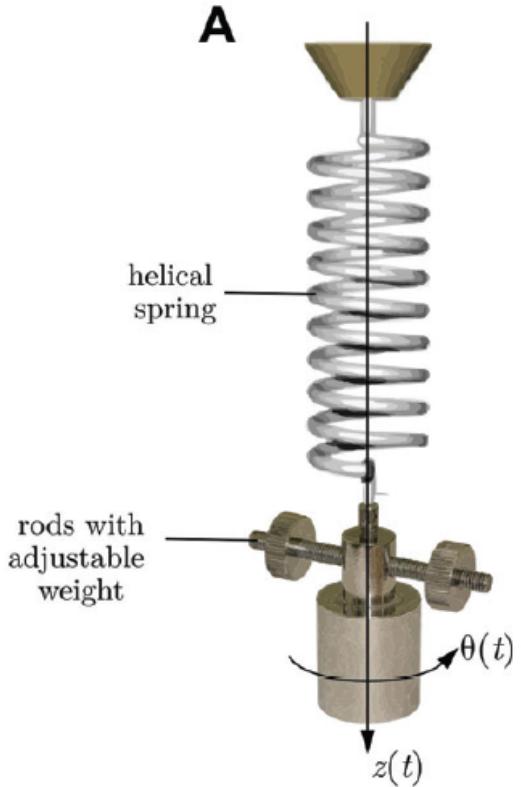
Columns mass B

t (s)	x (m)	y (m)
0.267	-0.187	0.211
0.300	-0.195	0.291
0.333	-0.200	0.367
0.367	-0.210	0.426
0.400	-0.218	0.464
0.433	-0.225	0.491
0.467	-0.235	0.494
0.500	-0.238	0.517
0.533	-0.251	0.590
0.567	-0.265	0.668
0.600	-0.273	0.724
0.633	-0.287	0.784

# Recoiling projectile: Parallax-corrected motion



# Better parallax use case: Wilberforce pendulum video



# Wilberforce pendulum video analysis

Tracker

File Edit Video Track Coordinate System View Help

Track

New mass A mass B

mass A m 1.000 kg

mass A (t, x)

x (m)

t (s)

mass A (t, y)

y (m)

t (s)

Columns

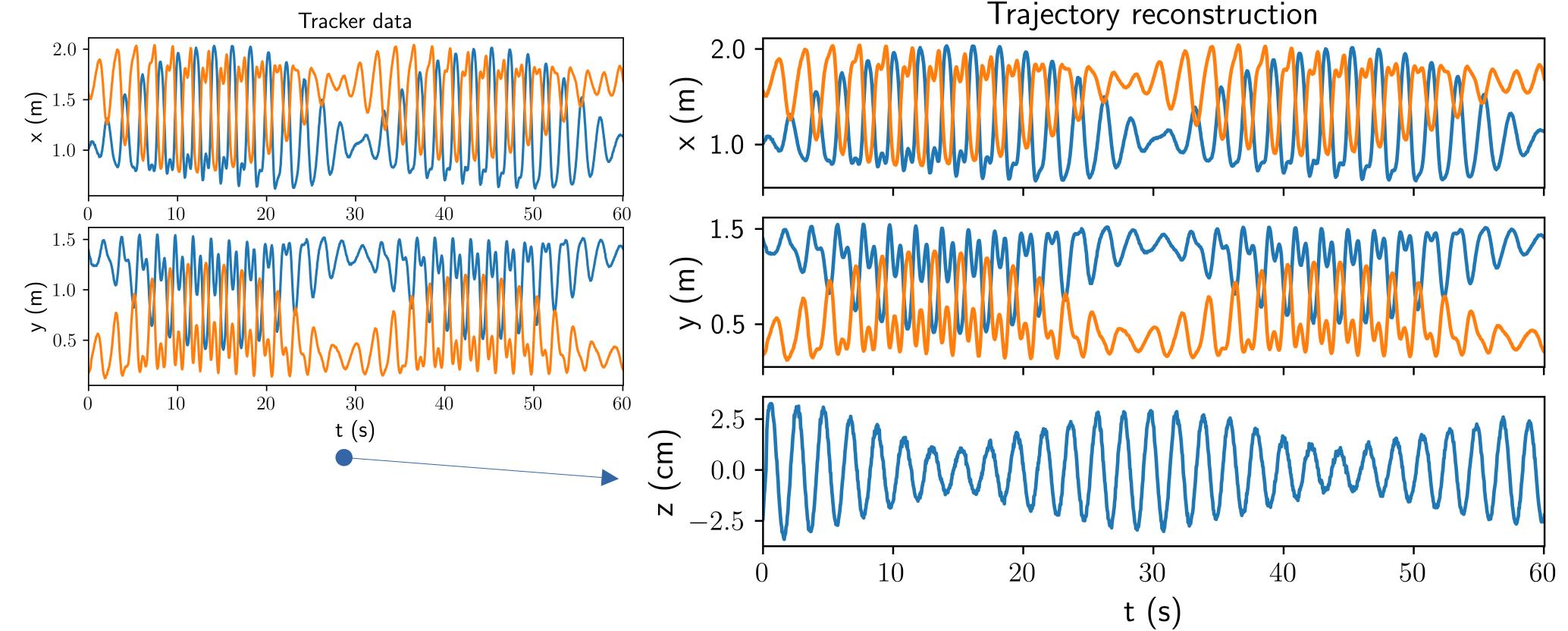
mass A

t (s)	x (m)	y (m)
1.833	1.089	1.492
1.866	1.117	1.492
1.900	1.133	1.492
1.933	1.164	1.484
1.966	1.198	1.476
2.000	1.216	1.466
2.033	1.242	1.454
2.066	1.258	1.440
2.100	1.278	1.420
2.141	1.294	1.410

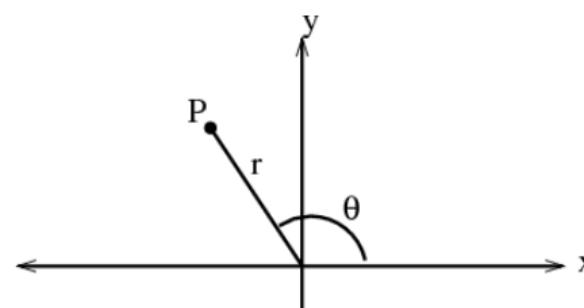
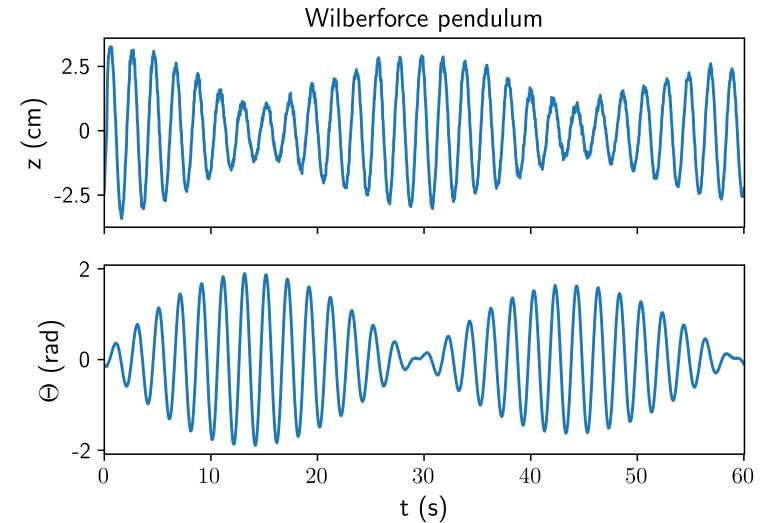
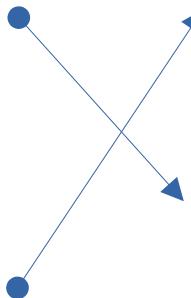
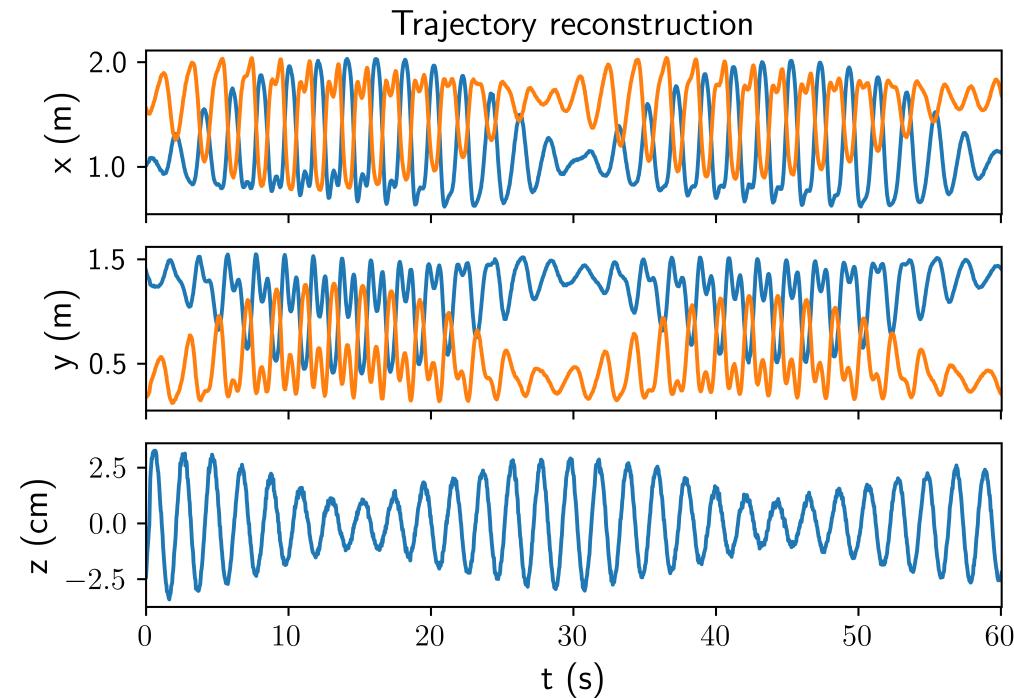
059 100% 25% 059 100% 25%

The image shows a screenshot of the Tracker software interface. On the left, a video frame of a Wilberforce pendulum is displayed. A red diamond marker is placed on the mass A, and a blue diamond marker is placed on the mass B. A vertical magenta line and a horizontal magenta line intersect at the center of mass A. A yellow box at the bottom of the video frame indicates: "mass A selected (set mass on toolbar, shift-click to re-mark highlighted position)". The top menu bar includes File, Edit, Video, Track, Coordinate System, View, and Help. The toolbar contains various icons for file operations and tracking. The main workspace has tabs for "Track" and "New mass A mass B". The "Track" tab shows a list of tracked objects: "mass A m 1.000 kg". The right side of the interface contains three plots: "mass A (t, x)" showing horizontal position vs. time, "mass A (t, y)" showing vertical position vs. time, and a table titled "Columns" showing the data for mass A. The table has columns for time (t), horizontal position (x), and vertical position (y). The last row of the table is highlighted in red and shows the values: t=2.141 s, x=1.294 m, and y=1.410 m. The bottom of the interface shows playback controls (059, 100%, 25%) and a timeline.

# Wilberforce pendulum: Parallax-corrected motion



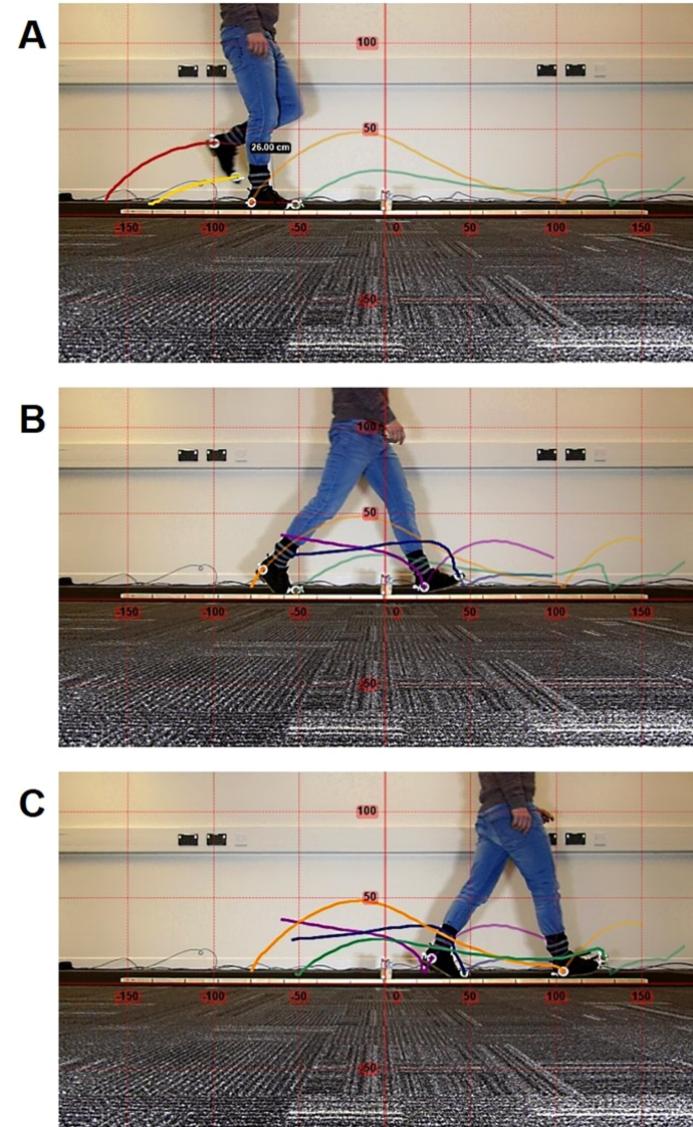
# Wilberforce pendulum: Changing coordinates for insight

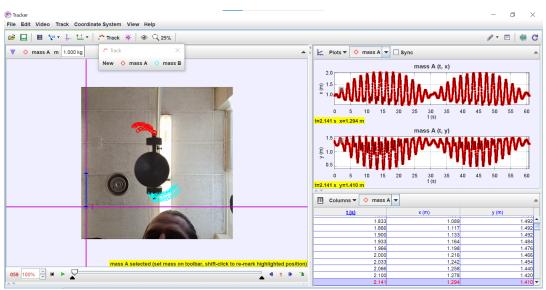


# Future possibilities

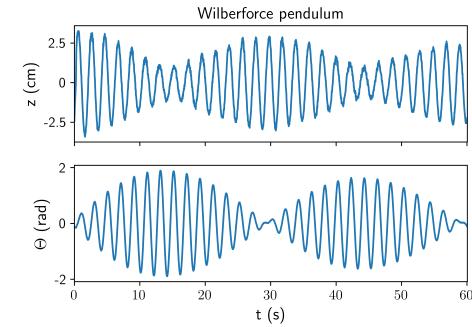
- Many possible projects for students involving athletics (Kinovea)
- Still photos over time can also be analyzed – e.g., from microscope slides

“A low-cost 2-D video system can accurately and reliably assess adaptive gait kinematics in healthy and low vision subjects,” Tjerk Zult, Jonathan Allsop, Juan Tabernero & Shahina Pardhan, *Scientific Reports*, Volume 9, Article number: 18385 (2019).





# Summary



- Video analysis gives students a taste of the “activist realism” inherent in scientific research
- Video analysis is a robust and well-developed pedagogy for teaching standard physics topics
- Video analysis can yield more information when we incorporate our insights about geometry