The Galactic Centre

Determination of the Mass Distribution in the Galactic Centre from the Stellar Motions

Jaroslava Schovancová, Ladislav Šubr

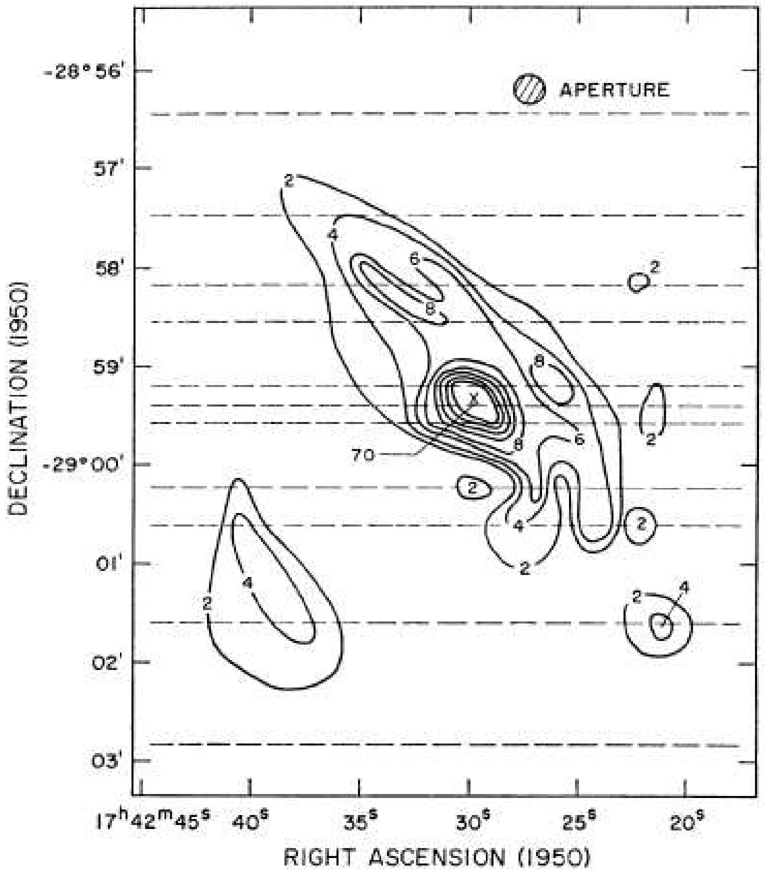
`schovan@sirrah.troja.mff.cuni.cz`

Astronomical Institute, Charles University in Prague

Argelander Institute for Astronomy, University of Bonn

Argelander-
Institut
für
Astronomie

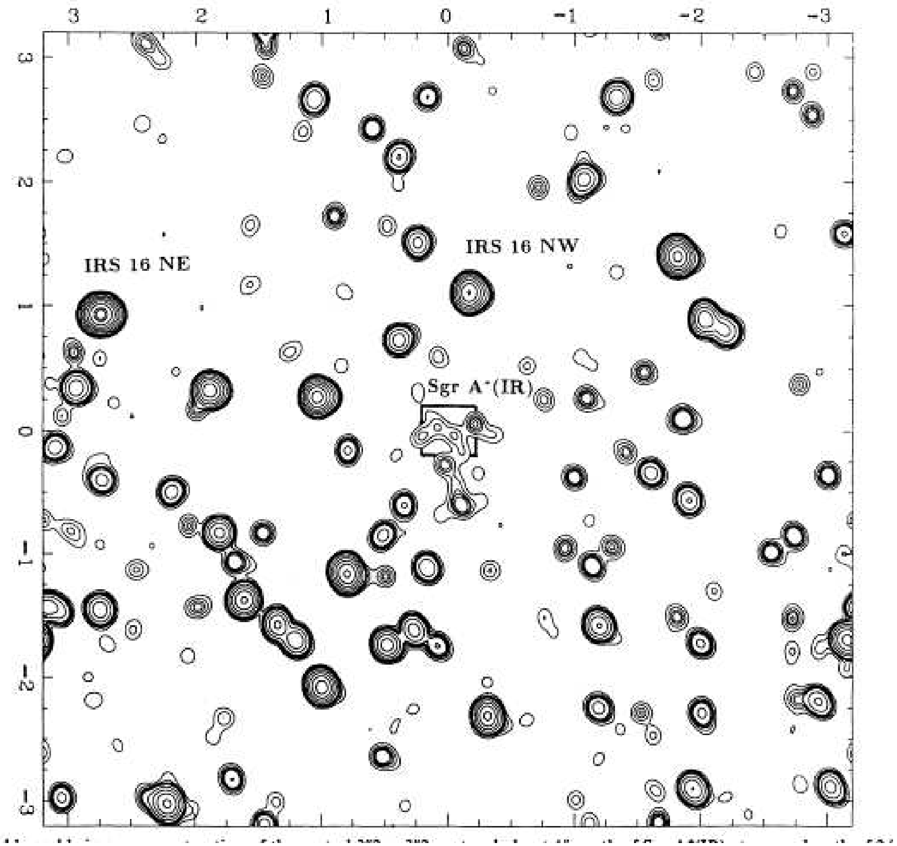
Focusing on the Galactic Centre



Becklin & Neugebauer (1968)

- distance to the Galactic Centre: $\sim$ 8 kpc
- observed in NIR and radio
- successful location of a source: Becklin & Neugebauer (1968) $\lambda = 2.2\ \mu$m, resolution 0.62 pc and 0.2 pc

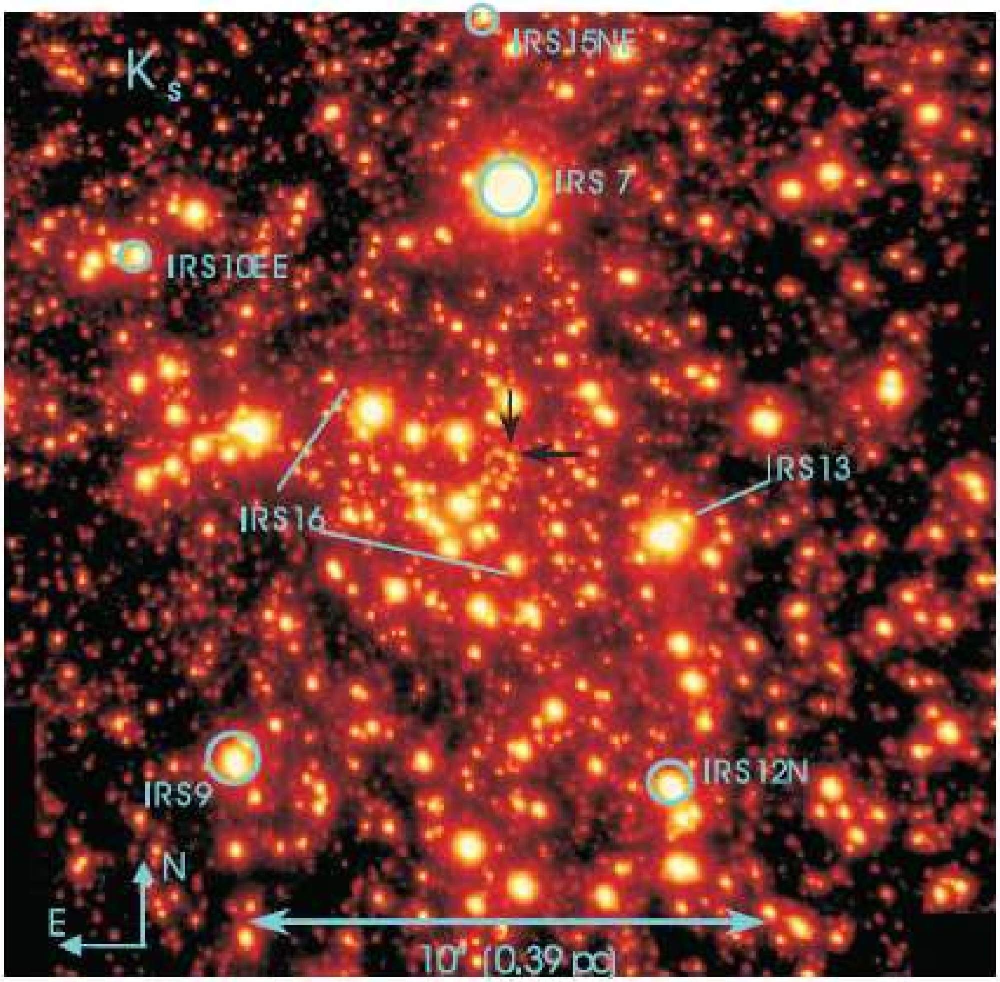
Focusing on the Galactic Centre



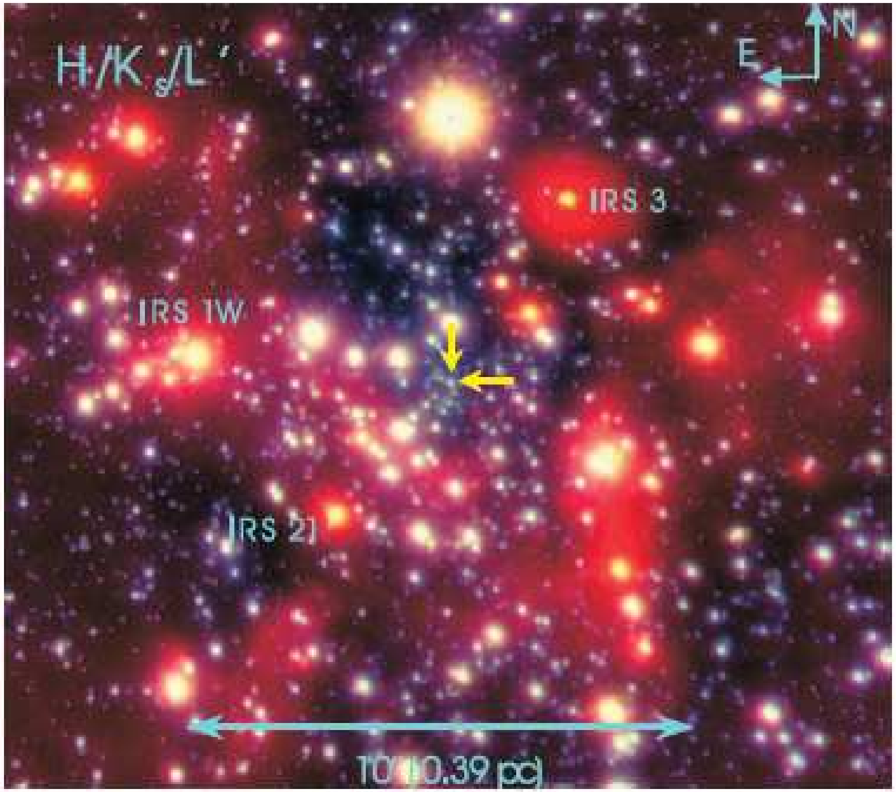
- 2D speckle imaging:
  - 600 individual stars resolved, 0.15 " resolution (0.006 pc) Eckart et al. (1995)
  - complex of NIR sources very close to Sgr A* Genzel, Eckart, Ott & Eisenhauer (1997)

Eckart et al. (1995)

The Central Parsec

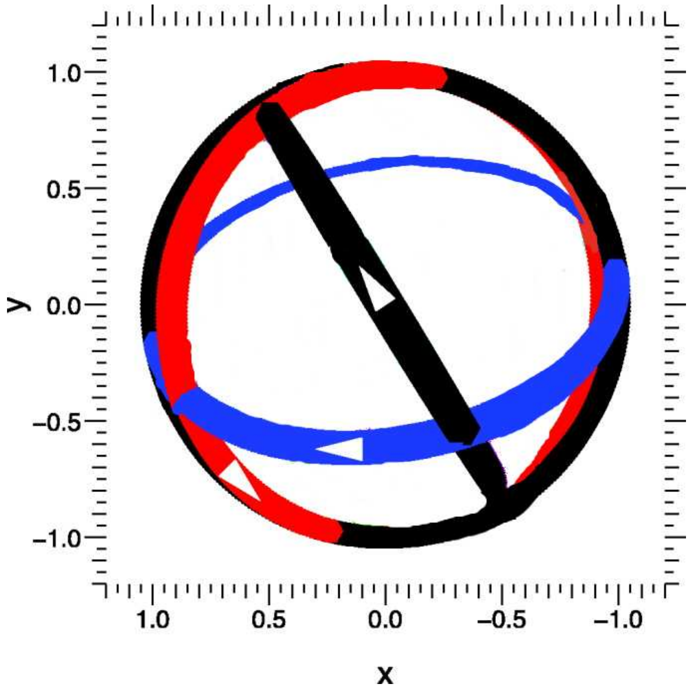


Genzel et al. (2003)



K-band: λ=2.20 μm
H-band: λ=1.60 μm
L-band: λ=3.45 μm

Stellar Disks in the Galactic Centre



- two coherent disks of massive O- & B-type stars $\simeq 0.1$ pc; Genzel et al. (2003), Ghez et al. (2005)
- well defined inner (0.04 pc) and outer (0.5 pc) radii
- geometrically thick: $h/R \sim$ 0.13

black: the Galaxy and sky
blue: clockwise stellar disk
red: counter-clockwise stellar disk
Paumard et al. (2006)

Stellar Disks in the Galactic Centre

- young stars: (6 $\pm$ 2) Myr $\Rightarrow$ recent star formation in GC; Paumard et al. (2006)
- similar disks detected in the centre of M31 Bender et al. (2005)
- flat mass function, mass $\sim$ 10^4 $M_\odot$
- significant eccentricities for some of stellar orbits
- clockwise disk: $e_{\rm rms} \in$ [0.2; 0.3] Paumard et al. (2006), Belobordov et al. (2006)
- counter-clockwise disk: $e_{\rm rms} \in$ [0.6; 0.7]
- hot topic: origin?

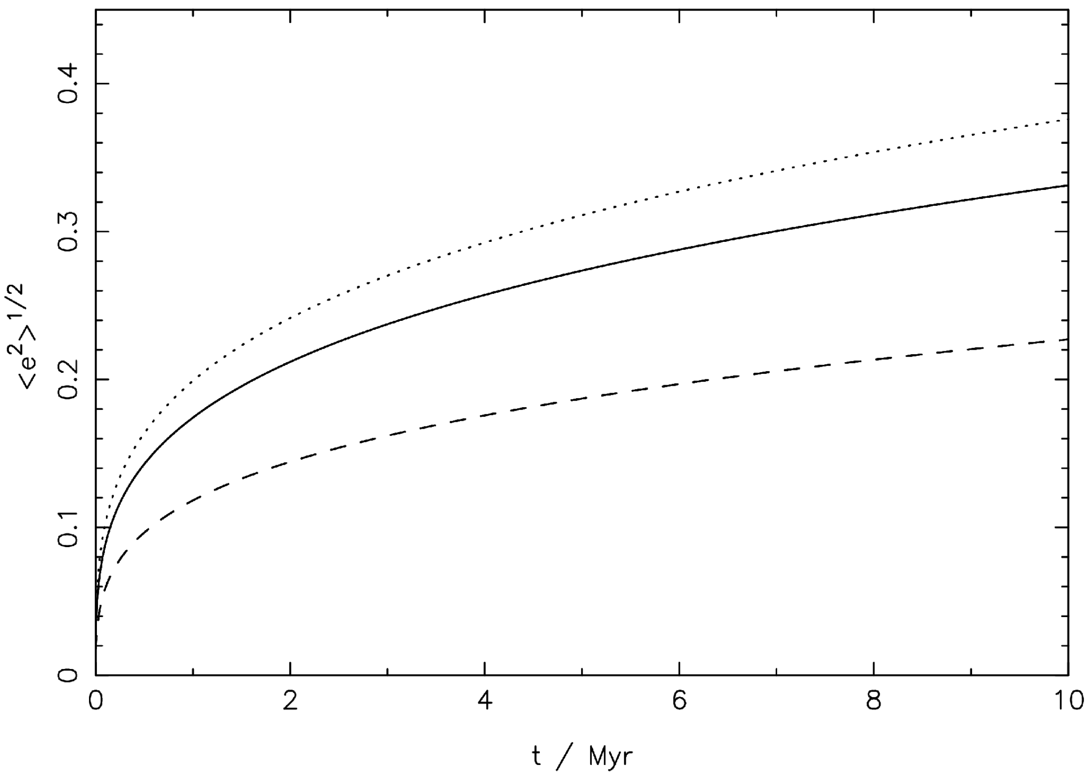
Popping the Clockwise Stellar Disk

- significant eccentricities for some of stellar orbits
- clockwise disk: $e_{\mathrm{rms}} \in [0.2; 0.3]$ Paumard et al. (2006), Beloborodov et al. (2006)
- counter-clockwise disk: $e_{\mathrm{rms}} \in [0.6; 0.7]$
- assuming originally circular orbits $\Rightarrow$ require presence of more massive stars in order to excite the eccentricities of these stars to those observed

- further reading on stellar disks in the GC:
  - Ghez et al. (2003),
    Genzel et al. (2003),
    Paumard et al. (2006), ...

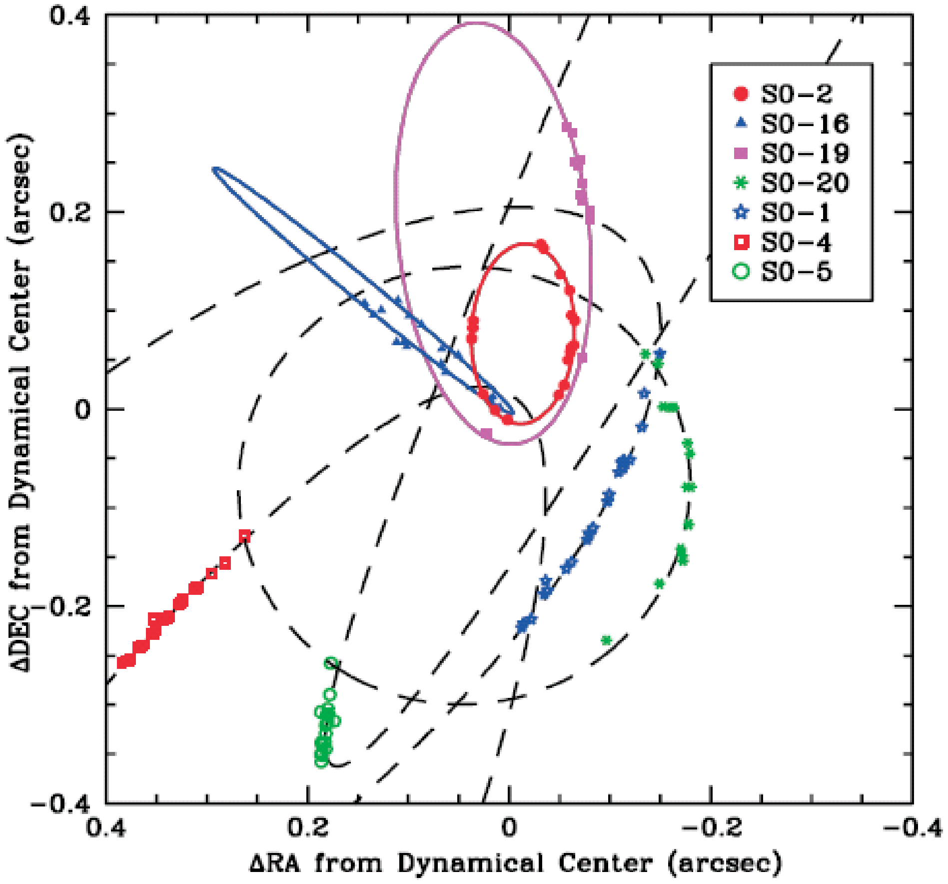
Popping the Clockwise Stellar Disk

- significantly flatter MF with Γ=1.35
  Paumard et al. (2006): M_1 = 125 $M_\odot$, M_3 = 5 $M_\odot$



Alexander et al. (2006), `astro-ph/0609812`

Youth Paradox – The S Stars



Ghez et al. (2005)

- number of B-type stars very close to GC ($\simeq$ 0.01 pc)
- $M \sim 20\ M_\odot$, eccentric orbits, $a > 10^4\ R_g$
- S2 star:
  - $a \sim$ 930 AU
  - $e \doteq$ 0.87
  - $M \doteq$ 25 $M_\odot$
  - $P \sim$ 15 yr
- hot topic: origin?

Thesis Guidelines

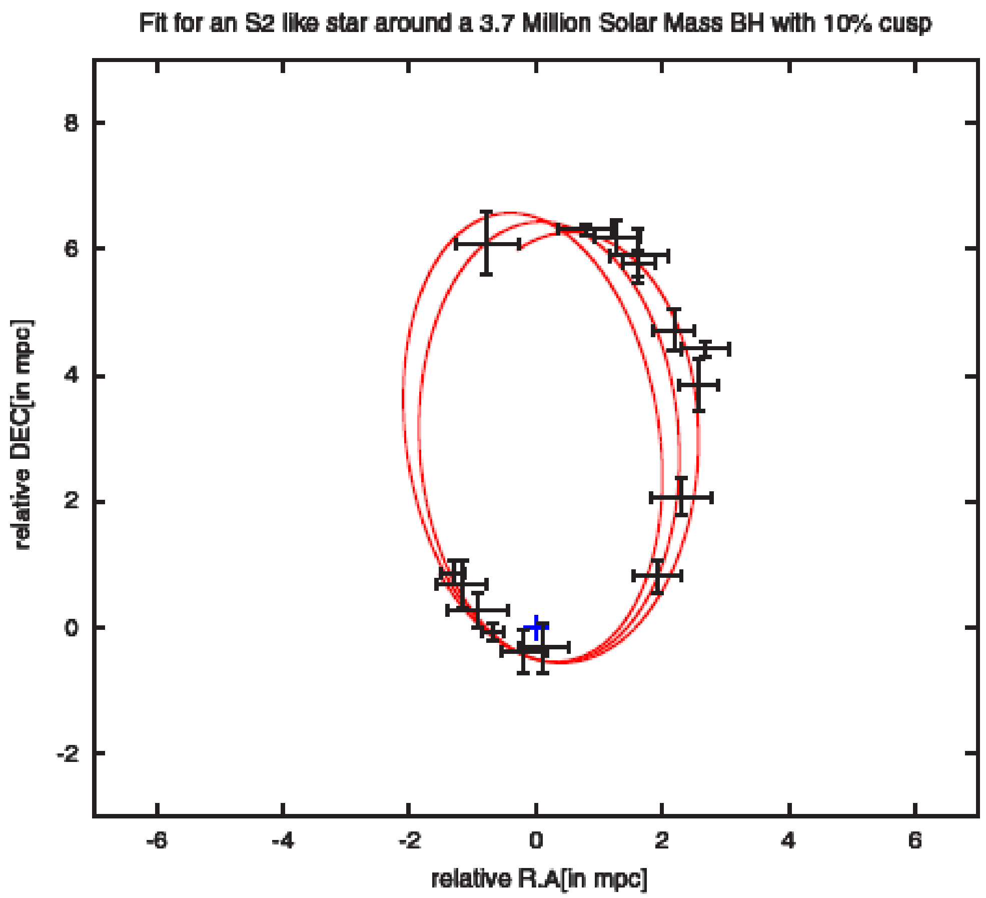
- Familiarise with recent Sgr A* observations with respect to mass distribution (gas and stars) and young stars kinematics
- Simulate orbital elements evolution, consider stars trajectories under influence of central SMBH potential and axi-symmetrical perturbation
- Explore parameter space of such perturbation in order to find a system setup consistent with observations

Preliminary results

- apocentre shift under spherical perturbing potential
- axi-symmetrical perturbing potential (ring)
- composite perturbing potential: ring + sphere

Spherical Perturbation

- influence of a spherical mass-distribution in the GC on the S2 orbit: Mouawad et al. (2003) & (2005)



Spherical Perturbation

- power-law in mass-density:

$$\rho(r) = \rho_0 \left(\frac{r}{r_0}\right)^{-\alpha}$$

- mass:

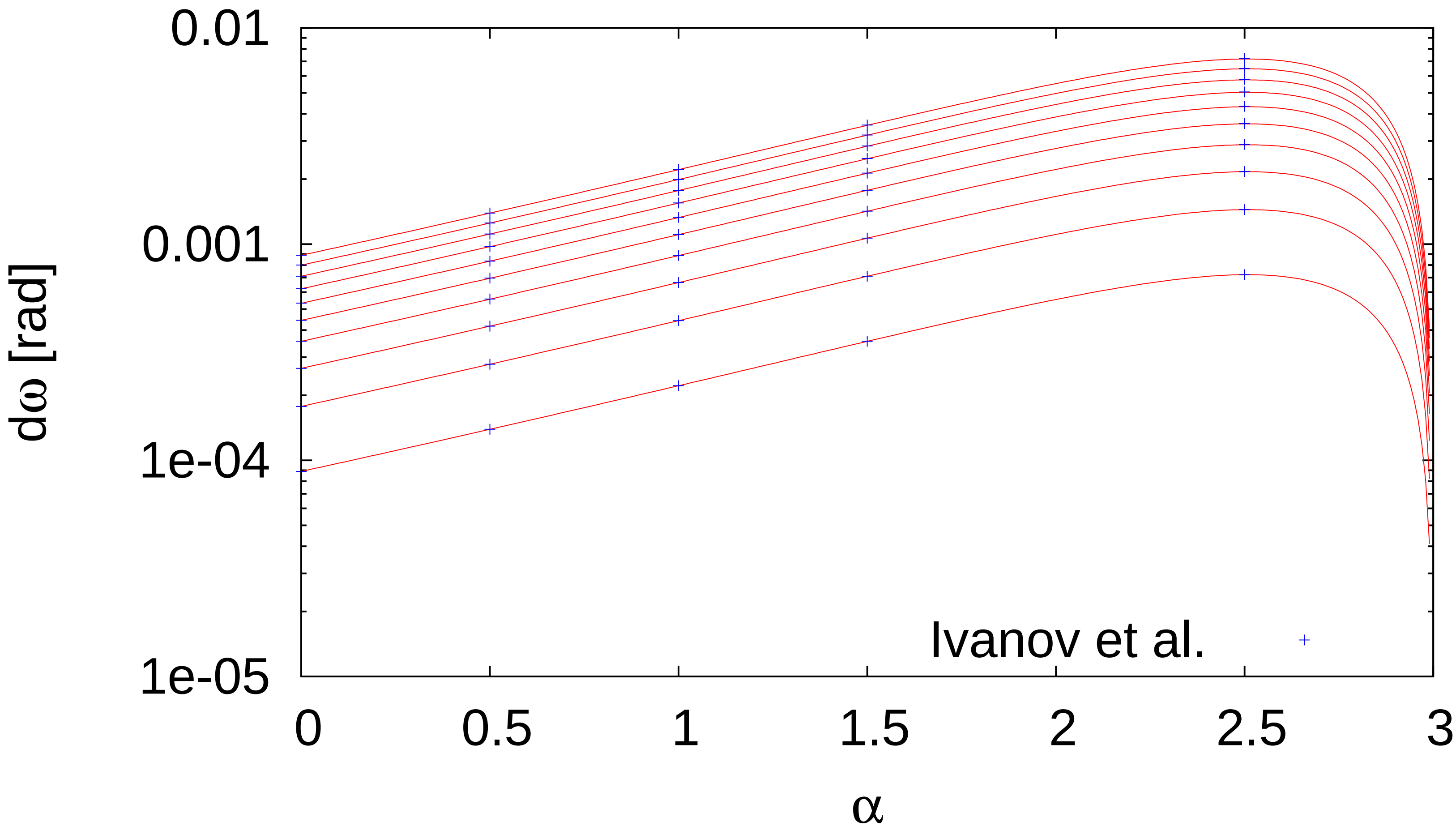
$$M(r) = M_\bullet \left(\frac{r}{r_0}\right)^{3-\alpha}$$

- potential:

$$\Phi(r) = \frac{GM_\bullet}{(2-\alpha)r_0} \left(\frac{r}{r_0}\right)^{2-\alpha}$$

Spherical Perturbation

$$\delta\omega = \frac{2k}{2-\alpha}\left(\frac{a}{r_0}\right)^{3-\alpha}\frac{\mathrm{d}}{\mathrm{d}\varepsilon}\left[\varepsilon^{7-2\alpha}\int_0^{\pi}\frac{\mathrm{d}\phi}{(1+e\cos\phi)^{4-\alpha}}\right]$$



Axi-symmetrical Perturbation

- ring potential:

$$\Phi(r) = -2G\lambda\sqrt{\frac{a}{R}}k\mathcal{K}(k),$$

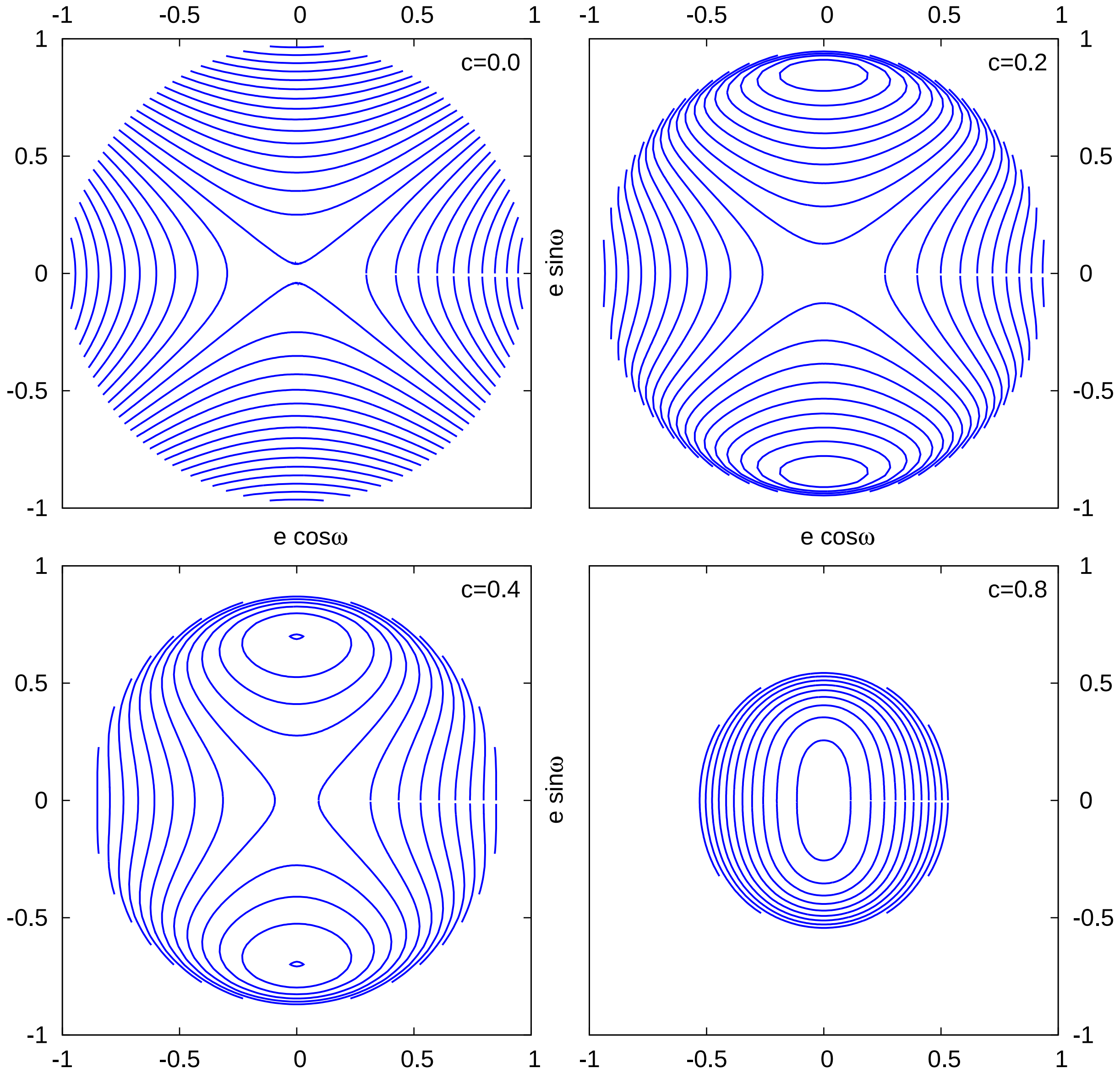
where

$$k^2 = \frac{4aR}{(a+R)^2 + (Z-z)^2}$$

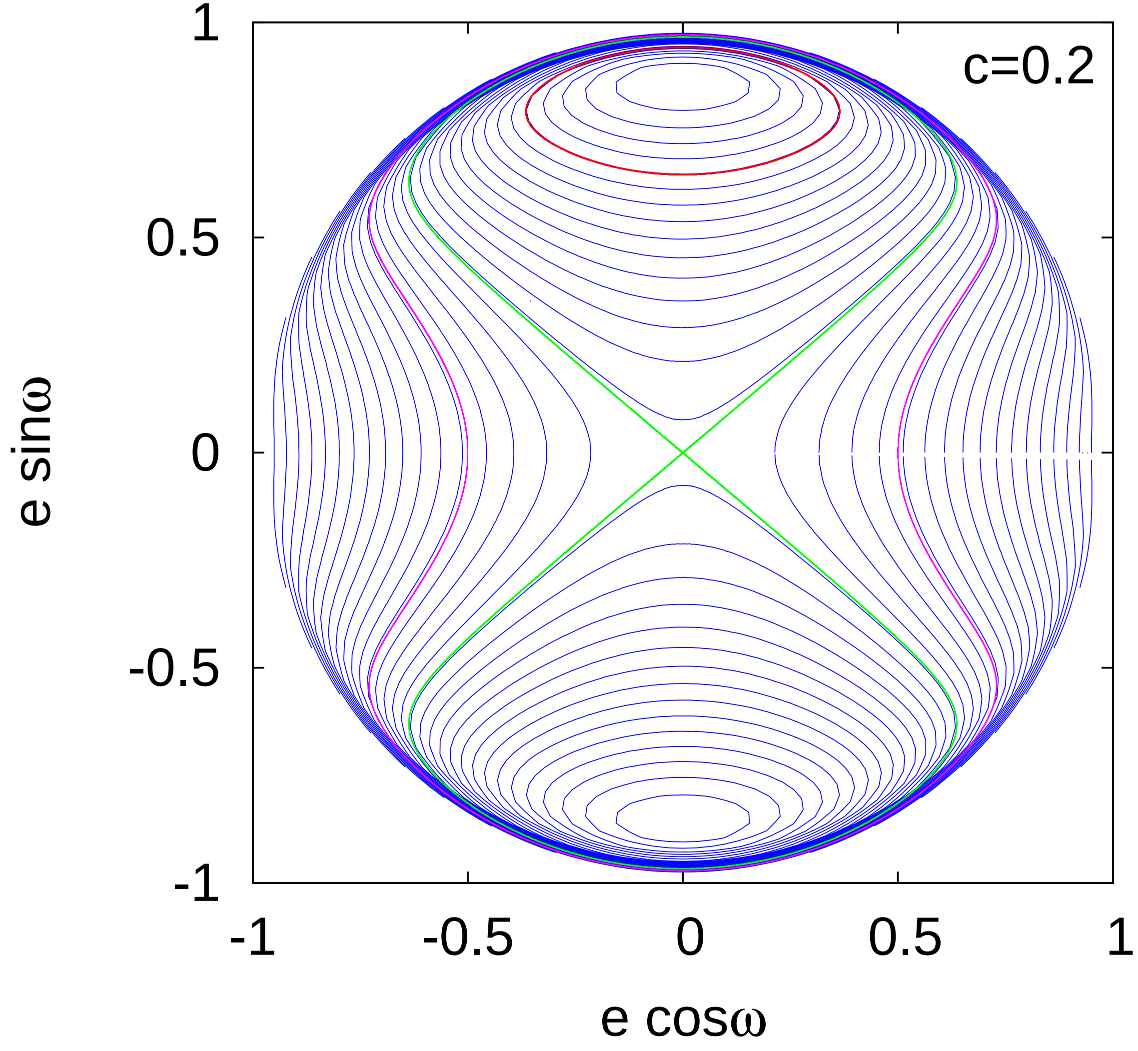
- Kozai constant:

$$c = \sqrt{1-e^2}\cos i$$

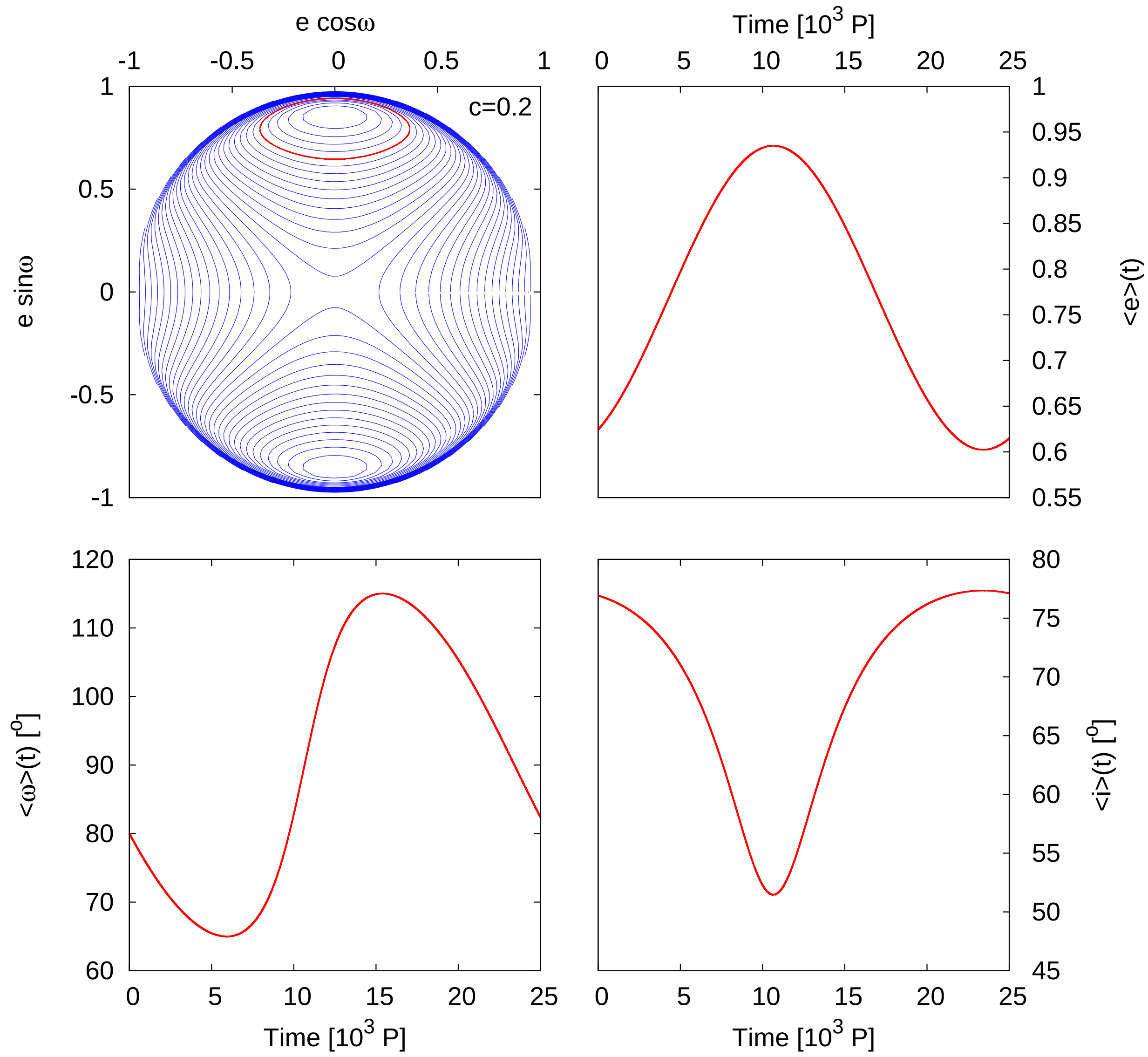
Axi-symmetrical Perturbation



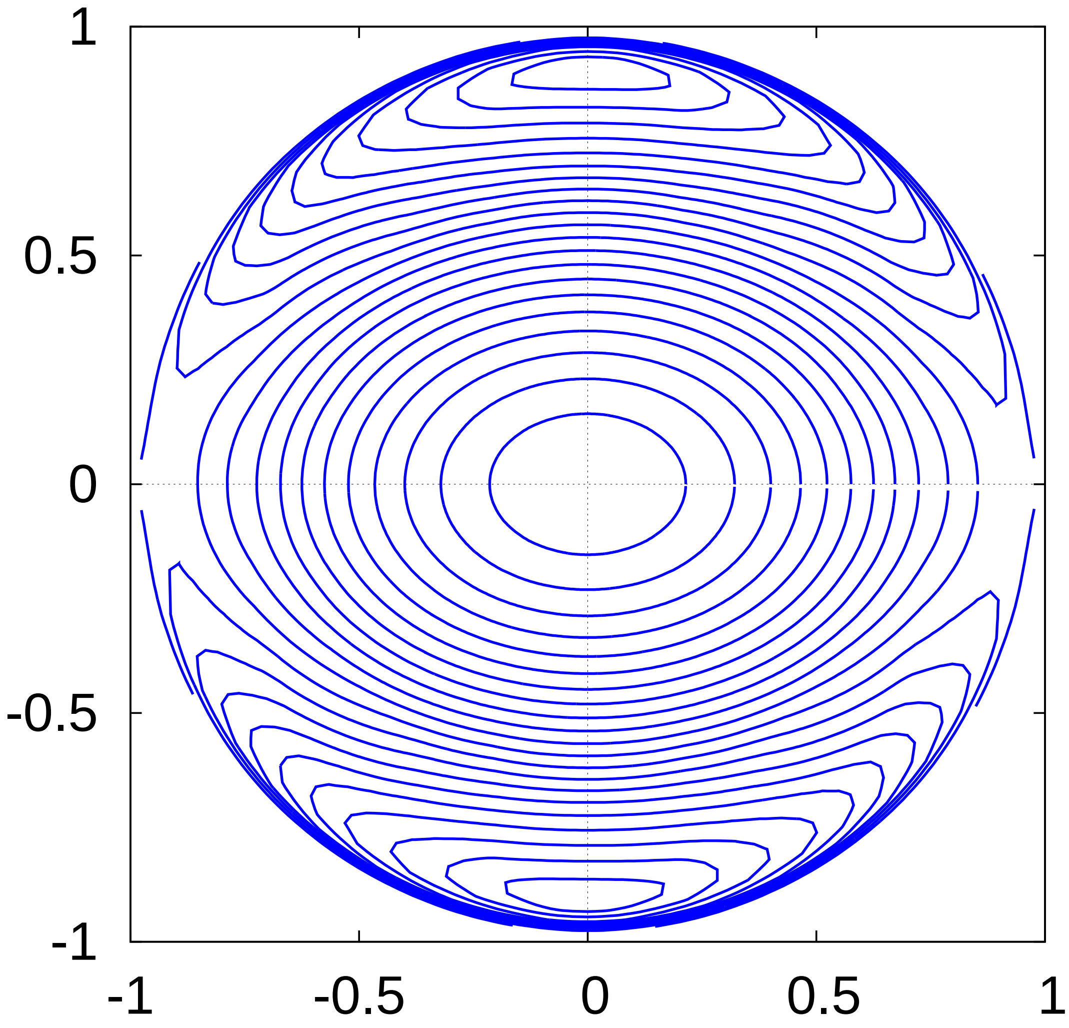
Axi-symmetrical Perturbation



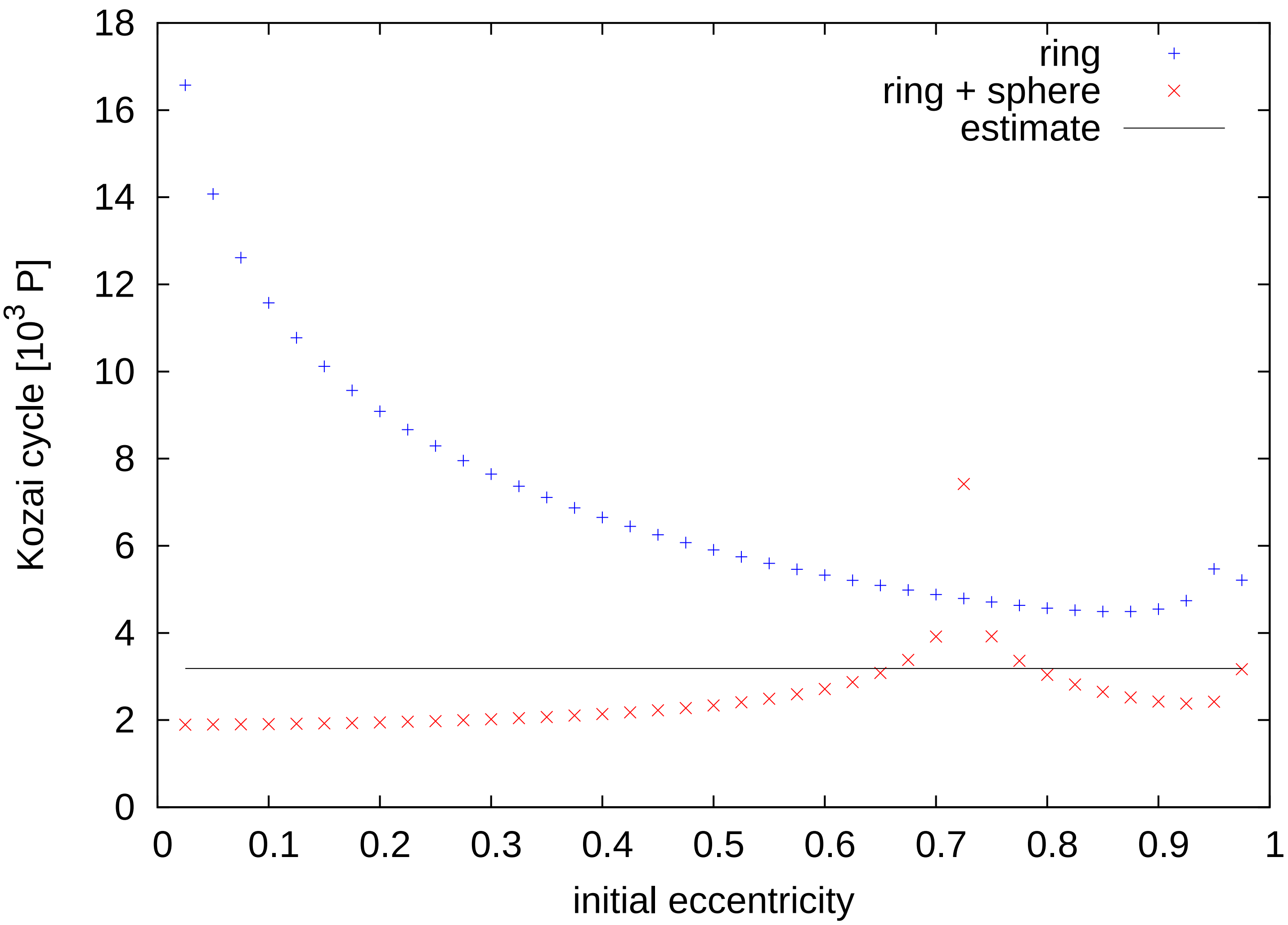
Axi-symmetrical Perturbation



Composite Perturbation



Composite Perturbation



The End

Thank you for your attention!