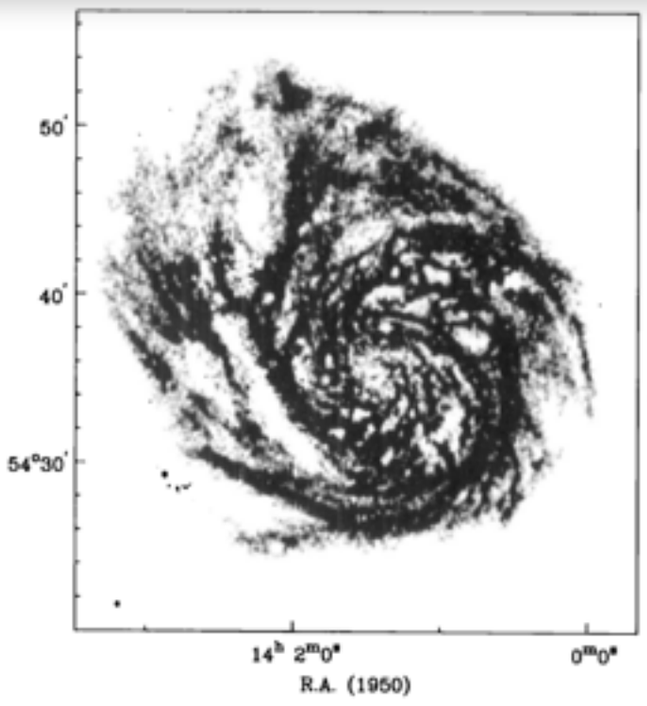
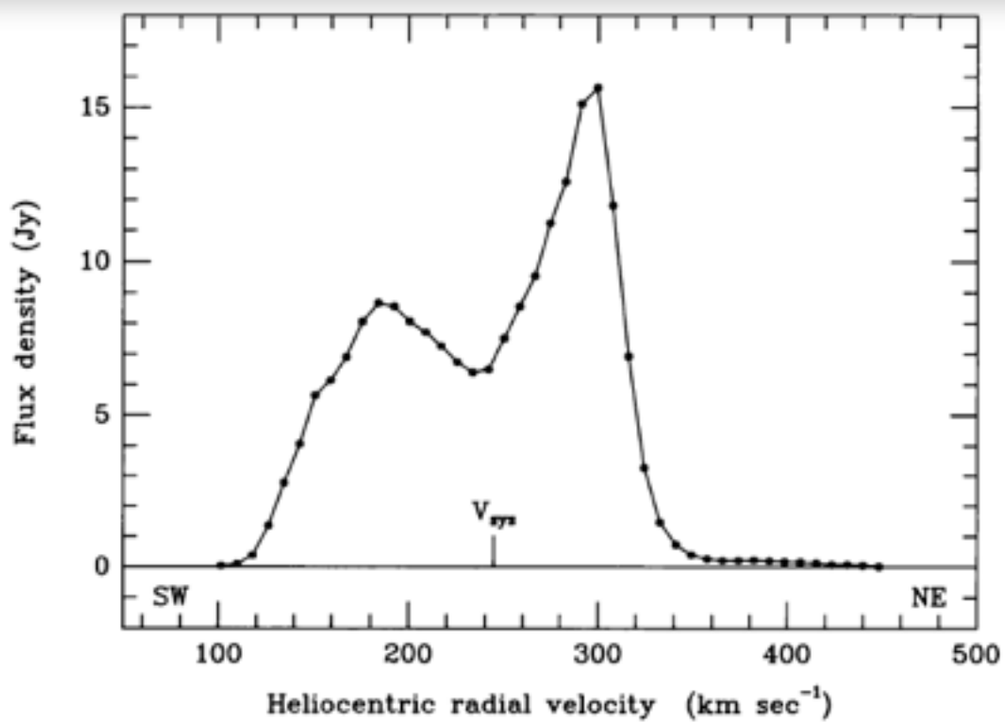
Probing galaxy merger activity through HI global profile asymmetries

Sarah Blyth (UCT), **Jamie Bok** (SAAO/UCT) & David Gilbank(SAAO)

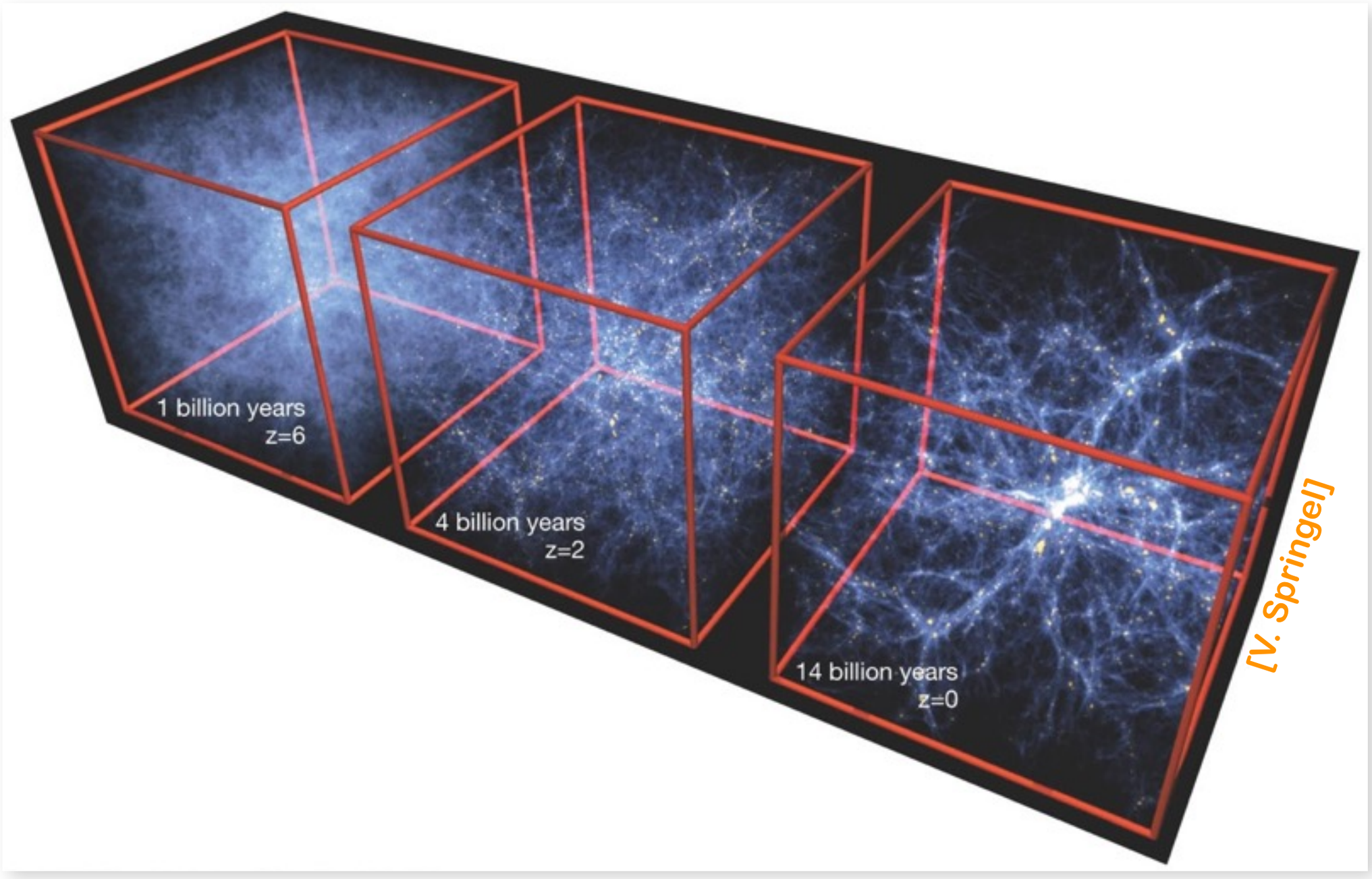
HI





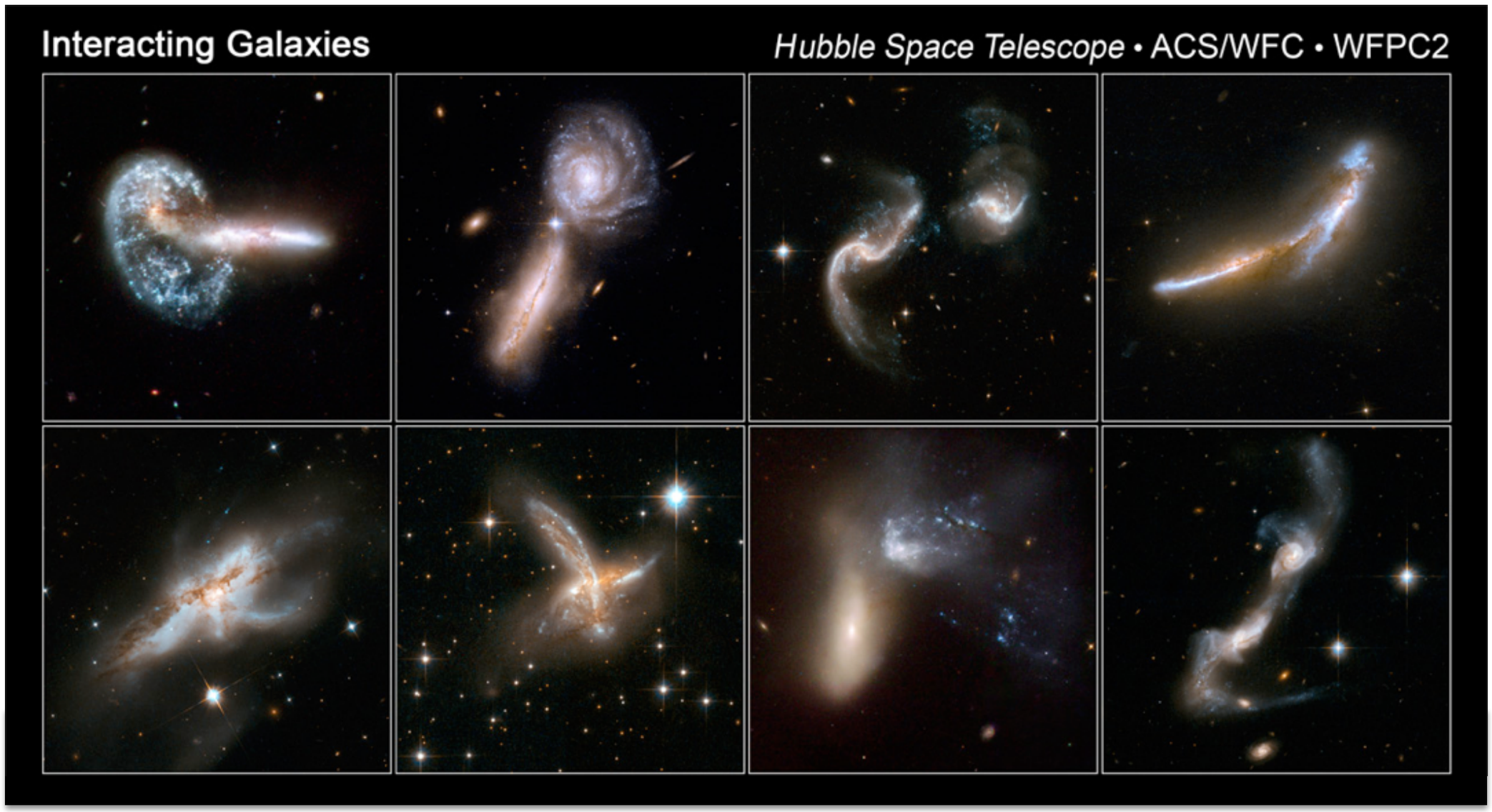
Galaxy evolution

Our current models of structure evolution imply galaxies evolve through the successive merging of smaller structures into larger ones…



Mergers

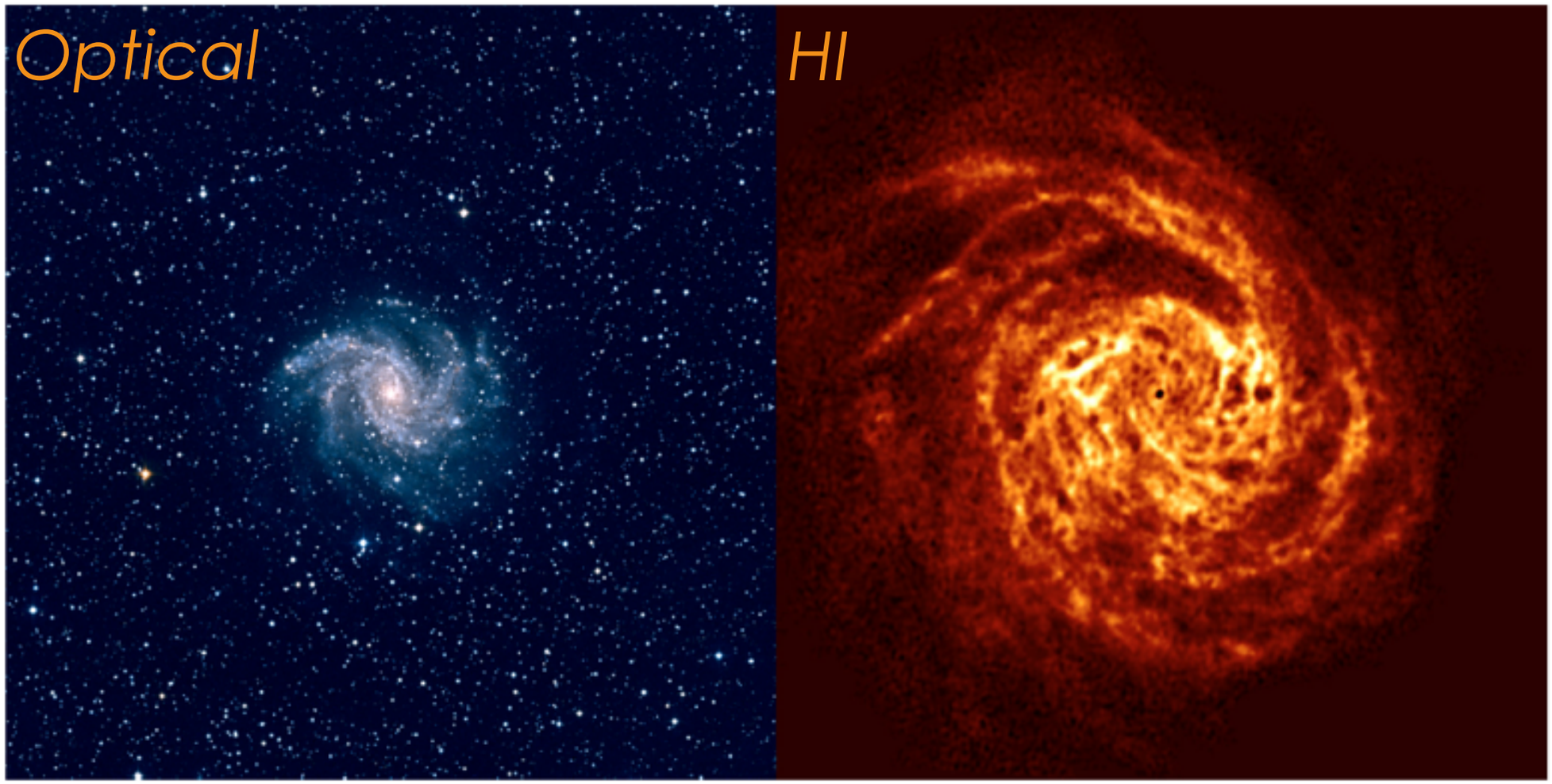
- Optically, mergers are identified by:
  - morphological distortions
  - tidal features
  - close pairs



Mergers and HI

HI is a good indicator of galaxy-galaxy interactions:

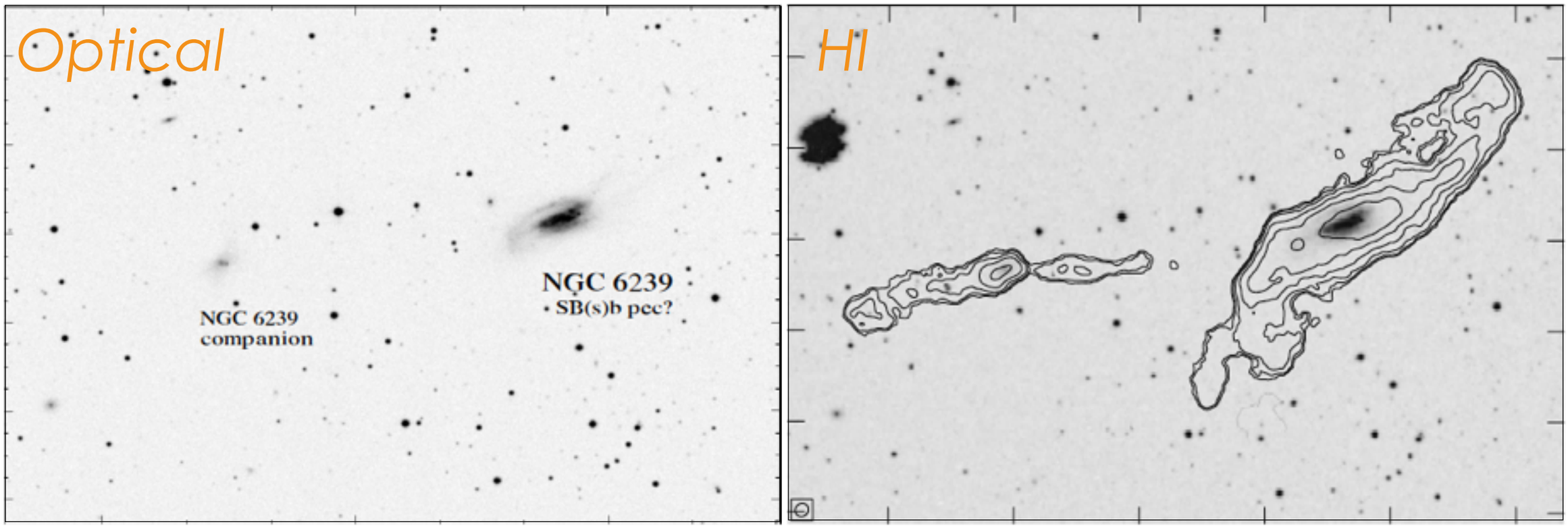
- HI typically located at larger R than stars where asymmetry more severe



Mergers and HI

HI is a good indicator of galaxy-galaxy interactions:

- HI typically located at larger R than stars where asymmetry more severe
- HI susceptible to tidal interactions, stripping, etc.



[Hogg & Roberts (2001), HI rogues gallery]

But… could be other causes for lopsidedness:

- accretion, outflows…

Quantifying distortions

There is a range of 'morphometrics' which are used to quantify galaxy distortions in 2D OPTICAL images:

- CAS parameters (concentration, asymmetry, smoothness)
  [Bershady+ (2000), Conselice+ (2000), Conselice (2003)]
- Gini [Abraham+ (2003)]
- M_{20} [Lotz+ (2004)]

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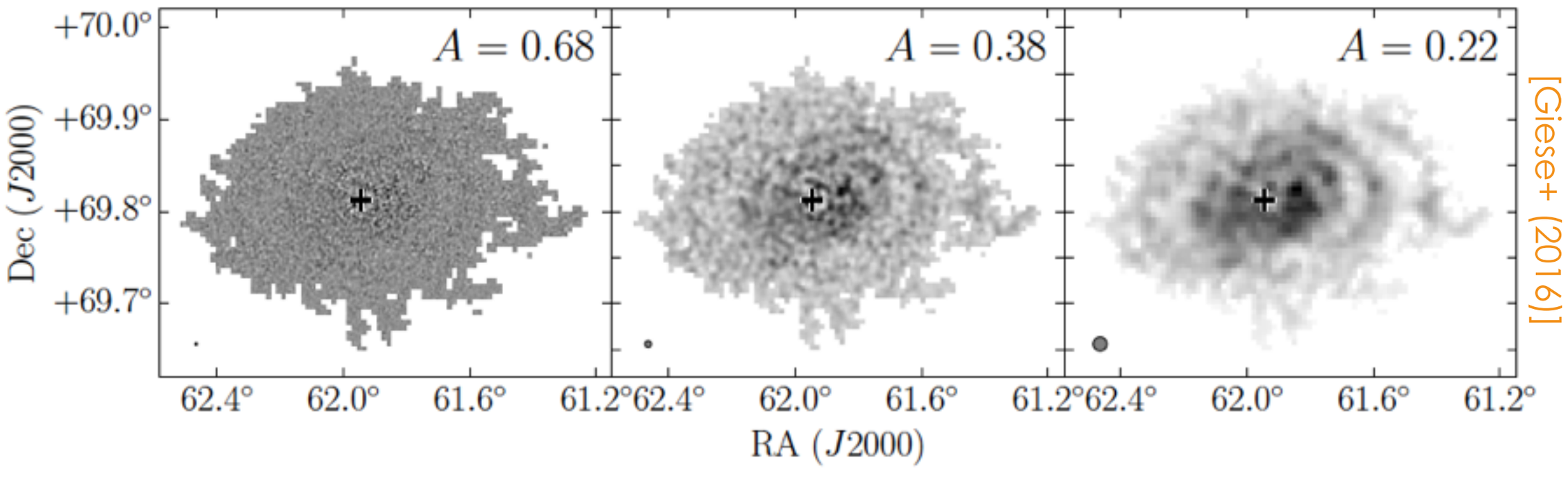
- Gini [Abraham+ (2003)]
- M_{20} [Lotz+ (2004)]
- Holwerda et al. & Giese et al. have recently applied these to HI image data

$$A = \frac{\sum_{i,j} |I(i,j) - I_{180}(i,j)|}{2 \sum_{i,j} |I(i,j)|}$$



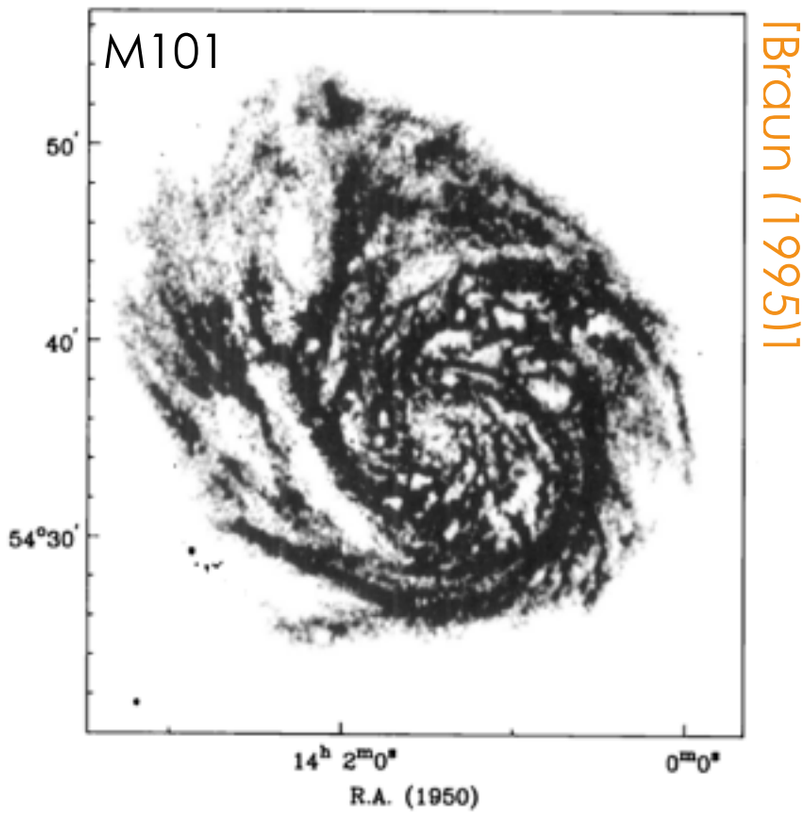
[Giese+ (2016)]

From 2D to 1D…

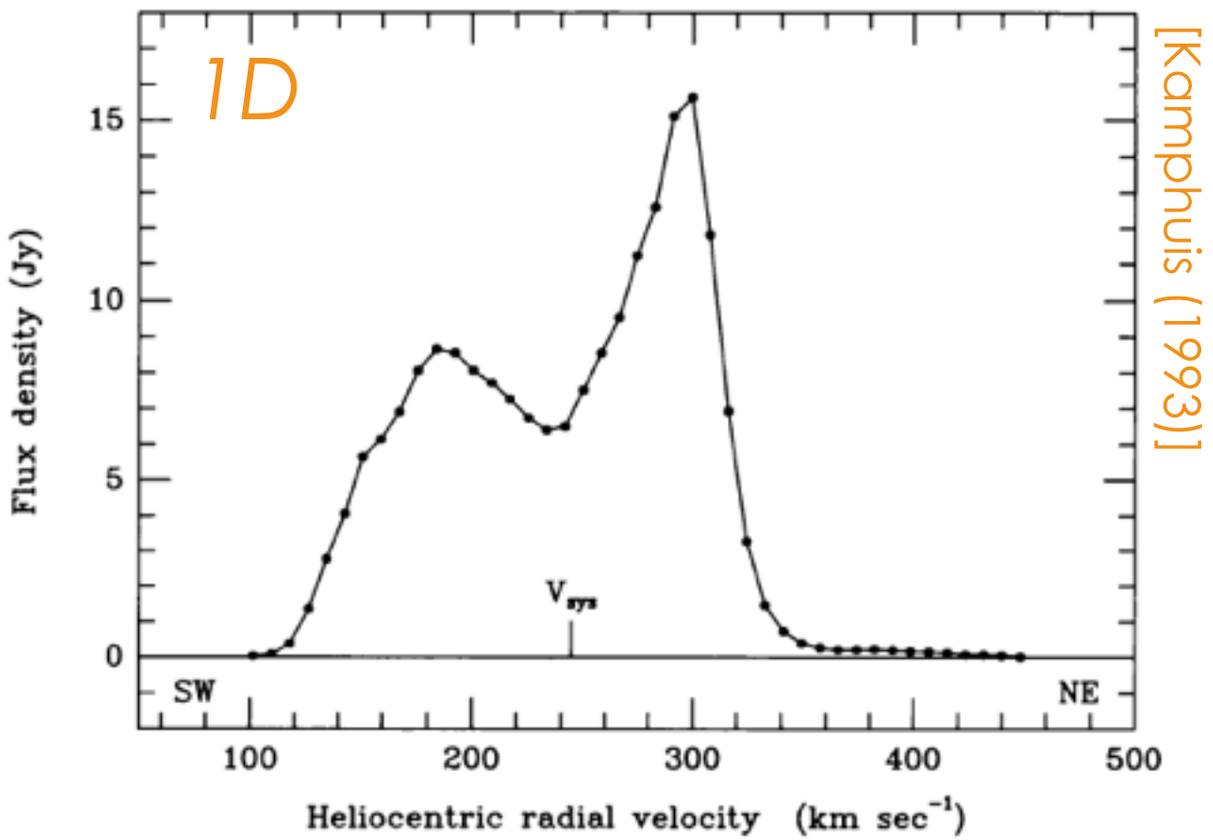
Upcoming SKA-pathfinder surveys (WALLABY + APERTIF surveys) will find 1000s of spatially resolved HI galaxies in the local universe…

- BUT, deeper HI surveys (CHILES, DINGO, LADUMA) will obtain 100s-1000s of **spatially unresolved** detections at higher z
- HI global profiles reflect large-scale structural properties of HI disks [Richter & Sancisi (1994)]

2D HI asymmetric distributions map to 1D HI global profile asymmetries:



[Braun (1995)]



[Kamphuis (1993)]

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- HI global profiles reflect large-scale structural properties of HI disks [Richter & Sancisi (1994)]

- A number of studies have focussed on quantifying HI global profile asymmetries in **field** and **isolated galaxy samples** [Richter & Sancisi (1994), Haynes+ (1998), Espada+ (2011)]

Q: Can HI global profile asymmetries be used to identify mergers?

Our approach

AIM:

- to investigate if HI global profile asymmetries can provide merger information

Approach:

- Define a sample of close pairs (with at least one HI detected galaxy member)
- Quantify the global HI asymmetry
- Compare with an isolated HI galaxy sample for reference

Data

We use a combination of ALFALFA HI data and SDSS optical data

- ALFALFA α40 catalogue [Haynes+ (2011)]
- Reliable detections (code 1s) with SDSS (DR7) optical counterparts (spectroscopic)

Pairs: (247)

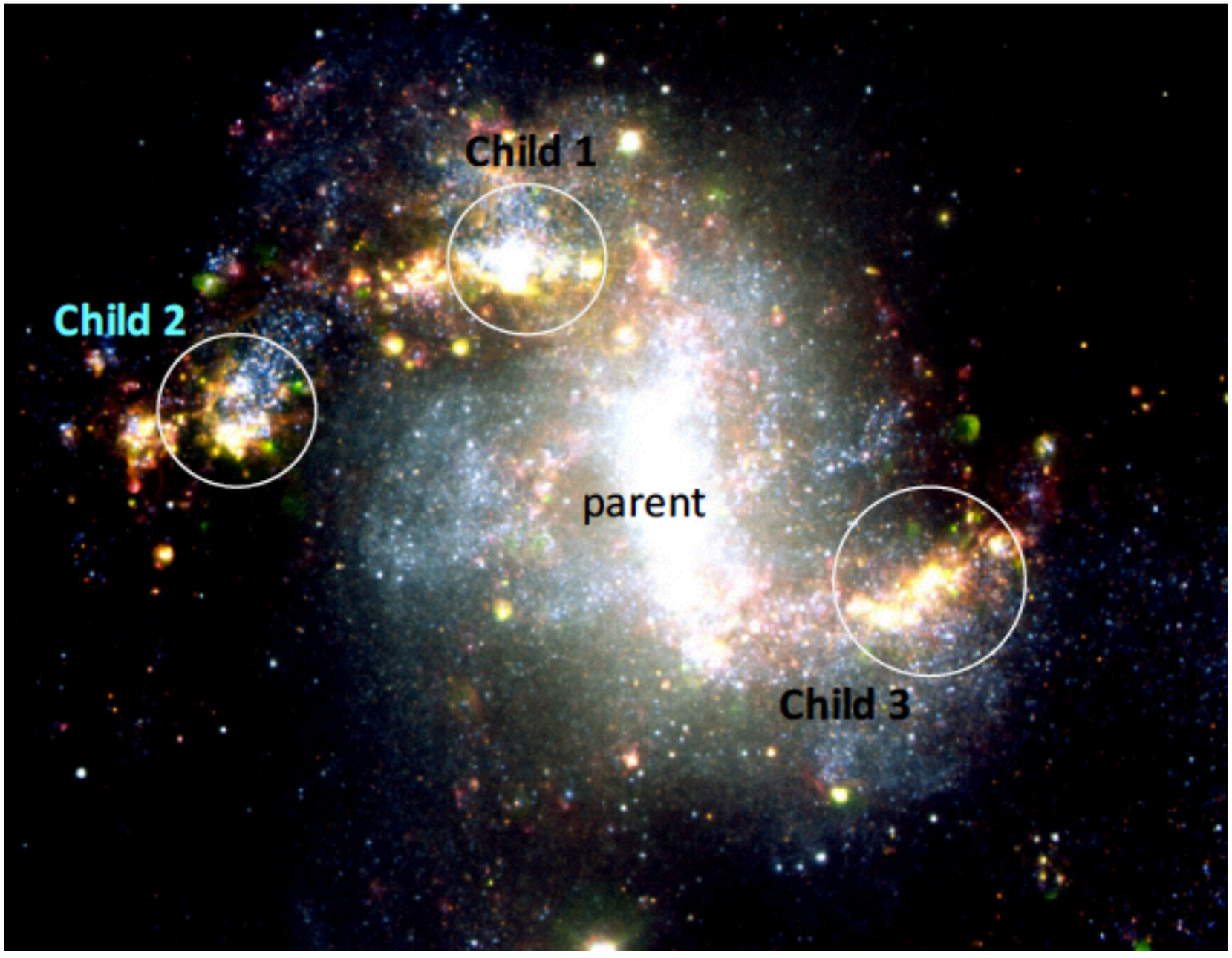
- Match HI optical counterpart (OC) to nearest neighbour in SDSS spectroscopic catalog
- **$r < 100$ kpc , $\Delta v < 1000$ km/s** (like [Robotham+, 2014])
- Also eliminate HI-HI pairs to minimise contamination from confusion

Isolated: (776)

- **$r > 500$ kpc , $\Delta v > 5000$ km/s**

Systematic checks

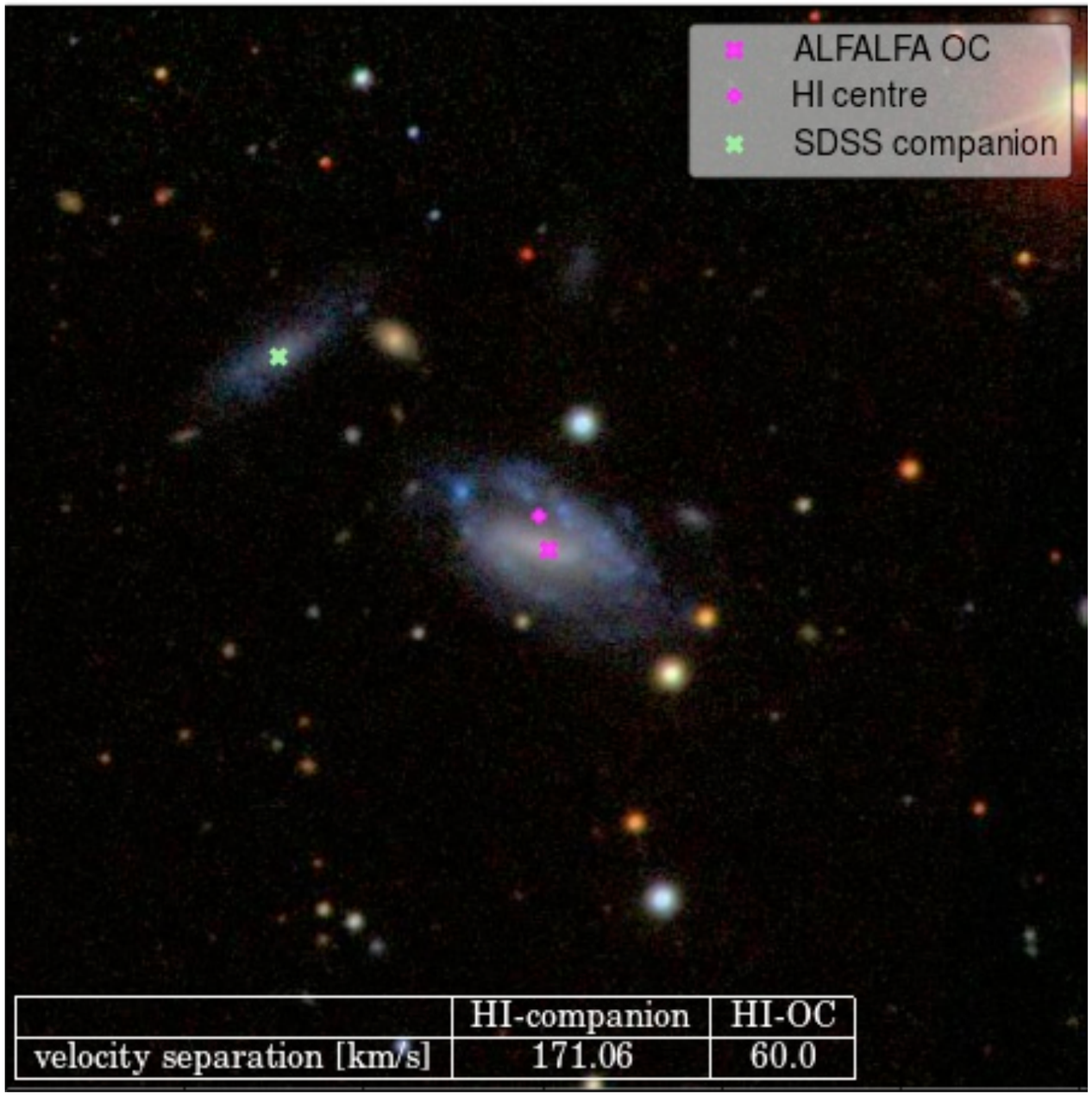
Deblended objects in SDSS can create problems - these are removed



Systematic checks

Optical counterpart matching is also checked…

Good match:



	HI-companion	HI-OC
velocity separation [km/s]	171.06	60.0

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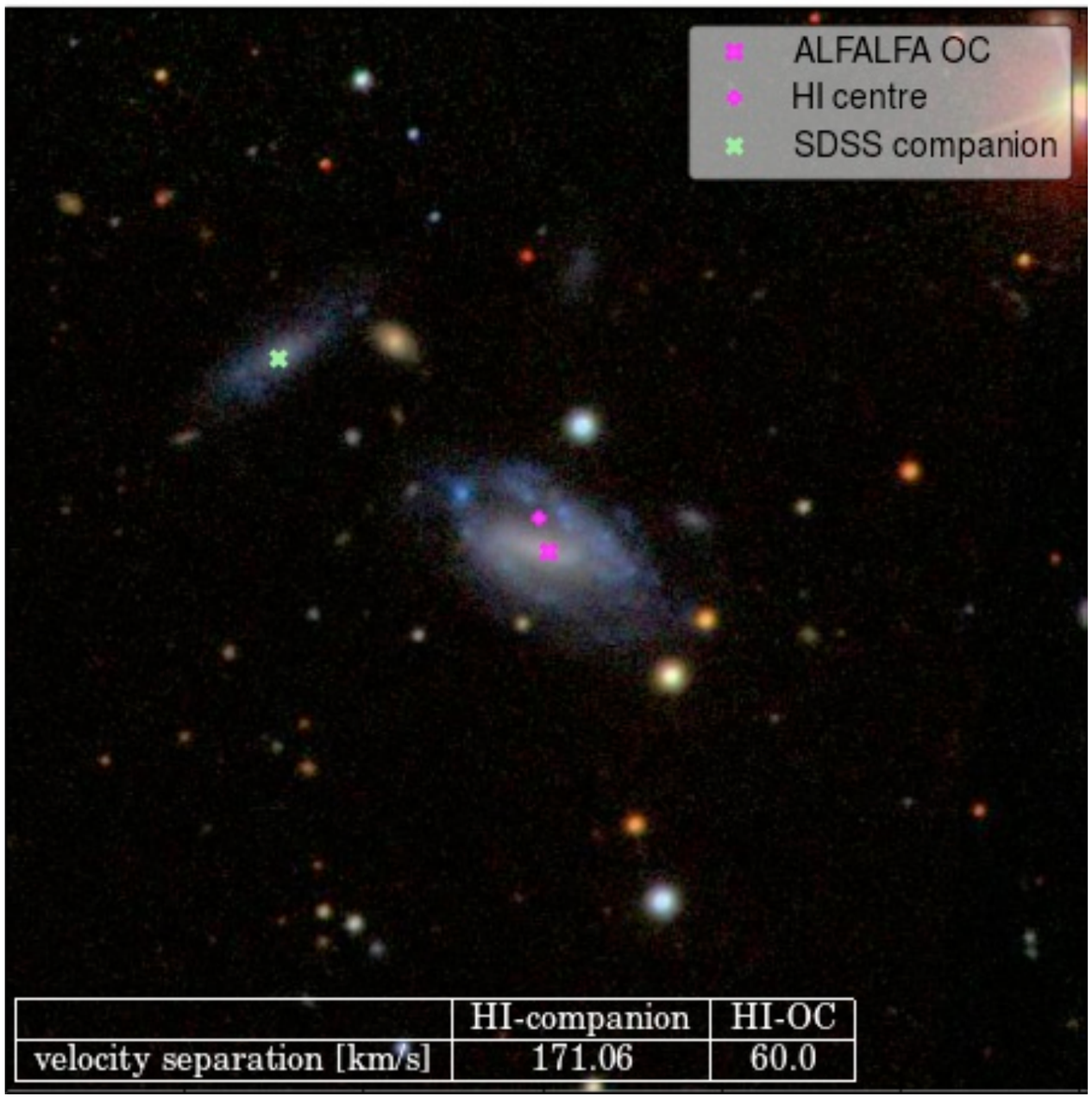
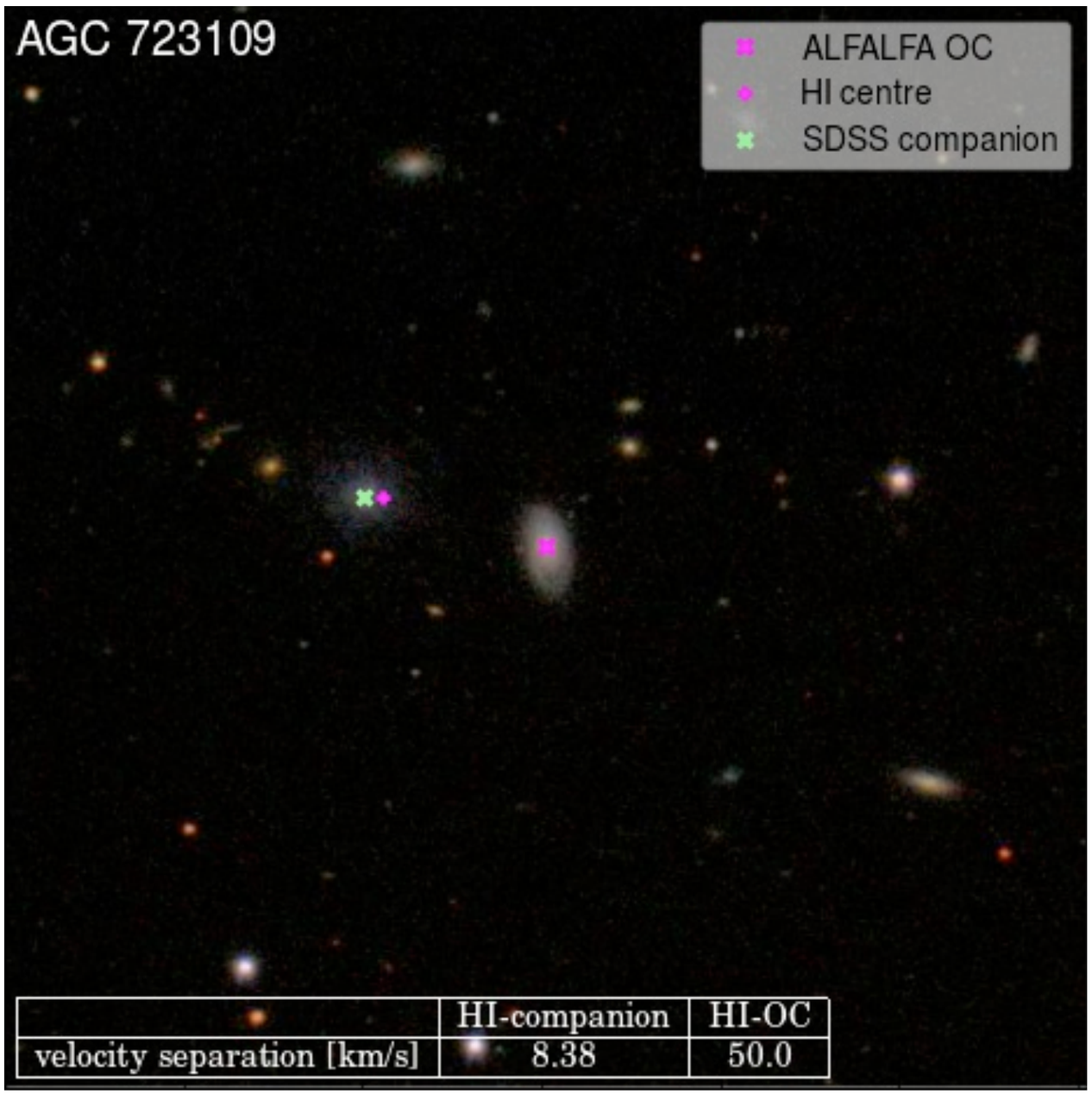


	HI-companion	HI-OC
velocity separation [km/s]	171.06	60.0

Bad match:

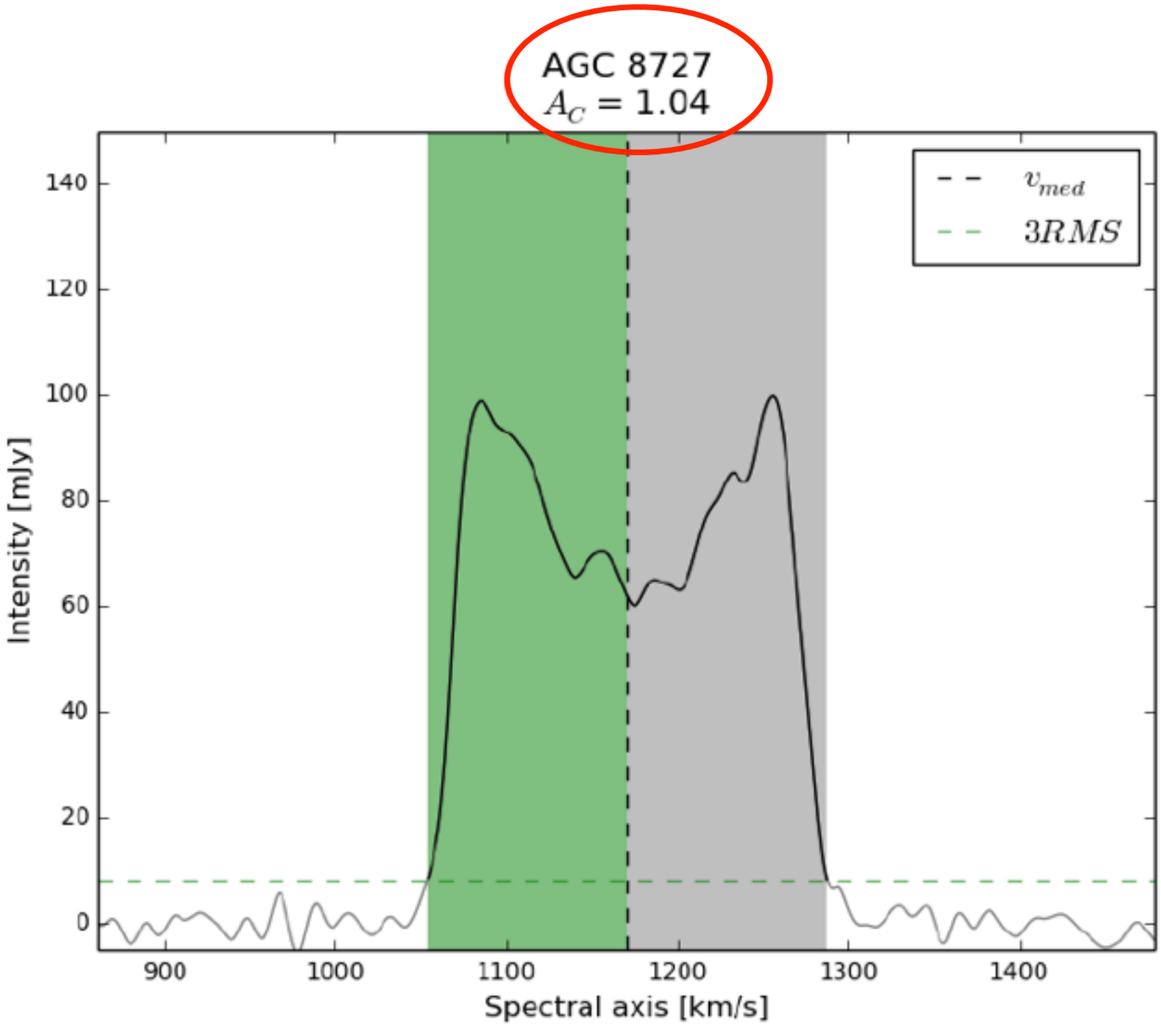


	HI-companion	HI-OC
velocity separation [km/s]	8.38	50.0

Determining profile asymmetries

Similarly to Haynes et al. and Espada et al., we use an areal flux ratio to determine the HI profile asymmetry

$$A_{\mathrm{l/h}} = \frac{S_{\mathrm{l}}}{S_{\mathrm{h}}} = \frac{\int_{V_{\mathrm{l}}}^{V_{\mathrm{m}}} S_v \mathrm{d}v}{\int_{V_{\mathrm{m}}}^{V_{\mathrm{h}}} S_v \mathrm{d}v}$$



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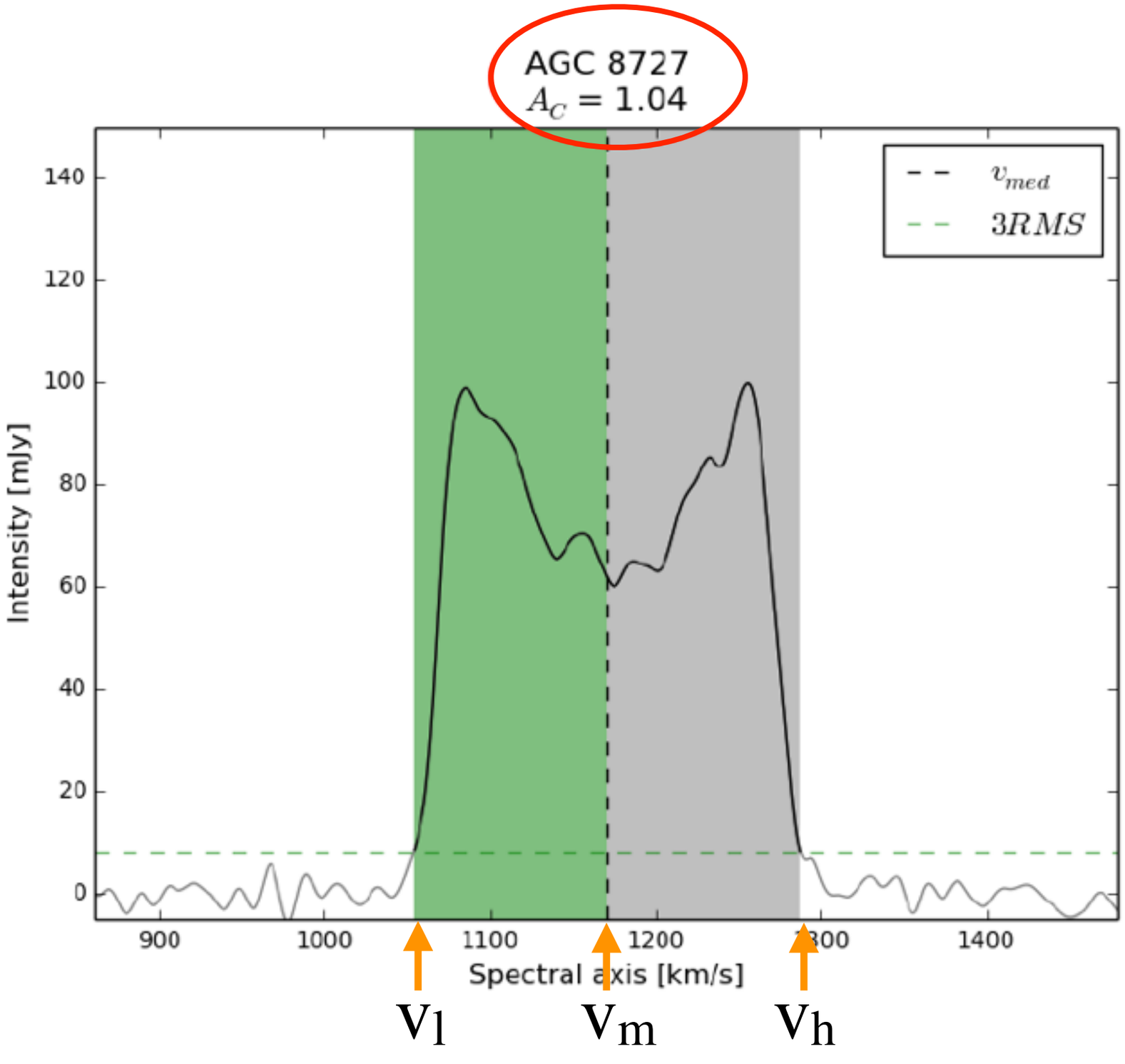

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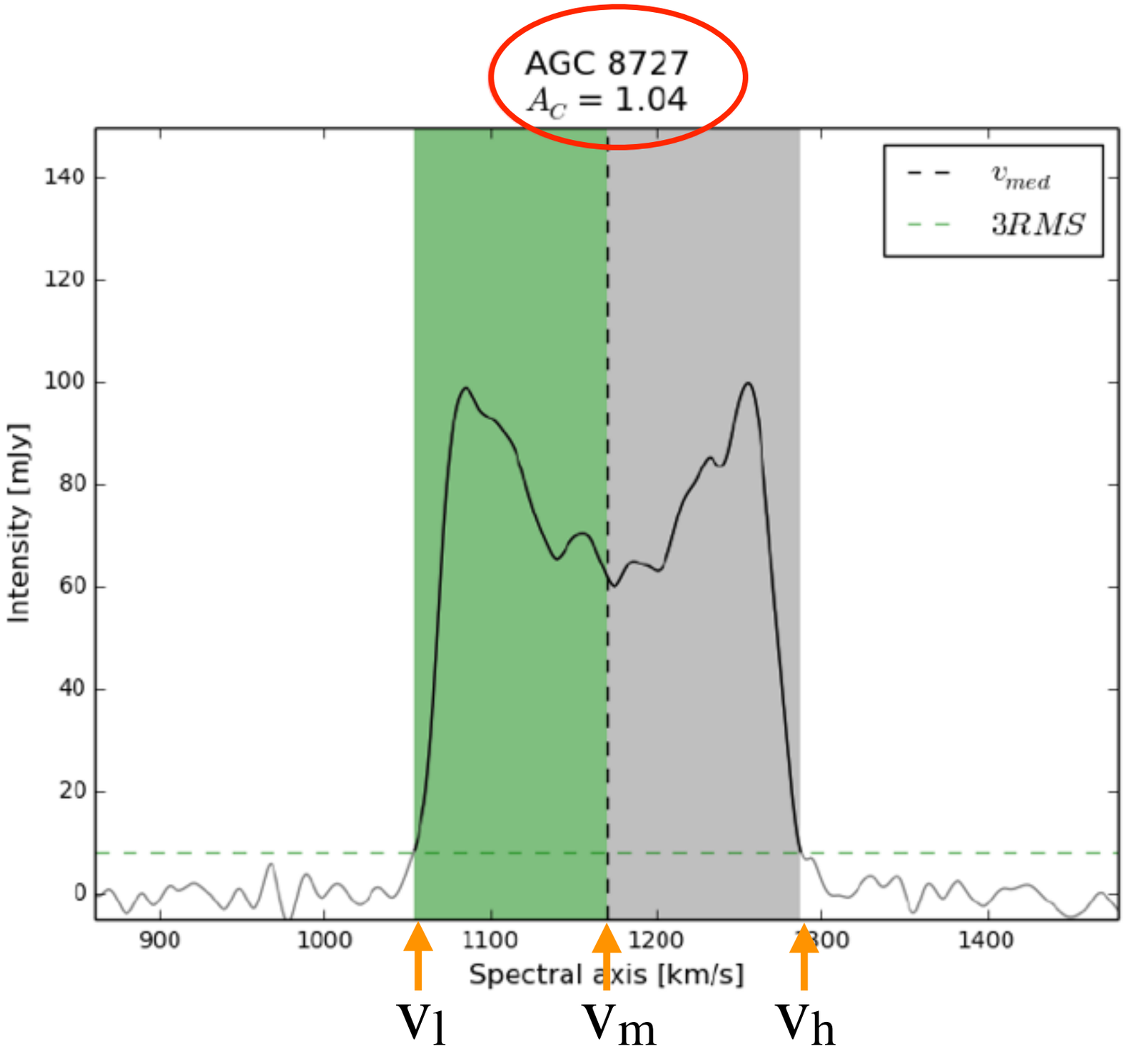
V_m = ALFALFA V_{helio}

width = Δv at 3 x rms

OR

w_{50}



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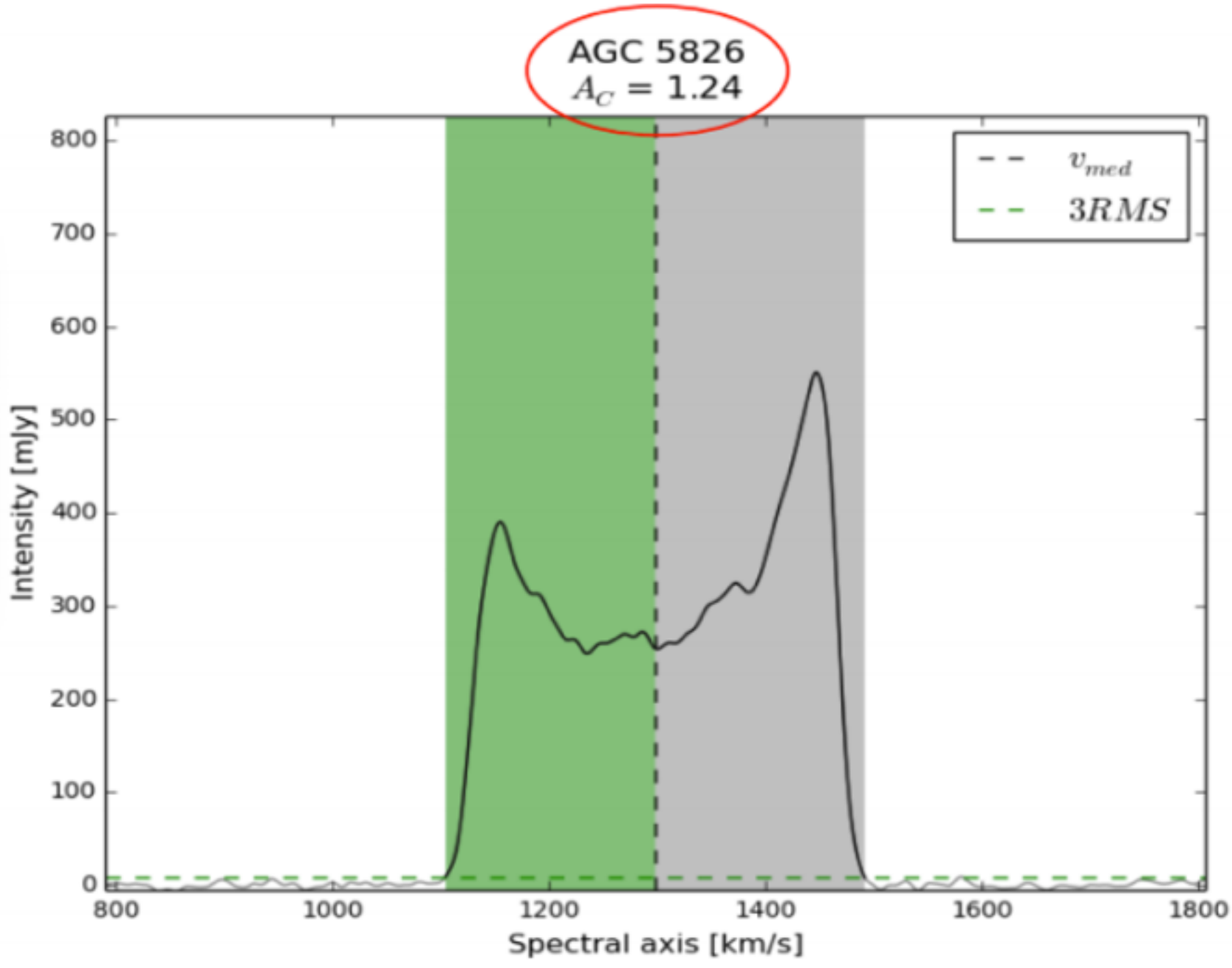

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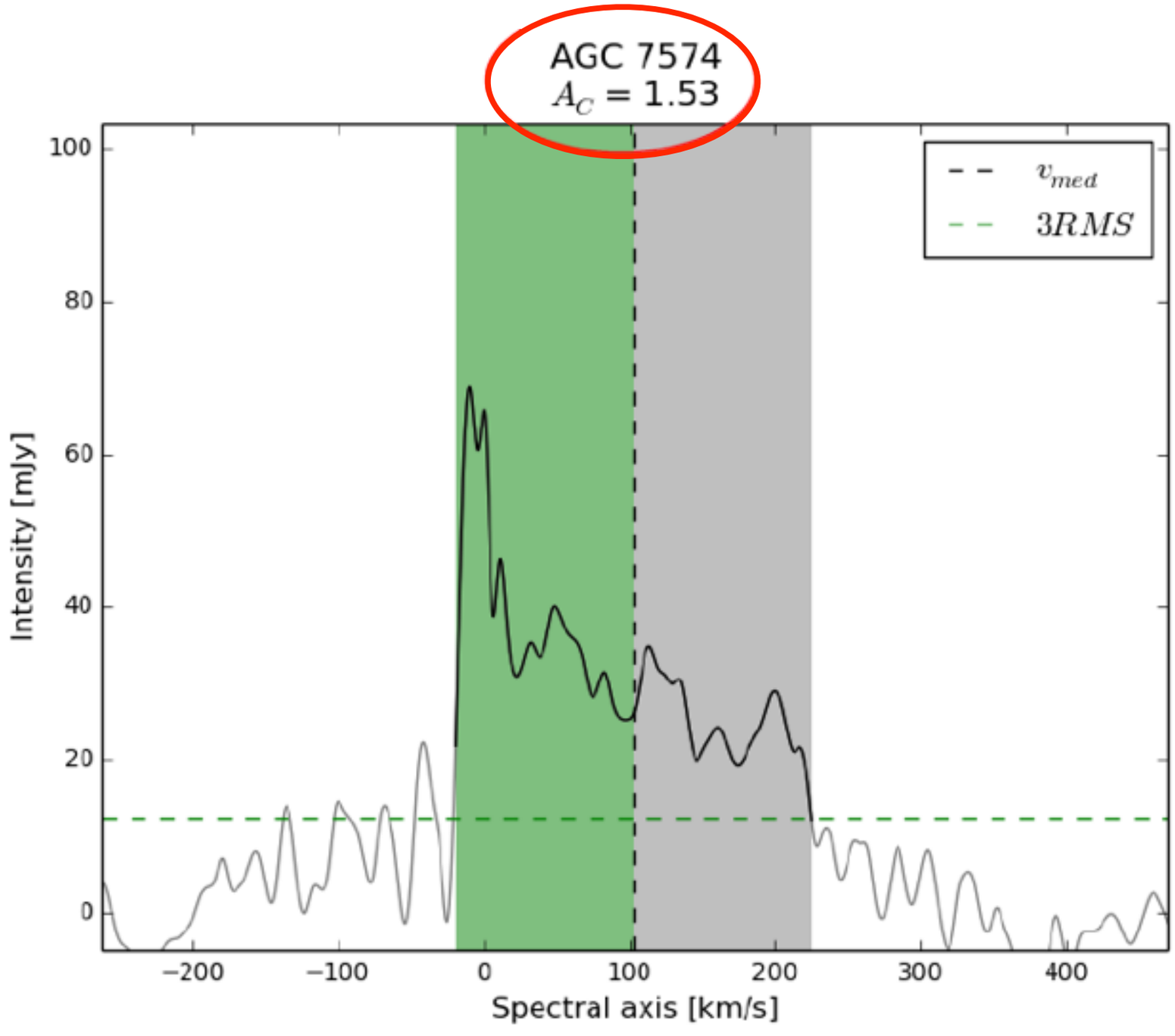
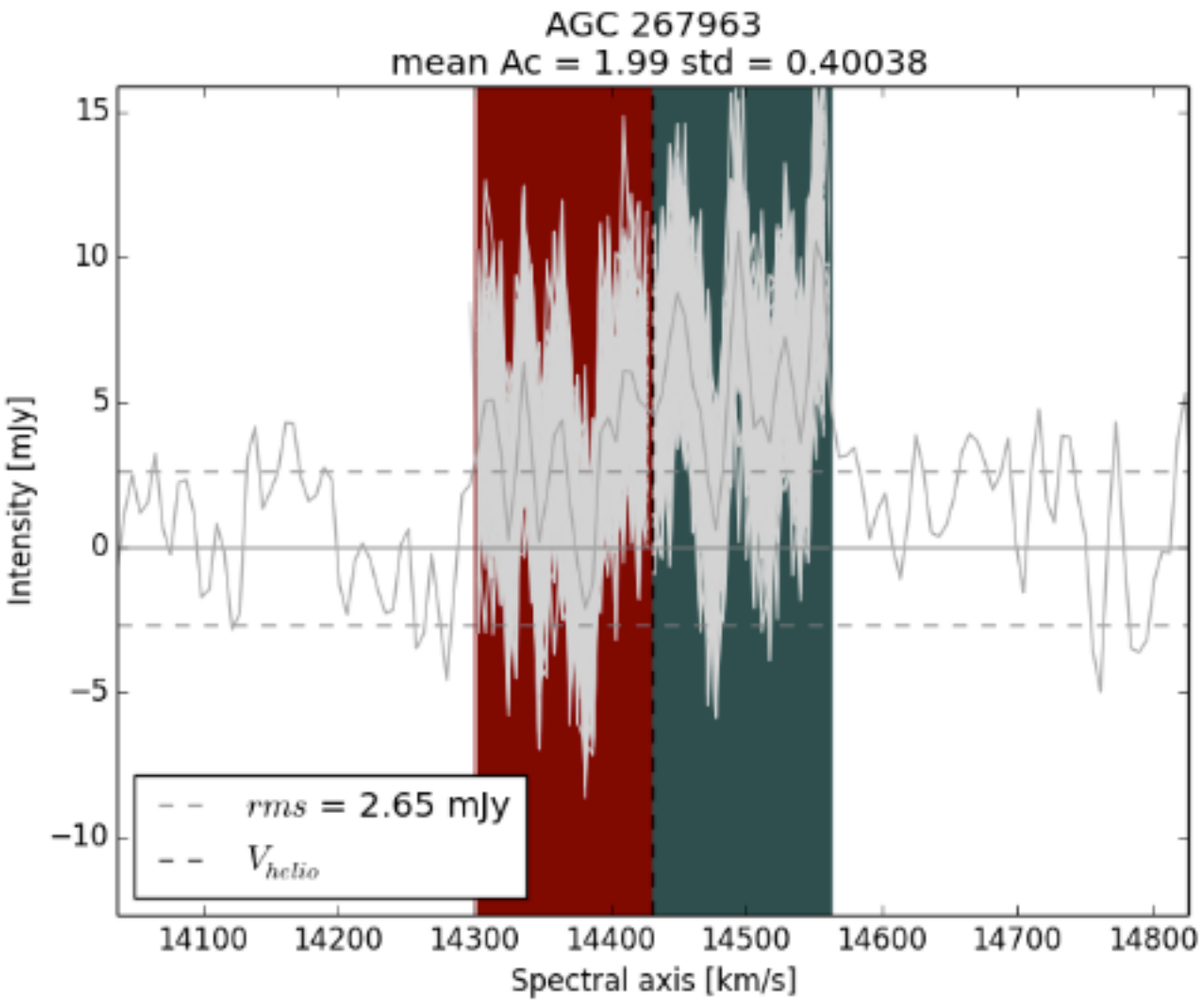


Bias checking

Low S/N profiles result in large uncertainties on the measured A_c parameter:



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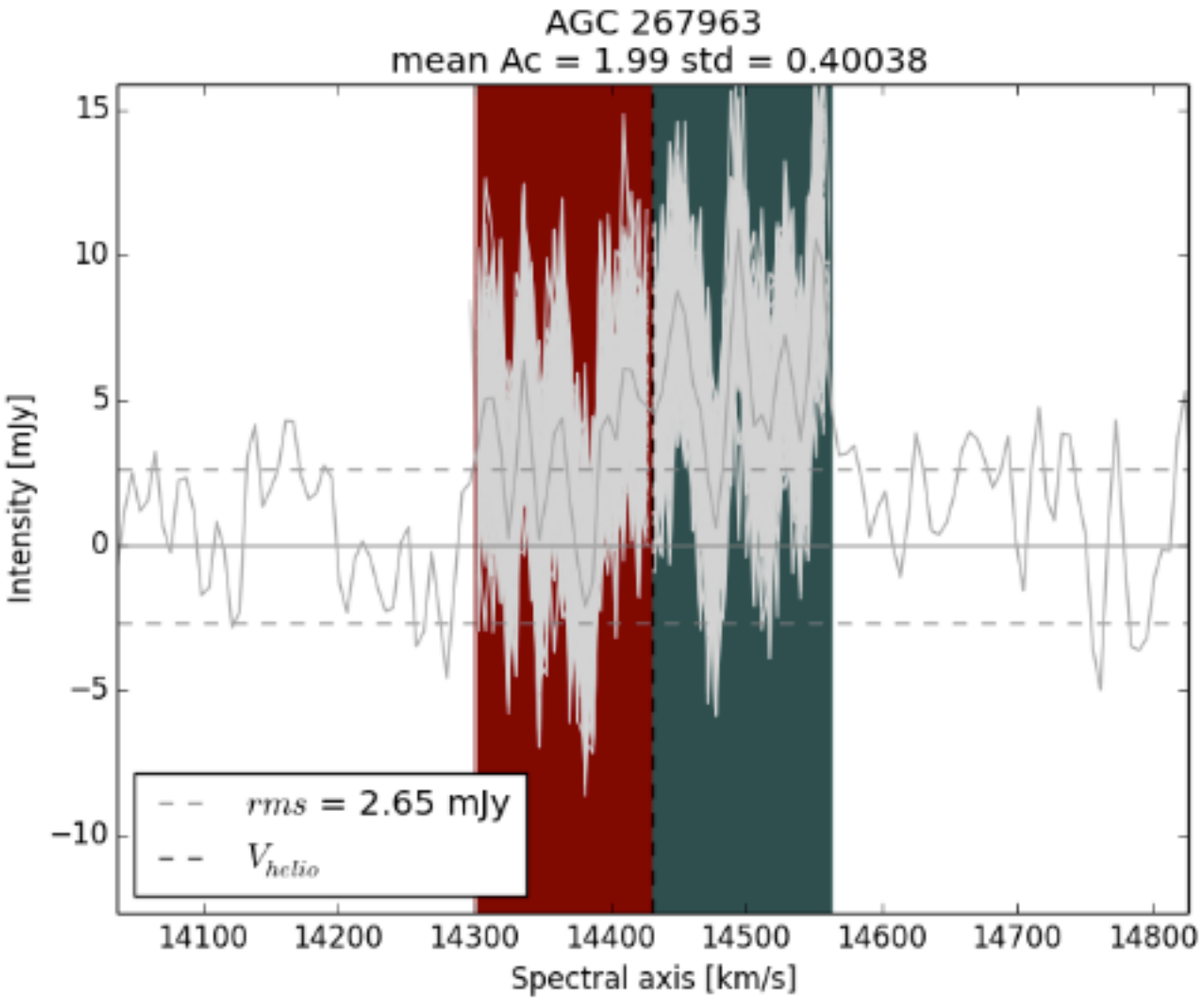

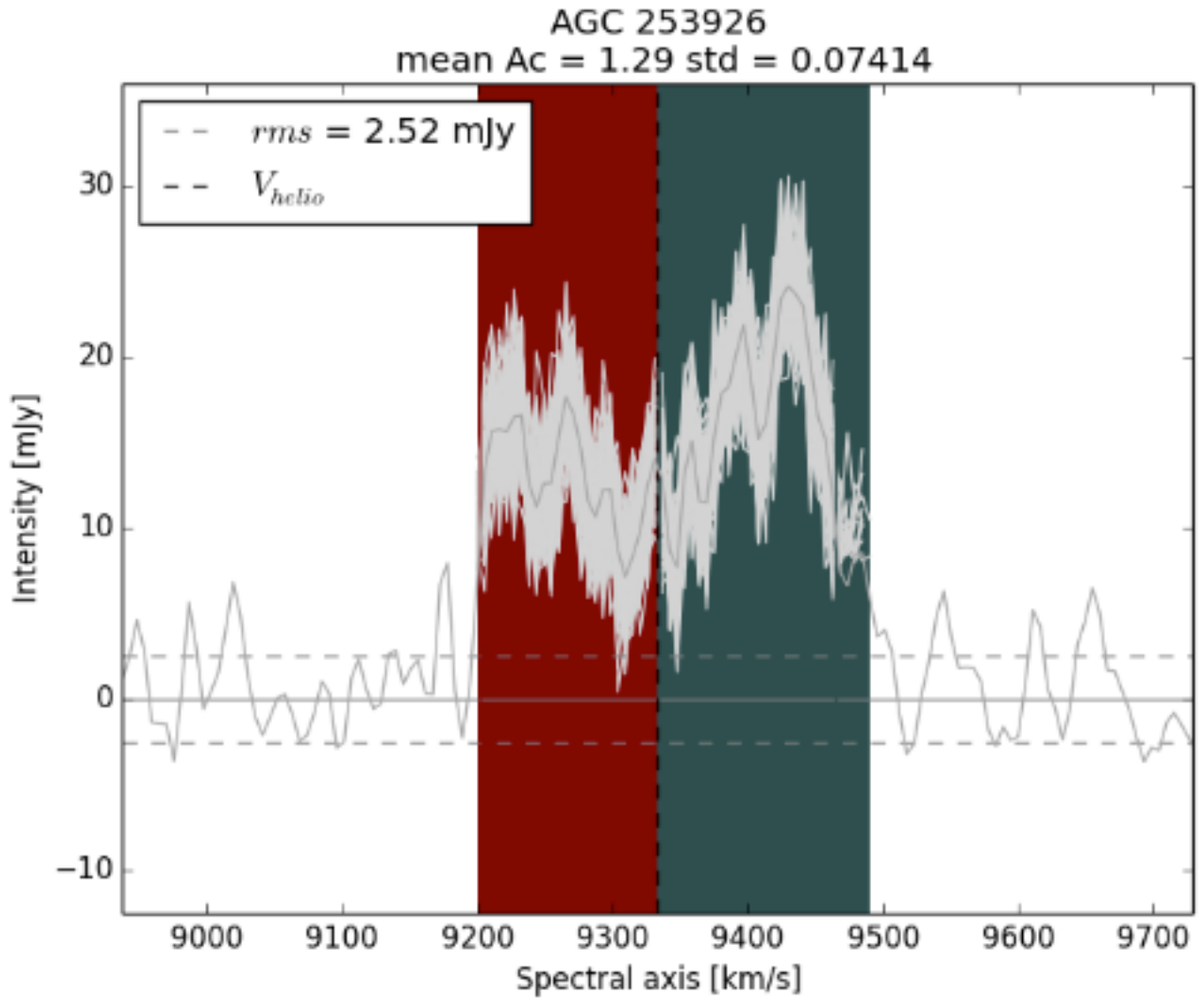

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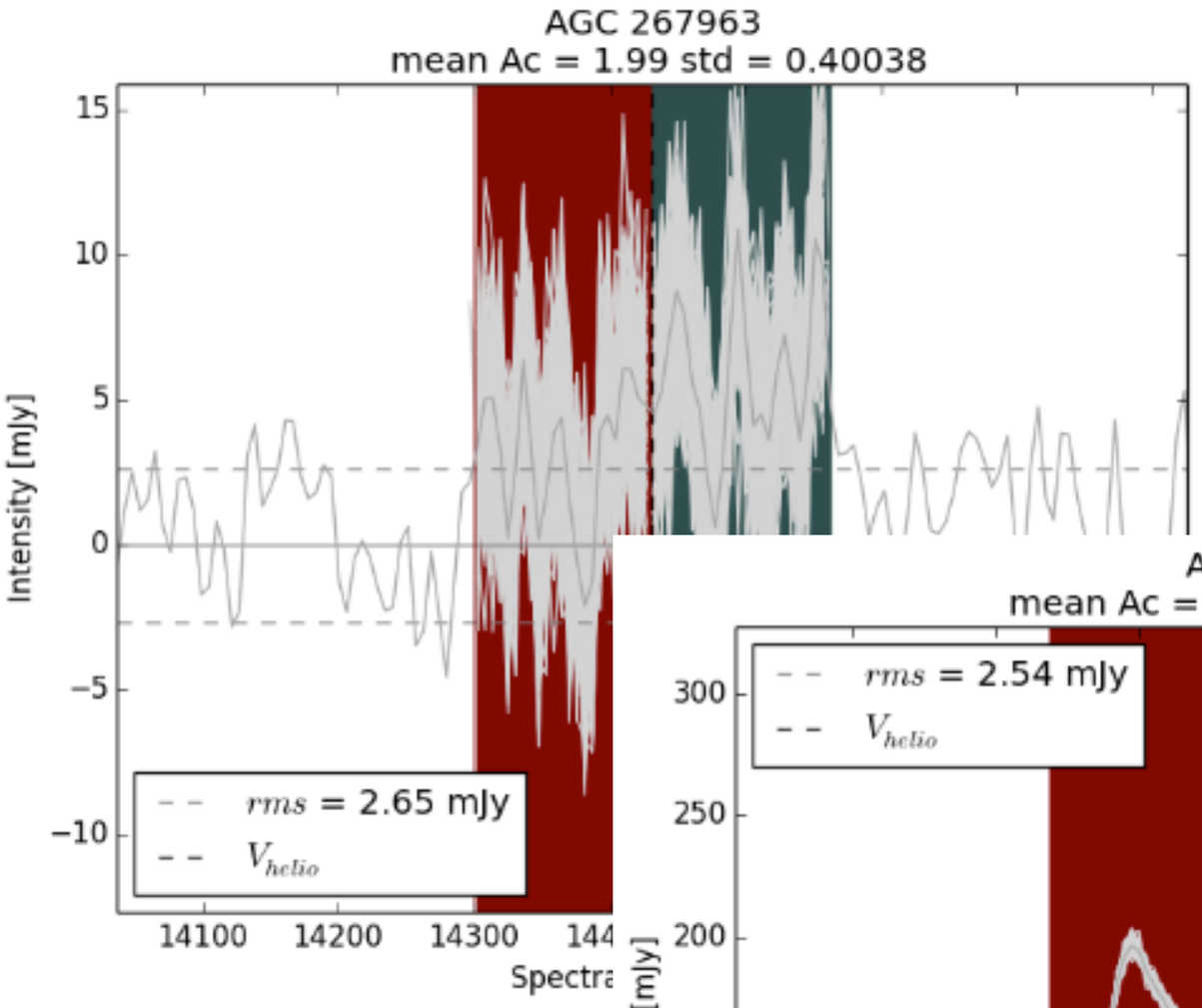
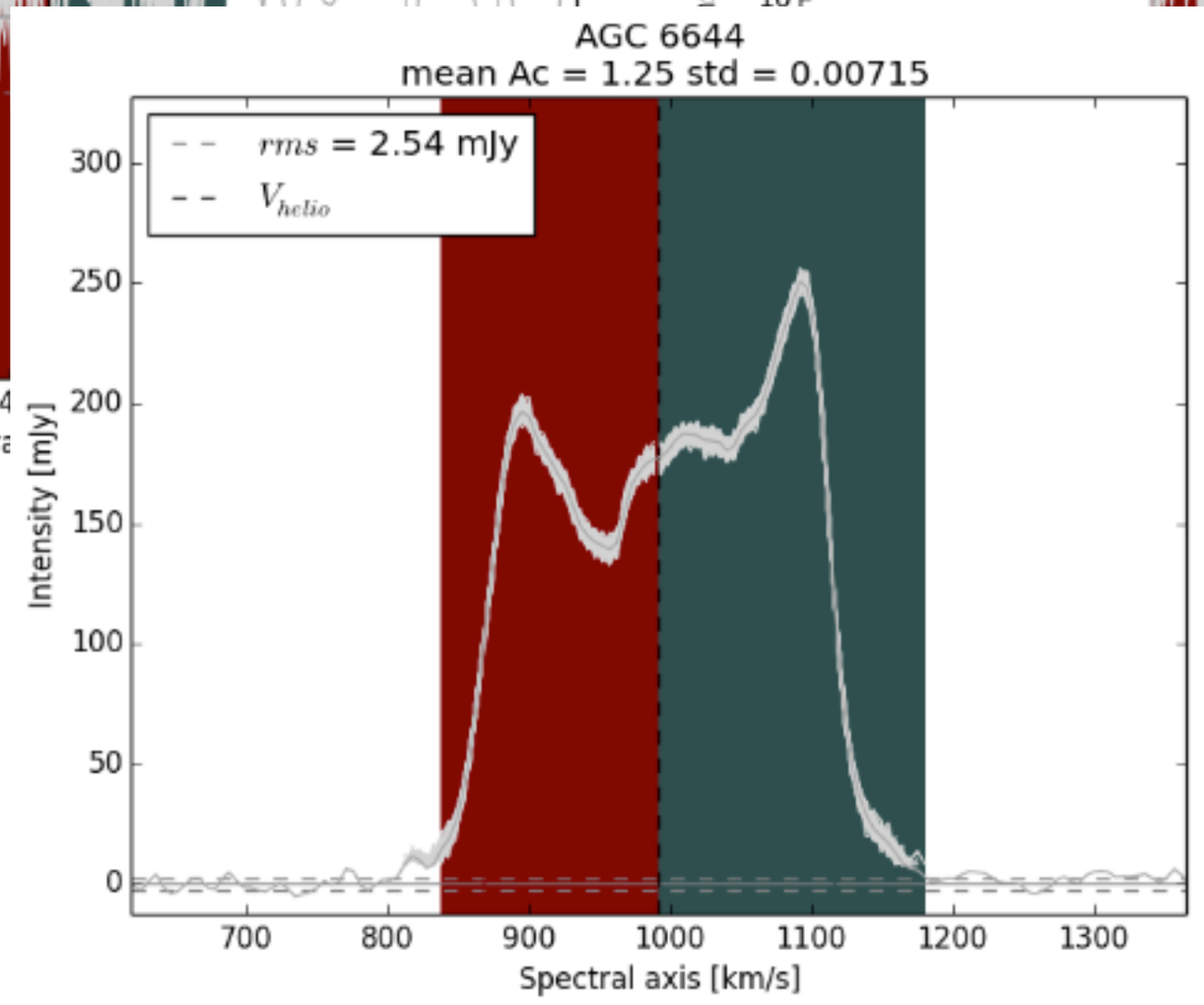
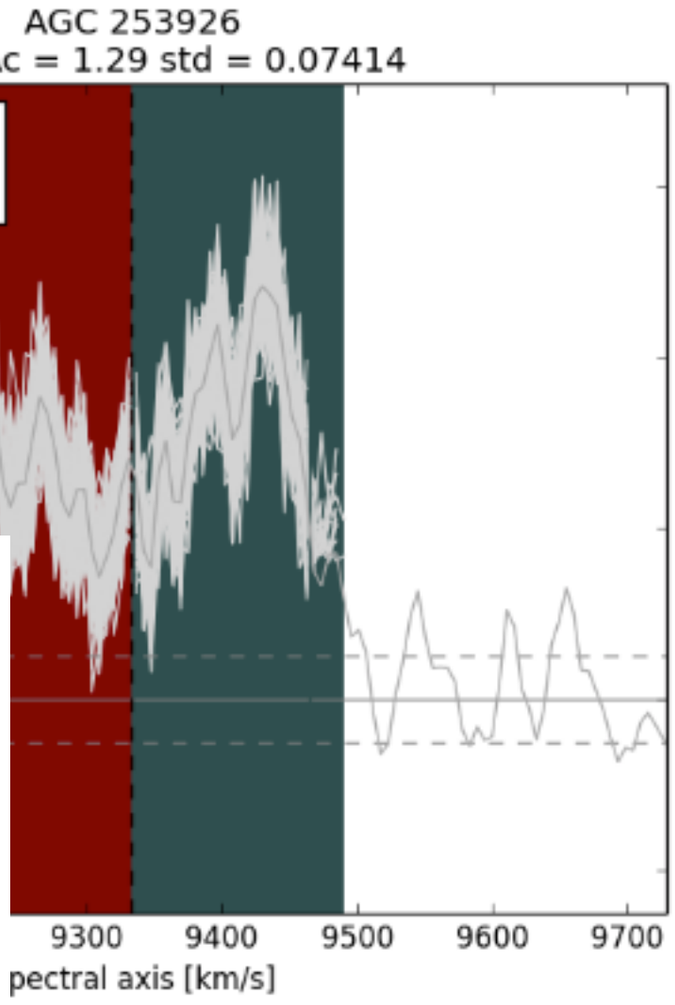


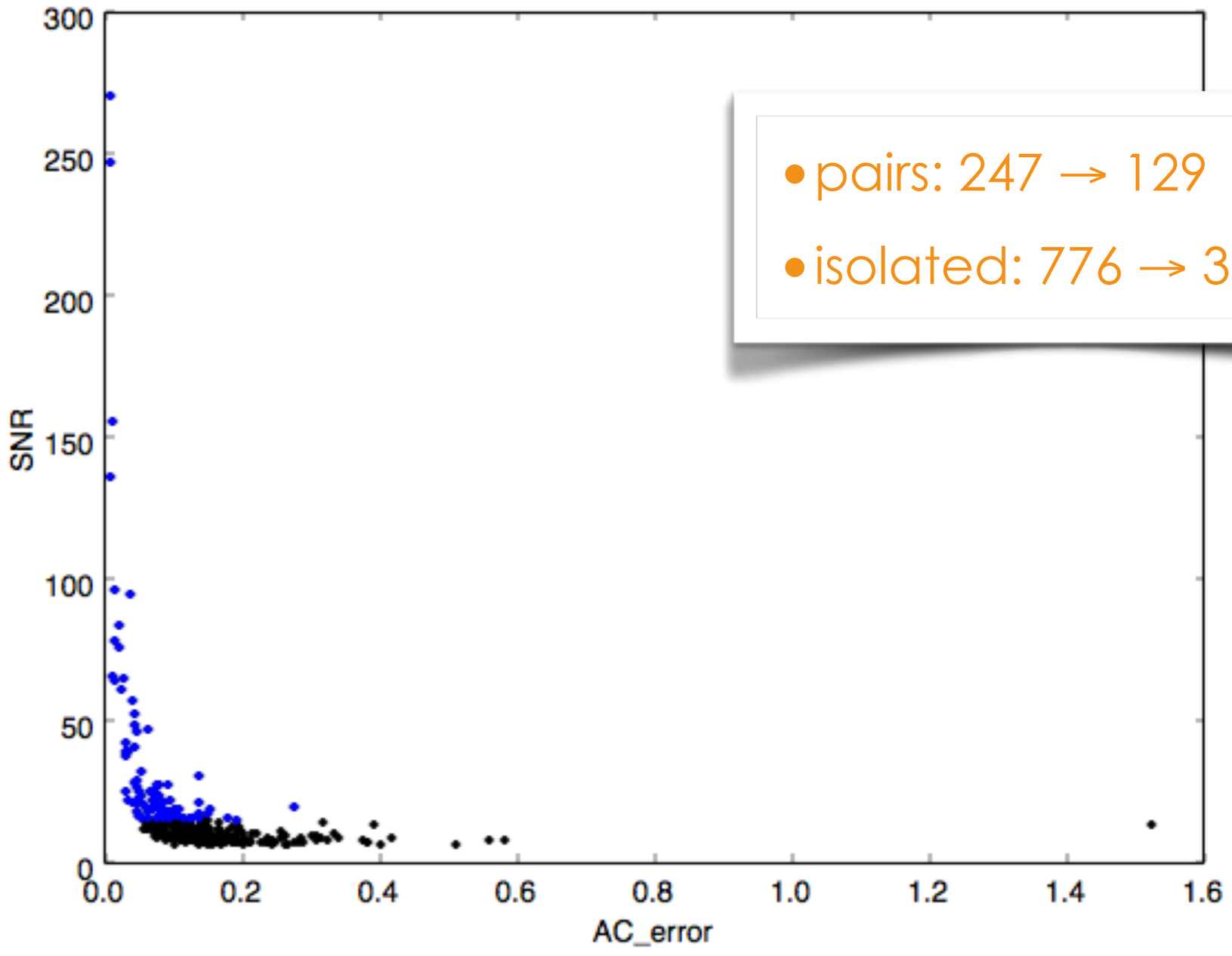




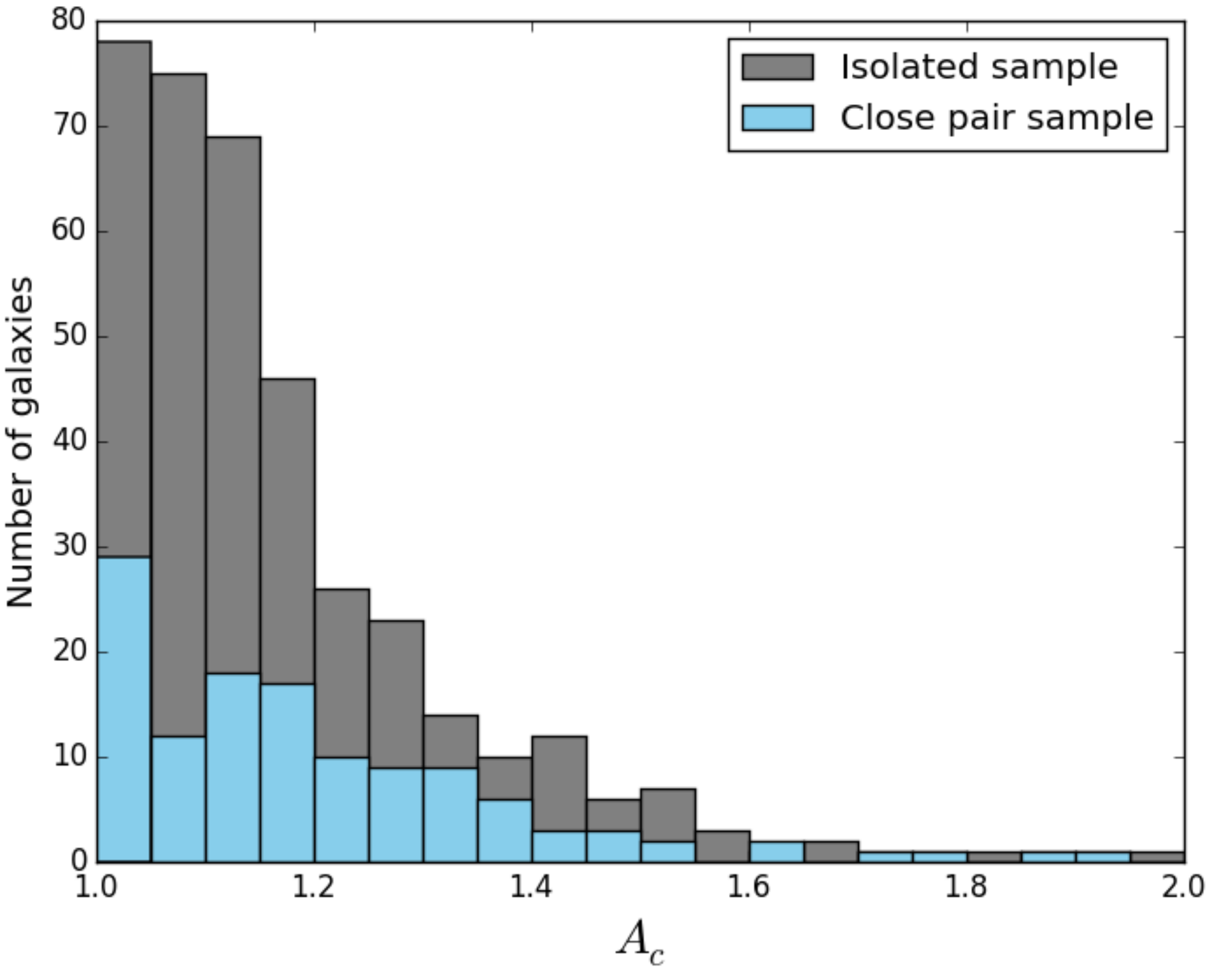
Bias checking

Low S/N profiles result in large uncertainties on the measured A_c parameter:

- We remove all profiles with **S/N <10** from both the isolated and pair samples

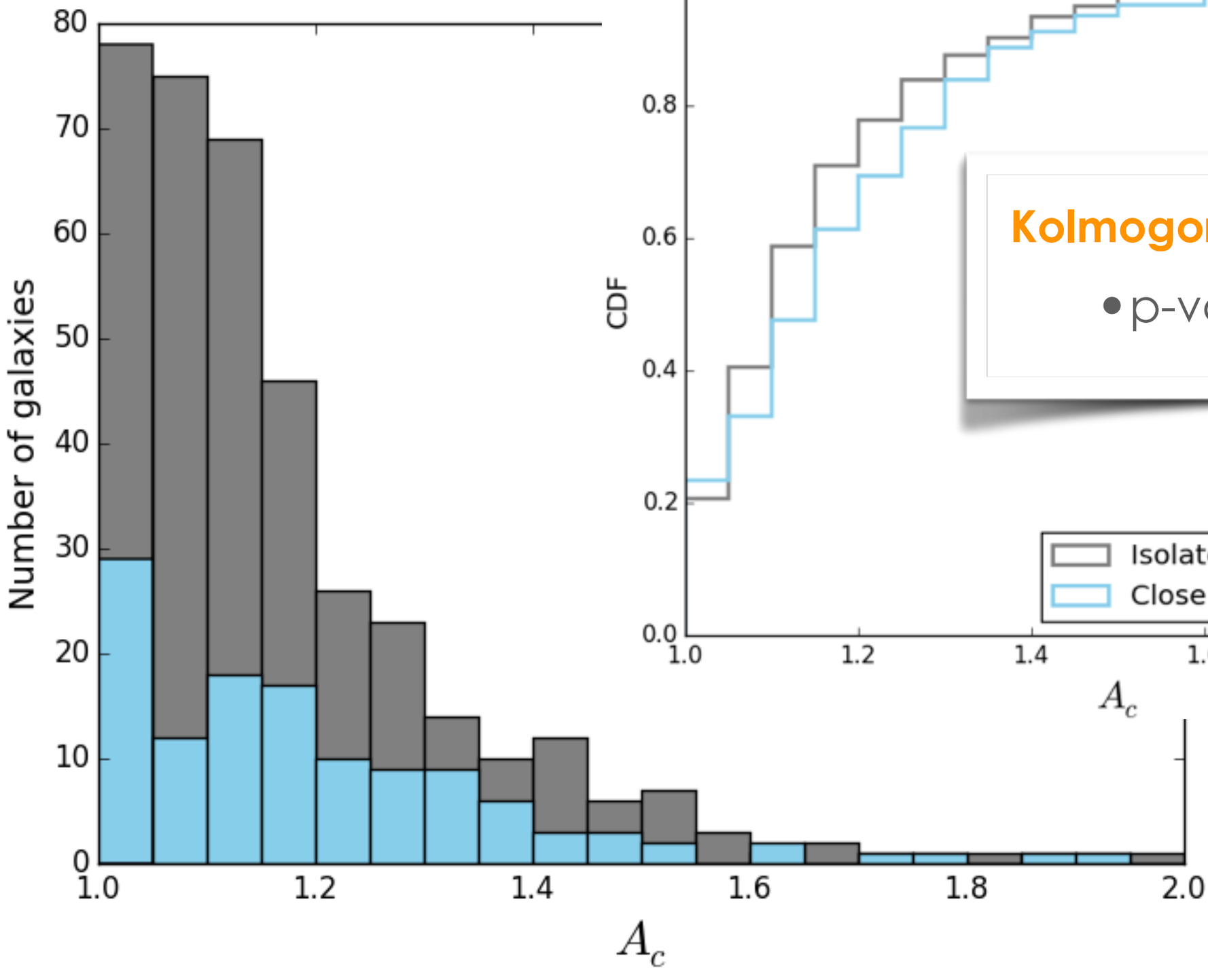


Results


Isolated sample
Close pair sample
Number of galaxies
0
10
20
30
40
50
60
70
80
1.0
1.2
1.4
1.6
1.8
2.0
A_c

Results

- The K-S test implies that our 2 samples are not drawn from the same distribution…



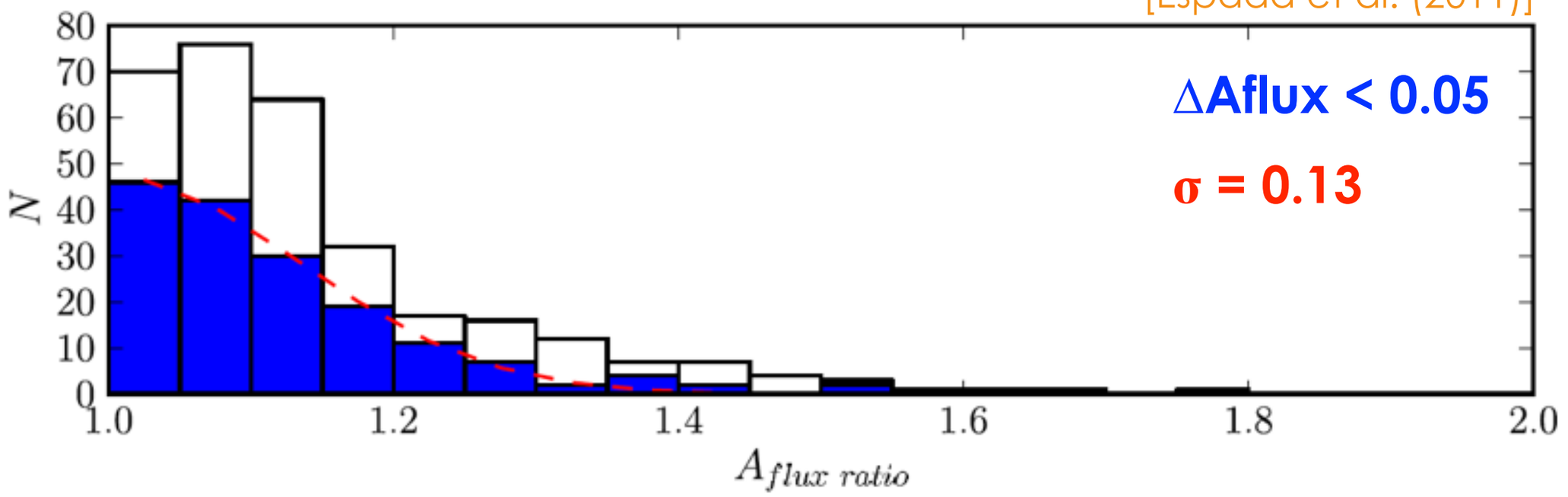
Kolmogorov-Smirnov test:

- p-value = 0.02

Results

- Espada et al. have measured the HI profile asymmetries in a very isolated sample of AMIGA galaxies [Verdes-Montenegro+, 2005]:

[Espada et al. (2011)]



- Although the HI data is not homogeneous, great care taken to estimate uncertainties due to:
  - noise in spectrum, V_m, telescope pointing errors

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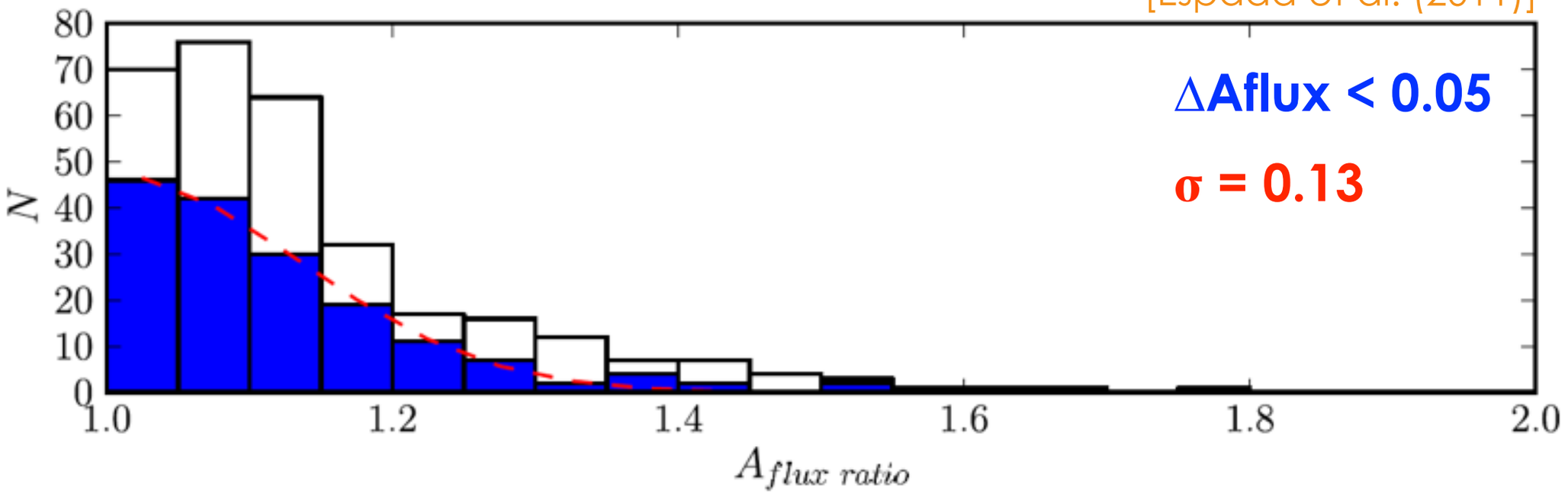

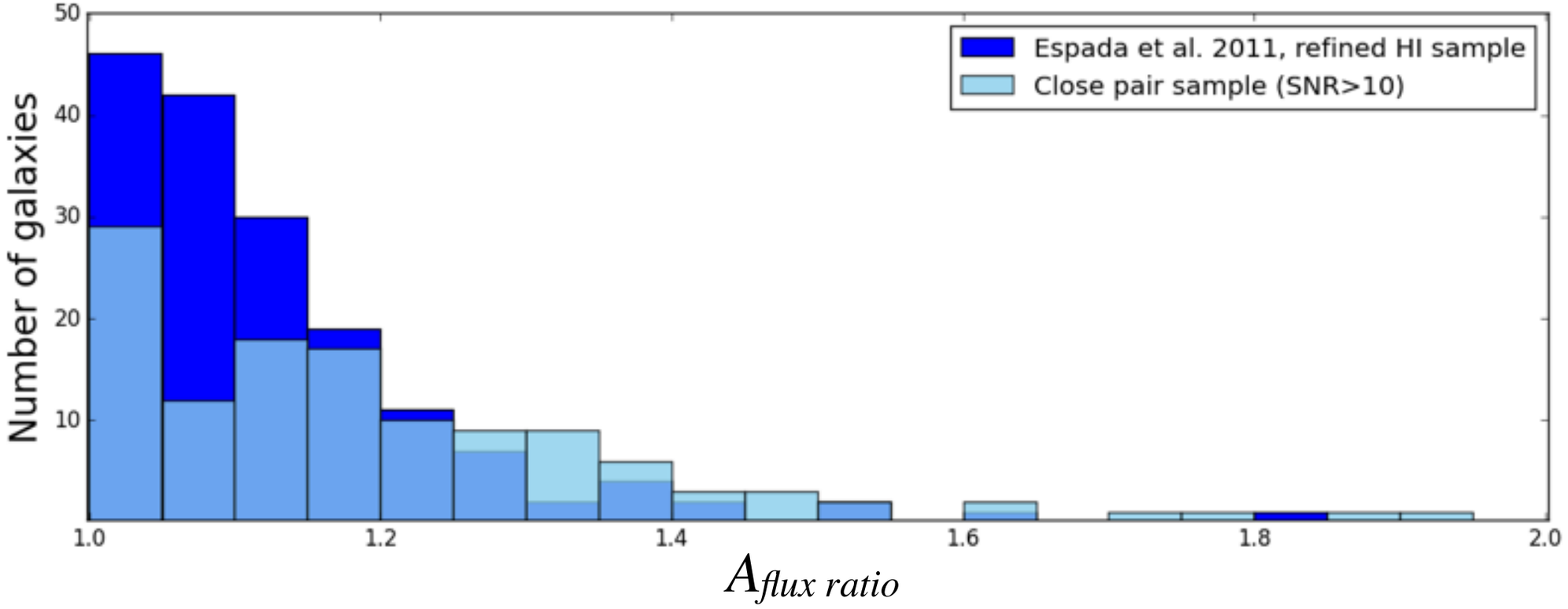

Results

[Espada et al., 2011]

Sample	N	σ	$A_{\text{flux ratio}} > 1.26$
H I refined subsample	166	0.13	9 %
Haynes et al. (1998)	104	0.13	9 %
Haynes et al. (1998) no CIGs	80	0.13	10 %
Matthews et al. (1998)	30	–	17 %
Bournaud et al. (2005)	76	0.23	22 %
Combined, no CIGs	186	0.17	16 %

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Isolated (this work)	378	21%
Close pairs (this work)	129	32%

- Our close-pair sample seems to show greater HI profile asymmetries than field and isolated samples

Summary & outlook

- Preliminary results indicate a higher rate of HI global profile asymmetry in close pairs than in our isolated sample and field / isolated samples in the literature

Next steps

- Further ‘clean up’ our isolated sample
- Quantify uncertainties (check sensitivity to choice of V_m, confusion contamination, etc.)
- Identify Ac dependence on pair mass-ratio (major vs. minor mergers)
- Compare optical and HI asymmetries in the samples (in progress)