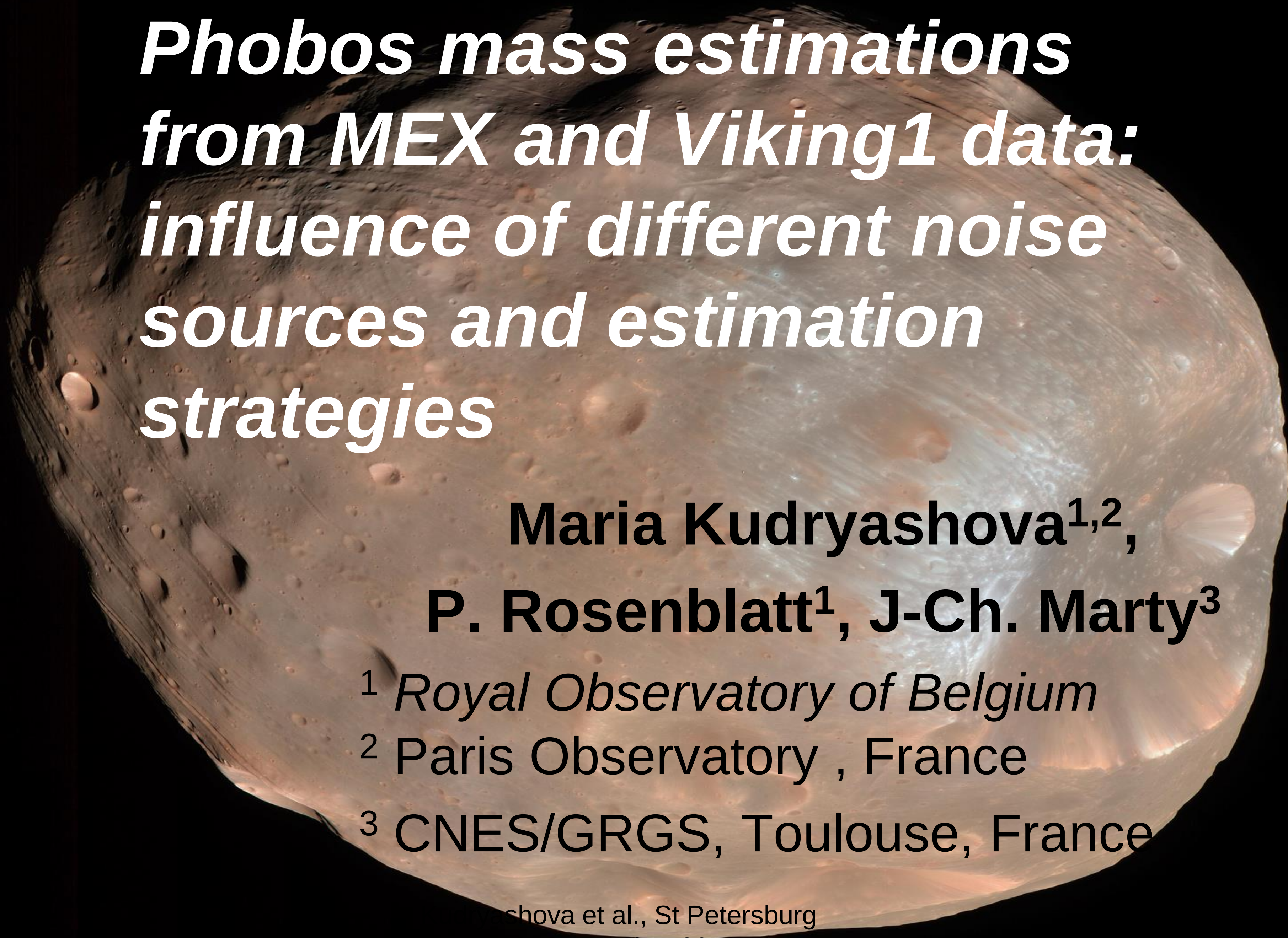

Phobos mass estimations from MEX and Viking1 data: influence of different noise sources and estimation strategies

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Motivation

- Origin of Martian moons?
- We can get clues from geodetic parameters: bulk density; mass distribution; composition; dissipative properties…

$$\theta = \frac{2e}{1 - \frac{C}{3(B-A)}}$$

$$C_{20} = \frac{\frac{(A+B)}{2} - C}{Mr_0^2}$$

$$C_{22} = \frac{B - A}{4Mr_0^2}$$

➢ Internal mass distribution related to principal moments of inertia (A<B<C).

➢ Principal moments of inertia are also related to quadrupole gravity coefficients ***C20*** and ***C22*** and the libration amplitudes $\boldsymbol{\theta}$

Where M is the mass of Phobos, *r0* is the mean radius of Phobos and *e* is the ellipticity of its orbit around Mars.

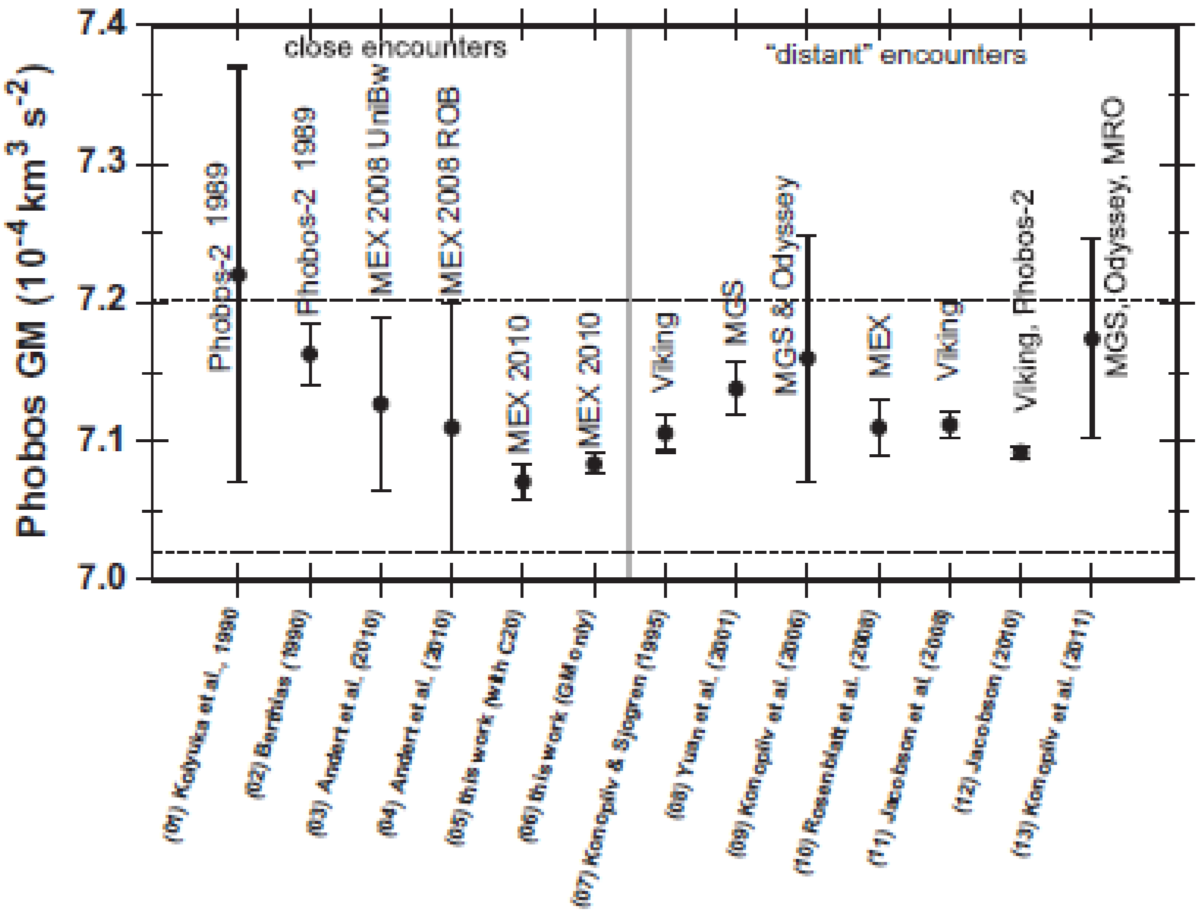
Why are we interested in very precise Phobos mass?

- Geodetic parameters (C_{20}, C_{22}) of heterogeneous interior departs by a few percents (<10%) from the homogeneous interior (*Rivoldini et al., 2011, Rosenblatt et al, 2013);*

- C_{00} (GM) is correlated with C_{20} and C_{22};

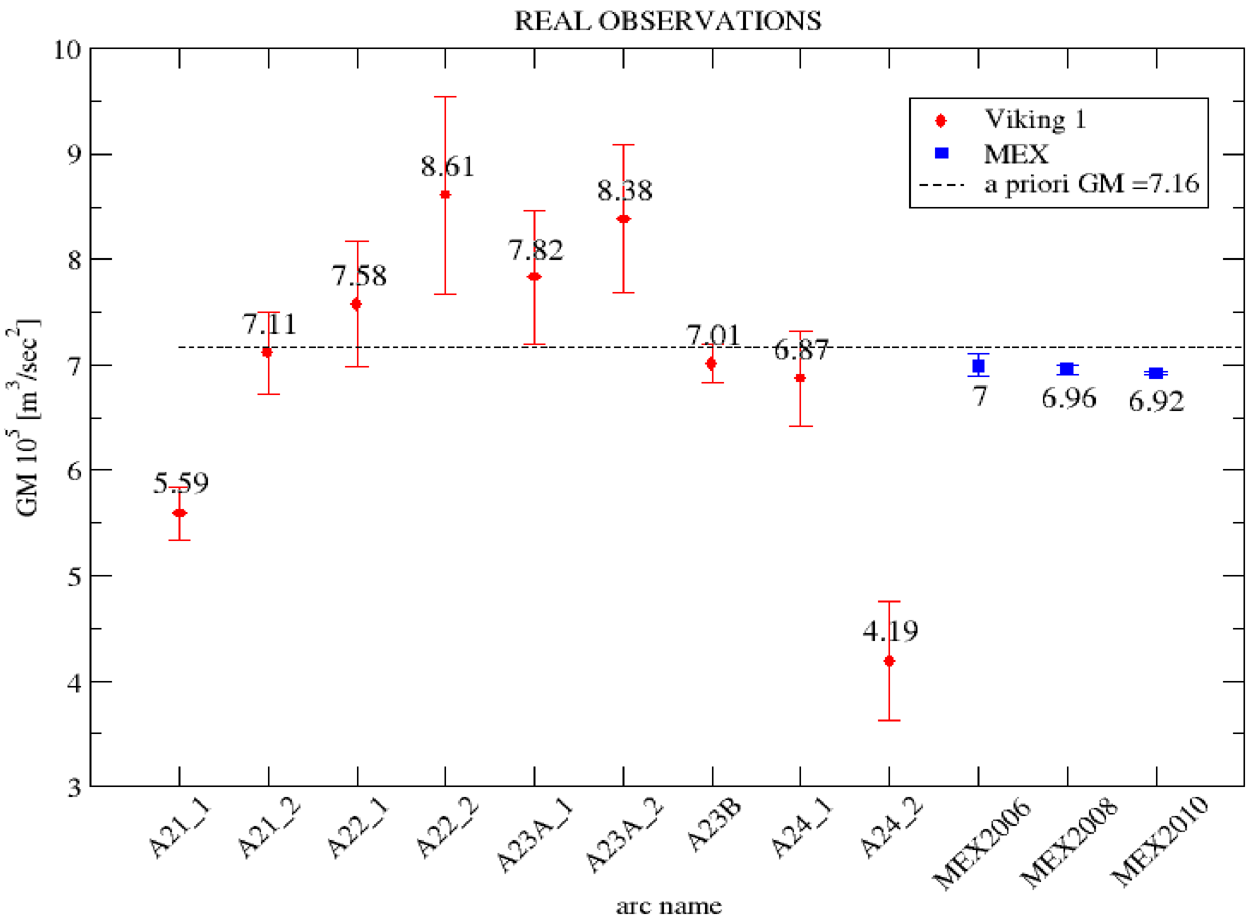
- Thus, GM need to be known with precision ~0.1% (MEX simulations, *Rosenblatt et al, 2013);*

Phobos mass determination from different spacecraft/strategies



Pätzold et al., 2014

Phobos mass determination from similar strategy: Viking 1 and MEX



Close encounters only

Estimated parameters:
for both s/c:
- initial state vector,
- Phobos GM,
- radiation pressure coefficients.

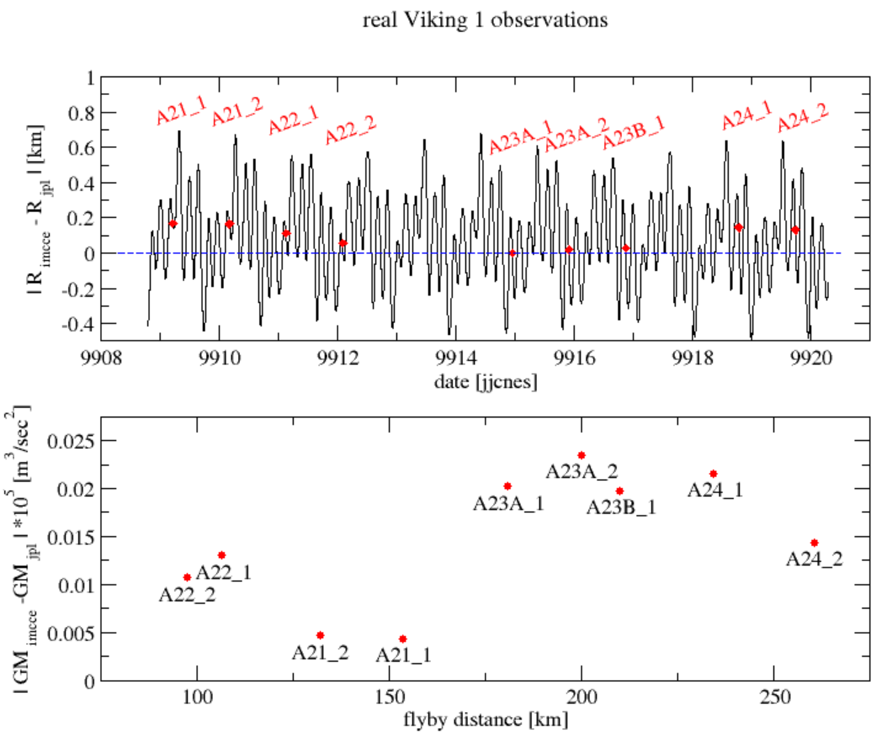
In case of MEX:
- atmosph drag,
- Doppler frequency offset,
- range bias,
- thruster parameters

Actual precision of Phobos mass determination

- Aim: to quantify the impact of different error sources on the Phobos GM estimations from flyby data.

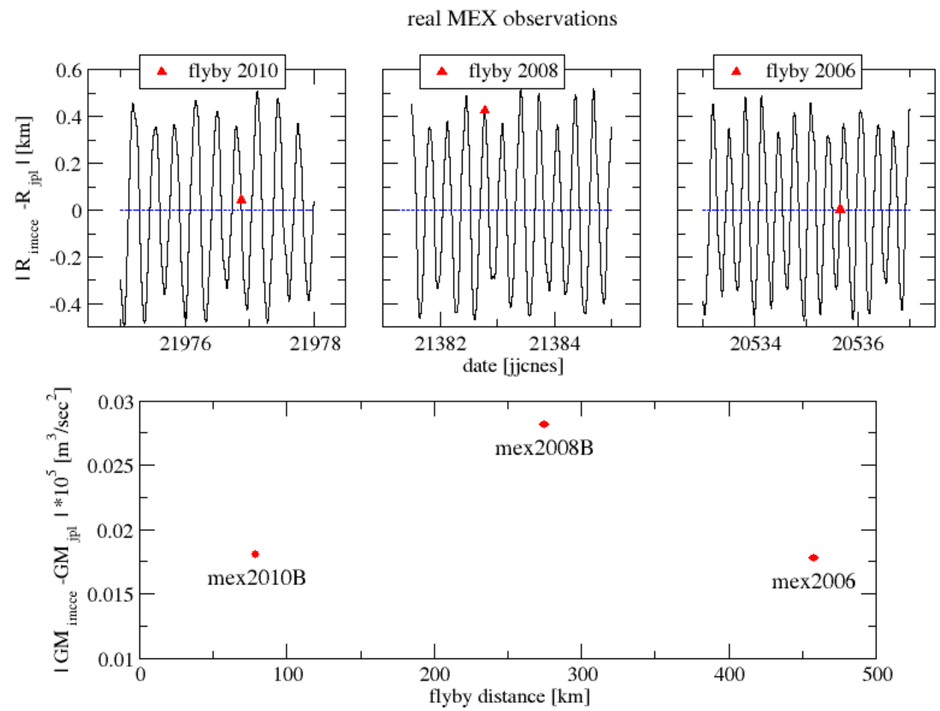
- Considered error sources:
  - Phobos a priori ephemerides;
  - Phobos a priori GM value;
  - measurements noise;
  - different strategies;
- Methods:
  - real data analysis;
  - simulations.

Real data: sensitivity of GM estimations to the errors in a priori Phobos ephemerides



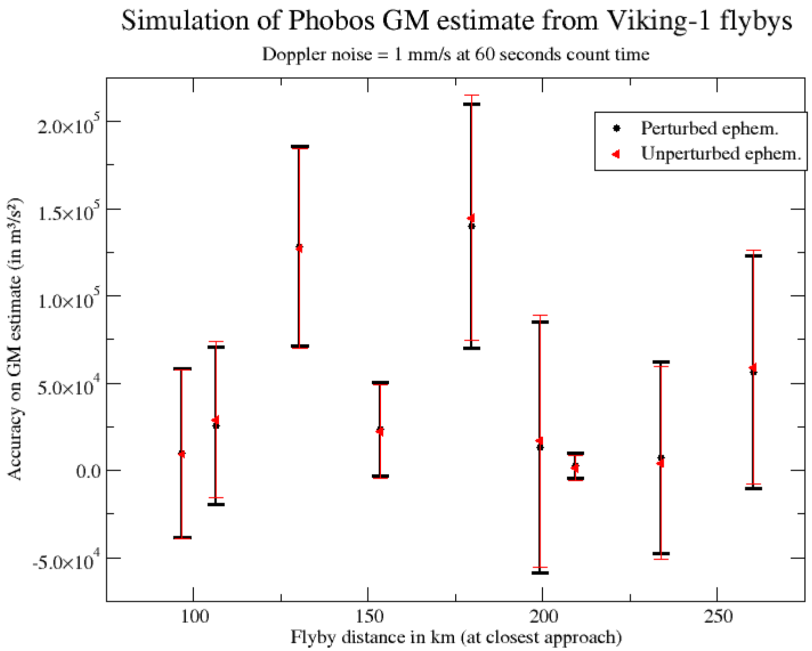
not sensitive

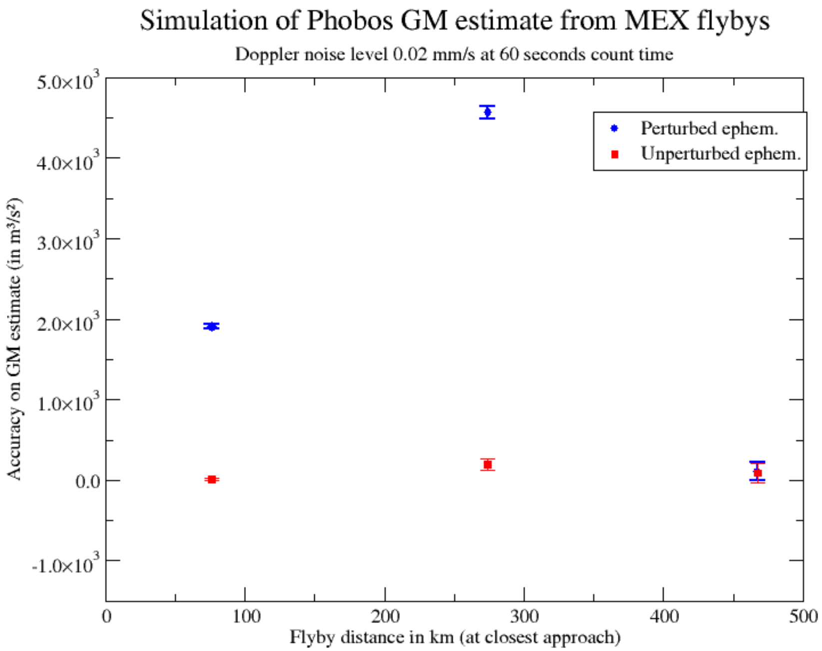
sensitive



Lainey, 2007 (IMCCE), Jacobson, 2010 (JPL)

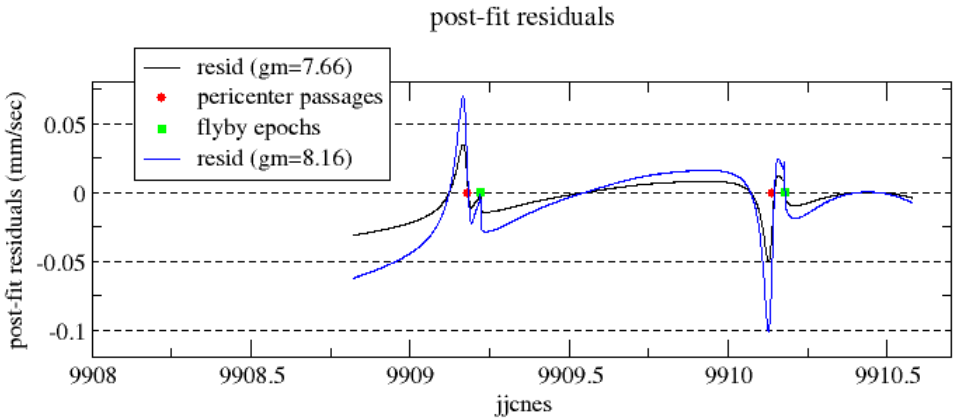
Simulations: impact of errors in a priori Phobos ephemeris on the Phobos GM

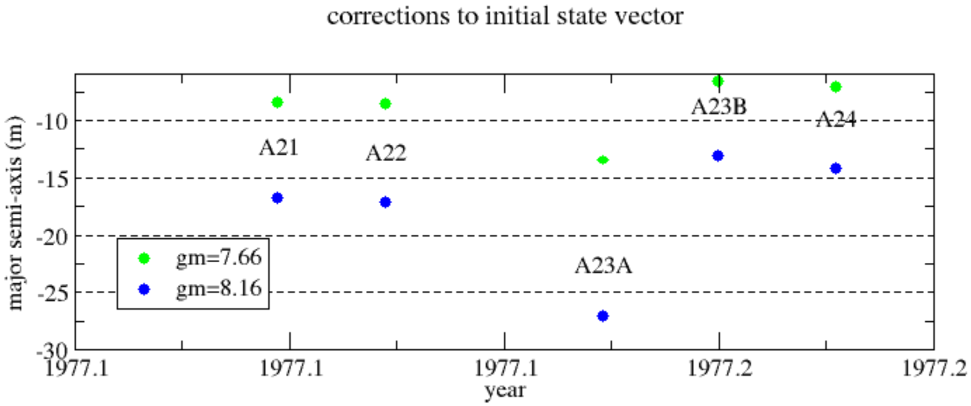




Simulations: IMCCE (Lainey, 2007) ephemeris + X-band/S-band noise level for MEX/Viking1;
Reconstruction: a) IMCCE Phobos ephemeris -1 km (perturbed) and b) IMCCE ephemeris (unperturbed) + same noise level as for simulations in all cases.

Simulations: sensitivity of the measurements to the a priori GM value



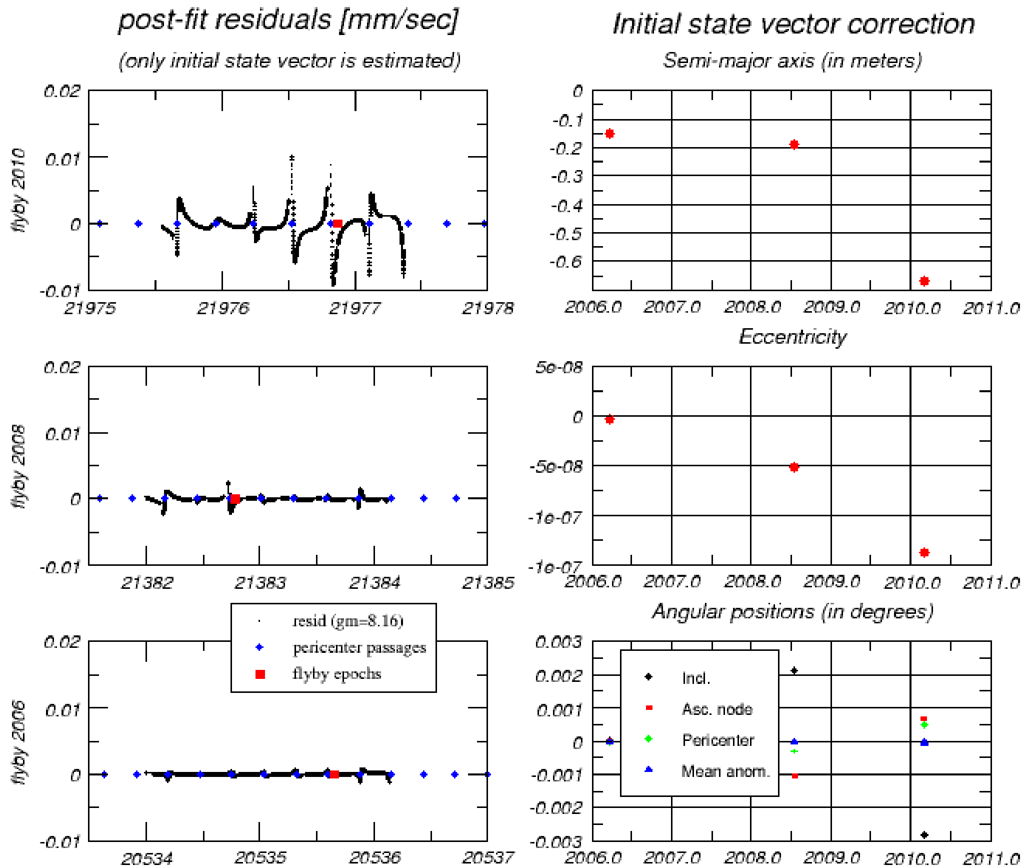


Simulations: zero noise+ IMCCE a priori ephemerides $+GM_{PH}$ = 7.16 * 105 m^3/sec^2.

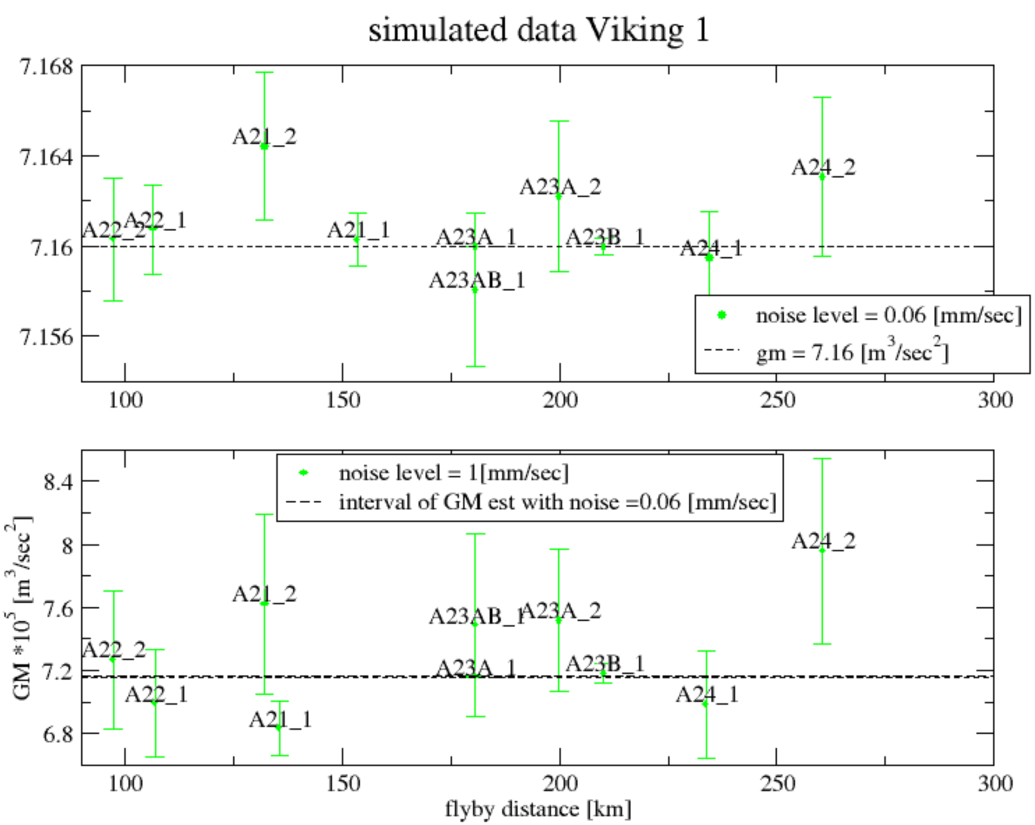
Reconstruction: zero noise+ IMCCE a priori ephemerides + GM^1_{PH} = 7.66 $*10^5$ and GM2PH= 8.16 $*10^5$ m^3/sec^2.

Only initial state vector is estimated during simulated orbit reconstruction.

Simulations: sensitivity of the measurements to the a priori GM value



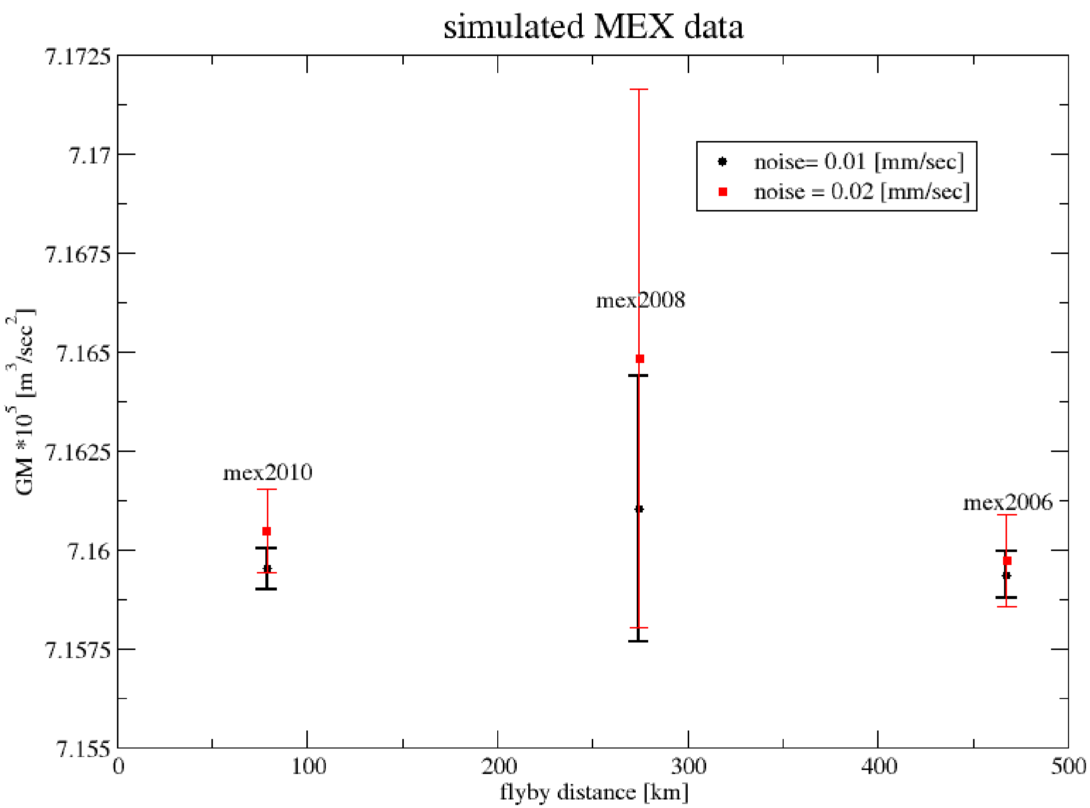
Sensitivity of the measurements to the observational/modeling noise



simulations and orbit reconstructions: IMCCE Phobos ephemeris.
Viking1 data: noise level 0.06 mm/sec and 1 mm/ sec

decreasing the value of the noise diminish the GM formal errors and bringing the values of GM closer to one another

Sensitivity of the measurements to the observational/modeling noise



MEX data with the noise levels 0.01 and 0.02 mm/sec .

CONCLUSIONS

Accuracy and precision of GM estimations increase with decreasing of the value of the noise for both spacecraft.

VIKING1:

•neither distances of flybys nor a priori ephemerides show clear correlation with the GM_{PH} estimations and their formal errors;

•the post-fit Doppler residuals are not very sensitive to the errors in GM_{PH}: changes of the spacecraft velocities due to $\Delta GM_{PH} = 10^5$ [m^3/sec^2] (14% a priori GM_{PH}) are at the level of 0.06 mm/sec which corresponds to the most optimistic estimation of the observational noise level in case of Viking 1;

Observational noise dominates all other considered sources of errors

CONCLUSIONS

MEX:

● there is a clear dependence between Phobos GM estimations and a priori ephemerides used: the bigger the difference in a priori ephemerides (which reaches 0,5 km for the flyby of the year 2008) the bigger the difference in GM estimations.

● Changes of the spacecraft velocities due to $\Delta GM_{ph} = 10^5$ [m^3/sec^2] (14% of Gm_{ph}) could be observed (>= noise level) from very distant flybys (at distance 467 km it produces vel changes 0.02 mm/sec) and $\Delta GM_{ph} = 5*10^4$ (7% of GM_{ph}) can be observed starting from closer flybys (2010 at the distance about 78 km);

The uncertainties in Phobos a priori position dominate other sources of errors.

Thank you!

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