Environment and star formation of isolated galaxies in the local Universe

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- José Sabater Montes
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- IRAM
- UGR

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Overview of the presentation

Introduction

Isolation study

- Data analysis
- Isolation criteria
- Comparison samples
- Redshifts

Star formation in isolated galaxies

- Hα sample
- Observations
- Data reduction
- Hα subsample

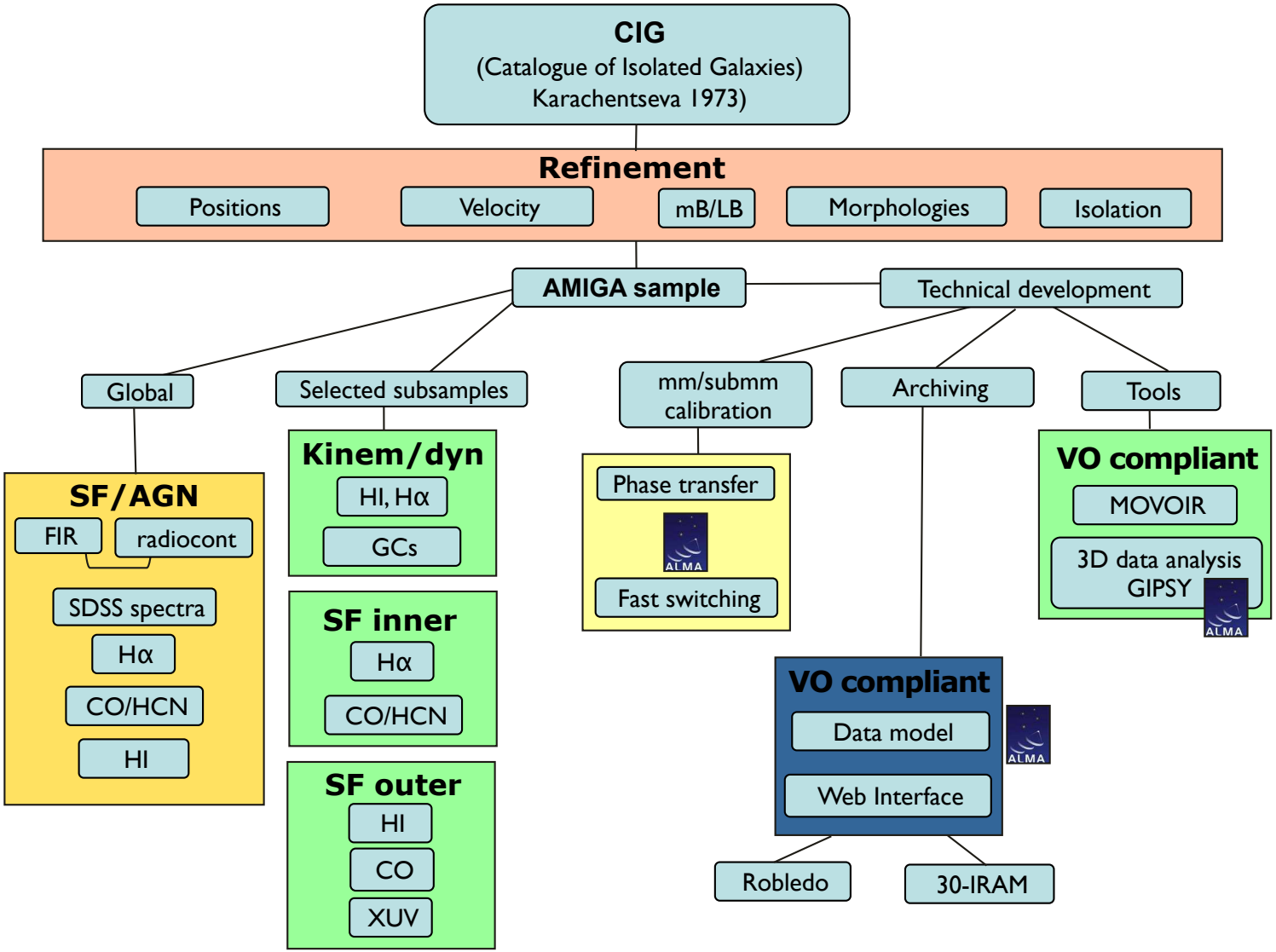
Conclusions and perspectives

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

AMIGA in one slide



ISM in isolated galaxies

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
- Public database
  - `http://www.amiga.iaa.es`

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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]:

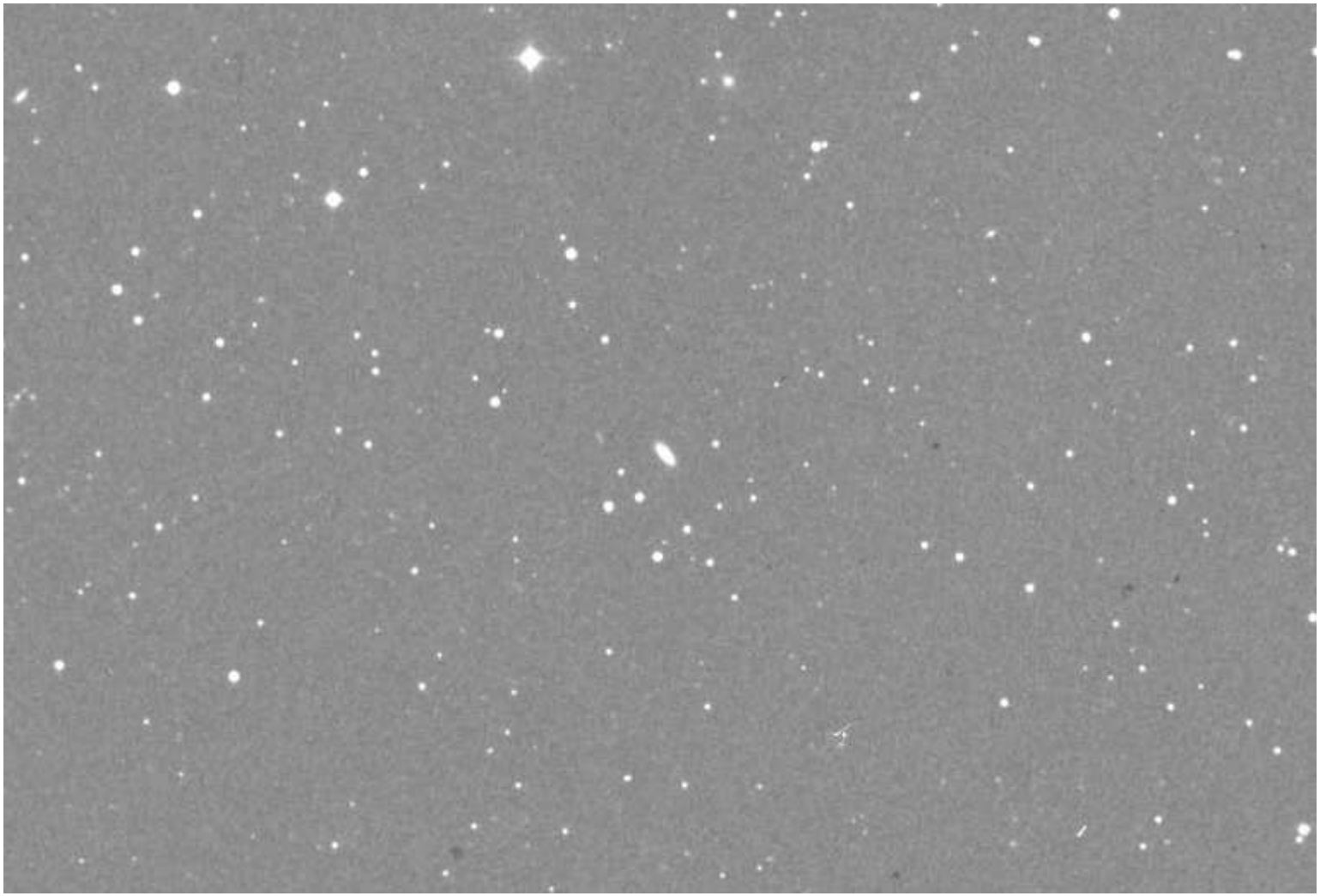
$$R_{ip} \geq 20 \times D_i$$

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

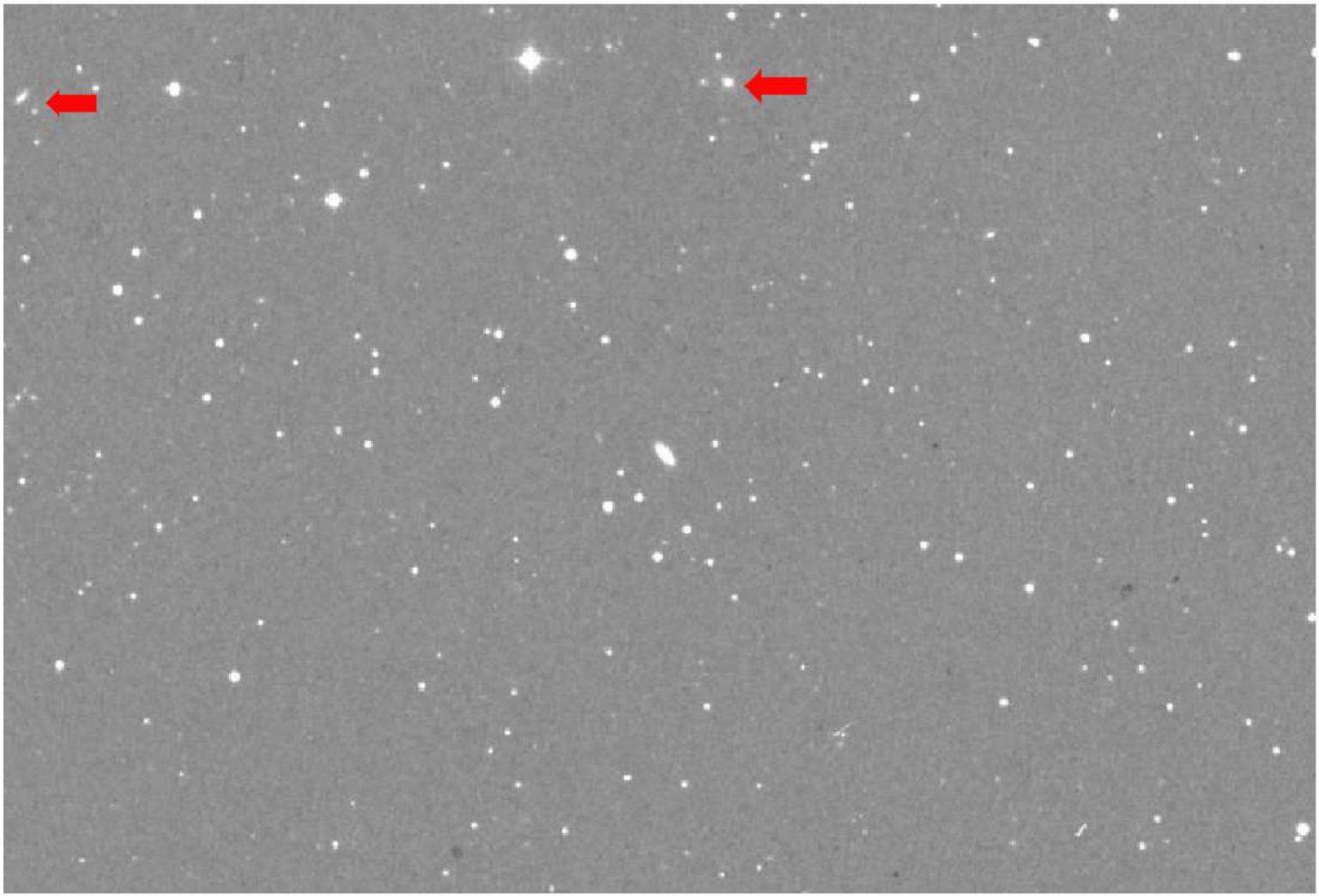
1050 galaxies (about 3% of all the galaxies in the CGCG)

[Zwicky et al., 1968]

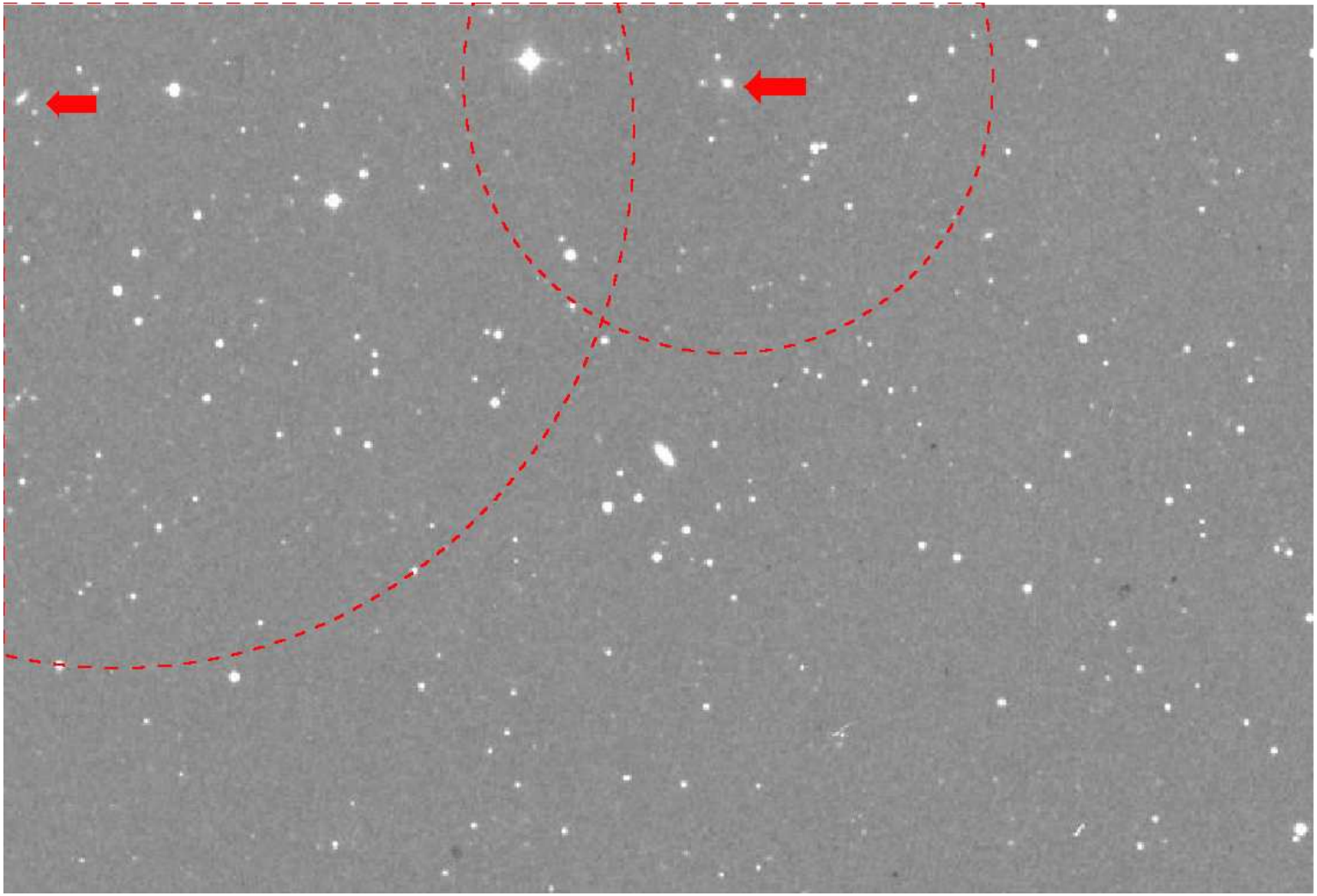
Isolation definition



Isolation definition

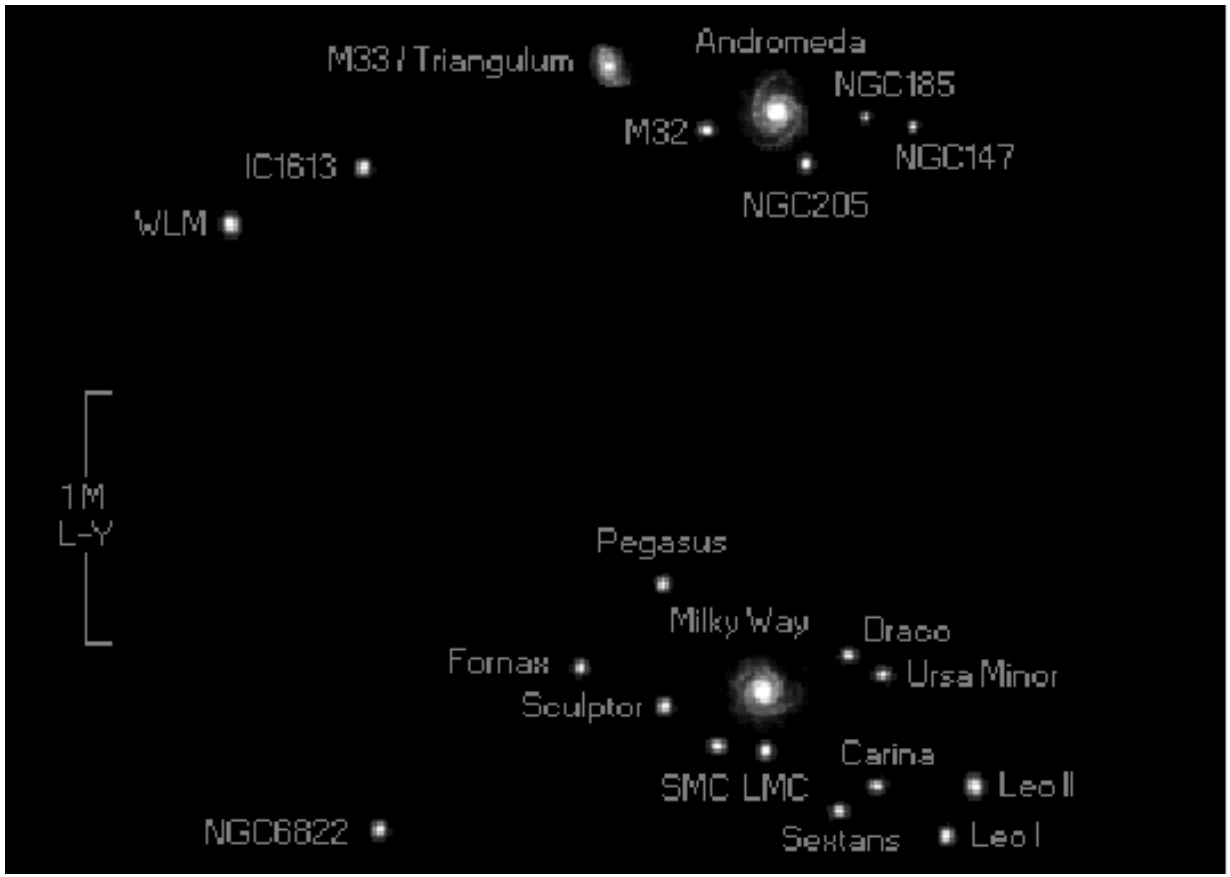


Isolation definition



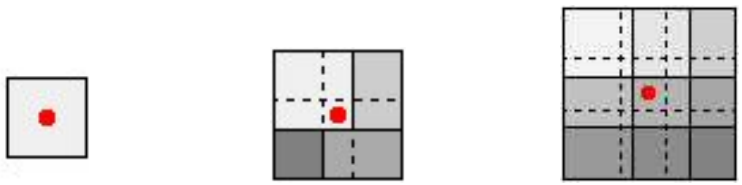
Local group

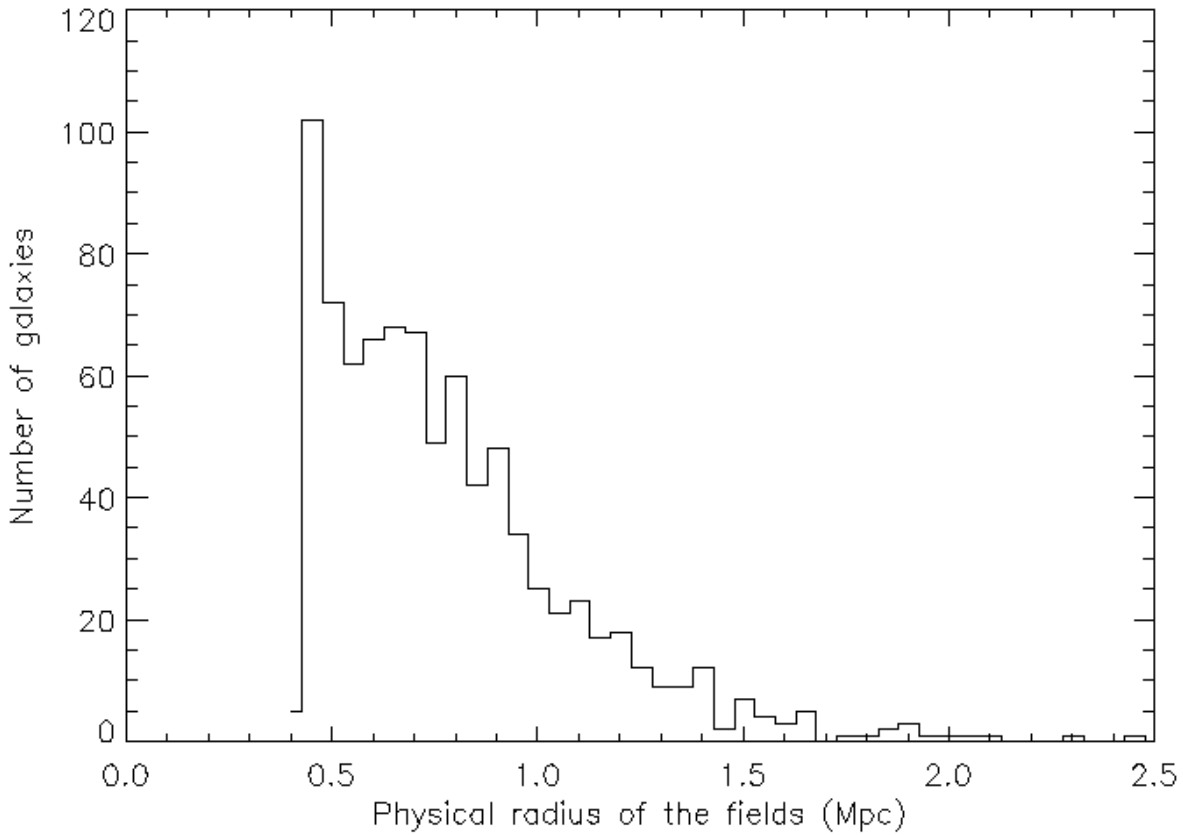
- Primary galaxy: Milky Way: D ≈ 30 kpc
  - Andromeda: D ≈ 40 kpc, dist. ≈ 725 kpc
  - M33: D ≈ 16 kpc, dist. ≈ 840 kpc
  - Large Magellanic Cloud: D ≈ 9 kpc, dist. ≈ 50 kpc



The AMIGA revision

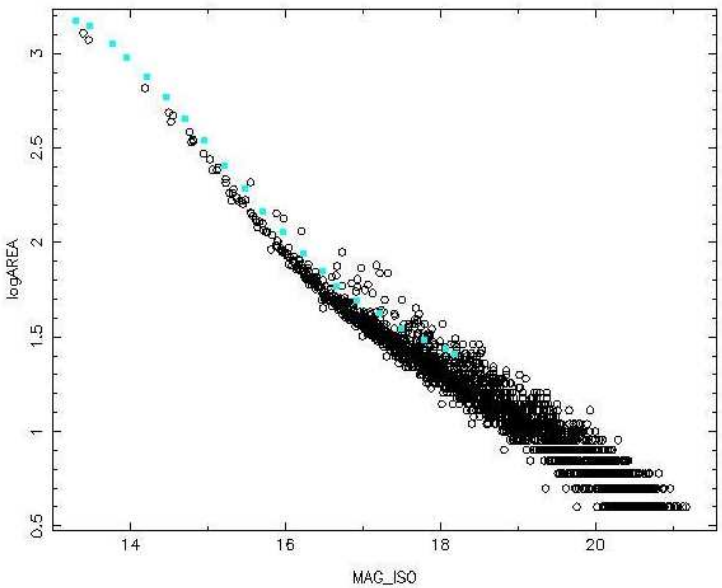
- concerns 950 CIGs ($V > 1500$ km s^{-1})
- minimum physical radius of 0.5 Mpc (3×10^9 years)
- squared fields: 55' (767), 110' (134), 165' (49)

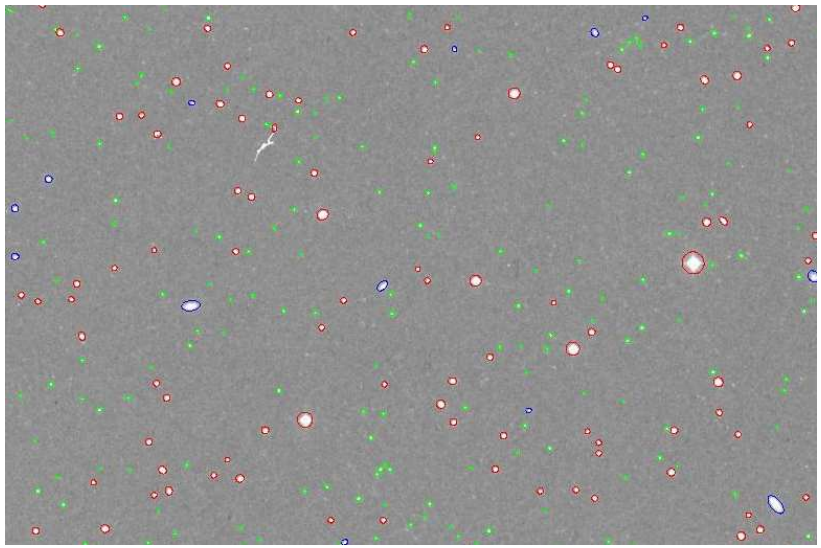




Isolation pipeline

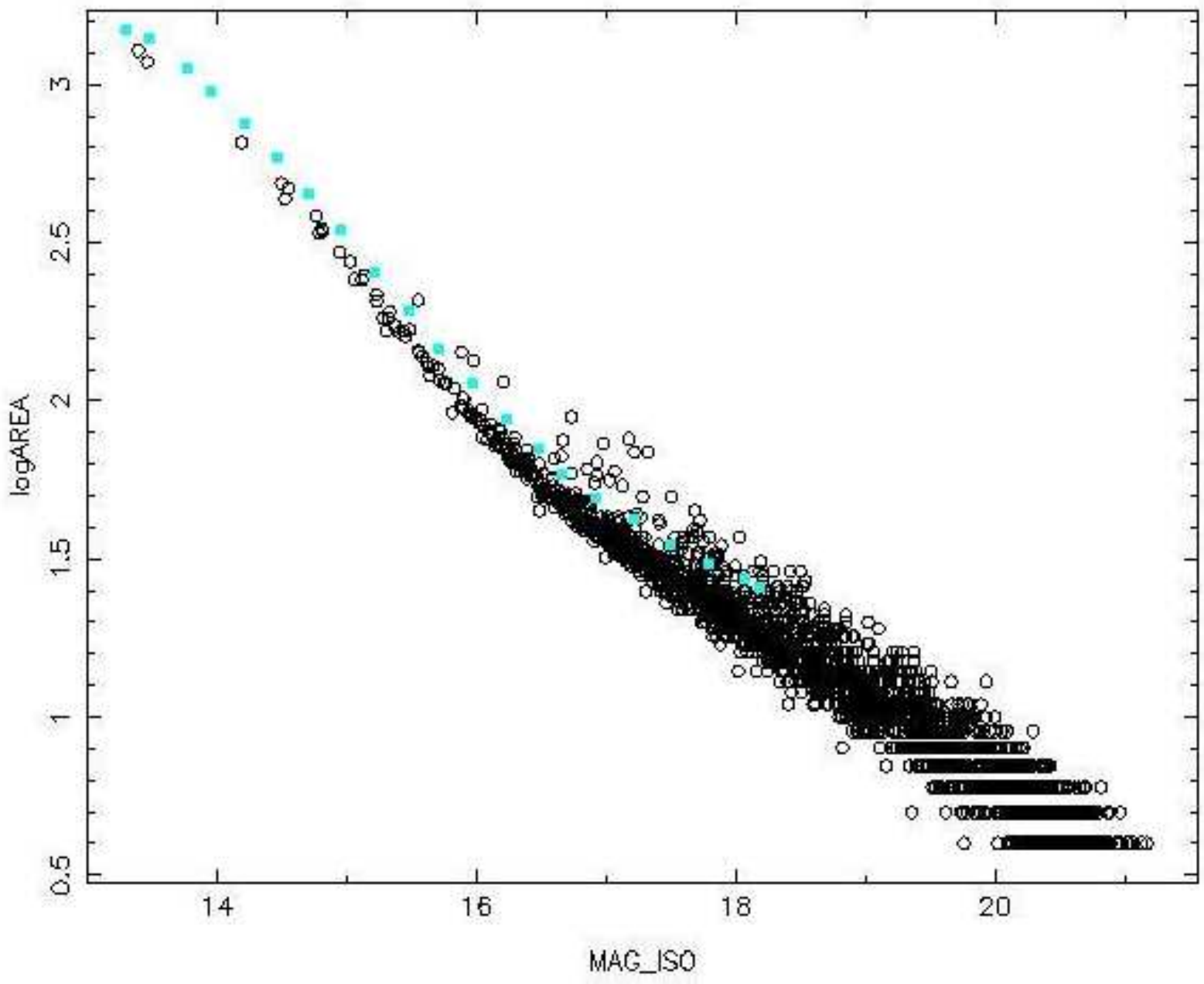
- POSS-I digitised plates (1.7 arcsec/pixel)
- SExtractor for the detection [Bertin & Arnouts, 1996]
- LMORPHO for the star/galaxy separation [Odewahn, 1995]
- POSS-II digitised plates (1.0 arcsec/pixel)





54,000 neighbours around 950 CIGs

Isolation pipeline



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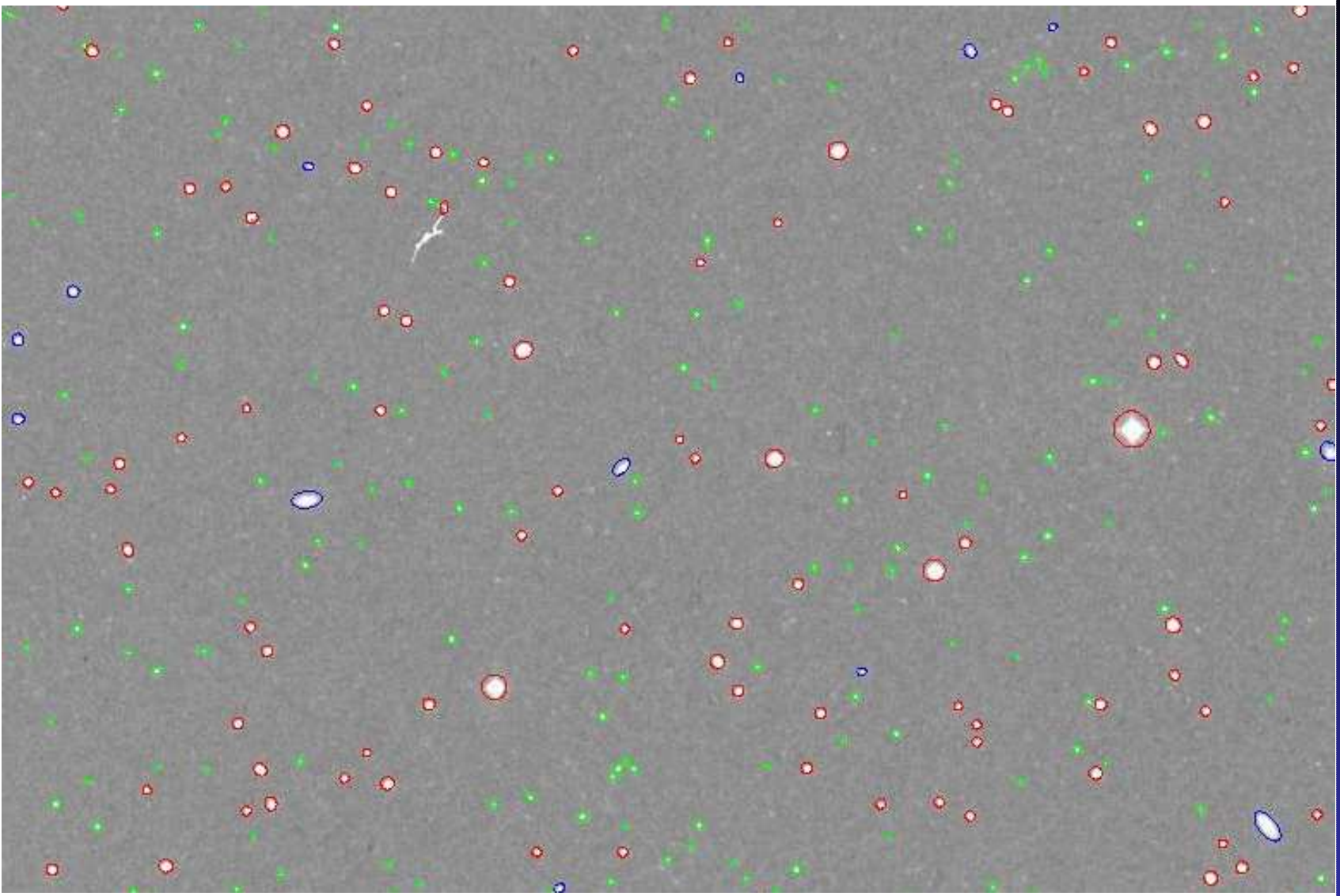


Isolation parameters

- **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

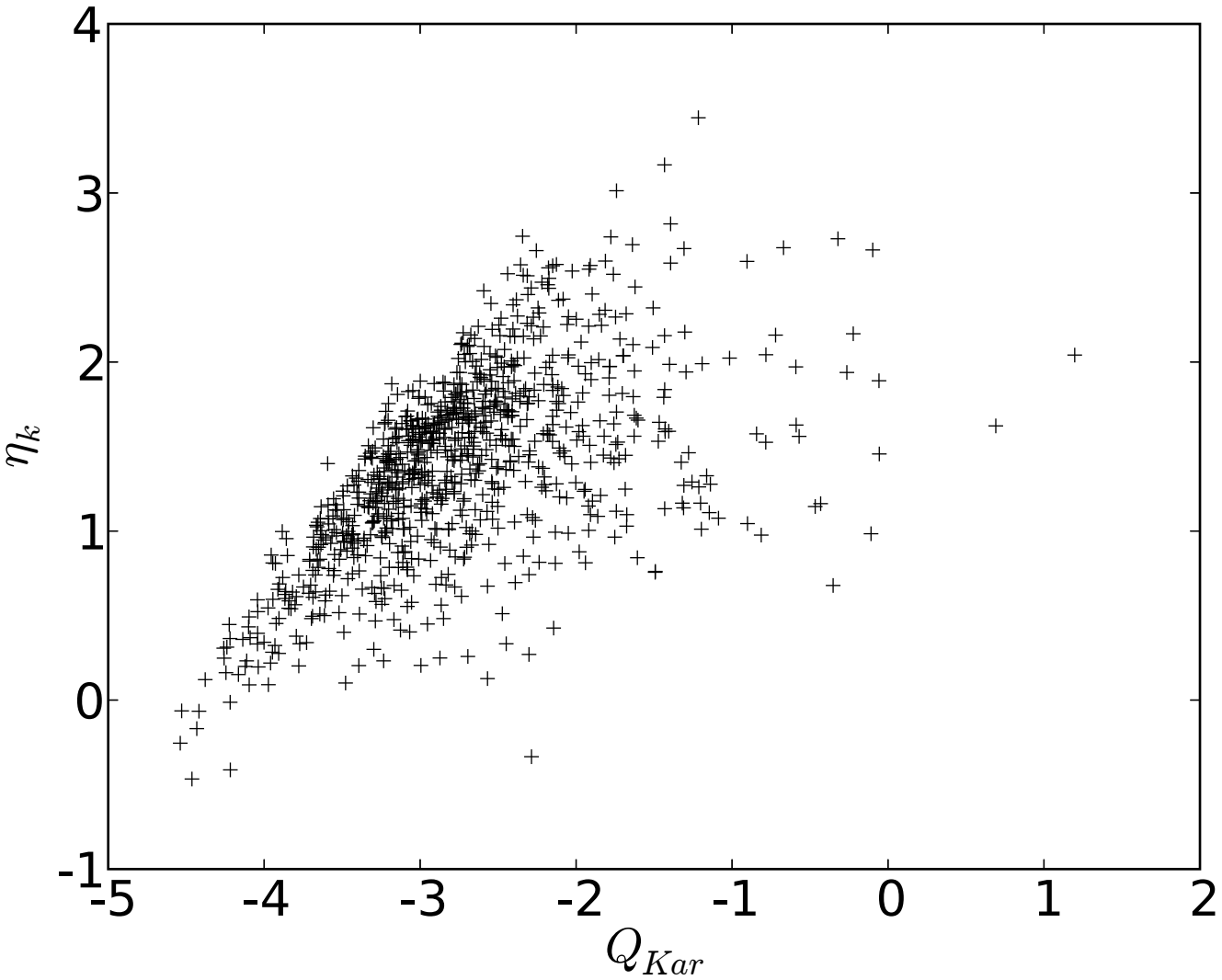
- **Tidal forces**
  [Dahari, 1984]

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

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

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

Complementarity between the isolation parameters



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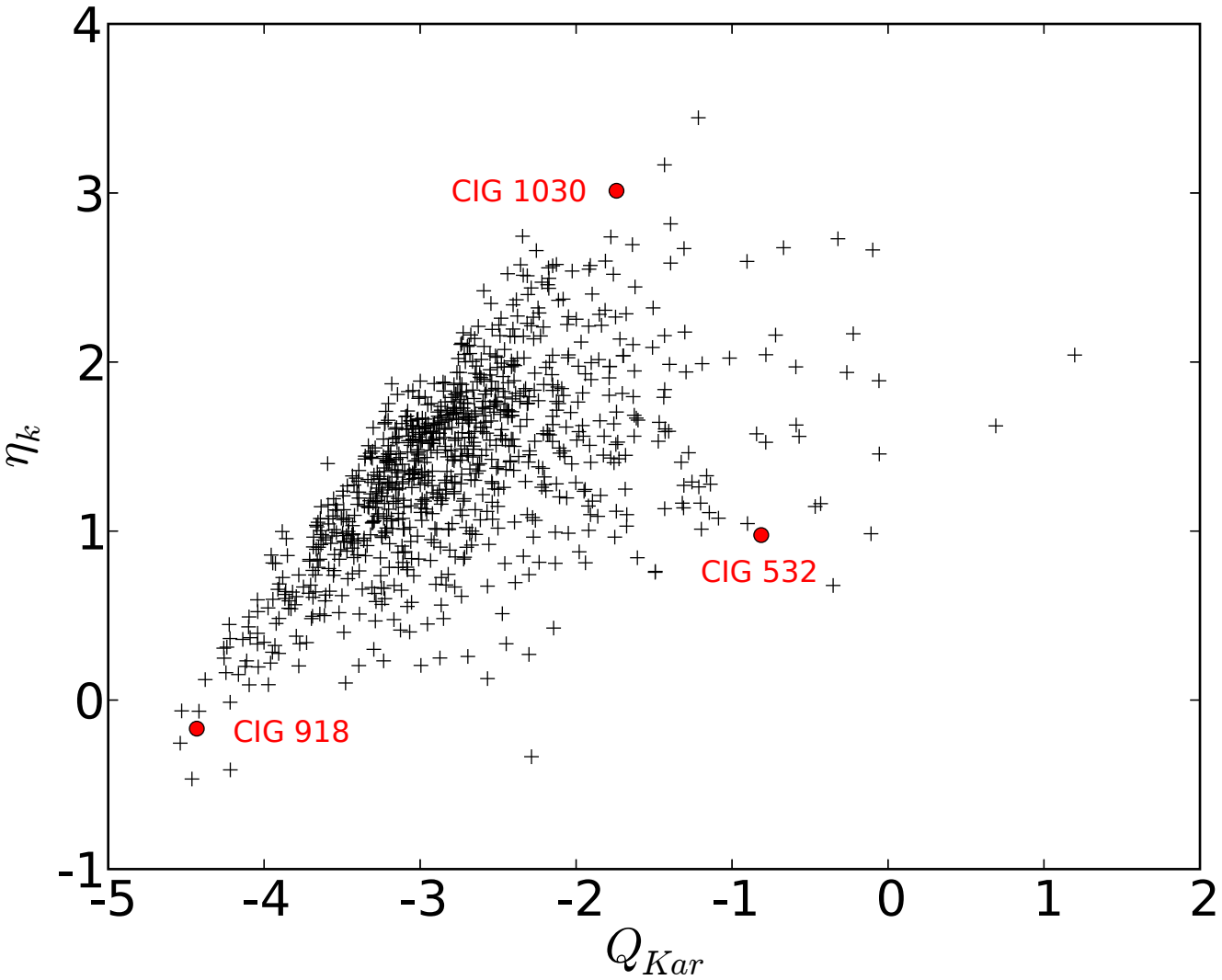
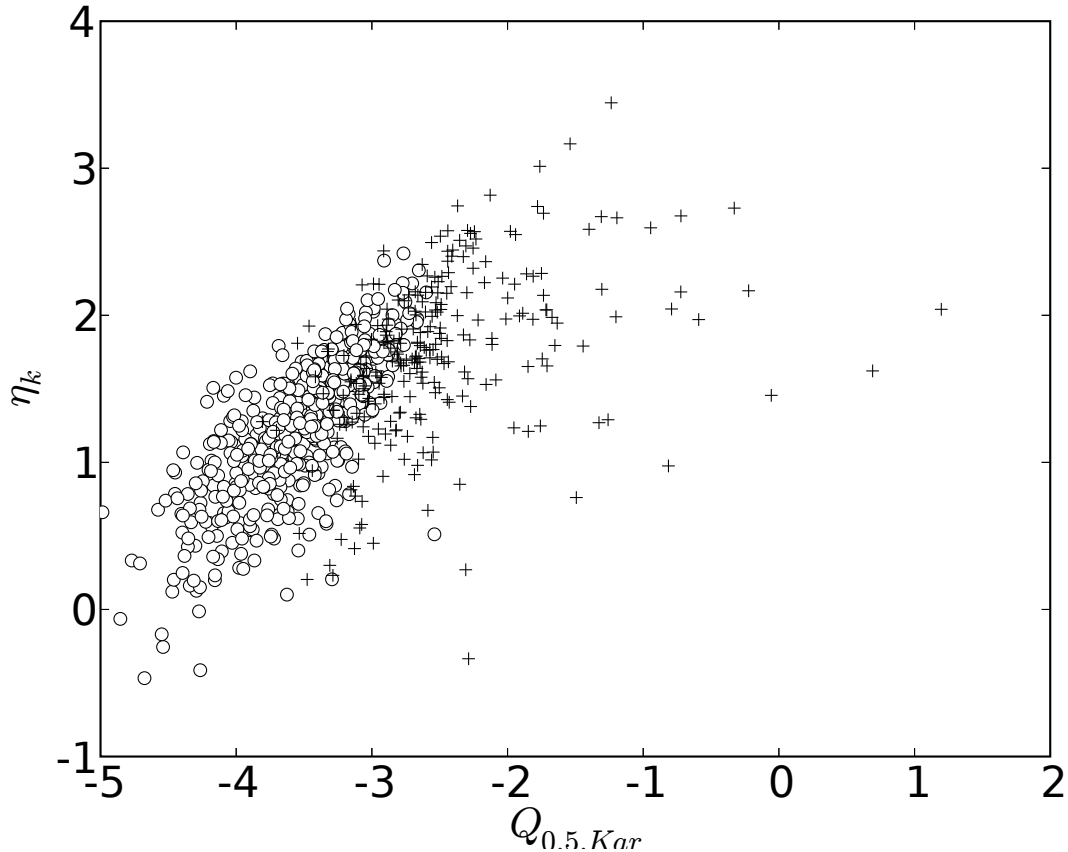


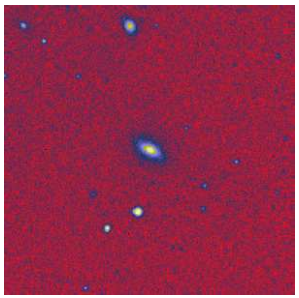
Karachentseva's criterion

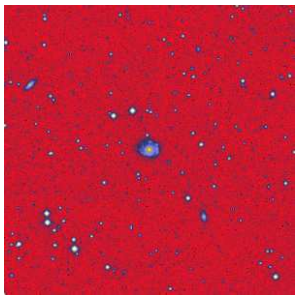
- 67 fields covering $80 \times D_p$: 54 CIG galaxies isolated
- 284 CIG galaxies violating Karachentseva's isolation definition; 666 remaining isolated

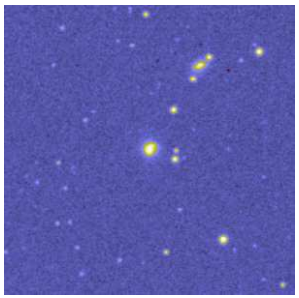


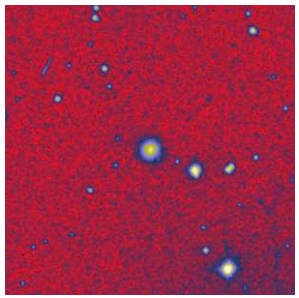
Pair candidates

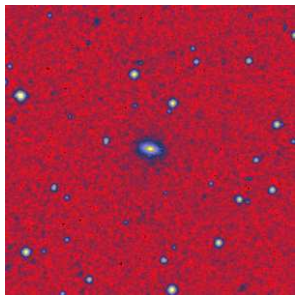
CIG galaxy with at least one companion (factor 2 in size with respect to D_p) within $5 \times D_p$:

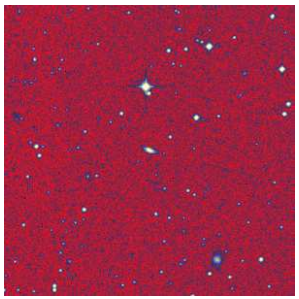

CIG 0019

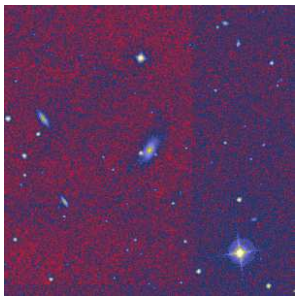

CIG 0036

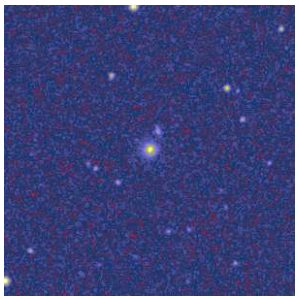

CIG 0074

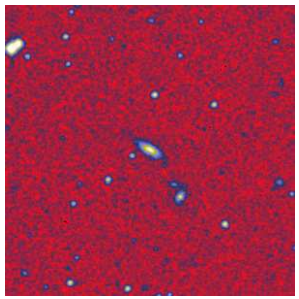

CIG 0178

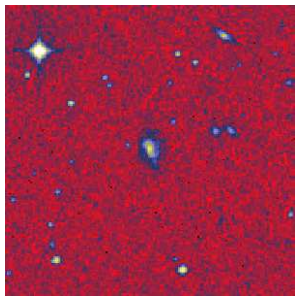

CIG 0233


CIG 0315


CIG 0488


CIG 0533


CIG 0683


CIG 0934

Comparison samples

1. Karachentseva Triplets of Galaxies (KTG)

   [Karachentseva et al. 1979]

2. Hickson Compact Groups (HCG)

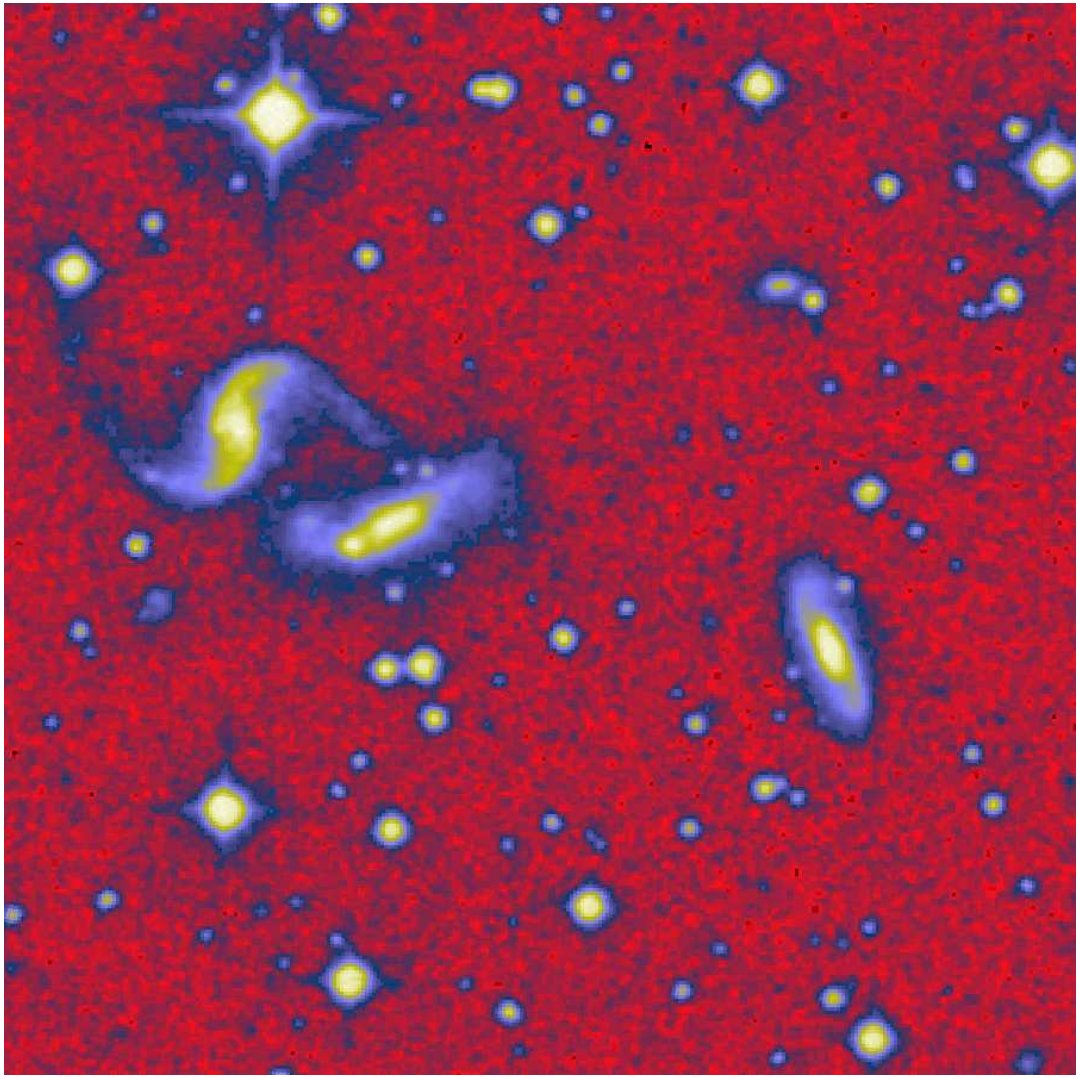
   [Hickson 1982]

3. Abell Clusters (ACO)

   [Abell 1958; Abell et al. 1989]

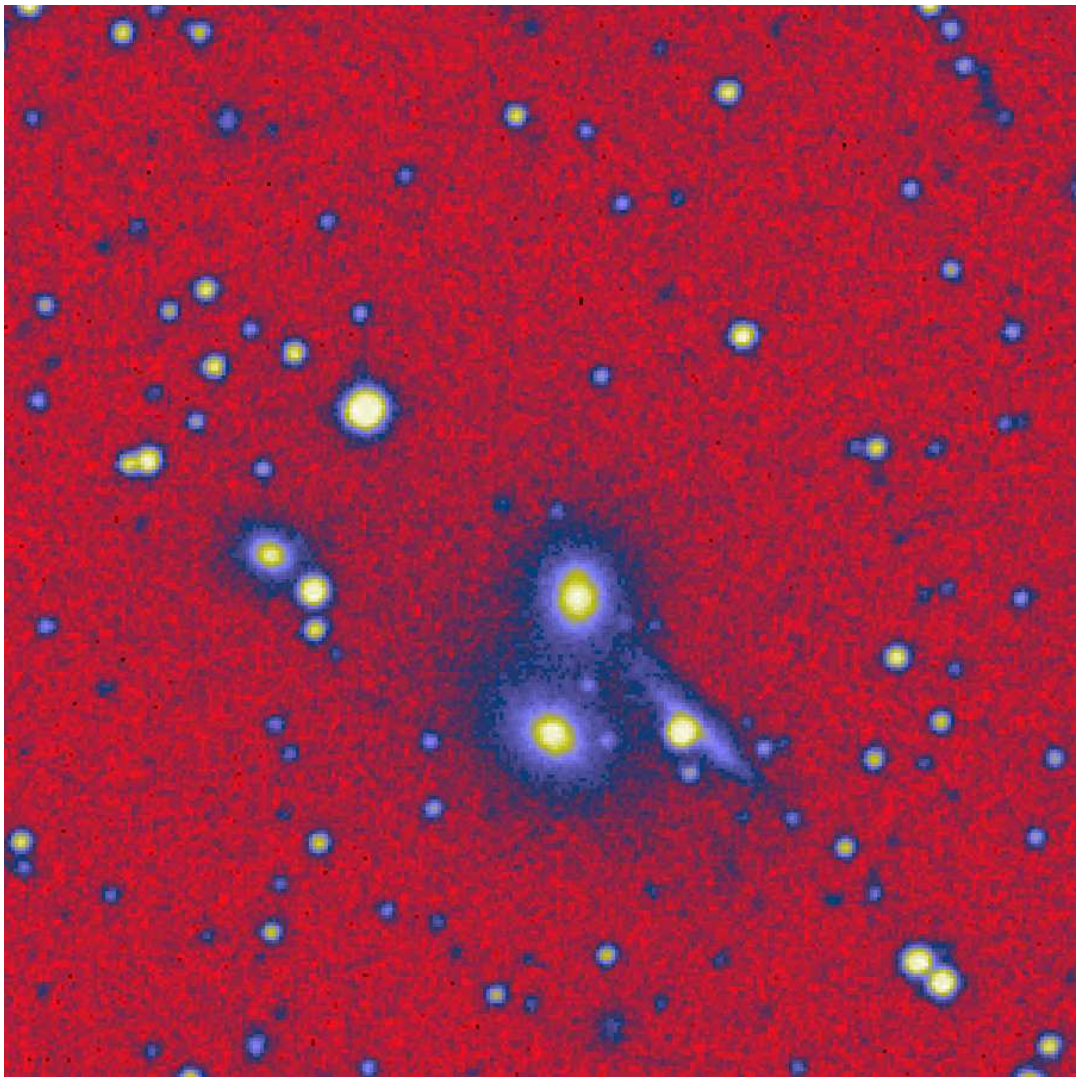
1. Karachentseva Triplets of Galaxies (KTG)

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



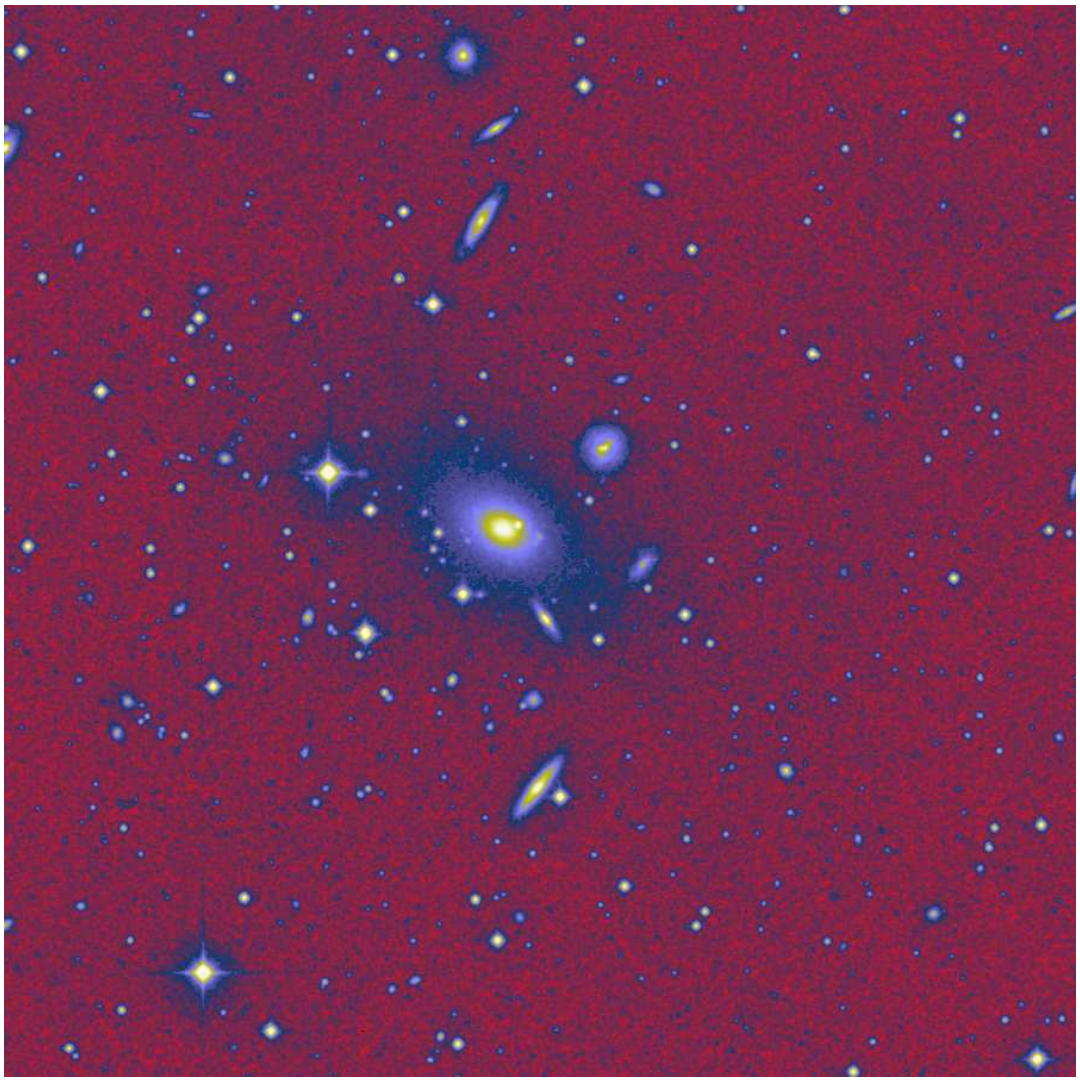
2. Hickson Compact Groups (HCG)

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

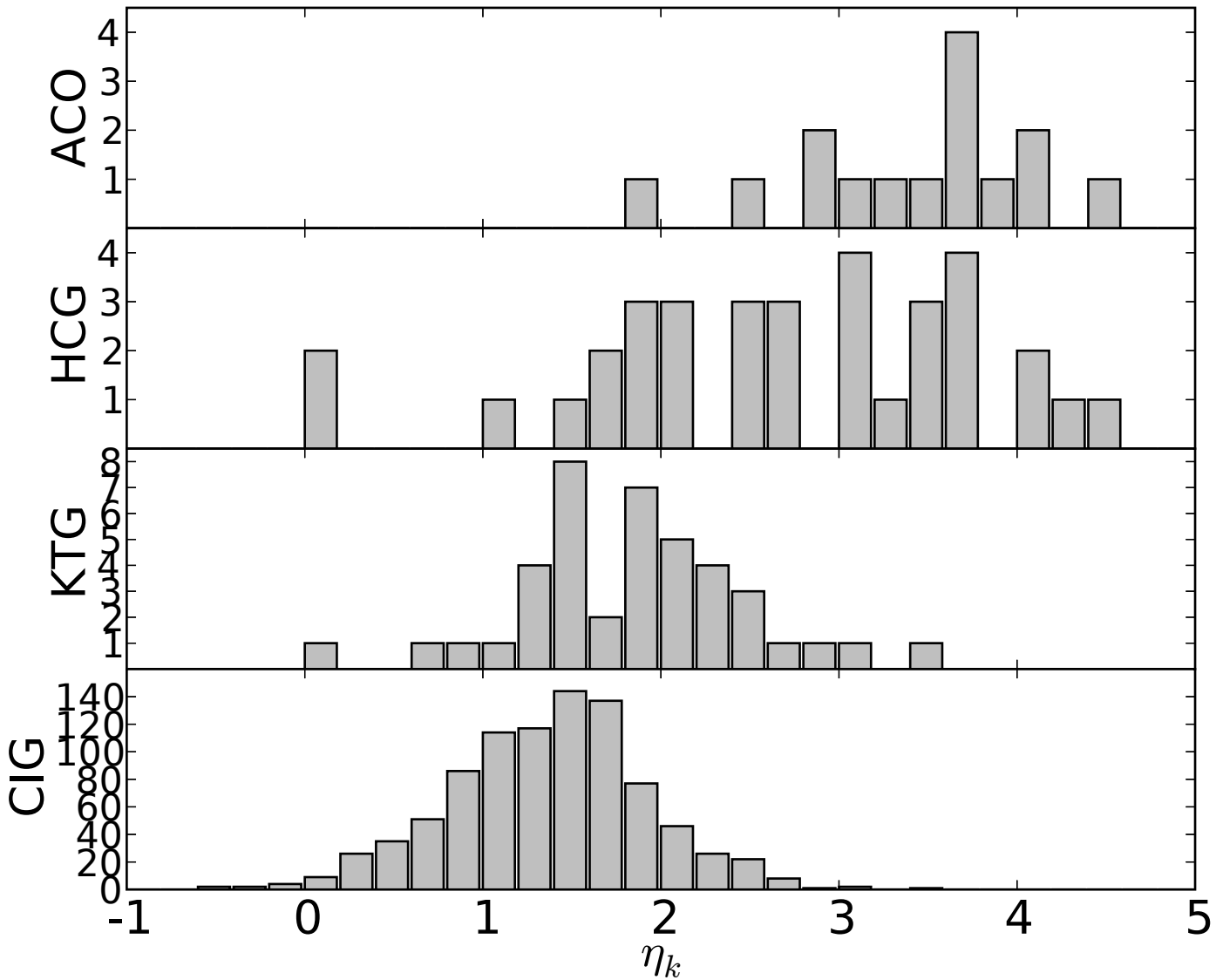


3. Abell clusters (ACO)

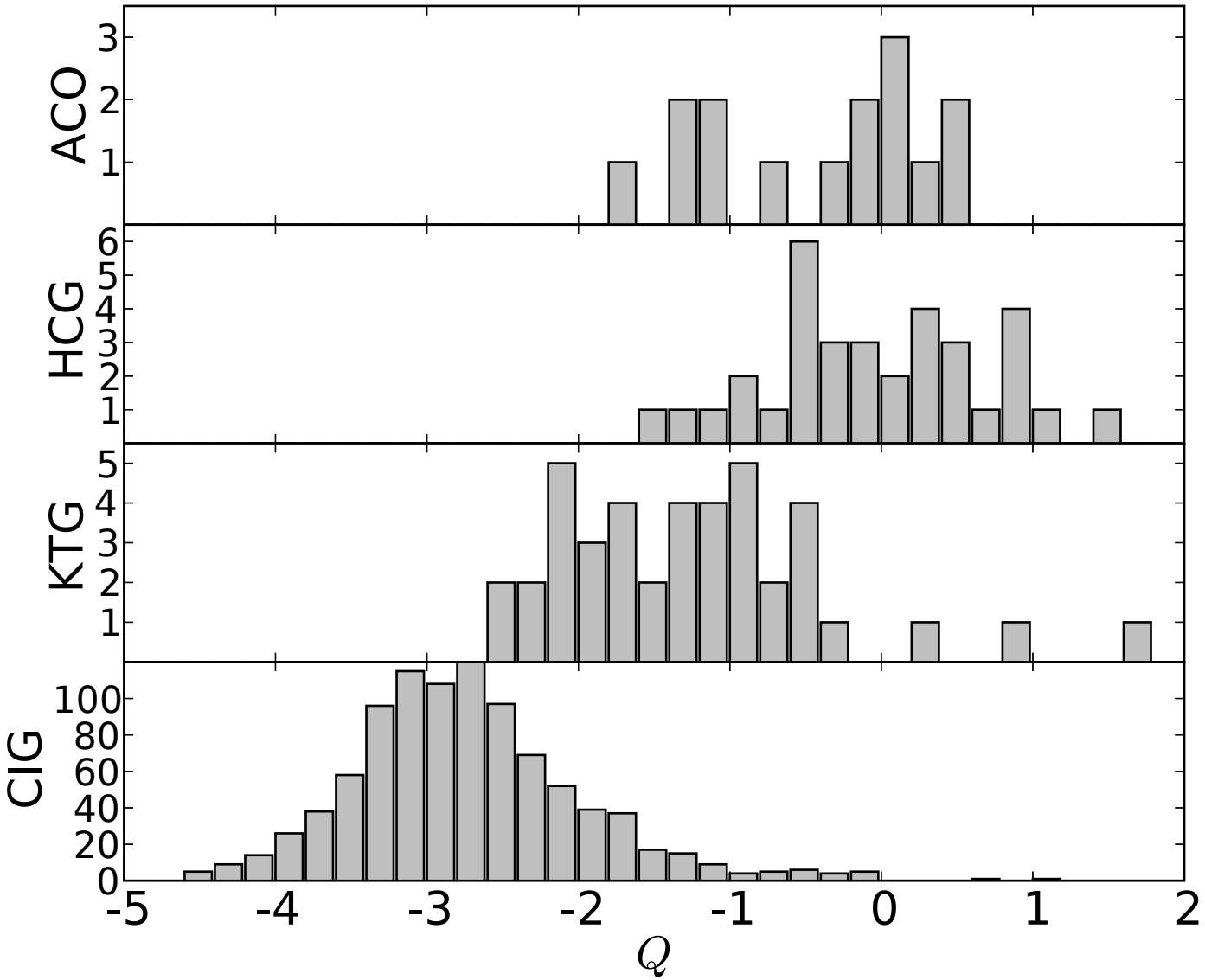
- 15 clusters selected
- primary galaxy = cD central galaxy, Brightest CG



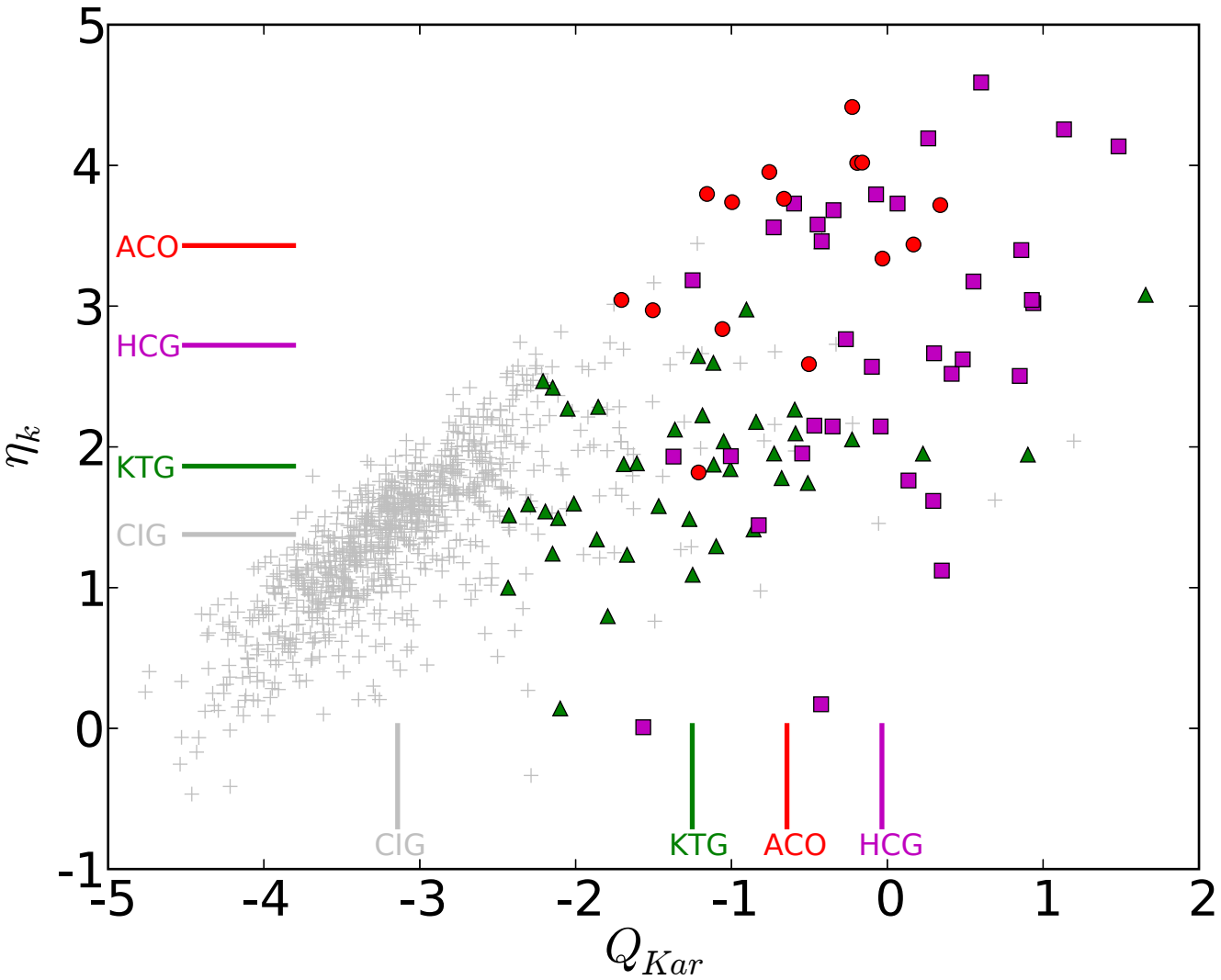
Distribution of the local number density η_k



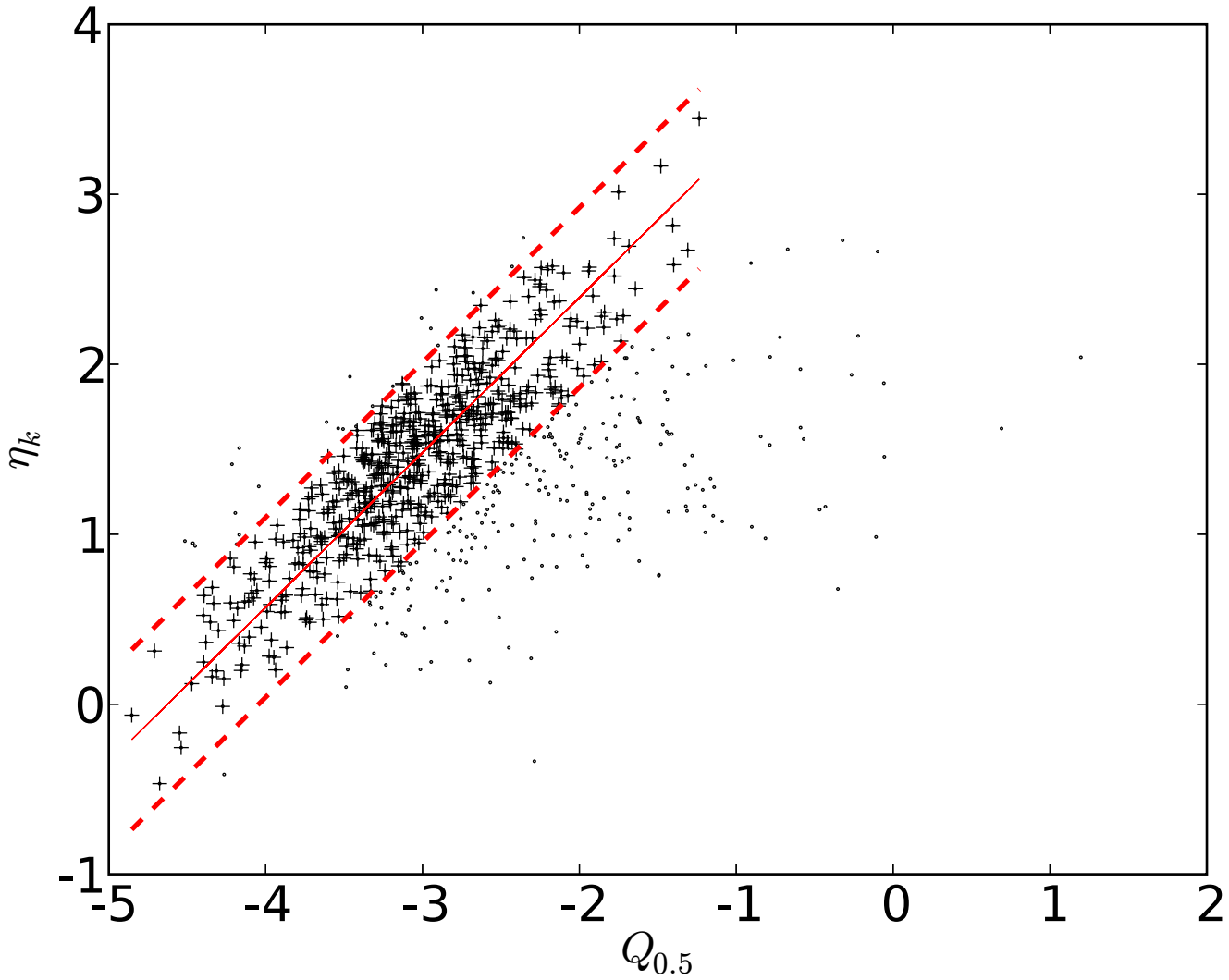
Distribution of the tidal strength Q



Comparison to denser samples



Selection of isolated galaxies



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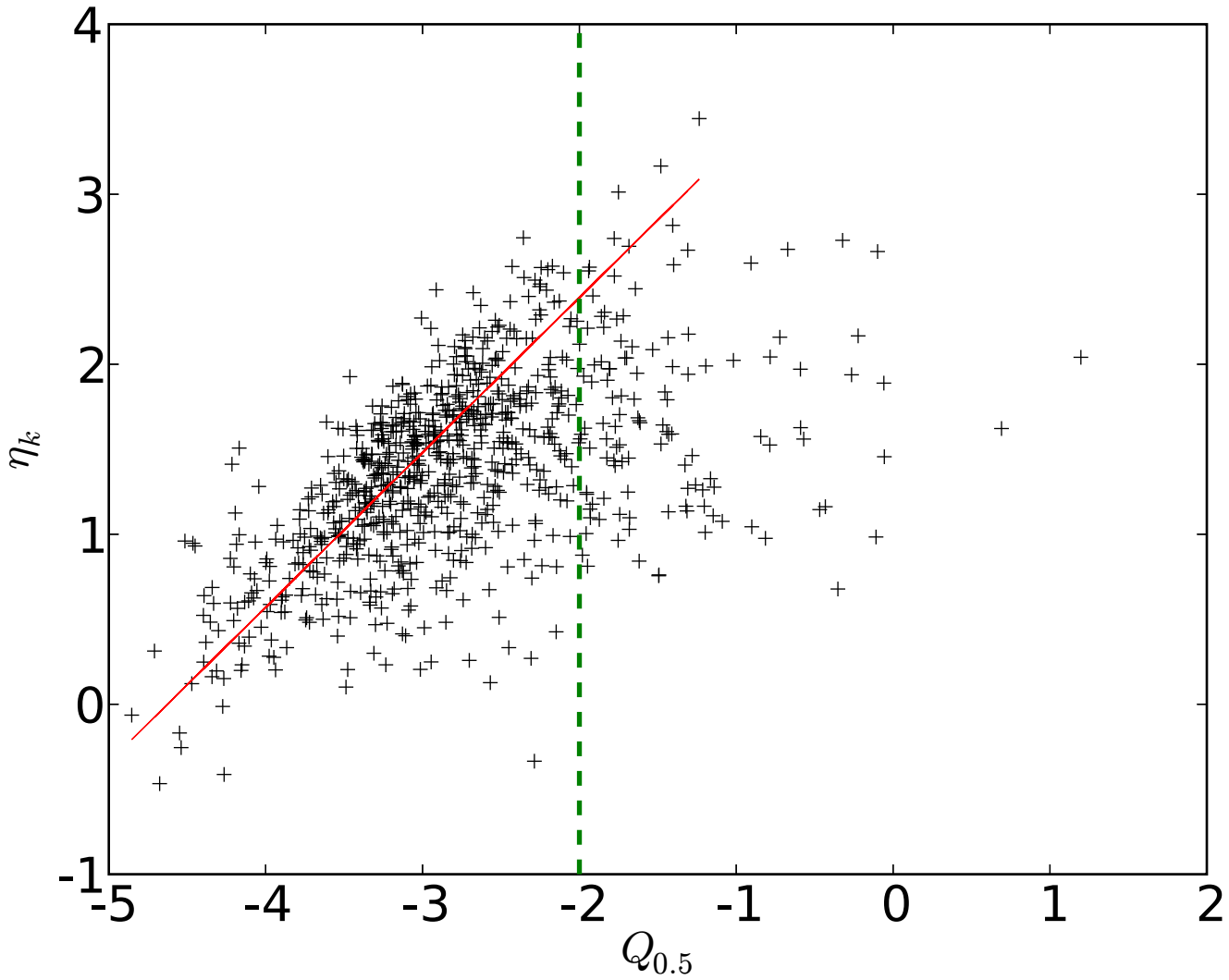
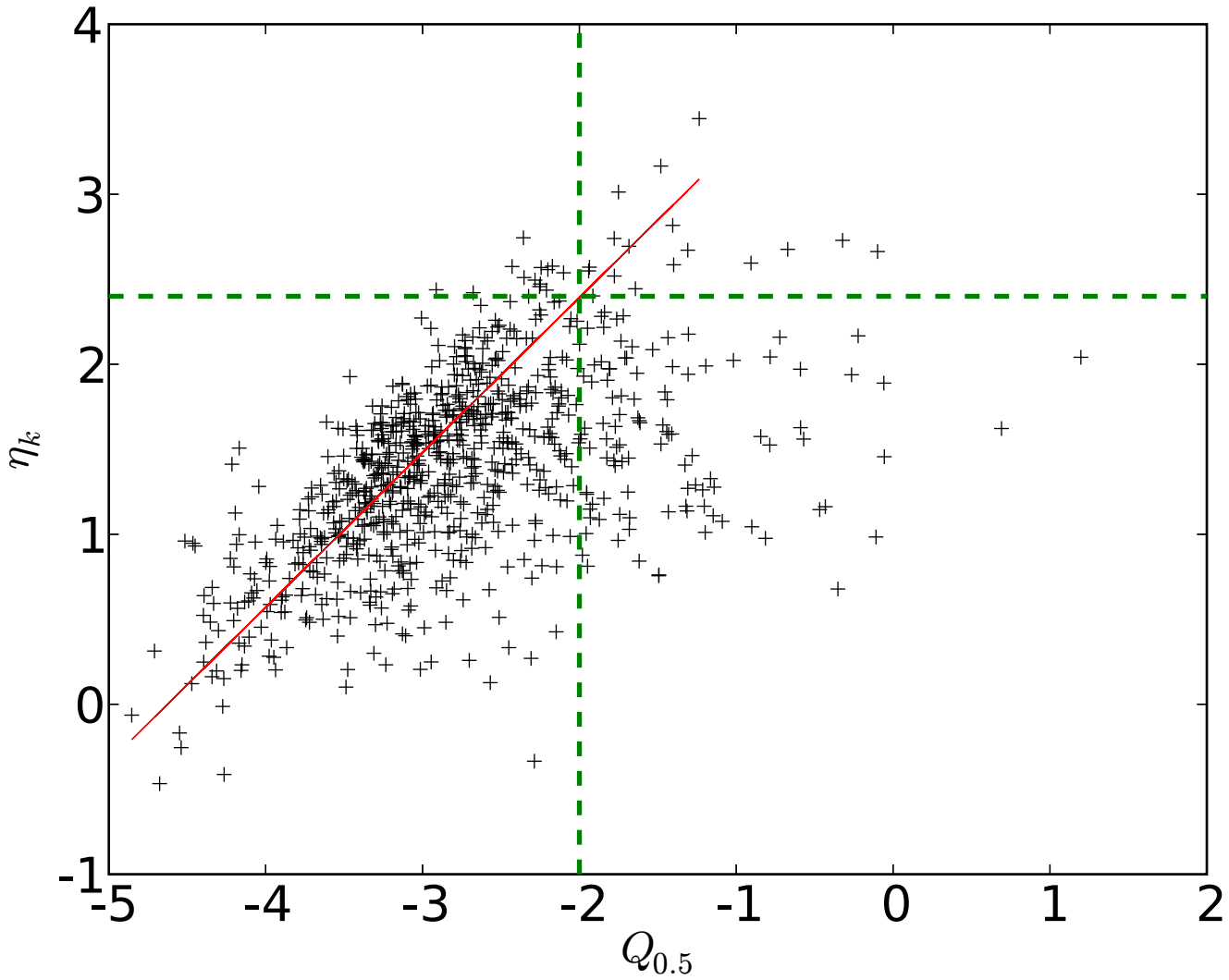


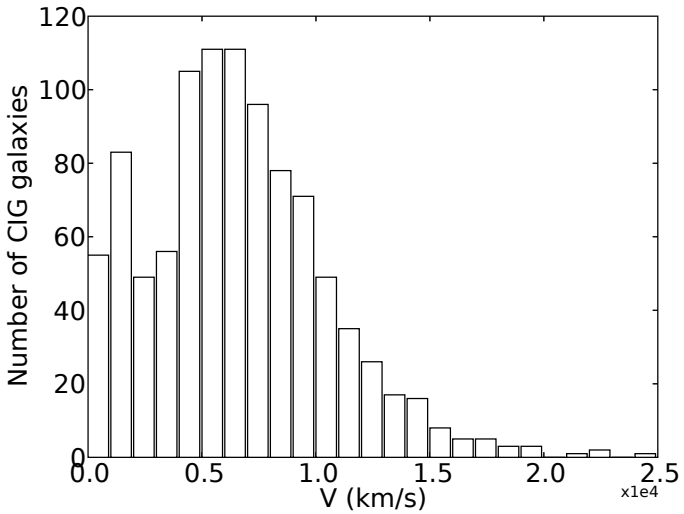
Selection of isolated galaxies

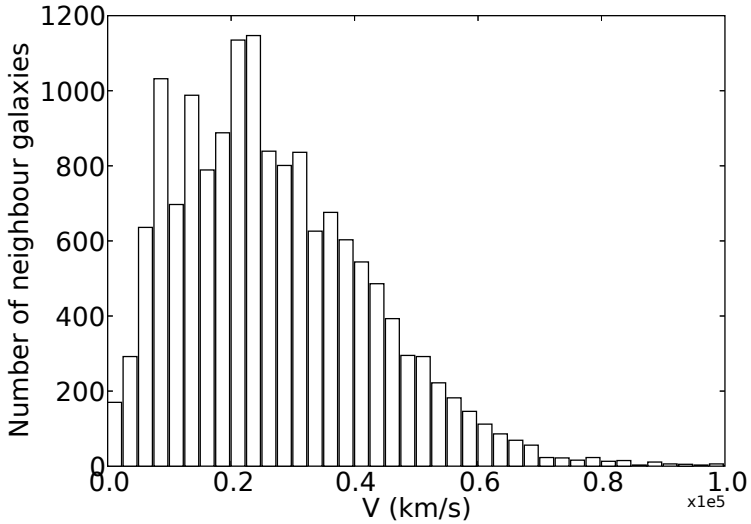


Redshifts

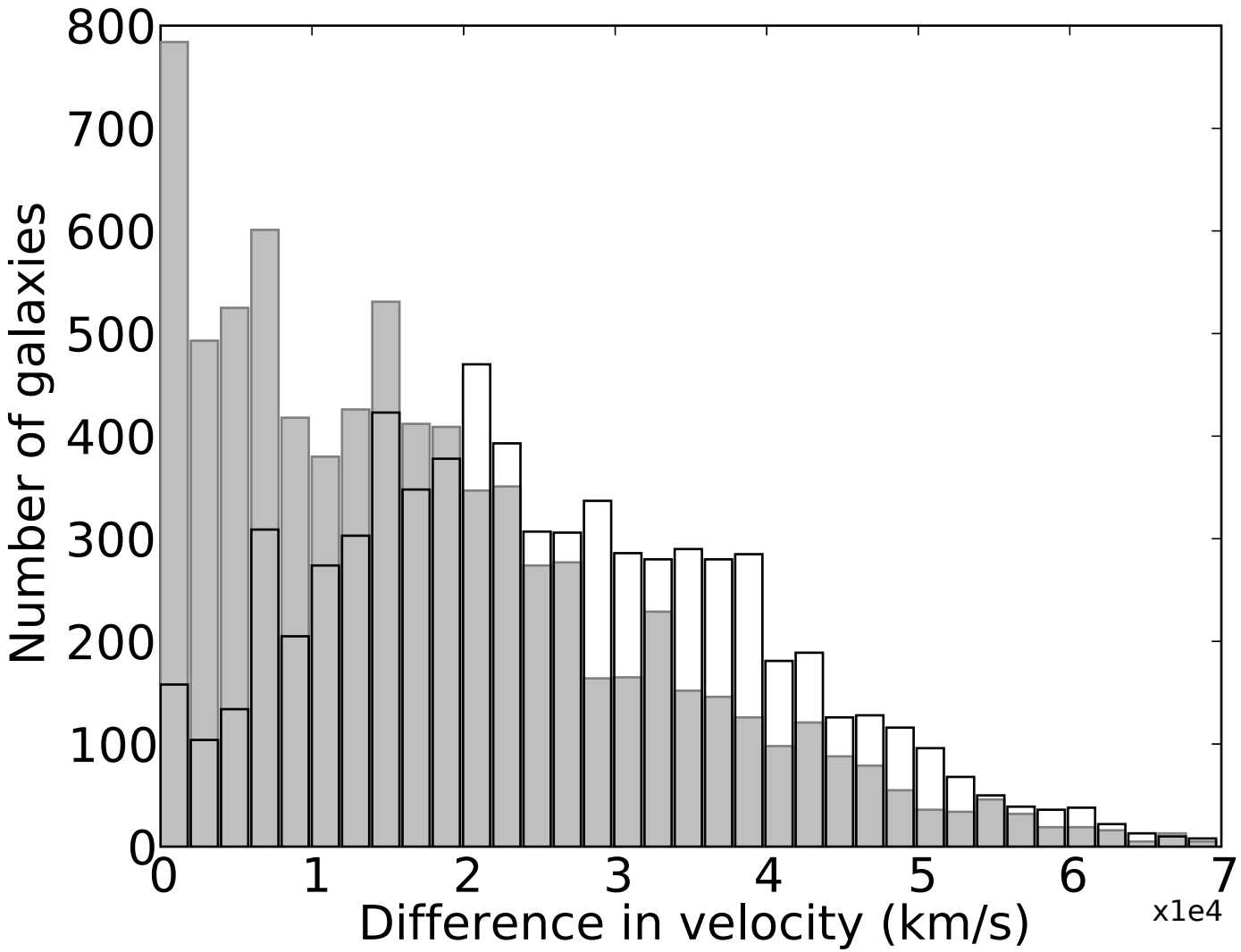
Database or survey	Number of redshifts	Number of matched objects	Percentage of Galaxy
NED	8024	35317	99.97%
hyperLEDA	11608	25614	99.99%
SDSS	12166	12166	99.79%
CfA (velocity)	8864	9103	99.86%
2dF	3018	3018	-
UZC	1461	1488	-
UZC J2000	1445	1485	-
CfA2	866	866	100%
CfA1	106	106	100%
NOG2	67	67	-
NOG4	66	66	-
SSRS2	50	50	-
	16126 (29.86%)		Galaxy (99.90%)

Redshifts of primary and neighbour galaxies



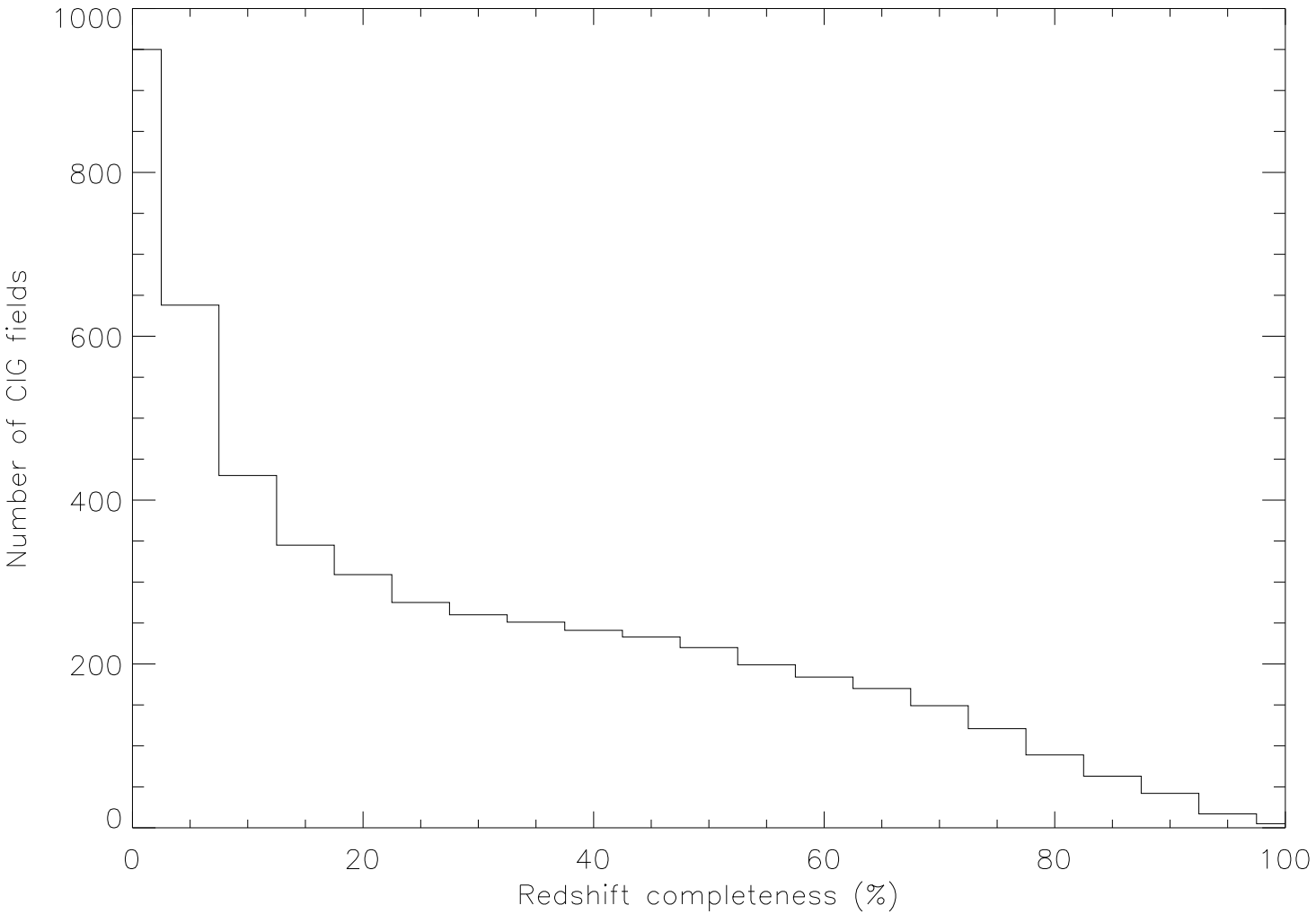


Velocity differences



Redshift Completeness

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



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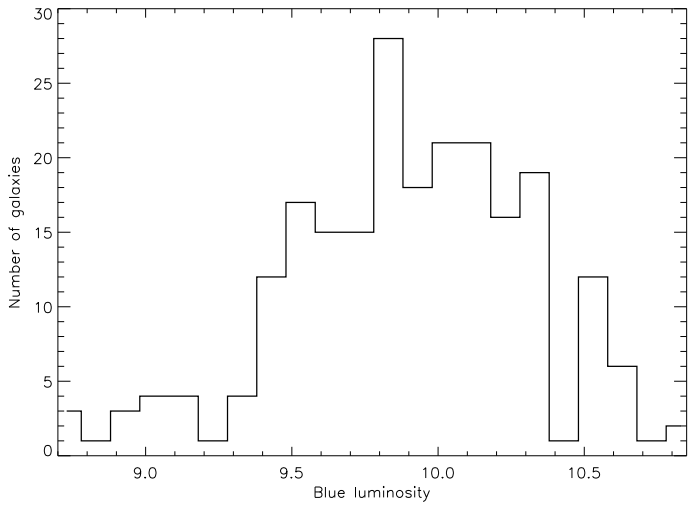
Definition of the Hα sample

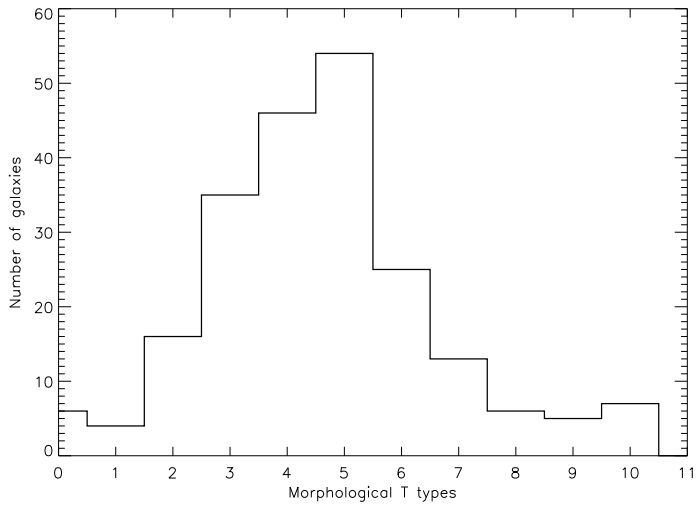
Hα:

- young hot stars ($T > 10\,000K$): UV photons can ionise the circumstellar medium
- recent star formation history tracer: last 10-100 Myrs, $M_\star > 20 M_\odot$

224 spiral CIG galaxies with observed recession velocity V:

$$1500 \text{ km s}^{-1} \leq \text{V} \leq 5000 \text{ km s}^{-1}$$





Observations

CCD photometry:

1. Hα
2. r Gunn
3. standard stars

} Complete for 200 galaxies

Telescopes:

1.	Observatorio de Sierra Nevada (IAA)	1.50 m
2.	Calar Alto Hispano-Alemán (MPI, IAA)	2.20 m
3.	Estación de Observación de Calar Alto (OAN)	1.52 m
4.	Jakobus Kapteyn Telescope (ING)	1.00 m
5.	San Pedro Mártir (UNAM)	1.50 m

The campaigns

Telescope	Date	Number of nights
OSN 1.5 m	03/31/2003 - 04/06/2003	7
	04/30/2003 - 05/03/2003	3
	08/25/2003 - 08/31/2003	7
	11/24/2003 - 11/30/2003	7
	06/18/2004 - 06/27/2004	10
	08/16/2004 - 08/20/2004	5
	09/13/2004 - 09/18/2004	6
	12/05/2004 - 12/12/2004	8
	01/10/2005 - 01/16/2005	7
	03/10/2005 - 03/16/2005	7
	04/11/2005 - 04/15/2005	5
	05/23/2005 - 05/23/2005	1
	06/06/2005 - 06/07/2005	2
	10/01/2005 - 10/01/2005	1
	11/13/2005 - 11/13/2005	1
CAHA 2.2 m	01/01/2003 - 01/06/2003	6
	08/01/2003 - 08/06/2003	6
	09/01/2003 - 09/01/2003	1
	09/16/2003 - 09/16/2003	1
	02/21/2004 - 02/26/2004	6
	04/20/2004 - 04/25/2004	6
EOCA 1.52 m	10/20/2003 - 10/25/2003	6
	02/22/2004 - 02/24/2004	3
	05/19/2004 - 05/21/2004	3
JKT 1.0 m	07/22/2003 - 07/31/2003	10
SPM 1.5 m	05/01/2003 - 05/04/2003	4
		129

Reduction process

- subtraction of the super-bias
- first rejection of cosmic rays
- division by the super-flat
- estimation and subtracion of the sky background
- division by the exposure time
- centering of all the images for any given galaxy
- equalizing the PSF of all the images for any given galaxy
- final combination in each filter
- scaling the continuum to the Hα image and subtraction

IRAF - Image Reduction and Analysis Facility

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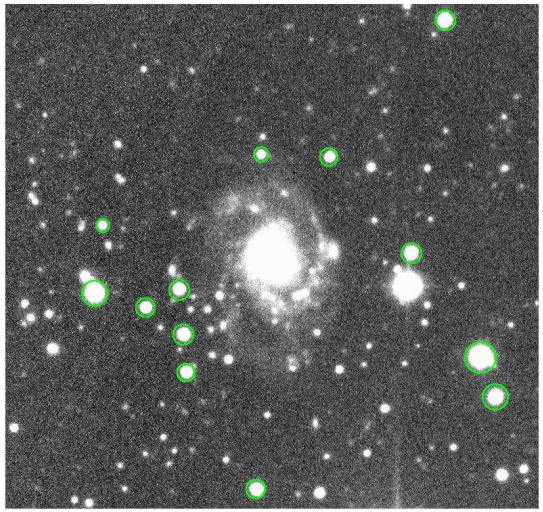
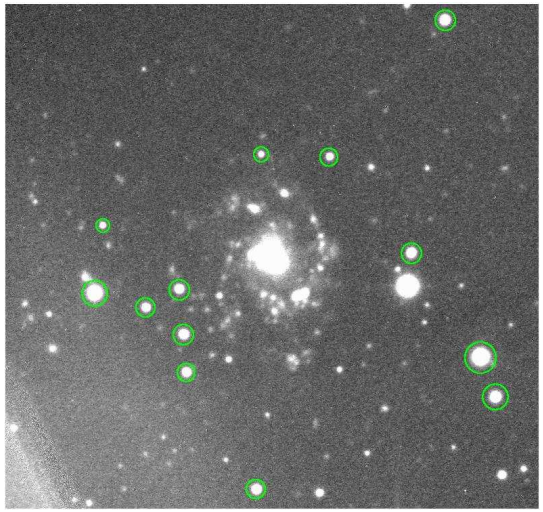
IRAF - Image Reduction and Analysis Facility

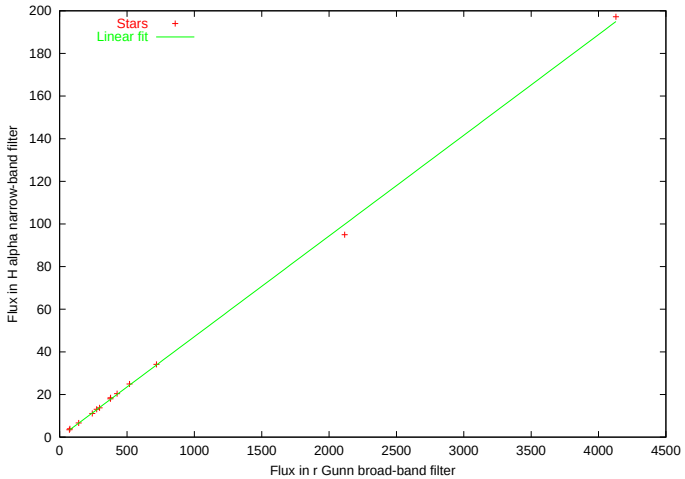
Hα - continuum images



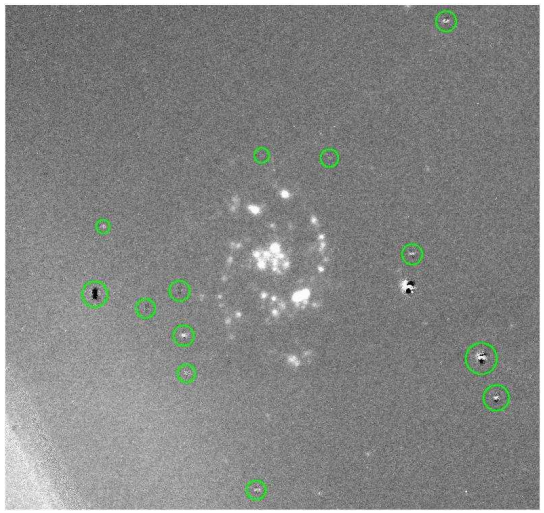
r Gunn



Hα



Scale factor

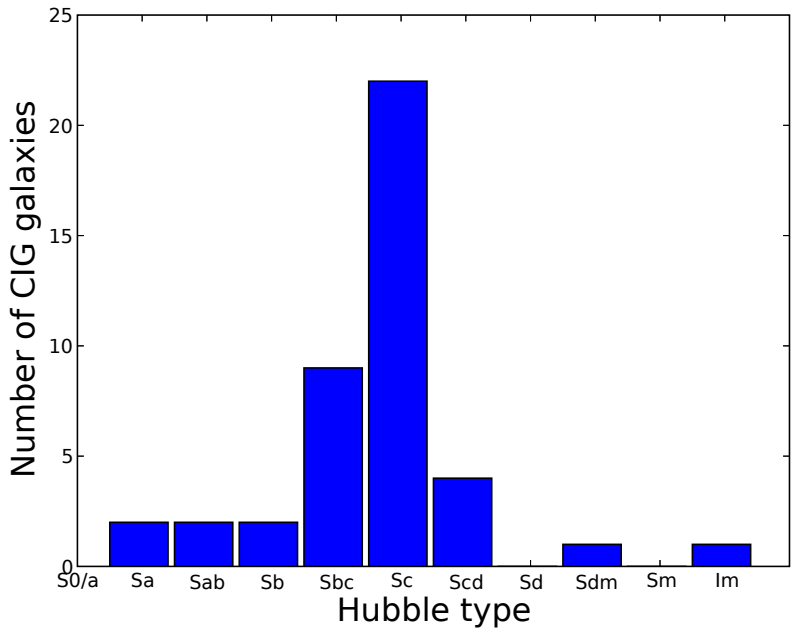


Hα - continuum

Hα subsample: 45 galaxies

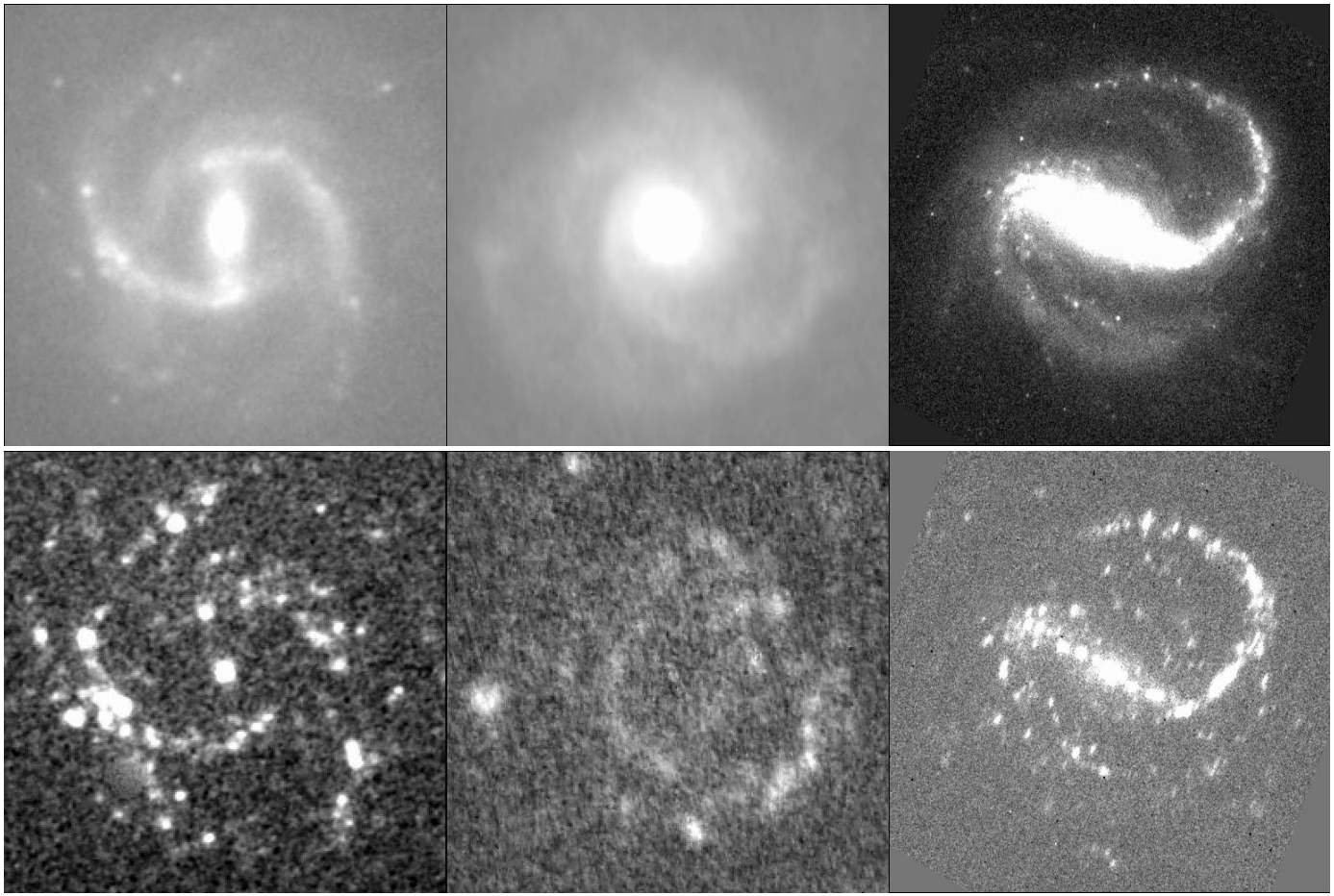
Sufficient spatial resolution In the case of our observations, this translates into galaxies having major axis greater or equal to **1 arcmin**;

Low-inclination In order to obtain a sufficiently accurate deprojection, the inclination has to be minor or equal to **50°**.



Main Groups (**E, F, G**)

CIG 0053 CIG 0084 CIG 1004



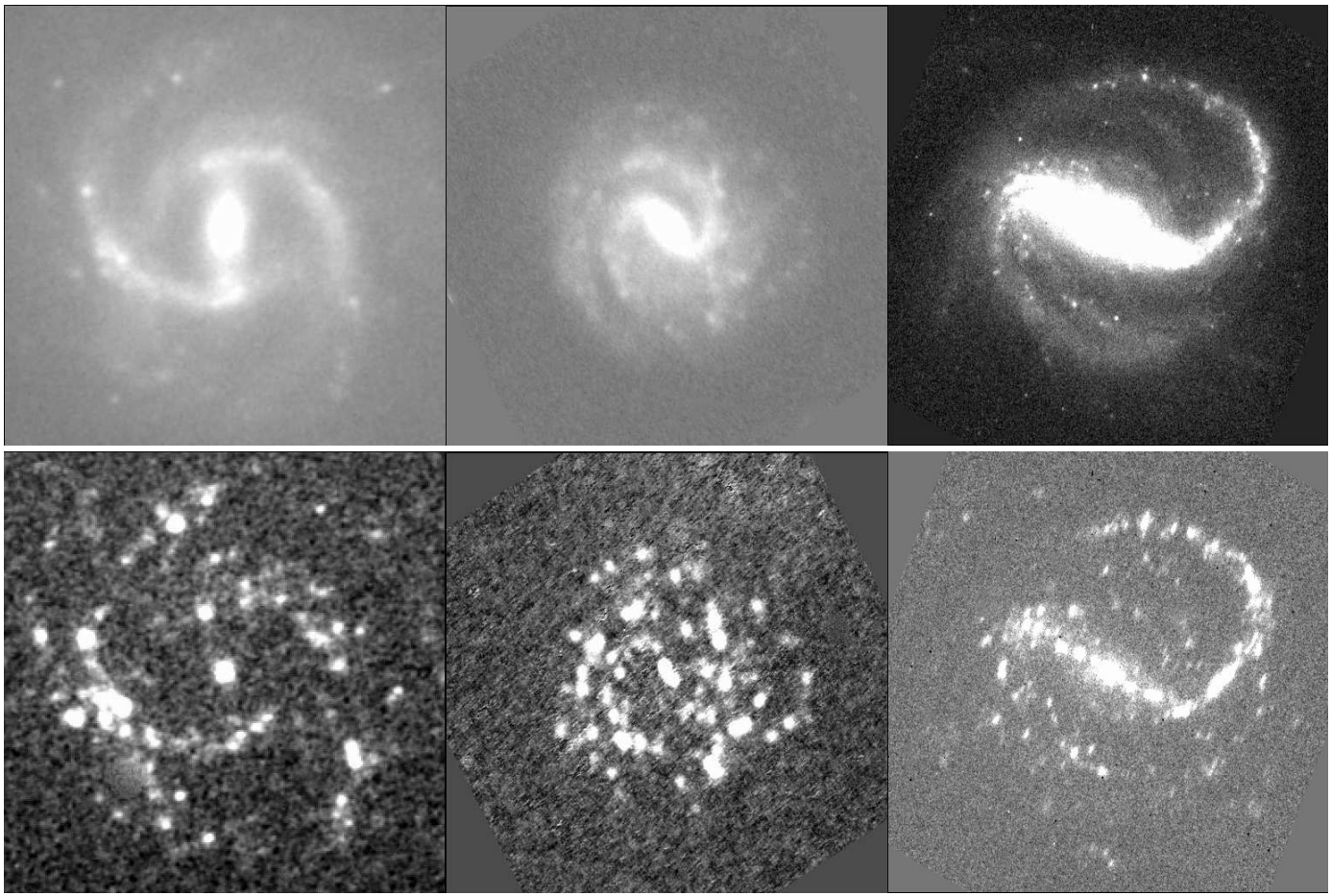
group **E** (19 galaxies)

group **F** (9 galaxies)

group **G** (8 galaxies)

Evolution of star formation in bars

CIG 0053 CIG 0512 CIG 1004

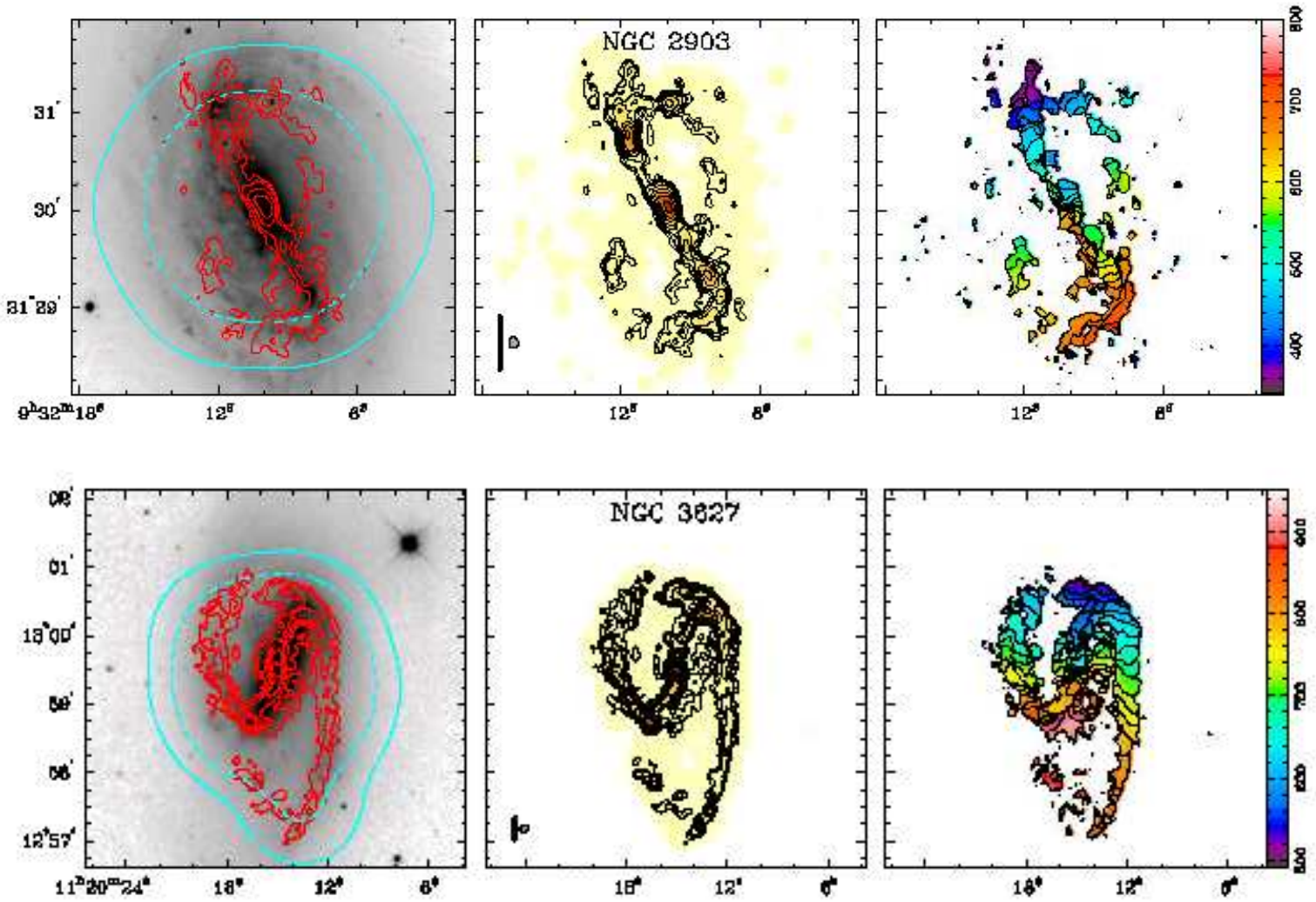


group **E**
(19 galaxies)
63%

group **EG**
(3 galaxies)
10%

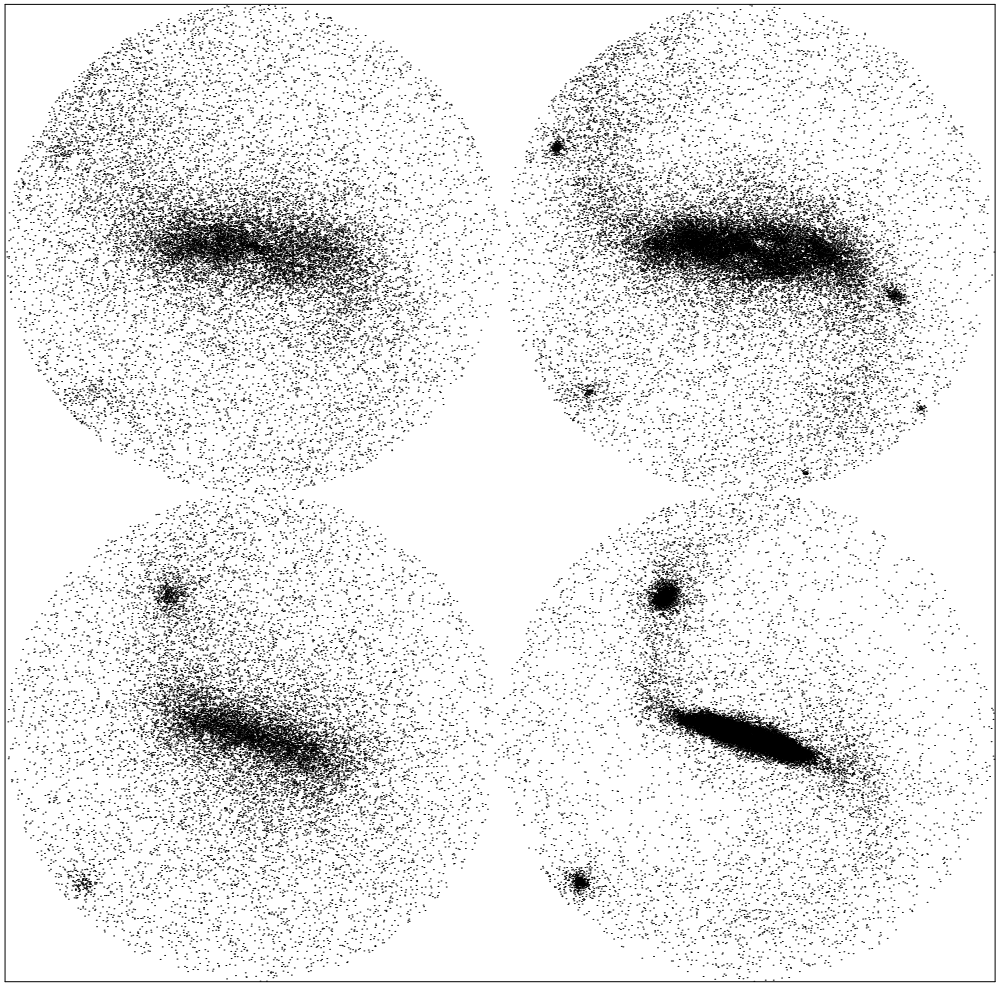
group **G**
(8 galaxies)
27%

BIMA SONG [Helfer et al. 2002]



Numerical simulations: gaseous component

Stars Gas 0.3Gyr

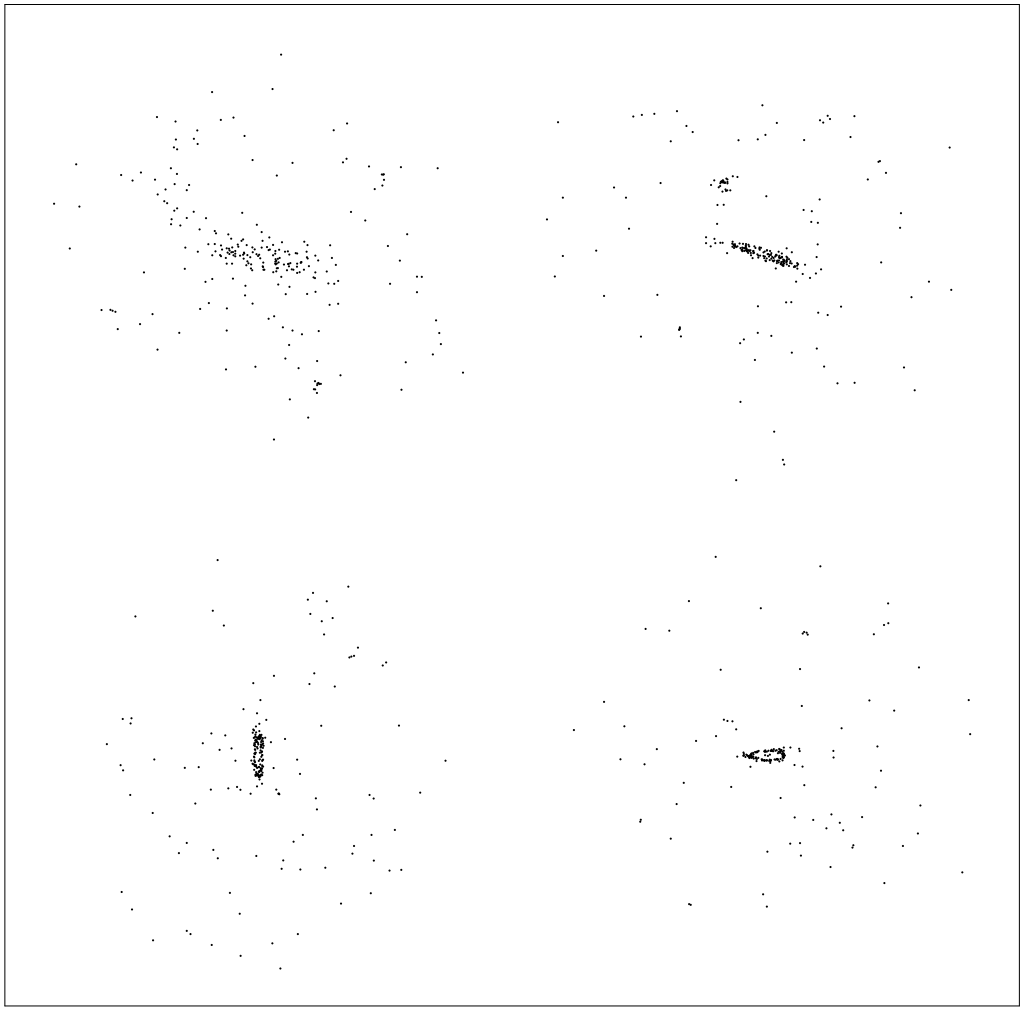


Stars Gas 0.7Gyr

Numerical simulations: stellar component

Ha 0.3Gyr

Ha 0.7Gyr



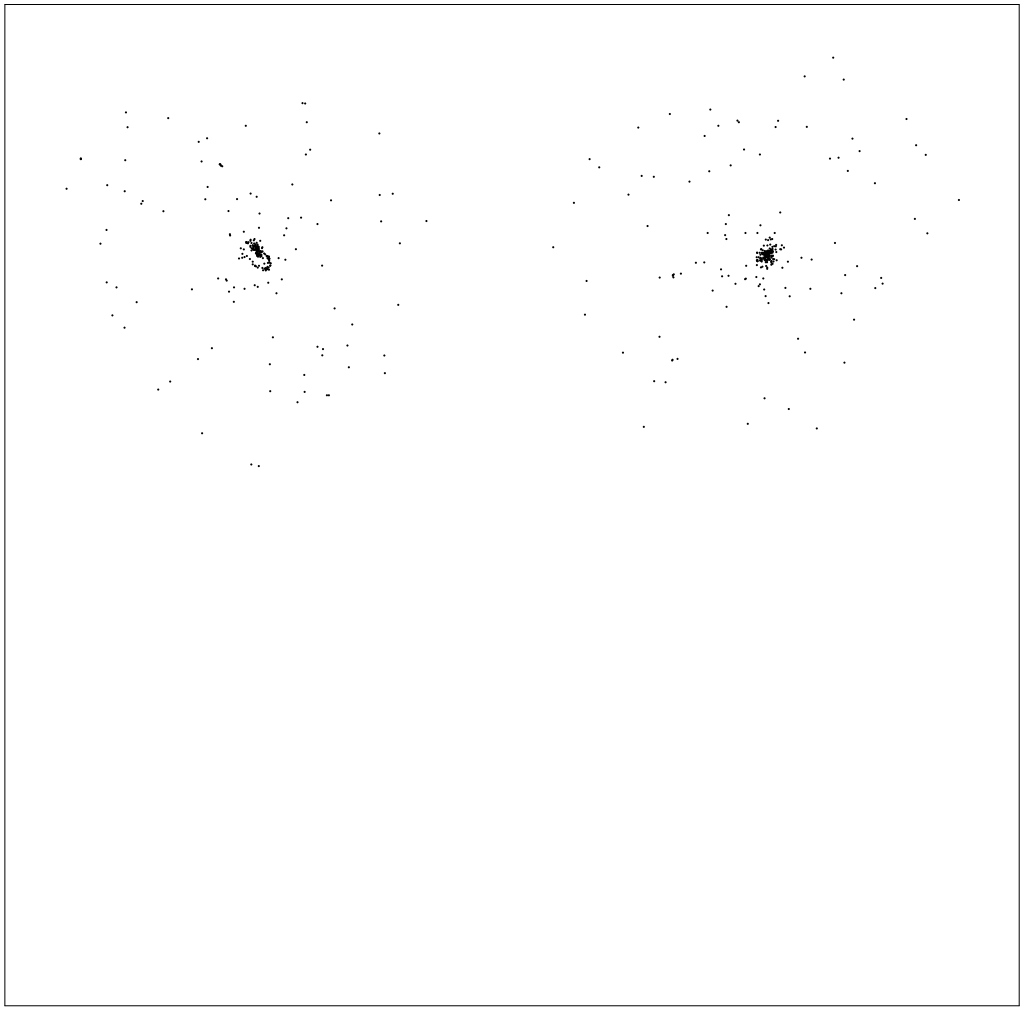
Ha 1.1Gyr

Ha 1.5Gyr

Numerical simulations: stellar component

Ha 1.9Gyr

Ha 2.4Gyr



Overview of the presentation

Conclusions

Isolation

- Computer processing: to *detect* and *classify* sources around 950 CIG
- Isolation degrees: continuous *isolation degrees* consistent for the whole sample and complementary
- Comparison samples: KTG, HCG, ACO
- Redshifts: verification of the type and 3-dimensional picture of the environment

Hα

- Observation of more than 200 galaxies
- Hα emission in bars and along the spiral arms
- Torques between Hα and bulk optical matter
- Modified Schmidt law

Perspectives

- Reduction of the whole sample to derive the local SFR and Hα OLF of isolated galaxies
- CO maps of some particular galaxies
- Fabry-Perot observations of some particular galaxies
- Numerical simulations
- Comparison of the ISM properties of the AMIGA galaxies with galaxies in denser environments