Cinema and Physics: when the birth of cinema and the scientific revolution met

FILM337, PHYS337, APHY337, HUMS359
Francesco Casetti, Michel Devoret

"Science without conscience is but the ruin of the soul"
François Rabelais, *Pantagruel* (1532)

In the first two decades of the 20th Century, when the critical comments on cinema began to spread, early film scholars noticed that movies were able to present a world obeying laws different from that of traditional, classical Physics. Acceleration and reverse motion violated the laws of the flow of time; editing and montage created a compressed world; close-ups made visible what no human eye was able to see; point-of-view shots included the observer into the core of the action. The new invention definitely required a new idea of the universe. In the same years, Einstein's status as a celebrity revealed to the public at large a scientific revolution underway. Physics was rapidly mutating, and, correspondingly, some of the new ideas matched cinema's unusual ways of representing action. Far-sighted film theorists like Jean Epstein tried to capture the connection; despite many misunderstandings, the attempt helped to better investigate the very nature of film.

Taking up the parallelism between the evolution of art, science and technology at the turn of 19th and 20th centuries, our course will explore the bidirectional relationship between the art of moving pictures and the science of fundamental physical laws. Such a dual perspective, based on a selection of particularly telling movies, will present some of the crucial ideas that science and art dealt with in the last hundred years. Among these topics, we will address questions tied to the nature of time and space, the relativity of motion, the role of the observer in physical phenomena, the coexistence of the visible and invisible, the possible existence of parallel universes, as well as concepts like light and matter, fields and waves, chaos and order, uncertainty and chance, teleportation and quantum entanglement, boundlessness and infinity, space curvature and gravity. A radical question will also accompany us throughout the course: Can the humanistic and scientific forms of thinking converge and merge? Can they help each other to become more aware of themselves? And finally, can the rigorous exploration of the world, the language of poets, the pleasure of the performance, the magic of discoveries, productively work together?

The first part of the course (weeks 1 to 6) explores the stylistic and narrative strategies of early cinema, in their attempt to depict a new reality of the world, which is inspired by modern physics paradigms. The second part of the course (weeks 7 to 12) introduces and discusses concepts of contemporary physics that have found an echo in films. A 13rd week offers a synthesis of the ideas discussed in previous weeks and provides a conclusion.

This course is particularly suited for students who are pursuing a double major in STEM and in Humanistic disciplines. It does not require detailed knowledge of calculus.
Prerequisite: high-school physics.
Attention: PHYS/APHYS majors planning to take this course and make it count as one of their electives should both get in touch with the instructors, and with the relevant DUS's.

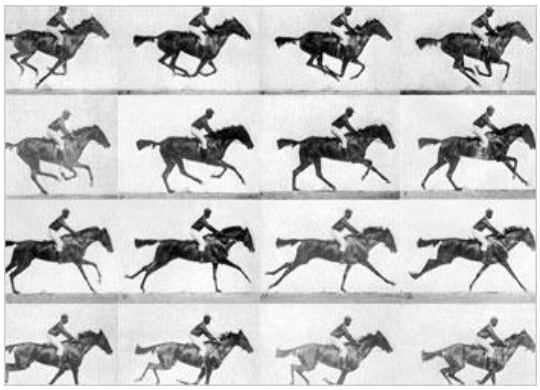
<u>Assignments</u>
Participation: students are expected to raise questions and offer comments in class to weekly readings and movies.
Canvas Discussion: Students will be expected to post at least five 400-word contributions, commenting assigned readings and/or assigned movies.

Midterm Paper (due by the end of week 7): Students will be asked to answer to four simple questions regarding topics that have been presented in class. Papers should be 4-5 page long, double-spaced.
Final Paper (due by the end of week 13): Drawing on the material covered in the class, primary sources, and their experience, students will analyze a movie or a movie sequence, and discuss it in the light of physical reality questions. Topic to be chosen in consultation with instructors. An initial proposal will be due by week 6.
Special supplementary assignments will be given to PHYS/APHY majors taking this course as an elective.
Evaluation:
Participation in class: 20%
Canvas discussion: 20%
Midterm paper: 20%
Final paper: 40%

The instructors encourage group work. It is possible to take a more ambitious final assignment and divide the work among 2 or 3 partners after a discussion with the instructors.

First Part. Film syntax and style meet a new understanding of reality

Week 1. Movement: discrete instants versus continuity of time
Film emerges at the outcome of several scientific experimental researches attempting to decompose movement—an endeavor based on a granular or atomistic approach of time. Does movement's re-composition by cinema restore the continuity of time?
Readings: Richard Feynman, "Atoms in Motion," Six Easy Pieces, Reading: Perseus Books, 1995, pp. 1-21;
Jimena Canales, "Movement before Cinematography: The High-Speed Qualities of Sentiment," *Journal of Visual Culture*, Vol 5(3), 2006, pp. 275–294;
Tom Gunning, "Never Seen This Picture Before. Muybridge in Multiplicity," *Muybridge and the Instantaneous Photography Movement*, Phillip Prodger ed., Oxford University Press, 2003, pp. 222-257
Still/Moving Images: Eadweard Muybridge: https://www.youtube.com/watch?v=3sRwzbTz0_8
Étienne Jules Marey: https://www.youtube.com/watch?v=N4s-umeNkEs
Étienne Jules Marey, Child motion: https://www.youtube.com/watch?v=FOJjSsUbKx0
[for a wider anthology of Marey's work, see Experiments 1890-1904 : https://www.youtube.com/watch?v=SKs_l1s-rhg (images include nudity)]


Muybridge, 1878

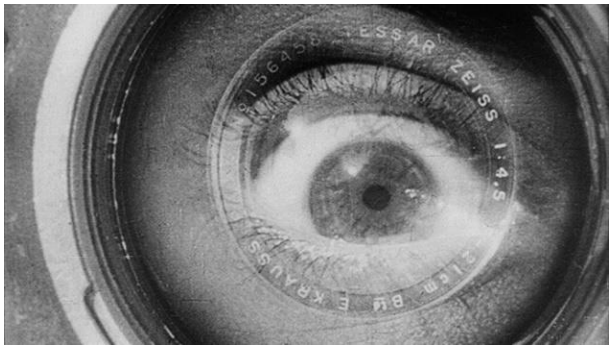

Marey, 1892

Week 2. The observer and the event

Is the observed reality changed by the observer? And does the medium of cinema work as an observer? In its narrative, film often includes characters who filter what spectators see, consequently displaying events which depend by observers—as in the sequence of the meal at the Dry Fork station in John Ford's *Stagecoach*. More radically, Dziga Vertov explored the interplay between the reality "as it is", the reality as captured by film, and the reality of film itself, echoing issues raised by quantum physics about experimental observations modifying the state of the physical system under study.

Readings: David Deutsch, "Shadows," *The Fabric of Reality*, Penguin Books, (1997) Chap. 2;
Nick Browne, "The Spectator-in-the-Text: The Rhetoric of Stagecoach," *Narrative, apparatus, ideology: a film theory reader*, Phil Rosen ed., New York, Columbia University Press, 1986
Dziga Vertov, "A comment of Vertov on *The man with the Movie Camera*" (1929), manuscript, unpublished; "We: variant of a manifesto" (1922) and "Kinoks: a Revolution" (1923) in *Kino Eye: the Writings of Dziga Vertov*, Berkeley-Los Angeles, University of California Press, 1984, pp. 6-12

***Films*:** Dziga Vertov, *The man with the camera*, 1929:
https://www.youtube.com/watch?v=3C-2RgK3WwA
John Ford, *Stagecoach*, 1939 [sequence starts at 23.48, ends at 31.35]:
https://www.youtube.com/watch?v=D0w_d3aiUnU



Week 3. Multiplicity of times

Is there only one universal time, or multiple times, not only according to different states of mind, but also according to different situations, like in Einstein's relativity where each observer with different velocity has its own time?

***Readings*:** David Mermin, "The principle of relativity," *It is about Time*, (Princeton U.P., 2005) Chap. 1; Noam Elcott, "The Master of Time: Jean Epstein's nonhuman time axis manipulation," *Time Machine*, Antonio Somaini ed. (Milan: Skira, 2020), pp. 163-183
[Elcott—as well as Alloa in the mandatory reading for week 3—mention an influential contribution by the German media theorist Friedrich Kittler, "Real Time Analysis. Time axis manipulation," *Cultural Politics*, 13.1 (March 2017), p. 5-18. Kittler's text is not mandatory, yet we recommend it]

***Films*:** Jean Epstein, *The Tempest Tamer* [*Le tempestaire*], 1947
https://www.youtube.com/watch?v=hUfwOl3ZB1Y

Week 4. Reversibility of time

Is time reversible? Can we go backward, in the same way we go forward? Cinema (with reverse motion and time lapse sequences) and physics offer answers that strongly diverge. We will also look at *palindromes*, i.e. texts, musical pieces, or movies that can be read, listened at, or seen either forward or backward.

***Readings*:** Richard Feynman, "The distinction of Past and Future," *The Character of Physical Laws*, (Cambridge: MIT Press, 1965) Chap. 5; Emmanuel Alloa, "Spaced-out Time. On time axis manipulation," *Time Machine*, Antonio Somaini ed. (Milan: Skira, 2020), pp. 53-70

***Films*:** Lumière Brothers, *Démolition d'un mur*, 1896:
https://www.youtube.com/watch?v=PI_Rxa0YFWg
Edison, *Dog Factory*, 1904: https://www.youtube.com/watch?v=ac2fWCwDH9Y
Yann Pineill, *Symmetry. A Palindromic Film*, 2014: https://www.youtube.com/watch?v=Nrf6xM9-SQM

Week 5. Speed

The ability of film to capture and modify speed—by accelerating or slowing the pace of events—was the most celebrated feature of the new art. The film theorist Jean Epstein went to declare that an accelerated time was eliciting a new kind of reality, which film was able to explore in conjunction with physics, for which a traveler to distant stars and back would age less and less than its twin left on earth, as the speed of the spaceship approaches the speed of light.

***Readings*:** Ricciotto Canudo, "The Birth of Sixth Art," (1911) in Richard Abel, *French Film Theory and Criticism: 1907-1939* (Princeton, N.J.: Princeton University Press, 1988), vol.1, pp. 58-66

***Films*:** David W. Griffith, *Intolerance*, 1916; https://www.youtube.com/watch?v=SyqDQnoXa70

Week 6. The scales of reality
Movies record reality not only from different points of views, but also according different scales. Hence the question of what "[extremely] big" and "[extremely] small" mean comes to the fore.
***Readings*:** Jean Epstein, "Magnification," (1921) in Abel, vol. 1, pp. 235-241; Béla Balázs, *Visible Man, Or the Culture of Film*, in *Béla Balász: Early Film Theory*, ed. Erica Carter (New York: Berghahn Books, 2010); Mary Ann Doane, "Scale and negotiation of 'real' and 'unreal' space in the cinema," Nagib L., Mello C. (eds) *Realism and the Audiovisual Media*. London: Palgrave, 2009, pp. 63-81
***Films*:** Carl Theodor Dreyer, *The Passion of Joan d'Arc*, 1928: https://vimeo.com/169369684
Charles and Ray Eames, *Powers of Ten*, 1977
https://www.youtube.com/watch?v=0fKBhvDjuy0&list=PLr1QbUUmEKI438N7lFfQwyMYAXKJVk-Bn

Second Part. Frontier questions in physics echoed in cinema

Week 7: Travels in time and causality (special relativity)
Modern physics has put in question the traditional notion of time and the relation between past and future. It is now understood that time can flow at different rate for different observers. Also, between two events, which came first can be viewed differently by these different observers.
***Readings*:** Albert Einstein and Leopold Infeld, *The evolution of physics* (Cambridge University Press, Kindle Edition), Part III; George Gamow, Mr. Tompkins explores the atom (Cambridge U. P. , new edition: Mr Tompkins in Paperback, Kindle), Chap. 1.

***Movies*:** Chris Marker: *The Jetty*; Terry Gillian: *12 Monkeys.*

Week 8: Travels through curved space and wormholes (general relativity)
Einstein's theory of general relativity provides a new understanding of gravity as curvature of space-time and implies that short-cuts might possibly exist between distant parts of the universe. Another interesting consequence is that time passes at different rates, depending on one's location in the universe. Visiting the neighborhood of a black hole makes you age slower than someone waiting for you where gravity is zero.
***Readings*:** John Archibald Wheeler, *A Journey into gravity and spacetime*, (Scientific American Library, 1990) Chapter 1; Jean-Pierre Petit: *The Black Hole* (50 page graphic novel, Belin 1990, translated in English by Ian Stewart).
***Movie*:** Christopher Nolan: *Interstellar*.

Week 9: Objectivity and subjectivity in the description of physical reality (quantum physics 1)
Our senses sometimes trick us and make us see the world not as it really is, but as a simplified model, in which subtle complications are erased. Some other times, we have an excellent predictive intuition of which motions and phenomena are possible and which are not. Cinema plays with our senses but also acknowledges there are physical limits intuitively understood by the mind.
***Reading*:** Richard Feynman: *The Character of Physical Laws* (MIT Press) Chapter 6.
Movies: Tex Avery: *Wile E. Coyote vs the Road Runner*.
https://www.youtube.com/watch?v=EdGxf5sYdsU

Week 10: The world at the quantum level: is there a boundary between the microscopic and the macroscopic? (statistical mechanics)
Physics opposes the microscopic world, in which laws are time-reversible, like Newtonian or quantum mechanics, to the macroscopic, level in which laws, like those of thermodynamics, impose a unique arrow of time. A possible inconsistency has been exposed by James Clerk Maxwell, through Maxwell's demon, in the 19th century, which has been resolved by modern physics. In cinema, interestingly, certain sequences can be shown in reverse and still make perfect sense, while many others cannot.
Reading: George Gamow, "Maxwell Demon," *Mr. Tompkins in paperback*, Chap. 9.;
Assa Auerbach: *Max the Demon* (50 page graphic novel).
Films: Richard Fleischer: *Fantastic voyage*; Christopher Nolan: *Tenet*.

Week 11: Being in two places at once (quantum mechanics 2)
In quantum mechanics, particles are not either in one place or another, they can be in several places at the same time. This superposition principle has a corollary: Heisenberg's uncertainty principle, which says that as you measure a quantity more and more precisely, the back-action on the conjugate quantity, indetectable at the human scale, will become more and more important, and eventually, this quantity is completely uncertain. The retrocausal interpretation of Quantum Mechanics views the superposition principle as a manifestation of particles to go back and forth in times.
Reading: R. Feynman: *Six Easy Pieces*, chapter 6. ; R. Feynman: *QED the strange theory of light and matter*, chapter 3.
Film: Mr Peek-A-Boo https://www.youtube.com/watch?v=Sir3rG5AW5Q

Week 12: Entanglement and parallel universes (quantum mechanics 3)

In quantum physics, reality is not absolute. It is created by the act of observation. Several potential realities can coexist, according to an interpretation of the superposition principle. Entanglement refers to the situation where Alice and Bob each know perfectly what the other is doing, but no one else can access to their multiple realities.
***Reading*:** Nicolas Gisin: *Quantum Chance: Nonlocality, Teleportation and other quantum marvel*s, Chapters 1 and 5.
Films: Frank Capra: *It's a wonderful life.*

Week 13: Conclusion of the course: The act of discovery and the use/misuse of science in cinema.
The life of scientists in search of spiritual enlightenment, including their ambivalent role as both enablers of material well-being and attendants to the fabrication of weapons of mass destruction, is a recurring theme in cinema. Do movie-makers and physicists both re-invent the world?
Reading: *Radioactive* by Lauren Redniss (Graphic novel, first half).
Films: Mervyn Le Roy, *Marie Curie* (Turner Classic Movies version), Valerio Jalongo, *CERN and the Sense of Beauty*.