5.1: Time? No. Spacetime Map? Yes.

no such thing as the unique time of an event!

Events are the sparkling grains of history. They define spacetime. Spacetime, yes. Time, no.

" Time" of an event has no unique meaning

"Time, no"? How come? Time here in Tokyo, at this enthronement of the successor of the Emperor Hirohito? Where is any meter to be seen that shows any such quality of location as time? Meter to measure the temperature here and now? Yes, this thermometer. Meter to measure atmospheric pressure here and now? Yes, this barometer. But look as we will, nowhere can we see any meter that we can poke into the space hereabouts to measure its "time. "The time of an event? Impossible! No such thing. Time is not "meterable."[1]

Car mileage depends on car's path between places

Anything with which to compare time? Yes. Odometer reading, whether miles or kilometers, on the dashboard of our car. There's no such thing as the odometer reading of Tokyo. Try every gadget one can, thrust it out into this Tokyo air, not one will register anything with the slightest claim to be called the odometer reading of these hereabouts.[2]

What about looking at the dashboards of the cars in this neighborhood? Not all of them; that would be nonsense. Only the cars that were new, with odometer reading zero, at the time of Hirohito's own enthronement.

Now at last we are getting into a line of questioning that shows some prospect of clearing up what we mean by "time." We ask our companion, "What do all those day-and-year-counting wristwatches now read that were set to zero at the time of that earlier ceremony?"

"Sixty-two years, two days," is her first reply. But then we ask, "What about that team that zoomed out to the nearest eye-catching star, Alpha Centauri, and back with almost the speed of light? Didn't they get back ten years younger than we stay-at-homes?"

Wristwatch reading depends on its history of travel between events

"Yes," she agrees, "surely their wristwatches now read fifty-two years, not sixty-two. So let me draw the lesson. There is no such thing as time. There is only totalized interval of time, time as that interval is racked up between the enthronement of Hirohito and the enthronement of the new Emperor Akihito, between event A and event B, on a wristwatch that has undergone its own individual history of travel from A to B."[3]

"I agree. The concept of time does not apply to location in spacetime. It applies to individual history of travel through spacetime."

"How apt the comparison with odometer reading. Each dashboard shows, not the kilometerage of Akihito, but the kilometers traveled by that particular car between the one imperial ceremony and the other."

Geographic mop assigns kilometer coordinates to places

Yes, it is nonsense to attribute a kilometer reading to Tokyo. However, it is not at all nonsense to make a map showing where Tokyo lies relative to all the towns roundabout, a map in which kilometers do appear, kilometers north and south, kilometers east and west.[4] Likewise the term "the time" of an event is totally without meaning. However, that event — and every event near it — lends itself to display on a spacetime diagram (Figure 5.1.1), with distance (the locator of latticework clock) running in one direction, and in another direction time (the reading printed out by that clock on the occasion of that event).

Spacetime map assigns space and time coordinates to events

Time as employed in this sense acquires meaning only because it serves as a measure on a latticework-defined map. A different latticework? A different set of clocks, different readings on those clocks, a different map — but same events, same spacetime, same tools to measure the history-dependent interval between event and event.[5]

Only on such a spacetime plot does one see at a glance the layout of all nearby events, and how one history of travel from event A to event B differs from another.

Limit attention to one space dimension plus one time dimension

One problem in making our map: Spacetime has four dimensions— three space dimensions plus time. We picture our event points most readily when they occupy a two-dimensional domain and let themselves be dotted in on a two-dimensional page. Therefore for the present we limit attention to time and one space dimension; to events, whatever their timing, that occur on one line in

space.[6] All events that do not occur on this line we ignore for now. The space location of each event on this line we plot along a **horizontal axis** on the page. The lattice-clock time at which an event occurs we plot along a vertical axis, from bottom to top of the page. Space and time we measure in the same unit, for example meters of distance and meters of time — or light-years of distance and years of time. We call the result a **spacetime map** or a **spacetime diagram**. Each spacetime map represents data from a particular reference frame, for example "the laboratory frame." Figure 5.1.1 shows such a spacetime map.

Five sample event points appear on the laboratory spacetime map of Figure 5.1.1, events labeled O, A, B, C, and D.

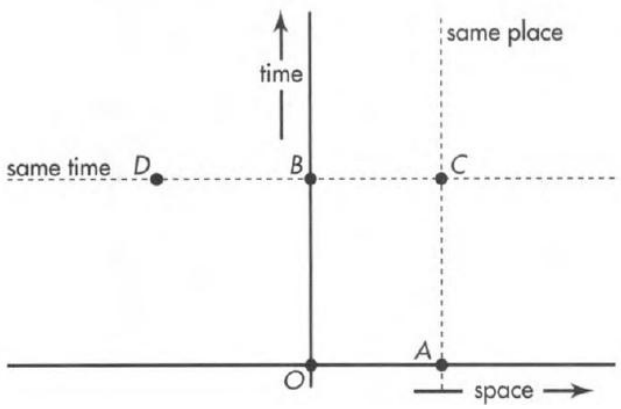

Figure 5.1.1: Laboratory spacetime map, showing the reference event O, other events A, B, C, and D, a horizontal dashed line of simultaneity in time, and a vertical dashed line o f equal position in space.

- **Event O** is the reference event, the firing of the starting gun, which we take to locate zero position in space and the zero of time. For our own convenience, we place point O at the origin of the spacetime map and measure space and time locations of all other events with respect to it.
- **Event B** stands on the vertical time axis, directly above reference event O. Therefore event B occurs at a later time than event O. Event B lies neither to the right of the reference event nor to the left; its horizontal (space) location is zero. Therefore it occurs at the same place as the reference event O in the laboratory but later in time.
- **Event A** lies on the horizontal space axis, directly to the right of reference event O. Therefore event A occurs at a different space location than event O. It is neither above nor below event O; its vertical (time) location is zero. Therefore it occurs at the same time as reference event O as observed in the laboratory.
- **Event C** rests above and to the right of the reference event. Standing higher than the reference event on the map, event C occurs later in time than O in this frame. Since it lies to the right, event C occurs at a positive space location with respect to event O in this frame.
- **Event D** reposes above and to the left of the reference event. It also occurs later in time than reference event O but at a negative space location with respect to event O as observed in the laboratory.

Scatter other event points on the spacetime map. Each event point can represent an important happening. Then a single glance at the spacetime map gives us, in principle, a global picture of all significant events that have occurred along one line in space and as far back in time as we wish to look. The spacetime map puts all this history at our fingertips!

Horizontal line on spacetime diagram picks out events that are simultaneous in this frame

In exploring history, we may want to know which events occurred at the same time as others in the laboratory free-float frame. Two events that occur at the same time have the same vertical (time) location on the spacetime map.[7] A horizontal line drawn through one event point passes through all events simultaneous with that event in the given frame. In Figure 5.1.1, the dashed horizontal line shows that events B and D are simultaneous as observed in the laboratory frame, although they occur at different locations in space. Similarly, events O and A are simultaneous as observed in this frame.

When we wish to "retell history," we draw a sequence of horizontal lines above one another on the spacetime map. We mimic the advance of time by stepping in imagination from one horizontal line to the next horizontal line above it, noting which events occur at each time.

Vertical lines on the spacetime map indicate which events occur at the same place along the single line in space. Events A and C in Figure 5.1.1 occur at the same space location as measured in the laboratory, but at different times as measured in this frame. Similarly, events O and B occur at the same place as one another in the laboratory.

1 "Time" of an event has no unique meaning

2 Car mileage depends on car's path between places

3 Wristwatch reading depends on its history of travel between events

4 Geographic map assigns kilometer coordinates to places

5 Spacetime map assigns space and time coordinates to events

6 Limit attention to one space dimension plus one time dimension

7 Horizontal line on spacetime diagram picks out events that are simultaneous in this frame

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