The Milky Way Nuclear Star Cluster beyond 1 pc

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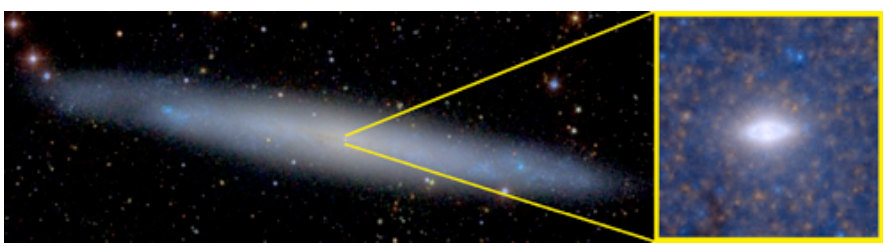
Nuclear Star Clusters (NSCs)

NGC 4395

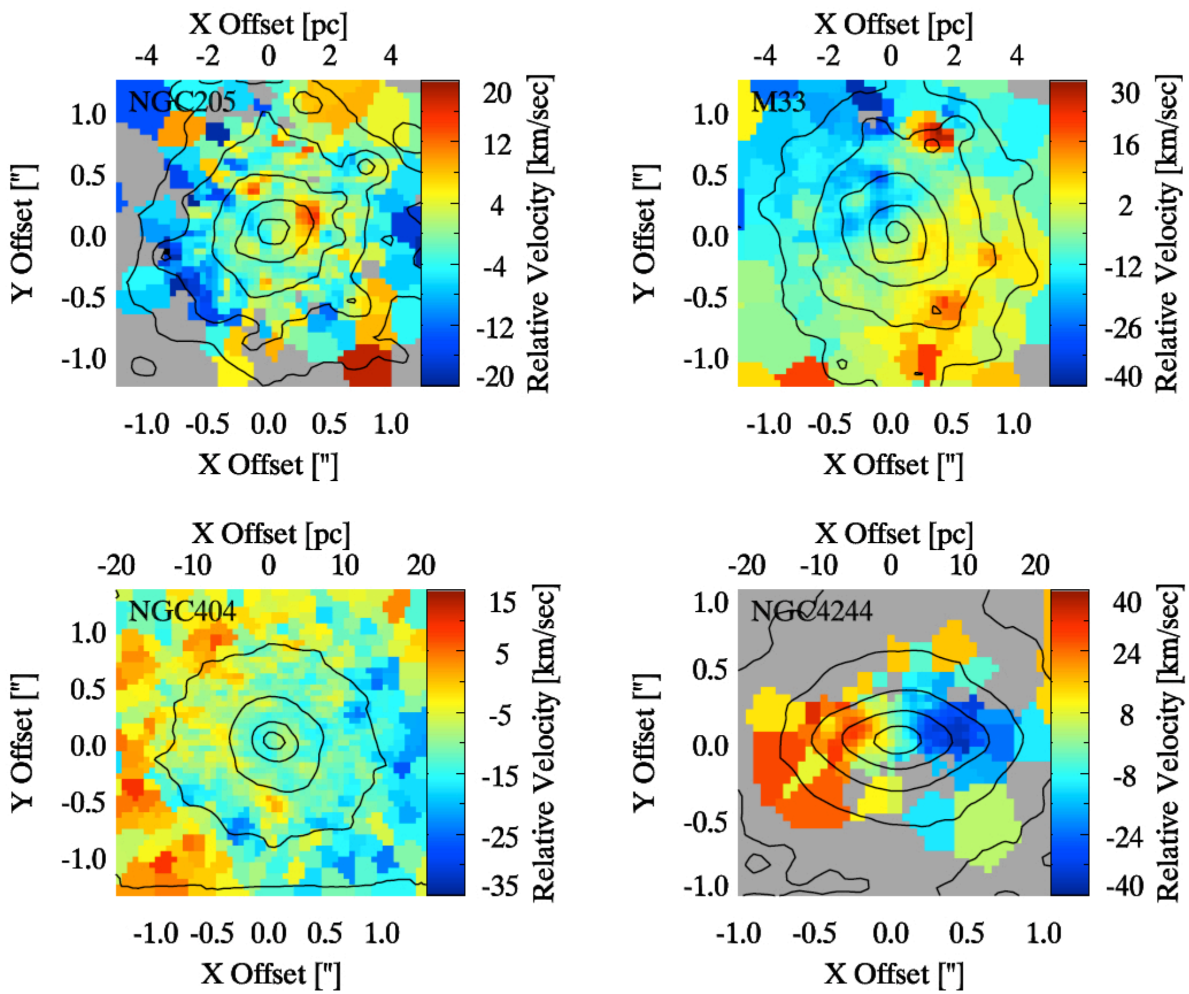
Milky Way



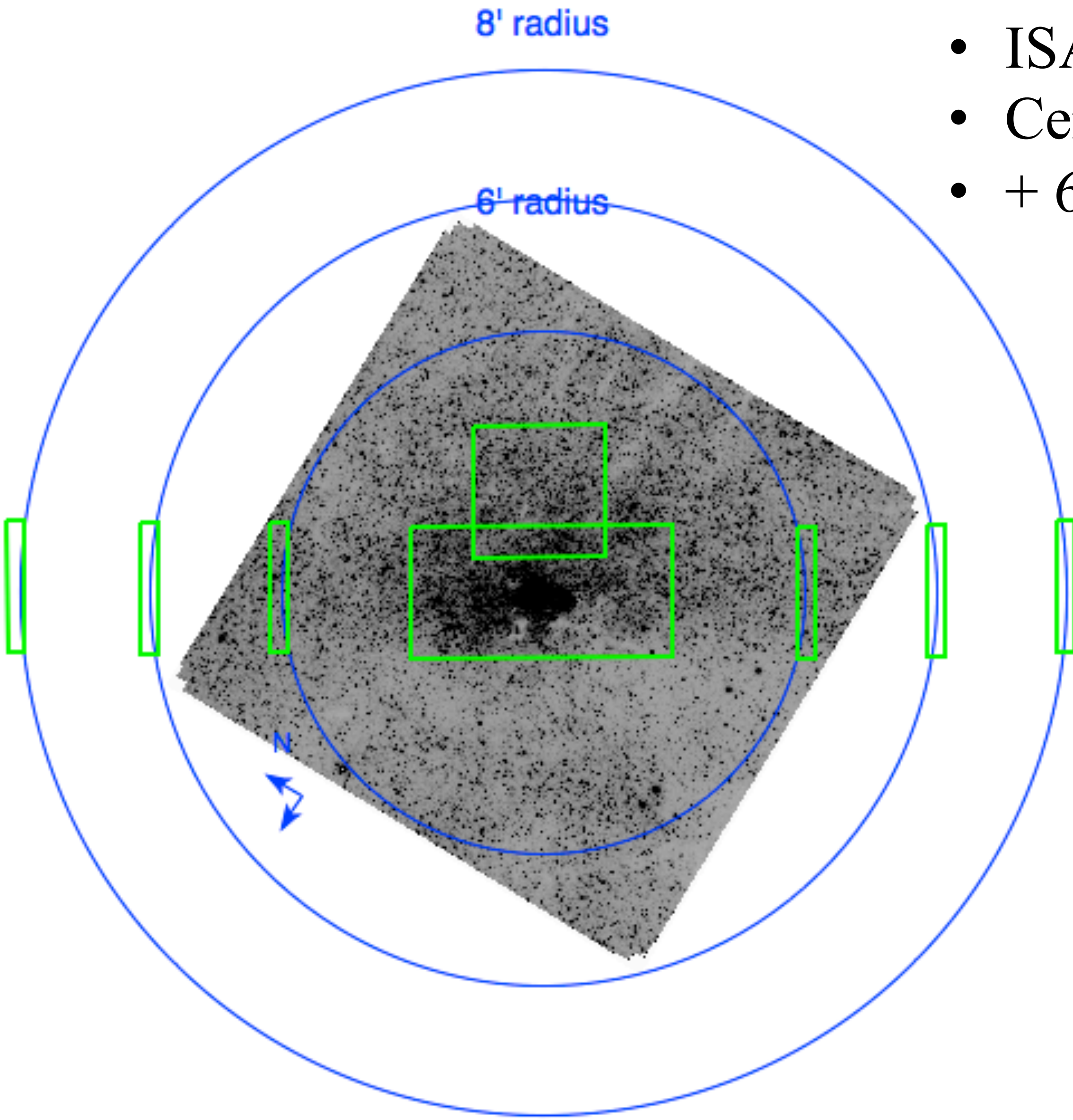
NGC 4244

- Detected in 50% to 75% of all galaxies
- Half-light radius 2-5 pc
- Dynamical mass 10^6 - 10^7 M_{sun}
- Complex SF history
- Scaling relations with galaxy properties
- Some contain a MBH

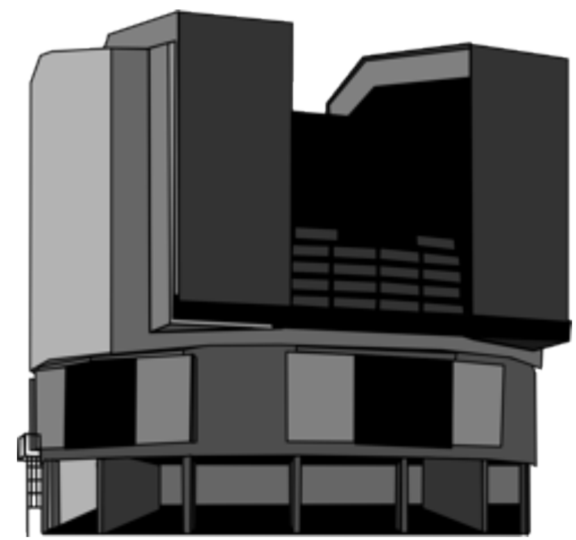
Nuclear Star Clusters (NSCs)



Kinematic data set



- ISAAC long slit spectrograph
- Central field: ~4'x3.5'
- + 6 fields of 2'x16" size



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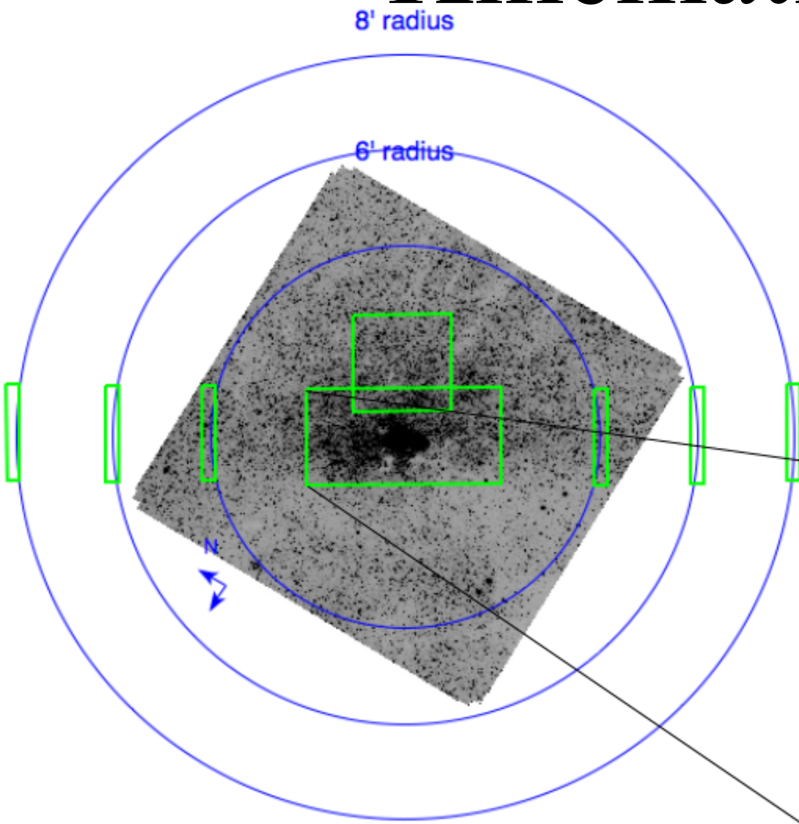

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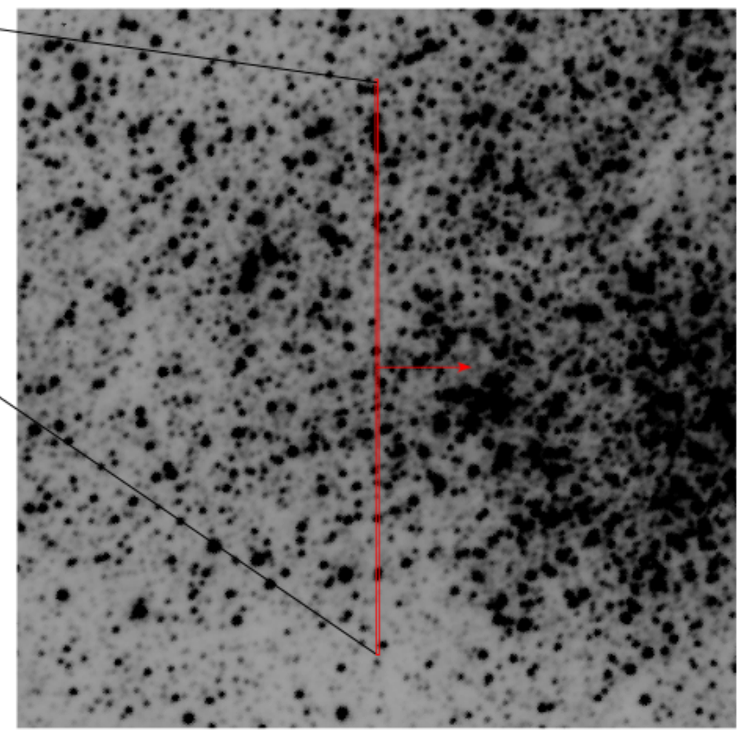
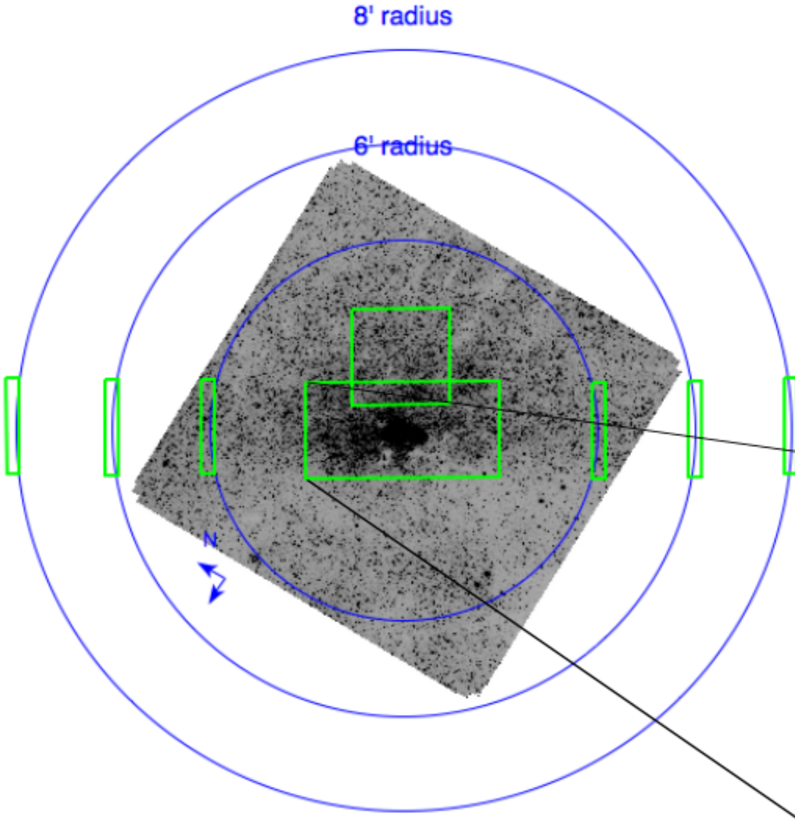
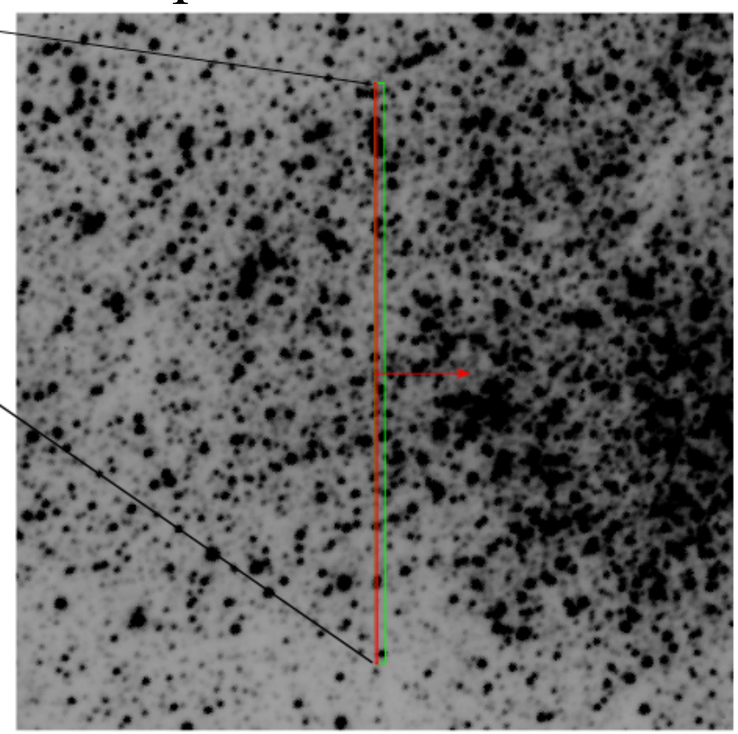


Slit length: 120"
Slit width: 0.6"

Kinematic data set



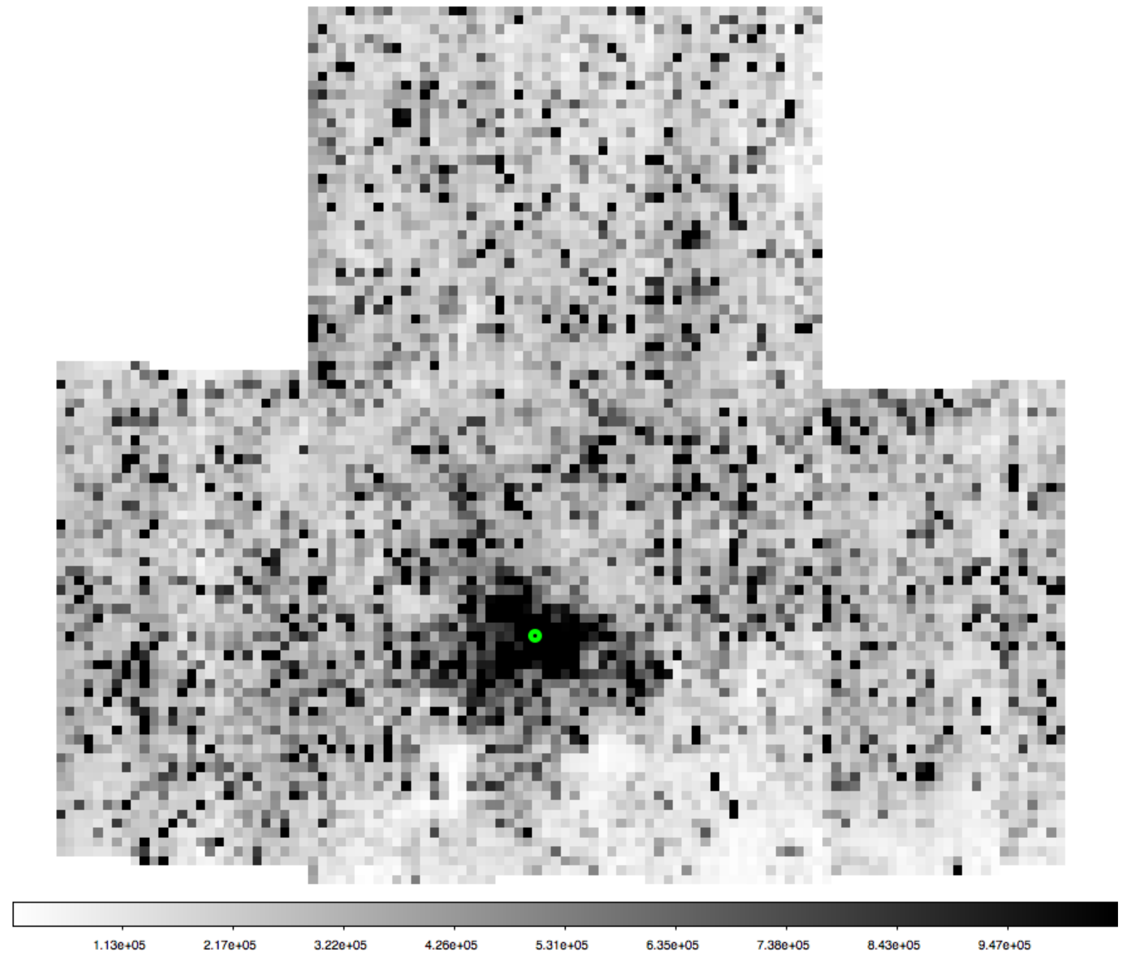
- ISAAC long slit spectrograph
- Central field: ~4’x3.5’
- + 6 fields of 2’x16” size
- ~2.29 – 2.41 micron,
- spectral resolution 68 km/s



Slit length: 120"
Slit width: 0.6"
Drift: 2"

Kinematic data set

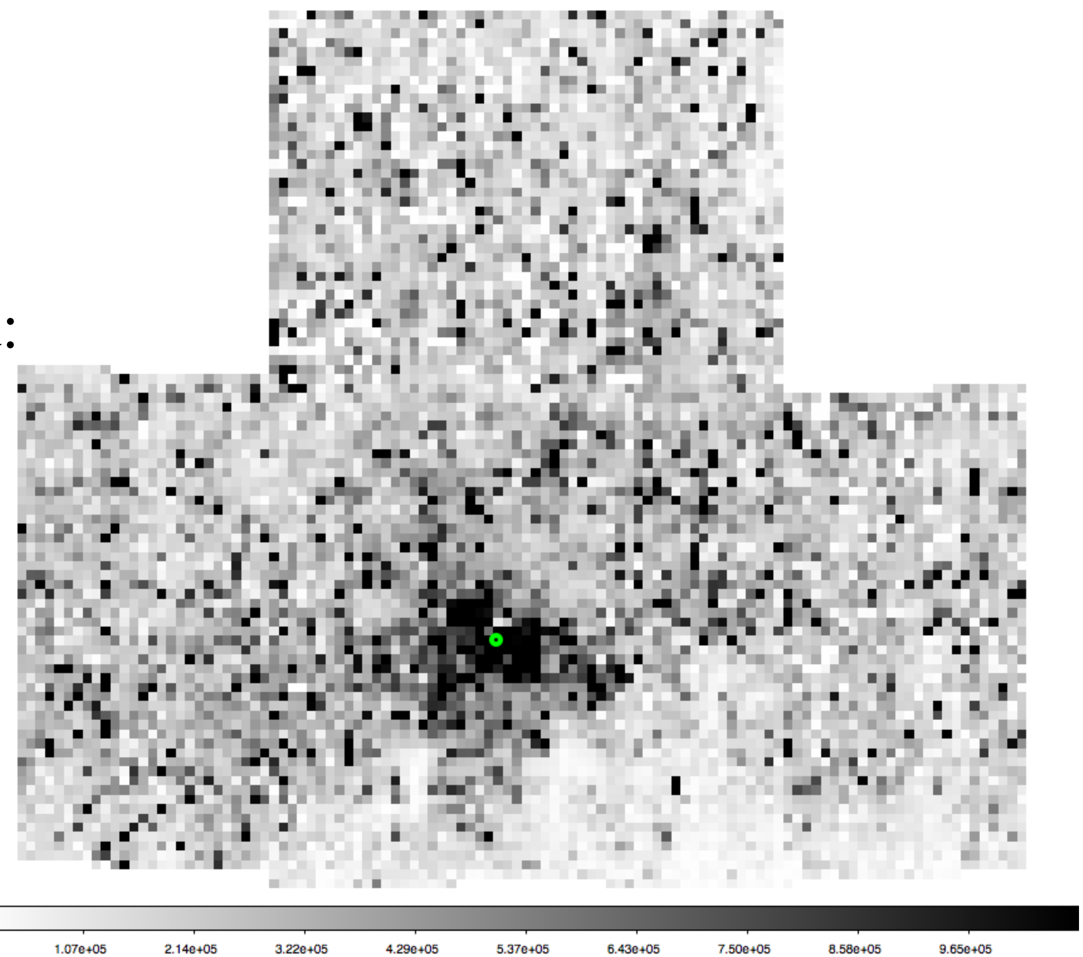
Full area 4’ x 3.5’
~ 9.6 x 8.4 pc
Binning to 2.22” x 2.22”



Kinematic data set

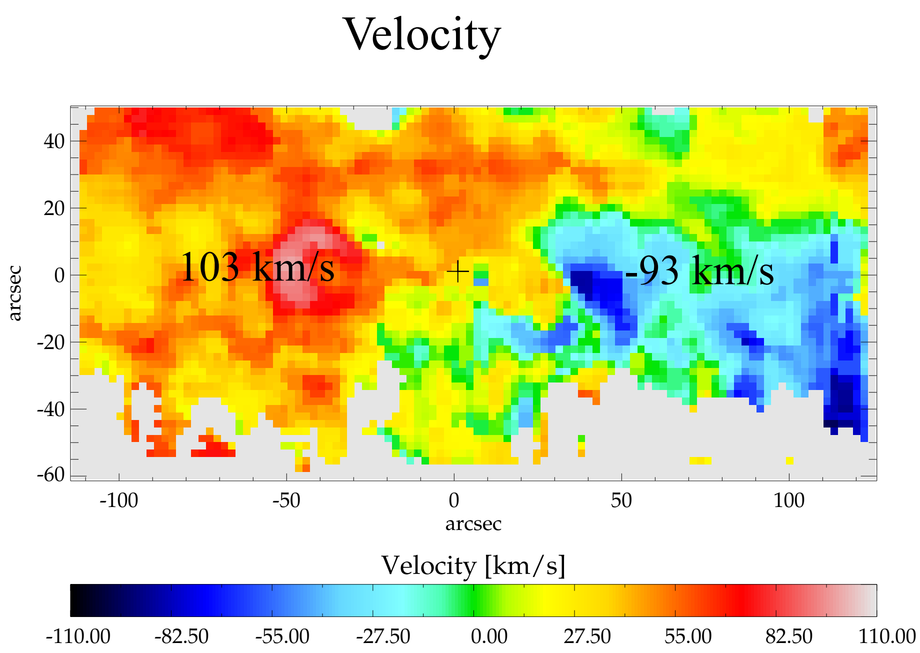
Full area 4’ x 3.5’
~ 9.6 x 8.4 pc
Binning to 2.22” x 2.22”

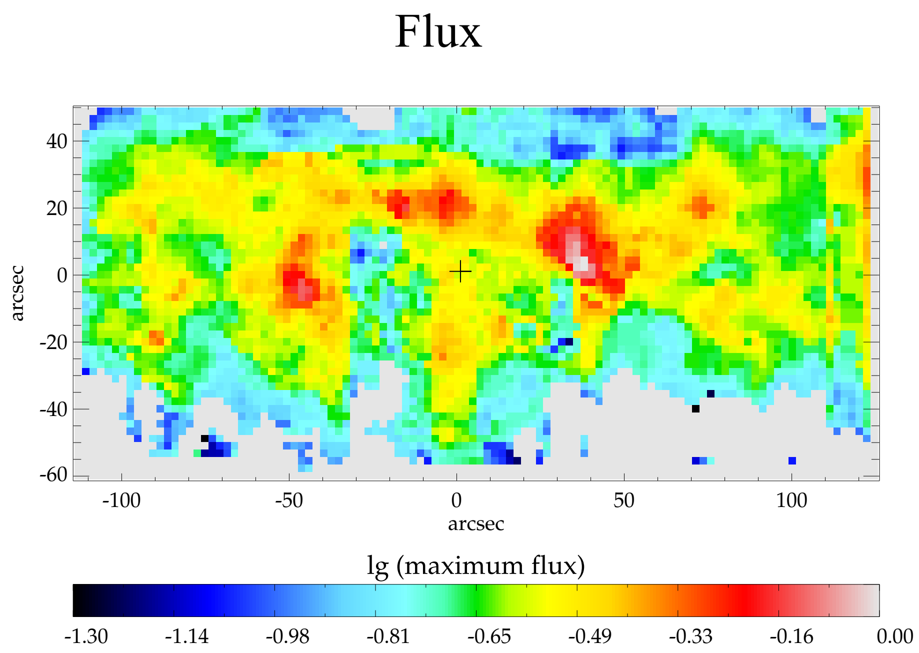
Foreground stars removed:
2MASS point source catalog
(Skrutskie et al. 2006)
& SIRIUS/IRSF catalog
(Nishiyama et al. 2006)
Only Stars with
1.5<H-K<3.5 in cube
(Schödel et al. 2010)



H_2 gas emission

- Gaussian fit to H_2 emission line at 2.4066 µm 1-0 Q(1)





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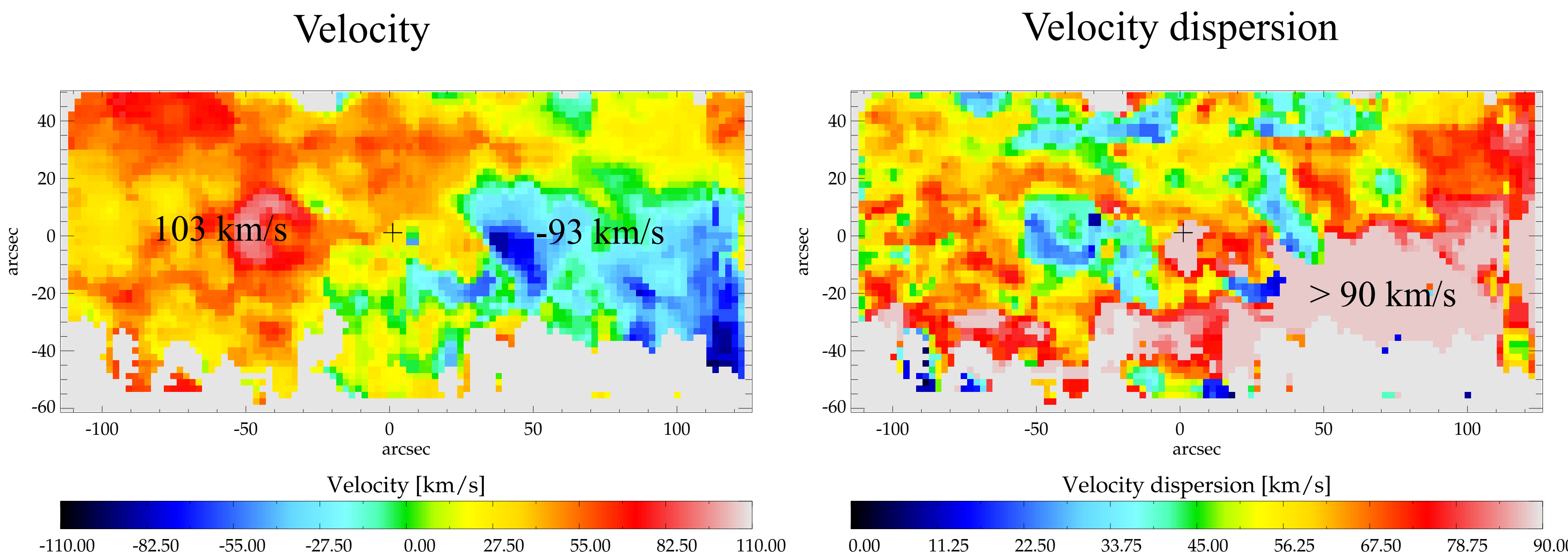

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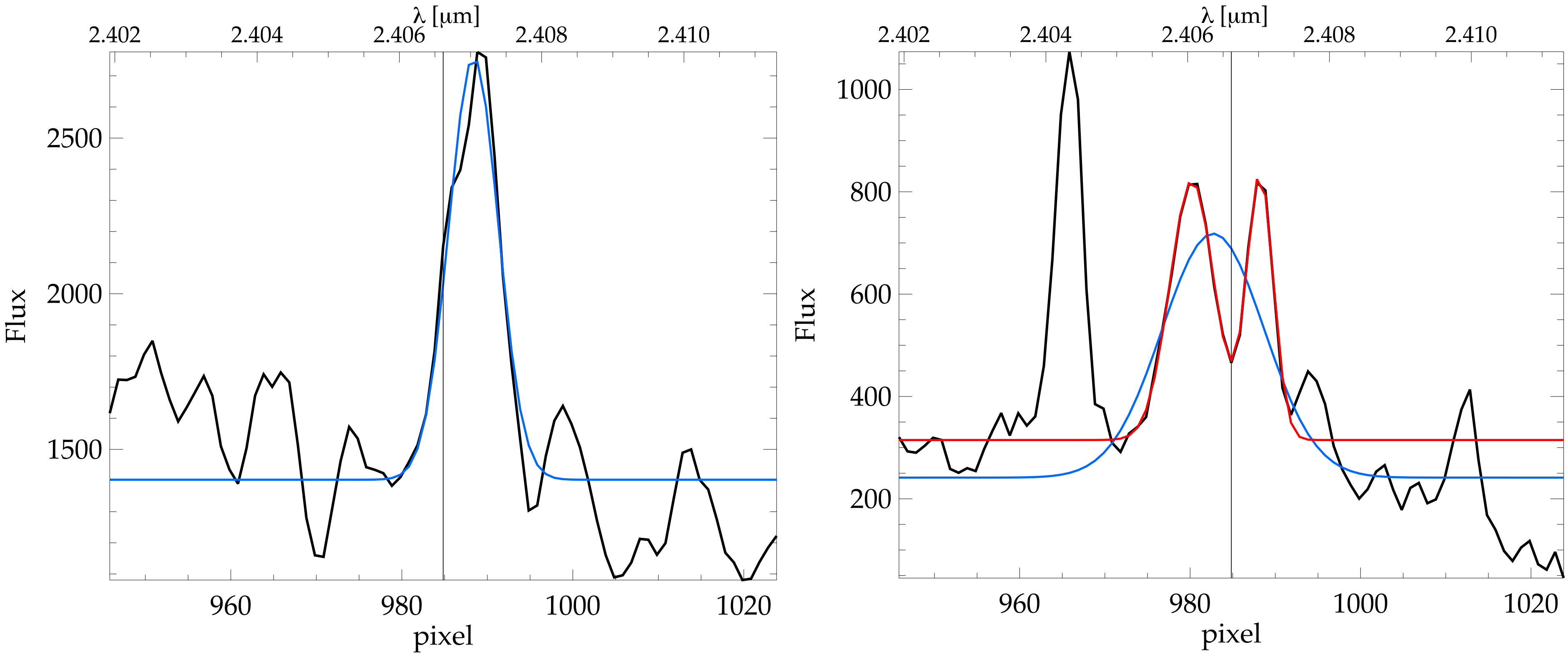
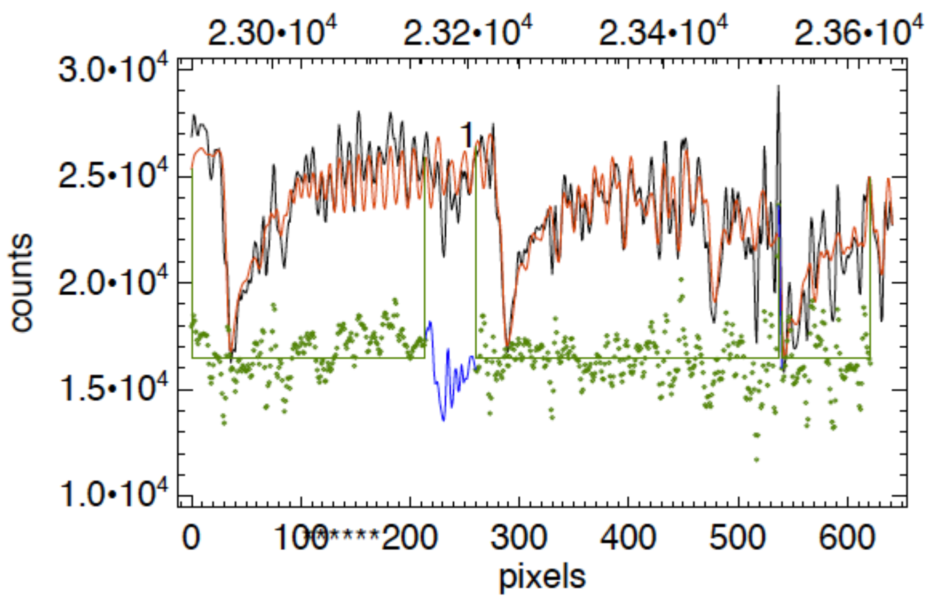
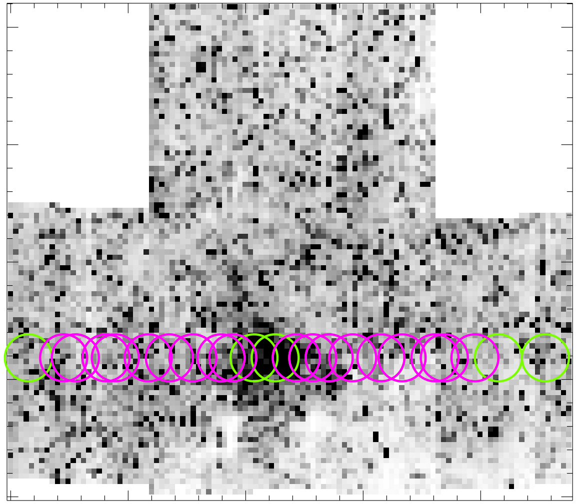


Stellar CO absorption

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

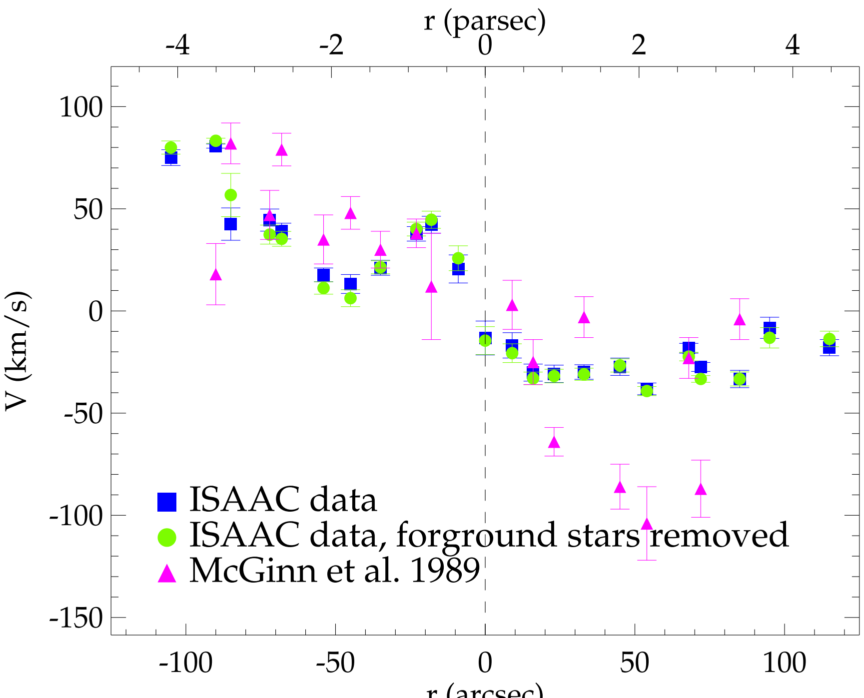


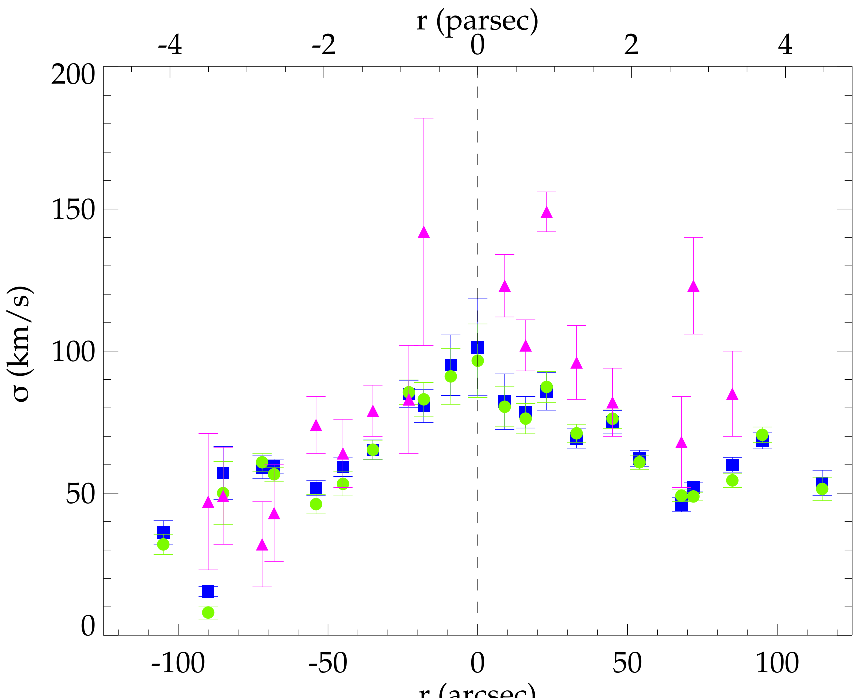
Stellar CO absorption



Comparison to previous results

(McGinn et al. 1989)

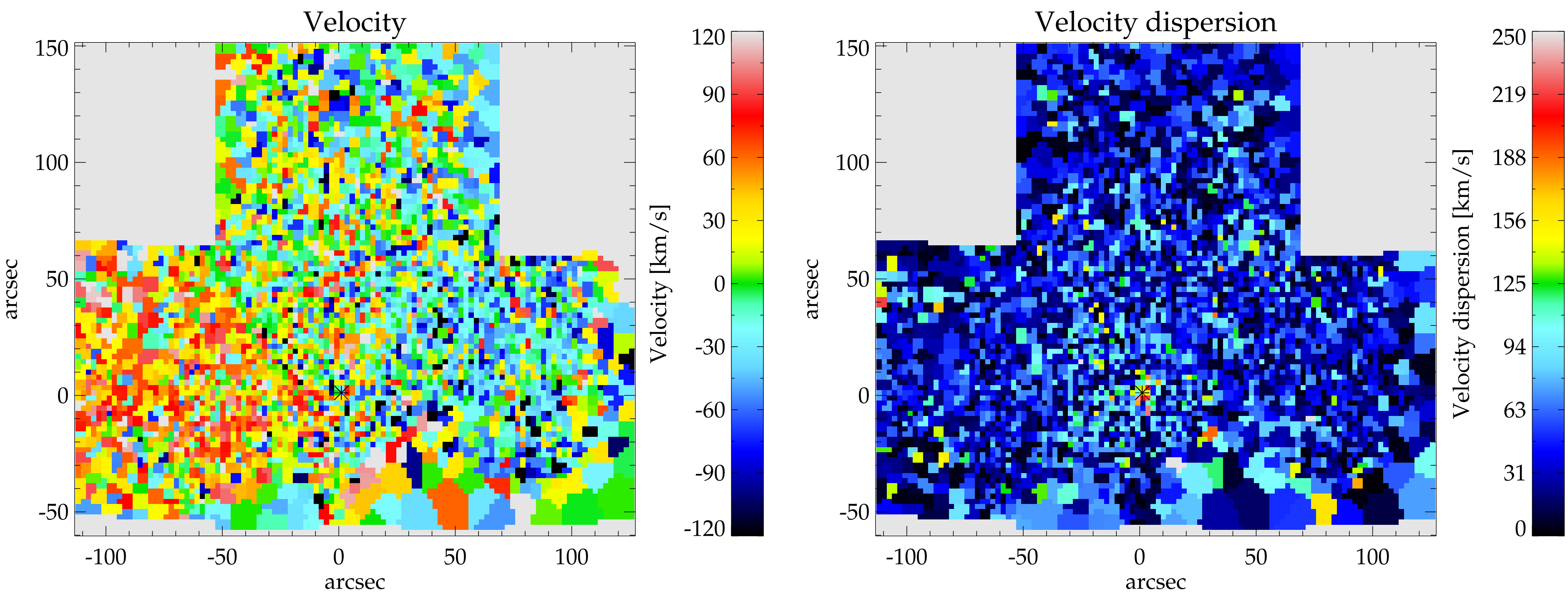




Stellar CO absorption

Voronoi binning (Cappellari & Copin 2003)

effect of binning



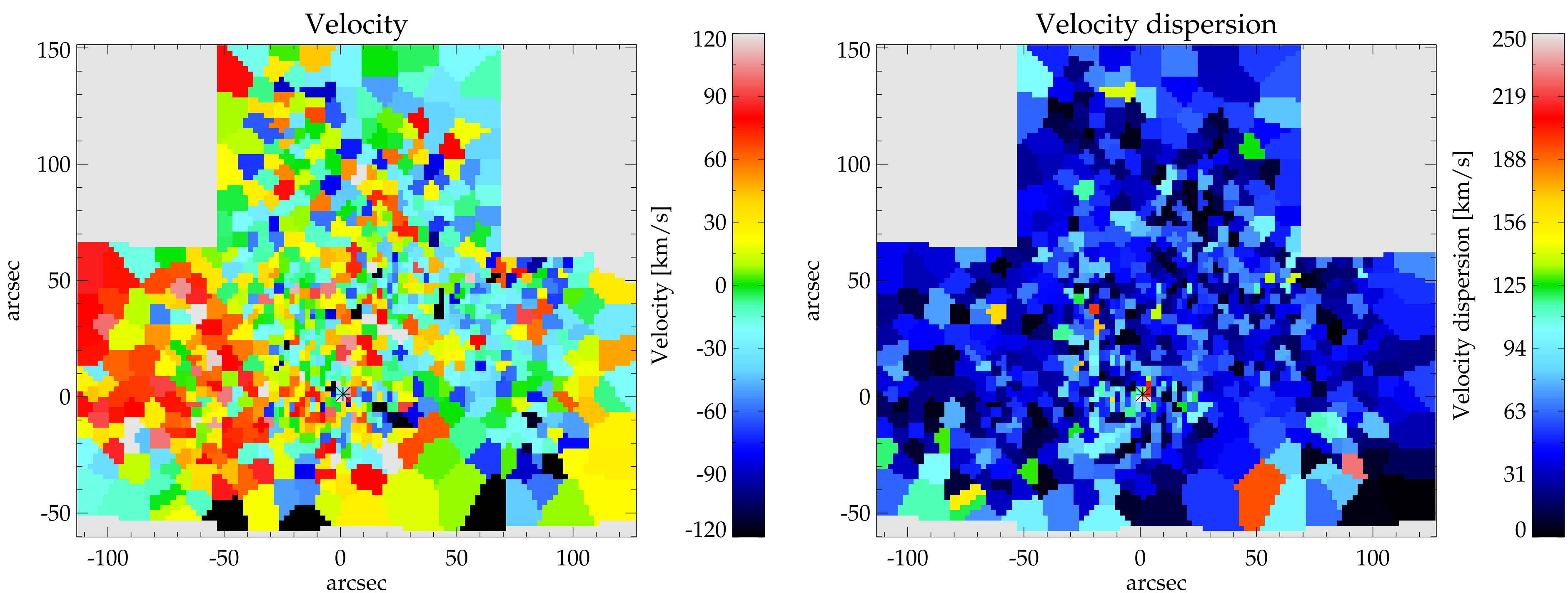
S/N =20, resolution ~3.5" or 0.14 pc

Equivalent to Galaxy at ~290 kpc distance observed with 0.1" resolution

Stellar CO absorption

Voronoi binning (Cappellari & Copin 2003)

effect of binning



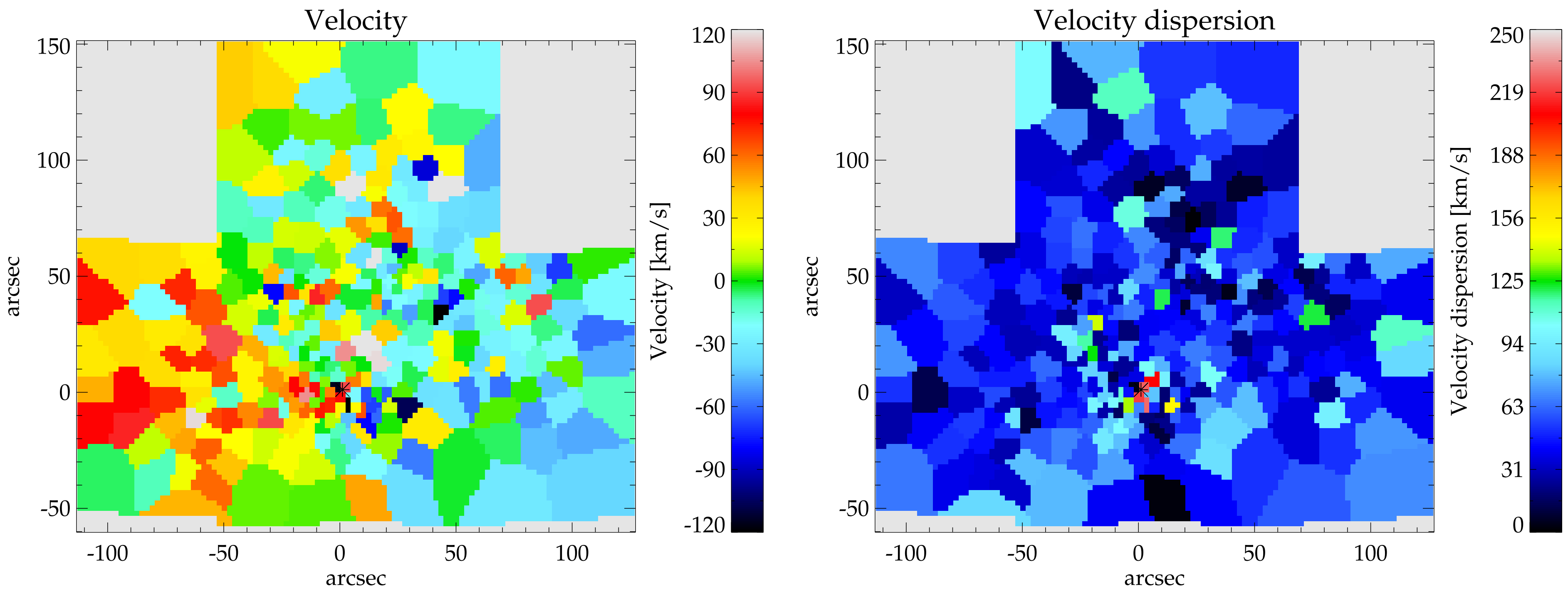
S/N =40, resolution ~12” or 0.5 pc

Equivalent to Galaxy at ~1 Mpc distance observed with 0.1” resolution

Stellar CO absorption

Voronoi binning (Cappellari & Copin 2003)

effect of binning

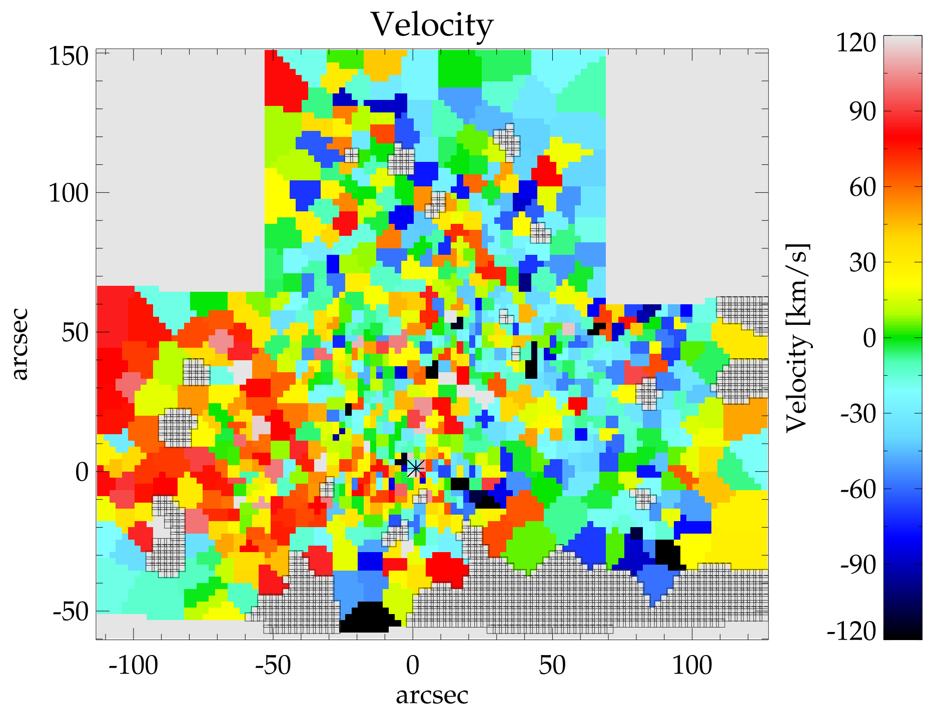


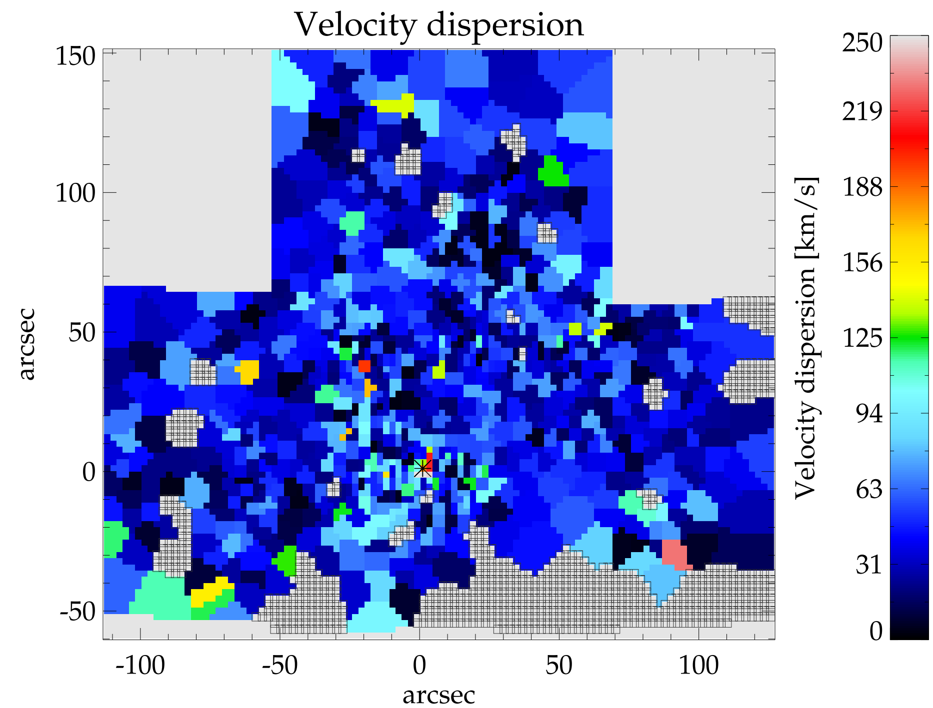
S/N =60, resolution ~20” or 0.8 pc

Equivalent to Galaxy at ~1.6 Mpc distance observed with 0.1” resolution

Stellar CO absorption

effect of foreground stars

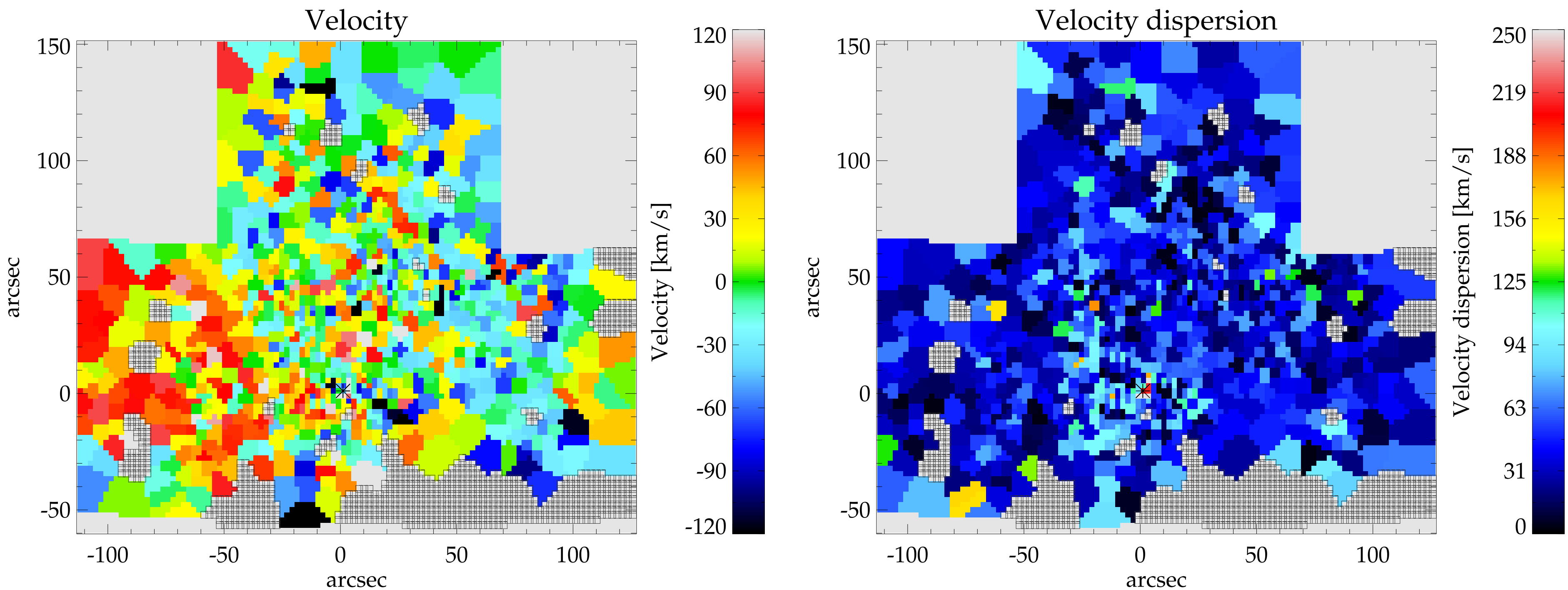




S/N =40, including foreground stars

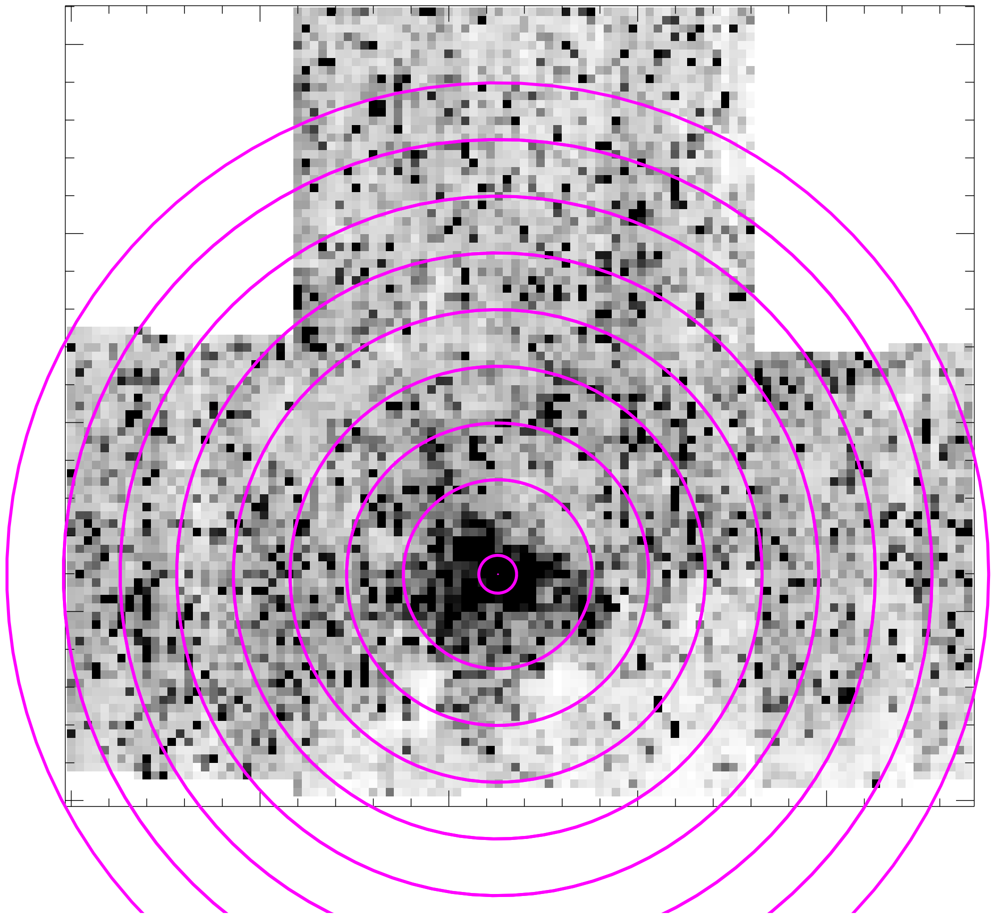
Stellar CO absorption

effect of foreground stars



S/N =40, after foreground star correction

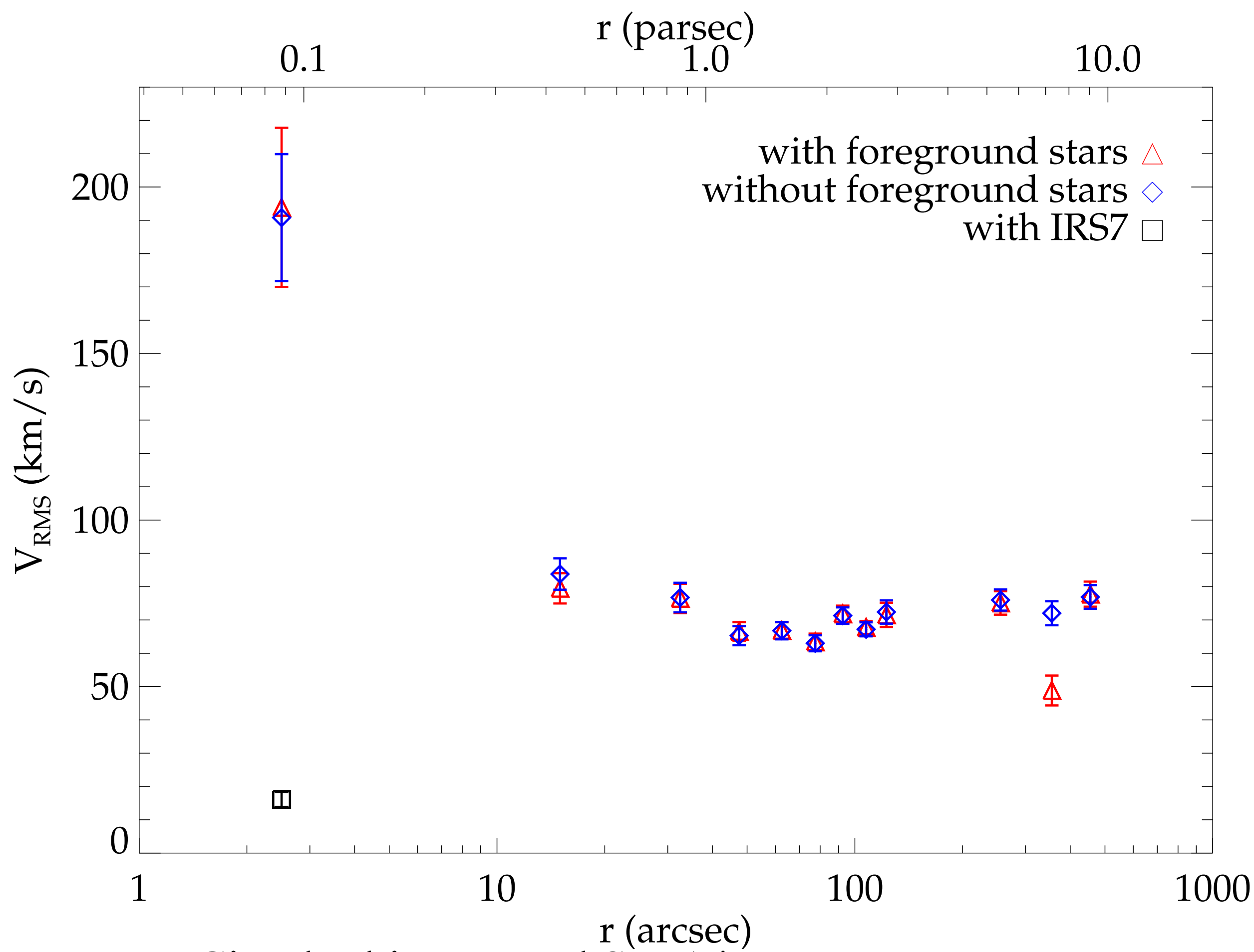
Stellar CO absorption
1-dim profile



Circular bins around Sgr A*
$V_{rms} = SQRT(V^2+\sigma^2)$

Stellar CO absorption

1-dim profile

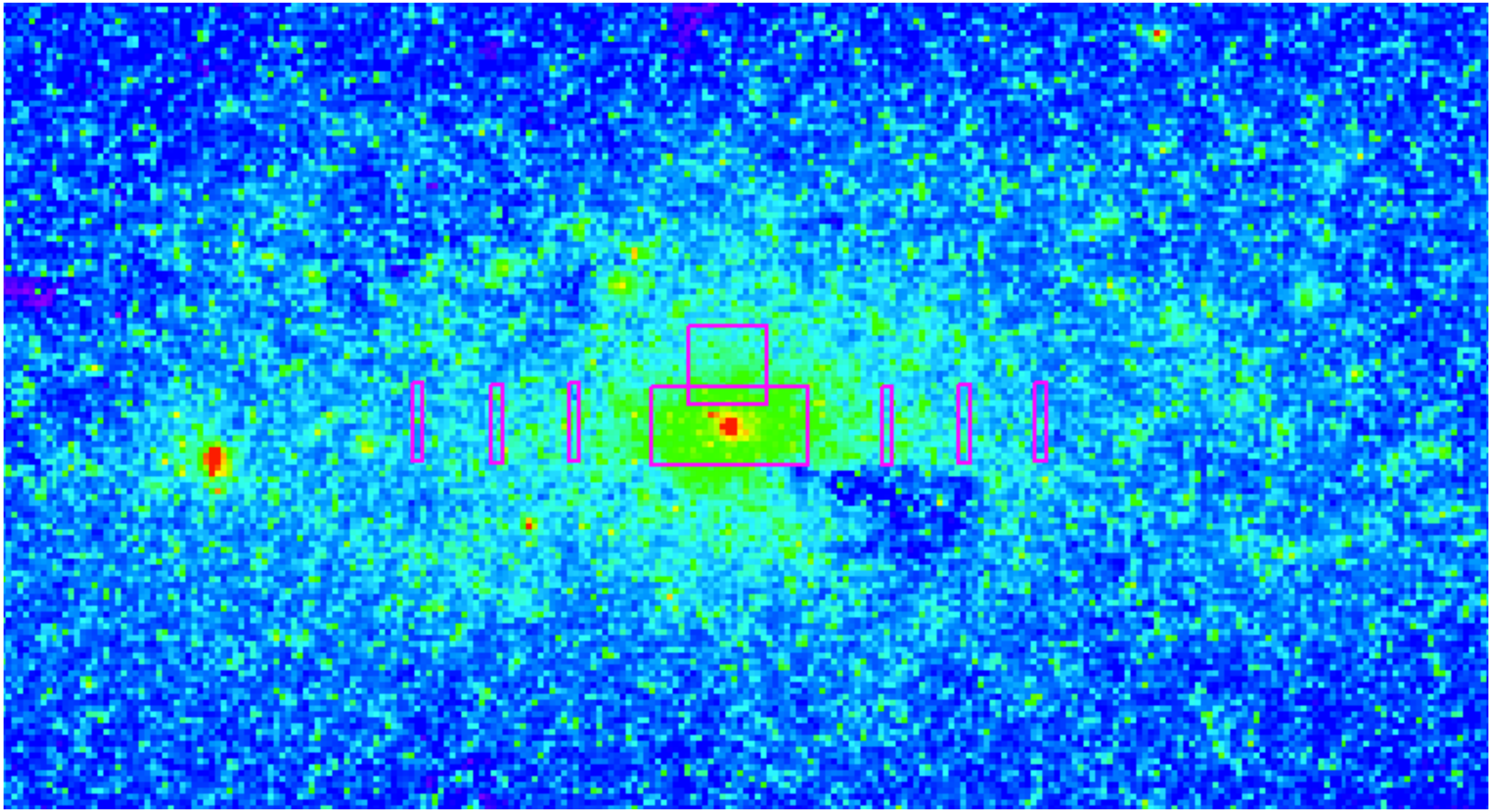


Circular bins around Sgr A*

$V_{rms} = \mathrm{SQRT}(V^2+\sigma^2)$

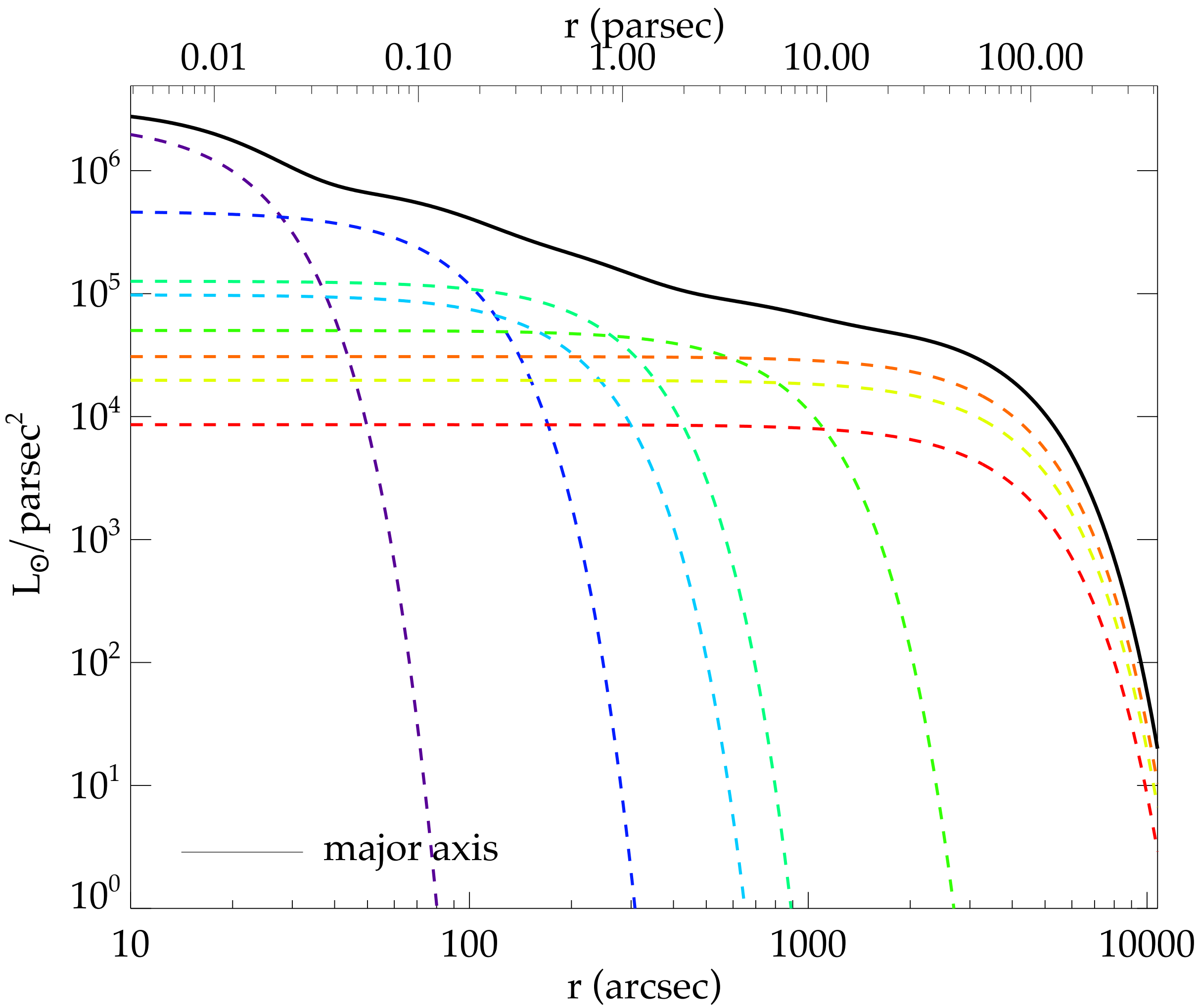
Photometry from Spitzer/IRAC survey

4.5μm image (Stolovy et al. 2006)
Dust and extinction corrected (Poster by Devaky Kunneriath)



Photometry from Spitzer/IRAC survey

Multi-Gaussian expansion fit (Cappellari 2002)



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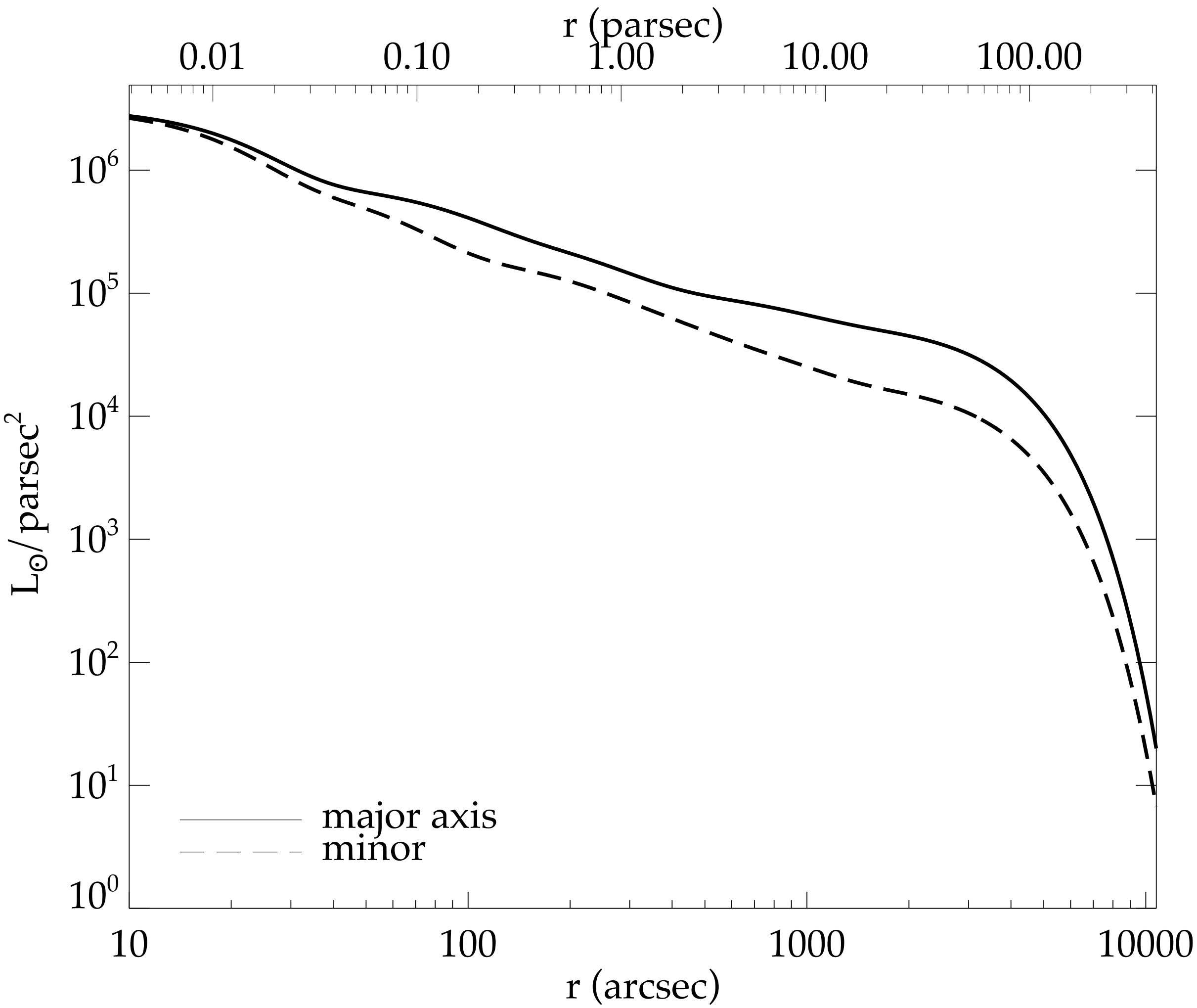

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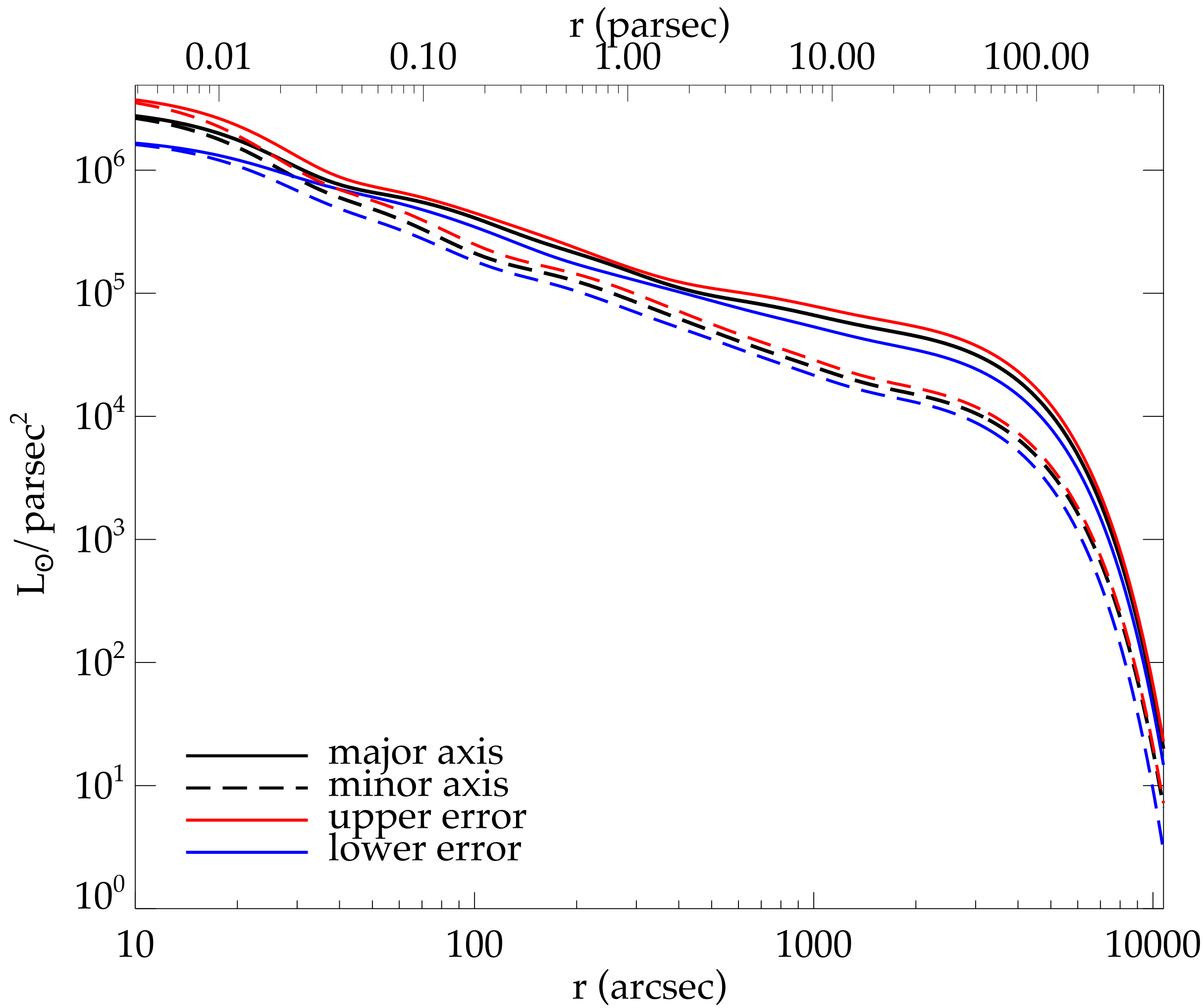
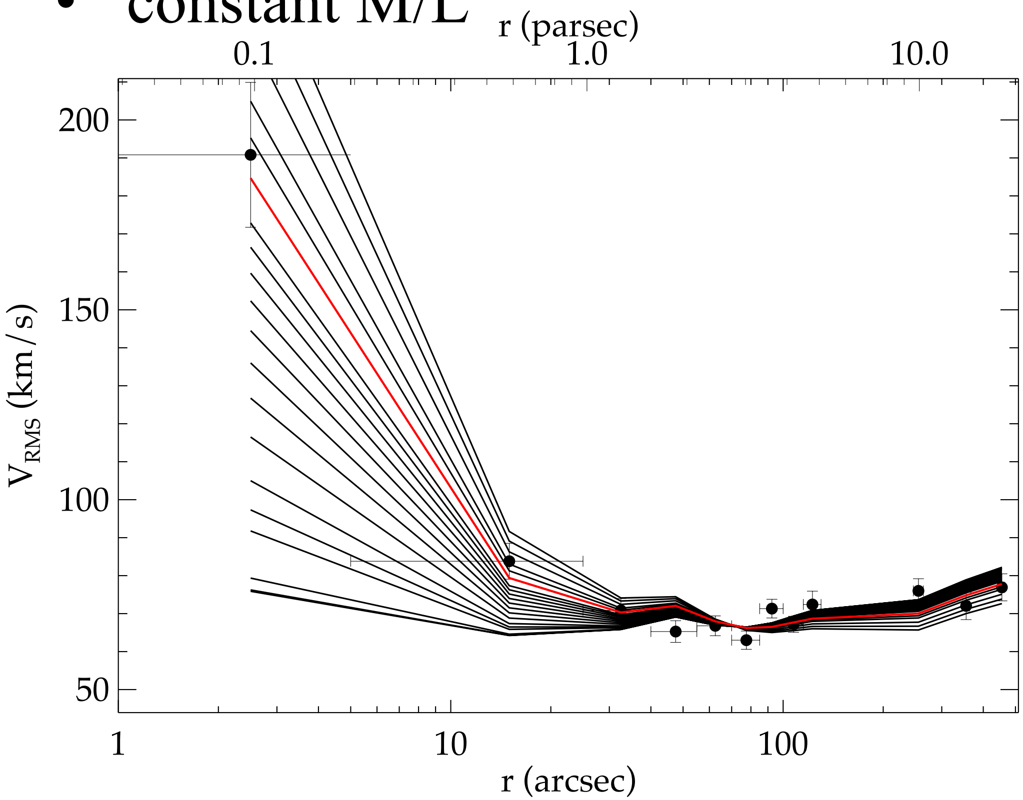


Axisymmetric Jeans models

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



Best fit with $\chi^2 = 21.84$,
$\beta = 0.6$ (radial),
$M/L_{4.5\mu m} = 0.32^{+0.28}_{-0.17}\ M_{sun}/L_{4.5\mu m,sun}$
$M_{BH} = 2.e6 \pm 1.e6\ M_{sun}$

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