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Sculpting the central parsec of our Galaxy

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Abstract. Recent observations have revealed various structures within the gravitational influence of Sgr A* – the massive black hole in the Galactic center. These structures apparently defy the fundamental principles of star formation and stellar dynamics. On one hand, the red giants display a flat density profile, contrary to the cuspy one predicted by conventional stellar relaxation. On the other, Wolf-Rayet and OB stars are observed where in-situ star formation should have been prohibited by the strong tidal force from Sgr A*, and their spatial and phase-space distributions also contradict our understanding of stellar dynamics. To explain each of these inconsistencies, many scenarios have been proposed, which render the model increasingly complicated. Here, we suggest that the sub-parsec stellar disk surrounding Sgr A*, which was recently discovered, can reconcile all the above inconsistencies. We show that during the fragmenting past of this disk, the star-forming clumps could efficiently deplete red giants by repeatedly colliding with them. We also show that because of the torque exerted by the disk, stars within the central arcsec from Sgr A* would quickly mix in the angular-momentum space, which naturally explains the observed distributions of Wolf-Rayet and OB stars. Our results imply that Sgr A* was fueled by gas and stars several millions years ago and could have been an energetic AGN. We discuss future observations that can further testify our model.

Keywords. black hole, Galactic center, dynamics

There are at least three dilemmas that theorist face when they are confronted with the rich phenomena in the Galactic Center (GC) (see Genzel *et al.* 2010 for a review):

(*a*) **The missing red giant problem**: the lack of a cusp in the density distribution of the red giants, which contradicts a longstanding hypothesis that old stars in the deep potential well of a supermassive black hole can develop a cusp under the dynamical process of two-body relaxation.

(*b*) **The paradox of youth**: the existence of a dynamically (nearly) relaxed B-star cluster (S-cluster) in the central 1 arcsec (0.04 pc) region around Sgr A*, where neither in-situ star formation nor fast stellar relaxation is thought possible.

(*c*) **The inverse mass segregation**: a counterintuitive stellar distribution such that the less-massive B-stars are populating the central 1 arcsec region but the more-massive Wolf-Rayet and O-stars are exclusively further out.

Conventionally, these problems were thought to be unrelated and hence many separate solutions have been devised. This is not ideal as it renders the dynamical model of the GC progressively more complex.

Motivated by the recent discovery of a "mini disk", which consists of hundreds of massive young stars revolving closely around Sgr A*, we study the dynamical impact of this disk on the other structures. We find that the interplay between the mini disk and the other stellar components provides a single, unified resolution to all the previous inconsistencies between theory and observation:

(*a*) Following analytical arguments, we found that during the star-forming phase of the disk, the gaseous clumps, which must have existed to give birth to the massive stars, could efficiently strip the envelopes off the red giants through repeatedly collisions. These clumps are the culprits of the missing red giants (Amaro-Seoane & Chen 2014).

Predictions: (1) The cores released from the destructed RGs are still populating the GC. (2) The surviving RGs lie preferentially on the inclined orbits relative to the mini disk, otherwise, they cannot avoid large number of collisions and should have been depleted.

(b) Considering the possibility that the disk in the past was more massive and extended closer to Sgr A, we showed that it will induce a rapidly evolving region in the GC where a star could quickly migrate in the eccentricity space. This theoretical discovery provides a mechanism that fully resolves the paradox of youth (Chen & Amaro-Seoane 2014).

Predictions: (1) The gravitational torque of the disk will induce a super-thermal distribution in the eccentricities of S-stars. (2) The old stellar population are subject to the same disk torque and will also exhibit a super-thermal distribution.

(c) Now the phenomenon of the inverse mass segregation also can be understood: the orbits of the inner Wolf-Rayet and O stars, within the rapidly evolving region, could be perturbed sufficiently such that they are placed on highly eccentric orbits, leading to their tidal disruption by Sgr A* (Chen & Amaro-Seoane 2014).

Predictions: (1) The surviving Wolf-Rayet and O stars should lie exclusively outside the rapidly evolving region. (2) S-stars in a narrow radial range of $0.5 \sim 0.8$ arcsec should also be depleted due to tidal disruption.

Our results point to a picture that several million years ago Sgr A* was surrounded by an accretion disk and our GC was an active galactic nucleus (AGN); this AGN was powered by gas accretion as well as by tidal disruptions of WR/O stars.

References

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