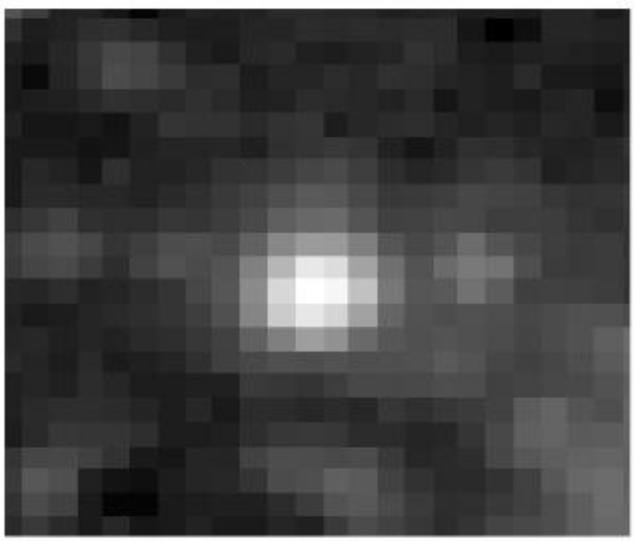
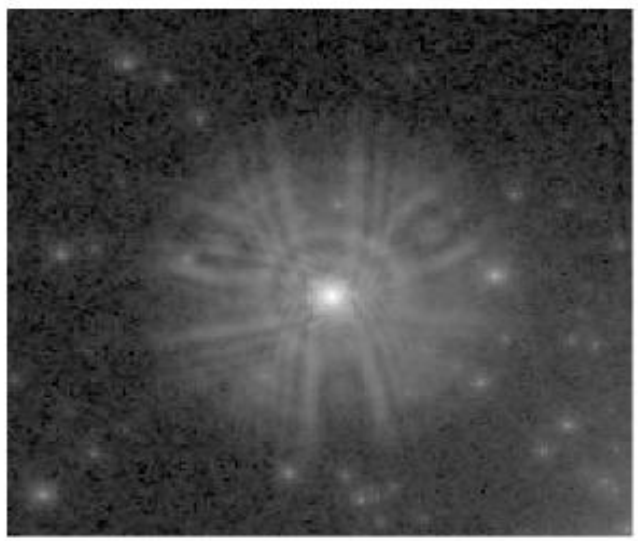
Extra Galactic Astronomy with HST:
Proposal Writing and Current Hot Topics

HST: Brief History

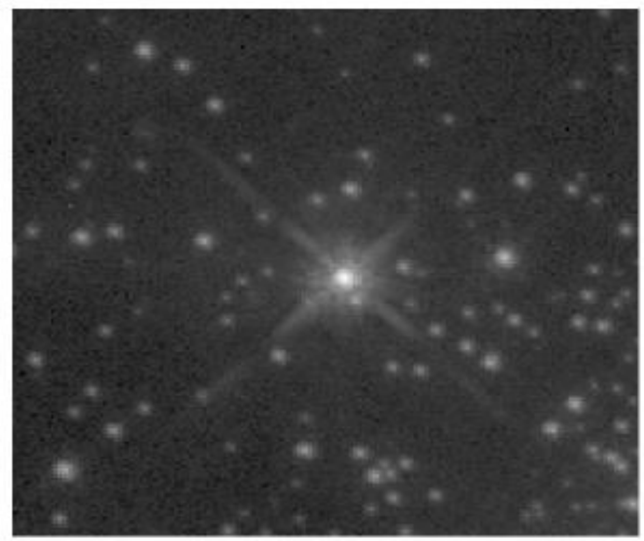
- Envisioned in the 1940s, built in the 70s-80s
- $1.7 billion
- 2.4-meter reflecting telescope
- Deployed in a low-Earth orbit (600 km) by the crew of Discovery on 25 April 1990.
- Spherical Aberration discovered ~month after launch. Endeavour corrected with COSTAR in 1993 (SM1)



Ground Image



Wide Field and Planetary Camera 1



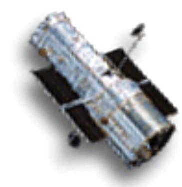
WFPC2

Wide Field Planetary Camera 1

Wide Field Planetary Camera 2

M100

Hubble is As Powerful As Ever

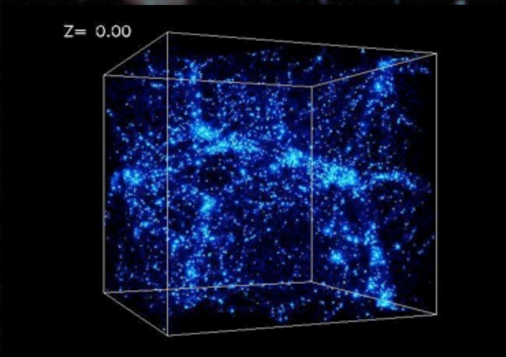


Sembach

Deep, precise, stable pan-chromatic imaging

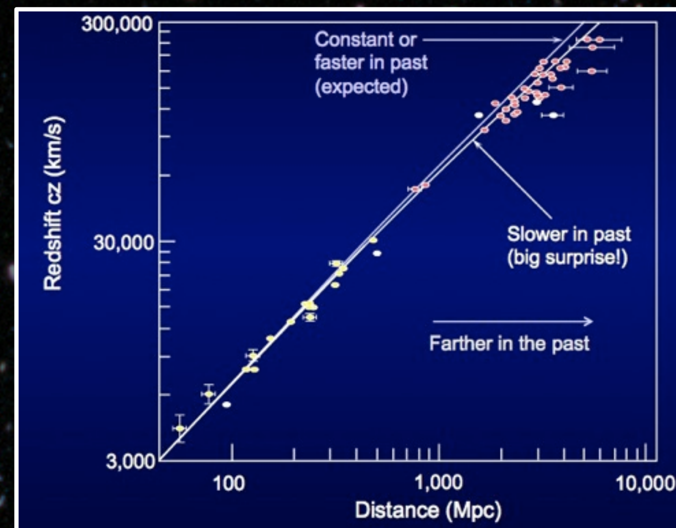
Slitted and slitless spectroscopy, coronagraphy, astrometry

Architecture of the universe

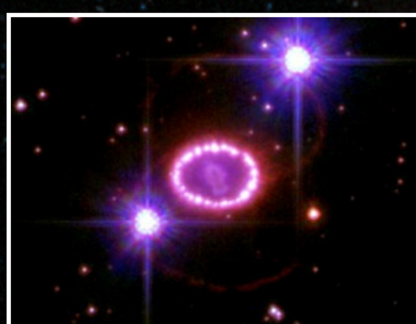


Life stories of galaxies

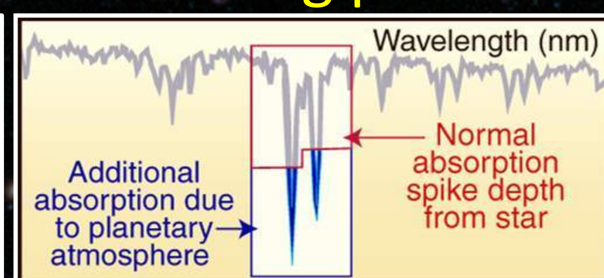
Mysteries of dark matter and dark energy



Births and deaths of stars

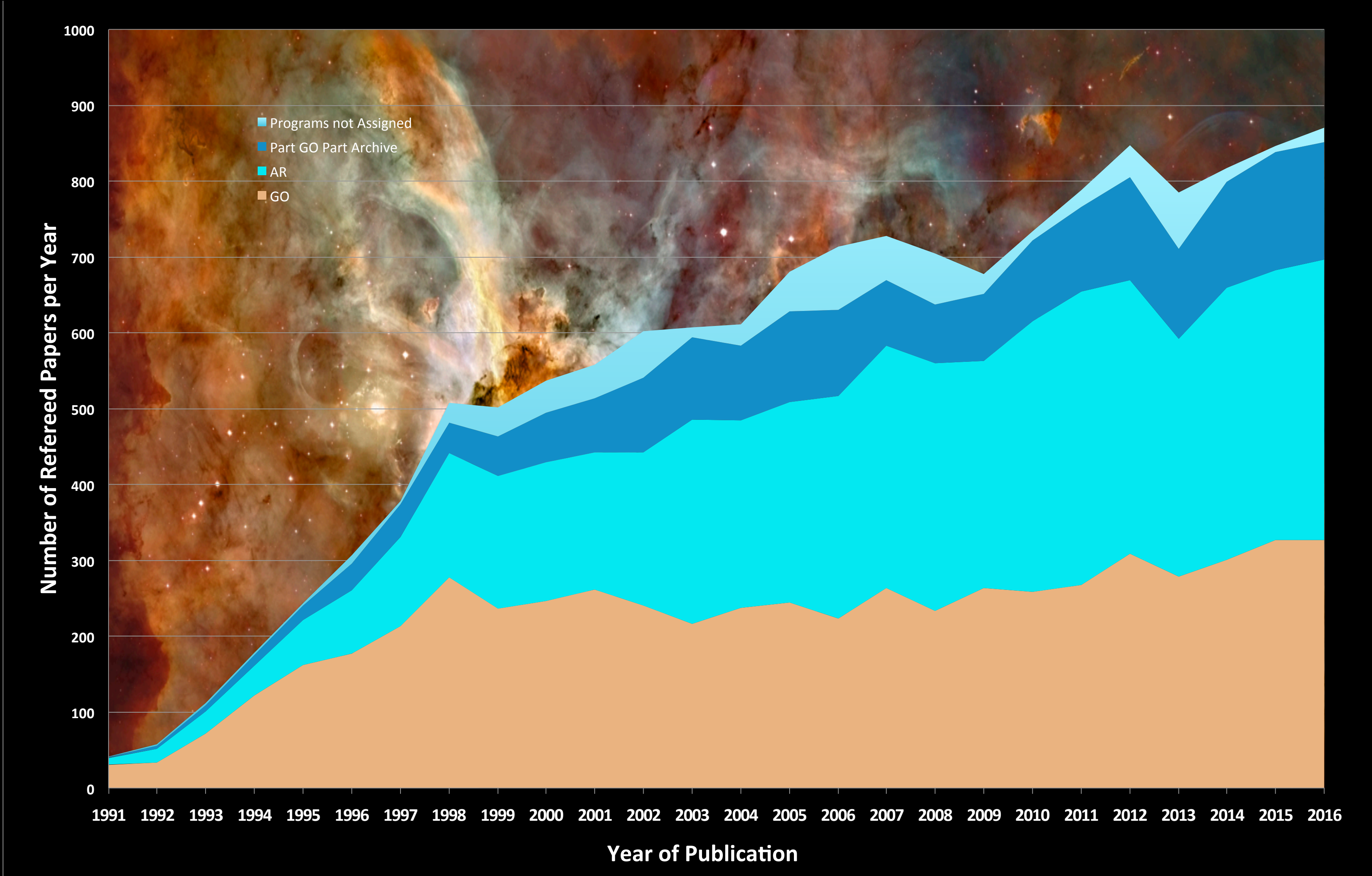


Recipes for building planets



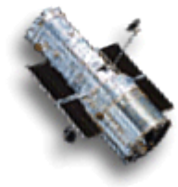
Hubble Scientific Productivity is Outstanding

- >13,800 papers based on HST data, with >600,000 citations
- >14,800 individuals have (co)authored a paper based on HST data
- Nearly 600 PhD theses have been based on HST data



SM4 Servicing Mission (2009)

- On-site repair of ACS and STIS, added COS, WFC3
- Replaced all of HST's batteries (18 yrs old)
- 6 new gyroscopes added (to point the telescope)
- Fine guidance sensor (locks onto stars)
- New Outer Blanket Layers : insulating panels covering key equipment (replacing old protective blankets)
- Soft Capture Mechanism installed: allows a robotic spacecraft to attach itself someday to HST to guide it through descent to Earth.



Operate Hubble out to 2020 or beyond so that there is at least one year of overlapping science observations with the James Webb Space Telescope, performed in a manner that maximizes the science return of both observatories by taking full advantage of Hubble's unique capabilities and the astronomical community's scientific curiosity.

How long will Hubble continue to operate?

As long as it remains scientifically productive

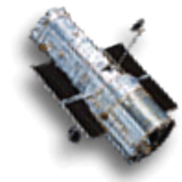
What is needed to keep Hubble scientifically productive?

Current best estimate:

>4 years of overlap!

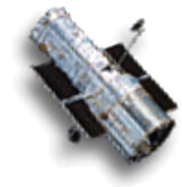
- An operating observatory
- Capable science instruments
- Scientific drivers (demand)
- Adequate staffing and user support
- Appropriate funding
- Common purpose & teamwork

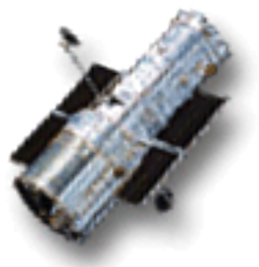
The Road to 2020+



	Current Status (2017)	Expectations (2017-2021)
Observatory Health	Excellent (even better than expected after SM4)	• Good reliability of science instruments and major systems well beyond 2020 (NESC) • Known modes of degradation
Orbit Decay	Nominal orbit	• Orbit stable until mid-2030s
Scheduling Efficiency	~50%, near all-time high Averaging >84 orbits/week	• Efficiency declines to ~40 upon transition to reduced-gyro mode (see next slide)
Scientific Productivity	~800 papers per year; ~40 PhDs per year	• Publication rate remains high • New discoveries continue
Demand	>1000 proposals per year; 6:1 oversubscription (time)	• No near-term decrease expected
Staffing	Lean operations	• Work efficiencies are harder to achieve beyond FY17 without loss of capability
Mission Funding	$98.3M/year total budget	• Uncertain mission budget presents challenges
Grant Funding	$28-30M/year in grants to the community	• Strong support for science analysis

Hubble is in Excellent Health



Observatory Systems Status		
 Science Instruments	ACS	Operating well. Improved CTE corrections and SBC cals.
	COS	Far-UV sensitivity remains excellent. Moving to LP4 in October 2017 with new operating strategy.
	STIS	Operating well. BAR5 coronagraphy competitive with ground reaching 1E-6 with ADI and KLIP. Spatial scanning now available.
	WFC3	Excellent stability, sensitivity, astrometry. Spatial scanning and Tiling (DASH) available. CTE corrections for UVIS channel. Persistence maps available for IR channel.
Fine Guidance Sensors		Slow degradation being monitored, understood.
Electrical and Power System		Batteries and solar arrays - no serious issues.
Pointing and Control System		GYRO lifetime estimates indicate 3-gyro operation until ~2023. One-gyro science operation >2036.
Data Management System		Lockups are rare (1-2x per year) and understood.
Thermal Control System		Excellent, no serious issues.

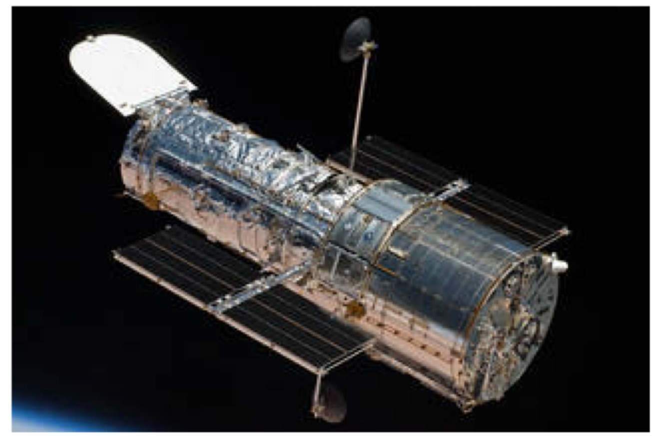
But ....

Hubble

Jan. 8, 2019

Wide Field Camera 3 Anomaly on Hubble Space Telescope

At 17:23 UTC on Jan. 8, the Wide Field Camera 3 on the Hubble Space Telescope suspended operations due to a hardware problem. Hubble will continue to perform science observations with its other three active instruments, while the Wide Field Camera 3 anomaly is investigated. Wide Field Camera 3, installed during Servicing Mission 4 in 2009, is equipped with redundant electronics should they be needed to recover the instrument.

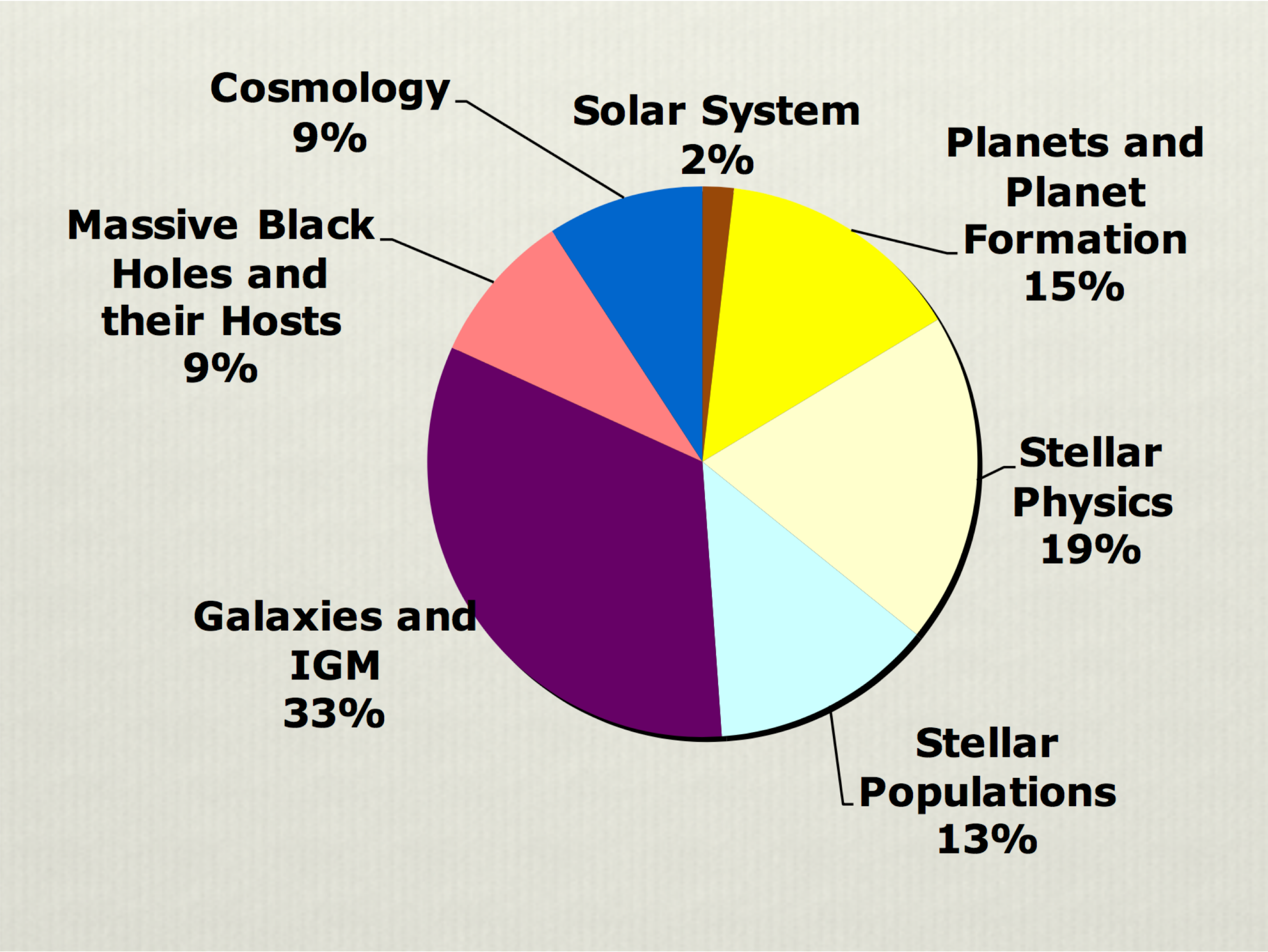


Hubble Space Telescope in orbit.
Credits: NASA

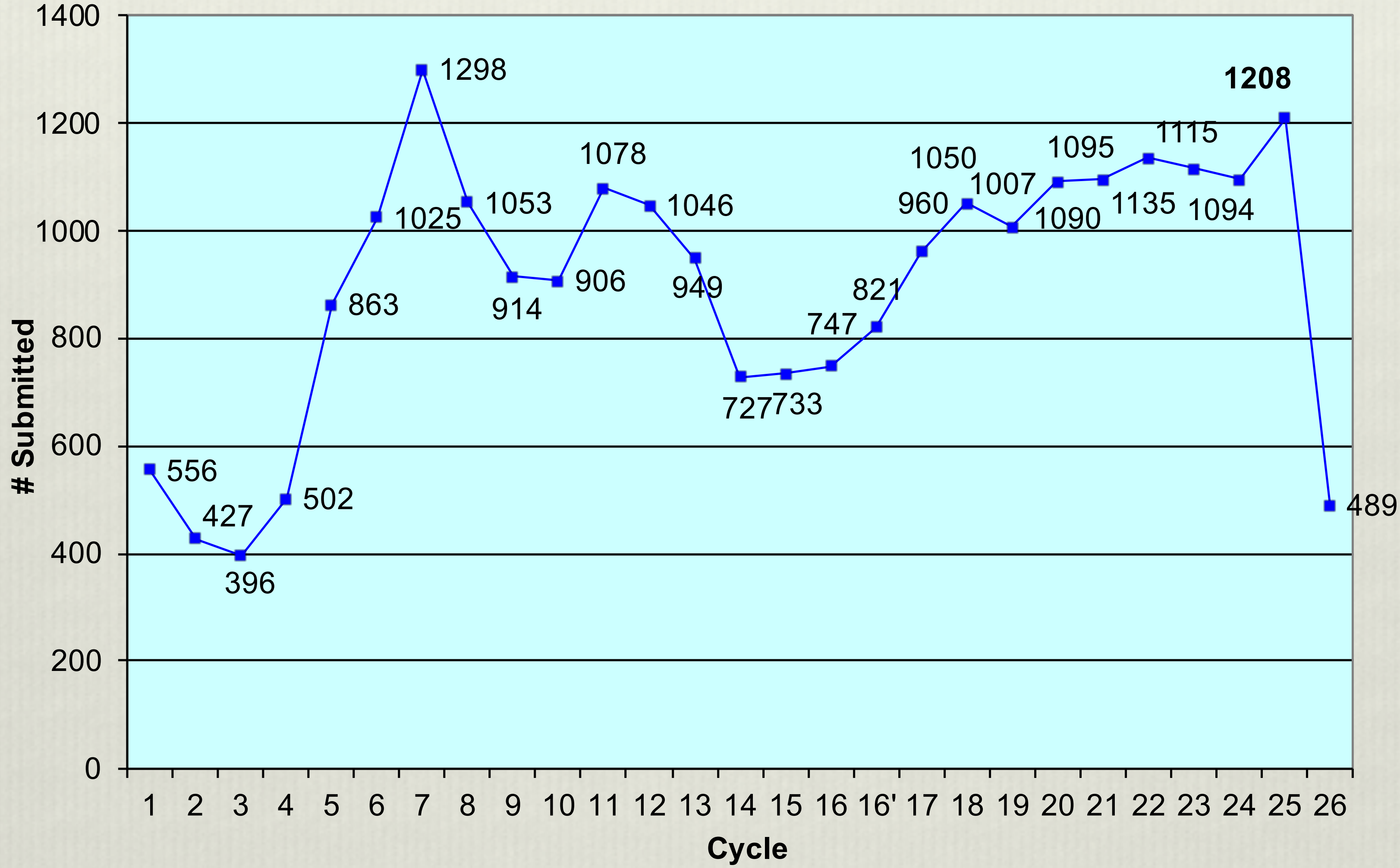
Last Updated: Jan. 8, 2019
Editor: Rob Garner

Tags: Hubble Space Telescope

Cycle 25


Cosmology
9%
Solar System
2%
Planets and
Planet
Formation
15%
Massive Black
Holes and
their Hosts
9%
Stellar
Physics
19%
Galaxies and
IGM
33%
Stellar
Populations
13%

HST Proposal Submissions



Over Subscription

HST Cycle 22

Proposals x 4.25 Orbits x 5.4

Total: 1135 Submitted → 263 Accepted

Cycle 25 : 1205 proposals → 340 accepted. x 3.5

Cycle 26-→ Factor of 11!!

Table 1. Summary of Cycle 25 Results

Proposals	Requested	Approved	% Accepted
General Observer	971	271	27.9%
Snapshot	52	12	23.1%
Archival Research	105	31	29.5%
AR Legacy	13	2	15.4%
Theory	64	24	37.5%
Total	1,205	340	28.2%
Primary Orbits	***23,365***	***4,800***	***20.5%***

NSF AST Program : 2014 ~ 17 % acceptance rate (2007 it was 24%)

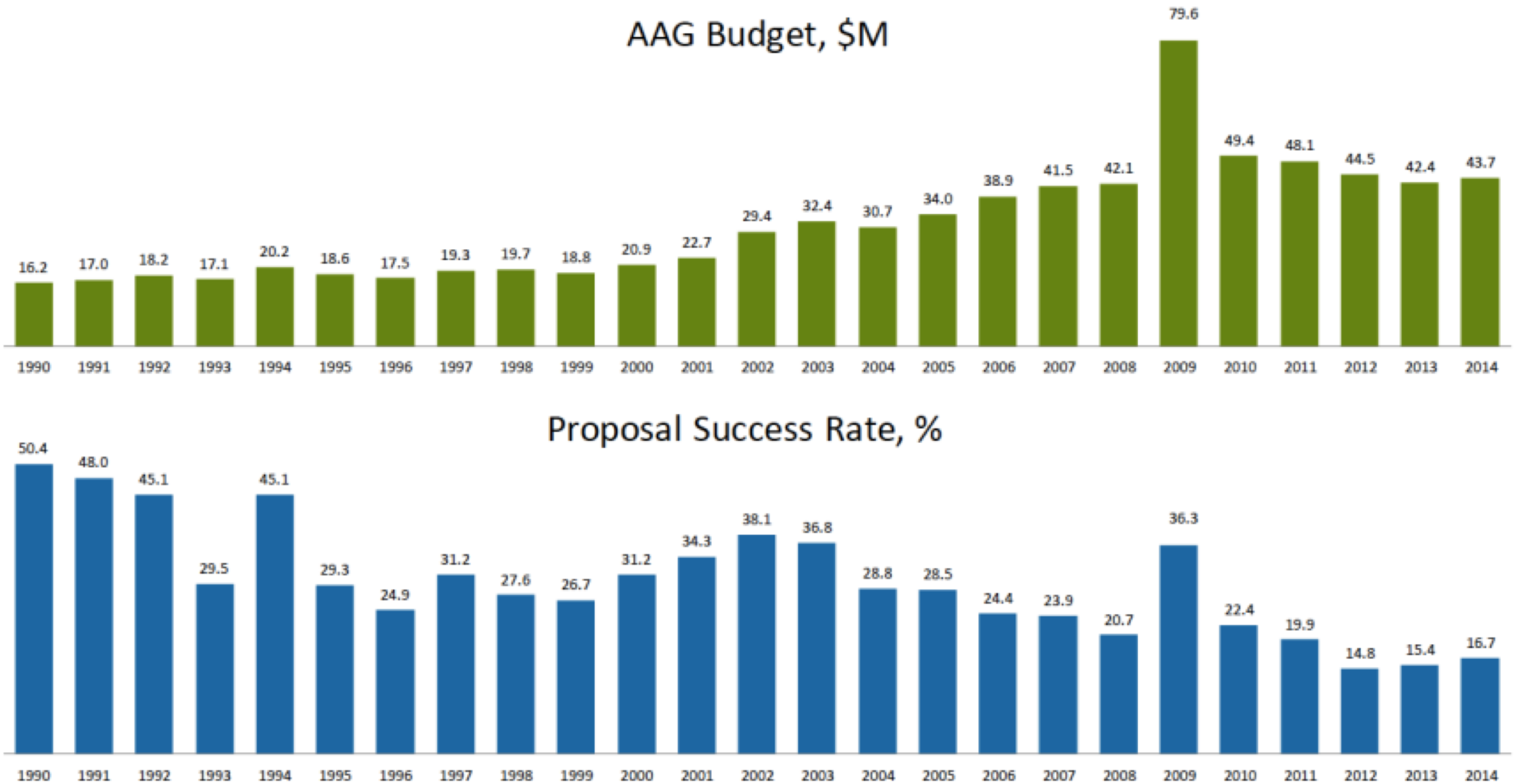
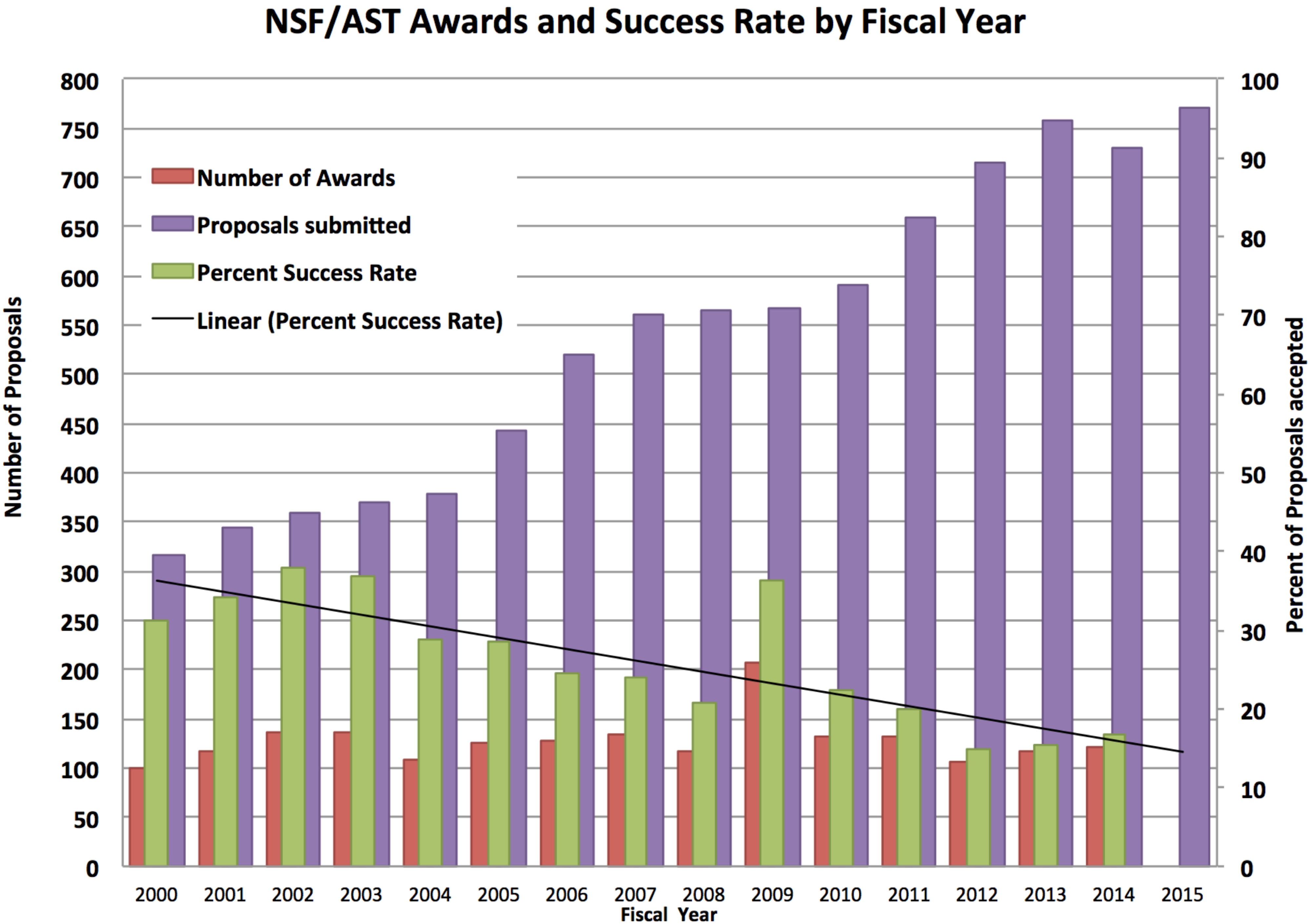


Figure 1: NSF/AST AAG Budgets and Proposal Success Rates from 1990 to 2014. The anomalous spike in FY09 is due to the one-time stimulus provided by the American Recovery and Reinvestment Act.


NSF/AST Awards and Success Rate by Fiscal Year
Number of Awards
Proposals submitted
Percent Success Rate
Linear (Percent Success Rate)
Number of Proposals
Percent of Proposals accepted
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
0
10
20
30
40
50
60
70
80
90
100
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Fiscal Year

HST Major Categories

1. Stellar Populations
2. Massive Black Holes and their Hosts
3. Galaxies and IGM
   - 3.1 ISM
   - 3.2 Structure & Evolution
4. Cosmology

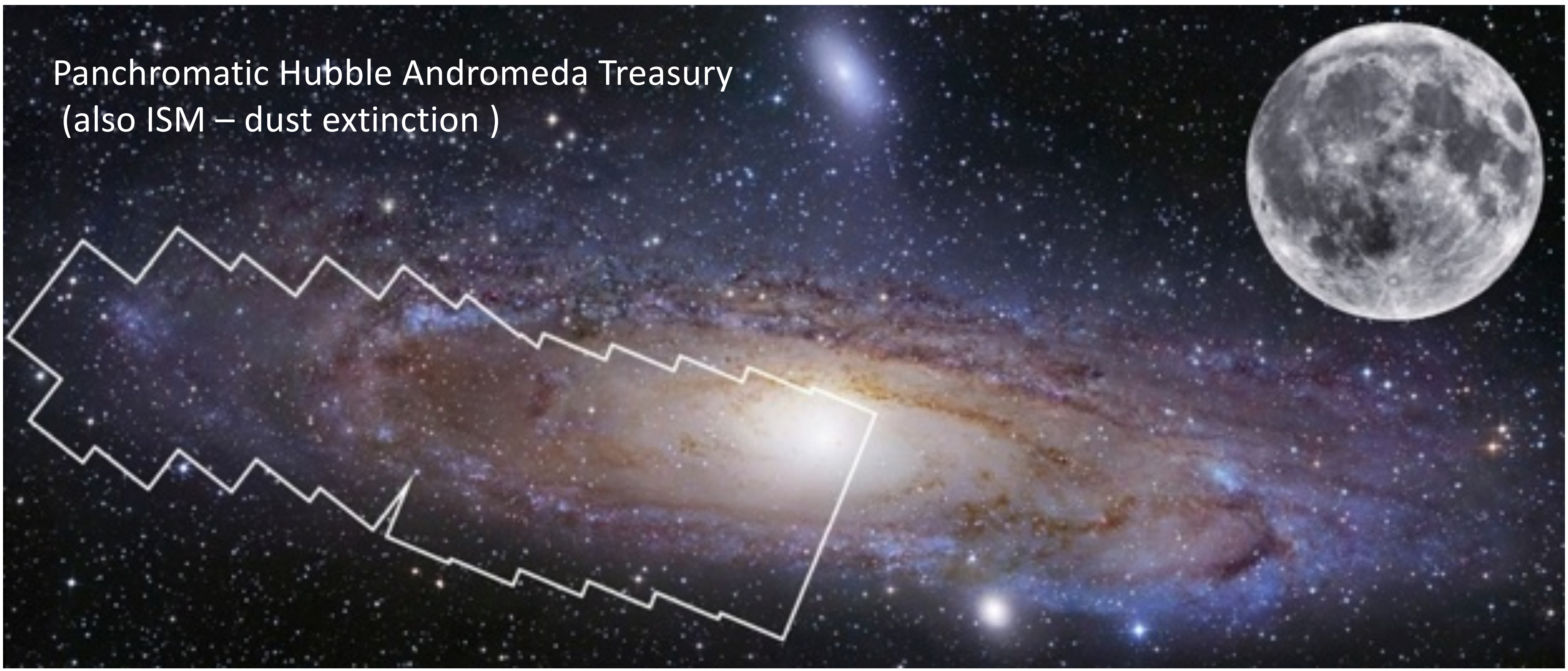
https://github.com/gurtina/ASTR520_2019

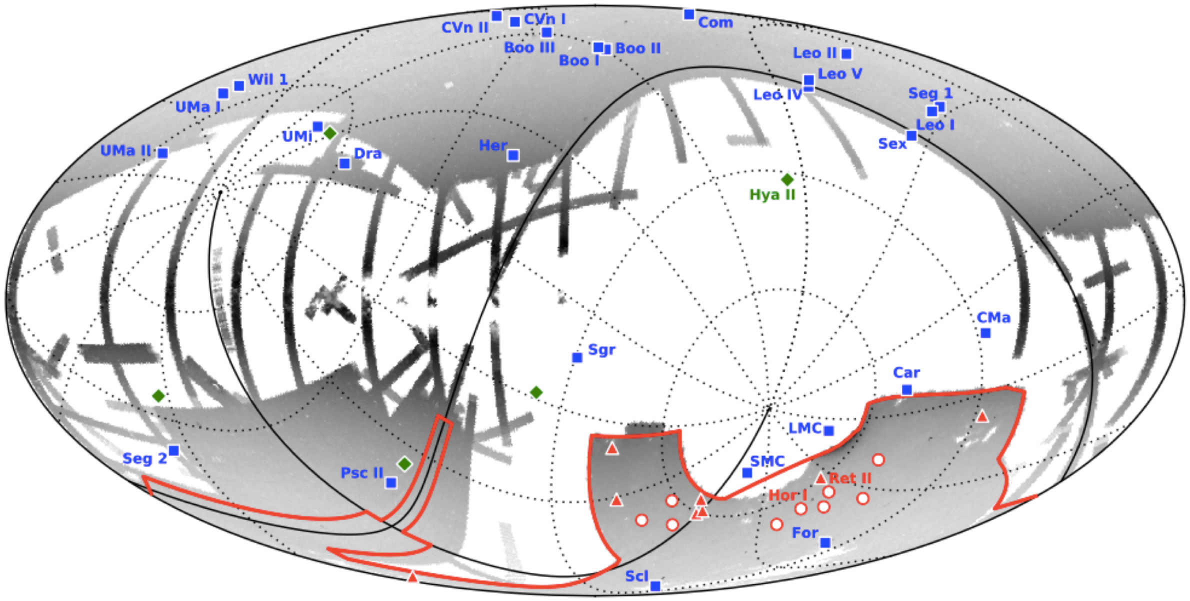
1. Stellar Pops (< 10 Mpc)

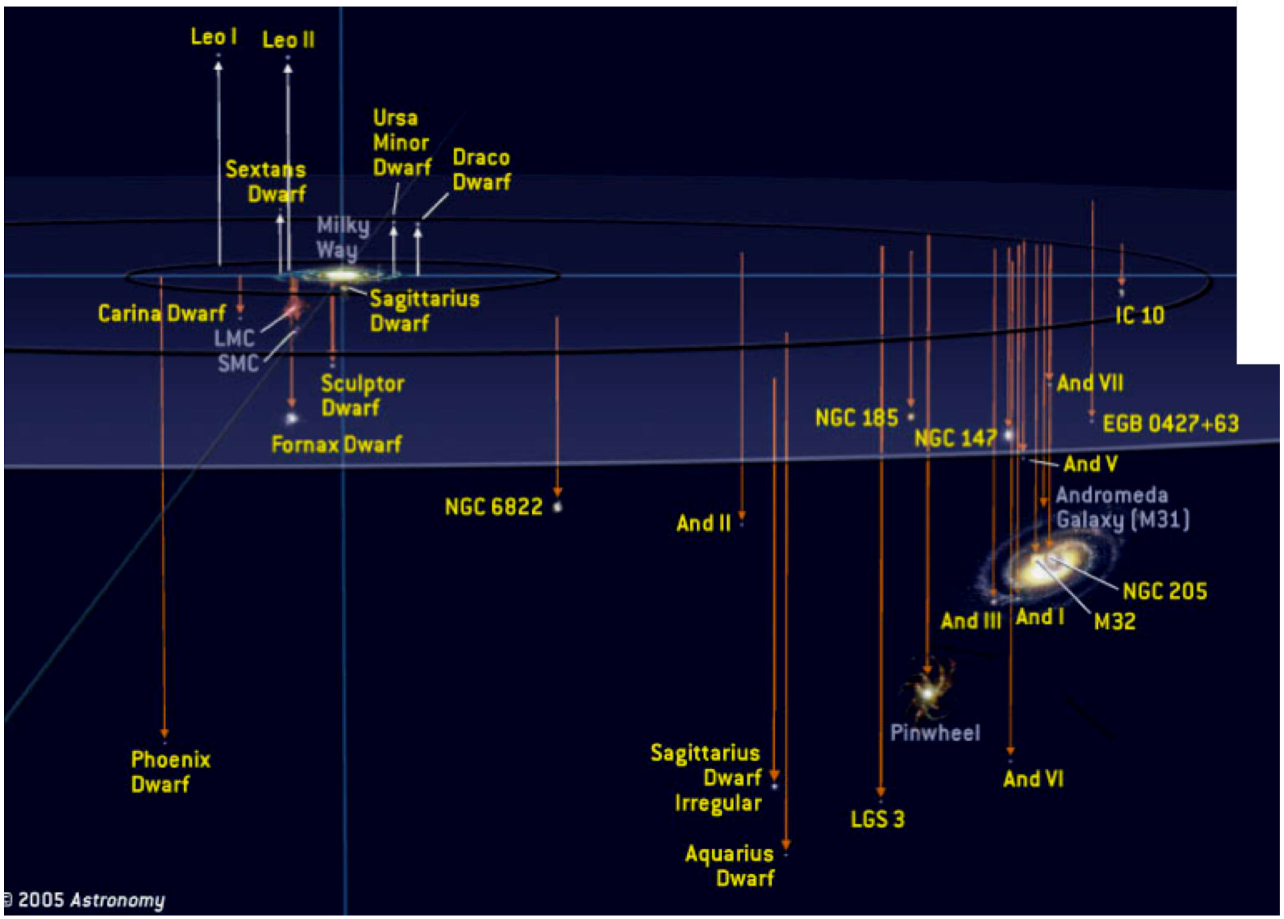
WFC3 & ACS , Archival programs

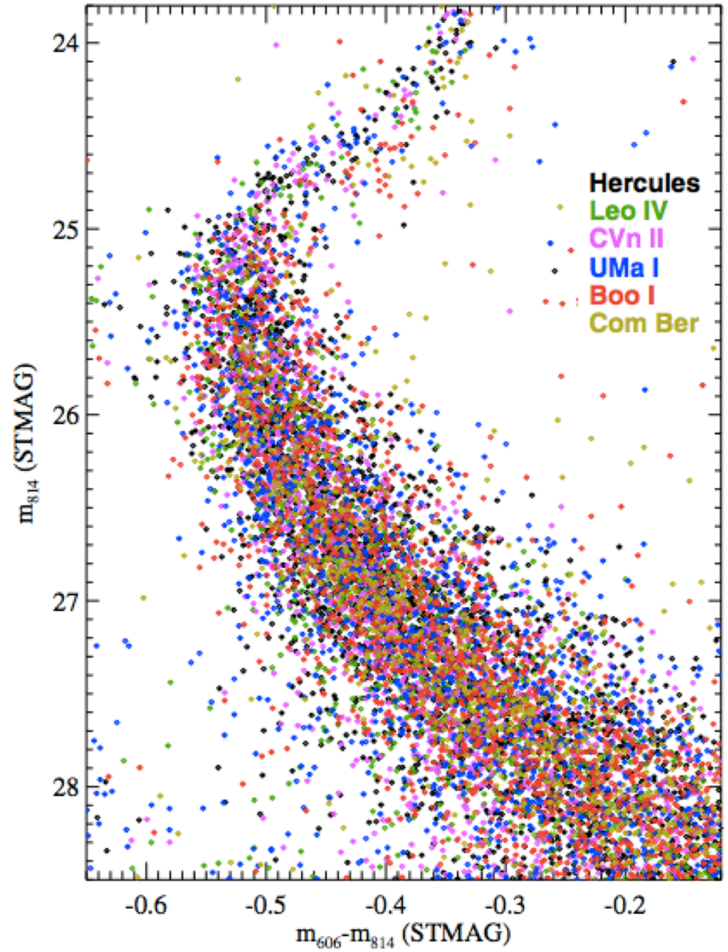
- Star formation histories (Local Volume – e.g. ANGST)
- Stellar Halos (ages, metallicities) – M31, NGC 5128
- Archival programs – long baselines for proper motion studies

(First proper motion of M31)



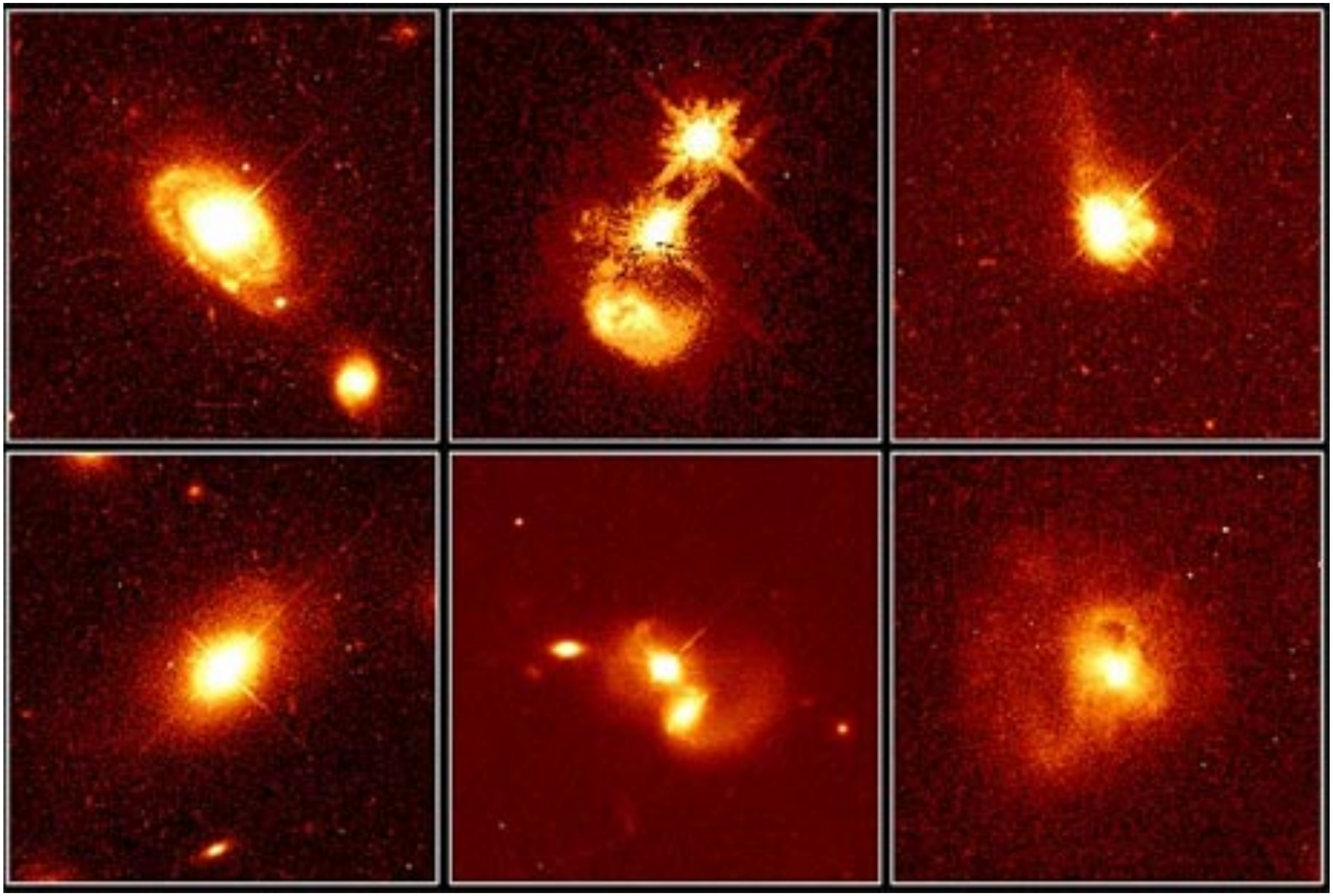






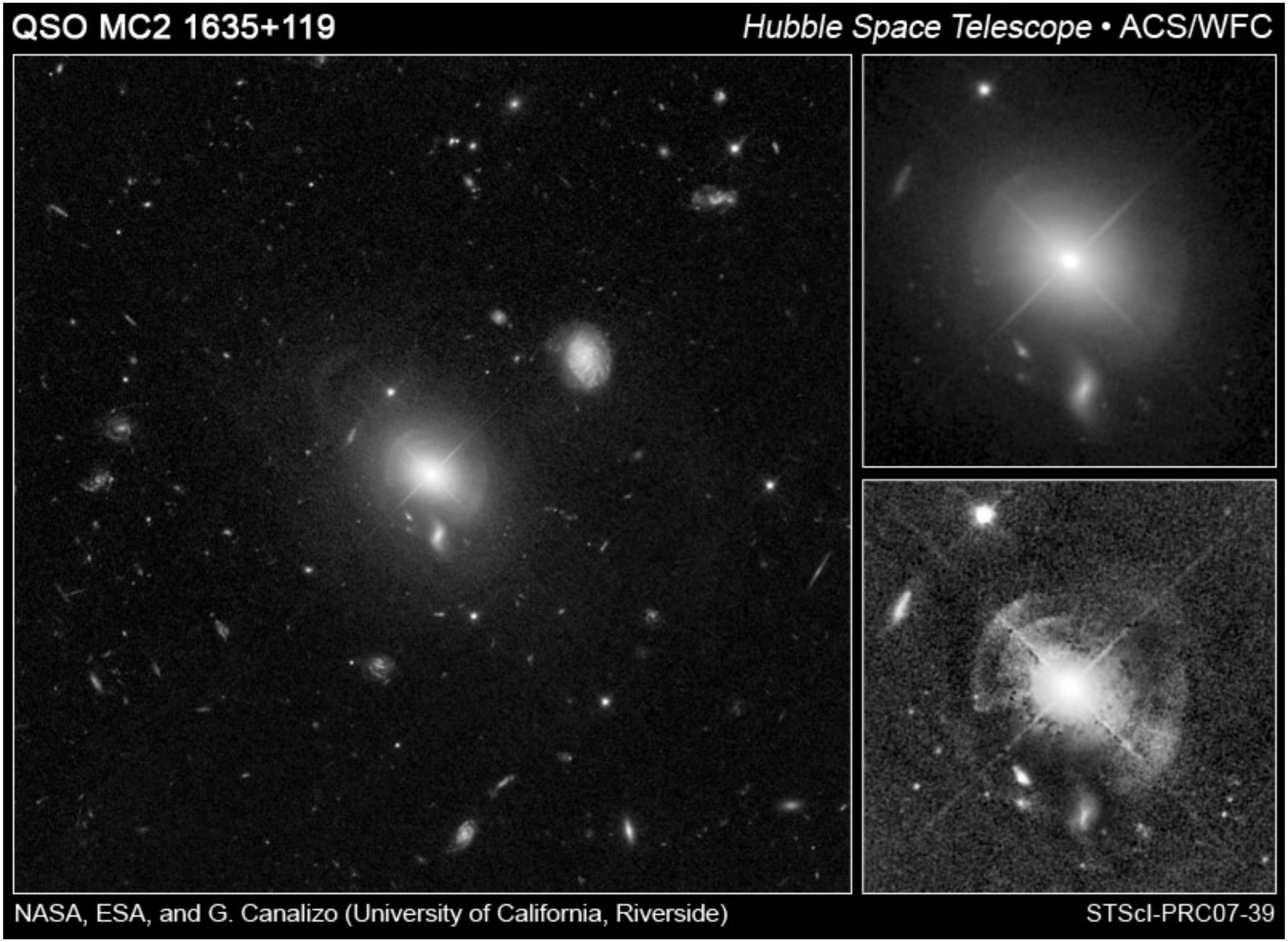
CMDs
IMF
Globular Clusters
Near Field Cosmology

Massive Black Holes: Quasar Hosts



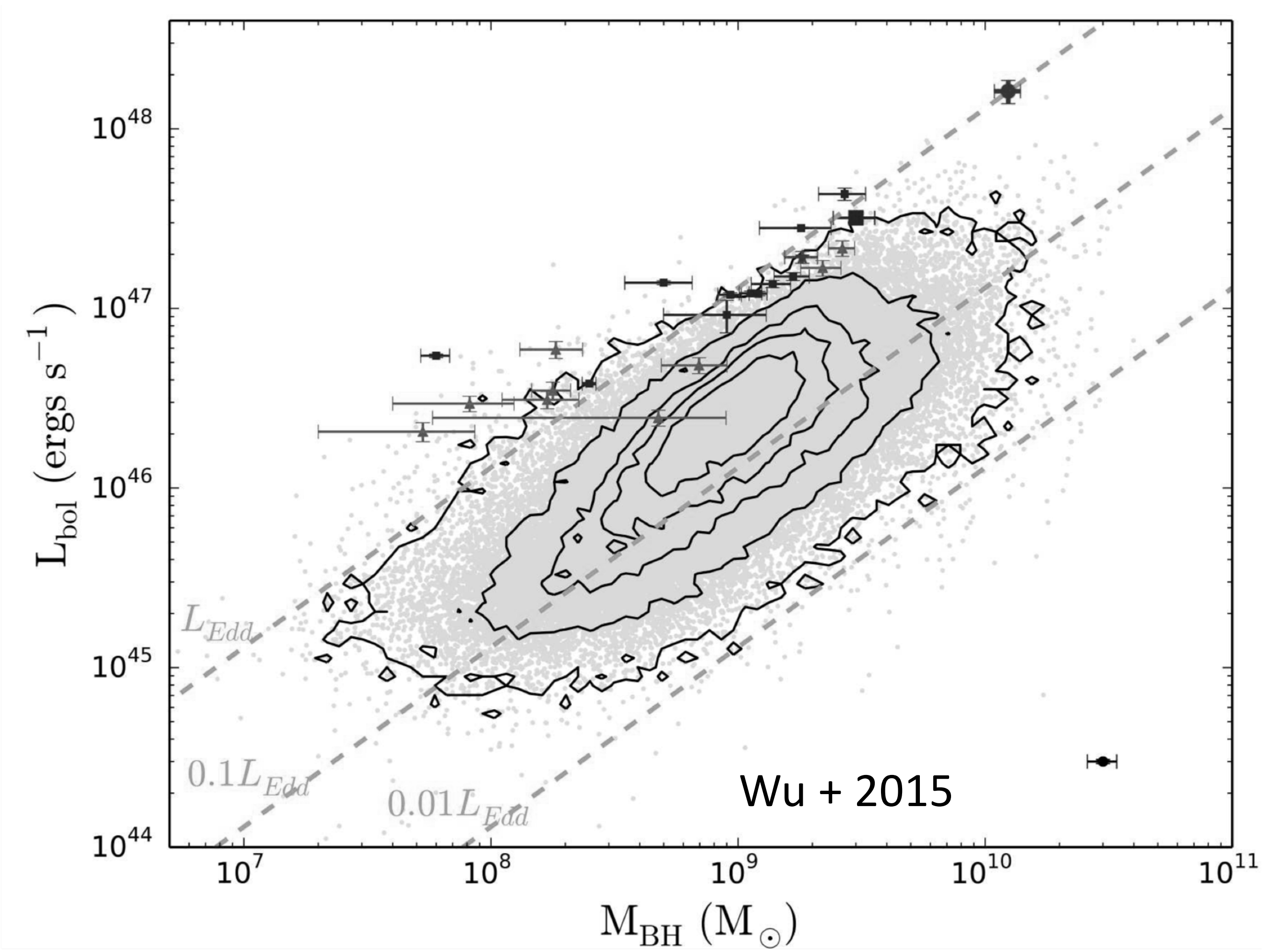
- Connection to mergers?
- Highest Redshift QSOs – environment, properties?

AGN/Merger connection?
QSO with shells



Mass & Hosts of the earliest SMBHs?

- Most massive QSO SMBH at z > 6.3
- Isn't super high z, but *much more massive*

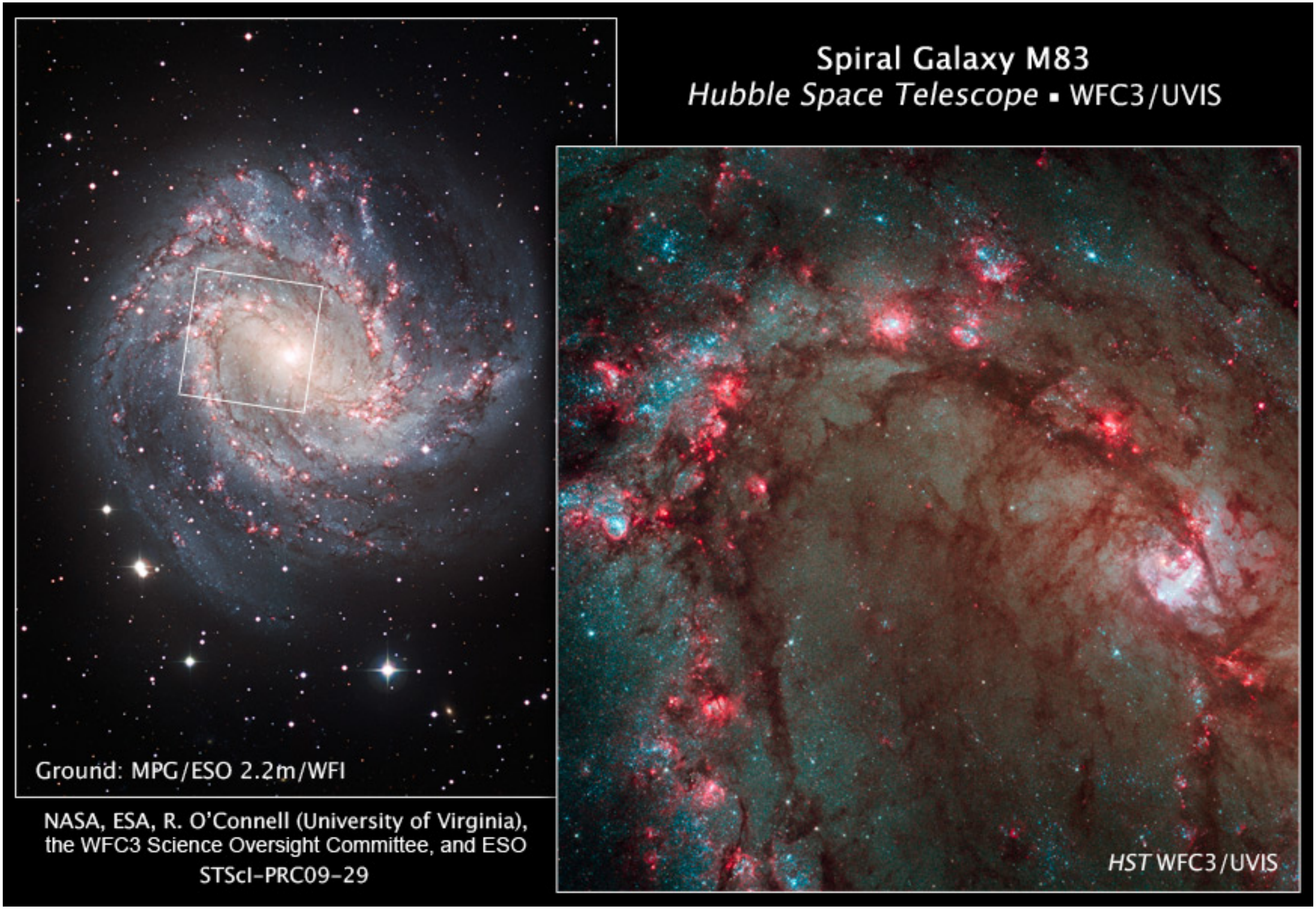


(Originally thrown out since bright enough to be in 2MASS!)

May suggest that BHs grow faster than hosts at high z ??

What is host environment??

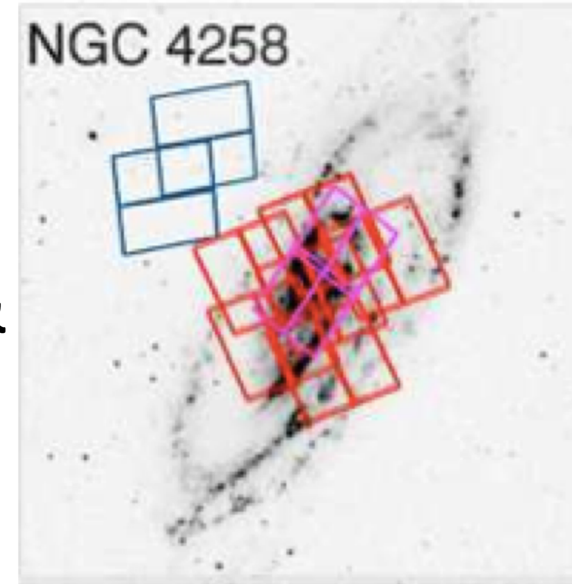
Galaxies - ISM



ISM in External Galaxies

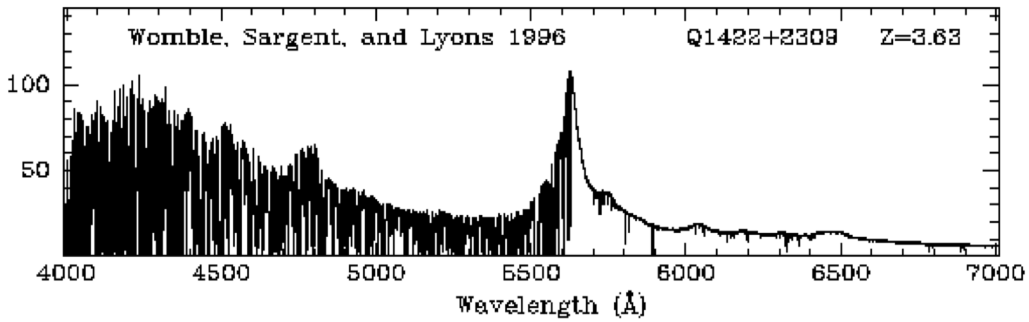
- Star Formation (e.g. in mergers)
- Star Clusters
- Stellar Feedback (impact on structure & SFHs of galaxies)
- Lyman Alpha Emission
- Dust/Extinction
- Blue Compact Galaxies

- LEGUS Survey (Calzetti et al.)

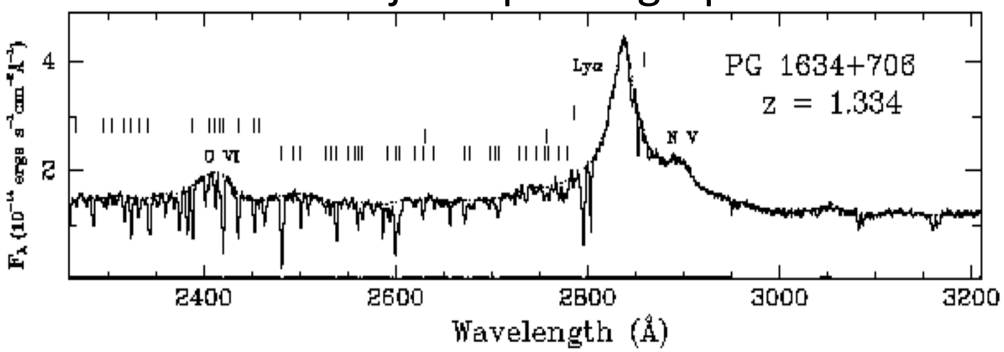


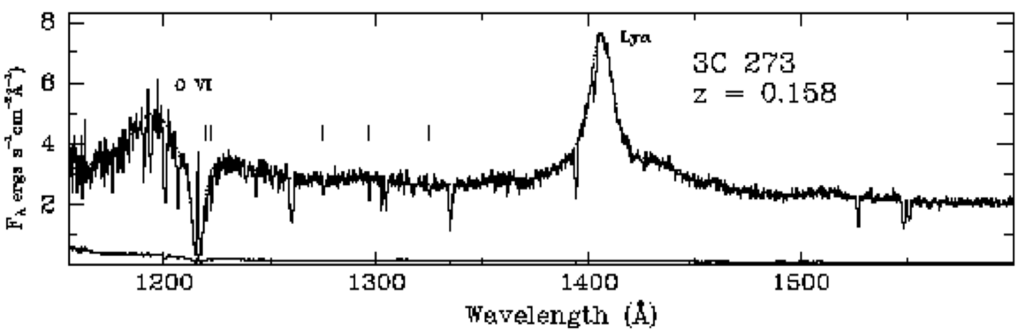
Galaxies - IGM/QSO Absorption Lines

Keck



HST – Faint Object Spectrograph



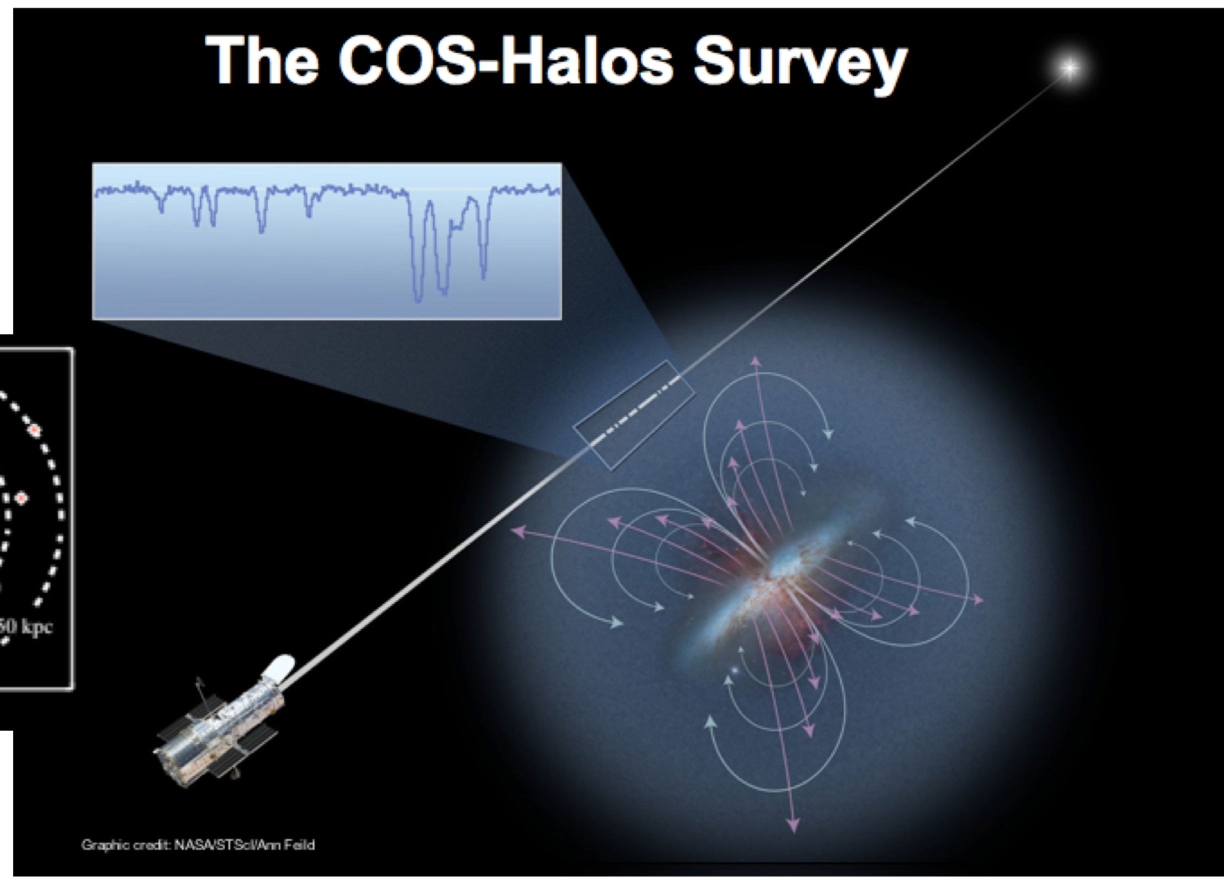


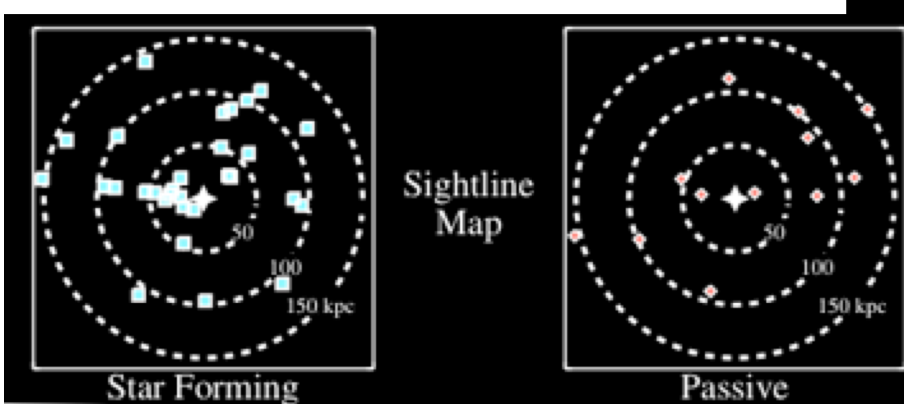
Evolution of the IGM from : Jannuzi

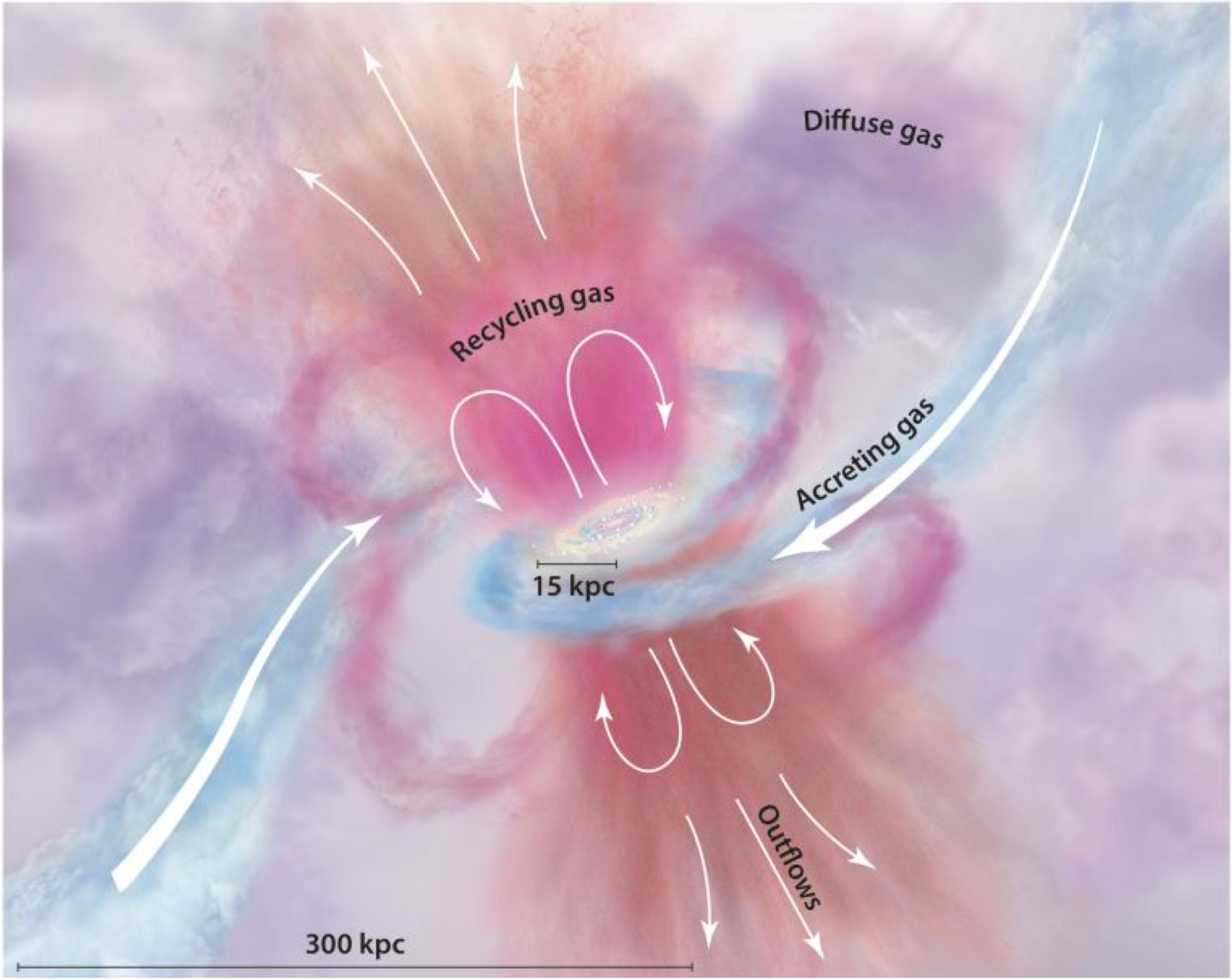
- **HST Key Project: Quasar Absorption Lines Survey (Cycles 1-4)**
- Large, homogeneous catalogue of absorbers suitable for the study of the nature of gaseous systems and their evolution (Bahcall+1993).
- UV Absorption lines towards 89 QSOs
- Can’t do this from the ground for nearby galaxies (can for high z, except far-UV, He-II)

IGM/QSO Absorption Lines: COS (UV)

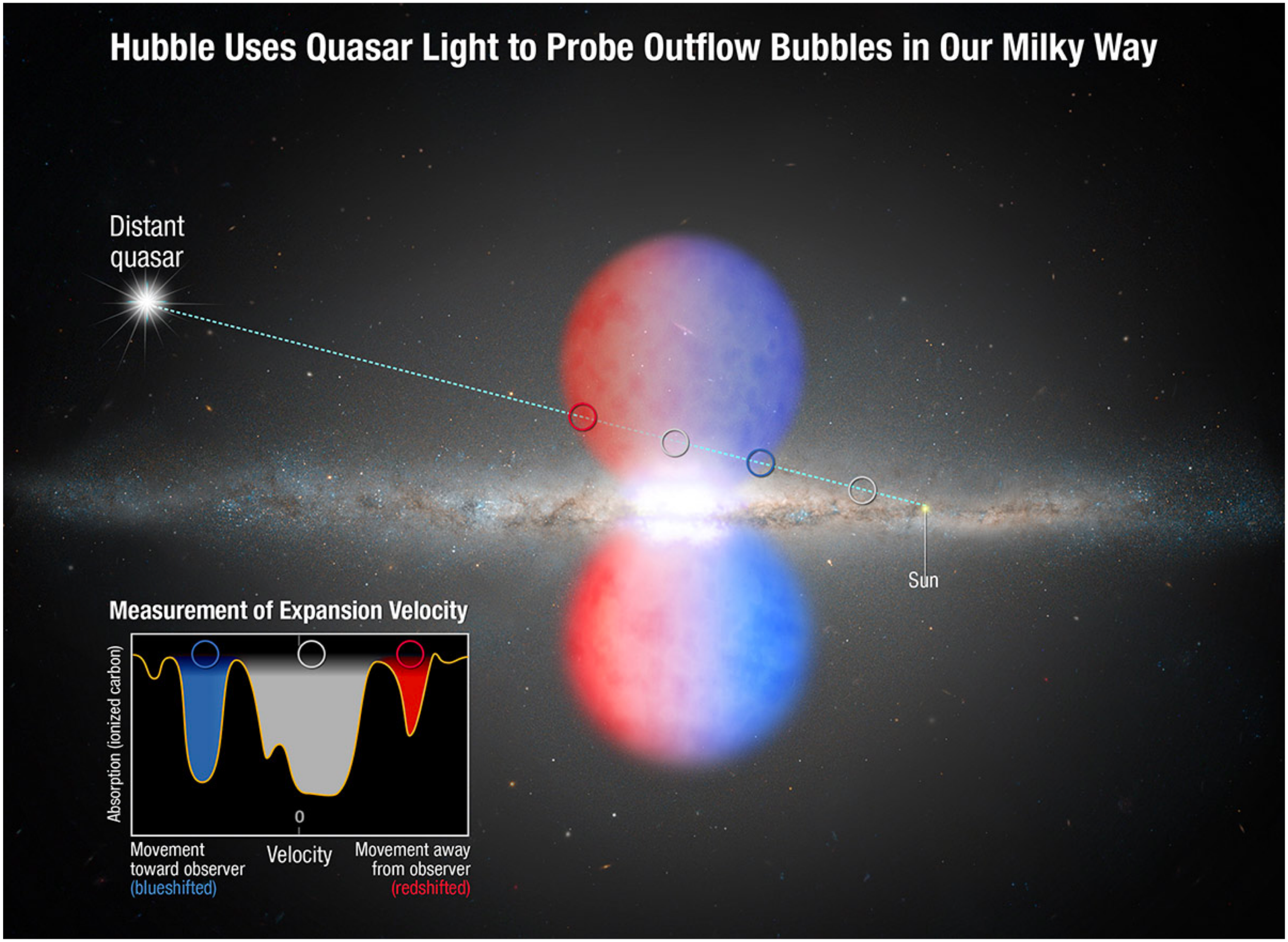
- outflows and cosmological simulations – distribution of metals around galaxies.
- Quenching in the CGM?
- Baryon budget?
- Baryon Cycle?





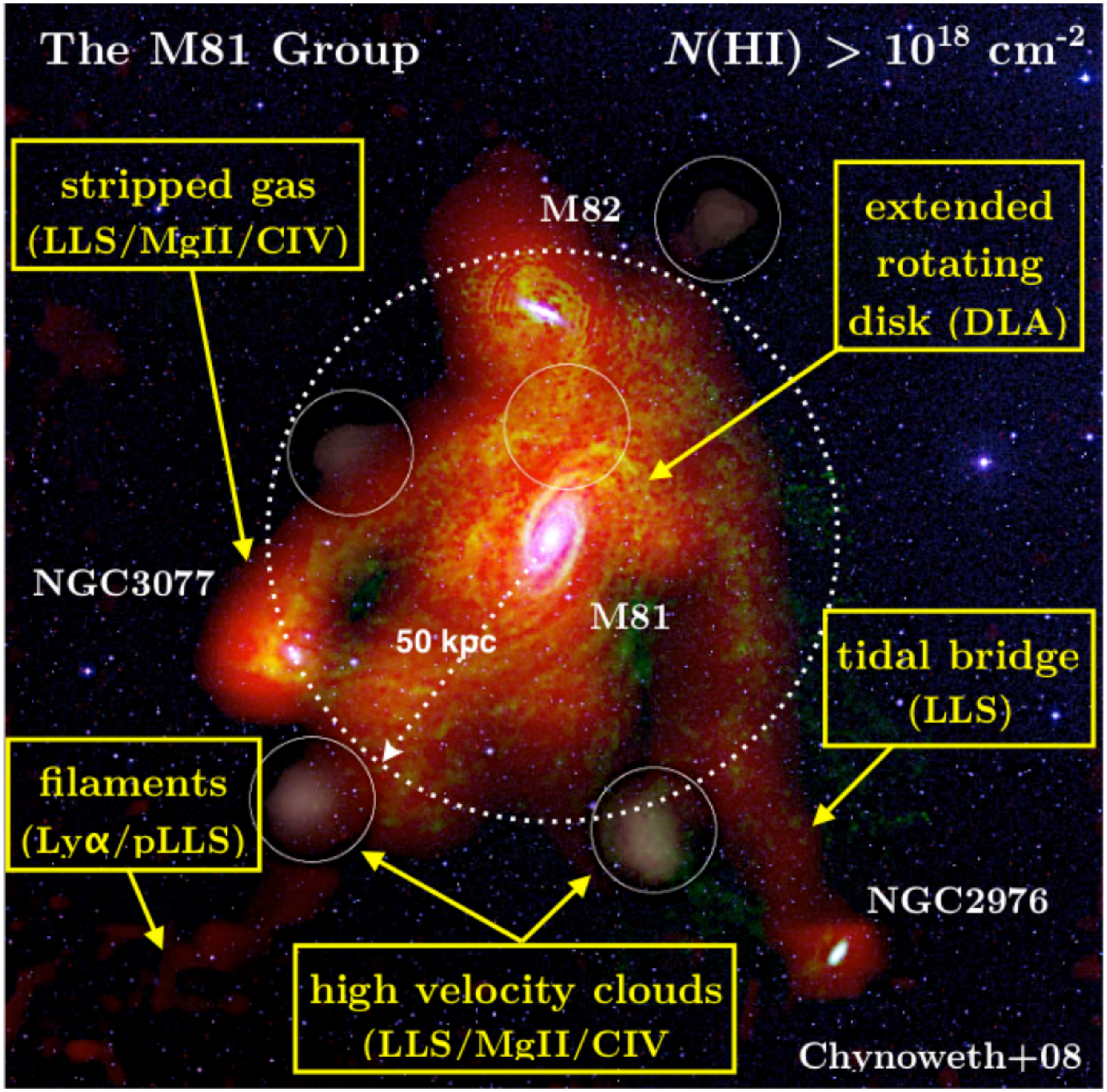

Diffuse gas
Recycling gas
Accreting gas
15 kpc
Outflows
300 kpc

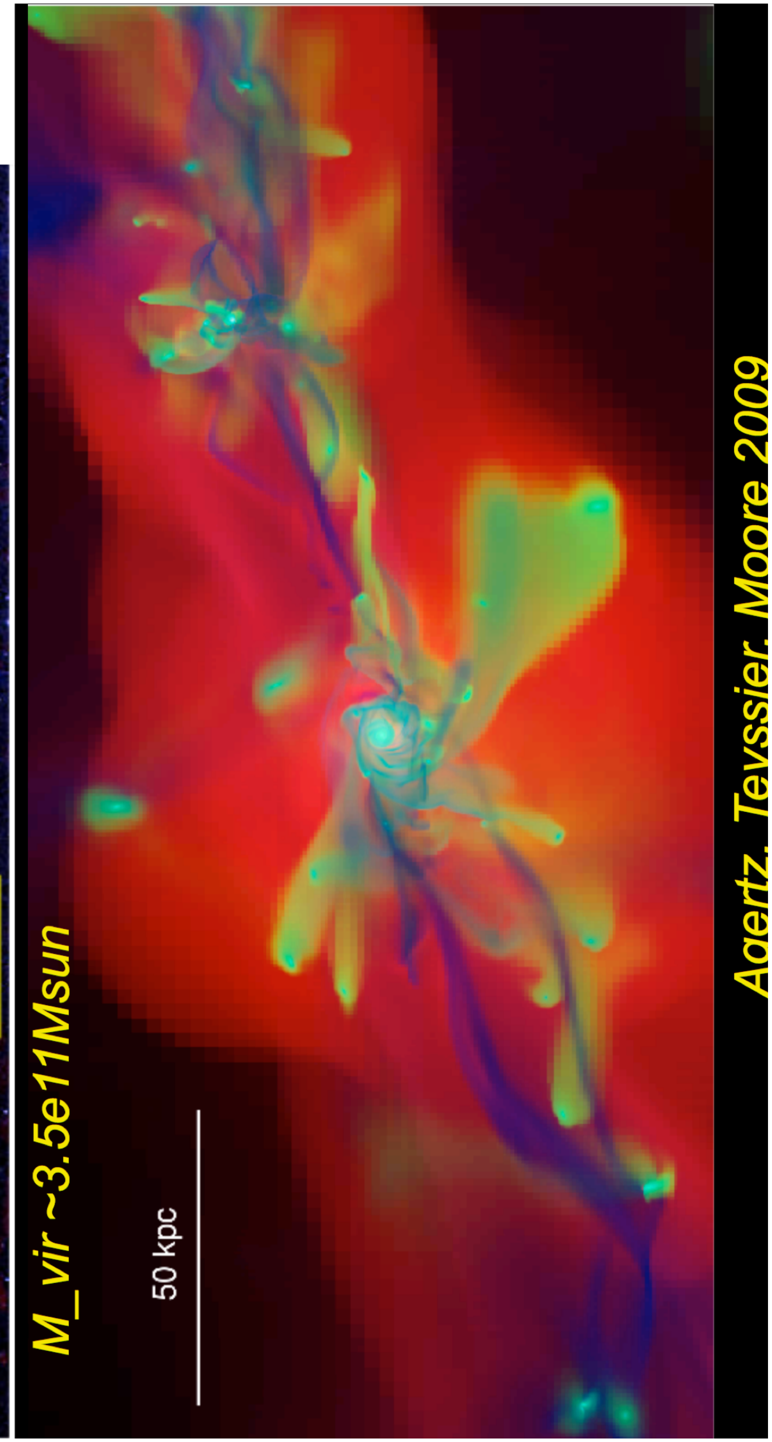
Studying the Fermi Bubble!



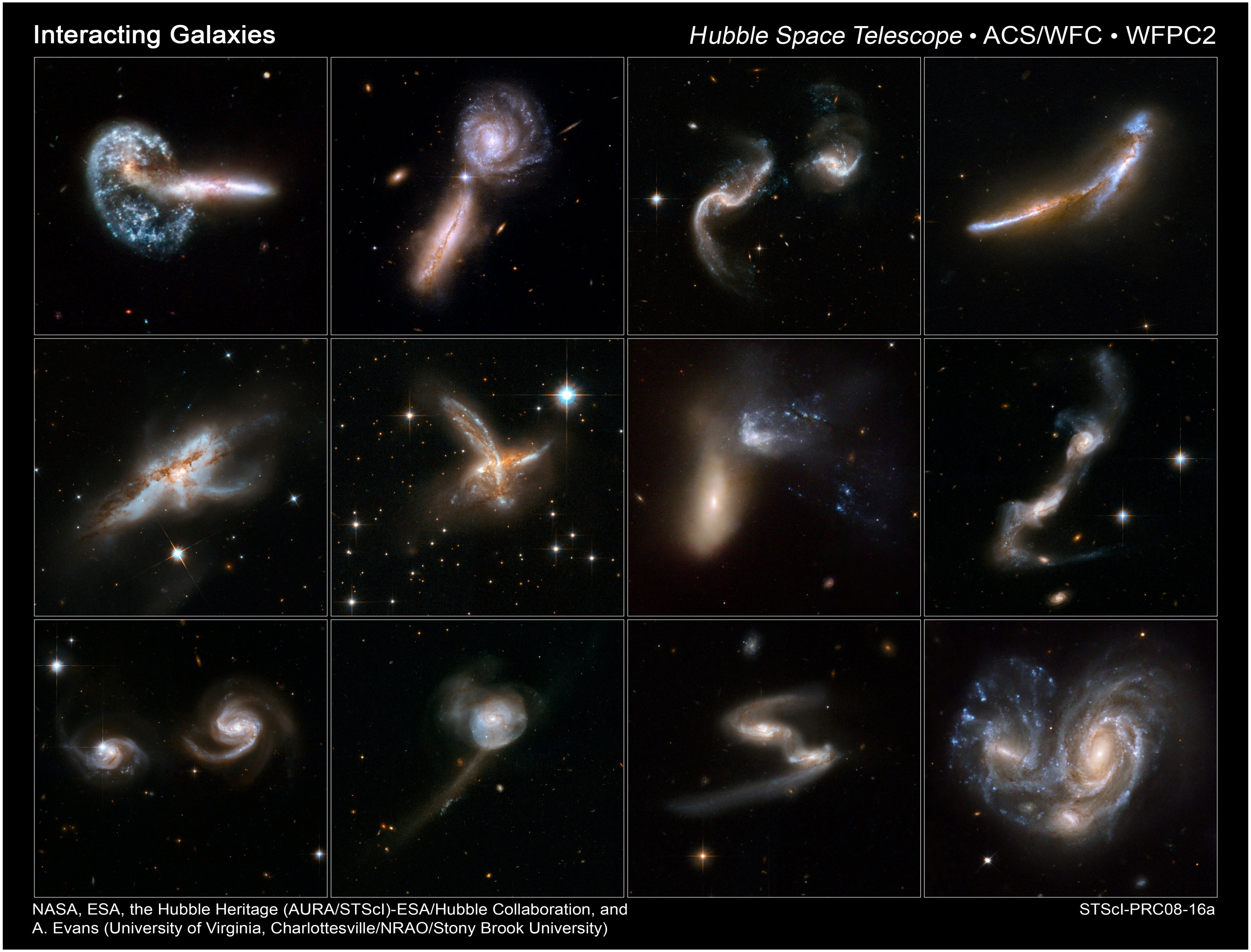
Fox et al.

Groups and Filaments





Galaxies – Structure/Evolution

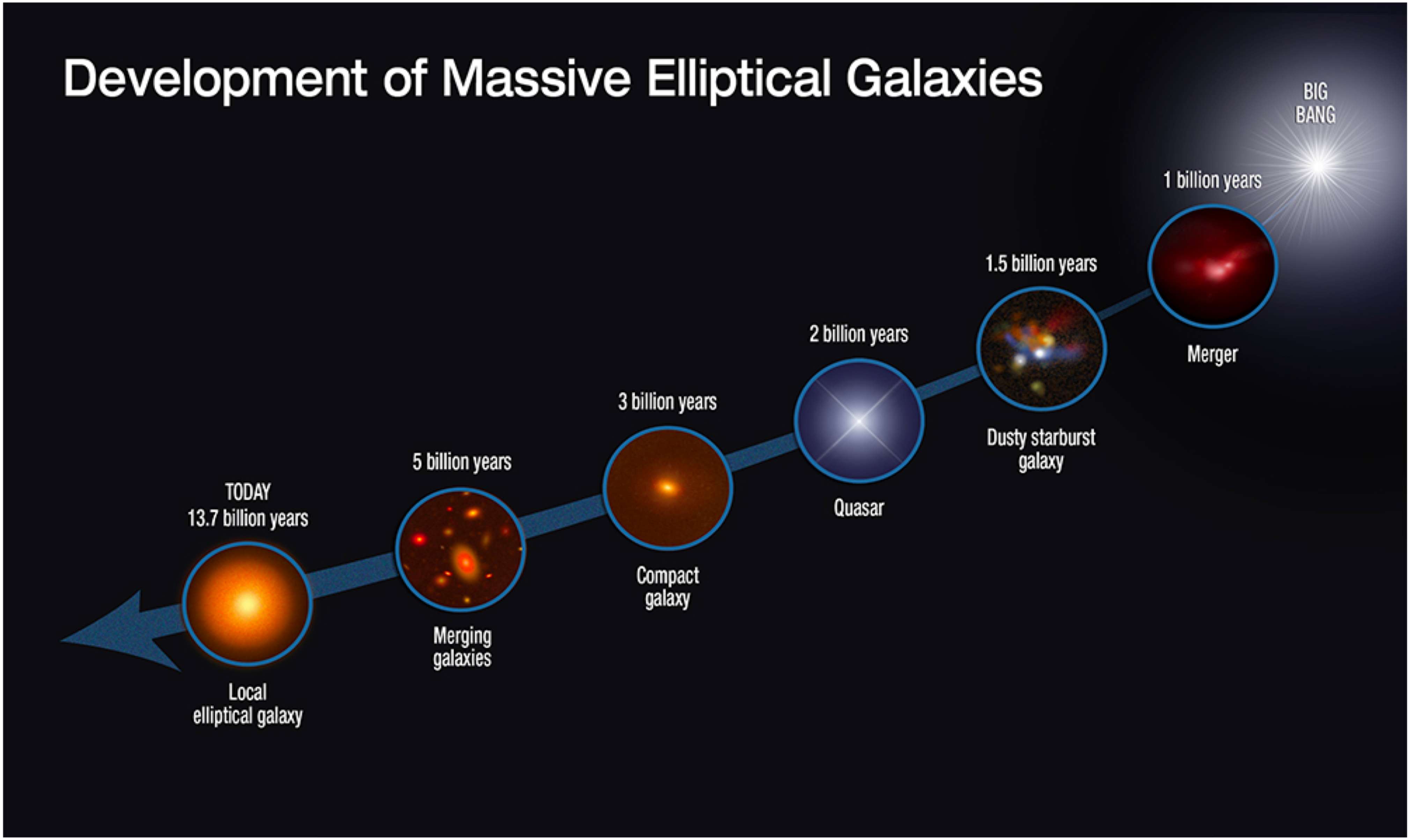


Modeling the merger sequence

Computer Simulation

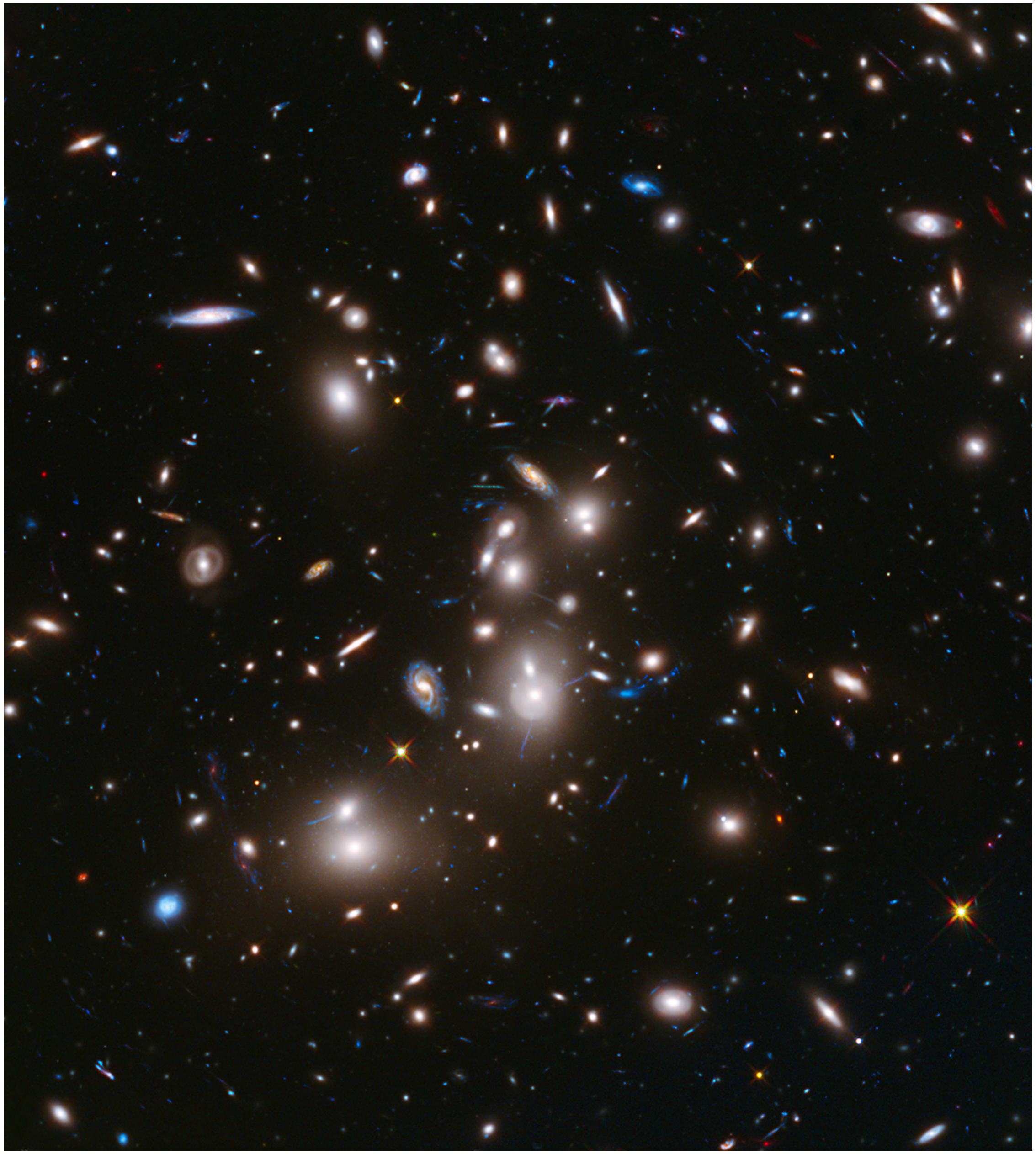
Hubble Image

Time Evolution of Massive Ellipticals?



A crap ton of surveys

http://archive.stsci.edu/hst/tall.html

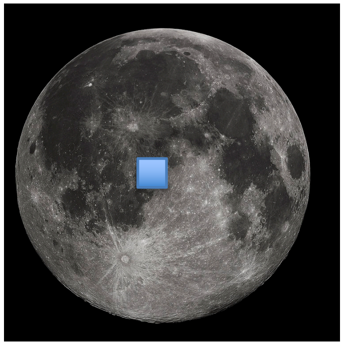


COSMOS
AEGIS
GOODS
3DHST
CANDELS

Frontiers Fields

Cluster: Abell 2744
Magnification of ~ 3000 background galaxies

6 Clusters total

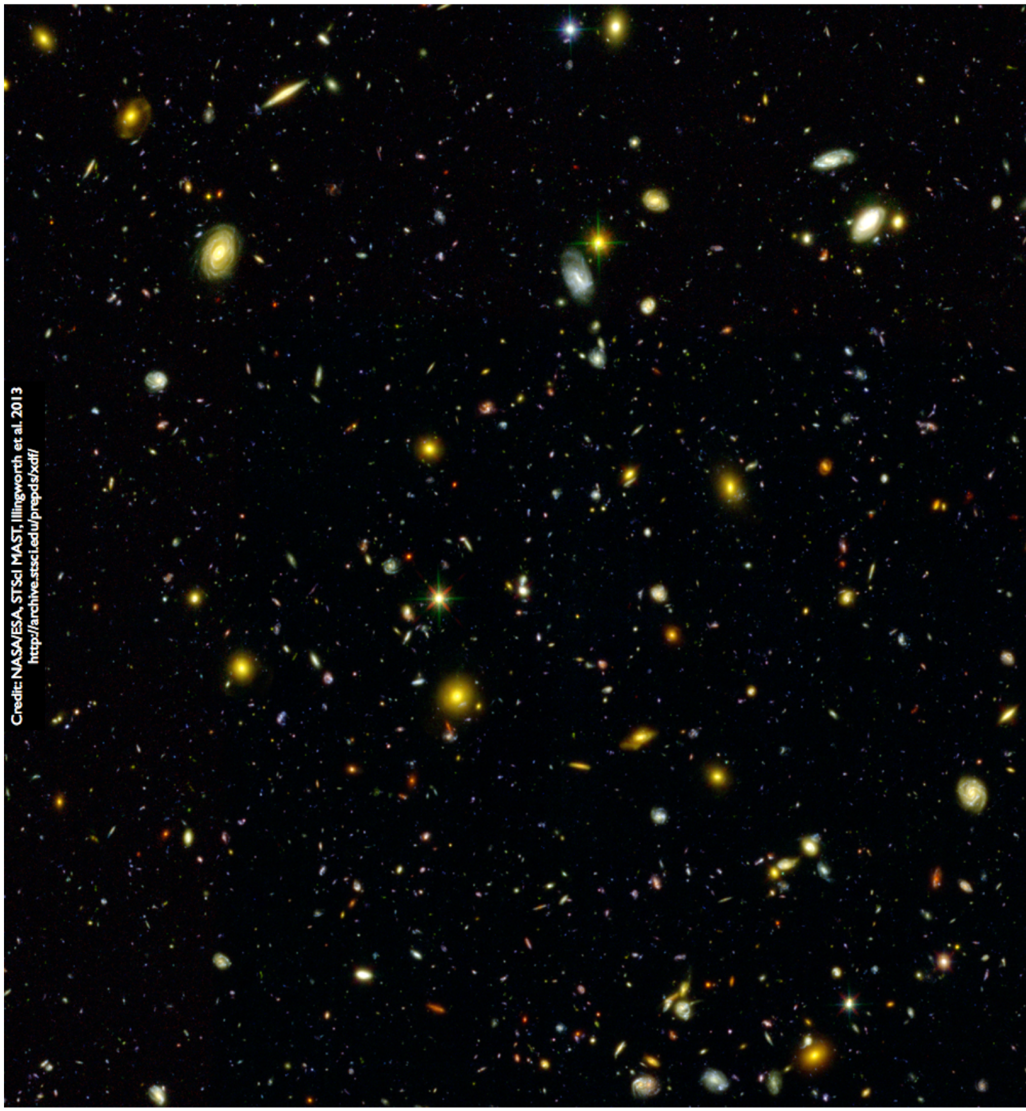


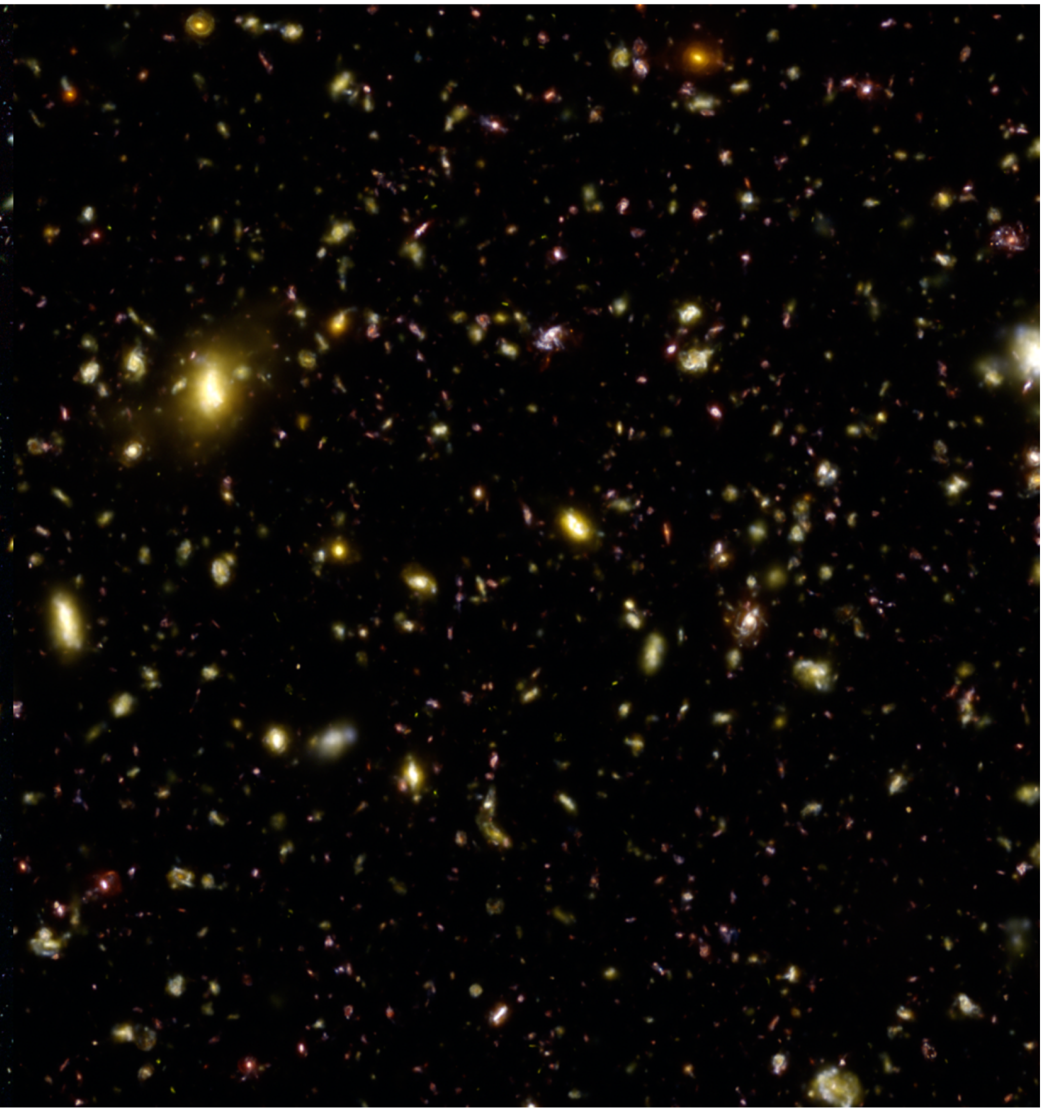
Deep Fields

ACS/WFC3 [TimeLapse]

XDF (subset of UDF field, all data)

Illustris





Credit: Greg Snyder

4. COSMOLOGY
Frontier Fields Will Be Completed this Summer

- Four clusters (+ four parallel deep fields) complete
- Continuing with final two clusters in Cycle 23
  - Abell S1063 - first epoch complete; second by early summer
  - Abell 370 - first epoch complete; second scheduled for July-September

Abell 2744

MACS0416

MACS1149

MACS0717

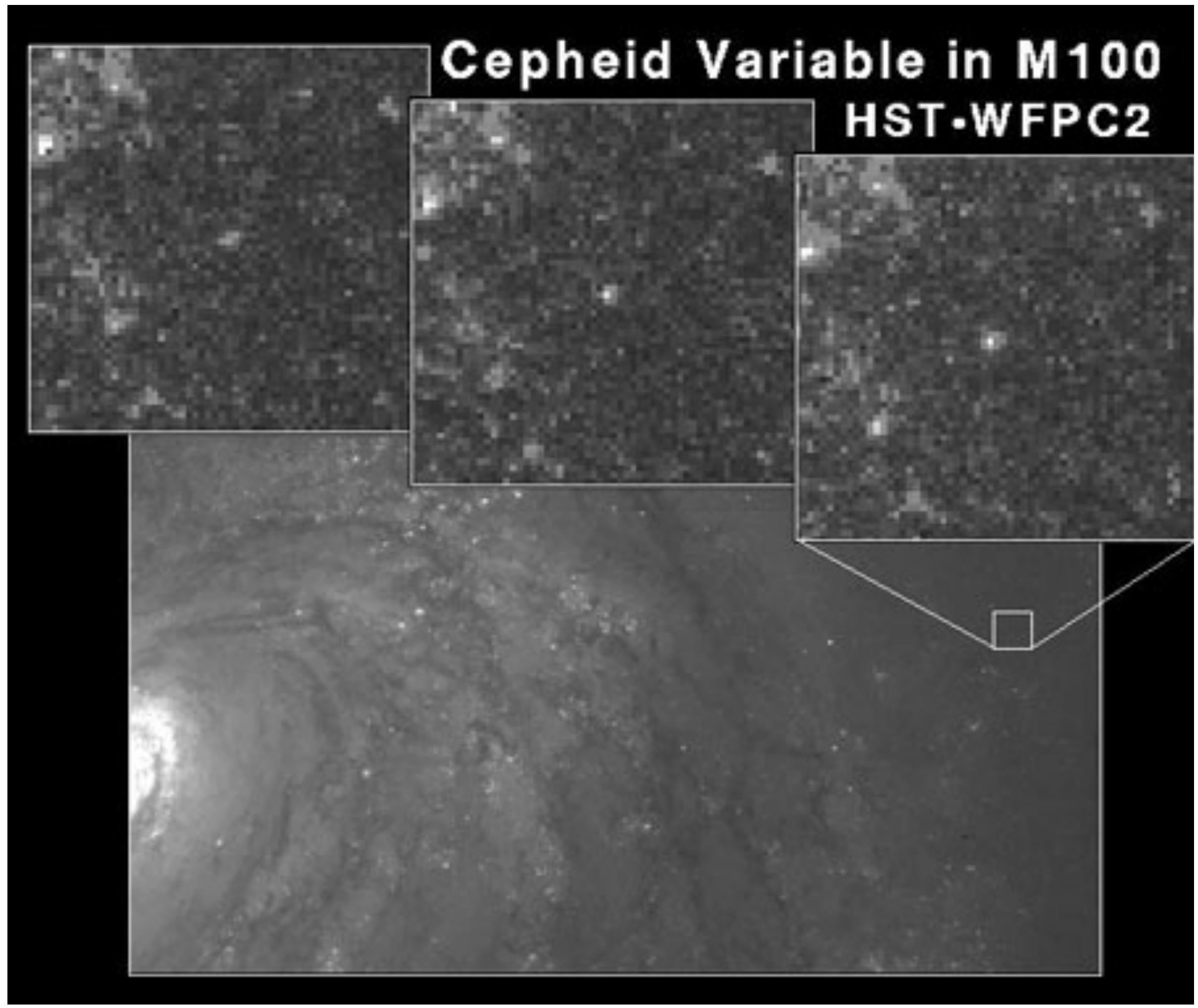
Key Project: Hubble Constant

- *"The distance scale path has been a long and tortuous one, but with the imminent launch of HST there seems good reason to believe that the end is finally in sight."*
  - Marc Aaronson (1985 Pierce Prize Lecture) [Who led the team when it was formed]

Accurate determination of Ho (+/- 10%) was one of the primary motivations for HST

Yielded Ho = 72 +/- 3 (statistical) +/- 7 (systematic) km/s/Mpc

Freedman & Madore 2010 AR&A Review for updates
Recent DES results (2018)
Cycle 22 program: Ho to 3%



HST Major Categories:

1. Stellar Populations
2. Massive Black Holes and their Hosts
3. Galaxies and IGM
   - 3.1 ISM
   - 3.2 Structure & Evolution
4. Cosmology (clusters, lensing, galaxy groups)

https://github.com/gurtina/ASTR520_2019