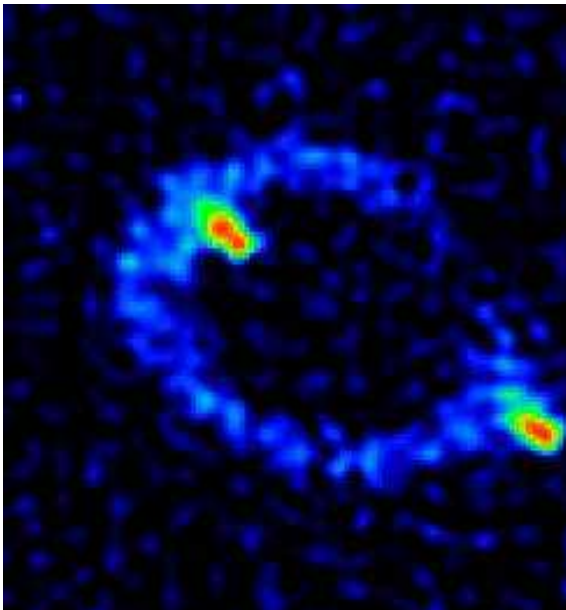
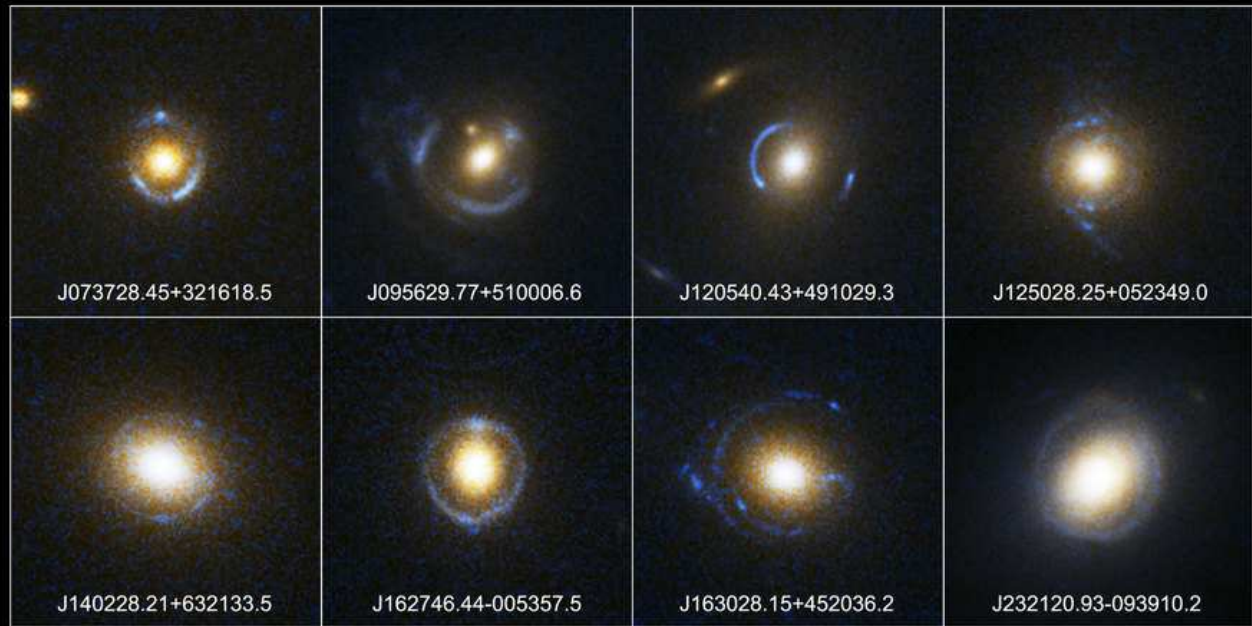


EINSTEIN RINGS





Einstein Ring Gravitational Lenses
Hubble Space Telescope • Advanced Camera for Surveys

EINSTEIN RINGS: COMMON FEATURES

- (a) yellowish blobs at centers
- (b) bluish arcs along periphery

EINSTEIN RINGS: COMMON FEATURES

- (a) yellowish blobs at centers
- (b) bluish arcs along periphery
- (c) arcs are non-circular
- (d) brightness variations within arcs, both smooth and blobby.
- (e) arcs don't close on themselves





PHYSICS OF GRAVITATIONAL LENSING

Fermat's principle

Light travels along paths that:

(high school physics) minimize the light travel time.

—or—

(university physics) are minima, maxima and saddle points of the light travel time.

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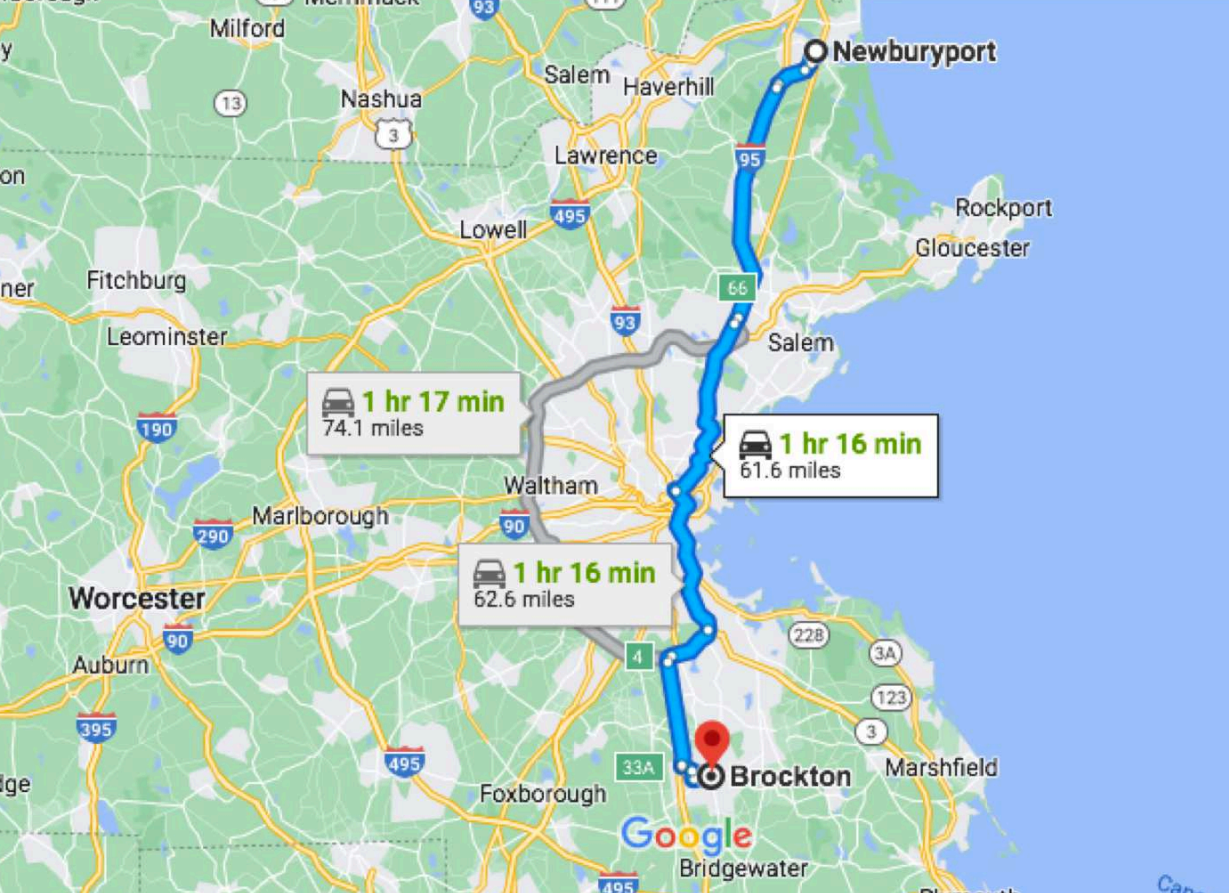
(high school physics) minimize the light travel time.

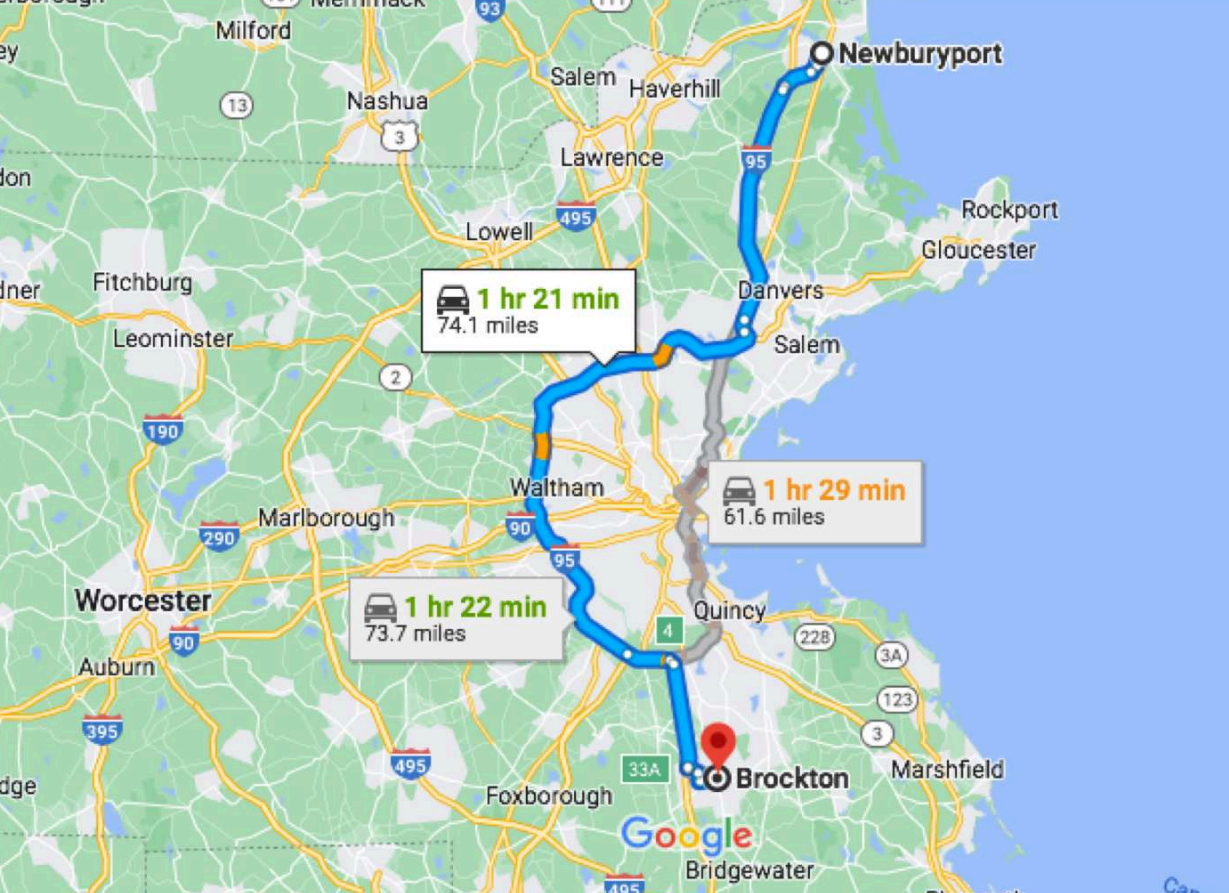
—or—

(university physics) are minima, maxima and saddle points of the light travel time.

General Relativity

Light experiences an “effective” index of refraction proportional to the strength of the gravitational potential.





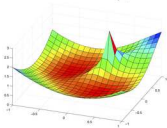
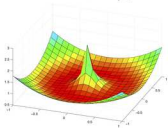
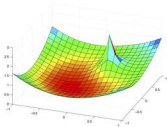
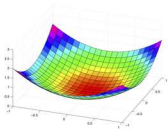
 **1 hr 21 min**
74.1 miles

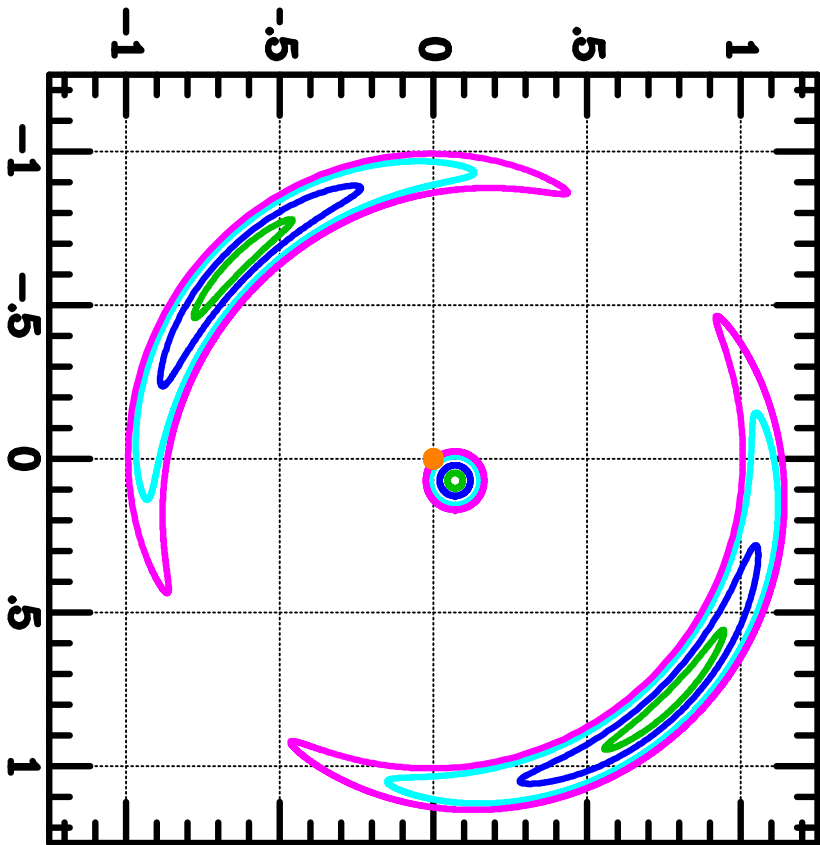
 **1 hr 29 min**
61.6 miles

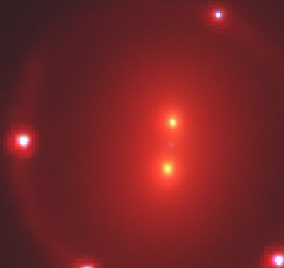
 **1 hr 22 min**
73.7 miles

Google

Light travel time







“The Importance of Einstein Rings”

**Authors: C. S. Kochanek, C. R. Keeton
& B. A. McLeod (2001)**

Abstract: ... The shape of an Einstein ring accurately and independently determines the shape of the lens potential and the shape of the lensed [source] ...

