


Numerical geodesy experiments for a Phobos laser ranging mission concept

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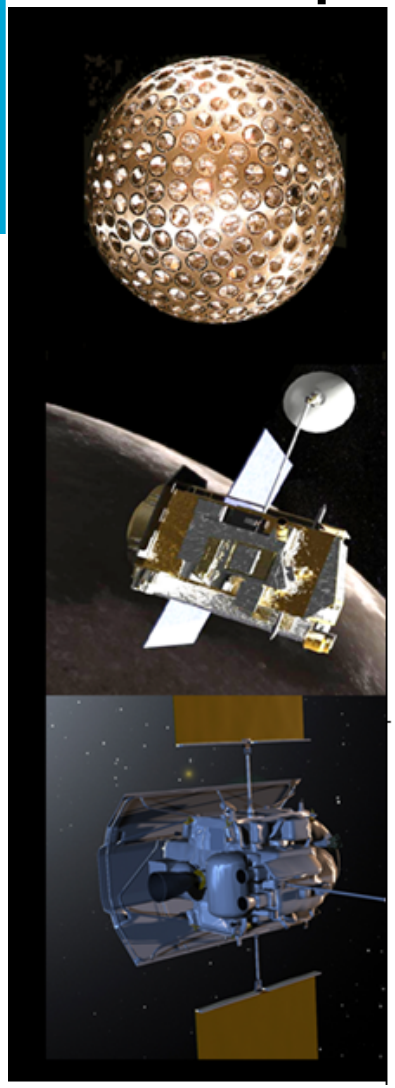
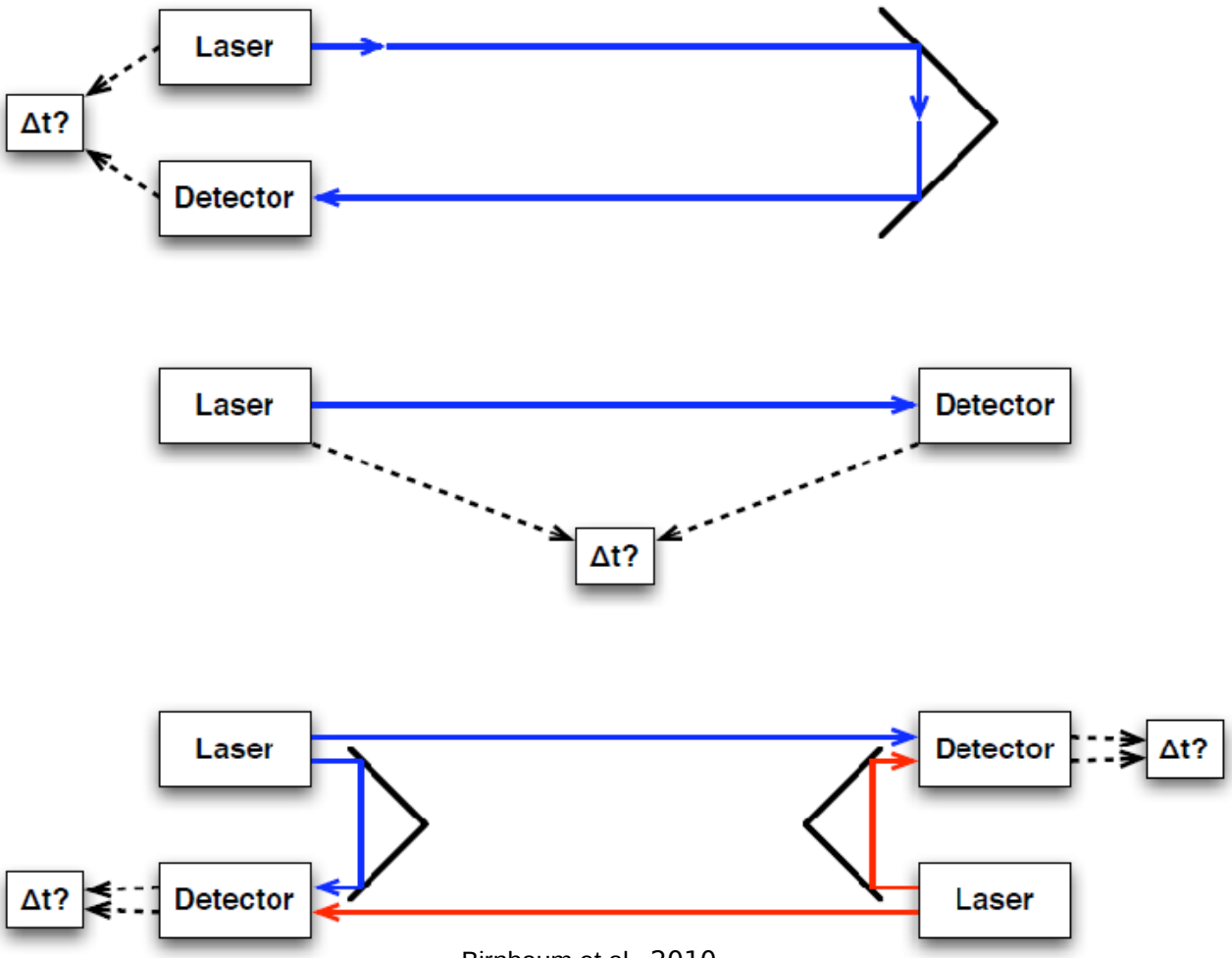
Interplanetary Laser Ranging





Birnbaum et al., 2010

Interplanetary Laser Ranging

Prospects

- Laser tracking can provide unprecedented range accuracy
  - Current radiometric range at ~1 m
  - Laser ranging at mm-cm
- Possibility of combination with
  - Laser altimetry
  - Laser communications
- Quality improvement in orbit & parameter estimation

Interplanetary Laser Ranging

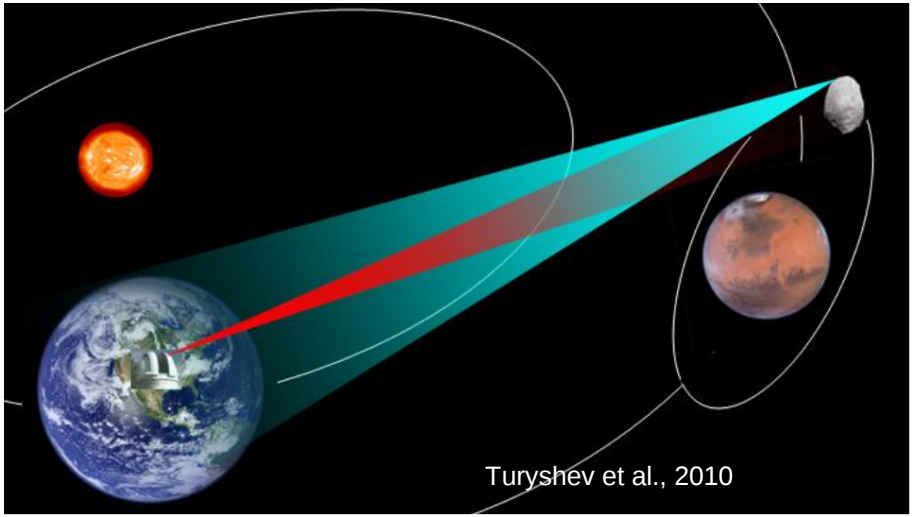
ESPaCE Project

- FP7 project for improvement of solar system ephemerides
  - Investigation of near-term potential of interplanetary laser tracking
- No interplanetary laser tracking operational
  - Simulations required for performance evaluation
- Performed in framework of Tudat software project
  - Modular C++ astrodynamics library
  - Development of orbit determination module

Link simulations

Test case

- Direct-to-Earth, two-way asynchronous laser ranging to Phobos
- Estimation of geophysical parameters of Mars; Phobos, ex.:
  - Phobos libration amplitudes
  - Phobos gravity field
  - Mars Love numbers
  - Mars quality factors
- Use of consider convariance analysis for influence of systematic errors



Link simulations

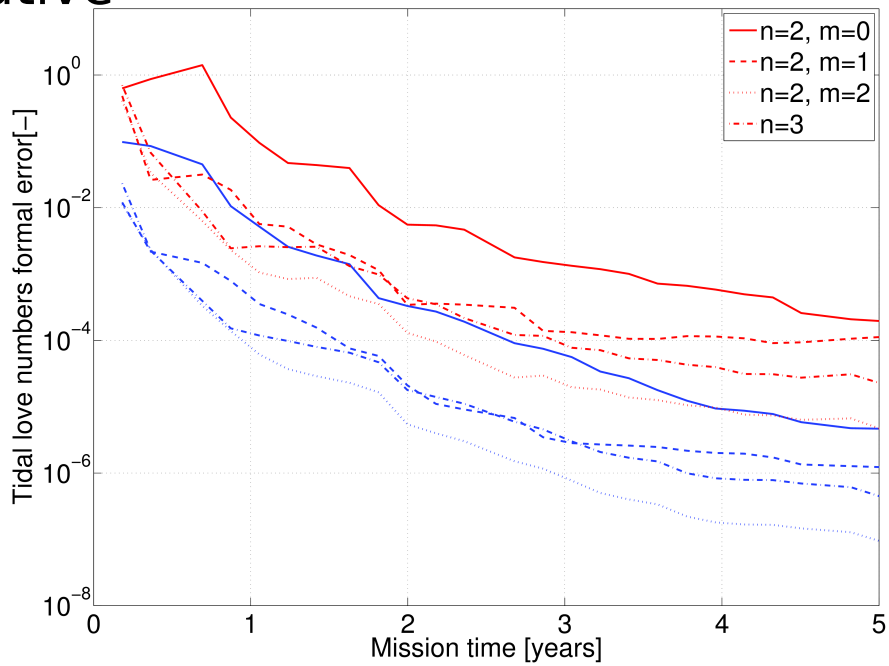
Phobos laser ranging settings

- Six SLR stations
  - Daily 30 min pass
  - 1 mm normal point per 60 s
- Observations constrained by
  - Sun avoidance angle (5°)
  - Elevation angles (10°)
  - Occultations

Link simulations

Mars Love number results

- Small influence of non-conservative forces
- Separate estimation of degree 2 Love numbers
- Very weak decorrelation of degree 2 and 3 Love numbers

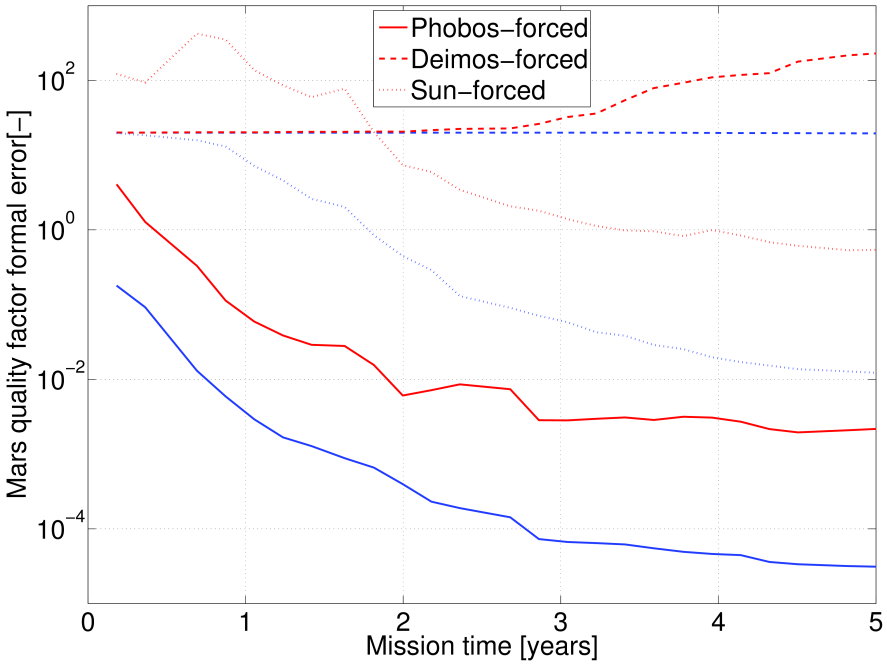


Blue: 1-mm precision, red: with 5-mm systematic errors

Link simulations

Mars quality factors results

- Separate estimation of Sun- and Phobos-forced tide
- Deimos-forced tide is unobservable
- Constraint on frequency-dependence



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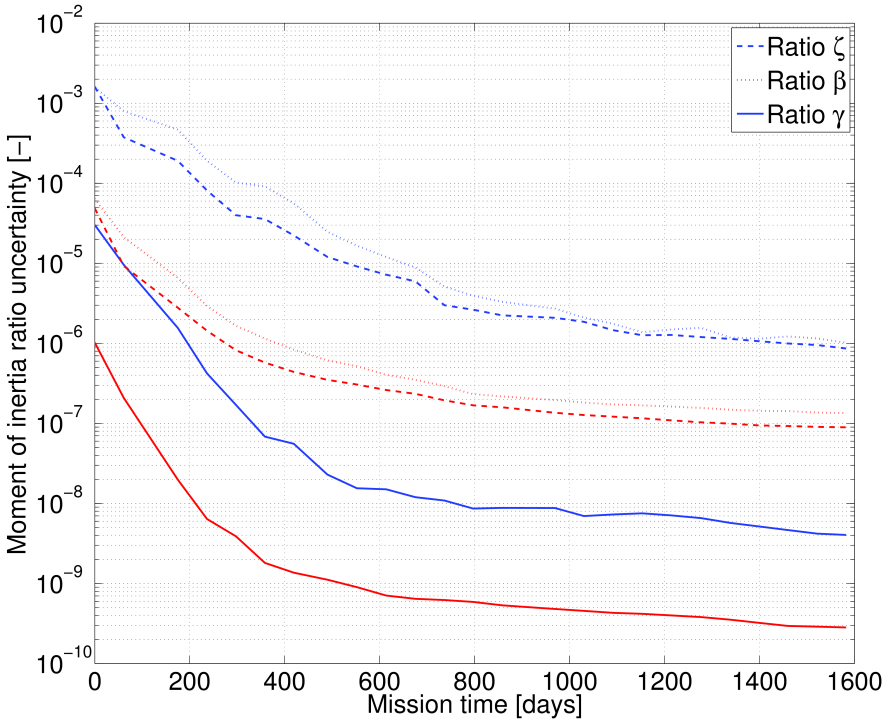
Link simulations

Phobos moments of inertia results

- Libration amplitudes constrain relative moments of inertia
- Precision of degree 2 gravity field estimation precise enough for decoupling



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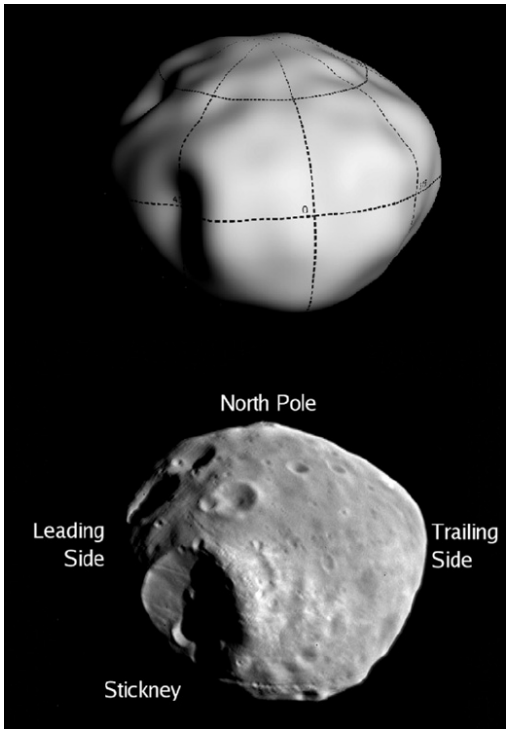
Link simulations

Discussion

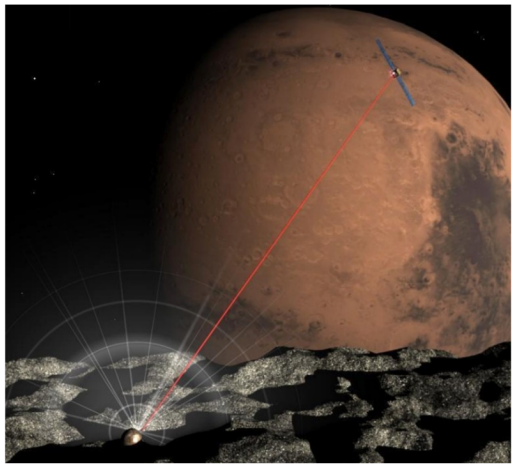
- Proper decorrelation of Phobos orbit; libration signal requires additional observables.
- Systematic errors more important than for radiometric tracking
- Mars interior results limited by:
  - Lack of seismic; heat; magnetic data
- Phobos interior results limited by:
  - Uncertainty in control point network (1%)



Willner, et al., 2010

Conclusions & Outlook

- Orders of magnitude improvement in Mars; Phobos geodetic observables
- Science results limited by complementary observations
- Strong influence of systematics
- Future steps:
  - Quantify system requirements from science requirements
  - Compare to combination with radiometric methods



Oberst et al., 2012