Explaining the orbits of the Galactic Center S-Stars

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The Galactic center

- SMBH $M = 4 \times 10^6 M_\odot$

- Stellar cusp $d \approx 3$ pc

- CW stellar disk
  - scale $0.04 - 0.4$ pc
  - mass $10^3 - 10^4 M_\odot$
  - age $\sim 5$ Myr

- S-cluster $N \sim 20$ B-type stars $a = 5 - 50$ mpc, random orientations

The Centre of the Milky Way
(VLT YEPUN + NACO)
The S-stars cluster

2005
N = 7 stars
early type stars
m~10-15 M☉
T ~ 10 Myr

Ghez et al. (2005)
Eisenhauer et al. (2005)
The S-stars cluster

2009
N = 20 stars
15 early-type stars
5 late-type stars

Gillessen et al. (2008)
The S-stars cluster
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Origin of the S-stars cluster

Proposed models:
* in-situ formation
* binary capture
* cluster infall

Properties of IMBH infall:
▶ stalling
▶ eccentric orbit
N-body simulations

BBH initial conditions:
- $M_{\text{SMBH}} = 4.5 \times 10^6 \, M_\odot$
- IMBH $q = 10^{-4} - 10^{-3}$
- $a = 10 - 80 \, \text{mpc}$
- $e = 0.2 - 0.5$

Stars initial conditions:
- orbits similar to those of tidally stripped stars, with a small thickness
N-body simulations

$q = 0.001$
$a = 15 \text{ mpc}$
$e = 0.5$

$t = 1 \text{ Myr}$
Orbital inclinations

Rayleigh parameter

\[ R = \frac{1}{N} \left| \sum_{i} r_i \right| \]

\[ a = 30 \text{ mpc} \]

\[ q = 1.0 \times 10^{-3} \]
\[ q = 5.0 \times 10^{-4} \]
\[ q = 2.5 \times 10^{-4} \]
\[ q = 1.0 \times 10^{-4} \]

Eccentricities

\[ M_{\text{IMBH}} = 4000 \, M_\odot \]
\[ a = 15 \, \text{mpc} \]
\[ e = 0.5 \]

Merritt, Gualandris, Mikkola, 2009, in press
astro-ph/0812.4517
Semi-major axes

\[ M_{\text{IMBH}} = 2250 \, M_\odot \quad e = 0.5 \]

\( a = 10 \, \text{mpc} \)

\( a = 20 \, \text{mpc} \)

\( a = 30 \, \text{mpc} \)

\( a = 40 \, \text{mpc} \)
Conclusions

* An IMBH can efficiently randomize the orbits of stars near the SMBH (T ~ 1Myr for $M_{\text{IMBH}} > 1500 M_\odot$ and $e > 0.5$)
* An IMBH can quickly transform the eccentricity distribution into a thermal distribution (T ~ 0.1Myr for $M_{\text{IMBH}} > 1000 M_\odot$)
* The final distribution of semi-major axes depends on the size of the IMBH orbit, but tight binaries can be produced

Observational consequences:
▶ Motion of the SMBH - astrometric wobble of SgrA* consistent with presence of an IMBH
▶ Changes in orbital parameters of the stars due to close encounters with IMBH
▶ Ejection of stars - one unbound star already observed