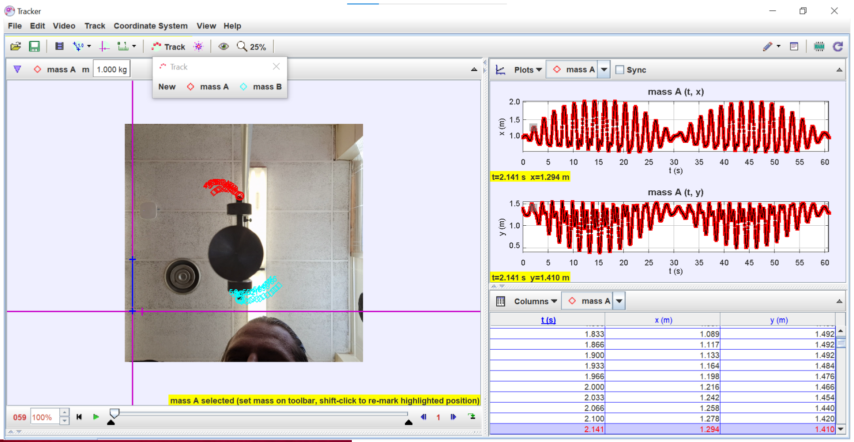
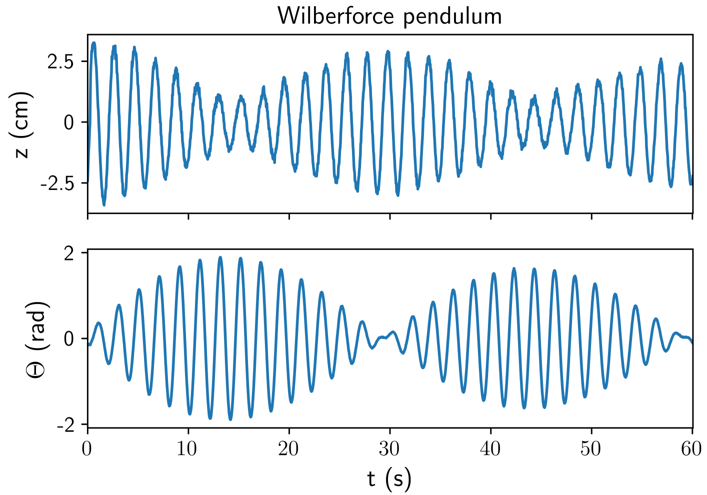
From image to insight:
Getting more out of video analysis





Dr. David Kordahl
Department of Physics and Engineering
Centenary College of Louisiana

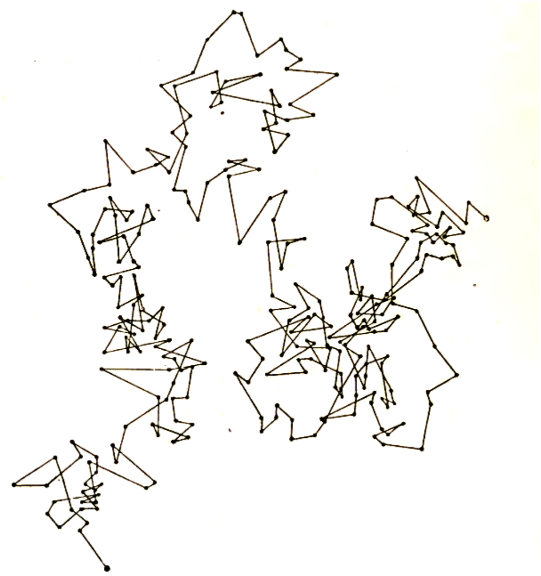
Full STEAM Ahead – 2025 Meeting

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 receeding, Wilberforce pendulum, recoiling projectile
- Conclusion and project suggestions

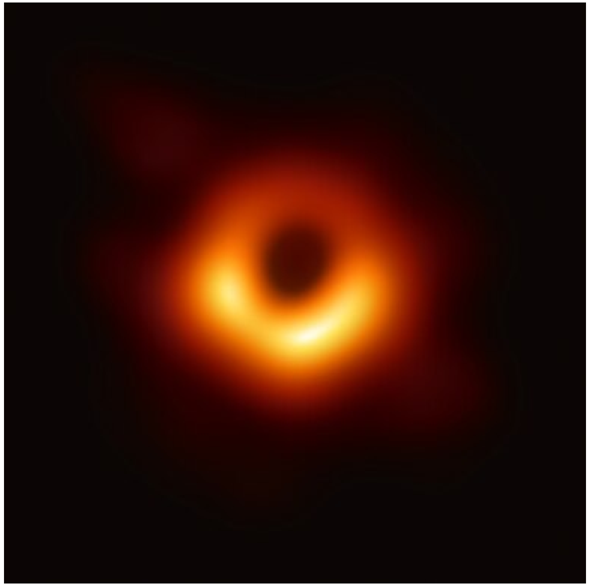
Why do we believe in science?

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



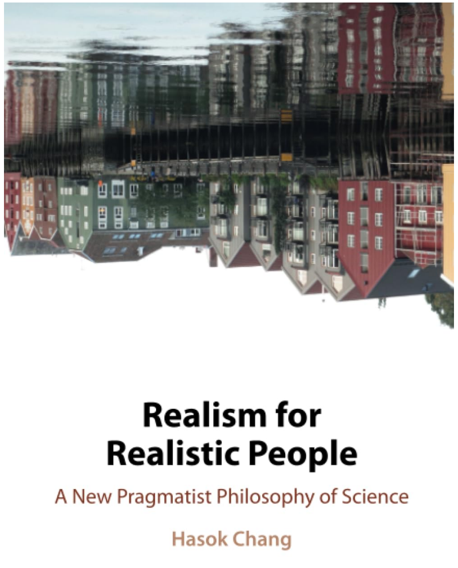
Evidence of atomic
Theory in *Les Atomes*
by Jean Perrin, 1913

“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

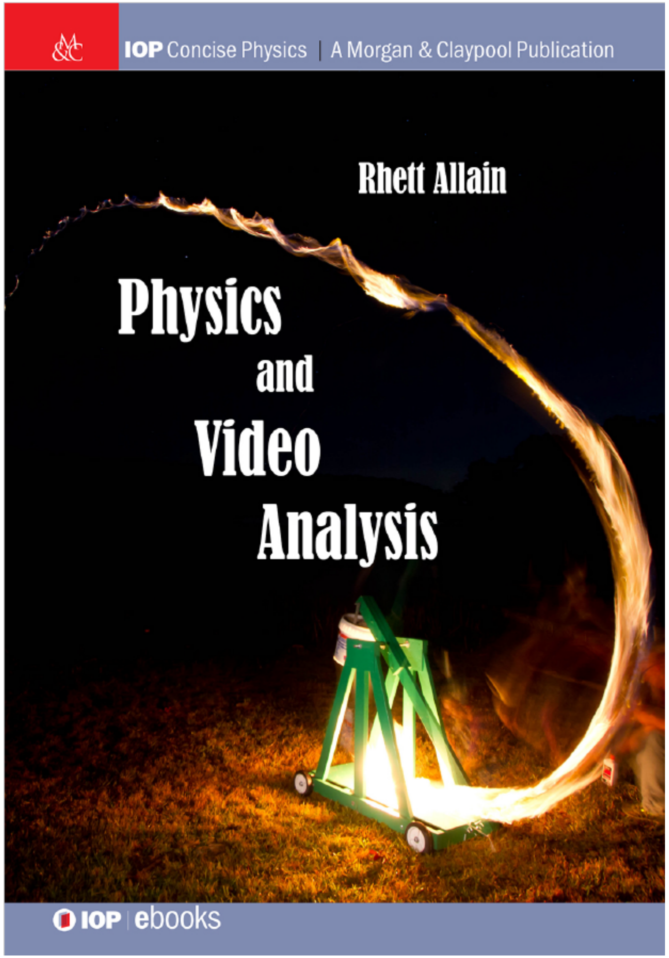


> Scientific realism is usually taken as a thesis that science states the truth about the world. In contrast, I conceive realism in and about science as a commitment to maximize our learning about realities. [...] While my conception of realism is modest in some clear ways, it is also ambitious, in that 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

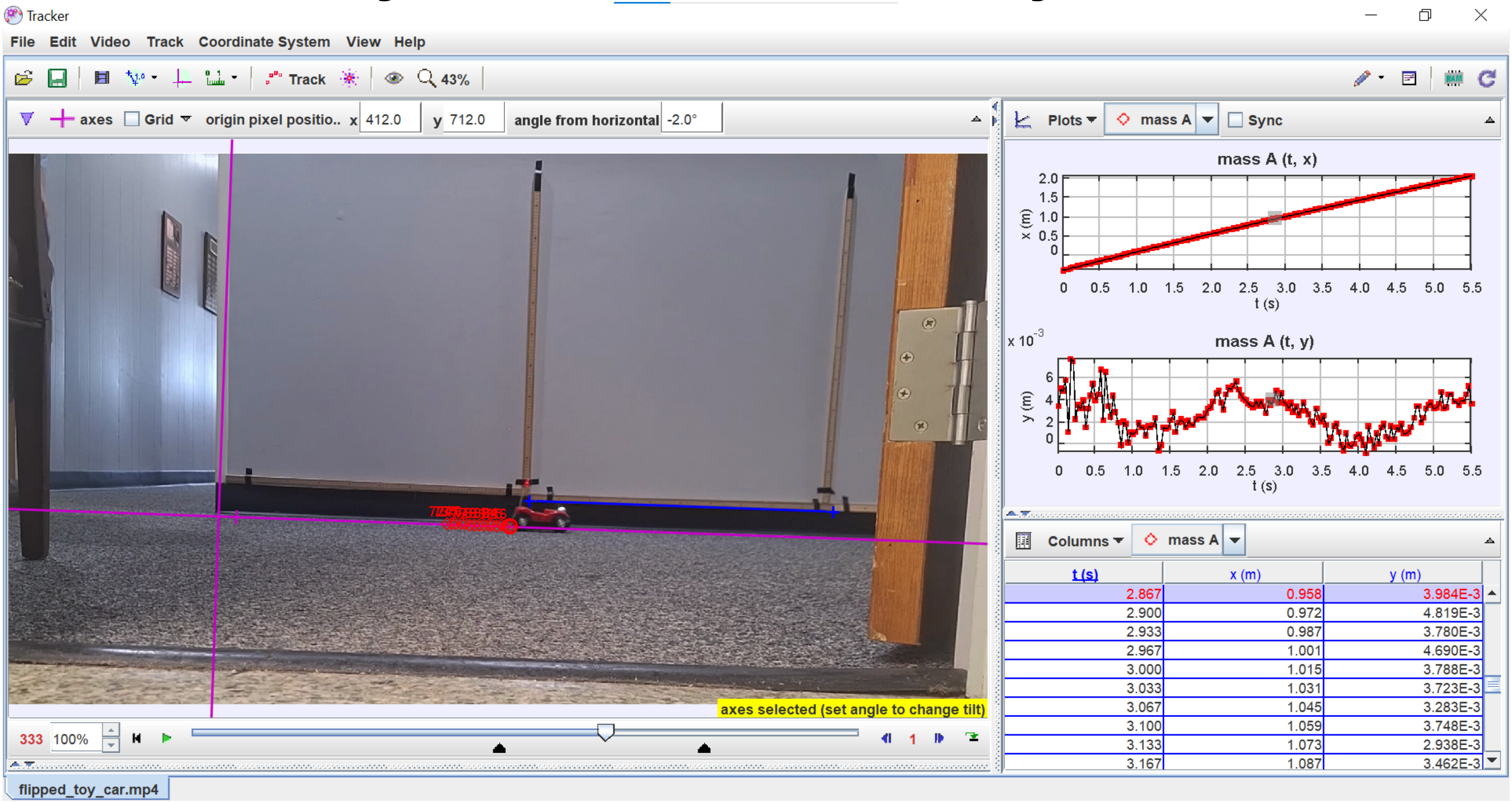
- Provides an active prototype of scientific inquiry and extends the possibility of genuine scientific discovery



Available packages

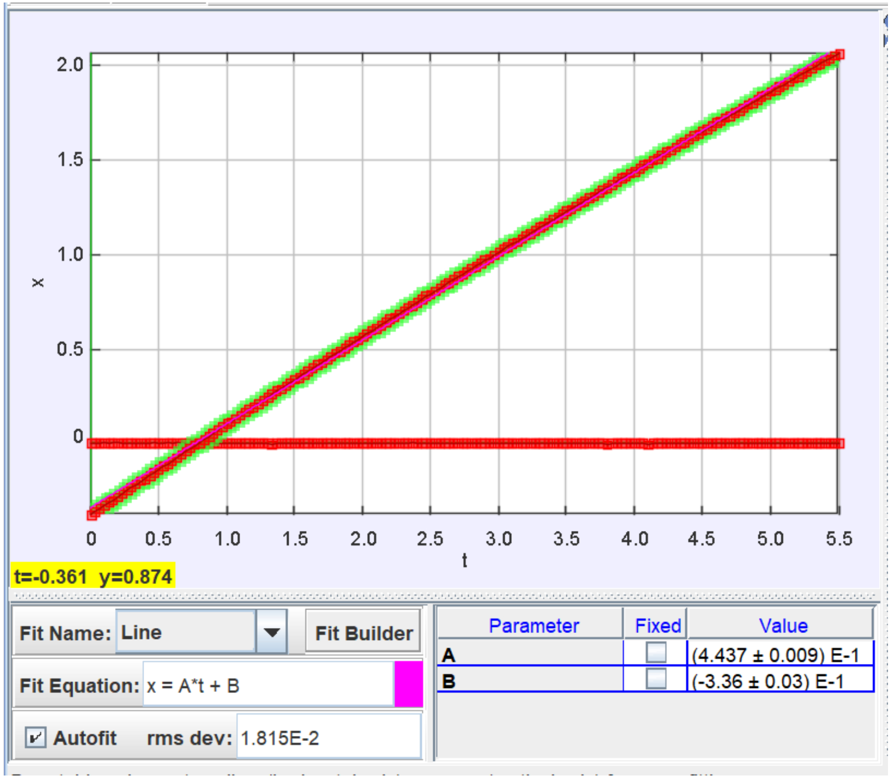
- Vernier Video Analysis is slick, but isn't free
- Tracker and Kinovea are functional and free

Toy car video analysis

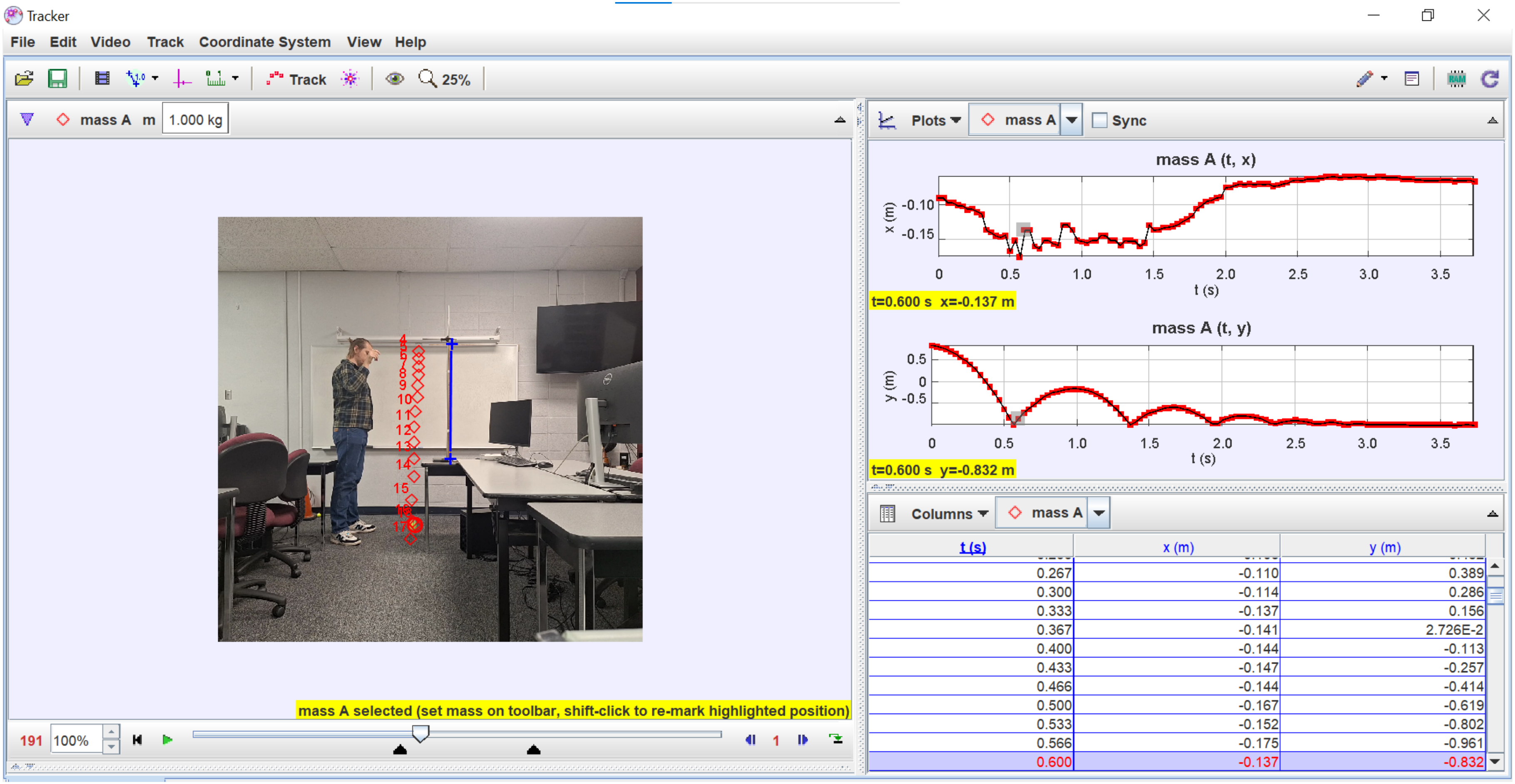


Toy car video: Constant velocity motion

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

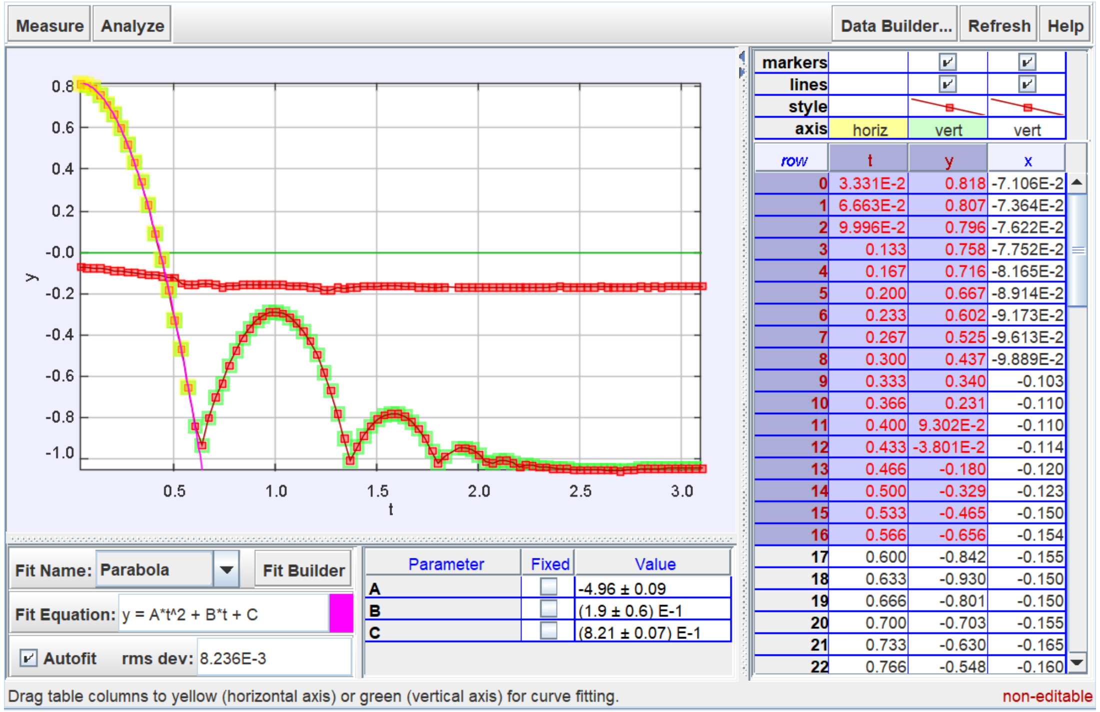


Dropped ball video analysis



Dropped ball: Accelerated motion

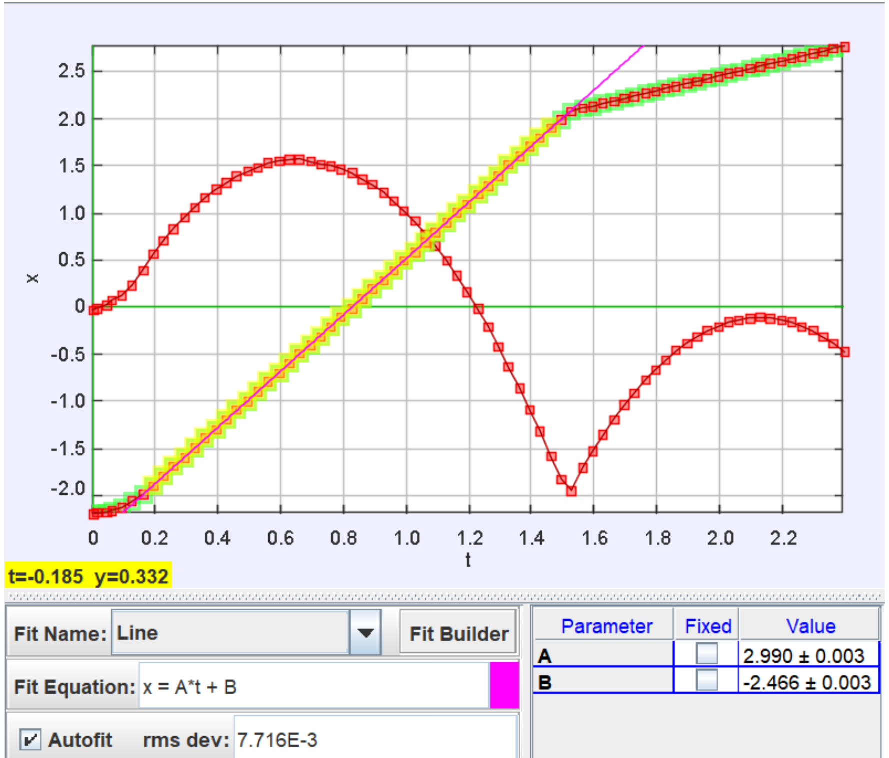
- **Physics**: accelerated motion looks parabolic

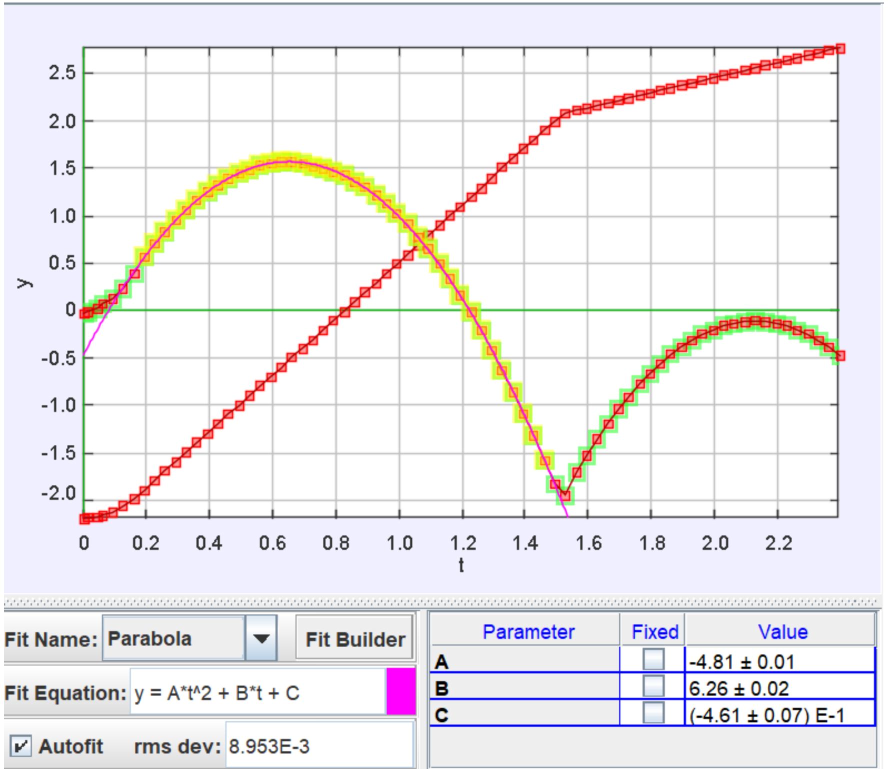


Projectile motion video analysis

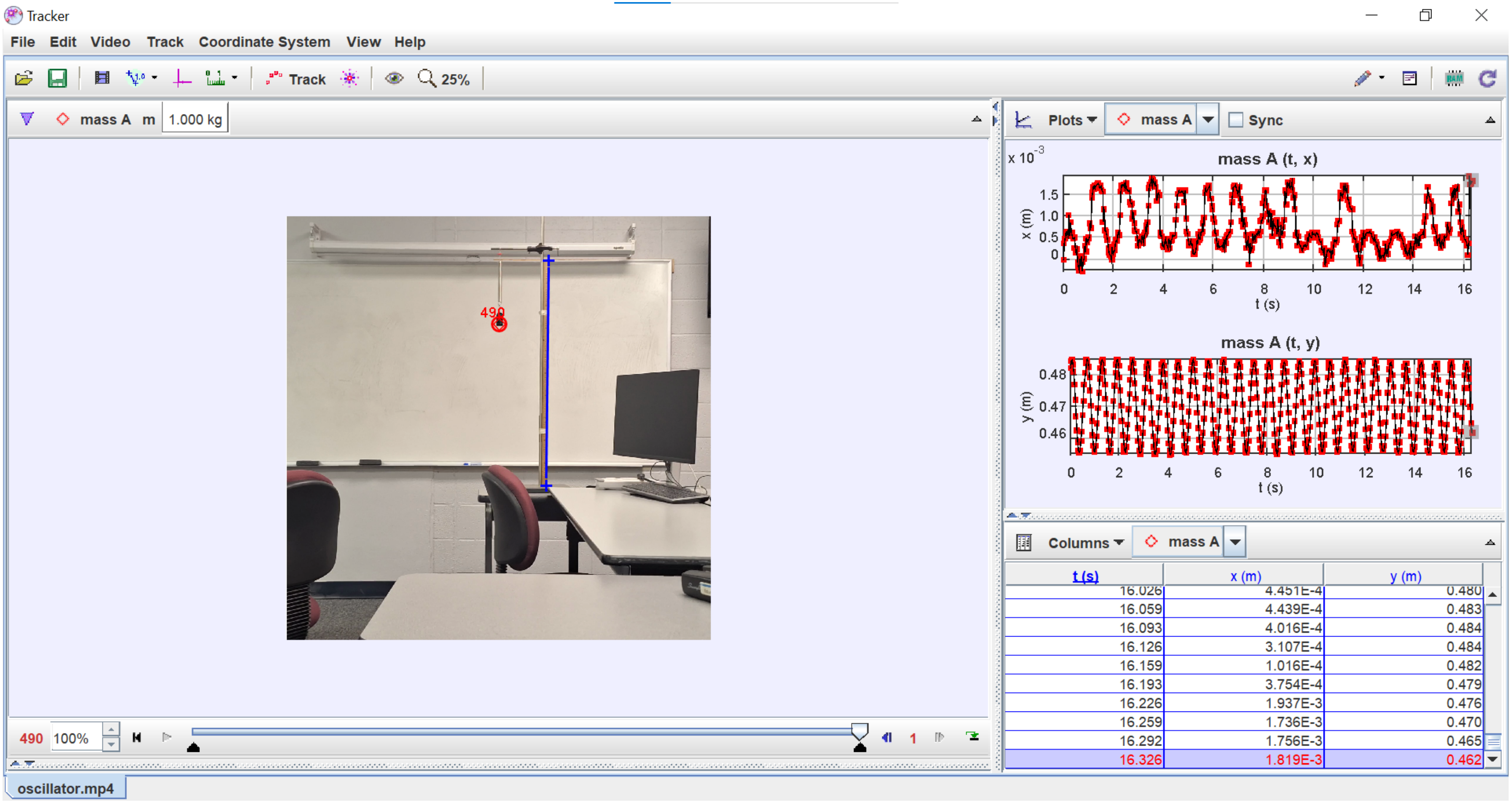
Thrown ball: Projectile motion

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



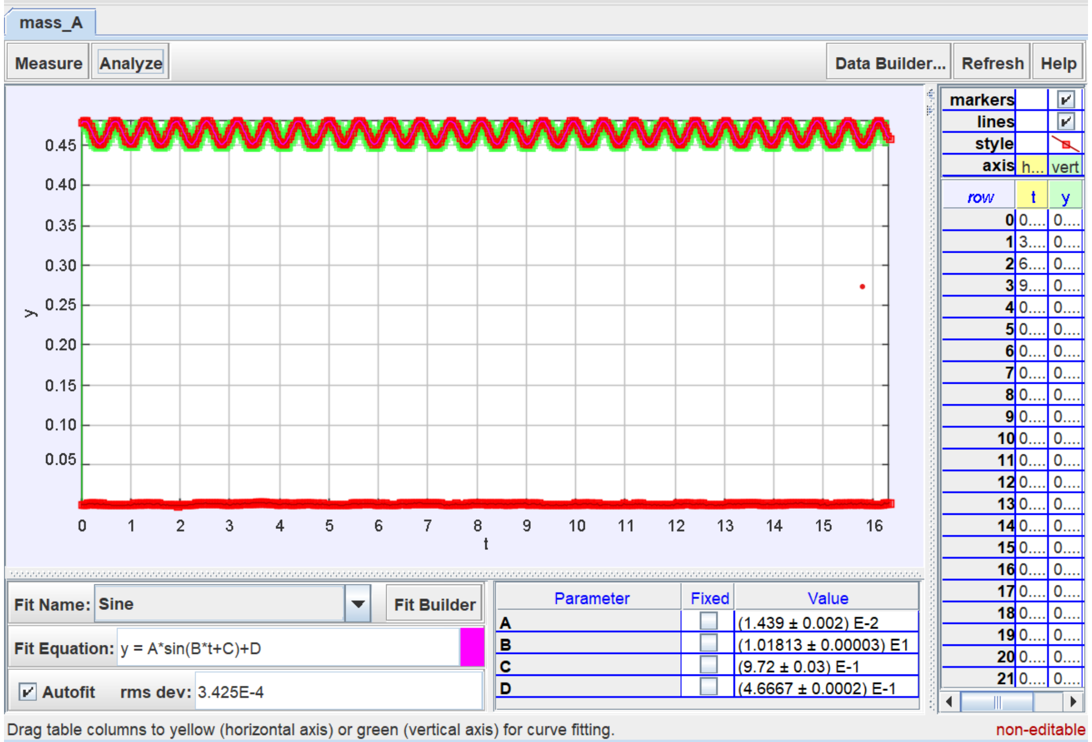


Mass on spring video analysis



Mass on spring: Oscilliatory motion

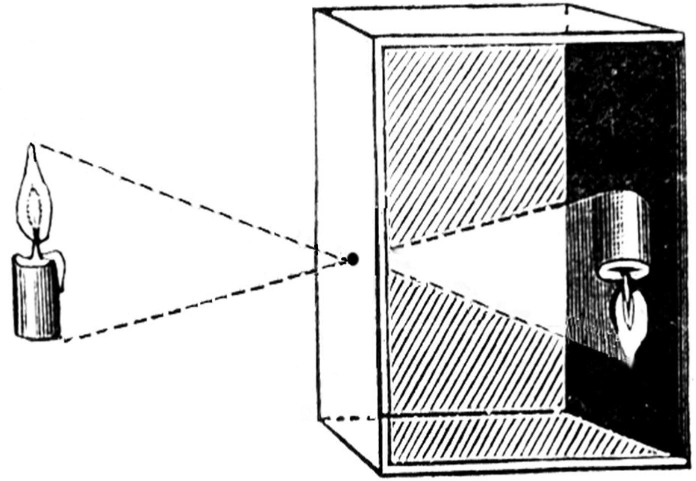
- **Physics**: oscillations look like sinusoids



Video analysis at face value: When does that work?

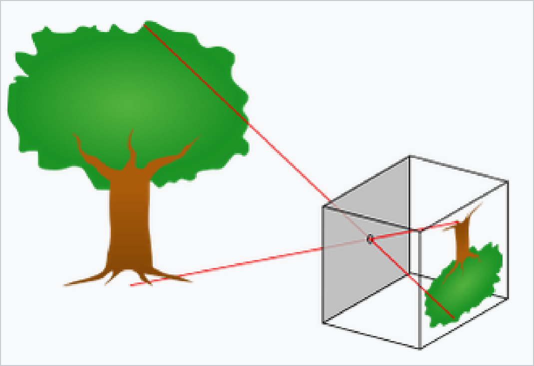
- Usually, video analysis maps points in one vertical plane to points in the image plane

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

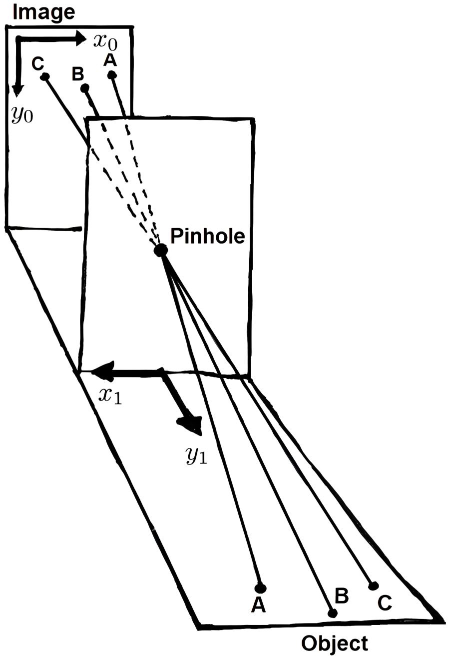


Video analysis *not* at face value: Motion outside a single plane

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

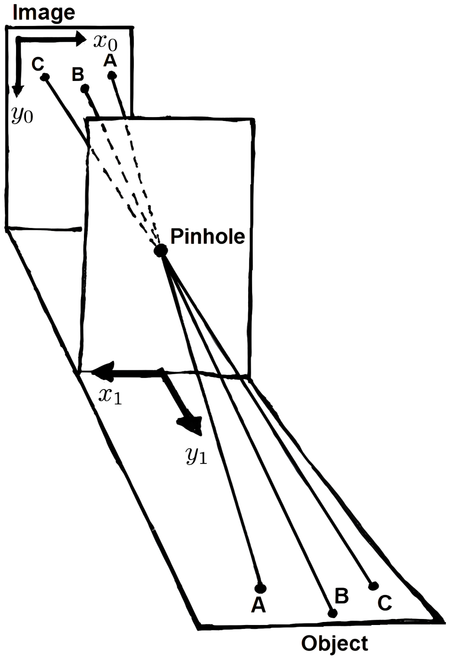


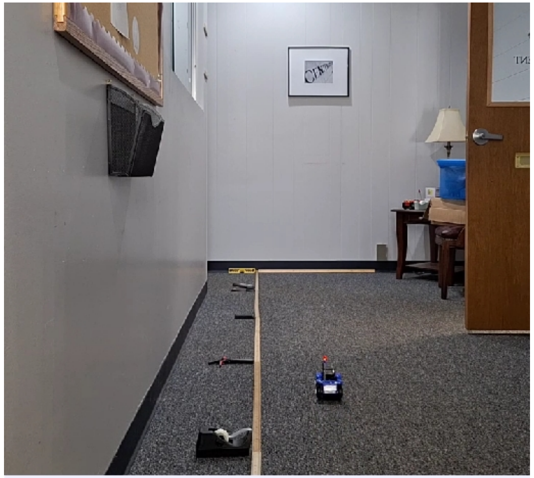
Early pinhole camera. Light enters a dark box through a small hole and creates an inverted image on the wall opposite the hole.[8]

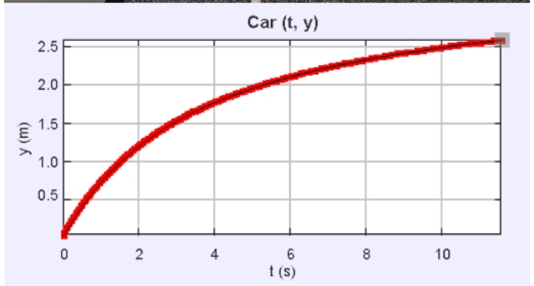


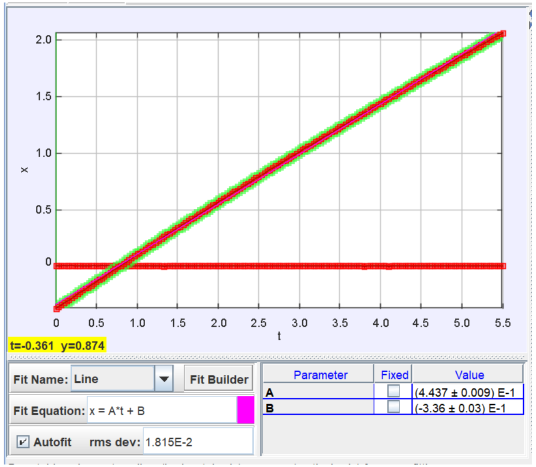
Receding toy car: Still constant velocity, but needs correction

- Apparent velocity is not the physical velocity!





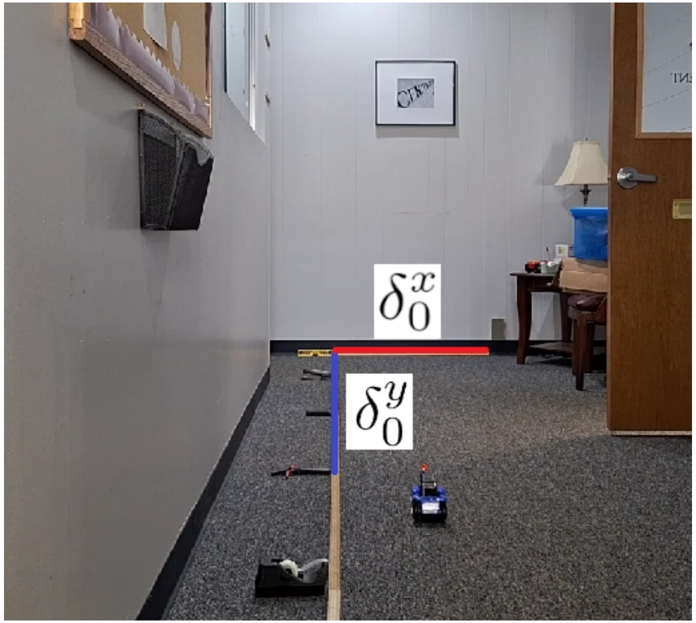




This graph represents the same motion as the graph above, but the apparent velocity (slope) decreases!

Corrected motion for receeding car is possible, but somewhat involved

- We can correct if we know the distance δ_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 δ_1^x setting the scale. Note the apparent video coordinates (x_0^A, y_0^A) of the end of the "vertical" length standard δ_y^1 that is farthest from the camera (i.e., the end whose distance from the camera base is δ_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 receeding car is possible, but somewhat involved

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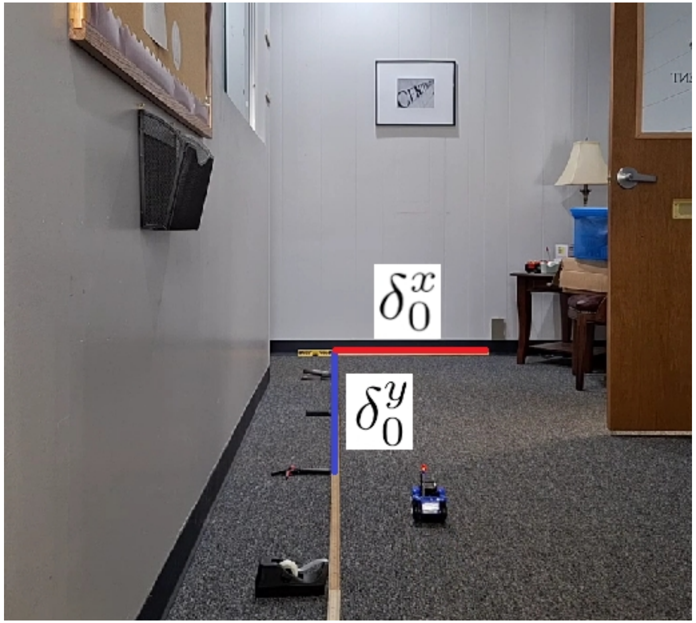
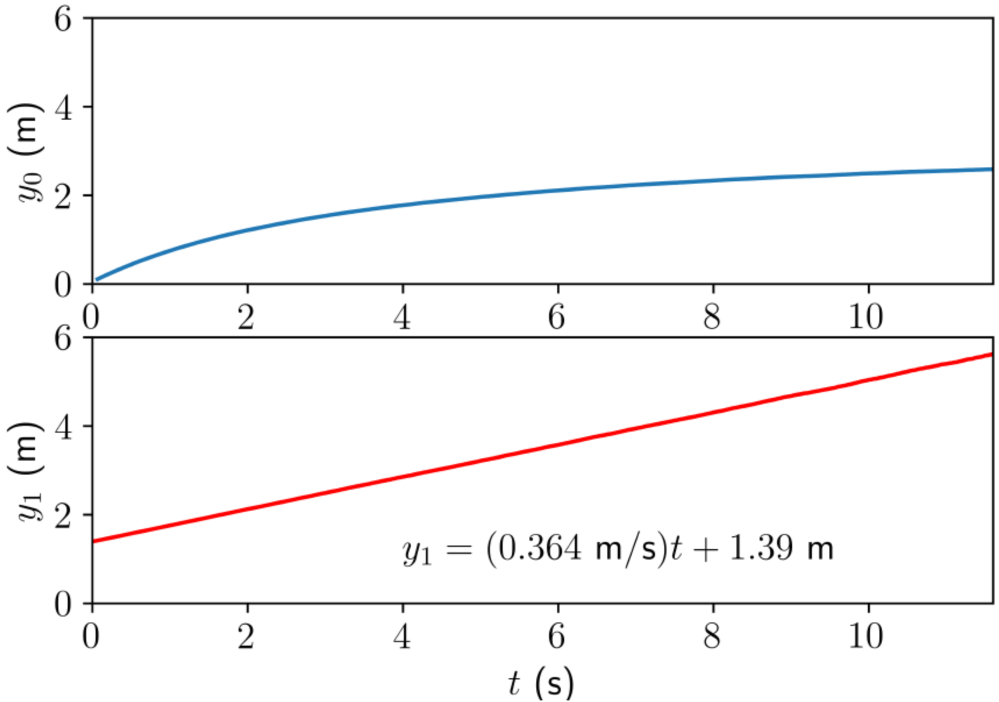
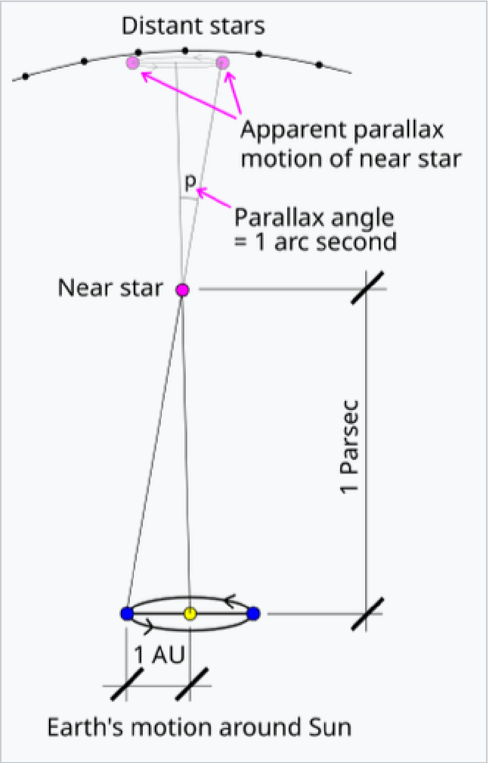






Stellar parallax is the basis for the parsec, which is the distance from the Sun to an astronomical object that has a parallax angle of one arcsecond. (1 AU and 1 parsec are not to scale, 1 parsec = ~206265 AU)

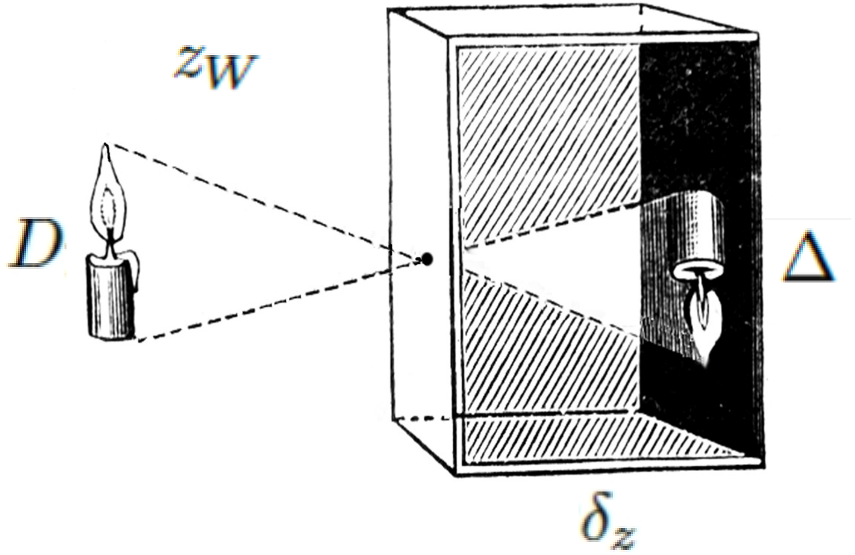
Simpler analysis: Use *parallax*

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

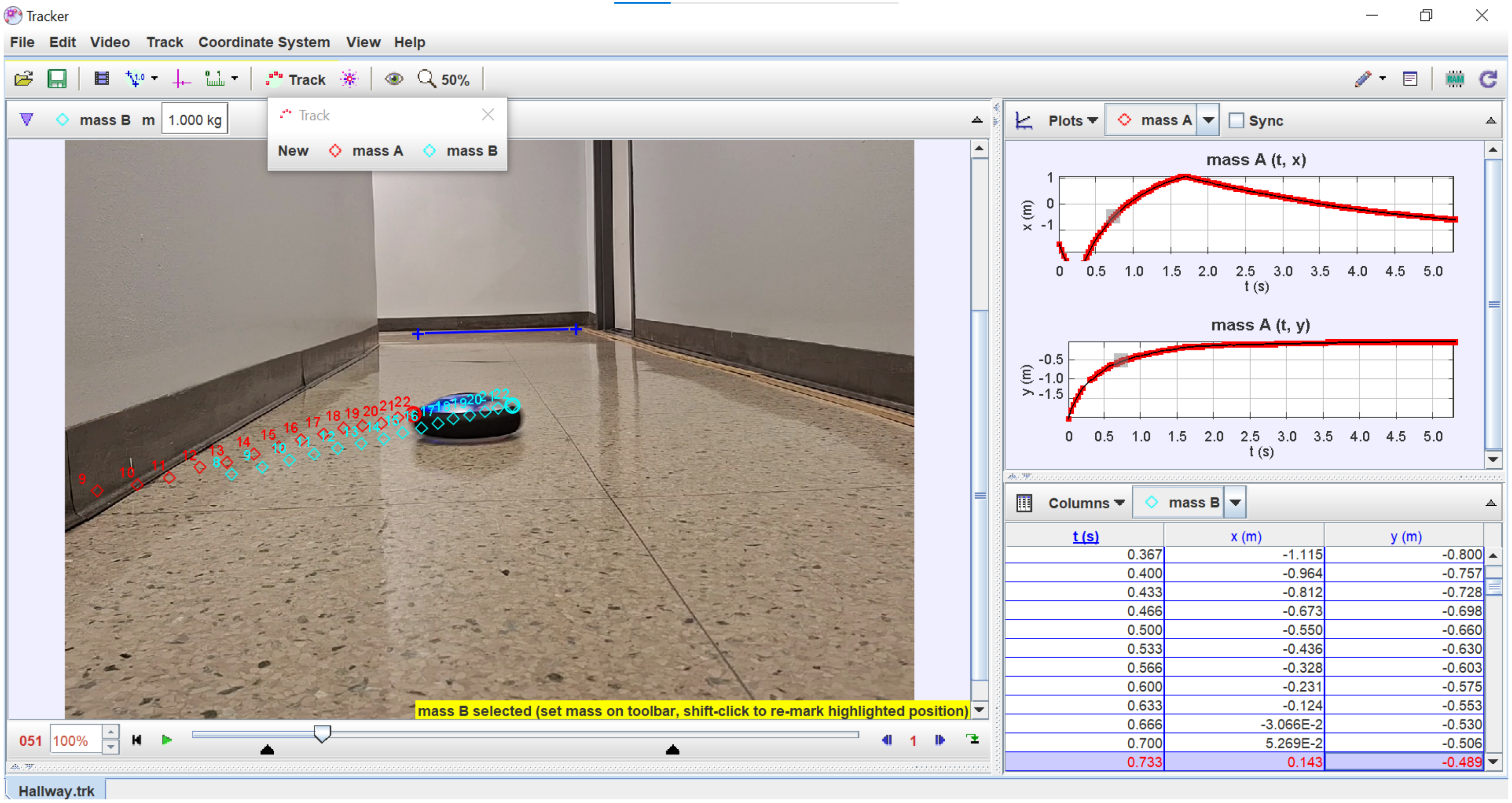
$$x_W = \frac{Dx_C}{\Delta}$$

$$y_W = \frac{Dy_C}{\Delta}$$

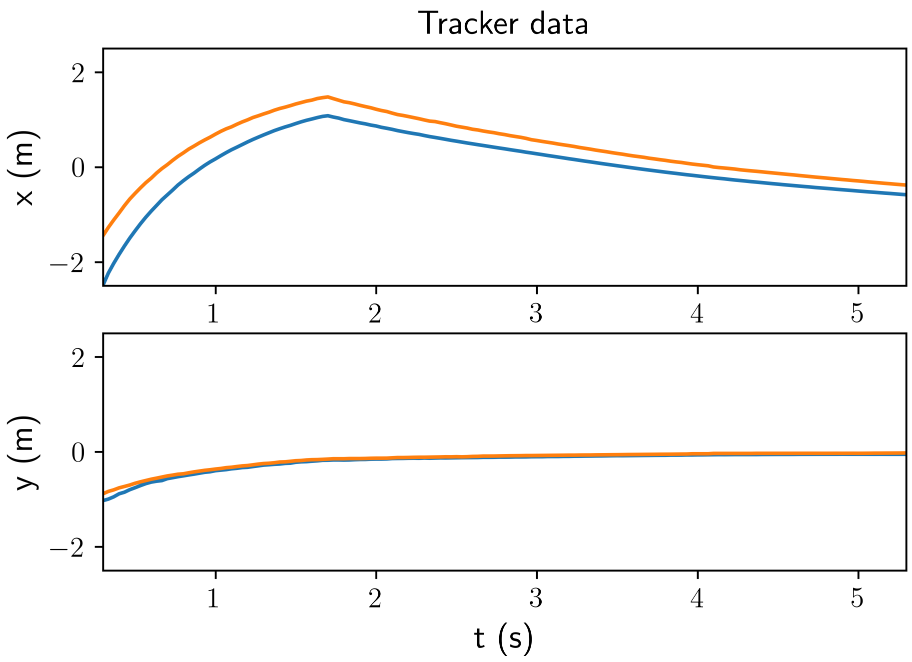
$$z_W = \frac{D\delta_z}{\Delta}.$$

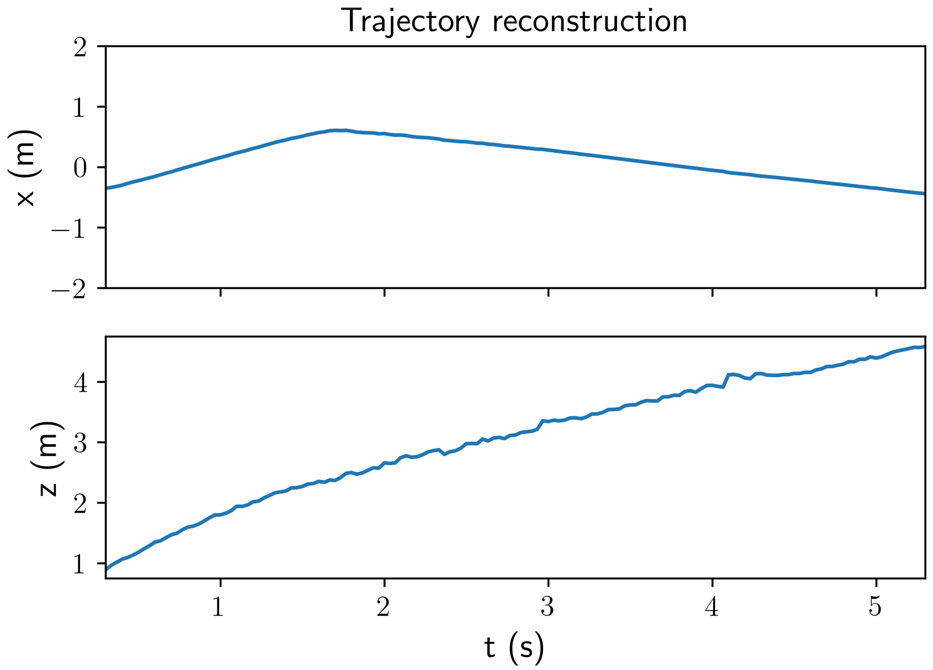


Receding hover puck video analysis

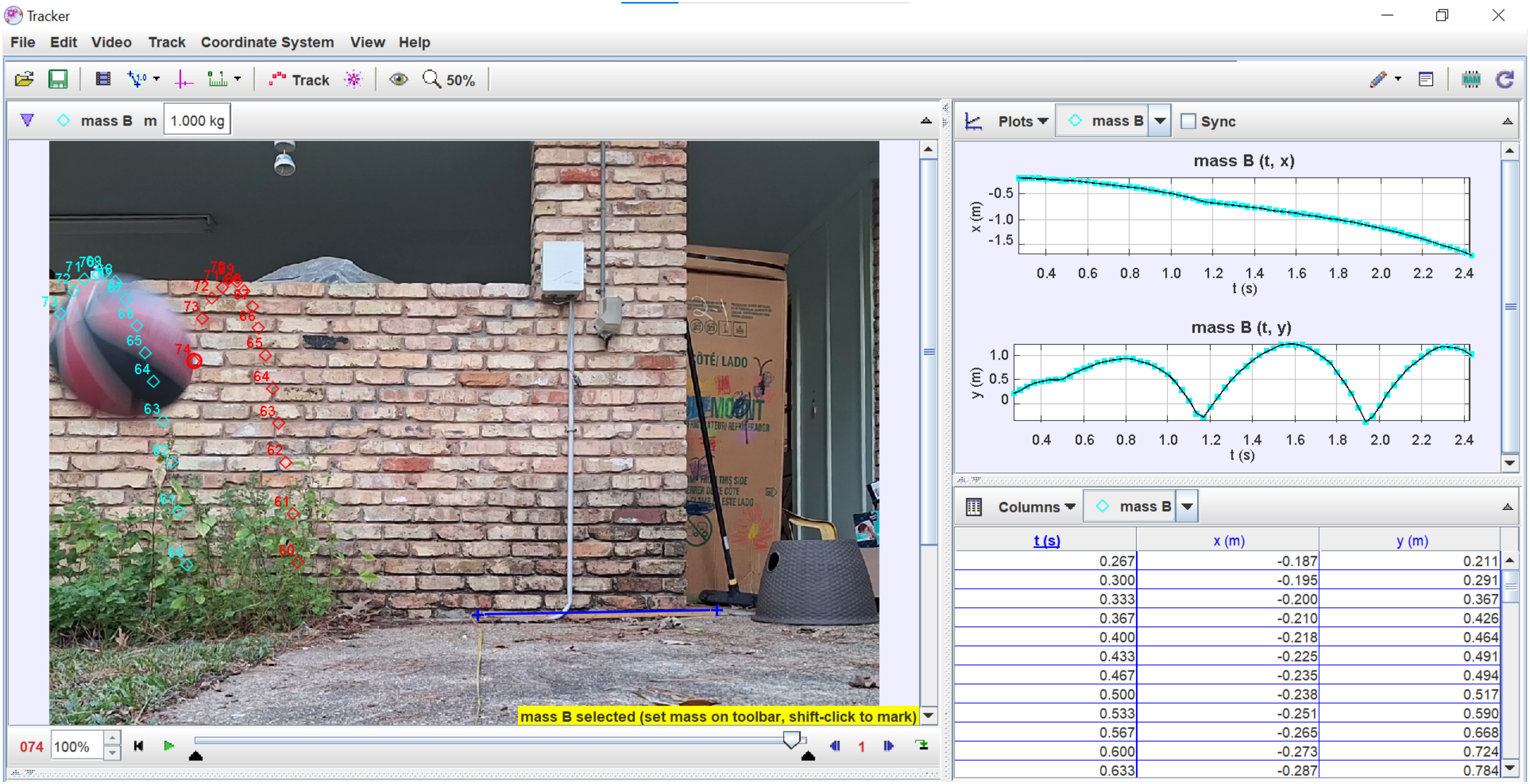


Receding hover puck: parallax-corrected motion

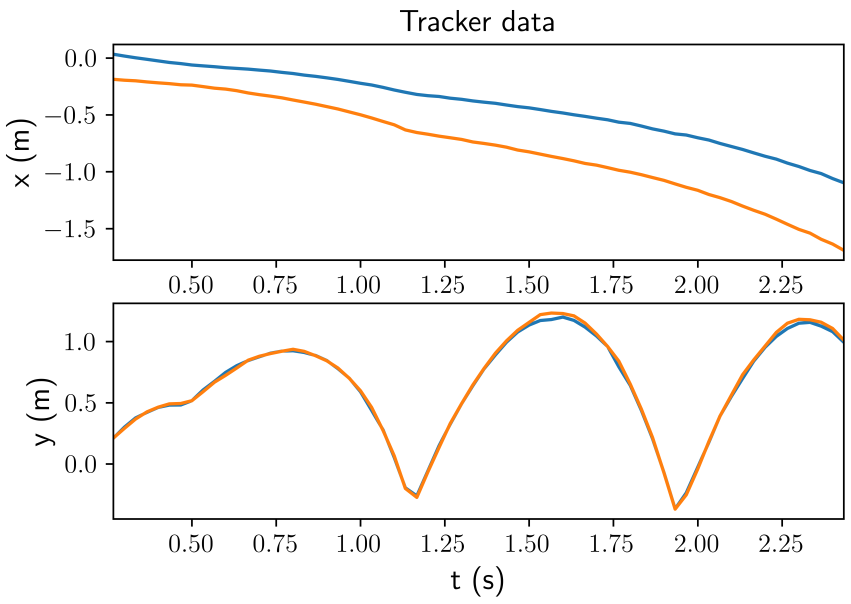


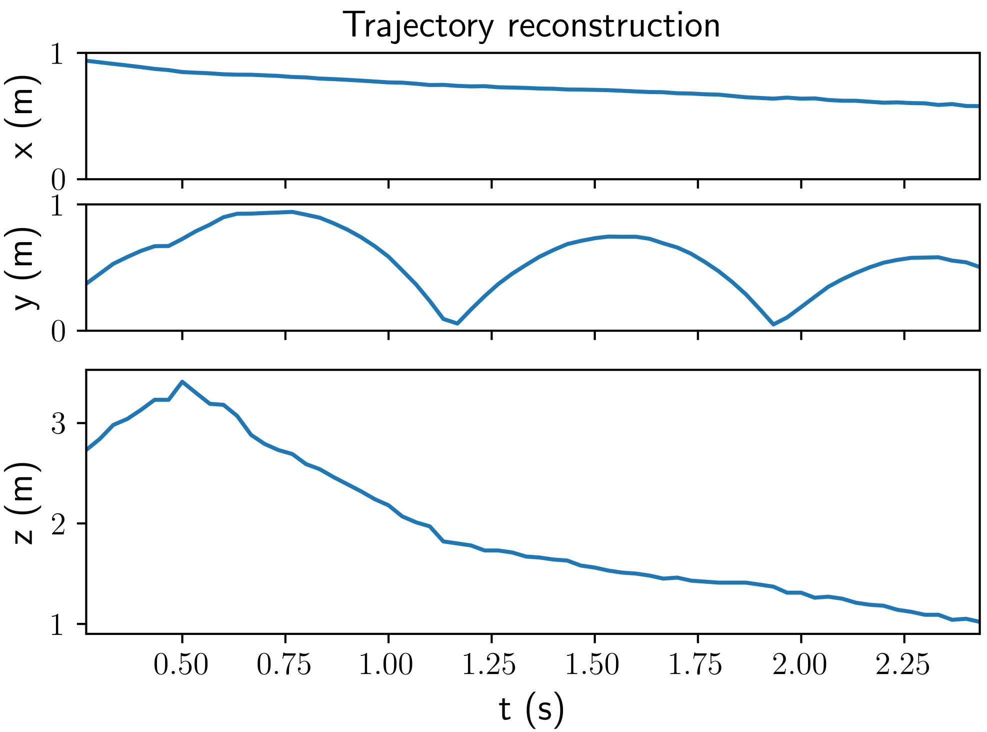


Recoiling projectile video analysis

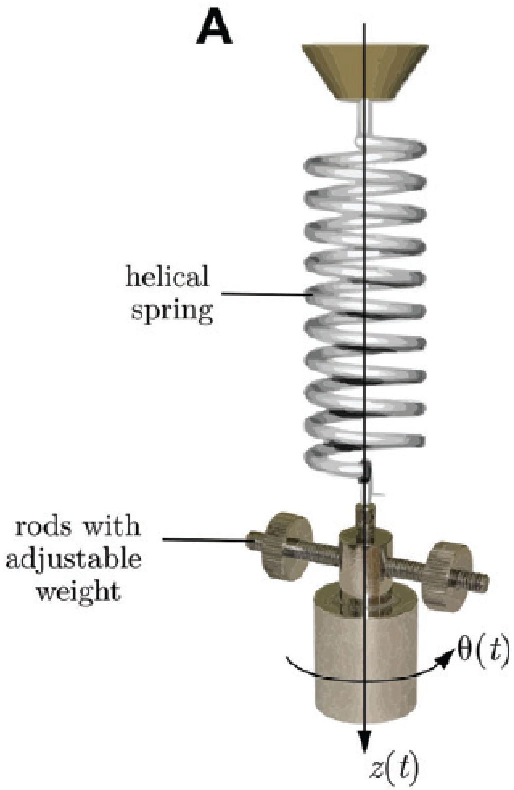


Recoiling projectile: Parallax-corrected motion

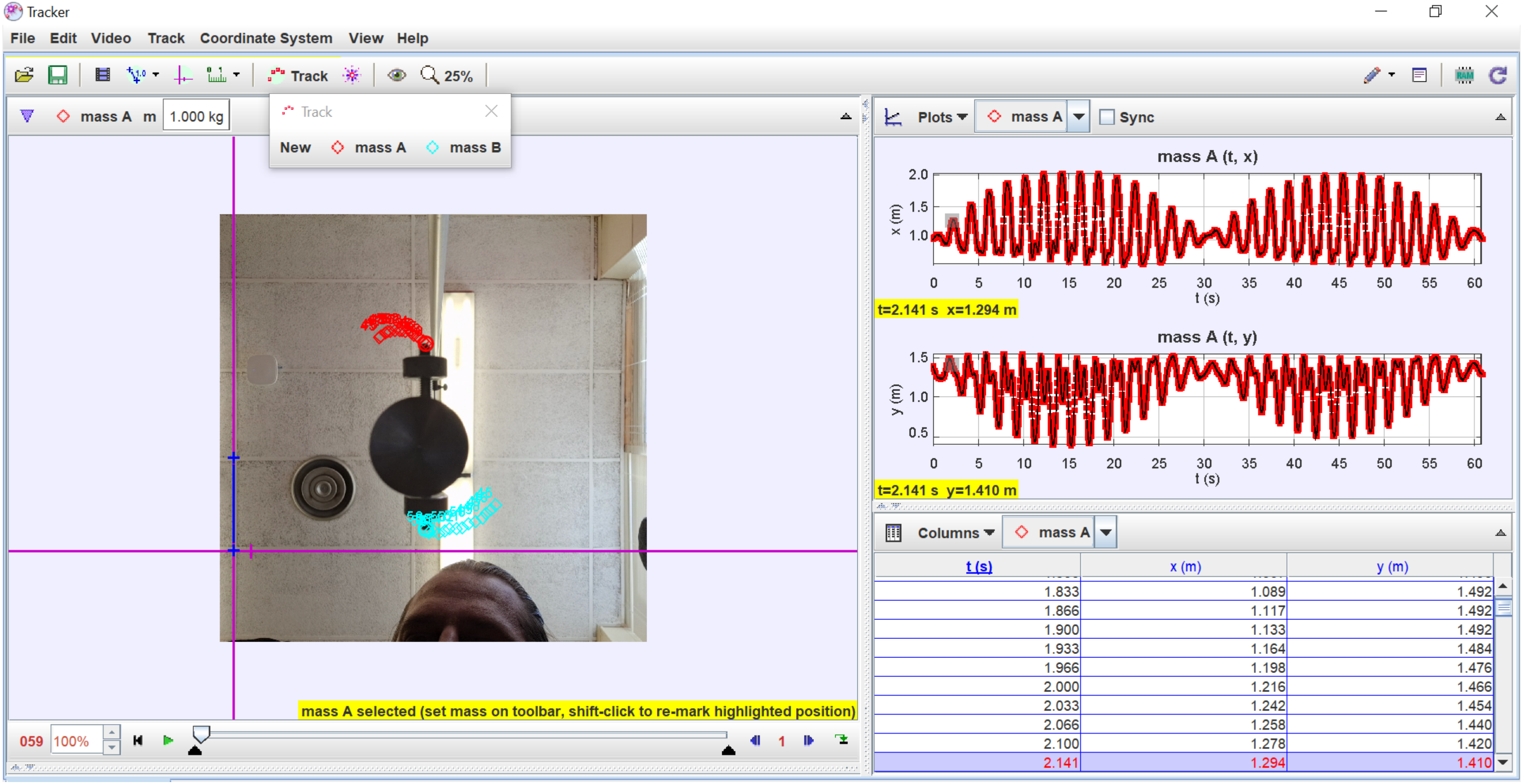




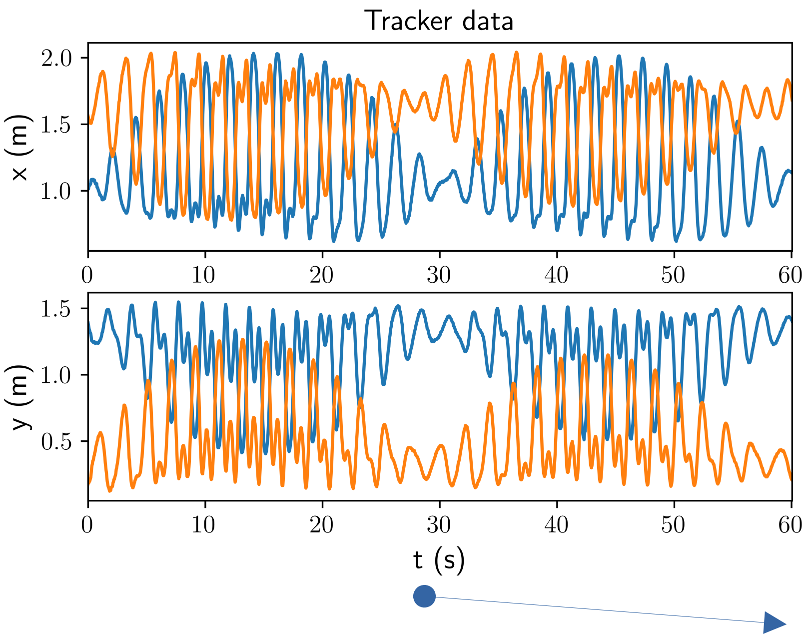
Better parallax use case: Wilberforce pendulum video

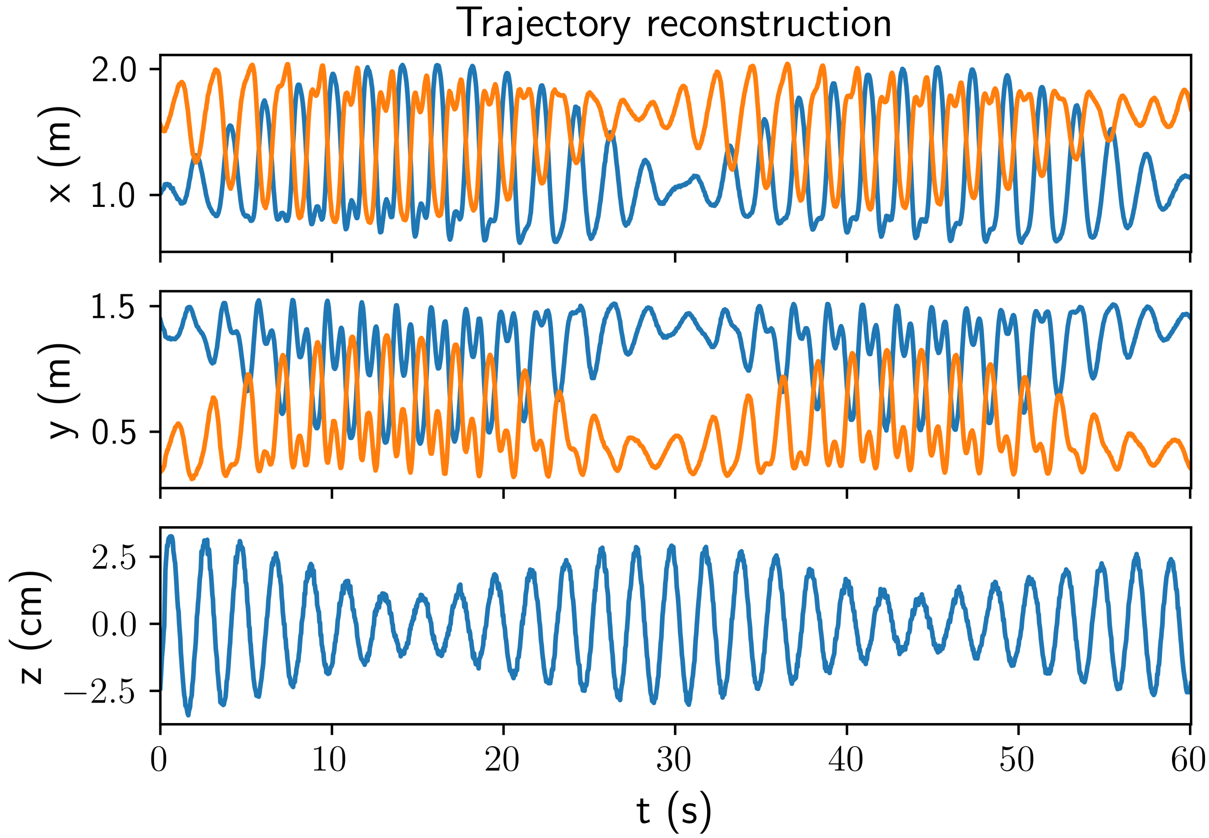


Wilberforce pendulum video analysis

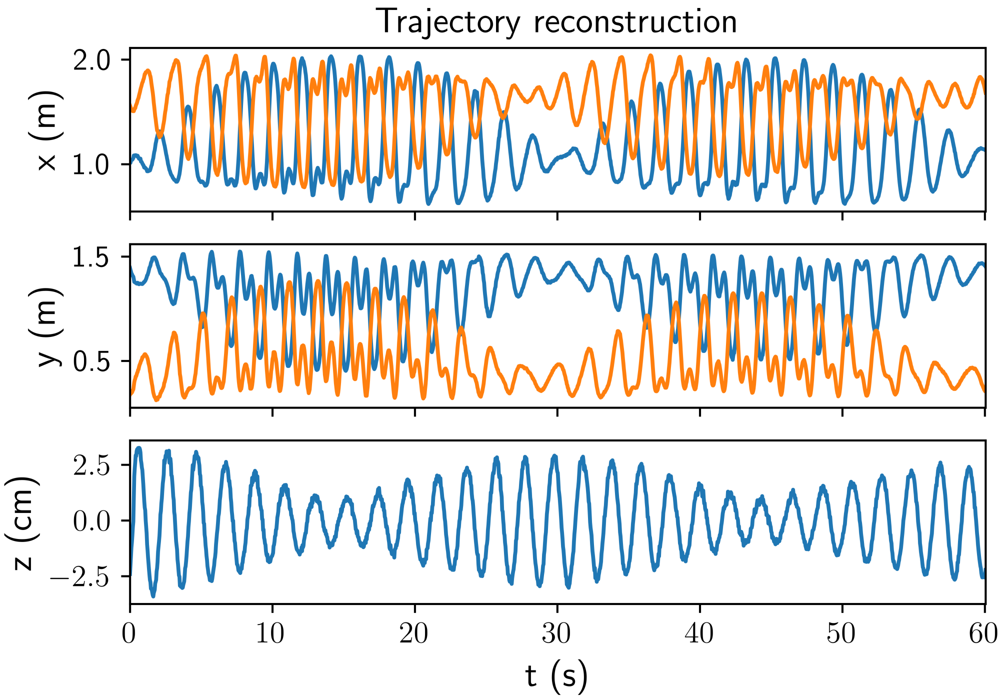


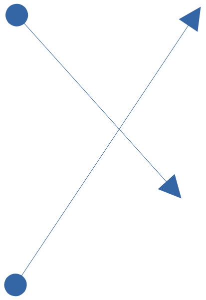
Wilberforce pendulum: Parallax-corrected motion

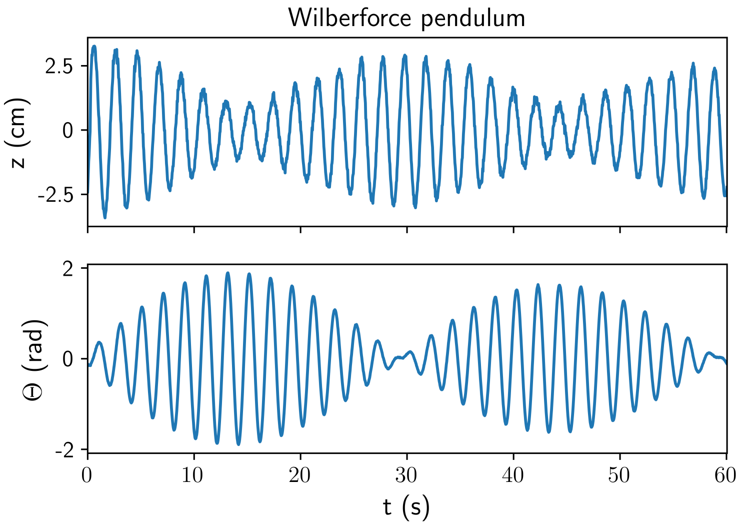


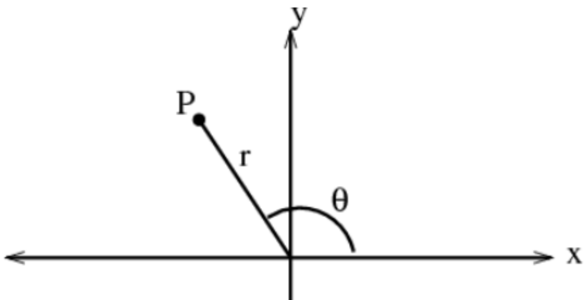


Wilberforce pendulum: Changing coordinates for insight





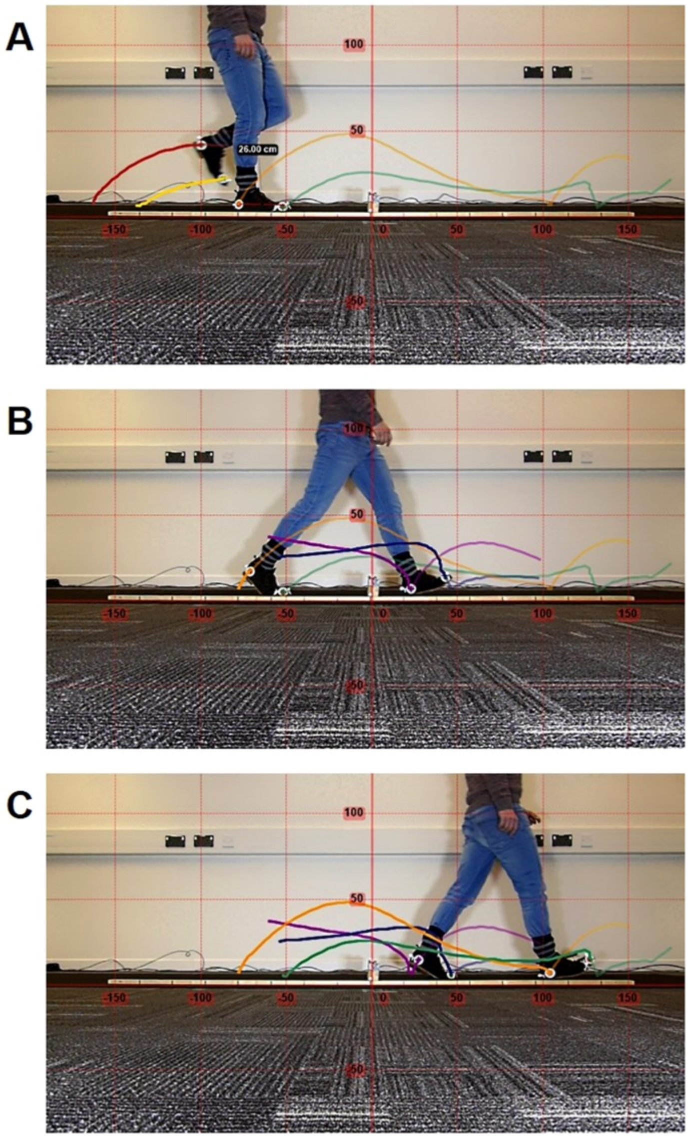


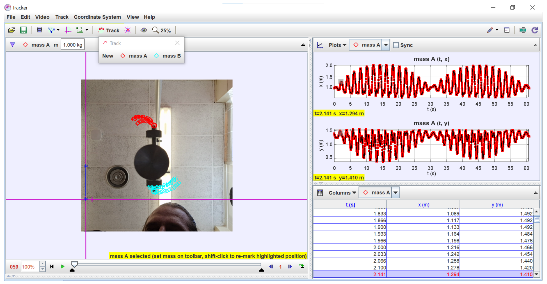


Future possibilities

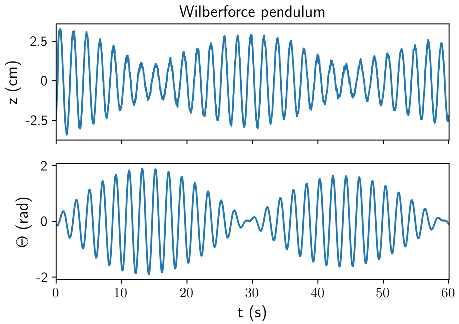
- Many possible projects for students involving athletics (Kinovea)
- Still photos over time can also be analyzed – e.g., from microscope slides

“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