Cosmic flows
Data analysis

Nicolas Bonhomme
PhD candidate
University of Lyon
IPNL

Advisor: Helene Courtois

NDG SAO Sept 2009

$$v_{obs} = v_{expansion} + v_{gravitationnal}$$

$$v_{expansion} = H_0 d$$

$$m - M = 5 \log d + 25$$

Tully, R. B., & Pierce, M. J. 2000, ApJ, 533, 744

$$v_{obs} = v_{expansion} + v_{gravitationnal}$$

$$v_{expansion} = H_0 d$$

$$m - M = 5 \log d + 25$$

$$\boxed{M_I^{i,b,k} = -21.43 - 8.11(\log W_R^i - 2.5)}$$

Tully, R. B., & Pierce, M. J. 2000, ApJ, 533, 744

HI - 21 cm

- Doppler effect
- $\lambda = 21cm (\nu = 1420.405751..MHz)$ hyperfine line
- $A_{10} \approx 2.85 \times 10^{-15} s^{-1}$
- The most abundant element in the universe
- Radio astronomy

Nancay, France 200x34m

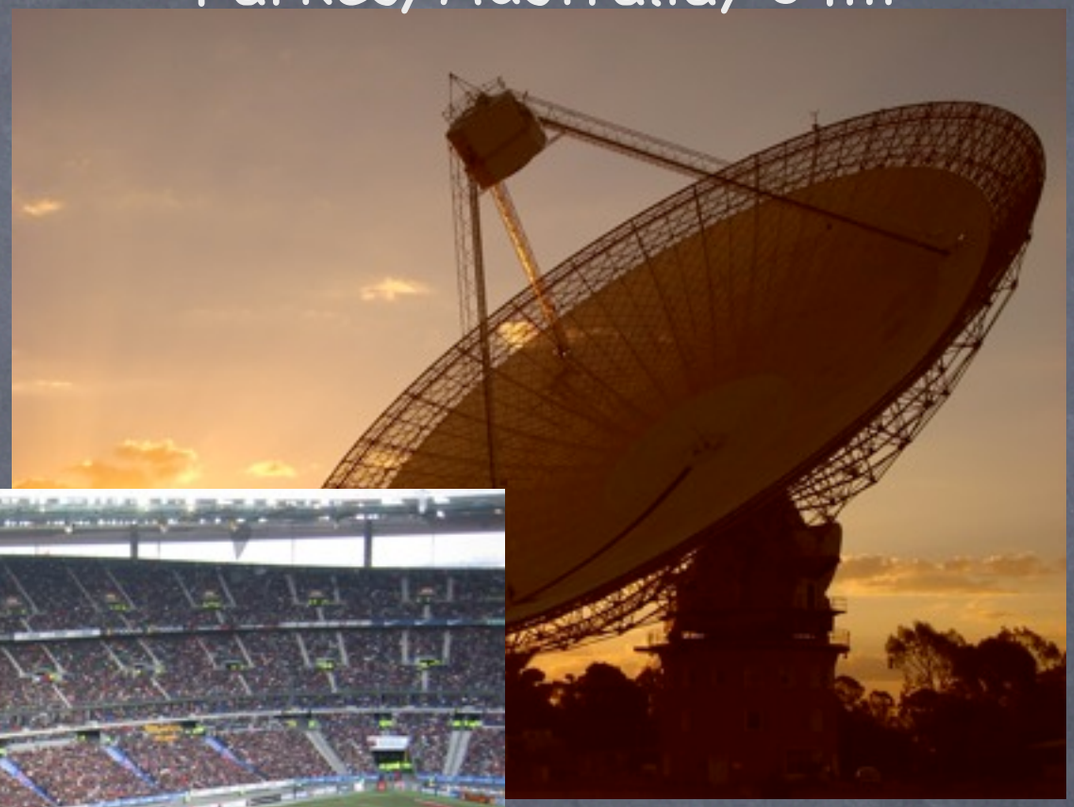
Parkes, Australia, 64m

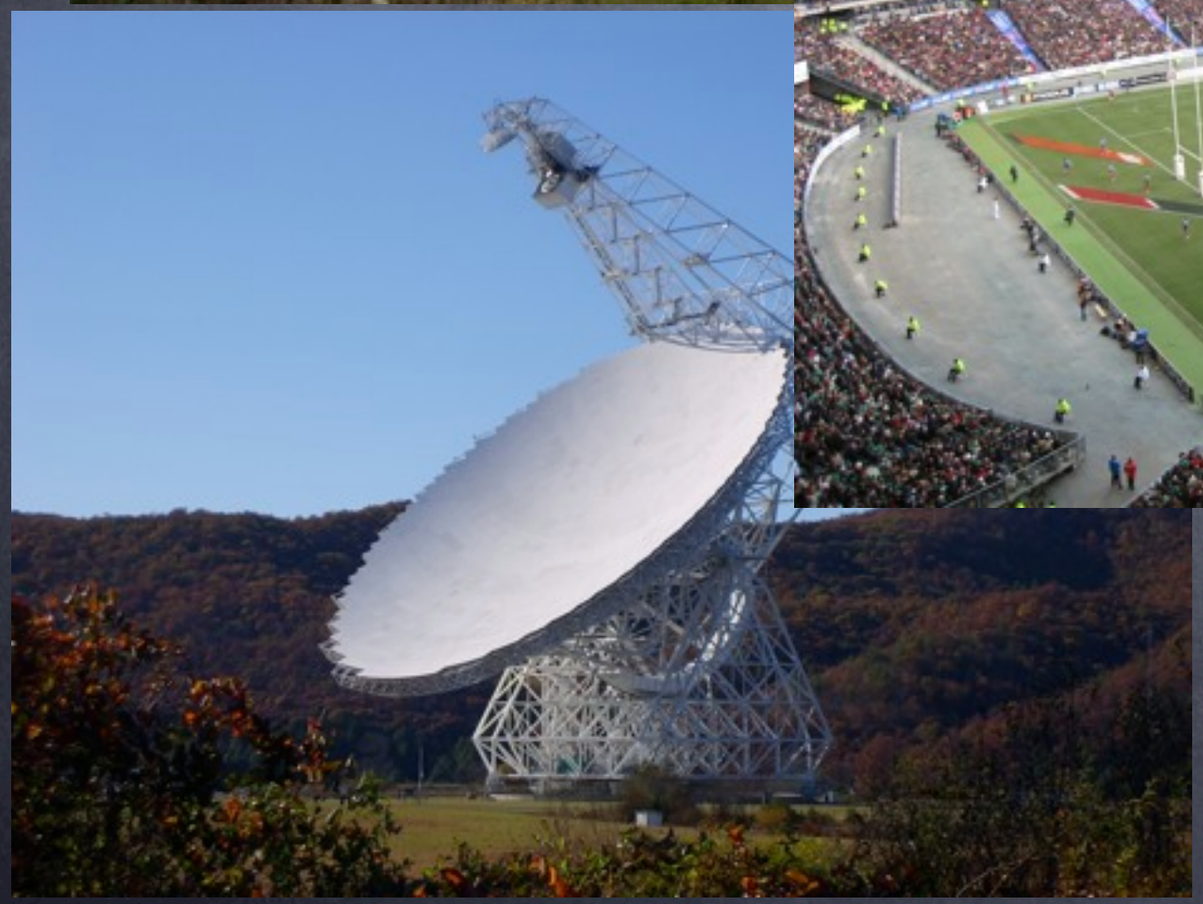
GBT, West Virginia, 110m

Arecibo, Puerto Rico, 302m

Nancay, France 200x34m

Parkes, Australia, 64m





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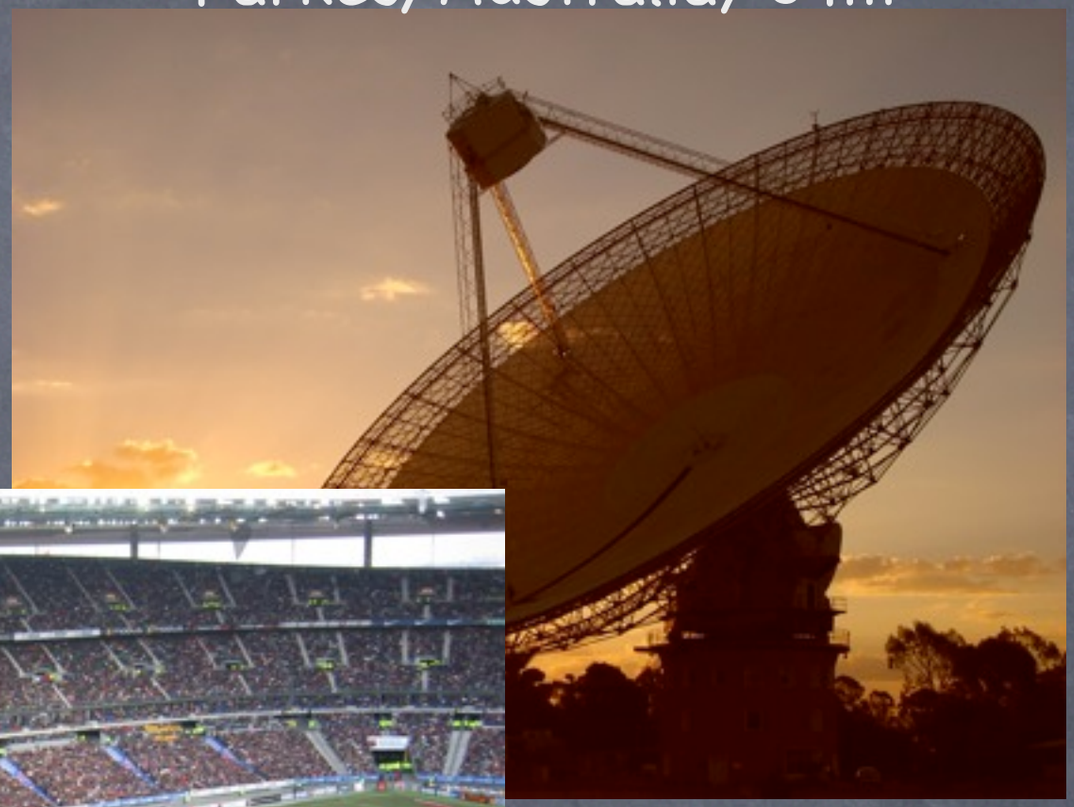
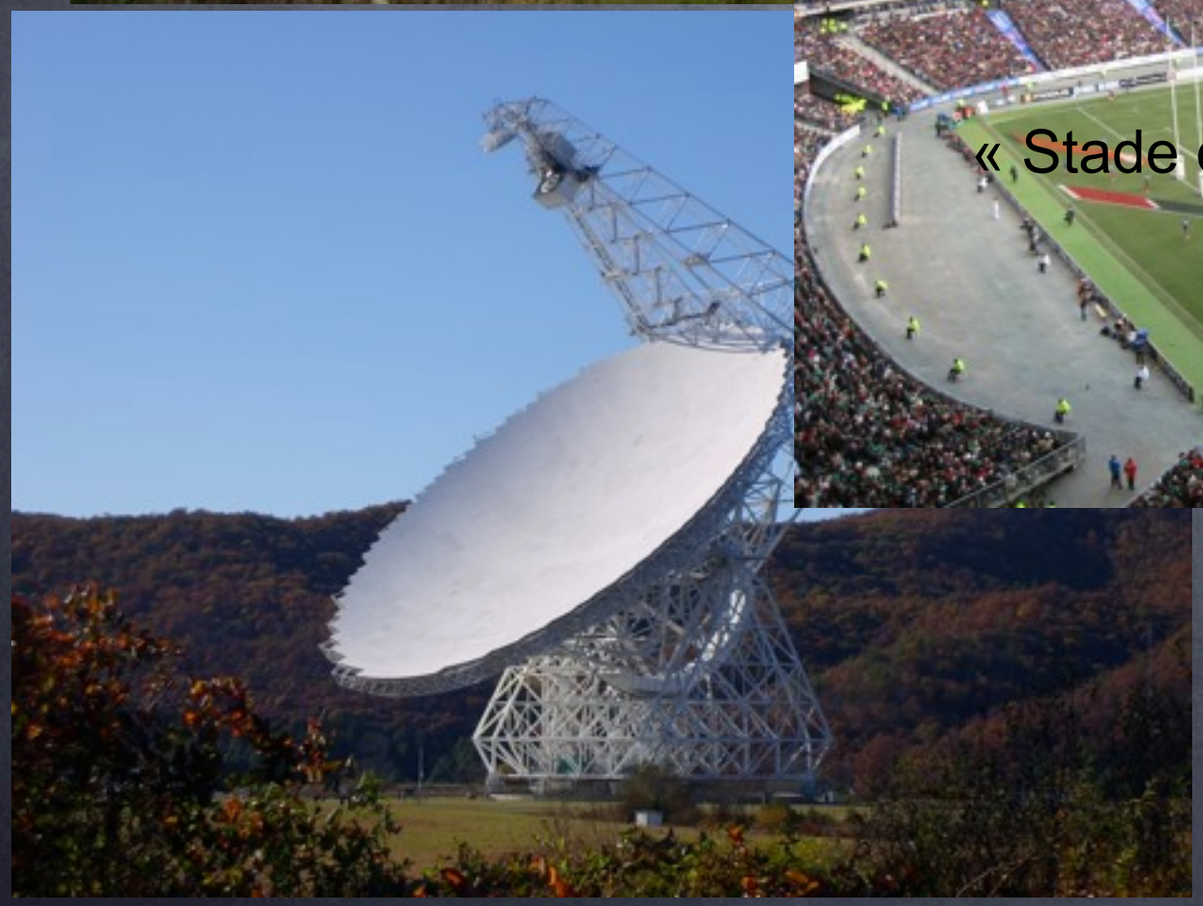




GBT, West Virginia, 110m

Arecibo, Puerto Rico, 302m

Table 1: Telescopes

Telescope	Diameter	Beam radius
Arecibo	305m	3’
Nancay	200x40m	4 x 22’
GBT	110m	9’
Effelsberg	100m	9’
GB300	91m	10’
Parkes	64m	14’
GB140	43m	21’

Samples:

- Supernovae Ia (84)
- Clusters (14) about 500 galaxies
- Zeropoint calibrators about 35 (Cepheids/TRGB)
- Optical selected sample at 3,000 km/s: 1,500 galaxies
- near IR selected sample at 6,000 km/s: 1,500 galaxies

Project: GBT08c-010
484 hours awarded
Project start date:
Semester 08C

- NRAO Large Program
- Cosmic Flows Proposal
- Green Bank Telescope
- Extragalactic Distance Database
- Pan-STARRS

Contact Information:

Hélène Courtois &
Nicolas Bonhomme
Université Lyon 1,
CNRS/IN2P3/INSU
Institute de Physique Nucléaire
Lyon, France

R. Brent Tully
Institute for Astronomy
2680 Woodlawn Drive
Honolulu, HI 96822

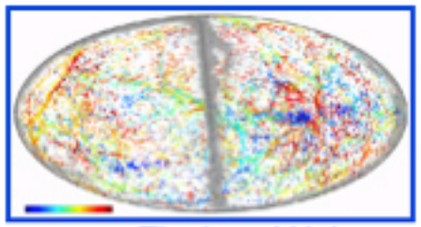
J. Richard Fisher
Nat'l Radio Astronomy Observatory
520 Edgemont Road
Charlottesville, VA 22903

Bulk Motions of Filaments in the Local Universe

- **Team Members:**
Hélène Courtois, *Université Lyon 1*
R. Brent Tully, *UH Institute for Astronomy*
J. Richard Fisher, *National Radio Astronomy Observatory*
Nicolas Bonhomme, *Université Lyon 1*

- **Project Description:**
Galaxies acquire motions that deviate from the universal expansion through gravitational interactions on a wide range of scales. The radial component of these deviant motions can be mapped with accurate measurements of distances. One of a variety of ways to measure distances makes use of the correlation between the luminosities of galaxies and their rotation rates. With appropriate photometric and spectroscopic information, the method can be applied to a majority of spiral galaxies. Samples of many thousands of galaxies can be acquired, giving the dense spatial coverage required to study the streams and eddies in the Cosmic Flow.

Photometry to measure the luminosities of galaxies has been carried out at optical bands with telescopes at Mauna Kea Observatory and a tremendous advance is about to be


The Local Universe

A typical target
-HI line profile
-surface brightness profile
-mask and ellipse fit

Measuring distances
-5 cluster template
-zero point calibration
-consistency

Preliminary results
-Local Void

Table 1: GBT observations

trimester	Hours	Observers
07A	55	Fisher,Courtois
07C	218	Fisher,Courtois,Zavodny,Bonhomme
08A	47	Courtois,Bonhomme
08B	50	Courtois,Bonhomme
08C	340	Courtois,Bonhomme

- 630 galaxies observed
- 69 not detected
- 59 confused
- 412 with high quality achieved for distance measurement purpose

Parkes: New data and archives

- 58 galaxies observed
- still in progress..
- Archives: 15 previous projects

Extragalactic Distance Database: EDD

http://edd.ifa.hawaii.edu/

HI linewidths

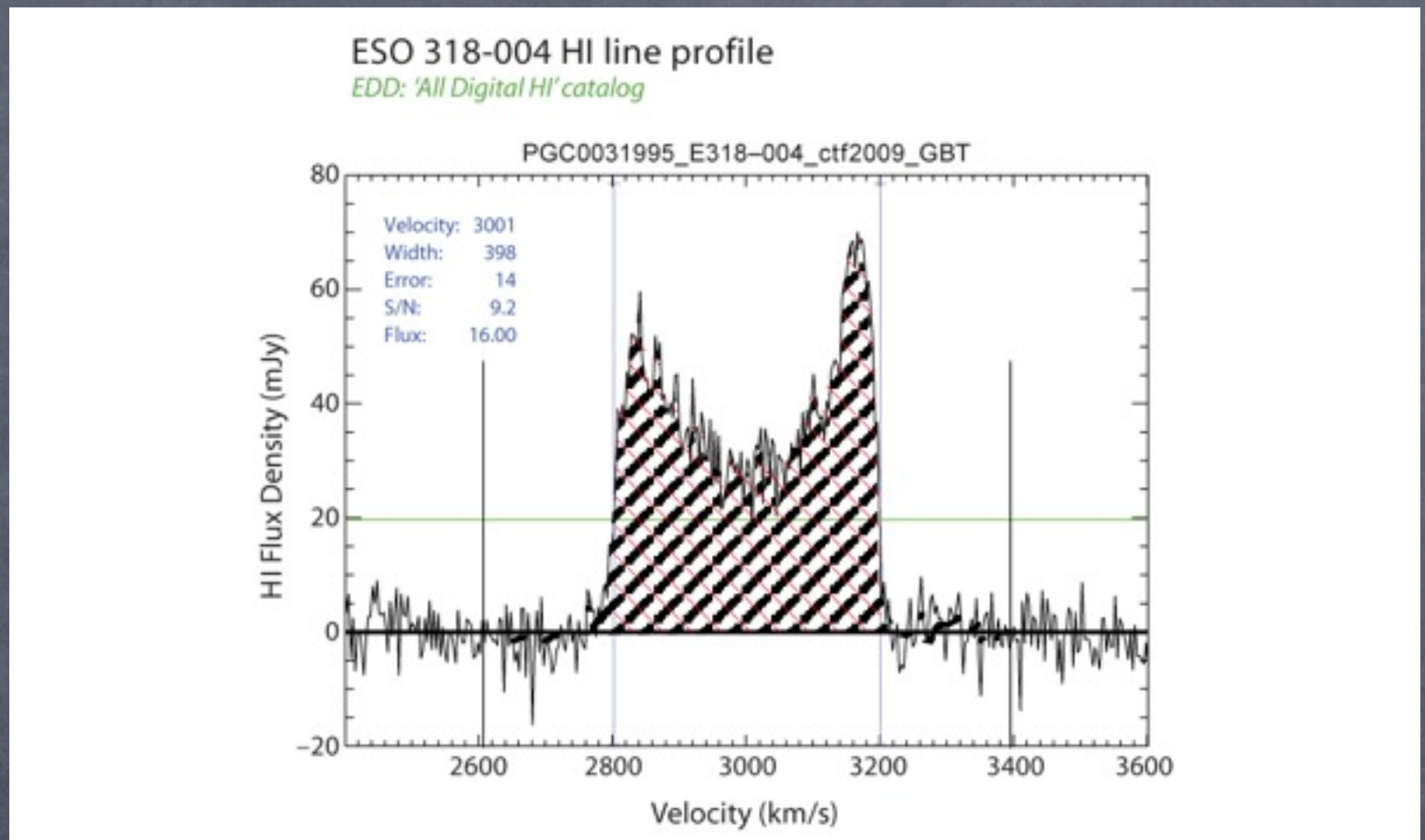
All digital HI

- 15,234 profiles
- 13,306 galaxies
- 10,521 galaxies with $e_W \leq 20 km.s^{-1}$
- Good, bad, ugly...

Courtois et al. 2009arXiv0902.3670C

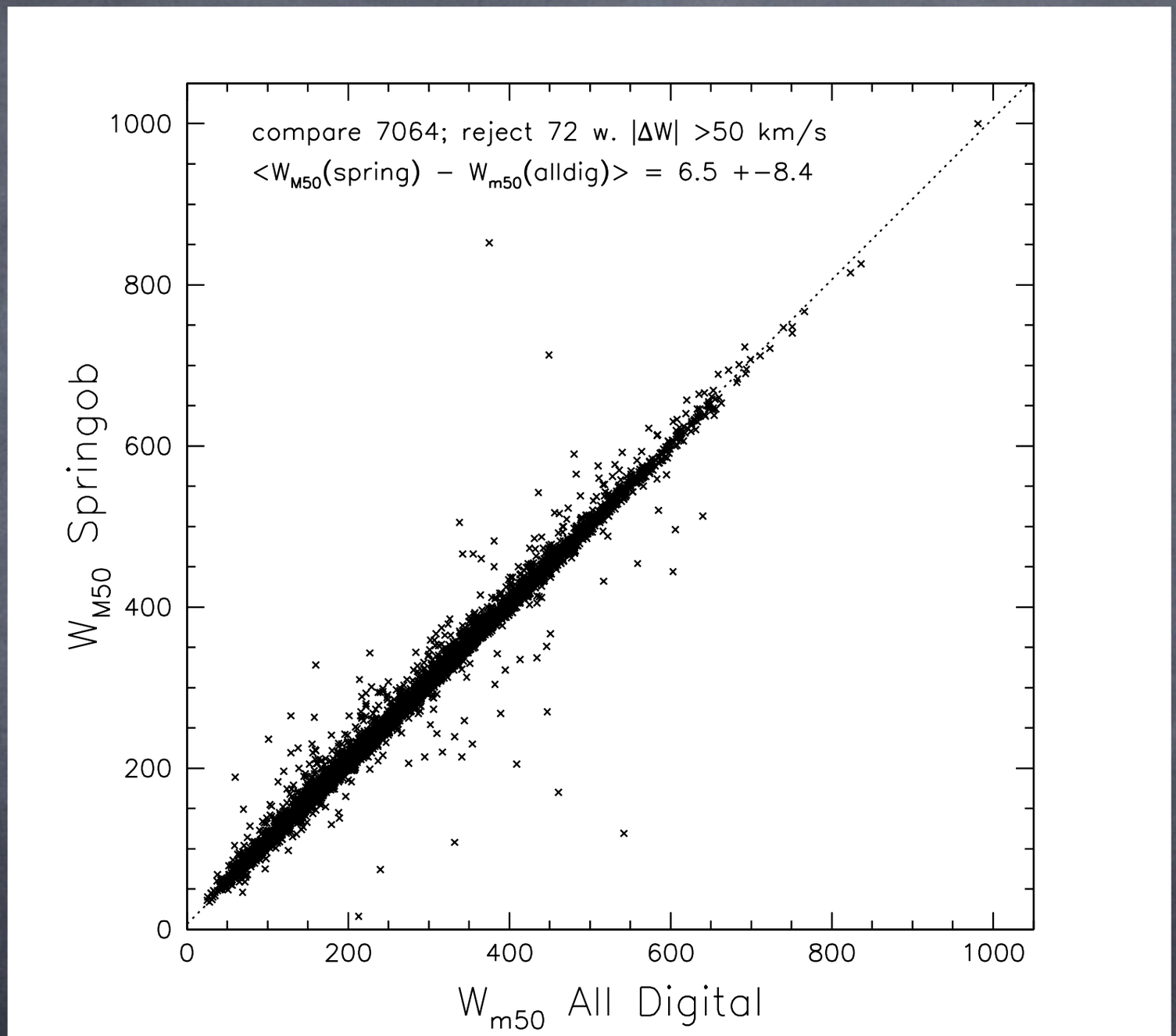
A new method to measure the linewidth

Courtois et al. 2009arXiv0902.3670C



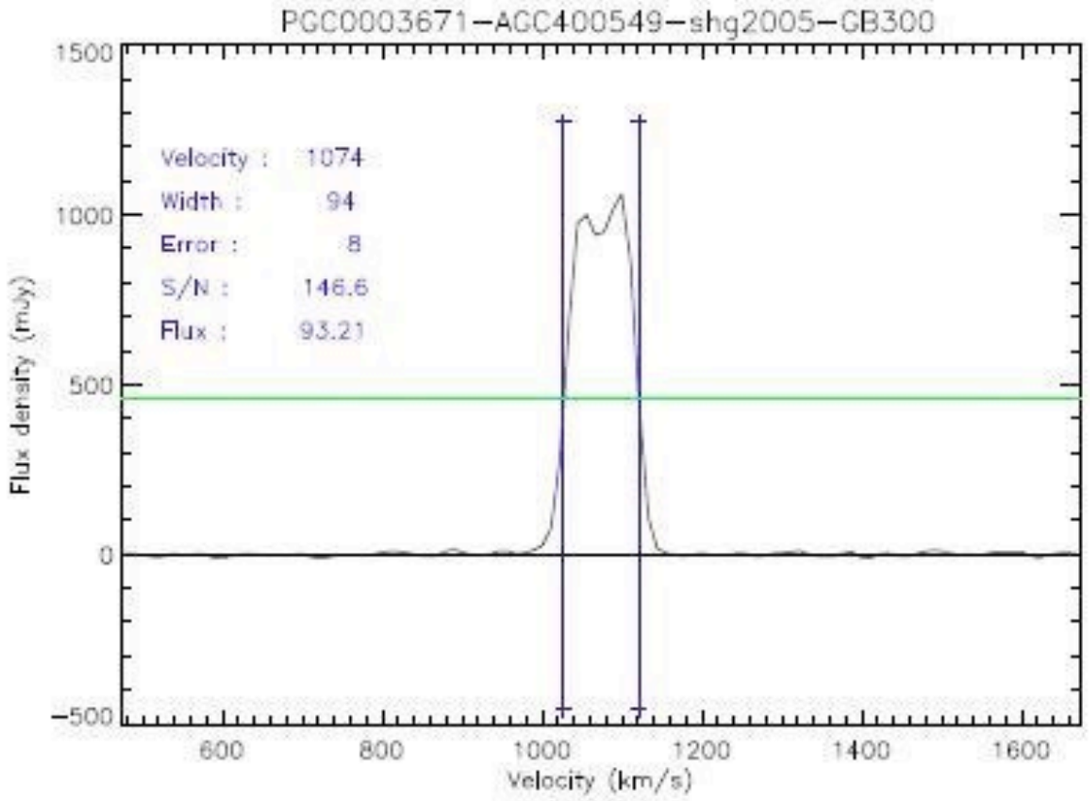
Linewidth.pro : 50% of the mean flux determined in a window excluding 5% of the integrated flux on each of the 2 wings

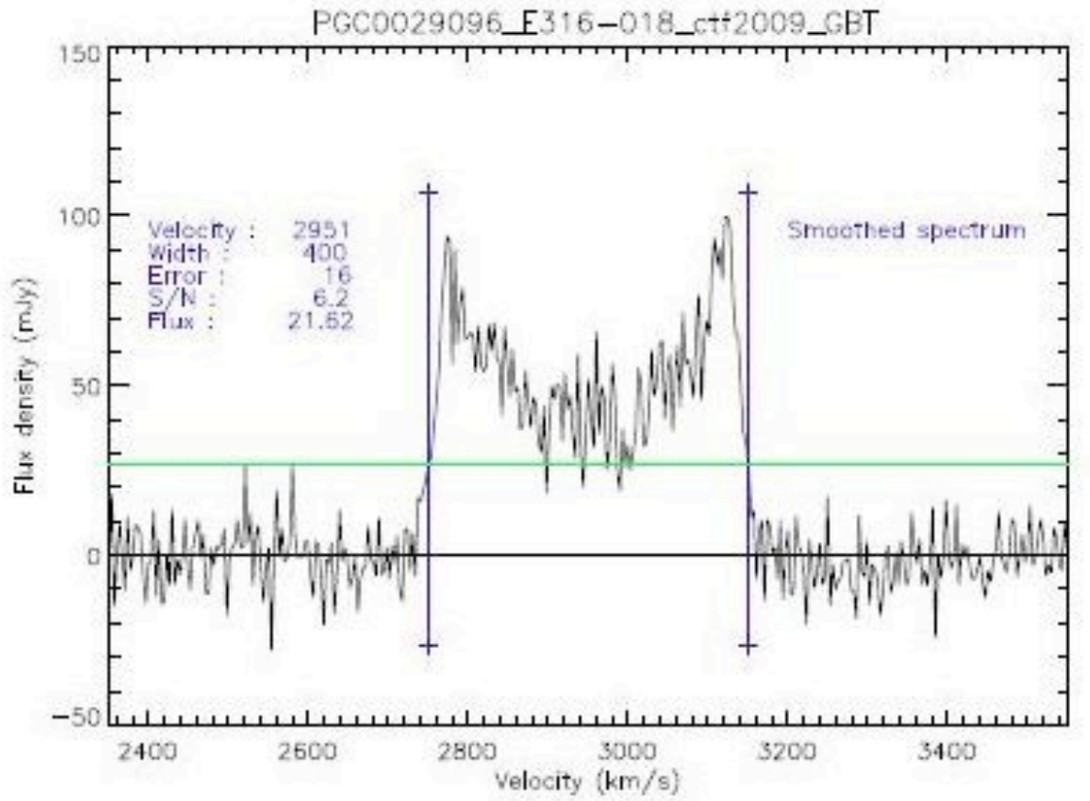
Comparison between 2 alternative estimators at 50% of mean flux: Wm50 from the Al l Digital HI catalog and WM 50 from the Springob/Cornell HI catalog.

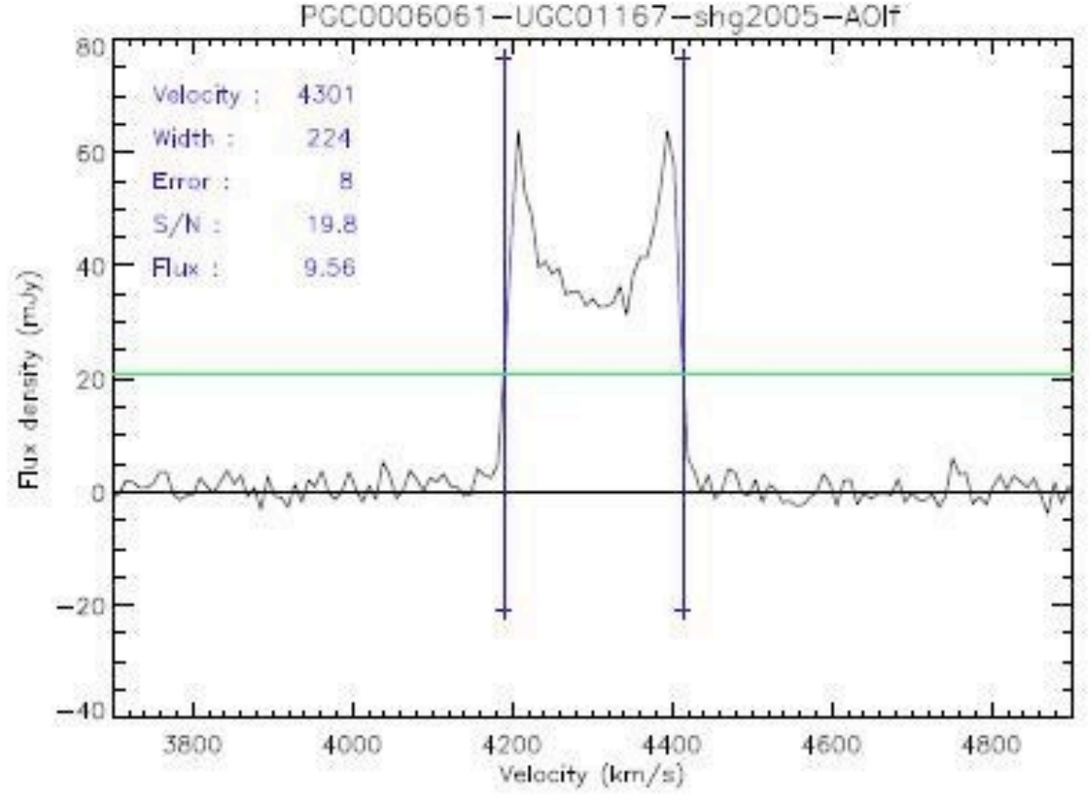


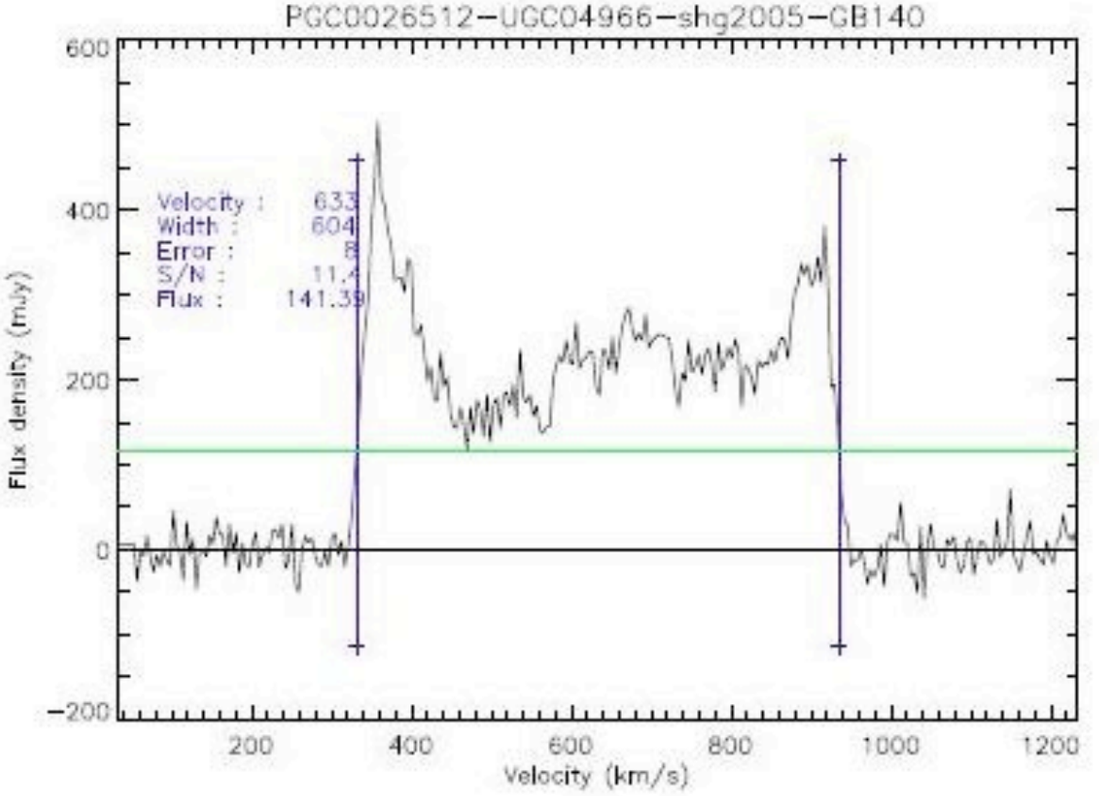
Courtois et al. 2009arXiv0902.3670C

Good: double horns









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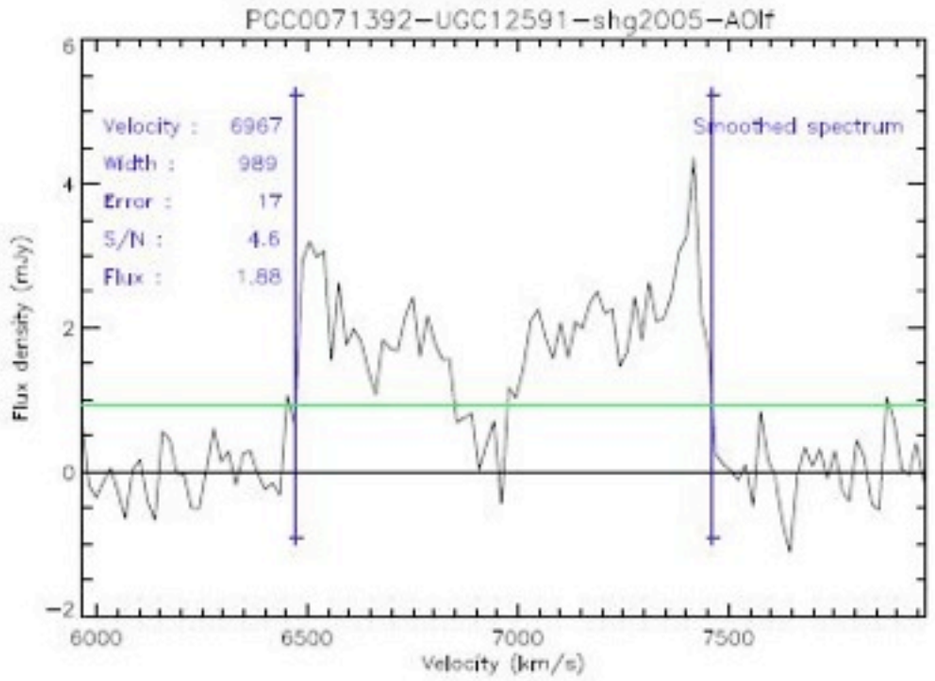
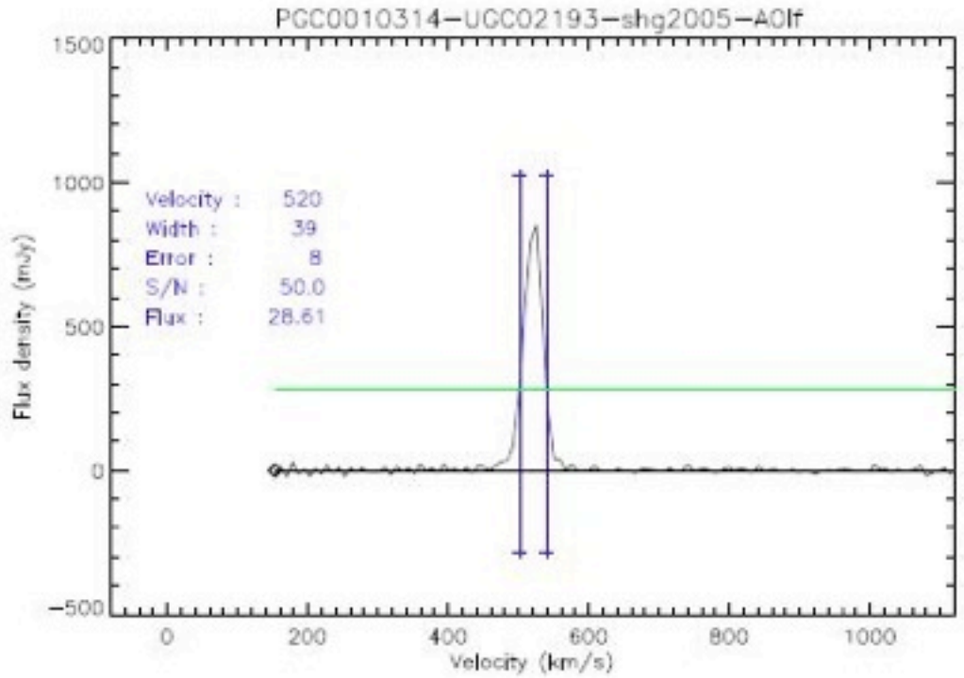
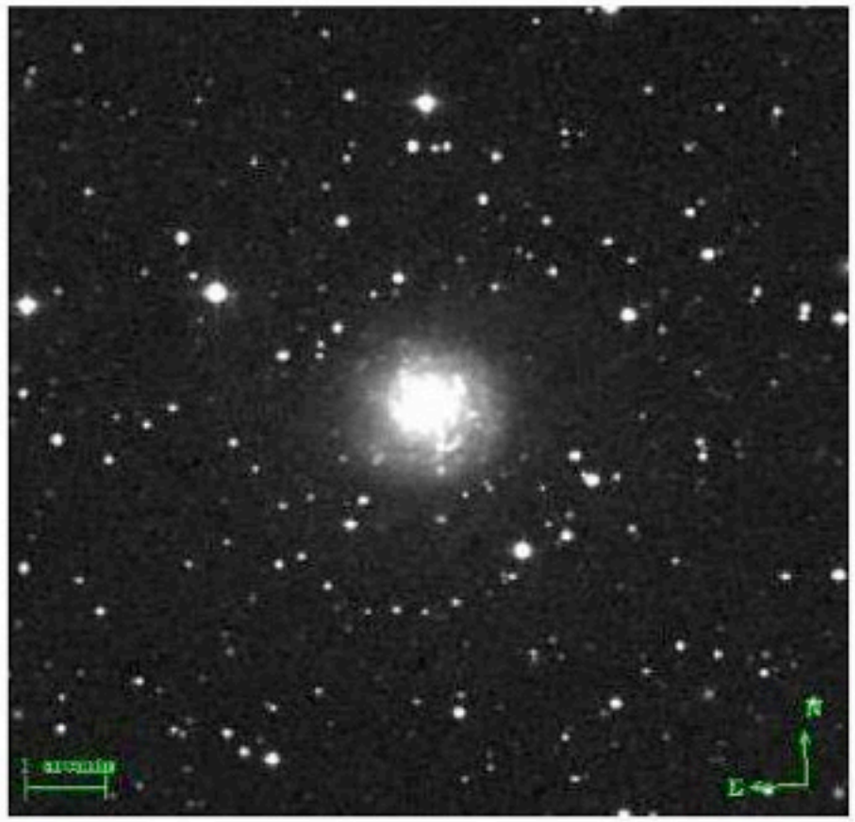


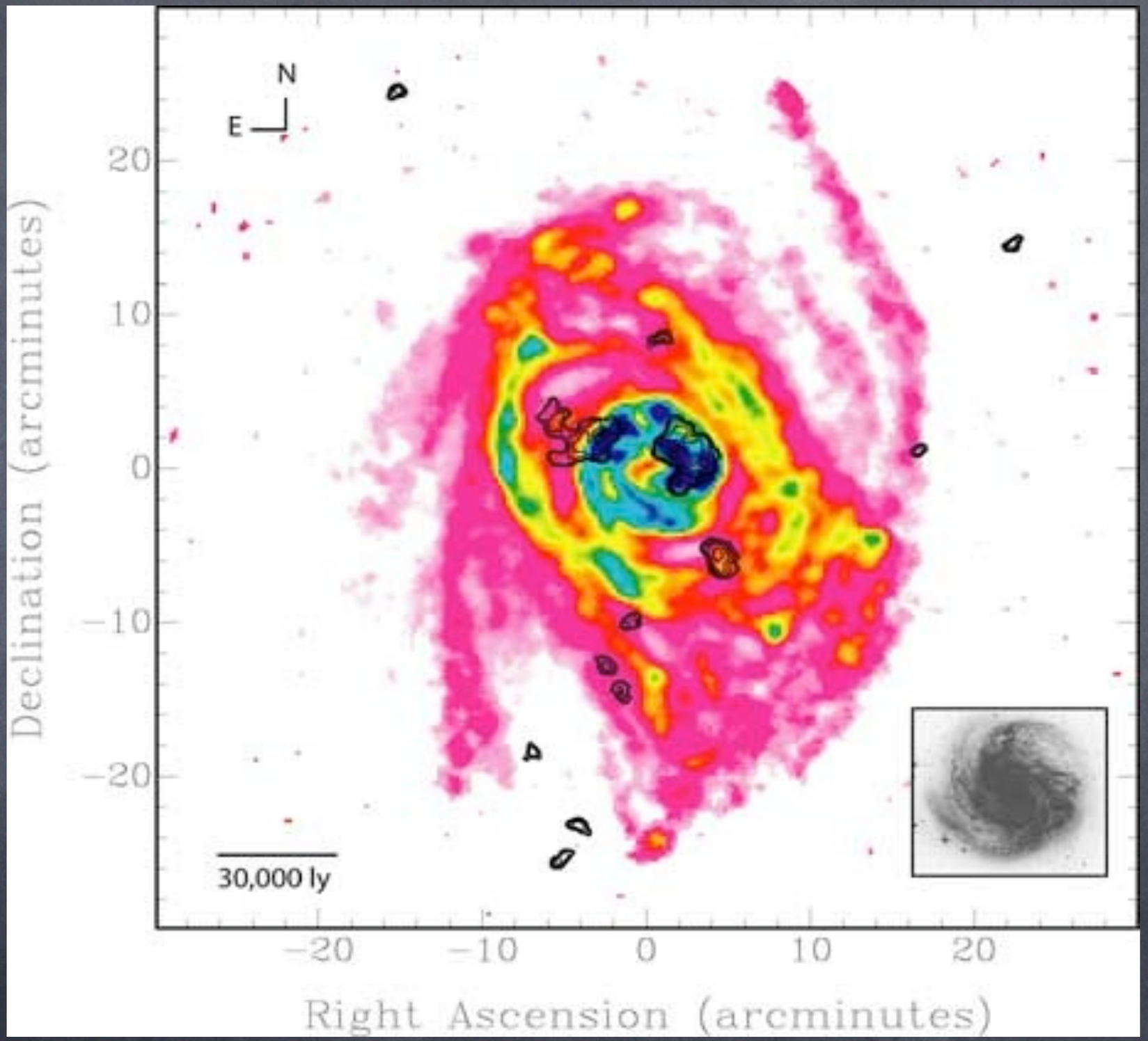




The biggest

The narrowest

Courtois et al. 2009arXiv0902.3670C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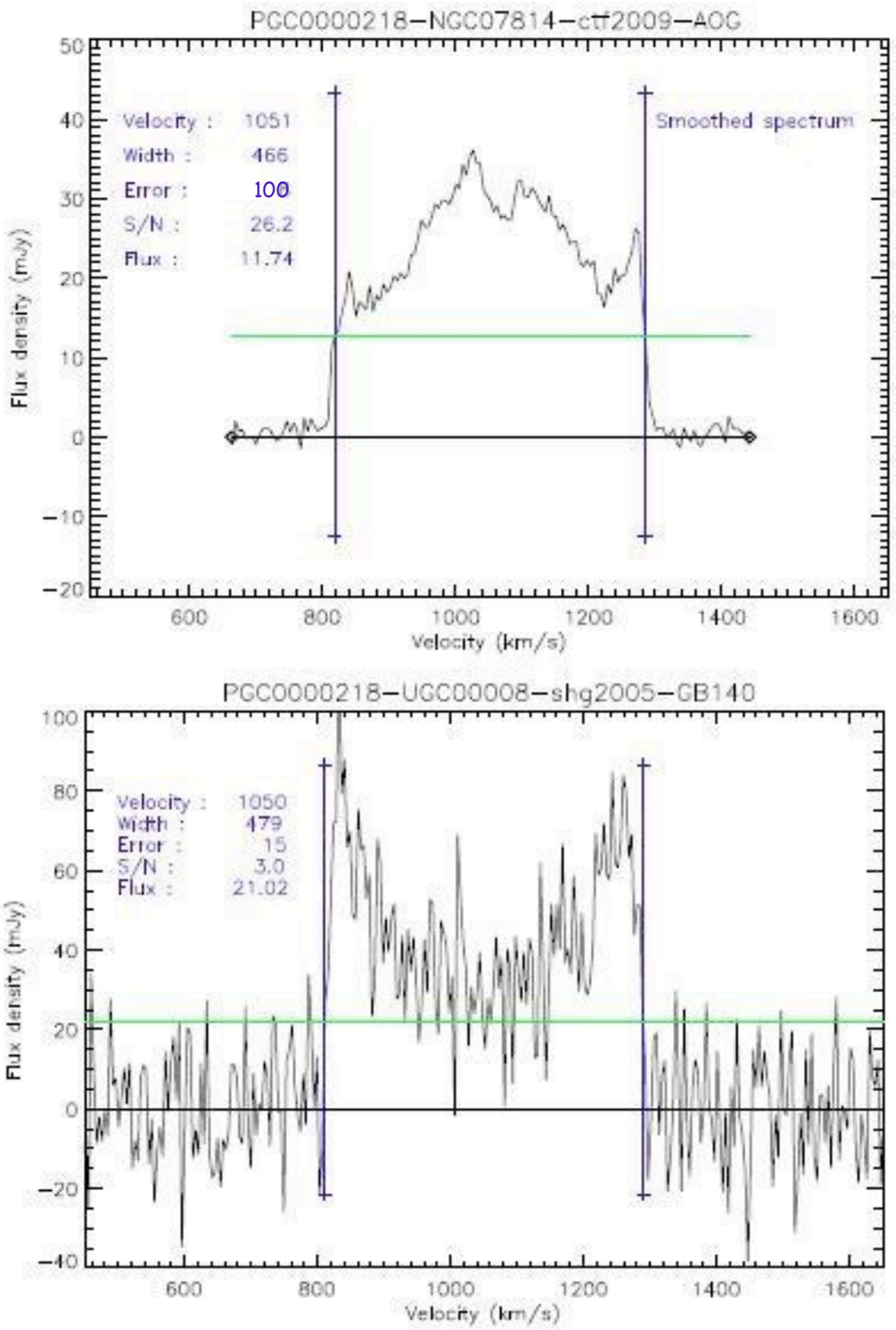
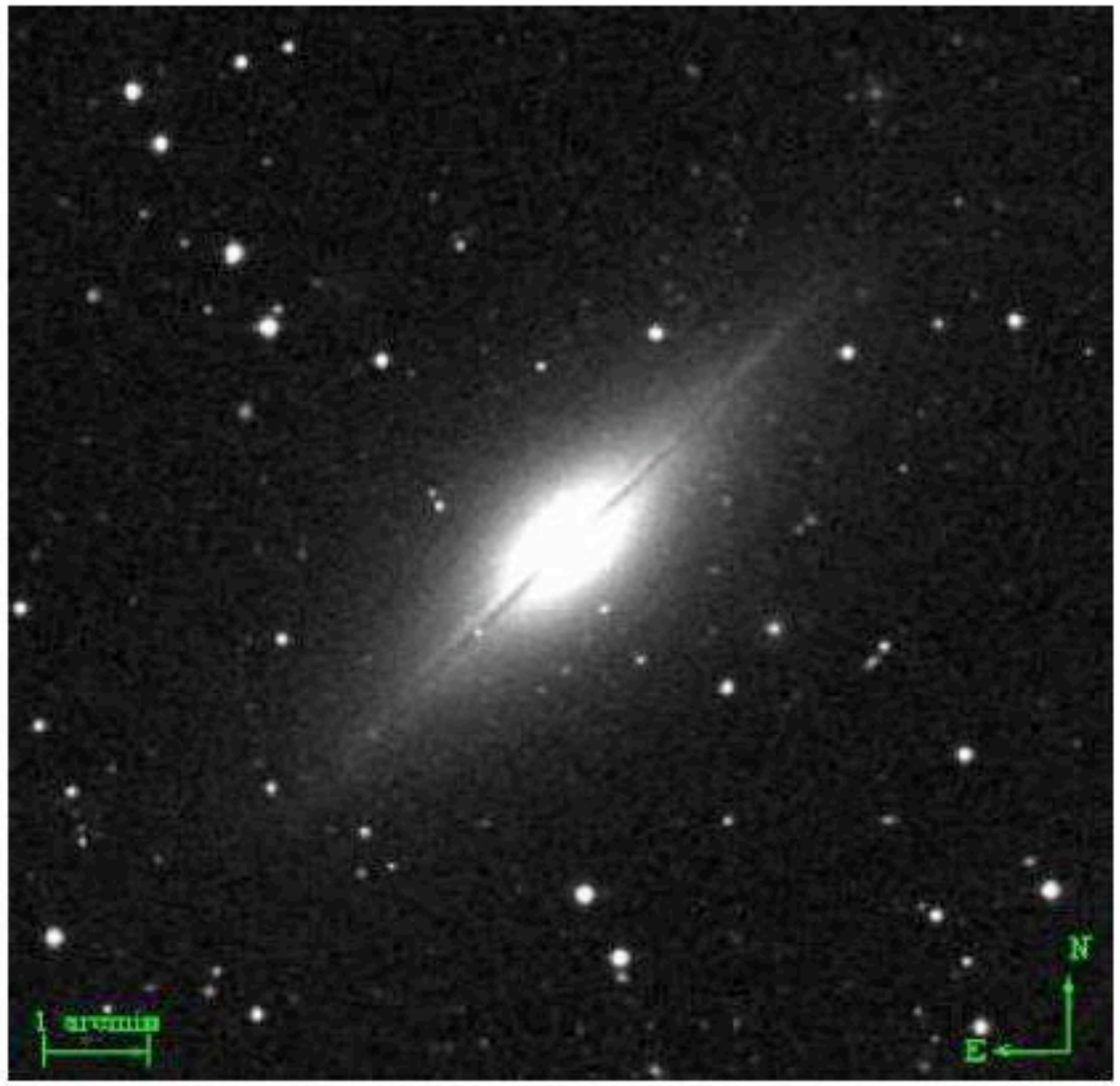
Declination (arcminutes)
Right Ascension (arcminutes)

Bad, ugly: Extended size of galaxy compared to telescope beam





PGC 218 (NGC 7814). Top profile: The 3′ half-power beam of Arecibo Telescope is smaller than the target galaxy causing flux to be lost and affecting the profile shape. Lower profile: All the flux emitted by the galaxy is captured within the beam of the Green Bank 140-foot Telescope.

Courtois et al. 2009arXiv0902.3670C

M81 group: tidal interactions

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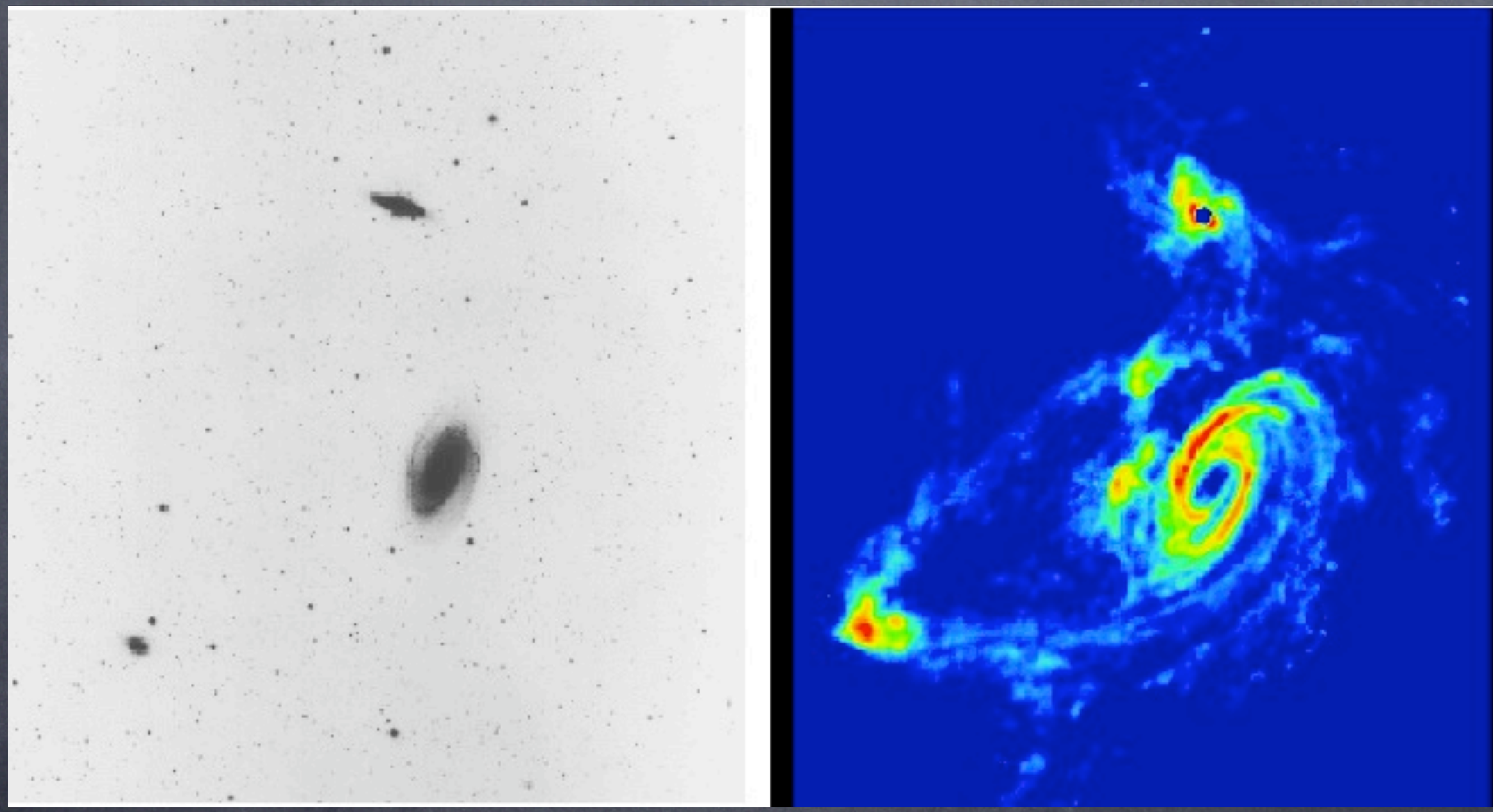
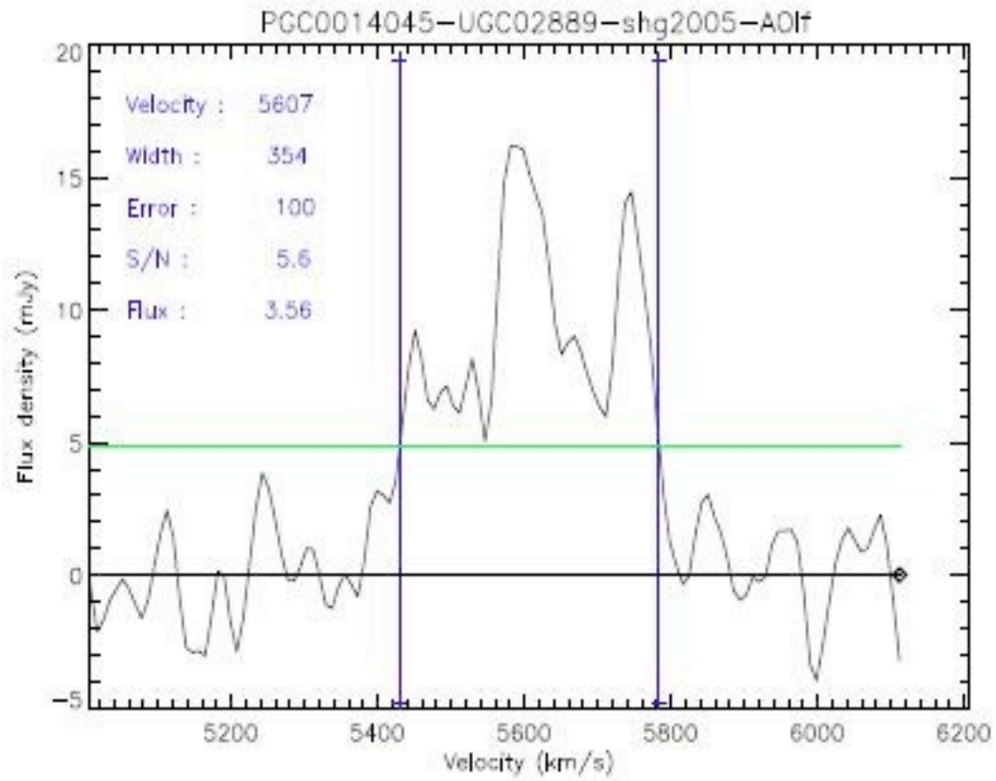
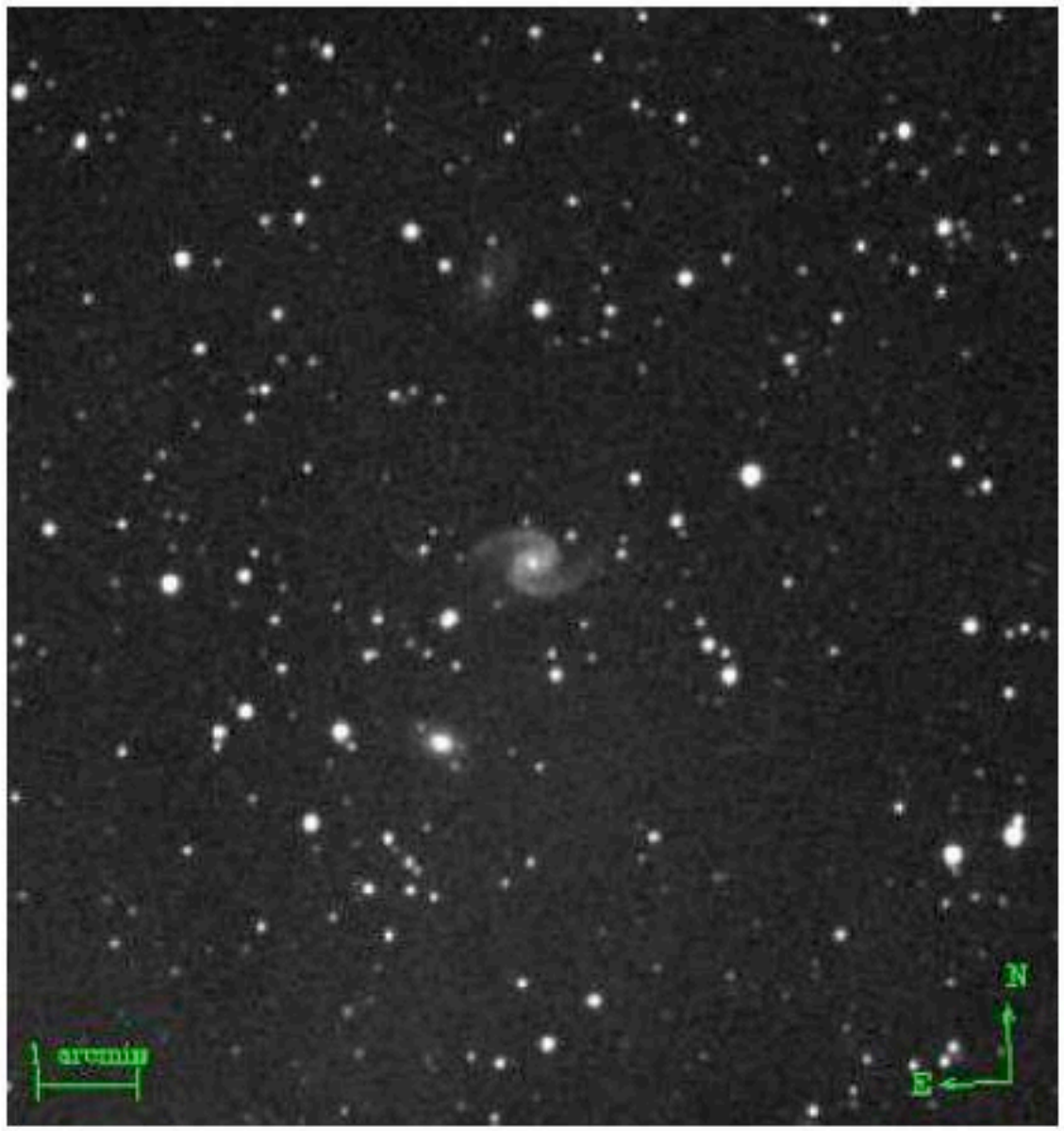


Bad, ugly: confused

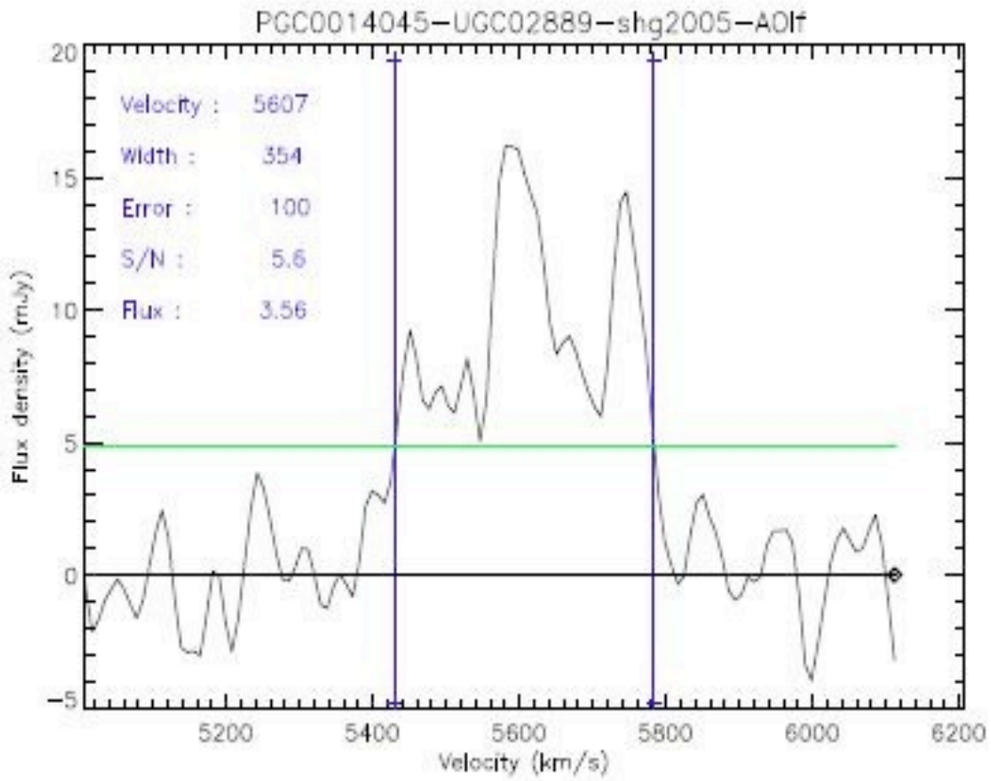


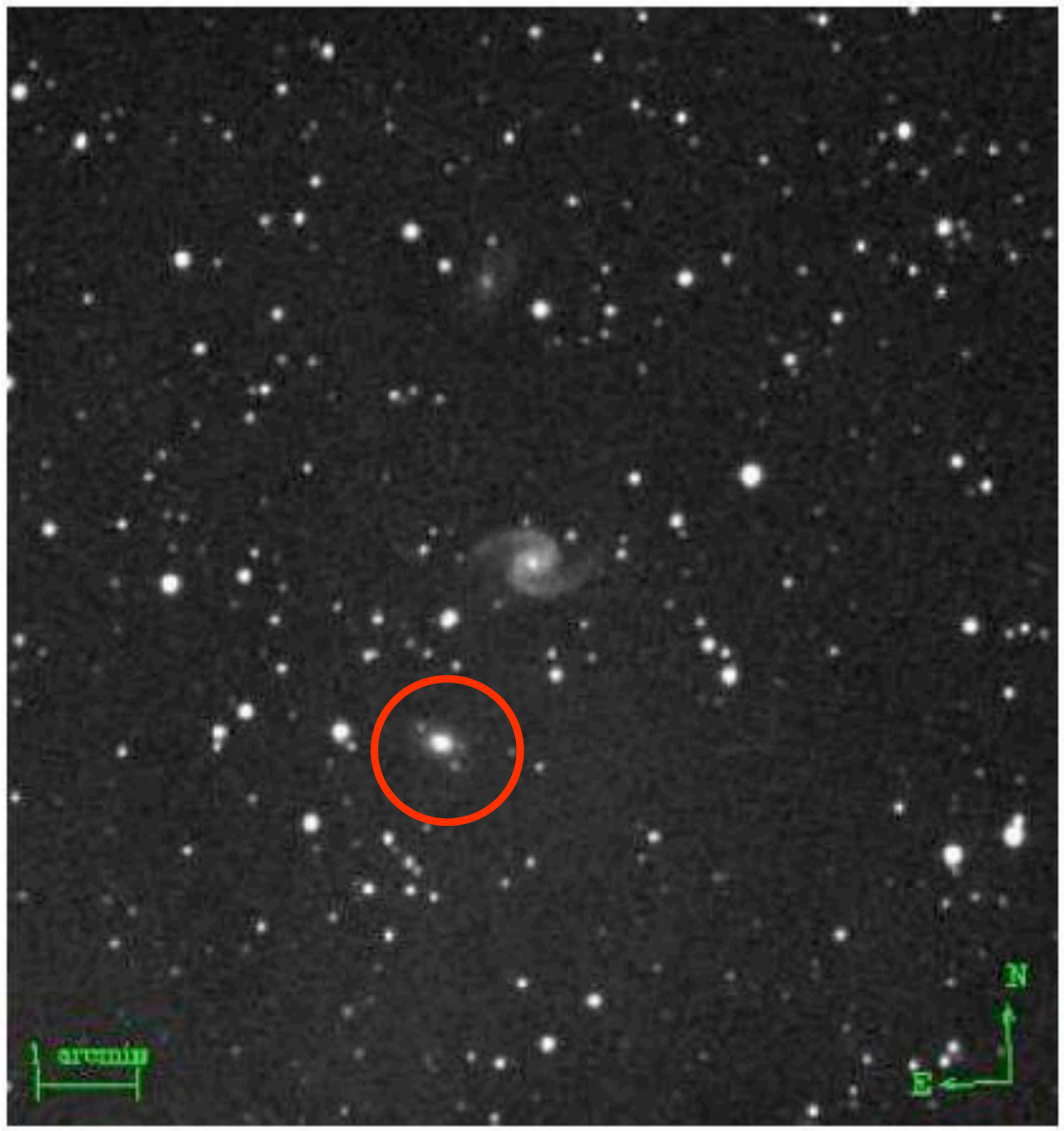


PGC 14045 (UGC 2889). Anomalous profile with central peak. Small galaxy with unknown velocity 2.0′ SW might contaminate

Courtois et al. 2009arXiv0902.3670C

Bad, ugly: confused





PGC 14045 (UGC 2889). Anomalous profile with central peak. Small galaxy with unknown velocity 2.0′ SW might contaminate

Courtois et al. 2009arXiv0902.3670C

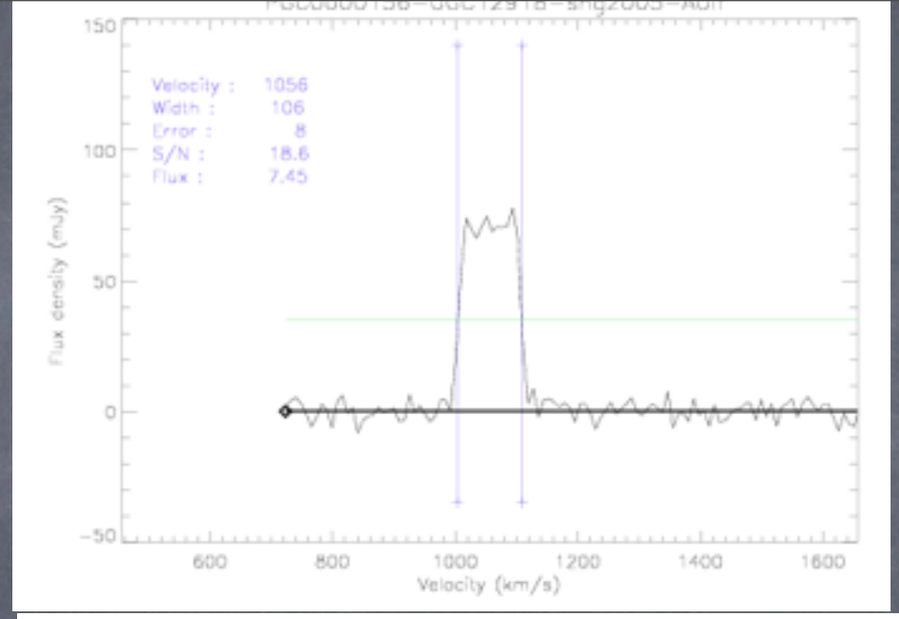
error on the linewidth

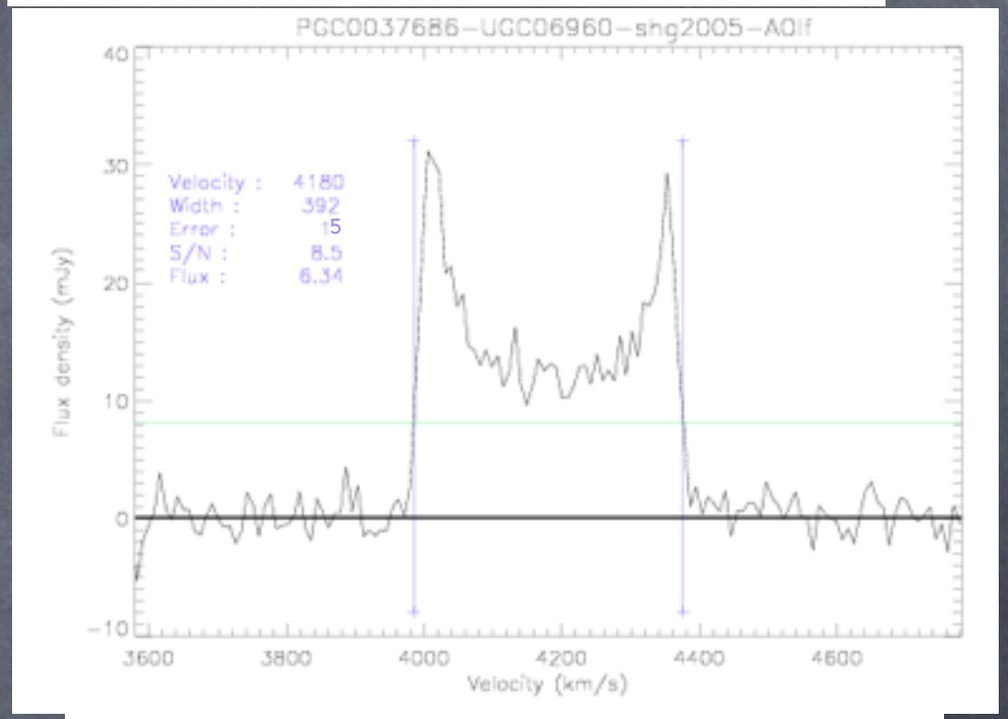
$$e_W = 8 km.s^{-1} \text{ if } S/N > 17$$

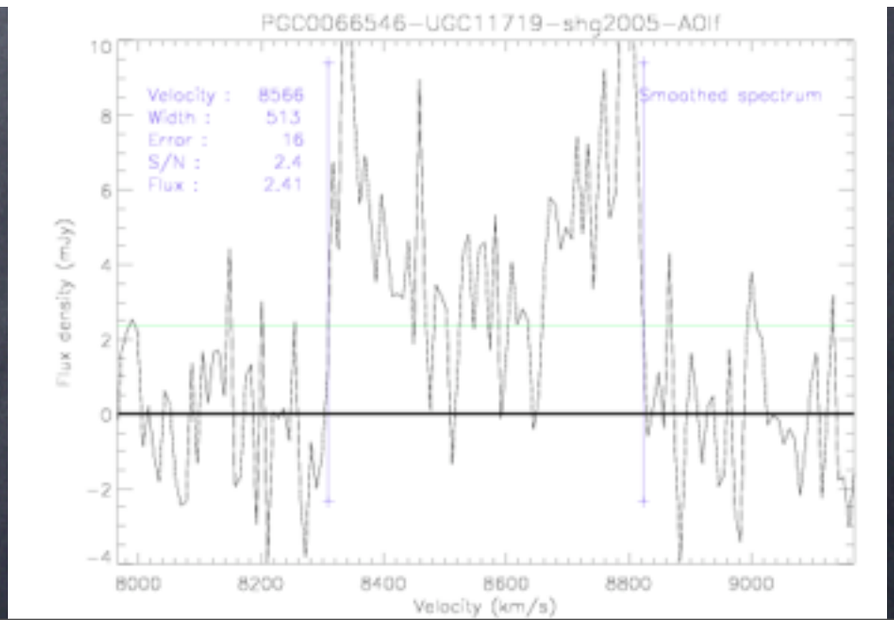
$$e_W = 21.6 - 0.8 S/N km.s^{-1} \text{ if } 2 < S/N > 17$$

$$e_W = 70 - 25 S/N km.s^{-1} \text{ if } S/N < 2$$

Courtois et al. 2009arXiv0902.3670C







Photometry

- UH88
- band I
- exposure time: 300 sec
- Reduced with IRAF and measured with Archangel

Courtois et al. in prep

Schombert 2007astro.ph0703646S

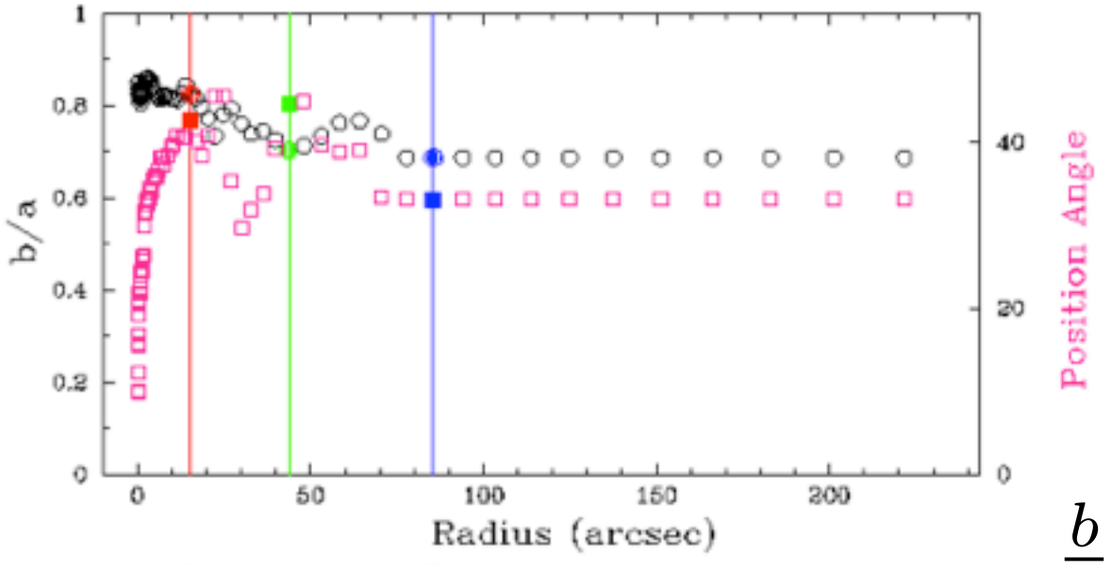
Table 1: Summary observations UH88

Date	Phot./Nights	Gals	Observers
01/02/2000	5.0 sur 5	134	BT
31/01/2003	3.0 sur 3	17	BT (optic)
19/12/2006	5.5 sur 6	162	KC,HC,LR,BT
12/03/2007	2.5 sur 8	150	KC,HC,LR,BT,MZ
14/09/2007	1.8 sur 3	84	BT,MZ
06/10/2007	1.0 sur 3	55	BT,MZ
28/02/2008	3.0 sur 5	137	HC.BT
23/07/2008	0.7 sur 2	24	HC,BT

BT: Brent Tully; KC: Kristin Chiboucas; LR:Luca Rizzi
HC: Helene Courtois; MZ: Max Zavodny

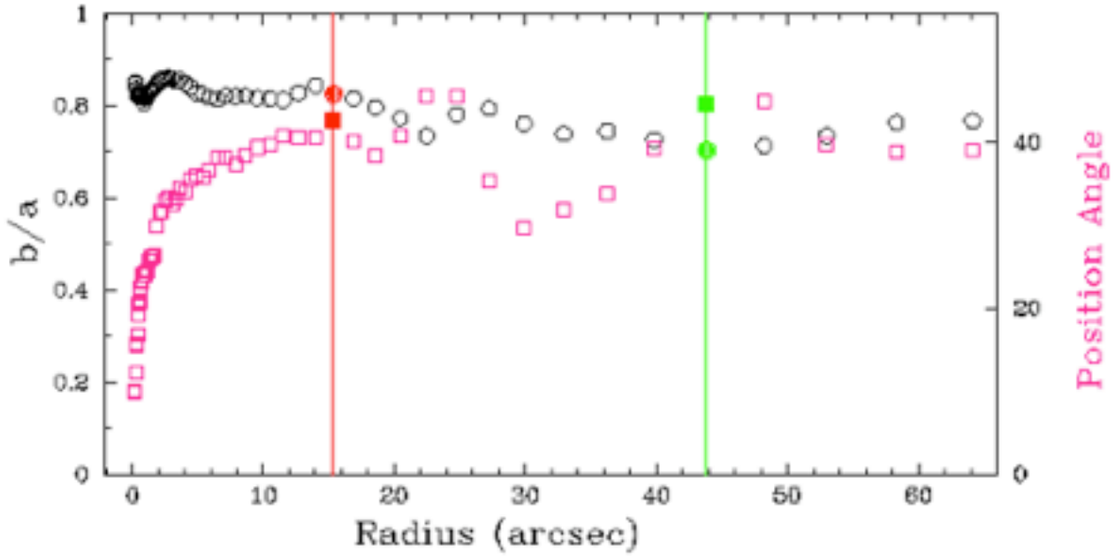
Brand new «prf_edit» plot from ARCHANGEL

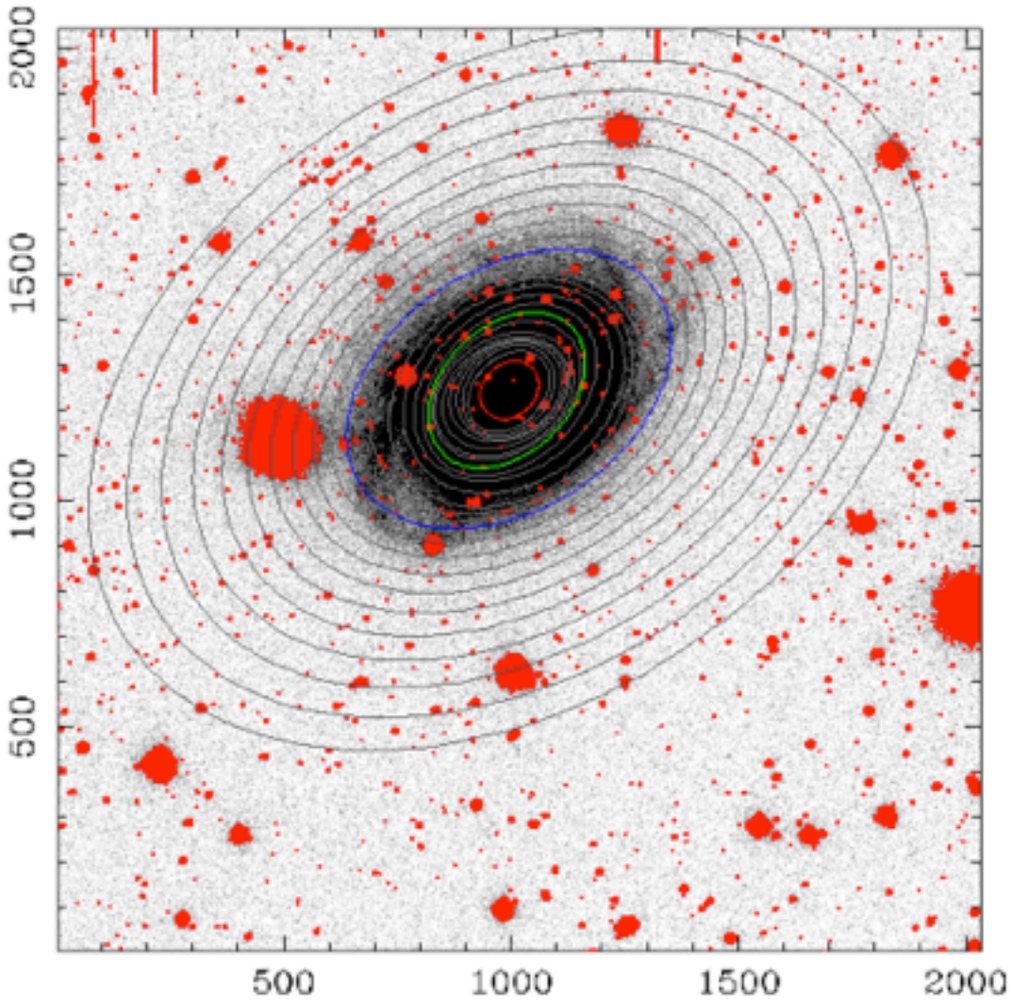
PGC30308

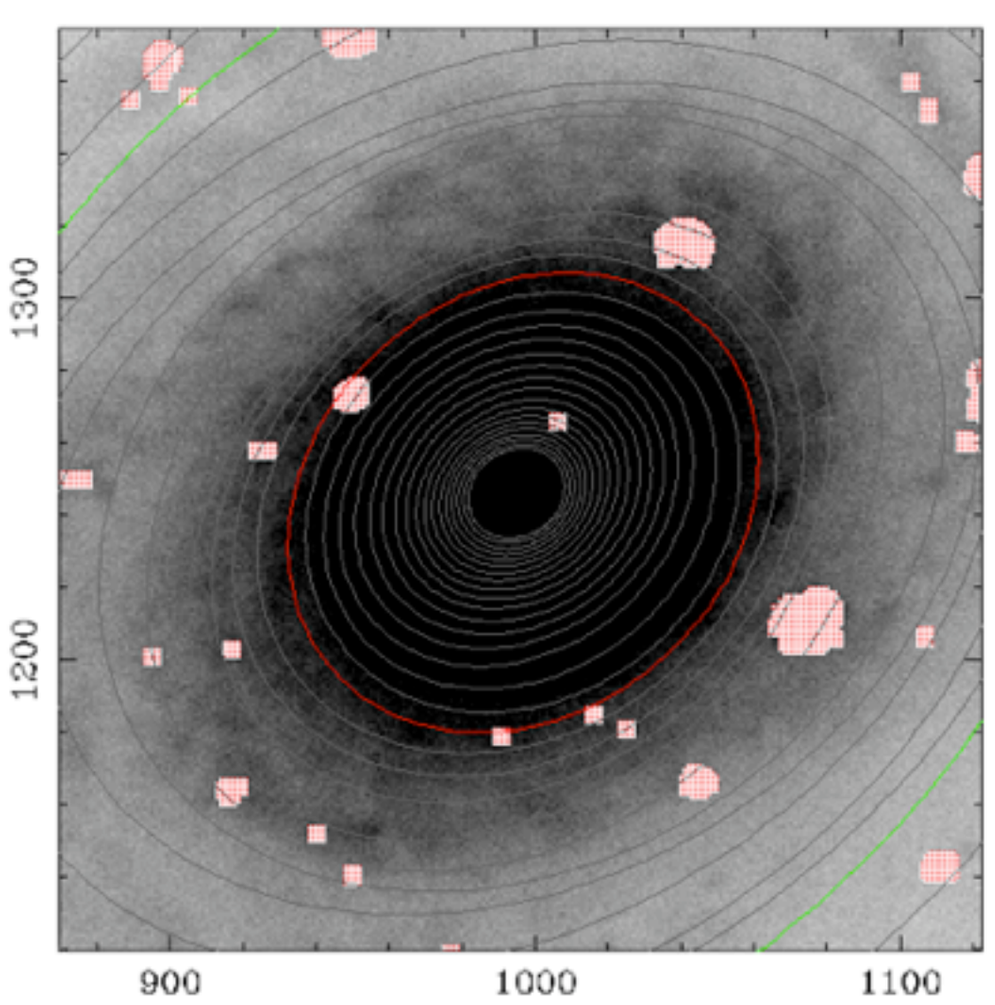


a20 a50 a80

$\frac{b}{a}$







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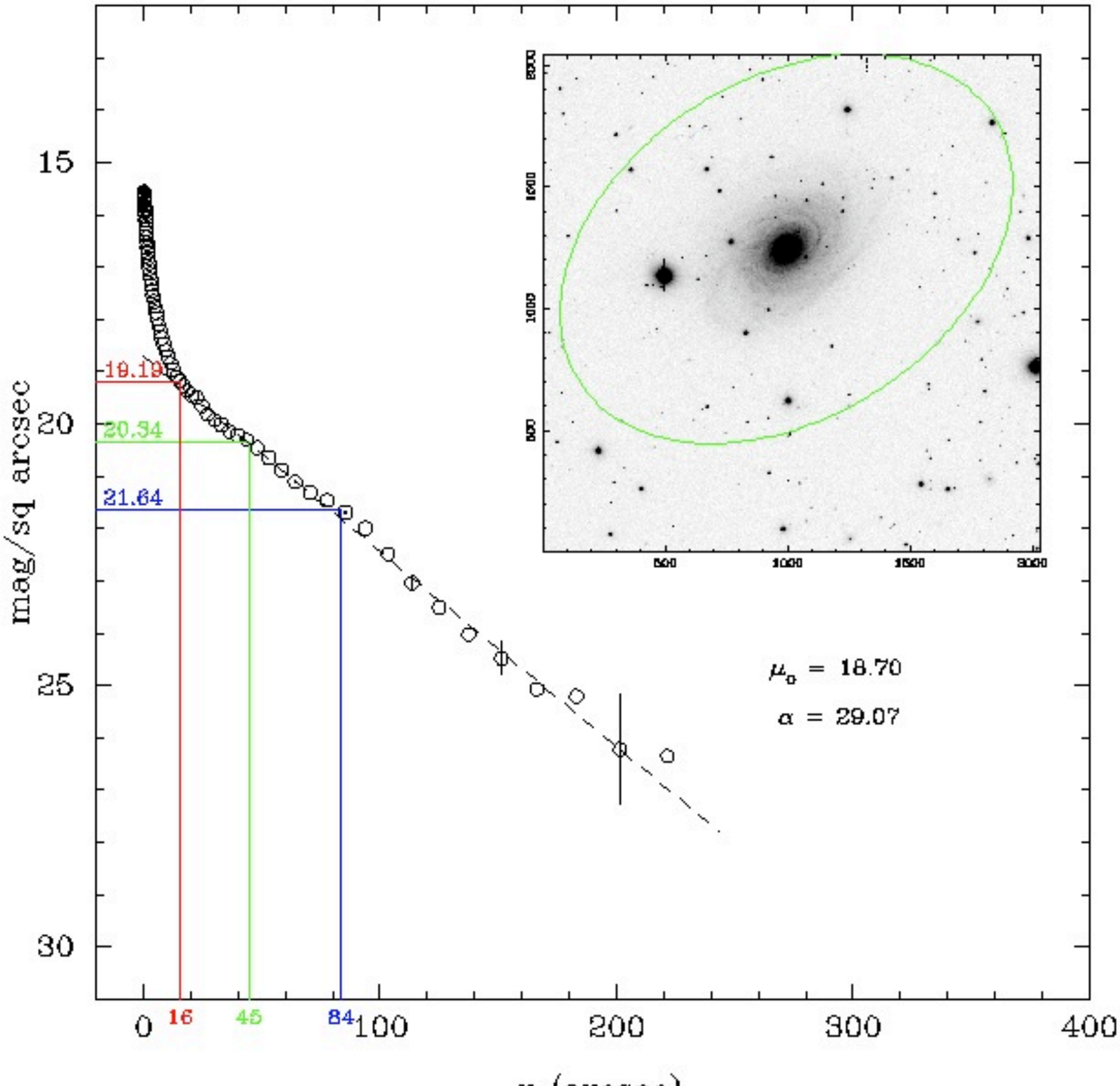
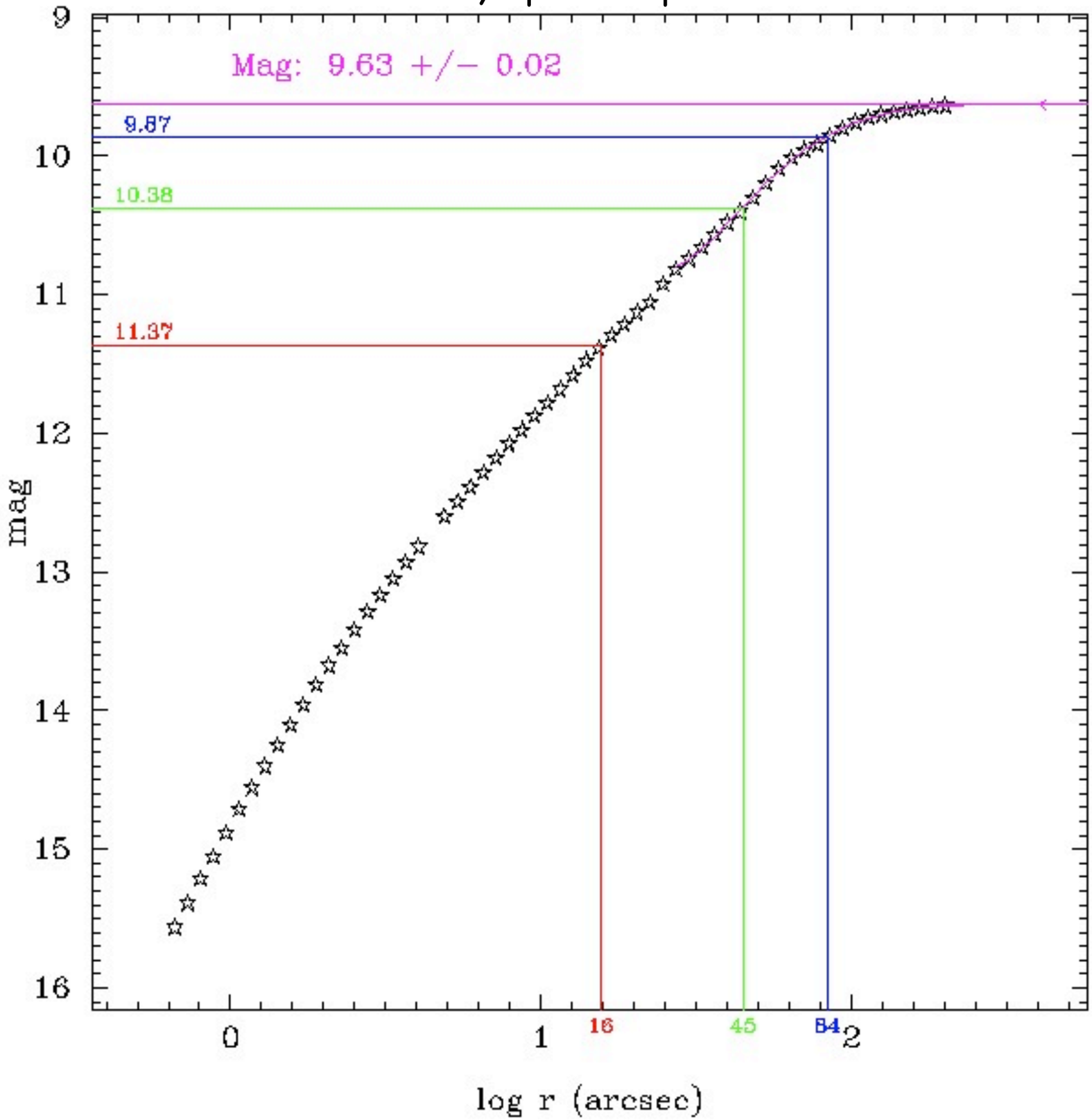
Brand new «bdd» plot from ARCHANGEL

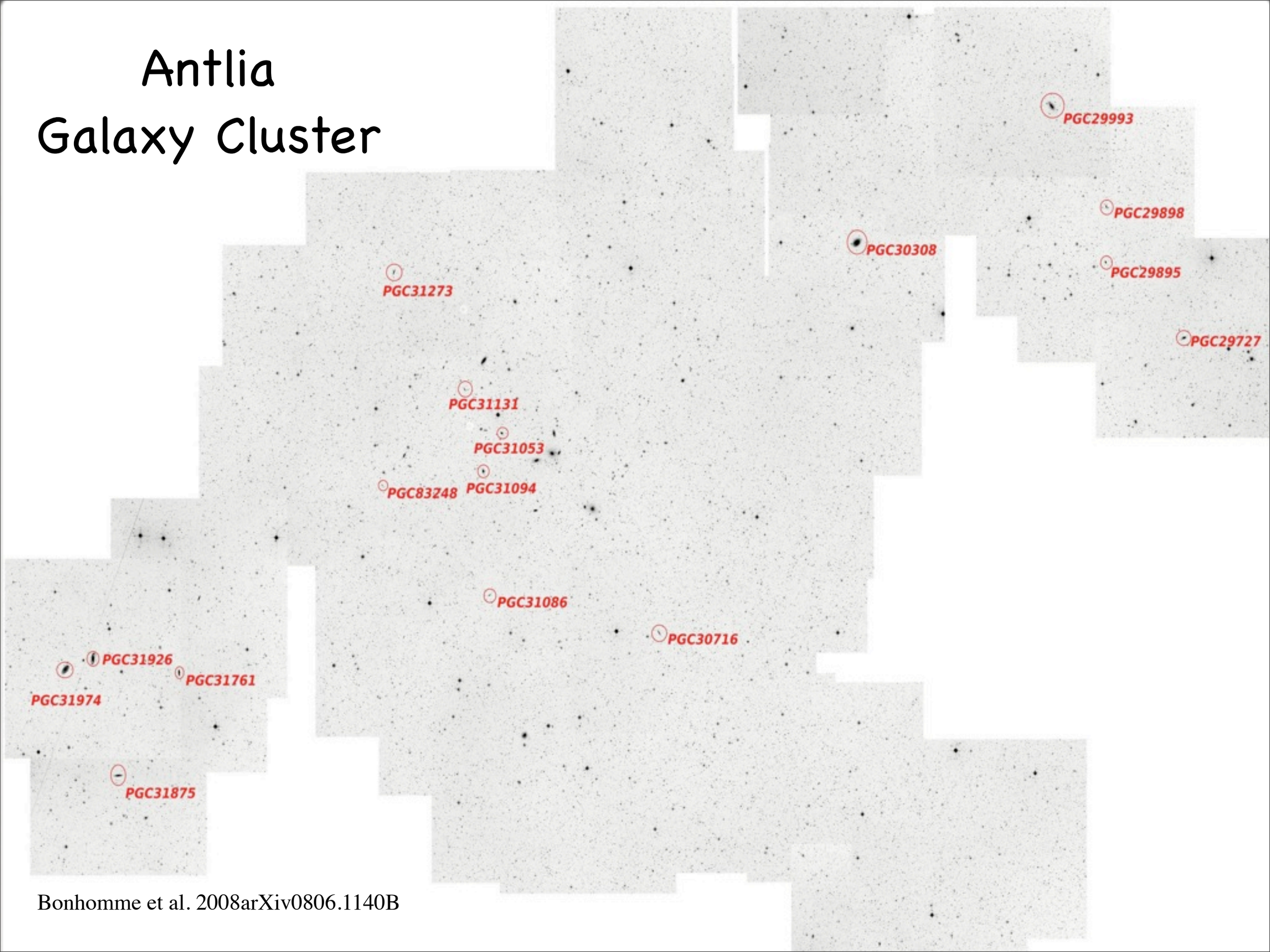


PGC30308

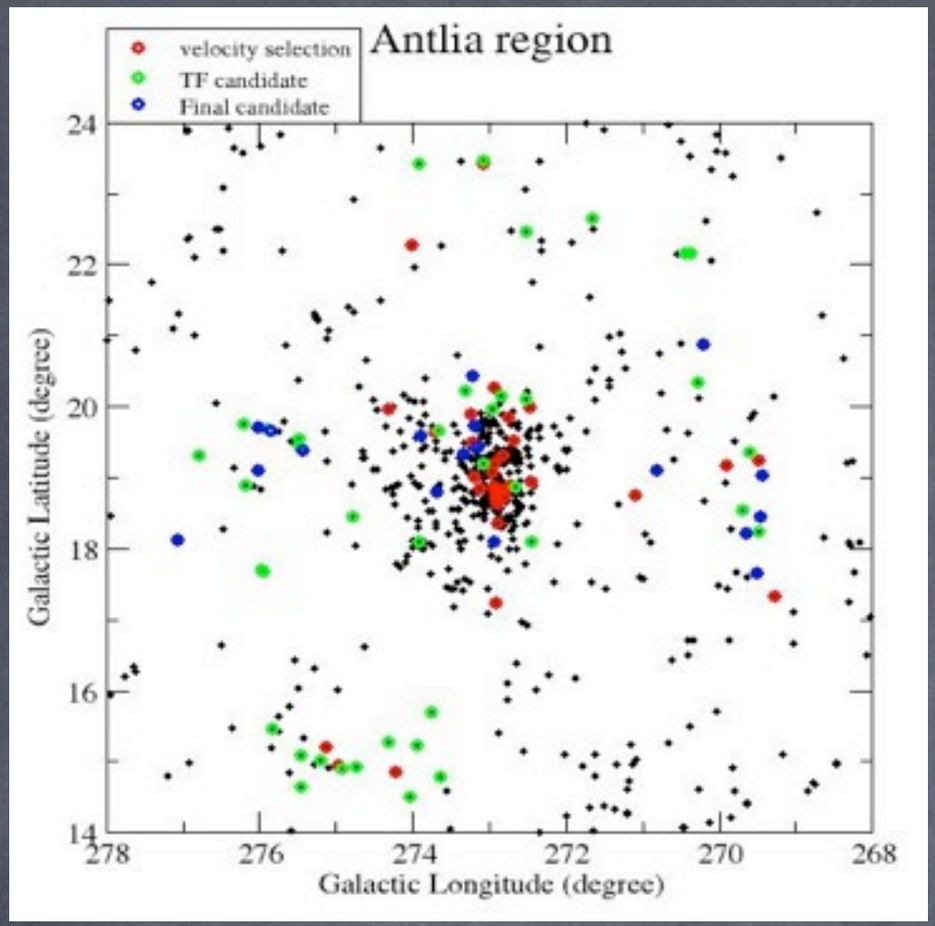
Brand new «asymptotic» plot from ARCHANGEL



Antlia Galaxy Cluster



Bonhomme et al. 2008arXiv0806.1140B


Antlia region
velocity selection
TF candidate
Final candidate
Galactic Latitude (degree)
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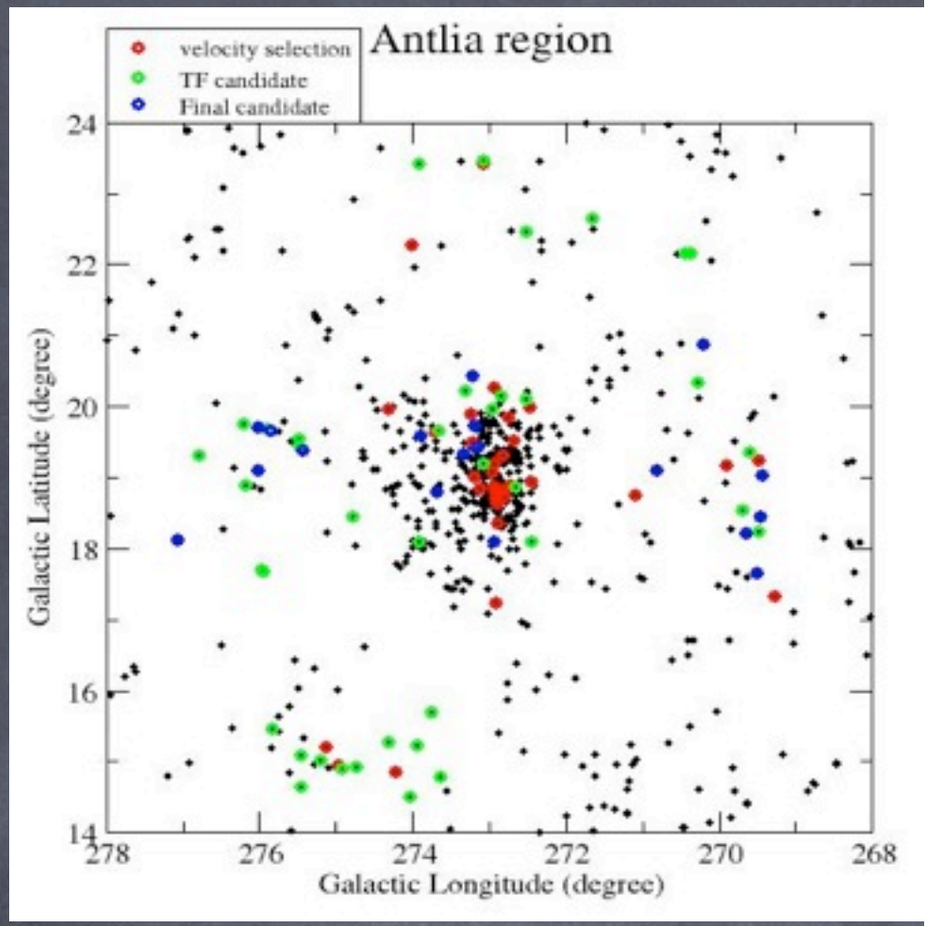
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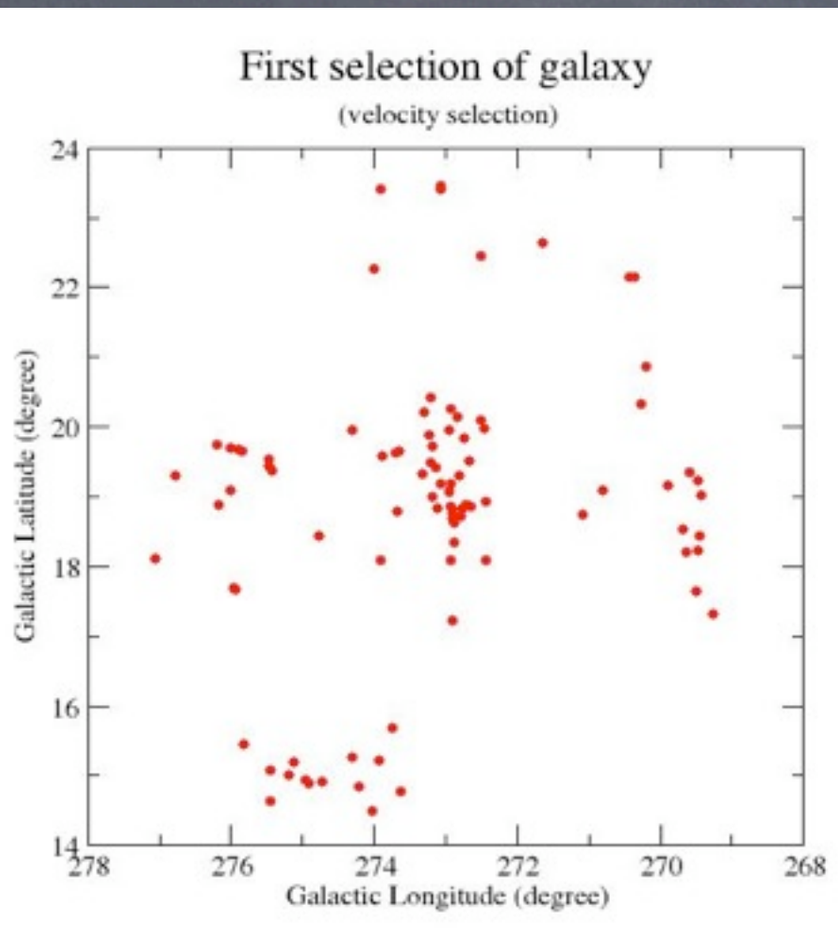
First selection of galaxy
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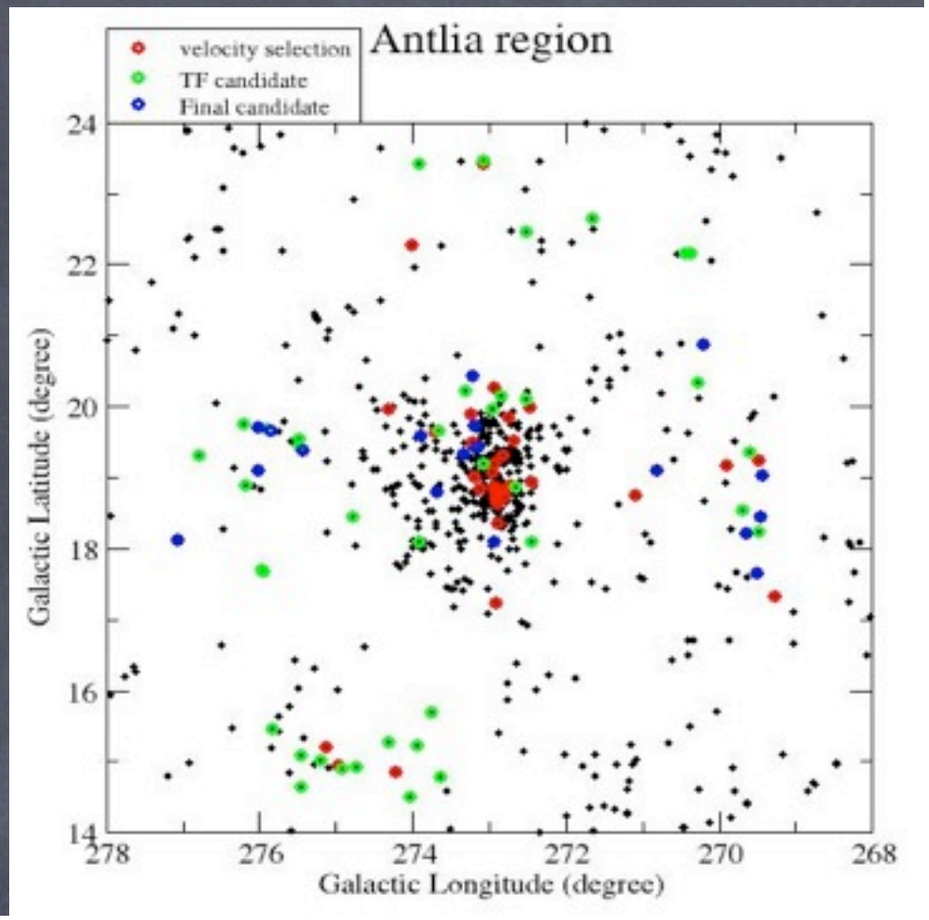
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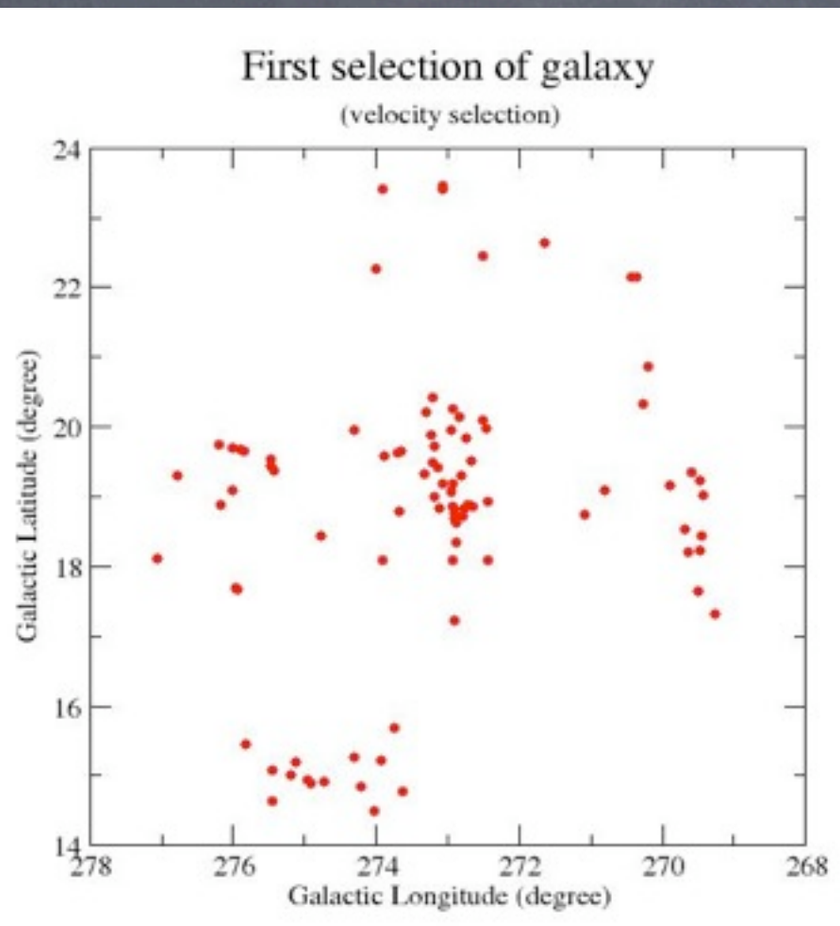
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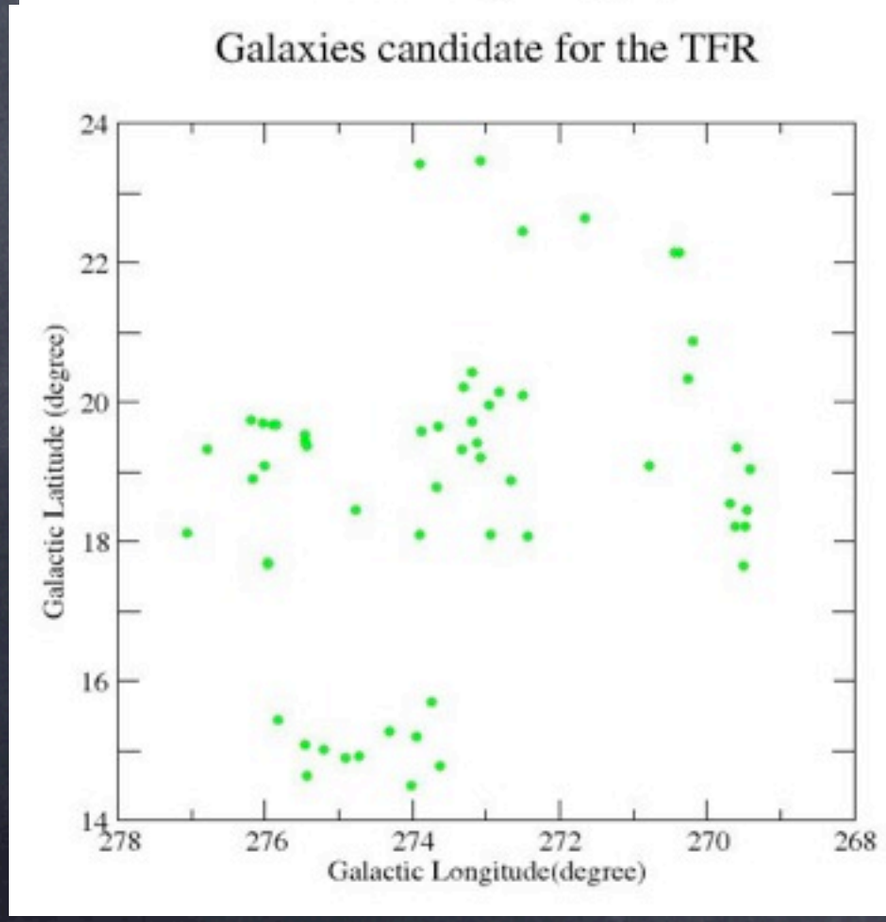
Galaxies candidate for the TFR
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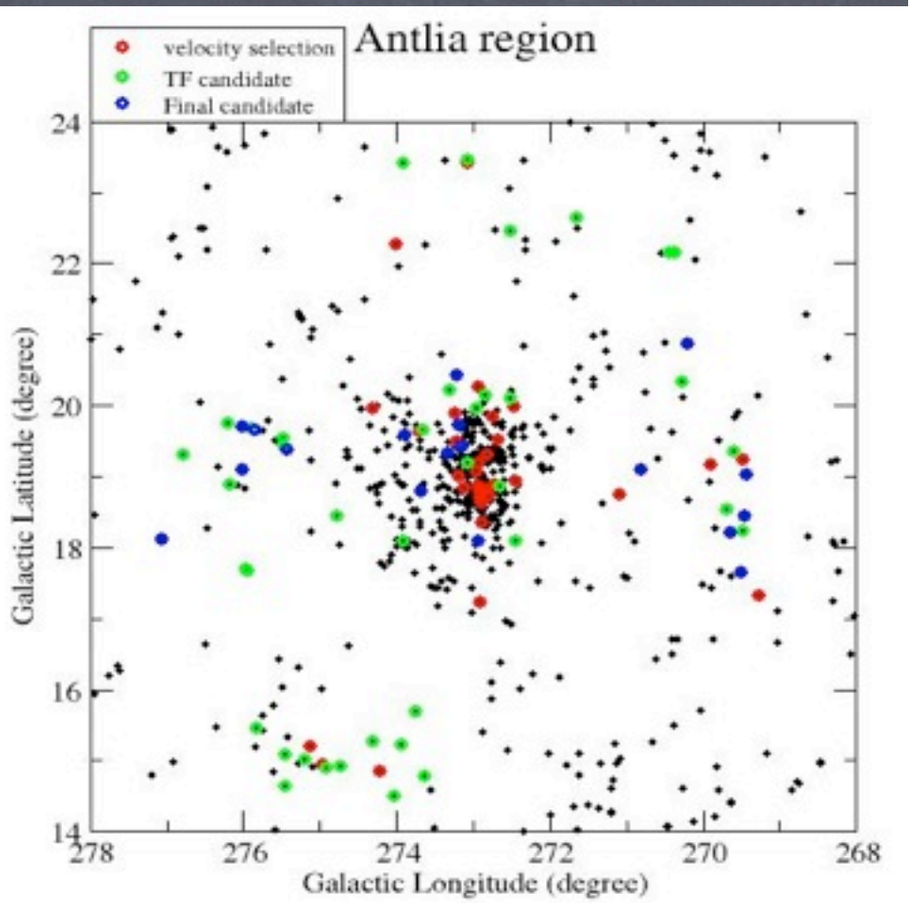
Antlia region
velocity selection
TF candidate
Final candidate
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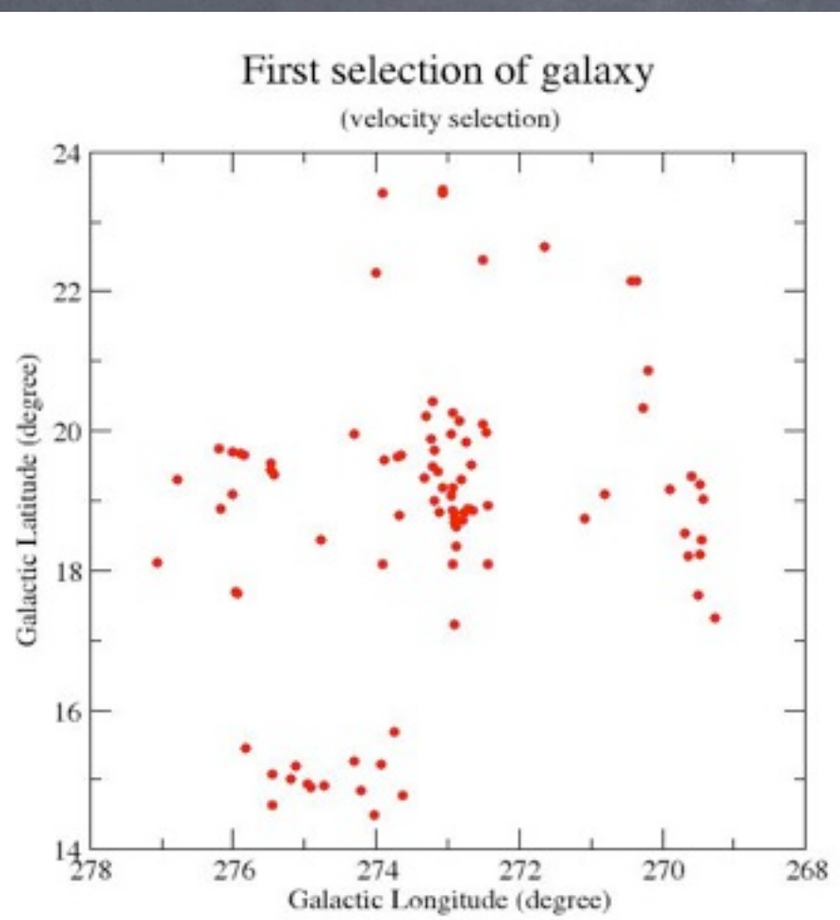
First selection of galaxy
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Galactic Latitude (degree)
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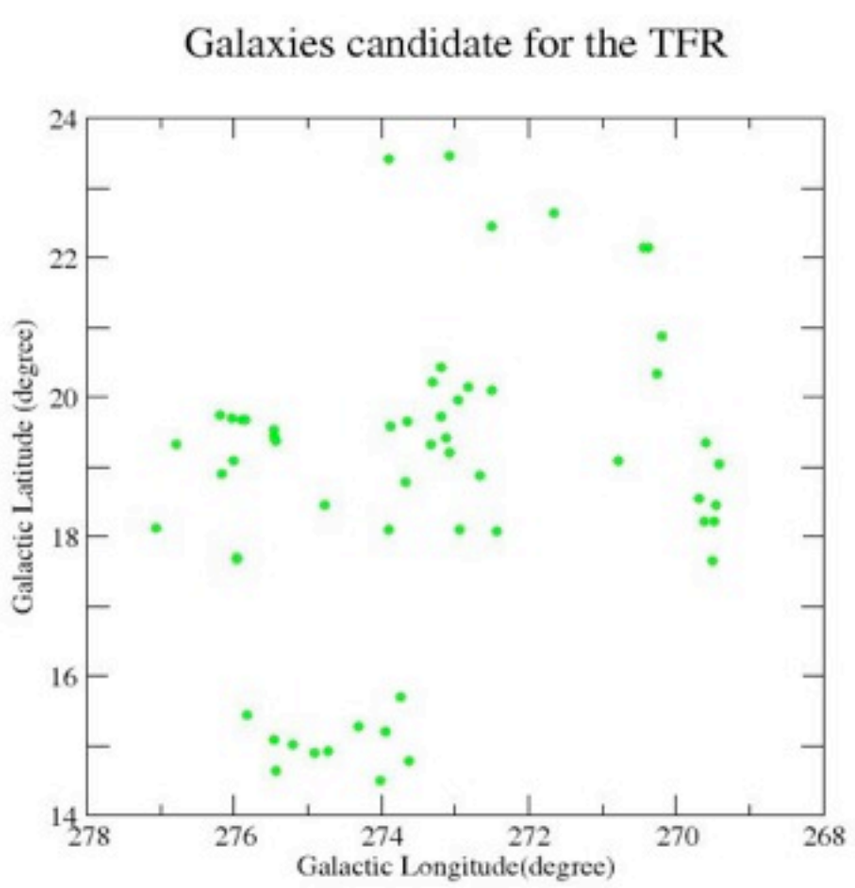
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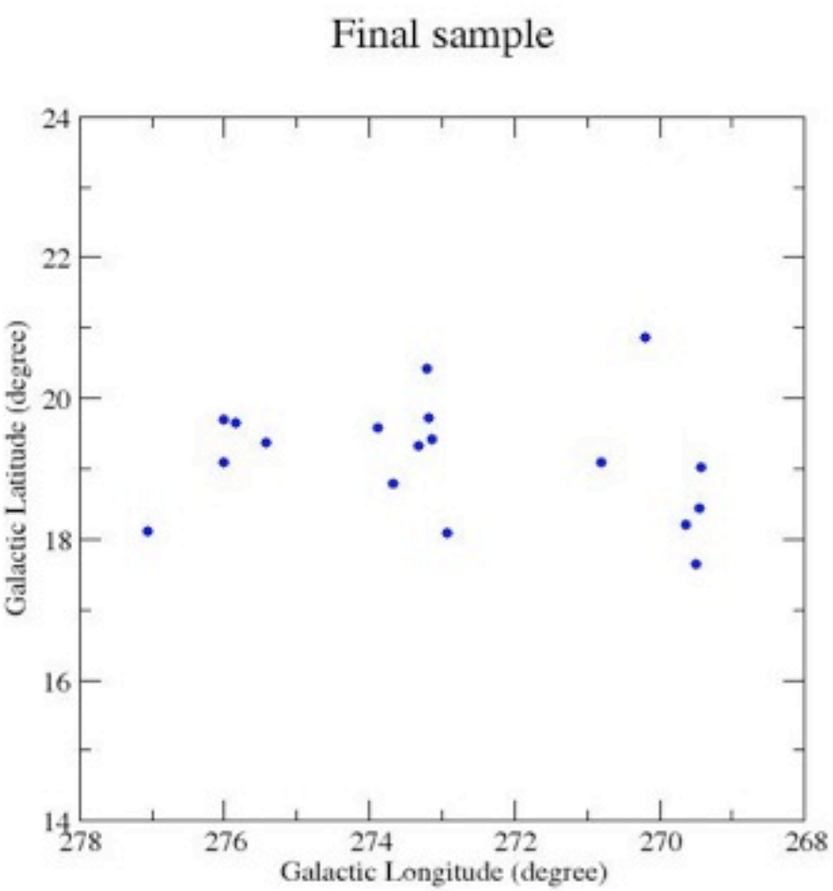
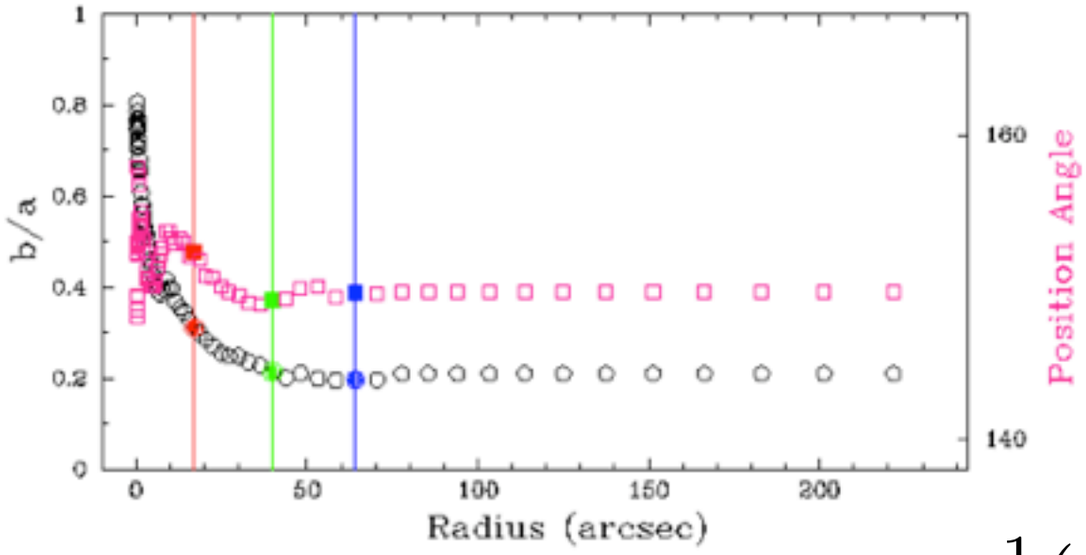
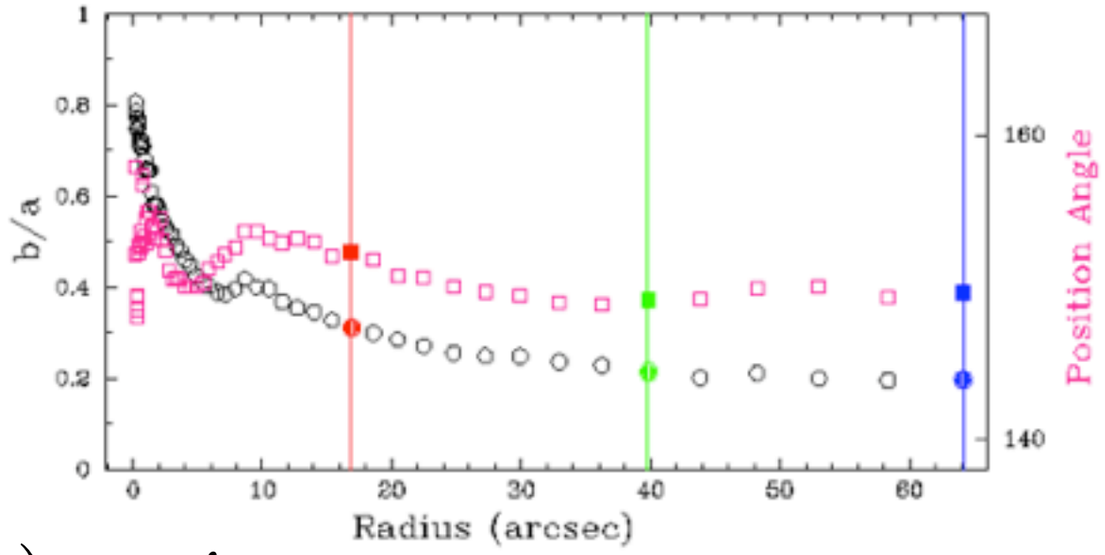
274
272
270
268

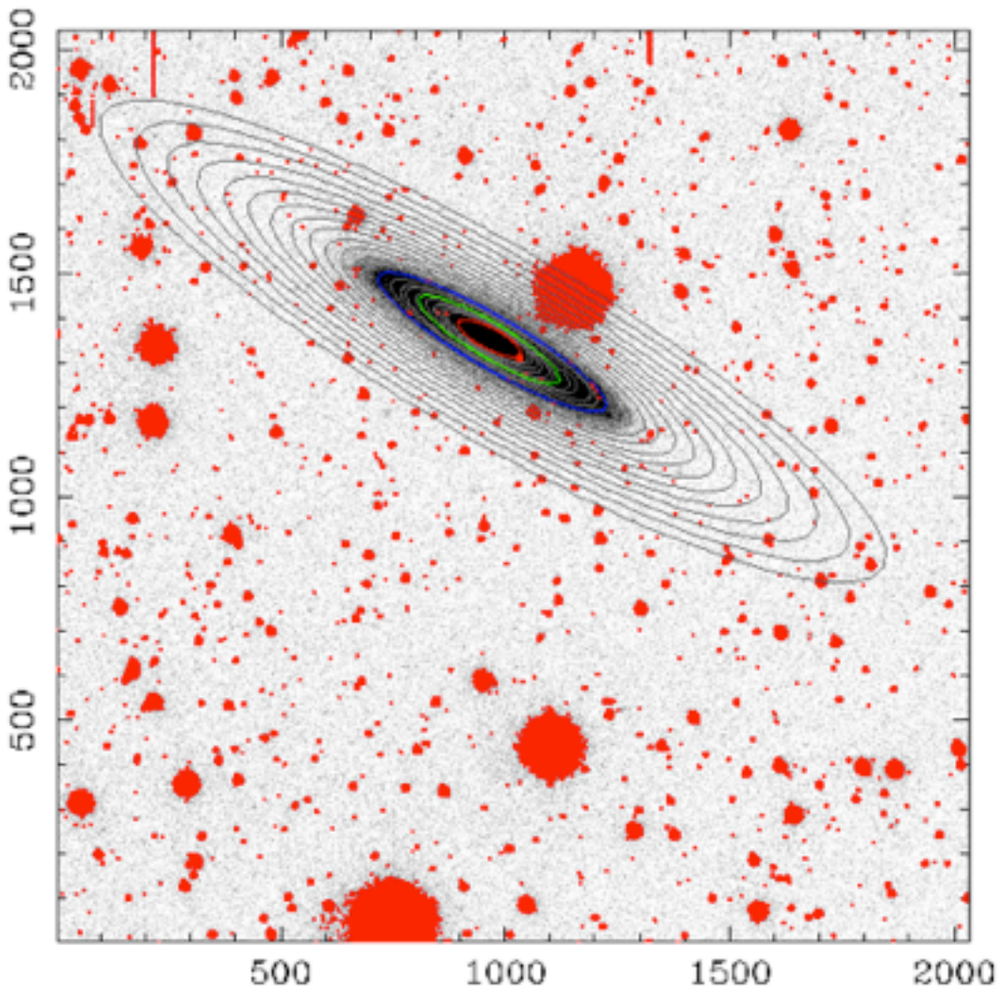

Final sample
Galactic Latitude (degree)
Galactic Longitude (degree)
24
22
20
18
16
14
278
276
274
272
270
268

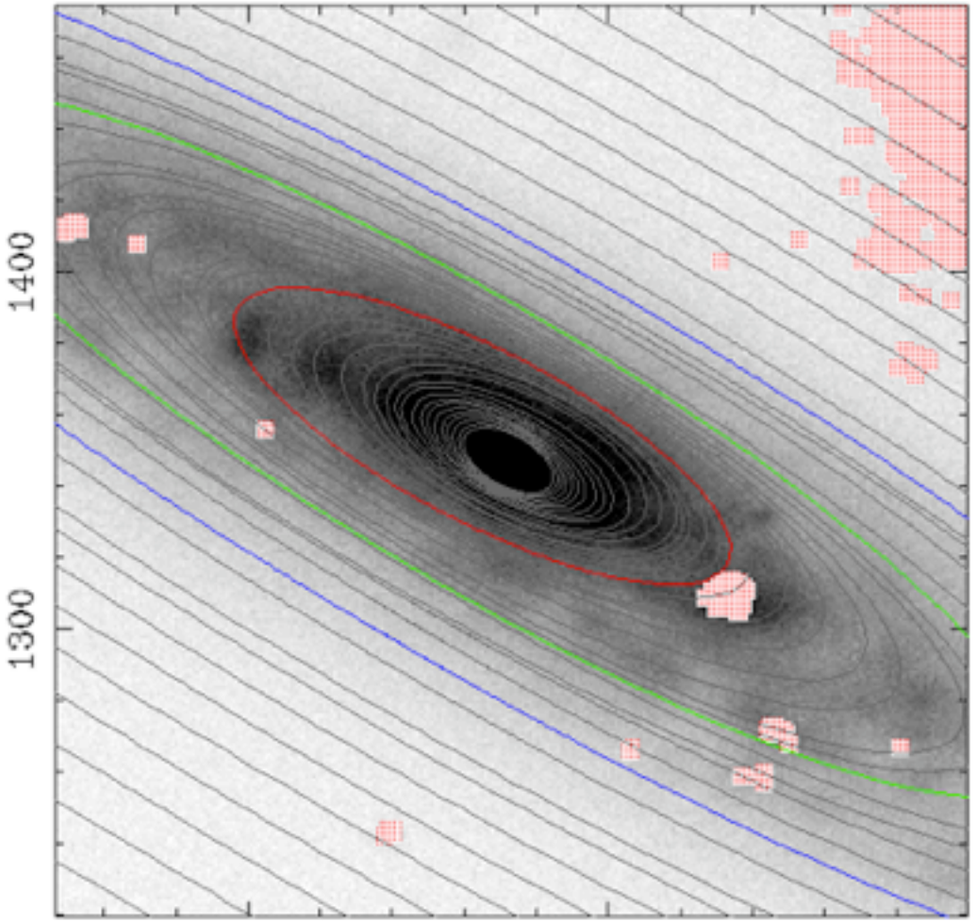
Archangel on PGC31995





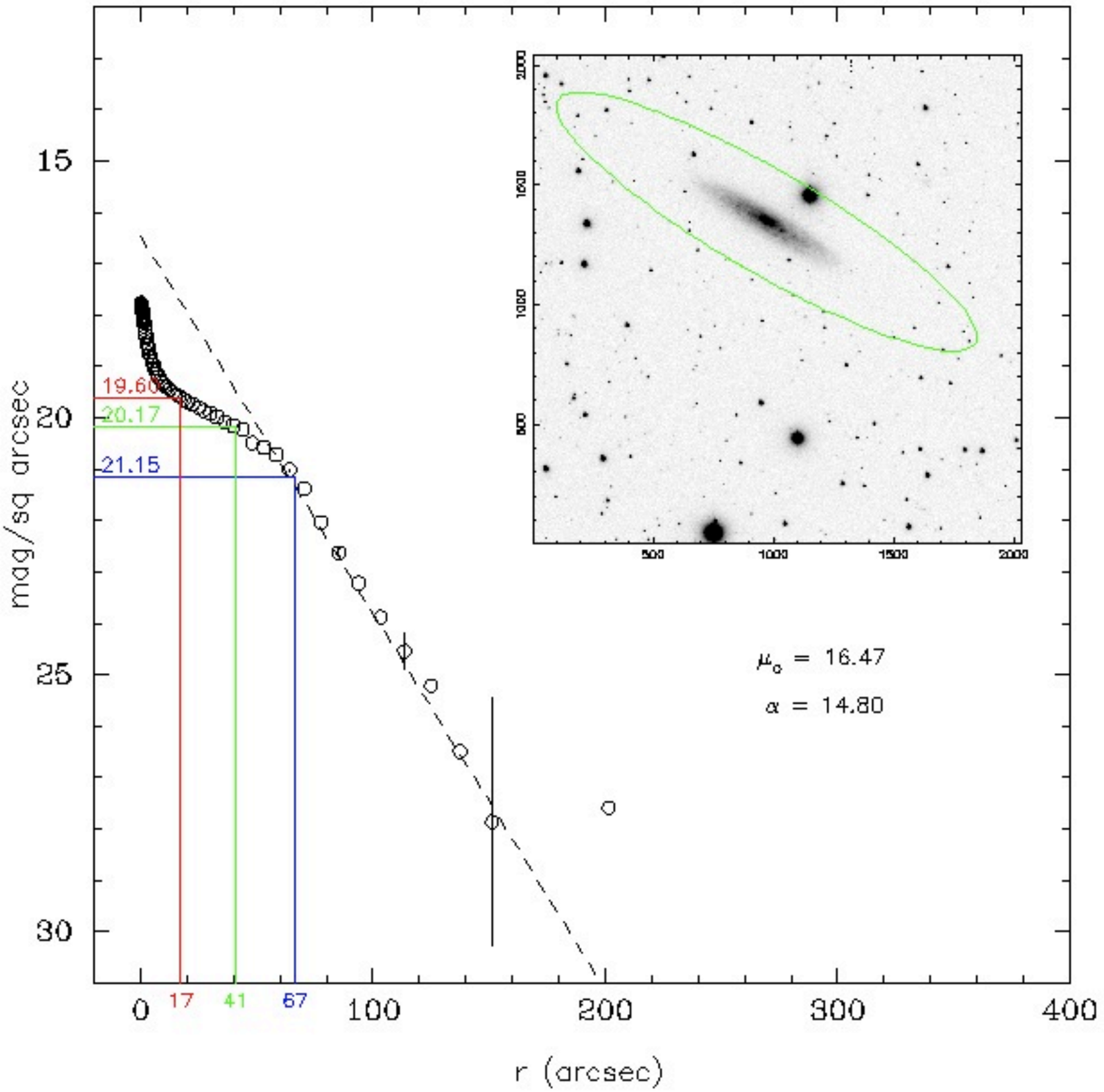
$$cos^{-1}\left(\frac{b}{a}\right) \Rightarrow i$$





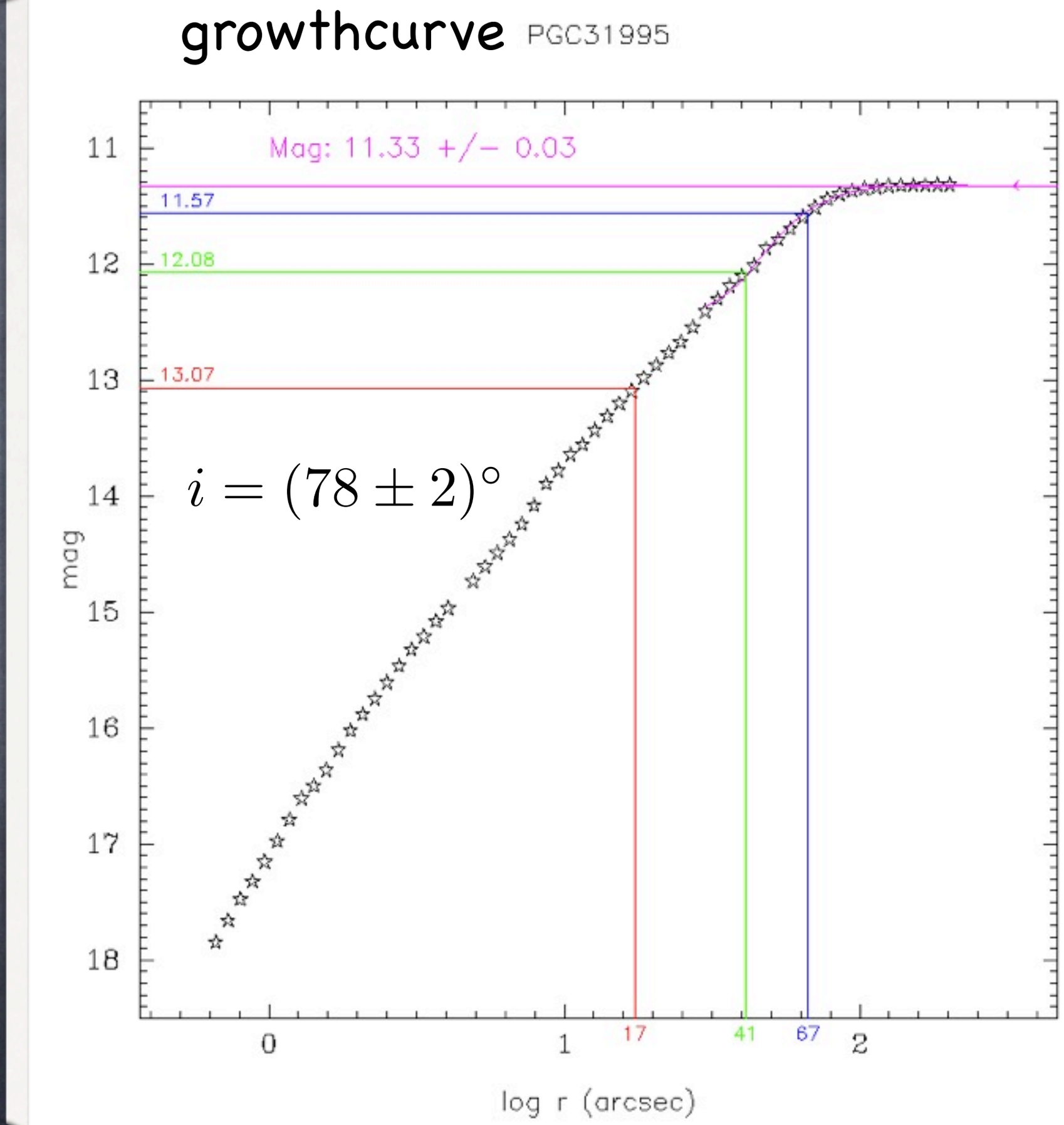
a80, a50, a20: radius on major axis containing 80%, 50%, 20% of the light

Surface brightness profile PGC31995



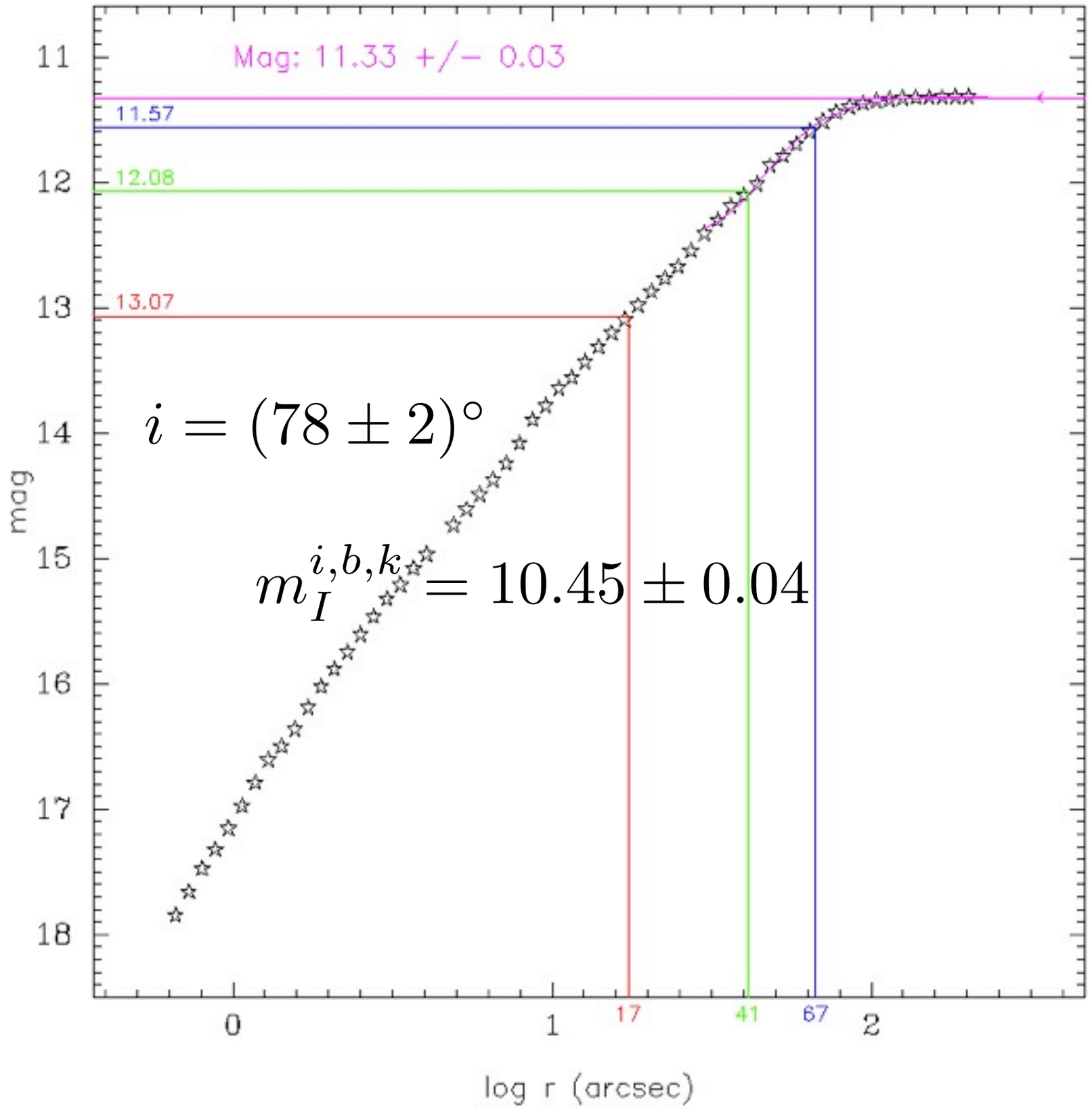
- With this study for the purpose of measuring distance, we also learn about morphology:
  - b/a
  - ratio luminosity disk/bulge with a80, a50, a20, c82 (a80/a20)
  - Surface brightness (exponential disk scale length alpha, Extrapolated exponential disk central surface brightness)

Error on b/a => error on i



Error on b/a => error on i

growthcurve PGC31995



$$i = (78 \pm 2)^\circ$$

$$m_I^{i,b,k} = 10.45 \pm 0.04$$

- error on the inclination leads to an error to the apparent magnitude AND the absolute magnitude (correction on W)

An error on $\frac{b}{a}$ leads to an error on i and then on W_R^i

To correct the apparent magnitude:

$$A_i^I = \gamma_I \log(\tfrac{a}{b})$$

$$\gamma_I = 0.92 + 1.63(\log W_R^i - 2.5)$$

Tully, R. B., & Pierce, M. J. 2000, ApJ, 533, 744

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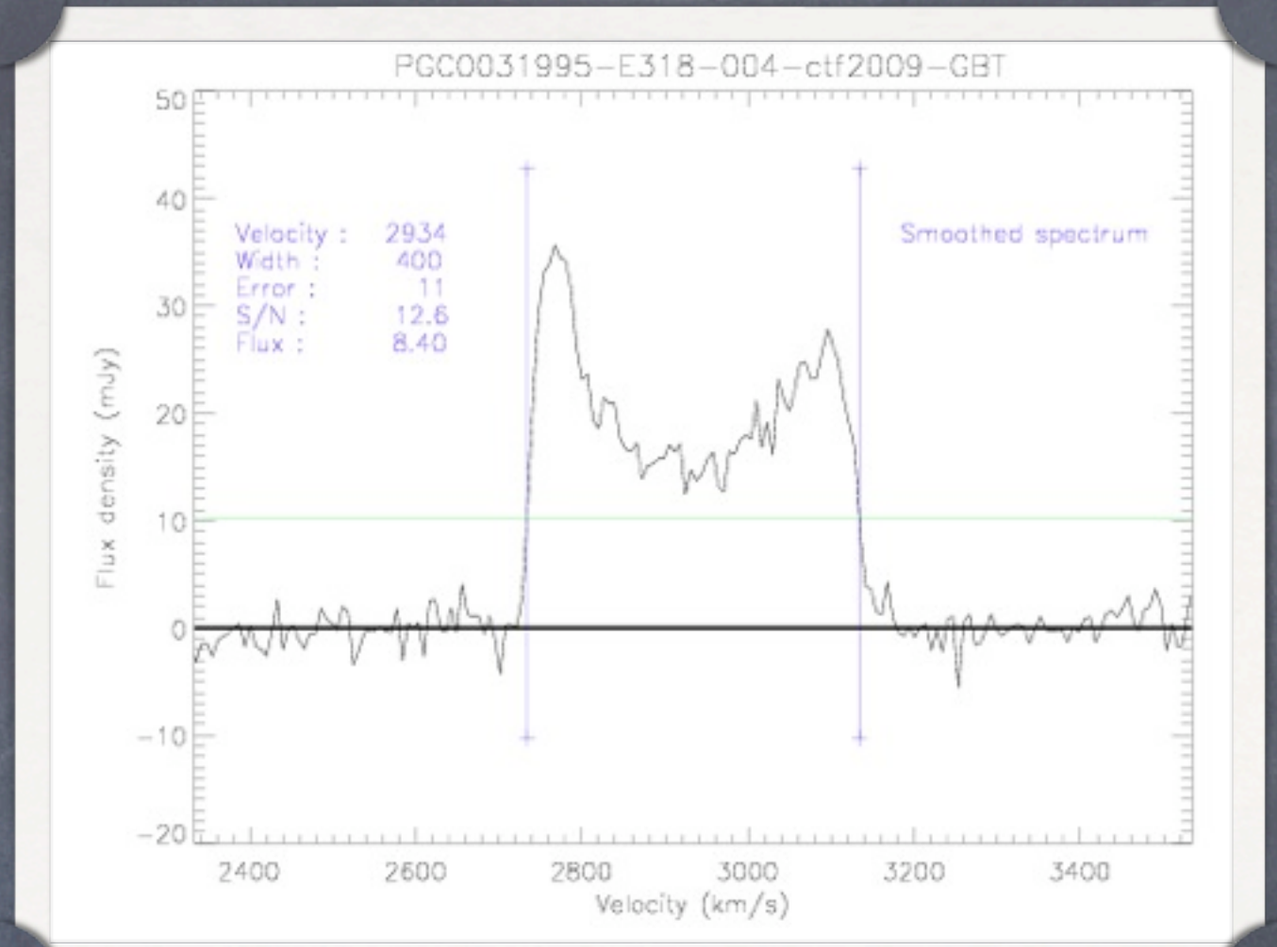
Tully, R. B., & Pierce, M. J. 2000, ApJ, 533, 744

Antlia - PGC0031995 HI
Preliminary result

$$W_R^i = \frac{W_R}{\sin(i)}$$



$$M_I^{i,b,k} = -21.43 - 8.11(\log W_R^i - 2.5)$$

$M_I^{b,i,k} = -22.34 \pm 0.35$

$m_I^{i,b,k} = 10.45 \pm 0.04$

$d = 36 \pm 6 Mpc$

$v_{pec} = 357 \pm 21 kms^{-1}$

«Large» error on a show case...

i deg	W_R^i km/s	$m_I^{i,b,k}$ mag	$M_I^{i,b,k}$ mag	d Mpc	v km/s
76	424	10.41	-21.99	30	336
78	409	10.45	-22.34	36	357
80	395	10.49	-22.69	42	378

«Large» error on a show case…

«Large» error on a show case...

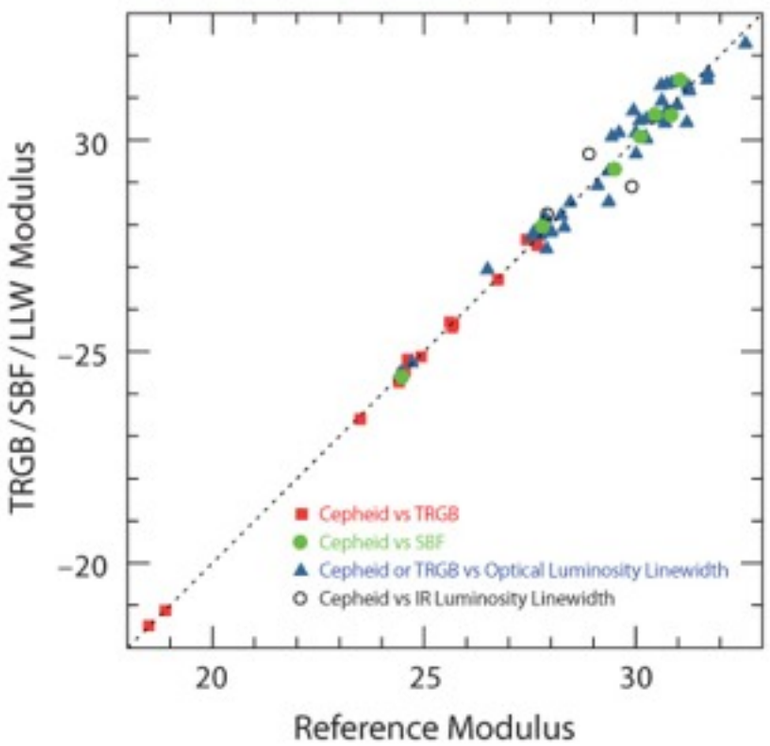
- Take a great care about the inclinaison!!

Summary

- Take a great care about error on the linewidth (HI) and on b/a (Photometry)
- HI completed (almost)
- Photometry in progress: comparison between our data and other observations
- soon: finish the analysis to our whole sample
- future: PanSTARR, SKA (MeerKAt, ASKAP..)

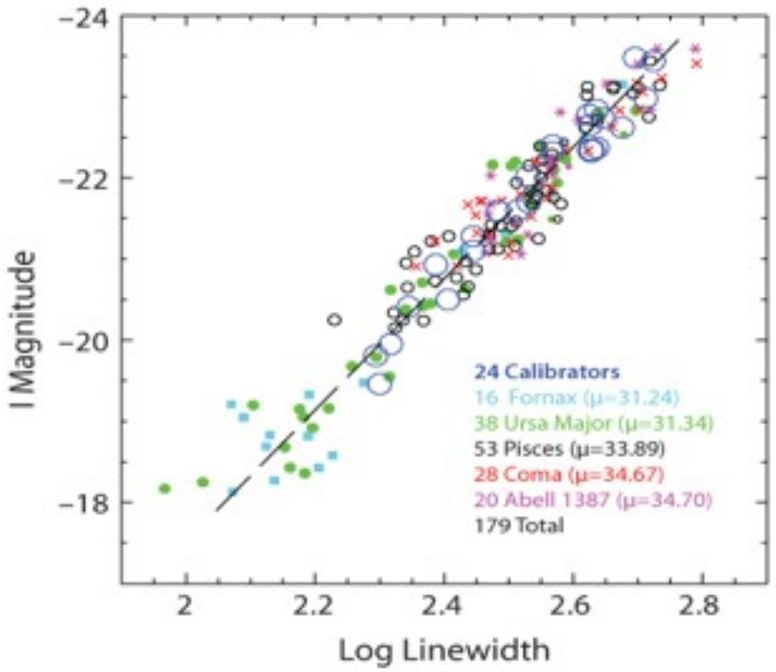
Commonality of Cepheid, TRGB, SBF, and Luminosity-Linewidth zero point

Tully et al. 2008, ApJ, 676, 184



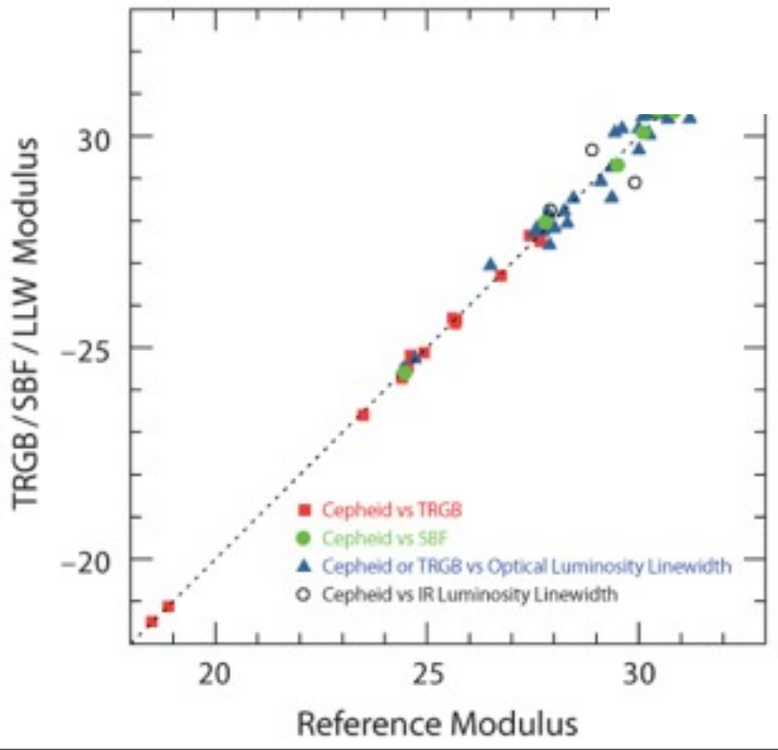
Luminosity-Linewidth 5 cluster template

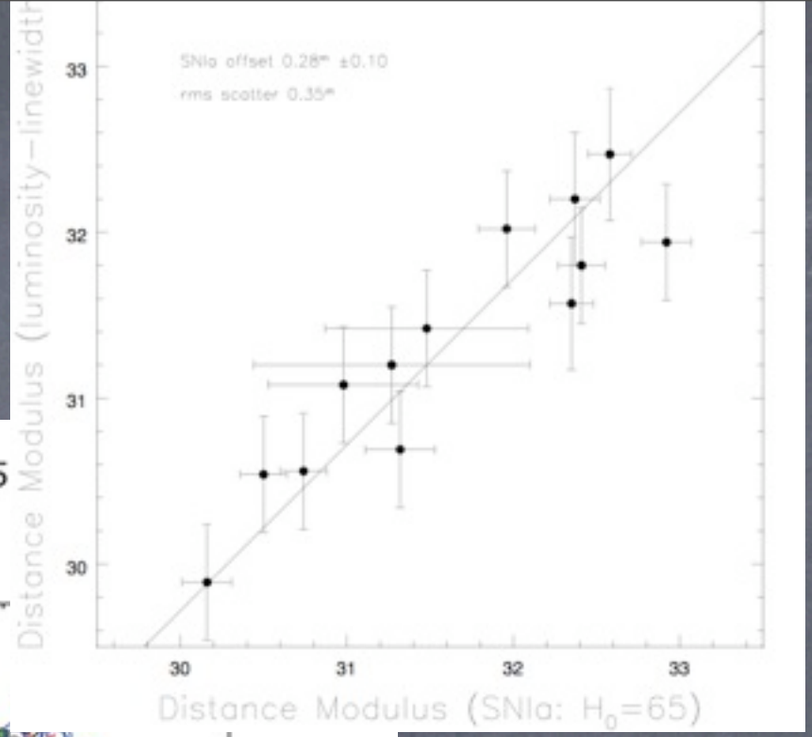
Tully & Pierce. 2000, ApJ, 533, 744

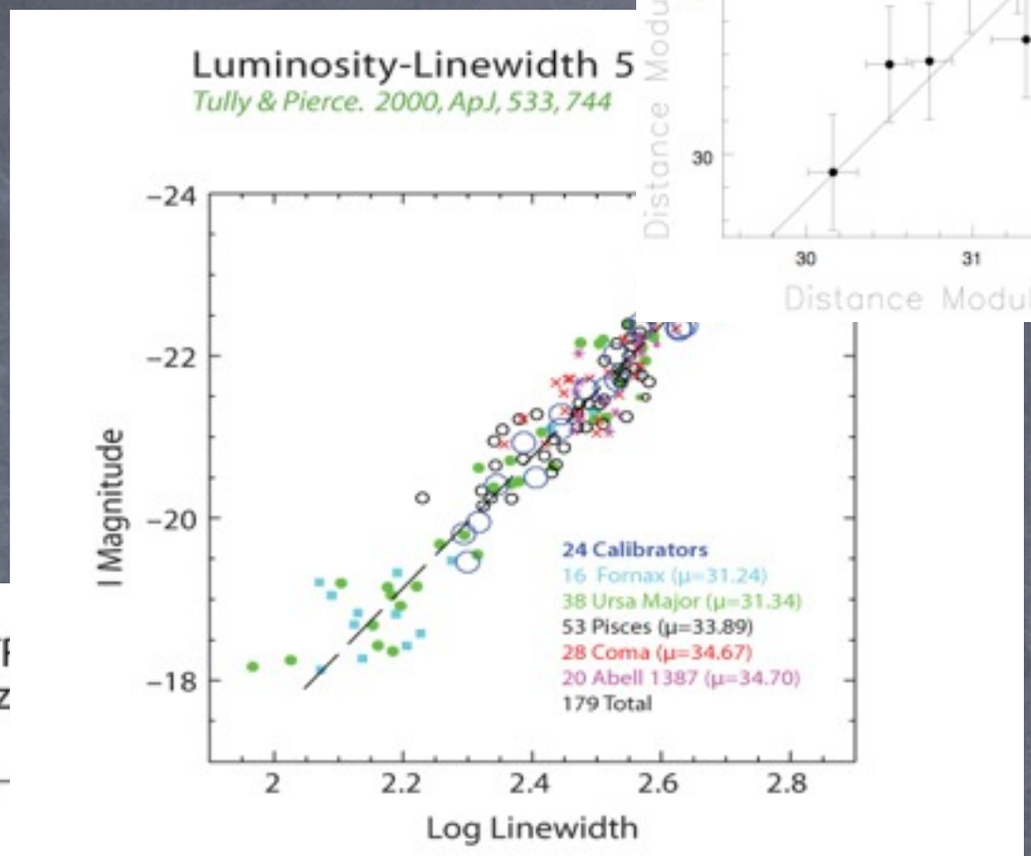


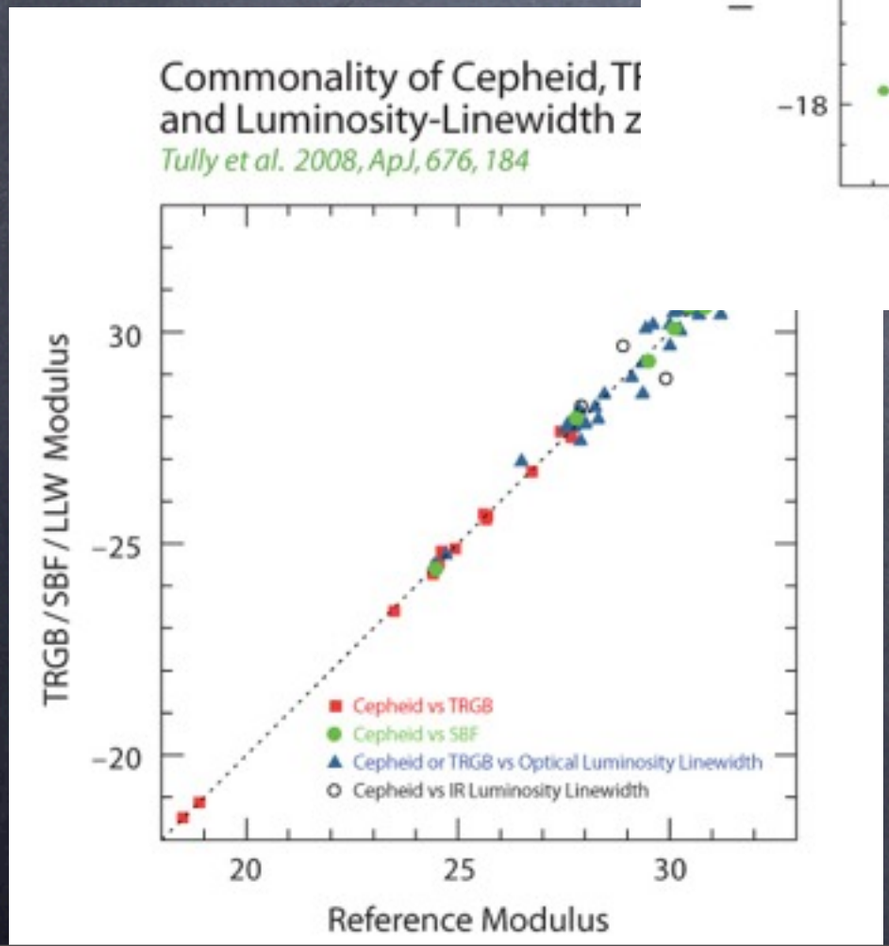
Commonality of Cepheid, TF and Luminosity-Linewidth z

Tully et al. 2008, ApJ, 676, 184




SNIa offset 0.28m ±0.10
rms scatter 0.35m
Distance Modulus (luminosity−linewidth)
Distance Modulus (SNIa: H0=65)
30
31
32
33


Luminosity-Linewidth 5
Tully & Pierce. 2000, ApJ, 533, 744
I Magnitude
Log Linewidth
−24
−22
−20
−18
2
2.2
2.4
2.6
2.8
24 Calibrators
16 Fornax (μ=31.24)
38 Ursa Major (μ=31.34)
53 Pisces (μ=33.89)
28 Coma (μ=34.67)
20 Abell 1387 (μ=34.70)
179 Total


Commonality of Cepheid, TF
and Luminosity-Linewidth z
Tully et al. 2008, ApJ, 676, 184
TRGB / SBF / LLW Modulus
Reference Modulus
30
−25
−20
20
25
30
Cepheid vs TRGB
Cepheid vs SBF
Cepheid or TRGB vs Optical Luminosity Linewidth
Cepheid vs IR Luminosity Linewidth