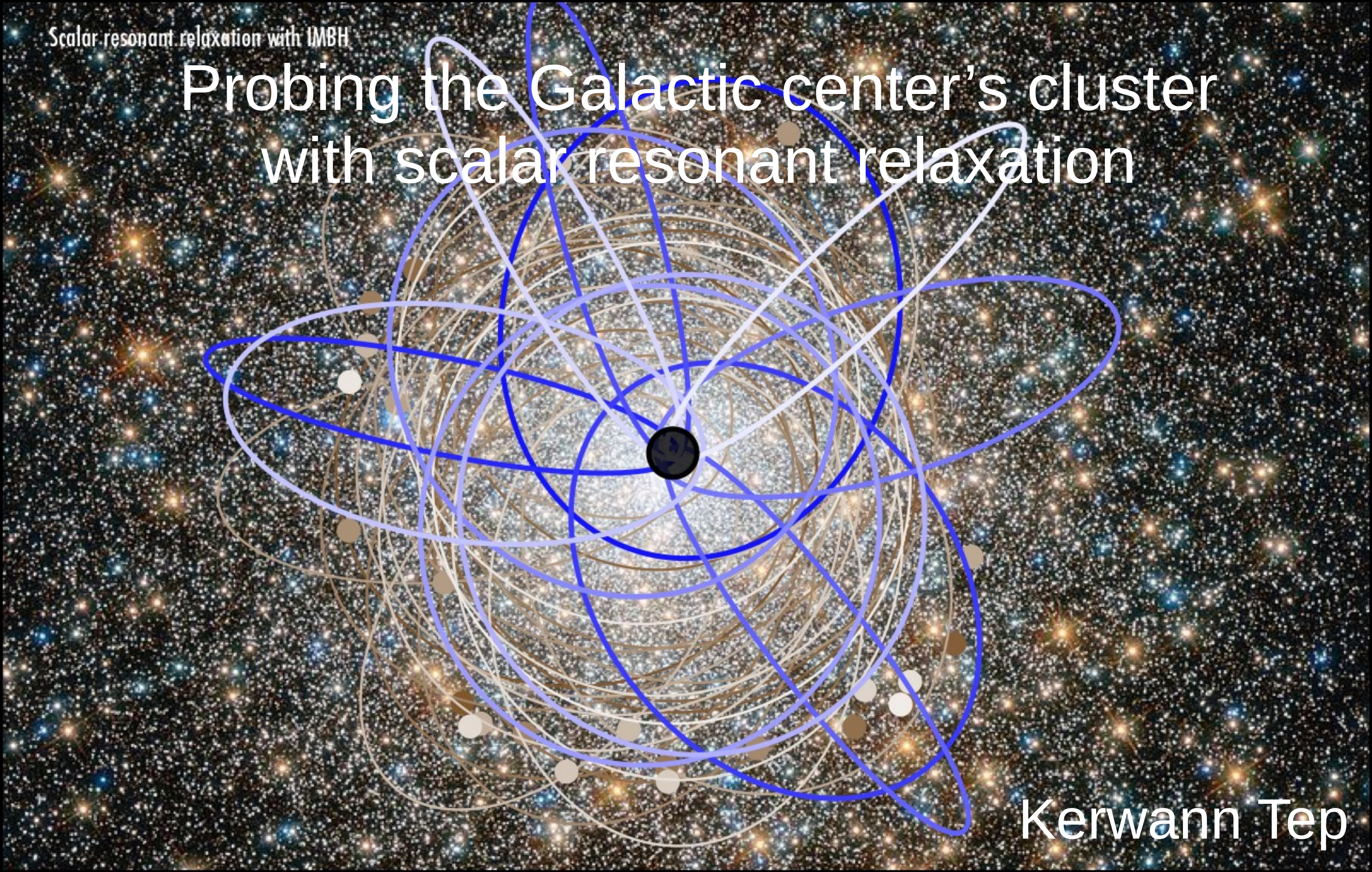
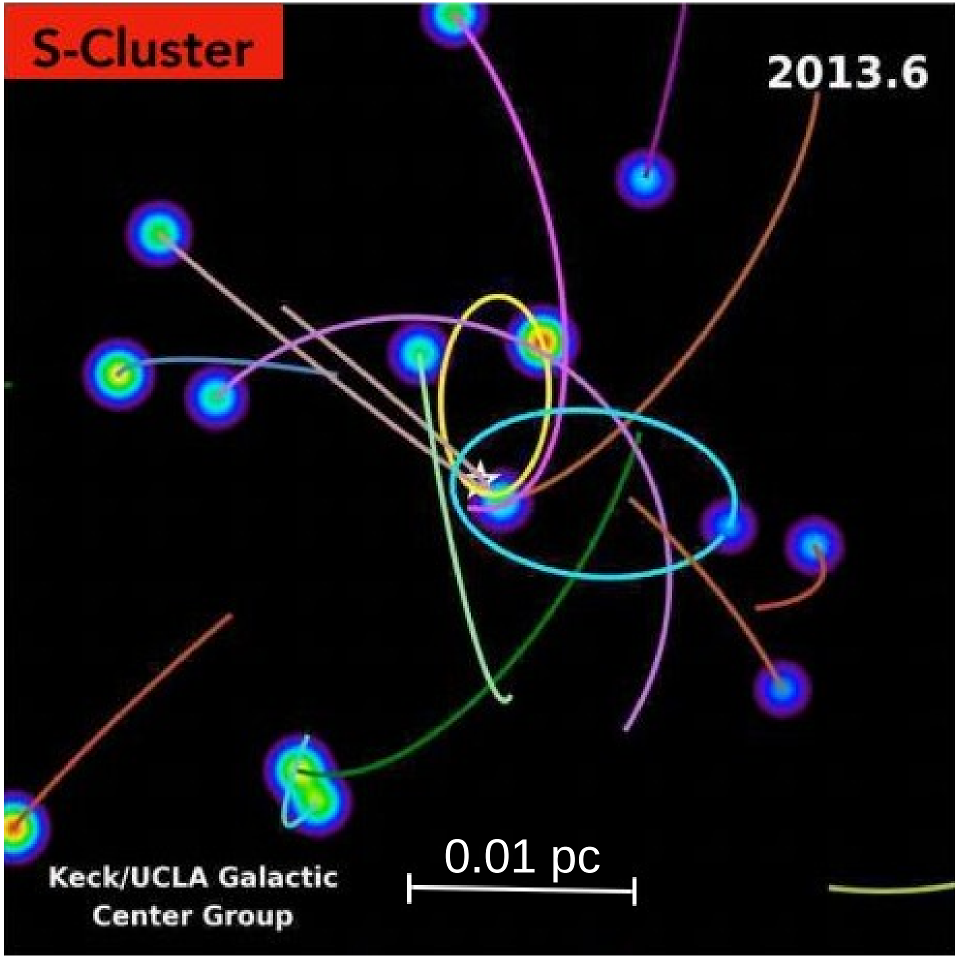
Probing the Galactic center’s cluster with scalar resonant relaxation



Kerwann Tep

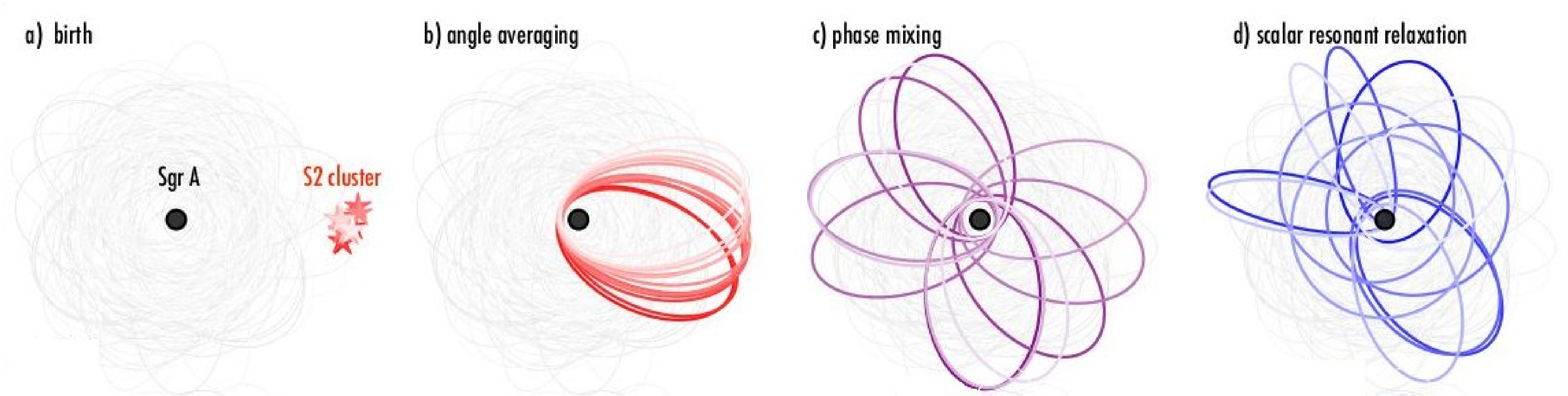
Context



Orbits of S-cluster’s stars near Sgr A*

- Galactic center and S-Cluster
  - → Fast Keplerian orbits
  - → High density of stars
  - → Supermassive black hole (SMBH) Sgr A*
- Formation
  - → Intermediate mass black holes (IMBH) ?
  - → Mass segregation
- Accessible data
  - → GAIA
  - → VLT (through the instrument Gravity)

Dynamics and time scales

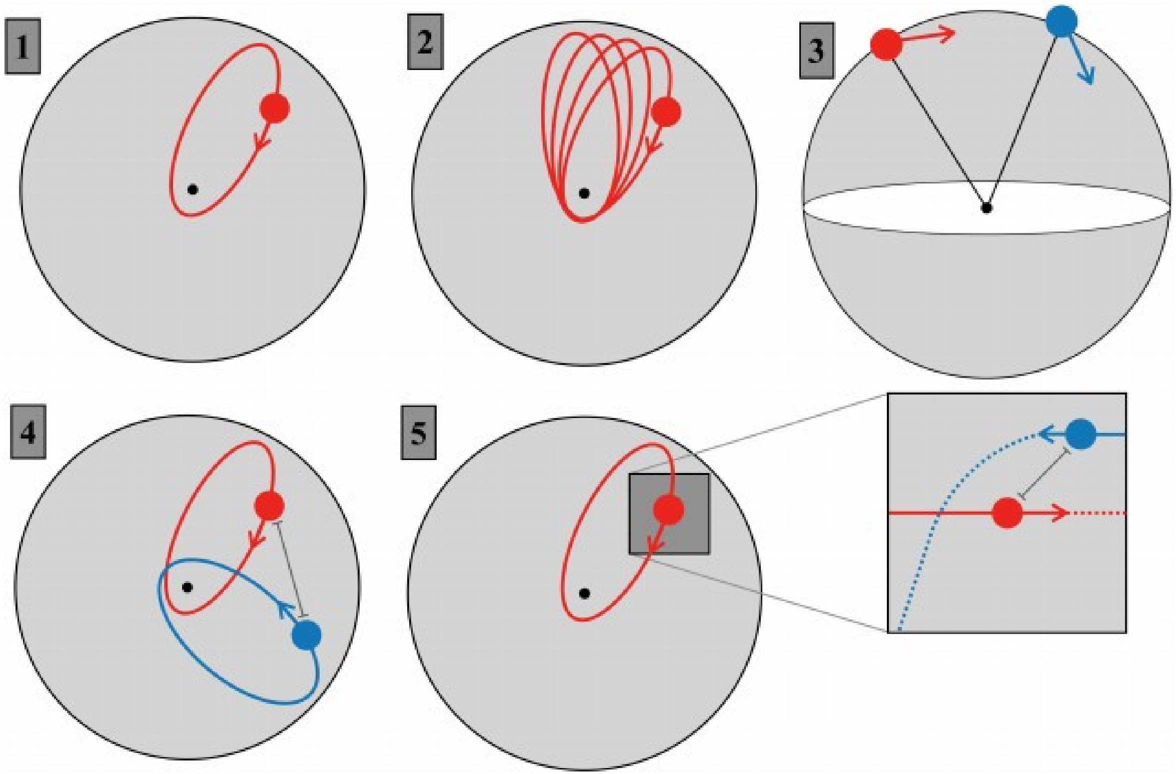


→ Constrain the SMBH diet

→ Invisible matter experiment

→ Five processes influence stars' orbits : from orbital time to secular time

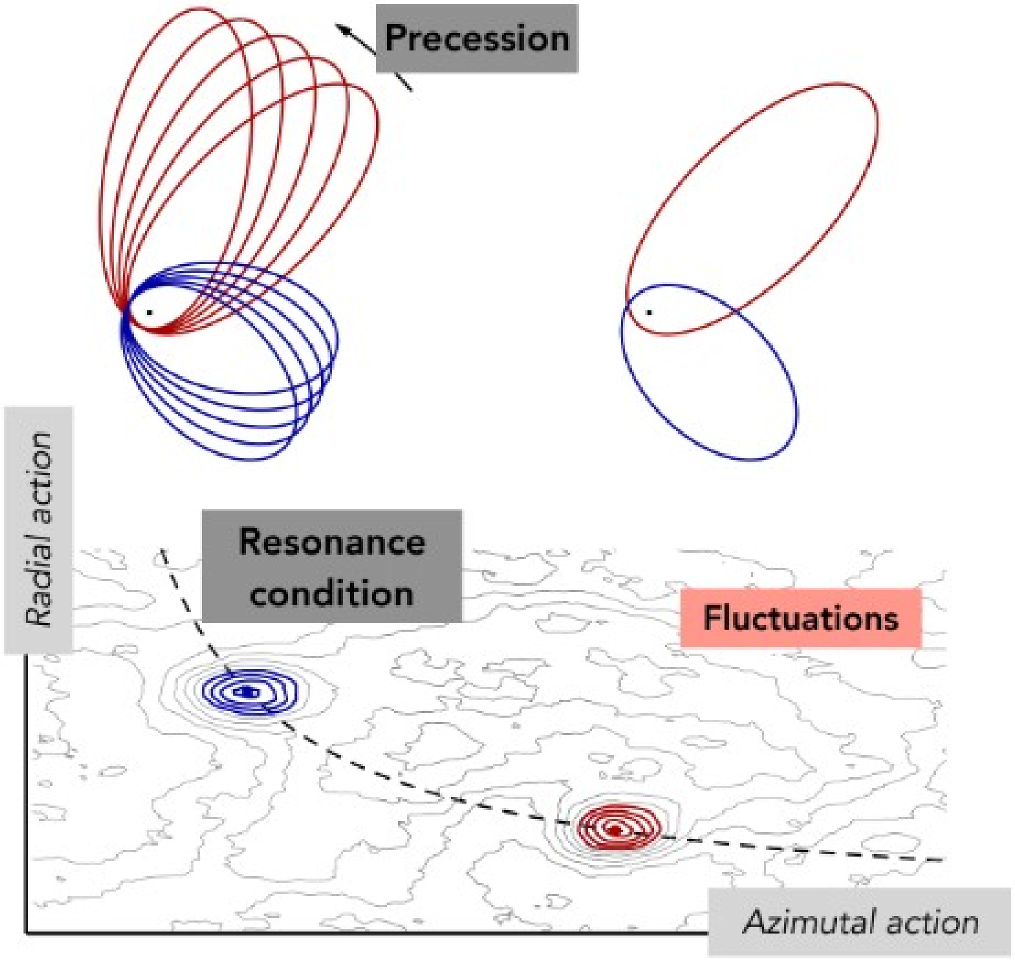
Dynamics and time scales



Dynamical processes in the Galactic center

1) Orbital time
2) Precession time
3) VRR time
4) SRR time
5) NR time

Scalar resonant relaxation



Resonant interactions in orbital space

$$\frac{\partial P}{\partial t} = \frac{1}{2}\frac{\partial}{\partial j}\left[j D_{jj}\frac{\partial}{\partial j}\left(\frac{P}{j}\right)\right]$$

- Poisson noise
  - → Finite-N effects
- Non-local resonances
  - → Commensurable frequencies
  - → Strong correlation
- Sources orbital diffusion

SRR diffusion

$$D_{jj}(\mathbf{J}) \propto \frac{1}{N_*} \sum_{n,n'} n^2 \int \mathrm{d}a' \mathrm{d}j' F_{\mathrm{tot}}(a', j') \left| A_{nn'}(a, j, a', j') \right|^2 \times \delta_{\mathrm{D}}(n \nu_{\mathrm{P}}(a, j) - n' \nu_{\mathrm{P}}(a', j'))$$

$D_{jj}(\mathbf{J})$ Anisotropic diffusion

$\left| A_{nn'}(a, j, a', j') \right|^2$ Coupling coefficient

$\delta_{\mathrm{D}}(n \nu_{\mathrm{P}}(a, j) - n' \nu_{\mathrm{P}}(a', j'))$ Resonance condition

$1/N_*$ Finite-N effects

n^2 Resonance numbers

$F_{\mathrm{tot}}(a', j')$ Invisible cluster distribution function

Resonance line

- Precession : 2 contributions

  → Relativistic (BH) effects

  → Invisible cluster's mass

- Asymptotic behaviours :

  → GR effects

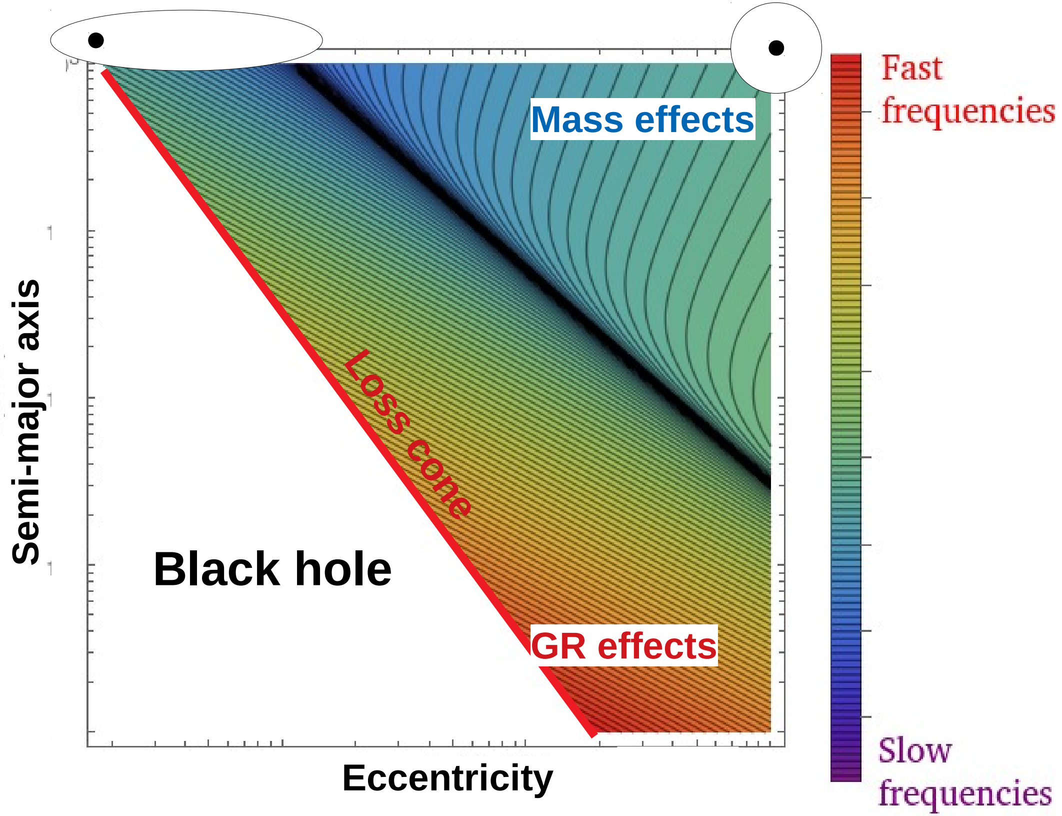
  (very elliptic orbits close to BH)

  → Cluster mass effects

  (circular orbits away from BH)

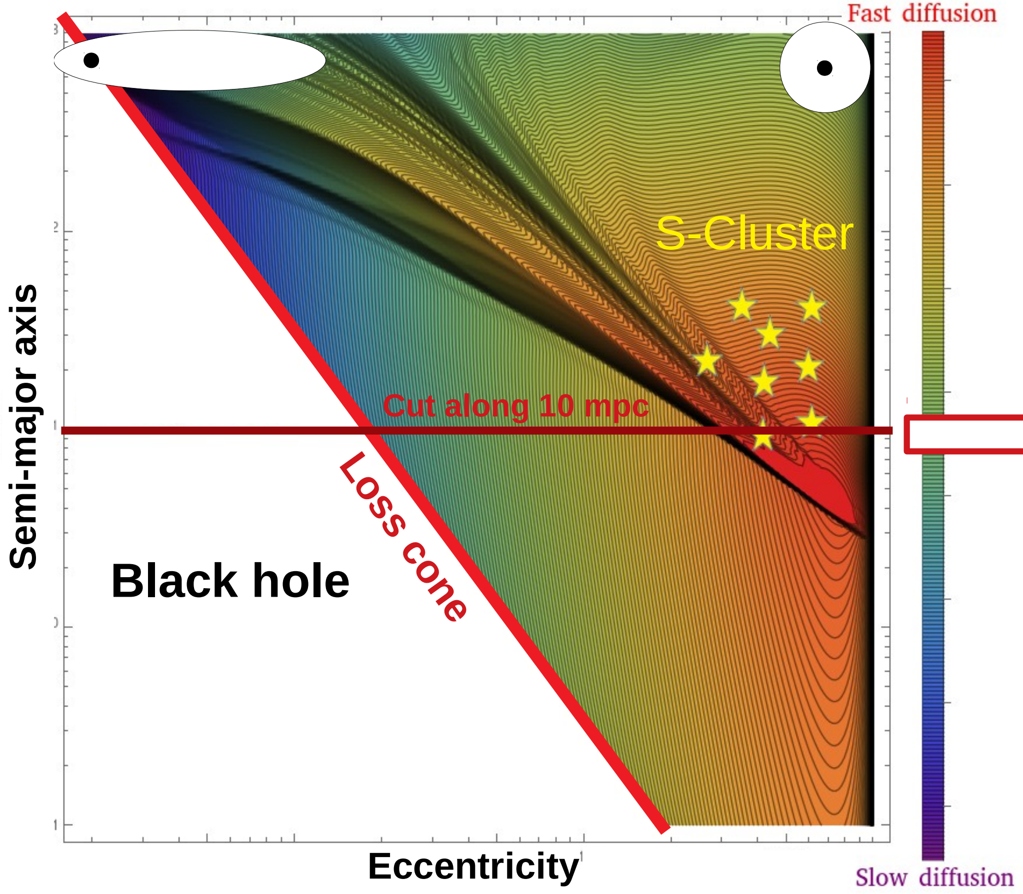
- Loss-cone

  → Stars fall into the BH

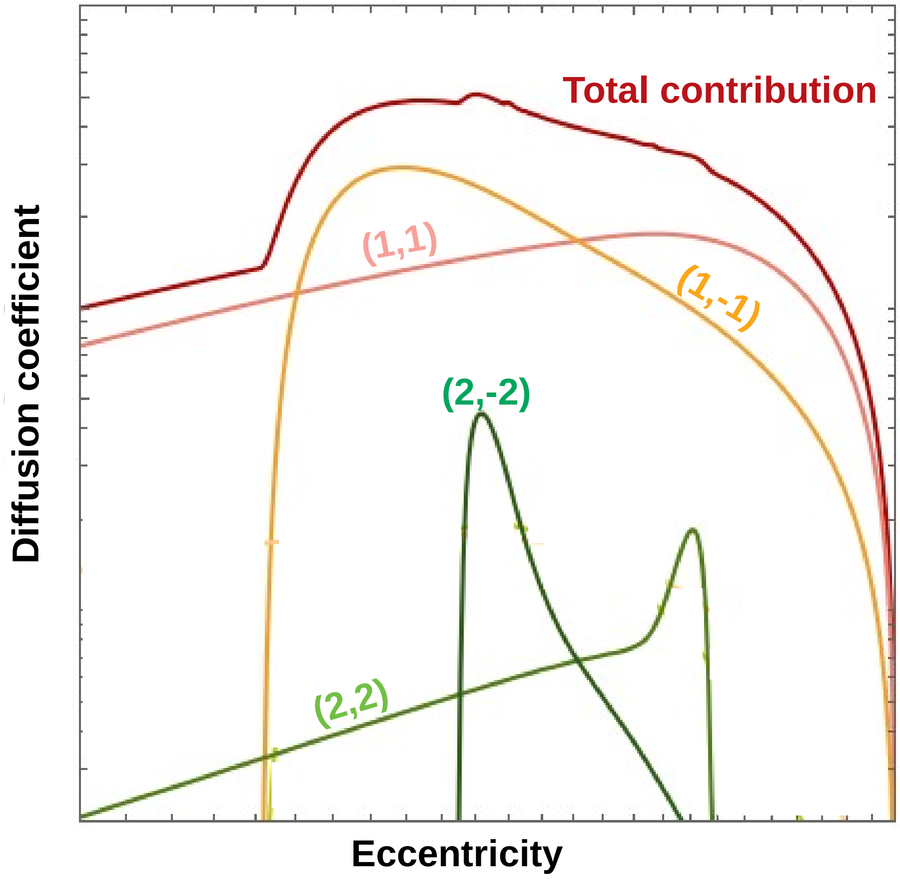


Iso-contours of the precession frequency

Diffusion coefficients



SRR Diffusion coefficients



Contribution of each resonances

Comparing two cluster models

- Model-dependent

  → IMBHs increase efficiency

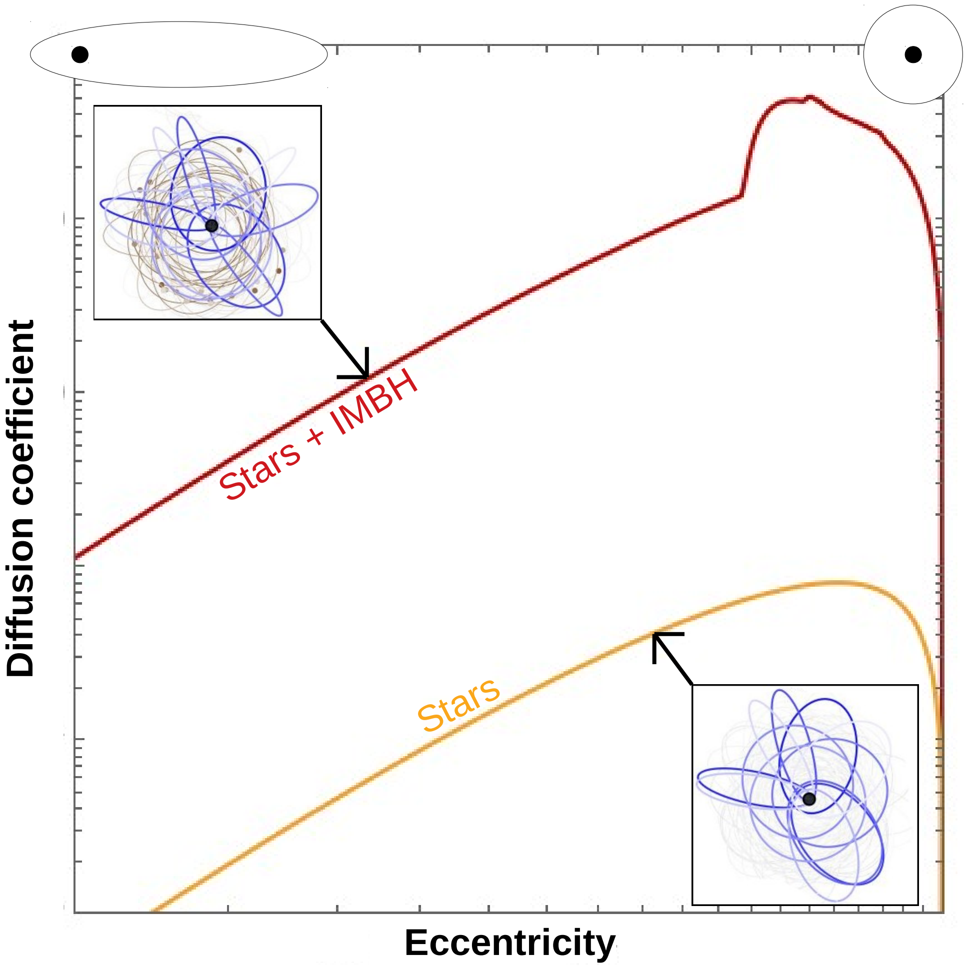
  → Different resonances

- Efficient computation

  → Parallelized code

  → Linear (sampling) time

  → Exploration of parameter space (add more curves)



Observations

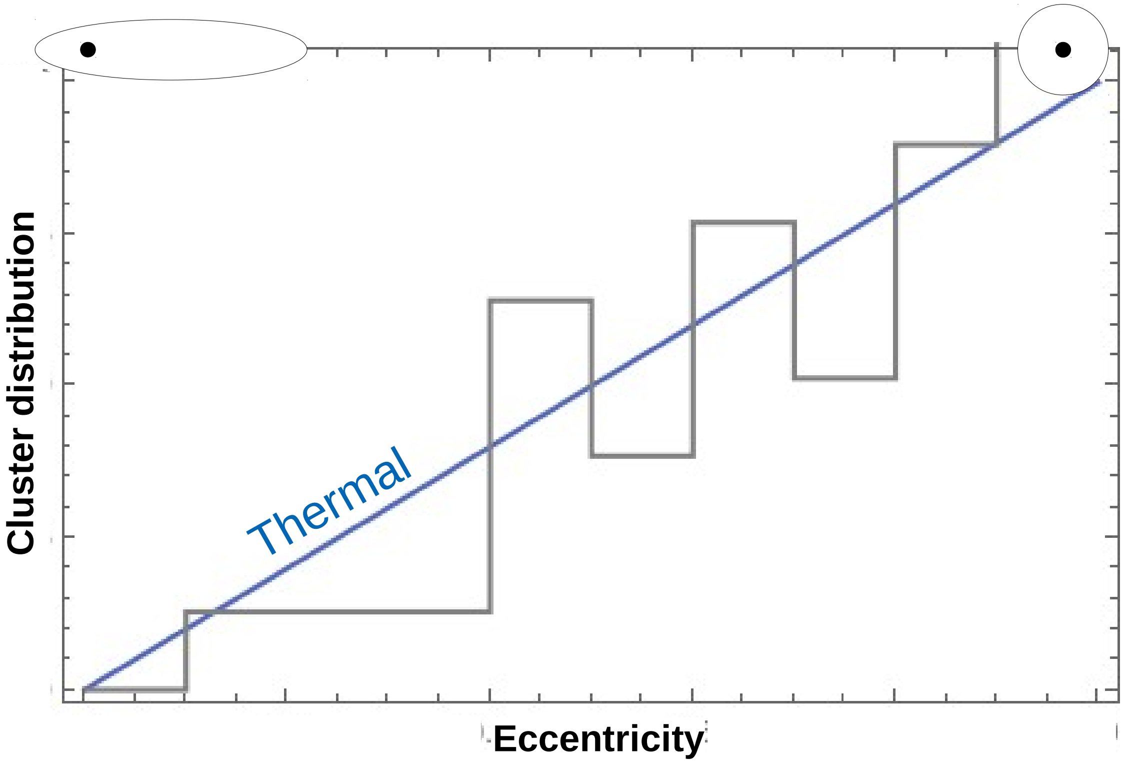
$$\frac{\partial P}{\partial t} = \frac{1}{2}\frac{\partial}{\partial j}\left[j D_{jj} \frac{\partial}{\partial j}\left(\frac{P}{j}\right)\right]$$

- Diffusion equation of the PDF

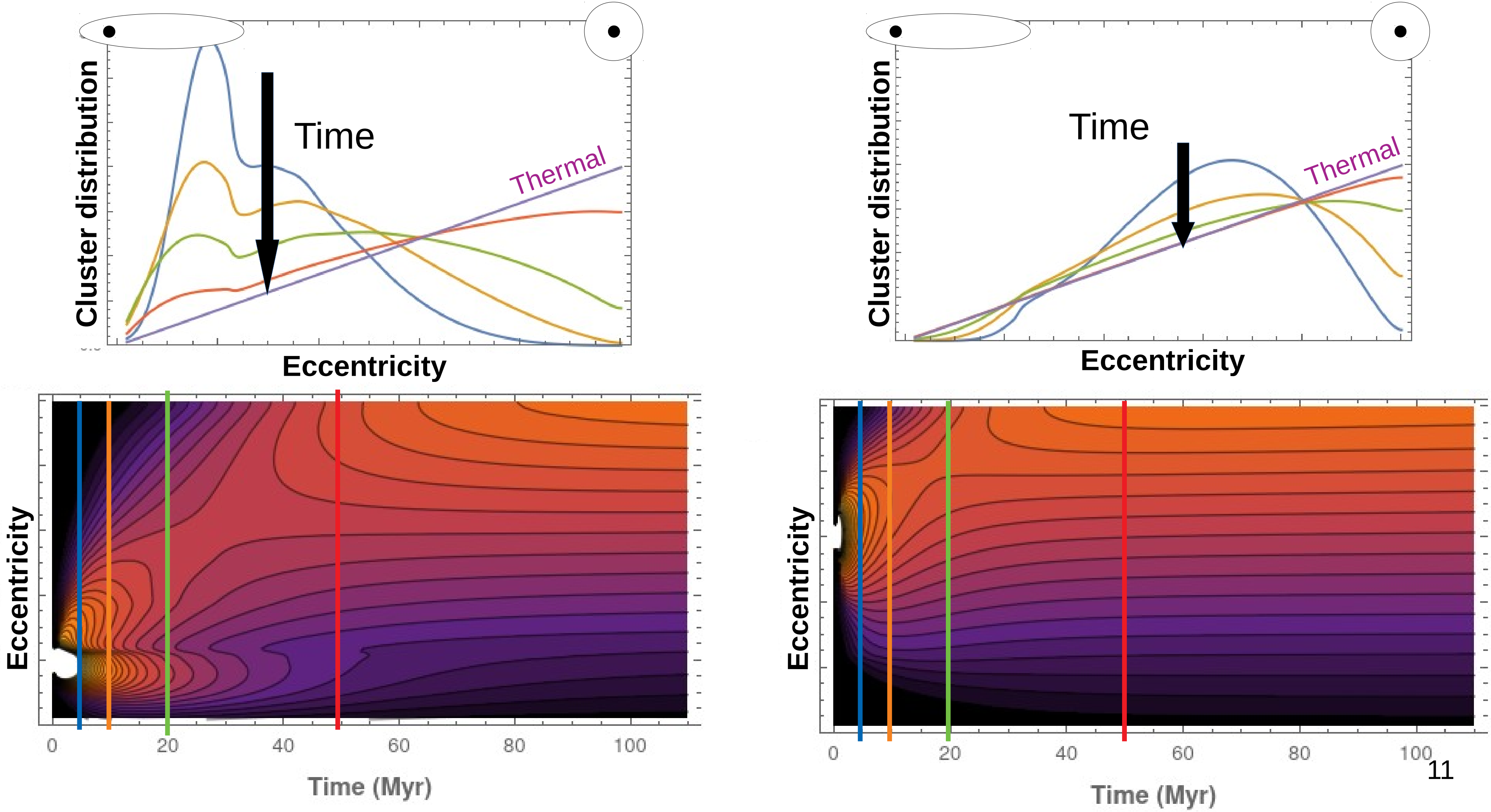
  → Equilibrium : P(j) = 2 j

- Thermalization of stars

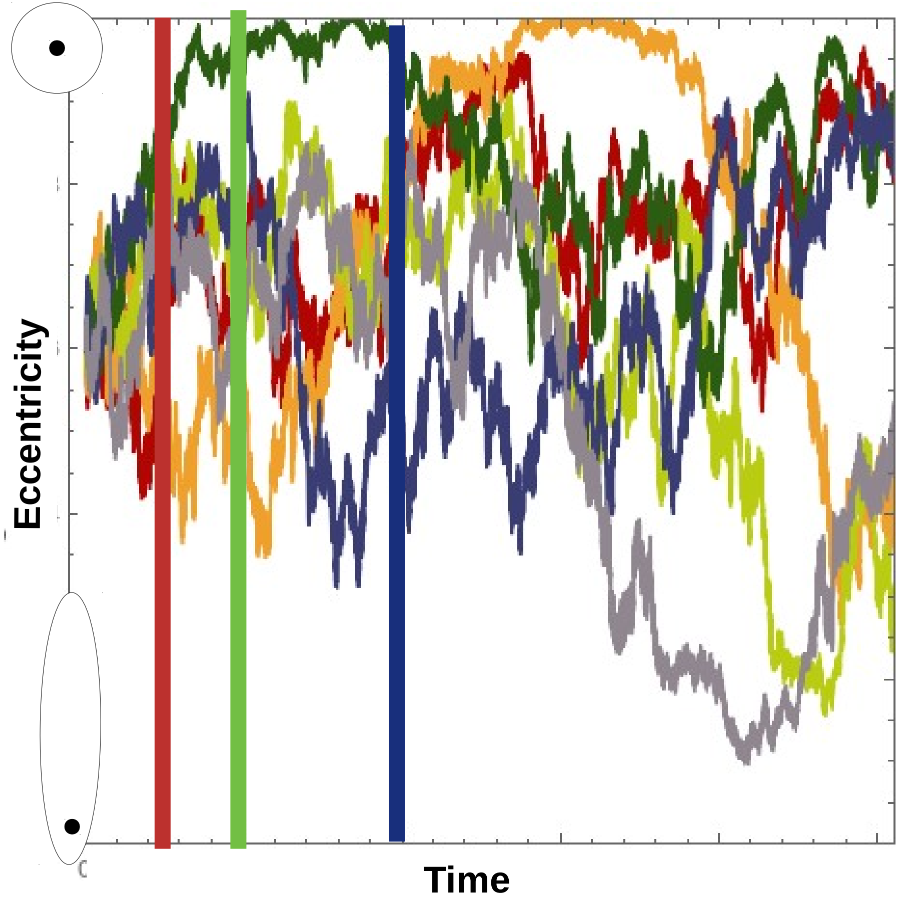
  → Diffusion must be efficient

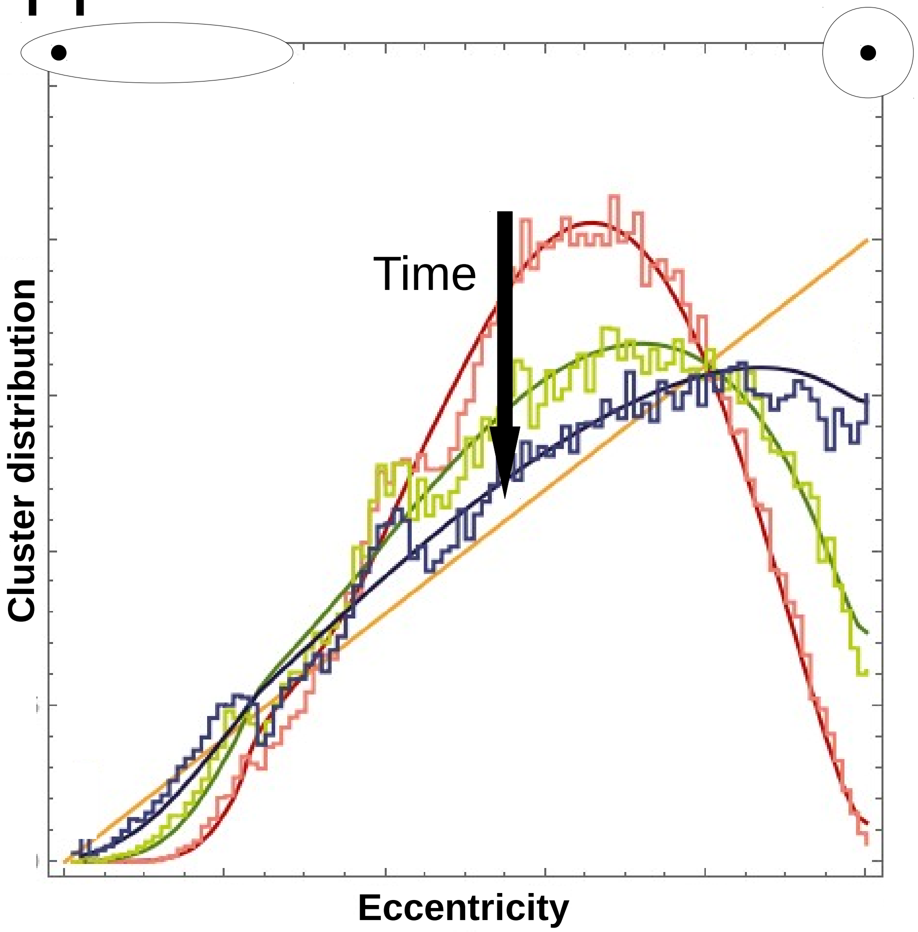


Diffusion equation integration



Stochastic approach

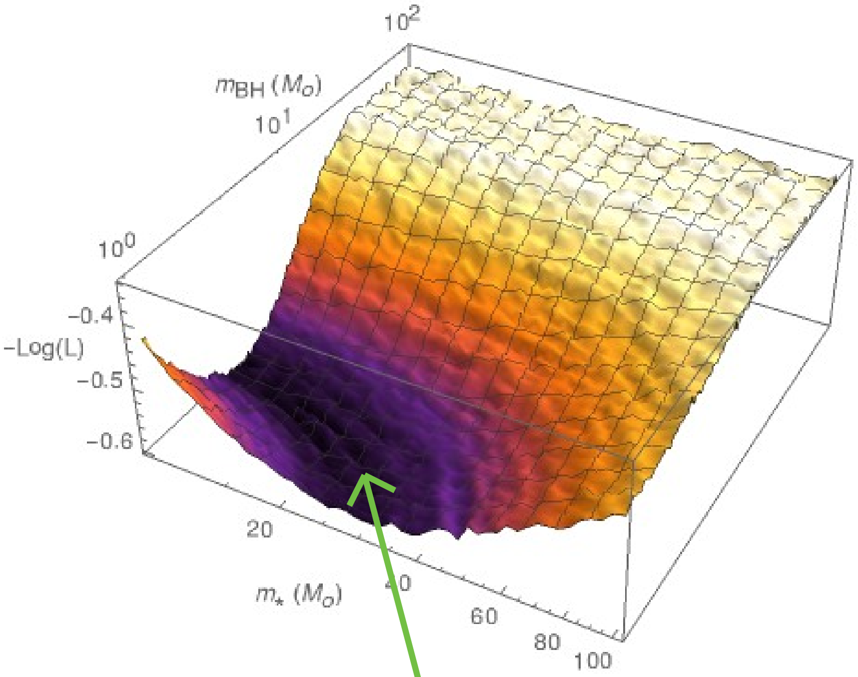




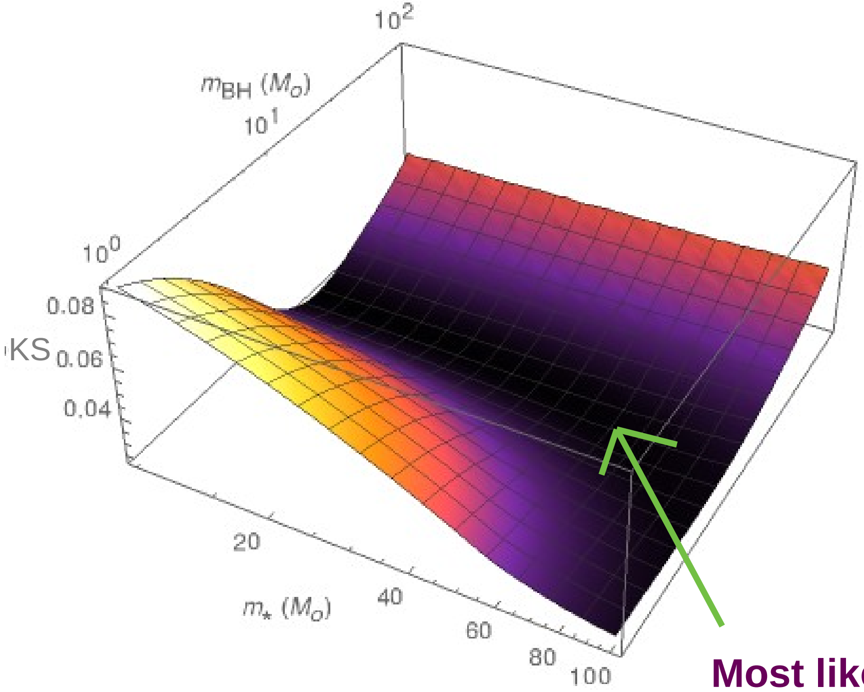
$$\Delta j_t = D_j \Delta t + \sqrt{D_{jj} \Delta t}\, \xi_t$$

→ Monte-Carlo process

Constraining the models



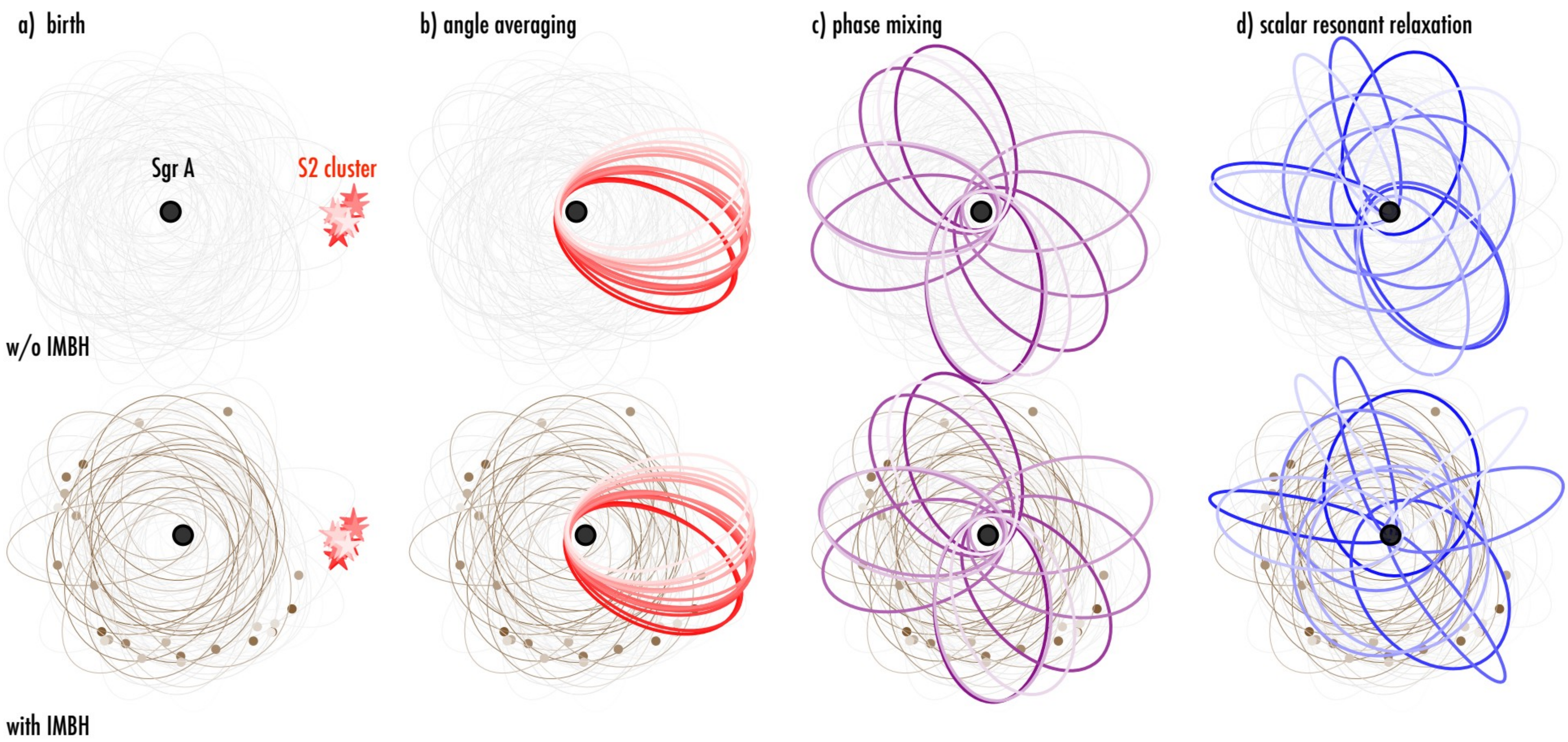
Most likely model



Most likely model

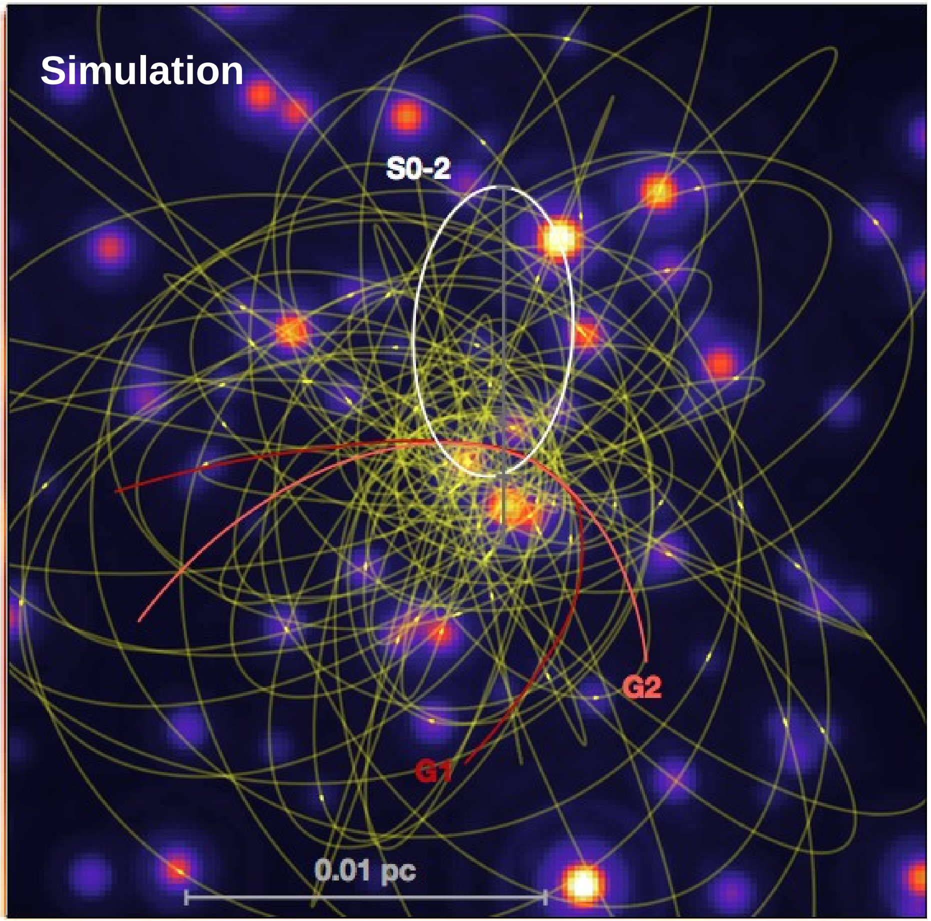
→ **We can constrain the models**

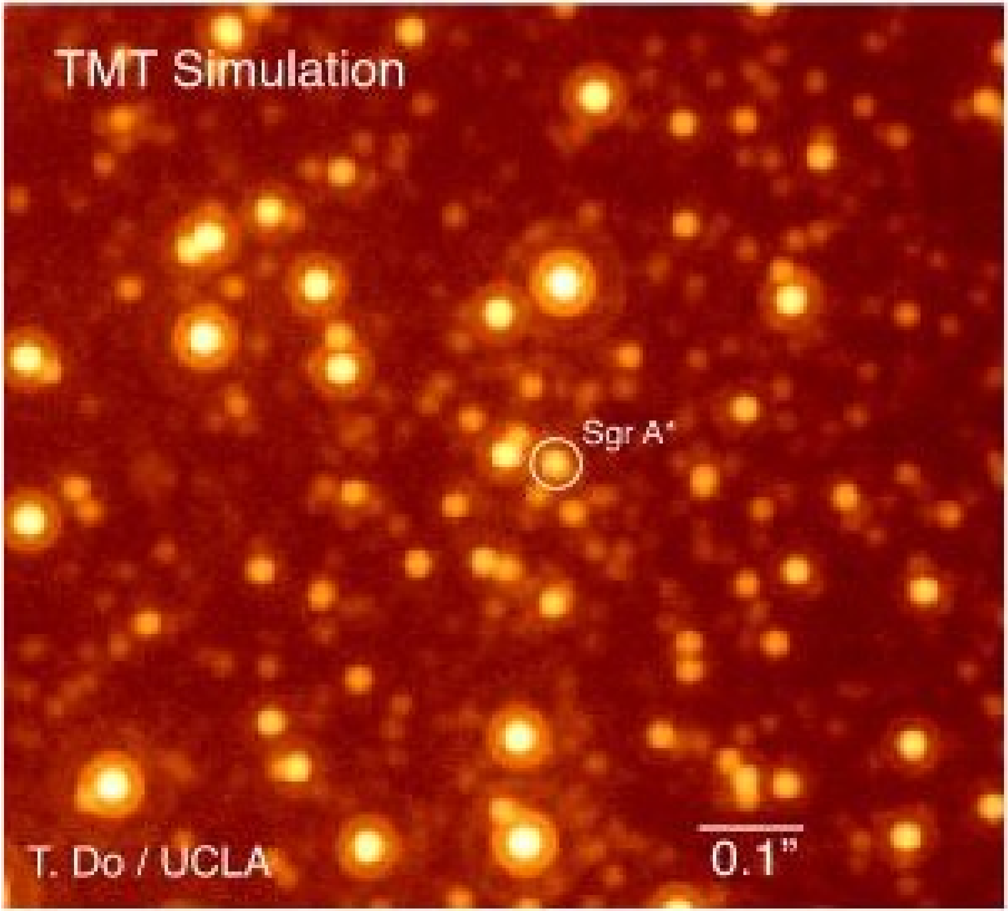
Conclusions



Secular evolution with and without IMBH

Perspectives





Last slide : key infos+images