Dynamics of young starburst clusters in the Galactic centre and the spiral arms

Andrea Stolte

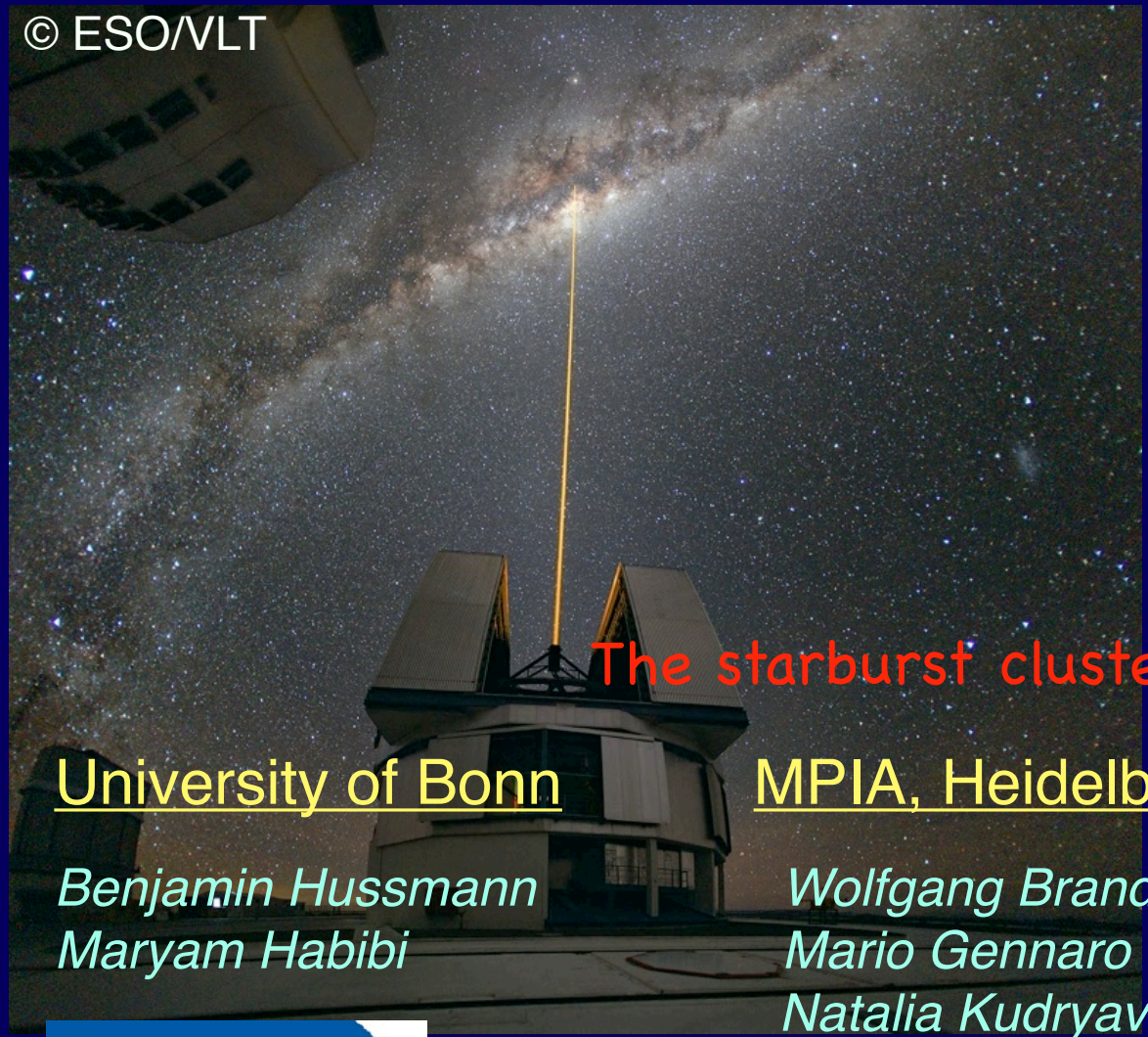
Argelander Institut für Astronomie
Universität Bonn

Dynamics of Low-Mass Stellar Systems

Santiago

4 - 9 April 2011

Dynamics of young starburst clusters in the Galactic centre and the spiral arms



The starburst cluster connection

University of Bonn

Benjamin Hussmann
Maryam Habibi

MPIA, Heidelberg

Wolfgang Brandner
Mario Gennaro
Natalia Kudryavtseva
Boyke Rochau
Arjan Bik

UCLA

Mark Morris
Andrea Ghez
Jessica Lu (Caltech)
Tuan Do
Will Clarkson (Indiana)
Nate McCrady (Montana)

Emmy Noether-Programm
Deutsche Forschungsgemeinschaft DFG

Dynamics of starburst clusters in the Galactic centre and the spiral arms

1. The Milky Way Starburst cluster surveys
2. Velocity dispersion measurements
   - in Galactic centre clusters
   - in spiral arm clusters
3. The luminosity-sigma relation of stellar systems
4. Open questions

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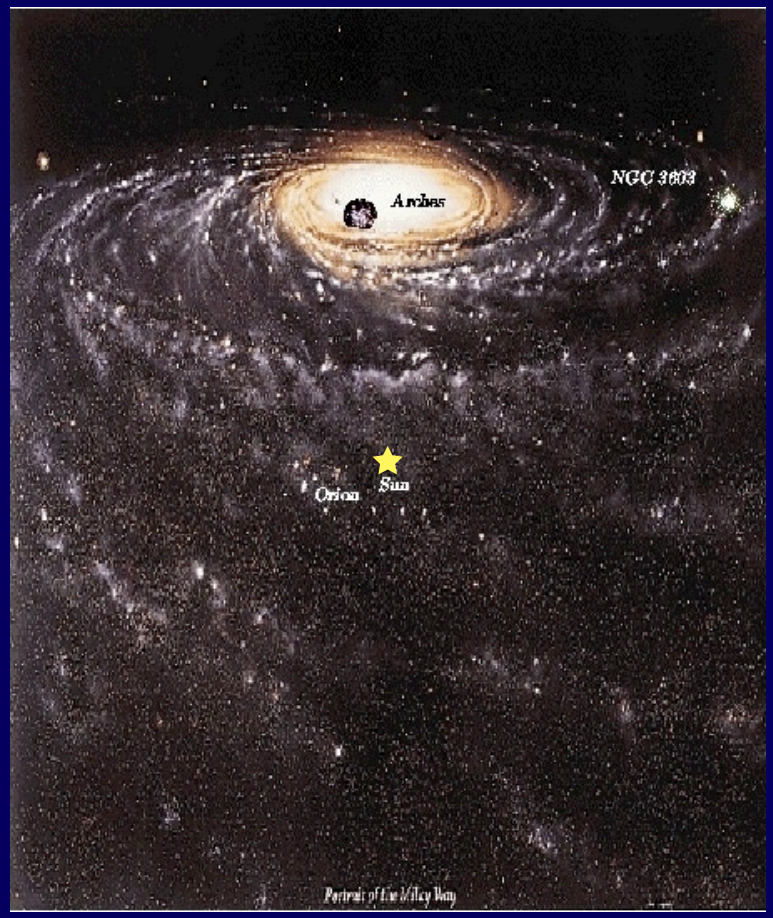
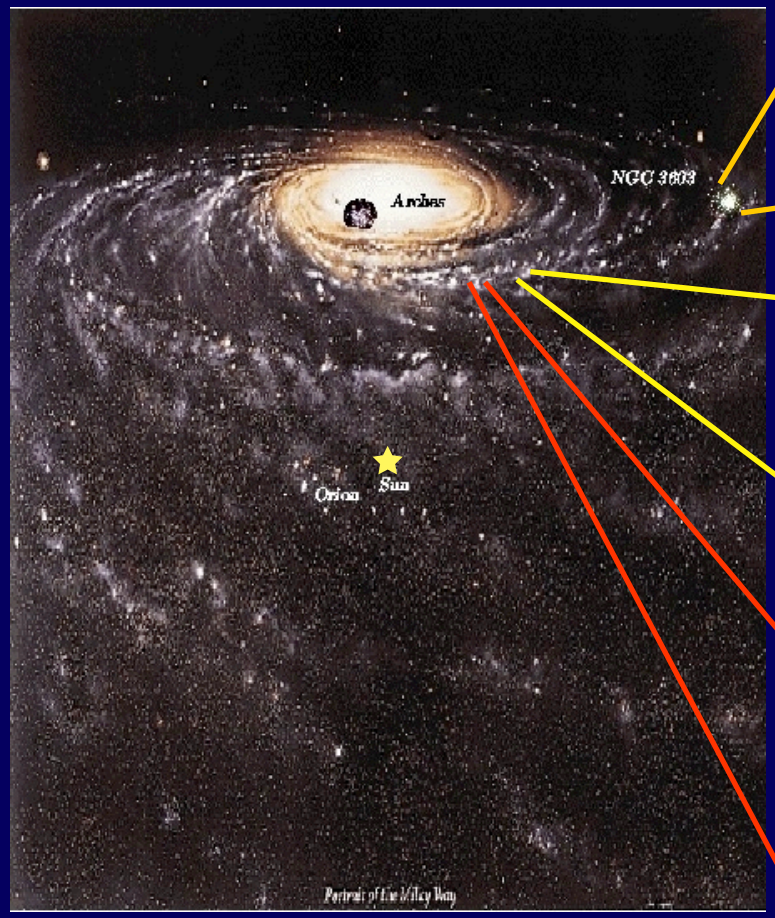
The Milky Way Starburst Cluster Zoo



Portrait of the Milky Way *Jon Lomberg*

The Milky Way Starburst Cluster Zoo



Portrait of the Milky Way *Jon Lomberg*

3'

NGC 3603 YC
Stolte et al. 2004

4'

Westerlund 1
Brandner et al. 2008

3.6'

Westerlund 2
Ascenso et al. 2007

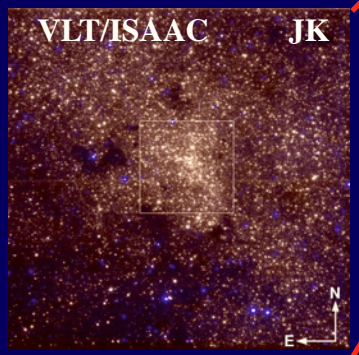
The Milky Way Starburst Cluster Zoo

27”

GC Arches
Stolte et al. 2005

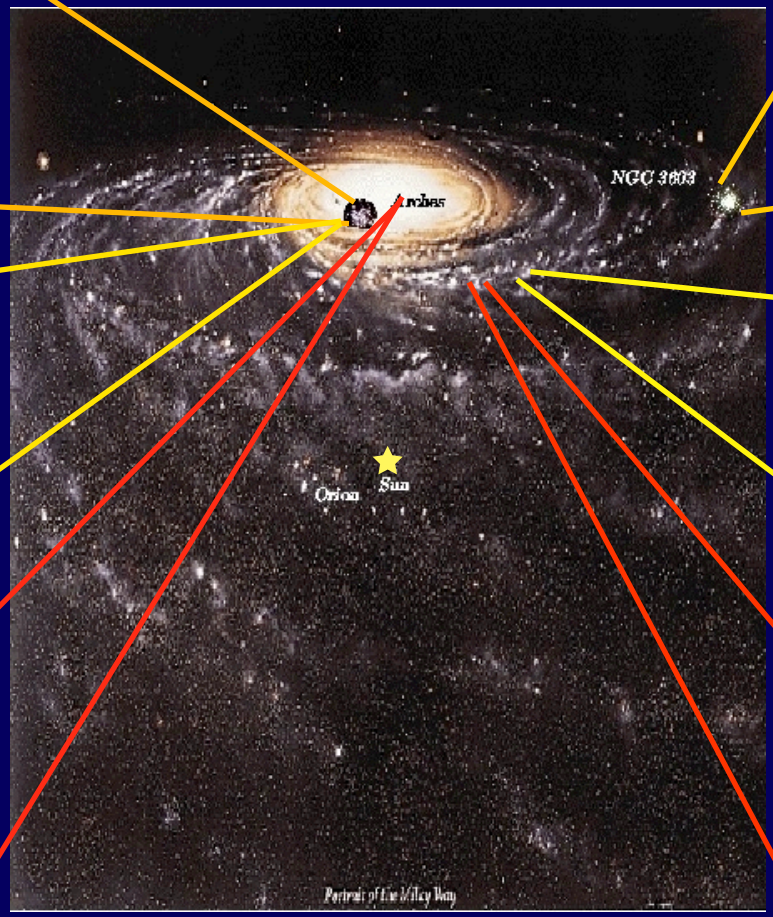
27”

GC Quintuplet
Stolte et al., in prep



2.5’

Nuclear cluster
Schoedel et al. 2007



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Proper motion survey of 4 Milky Way starbursts

Motivation & Aims

Galactic centre

Arches 2.5 Myr

Quintuplet 4-5 Myr

Comparison of

- cluster formation
- cluster dissolution
- stellar mass function

in the Galactic centre
and spiral arm environments

Carina arm

NGC3603 2 Myr

Westerlund 1 3-5 Myr

Internal cluster dynamics

- tidal debris, expansion & disruption
- velocity dispersion & radial variation

Andrea Stolte, Argelander Institut für Astronomie

Proper motion survey of 4 Milky Way starbursts

The Milky way starburst cluster survey

Method:

- precision astrometry
  from diffraction-limited imaging

- 4 clusters with 2 epochs

  VLT/NAOS-CONICA 27” field

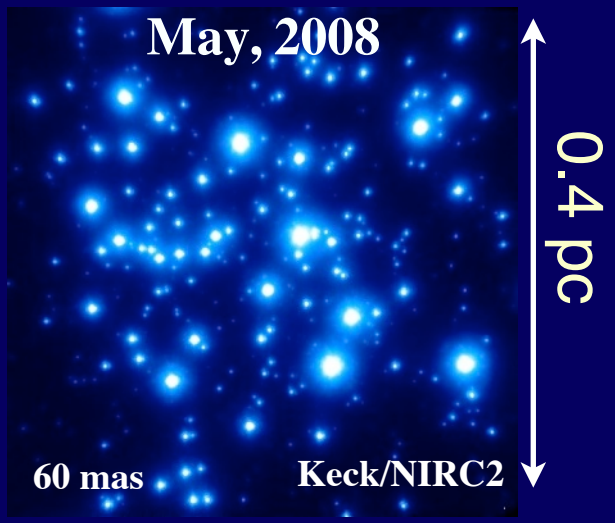
  HST/WFPC2 160” extent

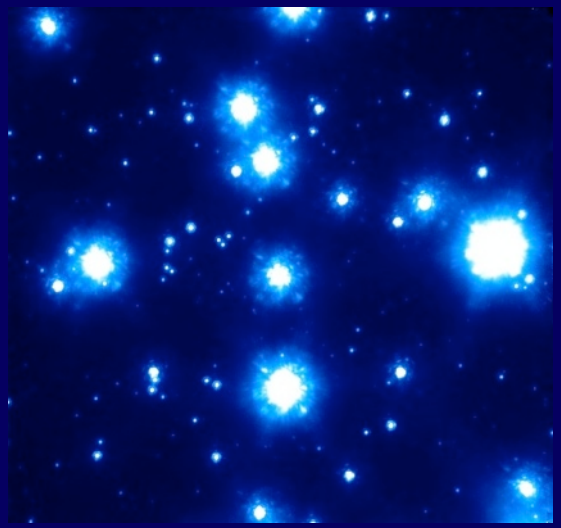
Rochau et al. 2010

Proper motion survey of Galactic centre clusters

UCLA Keck/NIRC2 survey:

- Arches & Quintuplet
- resolve the cores
- multi-epoch high-precisions



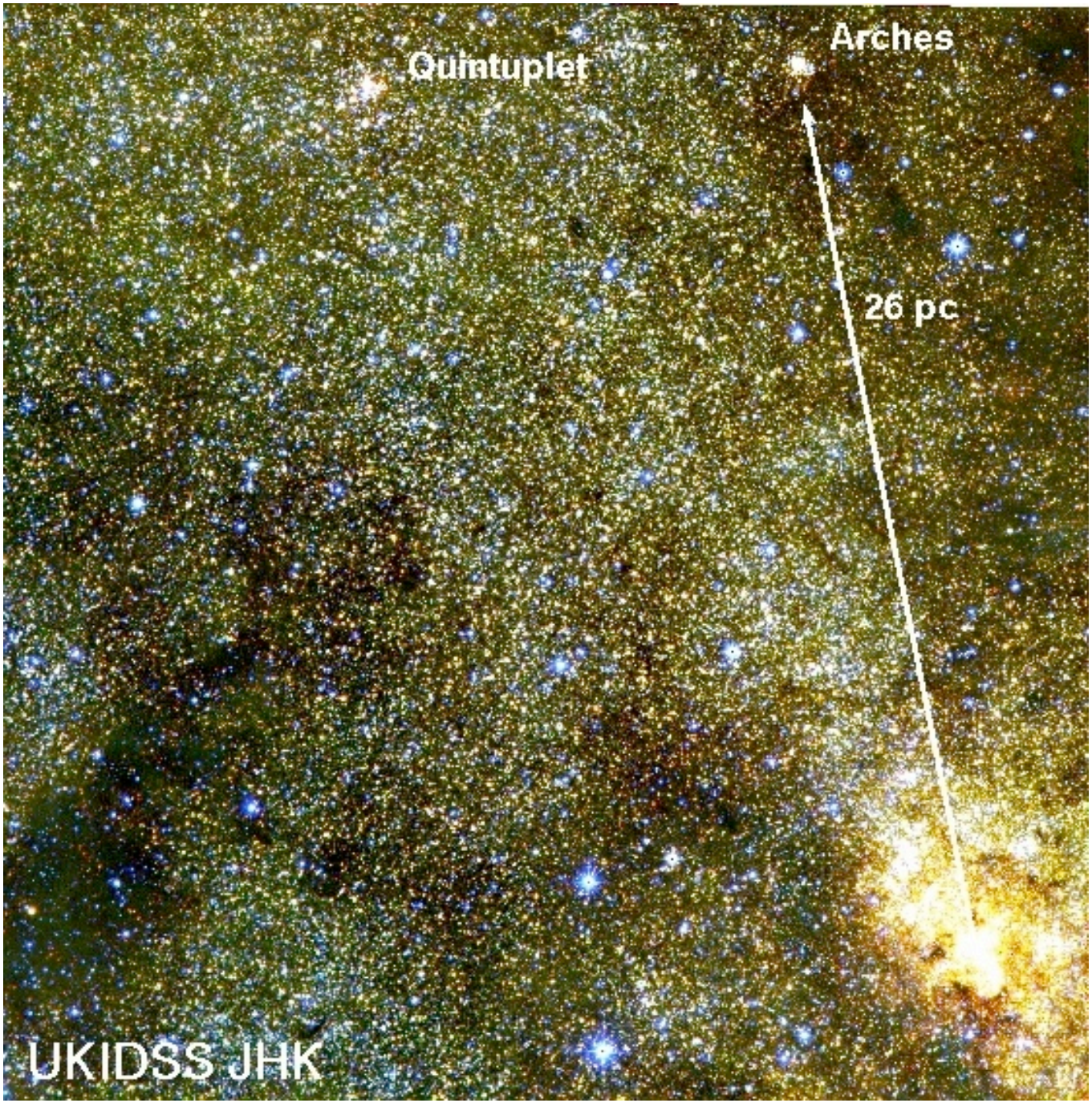


Keck/NIRC2 10” field

=> ideal for internal velocity dispersion

PI: *Mark Morris*

Starburst clusters near the Galactic centre



Starburst clusters near the Galactic centre

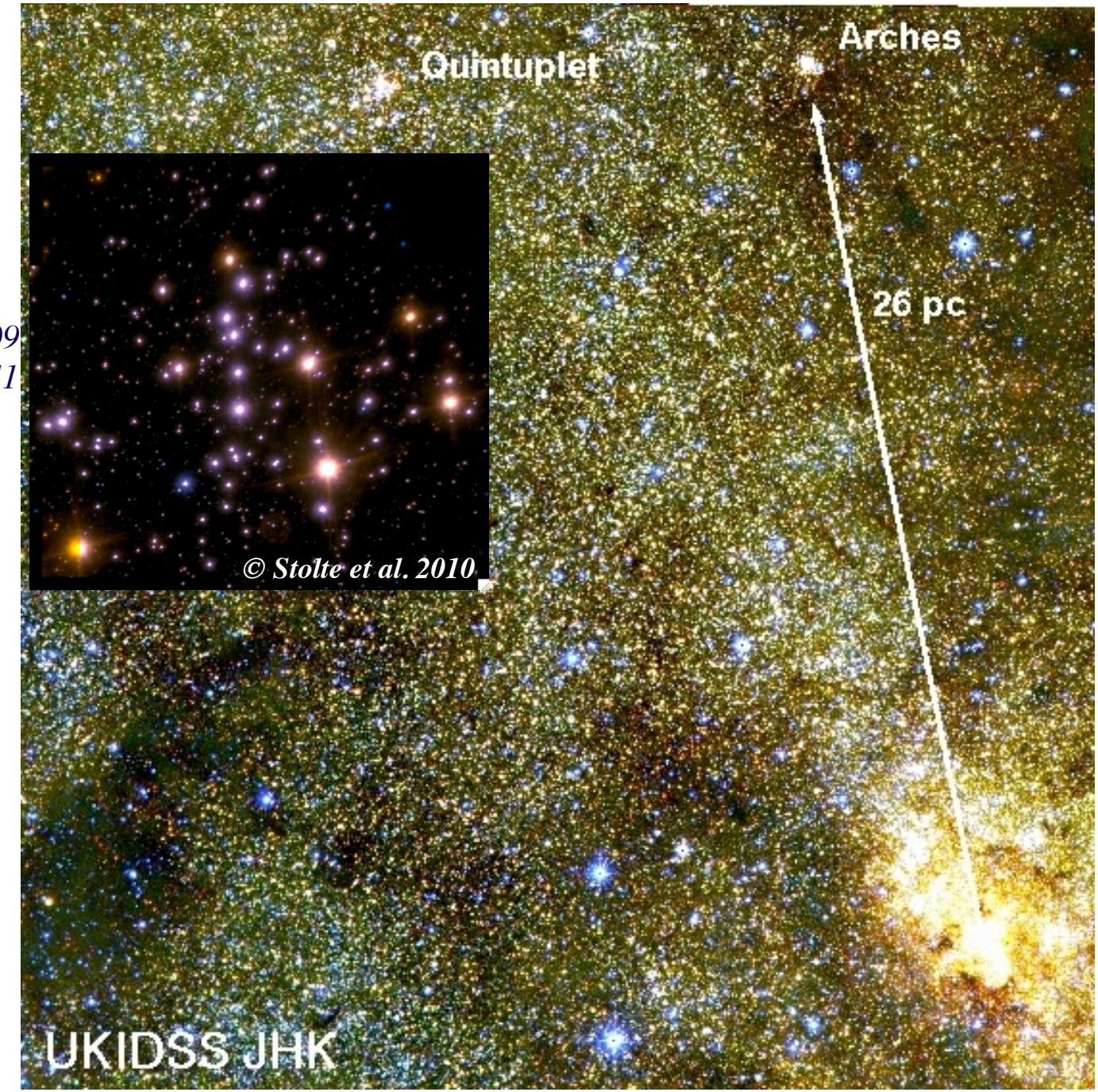
Quintuplet:

4-5 Myr

? Msun

r_gc = 32 pc

Figer et al. 2002
Liermann et al. 2009
Hußmann et al. 2011



Starburst clusters near the Galactic centre

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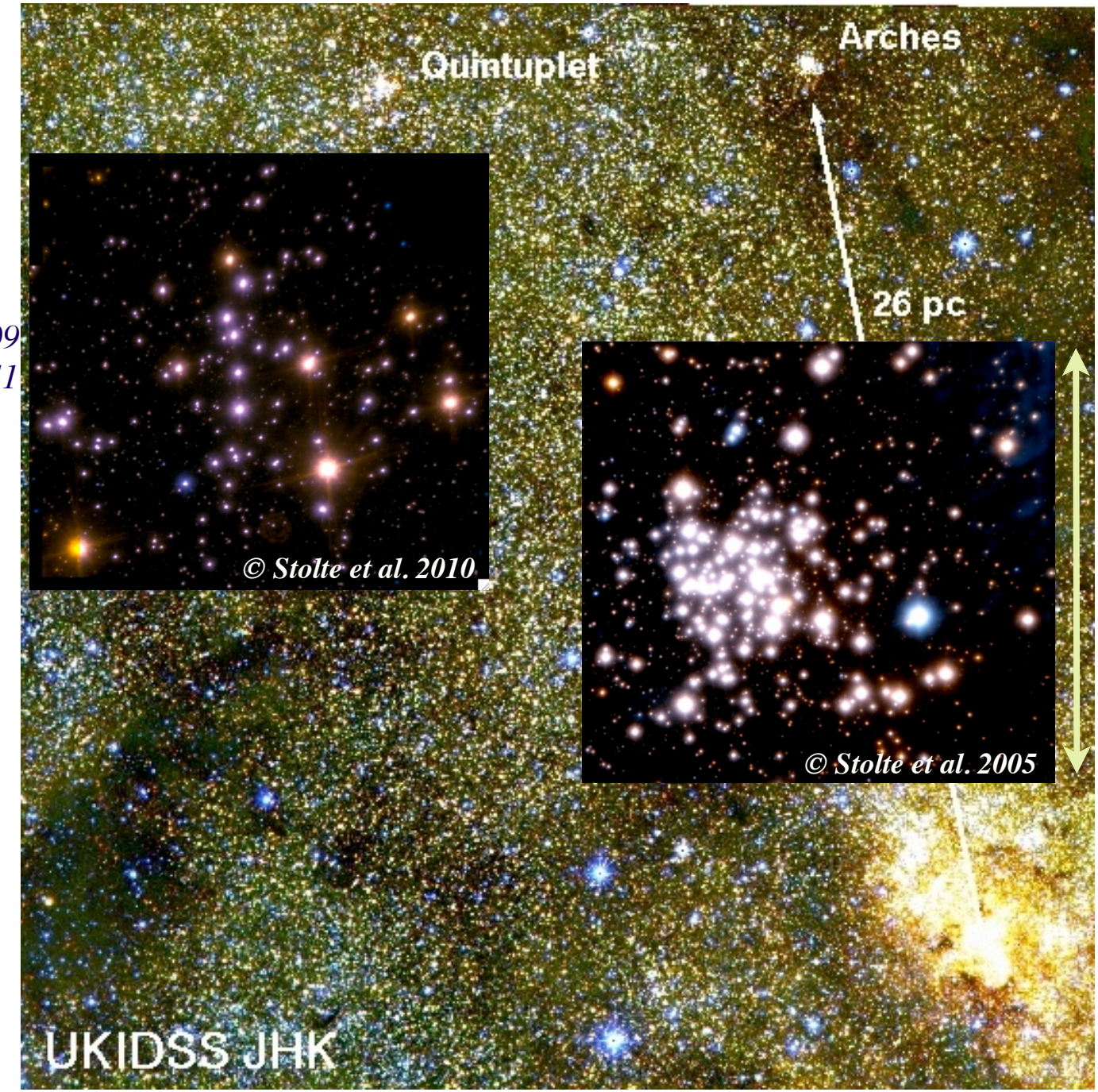


Arches:

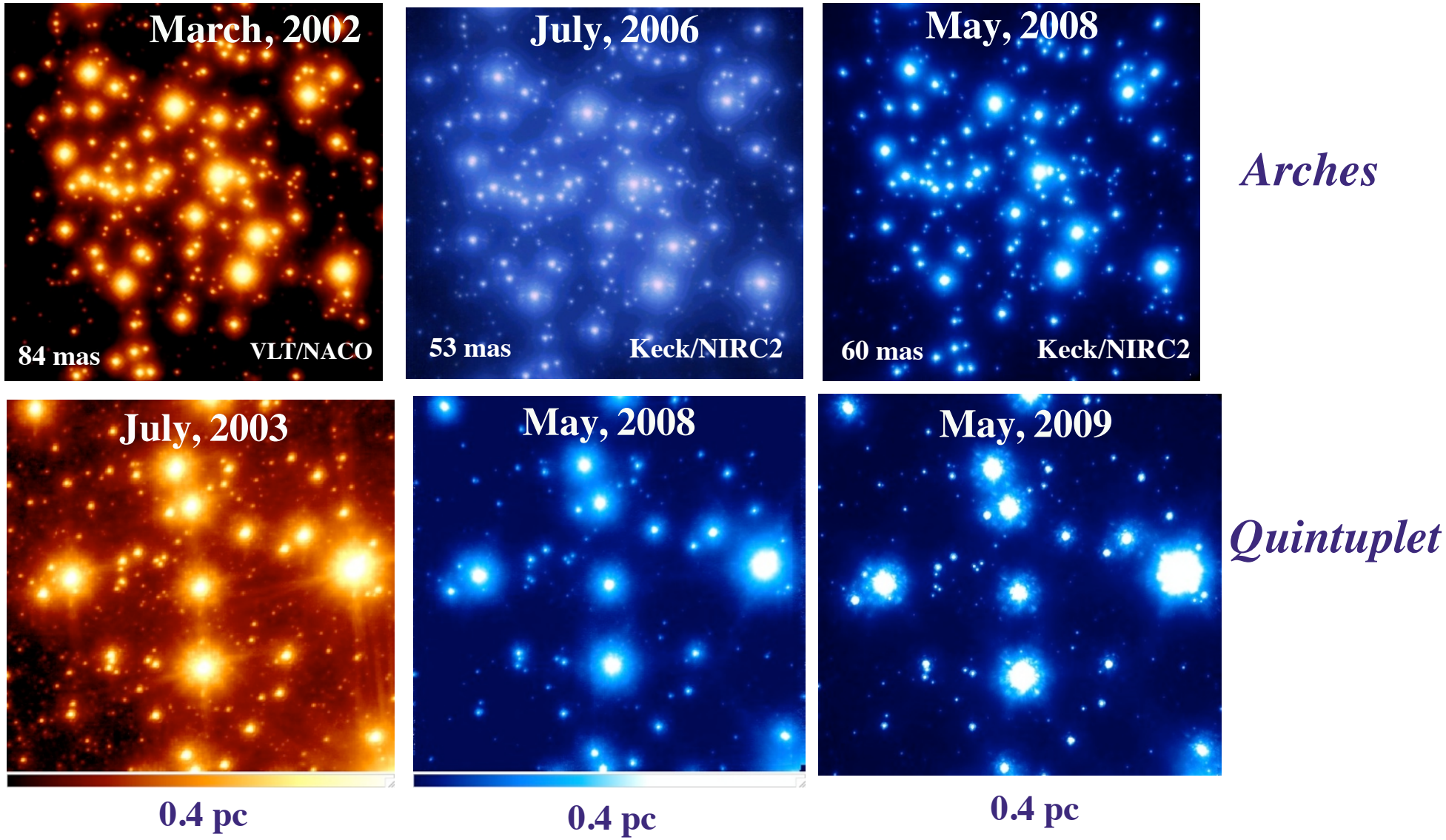
2.5 Myr
20,000 Msun
r_gc = 26 pc

120 O-stars
2 x 10^5 Msun/pc^3

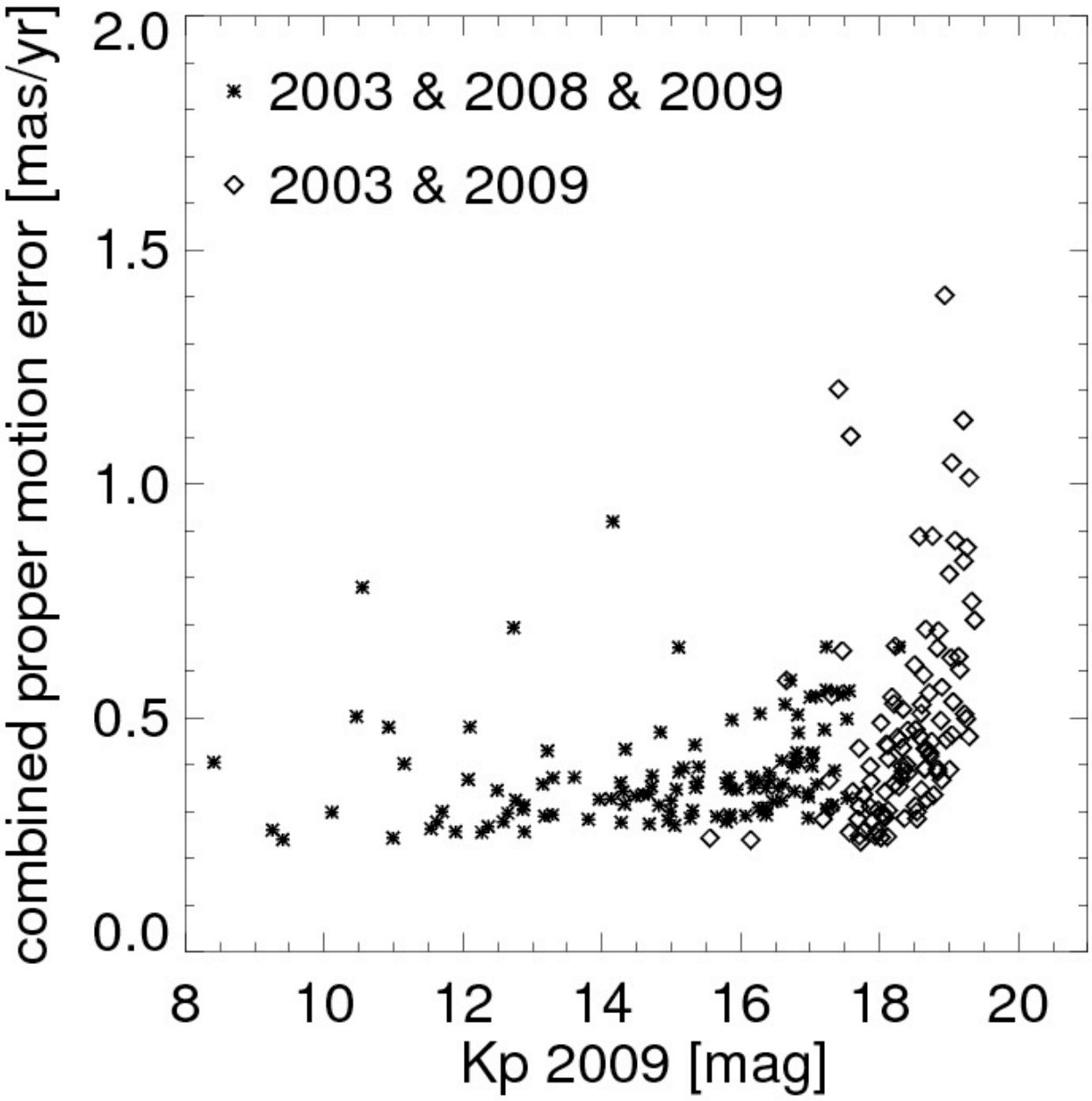
Figer et al. 1999
Stolte et al. 2005
Kim et al. 2006
Martins et al. 2008
Espinoza et al. 2009

Starburst clusters near the Galactic centre

VLT/NAOS-CONICA *Keck/NIRC2 LGS*



Proper motion uncertainties are below ***0.5 mas/yr*** (relative)



0.3 mas/yr

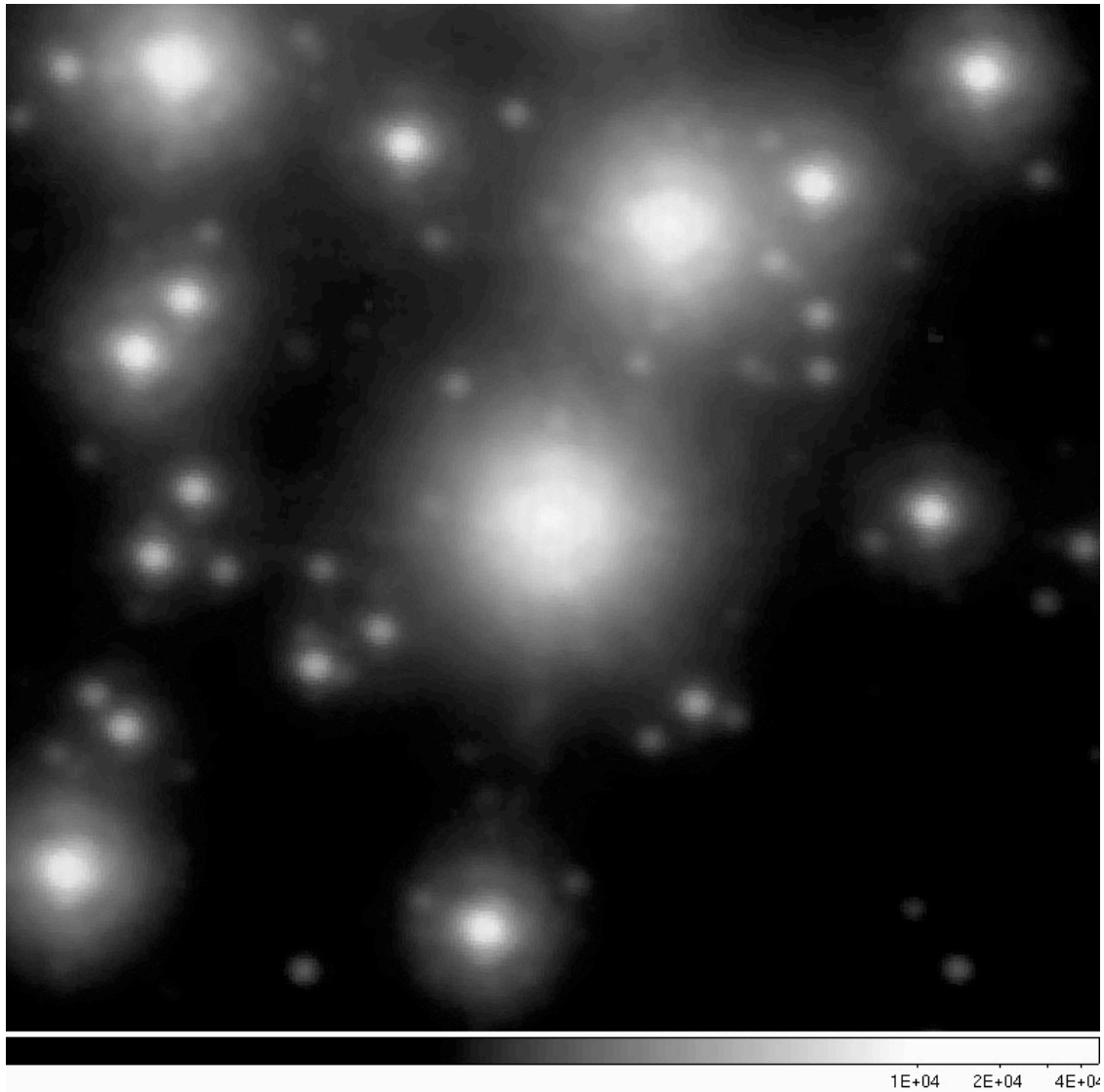
~

11 km/s

at 8 kpc

Deriving proper motions in the cluster reference frame

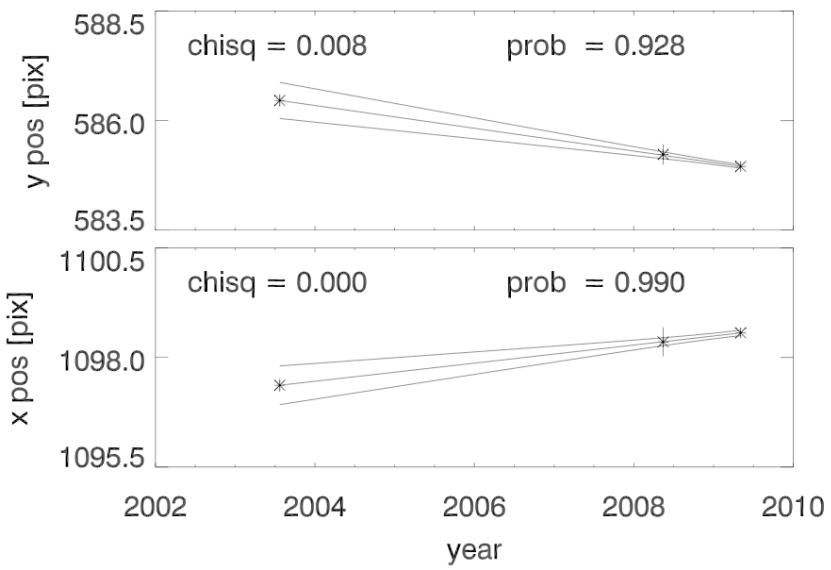
Using a 2nd order polynomial transformation ensures that the ***internal motions*** are ***not altered***

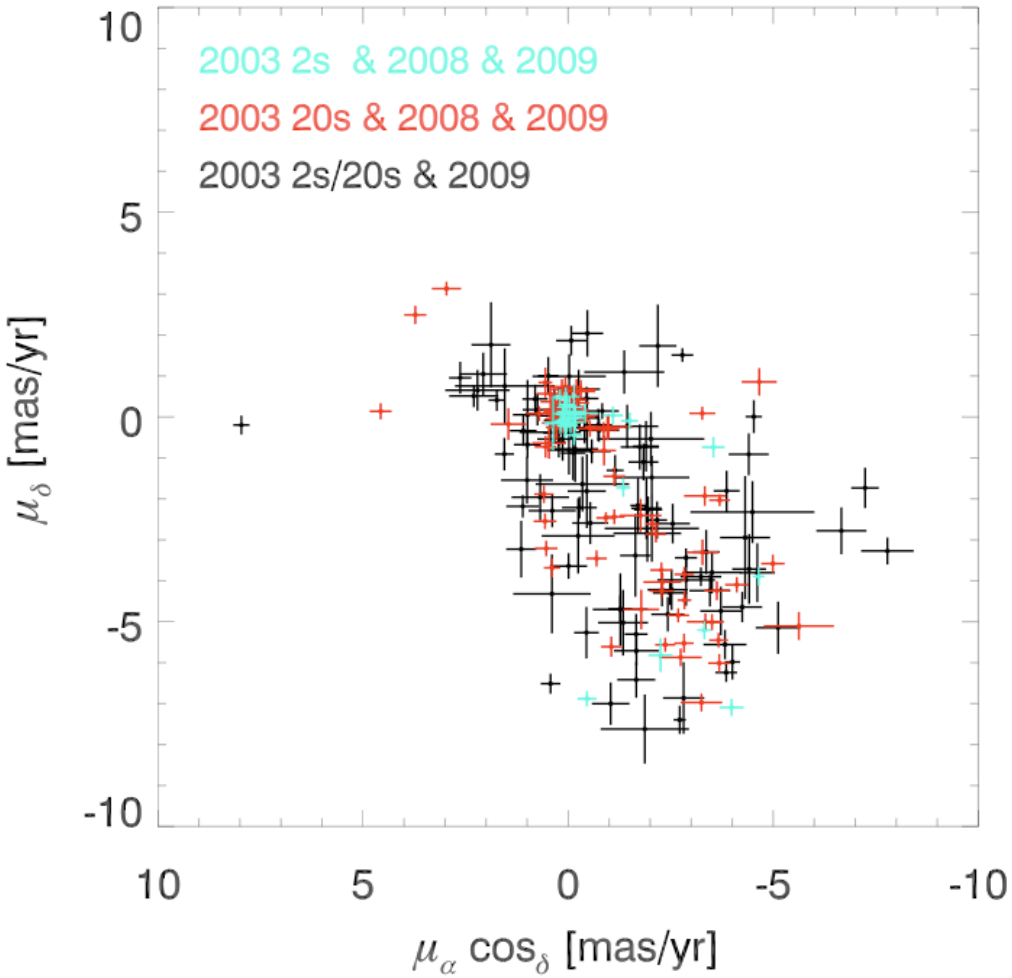


3.6 ”

VLT/NACO	2002	NGS
Keck/NIRC2	2006	LGS
Keck/NIRC2	2008	LGS

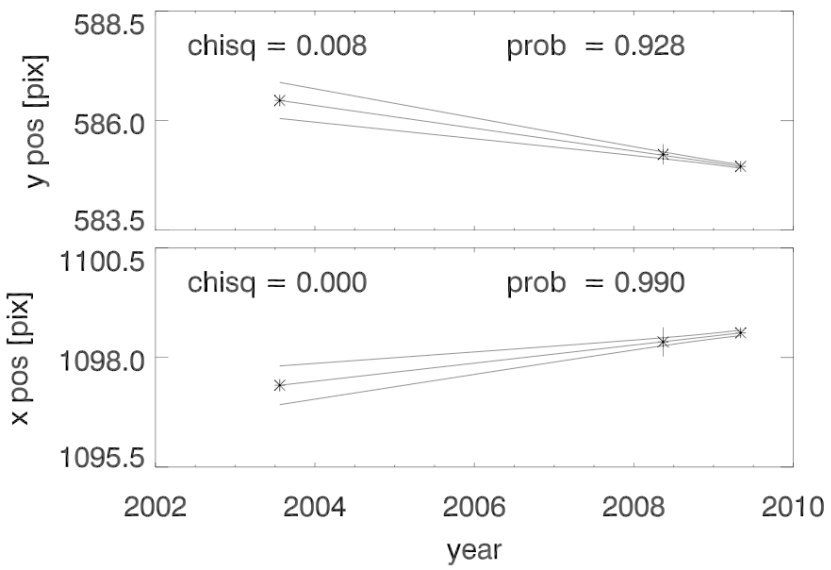
Quintuplet's internal velocity dispersion

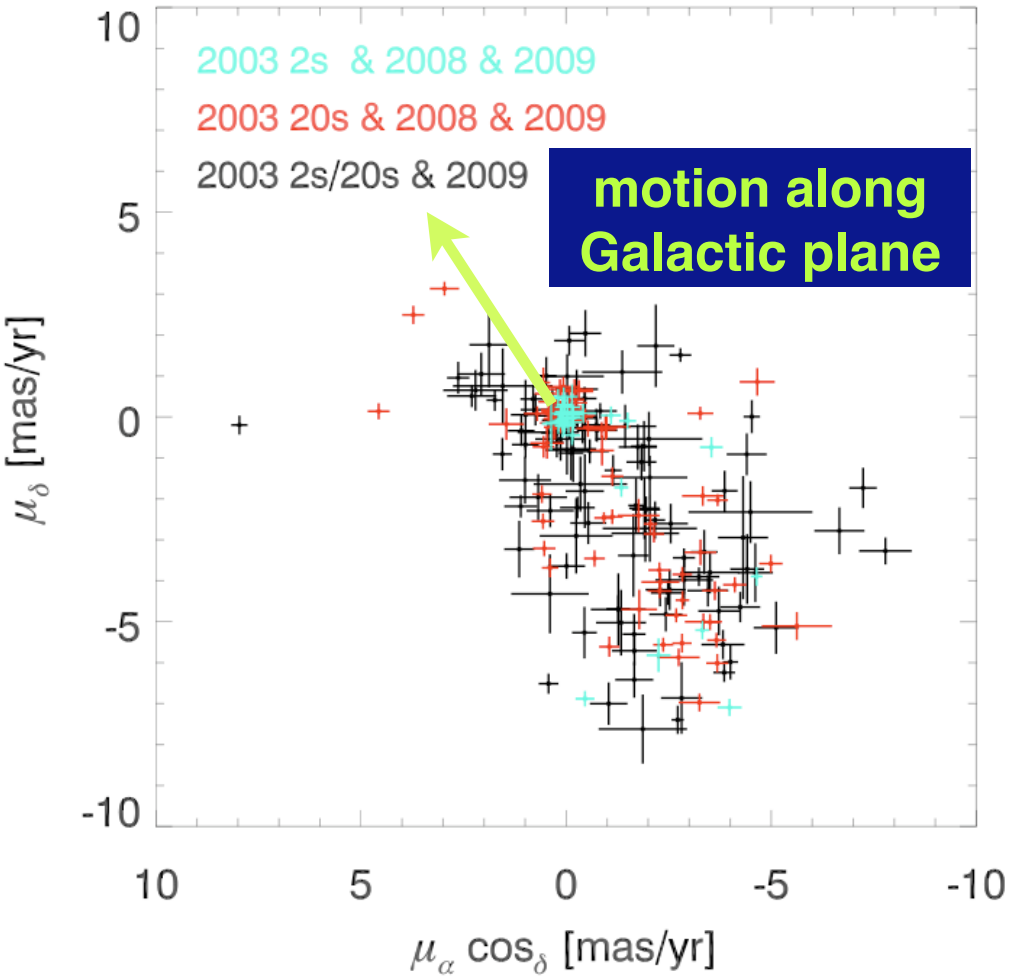




Stolte et al. 2011

Quintuplet's internal velocity dispersion





Stolte et al. 2011

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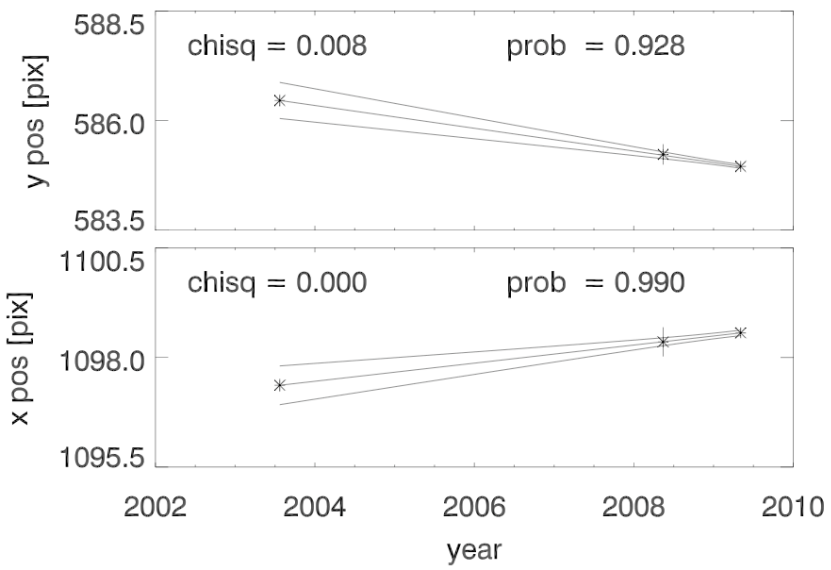
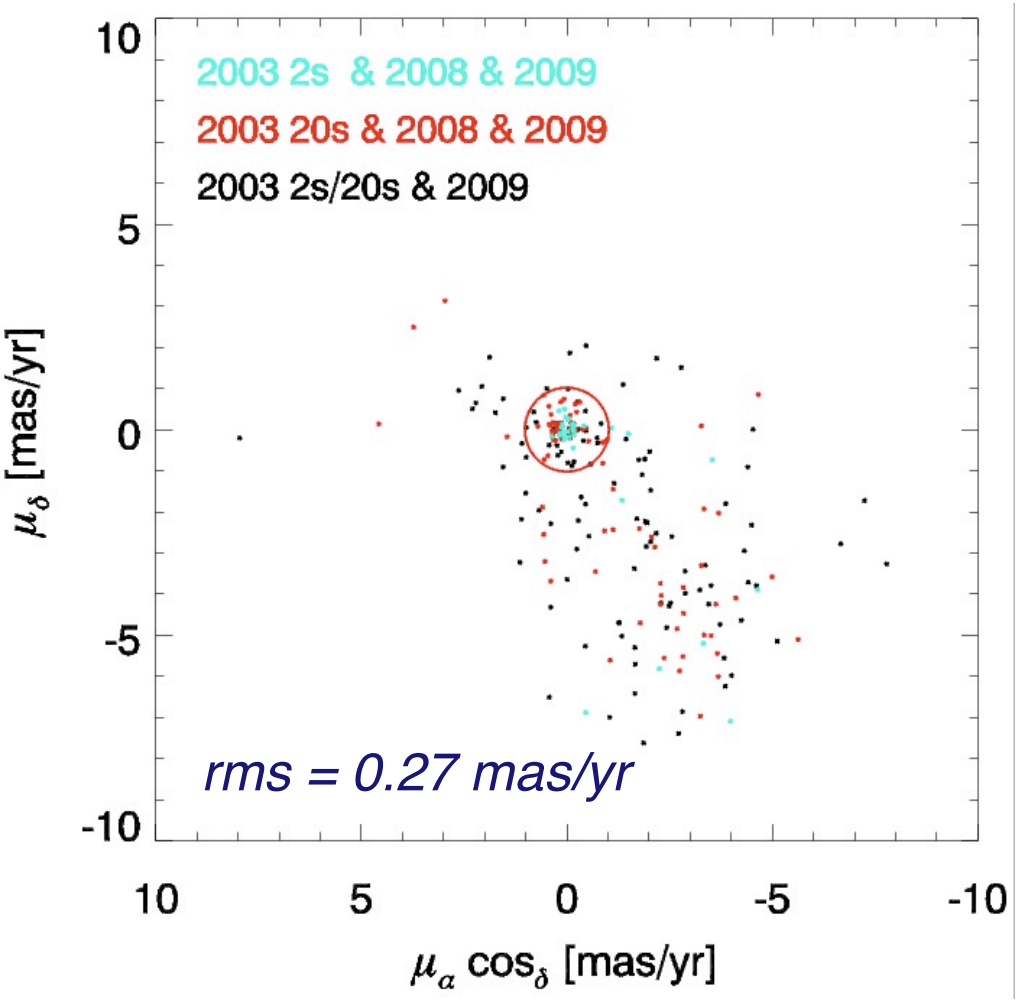
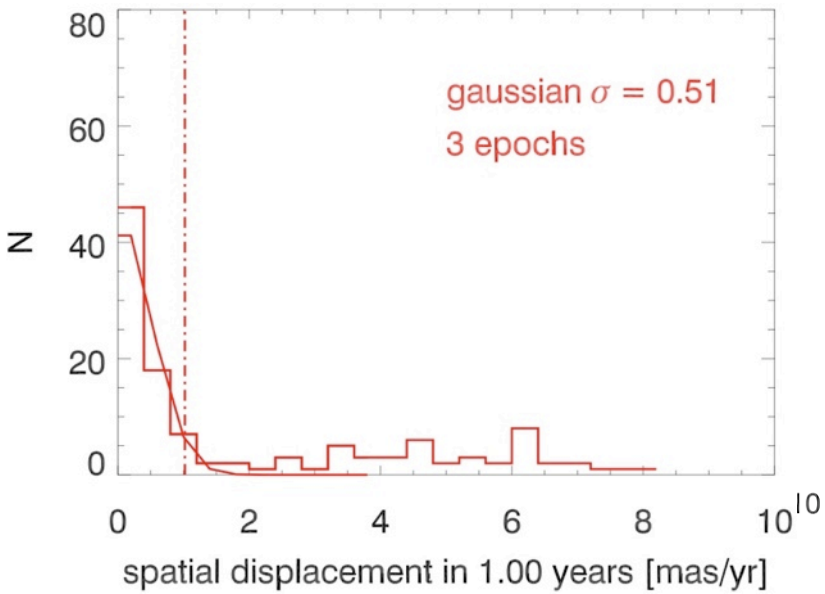


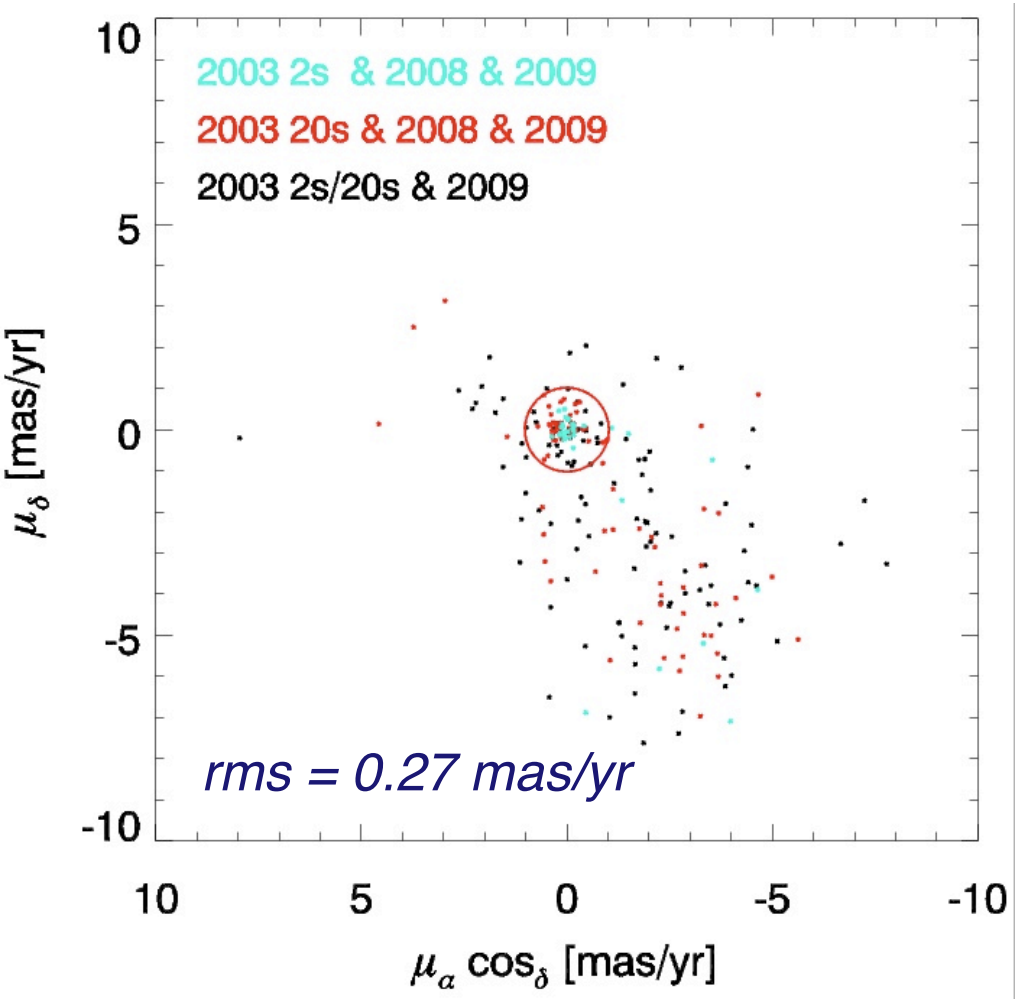


Stolte et al. 2011

Quintuplet's internal velocity dispersion

Sample selection





Stolte et al. 2011

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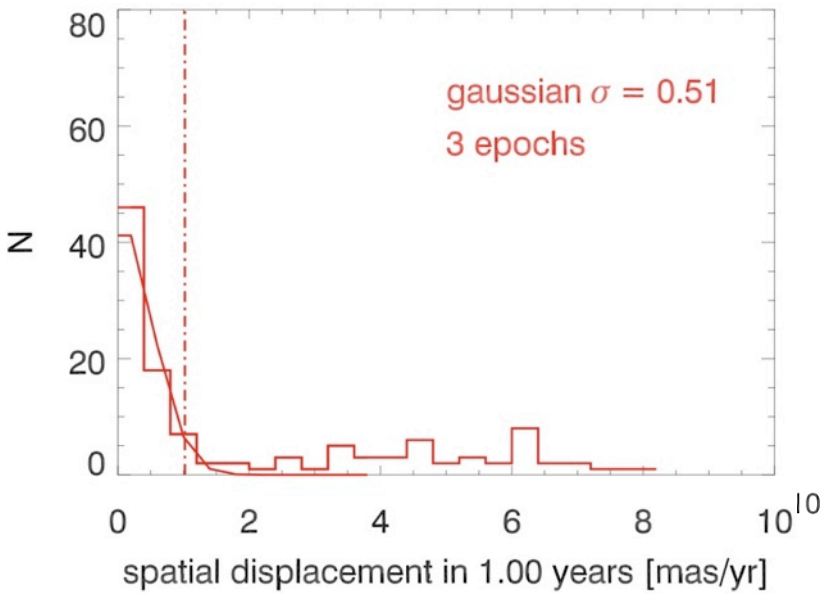
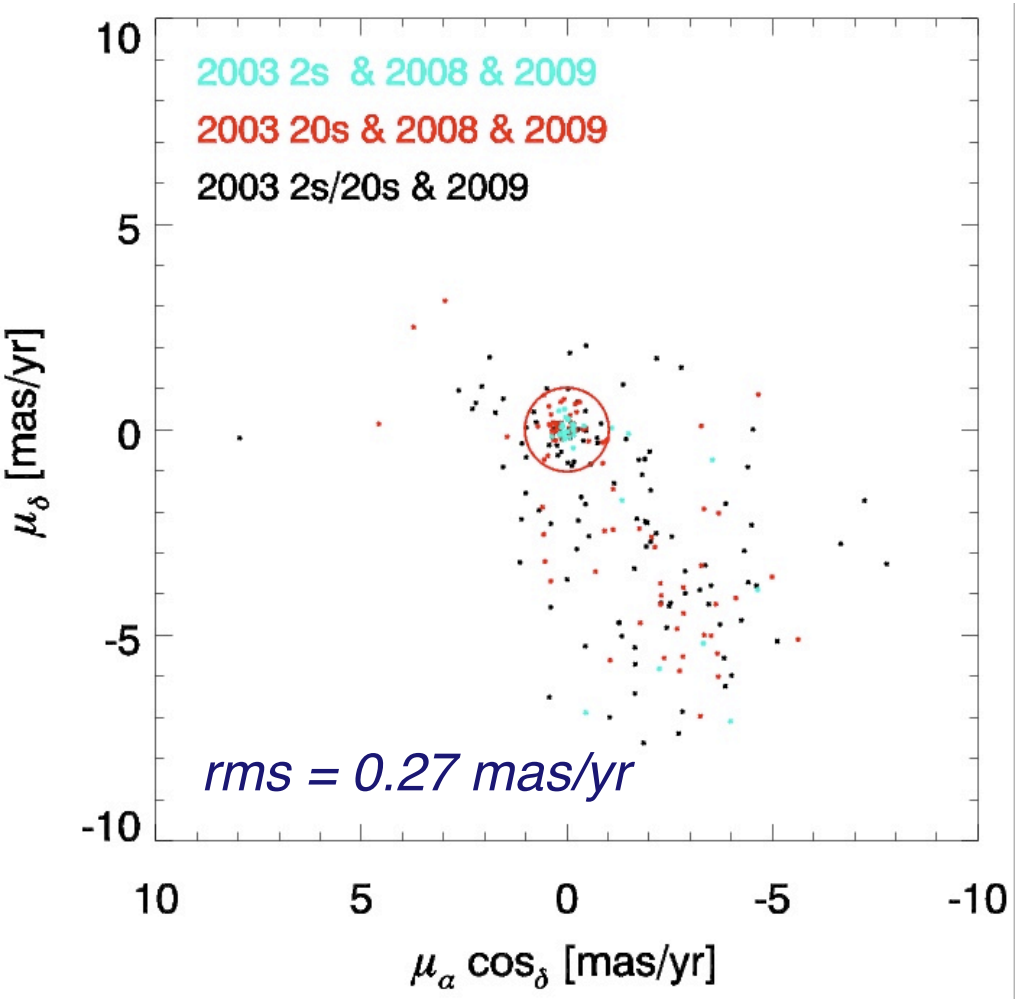


1D velocity dispersion:

σ_{1D} = 10.0 km/s

might be upper limit...



Stolte et al. 2011

Arches's internal velocity dispersion

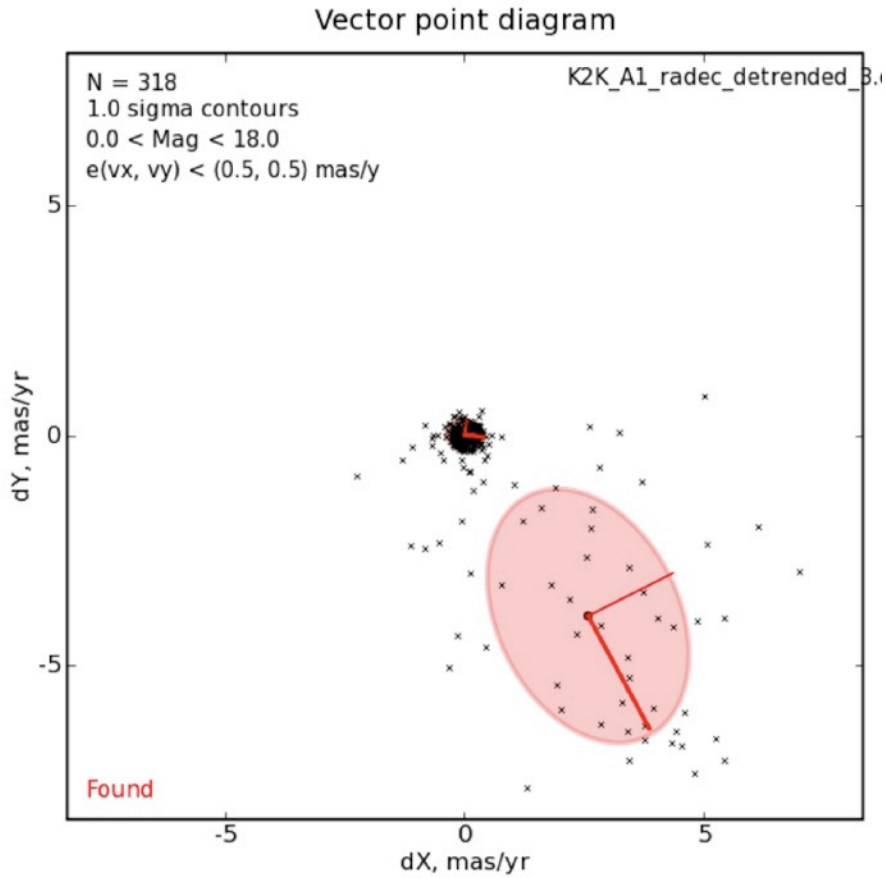
Arches 5 epochs with Keck/NIRC2

1D velocity dispersion

Arches

0.15 +/- 0.01 mas/yr

5.4 +/- 0.4 km/s



Clarkson et al. 2011

Arches's internal velocity dispersion

Arches 5 epochs with Keck/NIRC2

1D velocity dispersion

Arches

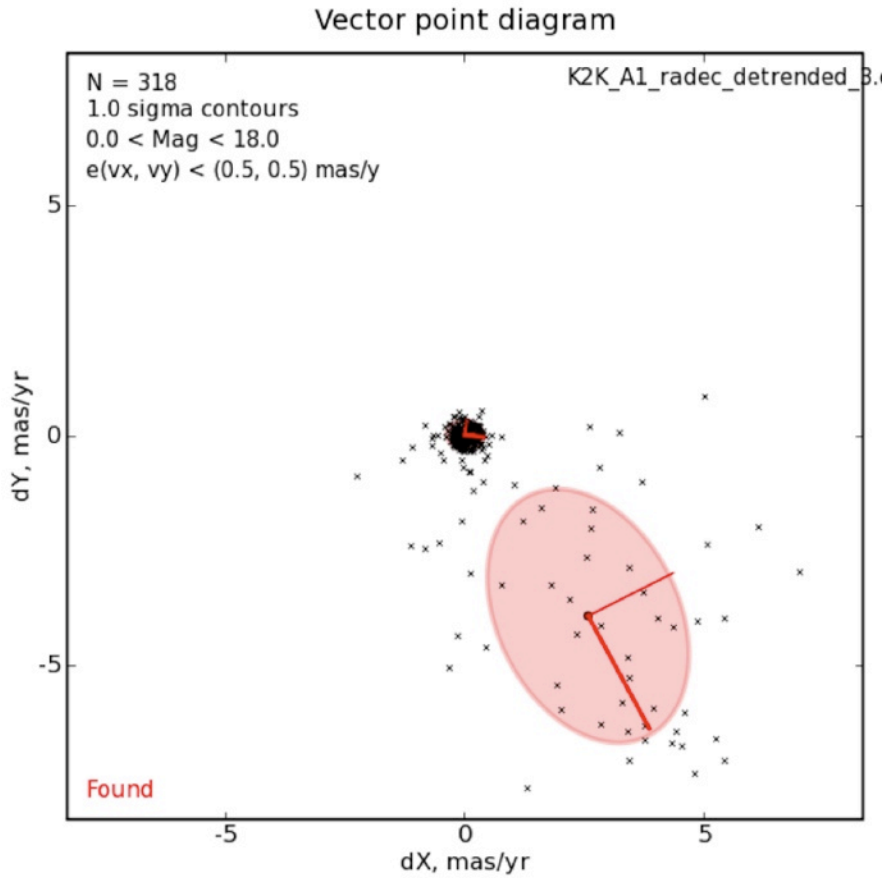
0.15 +/- 0.01 mas/yr

5.4 +/- 0.4 km/s

Quintuplet

0.27 mas/yr

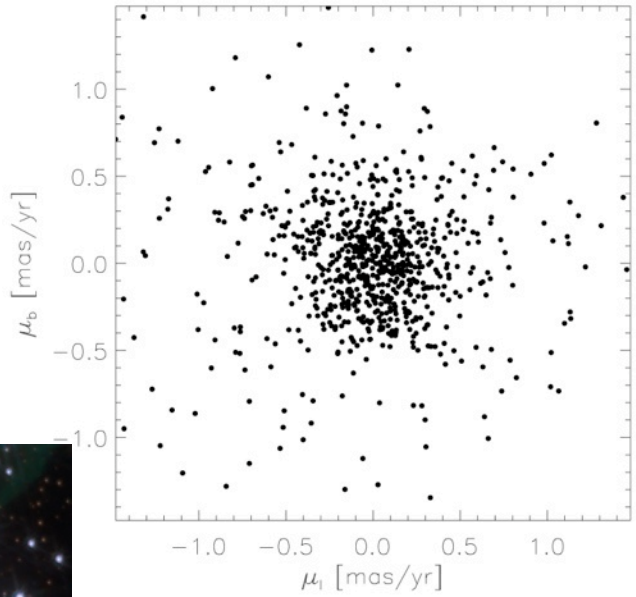
10.0 km/s

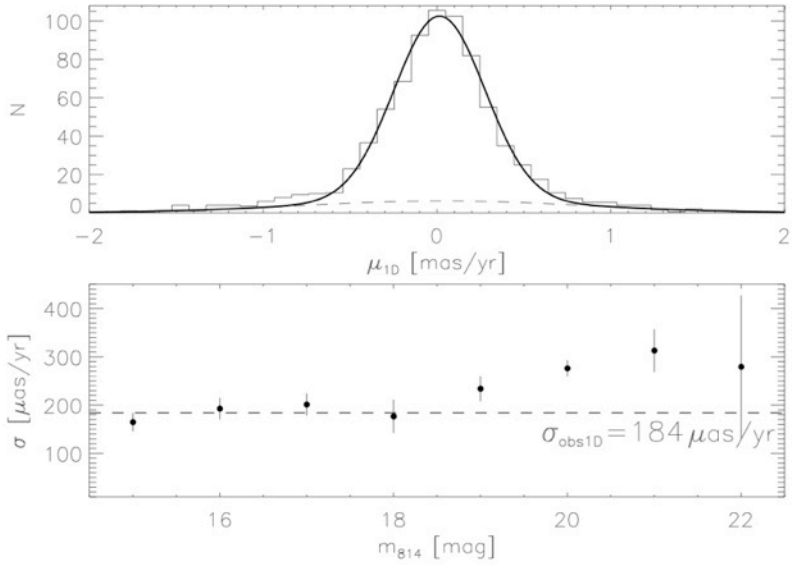


Clarkson et al. 2011

Spiral arm starburst clusters

NGC3603 2 Myr





$\sigma_{1D,\ NGC3603}$ = 4.5 +/- 0.8 km/s

Rochau et al. 2010

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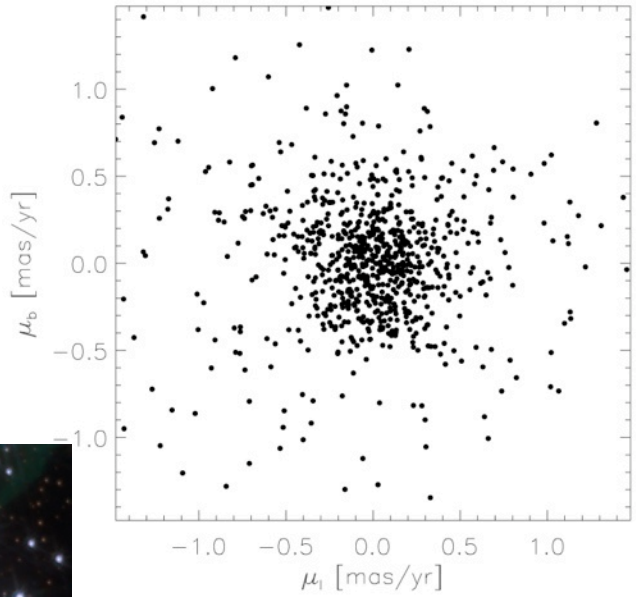
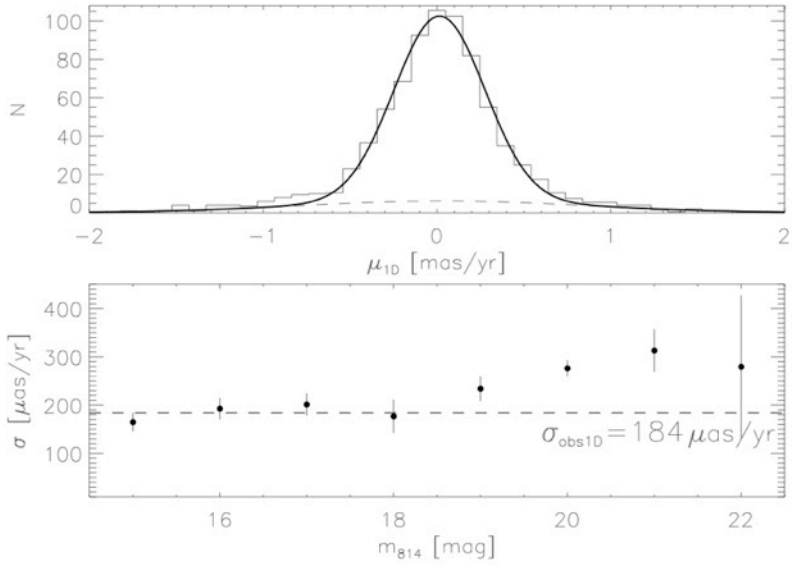




$\sigma_{1D,\ NGC3603}$ = 4.5 +/- 0.8 km/s *Rochau et al. 2010*

σ_{1D} , *Arches* = 5.4 +/- 0.4 km/s

=> similar age, similar evolution in Galactic centre & spiral arms

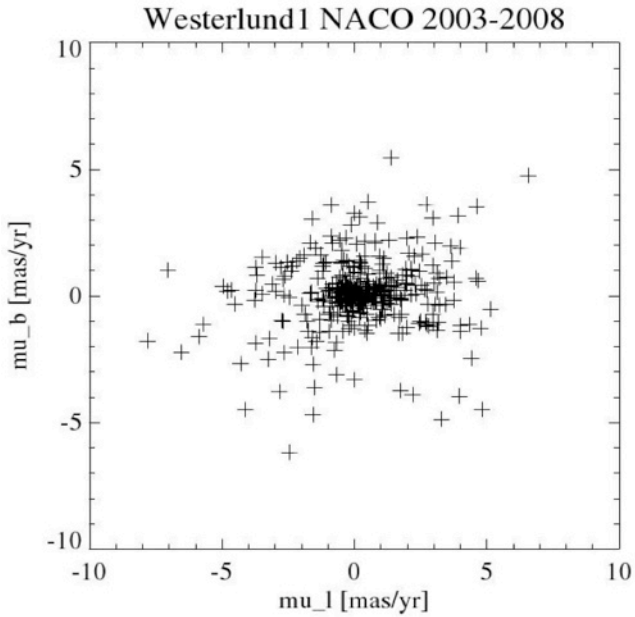
Spiral arm starburst clusters

Westerlund 1 3-5 Myr

$\sigma_{1D,\,long}$ ~ 6 km/s

$\sigma_{1D,\,lat}$ ~ 4 km/s

$\sigma_{1D,\,ave}$ ~ 5 km/s



Kudryavtseva et al. 2011

Spiral arm starburst clusters

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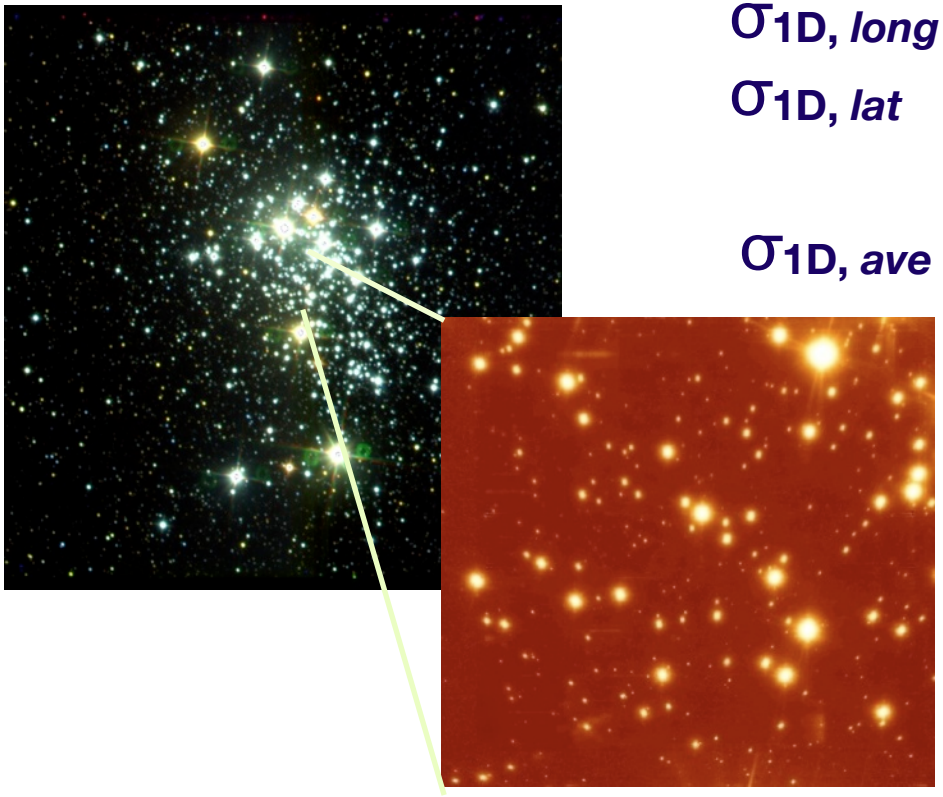

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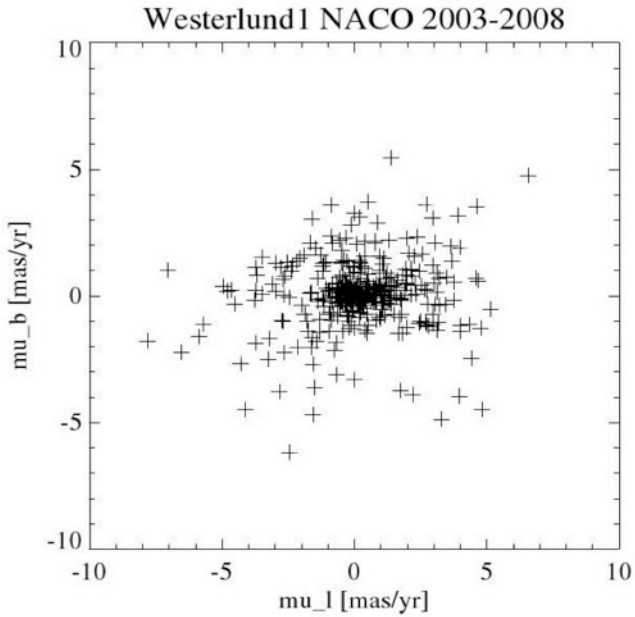

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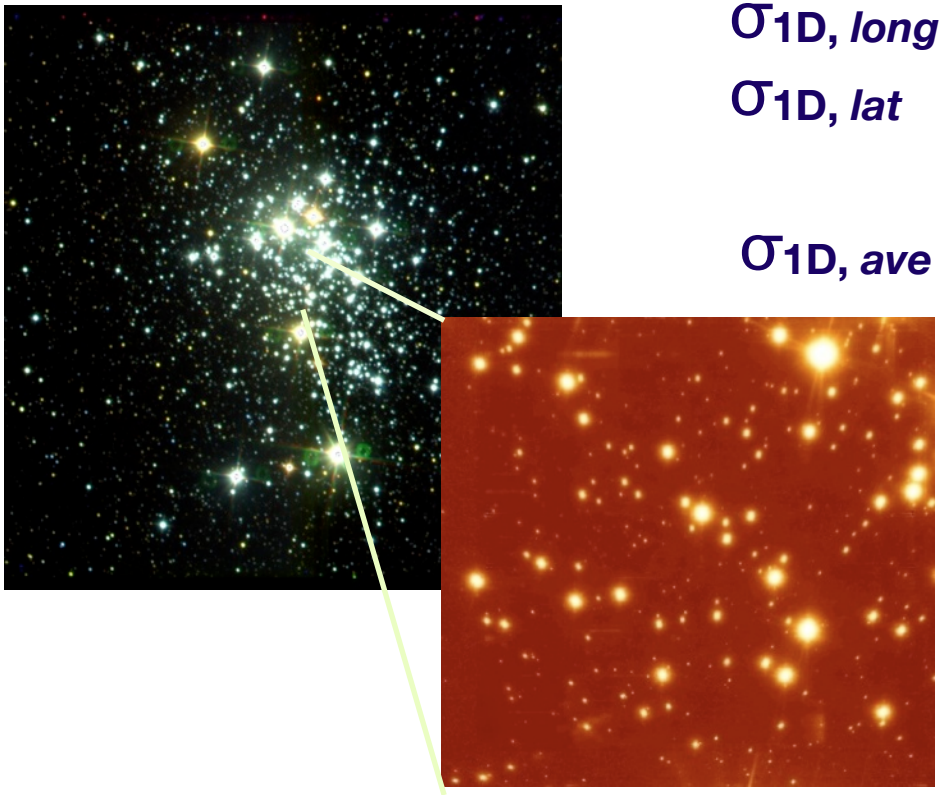

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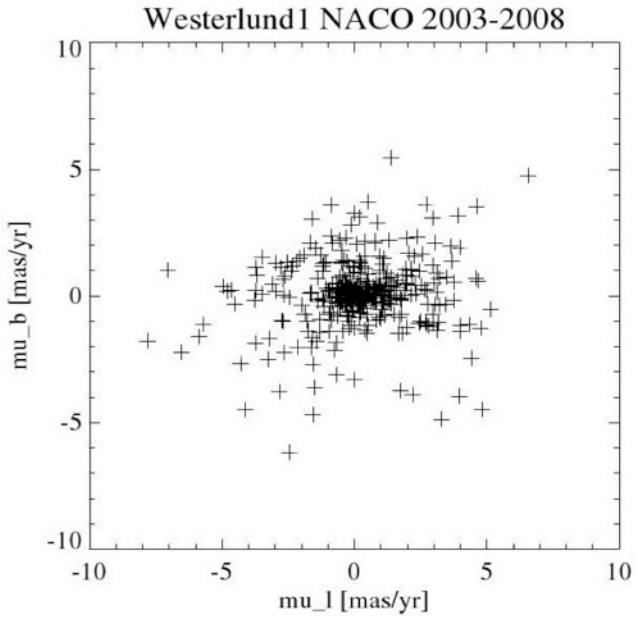

Kudryavtseva et al. 2011

line-of-sight velocity dispersion:

σ_{vrad} = 9.2 +/- 2.5 km/s

4 red supergiants
5 yellow hypergiants
1 B emission line star

Mengel & Tacconi-Garman 2009

Spiral arm starburst clusters

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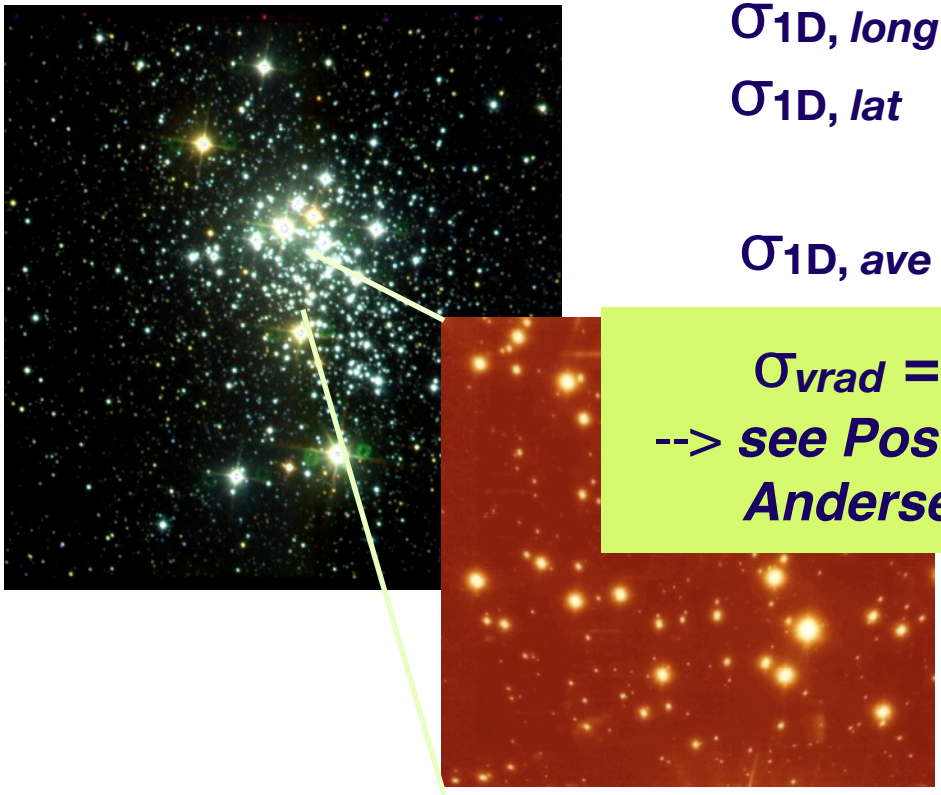

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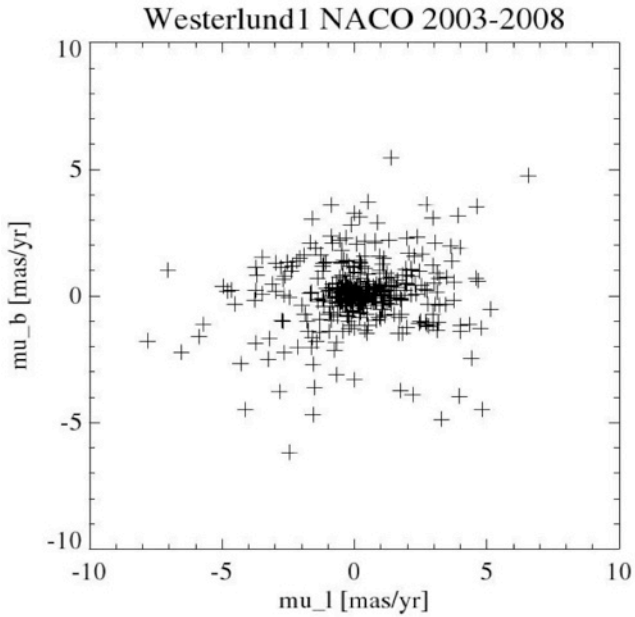
--> ***see Poster: Andersen et al***



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A "Faber-Jackson-type" relation for star clusters ?

Andrea Stolte, Argelander Institut für Astronomie

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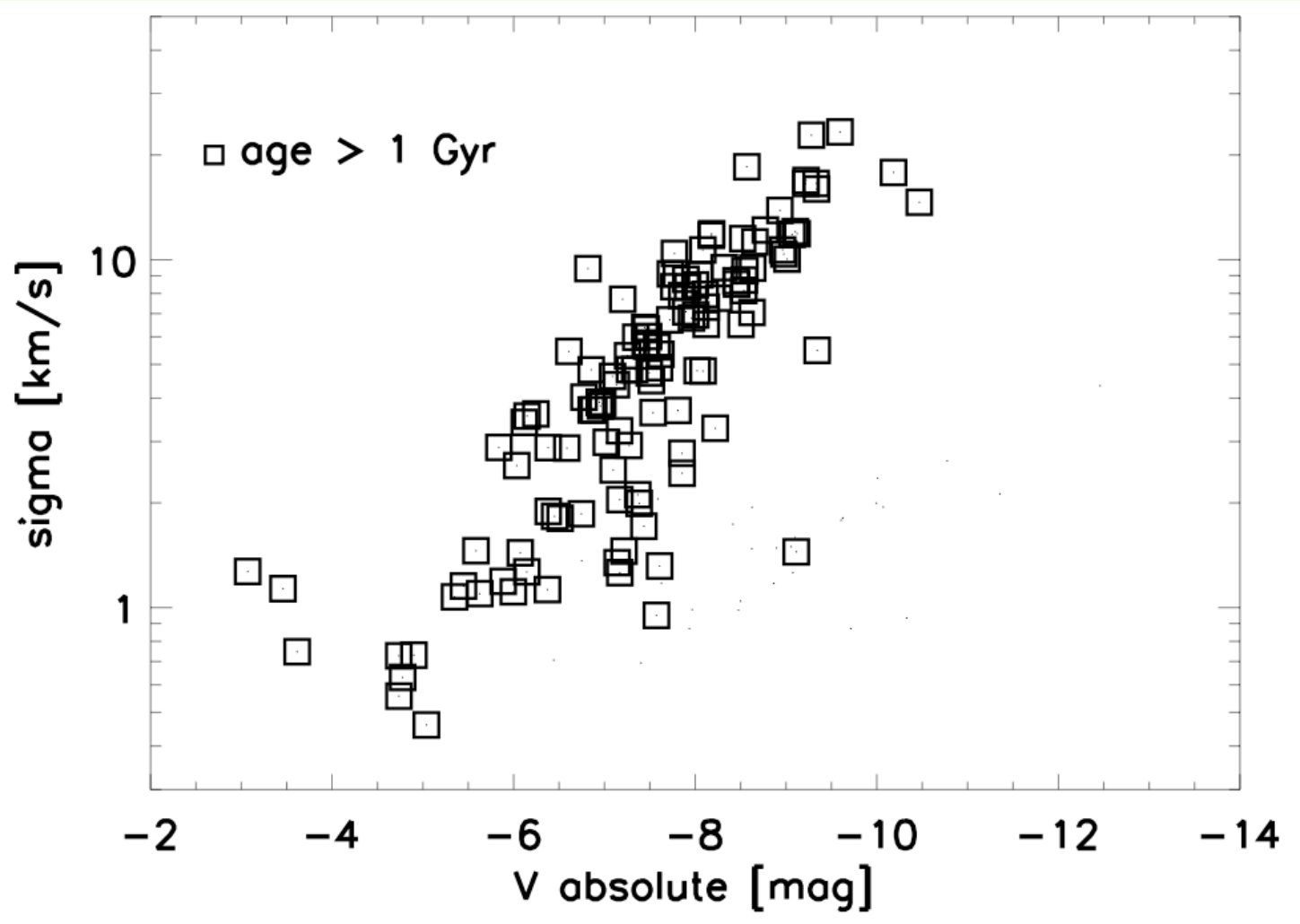
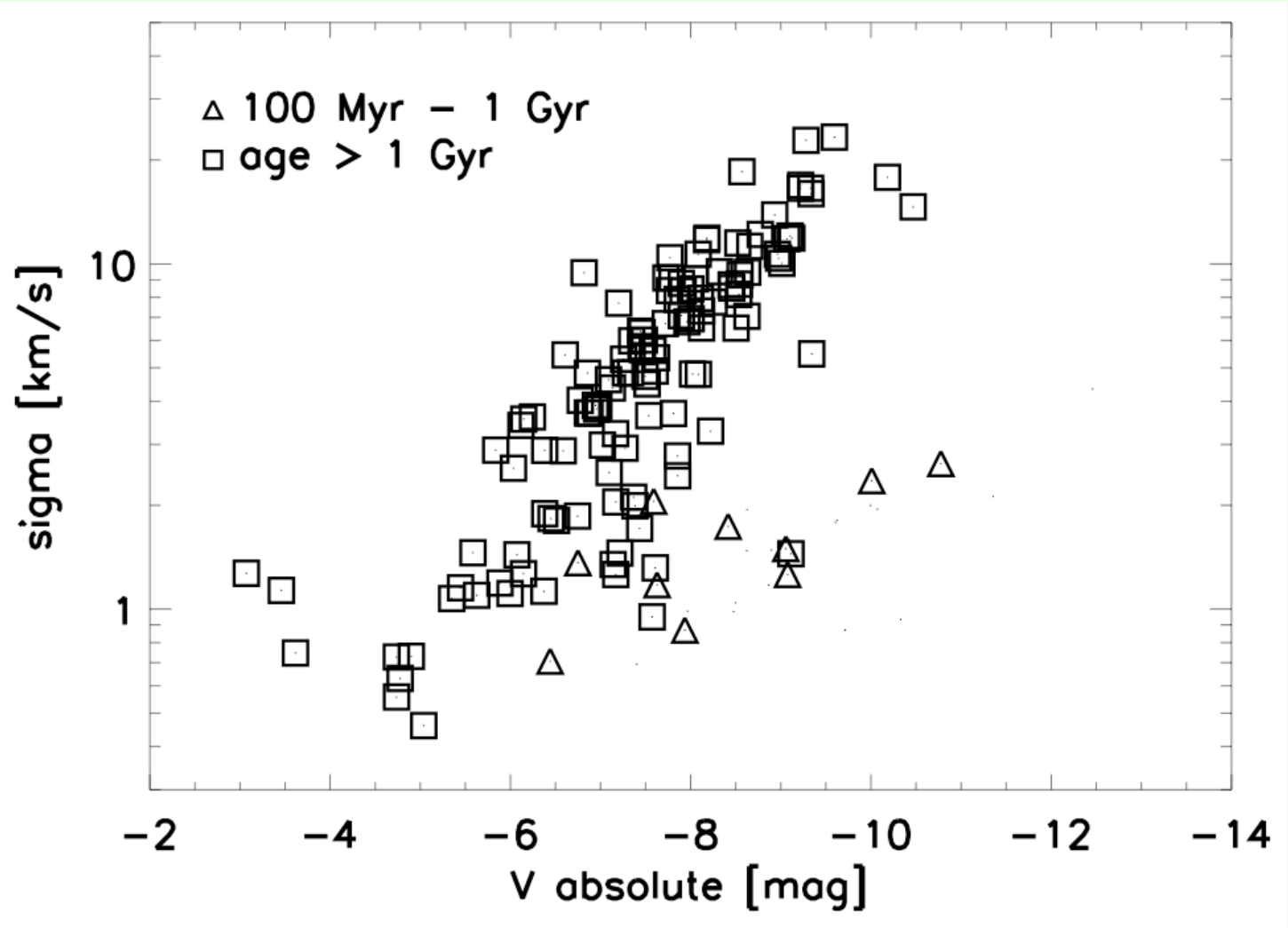


McLaughlin & van der Marel 2005

A “Faber-Jackson-type” relation for star clusters



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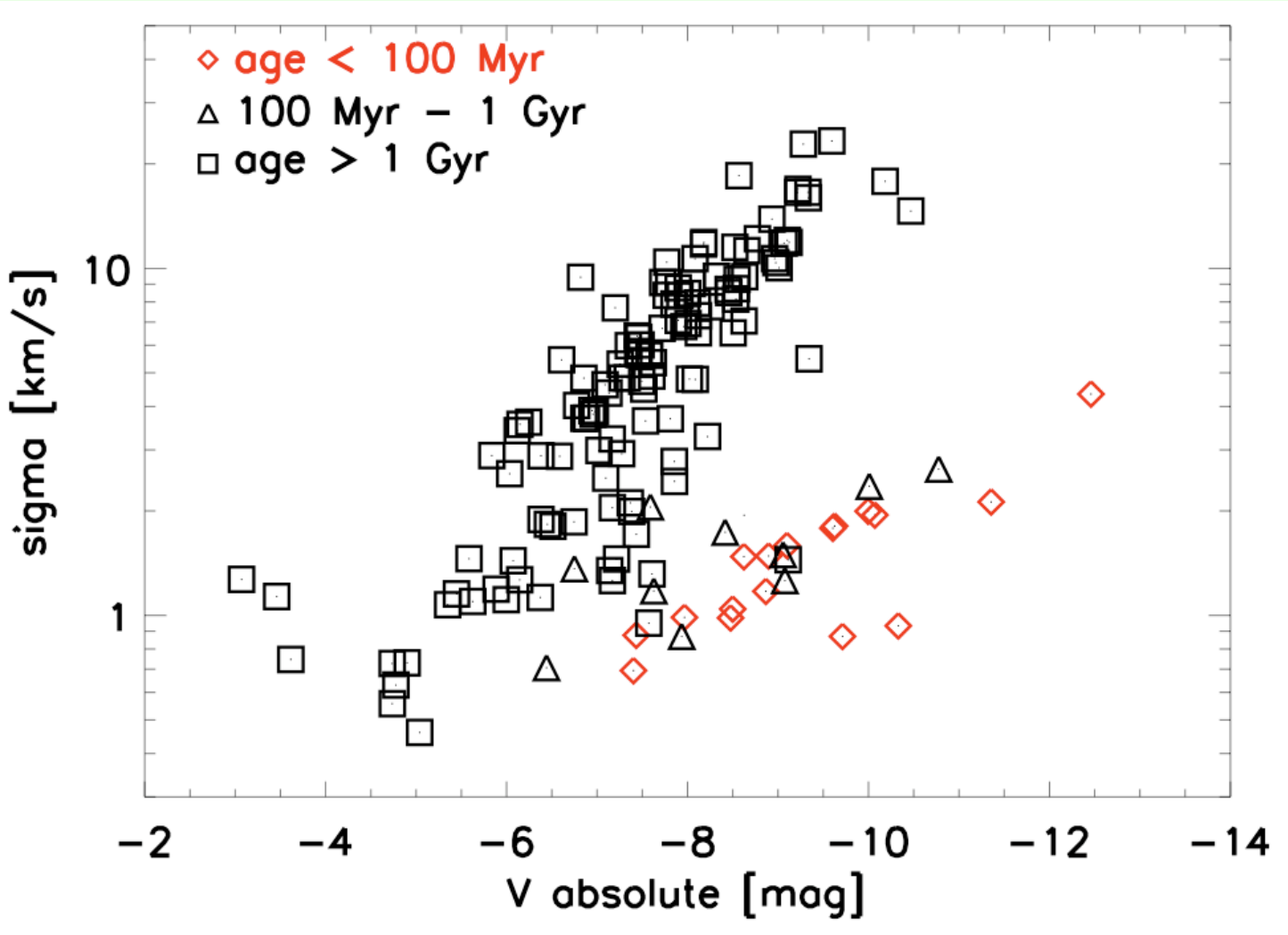
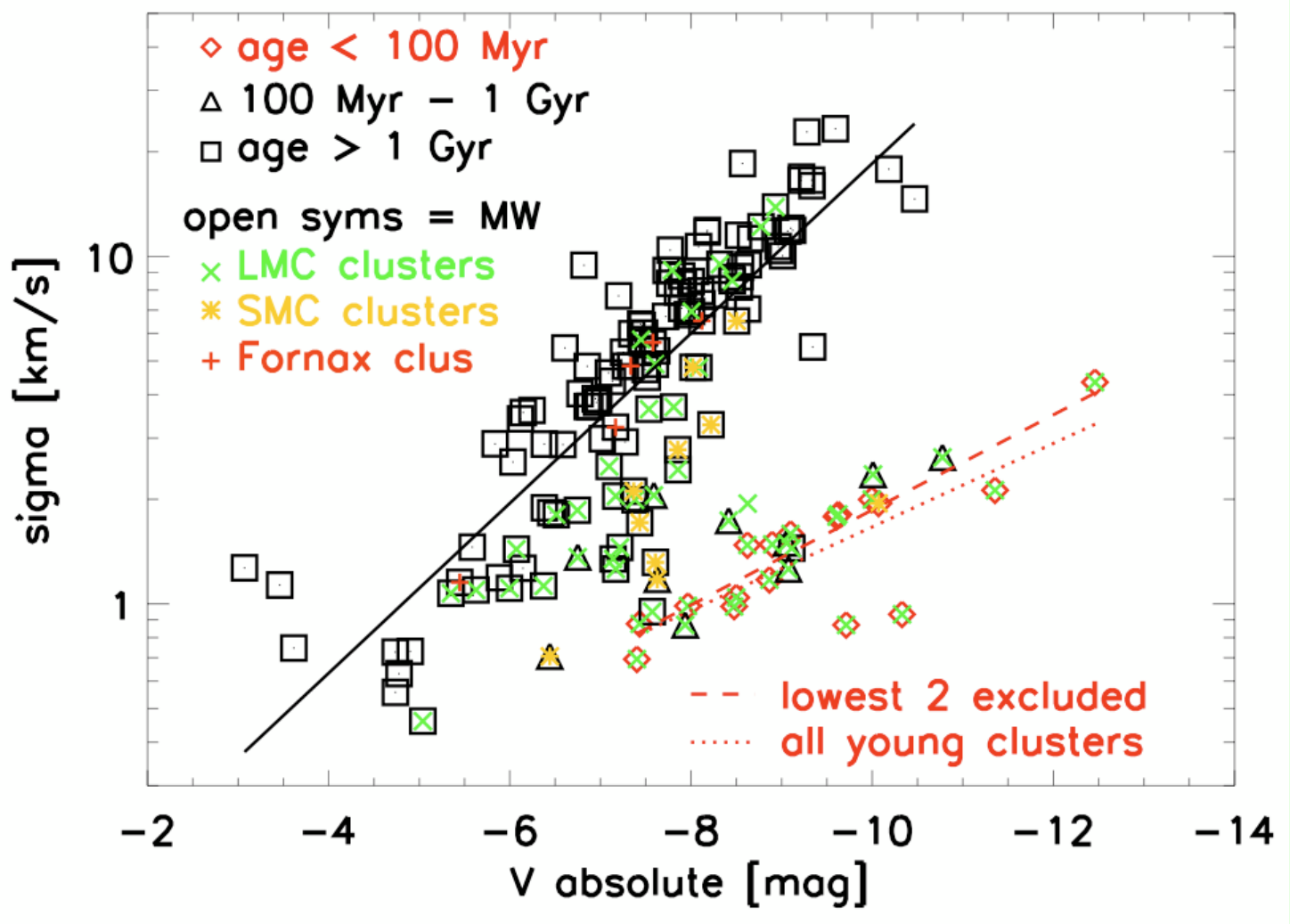
A “Faber-Jackson-type” relation for star clusters



McLaughlin & van der Marel 2005

A “Faber-Jackson-type” relation for star clusters



McLaughlin & van der Marel 2005

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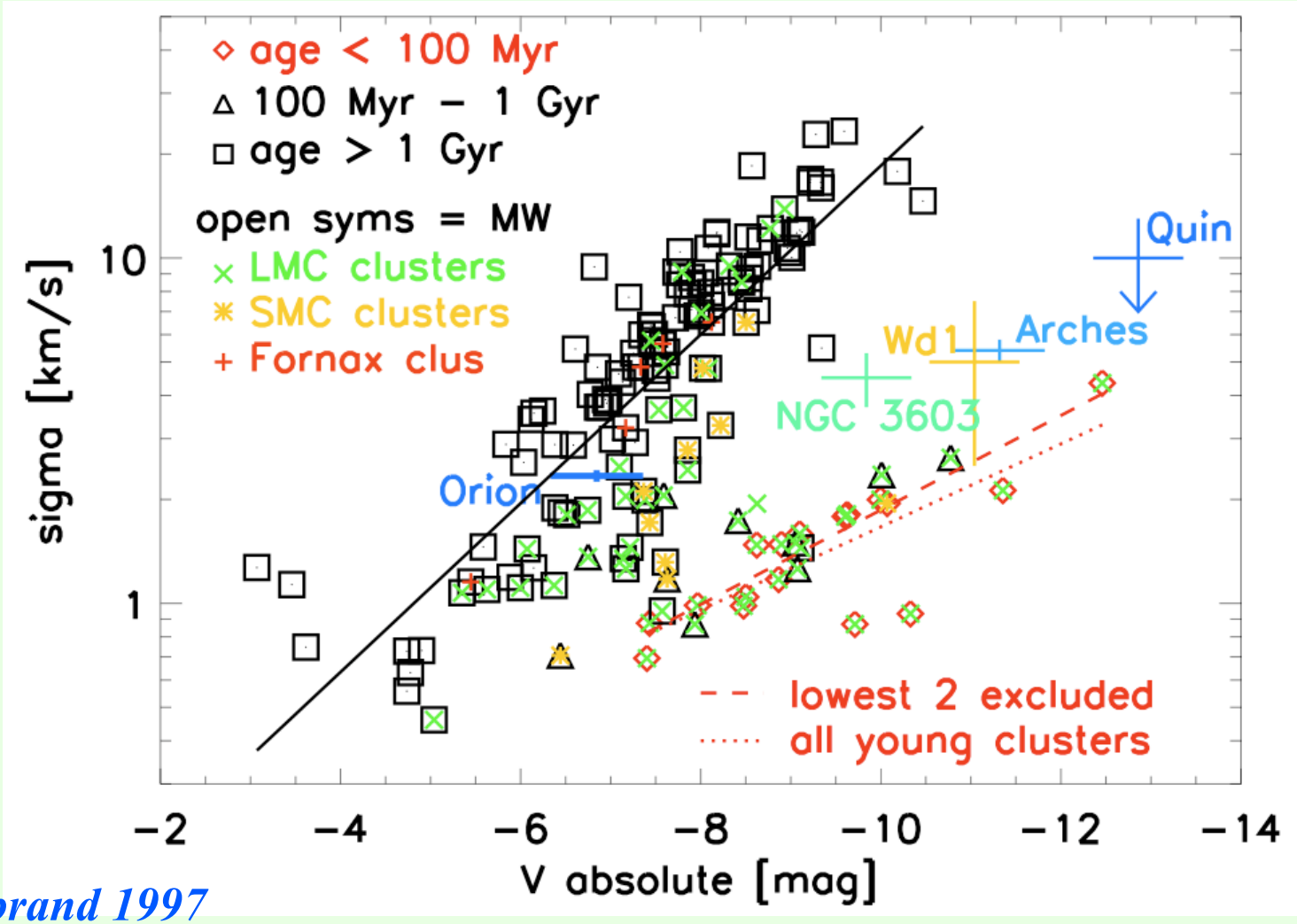
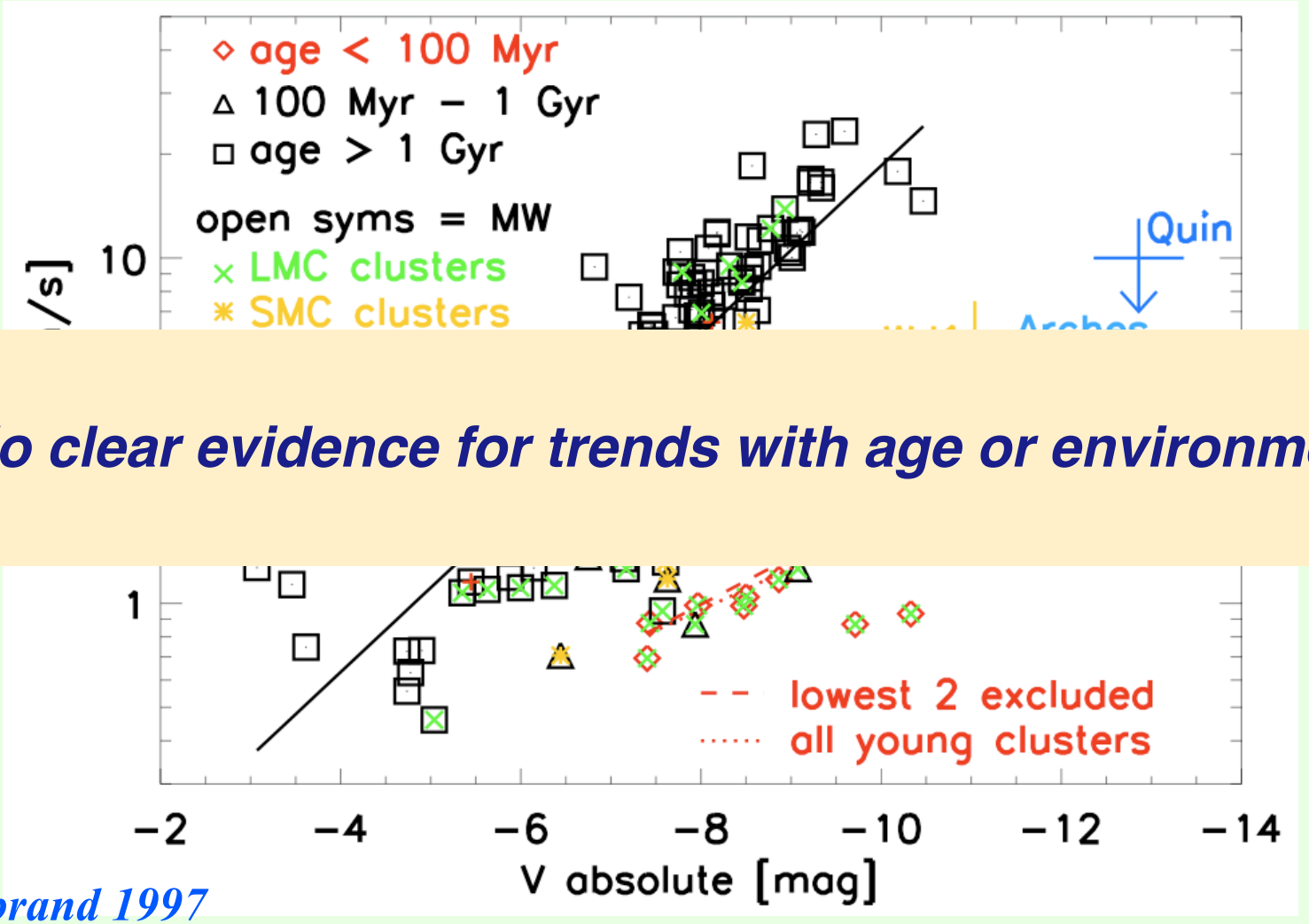


Hillenbrand 1997
Stolte et al. 2011
Clarkson et al. 2011
Rochau et al. 2010
Mengel & Tacconi-Garman 2009
Mengel & Tacconi-Garman 2007

McLaughlin & van der Marel 2005

A “Faber-Jackson-type” relation for star clusters



No clear evidence for trends with age or environment

Hillenbrand 1997
Stolte et al. 2011
Clarkson et al. 2011
Rochau et al. 2010
Mengel & Tacconi-Garman 2009
Mengel & Tacconi-Garman 2007

McLaughlin & van der Marel 2005

Questions & Outlook

* Is this relation meaningful?

* What is the physical implication?

* Is there an evolutionary sequence:

    young --> old clusters?

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  => difference between open clusters & starbursts?

* Dynamical stability & the Mag/Mass-sigma relation?

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Thanks!