



Resolved Stellar Populations with EAGLE

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**+ Yanbin Yang, Mathieu Puech, Matt Lehnert (GEPI);
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Jean-Gabriel Cuby (LAM); Simon Morris (Durham)**

DRM & DRSP Workshop – May 2009



Science & Technology Facilities Council
UK Astronomy Technology Centre



EAGLE Phase A study

- A multi-IFU, near-IR spectrometer for the E-ELT
- French-UK consortium
- PI: Jean-Gabriel Cuby (Marseille)
- 2 year study (09/07-09/09)
- Phase 1 review (07/08), Midterm review (02/09)





EAGLE Science

Science areas that drive the EAGLE requirements:

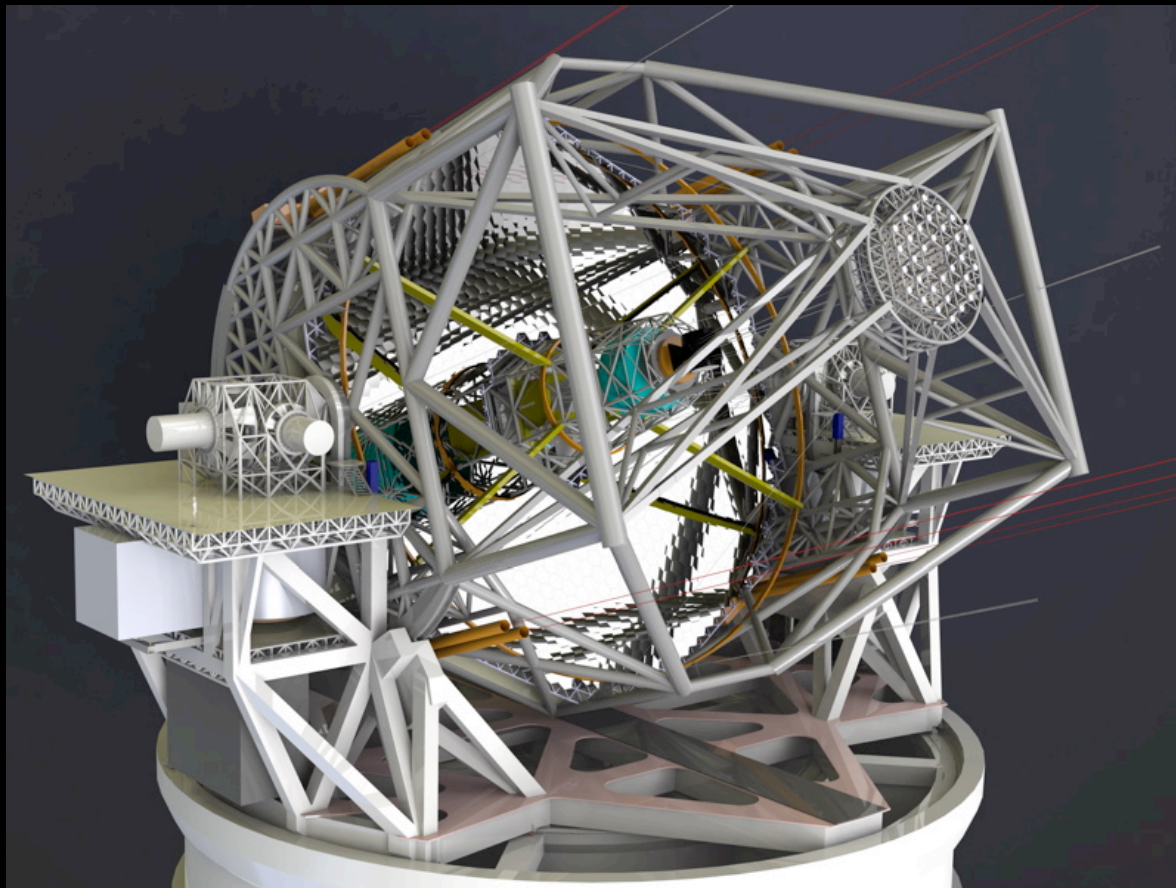
- Physics & evolution of high- z galaxies
 - See talk by [Mathieu Puech](#)
- Detection and characterisation of “first-light” galaxies
 - See talk by [Jean-Gabriel Cuby](#)
- Galaxy assembly/evolution from stellar archaeology
- Star-formation, stellar clusters and the IMF
- Co-ordinated growth of black holes and galaxies/AGN

EAGLE Baseline Design

Parameter	Specification
Patrol Field	5 arcmin (unobstructed) eqv. >7 arcmin (vignetted)
Science subfield (IFU FOV)	1.65 x 1.65 arcsec
Multiplex	20
Spatial Resolution	30% EE in 75mas (H-band)
Spectral resolving power	4,000 & 10,000
Wavelength range	0.8-2.5 μm

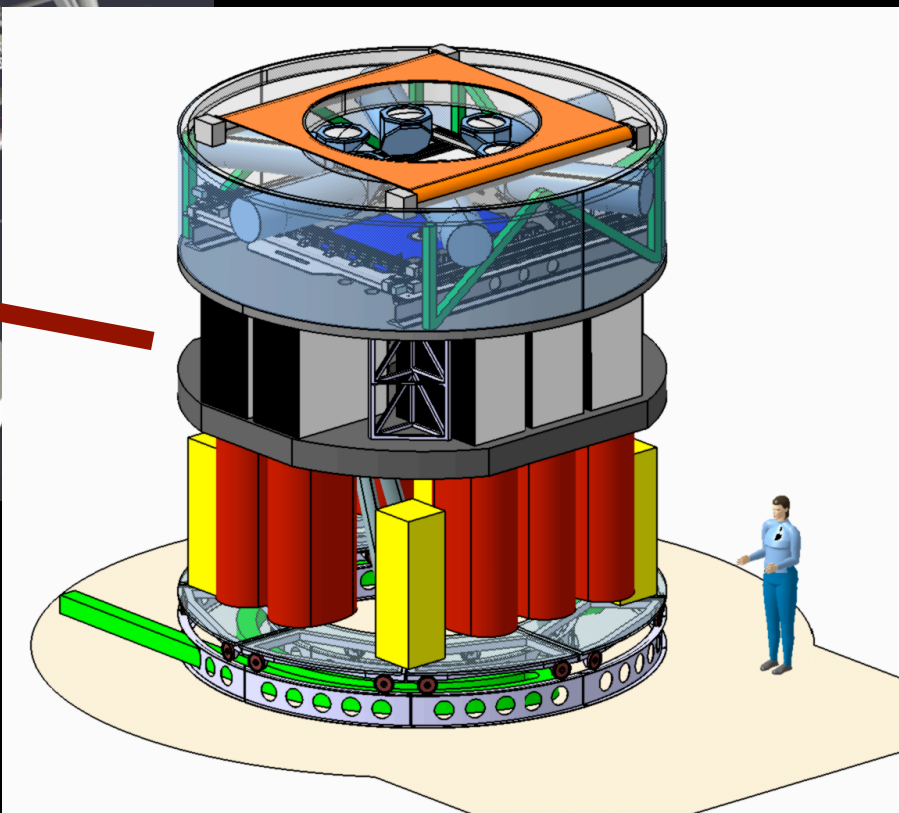
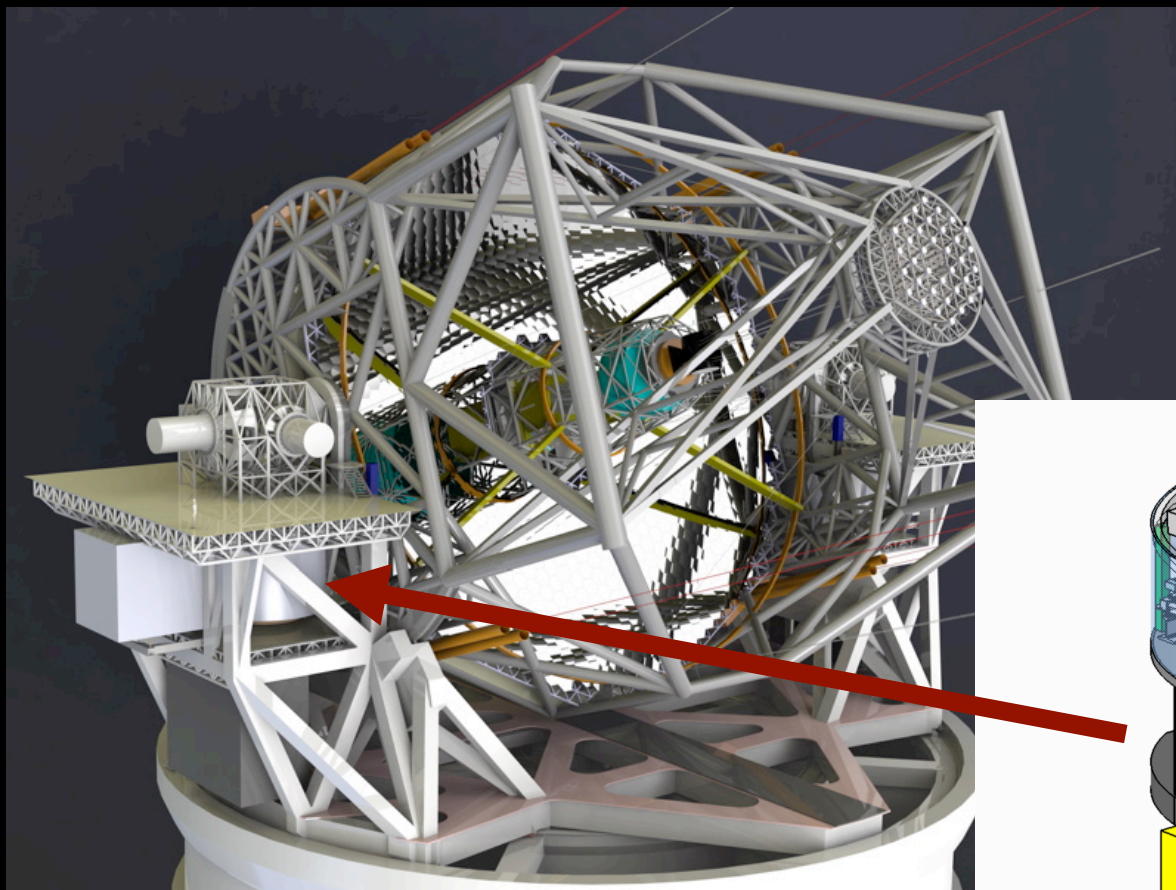


EAGLE Baseline Design



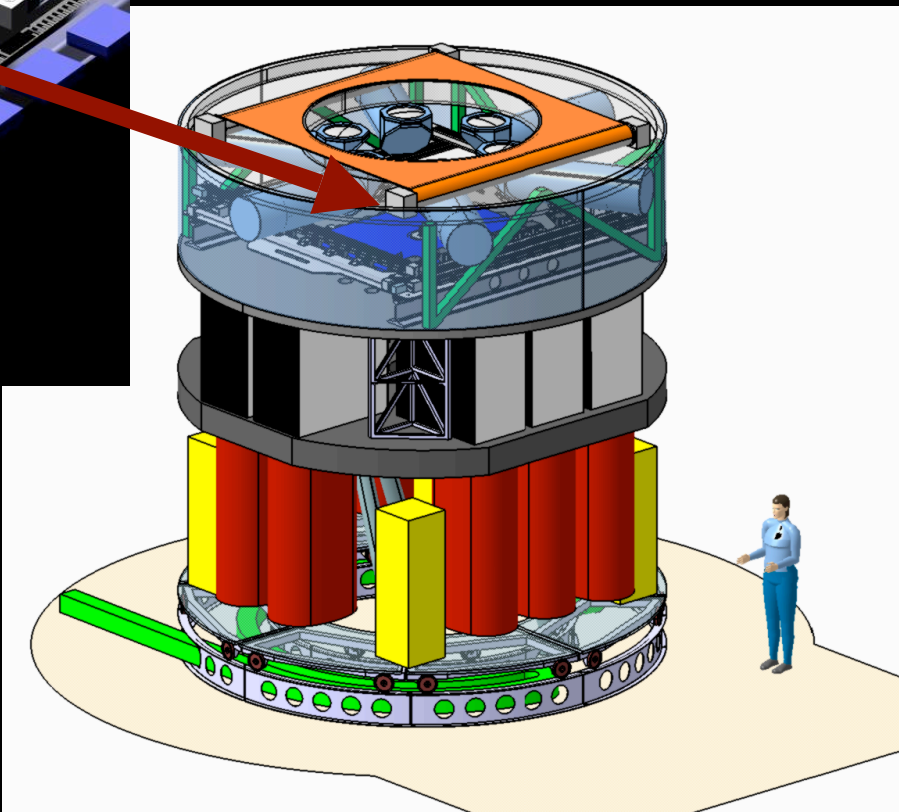
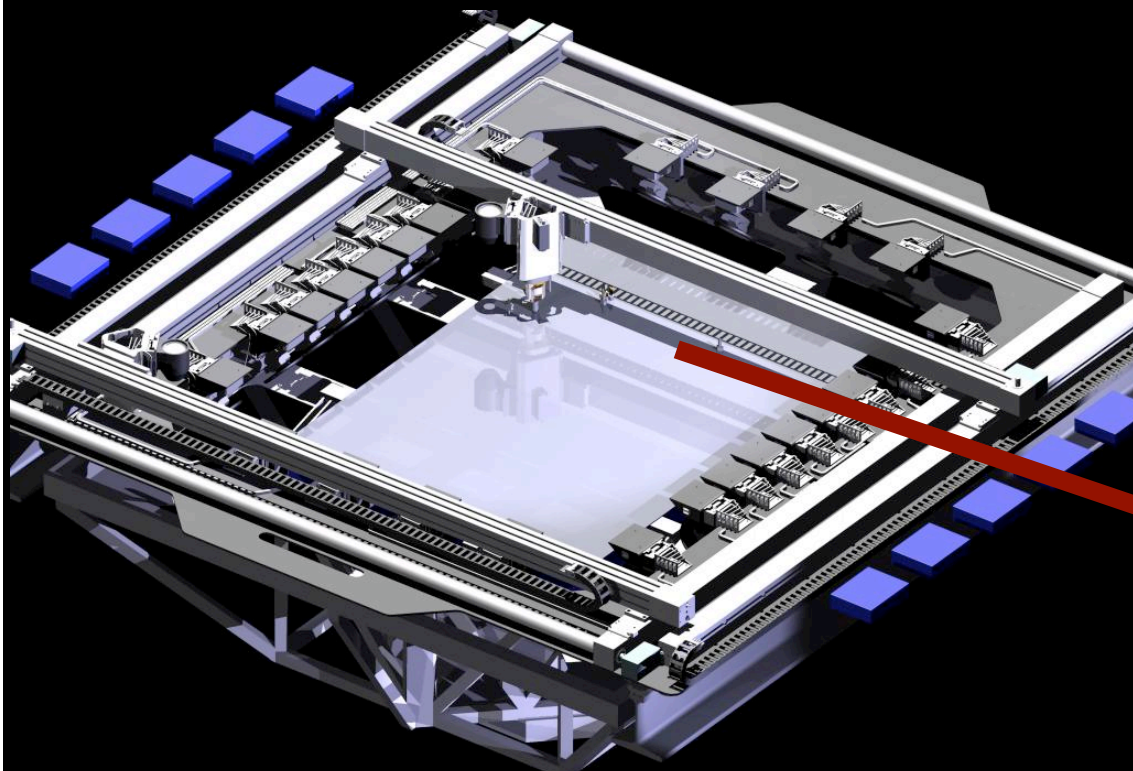


EAGLE Baseline Design



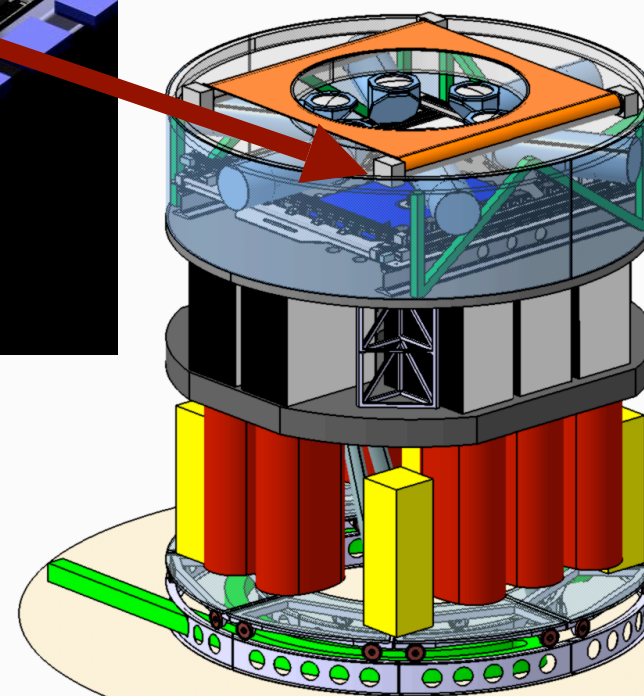
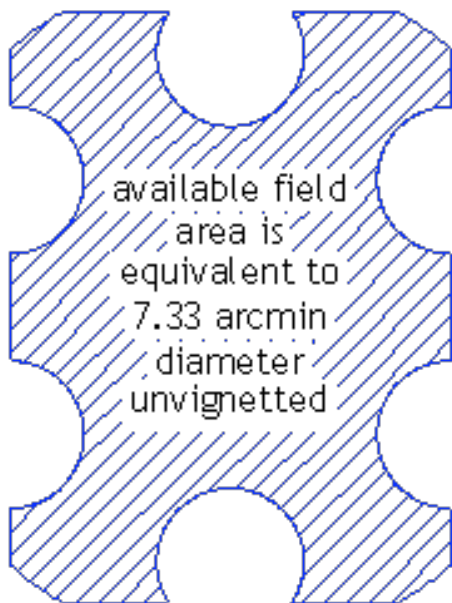
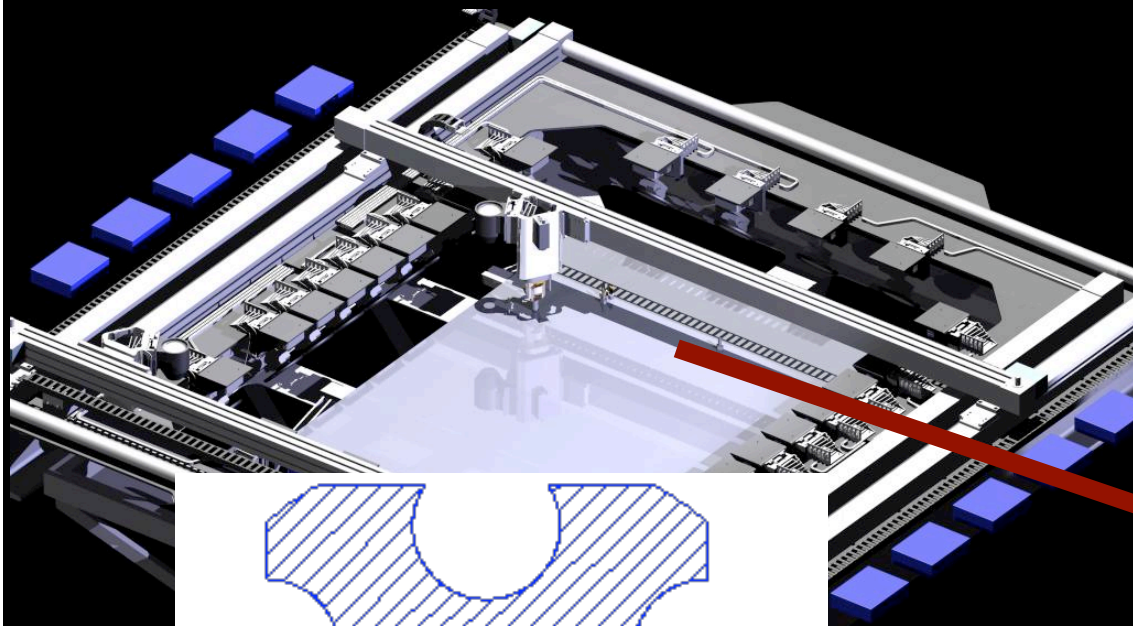


EAGLE Baseline Design





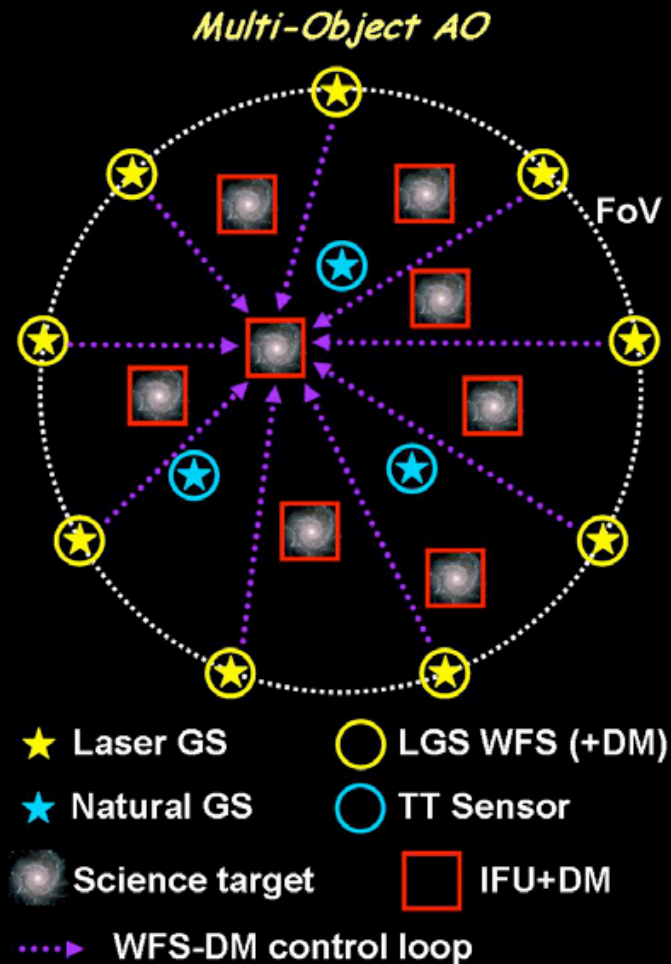
EAGLE Baseline Design





EAGLE AO

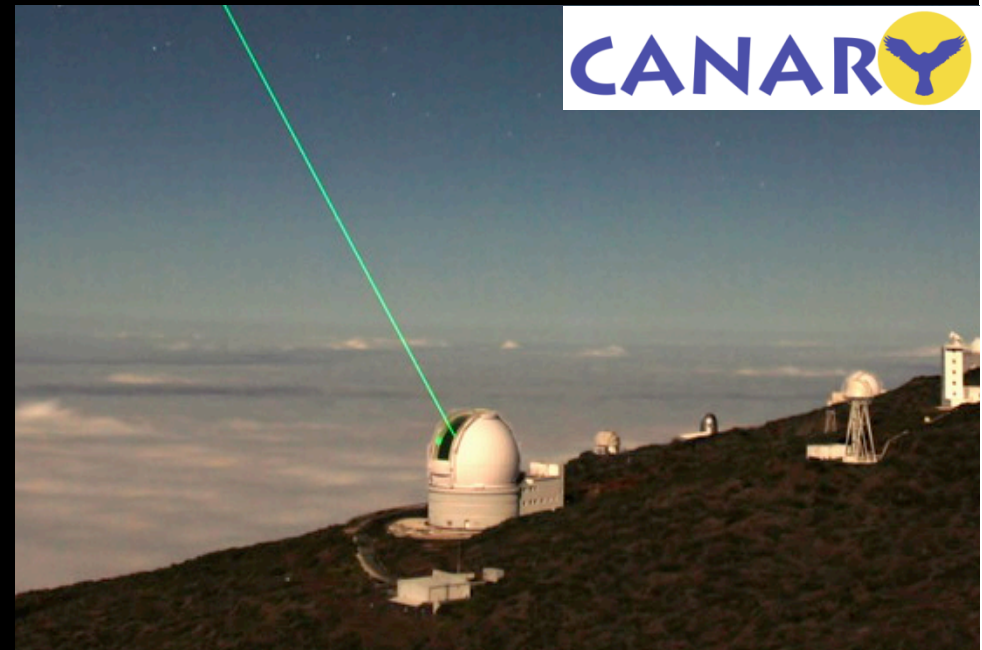
Multi-Object Adaptive Optics (MOAO)



© E. Marchetti / ESO / 2005

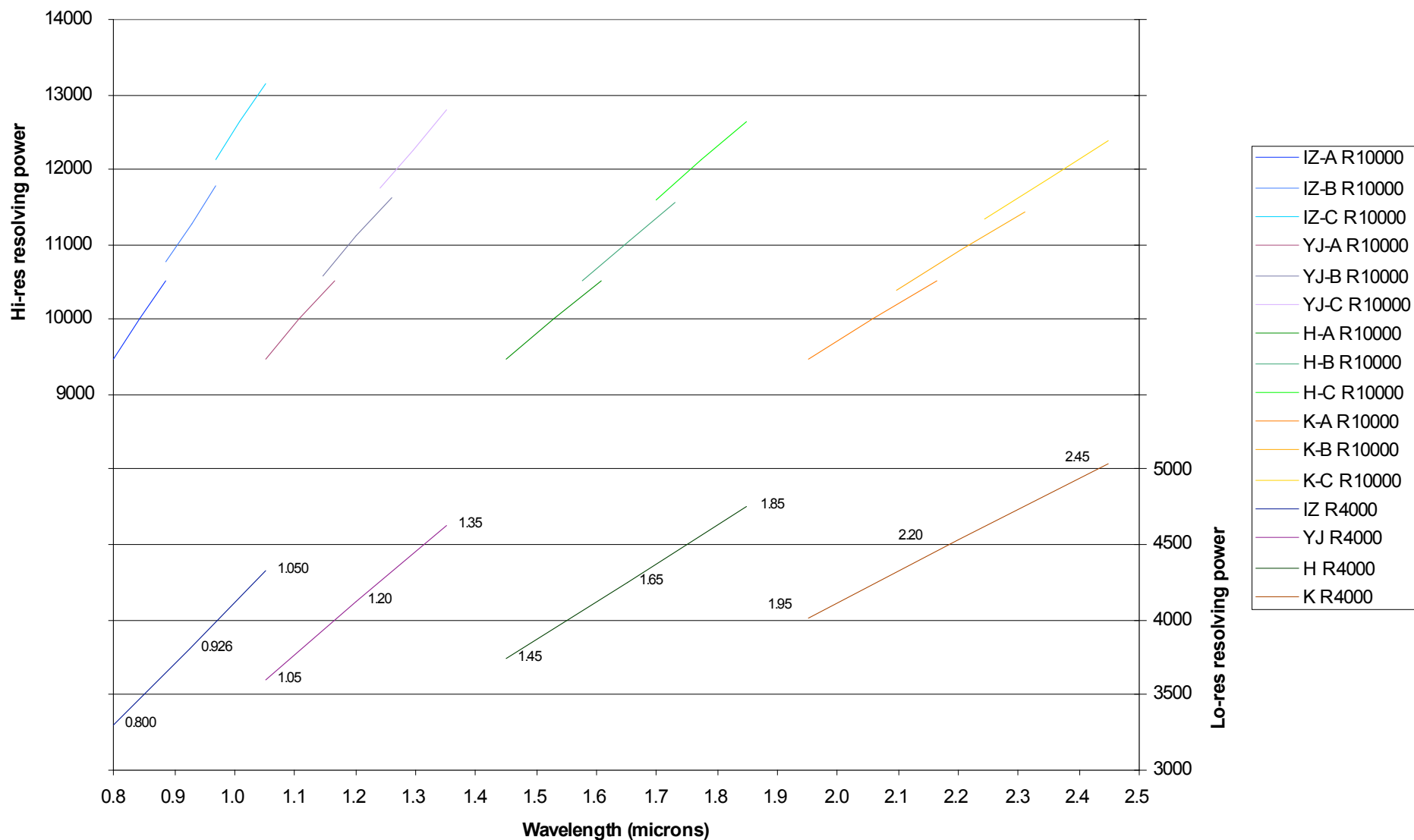
CANARY: 2010-2012:

- Demonstrate MOAO in EAGLE config.
- Improve real-time control techniques
- Develop calibration techniques





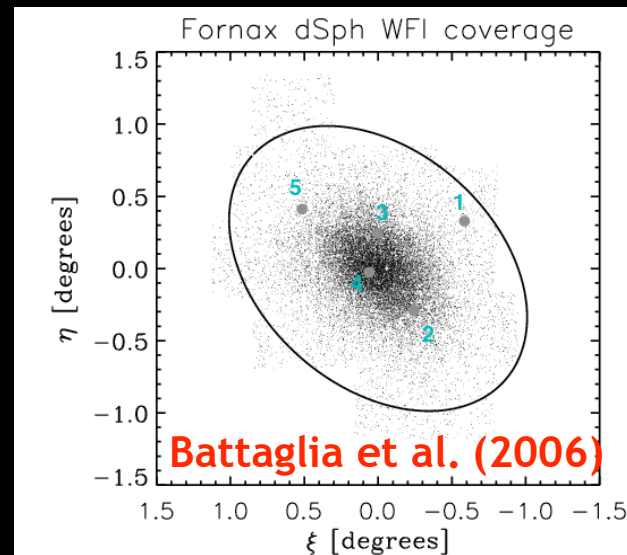
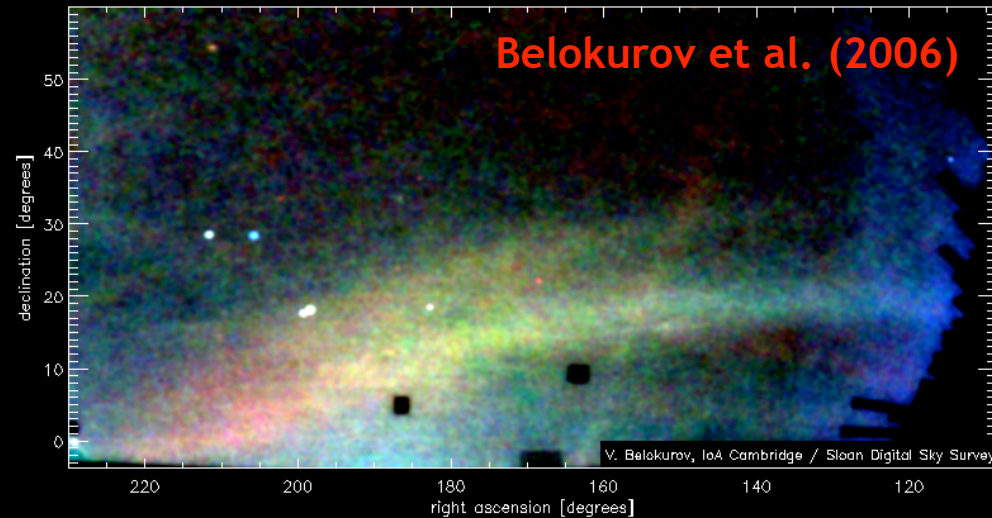
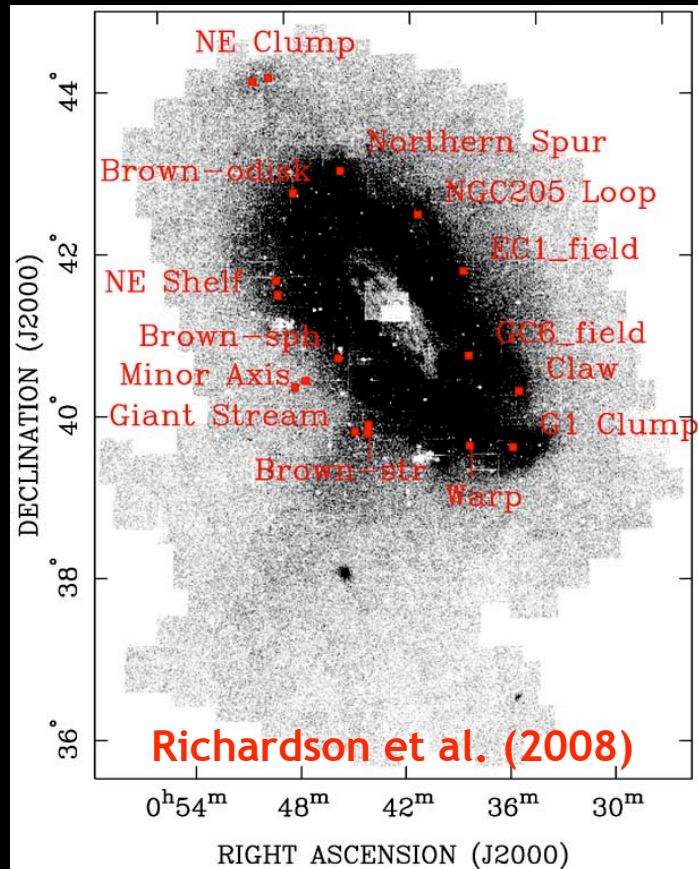
EAGLE: Spectral Coverage





The 8-m era

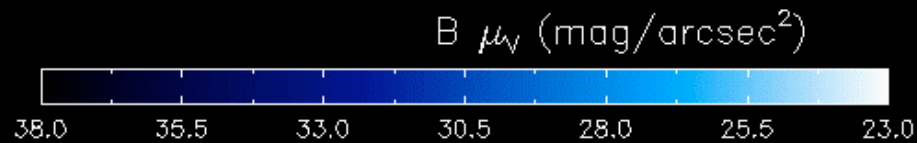
Resolved Stellar Populations in the Local Group



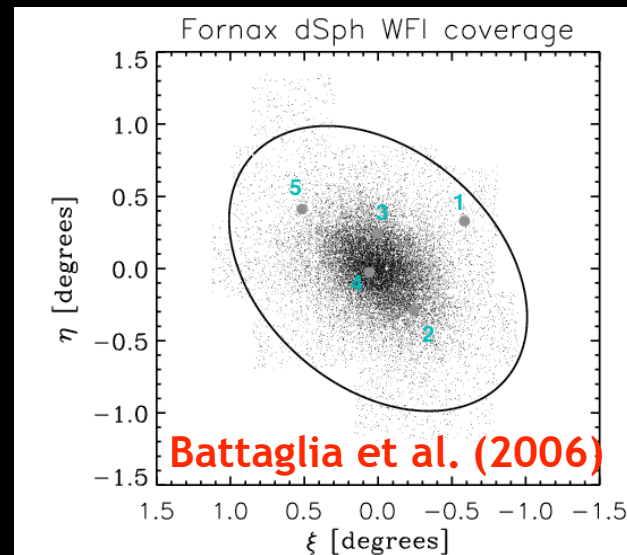


The 8-m era

Resolved Stellar Populations in the Local Group



Bullock, Johnston et al.

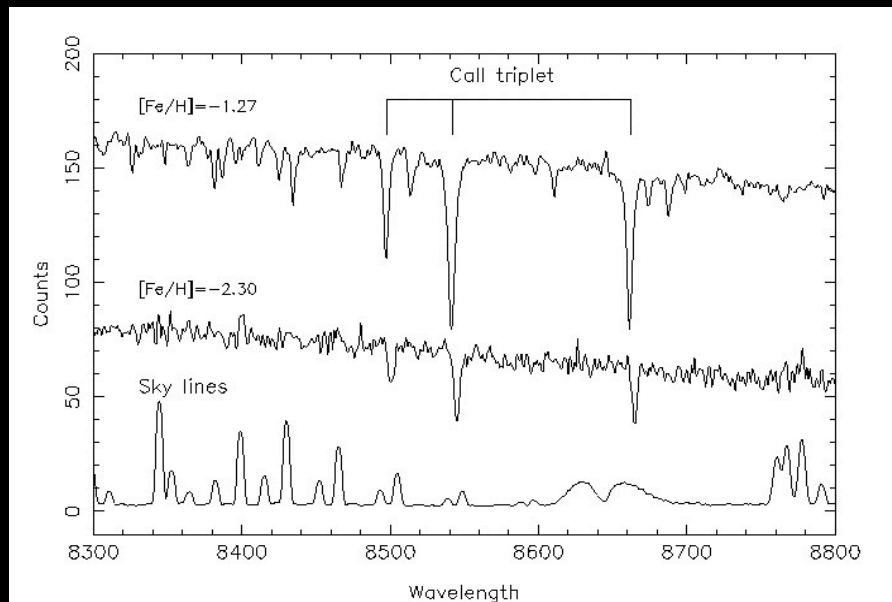




Spectroscopy of Resolved Stellar Populations

Abundances & kinematics

Moderate-resolution spectroscopy
of the Ca Triplet @860nm



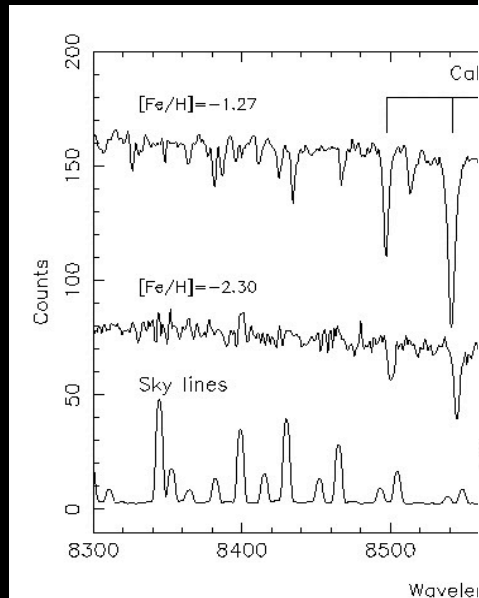
Tolstoy et al (2001)



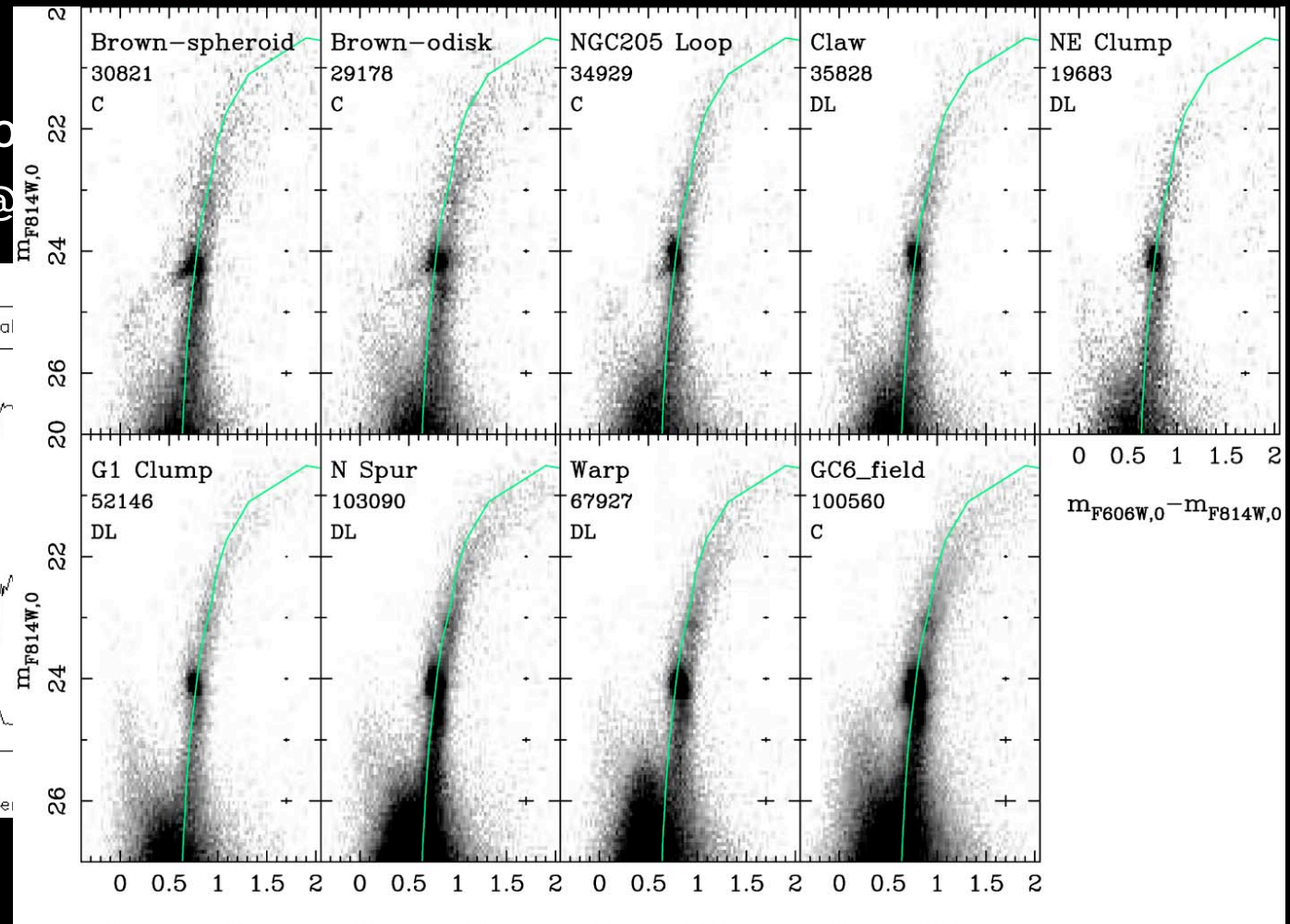
Spectroscopy of Resolved Stellar Populations

Abundances & kinematics

Moderate-resolution
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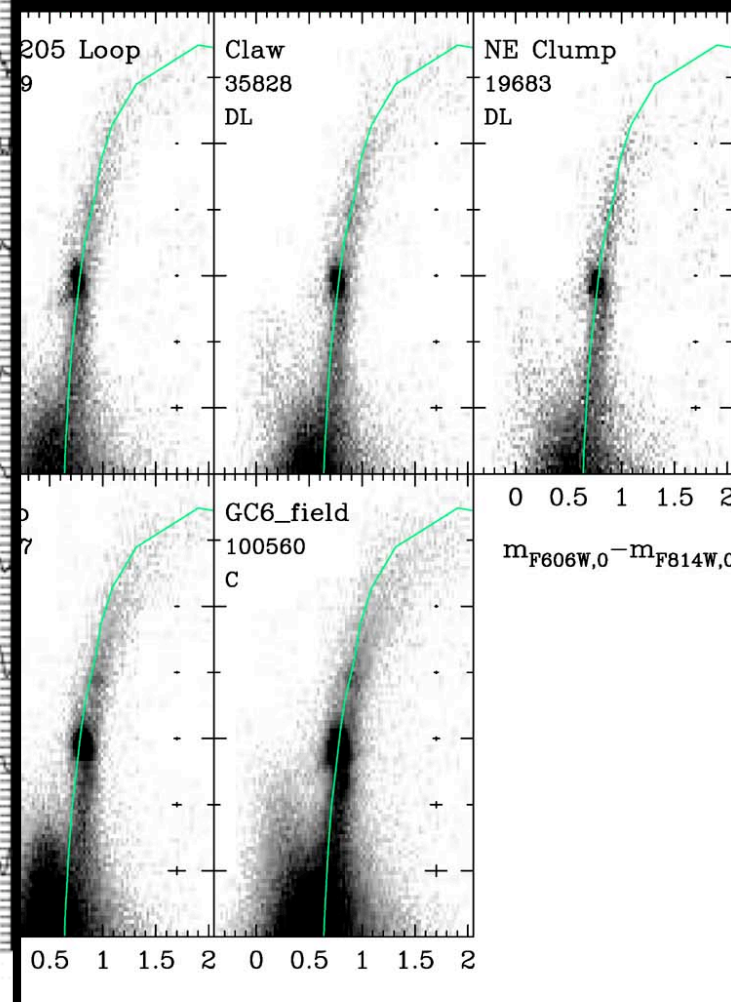
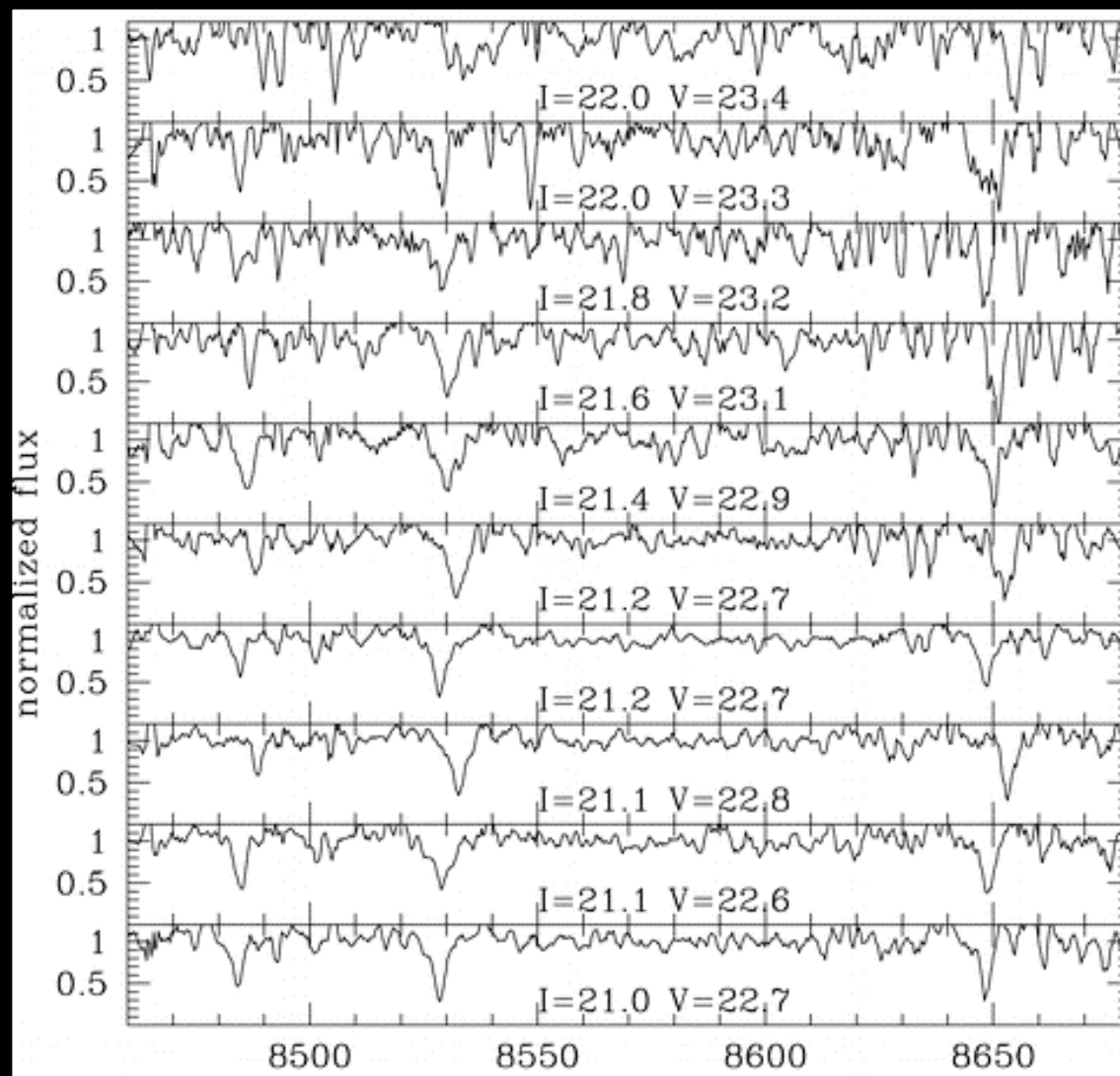


Tolstoy et al (2001)



Richardson et al. (2008)

Spectroscopy of Resolved Stellar Populations



KECK-DEIMOS in M31 Chapman et al. (2006)

Richardson et al. (2008)



The ELT era

Resolved Stellar Populations in the Local Volume

E-ELT/EAGLE will unlock a huge range of new targets, including:

- NGC 3109 & Sextans A (1.3 Mpc)
- Spiral-dominated Sculptor Group (2-4 Mpc)
- M83/NGC5128 grouping (4-5 Mpc)
- NGC3379 (11 Mpc)
- Virgo Cluster galaxies (16-17 Mpc)





EAGLE DRSP

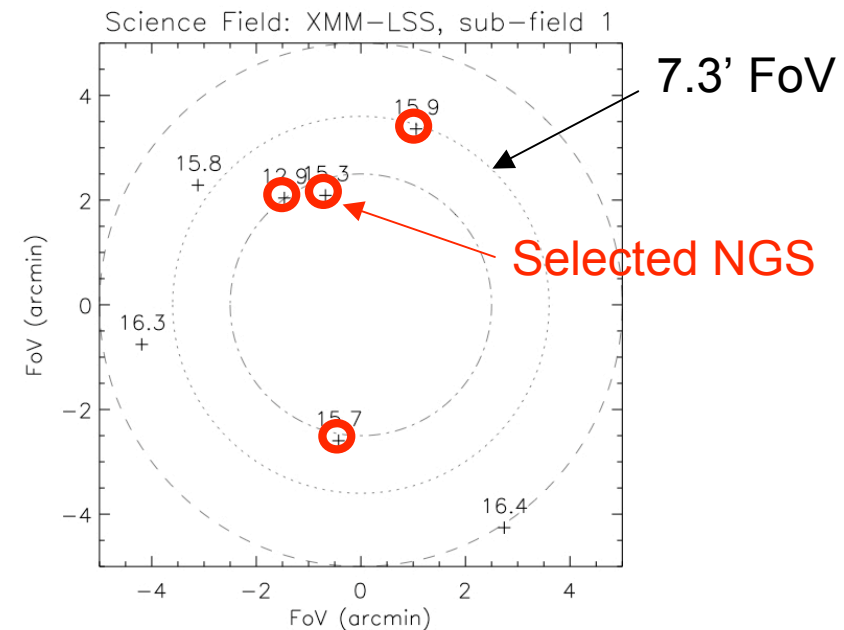
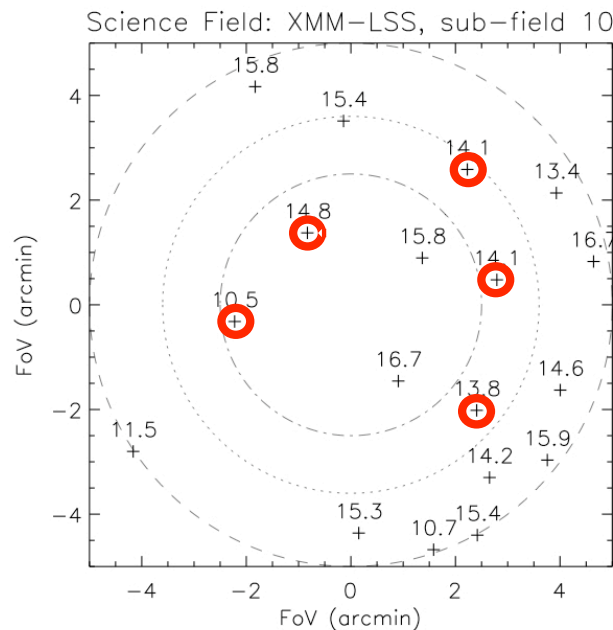
Formation & evolution of galaxies in the Sculptor “Group”

- Five spirals & numerous dwarfs
- Two distinct components:
 - NGC 55 & NGC 300 @ 1.9 Mpc
 - NGC 247, NGC 253 & NGC 7793 @ 3.6 Mpc
- Masses in the range $1.5\text{--}8 \times 10^8 M_{\text{sun}}$
- Excellent test for N-body/analytical models that struggle to reproduce the structure of late-type, lower mass spirals



MOAO performances

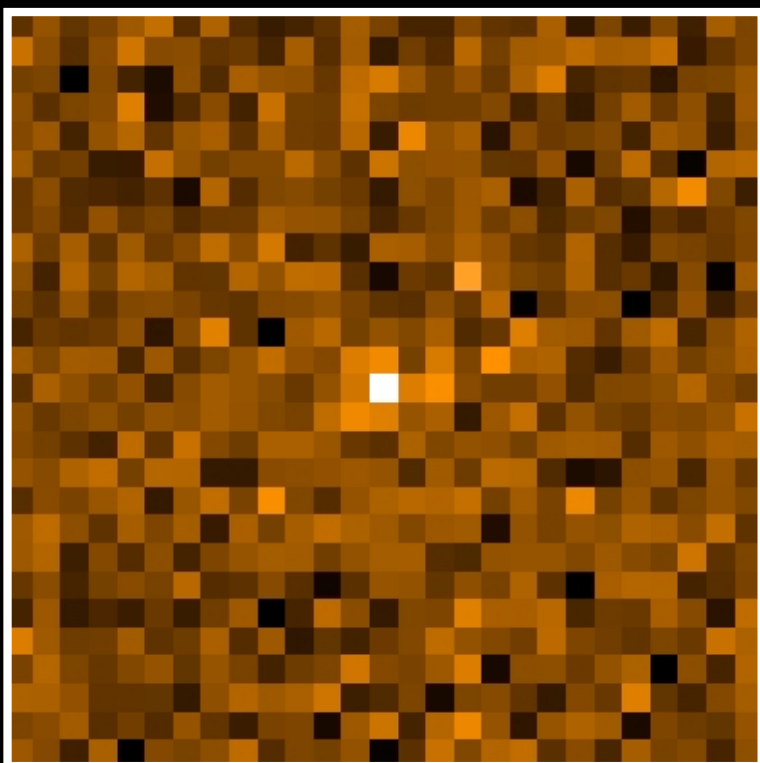
- MOAO PSFs from Francois Assemat et al. (ONERA)
- Seeing: 0.65" and 0.8"
- 84x84 DM; 2 x NGS configurations





MOAO performances

- MOAO PSFs from Francois Assemat et al. (ONERA)
- Seeing: 0.65" and 0.8"
- 84x84 DM; 2 x NGS configurations



42m primary

10 hr integration (20x1800s)

$\Delta\lambda = 8400\text{-}8750\text{\AA}$ @ $R = 10,000$

37.5 mas spaxels

1x1 arcsec IFU

Total th'put = 0.19

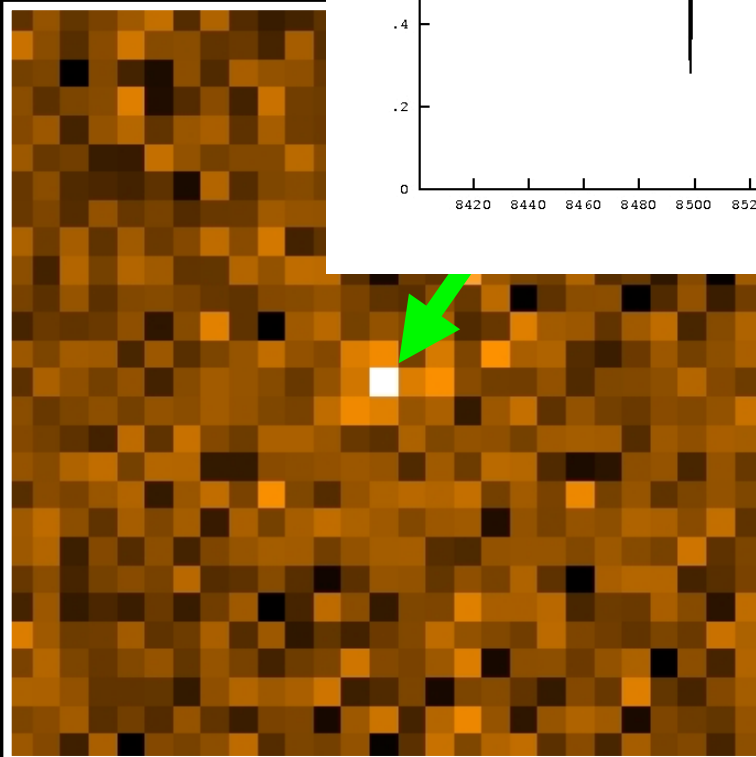
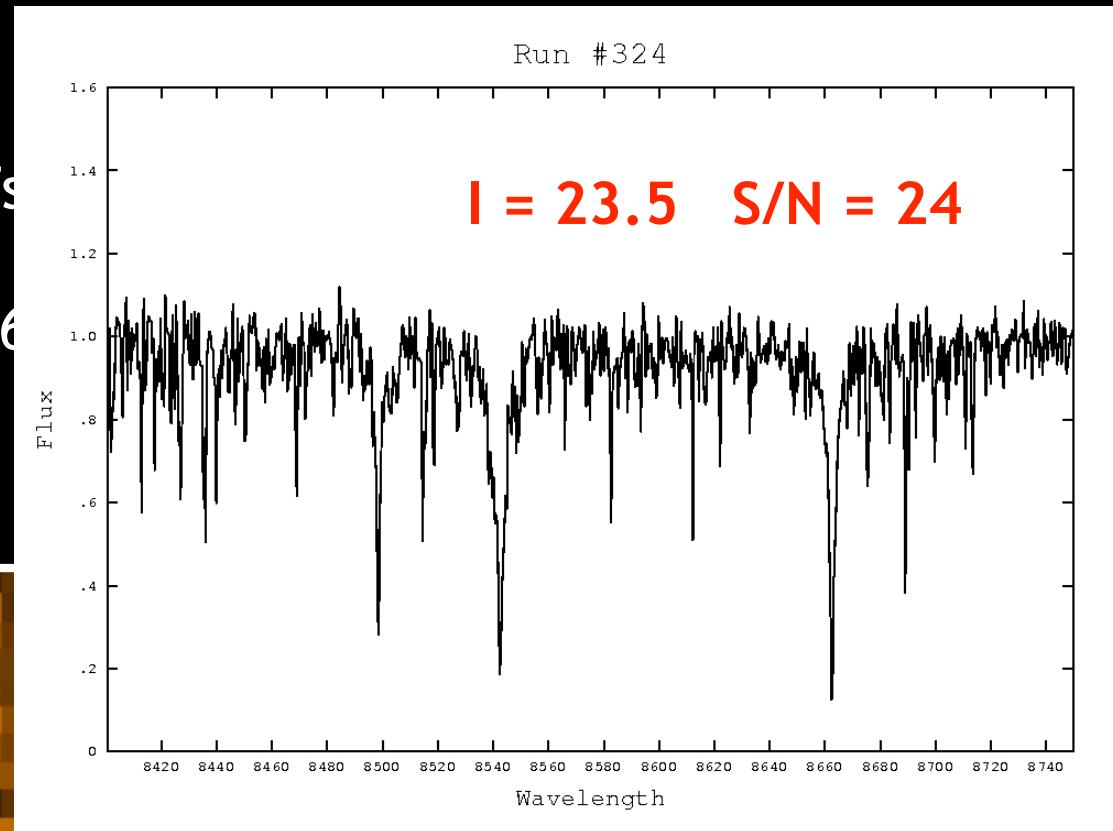
Ulisse Munari's spectral library

RON = 5e/pix, dark = 0.01e/pix/s

Puech et al. (2008)



- MOAO PSFs
- Seeing: 0.6
- 84x84 DM;



37.5 mas spaxels

1x1 arcsec IFU

Total th'put = 0.19

Ulisse Munari's spectral library

RON = 5e/pix, dark = 0.01e/pix/s

Puech et al. (2008)



EAGLE CaT performance

- Seeing = 0.8", 84x84 DM
- $t_{\text{exp}} = 20 \times 1800\text{s}$
- $R = 10,000$

NGS config 10

I (Vega)	S/N
22.5	42
23.5	24
24.5	11

NGS config 1

I (Vega)	S/N
22.5	25
23.5	12
24.5	6

cf. E-ELT ETC: LTAO/50mas/R=10,000/I=24.5/M2V S/N=14



EAGLE CaT performance

- Seeing = 0.8", 84x84 DM
- $t_{\text{exp}} = 20 \times 1800\text{s}$
- $R = 10,000$

**4 mags deeper than
FLAMES LR08 observations**

NGS config 10

I (Vega)	S/N
22.5	42
23.5	24
24.5	11

NGS config 1

I (Vega)	S/N
22.5	25
23.5	12
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cf. E-ELT ETC: LTAO/50mas/R=10,000/I=24.5/M2V S/N=14



EAGLE CaT performance

- Seeing = 0.8", 84x84 DM
- $t_{\text{exp}} = 20 \times 1800 \text{s}$
- NGS config 10

R=10,000

I (Vega)	S/N
22.5	42
23.5	24
24.5	11

R=4,000

I (Vega)	S/N
22.5	70
23.5	35
24.5	15



HST GHOSTS Survey

De Jong, Radburn-Smith et al., see: www.stsci.edu/~djrs/ghosts

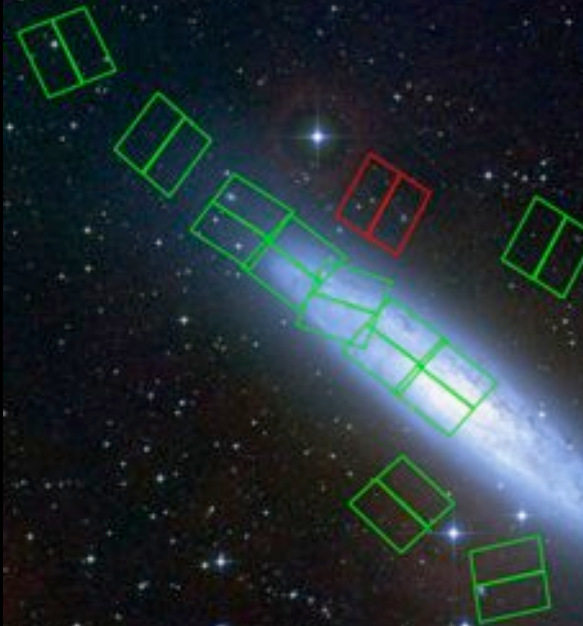
27 target galaxies out to ~17 Mpc

NGC0055



1.9 Mpc

NGC0253

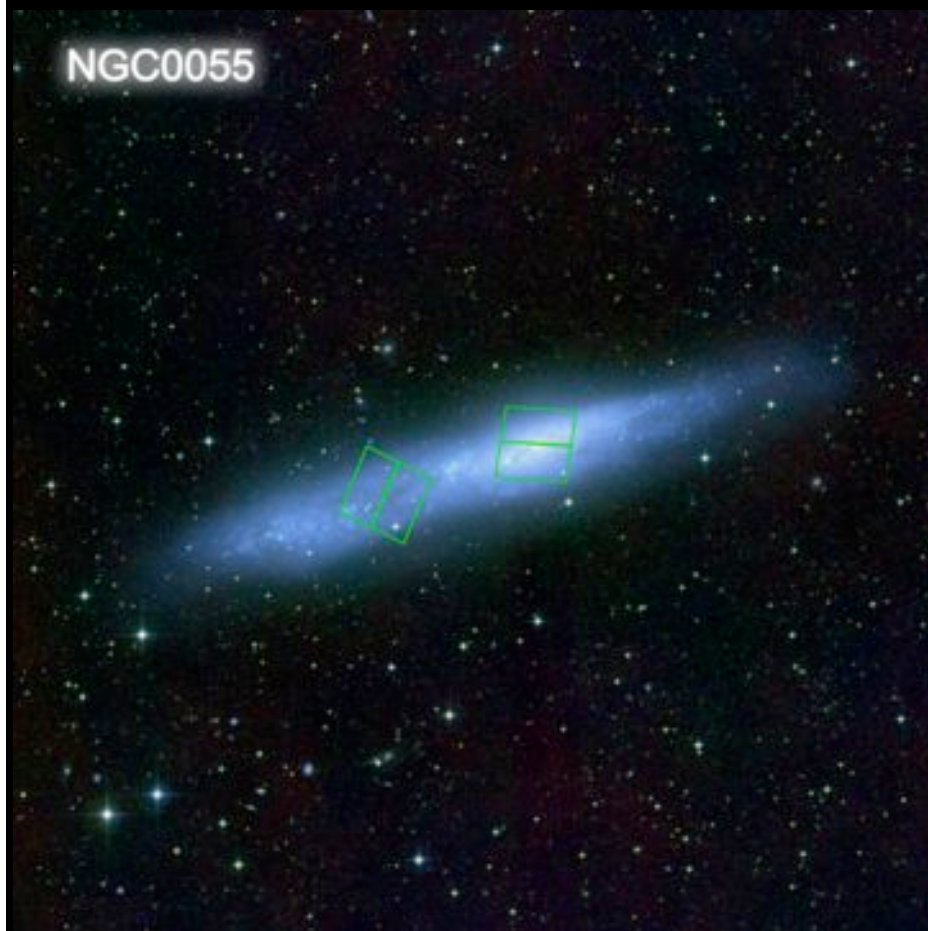


3.6 Mpc



EAGLE DRSP

ACS: F814W
[~3x3 arcmin]



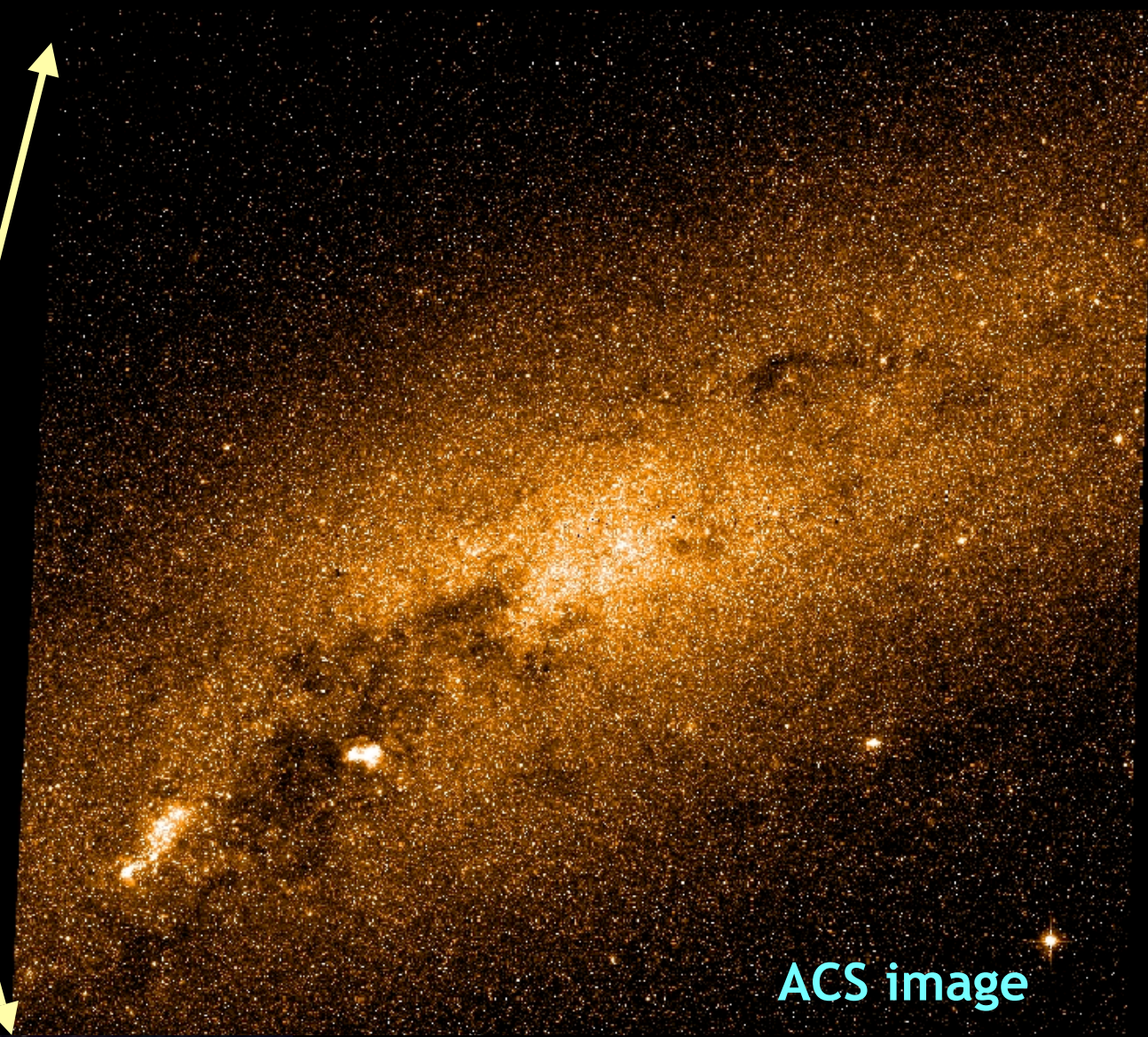
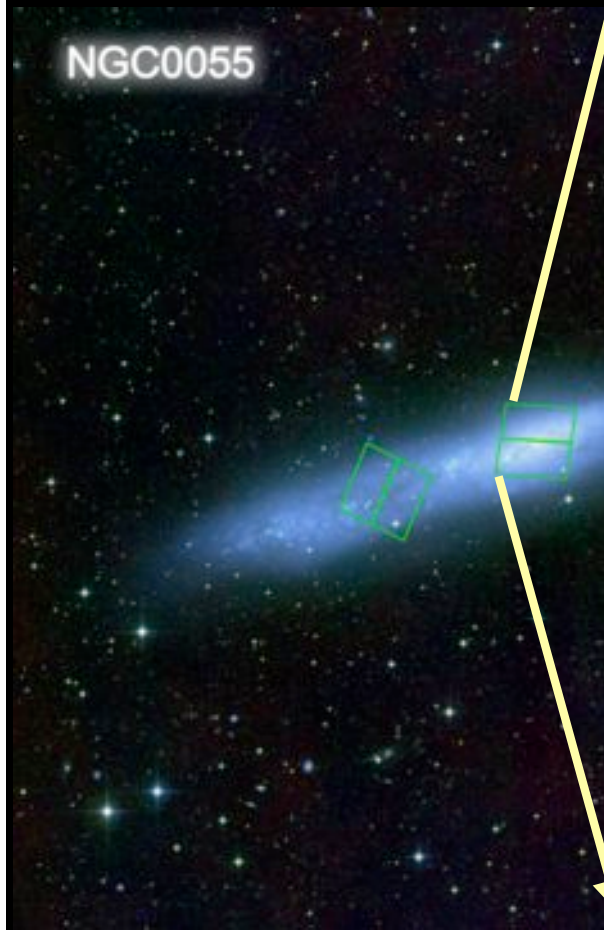


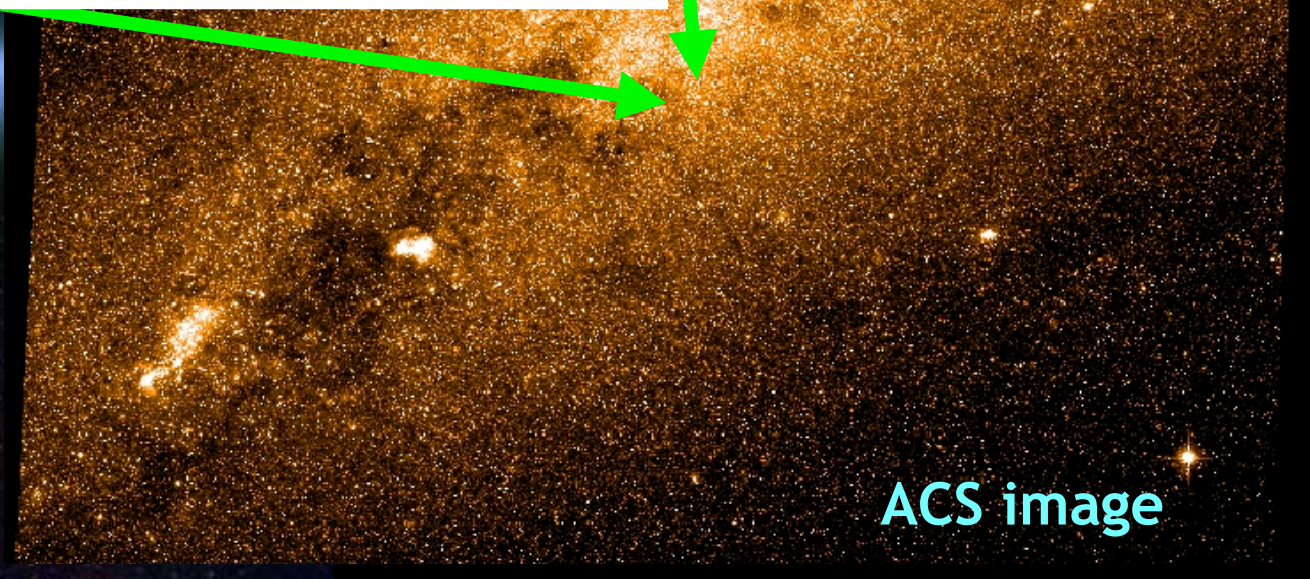
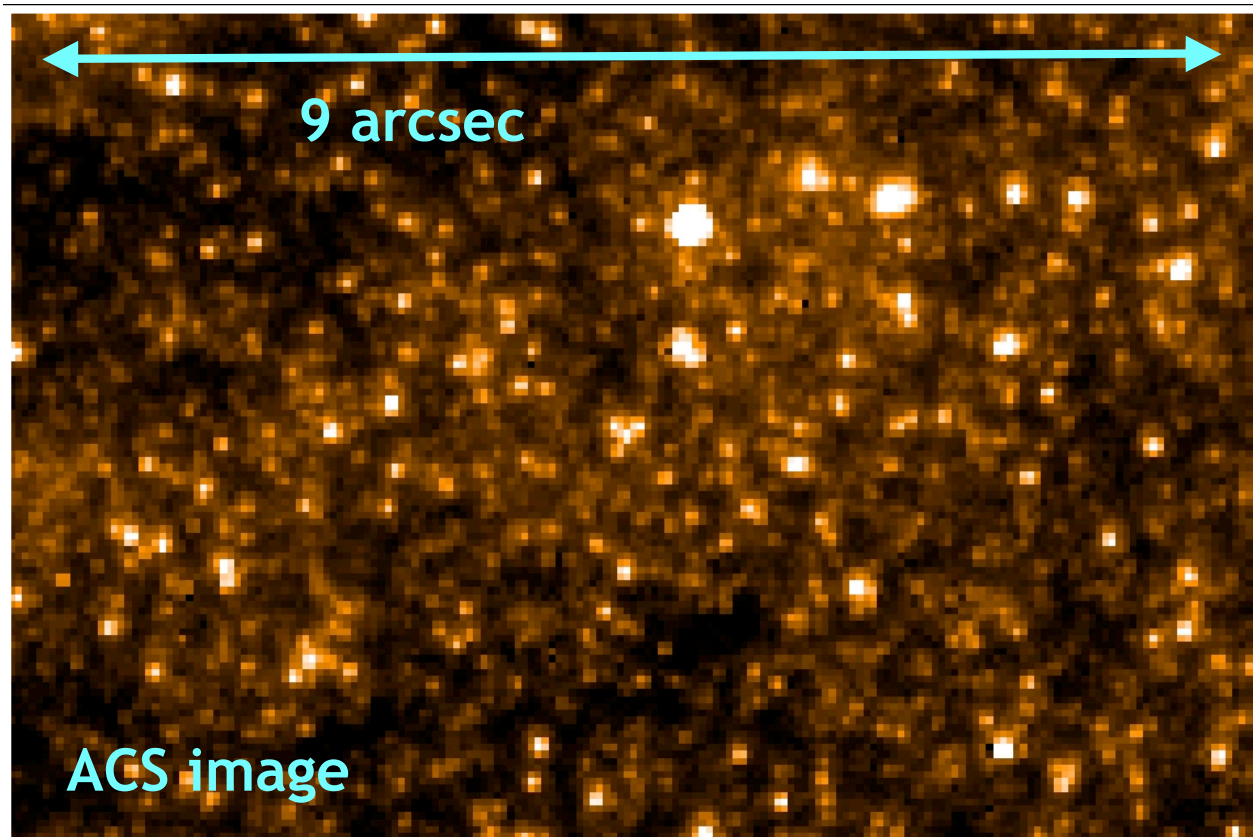
EAGLE DRSP

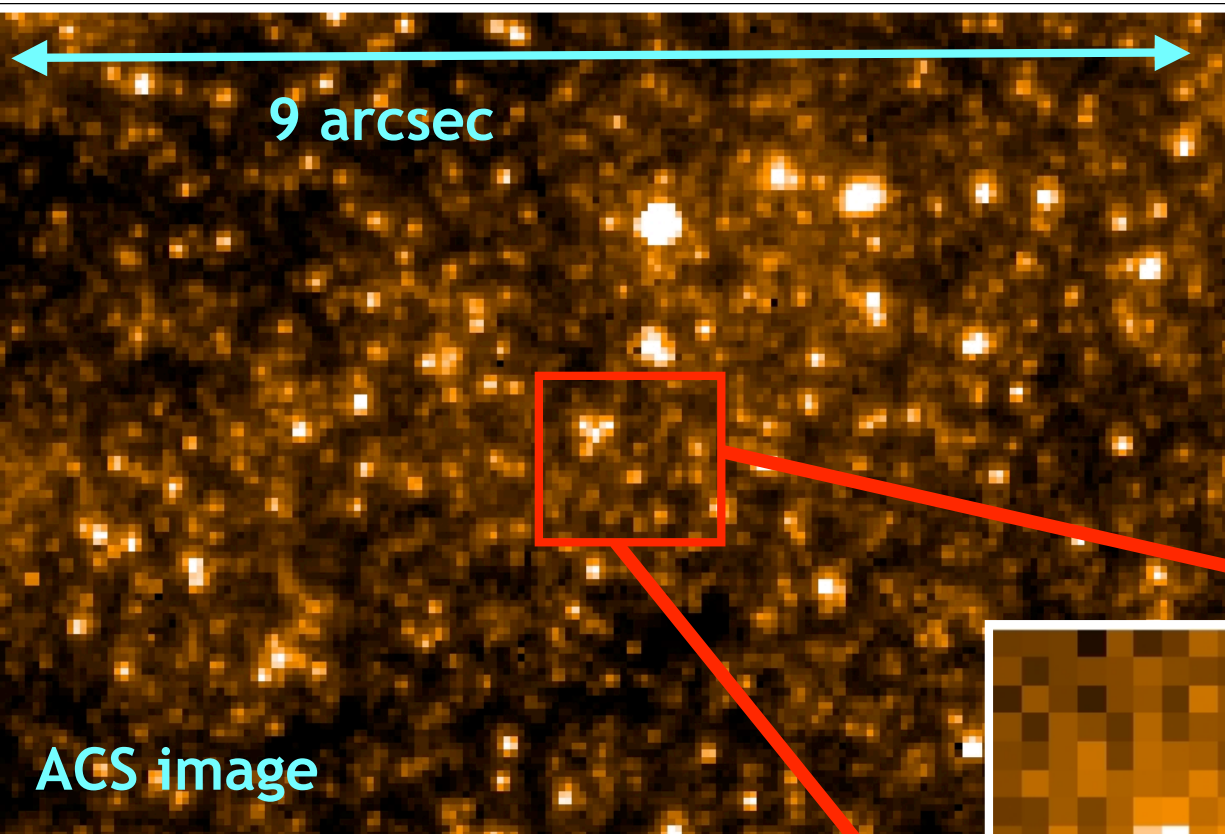
ACS: F814W
[~3x3 arcmin]

NGC0055

ACS image

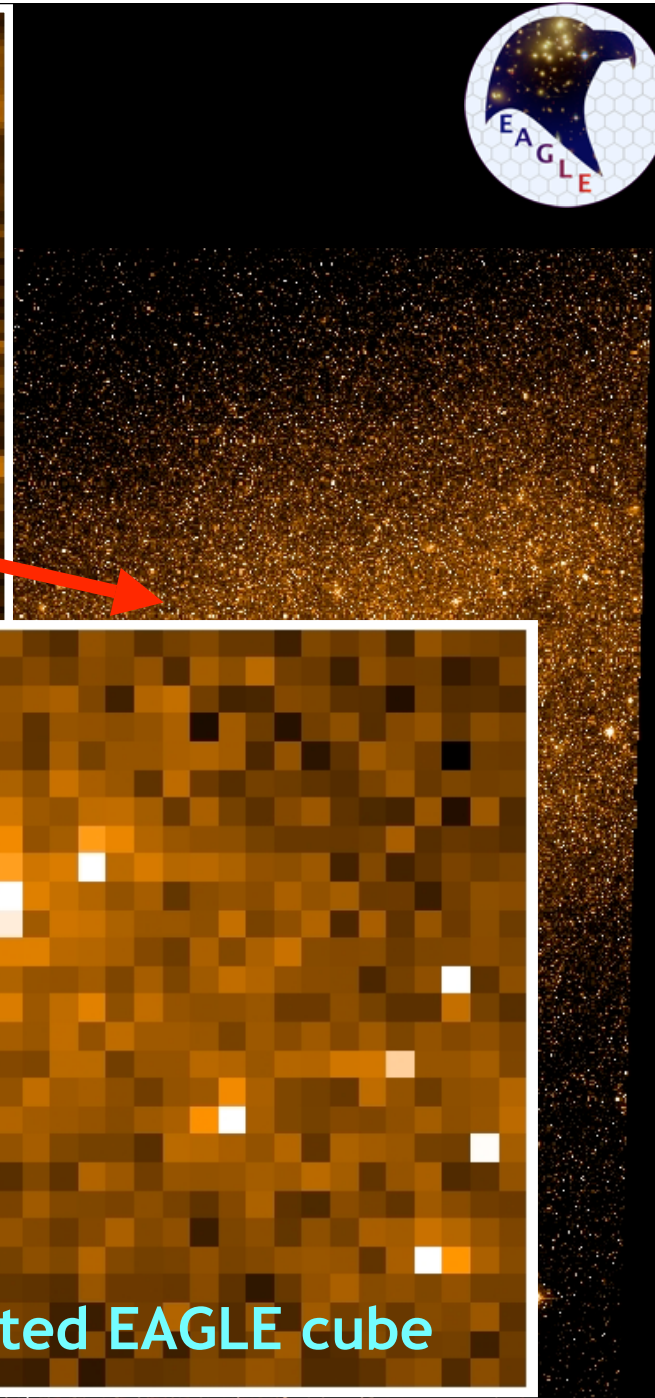






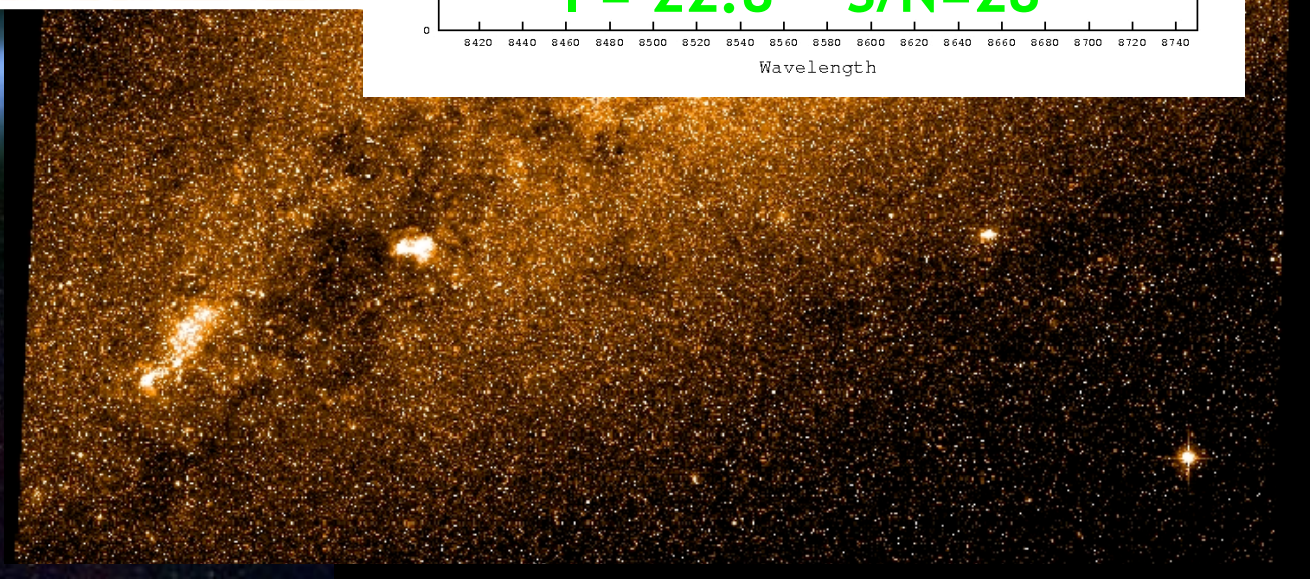
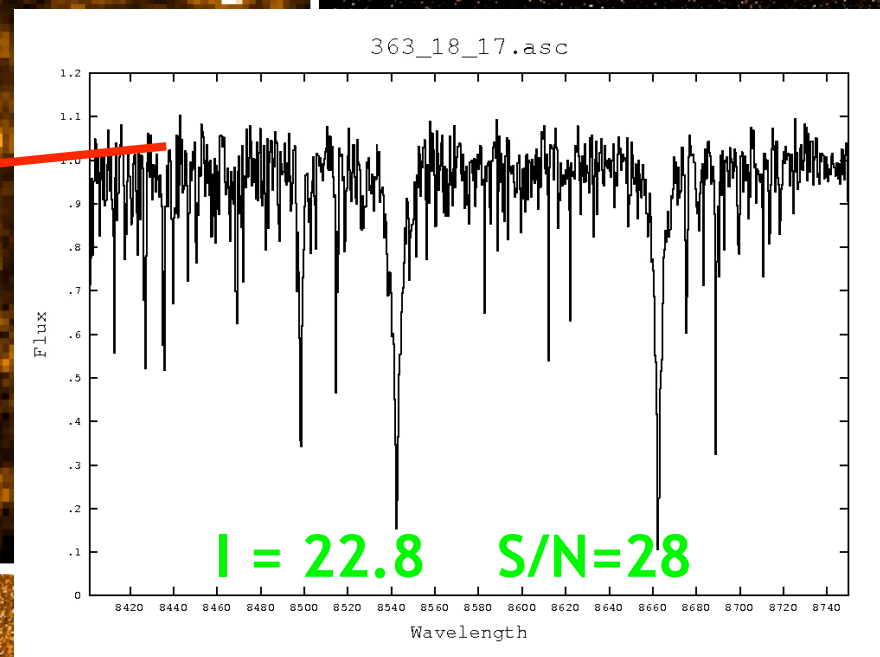
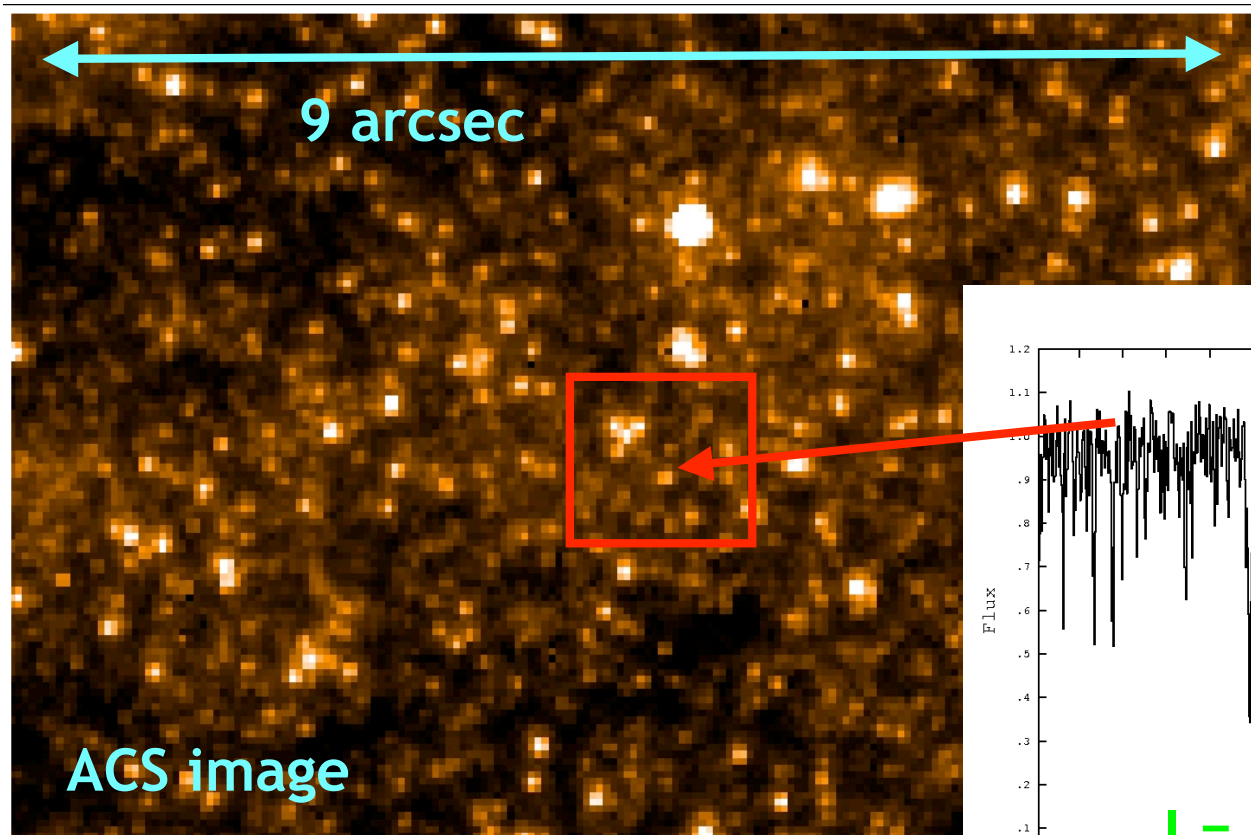
9 arcsec

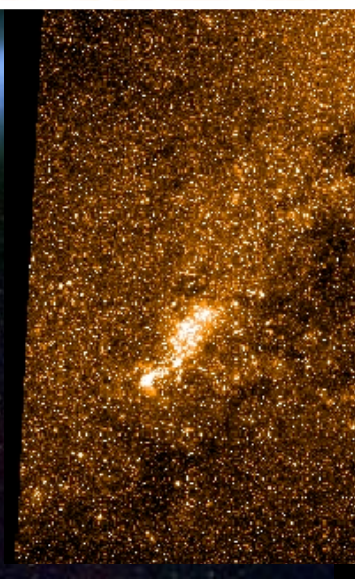
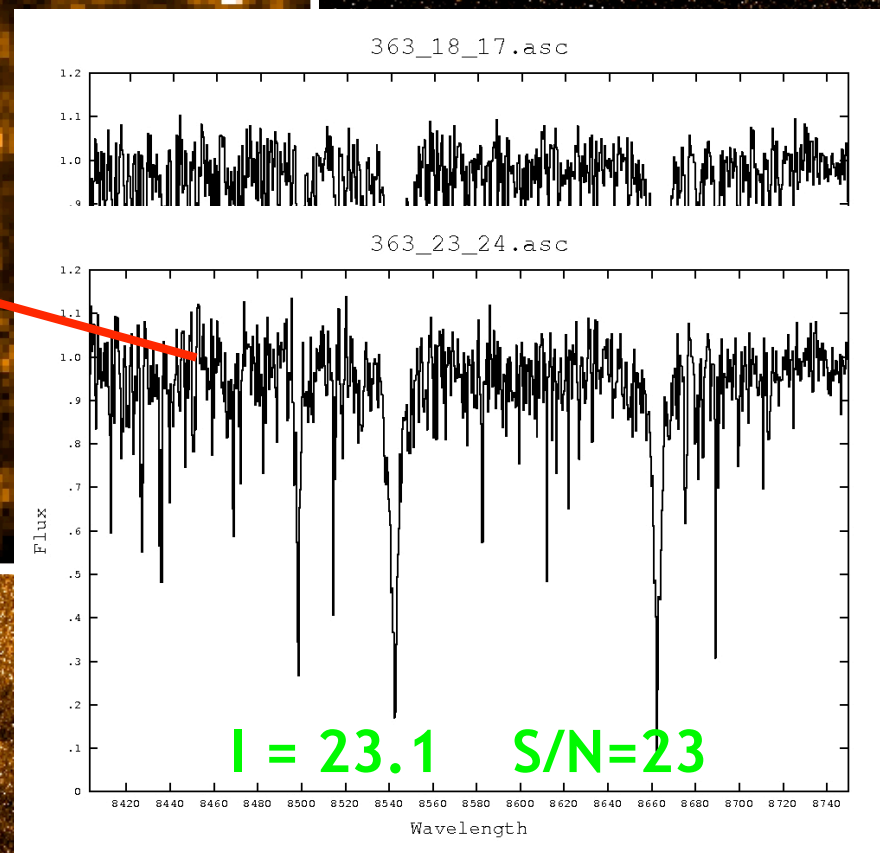
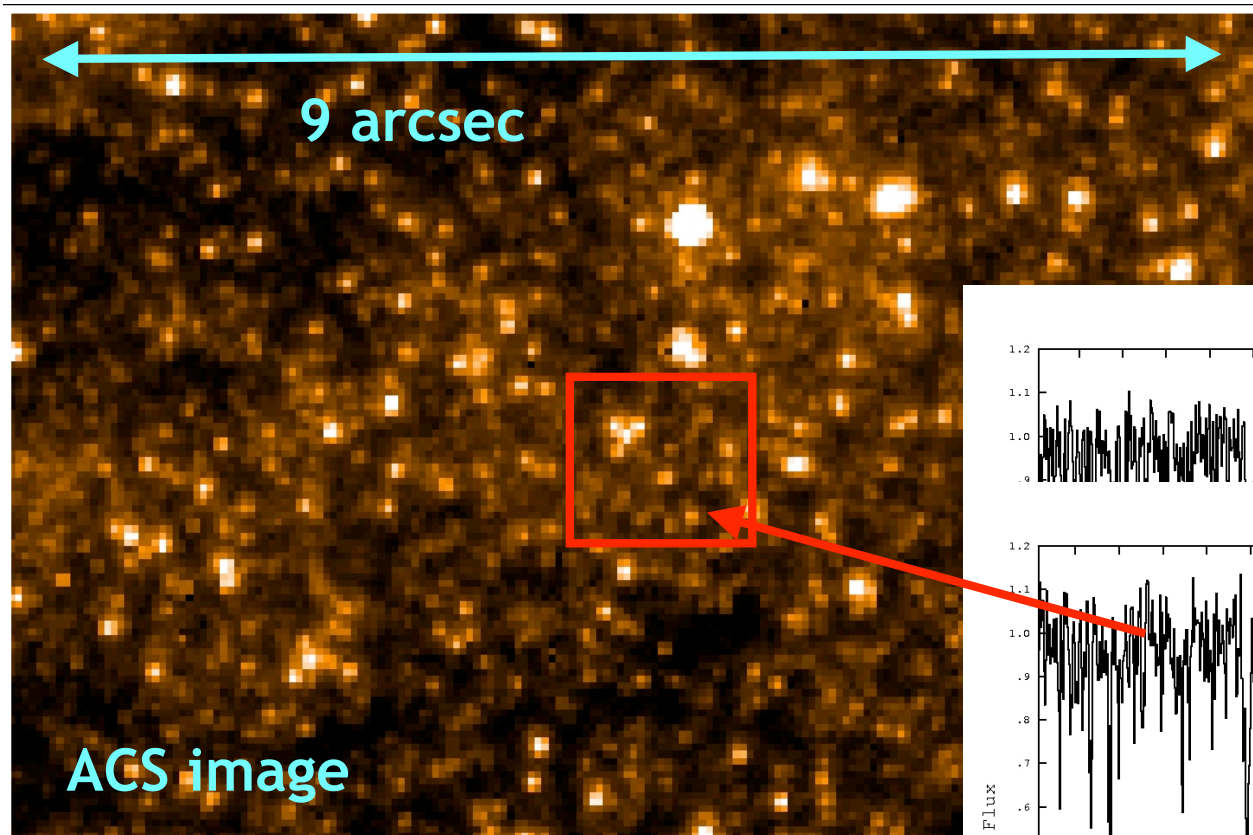
ACS image

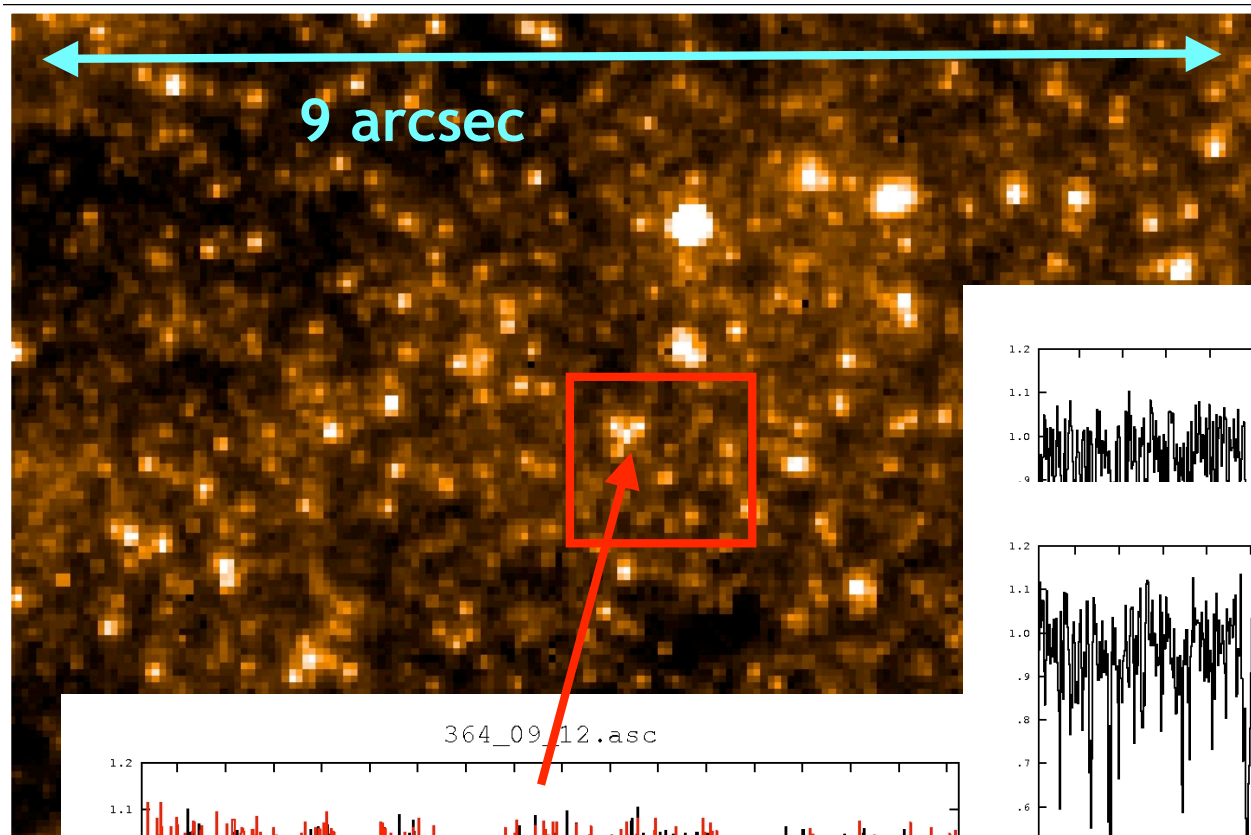


Simulated EAGLE cube



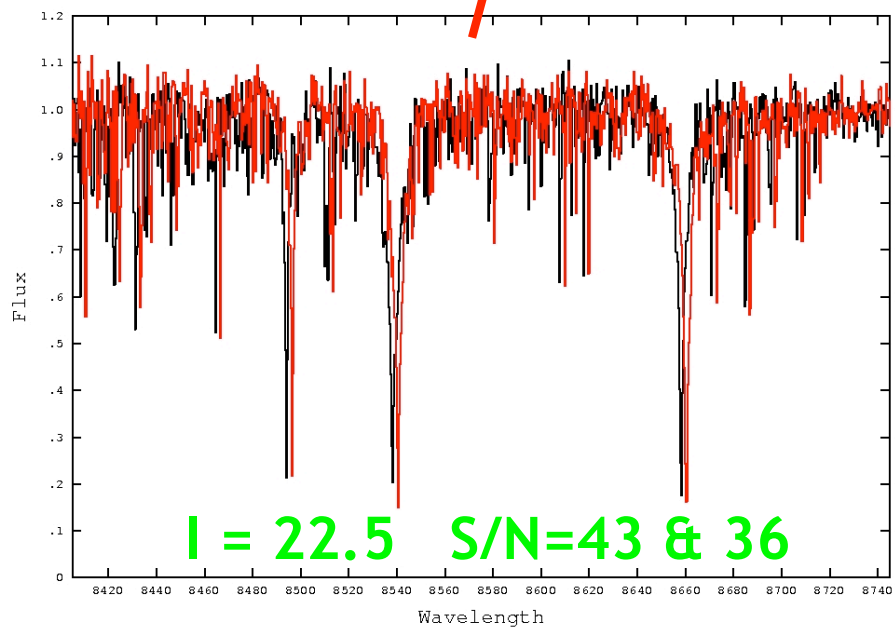






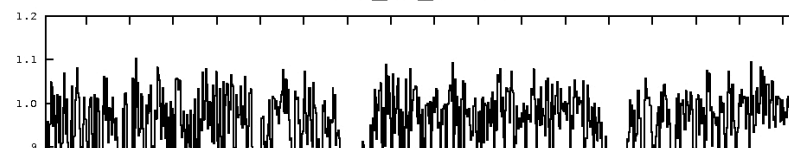
9 arcsec

364_09_12.asc

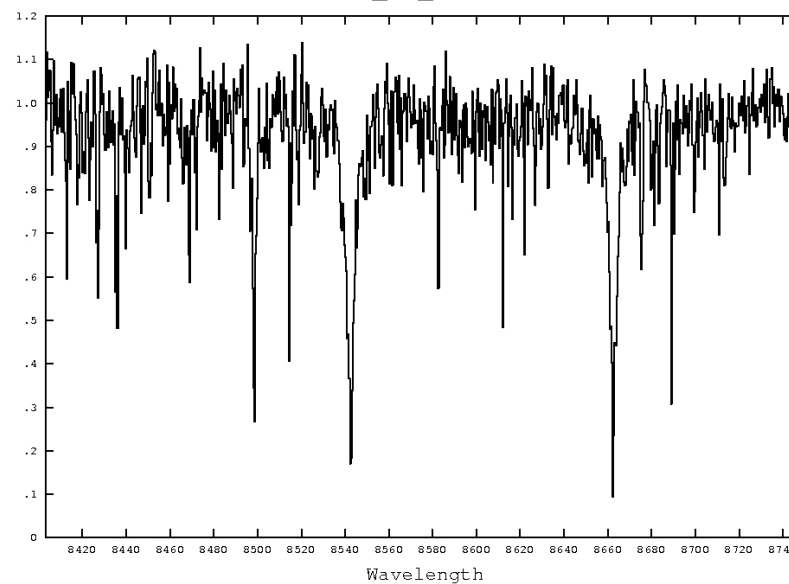


I = 22.5 S/N=43 & 36

363_18_17.asc



363_23_24.asc



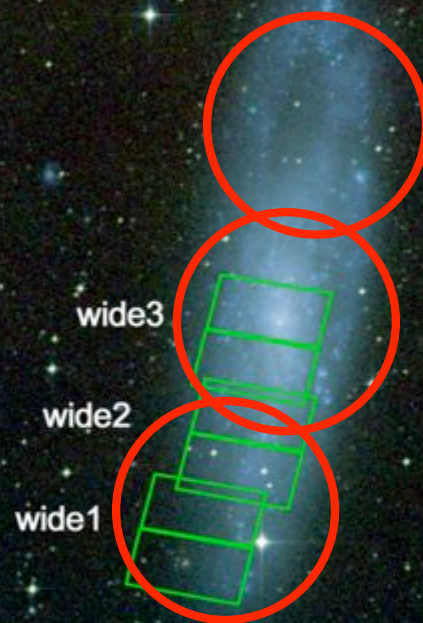


EAGLE DRSP

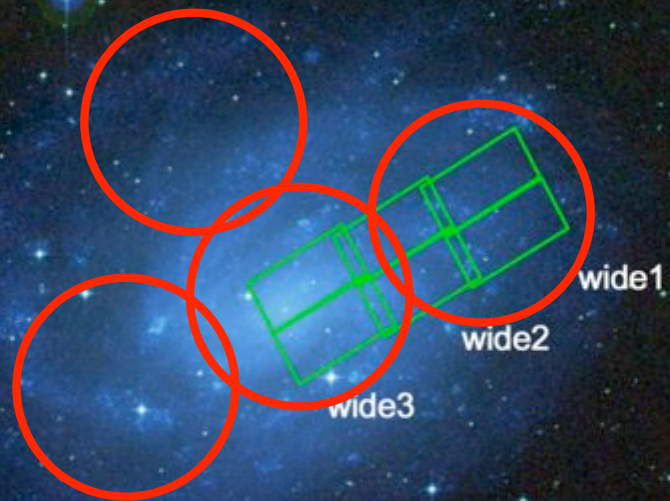
Formation & evolution of galaxies in the Sculptor “Group”

- CaT spectroscopy of the upper RGB ($-4 < M_I < -2$)
- 10 hrs/pointing: NGC 55, NGC 300
- 15 hrs/pointing: NGC 247, NGC 253, NGC 7793
- x19 pointings: **>1,000 stars in 240 hrs**

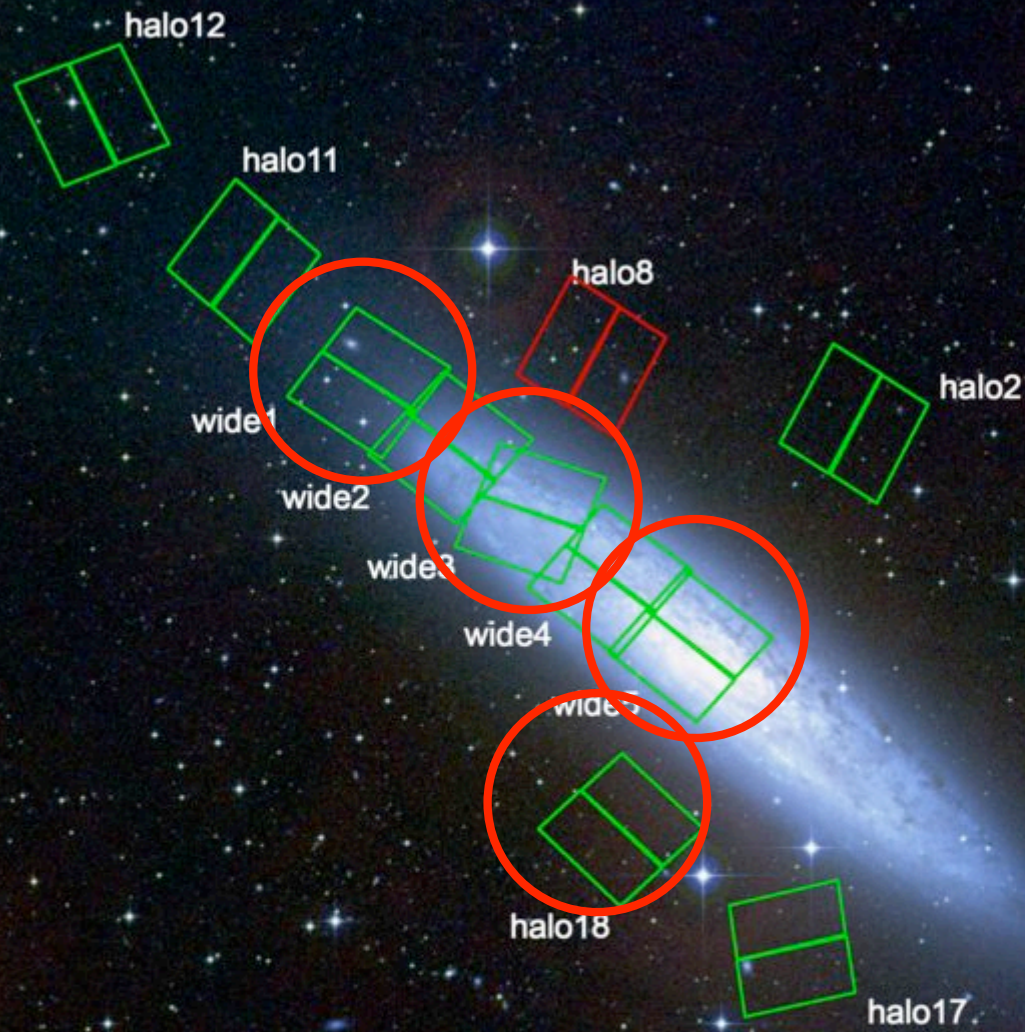
NGC0247



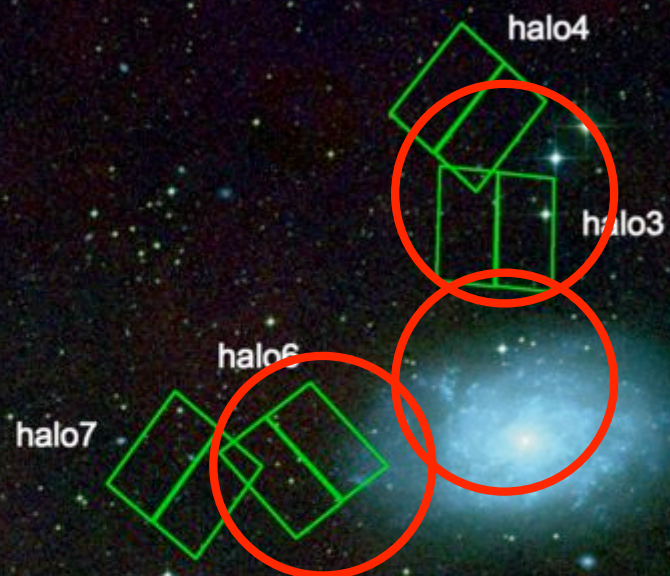
NGC0300



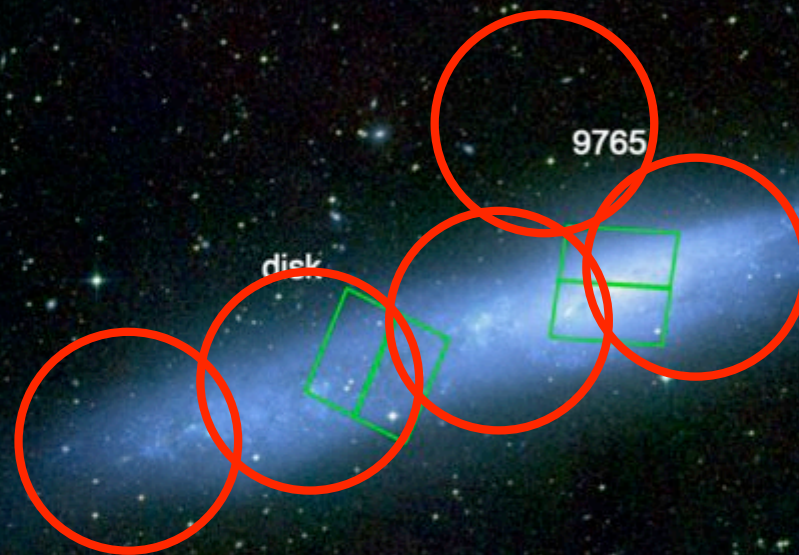
NGC0253



NGC7793



NGC0055





Summary

- $R=10,000$ CaT spectroscopy, $S/N > 10$ at $I \sim 24.5$ in 10 hrs
- Sculptor is just one conceivable “Large Programme”
- Multiple stars per IFU $\rightarrow$ much larger effective multiplex
- Large patrol field enables efficient surveys

