Rediscovering the Milky Way

Alyssa A. Goodman (Harvard-Smithsonian Center for Astrophysics)

with collaborators at (alphabetically by insitution):

Boston University: James Jackson

Caltech: Jens Kauffmann

Harvard - Smithsonian: Christopher Beaumont, Michelle A. Borkin, Thomas M. Dame

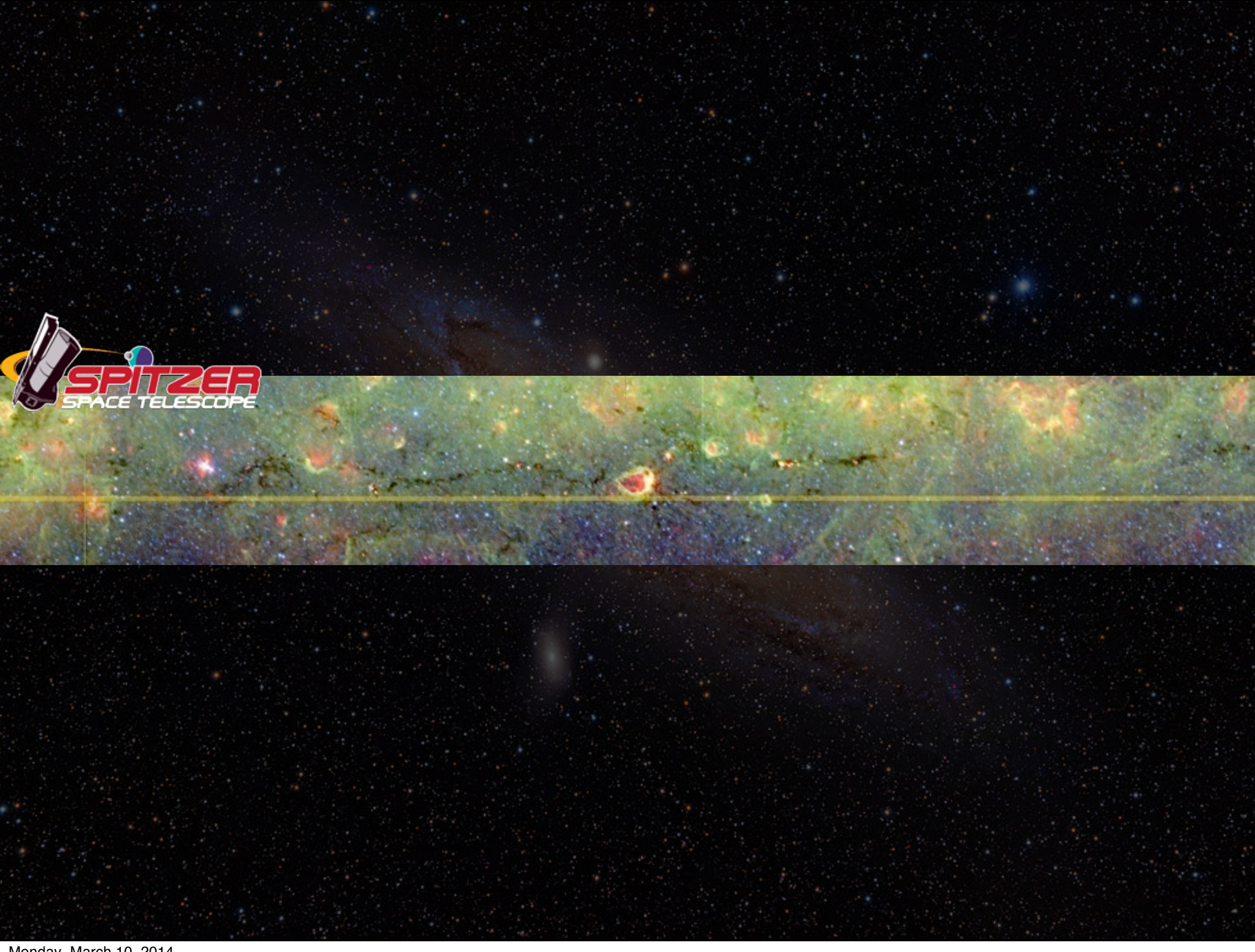
Max Planck Insitute for Astronomy: Thomas Robitaille

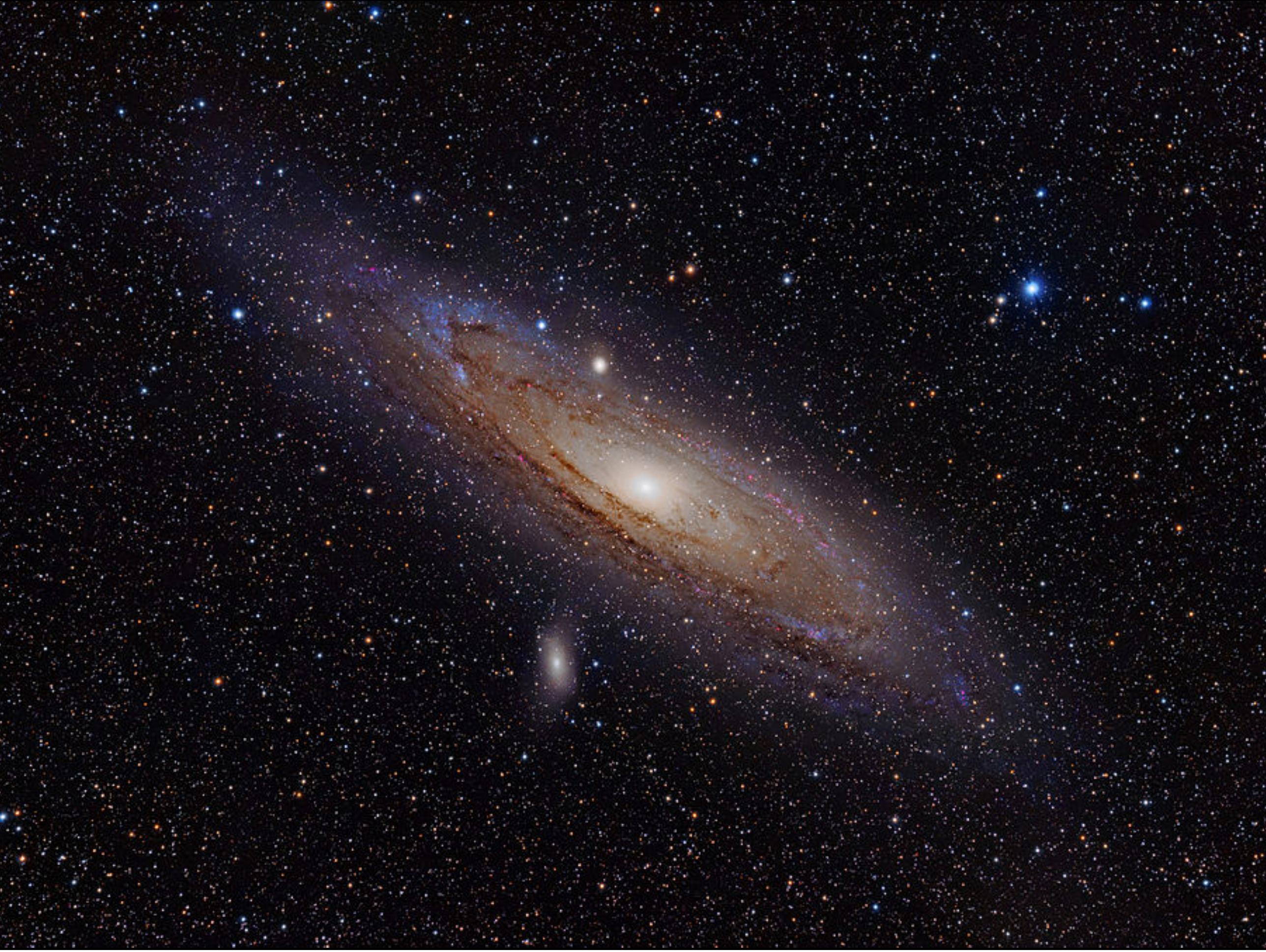
U. Munich: Andreas Burkert

U. Vienna: Joao F. Alves

U. Wisconsin: Robert A. Benjamin

Music: Davis Jerome, Richard Woodhams & The Mozart Orchestra - Oboe Concerto in C Major: II. Adagio , by Sir William Hershcel


SPITZER
SPACE TELESCOPE



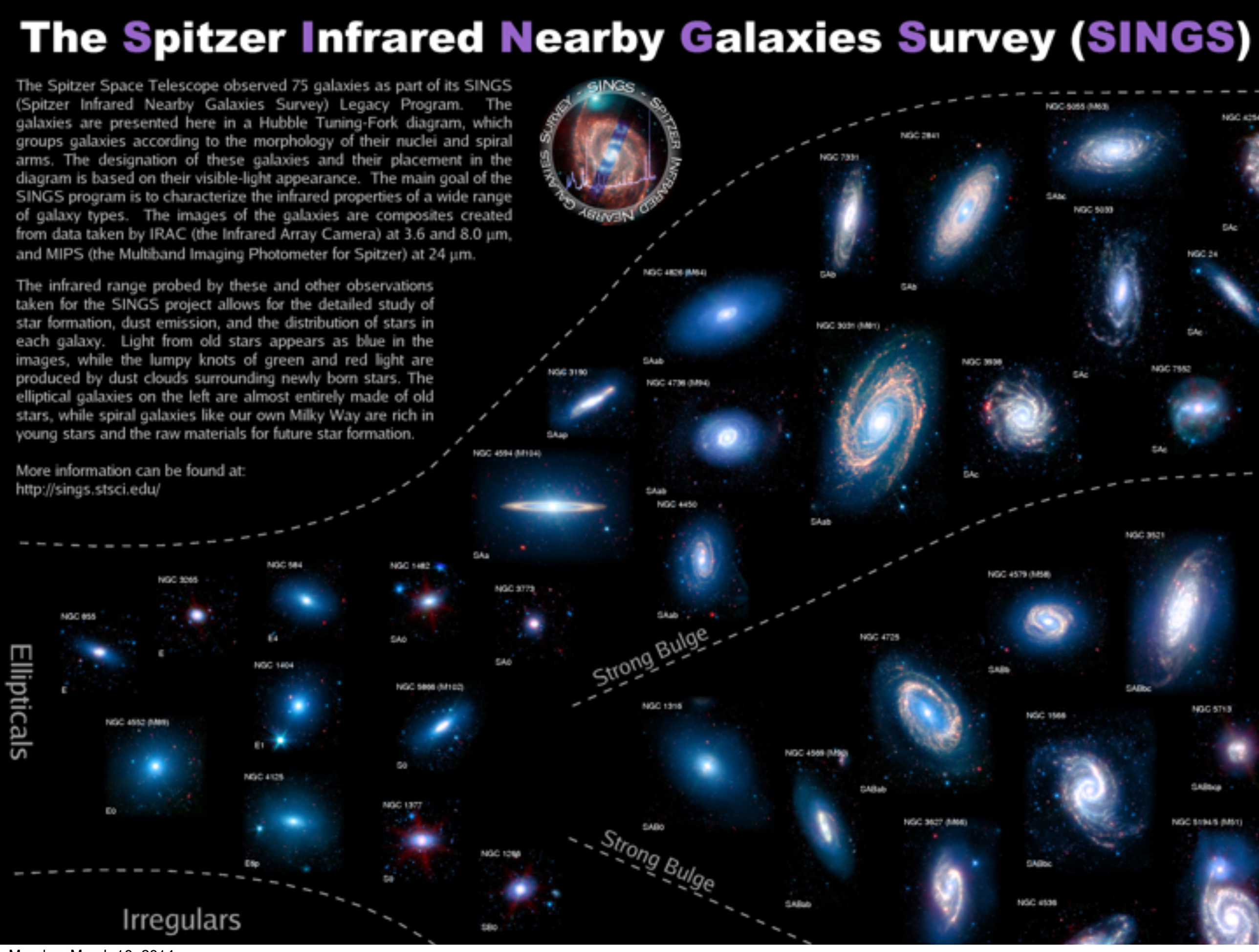
Monday, March 10, 2014

The Spitzer Infrared Nearby Galaxies Survey (SINGS)

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/



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Unbarred Spirals

Weak Bulge

Intermediate Spirals

Strong Bulge

Ellipticals

Irregulars

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

1936: "The Realm of the Nebulae" by Edwin Hubble

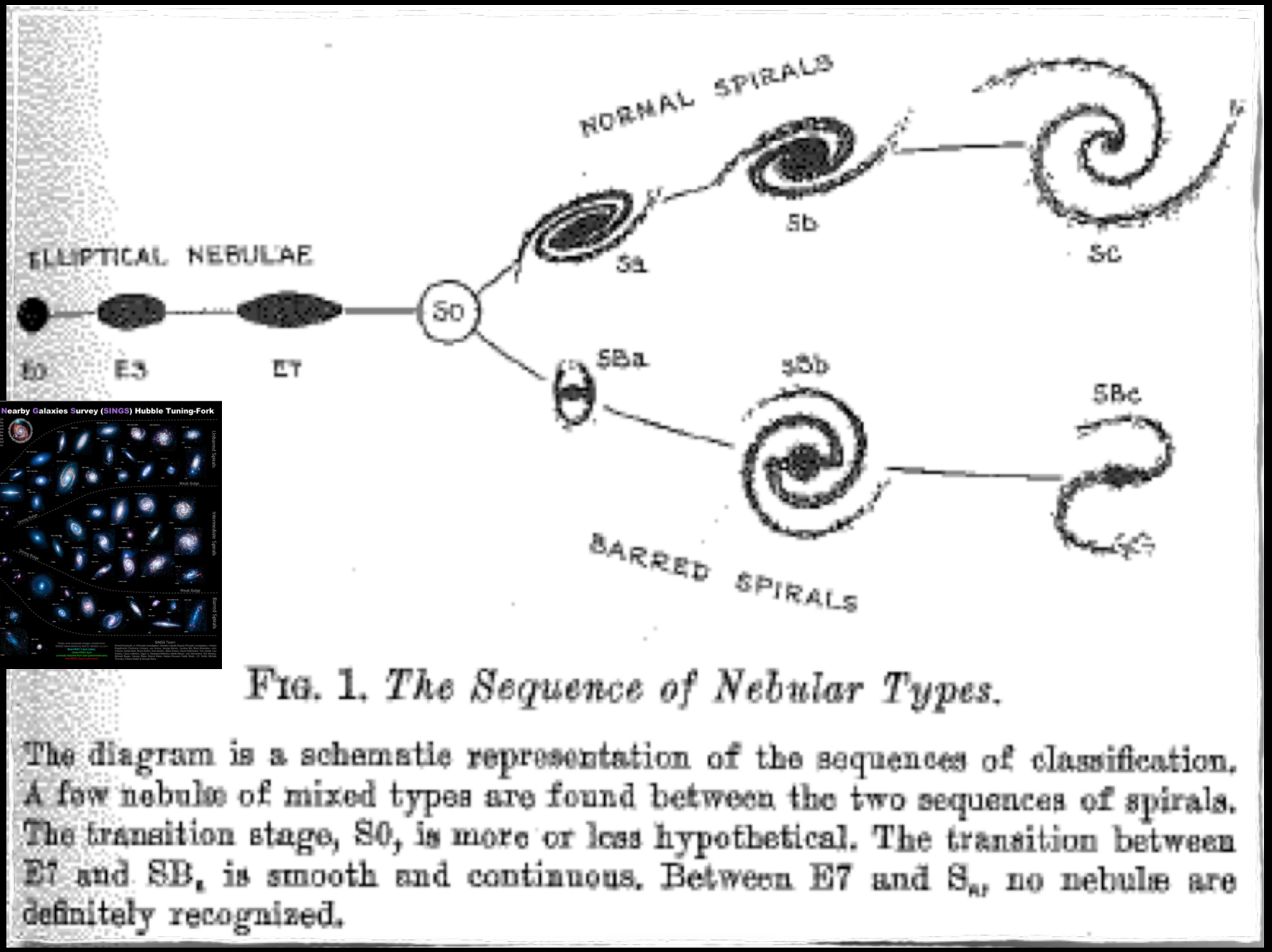


FIG. 1. *The Sequence of Nebular Types.*

The diagram is a schematic representation of the sequences of classification. A few nebulæ of mixed types are found between the two sequences of spirals. The transition stage, S0, is more or less hypothetical. The transition between E7 and SB$_a$ is smooth and continuous. Between E7 and S$_a$, no nebulæ are definitely recognized.

"Hubble's Tuning Fork Diagram"

The Shapley-Curtis Debate at the Smithsonian Natural History Museum, 1920

From National Academy of Sciences,
Smithsonian Institution, Washington, D. C.
(Carl H. Butman, Representative).

For Release to Afternoon Papers,
Monday, April 26

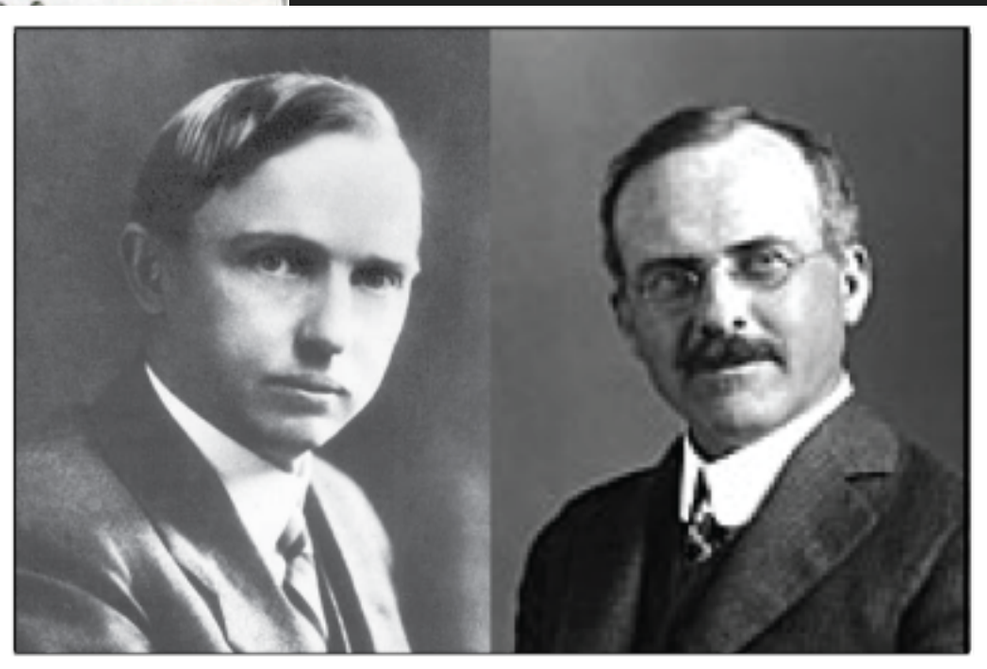
For Files

HOW MANY UNIVERSES ARE THERE?

This evening two California astronomers will discuss the Size of the Universe, and present their views as to whether or not there is only one or several universes, before the National Academy of Sciences, which is now in session in Washington.

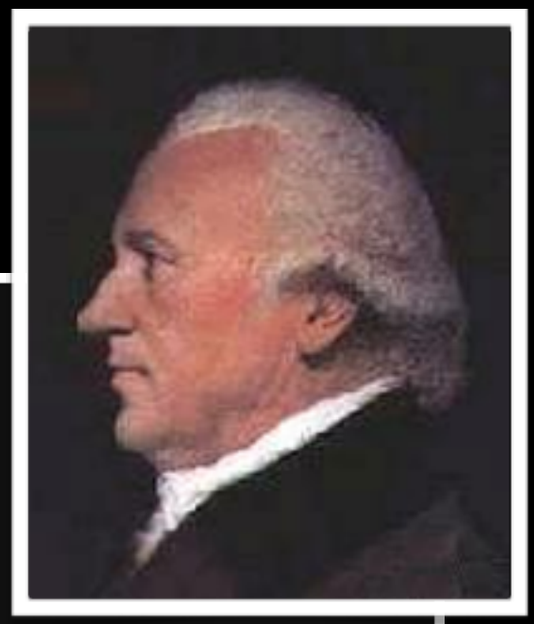
In this public meeting, Dr. Harlow Shapley of the Mt. Wilson Solar Observatory, will discuss recently secured evidence pointing to the dimensions of our galaxy of stars, known popularly as the Milky Way, which he believes to be ten times greater than is held in the older theories concerning the dimensions and compositions of the Milky Way. In other words, he claims that it takes light about three hundred thousands of years to cross from one side to the other of the space occupied by the 3,000,000,000 stars of which our sun is the nearest one. He holds the spiral nebulae, those clam-shell-like cloudy luminous objects seen by great telescopes, to be inside our system.

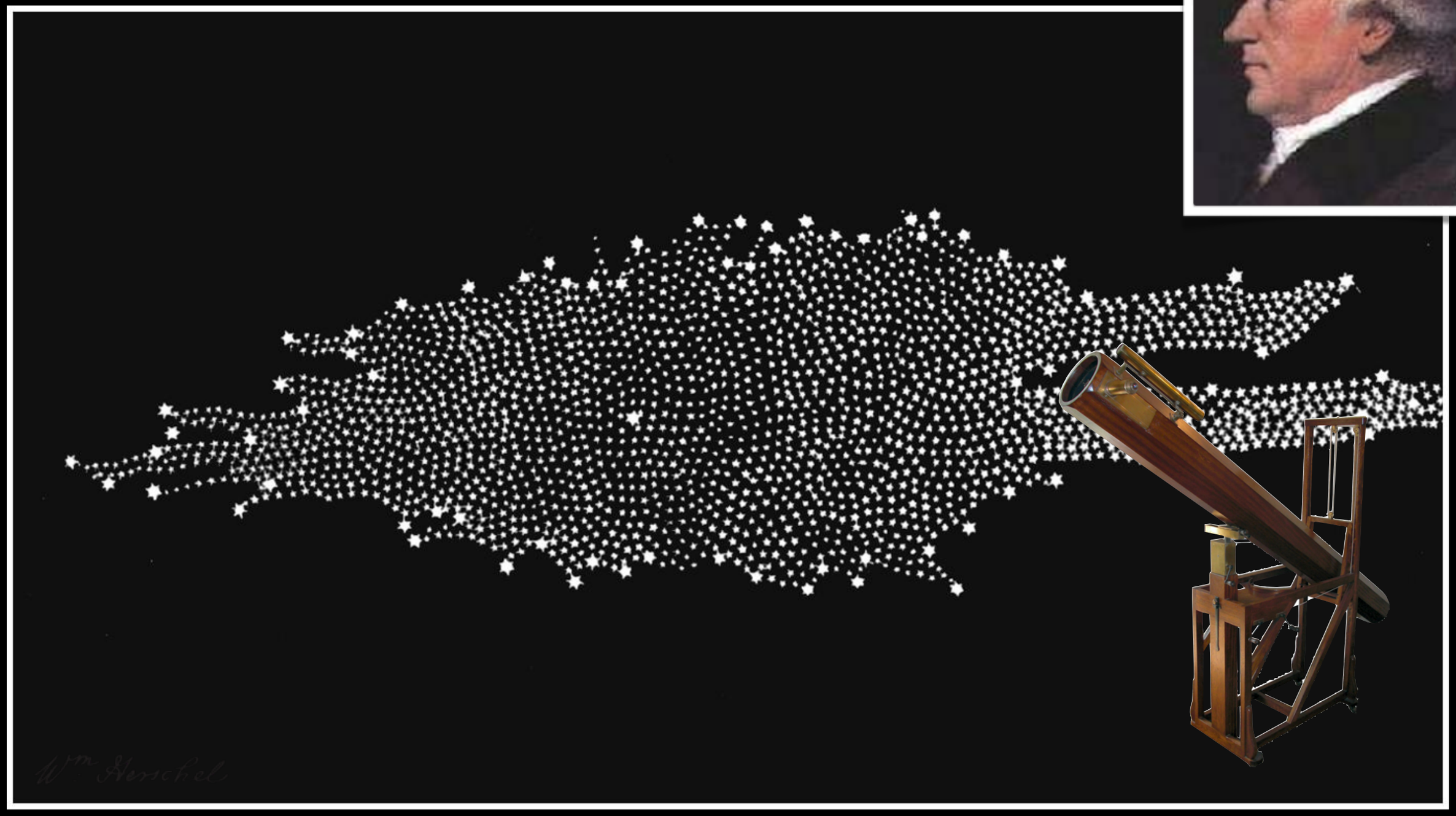
Doctor Shapley's views will be followed by the discussion of Doctor Heber D. Curtis of the Lick Observatory, who will defend the older view that our Milky Way is approximately of the dimensions suggested by Newcomb, about 30,000 light-years in diameter, with the spiral nebulae regarded as very probably individual galaxies of "island universes", like ours. Thus there may be [illegible] million other universes each having 3,000,000,000 stars. Inhabitants of [illegible] numerous universes would see our Milky Way as a spiral nebula. The lect[illegible] these two learned astronomers will be followed by a general discussion [illegible] the auditors present who are interested in the development of this new [illegible] in scientific research.



The Shapley-Curtis Debate at the Smithsonian Natural History Museum, 1920

William Herschel's Milky Way Galaxy in 1781





More info at http://cosmology.carnegiescience.edu/timeline/1781 (Herschel); http://cosmology.carnegiescience.edu/timeline/1920 (Shapley-Curtis)

The Andromeda Galaxy (M31)

The Andromeda Galaxy (M31)

The Andromeda Galaxy (M31)

Stars your Eyes would See

Optical

Dust + Dying Stars

"Glowing" Dust

Infrared

For fun...

Composite

Infrared & X-rays

"Dying" Stars

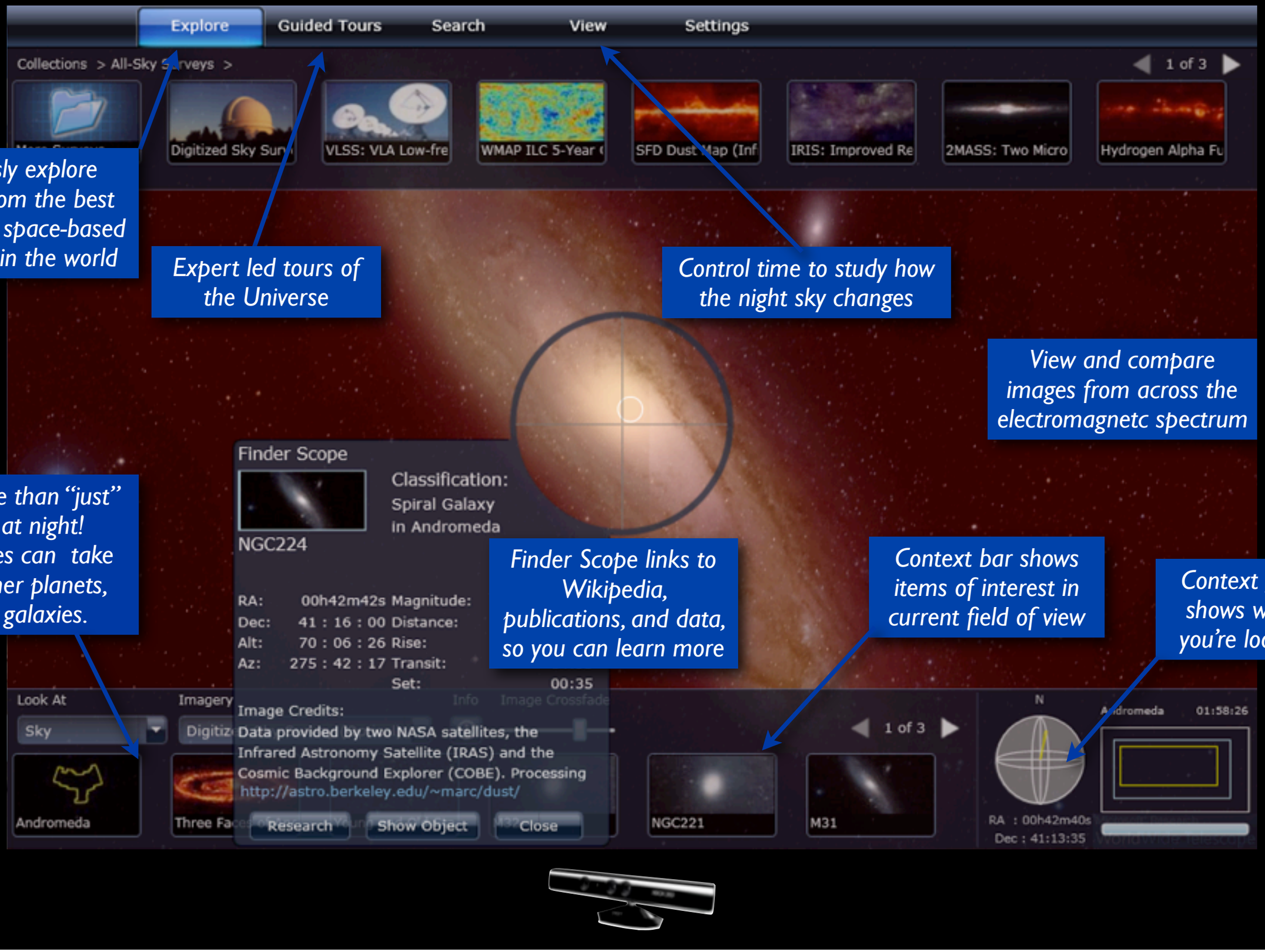
X-rays

The Andromeda Galaxy (M31)

Microsoft® Research WorldWide Telescope

[demo]

worldwidetelescope.org



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Context bar shows items of interest in current field of view

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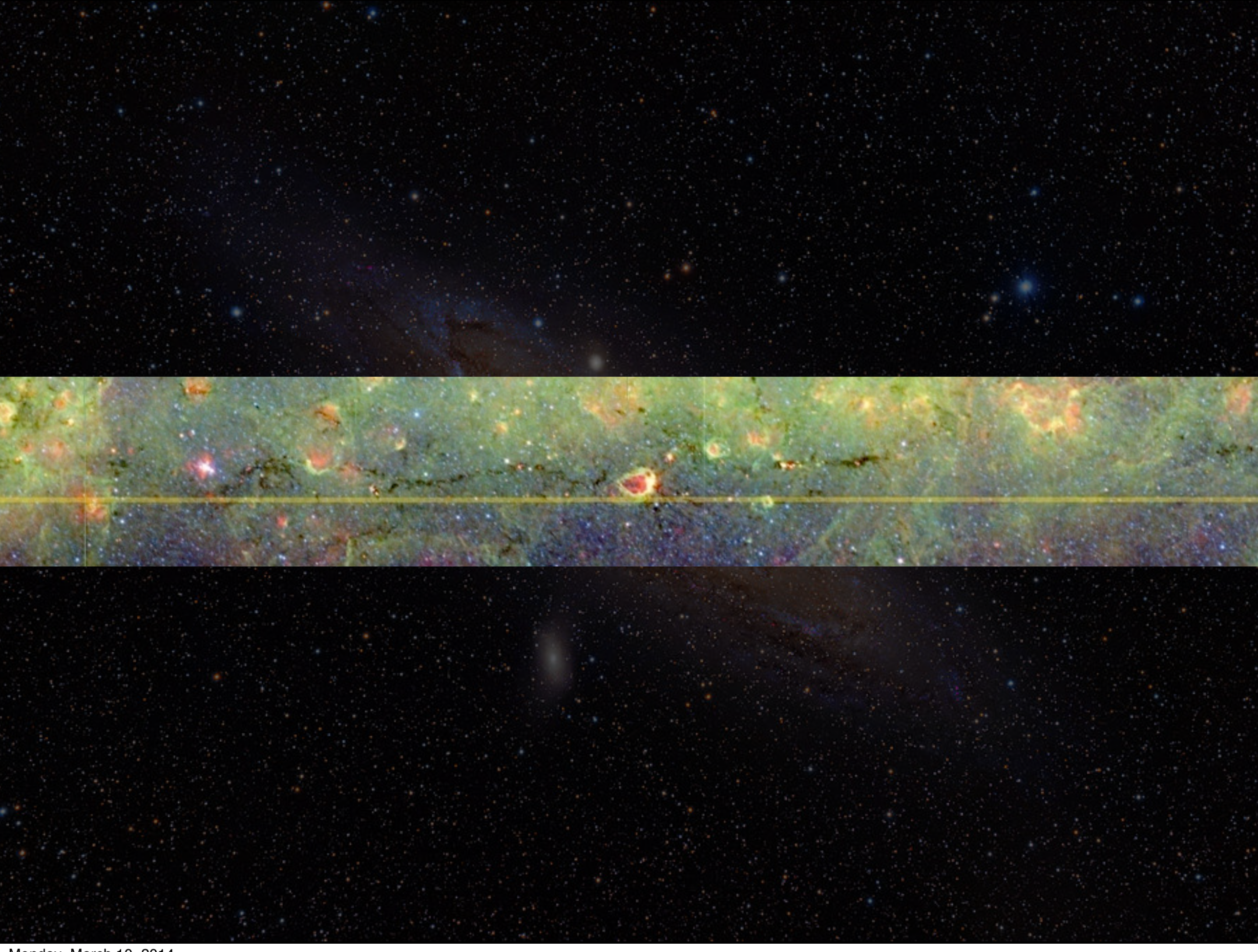

"The Bones of the Milky Way"

Open Access, Open Data (Authorea.com)

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The Bones of the Milky Way

Alyssa Goodman, João Alves, Chris Beaumont, Tom Dame, James Jackson, Jens Kauffmann, Thomas Robitaille, Alberto Pepe, Michelle Borkin, Andreas Burkert, Robert A Benjamin + Add author

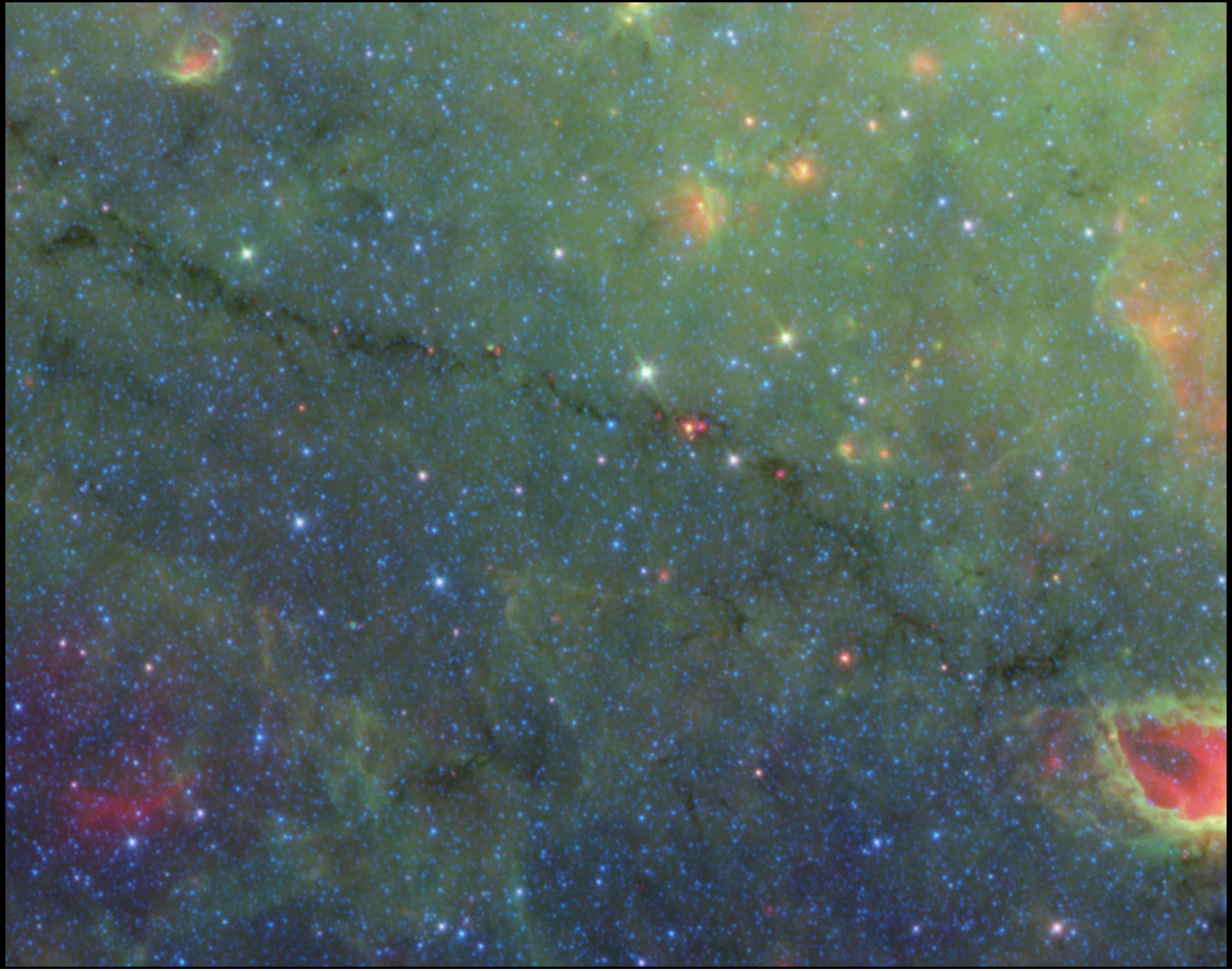
NOTES TO ONLINE READERS

This article was submtted to the Astrophysical Journal in December 2013.

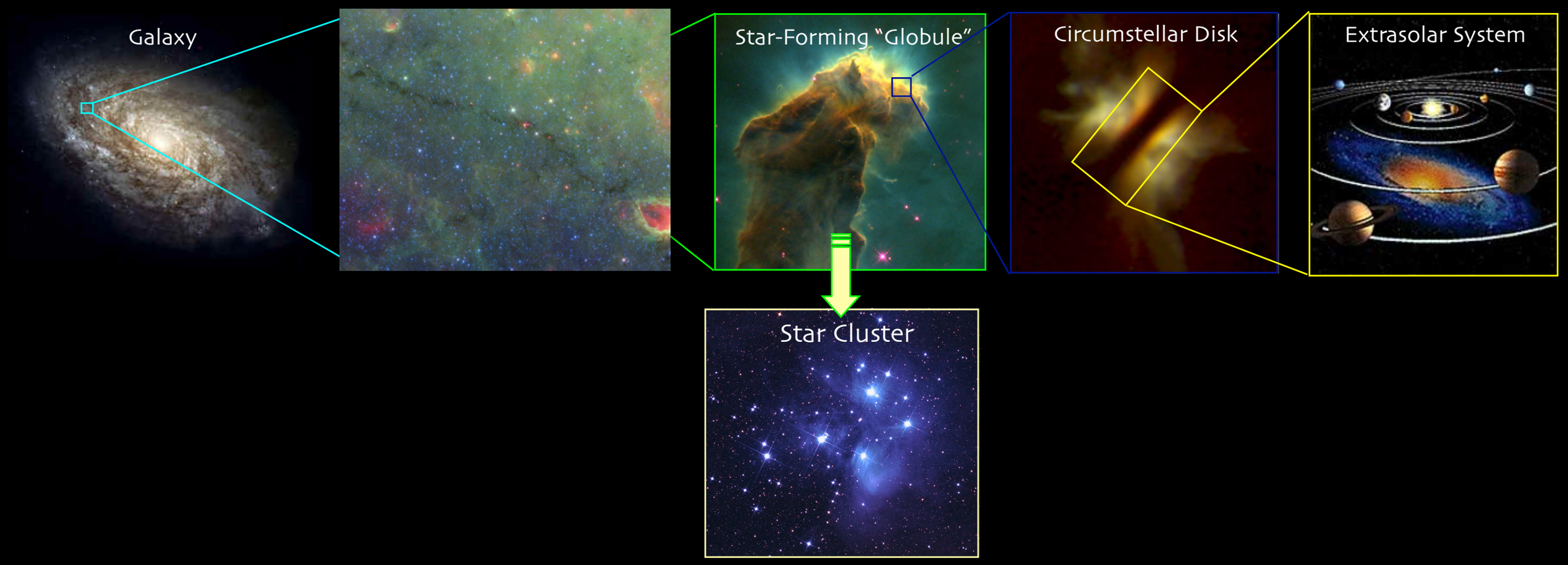
The current online version is citable as an online "Authorea" preprint, and you can use the article's URL to do

Once upon a time (2012), in an enchanted castle (in Bavaria)

...at a conference about star formation



Star and Planet Formation



Once upon a time (2012), in an enchanted castle (in Bavaria)

...at a conference about star formation

Question *Andi Burkert*: Is Nessie "parallel to the Galactic Plane"?

Answer *no one* immediately knew the answer!

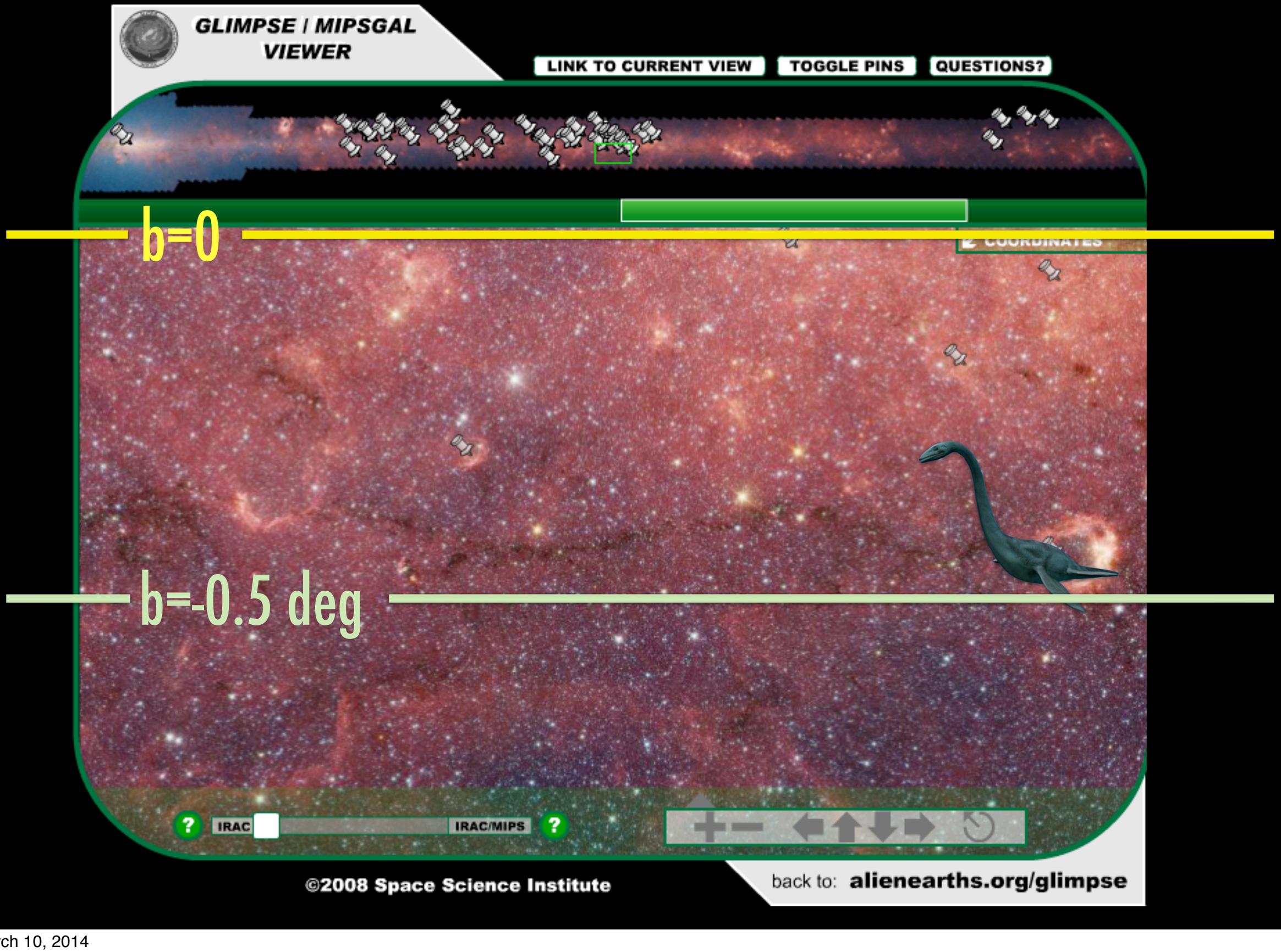
The Milky Way

“Galactic Plane”

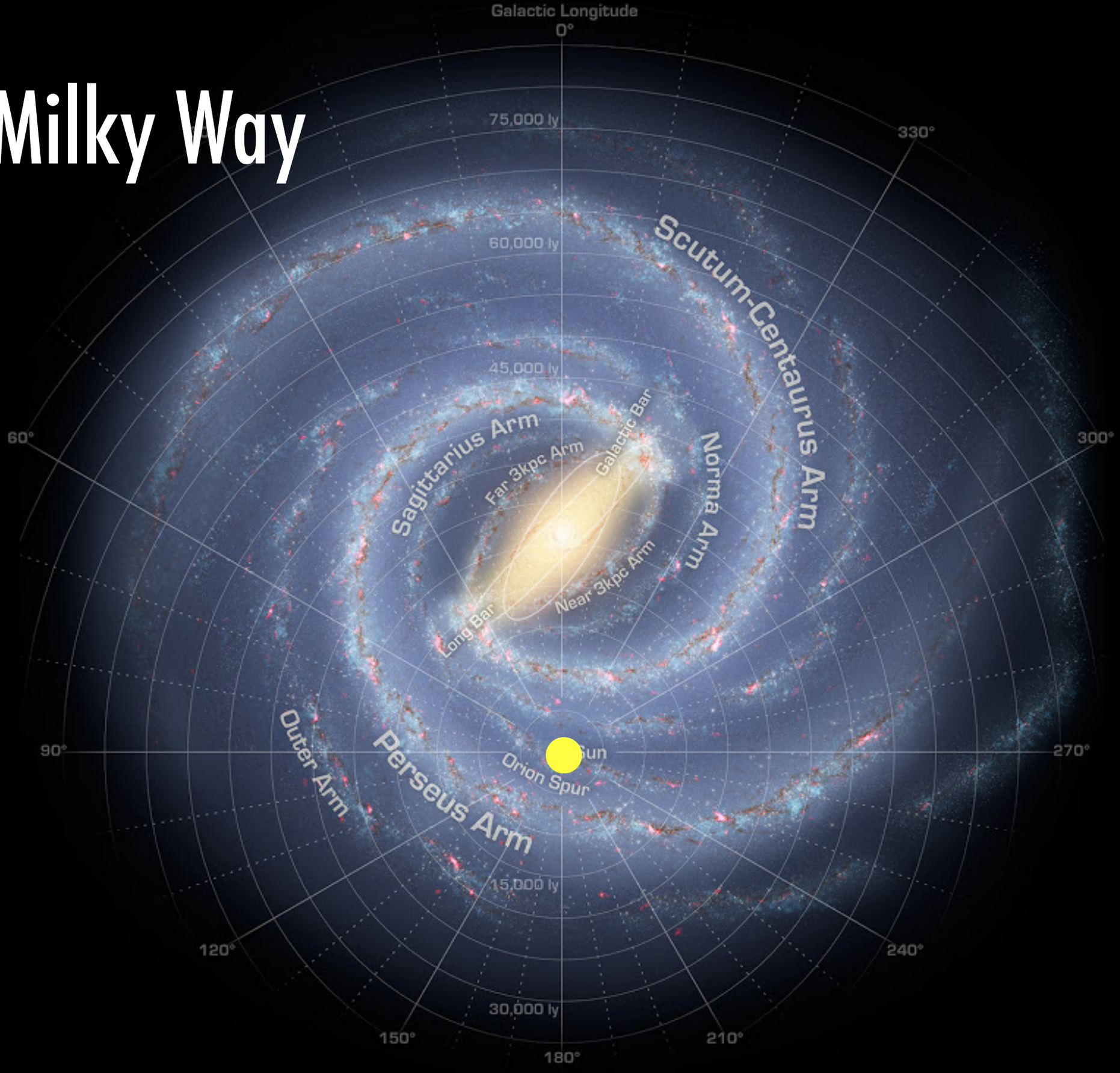
The Milky Way
(Artist's Conception)

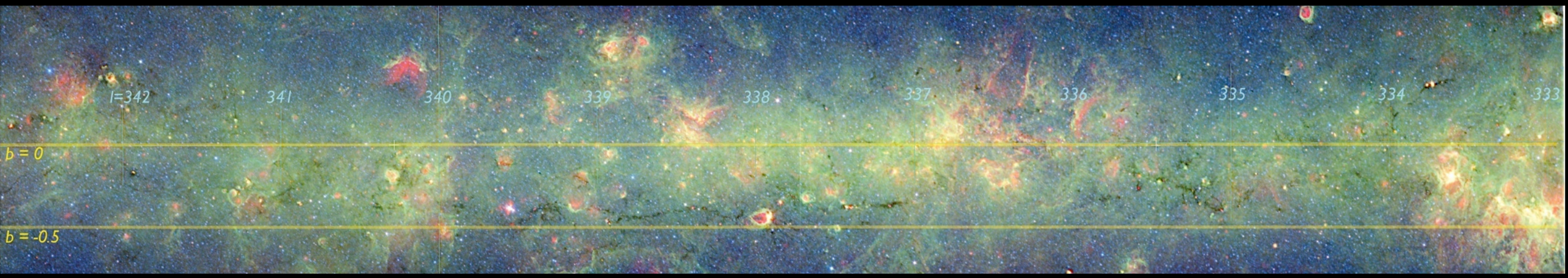
"Is Nessie Parallel to the Galactic Plane?"

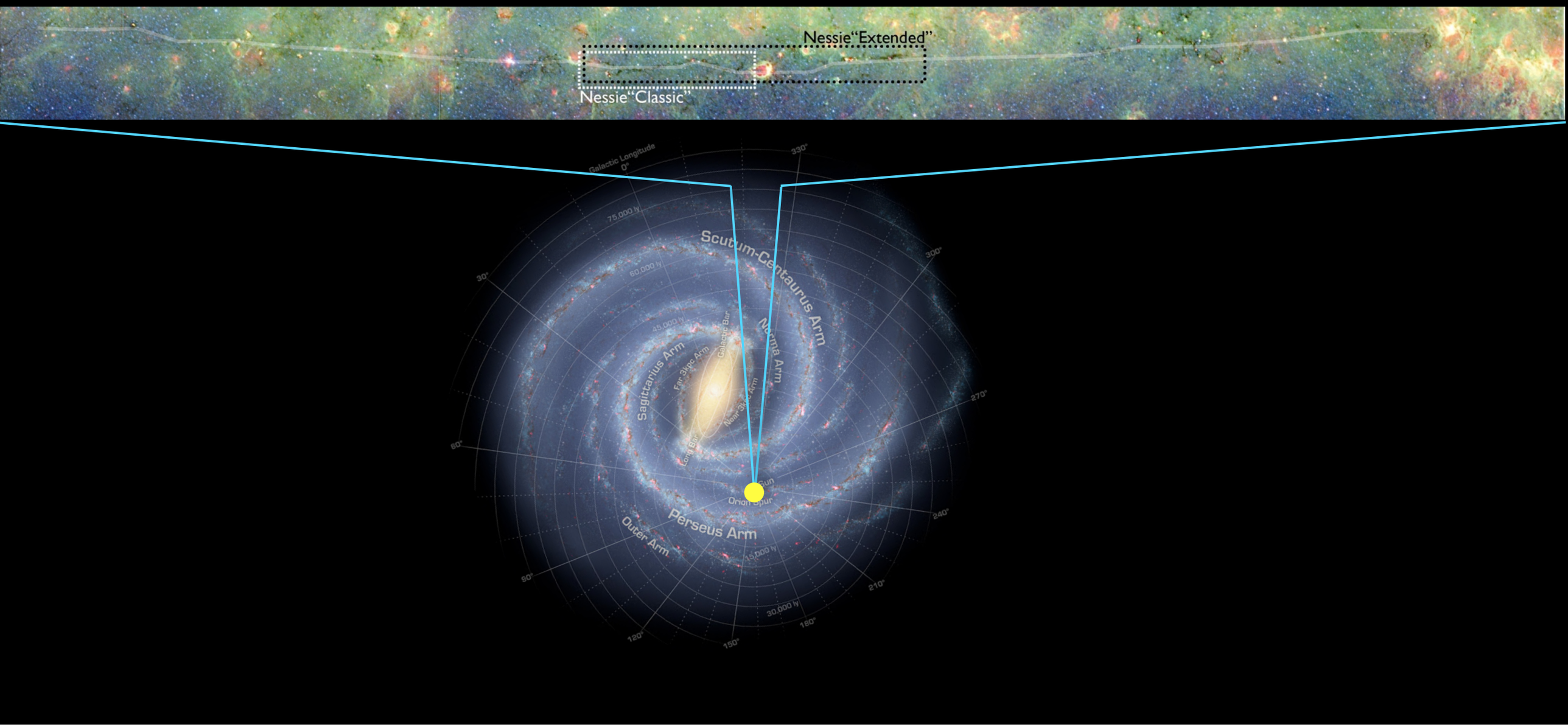
Yes, but why not at Zero of Latitude (b=0)?

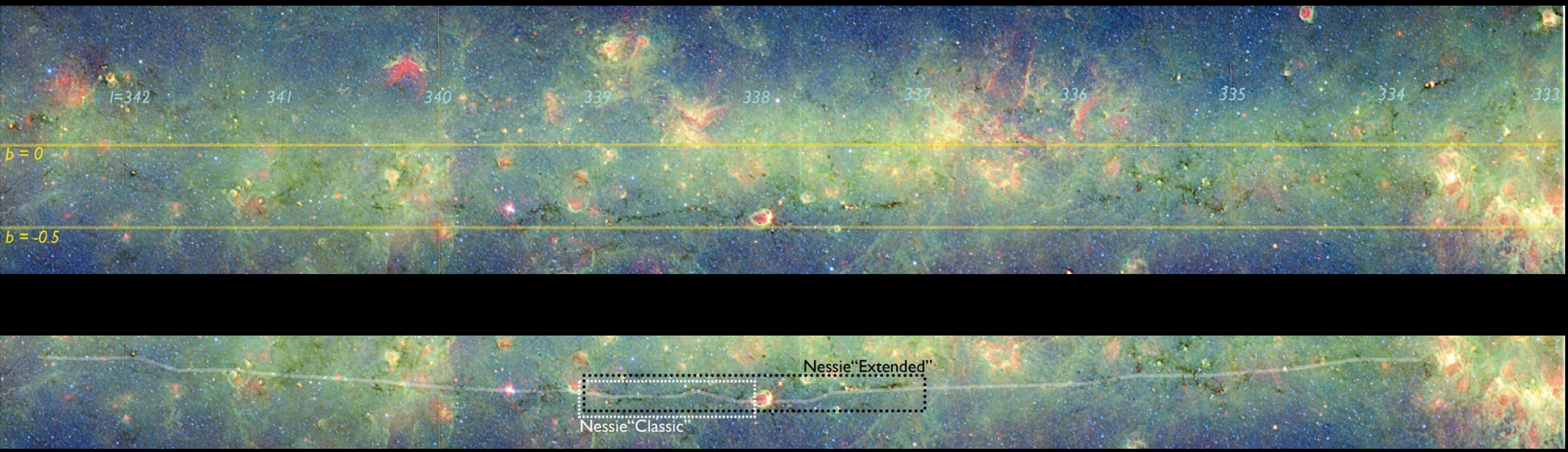


The Milky Way




l=342
341
340
339
338
337
336
335
334
333
b = 0
b = -0.5


Nessie "Extended"
Nessie "Classic"
Galactic Longitude
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
15,000 ly
30,000 ly
45,000 ly
60,000 ly
75,000 ly
Scutum-Centaurus Arm
Norma Arm
Sagittarius Arm
Perseus Arm
Outer Arm
Far 3kpc Arm
Near 3kpc Arm
Galactic Bar
Long Bar
Sun
Orion Spur



"Nessie Extended"

~500 light years long & 1.5 light years thick

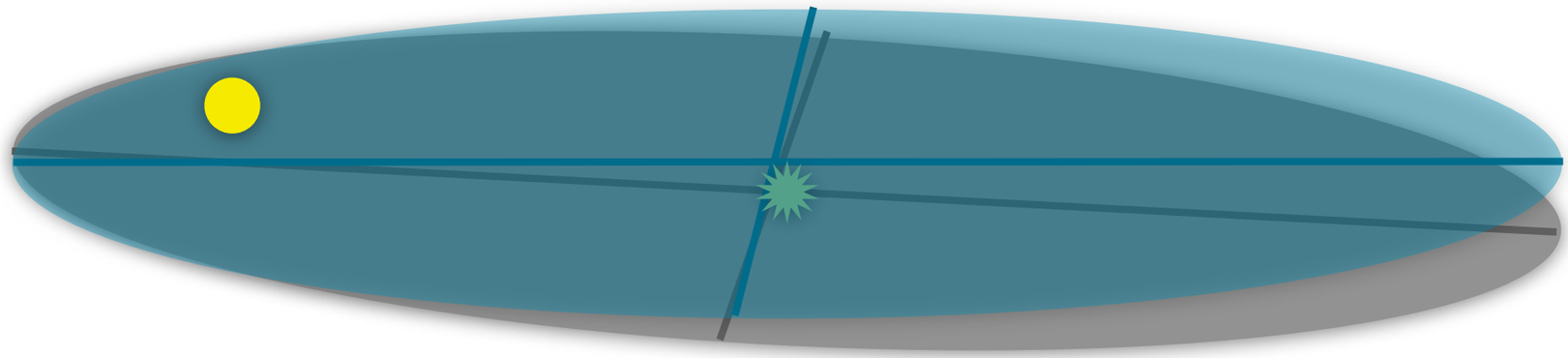
300:1 axial ratio

200,000 solar masses

BUT, why is it near b=-0.5, and not b=0?

Where are we, really?

"IAU Milky Way", est. 1959



True Milky Way, modern

The equatorial plane of the new co-ordinate system must of necessity pass through the sun. It is a fortunate circumstance that, within the observational uncertainty, both the sun and Sagittarius A lie in the mean plane of the Galaxy as determined from the hydrogen observations. If the sun had not been so placed, points in the mean plane would not lie on the galactic equator.

[Blaauw et al. 1959]

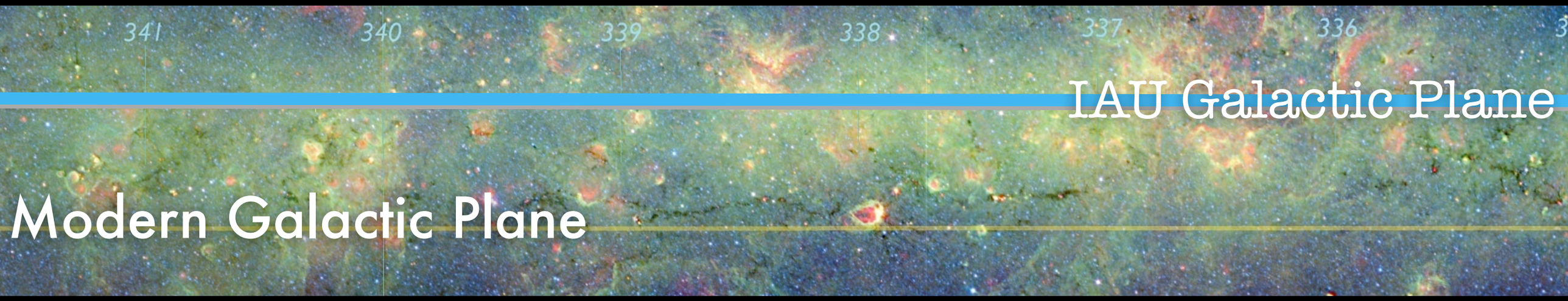
Sun is ~75 light years "above" the IAU Milky Way Plane

+

Galactic Center is ~20 light years offset from the IAU Milky Way Center

=

The **Galactic Plane is not quite where you'd think it is** when you look at the sky

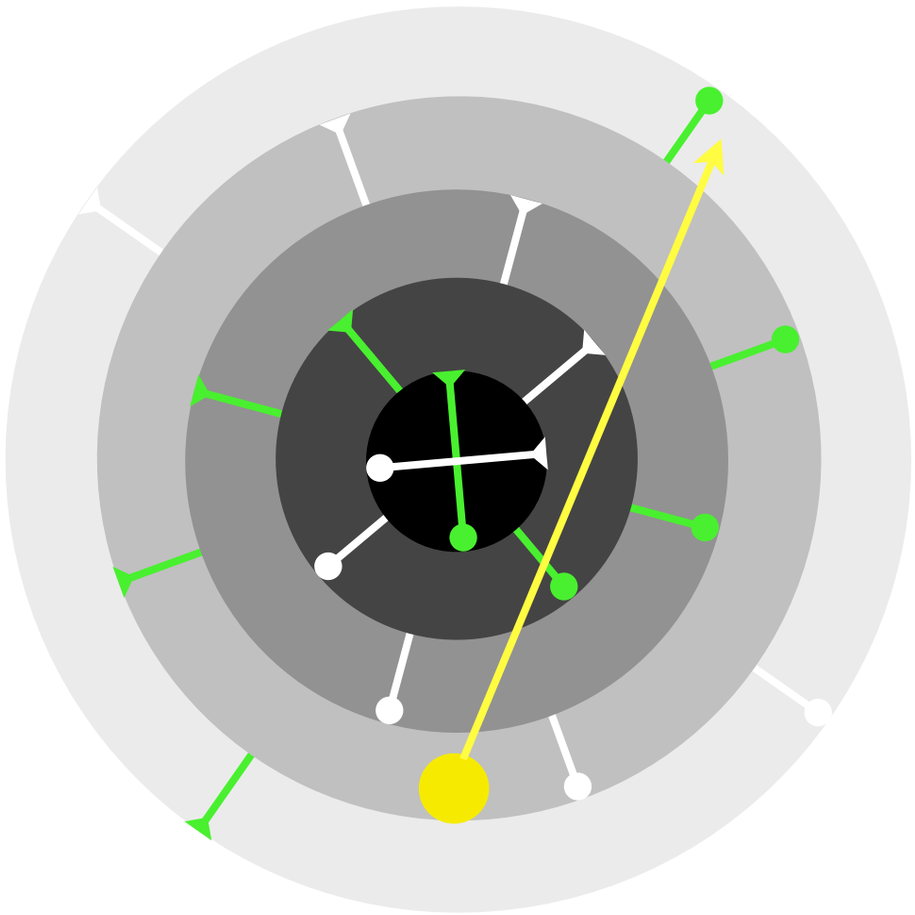


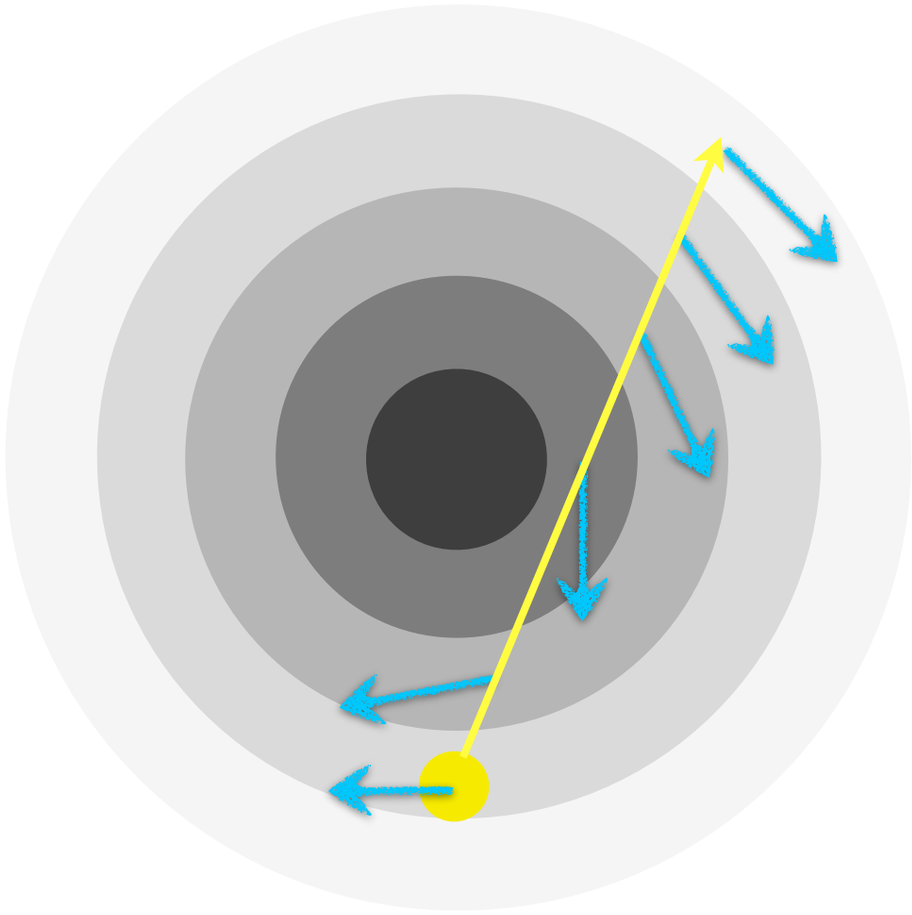
Yes, Nessie is EXACTLY in the Galactic Plane!

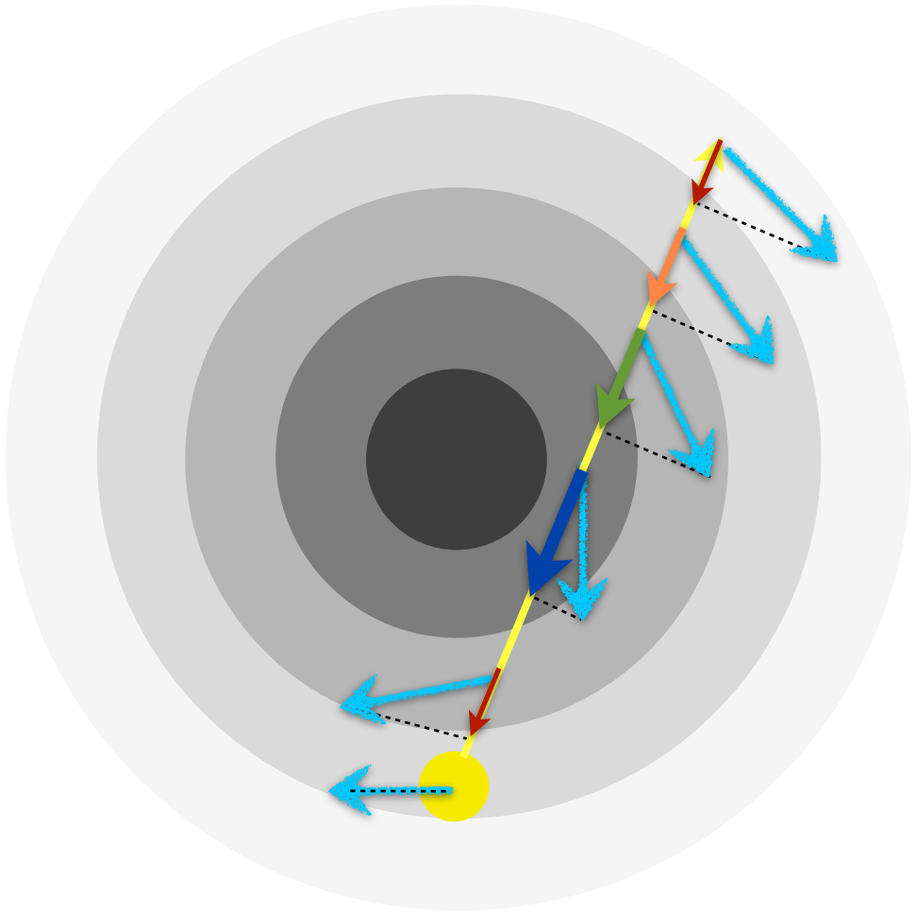
What about its distance?

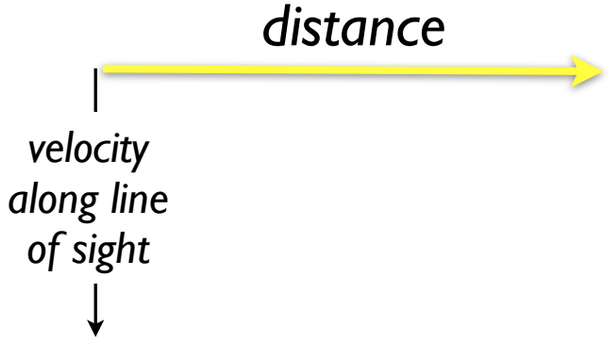
we can use “radial velocities” to estimate distance in a rotating galaxy...

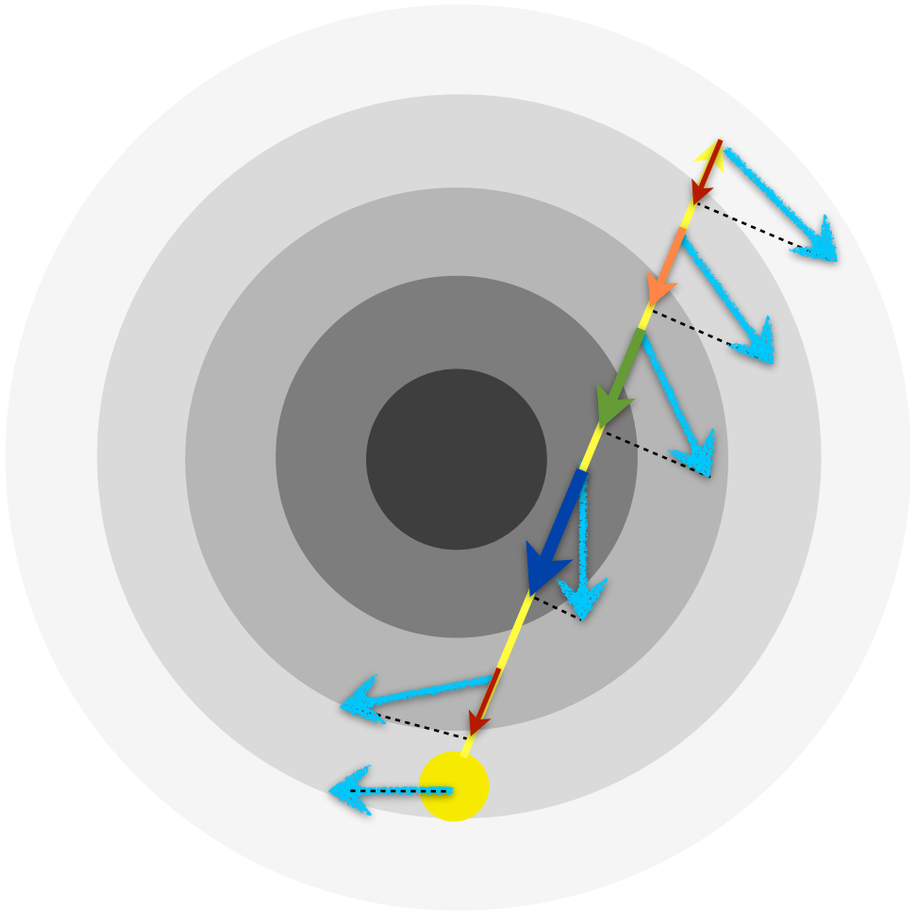
A Rotating (Spiral) Galaxy Observed from its Outskirts...

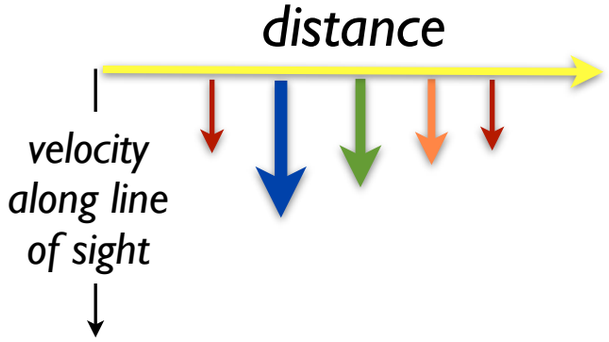




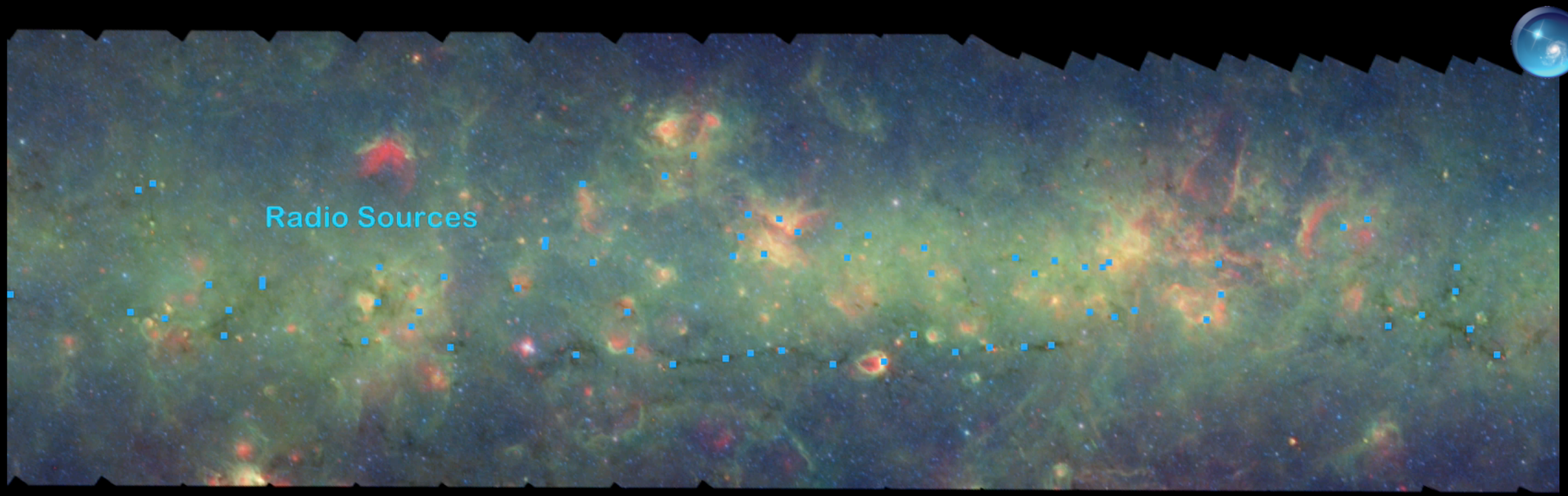



distance
velocity
along line
of sight

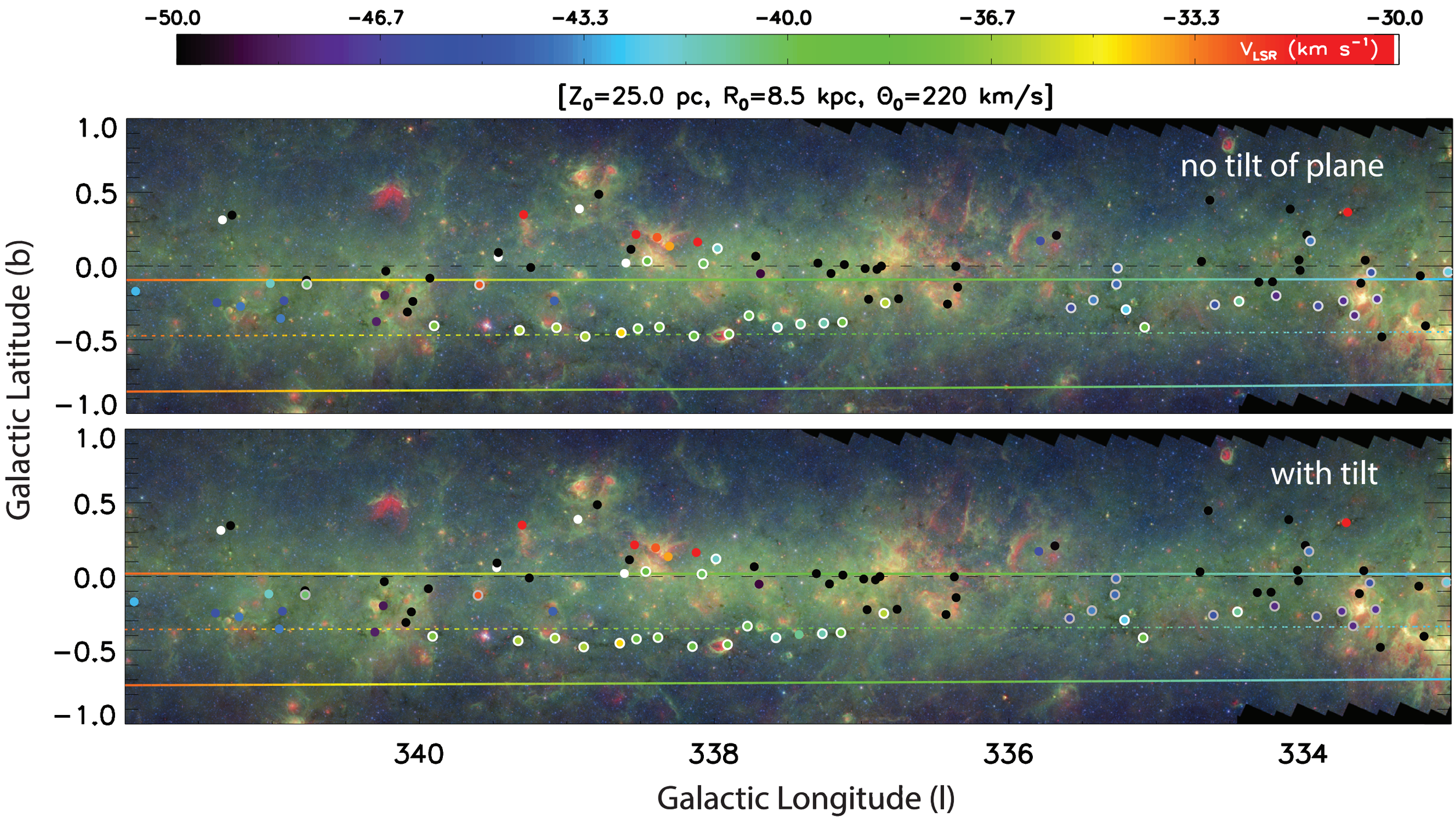


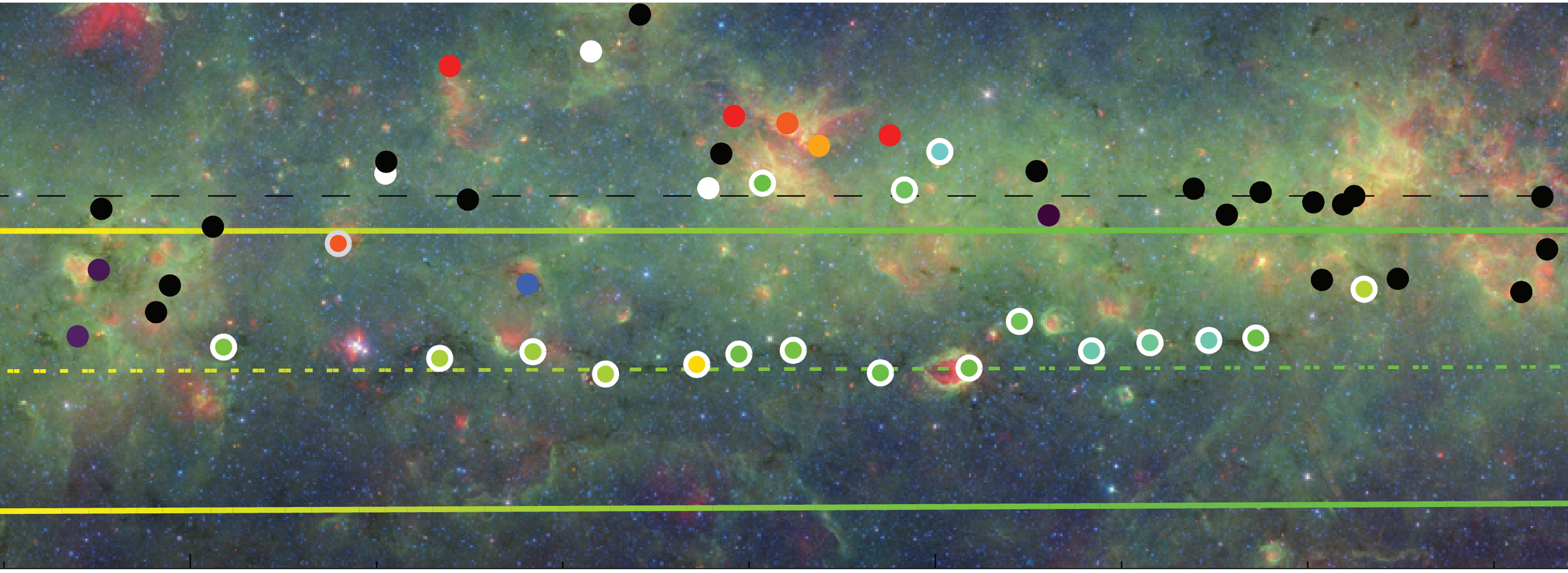

distance
velocity
along line
of sight

Velocity to Distance



In the plane and at the distance of spiral arm!





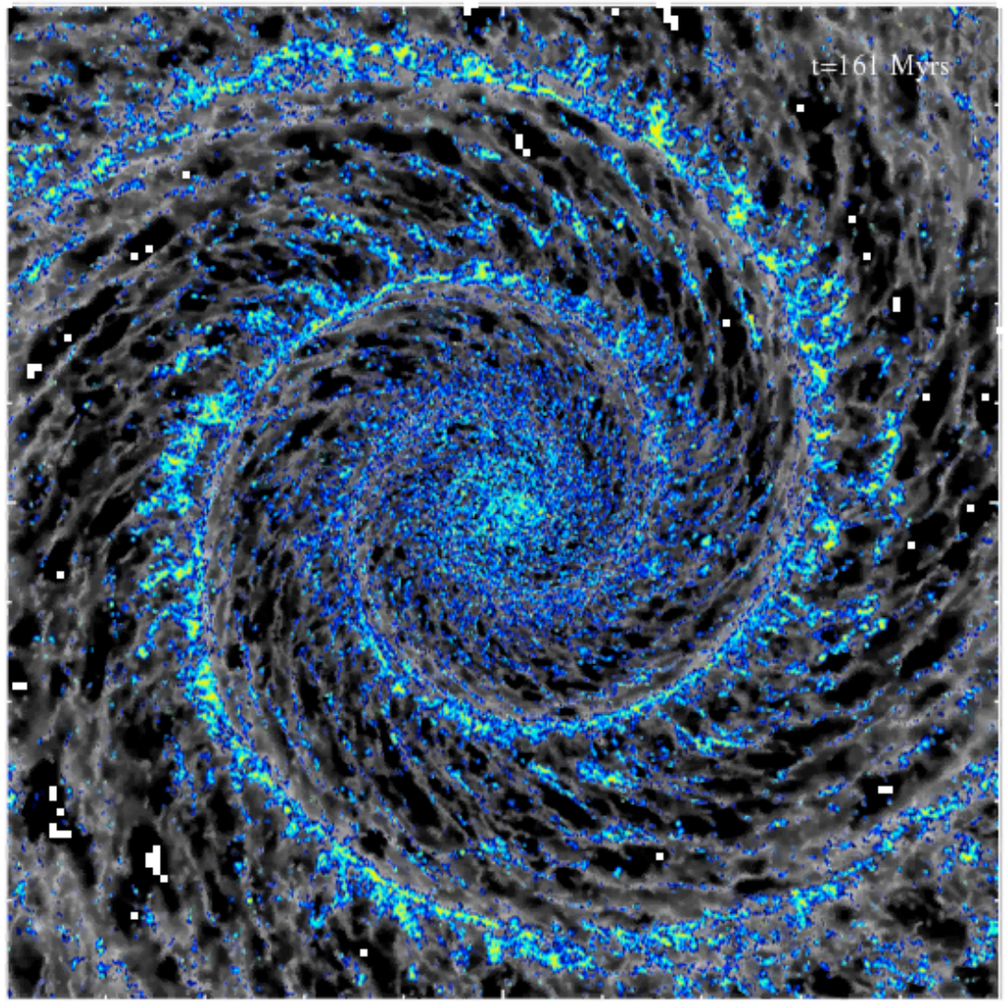
...eerily precisely...

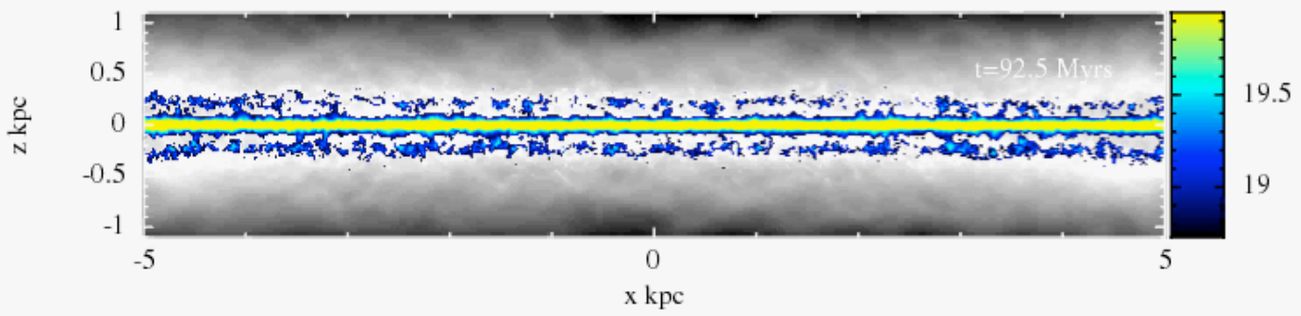
Monster to Bone

There could be 1000s more of these to find...a full skeleton perhaps?

A full 3D skeleton?

(flipped) image of IC342 from Jarrett et al. 2012; WISE Enhanced Resolution Galaxy Atlas

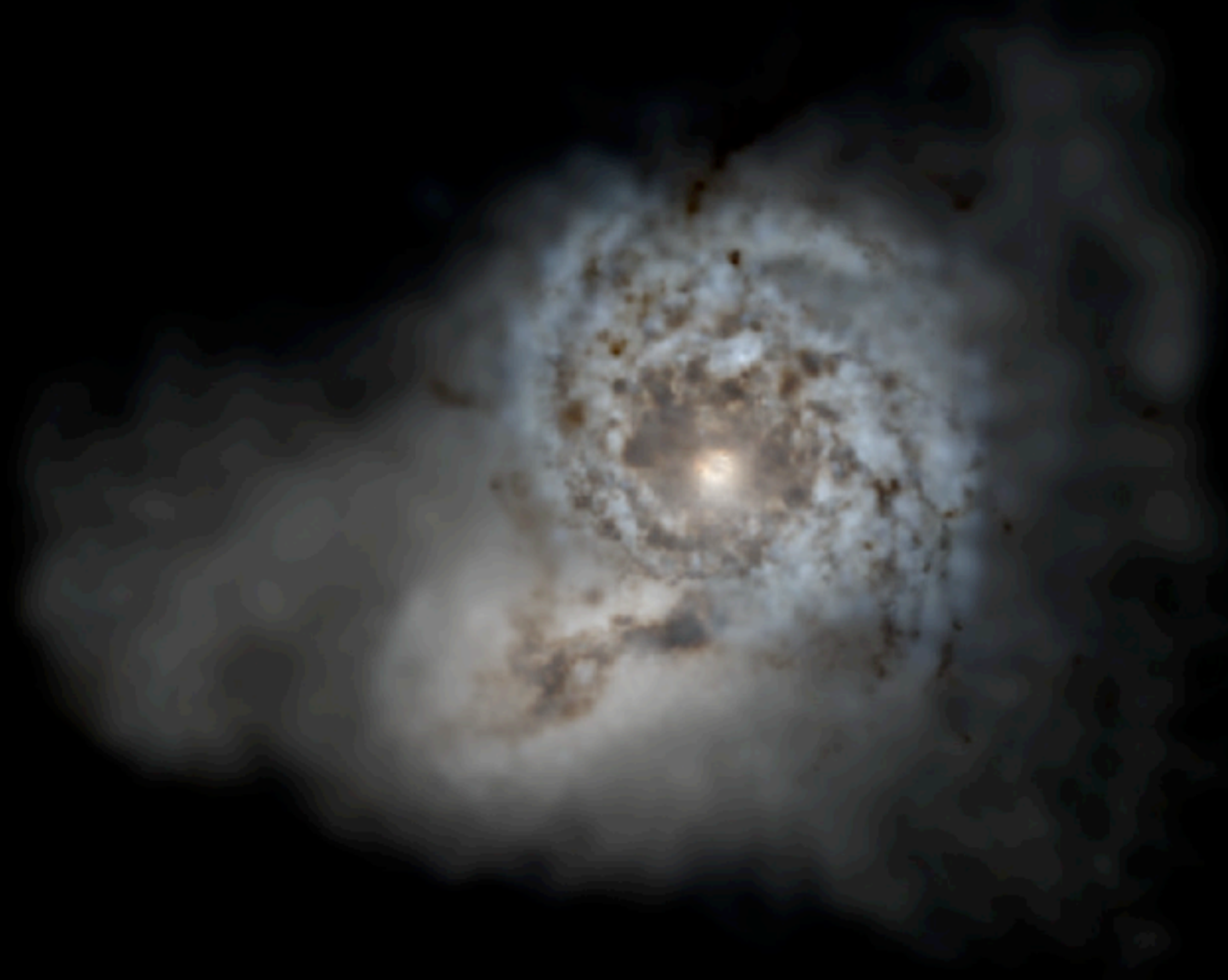




simulations courtesy Clare Dobbs

z=0.00

Formation of a Milky-Way-like Galaxy (Stars)



http://www.tapir.caltech.edu/~phopkins/Site/Movies_cosmo.html

Future of the Milky Way (Collision with Andromeda)

Sea Monster to Skeletal Shadow

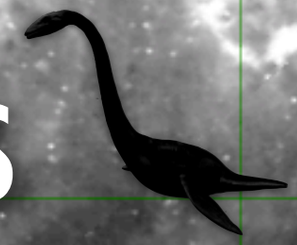
Spitzer GLIMPSE Image

Peculiar dust cloud named “Nessie” much larger than thought.

Nessie more important as “bone” than sea monster.

Sun’s height above Plane may make full Milky Way skeleton mappable.

The Bones of the Milky Way: Credits



Seamless Astronomy-style tools used in this project

SEAMLESS ASTRONOMY
Linking scientific data, publications, and communities

authorea.com (open publishing)

theastrodata.org (open data)

glueviz.org (open source tools)

universe3d.org (collaborative data)

worldwidetelescope.org (universe information system)

virtual observatory standards (international online information-sharing systems)

Supported by

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VERITAS

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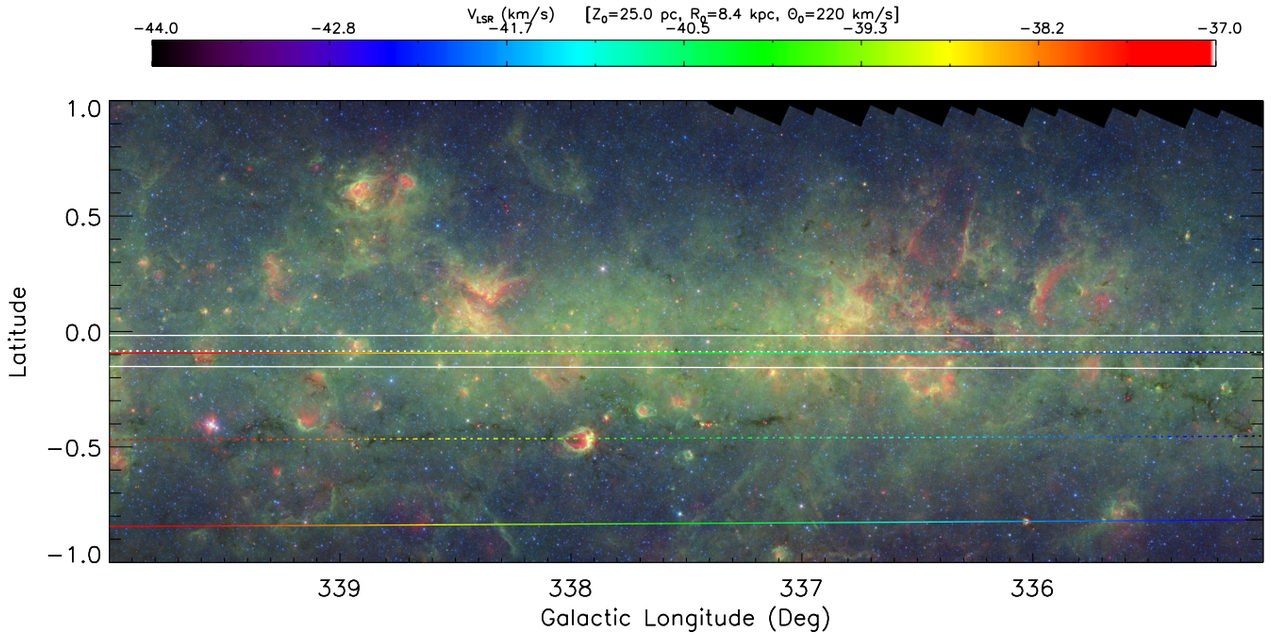
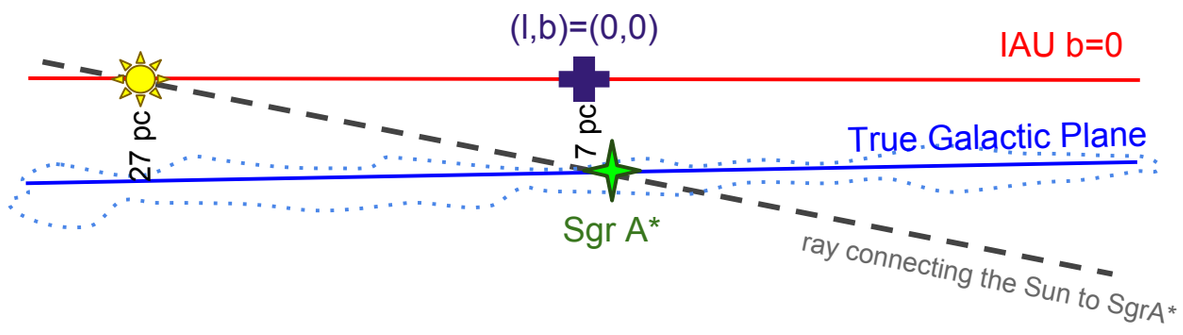
milkywaybones.org
worldwidetelescope.org

Where is "Nessie," in 3D?

How close to "in" the plane?



Drawing is schematic--NOT to scale



Notes:
IAU b=0 set from HI, which is uncertain by ~0.1 degrees
tilt of red w.r.t. blue would be (20/8400)*180/pi=0.13 degrees

At what distance & inclination to l.o.s?