Next Generation AO for the Galactic Center

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Galactic Center

- The best and closest case of a central supermassive black hole in a normal galaxy:
  - Ghez et al. (1998) -- Velocity Dispersion; Ghez et al. (2000) -- Accelerations; Ghez et al. (2005) -- Orbits

- A unique lab for understanding galactic nuclei

Keck/UCLA Galactic Center Group
Galactic Center Science

- Is there a halo of dark matter or compact remnants surrounding the black hole?
- What is the distance to the Galactic center ($R_0$)?
- Can we test post-Newtonian physics (e.g. general relativity, black hole spin)?
- Where did the apparently young stars form?
- Why is the accretion flow onto the black hole so under luminous ($10^{-9} L_{Ed}$)?
Currently:
• have 8-10 stars with \( K < 16.0 \)
  with orbits.

• only diffraction limited at \( K \)
  (2.2 microns)

• limited by astrometric biases
  from undetected faint stars on
  the brighter star population
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Encircled: Speckle points
- $S0-24$ not detected,
- $S0-16$ biased by $\sim 40$ mas
Precision Stellar Dynamics

• NGAO+laser allows us to find additional (fainter) stars.

• Need high strehl J+H to increase spatial resolution and contrast.

• Need spectro-imaging to extract radial velocities in crowded region with diffuse emission.

• Astrometry: 100 µas

• Radial Velocities: ~10 km/s
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Sgr A*

- Monitoring of Sgr A* is best done in the L-band (3.8 microns).

- Requires short time scale (30 sec) images of high quality

- May be able to observe orbital motion of hot spots in accretion disk:
  - photocenter shifts
  - periodic variability
NGAO Requirements

• Astrometry: 100 µas

• Radial Velocities: ~10 km/s

• Contrast: Δmag = 4 at first PSF null (radius = 55 mas in K)… or as close as we can get.

• R~ 4,000 high throughput OSIRIS (75 km/s resolution)

• 10 arcsec imager with JHKLM filters.
  • Optical distortion must be well calibrated.
  • Polarimetry mode for Sgr A* monitoring.

• May need R~15,000 capability.
Simulation Plan

• Construct faint population and orbits for all stars.

• Use simulated PSF to generate artificial images.

• Run through analysis process.
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- Construct faint population and orbits for all stars.
- Use simulated PSF to generate artificial images.
- Run through analysis process.
- Characterize astrometric precision and constraints on science measurements.

\[ 1 \text{ pixel} = 10 \text{ mas} \]
Galactic Center Science

- Is there a halo of dark matter or compact remnants surrounding the black hole?
  Can detect 1000 Msun at 0.01 pc of extended mass distribution

- What is the distance to the Galactic center ($R_o$)?
  Measurable to ~0.1% accuracy.

- Can we test post-Newtonian physics (e.g. general relativity, black hole spin)?
  Measure relativistic prograde precession, and possibly frame-dragging (spin of black hole).

- Where did the apparently young stars form?
  Measure accelerations of stars out to $r=5''$ ... get 3D positions.

- Why is the accretion flow onto the black hole so underluminous ($10^{-9} L_{Ed}$)?
  1% photometry at HKL at mags of 19,17,14 on minute timescales. Polarimetry.