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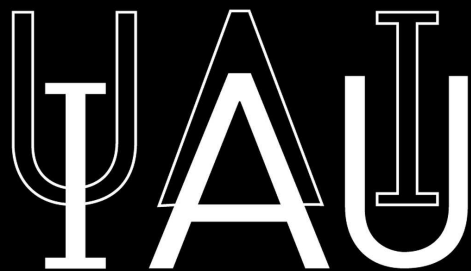
XXVIII General Assembly

20-31 August, 2012

Beijing, China

Search for and Characterisation of obscured and distant stellar clusters

Dirk Froebrich



Thanks for financial Support!

Beijing, 23/08/2012



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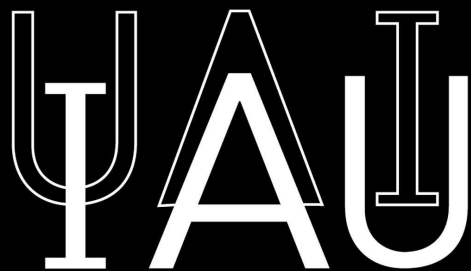
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Search for and Characterisation of obscured and distant (young/massive) stellar clusters

Dirk Froebrich



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Apologies to everyone whose work I have missed or did not list explicitly.

There are ~900 papers in the last 10 years containing the words “young”, “embedded” and “cluster” in the abstract!



Layout of Talk

Cluster Identification Methods

unbiased, targeted, serendipitous

visual, algorithms

Surveys & Catalogues

Cluster Characterisation

age, distance, reddening, mass

photometry, spectroscopy



Cluster Identification Methods

Visual Searches:

Kronberger et al. (2006)

inspection of selected regions in 2MASS

Dutra & Bica (2009)

as above, targeted Galactic Centre

(+HII regions, dark clouds)



Cluster Identification Methods

Dutra et al. (2003), Bica et al. (2003)

as before, targeted Galactic Plane

(optical and radio nebulae)

Borissova et al. (2011)

visual overdensities in VVV





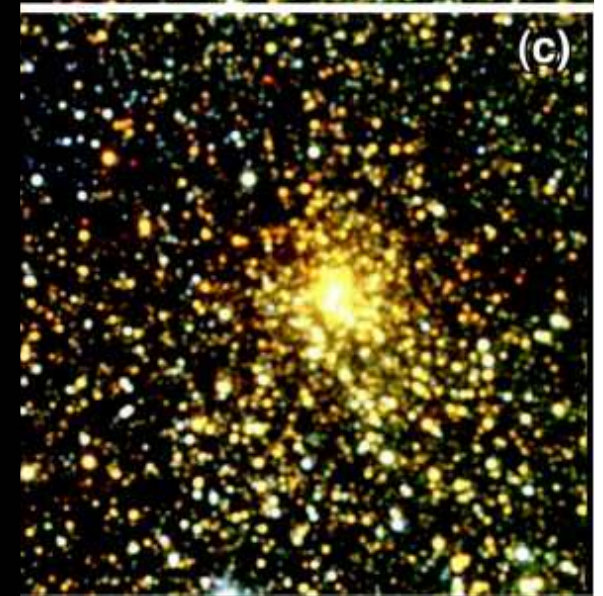
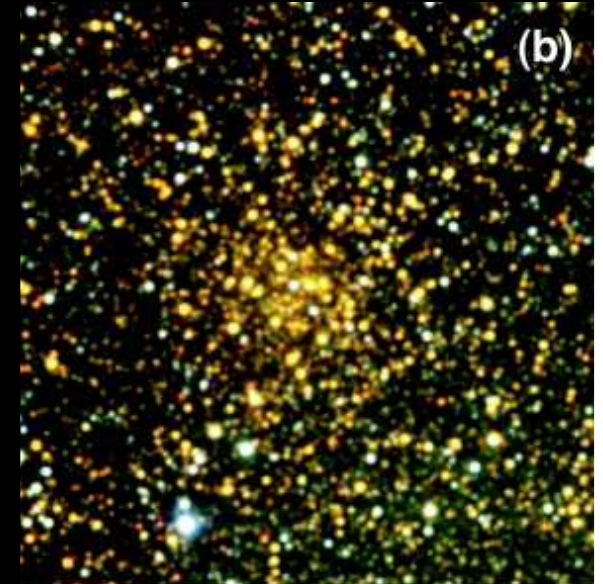
Cluster Identification Methods

Hurt et al. (2000)

Serendipitous GICs in 2MASS
in quality reviews

Messineo et al. (2008)

Serendipitous massive cluster





Cluster Identification Methods

‘special’ targets to find candidate massive clusters:

γ -ray or X-ray sources, SGRs, LBVs, WRs,
young pulsars, SNRs, RSGs, YSGs, BSGs, HII-regions

i.e. any kind of stellar remnant or massive star

Vrba et al. (2000) SGR; Messino et al. (2008) HESS,...



Cluster Identification Methods

Algorithm Searches (require reliable photometric catalogues):

Reyle & Robin (2002)

star density and flux increases in DENIS

Froebrich et al. (2007)

star density enhancements in 2MASS



Cluster Identification Methods

Mercer et al. (2005)

Poisson model over densities in GLIMPSE

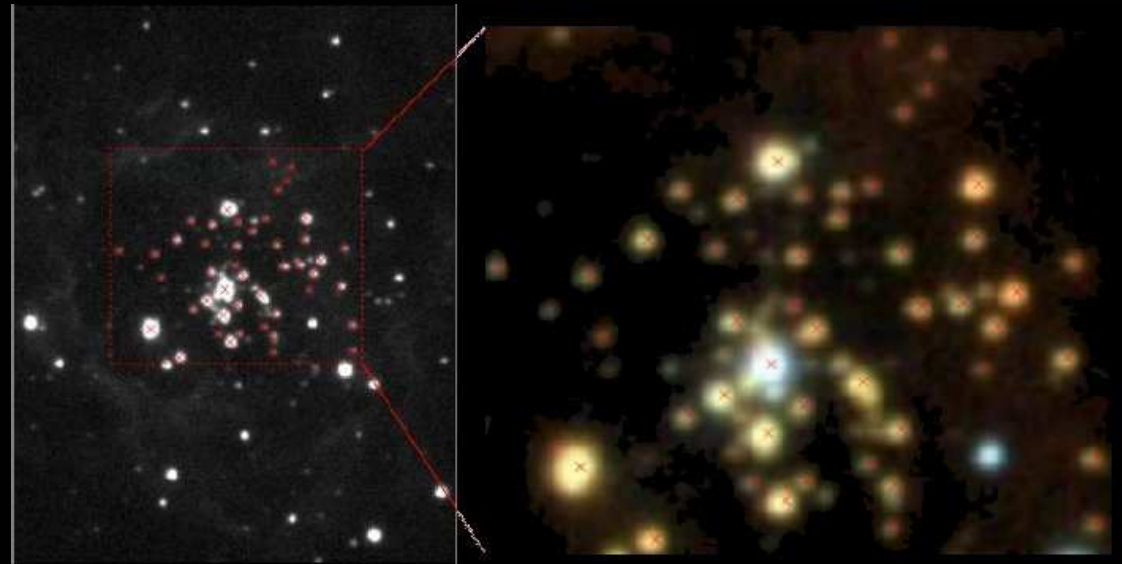
Solin et al. (2012), Lucas et al. (2010,11,12)

Bayesian search in UKIDSS GPS

2MASS extended sources

UCECs Alexander & Kobulniky 2012

Red and Bright in 2MASS/Glimpse





Cluster Identification Methods

Odenkirchen et al. (2001)

Searches in colour-magnitude space

SDSS, tidal tails of Pal5

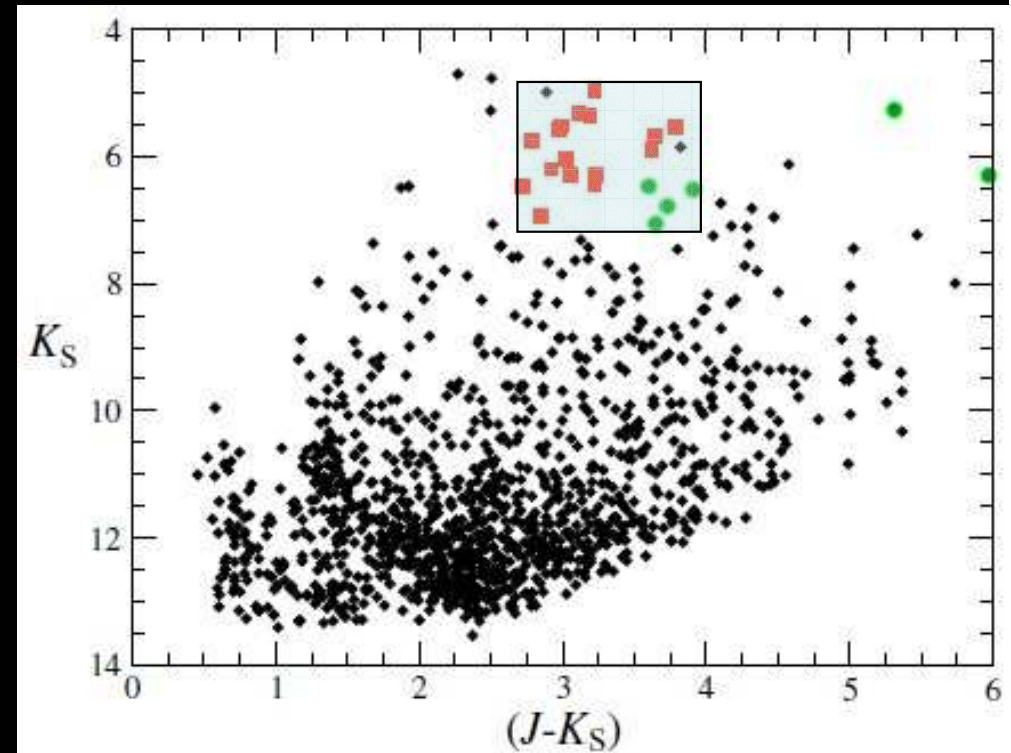
Can we re-discover the RSG clusters?

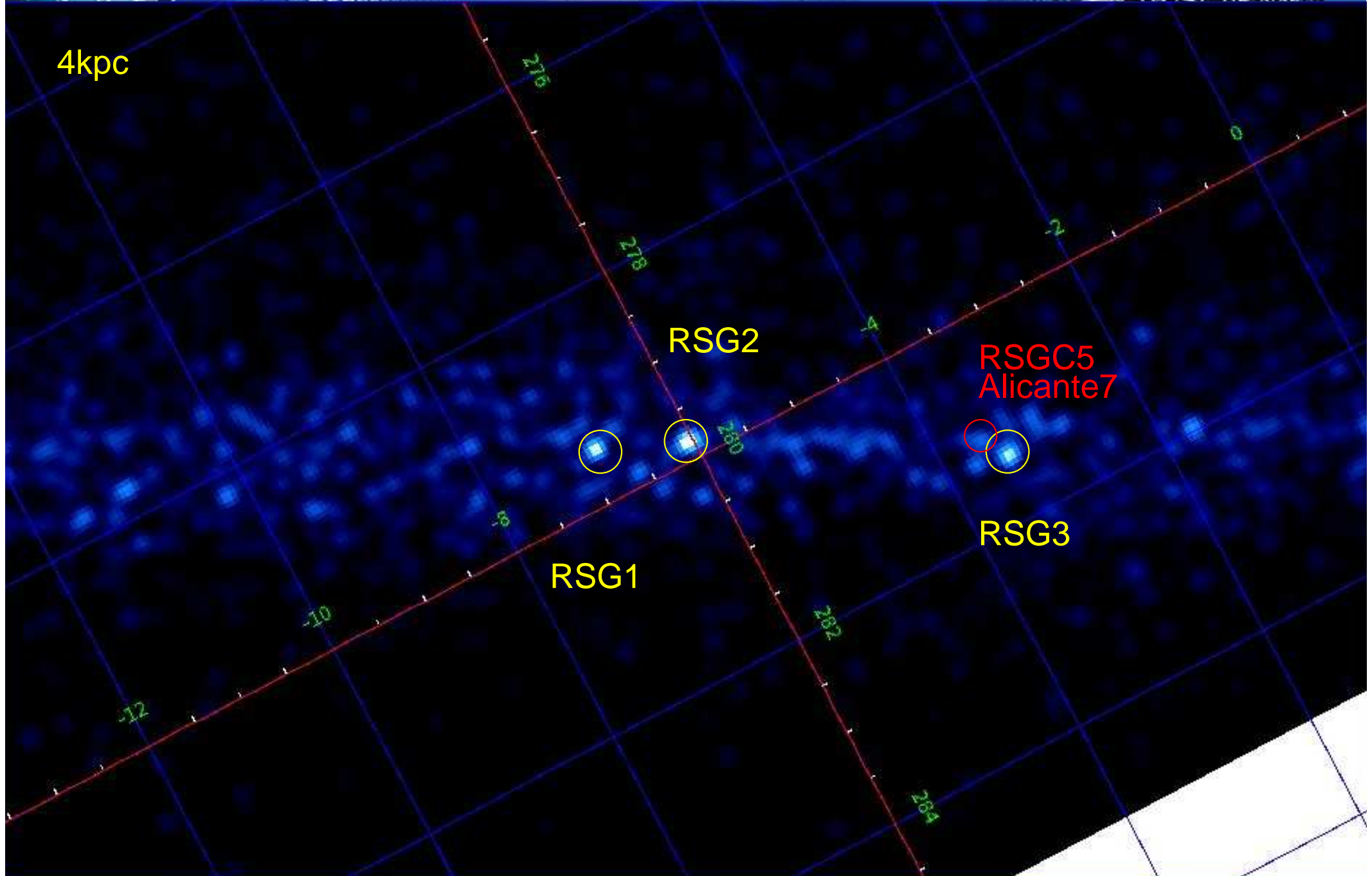
RSGC1 Figer et al. (2006)

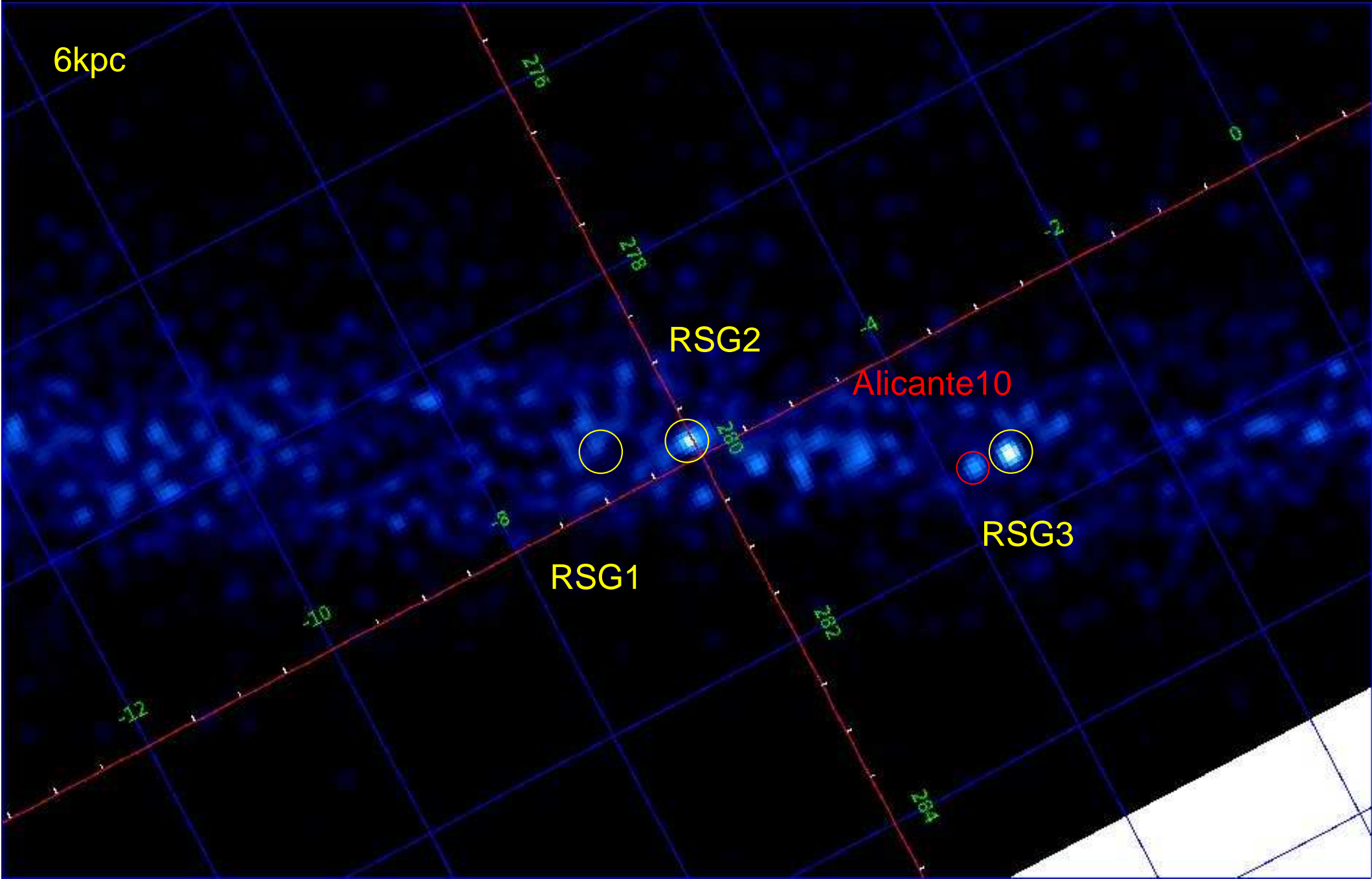
RSGC2 Ortolani et al. (2002)

Davies et al. (2007)

RSGC3 Clark et al. (2009) →

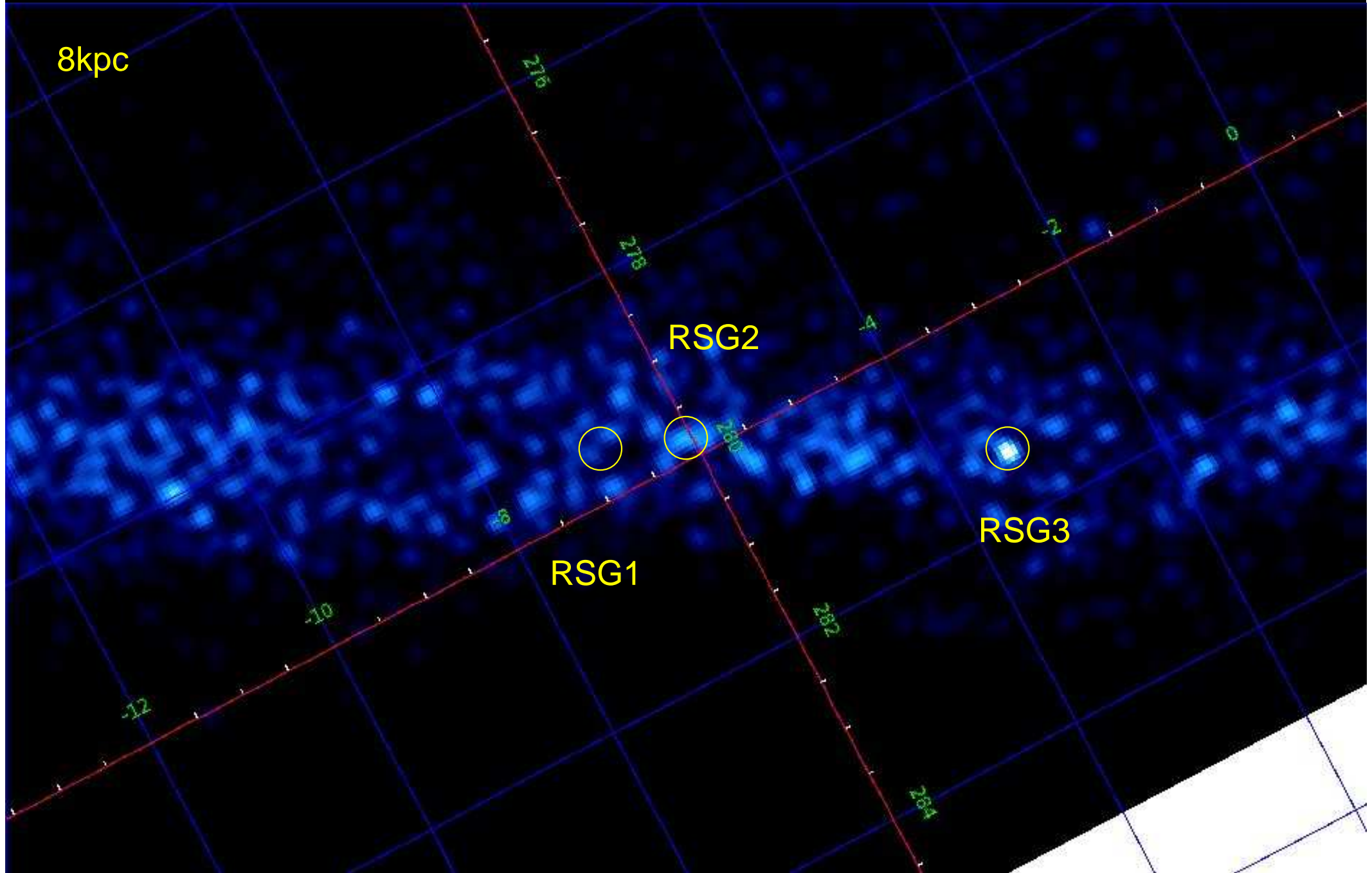








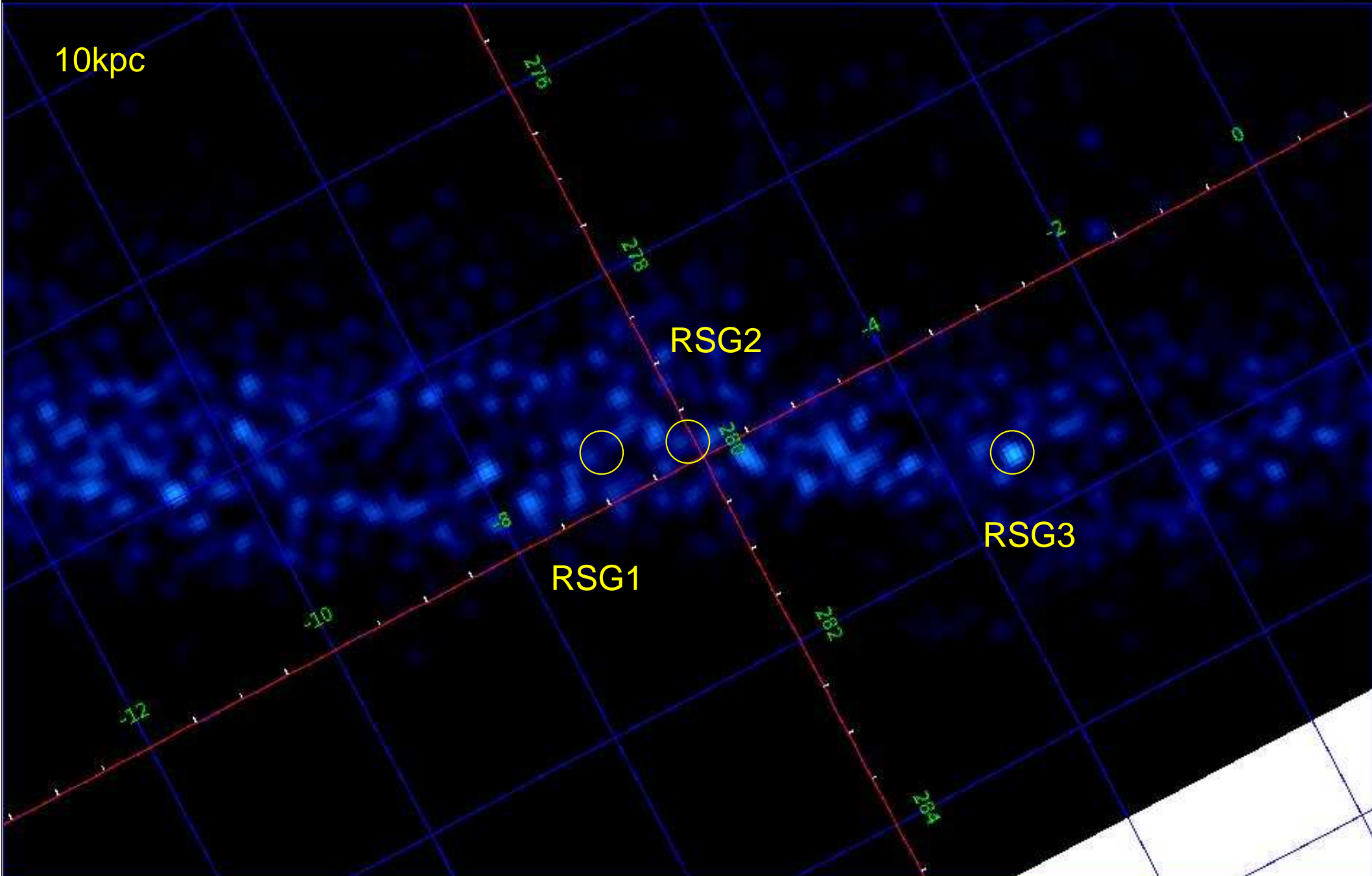
8kpc



RSG2

RSG1

RSG3





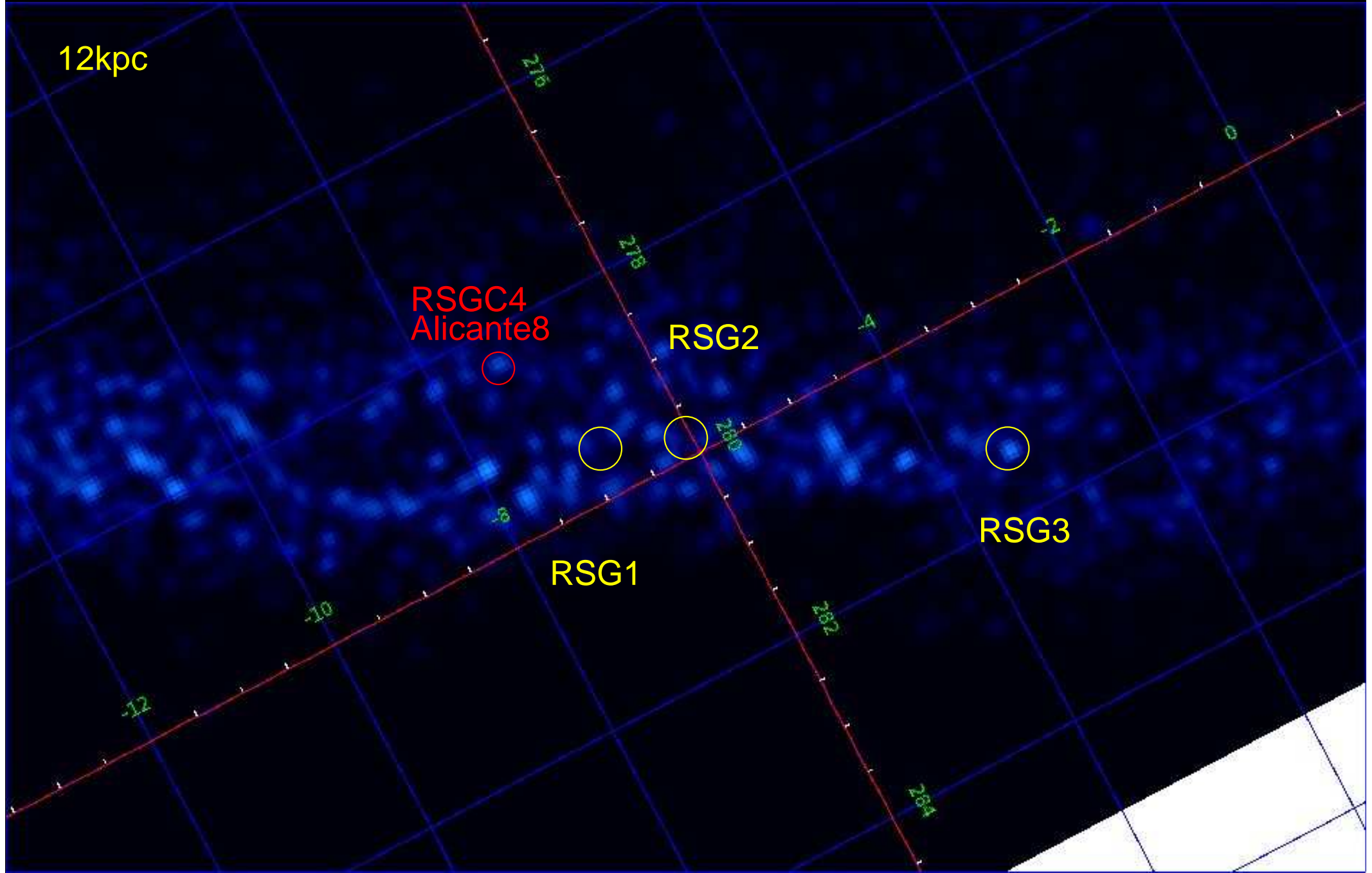
12kpc

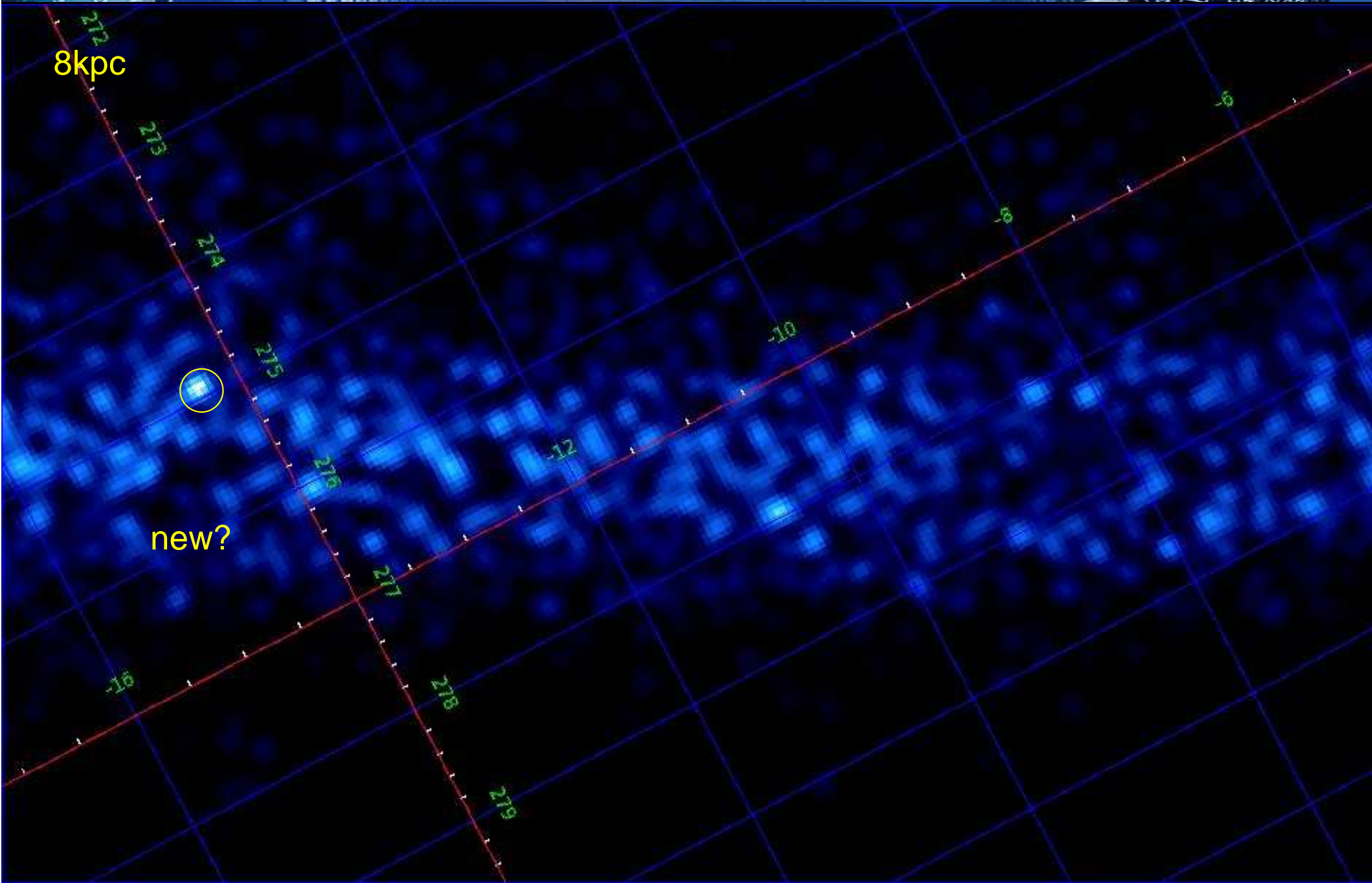
RSGC4
Alicante8

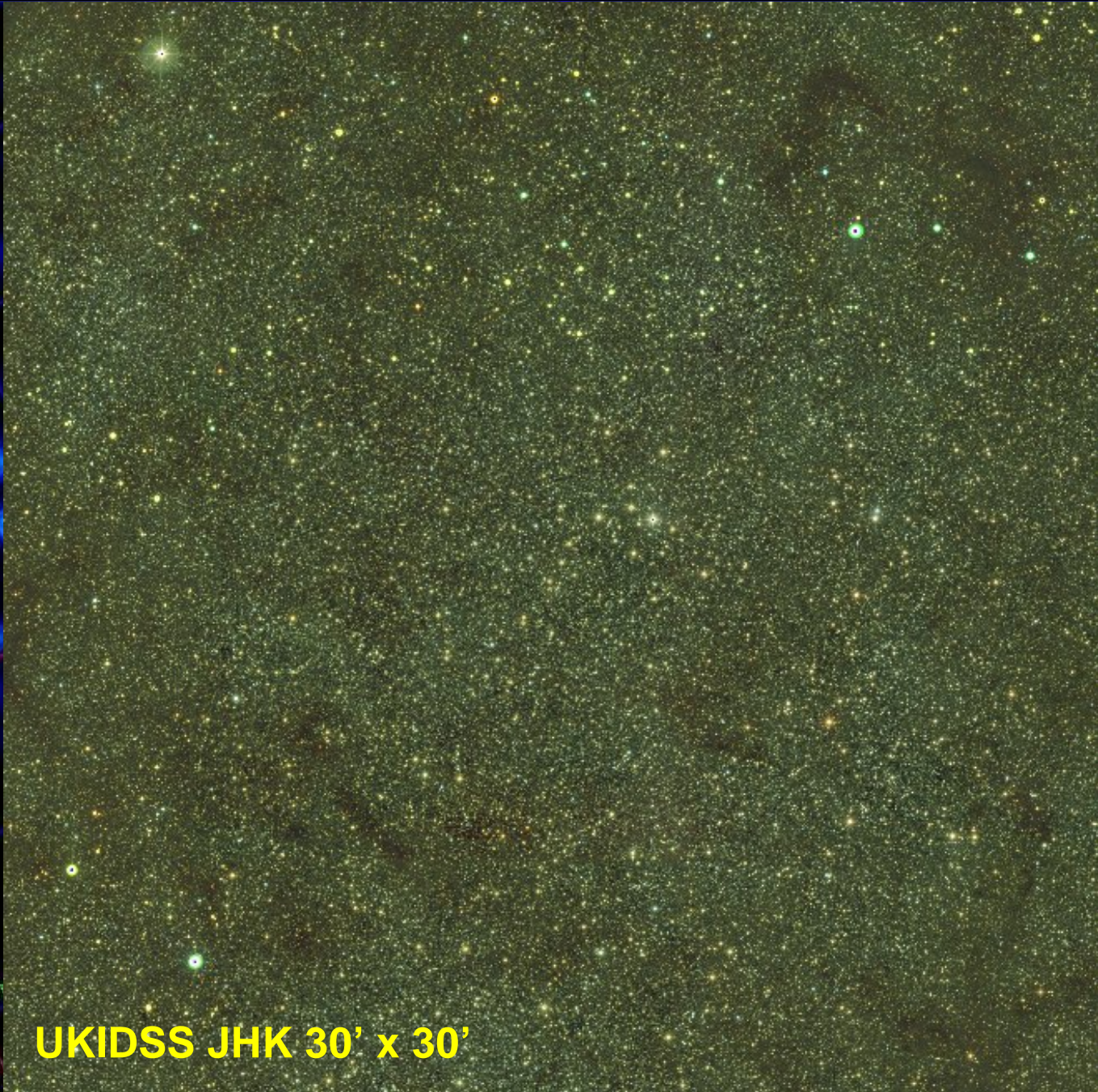
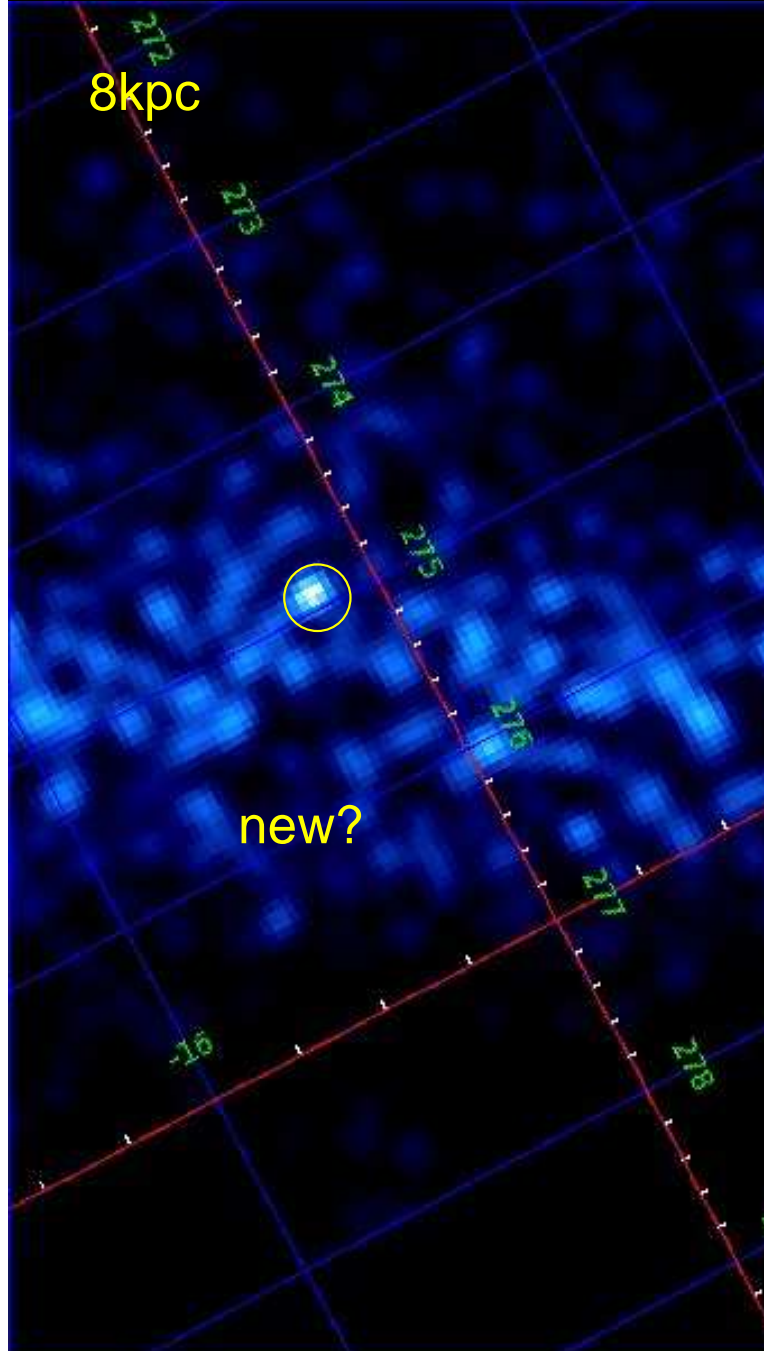
RSG2

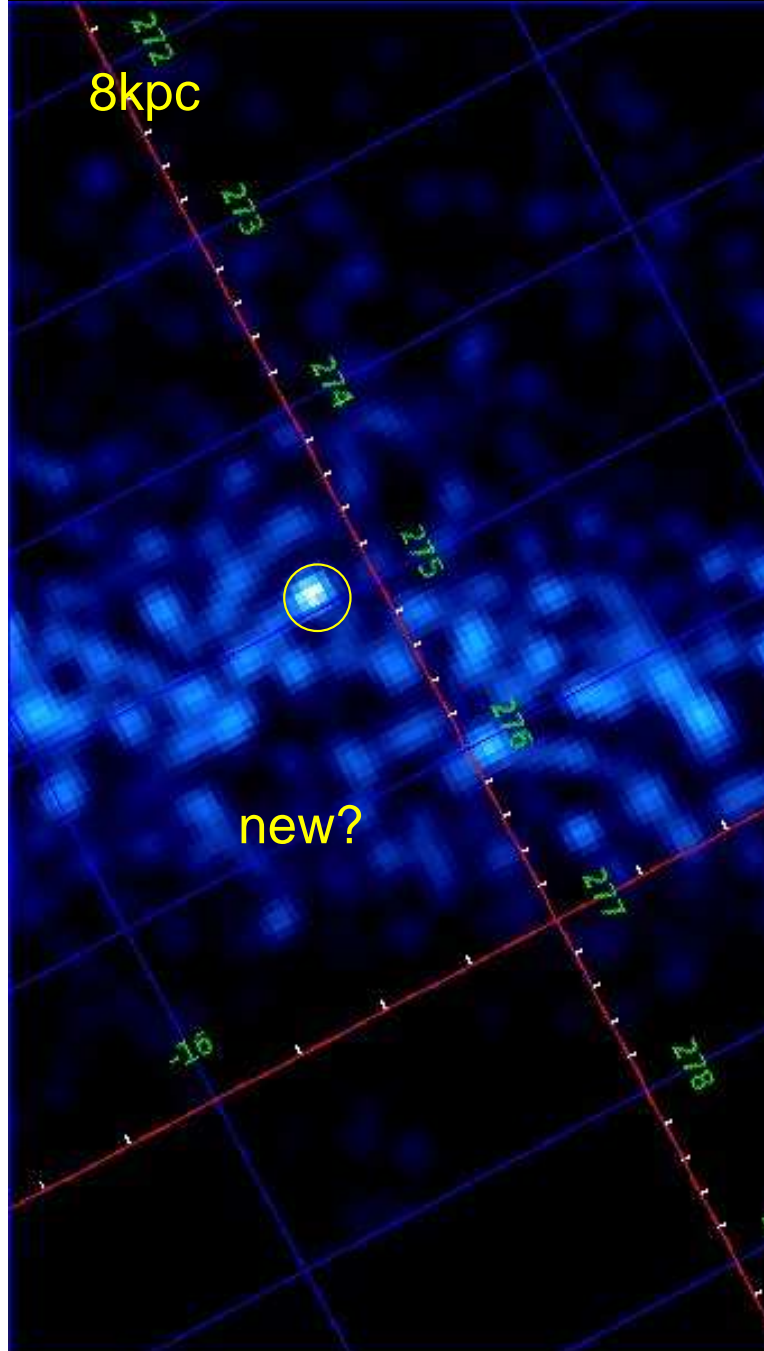
RSG1

RSG3











Survey Summary

SDSS, PANSTARRS?

2MASS, DENIS

UKIDSS-GPS, VISTA-VVV

Glimpsel, II, 360, Deep-Glimpse?

WISE (Majaess et al. 2012 – FSR0579; others in prep.), **AKARI**

see posters by Zahorecz et al. and Toth et al. (IAUS292)



Cluster Lists/Databases

WEBDA - 681 - (<http://www.univie.ac.at/webda/navigation.html>)

Dias list - 2135 - (<http://www.astro.iag.usp.br/~wilton/>)

Kharchenko - 650 – (<http://adsabs.harvard.edu/abs/2009A%26A...504..681K>)

SAI catalogue - 200 - (<http://ocl.sai.msu.ru/catalog/>)

FSR list - 1788 - (<http://astro.kent.ac.uk/~df/clusters/index.html>)

Harris - 157 - (<http://adsabs.harvard.edu/abs/2010arXiv1012.3224H>)

Lada & Lada - 76 - (<http://adsabs.harvard.edu/abs/2003ARA%26A..41...57L>)



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There are about 30.000 star clusters in the Galaxy

(e.g. Portegeis Zwart et al. 2010)

We know about 5-10% of these

(currently in the online list of Dias et al. 2002)

Less than half have been studied properly

(e.g. Chené et al. 2012)



It is highly likely that we already know a large fraction of the massive clusters in the Galaxy.

We just do not know that we know them.

Many clusters were not recognised as massive for a long time:

Westerlund1 (1961 – 87), Clark et al. (1998), Piatti et al. (1998)

RSGC1 (2006) = [BDS2003]122

RSGC2 (2002/7) = Stephenson2 (1990)



Cluster Characterisation Methods

Distance, Age and Reddening can usually not be determined independently from each other.

I will concentrate on methods to characterise distant (i.e. no normal, pre-Gaia parallax) and obscured clusters of an age above 10^6 yrs.



Cluster Characterisation Methods

Isochrone Fitting:

incl. metallicity, rotation, mass loss rates, opacity, EOS,
reaction rates, magnetic fields, convection, diffusion

Lejeune & Schaerer (2001), Seiss et al. (2000), Meynet & Maeder (2000),
Schaerer et al. (1993), Schaller et al. (1992), Meynet et al. (1994),
Talon & Charbonnel (2005), Denissenkov & Pinsonneault (2007),
Maeder & Meynet (2010), Ekström et al. (2012),

...



Cluster Characterisation Methods

Distance:

radial velocities & galactic rotation curves

(Koches & Dougherty 2007, Brand & Blitz 1993)

from associated clouds

for cluster stars (membership determination)

Maser parallax for massive stars / SF regions

(e.g. Sanna et al. 2009, Rygl et al. 2012, Xu et al. 2012, Reid et al. 2009)



Cluster Characterisation Methods

Photometric Parallax – (Isochrone fitting)

‘easy’ for older clusters with giants

manually – ‘by eye’

Bayesian fitting (Sale et al. in prep.)

3D Av mapping (e.g. Marshall et al. 2006, Negueruela et al. 2010)

distance + reddening



Cluster Characterisation Methods

Counting of foreground stars + Galaxy Model (Robin et al. 2003)

Photometric Membership Probabilities

(e.g. Bonatto & Bica 2010, Froebrich et al. 2010)

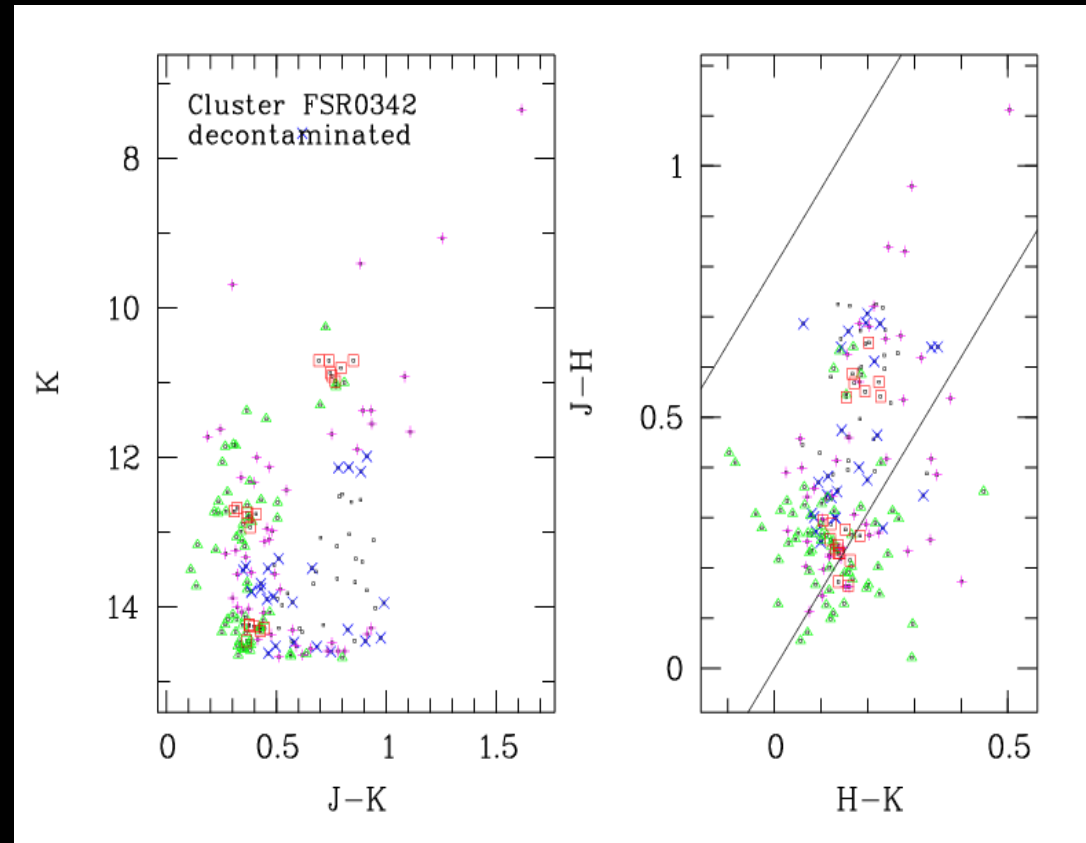
'blue' foreground stars

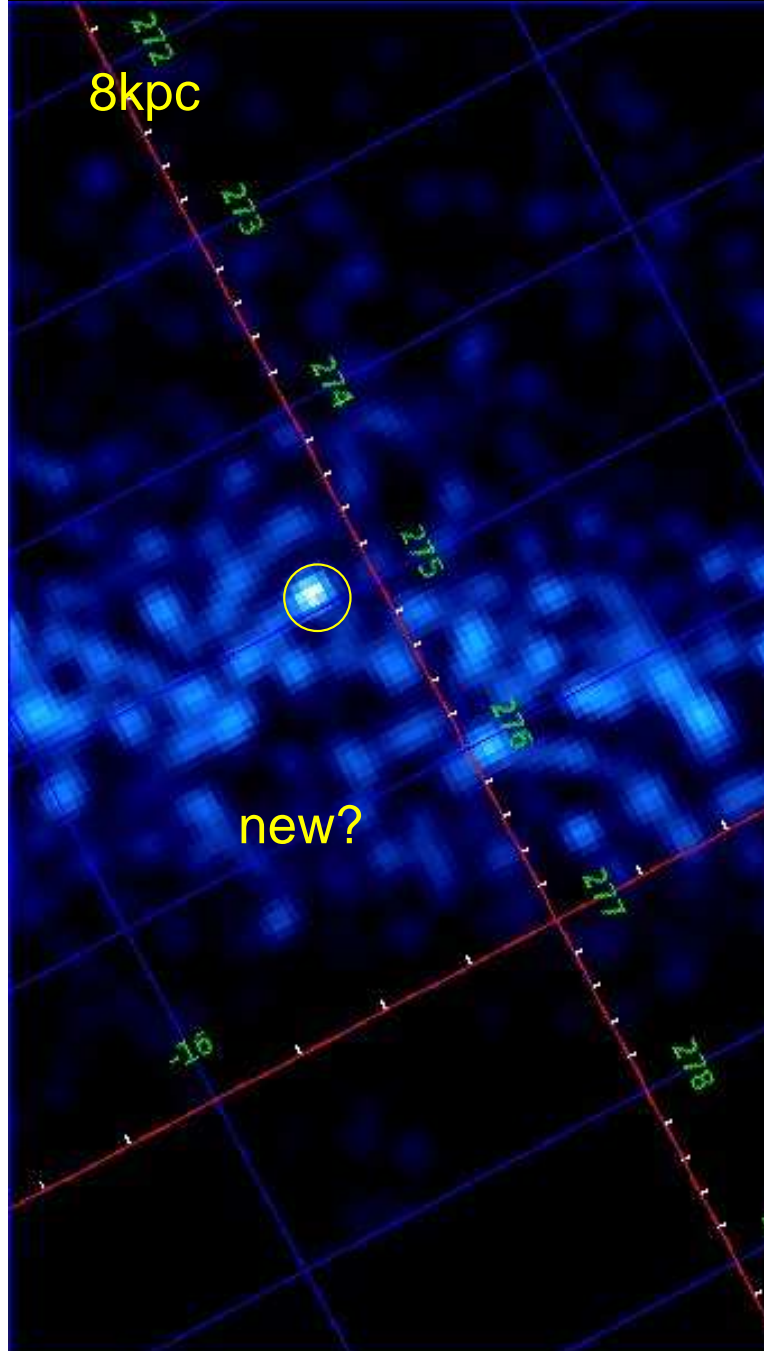
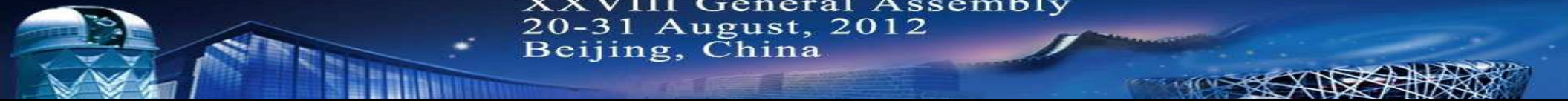
Buckner & Froebrich (2012 in prep.)

recovers intrinsic scatter
of calibration objects

Knude (2010), Foster et al. (2012),

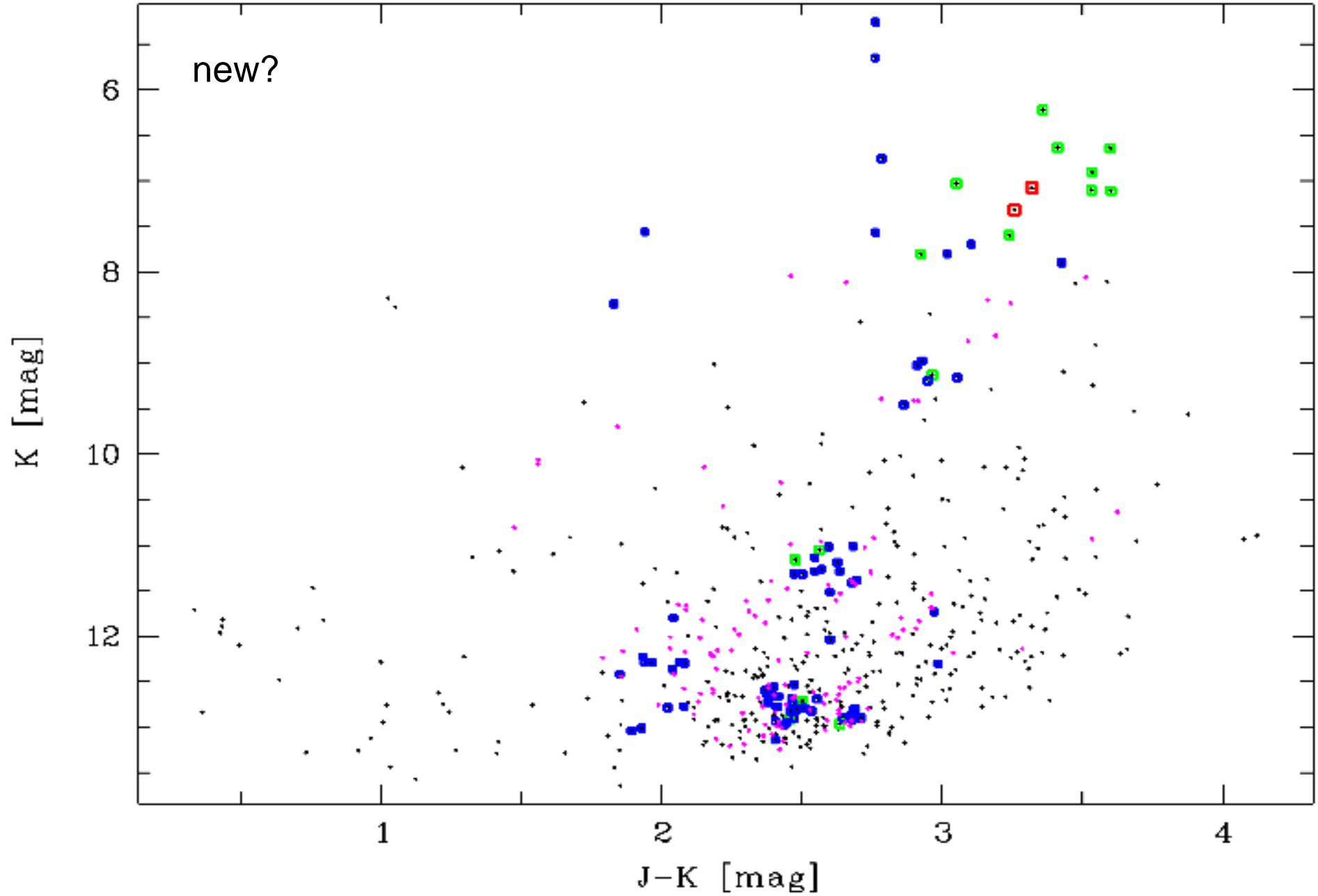
Ioannidis & Froebrich (2012)





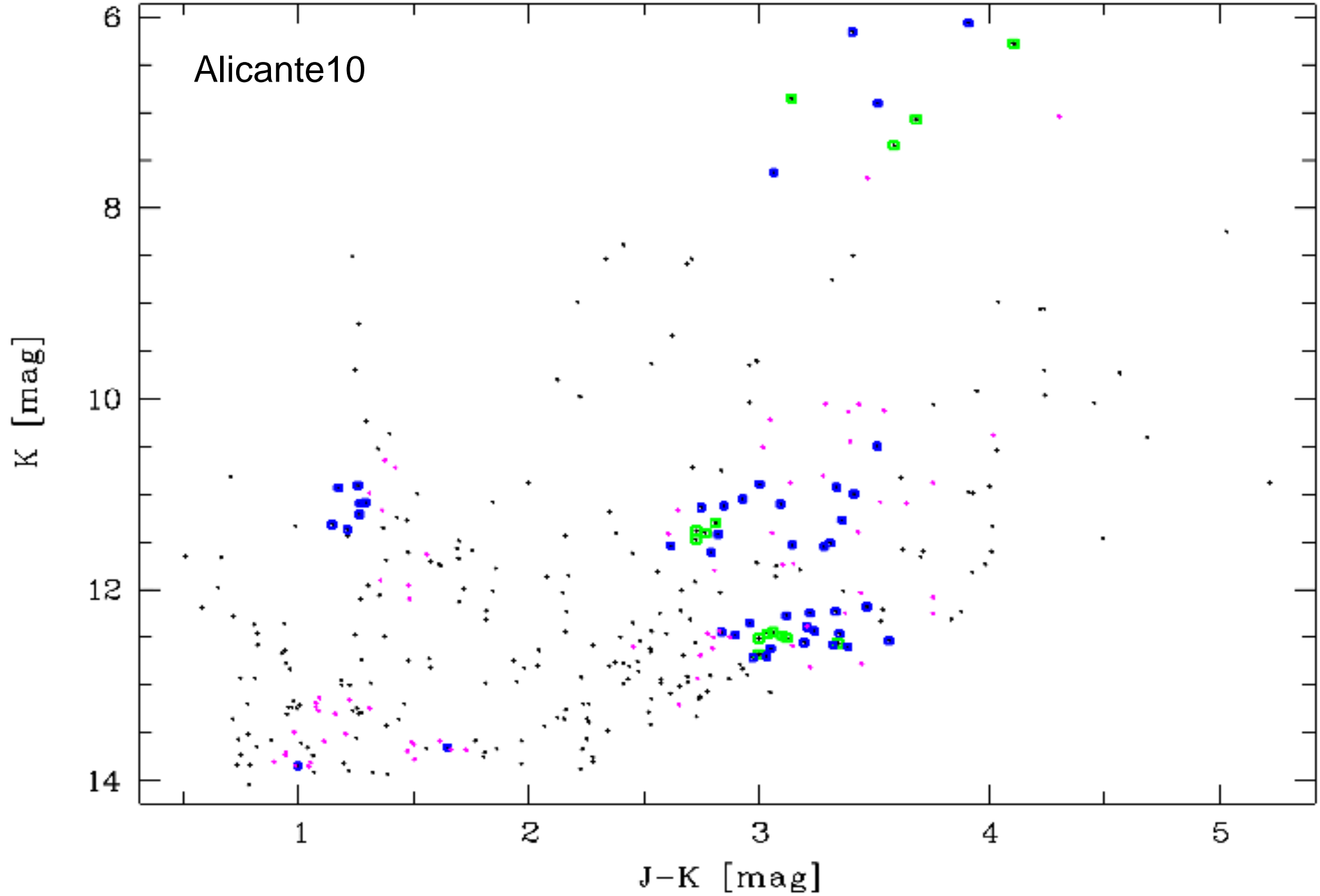


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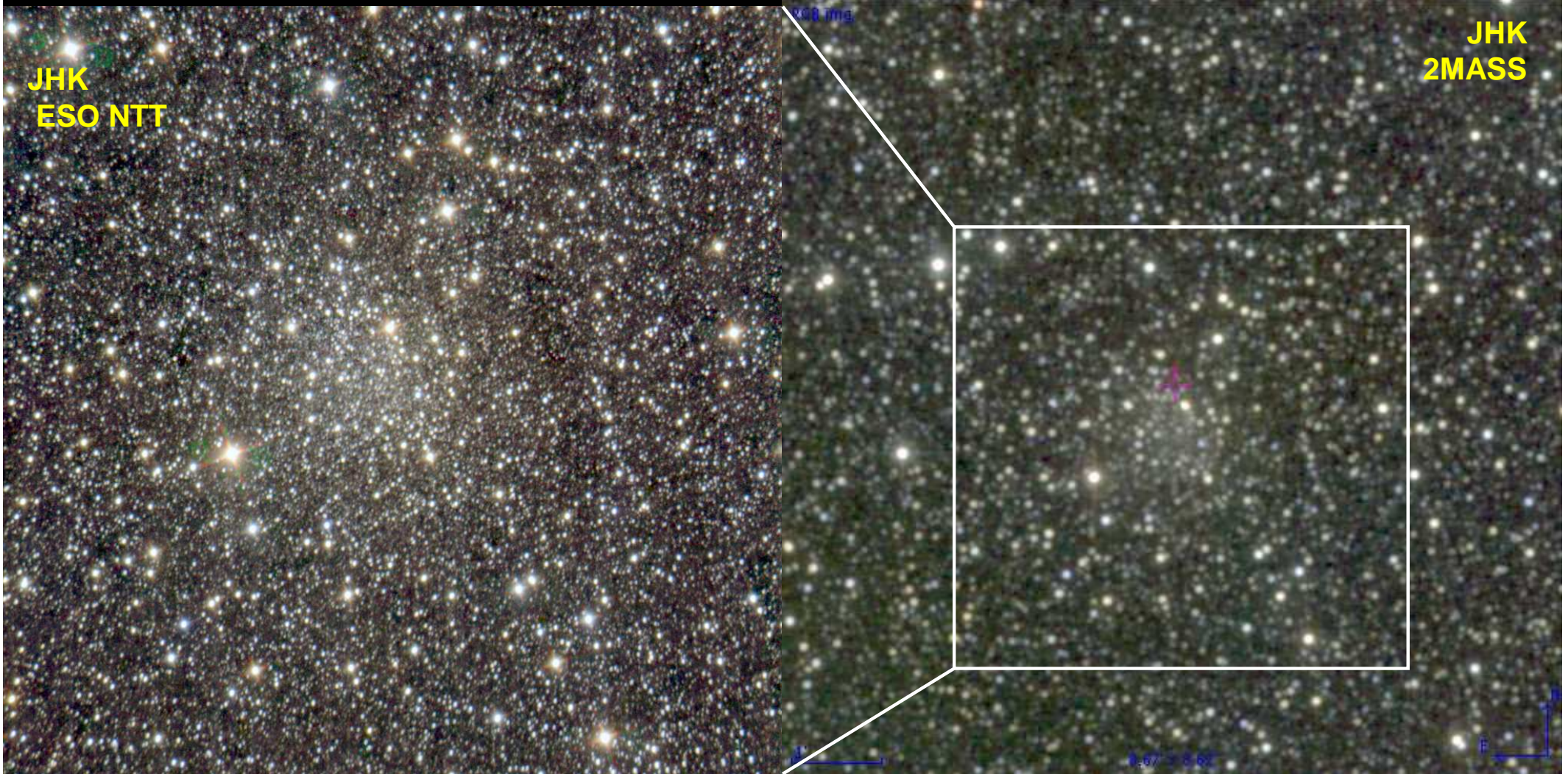




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Cluster Characterisation Methods

Reddening:





Cluster Characterisation Methods

Reddening:

(Isochrone fitting)

Colour excess

NIR, MIR – Rayleigh Jeans (Majewski et al. 2011)

+ reddening laws (e.g. Indebetouw et al. 2005,

Messineo et al. 2005, Mathis 1990, Stead & Hoare 2009,

Straizys & Lazauskaite 2008, Baume et al. 2009, Rieke & Lebovsky 1985)

ISM / parental cloud / envelope



Cluster Characterisation Methods

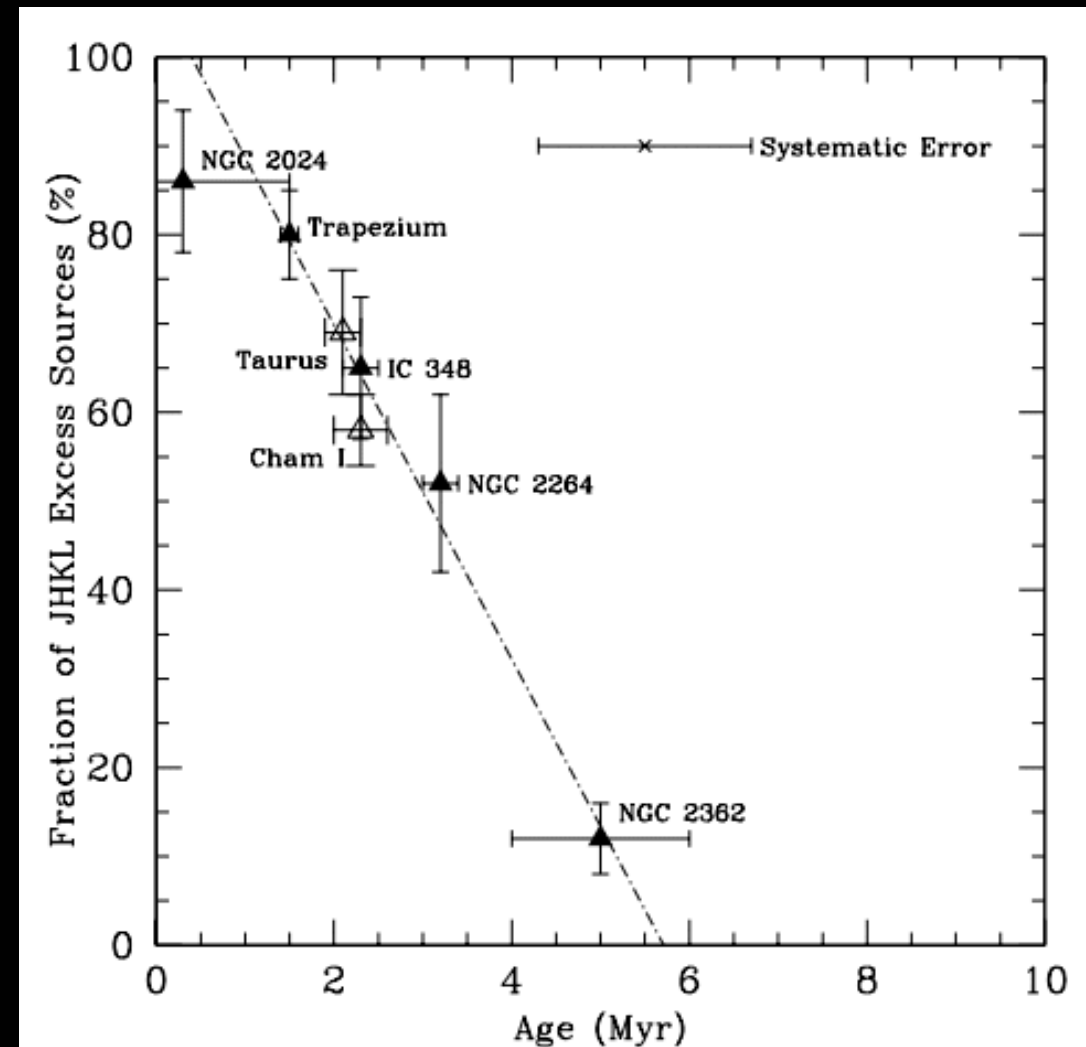
Age:

(Isochrone fitting)

Fraction of Disk excess

stars -- Lada & Lada (2003)

order of ages





Cluster Characterisation Methods

Age/Mass:

Population Synthesis Models

#s of WR, RSG, BSG, LBV

optical/NIR spectroscopy**

(CO, HeI, Br γ , FeI, CaII)

+ IMF (Salpeter 1955, Figer 2005, Kroupa), (+binary fraction)

Virial Mass — Mengel et al. (2002), Bastian & Goodwin (2006) — no equil.



Cluster Characterisation Methods

Galactic Distribution

Scale Height = $f(\text{mass, age})$

Radii = $f(\text{position, mass, age})$
(half light, core, ...)

Stellar Mass function

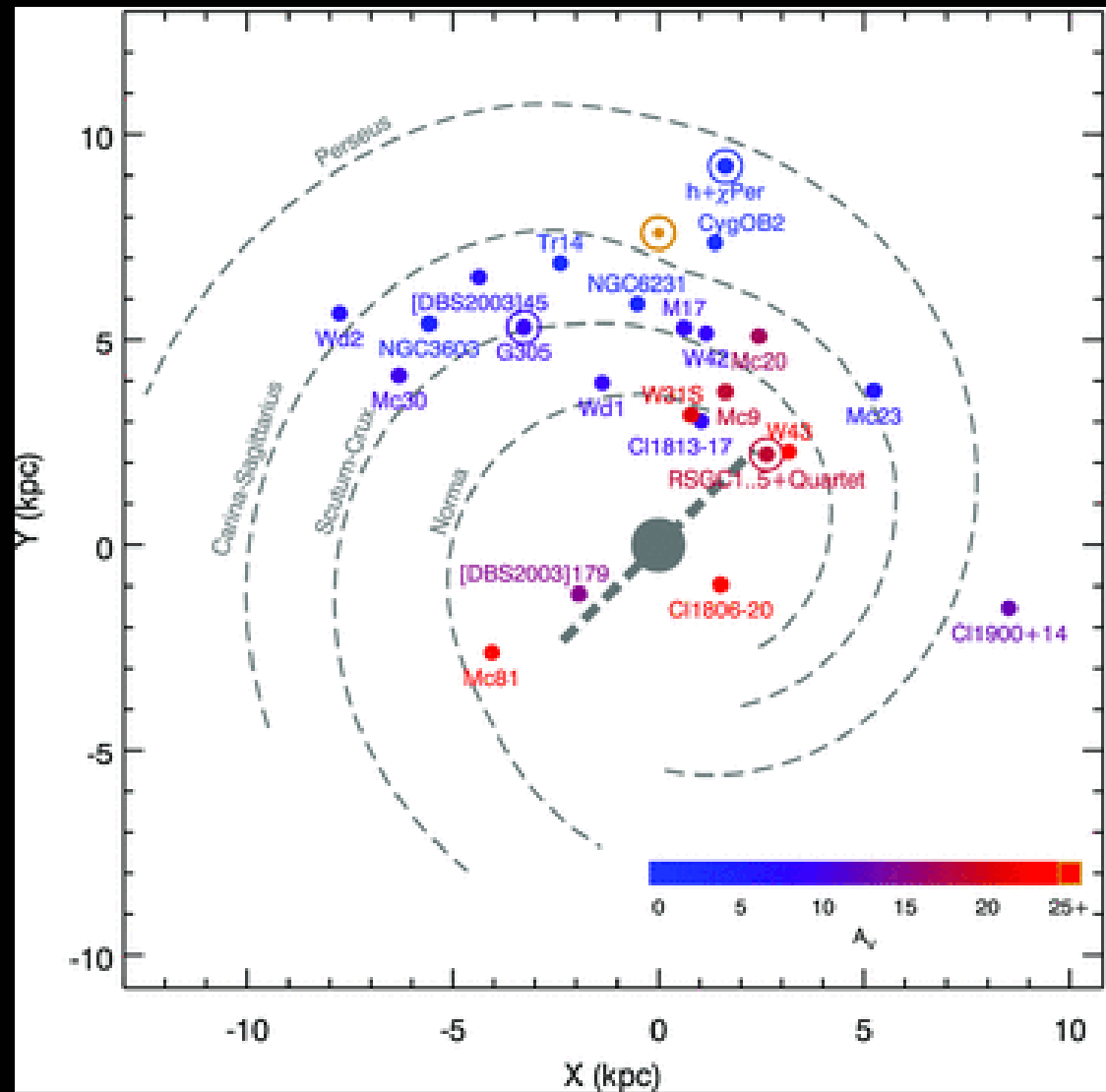
Cluster mass function

Structure (e.g. via MST analysis)

Mass Segregation

.....

Davies et al. (2012) →





What Next?

Exploration of time domain (e.g. via VISTA-VVV)
for variability (+ proper motions)

e.g. Chené et al. (2012), Barbá et al. (2012)

clusters with $M > 500 M_{\odot}$ have $\sim B0$ objects

→ EUV/FUV → fluorescence

What Next?

[BDS2003]10

JHK
UKIDSS

JKH₂
UKIDSS+UWISH2





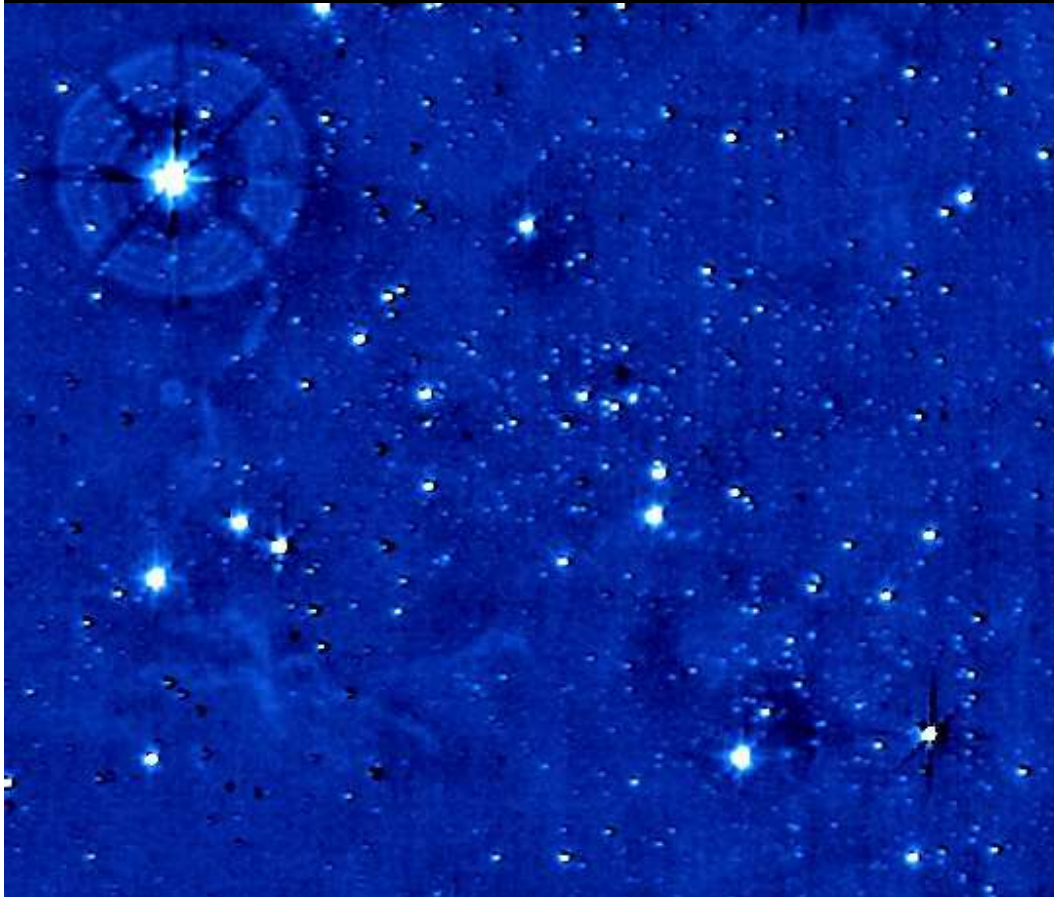
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What Next?

[BDS2003]10

H₂-K
UKIDSS+UWISH2

JKH₂
UKIDSS+UWISH2





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Exploration of time domain (e.g. via VISTA-VVV)
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e.g. Chené et al. (2012), Barbá et al. (2012)

clusters with $M > 500 M_{\odot}$ have $\sim B0$ objects

→ EUV/FUV → fluorescence

Large scale NIR NB surveys?

→ select properly to get WR/AGB classification???

1-0 S(1) H₂, Br- γ , CO, HeI, CIV, HeII, ...

(e.g. Shara et al. 2009 for WR identification)



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Questions?

Comments?

Additions?

Suggestions?

Corrections?