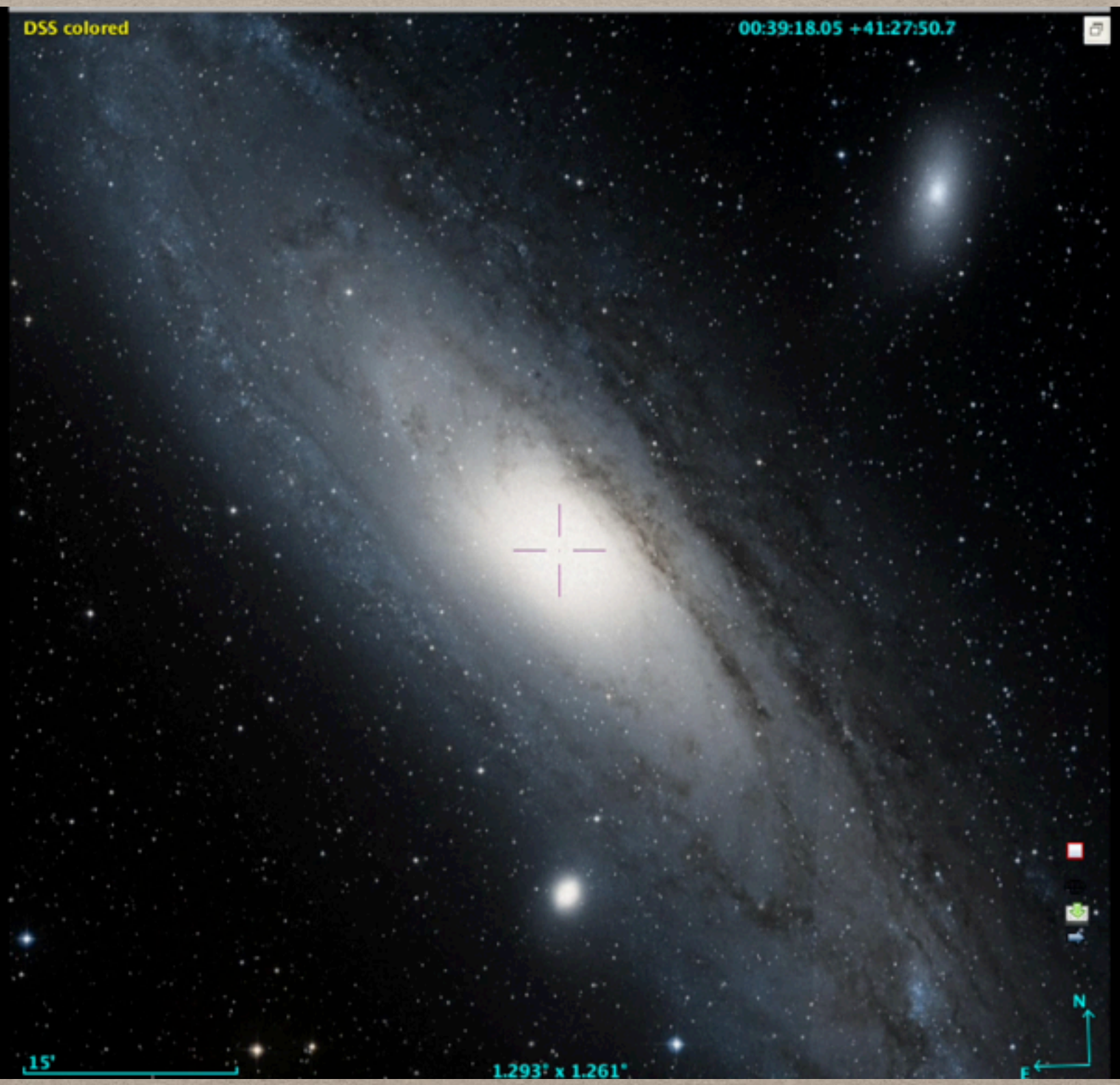
WHERE DO GALAXIES COME FROM?

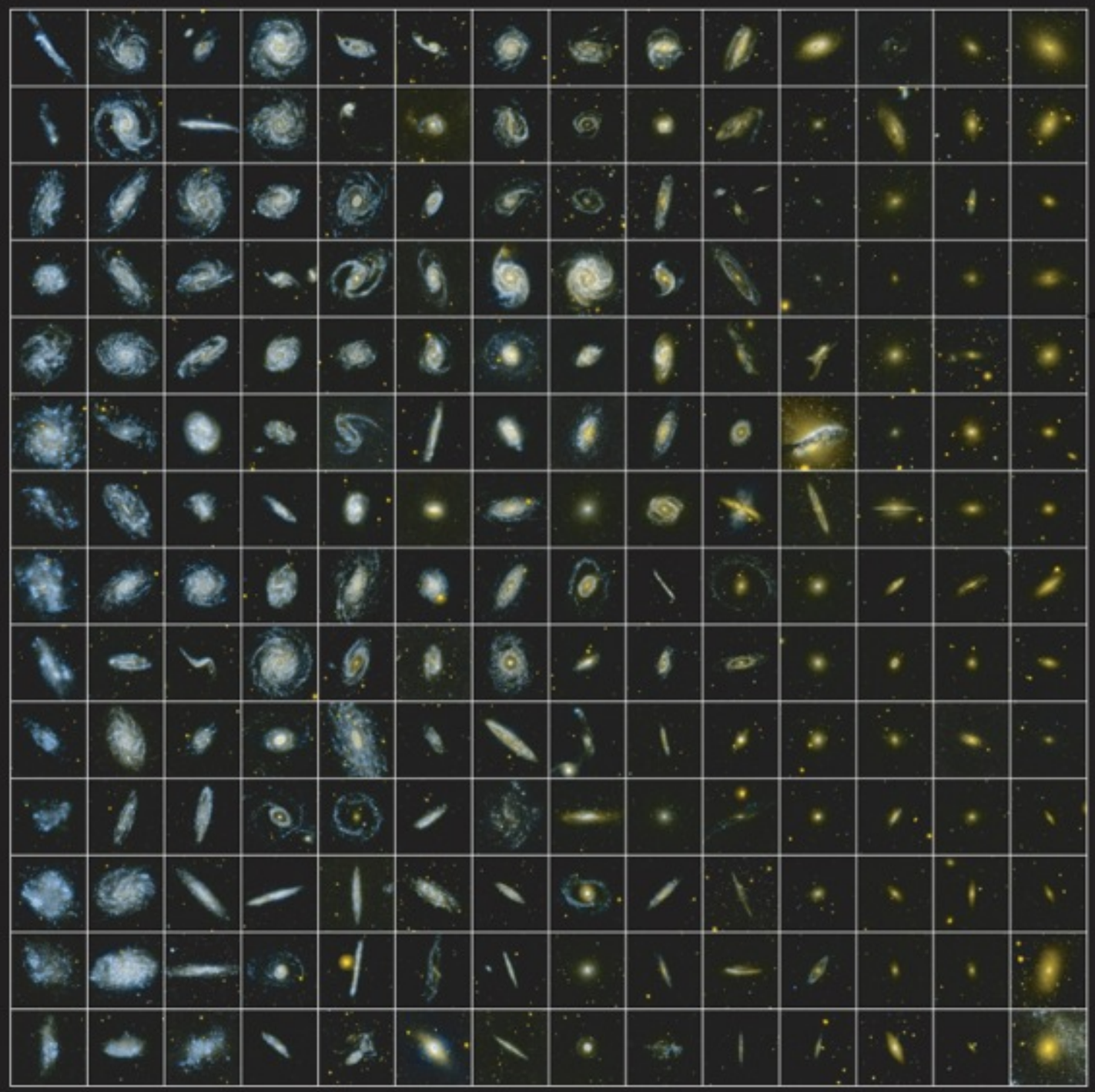
...a story of astronomical discovery

WHAT IS A GALAXY?



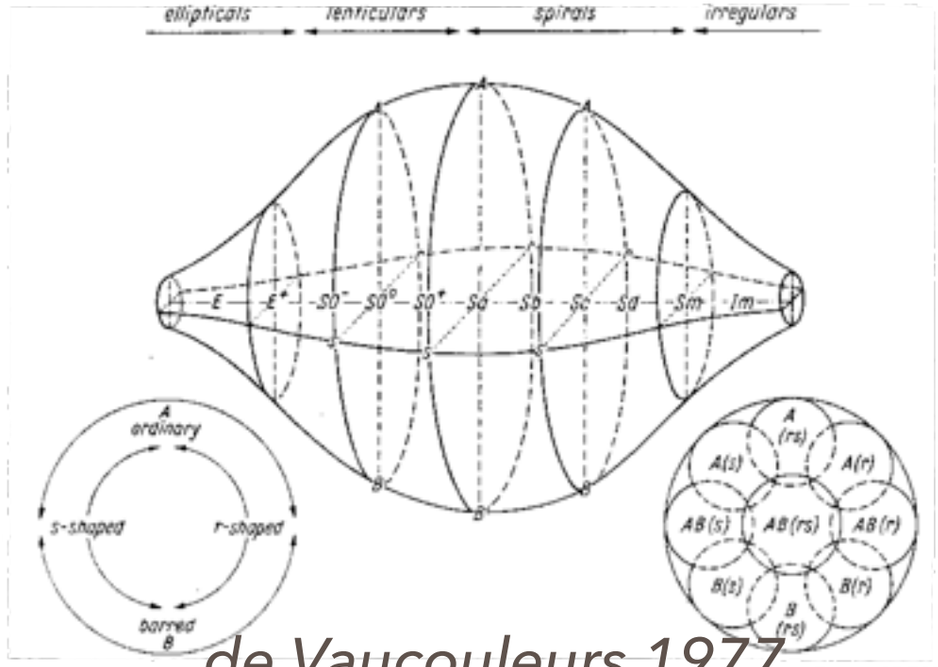
GALEX Galaxy Evolution Explorer

Ultraviolet Atlas of Nearby Galaxies



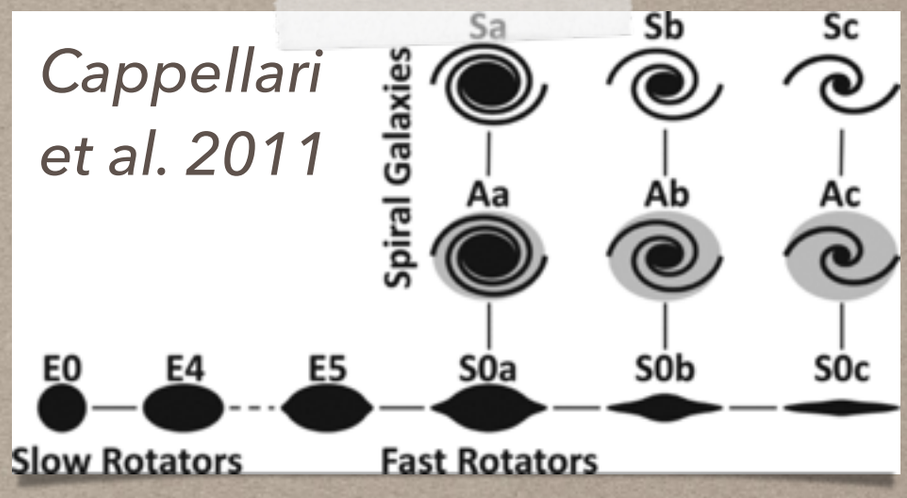
www.galex.caltech.edu

California Institute of Technology / The Observatories of the Carnegie Institution of Washington / Johns Hopkins University / University of California Berkeley
Laboratoire d'Astrophysique de Marseille / Yonsei University / University of California Los Angeles / Columbia University / Universidad Complutense de Madrid

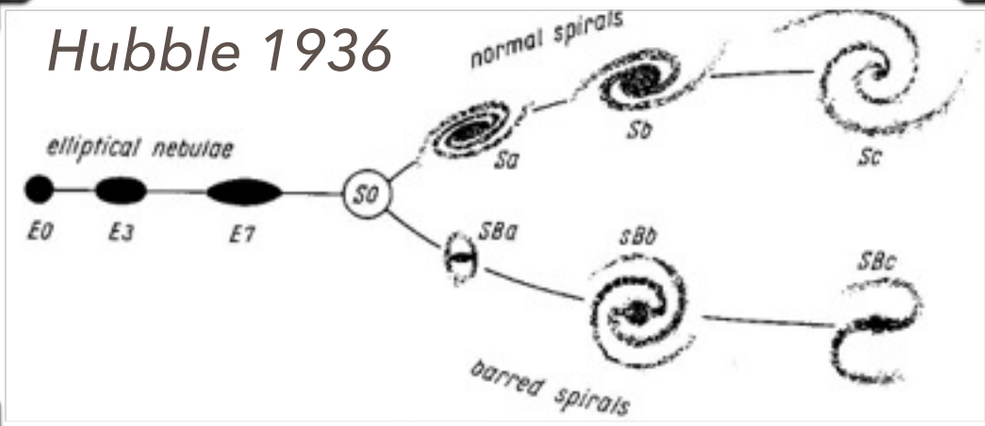


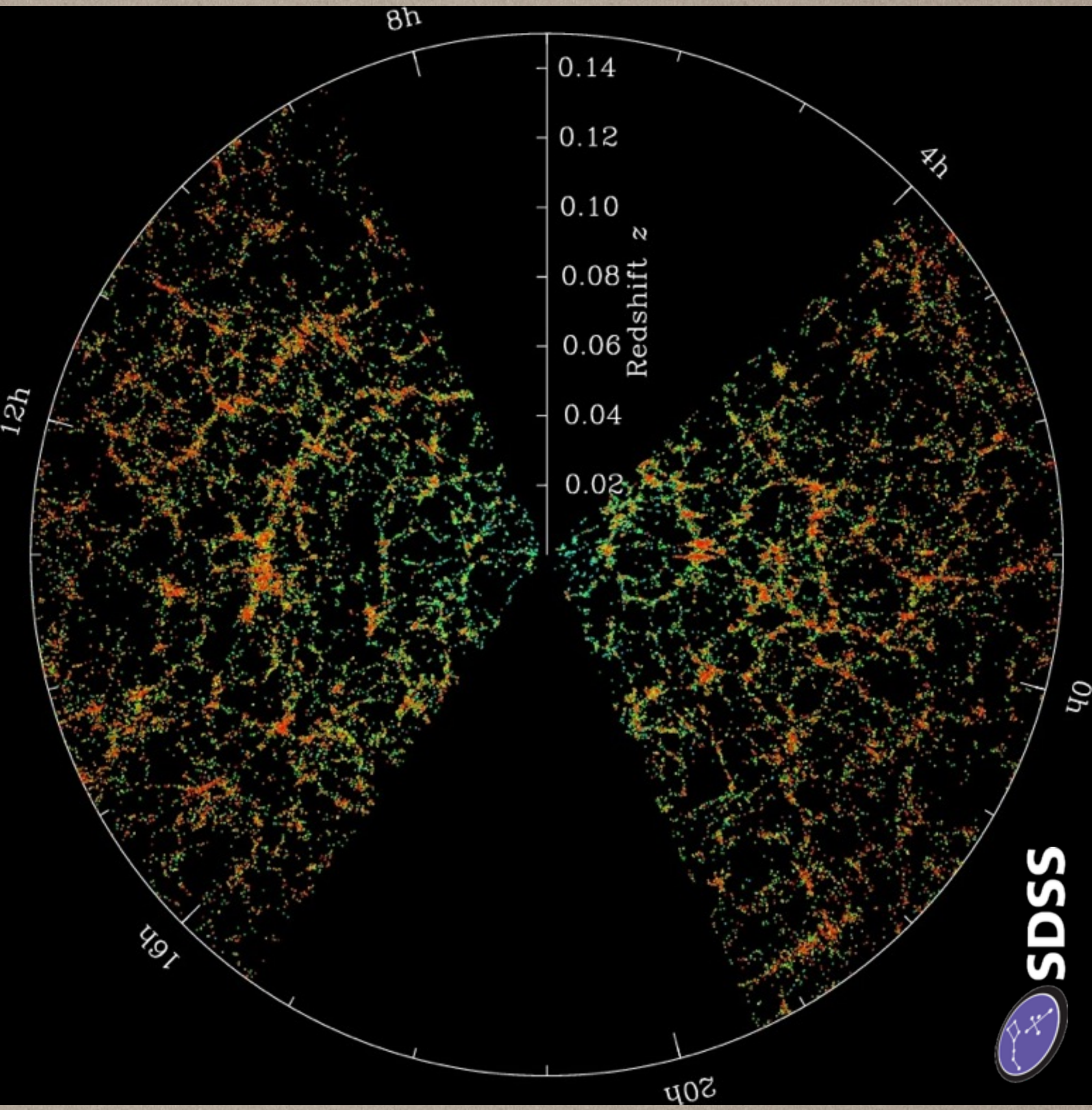
de Vaucouleurs 1977

Cappellari et al. 2011



Hubble 1936

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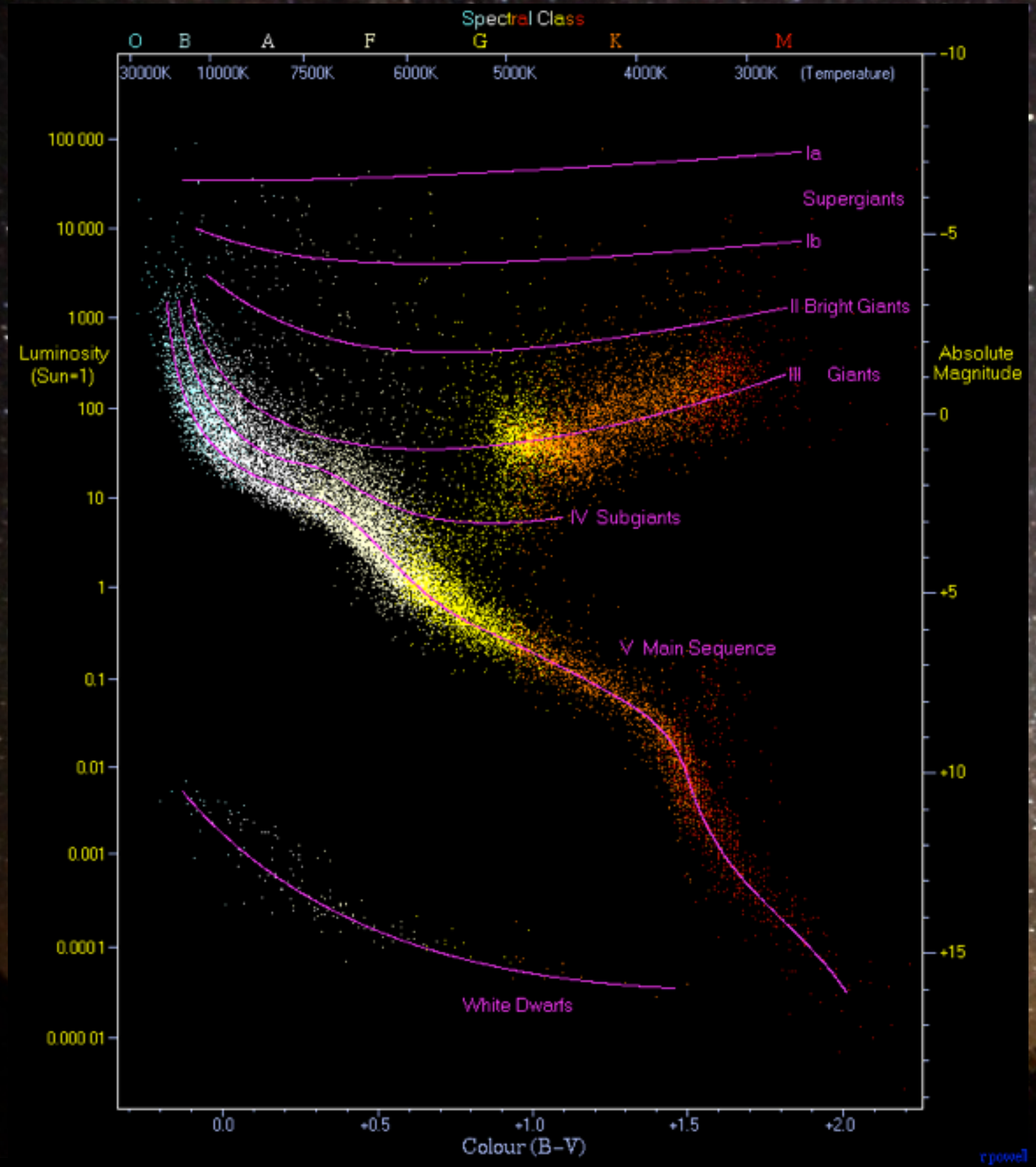
0.04
0.02
Redshift z
SDSS

How can we begin to understand all this complexity from our fixed viewpoint here on Earth?

HOW DO YOU BUILD A GALAXY?

- Stars
- Gas
- Dust
- Dark Matter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B
A
F
G
K
M
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10 000
1000
Luminosity
(Sun=1)
100
10
1
0.1
0.01
0.001
0.0001
0.000 01
-10
-5
0
+5
+10
+15
Absolute
Magnitude
Ia
Supergiants
Ib
II Bright Giants
III Giants
IV Subgiants
V Main Sequence
White Dwarfs
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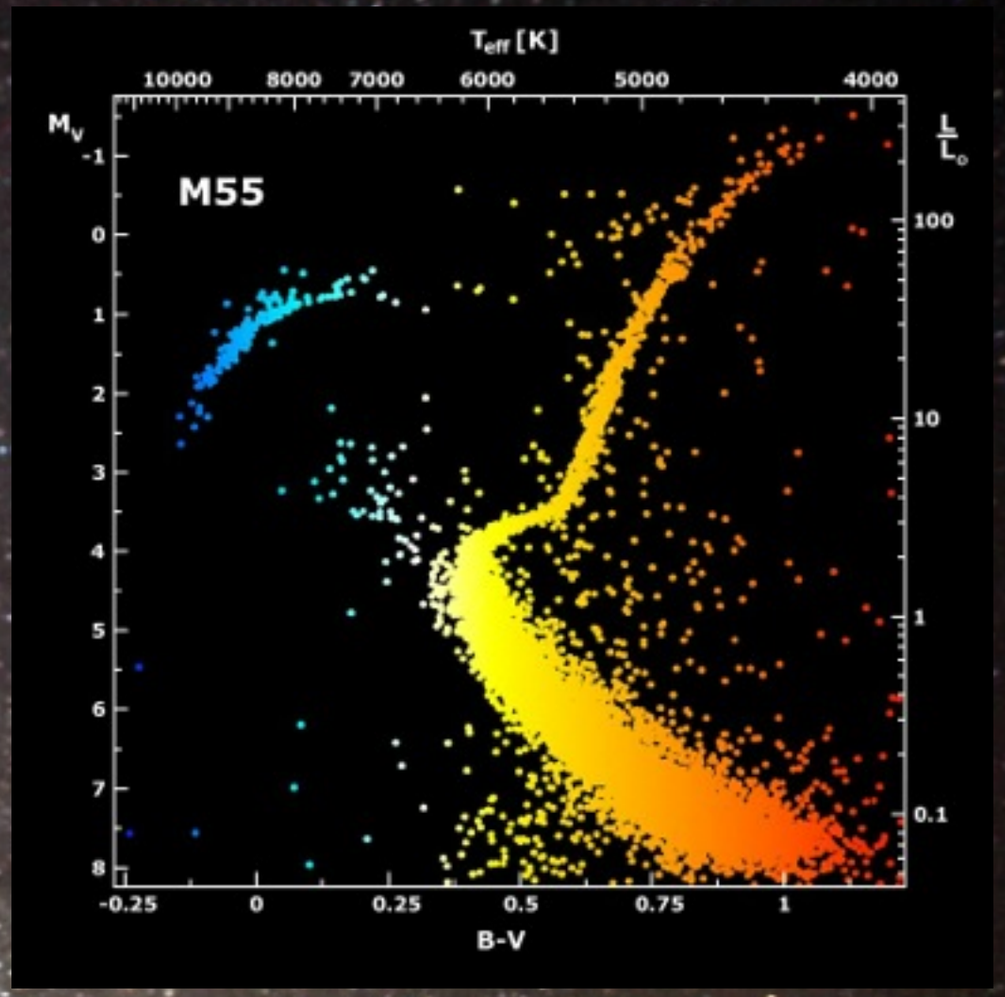
+1.0
+1.5
+2.0
Colour (B–V)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3
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8
M55
L/L_o
100
10
1
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-0.25
0
0.25
0.5
0.75
1
B-V

rpowell

Eagle Nebula

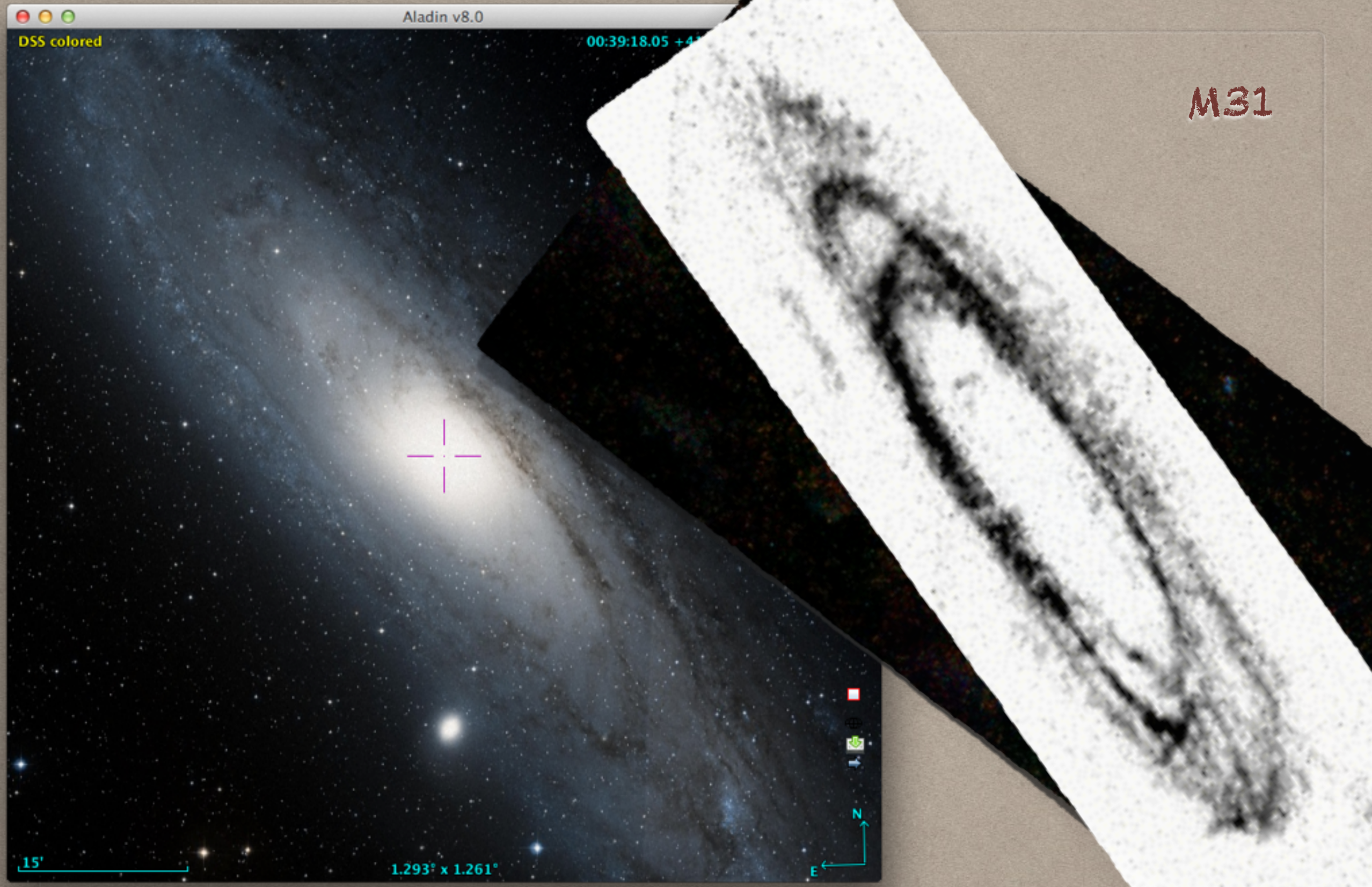
Star-forming region with cold filaments

W44 supernova remnant and stellar birth clouds

W48 star forming clouds

W3 Perseus Arm

Birth clouds in Rosette Nebula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15'
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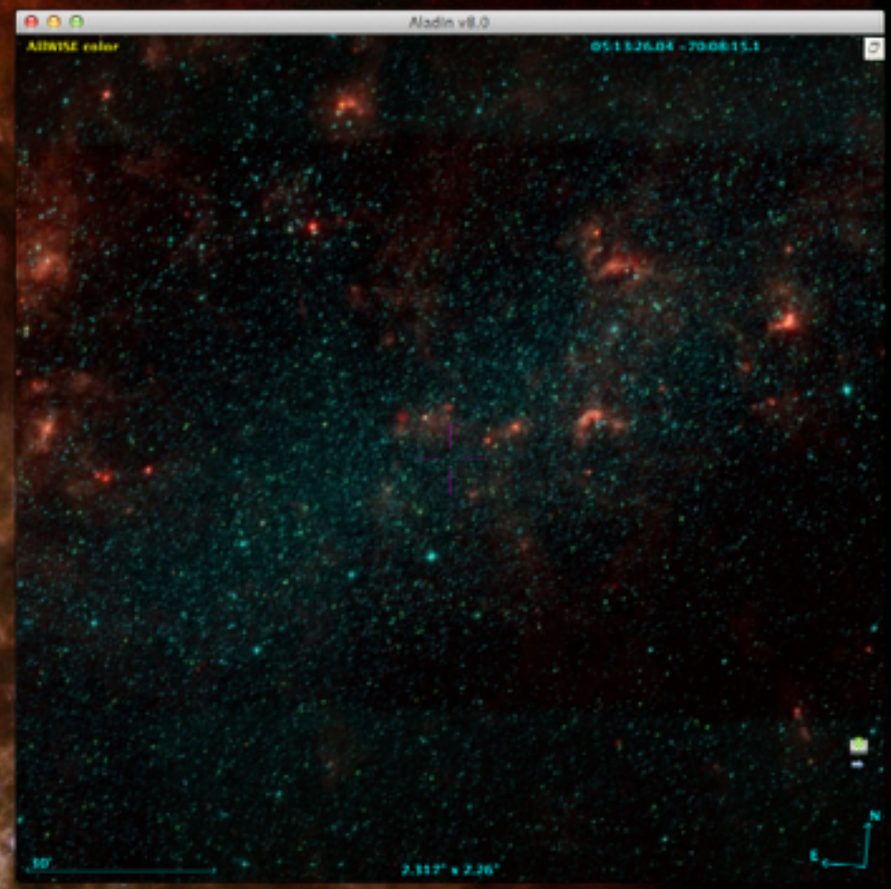
E

Large Magellanic Cloud

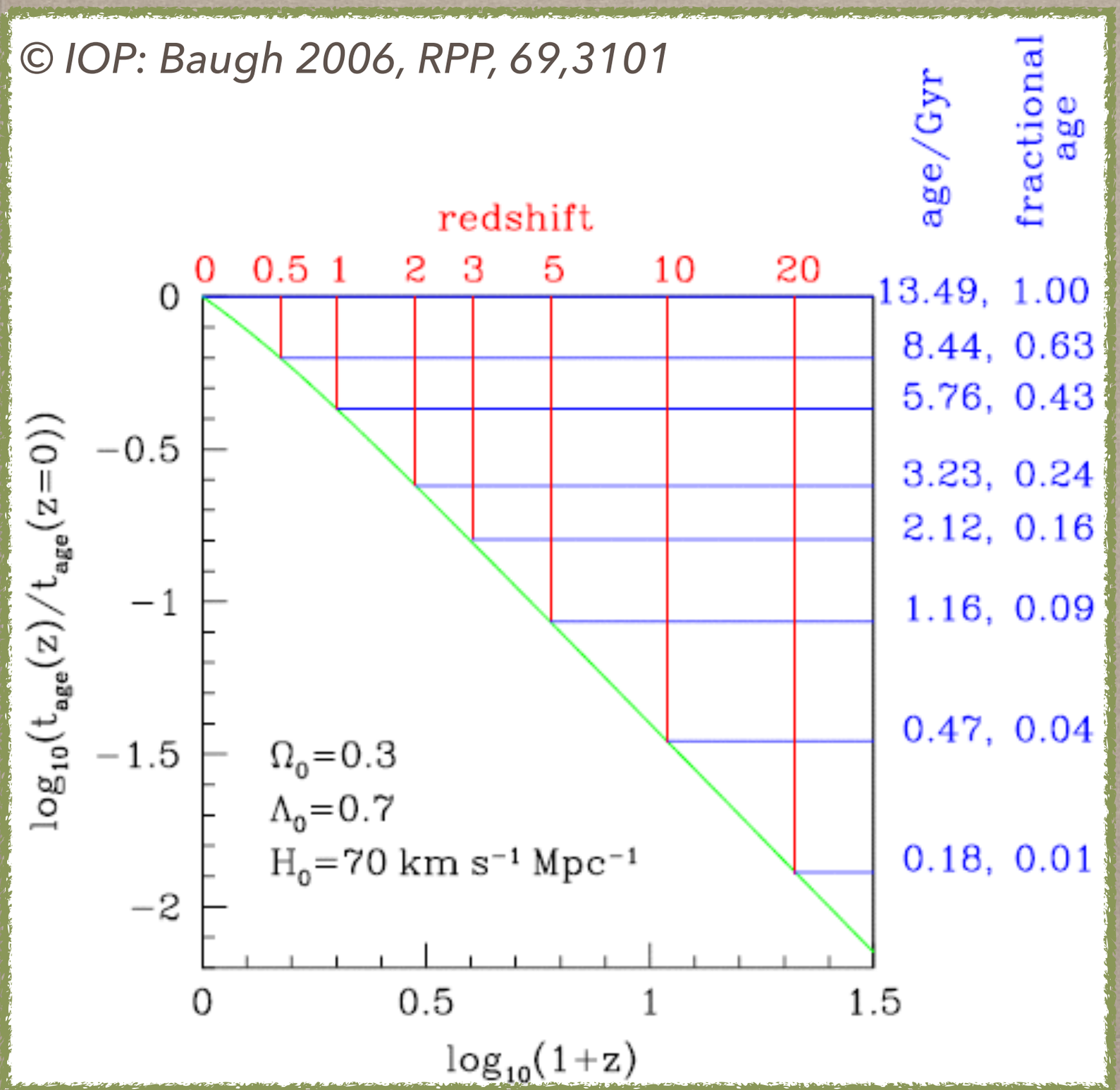


Dense clouds in galactic plane

Starfield in same region


© Subaru Telescope,

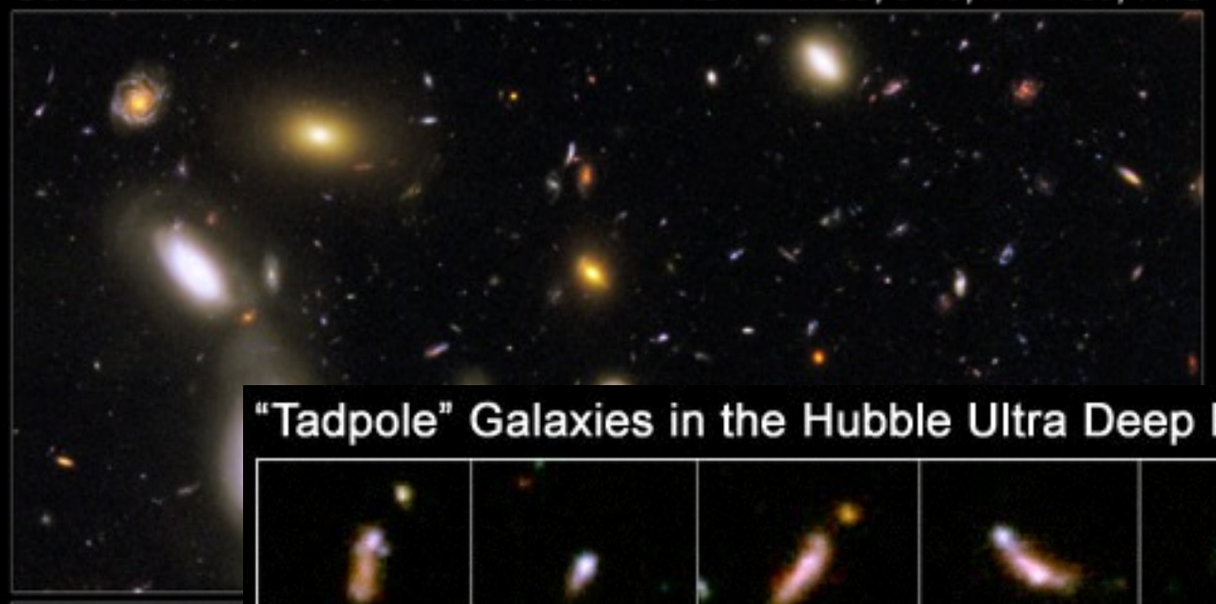
HOW TO LOOK BACK IN TIME?



Light travel time = distance x speed

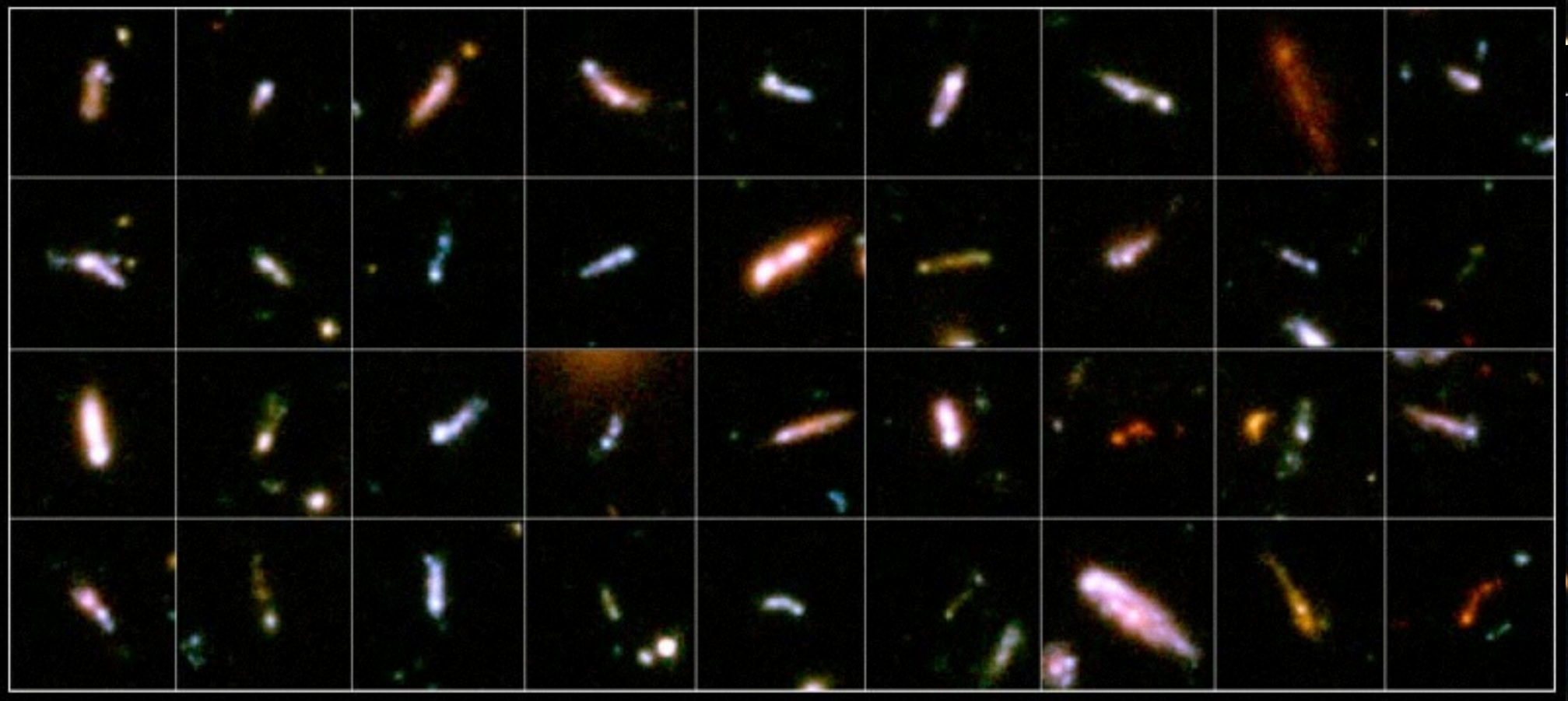
- constant speed c=300,000km/s
- distance = redshift

GOODS South ▪ WFC3 ERS Details *HST* ▪ WFC3/UVIS/IR ▪ ACS/WFC



2014 *HST* • ACS • WFC3

"Tadpole" Galaxies in the Hubble Ultra Deep Field *Hubble Space Telescope* ▪ ACS/WFC

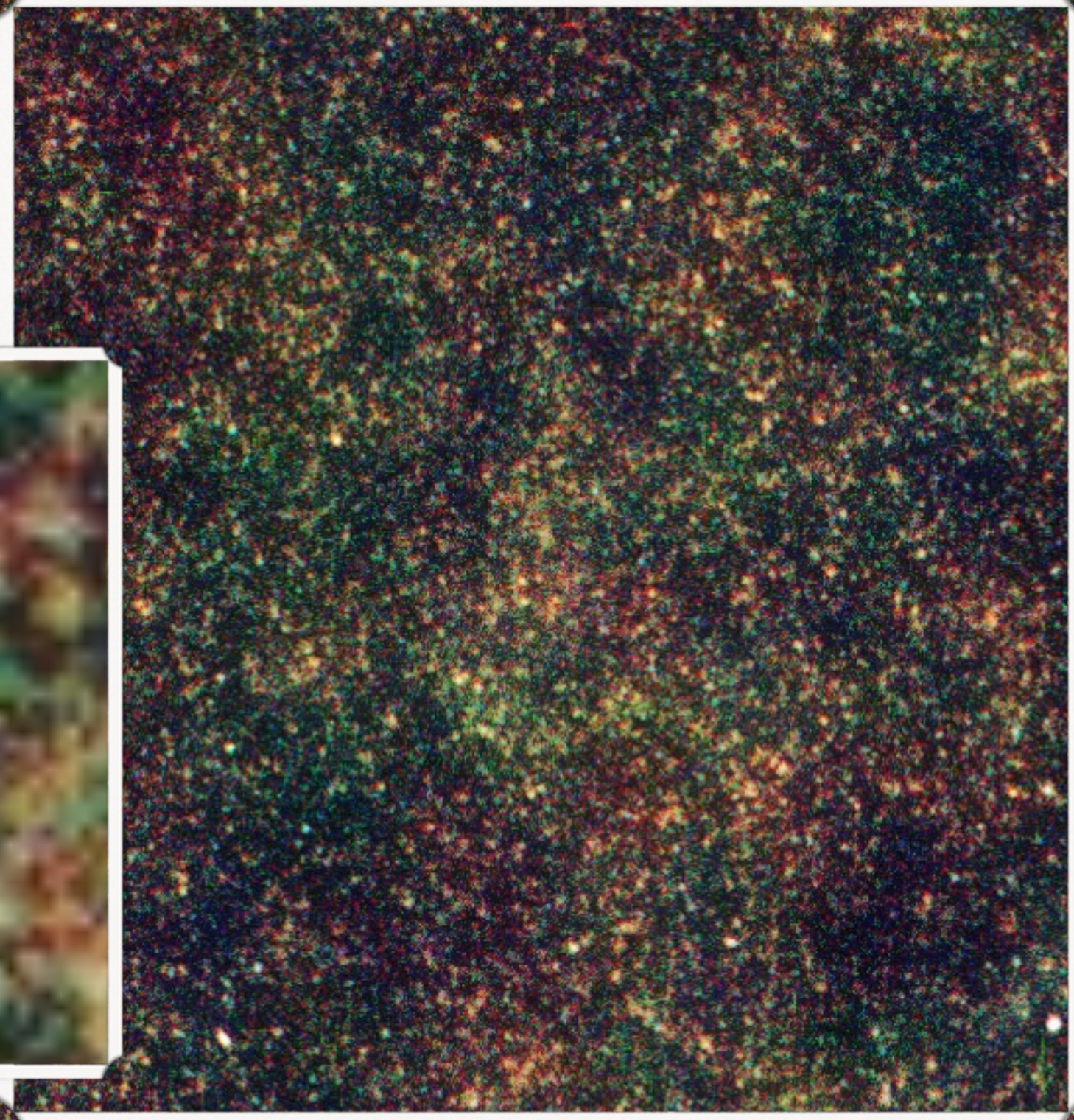


NASA, ESA, A. Straughn, S. Cohen and R. Windhorst (Arizona State University), and the HUDF team (STScI) STScI-PRC06-04

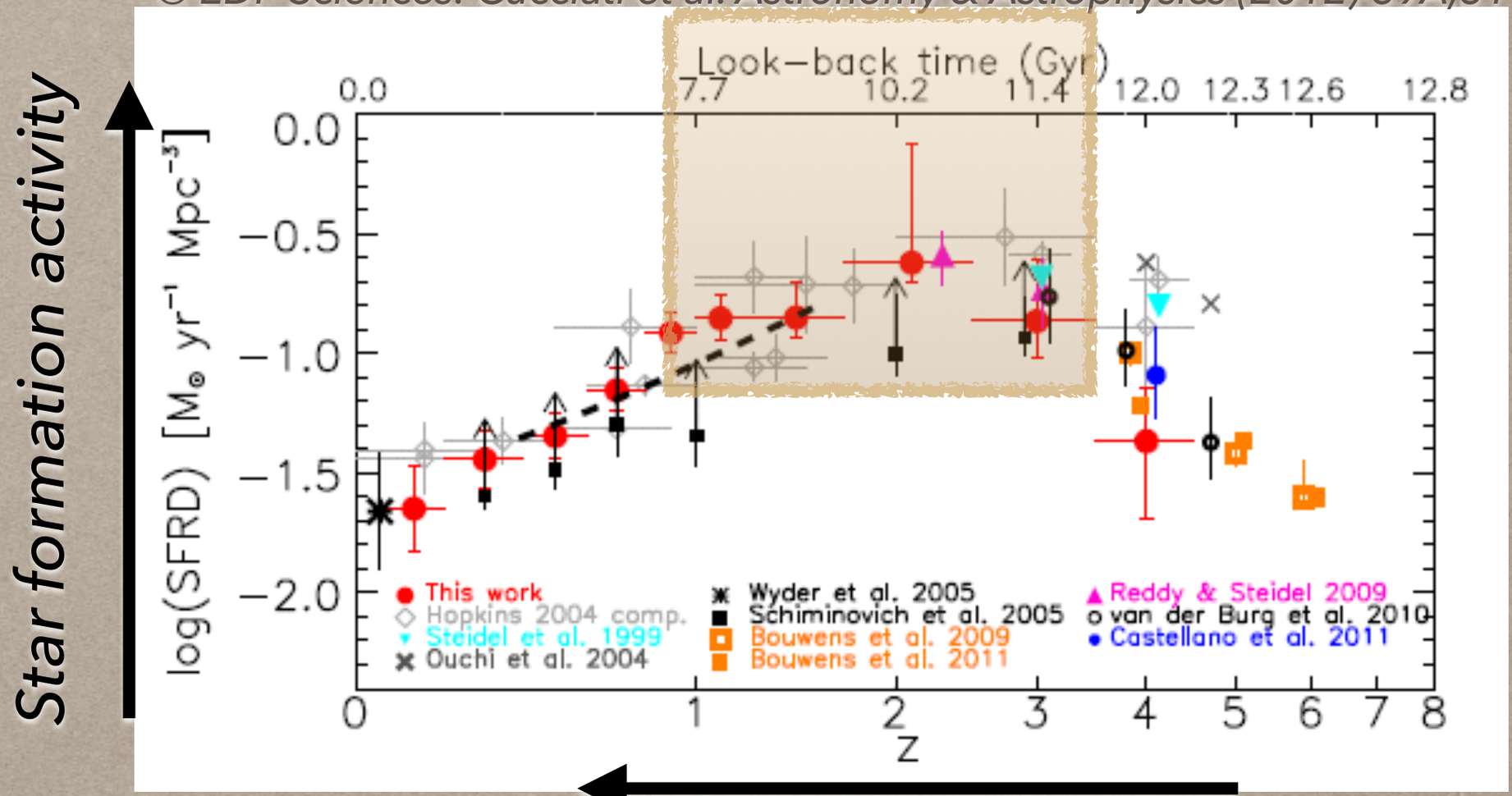
NASA, ESA, R. Windhorst (Arizona State University), P. McCarthy (Carnegie Institution of Washington), R. O'Connell (University of Virginia), and the WFC3 Science Oversight Committee STScI-PRC10-01b

HST ▪ ACS

NASA, ESA, J. Blakeslee and H. Ford (Johns Hopkins University) STScI-PRC04-21



SO WHEN DID ALL THE GALAXIES FORM?



- Most of the star formation occurred between 7-11 billion years ago (the universe is 13.8 bn years old)

The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at:
http://sings.stsci.edu/

Unbarred Spirals

Weak Bulge

Strong Bulge

Intermediate Spirals

Ellipticals

Irregulars

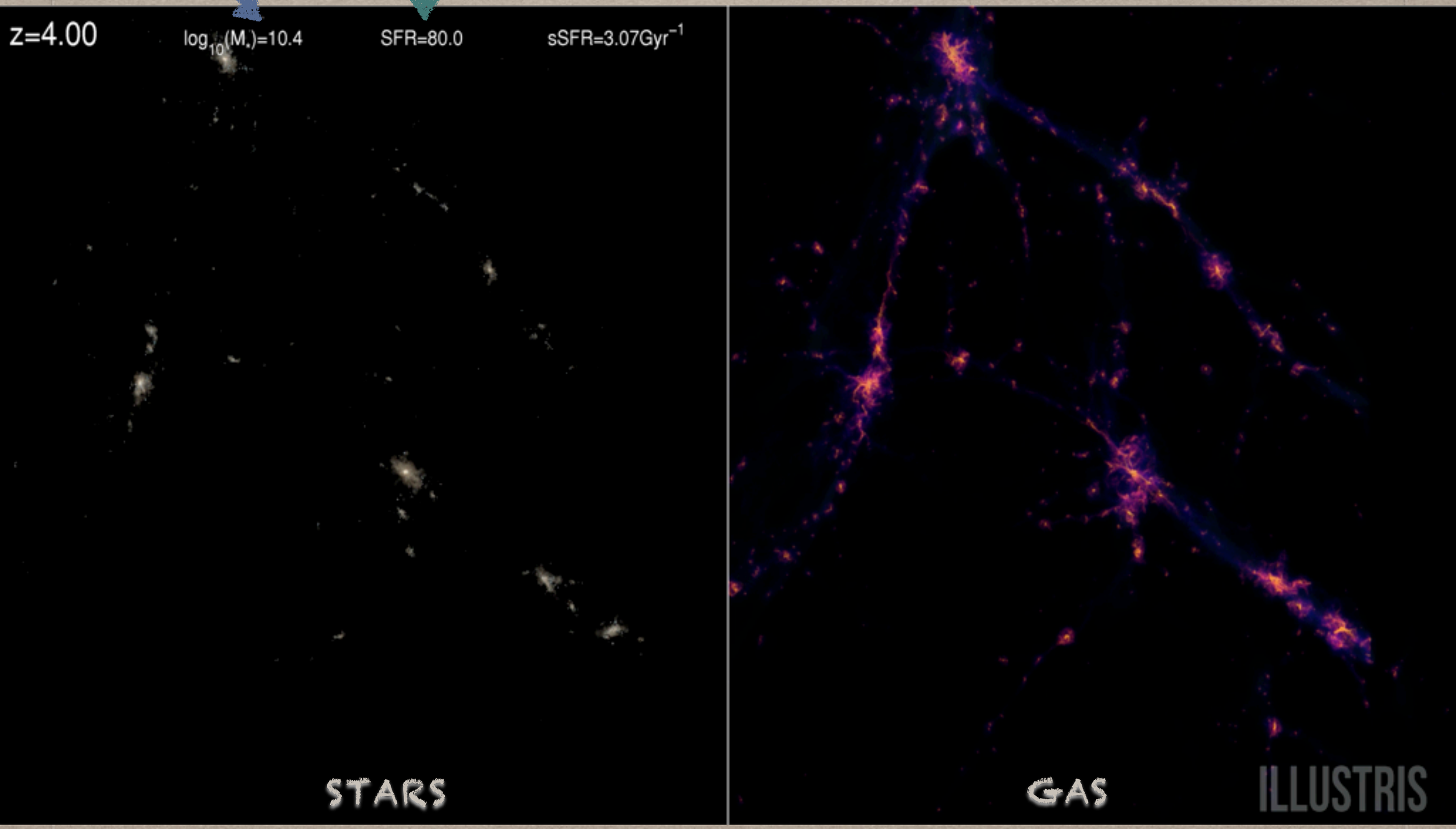
Weak Bulge

Barred Spirals

Poster and composite images created from SINGS observations by Karl D. Gordon (Oct 2007)
Blue=IRAC 3.6μm (stars)
Green=IRAC 8μm
(aromatic features from dust grains/molecules)
Red=MIPS 24μm (warm dust)

SINGS Team

Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Fabian Walter & George Helou



Credit: Illustris Collaboration

THANKS FOR LISTENING!

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- Joint Astronomy Centre Hawaii http://outreach.jach.hawaii.edu/SCUBA2/scuba2-images.html