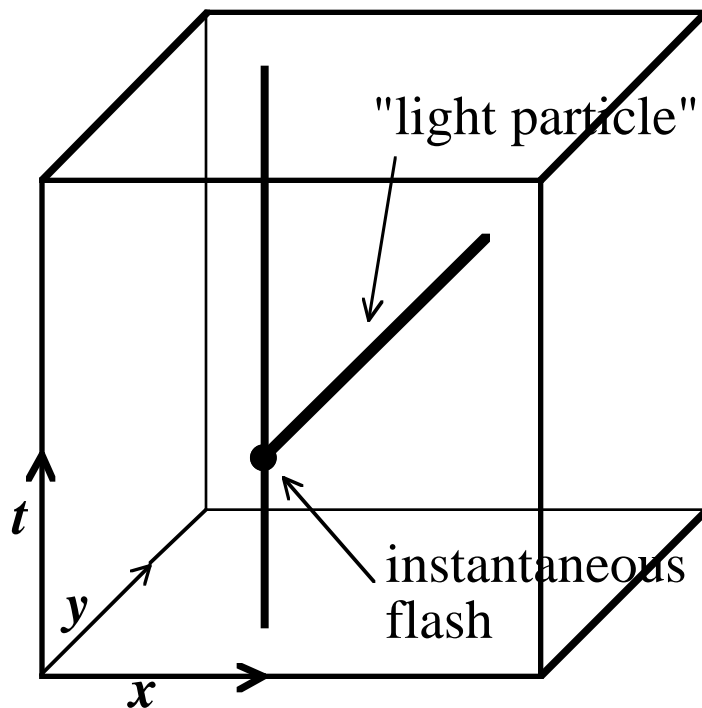


Objects and Processes in the “Aristotelian” Space-Time: Light and its Propagation

Light is a physical process that propagates in space with a certain velocity

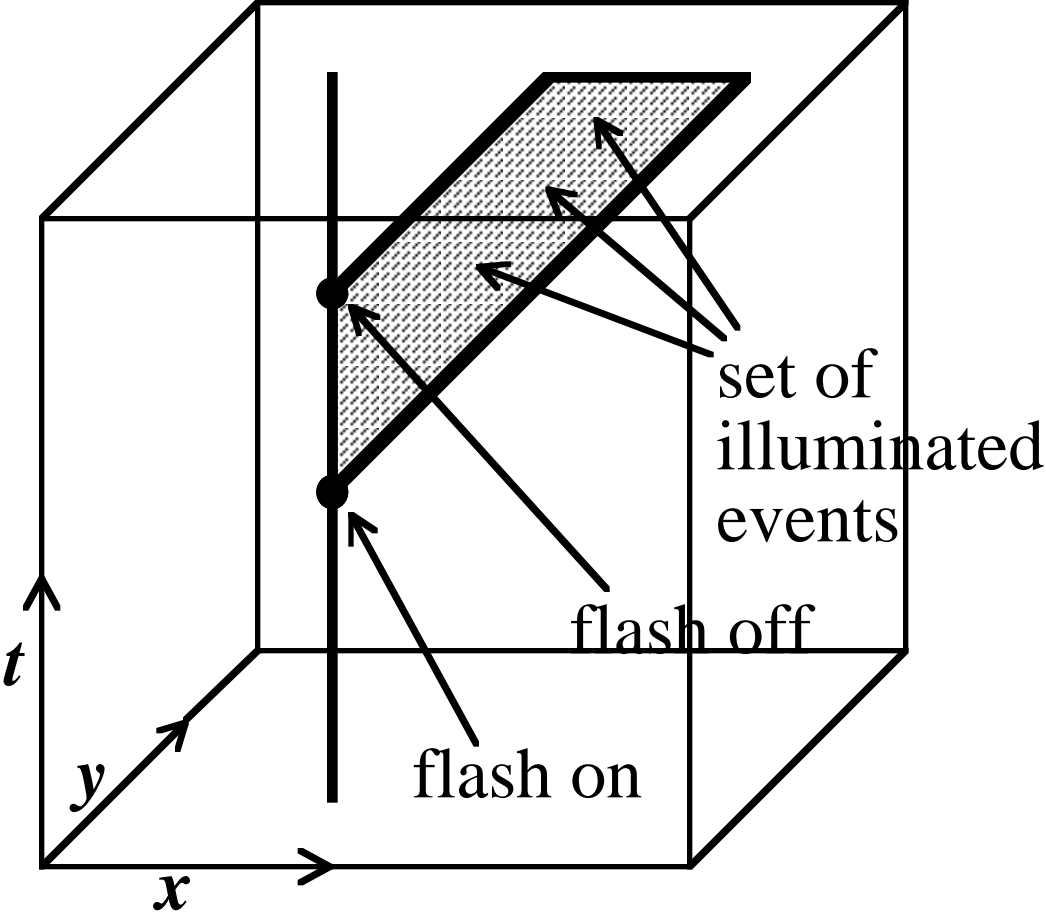
In many ways, the propagation of light is quite similar to the motion of particles (“light-particles”)

Unidirectional instantaneous flashlight
(light beam doesn't spread out)



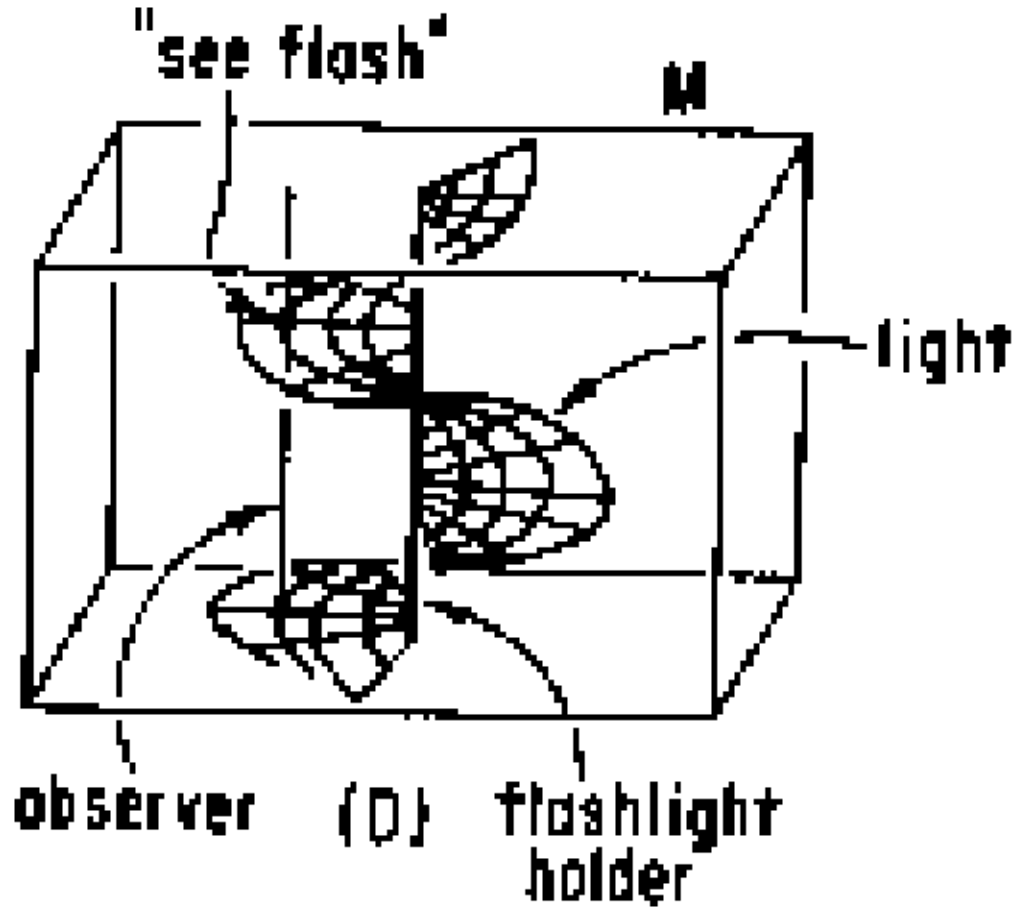
Based on Geroch, 2-15, p. 28

Unidirectional finitely-long flash of light



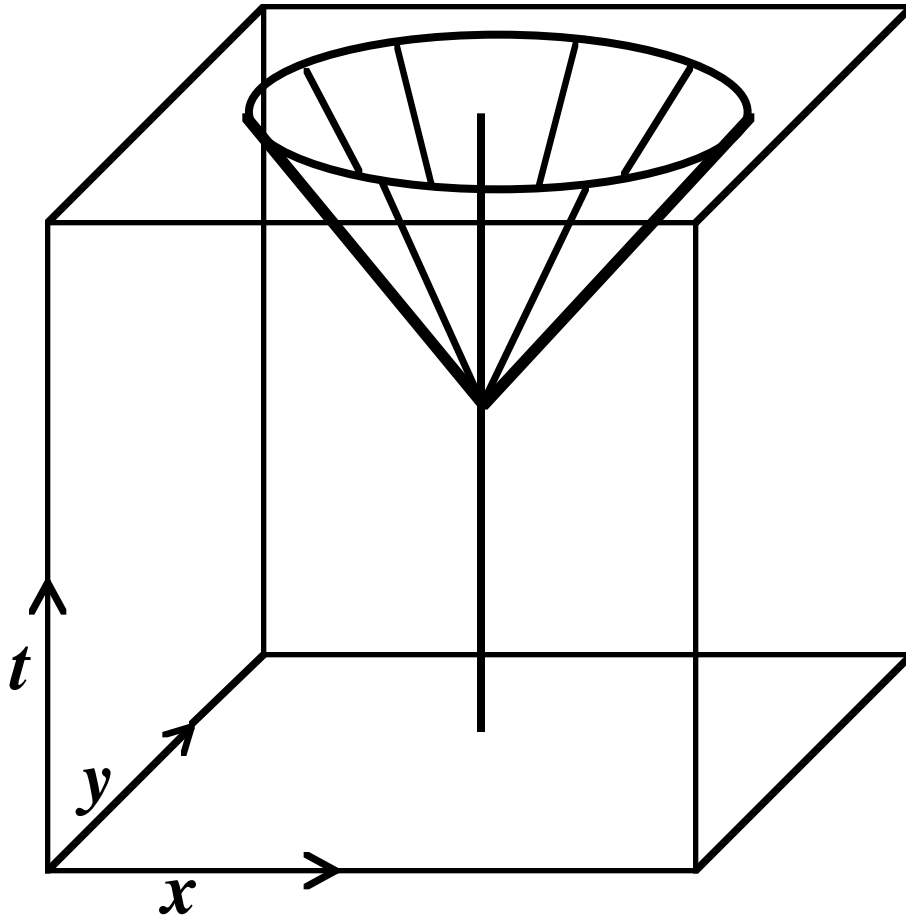
Based on Geroch, 2-15, p. 28

“Lighthouse”



Geroch, 2-14d, p. 27

Isotropic lights source: light-cone



Based on Geroch, 2-16, p. 30

Aristotelian view:

attributes a certain intrinsic structure to space-time: a structure within which certain questions about relationships among events *make sense*, i.e. can be meaningfully *asked* (and, in principle, answered—if anybody bothered)

is *not* a theory of physics.

- By itself, the Aristotelian structure of space-time does not place any restrictions on what can and what cannot happen in the physical world = does not incorporate any *laws of nature*.
- In particular, it does not, by itself, tell us how bodies *must* move. It merely provides a description of how they in fact move. A theory of physics (such as the theory of classical mechanics) must take us from here to tell us what should happen

At the same time, a particular structure of space-time *does* have an influence on *which* theories one considers. It strongly *predisposes* one to formulate certain theories and to avoid others. There is a *match* between the structure of space-time and a theory of motion one formulates within this structure.

A certain theory must *make sense* within a particular structure of space-time. One's reference to relationships between events within the statement of the theory must be only to those relationships, which are actually *available* according to a certain view of the structure of space-time.

Newton's Law of Gravitation

$$F = G \frac{m_1 m_2}{r^2}$$

The "Law of Light"

Light always travels at the speed of $c = 3 \times 10^{10}$ cm/sec.

General concept of space-time as a locus of events vs. a *particular structure* we impose on it, e.g., the Aristotelian structure

Statements that apply to the general idea of space-time:

- A particle is described by a world-line
- A collision of two particles is represented by the intersection of their world-lines

Statements that make sense only within a certain (e.g., Aristotelian) structure imposed on space-time but may not make sense within another structure:

- Two events occur at the same time
- This particle is at rest

E.g., to make sense of the first statement we must know how to characterize the locations of events in time, we need to apply a certain procedure to determine the times of the occurrences of the events. We know how to do it in the Aristotelian framework. Therefore, we can really determine, within this framework, whether two events occur at the same time or not. We just need to determine the times of their occurrences and then compare them. But in another framework, e.g. the relativistic one, the Aristotelian procedure will not work and the question as stated will remain unanswered—unless we change or qualify it in a certain way.

What is wrong with the Aristotelian view of space and time?

Back to the *Titanic* example

- “We are now in the exact position where the *Titanic* sank” = two events, the sinking of the *Titanic* so many years ago and our being here and now, have the same spatial location.

This statement makes sense only from a very restricted, “parochial” point of view—the point of view tied up to the Earth and the coordinate system (i.e., latitudes and longitudes) associated with it. The Earth, of course, means a whole lot to us, especially if we are thinking in the Aristotelian terms (remember, the Earth was for him the center of the universe). But physically speaking, Nature couldn’t care less about this tiny planet orbiting an average star which is itself located somewhere in the periphery of an average galaxy. Nature does not give any privilege to our planet and, hence, to the coordinate system associated with it. And from this wider point of view, the point of view of the physical Nature as a whole, the statement “We are now in the exact position where the *Titanic* sank,” is simply *wrong*. In the 80+ years elapsed since the *Titanic* accident, the Earth has traveled a huge distance in space, together with the whole Solar system. So the event of the sinking of the *Titanic* may be billions miles away from where we are right now.

The Aristotelian framework is very *person-centered* (egocentric?) and *undemocratic*. In this framework, we determine the positions and times of all events in some very special coordinate system tied up to the location of a particular singular observer (a store manager, a ship traveler, etc.). The statements made in such a coordinate system about the spatial (and temporal) locations of other events make sense only in reference to this particular observer. From the point of view of another observer, they would just be wrong. But physically speaking, there is *nothing special* about any single observer with his or her Aristotelian coordinate system—there is nothing special about his or her individual perspective. All such local, personalized Aristotelian perspectives are *on a par*. In order to describe what's going on in the physical world, from an Aristotelian point of view, we must reference all such goings-on to a particular personalized perspective. But since all perspectives are *no a par*—since Nature does not objectively privilege any of them—we confront a serious dilemma.

- Either we have to provide descriptions of physical goings-on (of everything that has happened, is happening, and will happen in the universe) in *all* individual Aristotelian perspectives.
- Or we have to impose a certain *democracy* on our description, in order to make it insensitive to the choice of a particular Aristotelian perspective

One way to do the latter is to attribute to space-time itself only *as much* intrinsic structure as is *enough* to bring out the *universal* features of phenomena, which are common to all Aristotelian perspectives, and to deprive space-time of *excessive* structure that was due to an individual perspective of a particular Aristotelian observer. For this, we need another space-time framework, one that would not be tied up to any individual point of view.

- In any framework we are using, we *always* need to draw a line separating the subjective features of phenomena, those perceived by individual observers and associated with their personal perspectives, from the objective features of those phenomena which we attribute to “Nature herself.” Some such separation or other must always be made. The question, however, is: WHERE exactly to draw the line separating these two aspects of phenomena.
- The drawing of this line suggested by the personalized Aristotelian view is inconvenient and physically inadequate because it endows space-time a lot of excessive structure.

“If everything (the whole Aristotelian set-up) is to be attributed only to individuals who do the observing, then nothing is left which can be regarded as “pure structure on space-time itself, without explicit reference to observers.” One would much prefer to redraw these lines in such a way that space-time retains at least some—preferably, as much as possible—“universal, observer-independent structure.” ... The Aristotelian view includes in part some universal structure of space-time itself and in part some internal features about the observer. **What we wish to do is separate out the former and clearly post it within space-time.** We shall describe observers, as we always have, by their world-lines in space-time. From the “universal structure” of space-time, together with the information of the world-line of the observer, we shall be able to recover the various actual experiences of our observer. The observer, then, will be reduced from “an Aristotelian set-up” to a “world-line,” **with the additional information thus lost in the reduction permanently implanted in space-time**” (Geroch, pp. 35–36, my emphasis).

Appendix: A Bit of Philosophy of Time

Introducing the space-time framework implies a major change in our view of the nature of time.

- Trajectories in space vs. world-lines in space-time
- Implications of space-time diagrams for *determinism* and *fatalism* (highly controversial)
- The “passage” (“flow”) of time—non-existent?

“The objective world simply is, it does not happen. Only to the gaze of my consciousness crawling upward along the life line of my body, does a section image in space which continuously changes in time” (Hermann Weyl, *Philosophy of Mathematics and Natural Science* (Princeton, 1949), p. 116)

“Events do not happen, they are just there and we come across them. The formality of taking place is merely the indication that the observer has on his voyage of exploration passed into the absolute future of the event in question” [A.S. Eddington, *Space, Time and Gravitation* (Cambridge, 1920), p. 51]

“... The tapestry [of space-time] cannot consistently be divided into those parts which are already woven and those which are still to be woven. ... The shortest cut to logical consistency was to suppose that the tapestry is already woven throughout its full extent, both in space and time, so that the whole picture exists, although we only become conscious of it bit by bit—like separate flies crawling over a tapestry” [James Jeans, “Man and the Universe” (1935)]