Pioneer's Anomaly

The anomalous acceleration
of Pioneer 10 and 11

10/3/06

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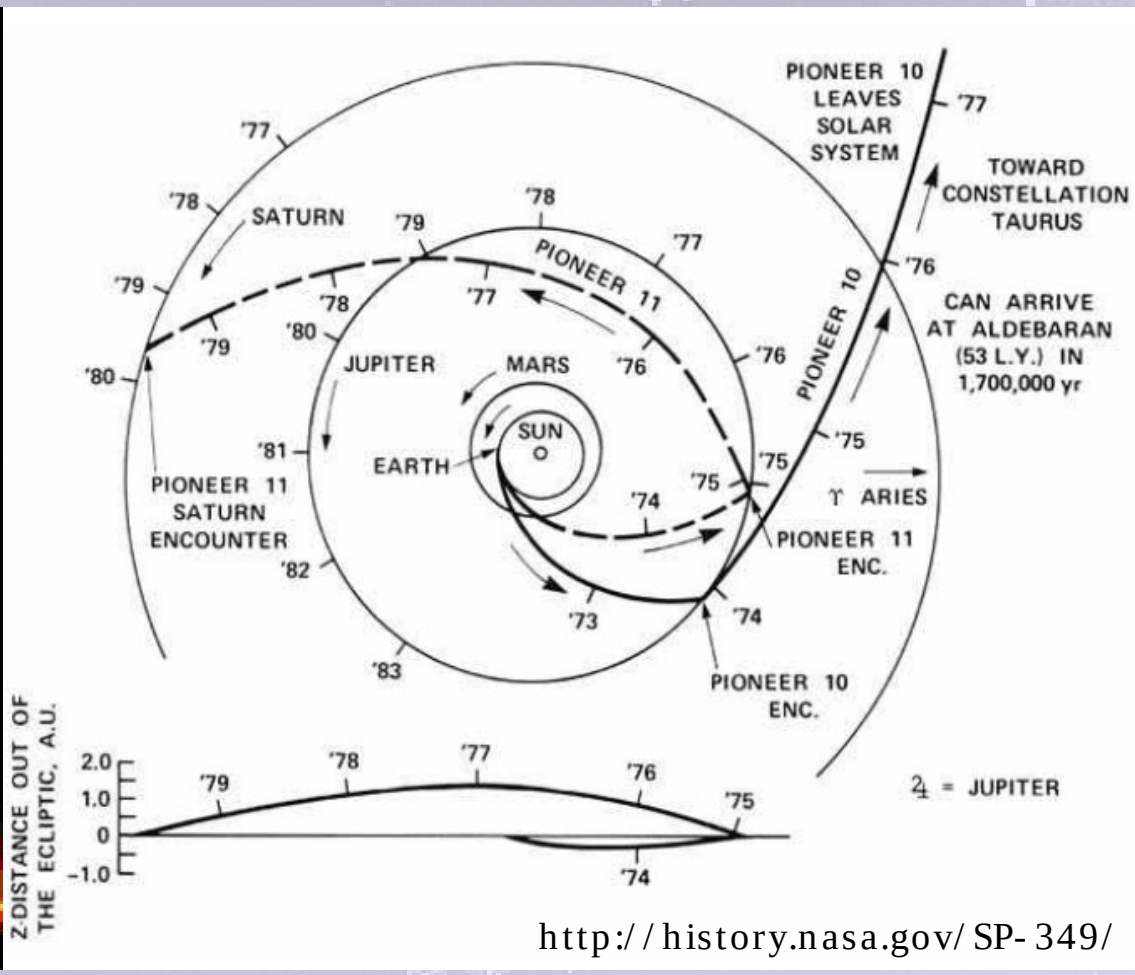
Introduction

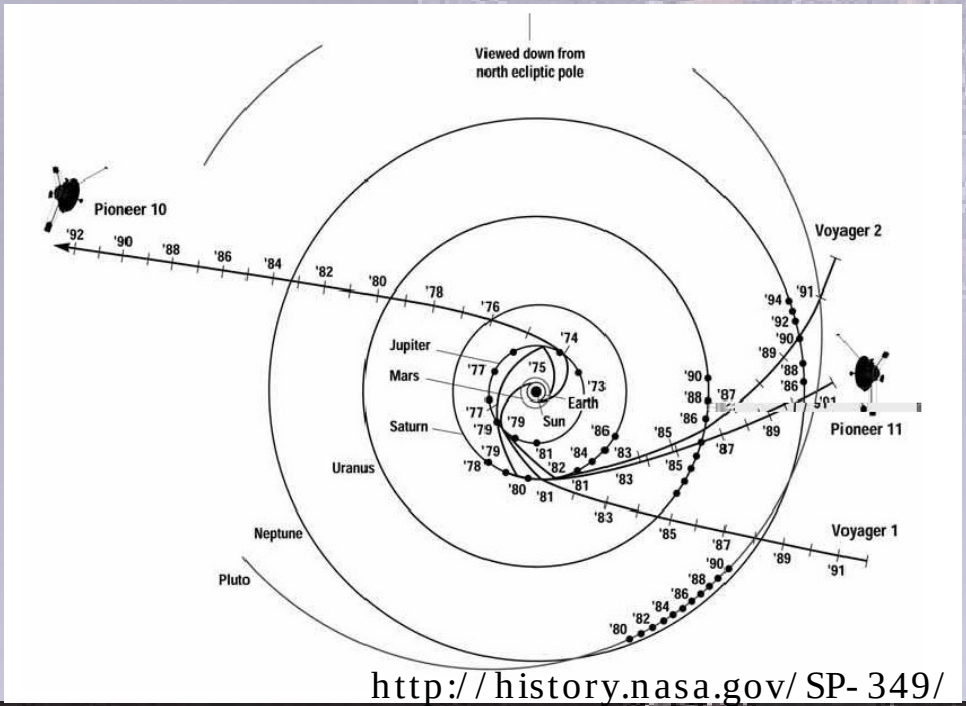
- Pioneer 10 was launched on 2 March 1972
- Its sister carft, Pioneer 11, was launched on 5 April 1973



http://history.nasa.gov/SP-349/

Pionieer 11

- After Jupiter and Saturn encounters Pioneer 11 followed escape hyperbolic orbit.
- The last telemetry data point was obtained on 1 October 1990 (~30AU)
- The science mission ended on 30 September, 1995
- Latest contact was on November, 1995



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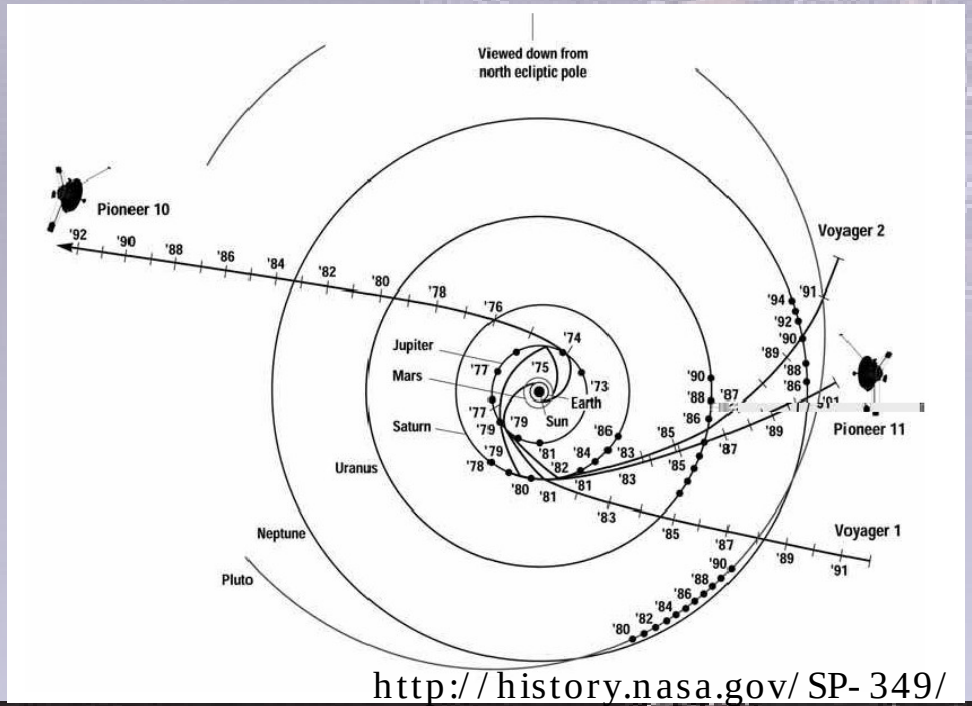
Pionieer 10

- After Jupiter encounters the craft followed escape hyperbolic orbit.
- The science mission ended on 31 March, 1997
- Latest contact was on 7 February, 2003
- The last telemetry data point was obtained on 27 April 2002 (~80AU)



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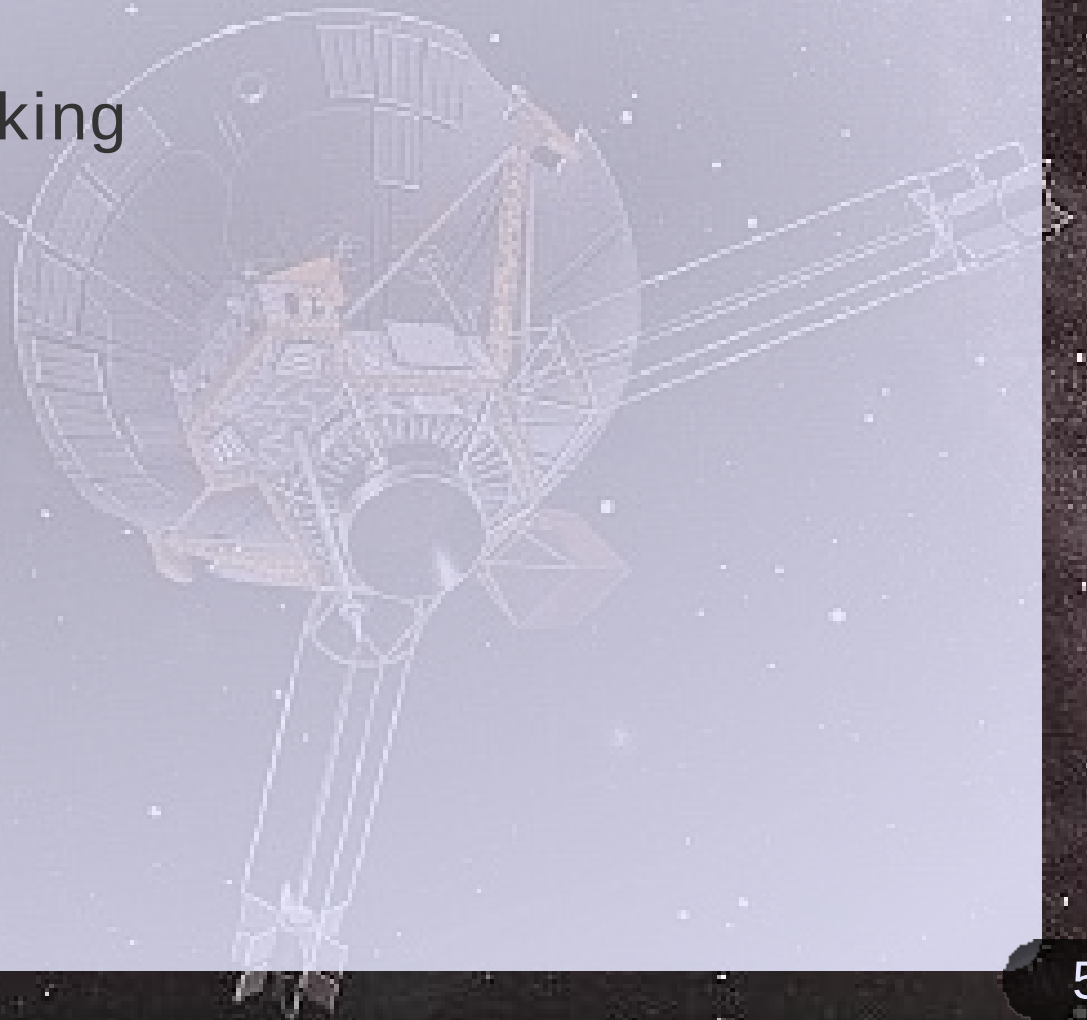
Pionieer 10/ 11

- The Pioneers are excellent craft for the purposes of precision celestial mechanics experiments, due to:
  - Their attitude control
  - Power design
  - Precise Doppler tracking



The Pioneer Anomaly

The analysis of the Pioneer 10 and 11 data (Anderson et al. 1998, 2002) demonstrated the presence of anomalous Doppler frequency blue shift drift (Turyshev et al. 2005)

$$\sim 6\times 10^{-9}\,\mathrm{Hz/s}.$$

This drift can be interpreted as existence anomalous sunward constant acceleration

$$= (8.74\pm 1.33)\times 10^{-10}\,\mathrm{m/s^2}.$$

This anomaly is present in four independent and different navigational computer programs (Anderson et al. 1998, 2002, Markwardt 2002, Olsen 2005)

Basic properties of the Pioneer anomaly

- Distance: It is unclear how far out the anomaly goes, but the Pioneer 10 data supports its presence at distances up to ~70AU from the Sun. The Pioneer 11 data shows the presence of the anomaly as close in as ~20AU.
- Direction: generally pointing in the innermost region of the solar sytem.
- Constacy: Both temporal and spatial variations of the anomaly's magnitude are of order 10% for each craft, while formal errors are significantly smaller.

Original efforts to explain the anomaly

(Anderson et al. 1998, 2002, Turyshev et al. 1999)

- Effects with sources external to the spacecraft.
  - The solar radiation pressure
  - Solar wind
  - The effect of the corona on the propagation of a radio wave signals
  - The influence of the Kuiper belt's gravity
  - Galactic gravity
  - Electromagnetic Lorentz forces
  - Errors in accepted values of the Earth's orientation parameters:
    - Precession
    - Nutation
    - Effect due to the troposphere and ionosphere

Original efforts to explain the anomaly

(Anderson et al. 1998, 2002, Turyshev et al. 1999)

- Study of the on- board systematics
  - Differential emissivity of the Radioisotope Thermoelectric Generators (RTGs)
  - Radiative cooling of the spacecraft
  - Propulsive gas leaks from trusters of the attitude control system
- Computational Systematics
  - Mismodelling of maneuvers
  - Solar corona model used to describe the propagation of radio waves

Recent efforts to explain the anomaly

- Search for independent confirmation
  - Attempt to verify the anomaly using other spacecraft (Voyager, Galileo, Ulysses, Cassini) proved disappointing
  - Many of the deep space missions that are currently being considered may not provide the needed navigational accuracy
- Conventional physics mechanisms
  - Kuiper belt objects or dust could explain the anomaly by
    - Gravitational acceleration
    - Additional drag force
    - Frequency shift of the radio signals proportional to the distance
- Numerical coincidence $a_p \approx cH_0$.

Recent efforts to explain the anomaly

Possibility for new physics?