AMIGA project: Quantification of the isolation of 950 CIG galaxies

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on behalf of the AMIGA team

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Overview of the presentation

Influence of the environment

- Role of the environment in the formation and evolution of galaxies
- Properties of the ISM in isolated galaxies, and its relation to luminosity, morphology, star formation, nuclear activity
- Reference sample with minimum influence from the environment

ISM in isolated galaxies

AMIGA I-VII 2005-2009

Analysis of the Interstellar **M**edium of **I**solated **GA**laxies

(AMIGA project)

- The Catalogue of Isolated Galaxies (CIG)
  - Positions [Leon & Verdes-Montenegro 2003]
  - Redshifts and distances [Verdes-Montenegro et al. 2005]
  - Morphologies [Sulentic et al. 2006; Durbala et al. 2008]
  - Optical luminosity function [Verdes-Montenegro et al. 2005]
  - Isolation [Verley et al. 2007a,b]
- ISM multi-wavelength study
  - Hα [Verley et al. 2007c]
  - Far infrared [Lisenfeld et al. 2007]
  - Radio-continuum [Leon et al. 2008; Sabater et al. 2008]
  - Atomic gas [Espada et al. 2005; Espada 2006]
  - Molecular gas [Lisenfeld et al., in prep.]
- Public database
  - `http://www.amiga.iaa.es`

ISM in isolated galaxies

AMIGA I-VII 2005-2009

Analysis of the Interstellar **M**edium of **I**solated **GA**laxies

(AMIGA project)

- The Catalogue of Isolated Galaxies (CIG)
  - Positions — Galaxies in Isolation: Exploring Nature vs. Nurture
  - Redshifts and distances — Talk: J. Sulentic
  - Morphologies — Talk: J. Sulentic
  - Optical luminosity function — Talks: S. Verley, J. D. Santander-Vela
  - Isolation
- ISM multi-wavelength study
  - Hα — Posters: G. Bergond et al., S. Verley et al.
  - Far infrared — Poster: B. Ocaña Flaquer et al.
  - Radio-continuum — Talk: J. Sabater
  - Atomic gas — Talk: D. Espada
  - Molecular gas — Posters: U. Lisenfeld et al., V. Martínez-Badenes et al.
- Public database
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The Catalogue of Isolated Galaxies (CIG)

Primary galaxies with angular major-axis diameter D_p are considered isolated if any neighbours with diameters D_i, $D_p/4 \leq D_i \leq 4D_p$ have an apparent angular separation R_{ip}, from the primary galaxy under consideration, greater than $20D_i$ [Karachentseva, 1973]:

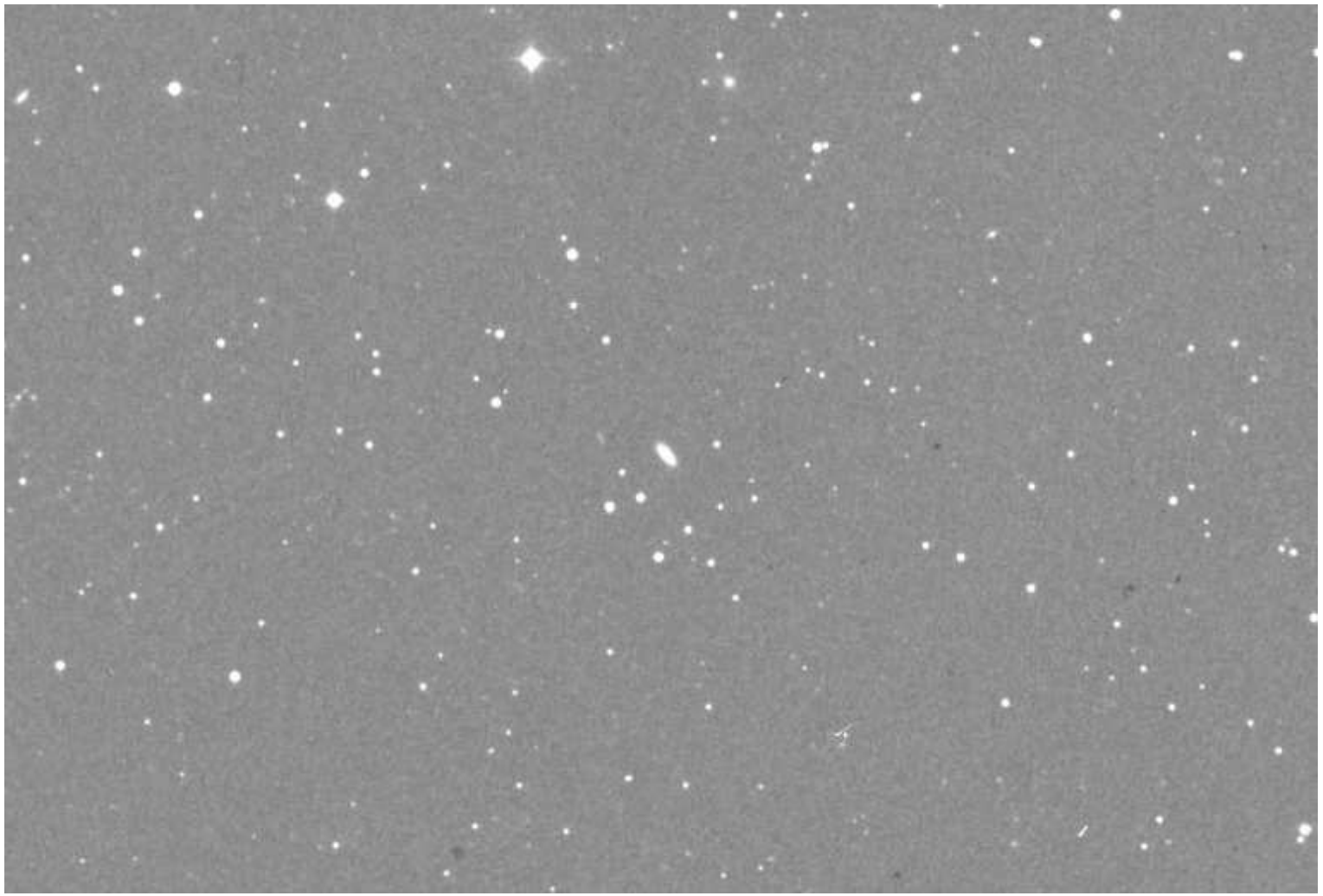
$$R_{ip} \geq 20 \times D_i$$

$$\frac{1}{4} \times D_p \leq D_i \leq 4 \times D_p$$

1050 galaxies (about 3% of all the galaxies in the CGCG) [Zwicky et al., 1968]

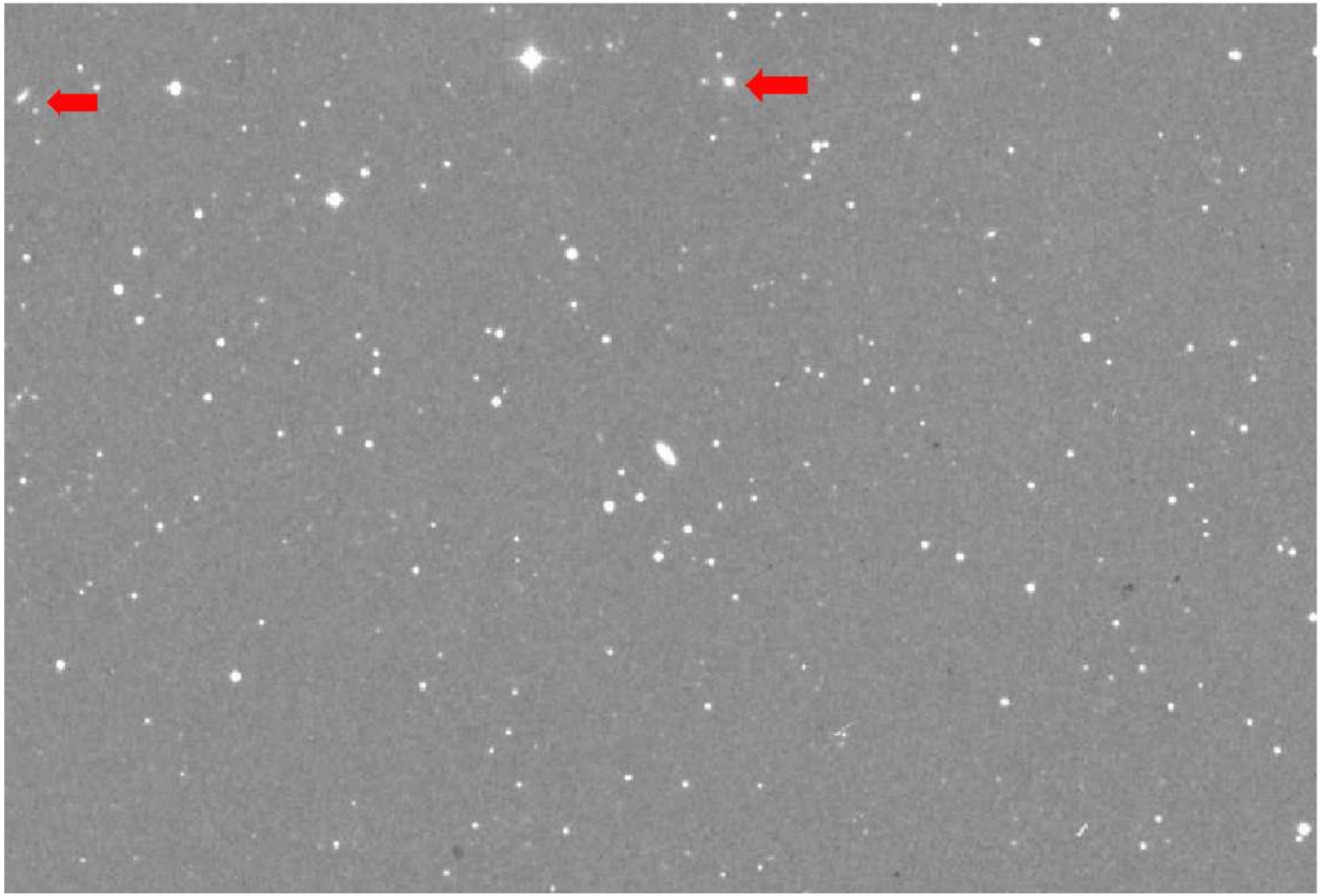
Isolation definition

Karachentseva 1973



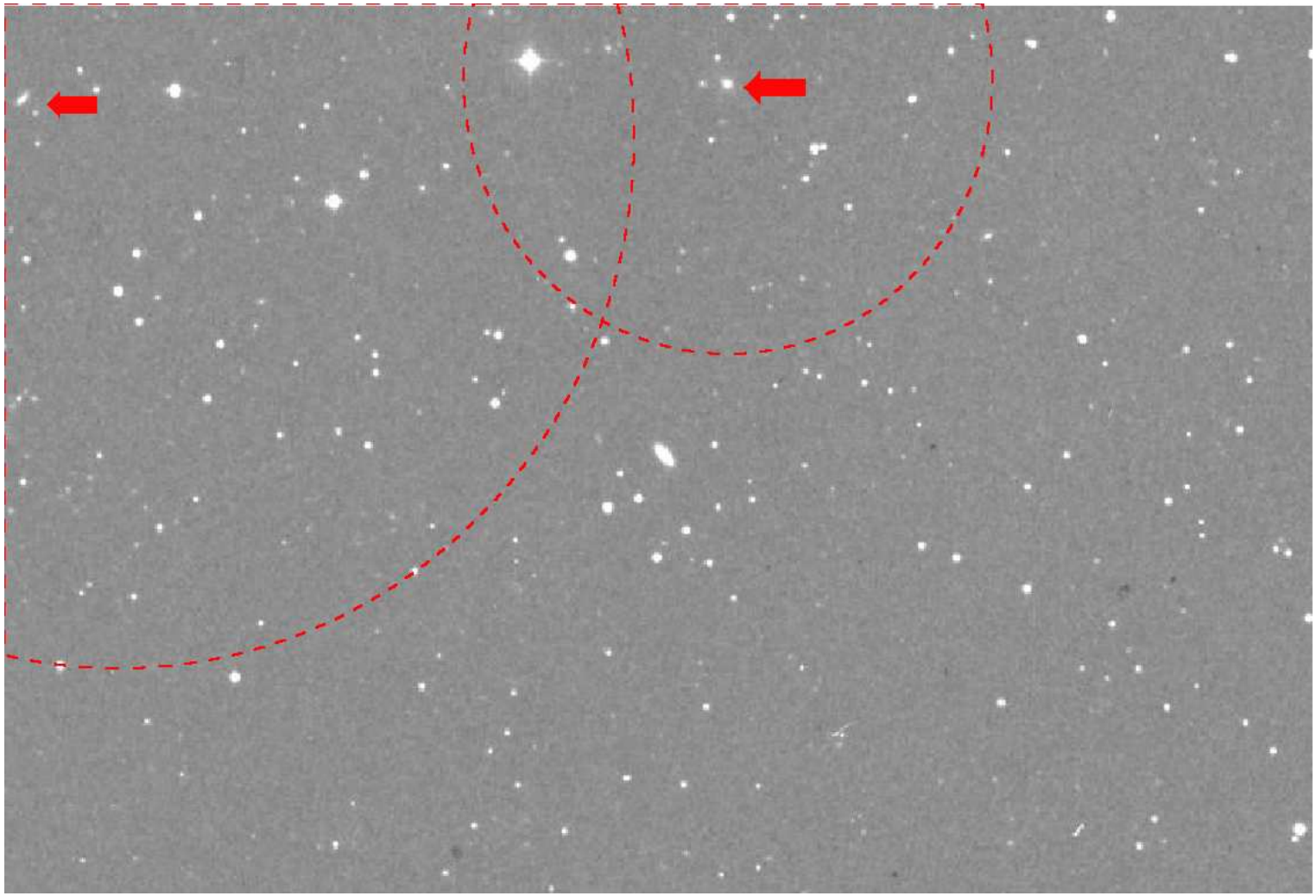
Isolation definition

Karachentseva 1973



Isolation definition

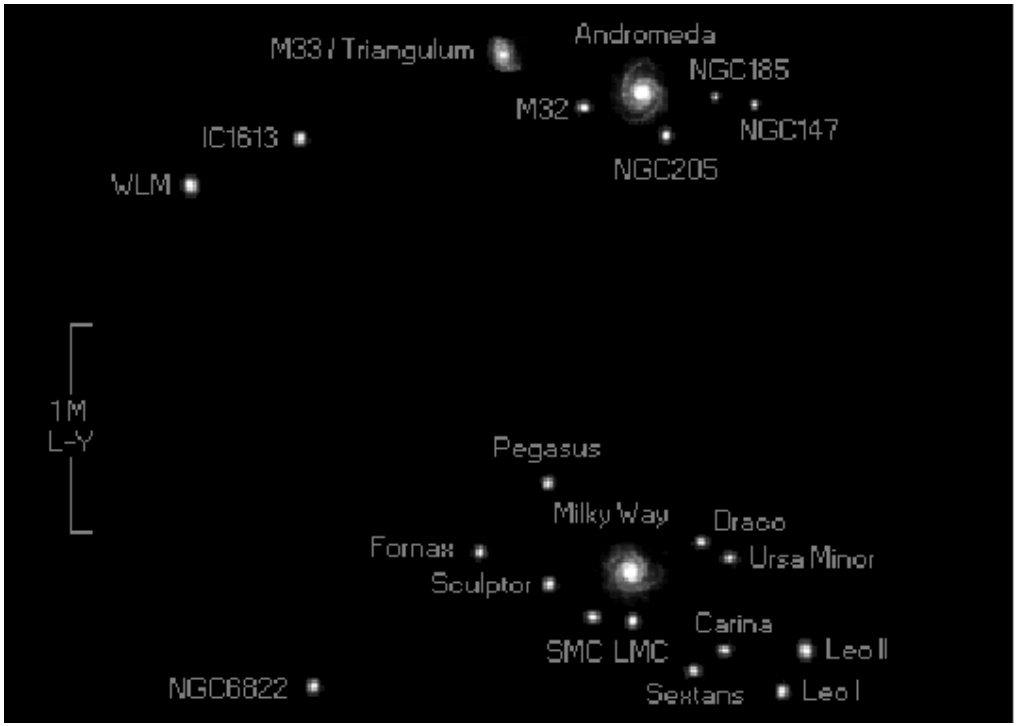
Karachentseva 1973



Local group

AMIGA-IV 2007, A&A, 470, 505

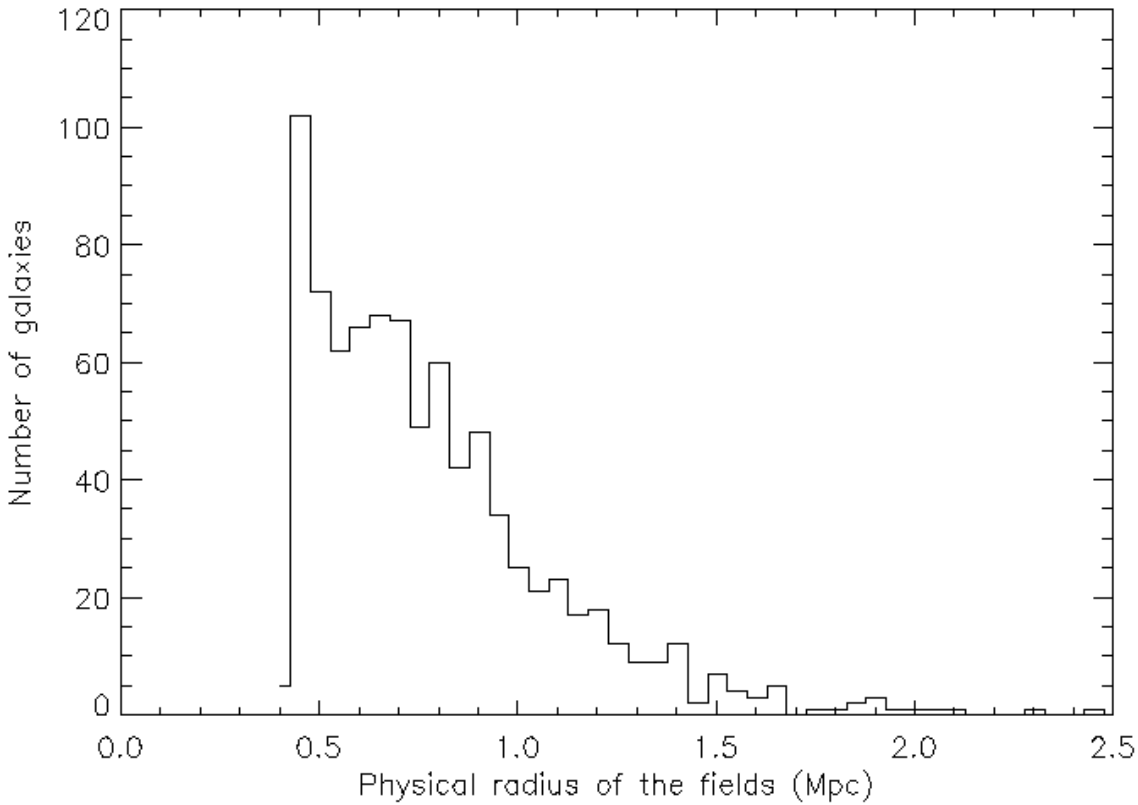
- Primary galaxy: Milky Way: D $\approx$ 30 kpc
  - Andromeda: D $\approx$ 40 kpc, dist. $\approx$ 725 kpc
  - M 33: D $\approx$ 16 kpc, dist. $\approx$ 840 kpc
  - Large Magellanic Cloud: D $\approx$ 9 kpc, dist. $\approx$ 50 kpc



The AMIGA revision

AMIGA-IV 2007, A&A, 470, 505

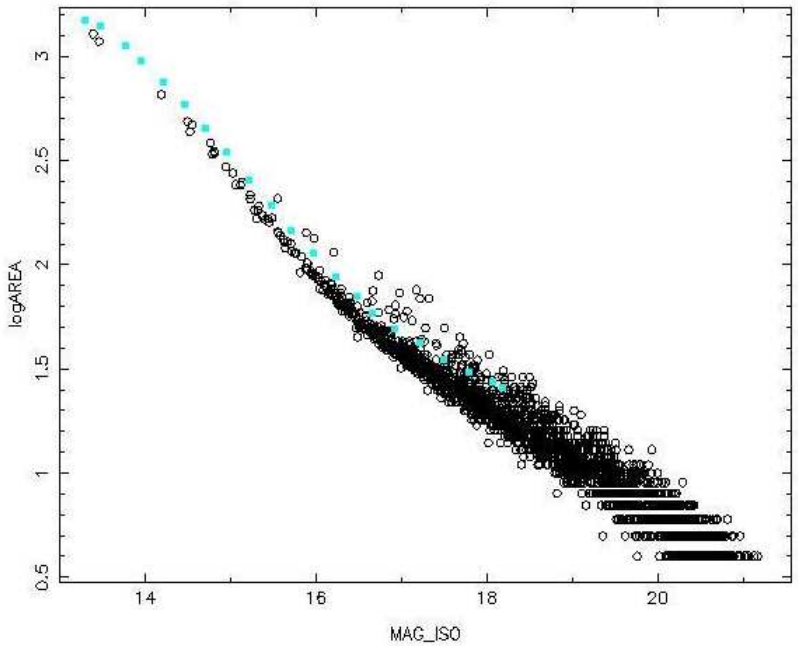
- concerns 950 CIGs ($V > 1500$ km s^{-1})
- minimum physical radius of 0.5 Mpc (3×10^9 years)
- squared fields: 55' (767), 110' (134), 165' (49)

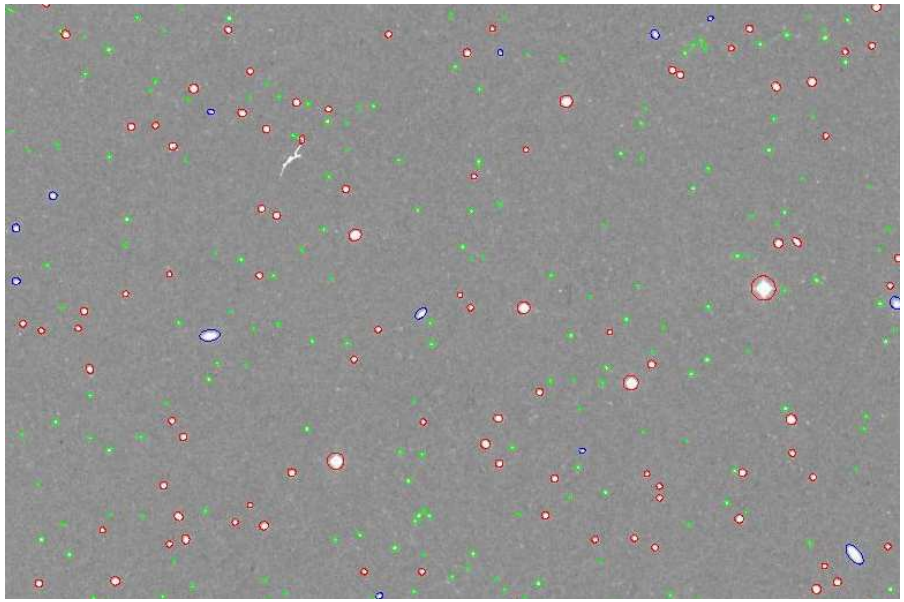


Isolation pipeline

AMIGA-IV 2007, A&A, 470, 505

- POSS-I digitised plates (1.7 arcsec/pixel)
- SExtractor for the detection [Bertin & Arnouts, 1996]
- LMORPHO for the star/galaxy separation [Odewahn, 1995]
- POSS-II digitised plates (1.0 arcsec/pixel)





Isolation parameters

AMIGA-V 2007, A&A, 472, 121

~53 000 neighbours around 950 CIGs

- **Local number density**
  [Casertano & Hut, 1985]

$$\eta_k = \frac{k-1}{V(r_k)}$$

with $V(r_k) = 4\pi r_k^3/3$, where r_k is the distance to the k^{th} nearest neighbour

- **Tidal forces**
  [Dahari, 1984]

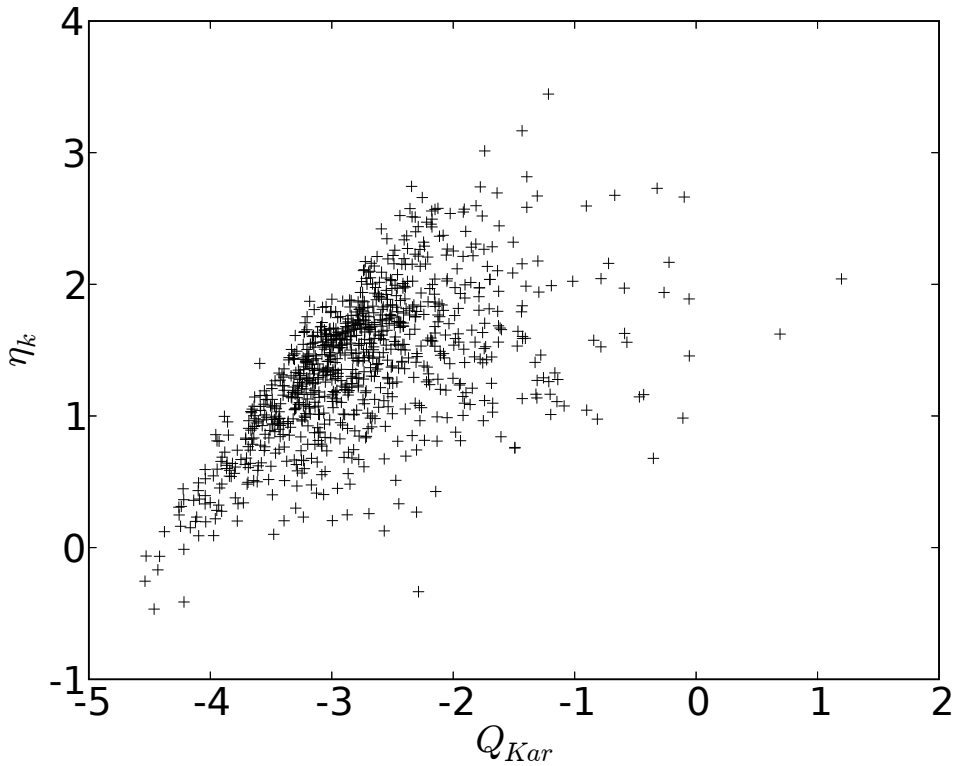
$$F_{tidal} \propto \frac{M_c \times \Delta R}{R^3} = \frac{M_c \times D_p}{S^3}$$

$$F_{bind} \propto \frac{M_p}{D_p^2}$$

$$Q \equiv \frac{F_{tidal}}{F_{bind}} \propto \left(\frac{M_c}{M_p}\right)\left(\frac{D_p}{S}\right)^3 \propto \frac{(\sqrt{D_p D_c})^3}{S^3}$$

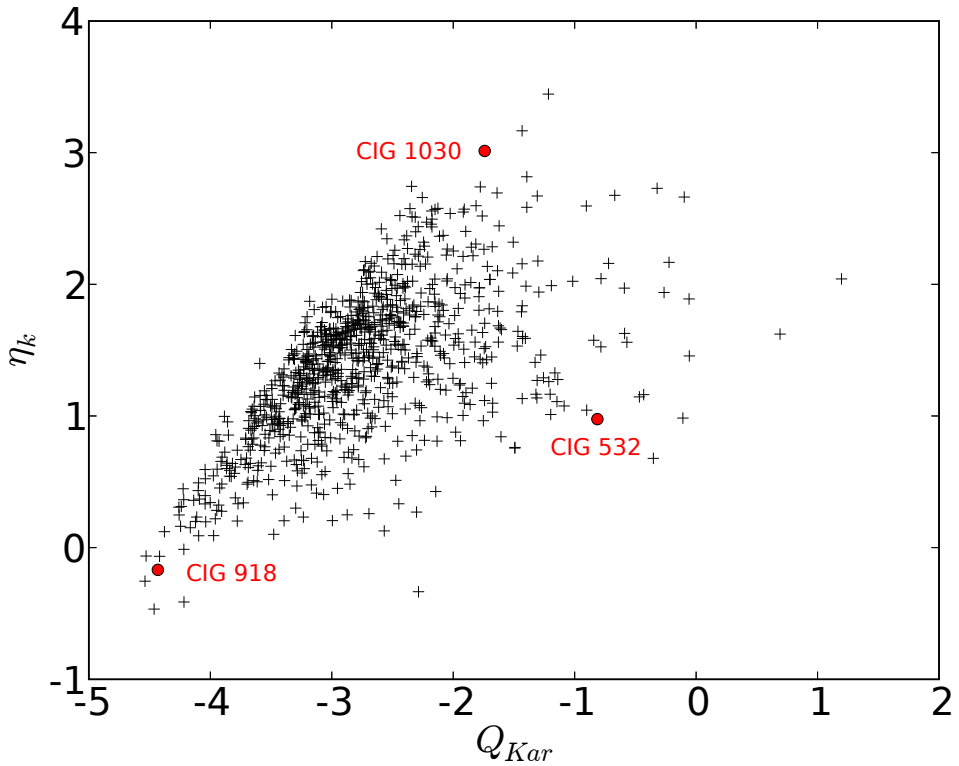
Complementarity

AMIGA-V 2007, A&A, 472, 121



Complementarity

AMIGA-V 2007, A&A, 472, 121

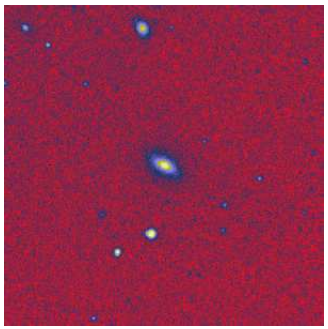


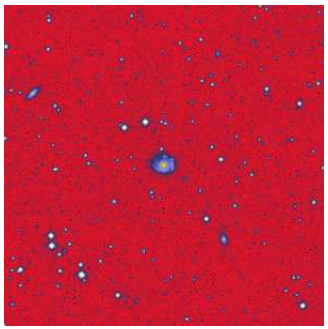
- CIG 918: 6 neighbours, all similar sizes, none violates
- CIG 1030: 131 neighbours, 4 violate
- CIG 532: 30 neighbours, 1 very near (35“) and violating

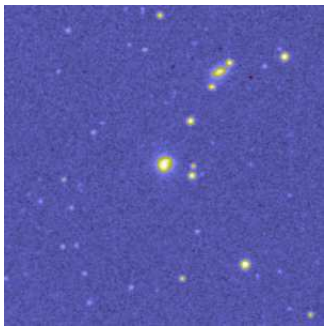
Pair candidates

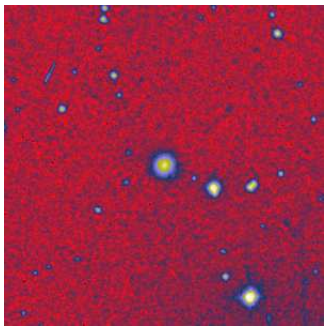
AMIGA-IV 2007, A&A, 470, 505

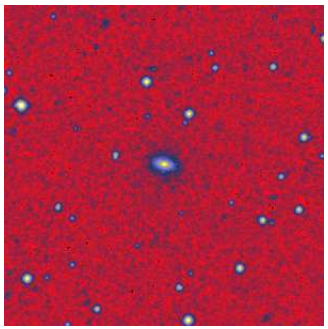
CIG galaxy with at least one companion (factor 2 in size with respect to D_p) within $5 \times D_p$:

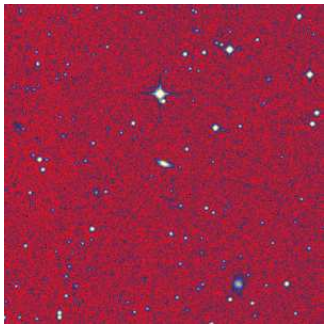

CIG 0019

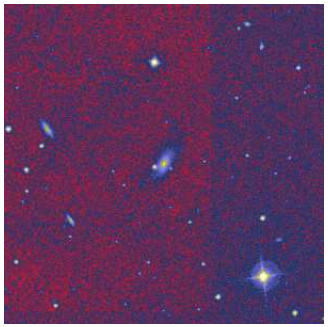

CIG 0036

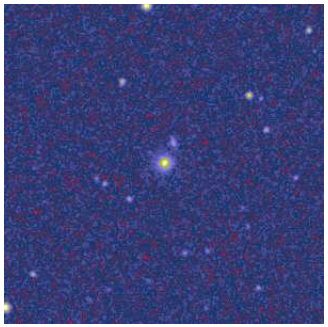

CIG 0074

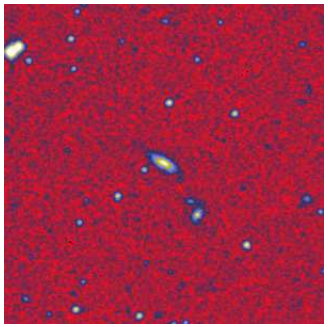

CIG 0178

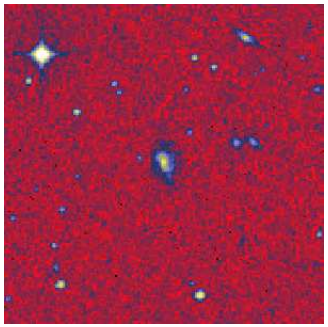

CIG 0233


CIG 0315


CIG 0488


CIG 0533


CIG 0683


CIG 0934

Comparison samples

AMIGA-V 2007, A&A, 472, 121

1. Karachentseva Triplets of Galaxies (KTG)

   [Karachentseva et al. 1979]

2. Hickson Compact Groups (HCG)

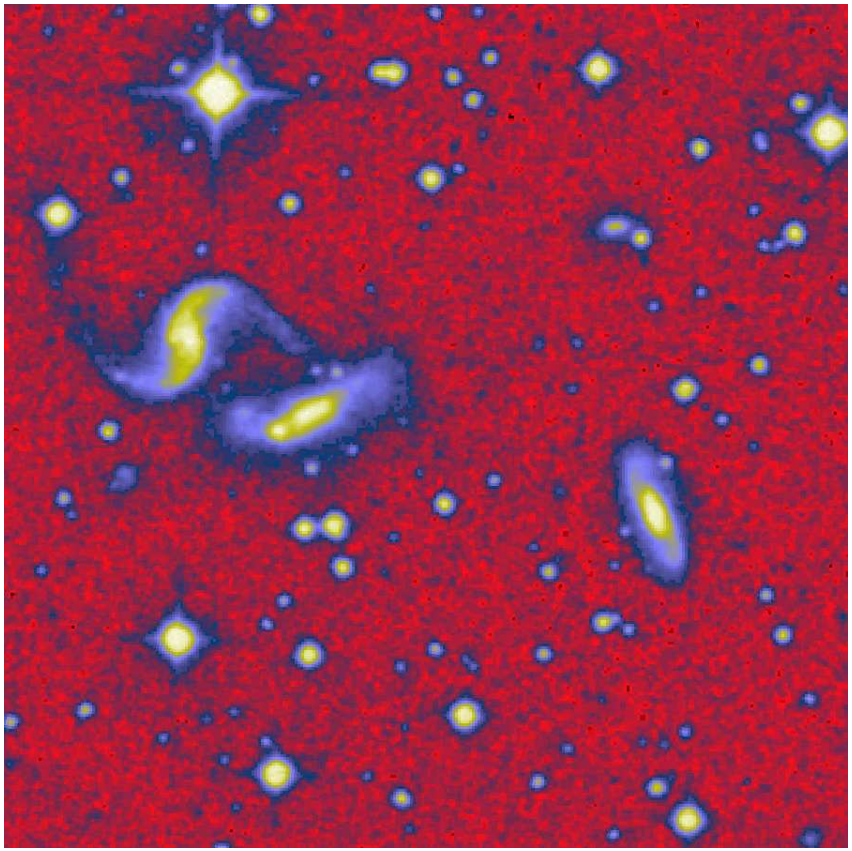
   [Hickson 1982]

3. Abell Clusters (ACO)

   [Abell 1958; Abell et al. 1989]

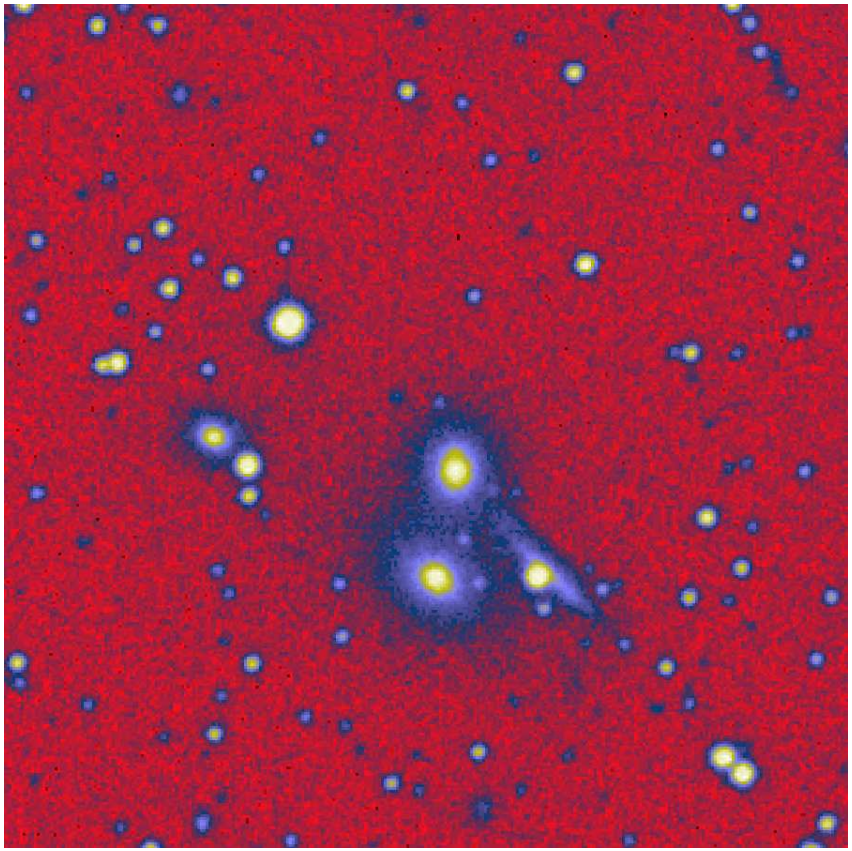
1. Karachentseva Triplets of Galaxies (KTG)

- 41 triplets selected
- primary galaxy = "A" galaxy



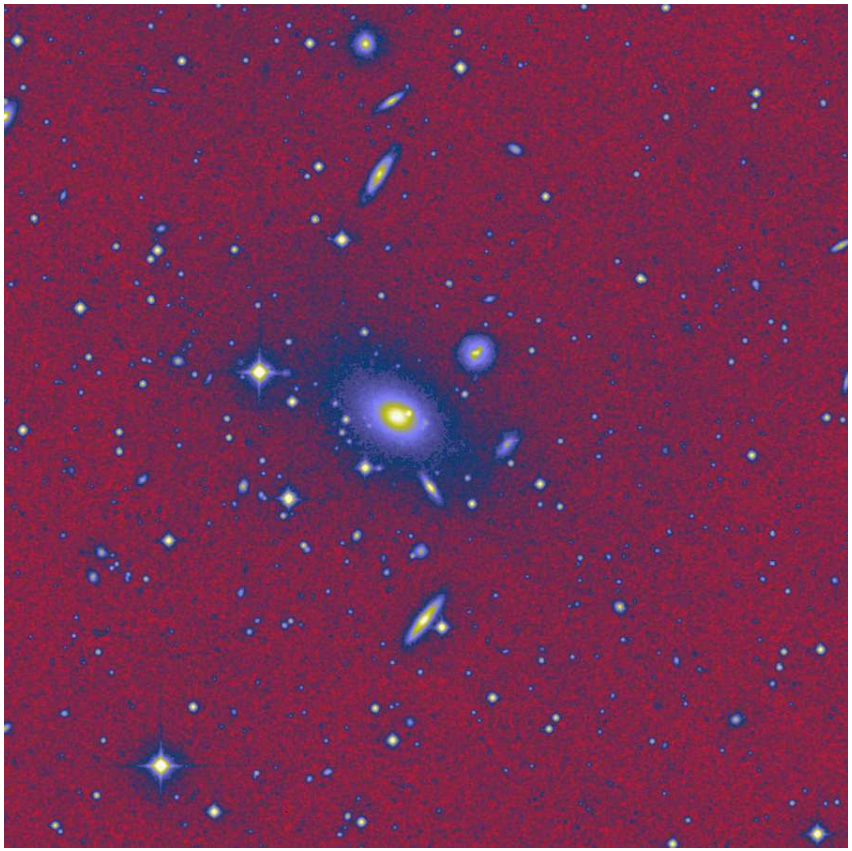
2. Hickson Compact Groups (HCG)

- 34 groups selected
- primary galaxy = "A" galaxy

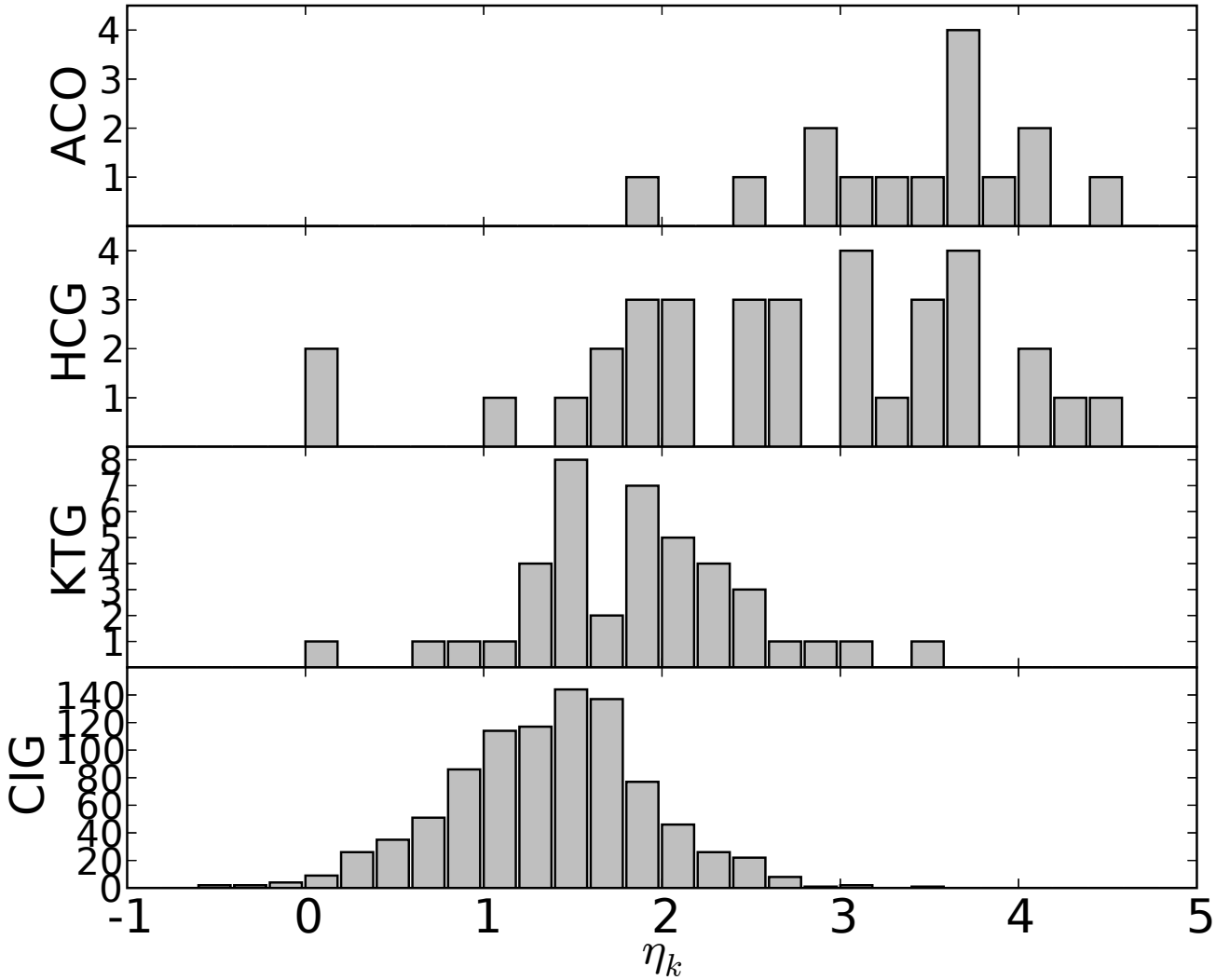


3. Abell clusters (ACO)

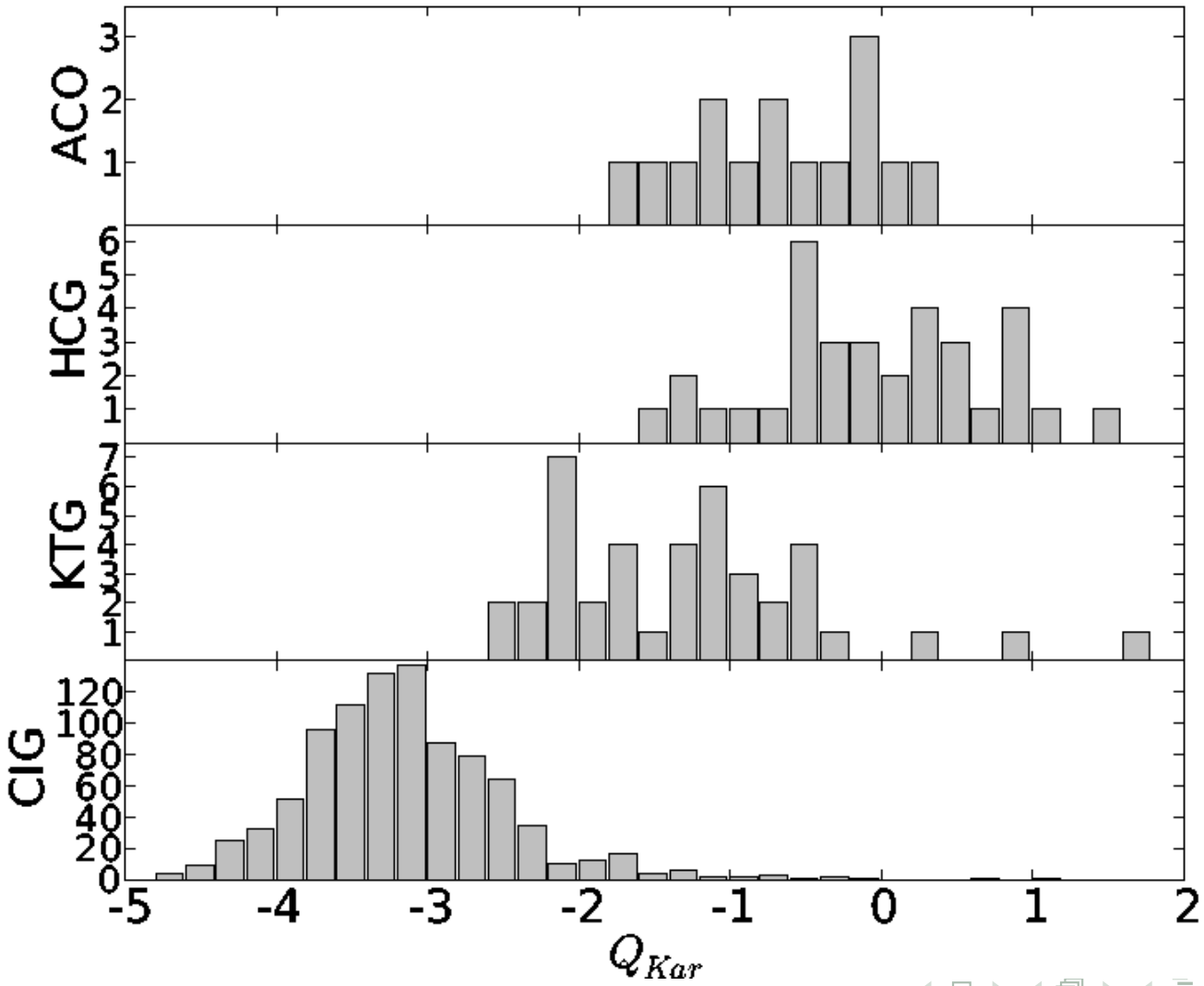
- 15 clusters selected
- primary galaxy = cD central galaxy, Brightest CG



Distribution of the local number density η_k

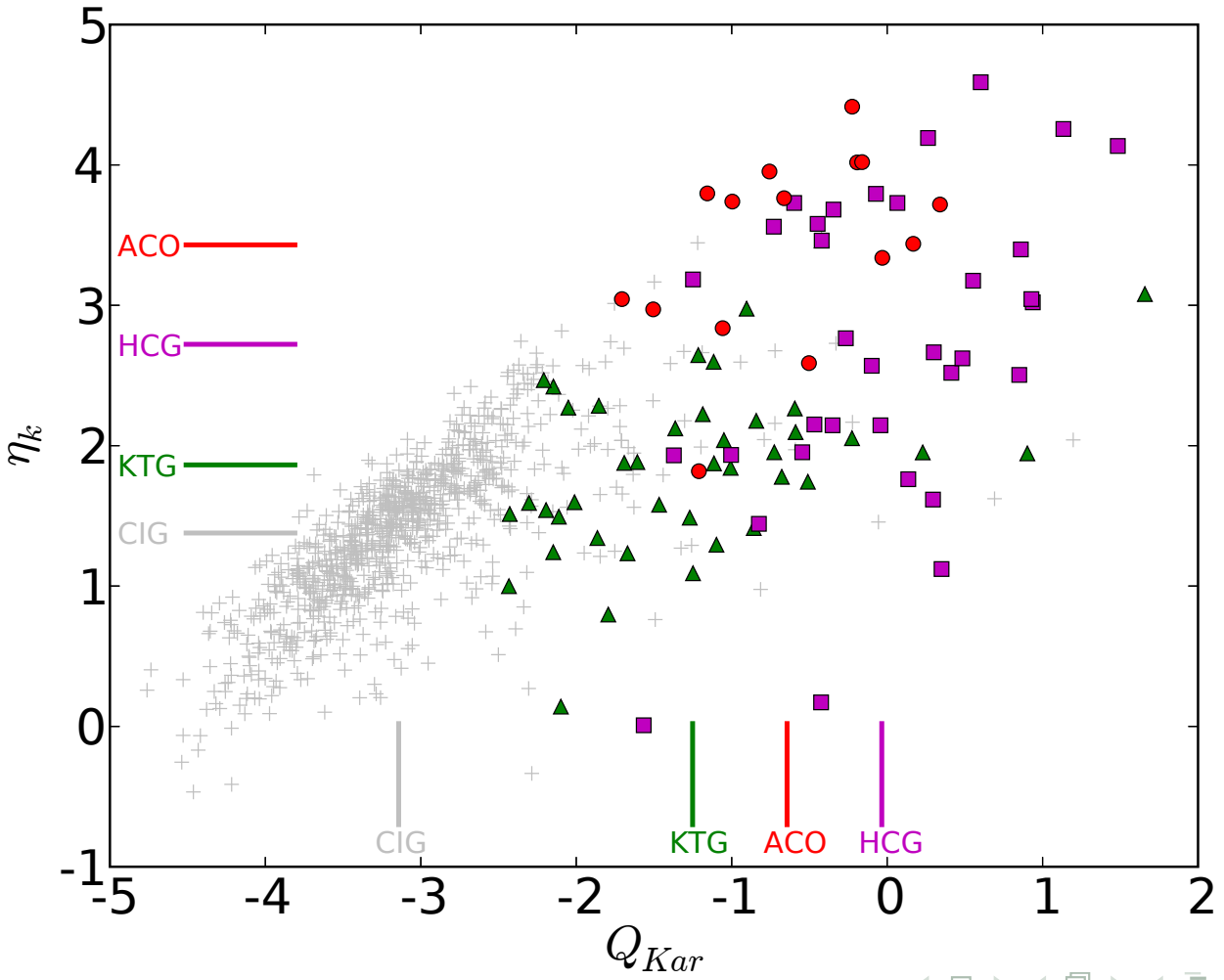


Distribution of the tidal strength Q_{Kar}



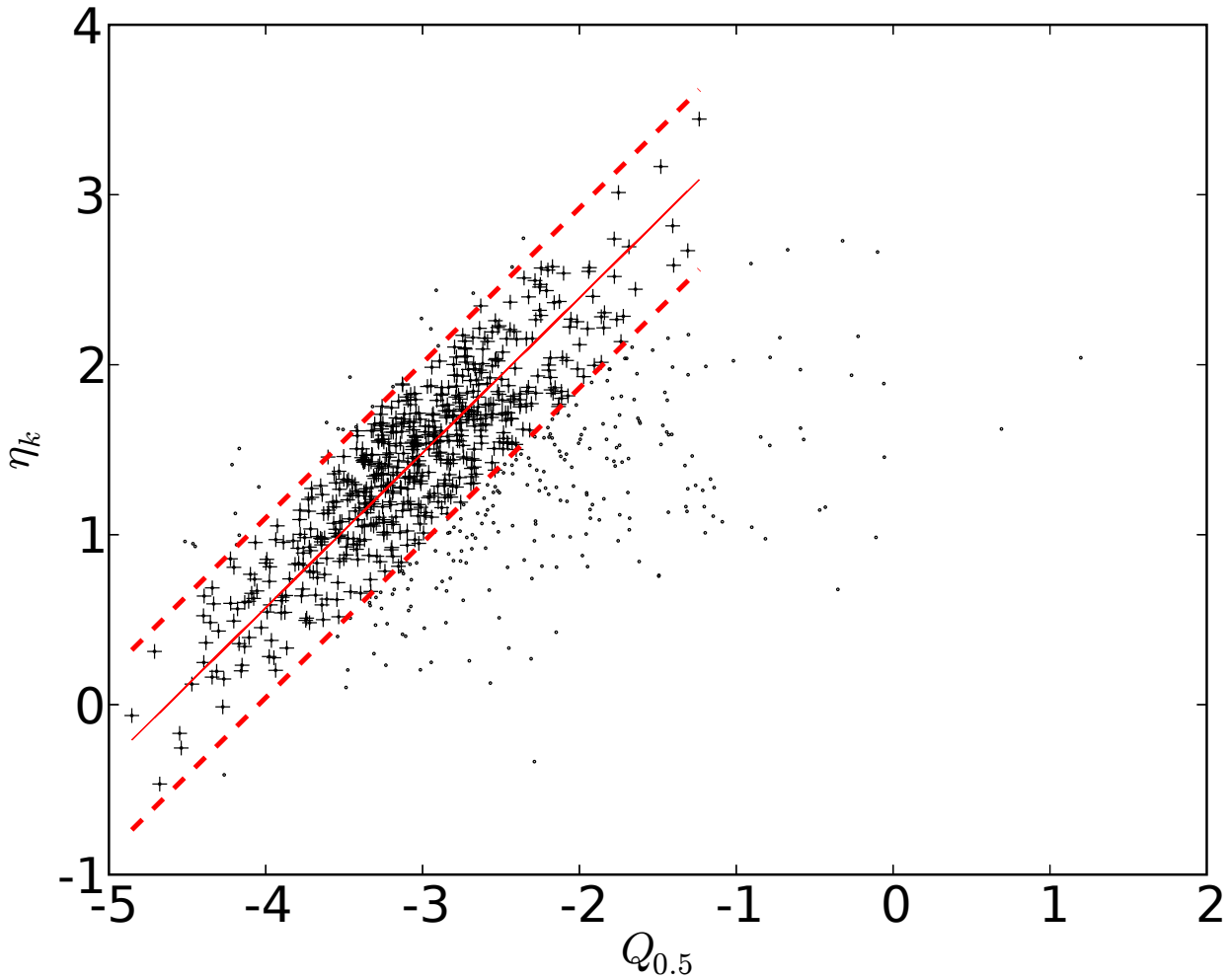
Comparison to denser samples

AMIGA-V 2007, A&A, 472, 121



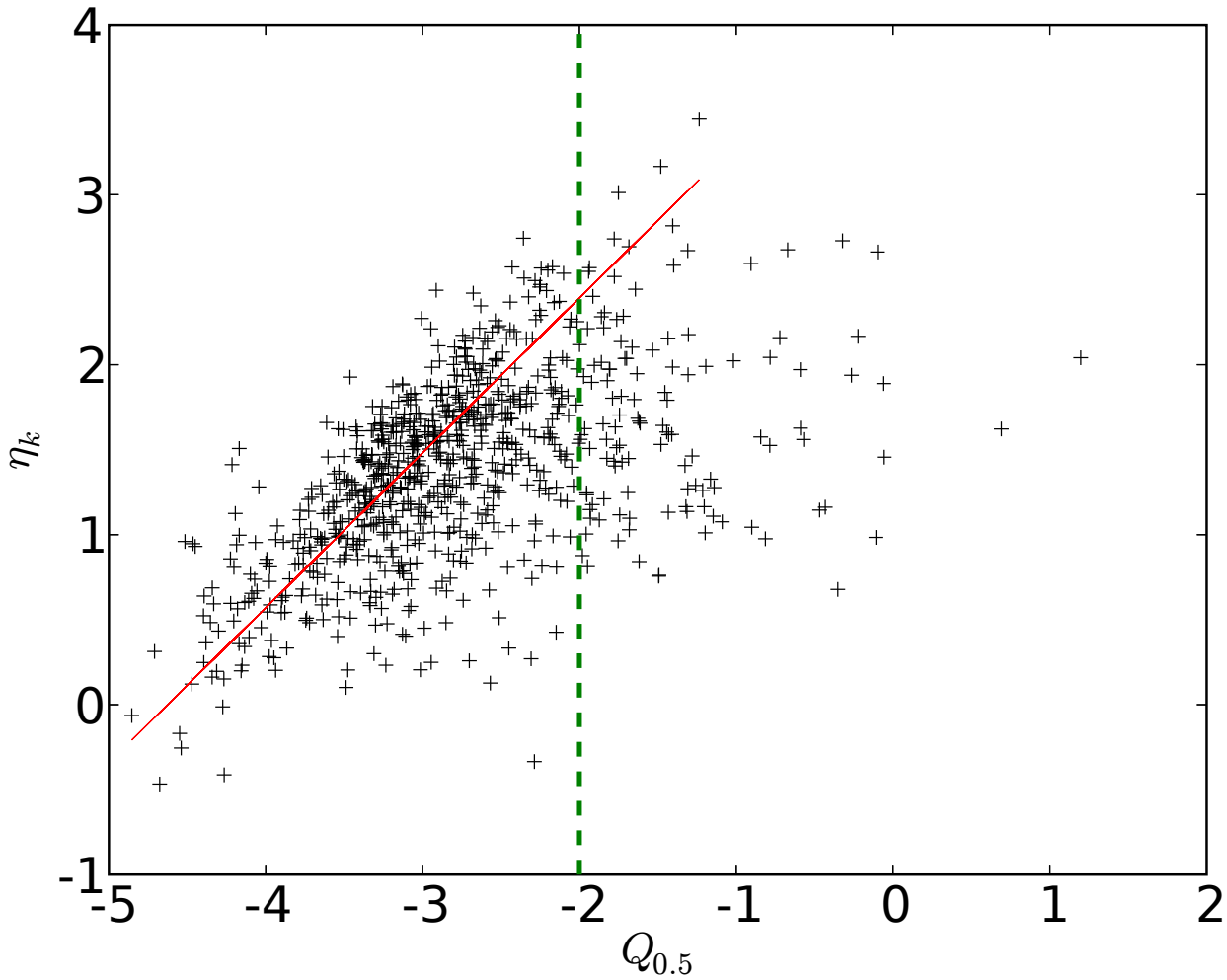
Selection of isolated galaxies

AMIGA-V 2007, A&A, 472, 121



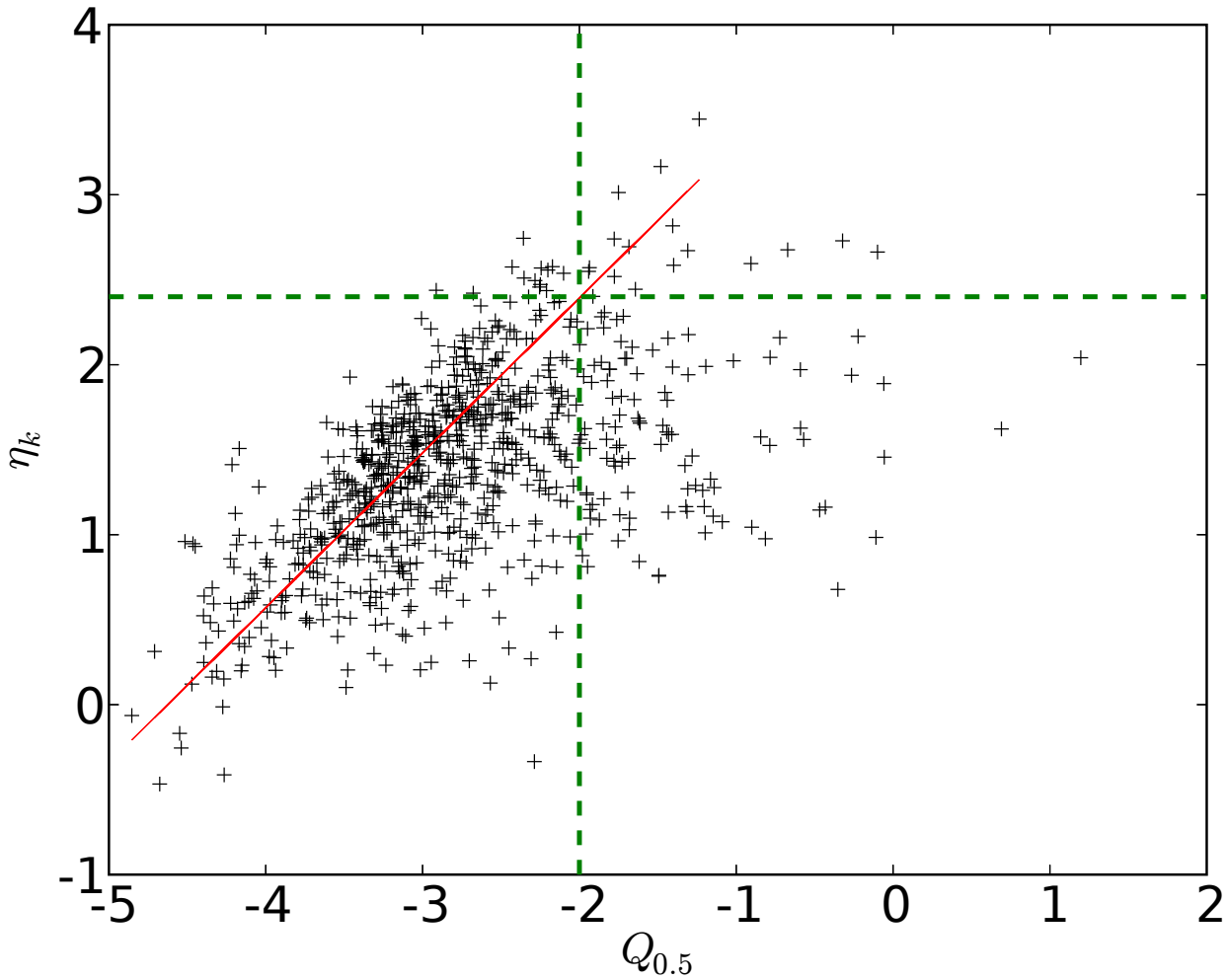
Selection of isolated galaxies

Athanassoula 1984, Phys. Rep.



Selection of isolated galaxies

AMIGA-V 2007, A&A, 472, 121

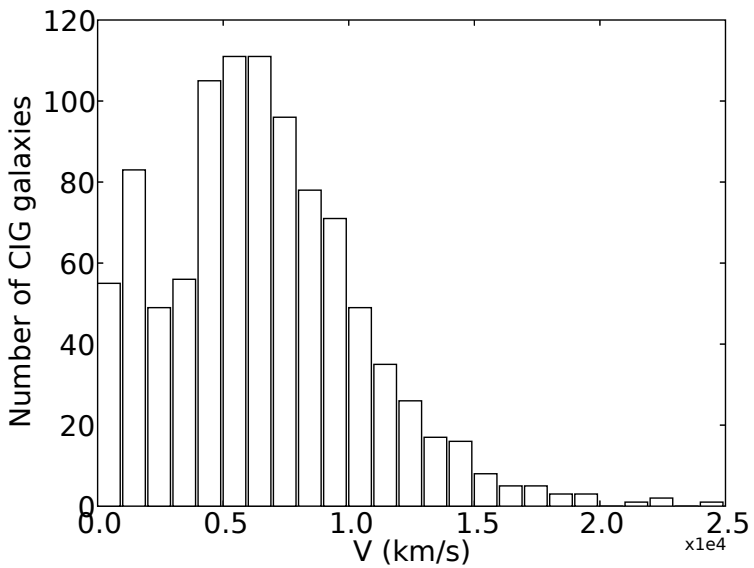


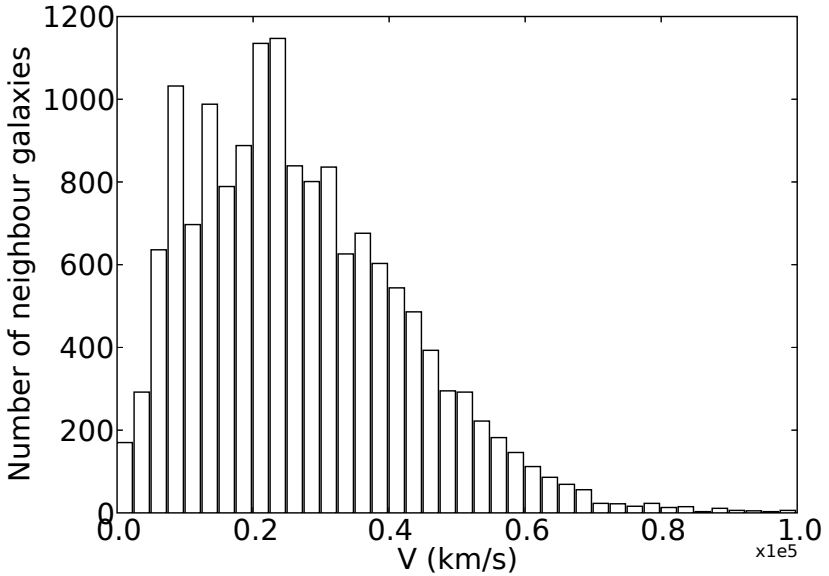
Redshifts

AMIGA-IV 2007, A&A, 470, 505

Database or survey	Number of redshifts	Number of matched objects	Percentage of GALAXY
NED	8024	35317	99.97%
hyperLEDA	11608	25614	99.99%
SDSS (DR3)	12166	12166	99.79%
CfA (velocity)	8864	9103	99.86%
2dF	3018	3018	-
UZC	1461	1488	-
UZC J2000	1445	1485	-
CfA2	866	866	100%
CfA1	106	106	100%
NOG2	67	67	-
SSRS2	50	50	-
	16126 (29.86%)		GALAXY (99.90%)

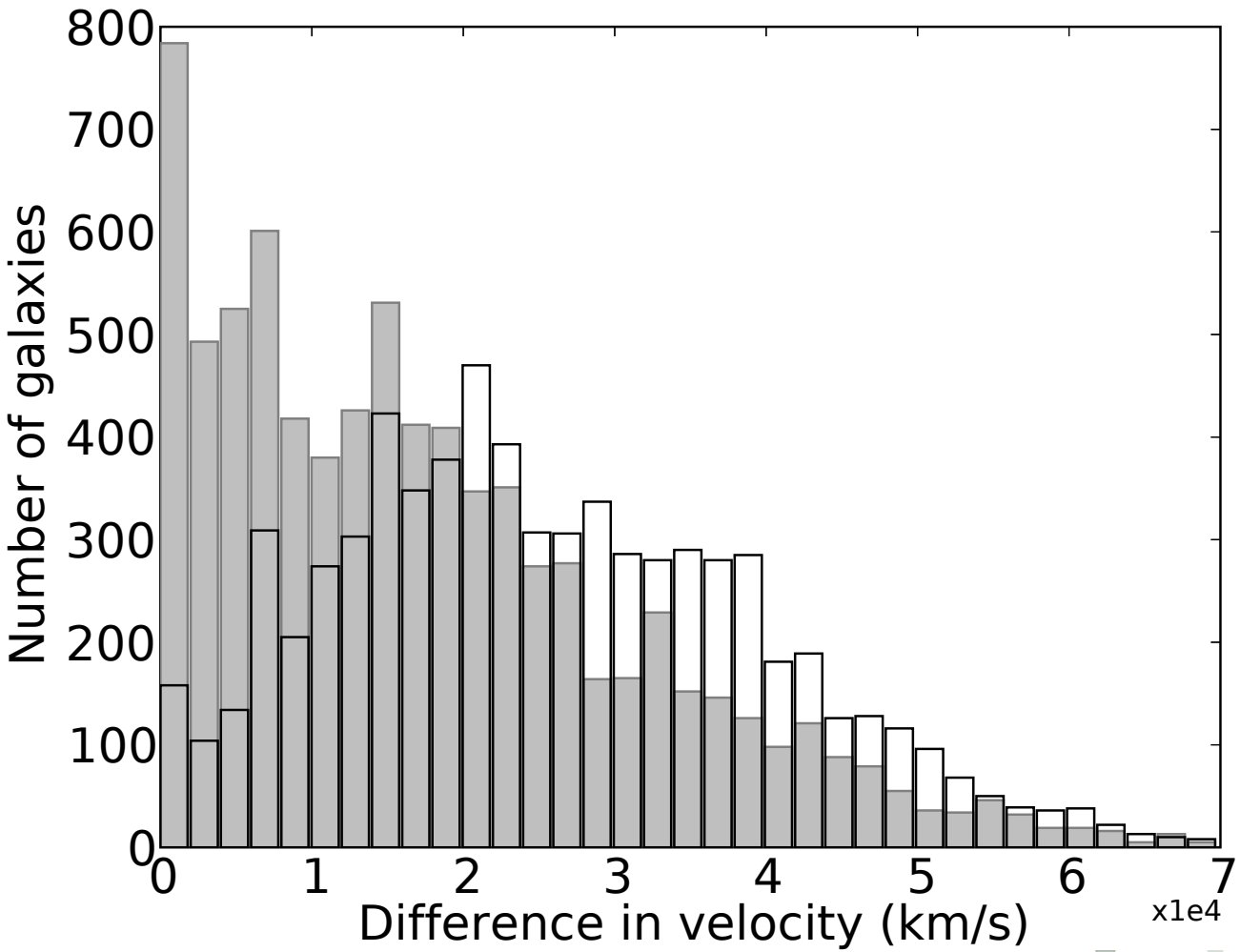
Redshifts of primary and neighbour galaxies





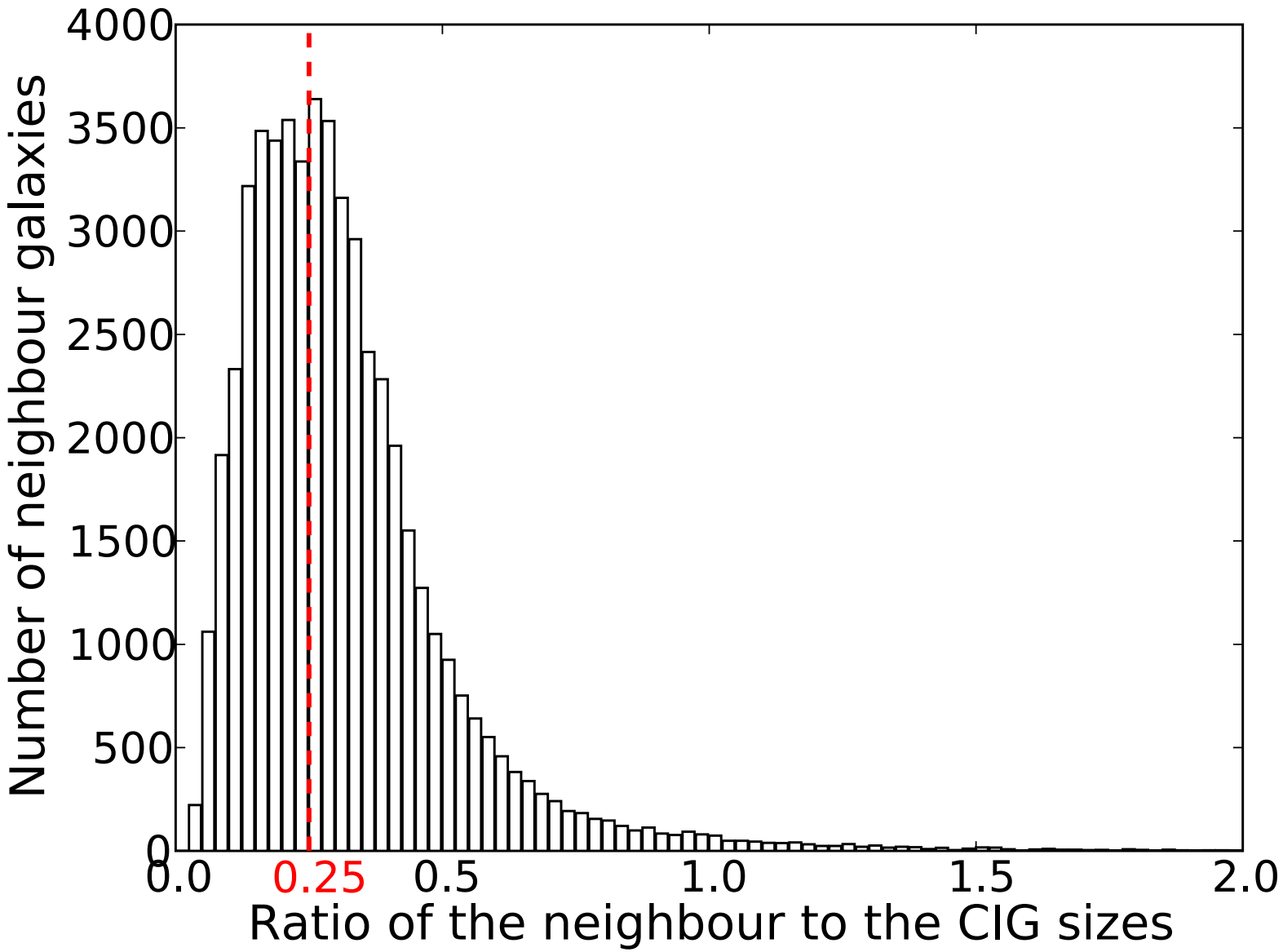
Velocity differences

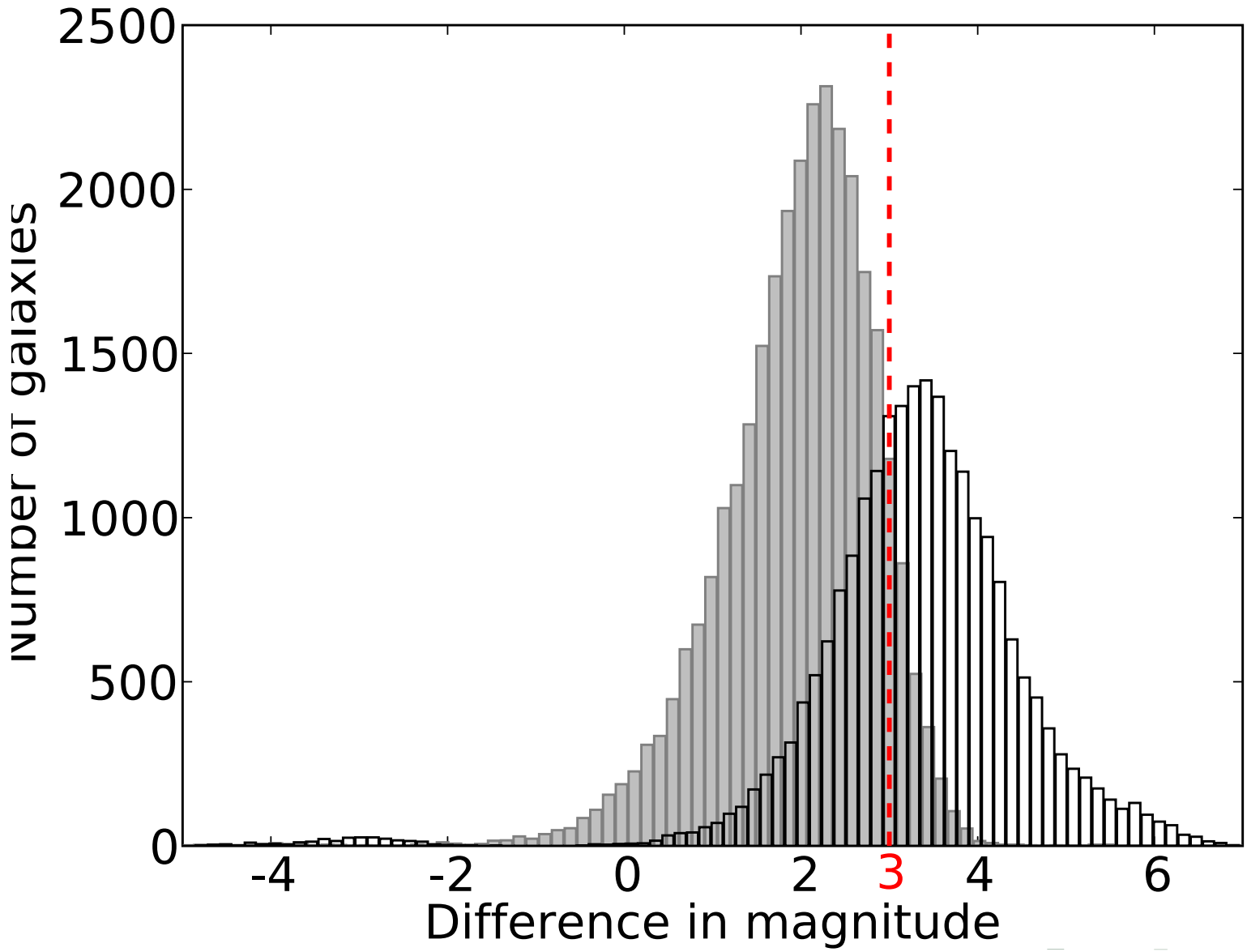
AMIGA-IV 2007, A&A, 470, 505

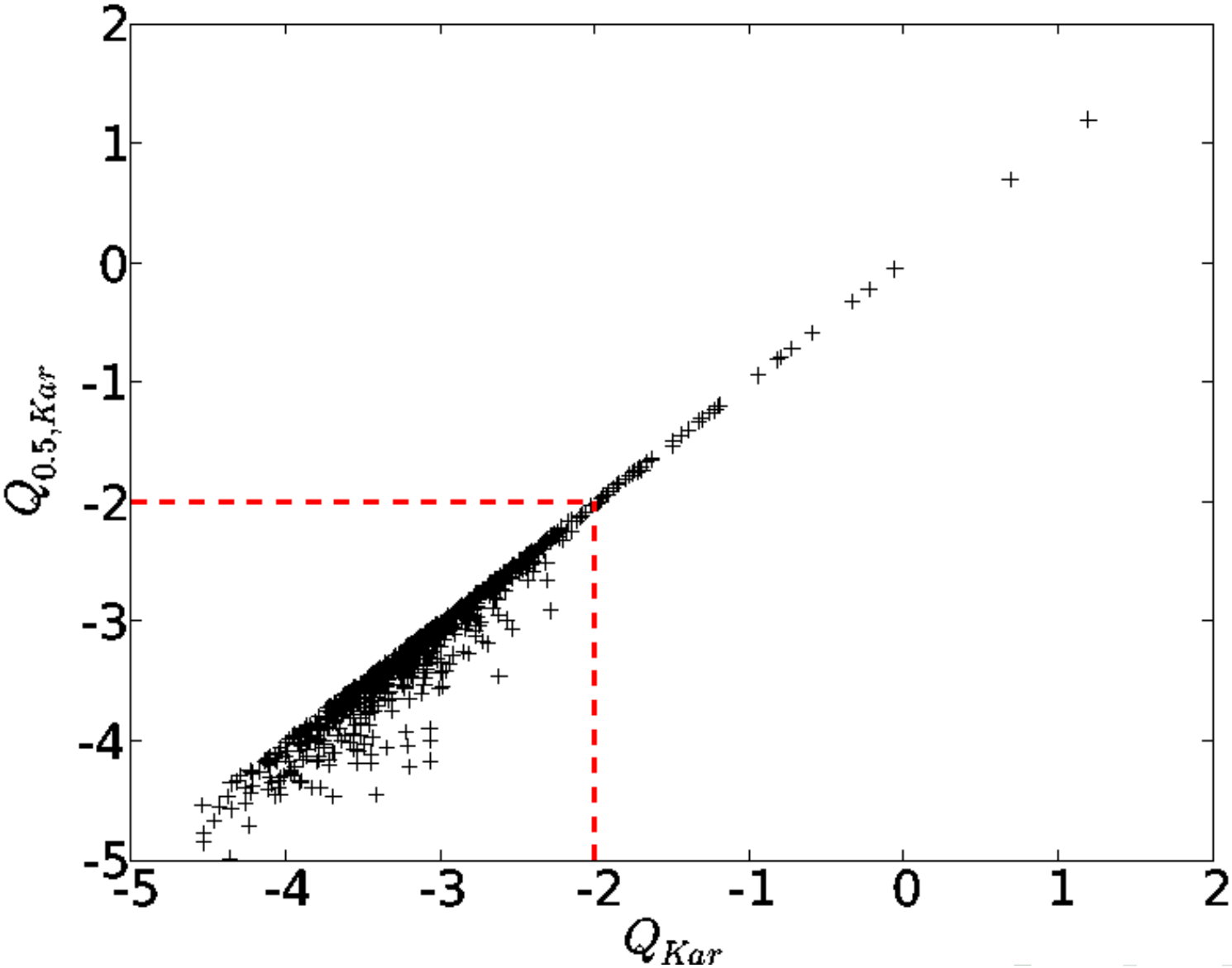


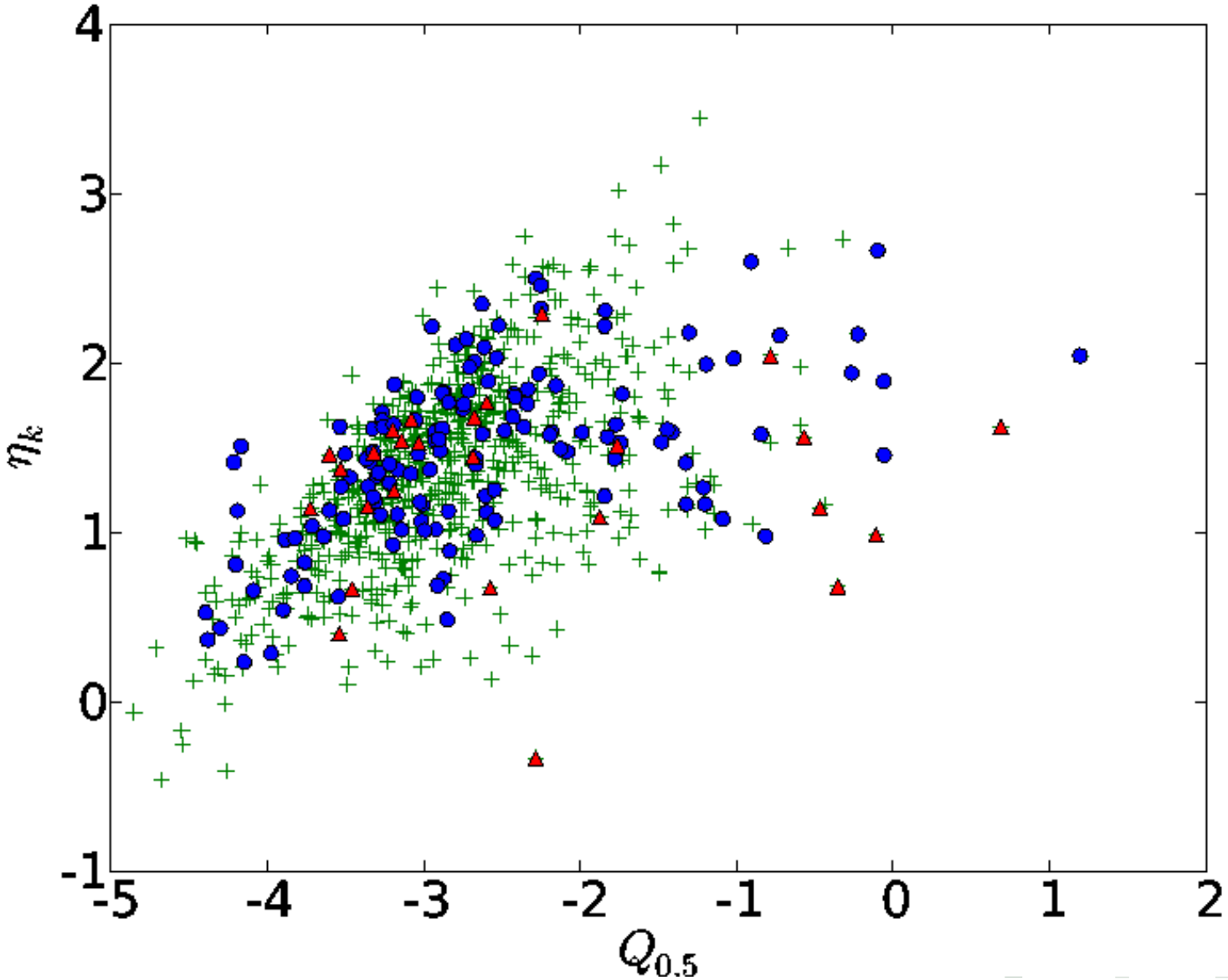
Conclusions

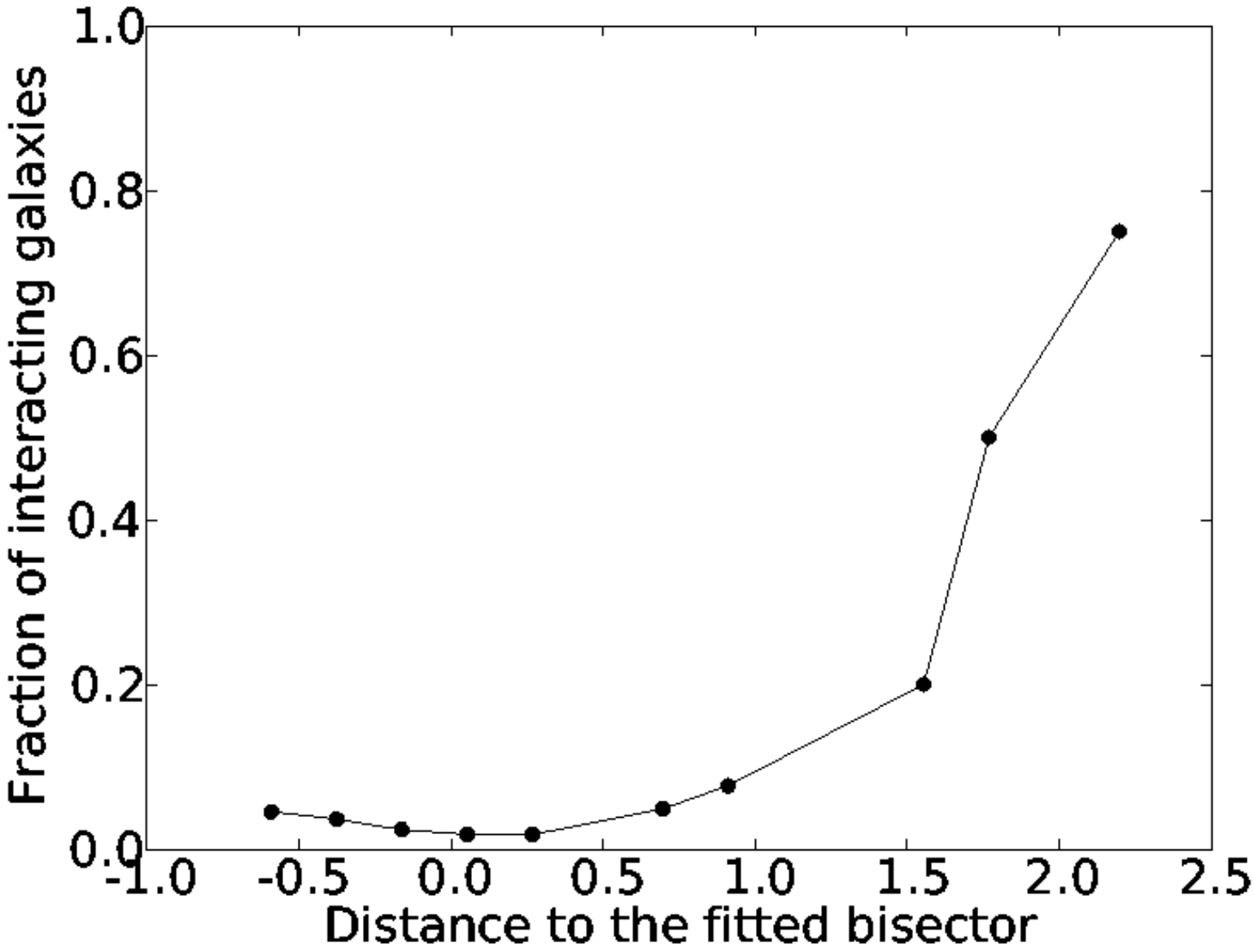
- Computer processing: to detect and classify sources around 950 CIG
- Continuous isolation parameters consistent for the whole sample
- Complementarity between the isolation parameters: comprehensive picture of the environment
- Comparison samples: KTG, HCG, ACO
- Sensitivity of the isolation parameters
- Redshifts: verification of the type (validation of our star/galaxy separation $> 99.90\%$) and partial 3-dimensional picture of the environment
- AMIGA refined catalogue of 791 isolated galaxies showing a continuous gradient of isolation but having their evolution dominated by their intrinsic properties


Number of neighbour galaxies
4000
3500
3000
2500
2000
1500
1000
500
0
0.0
0.25
0.5
1.0
1.5
2.0
Ratio of the neighbour to the CIG sizes


2500
2000
1500
1000
500
0
Number of galaxies
-4
-2
0
2
3
4
6
Difference in magnitude

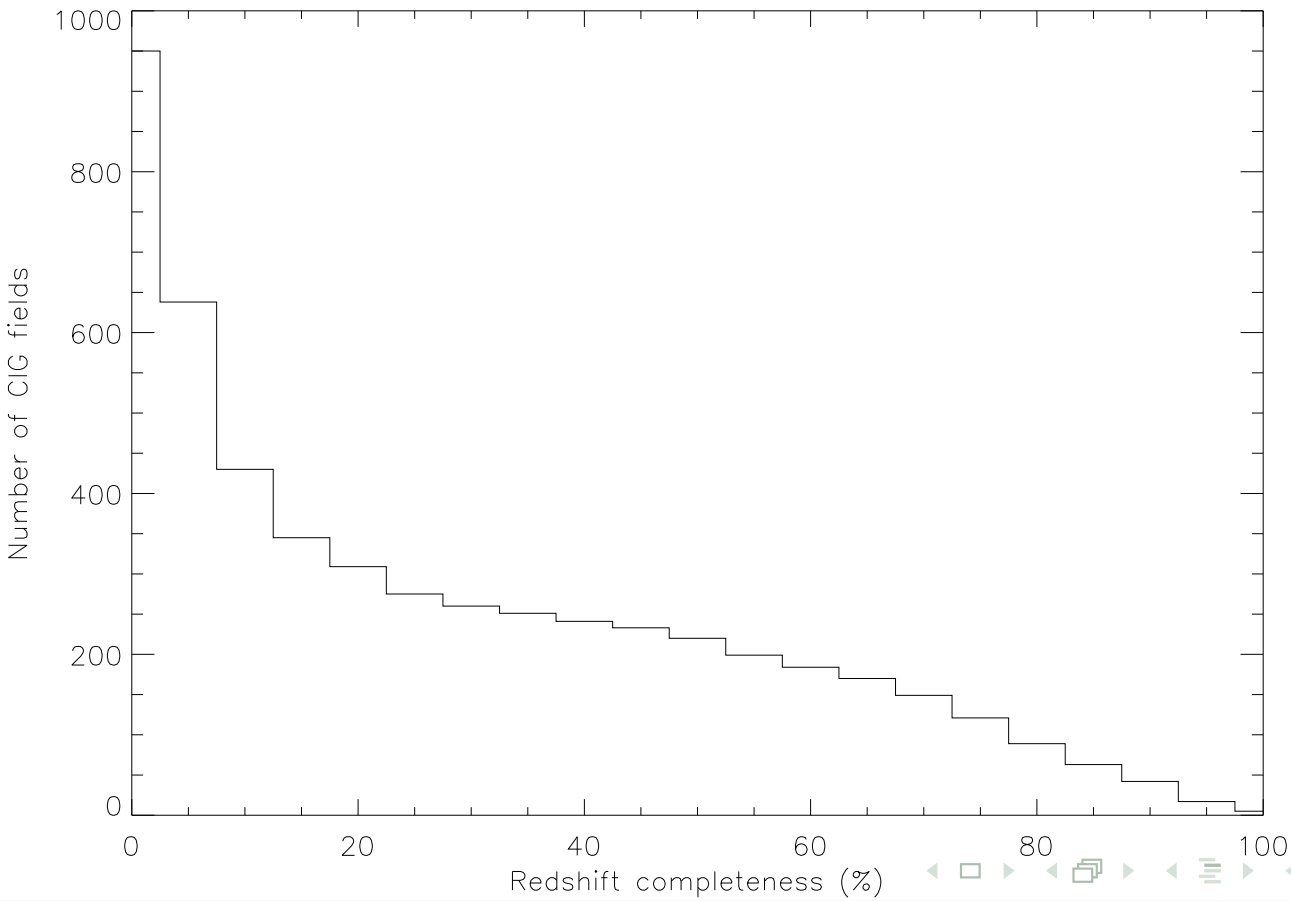

2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
$Q_{0.5,Kar}$
Q_{Kar}


4
3
2
1
0
-1
-5
-4
-3
-2
-1
0
1
2
η_k
$Q_{0.5}$


Fraction of interacting galaxies
1.0
0.8
0.6
0.4
0.2
0.0
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
Distance to the fitted bisector

Redshift Completeness

- completeness $\leq$ 20%: 641 fields
- completeness $\geq$ 80%: 89 fields



Redshifts

Database or survey	Number of redshifts	Number of matched objects	Percentage of GALAXY
NED	8024	35317	99.97%
hyperLEDA	11608	25614	99.99%
SDSS (DR3)	12166	12166	99.79%
CfA (velocity)	8864	9103	99.86%
2dF	3018	3018	-
UZC	1461	1488	-
UZC J2000	1445	1485	-
CfA2	866	866	100%
CfA1	106	106	100%
NOG2	67	67	-
SSRS2	50	50	-
	16126 (29.86%)		GALAXY (99.90%)

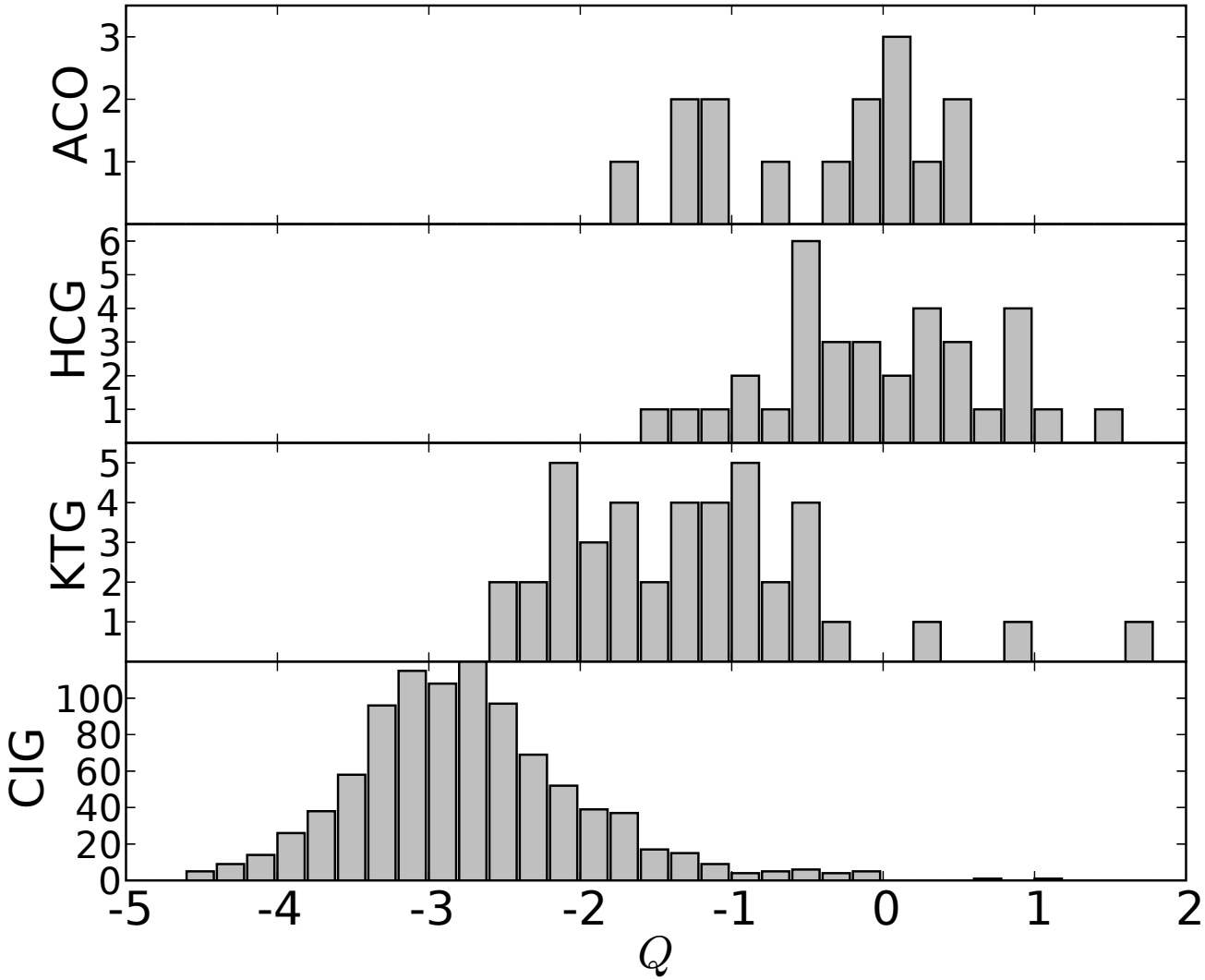
Redshifts

Database or survey	Number of redshifts	Number of matched objects	Percentage of GALAXY
NED	8024	35317	99.97%
hyperLEDA	11608	25614	99.99%
SDSS (DR6)	19031	19031	
CfA (velocity)	8864	9103	99.86%
2dF	3018	3018	-
UZC	1461	1488	-
UZC J2000	1445	1485	-
CfA2	866	866	100%
CfA1	106	106	100%
NOG2	67	67	-
SSRS2	50	50	-
	16126 (29.86%)		GALAXY (99.90%)

Redshifts

Database or survey	Number of redshifts	Number of matched objects	Percentage of GALAXY
NED	8024	35317	99.97%
hyperLEDA	11608	25614	99.99%
SDSS (DR7)	22332	22332	
CfA (velocity)	8864	9103	99.86%
2dF	3018	3018	-
UZC	1461	1488	-
UZC J2000	1445	1485	-
CfA2	866	866	100%
CfA1	106	106	100%
NOG2	67	67	-
SSRS2	50	50	-
	16126 (29.86%)		GALAXY (99.90%)

Distribution of the tidal strength Q



Karachentseva's criterion

AMIGA-IV 2007, A&A, 470, 505

- 67 fields covering $80 \times D_p$: 54 CIG galaxies isolated
- 284 CIG galaxies violating Karachentseva's isolation definition; 666 remaining isolated