The Milky Way Nuclear Star Cluster beyond 1 pc

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Nuclear Star Clusters (NSCs)

- Detected in 50% to 75% of all galaxies
- Half-light radius 2-5 pc
- Dynamical mass $10^6 - 10^7 \, M_{\text{sun}}$
- Complex SF history
- Scaling relations with galaxy properties
- Some contain a MBH
Nuclear Star Clusters (NSCs)

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Kinematic data set

- ISAAC long slit spectrograph
- Central field: \(~4’x3.5’\)
- + 6 fields of 2’x16” size
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Slit length: 120"
Slit width: 0.6"
Kinematic data set

- ISAAC long slit spectrograph
- Central field: ~4’x3.5’
- + 6 fields of 2’x16” size
- ~2.29 – 2.41 micron,
- spectral resolution 68 km/s

Slit length: 120"
Slit width: 0.6"
Drift: 2"
Kinematic data set

Full area 4’ x 3.5’
~ 9.6 x 8.4 pc
Binning to 2.22” x 2.22”
Kinematic data set

Full area 4’ x 3.5’
~ 9.6 x 8.4 pc
Binning to 2.22” x 2.22”

Foreground stars removed:
2MASS point source catalog
  (Skrutskie et al. 2006)
& SIRIUS/IRSF catalog
  (Nishiyama et al. 2006)
Only Stars with
1.5<H-K<3.5 in cube
  (Schödel et al. 2010)
**H$_2$ gas emission**

- Gaussian fit to H$_2$ emission line at 2.4066 µm 1-0 Q(1)
H$_2$ gas emission

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H$_2$ gas emission

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Stellar CO absorption

- pPXF fit to absorption lines (Cappellari & Emsellem 2004)
- High resolution spectra (Wallace & Hinkle 1996) convolved to lower resolution
Stellar CO absorption

Comparison to previous results
(McGinn et al. 1989)

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Stellar CO absorption

Voronoi binning (Cappellari & Copin 2003)

effect of binning

S/N = 20, resolution ~3.5” or 0.14 pc
Equivalent to Galaxy at ~290 kpc distance observed with 0.1” resolution
Stellar CO absorption
Voronoi binning (Cappellari & Copin 2003)
effect of binning

S/N =40, resolution ~12” or 0.5 pc
Equivalent to Galaxy at ~1 Mpc distance observed with 0.1” resolution
Stellar CO absorption

Voronoï binning (Cappellari & Copin 2003)

effect of binning

S/N = 60, resolution ~20” or 0.8 pc
Equivalent to Galaxy at ~1.6 Mpc distance observed with 0.1” resolution
Stellar CO absorption

effect of foreground stars

S/N =40, including foreground stars
Stellar CO absorption

effect of foreground stars

S/N = 40, after foreground star correction
Stellar CO absorption
1-dim profile

Circular bins around Sgr A*
\[ V_{\text{rms}} = \sqrt{V^2 + \sigma^2} \]
Stellar CO absorption
1-dim profile

Circular bins around Sgr A*

\[ V_{\text{rms}} = \sqrt{V^2 + \sigma^2} \]
Photometry from Spitzer/IRAC survey

4.5 \mu m image (Stolovy et al. 2006)
Dust and extinction corrected (Poster by Devaky Kunneriath)
Photometry from Spitzer/IRAC survey

Multi-Gaussian expansion fit (Cappellari 2002)
Photometry from Spitzer/IRAC survey

Multi-Gaussian expansion fit (Cappellari 2002)
Photometry from Spitzer/IRAC survey

Multi-Gaussian expansion fit (Cappellari 2002)
Axisymmetric Jeans models

- Jeans Anisotropic MGE dynamical models (JAM, Cappellari 2008)
- Inclination=90°, constant anisotropy $\beta$
- constant $M/L$

Best fit with $\chi^2 = 21.84$,
$\beta = 0.6$ (radial),
$M/L_{4.5\mu m} = 0.32^{+0.28}_{-0.17}$ $M_{\text{sun}}/L_{4.5\mu m,\text{sun}}$
$M_{BH} = 2.6e6 \pm 1.6e6$ $M_{\text{sun}}$
Conclusions

• First map of stellar velocities of the NSC
• Foreground star removal has no big influence on the results
• Result of black hole mass fit from Jeans model is largely consistent with black hole mass from direct measurements
• Black hole mass is too low → do we underestimate black hole masses in other Galaxies?
• Radially varying M/L can fit the required black hole mass
  → constrain the M/L with stellar population analysis using KMOS data