Study of an extreme starburst cluster: different star formation or dynamical evolution?

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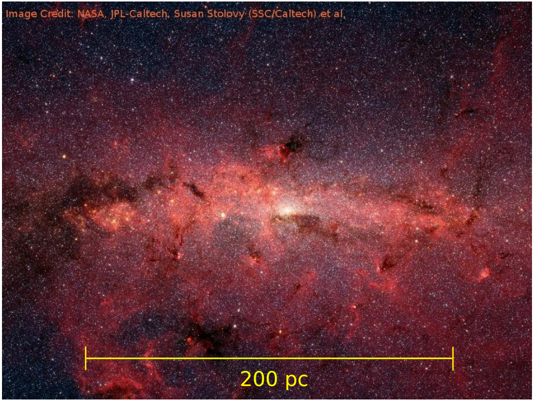
N-body meeting, Dec 4, 2012

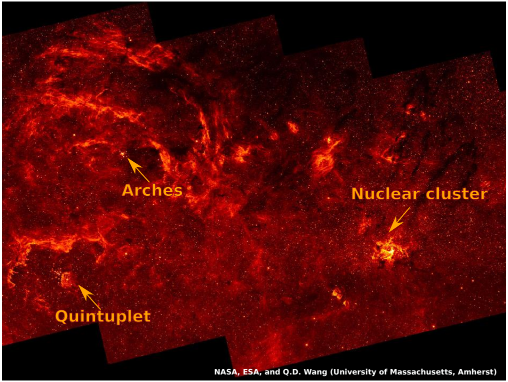
Outline

Star formation in the Galactic center



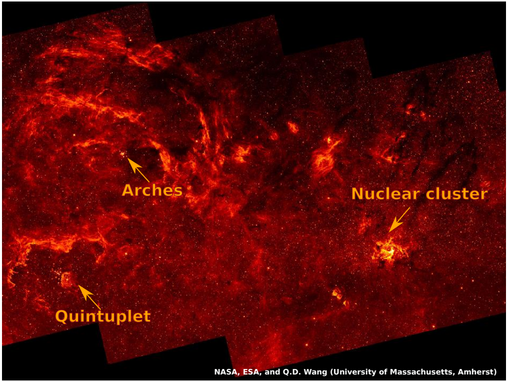
- Dense molecular clouds
- Massive-star formation
- High star formation rate
- Closest galactic nucleus

Star Forming Clusters in the GC



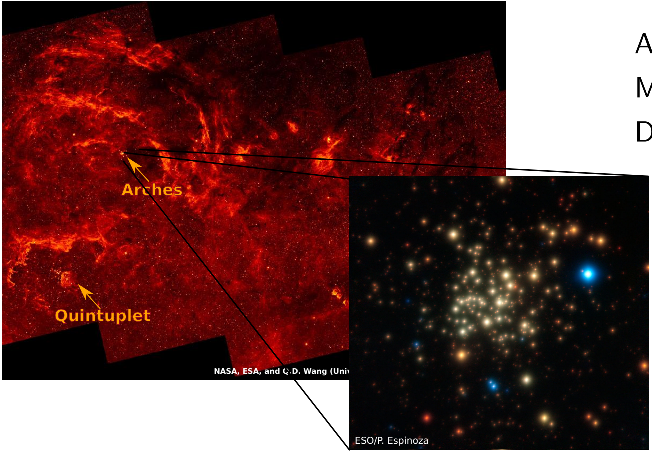
- Young
- Massive
- Heating nearby molecular clouds
- Flat IMF?

Star Forming Clusters in the GC



- Flat IMF? & claims for different star formation in GC (e.g. Klessen et al. 2007, Dib et al. 2007)

Star Forming Clusters in the GC

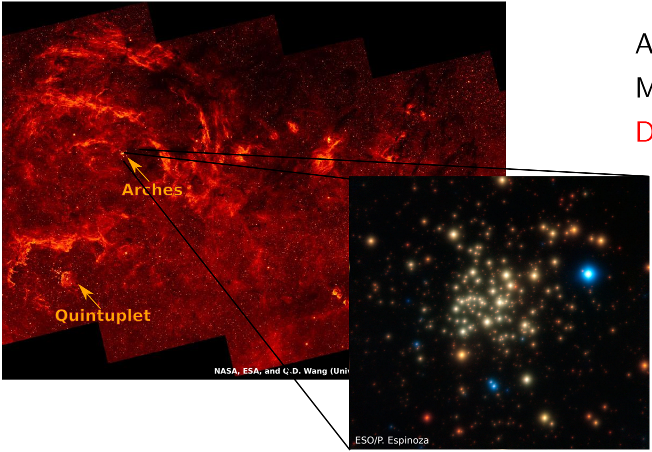


Age: ~ 2.4 Myr

Mass: $20,000 M_{\odot}$

Density: $2x10^5 M_{\odot}/pc^3$

Star Forming Clusters in the GC



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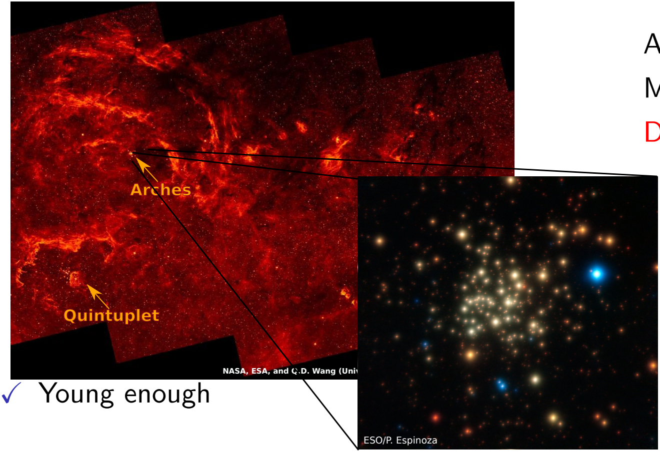

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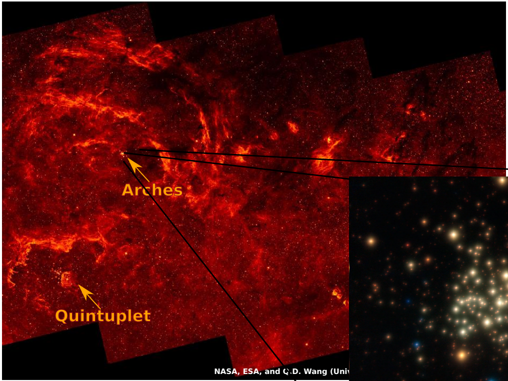
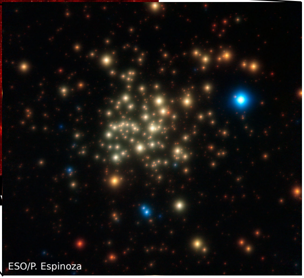
✓ Young enough

Star Forming Clusters in the GC





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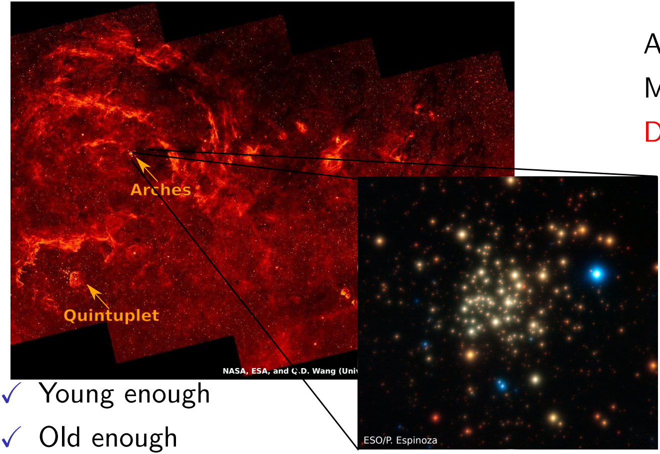

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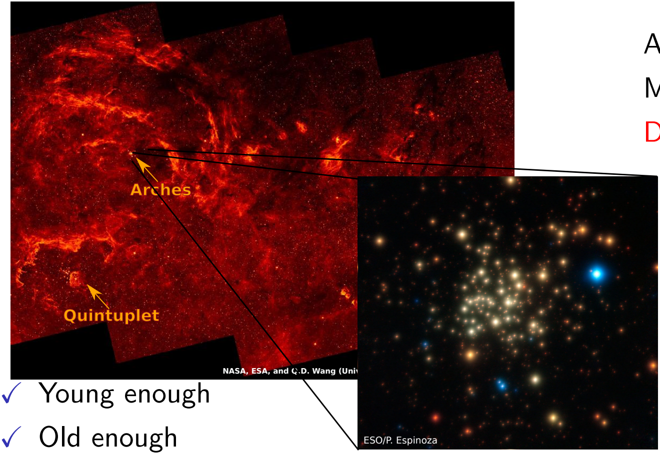

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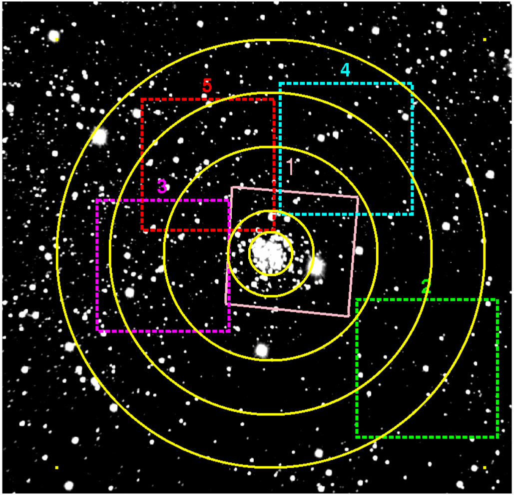
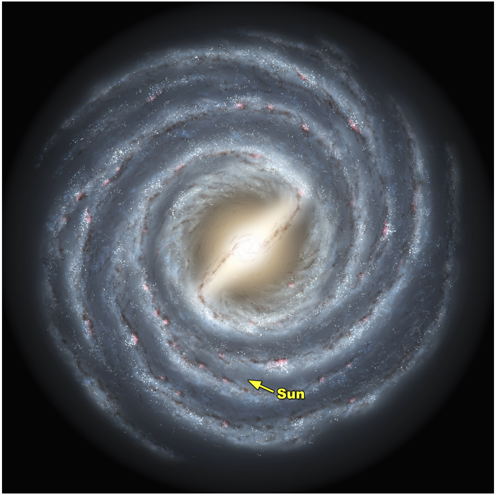
$\Longrightarrow$ **Probe IMF, high mass cut-off**

Near-infrared adaptive optic observation with VLT



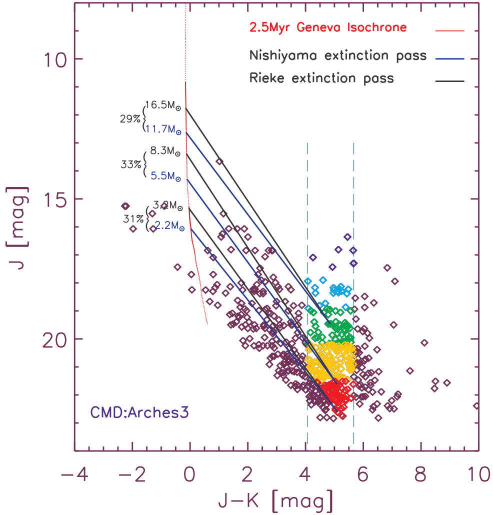
How do we see the GC?



- Through the disk
- Extincted by
  - the diffuse interstellar medium (ISM)
  - molecular cloud material
  - also through local molecular clouds

CMD

- Rieke & Lebofsky (1985)
  $A_\lambda \propto \lambda^{-1.6}$
- Nishiyama *et al.* (2009)
  $A_\lambda \propto \lambda^{-2.0}$



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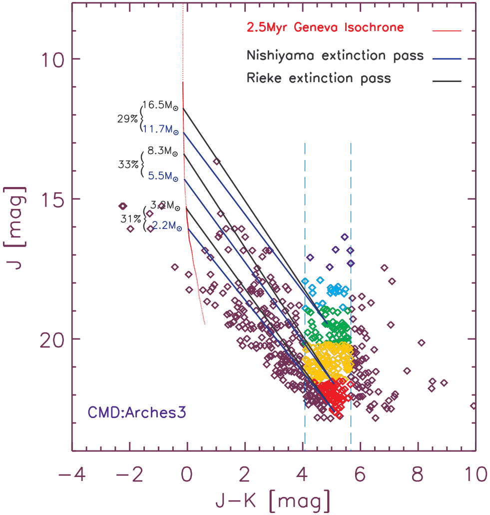
↬ individial extinction, intrinsic magnitude, mass



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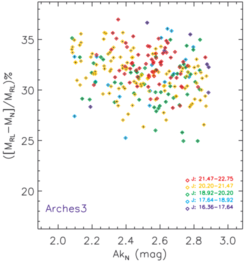
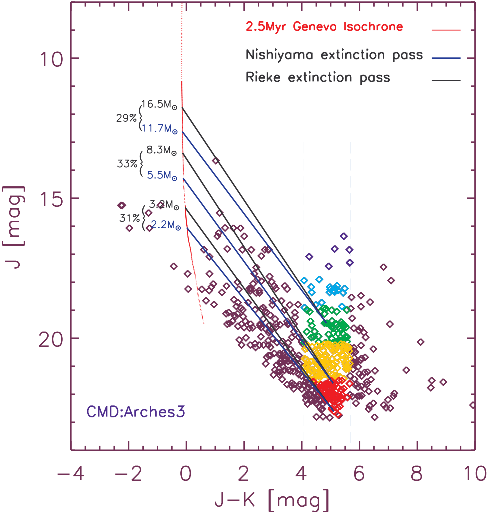
- different extinction laws: $\sim 30\%$ mass difference





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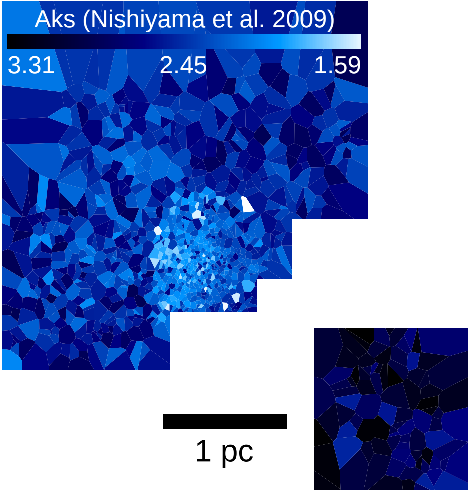
- different extinction laws: $\sim 30\%$ mass difference
- high and variable extinction:
  $2.8 < A_{K_s} < 4.21$ (Nishiyama)(mag)



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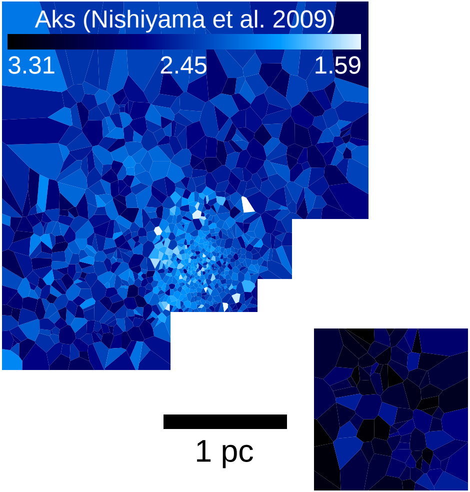
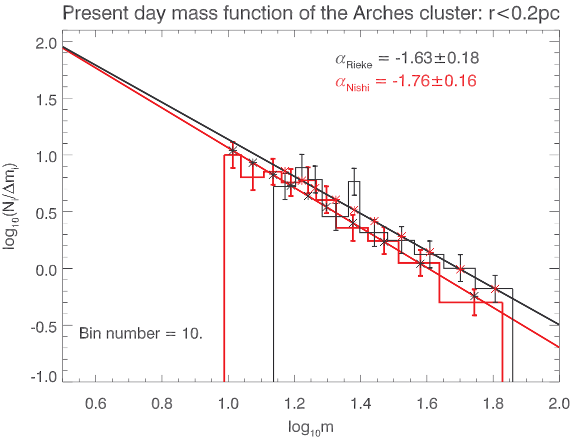


Mass function

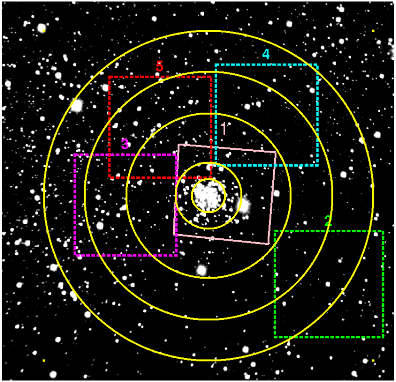


extinction-limited sample: lowest mass included in the PDMF is 10-17$M_\odot$

Highest mass detected:

PDM:66-70 $M_\odot$

IM: 81 $M_\odot \Longrightarrow$ 104 $M_\odot$



tidal radius of the cluster:

$r_t = (\frac{M_{cl}}{2\times M_g})^{1/3} \times r_g \simeq 1.3 - 2.5$ pc

M_g: enclosed mass in the inner Galaxy Launhardt et al. (2002)

r_g: Galactocentric range of 30-100 pc

total mass of the cluster:

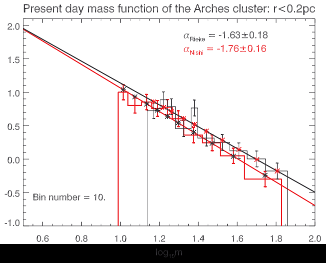
integrated over the mass range of 1 - 66 $M_\odot \Rightarrow$

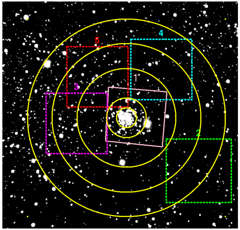
$M_{cl} = (1.8^{+0.4}_{-0.3}) \times 10^4 M_\odot$

Spatial mass function variation

Salepter mass function:
$\alpha = -2.35$

$r < 0.2$ pc





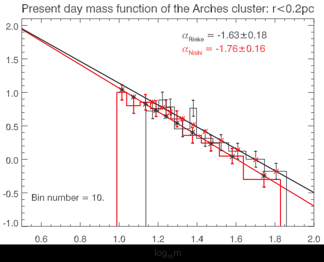
Spatial mass function variation

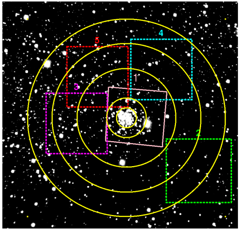
Salepter mass function:
$\alpha = -2.35$

$\alpha = -1.26$ Stolte *et al.*(2005)

$\alpha = -1.88$ Espinoza *et al.*(2007)

$r < 0.2$ pc





Spatial mass function variation

Salepter mass function:
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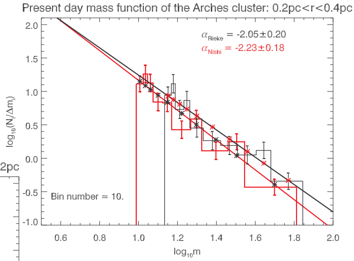
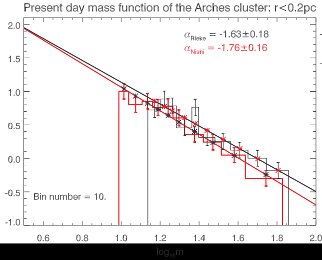
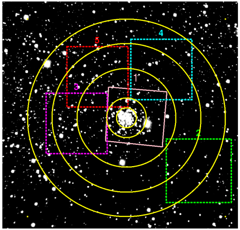


$r < 0.2$ pc





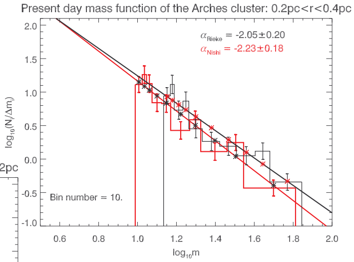
Spatial mass function variation

Salepter mass function:
$\alpha = -2.35$

$\alpha = -2.21$ Stolte *et al.*(2005)

$\alpha = -2.28$ Espinoza *et al.*(2007)

$0.2 < r < 0.4$ pc



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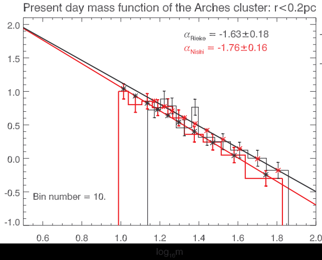
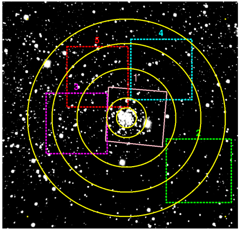
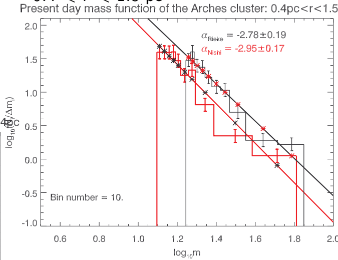




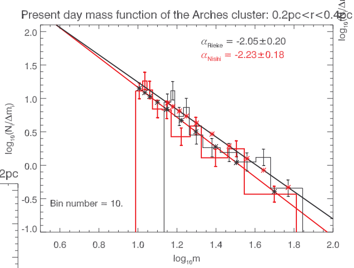
Spatial mass function variation

Salepter mass function:
$\alpha = -2.35$

$0.4 < r < 1.5$ pc



$0.2 < r < 0.4$ pc



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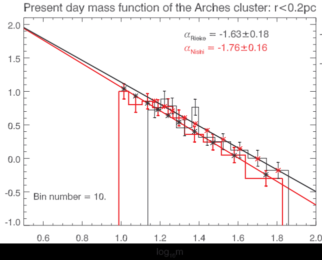

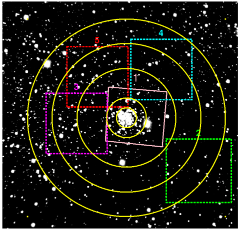

Dynamical evolution of the cluster

Large number of N-body simulations, Harfst et al. (2010)

List of models.

Model	W_0	IMF	m_{low} [$\mathrm{M}_\odot$]	M_{cluster} [$10^3\,\mathrm{M}_\odot$]	N_{cluster} [10^3]	$N(m > 10\,\mathrm{M}_\odot)$	parameter R_{vir}[pc]	parameter N_{MS}
IKW03F05	3	flat	0.5	22.9	6.9	423	0.1 – 1.0	100 – 300
IKW03F10	3	flat	1.0	20.5	3.7	421	0.1 – 1.0	100 – 300
IKW03S05	3	Salpeter	0.5	52.7	31.9	552	0.1 – 1.0	100 – 300
IKW03S10	3	Salpeter	1.0	39.7	12.5	552	0.1 – 1.0	100 – 300
IKW03S40	3	Salpeter	4.0	20.6	1.9	540	0.1 – 1.0	100 – 300
IKW05F05	5	flat	0.5	22.7	6.9	413	0.1 – 1.0	100 – 300
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IKW05S40	5	Salpeter	4.0	20.8	1.9	543	0.1 – 1.0	100 – 300
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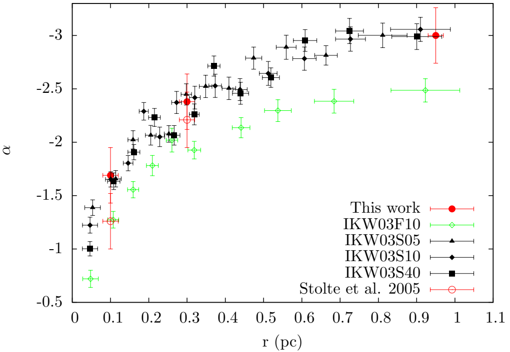
observed mass function in the core, density in the core, number of O-B stars

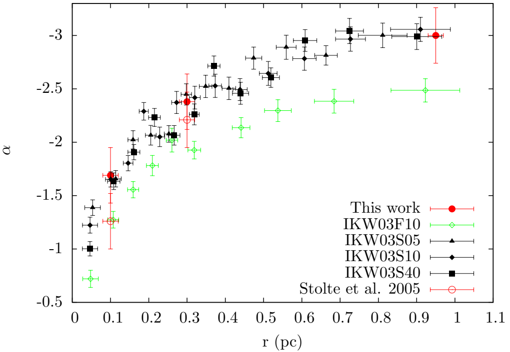
Dynamical evolution of the cluster

- flat IMF
- normal IMF



Dynamical evolution of the cluster

- flat IMF
- normal IMF
- deviate at $r > 0.4pc$



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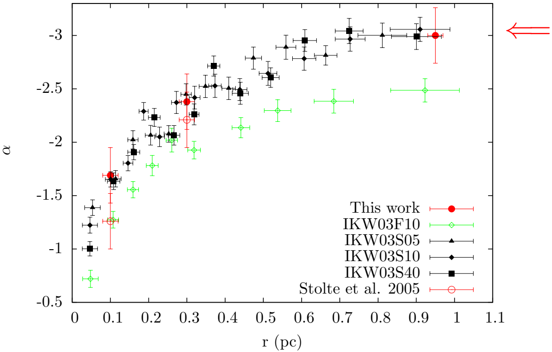
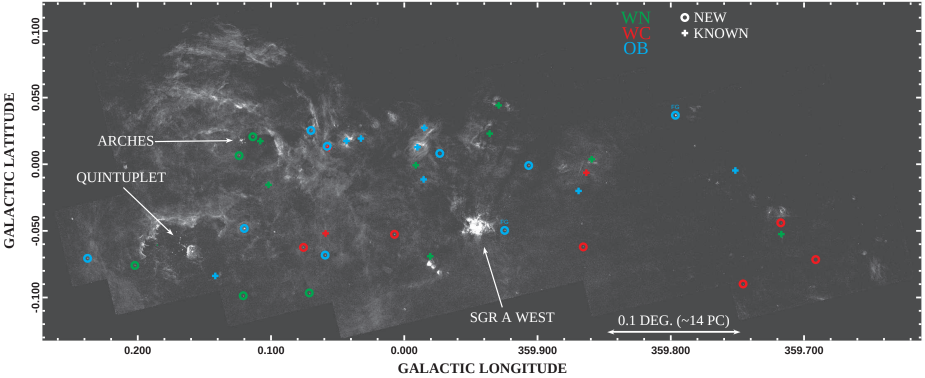


consistent with dynamical evolution of the cluster $\Longrightarrow$ no top-heavy IMF is required

Isolated massive stars in the GC

Paschen-alpha survey, Mauerhan et al. (2010)



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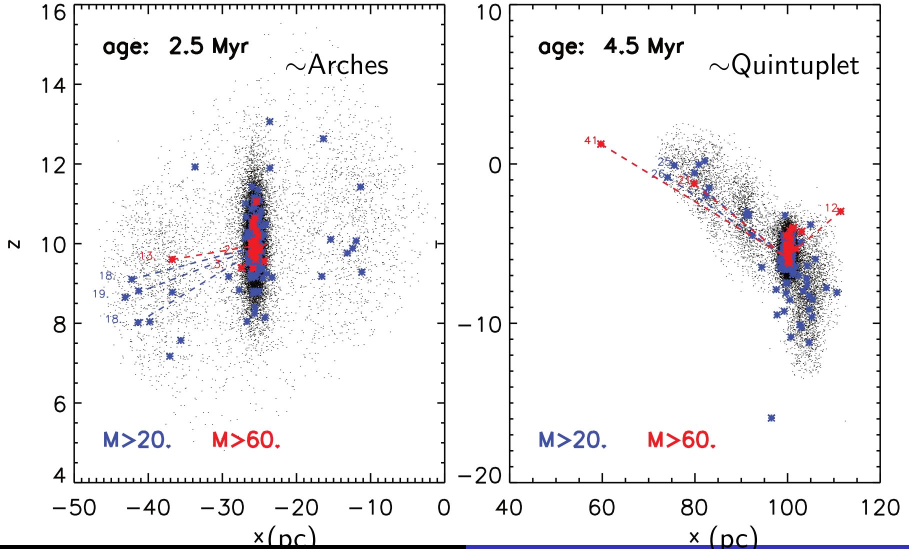

Summary

- Assuming two commonly used extinction laws :
  high and variable extinction ($2 < A_k < 4$)
  difference in extracted mass $\longrightarrow$ can reach up to 30%.
- Present-day mass function of the cluster:
  $\alpha = -1.76 \pm 0.22$ in the core
  $\alpha = -2.23 \pm 0.27$ in the intermediate annulus
  $\alpha = -2.95 \pm 0.26$, in the outer annulus.
- Comparing to Dynamical simulation of the cluster $\longrightarrow$ trend in the slope of mass function is consistent with dynamical mass segregation, no need to invoke different star formation scenario.
- To investigate the contribution of known clusters to the Galactic center environment $\longrightarrow$ can explain a considerable fraction of isolated WR population in the Galactic center region.

Thank you for listening.