Caught in the Act of Quenching?

Local Volume Satellites with Ongoing Star Formation

Rachael L. Beaton
Carnegie Observatories

In Collaboration with:
David Martinez-Delgado (Heidelberg), **Elena D'Onghia** (Wisconsin),
Kelsey Johnson (U. Virginia/NRAO), **Steven Majewski** (U. Virginia),
Stefano Zibetti (INAF) & **Jay Gabany** (BlackBird Observatory)

What is Quenching?

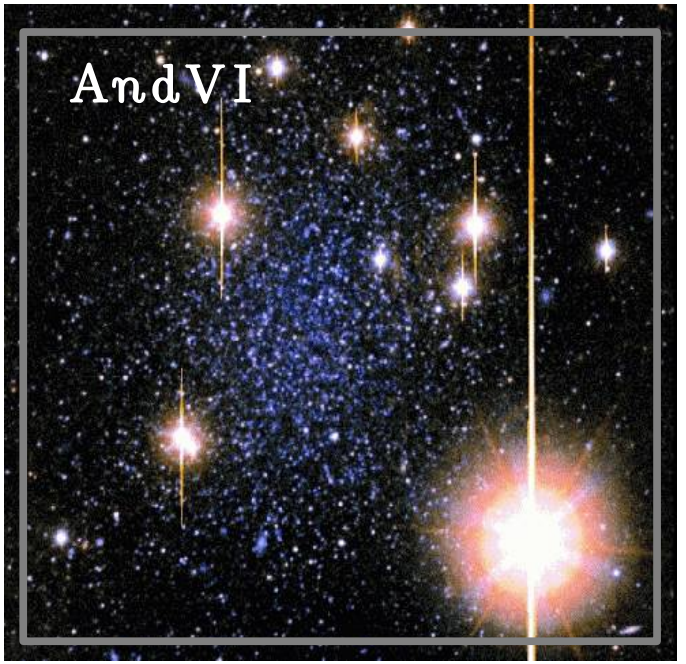
An evocative term describing morphological transitions in galaxies from gas-rich to gas-devoid.

RAM Pressure?

Tidal Stripping?

Star Formation?

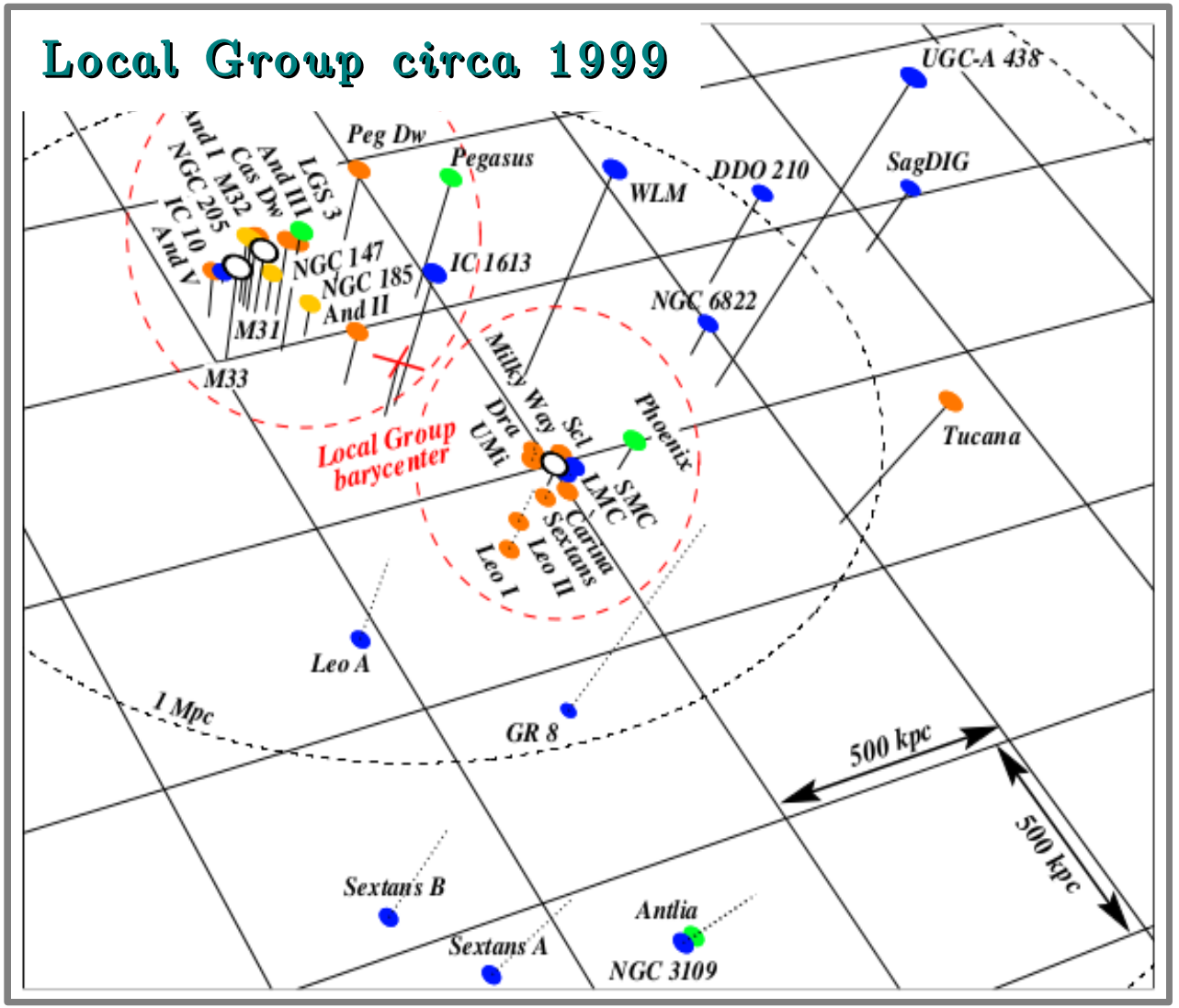
SN Blowout?



Field Dwarfs
dwarf Irregular

Satellites
dwarf Spheroidal

Density-Morphology Relationship



KEY

- dIrr
- dTrans
- dE
- dSph

Grebel et al. 1999

i.e.,pre-dwarf-splosion

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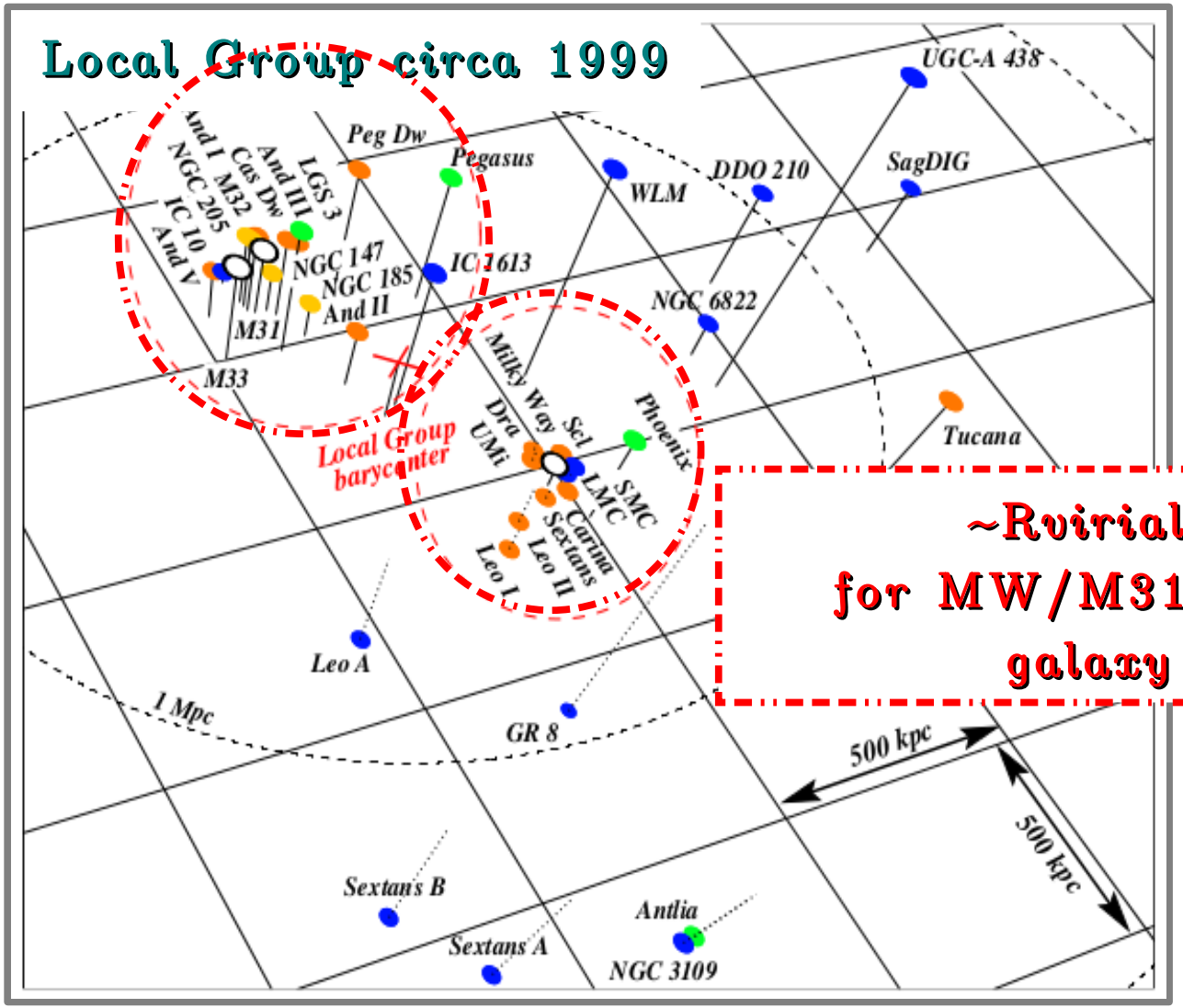

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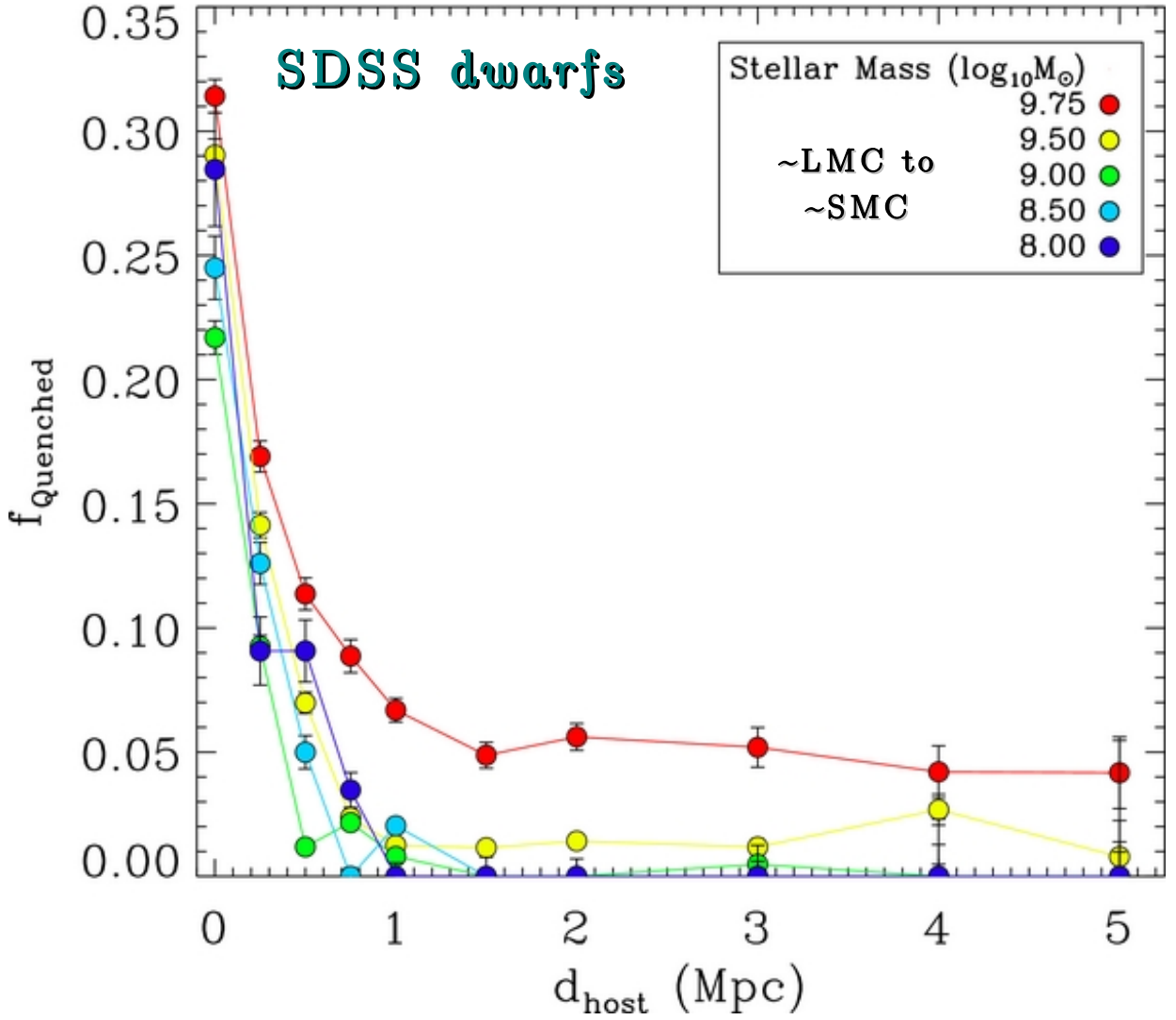
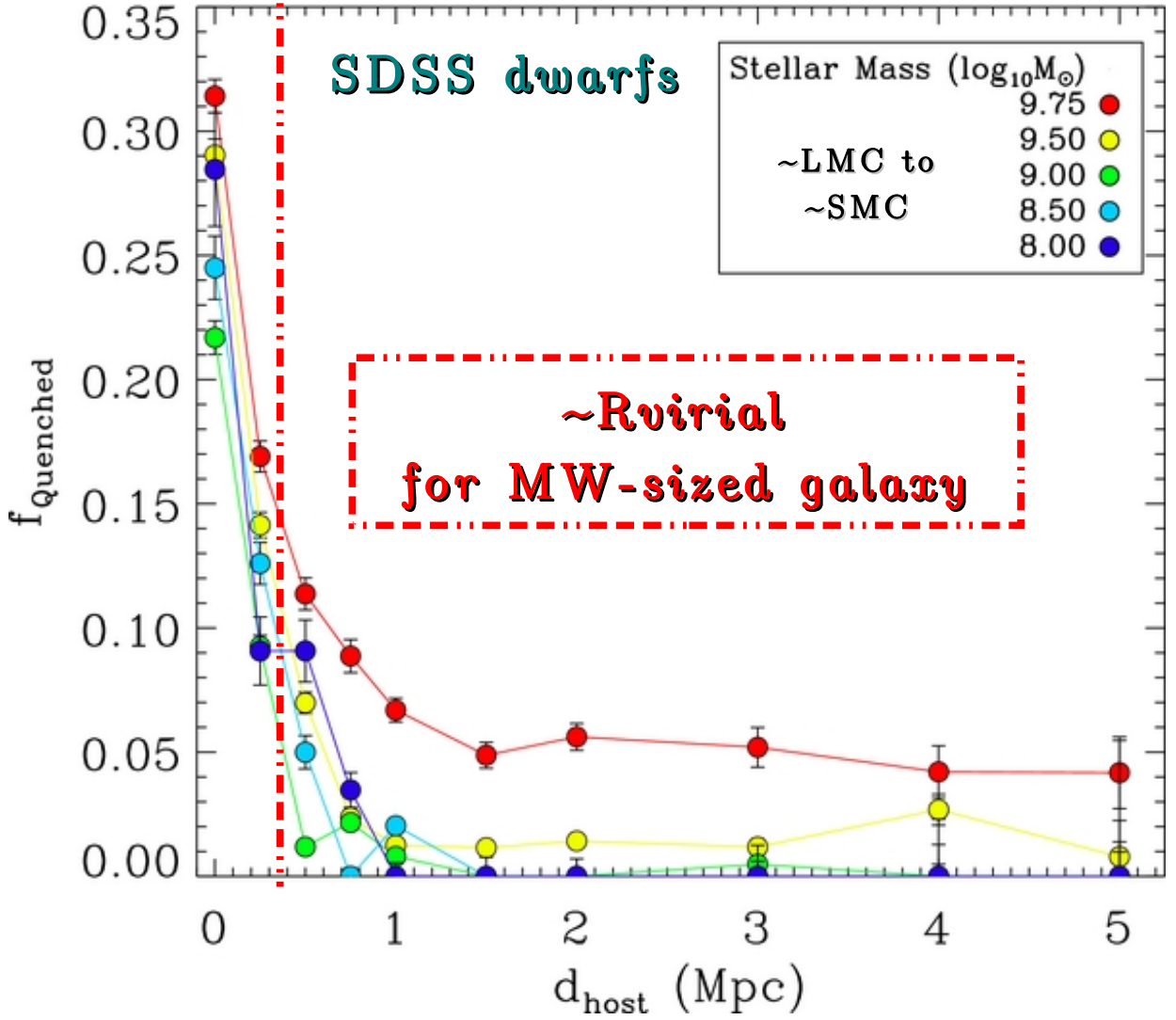
~Rvirial for MW/M31-sized galaxy

Not Just the Local Group



Geha et al. 2012

Not Just the Local Group



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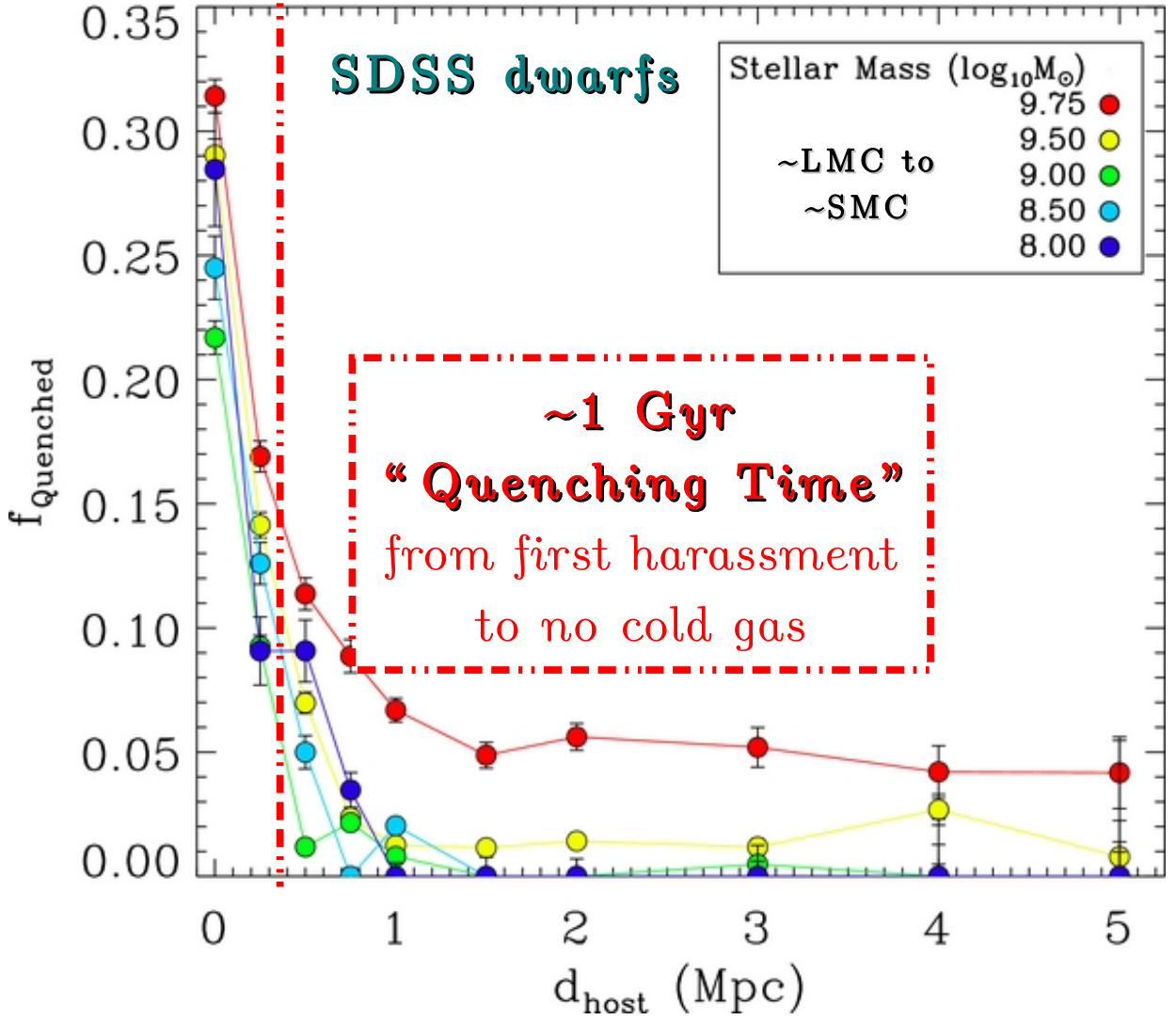
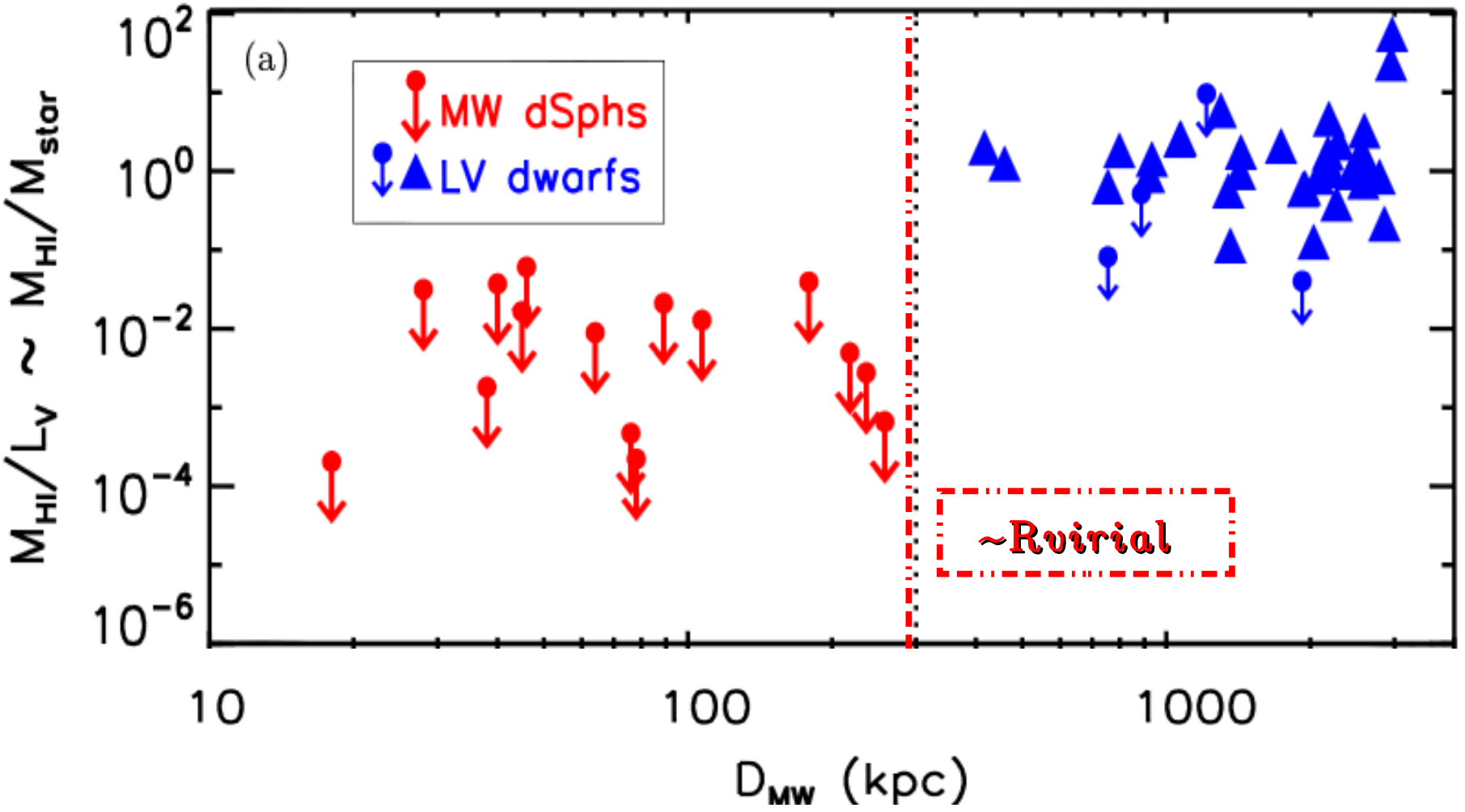


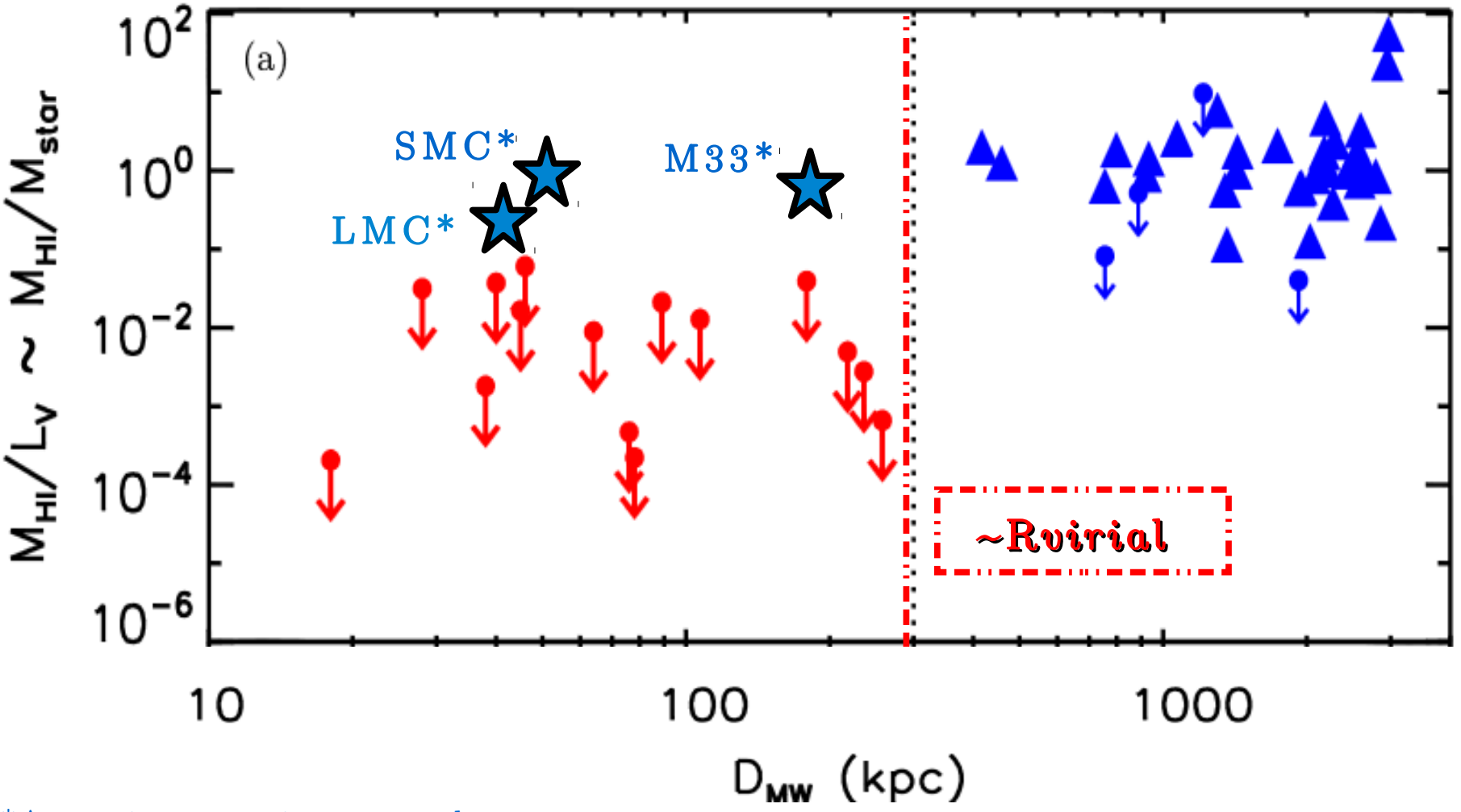
Wetzel et al. 2013

Density-Morphology Outliers



Spekkens et al. 2014

Density-Morphology Outliers



*Approximate ratio computed from McConnachie 2012

Spekkens et al. 2014

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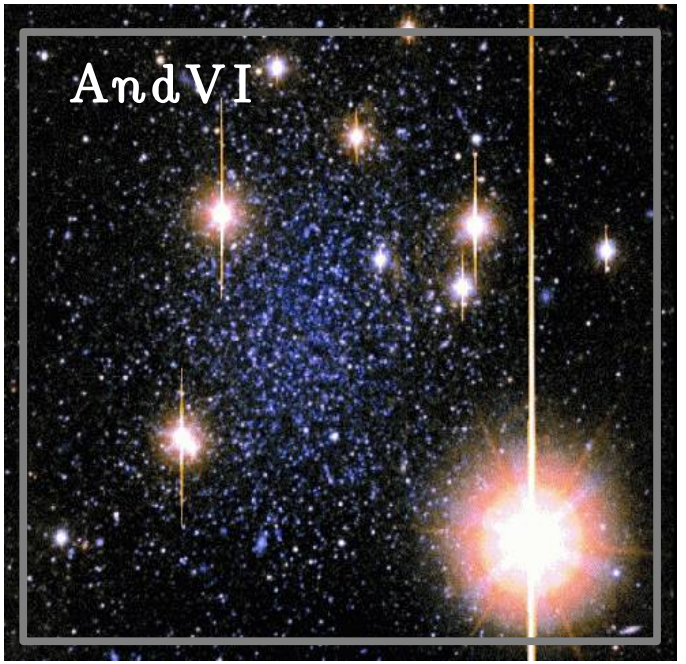

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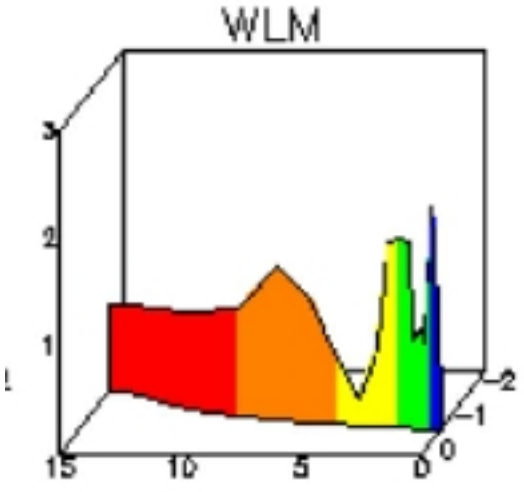

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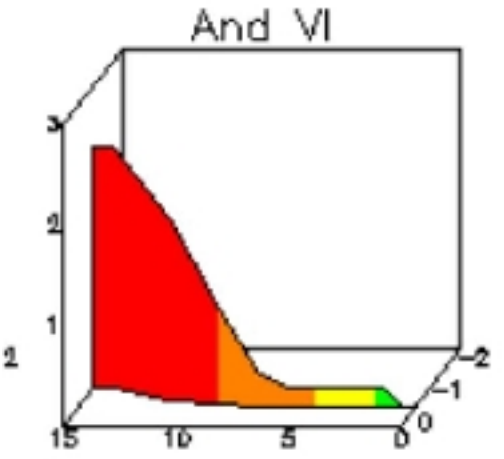


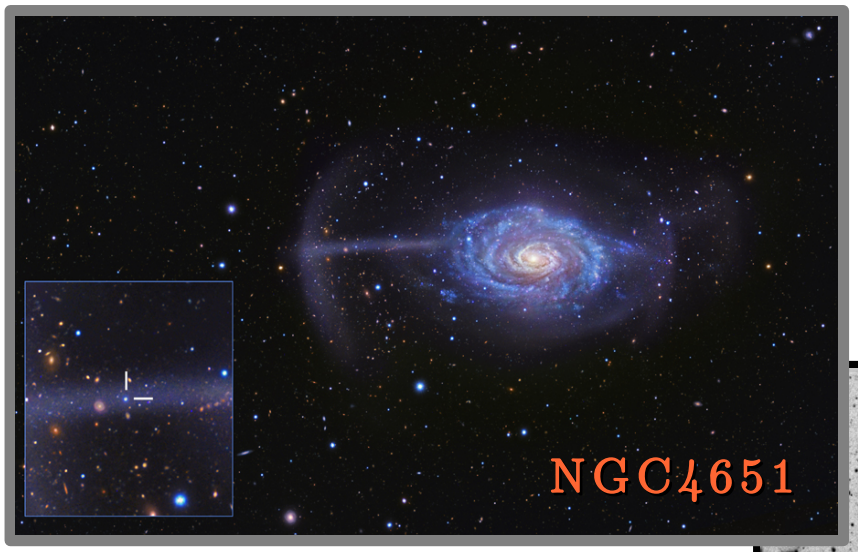
Field Dwarfs
dwarf Irregular

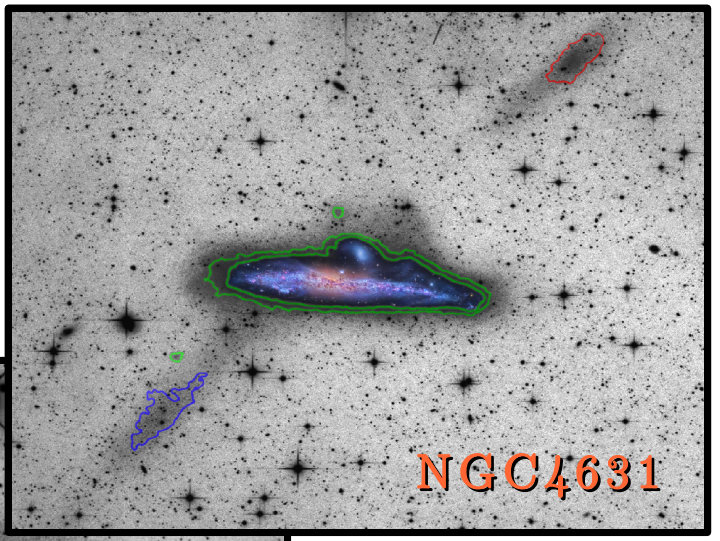
Satellites
dwarf Spheroidal

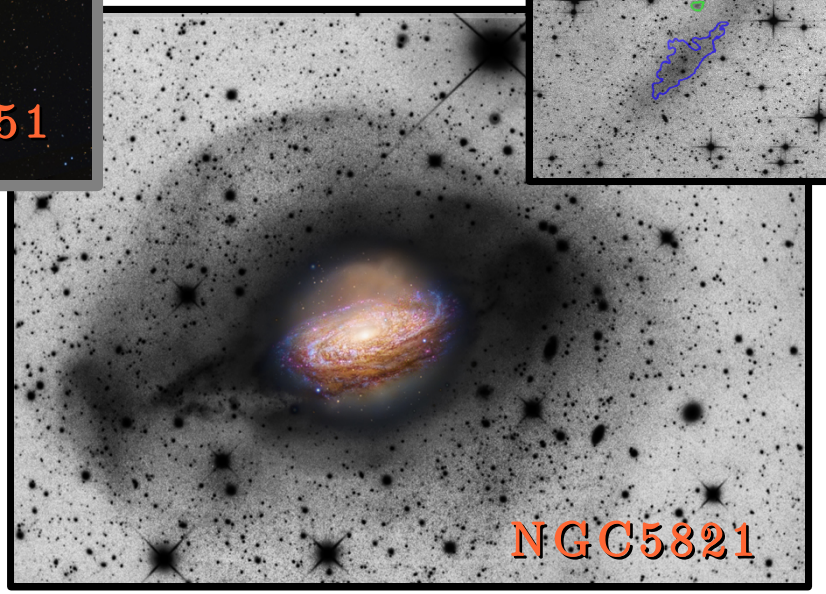
Dolphin et al. 2005

Look to Extra-Galactic Streams

In the same way that we find more stream morphologies in Extragalctic Searches, we can also find more dwarf morphologies.







Rachael L. Beaton

April 13, 2015

Satellites & Streams in Santiago

See Martinez-Delgado et al. 2010

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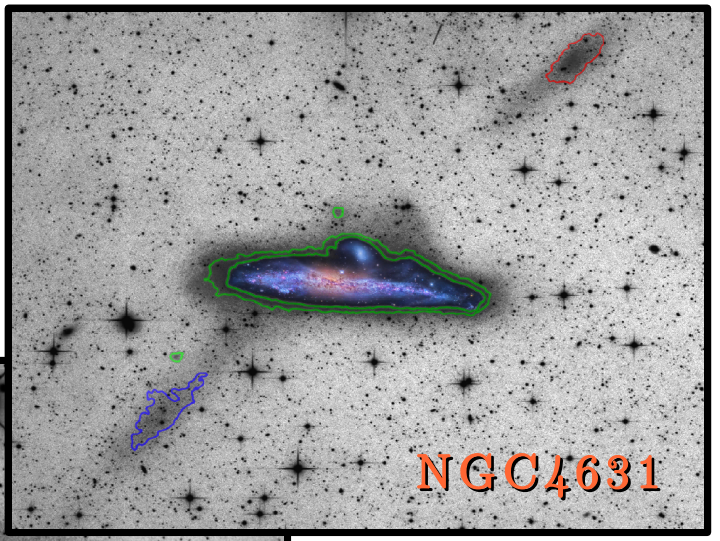

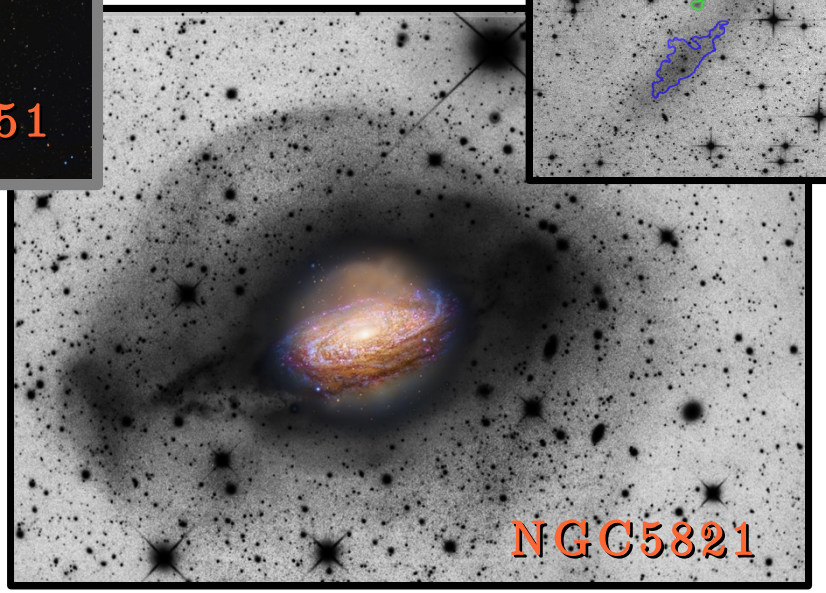

All in partnership with an *incredible*, *global* **Amateur Astronomy Network** led by **D Martinez-Delgado** (Heidelberg).

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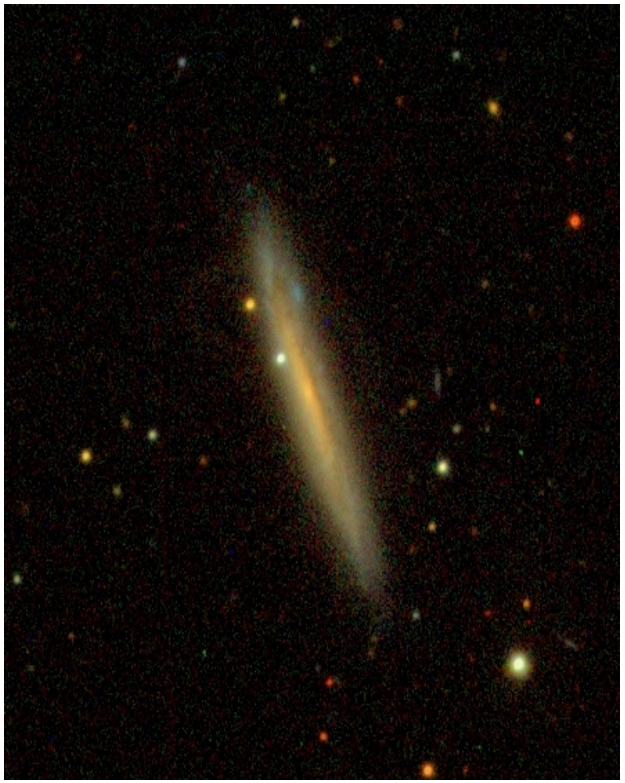
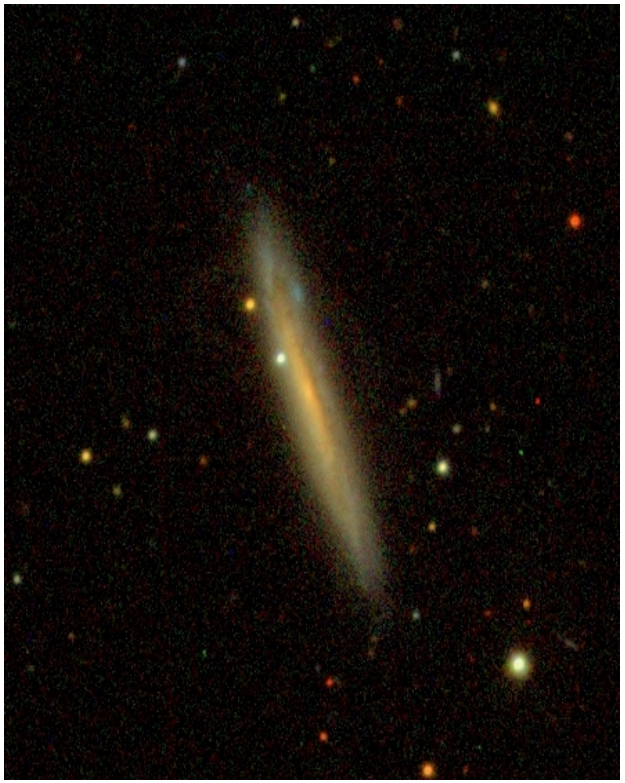
NGC 5387



SDSS Discovery Image

NGC 5387



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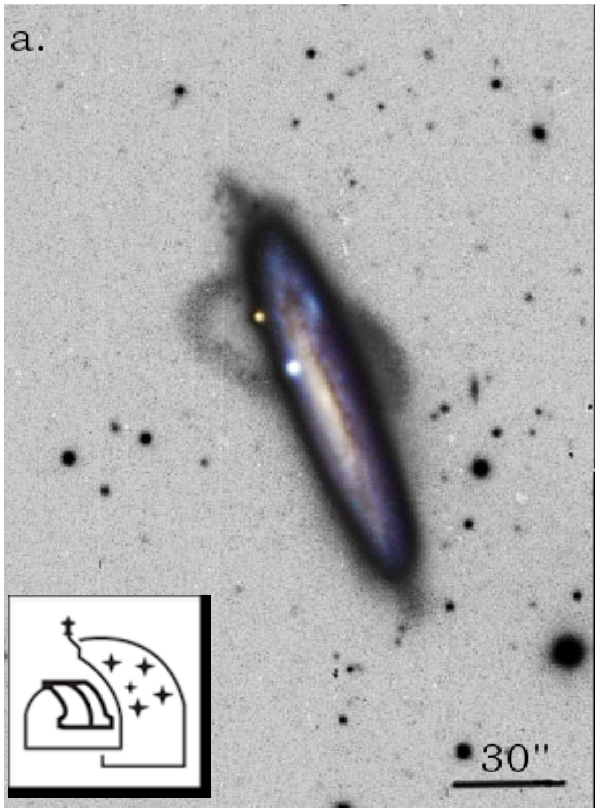

Greyscale: VATT R ~3 hours

Color: BlackBird Observatory (BBO)

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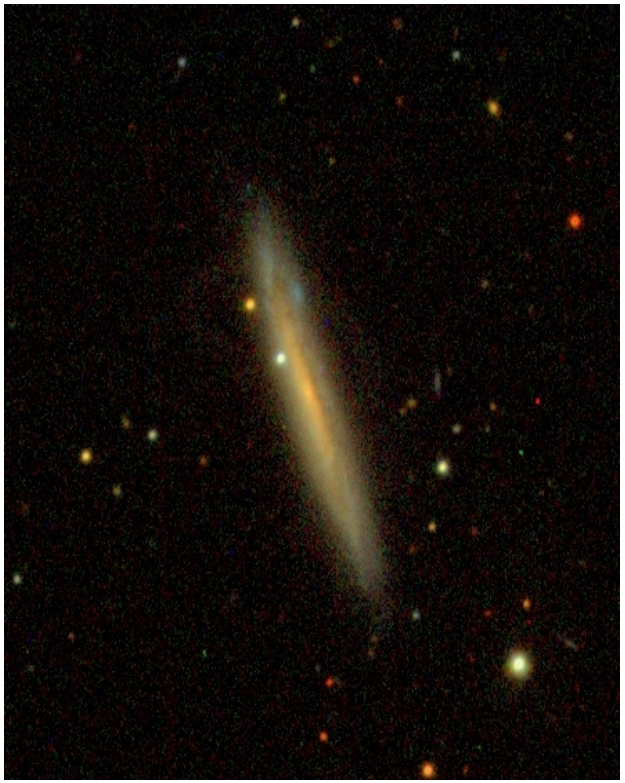

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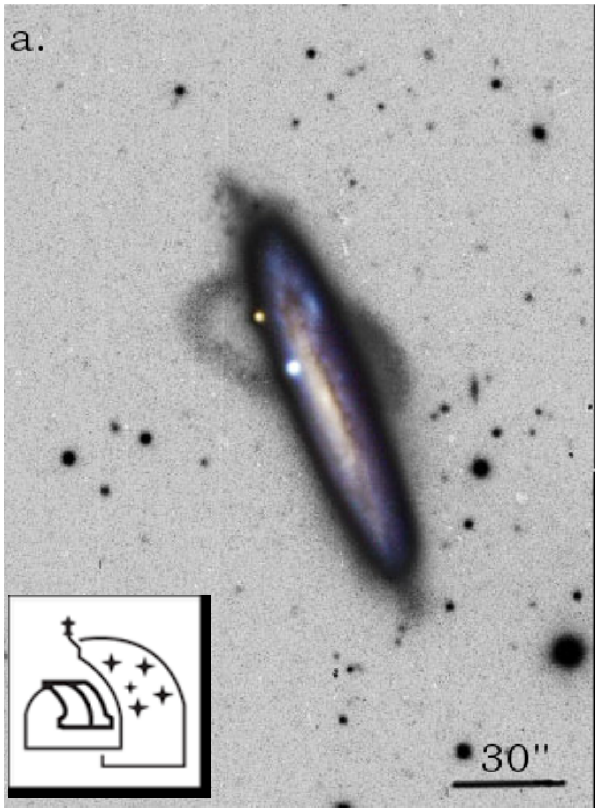

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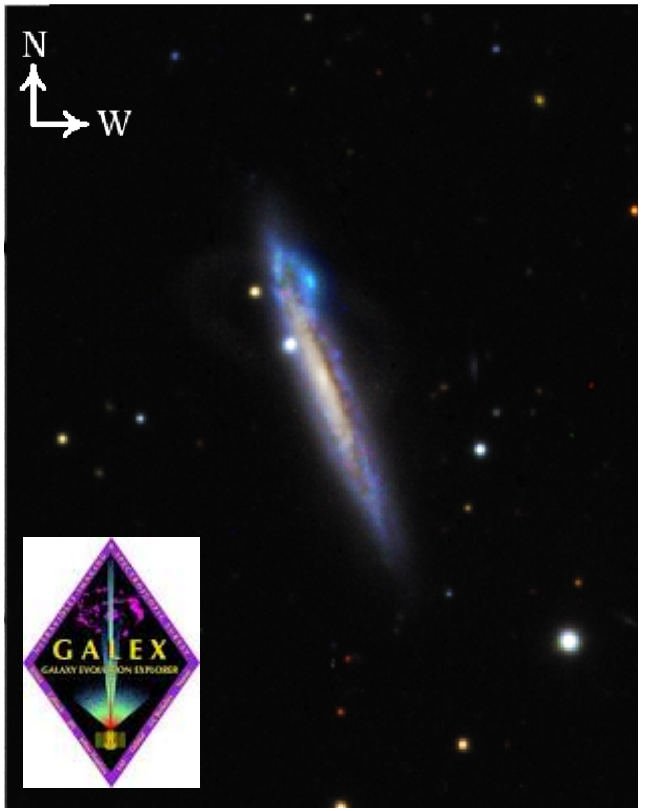

GALEX + BBO Optical

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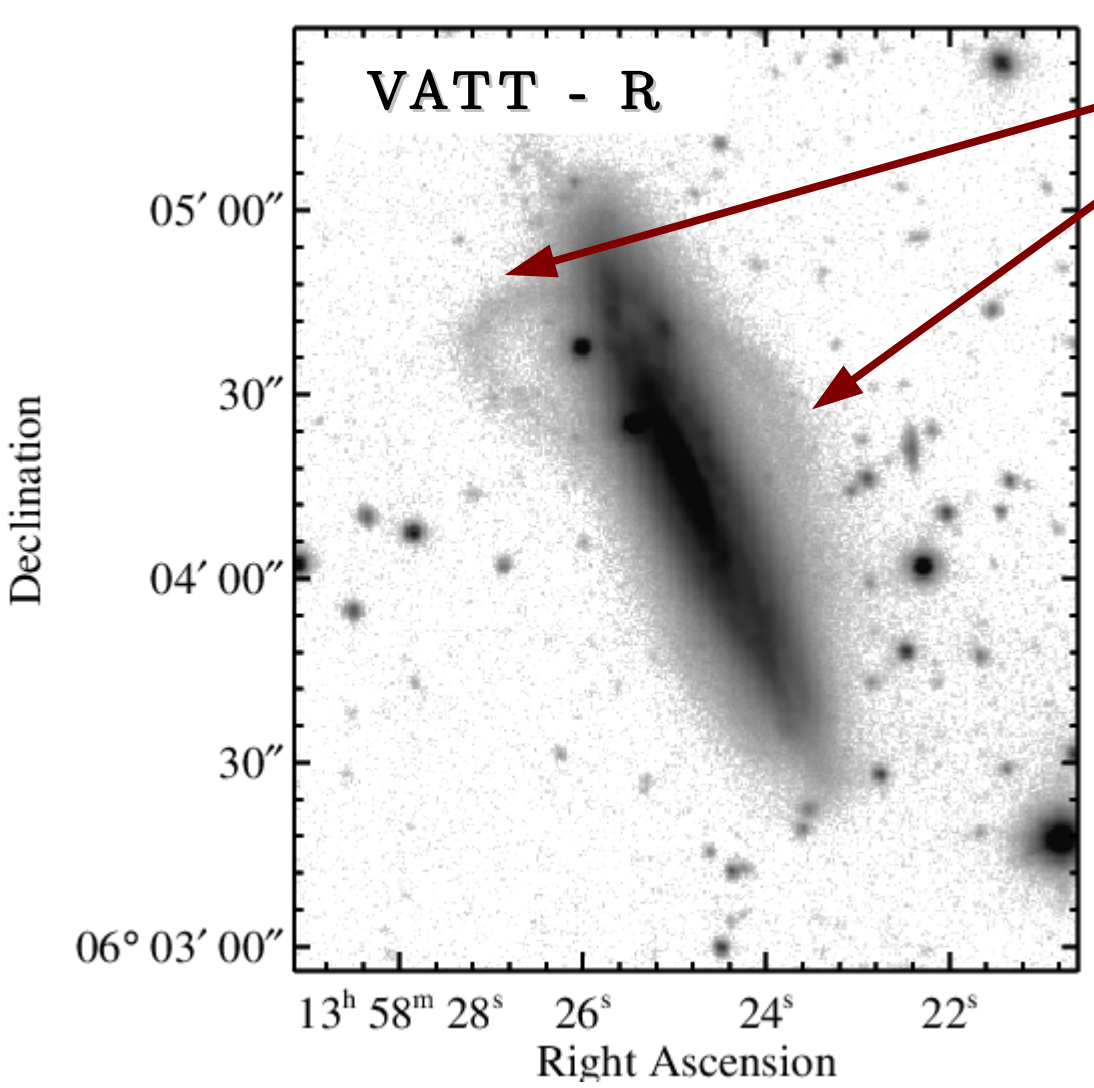
Satellites & Streams in Santiago

April 13, 2015

Beaton et al. 2014

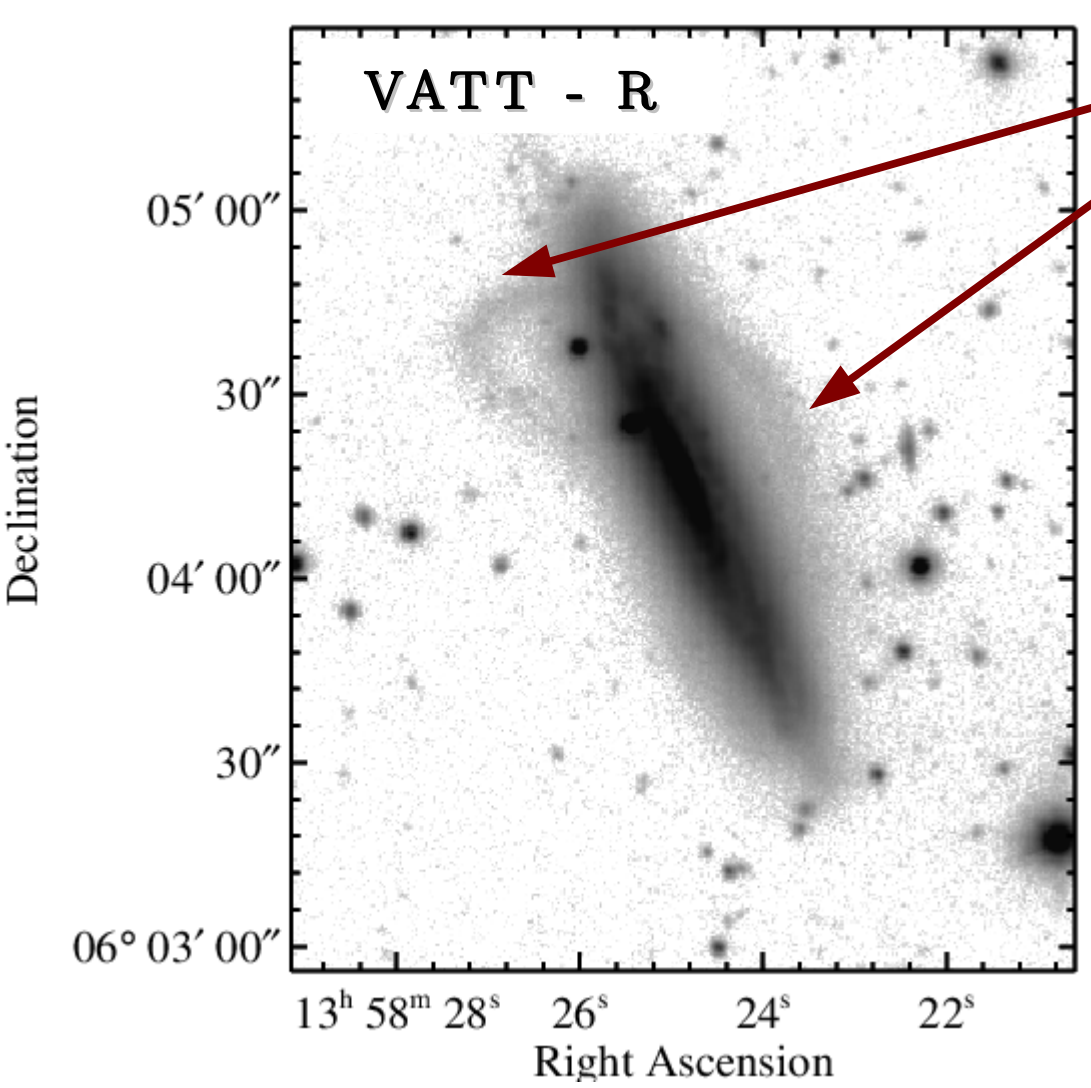
The Optical



Stellar Stream

Observable	Physical
(B-V) ~ 0.79 i.e., red	
~360 ° around + Rapo ~ 17 kpc	

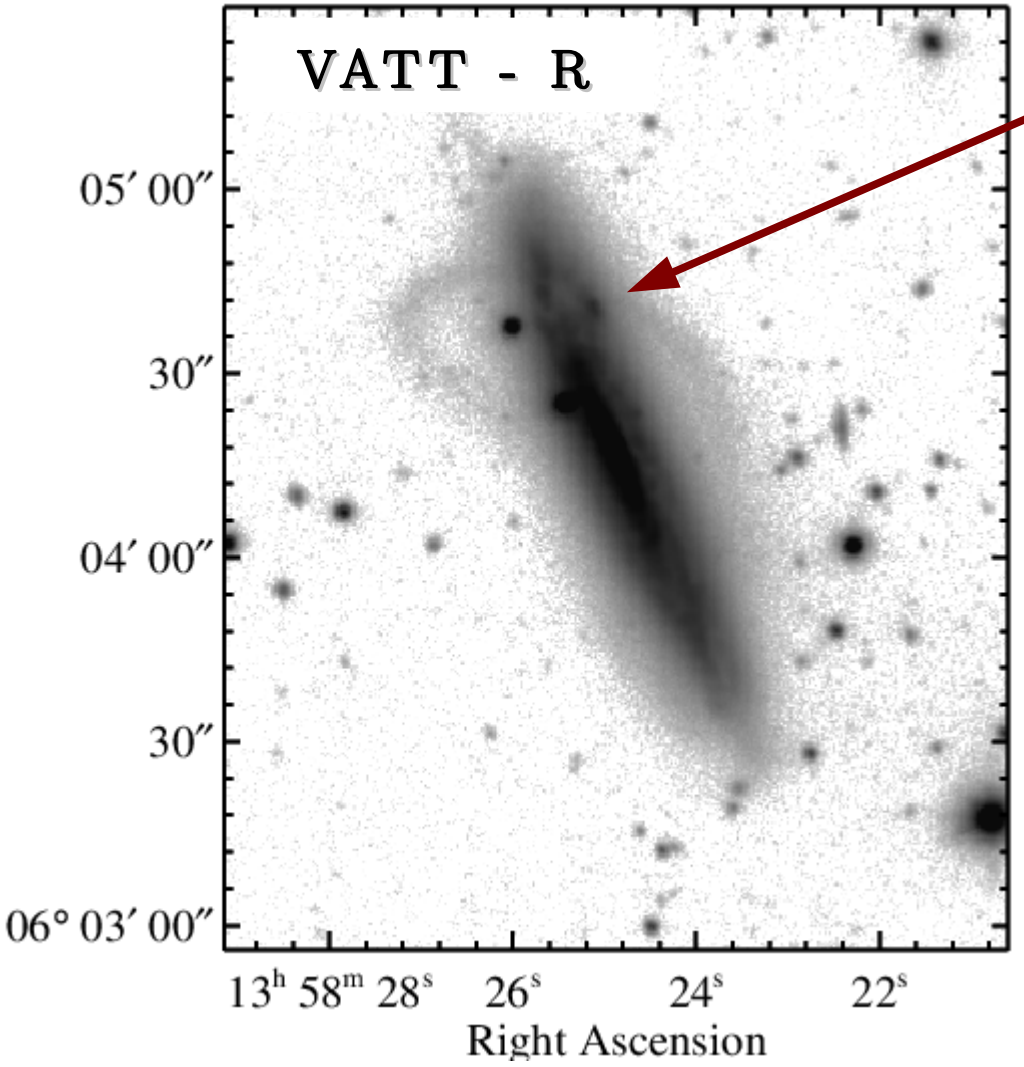
The Optical



Stellar Stream

Observable	Physical
(B-V) ~ 0.79 i.e., red	Int-Old Stellar Pops Stream ~10^8 Msolar
~360 ° around + Rapo ~ 17 kpc	tacr ~200-500 Myr Progenitor ~10^{10} Msolar

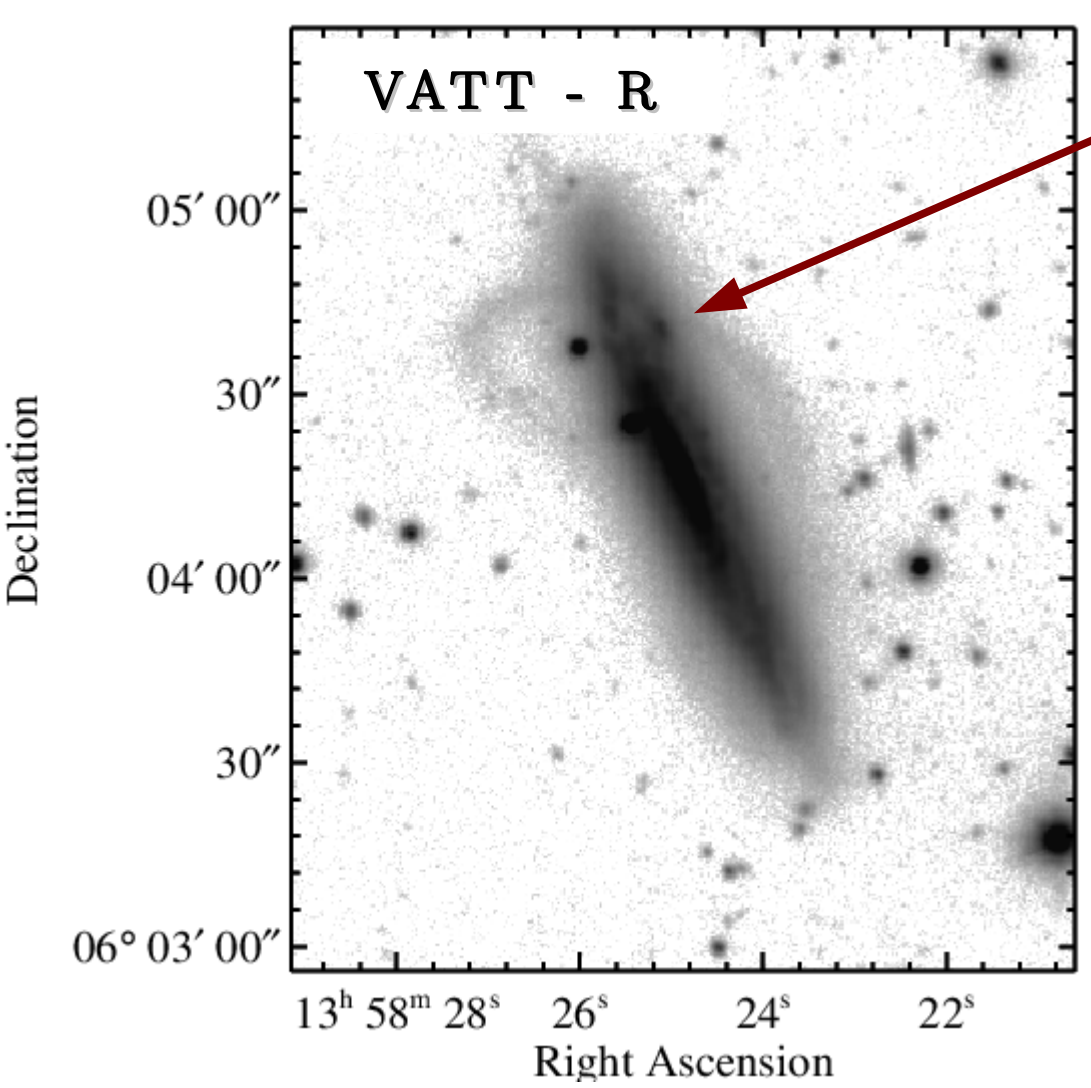
The Optical



Blue Overdensity

Observable	Physical
(B-V) ~ 0.28 (B-V)o ~ -0.04 i.e., blue	
1'' diameter	

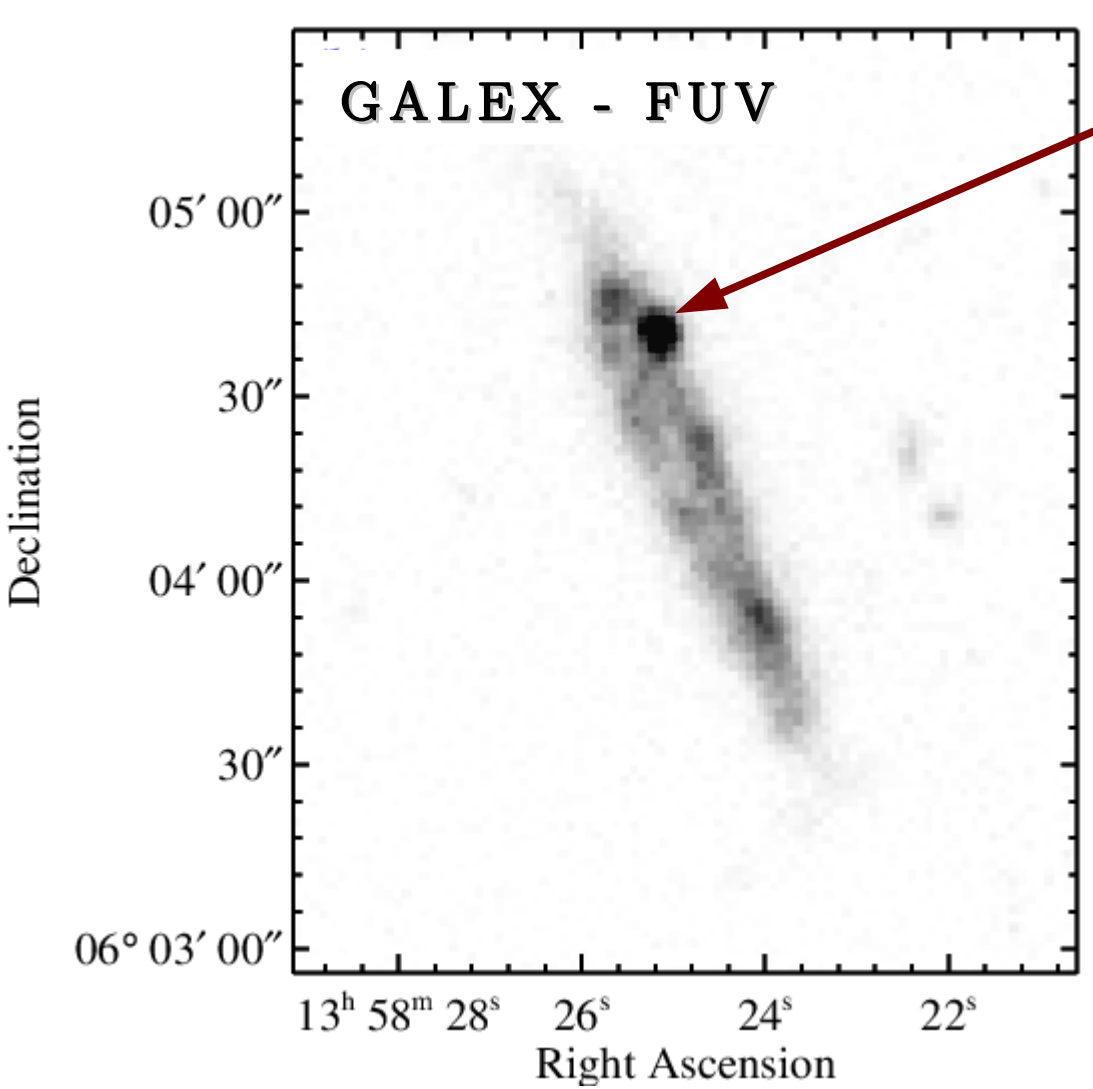
The Optical



Blue Overdensity

Observable	Physical
(B-V) ~ 0.28 (B-V)o ~ -0.04 i.e., blue	Young Stellar Pops ~10^7 Msolar
1'' diameter	~1 kpc

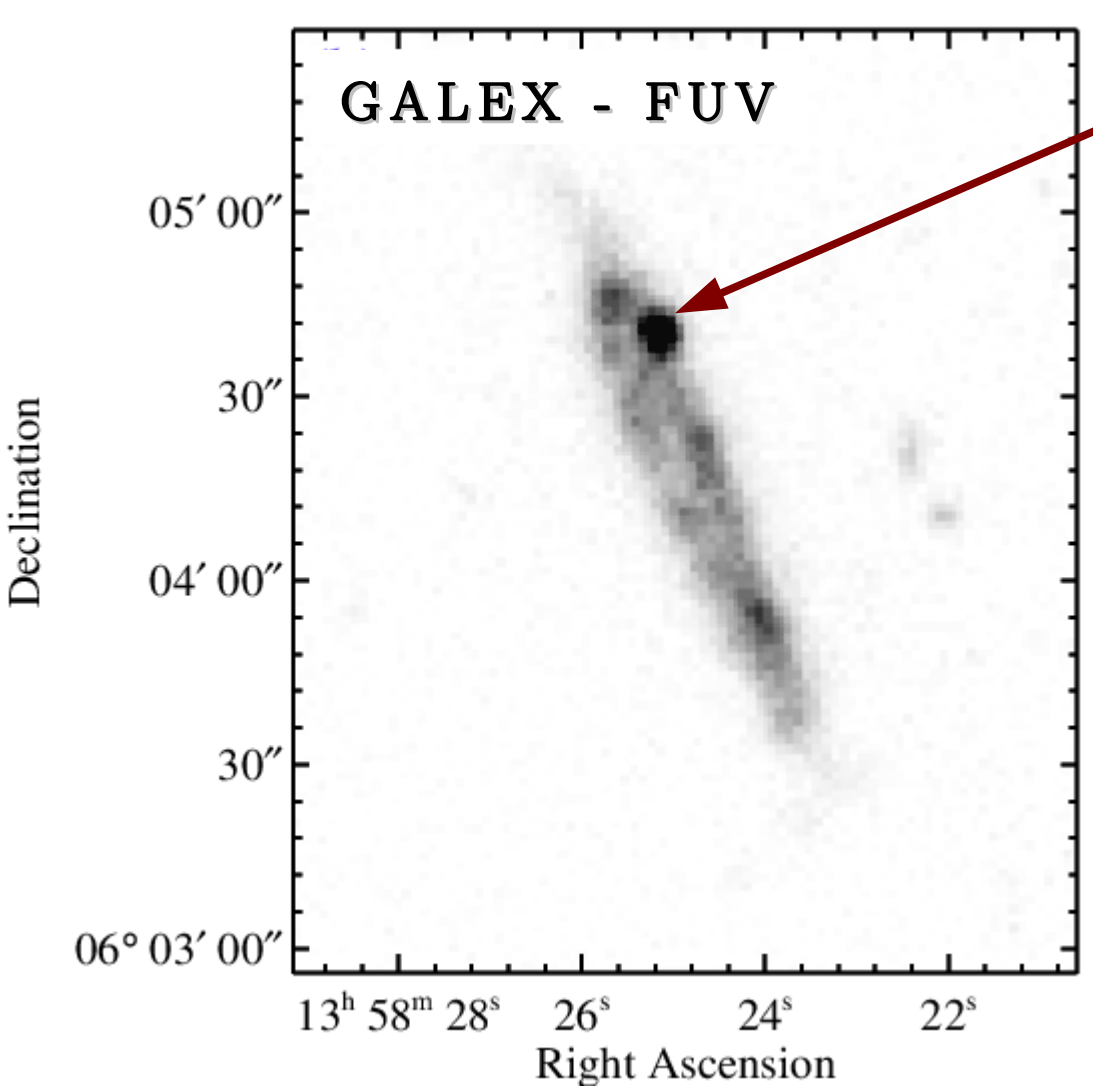
The FUV



Blue Overdensity

Observable	Physical
38% of Total UV Flux from NGC5387	
FUV Flux	
FUV Flux	
1'' diameter	

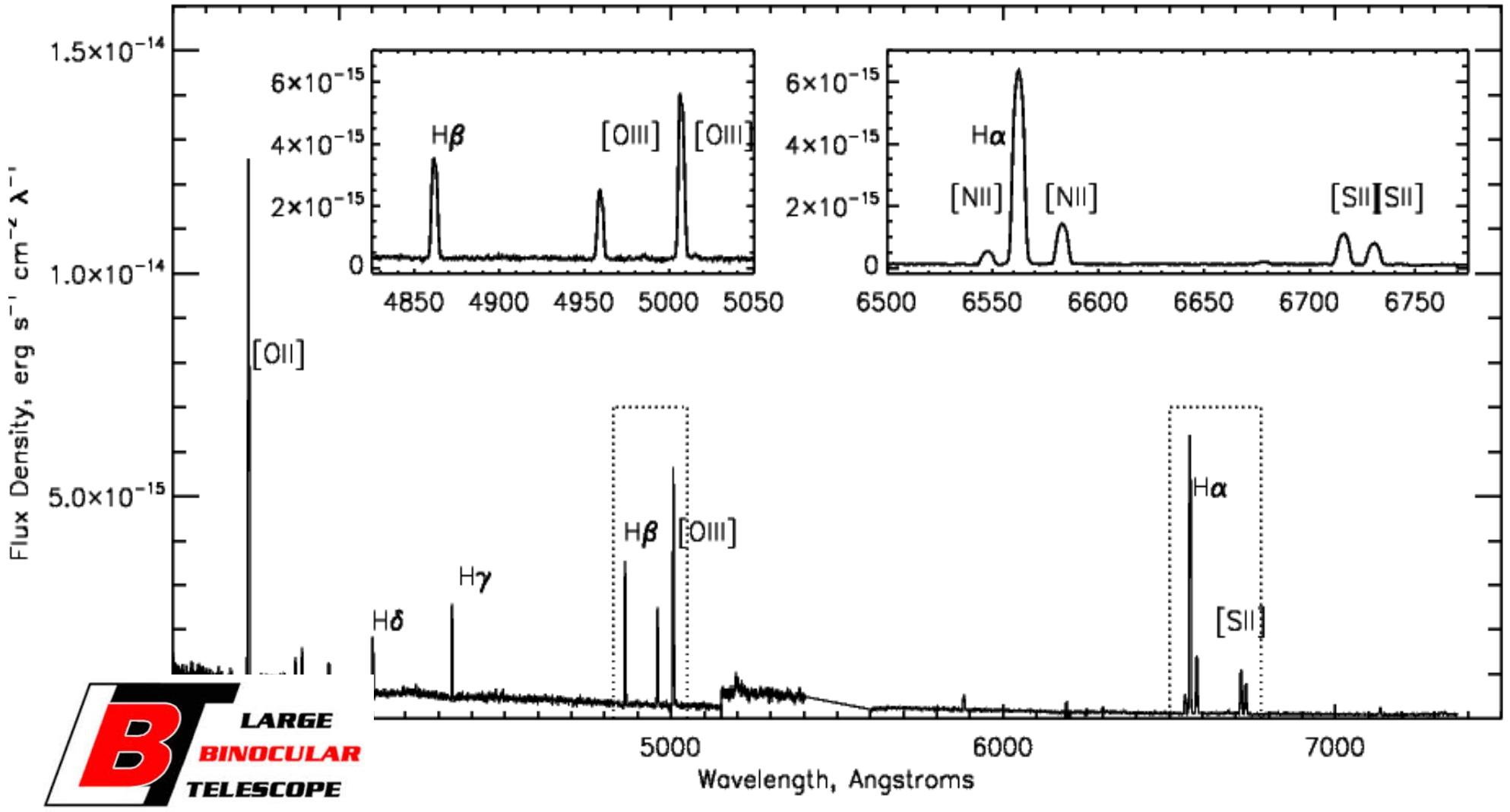
The FUV



Blue Overdensity

Observable	Physical
38% of Total UV Flux from NGC5387	Booming Star Formation
FUV Flux	< 400 Myr Stellar Populations
FUV Flux	SFR ~ 2 Msolar year^{-1}
1'' diameter	~1 kpc

Optical Spectroscopy

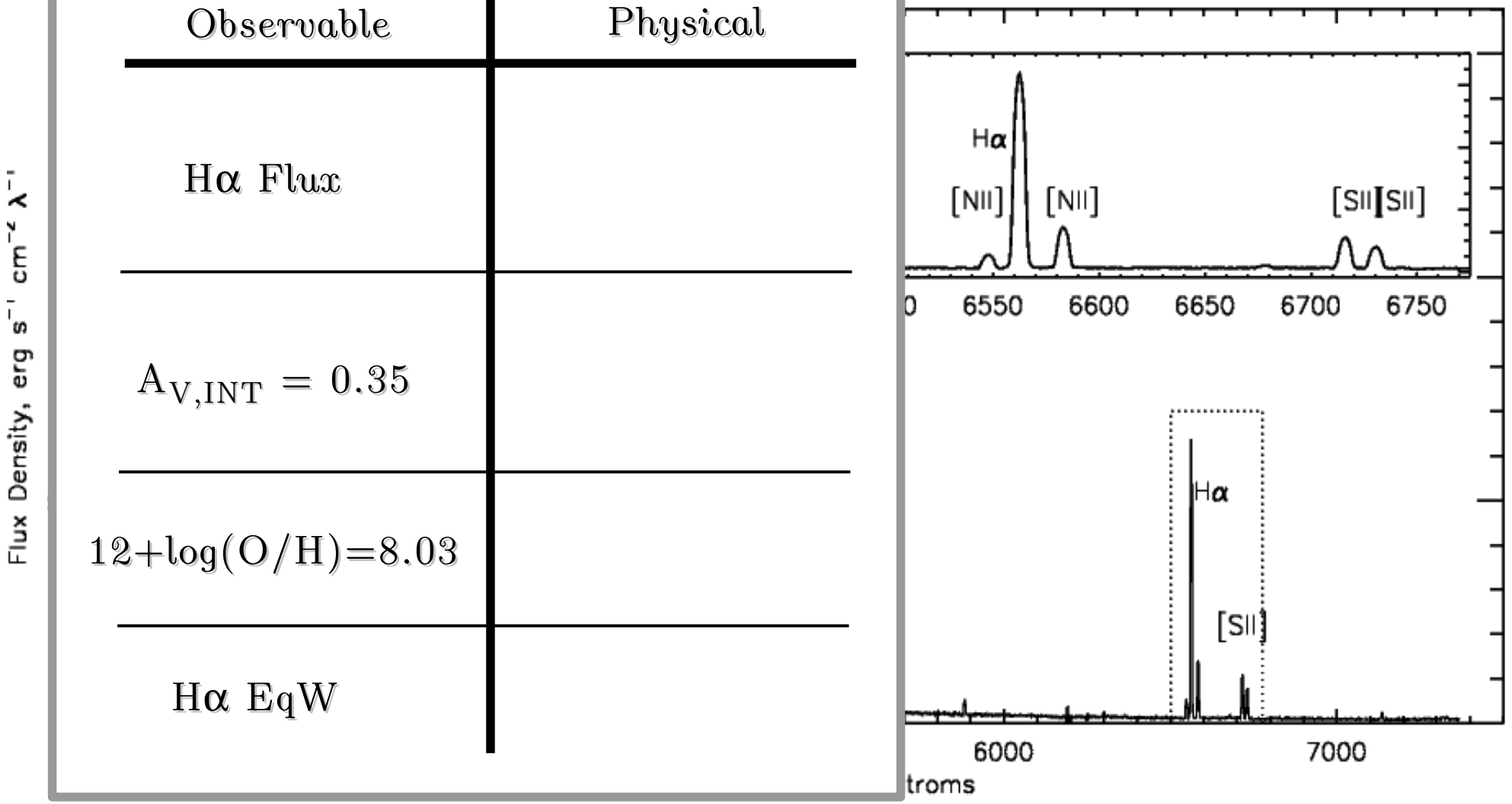


LARGE BINOCULAR TELESCOPE

Beaton et al. 2014

Optical Spectroscopy

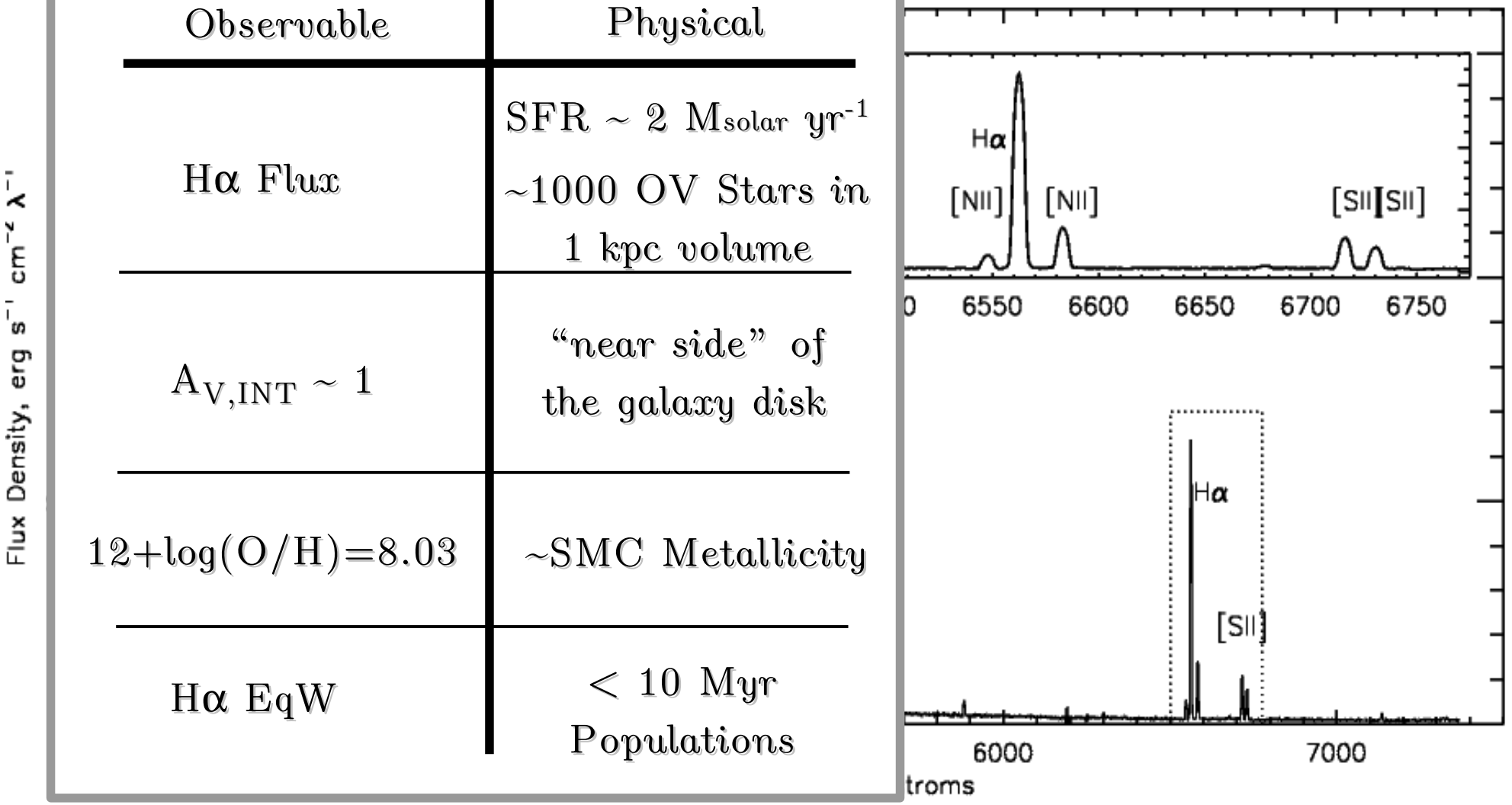
Observable	Physical
Hα Flux	
$A_{V,INT} = 0.35$	
12+log(O/H)=8.03	
Hα EqW	



Beaton et al. 2014

Optical Spectroscopy

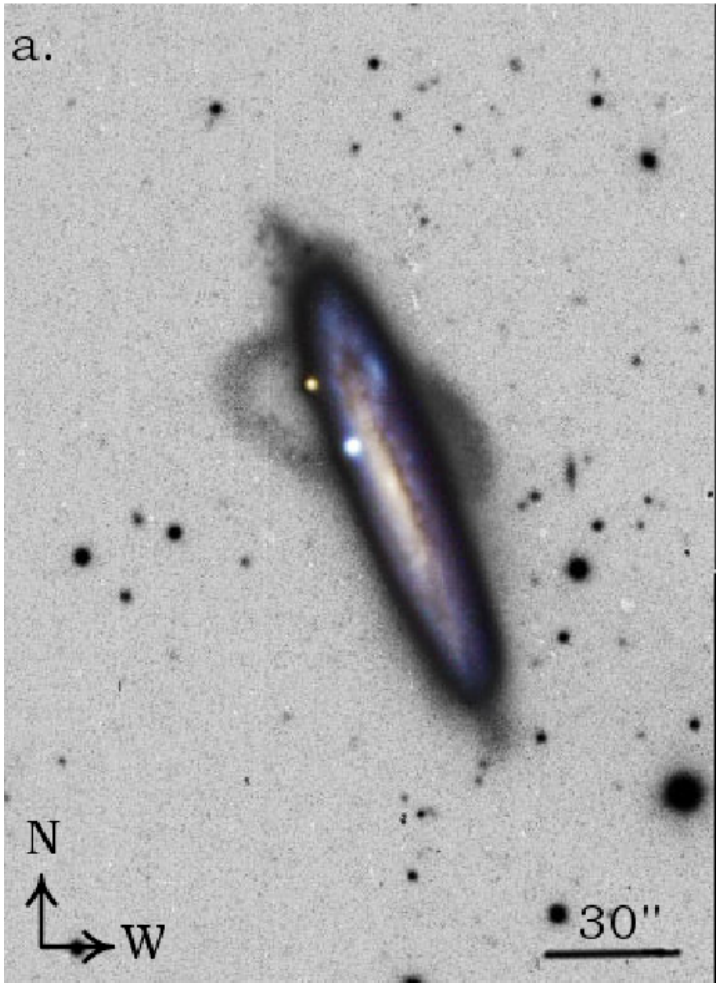
Observable	Physical
Hα Flux	SFR ~ 2 M_{solar} yr^{-1} ~1000 OV Stars in 1 kpc volume
$A_{V,INT}$ ~ 1	"near side" of the galaxy disk
12+log(O/H)=8.03	~SMC Metallicity
Hα EqW	< 10 Myr Populations



Beaton et al. 2014

What do we have here?

Star formation coincident with a stellar stream – Star Formation in the Disk? Or in the progenitor of the stream?



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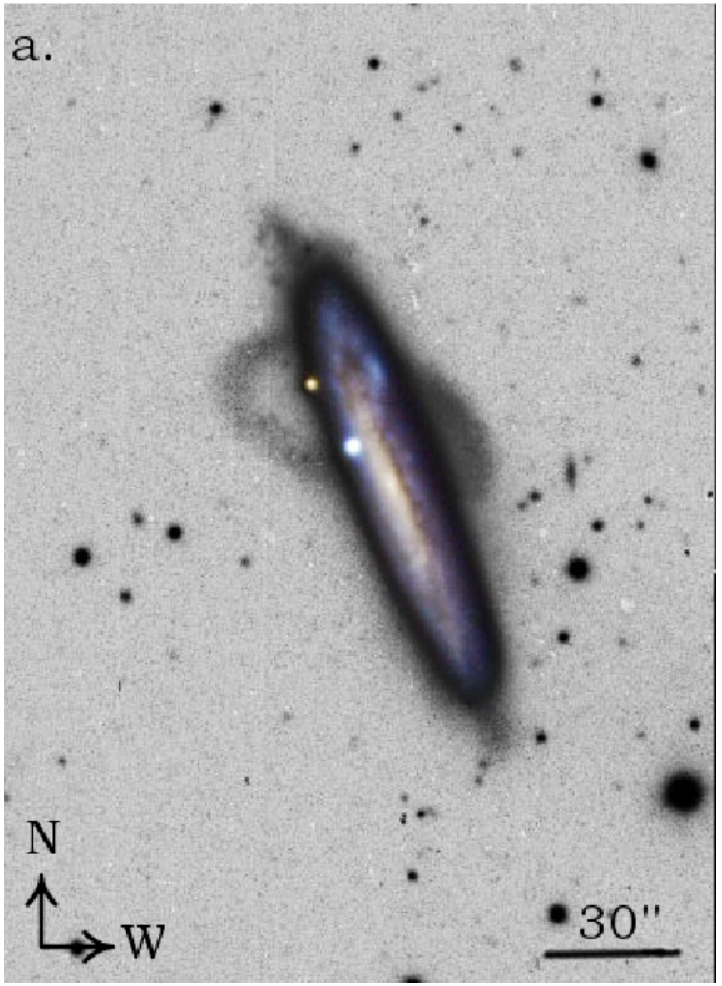
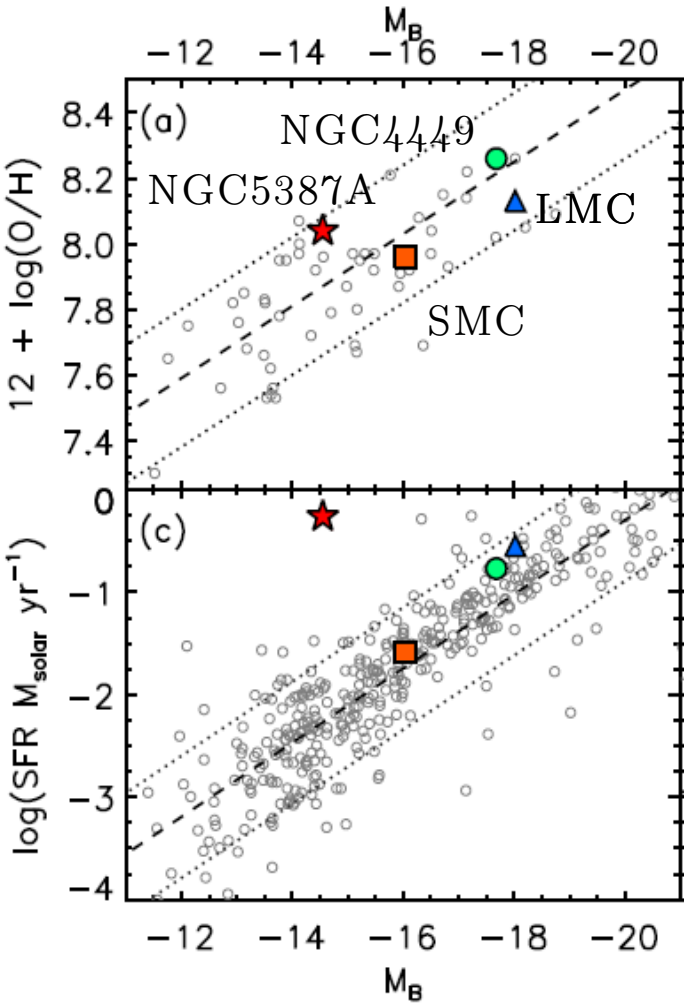
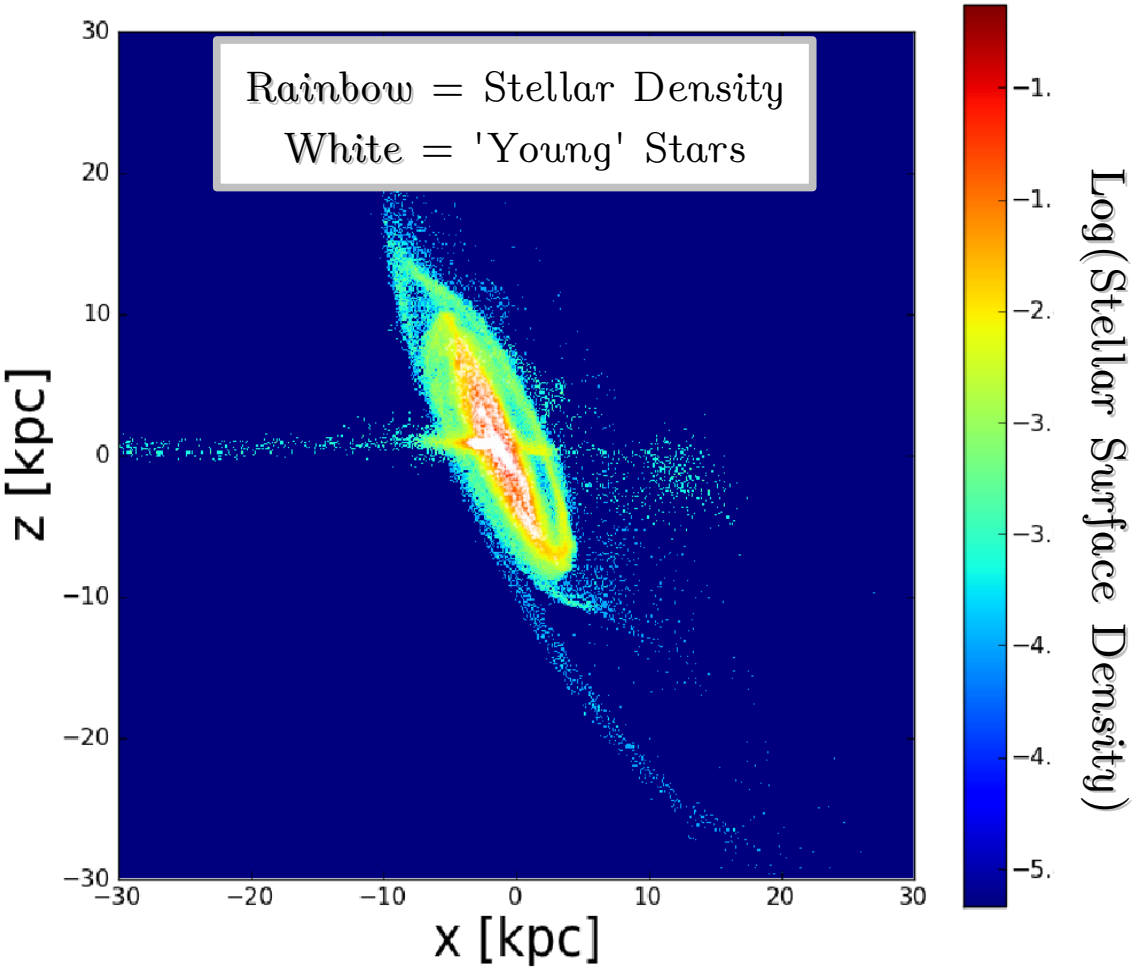




Beaton et al. 2014, *in prep.*

N-Body + Arepo Model

Able to reproduce qualitatively all of our inferred properties with a single interaction.



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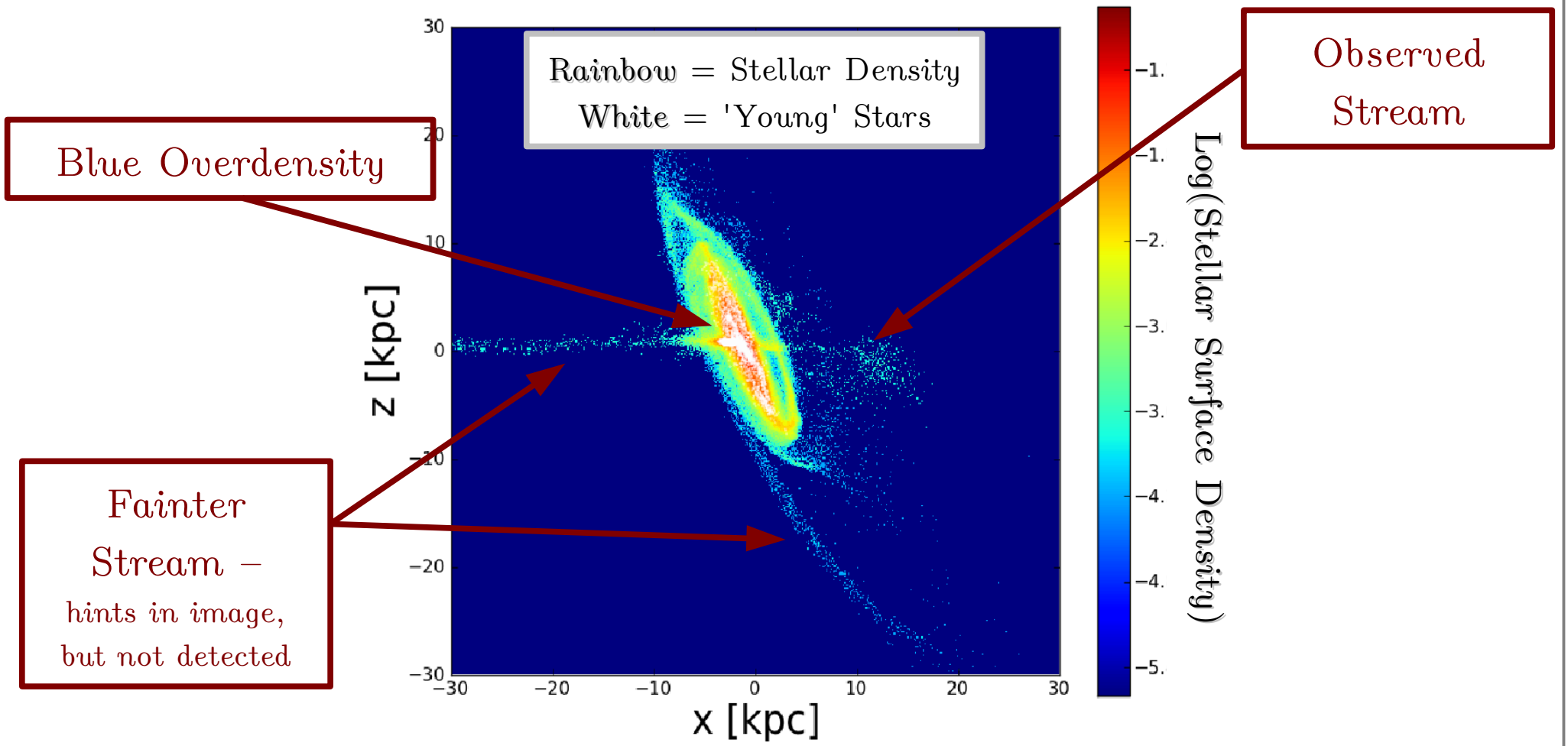
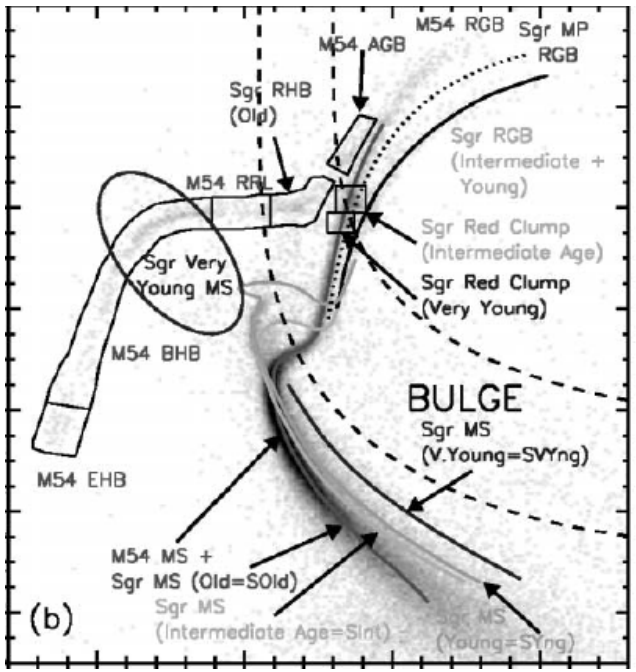
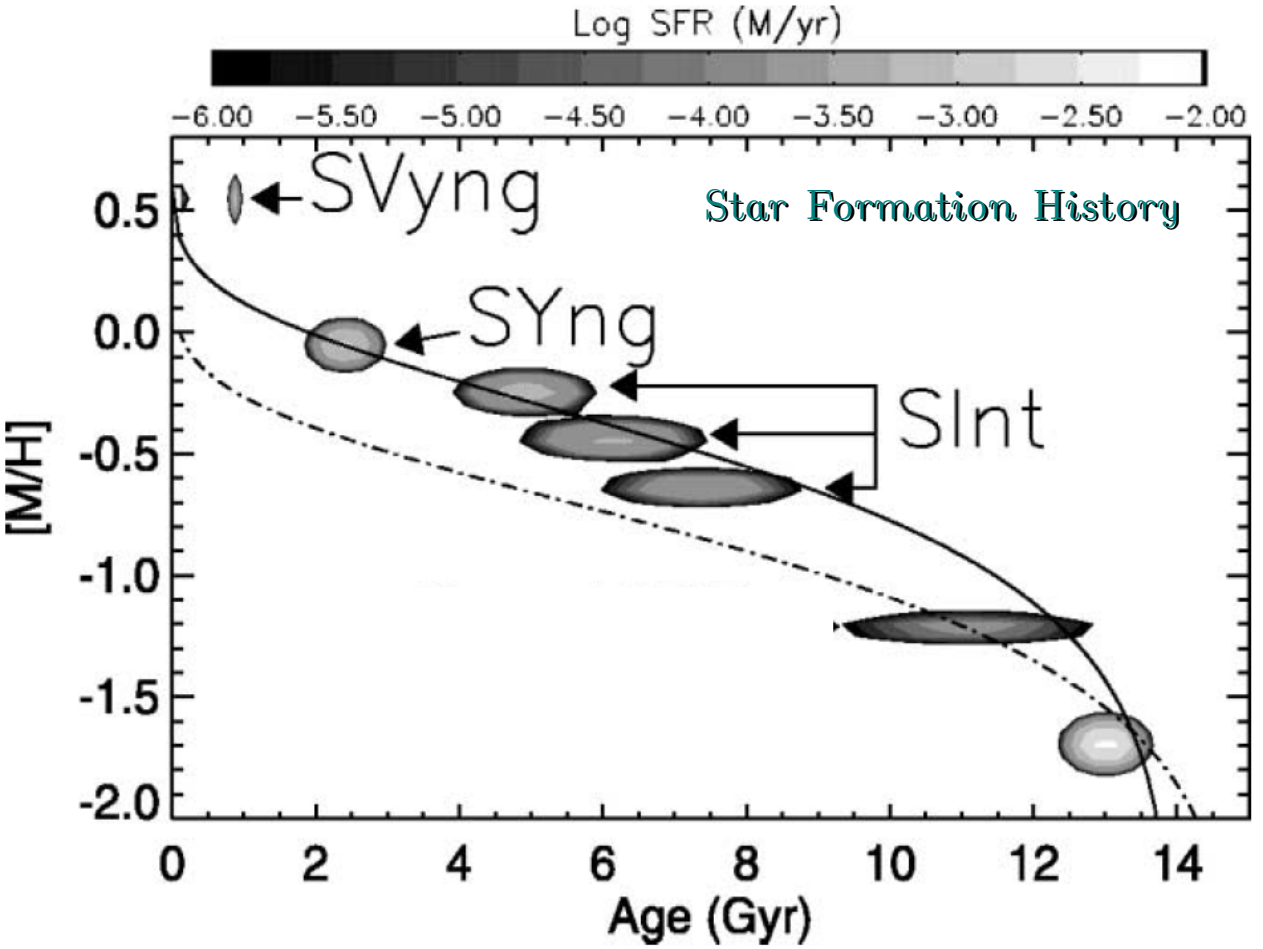


Gas after Satellite Passage?

Sagittarius dSph has extended star formation history – despite multi-Gyr interaction and multiple disk passages at ~13 kpc.



Sagittarius dSph in the background of M54



Siegel et al. 2007
ACS Globular Cluster Treasury

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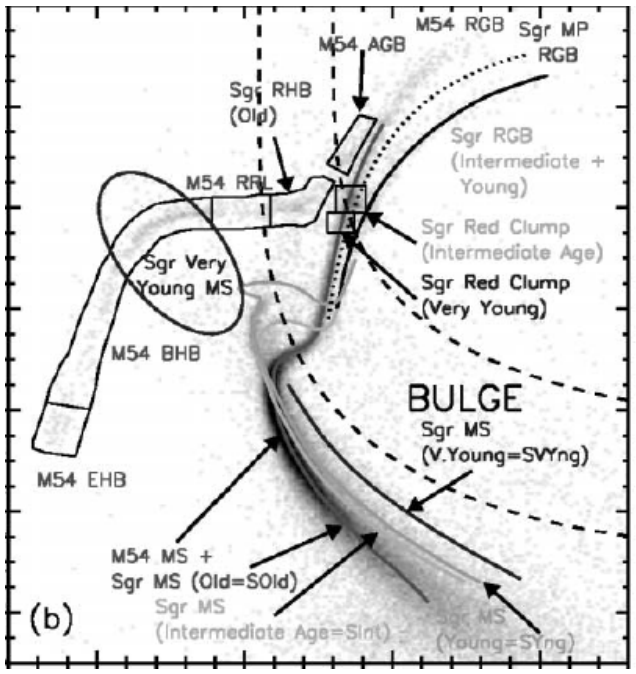

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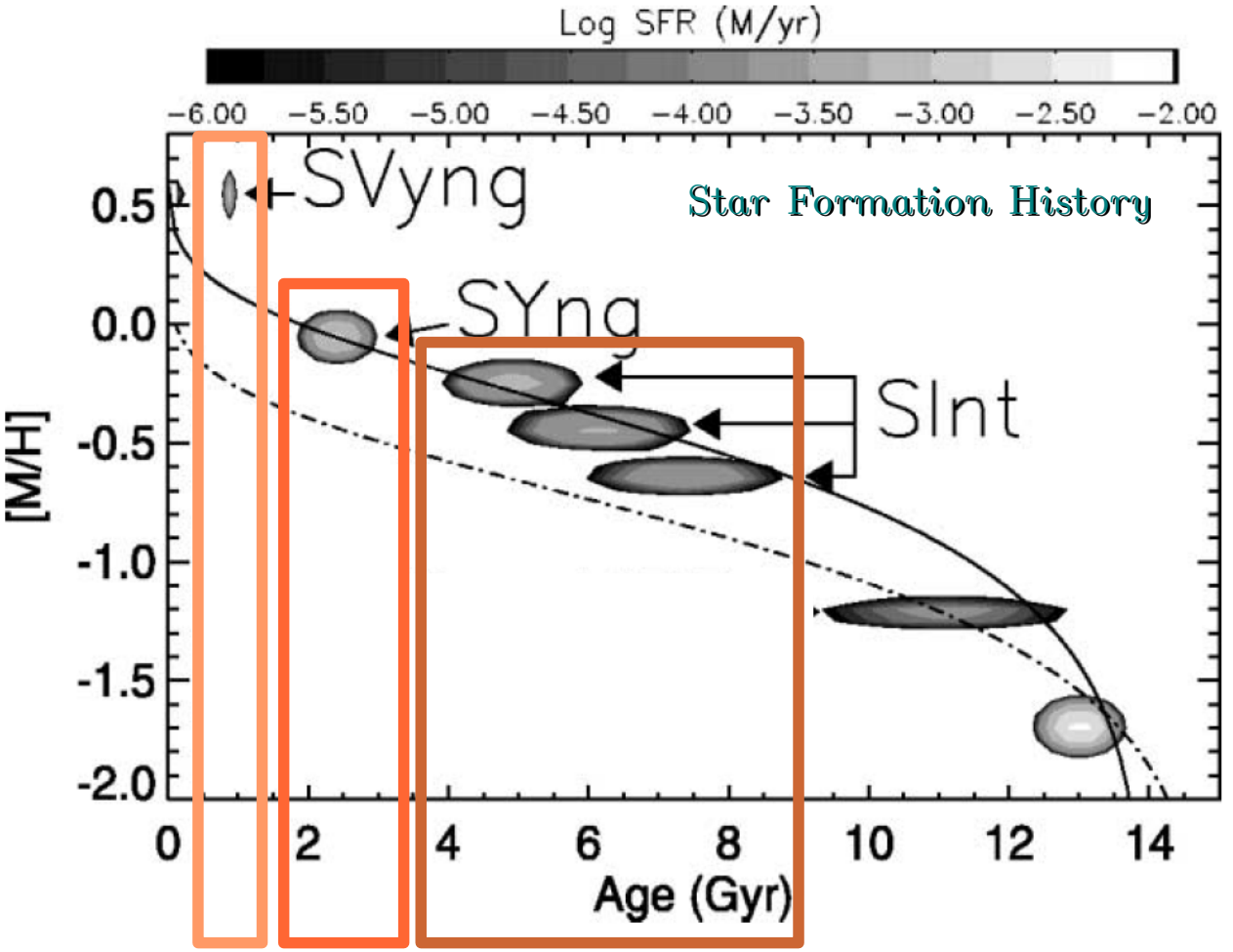
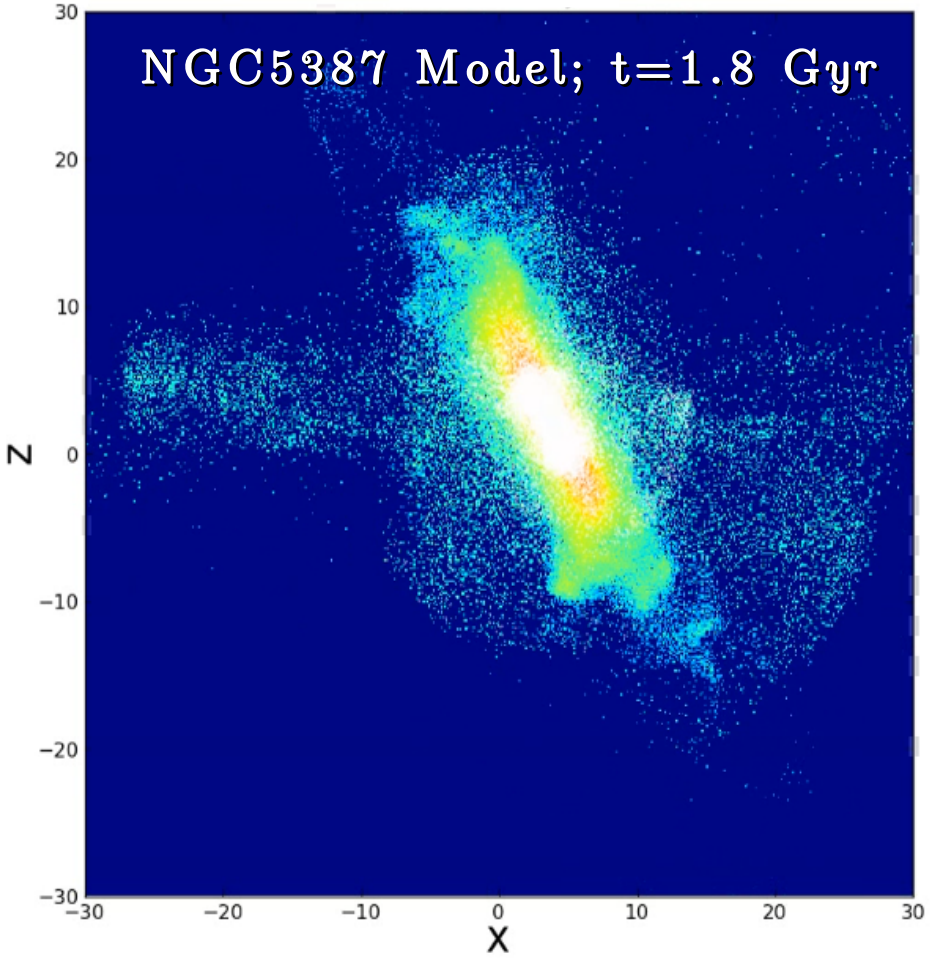


End-Game for this Merger?

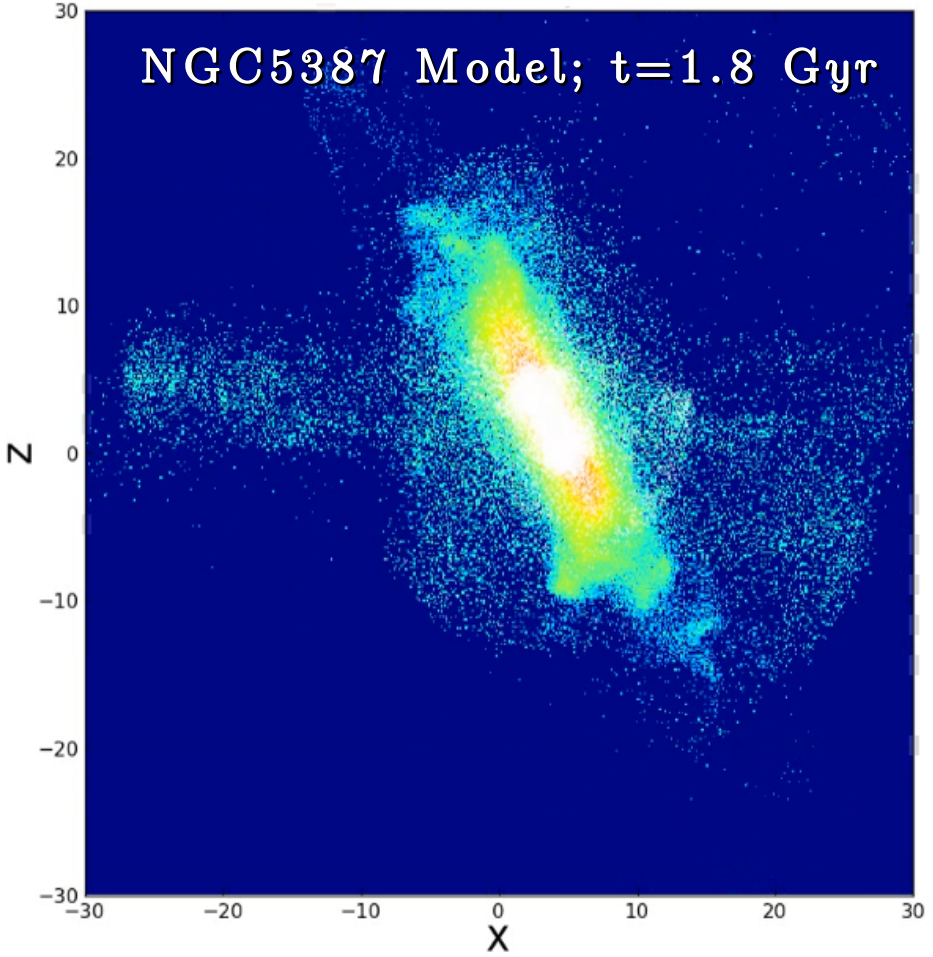


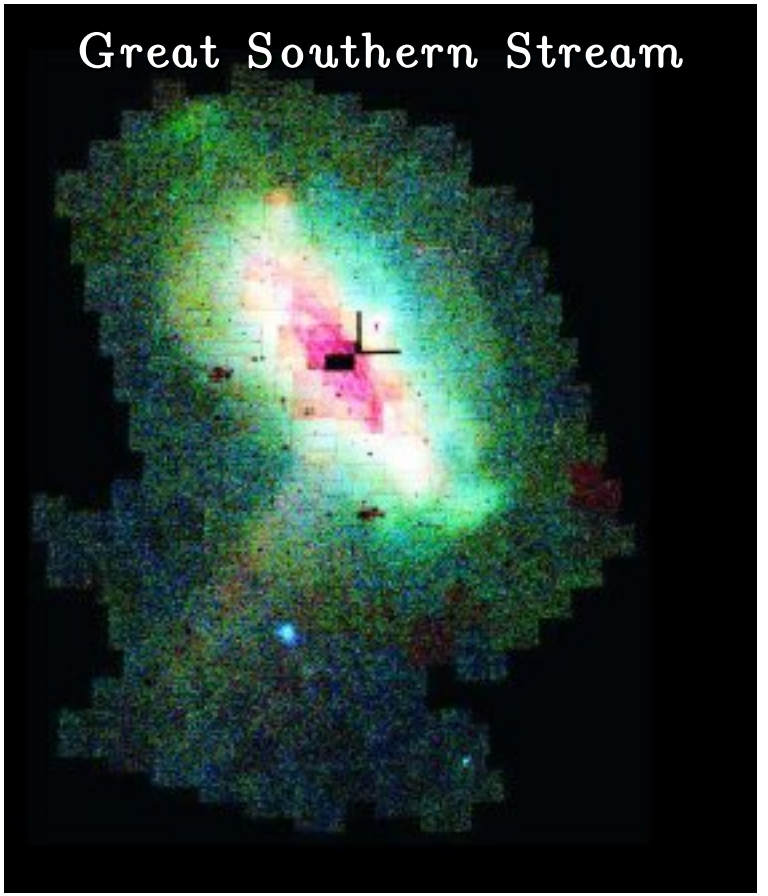
Forms stars for another passage

"Quenching Time" ~ 1 Gyr

Dwarf is unbound by ~1.8 Gyr from falling in or ~1.5 Gyr from first signs of harassment

End-Game for this Merger?





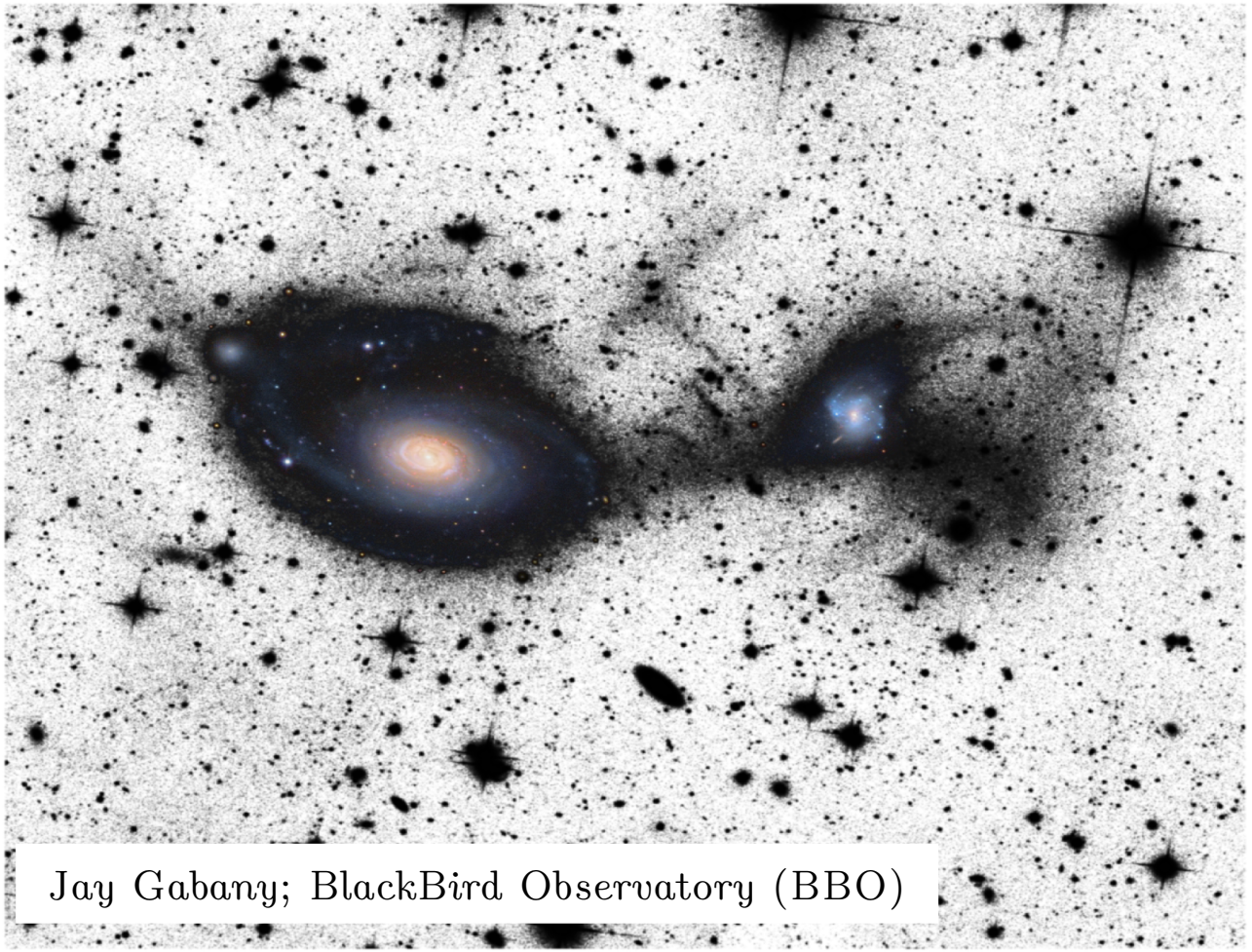
Remnant of an *infalling* disk galaxy.

Beaton et al. 2015 (*in prep.*)

Ferguson et al. 2002
Fardal et al. 2008, 2010
Gilbert et al. 2009

A unique event? Kind-of.

… but only in the sense (1) that all satellites & streams are both similar & different due to initial conditions and (2) this is a quick phase of satellite evolution.



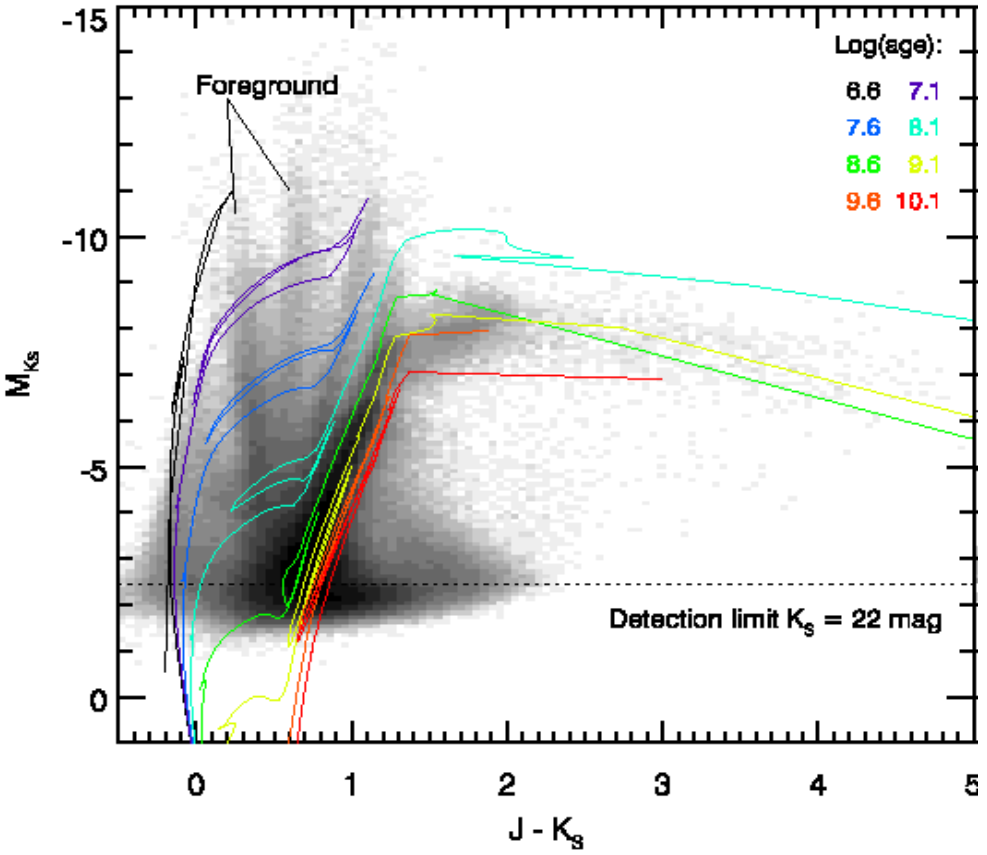
Jay Gabany; BlackBird Observatory (BBO)

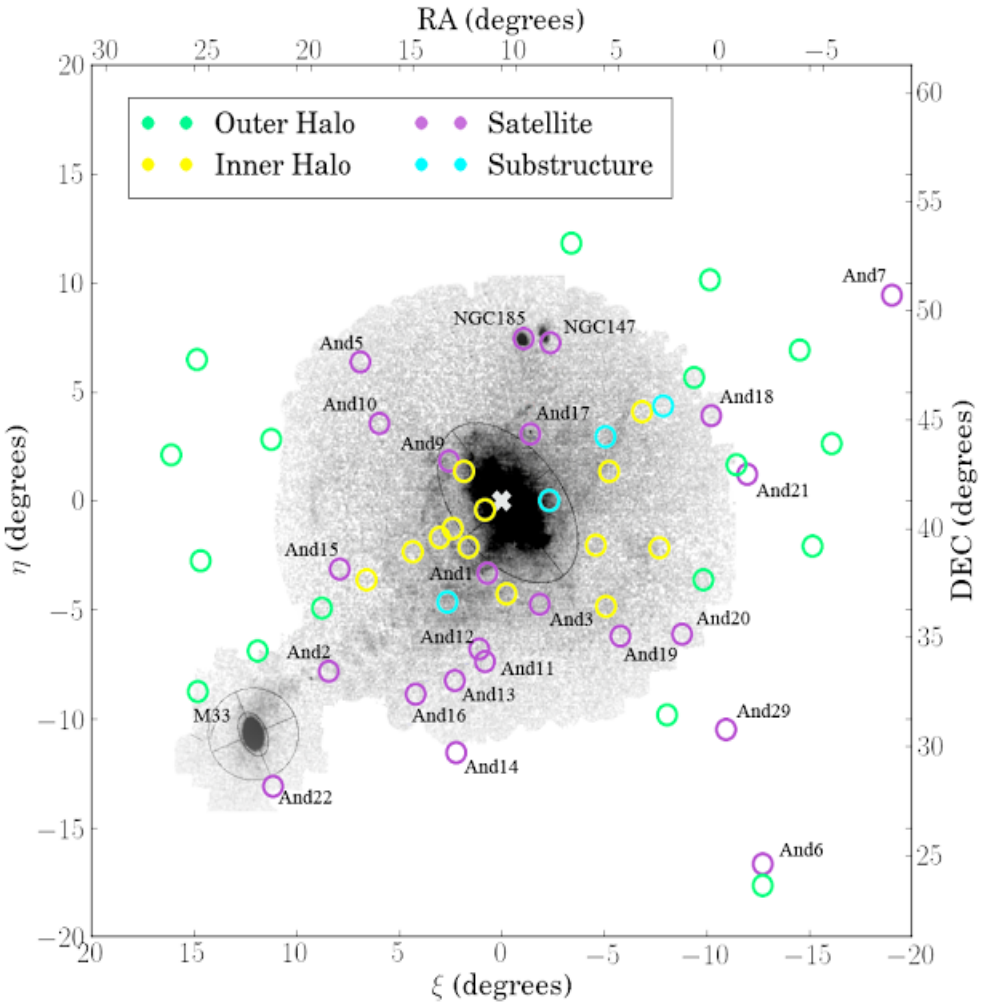
Intermediate Populations in M31

M31AGES; NOAO Survey; PI: Beaton & GuhaThakurta

See K. Hamren Poster!

LMC – SAGE (courtesy of M. Boyer)





Beaton et al. (in prep.)

Hamren et al. (in prep.)

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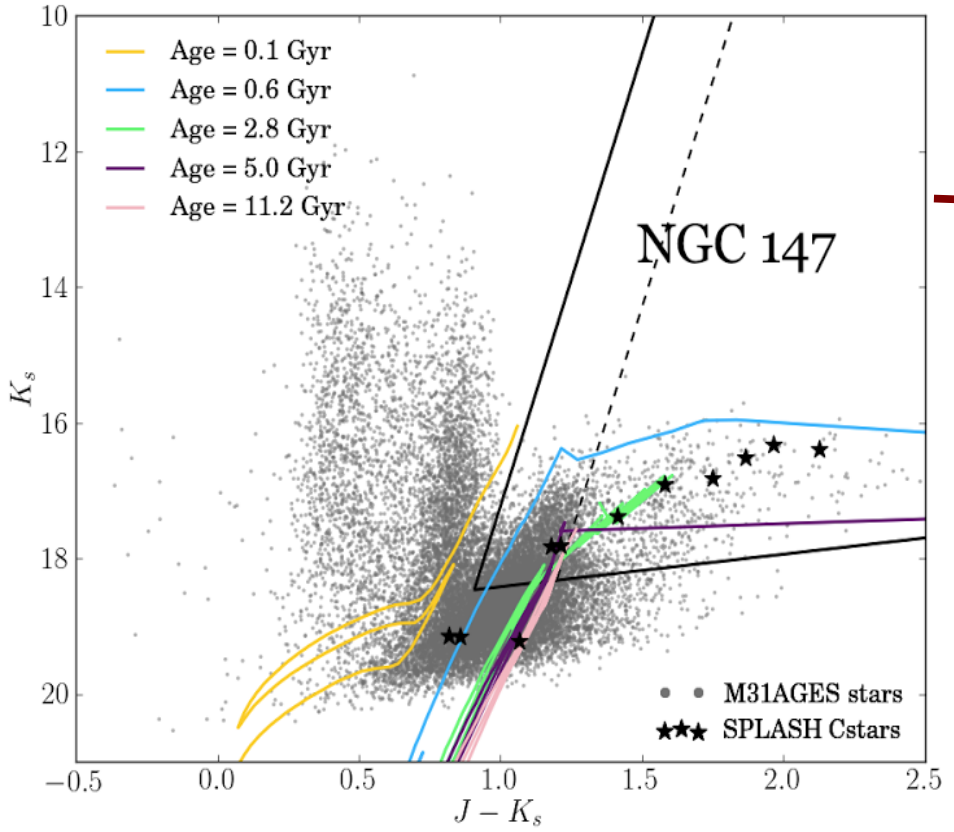
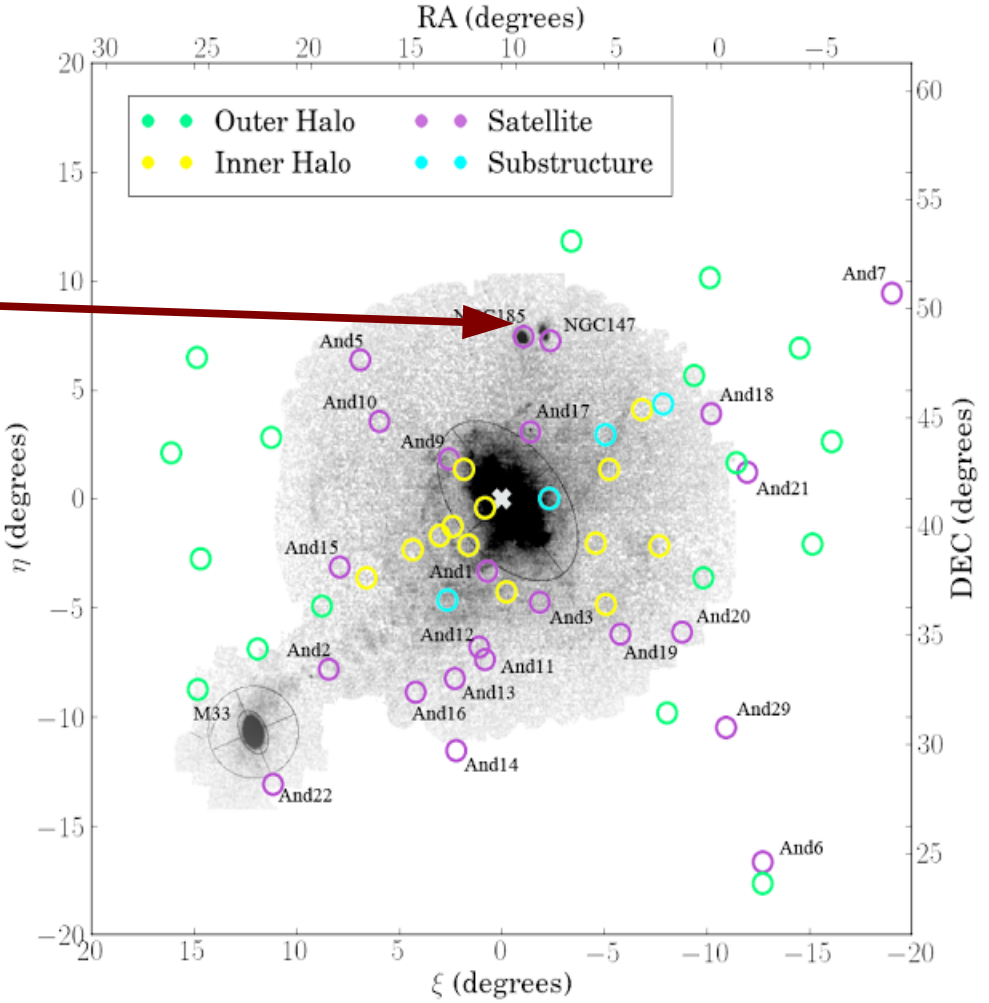
See K. Hamren Poster!





Beaton et al. (in prep.)

Hamren et al. (in prep.)

Summary

- Extragalactic systems let us probe and explore the *full* morphological parameter space for ***streams*** and ***satellites***.
- We can start to probe the ***quenching timescale*** – a brief but important phase of satellite evolution – that sets how gas is expelled or taken into the parent halo (and then rains onto disk).
- Inferences from external galaxies, allow us to ***better interpret*** Local Group mergers and ***pose tests*** to expand our understanding.
- We are probing the local quenching timescales with ***resolved stellar populations in Andromeda*** (see poster by K. Hamren).