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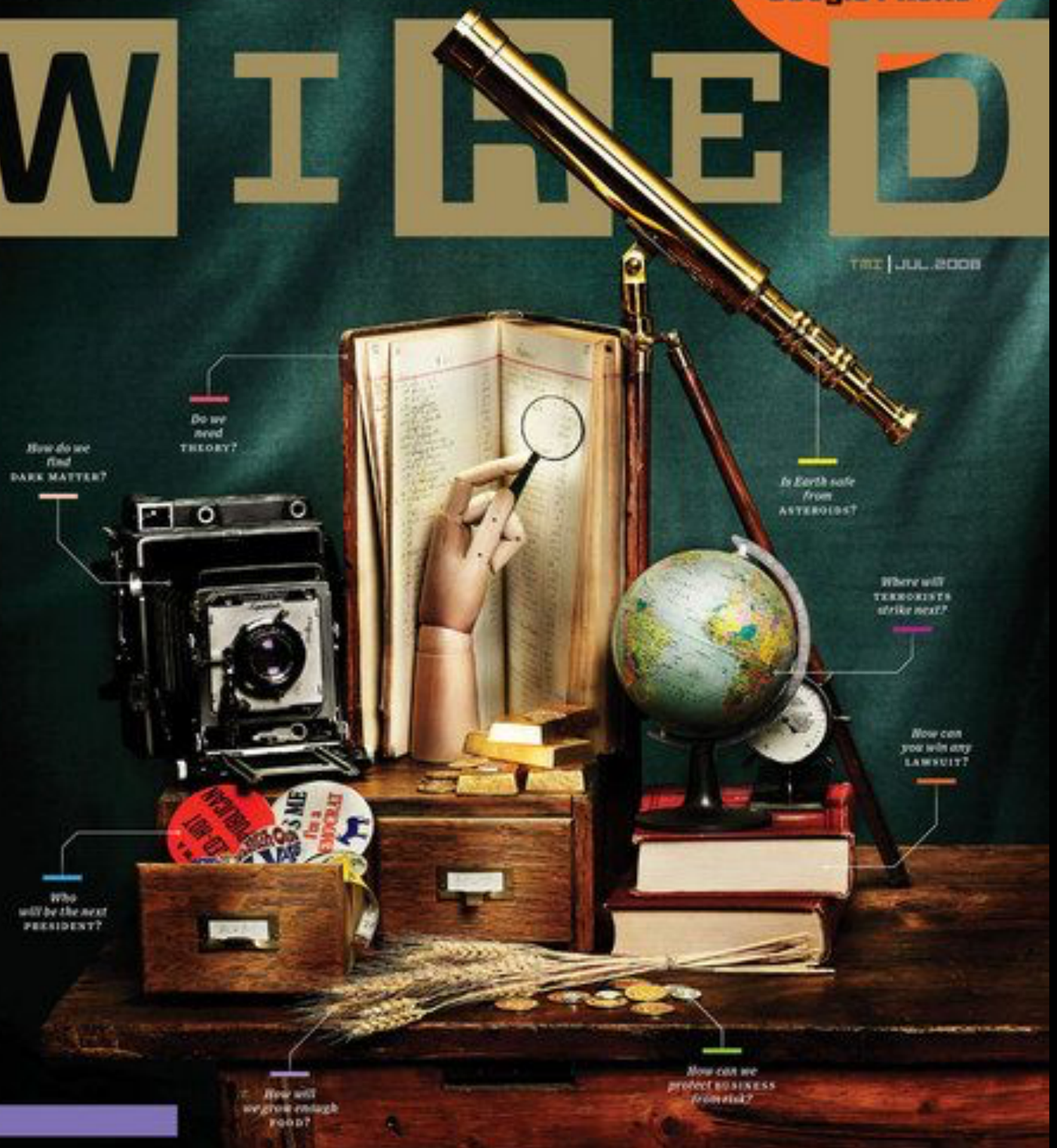

The End of Science

The quest for knowledge used to begin with grand theories. Now it begins with massive amounts of data. Welcome to the Petabyte Age.

RIS ANDERSON SCIENCE 06.23.08 12:00 PM

THE END OF THEORY: THE DATA DELUGE MAKES THE SCIENTIFIC METHOD OBSOLETE

What can humans + computers teach each other about the Universe?

Alyssa A. Goodman @aagie
Harvard Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

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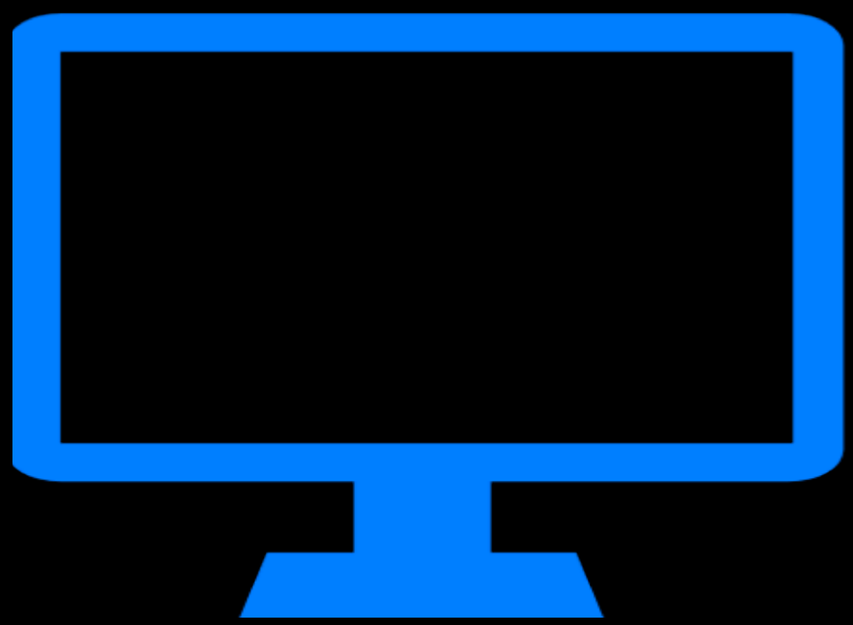

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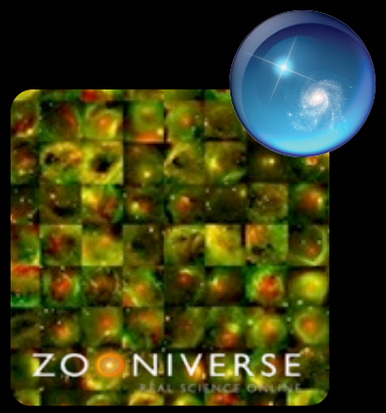
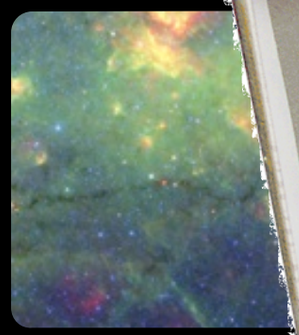
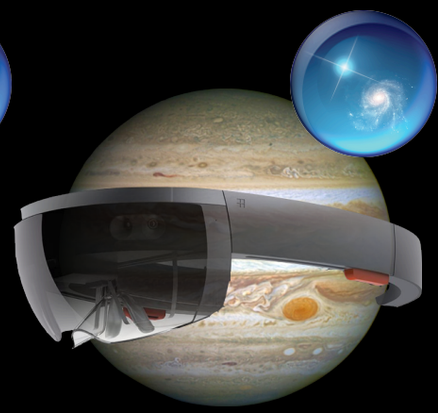
What can humans + computers teach each other about the Universe?

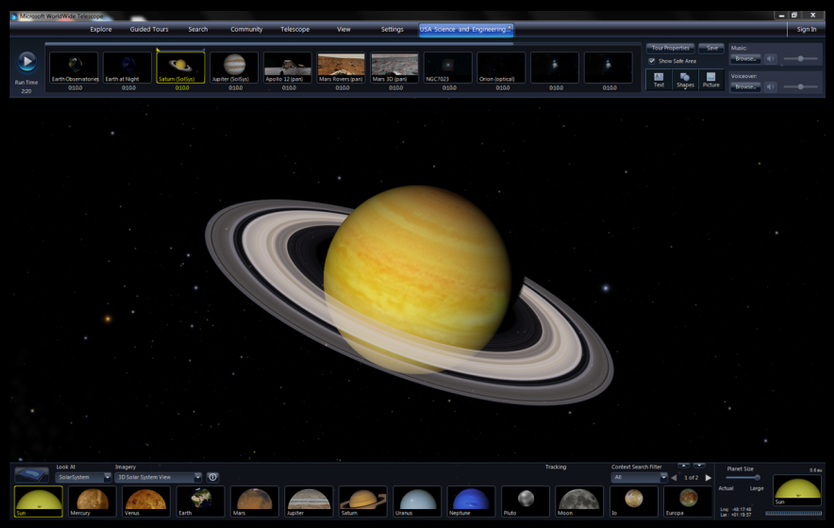
What can humans + computers teach each other about the Universe?

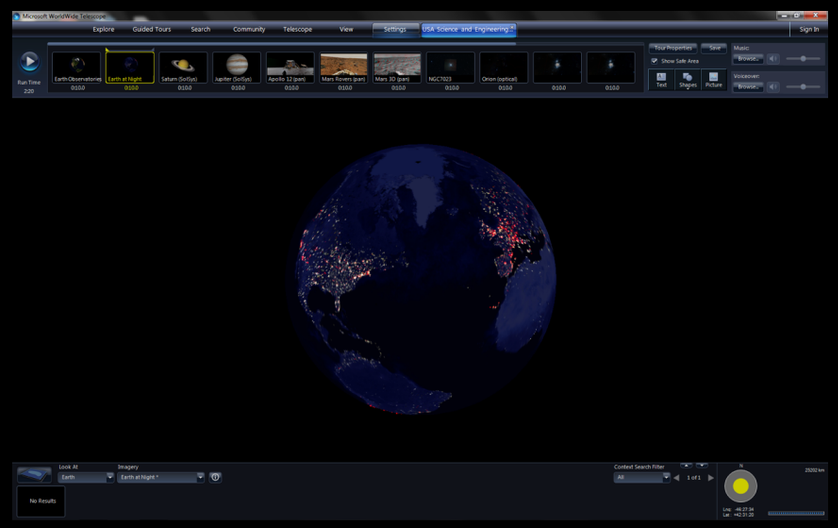


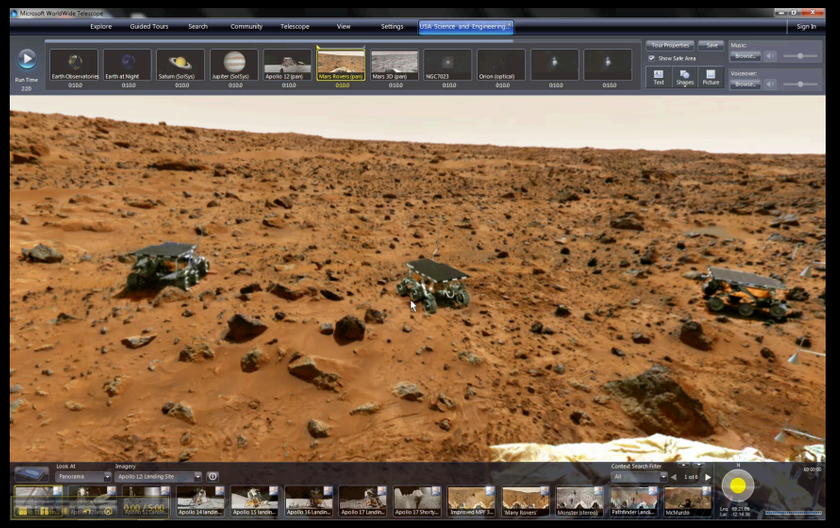


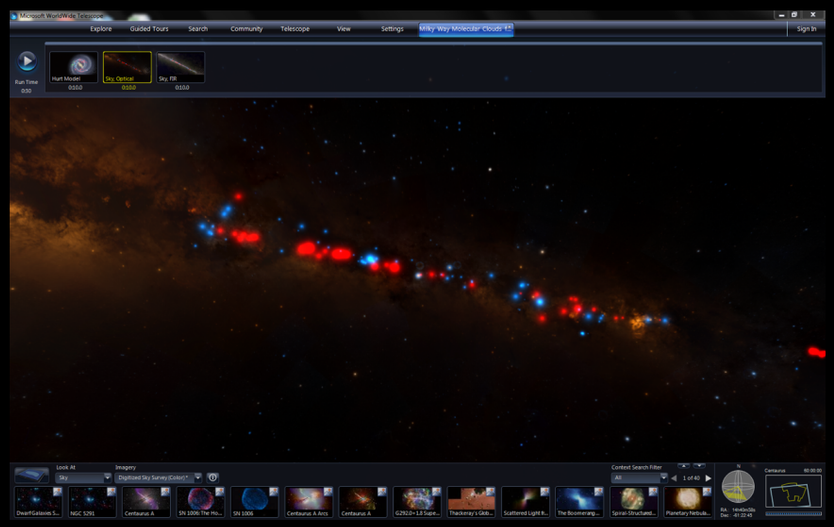


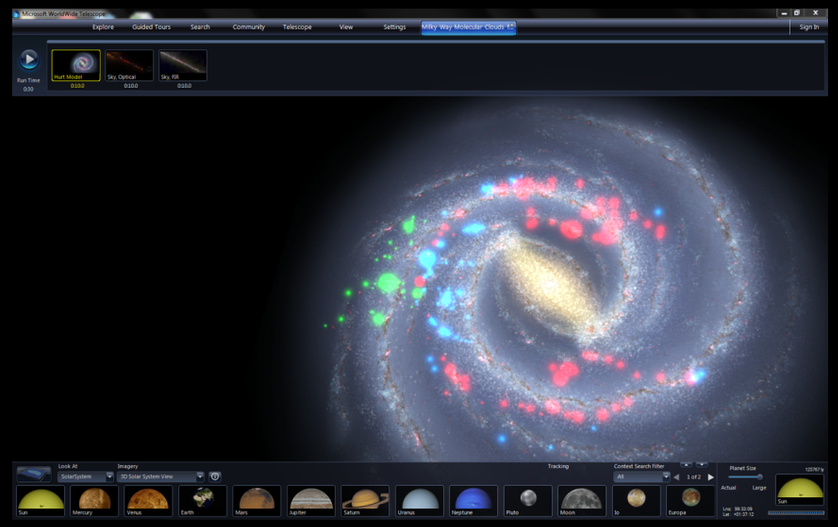
The Power of a "WorldWide Telescope"

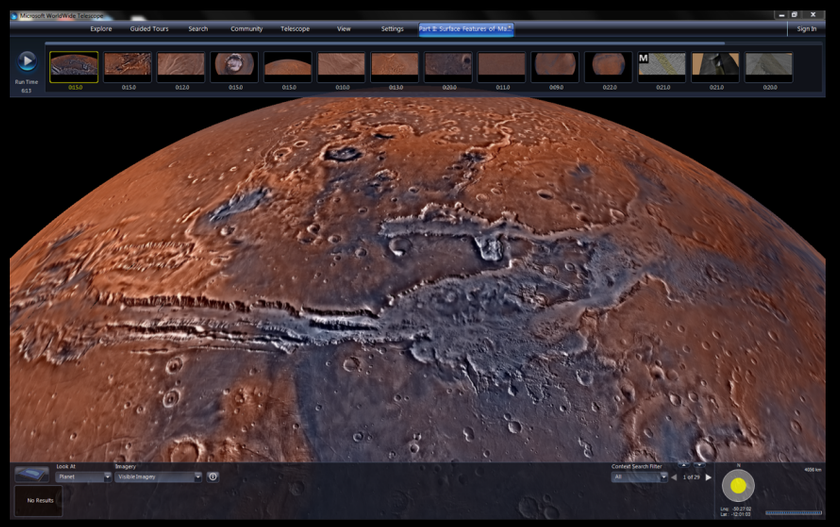


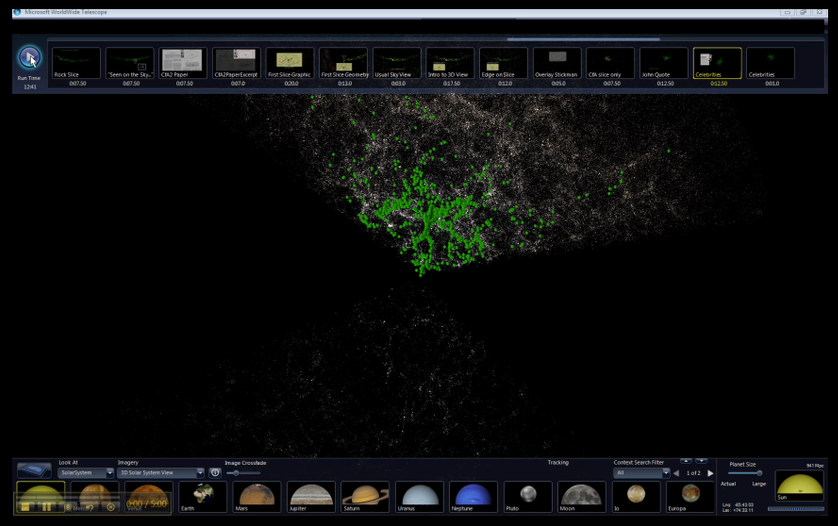


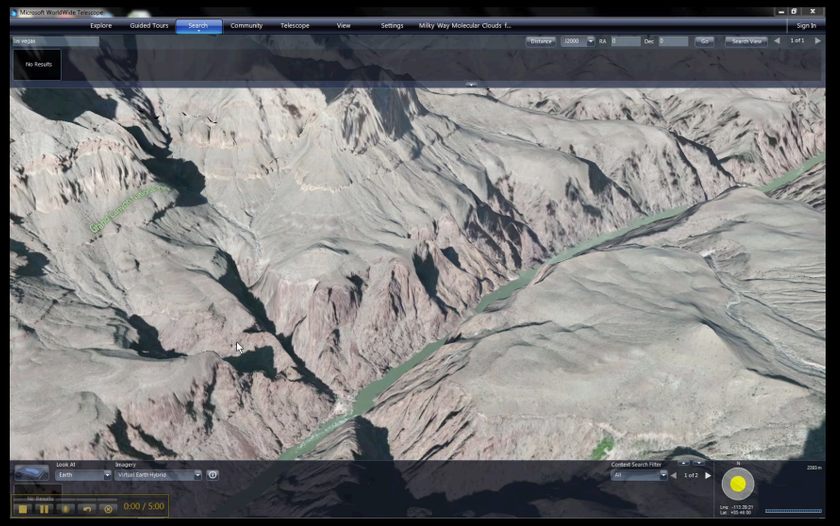












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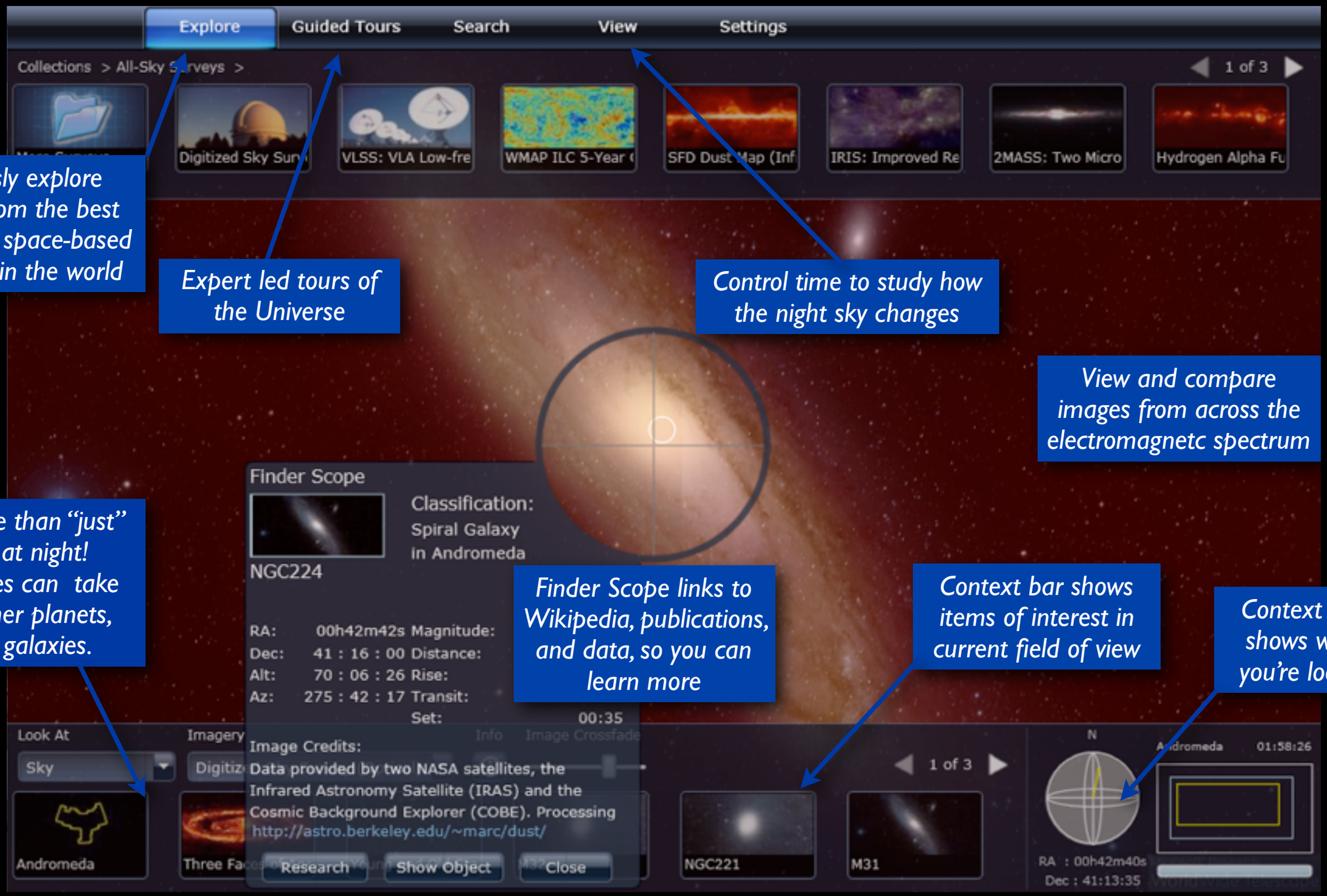

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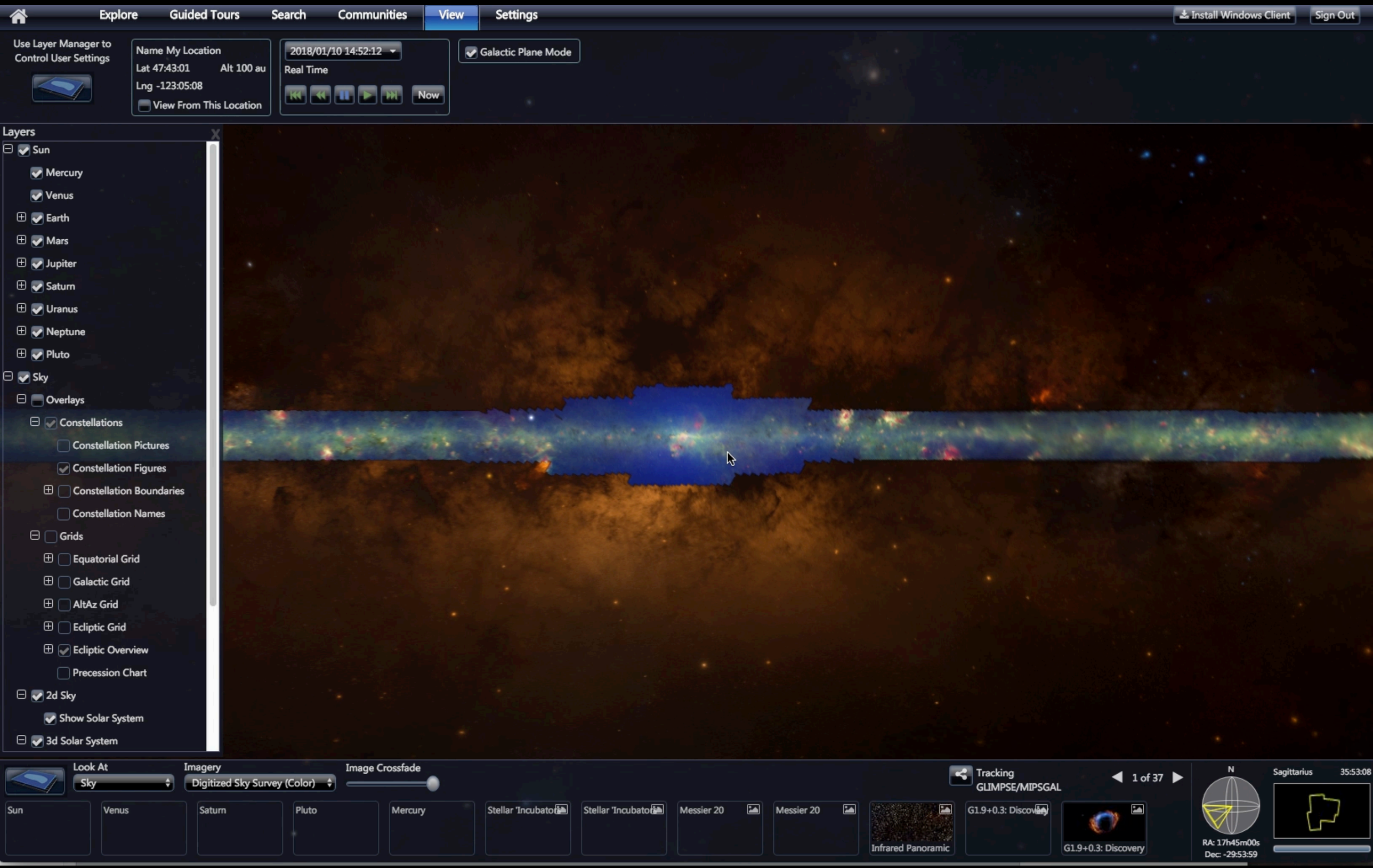
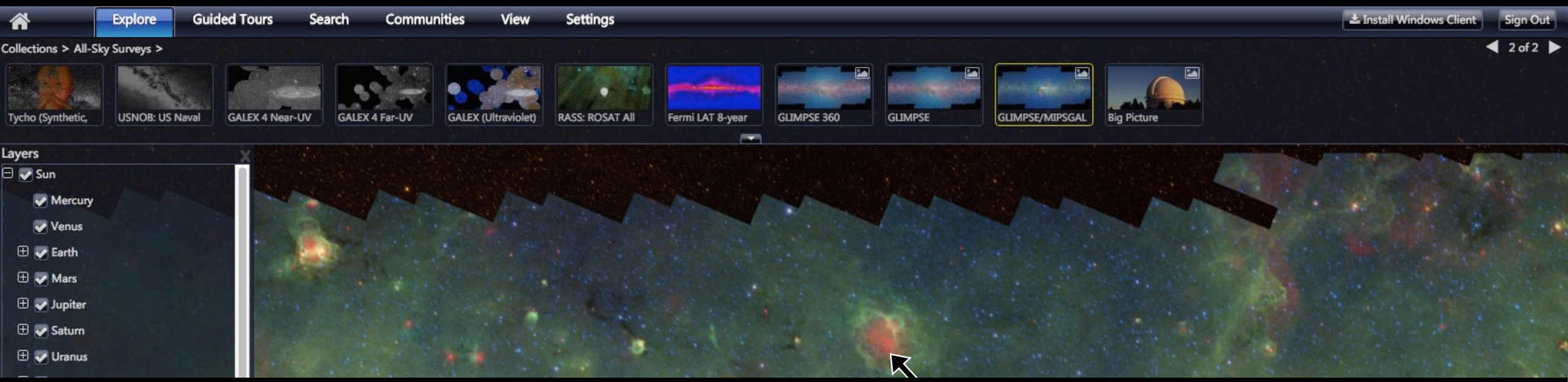
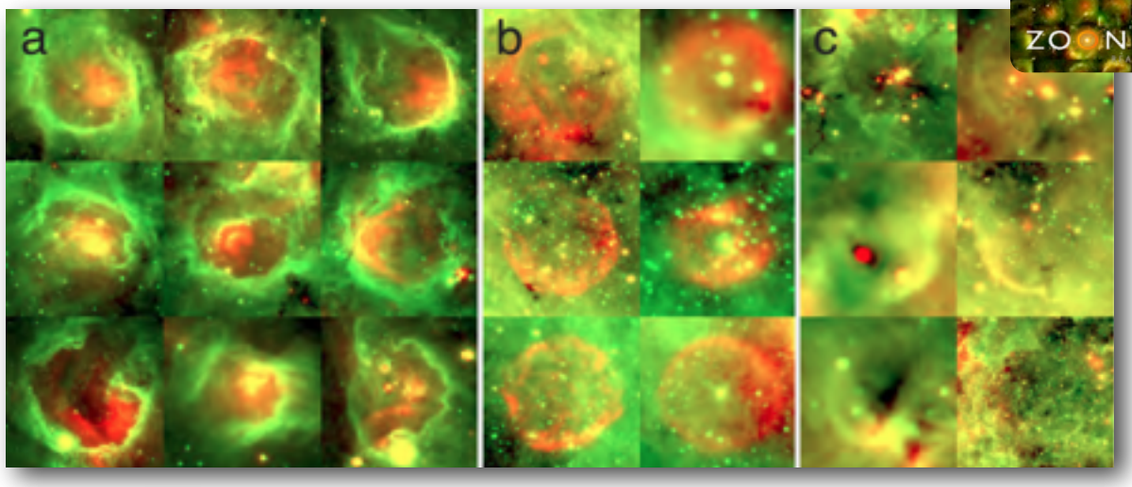


What is it?

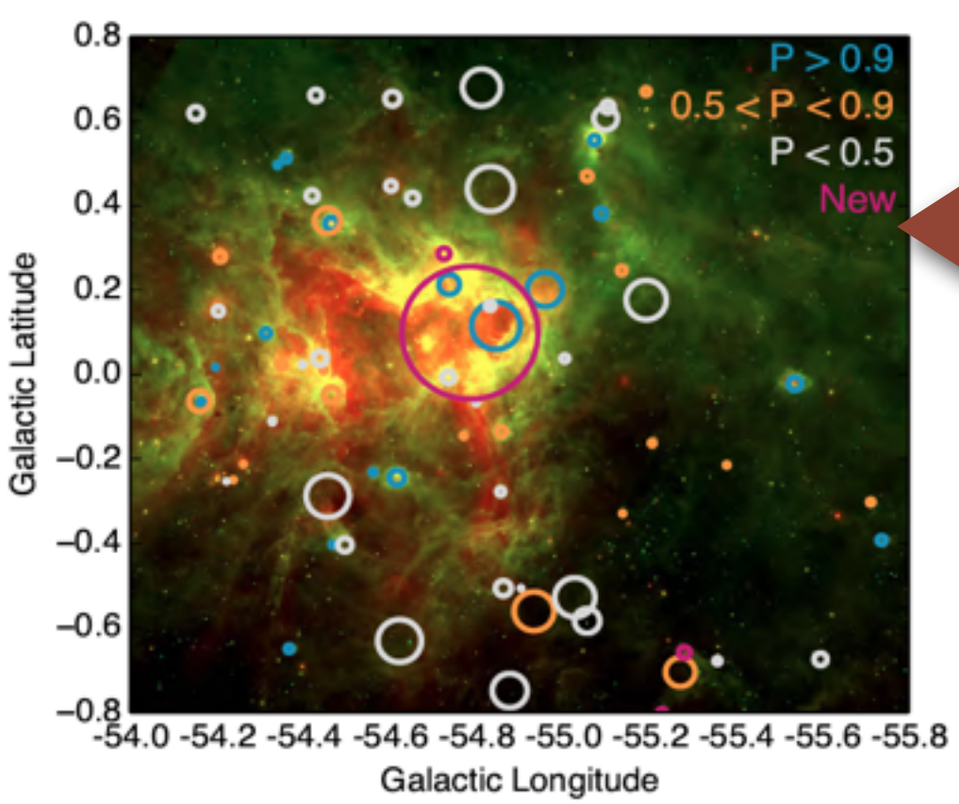


What can humans + computers teach each other about the Universe?

BIG DATA AND "HUMAN-AIDED COMPUTING"

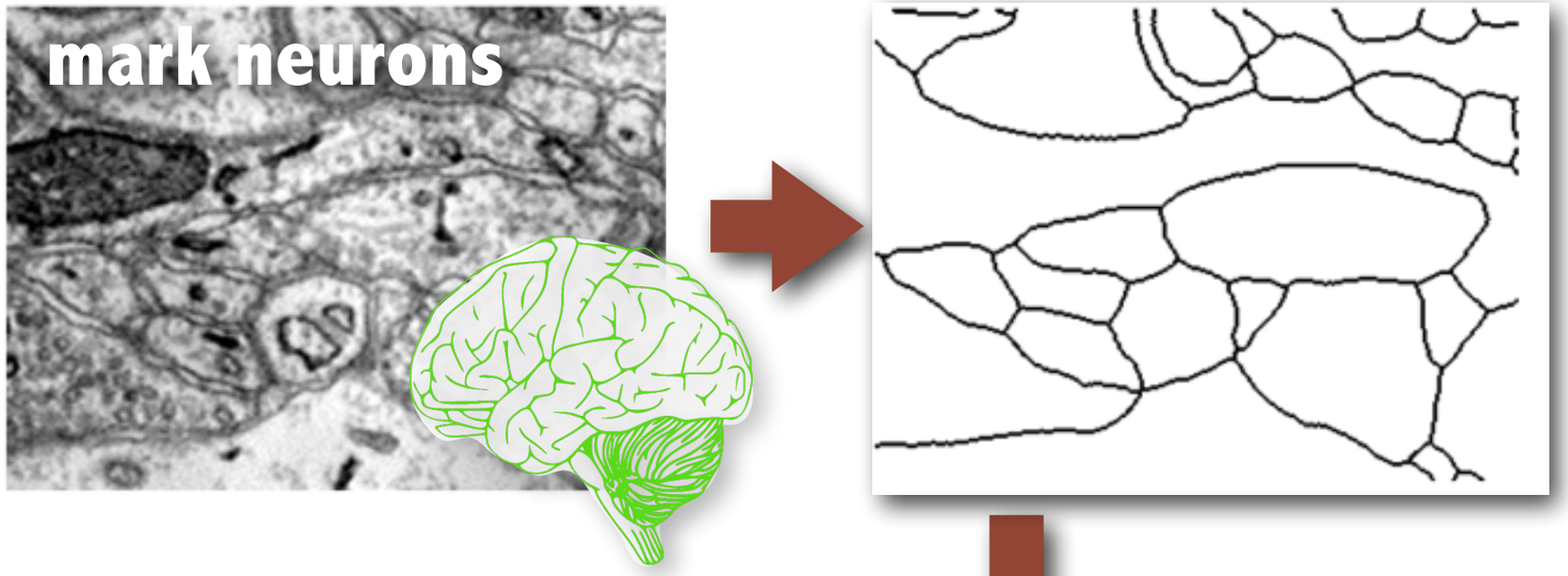


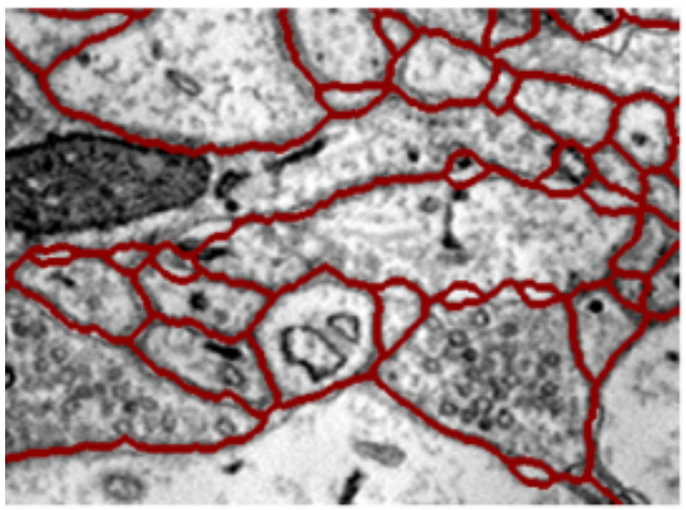
machine-learning algorithm (Brut)

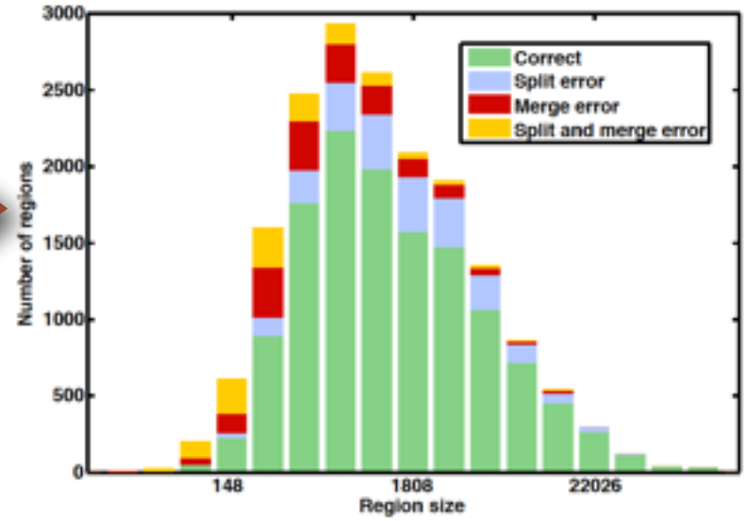


example here from: ***Beaumont****, Goodman, Kendrew, Williams & Simpson 2014; based on* ***Milky Way Project*** *catalog (Simpson et al. 2013), which came from* ***Spitzer/GLIMPSE*** *(Churchwell et al. 2009, Benjamin et al. 2003), cf. Shenoy & Tan 2008 for discussion of HAC;* ***astroml.org*** *for machine learning advice/tools*

BIG DATA AND "HUMAN-AIDED COMPUTING"

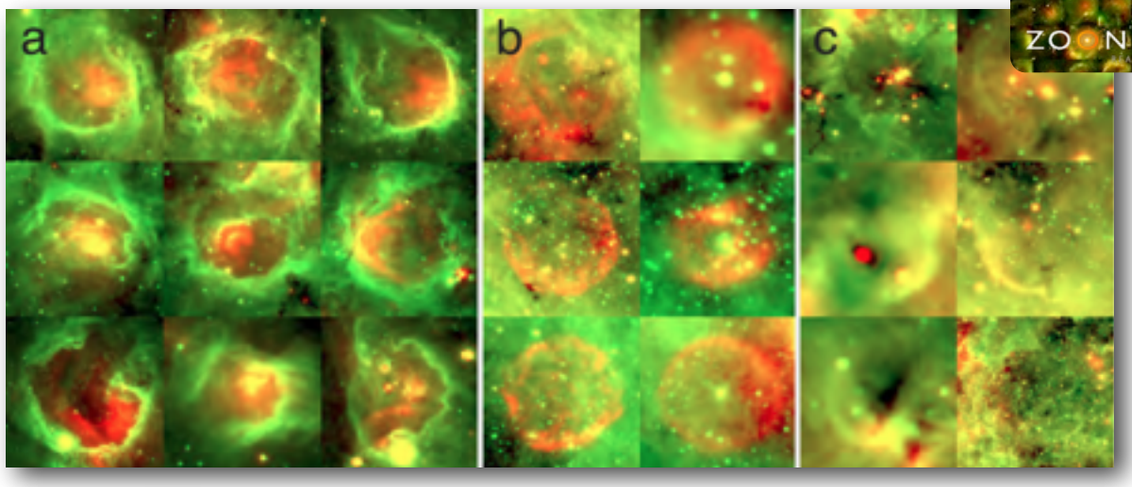






example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools (Note: RF=Random Forest; CRF=Conditional Random Fields.)*

BIG DATA AND "HUMAN-AIDED COMPUTING"



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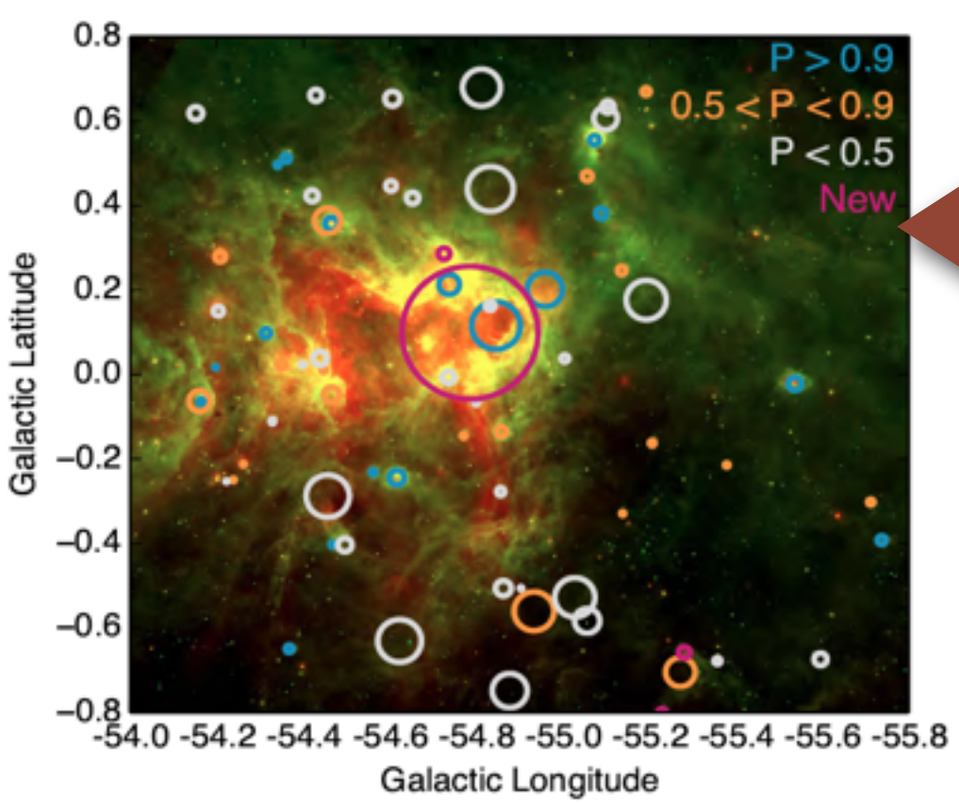

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multidimensional data exploration

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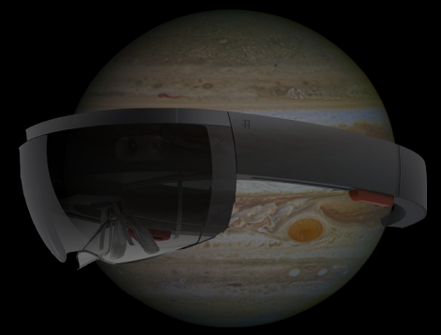
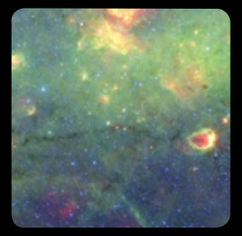
ALL SKY
SURVEY



“Is Nessie Parallel to the Galactic Plane?”

-A. Burkert, 2012



Celestial
North

The Milky Way Galaxy

The Milky Way
(Artist's Conception)

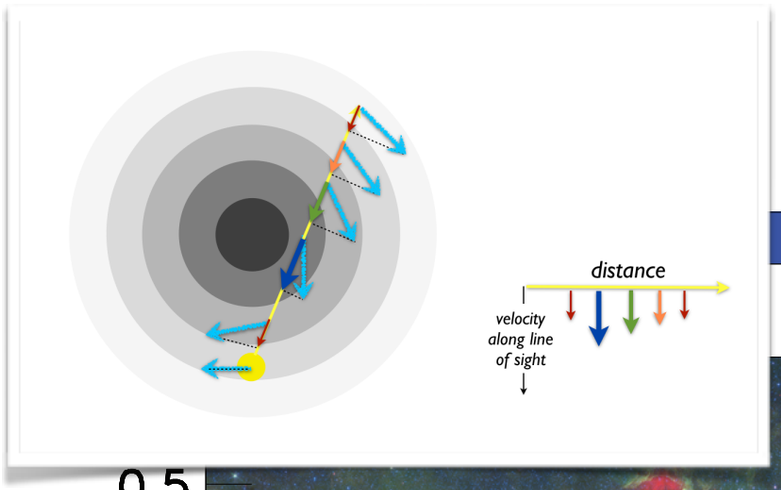
“Is Nessie Parallel to the Galactic Plane?”

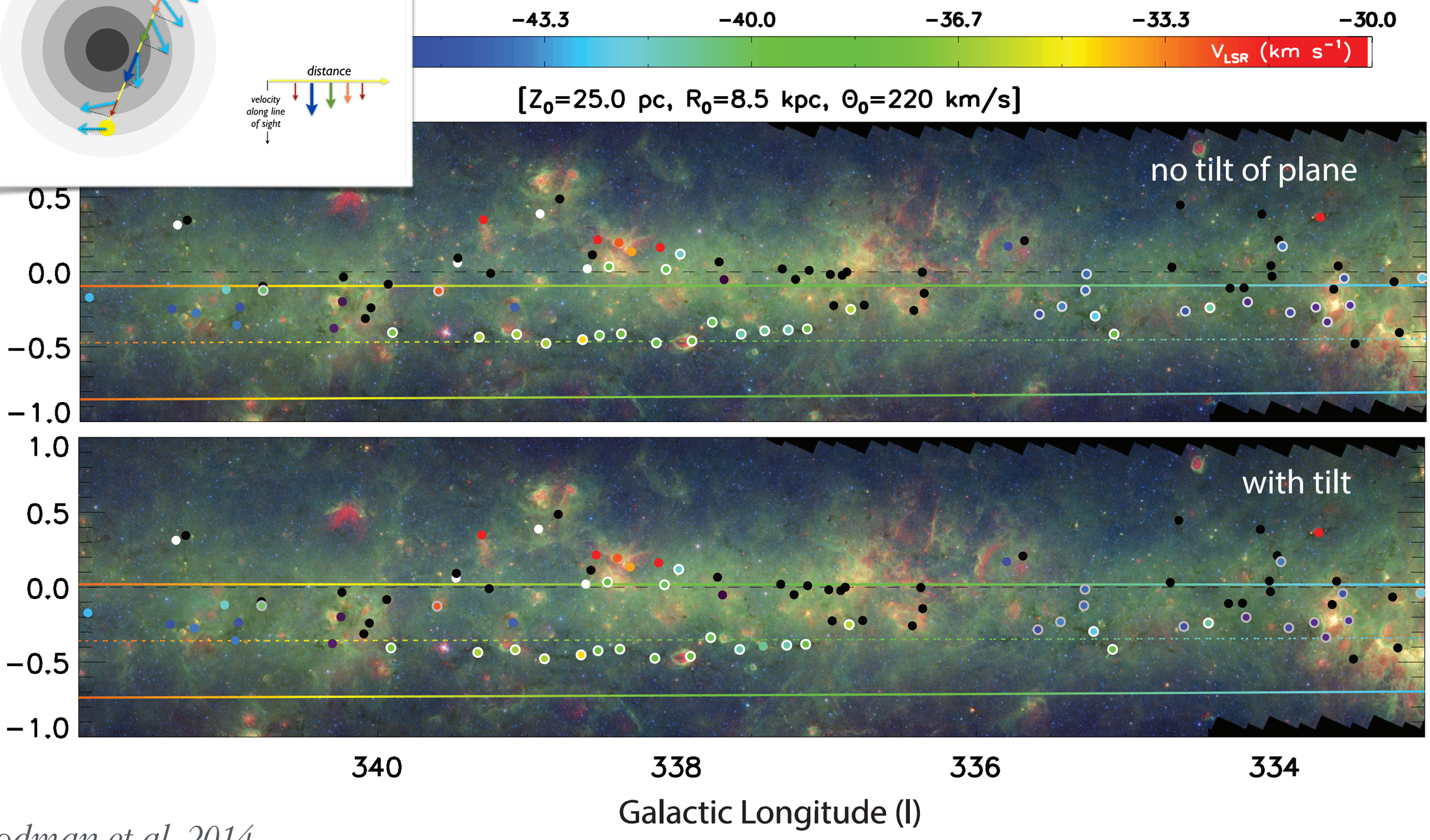
-A. Burkert, 2012

Celestial North

Yes!

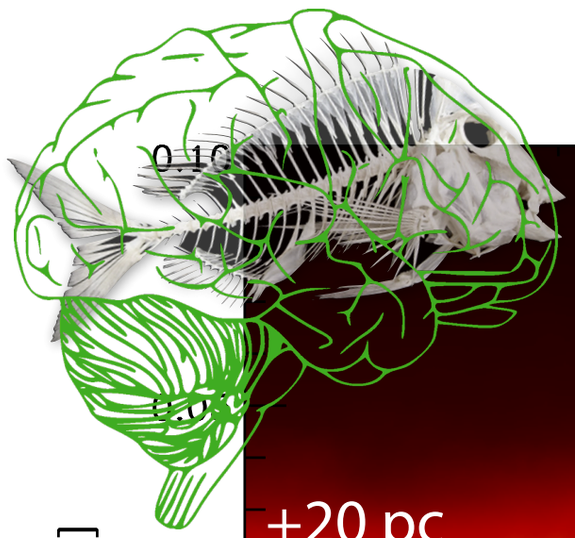
In the plane! And at distance of spiral arm!

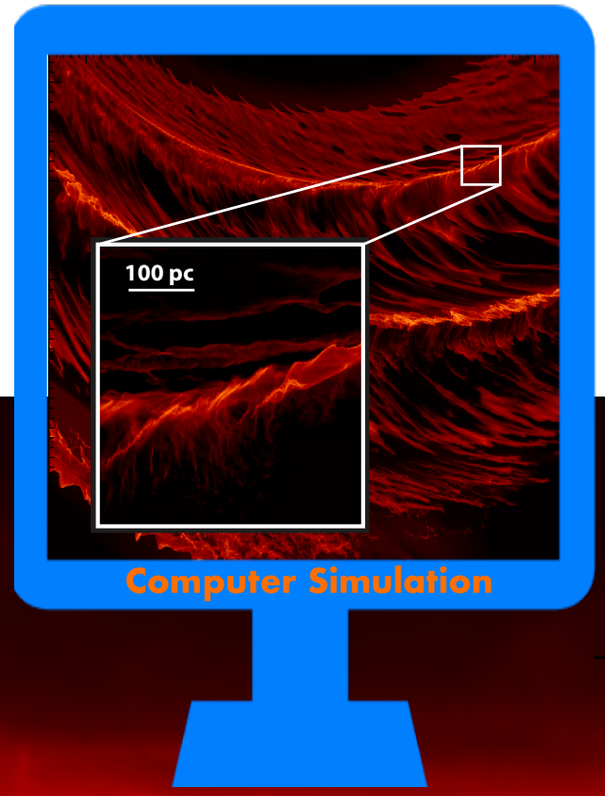


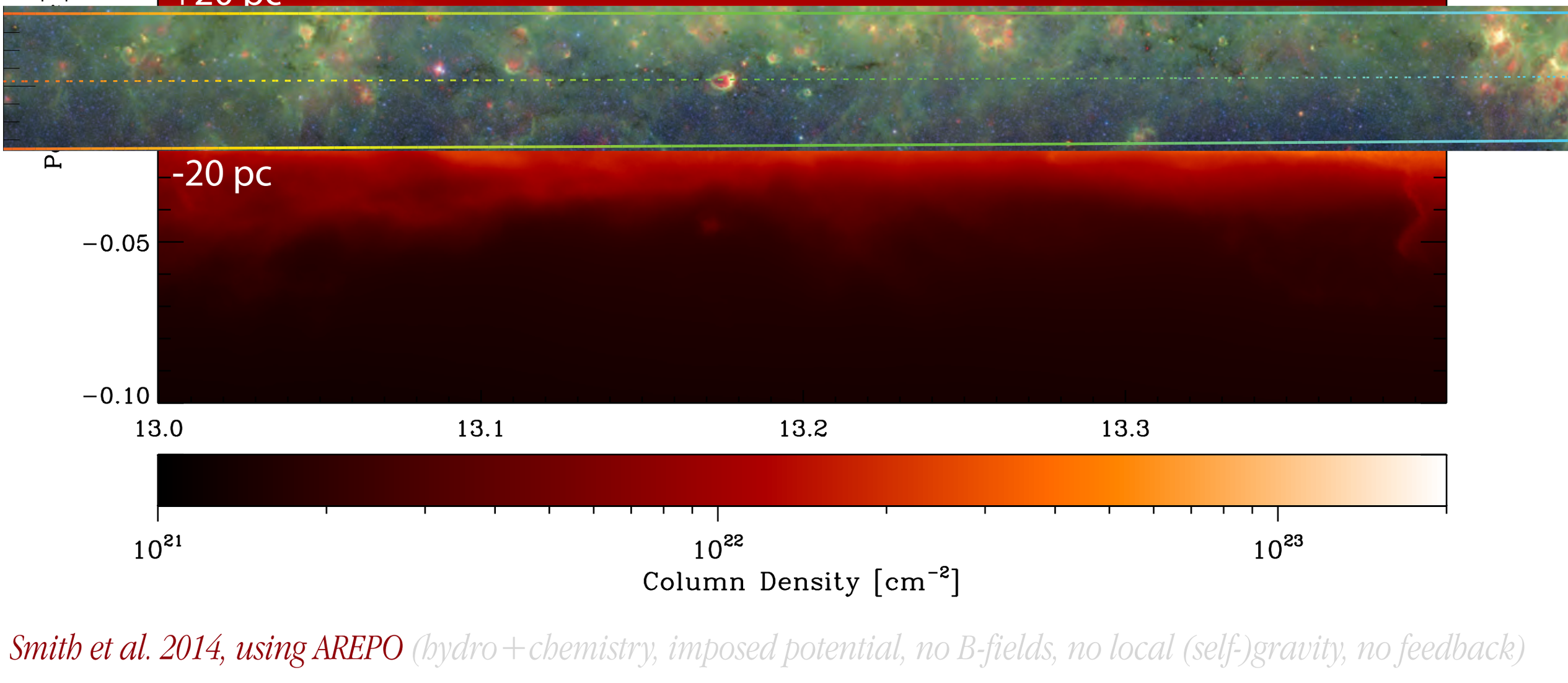


Goodman et al. 2014

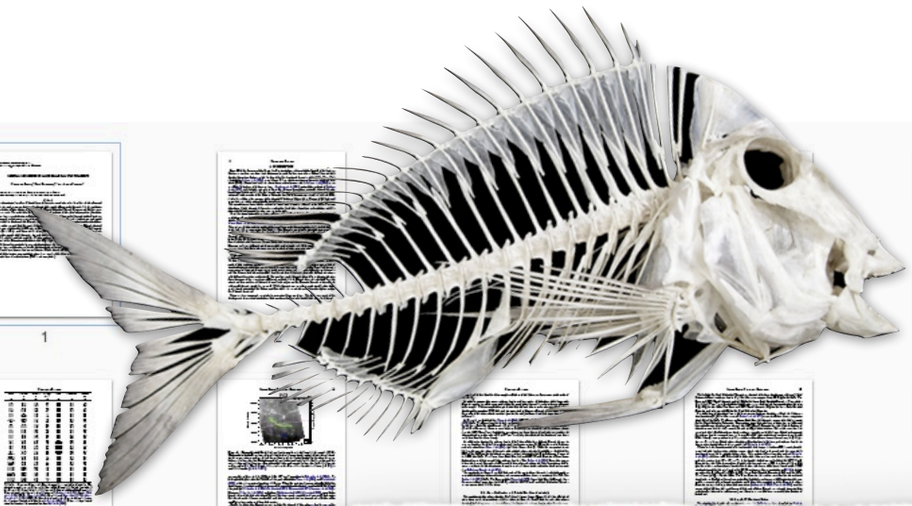
The “Skeleton” of the Milky Way







Smith et al. 2014, using AREPO (hydro+chemistry, imposed potential, no B-fields, no local (self-)gravity, no feedback)



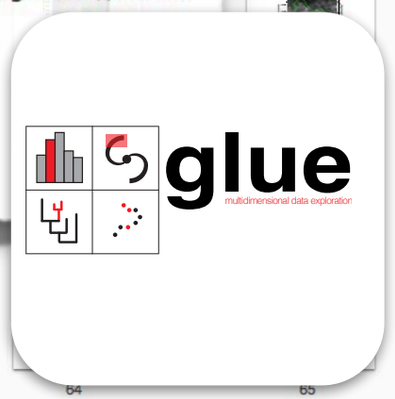
The Physical Properties of Large-Scale Galactic Filaments

Catherine Zucker, Cara Battersby, Alyssa Goodman

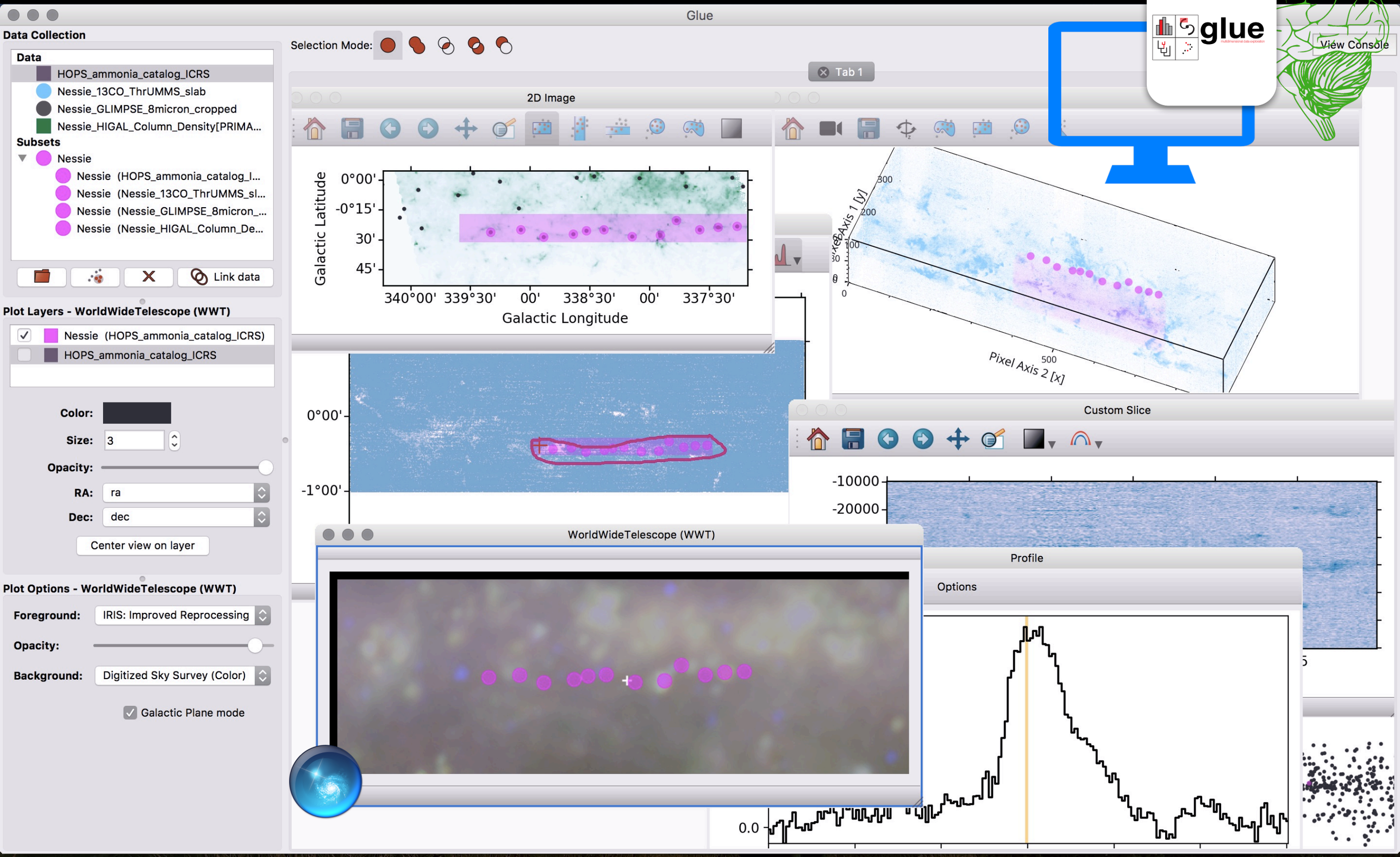
(Submitted on 27 Dec 2017)

The characterization of our Galaxy's longest filamentary gas features has been the subject of several studies in recent years, producing not only a sizeable sample of large-scale filaments, but also confusion as to whether all these features (e.g. "Bones", "Giant Molecular Filaments") are essentially the same. They are not. We undertake the first standardized analysis of the physical properties (densities, temperatures, morphologies, radial profiles) and kinematics of large-scale filaments in the literature. We expand and improve upon prior analyses by using the same data sets, techniques, and spiral arm models to disentangle the filaments' inherent properties from selection criteria and methodology. Our results suggest that the myriad filament finding techniques are uncovering different physical structures, with length (11–269 pc), width (1–40 pc), mass (3×10^3 $M_\odot$ $- 1.1 \times 10^6$ $M_\odot$), aspect ratio (3:1 – 117:1), and dense gas fraction (0.2–100%) varying by at least an order of magnitude across the sample of 45 filaments. As part of this analysis, we develop a radial profile fitting code, *RadFil*, which is publicly available. We also perform a *position* $-$ *position* $-$ *velocity* ($p-p-v$) analysis on a subset of the filaments and find that while 60%–70% lie in the plane of the Galaxy, only 30–45% also exhibit kinematic proximity to purported spiral arms. In a parameter space defined by aspect ratio, temperature, and density, we broadly distinguish three filament categories, which could be indicative of different formation mechanisms or histories. Highly elongated "Bone-like" filaments show the most potential for tracing gross spiral structure (e.g. arms), while other categories could simply be large concentrations of molecular gas (GMCs, core complexes).

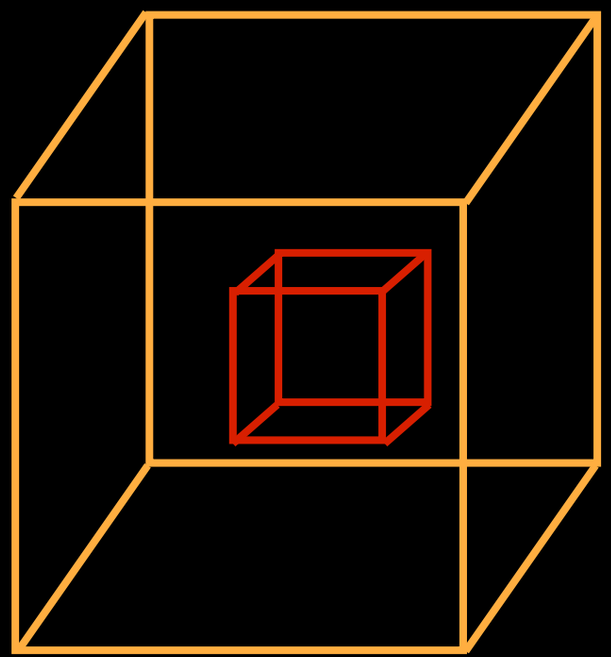
Comments: Submitted to The Astrophysical Journal
Subjects: **Astrophysics of Galaxies (astro-ph.GA)**
Cite as: **arXiv:1712.09655 [astro-ph.GA]**
(or **arXiv:1712.09655v1 [astro-ph.GA]** for this version)



NESSIE in glue + WorldWide Telescope



Linked Views of High-dimensional Data



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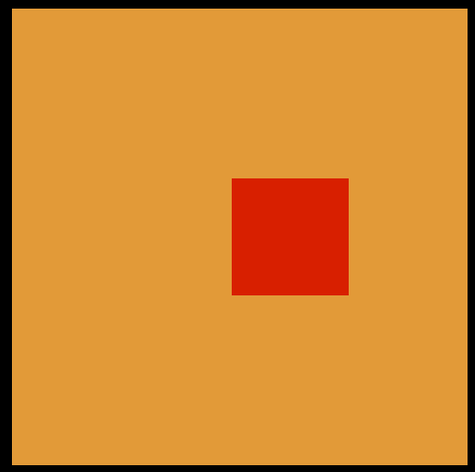

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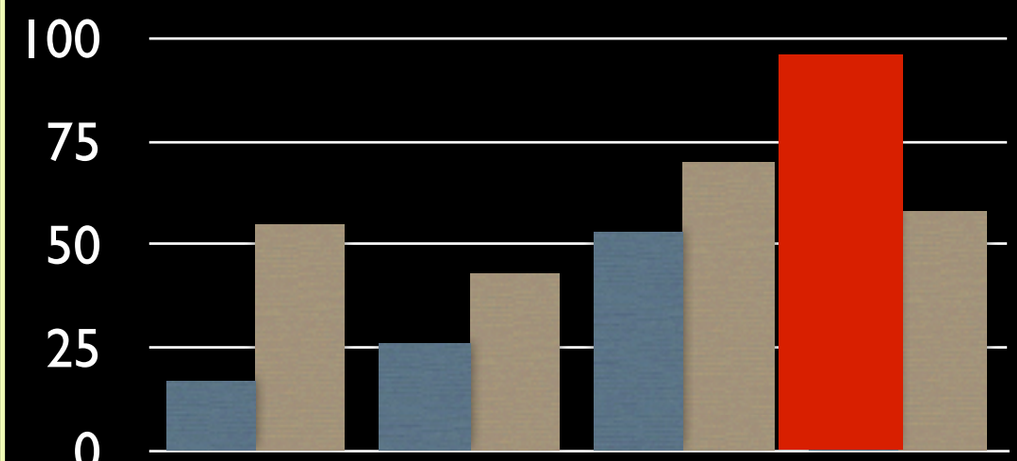
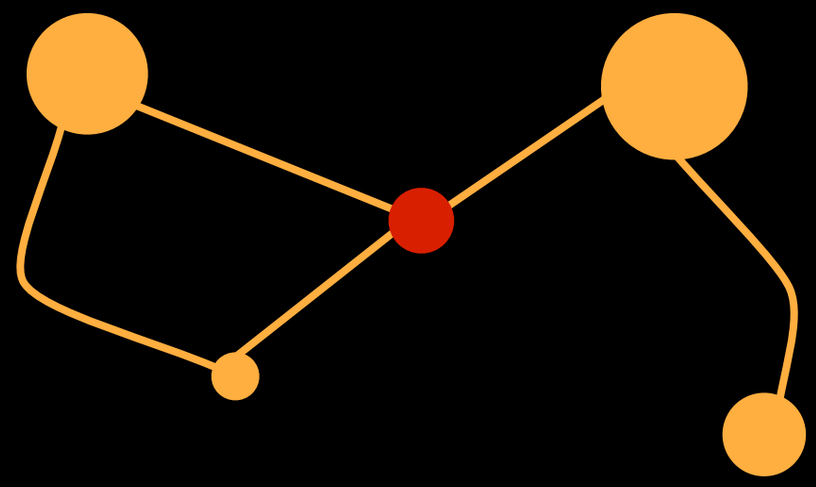
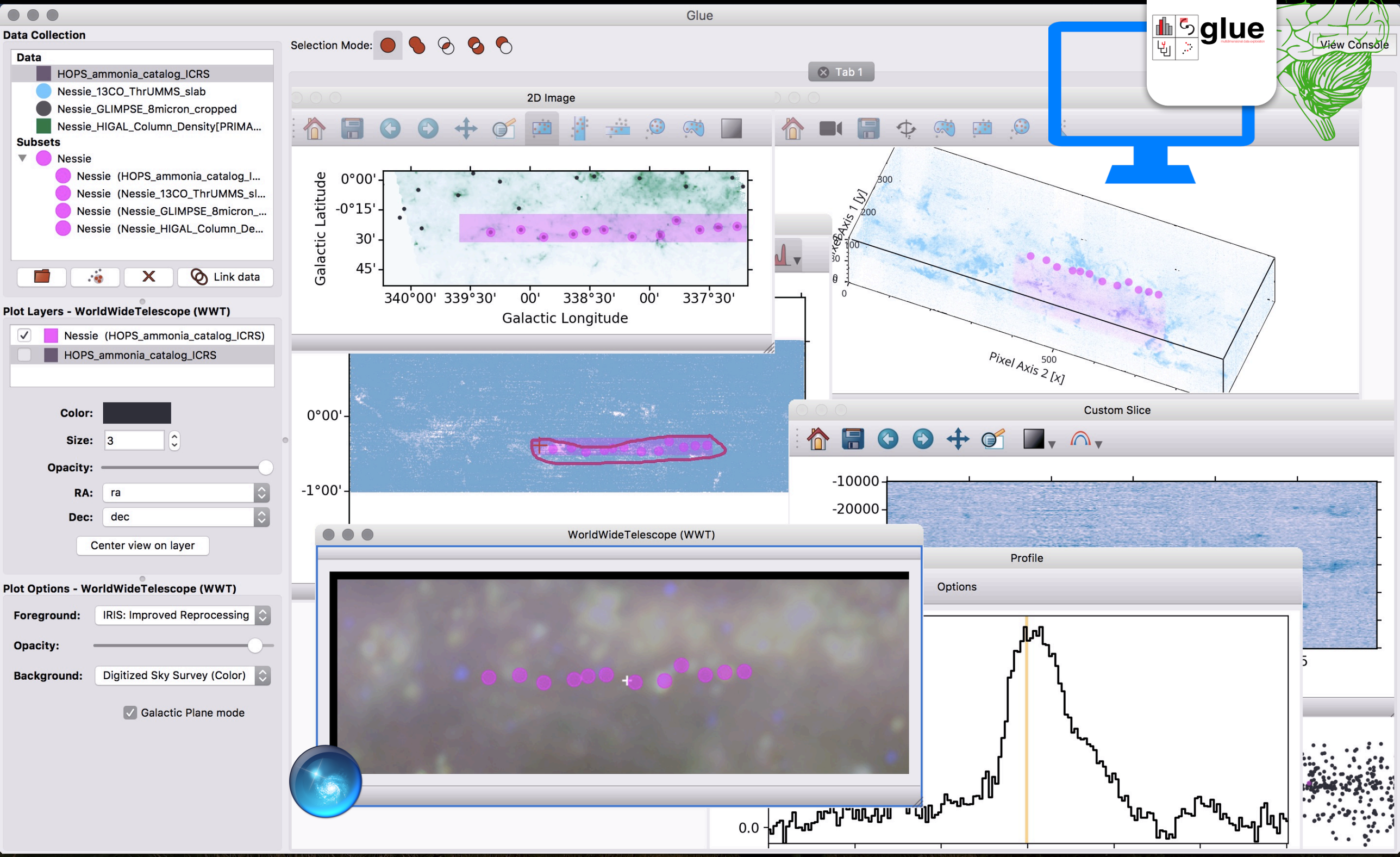


Data Abstraction

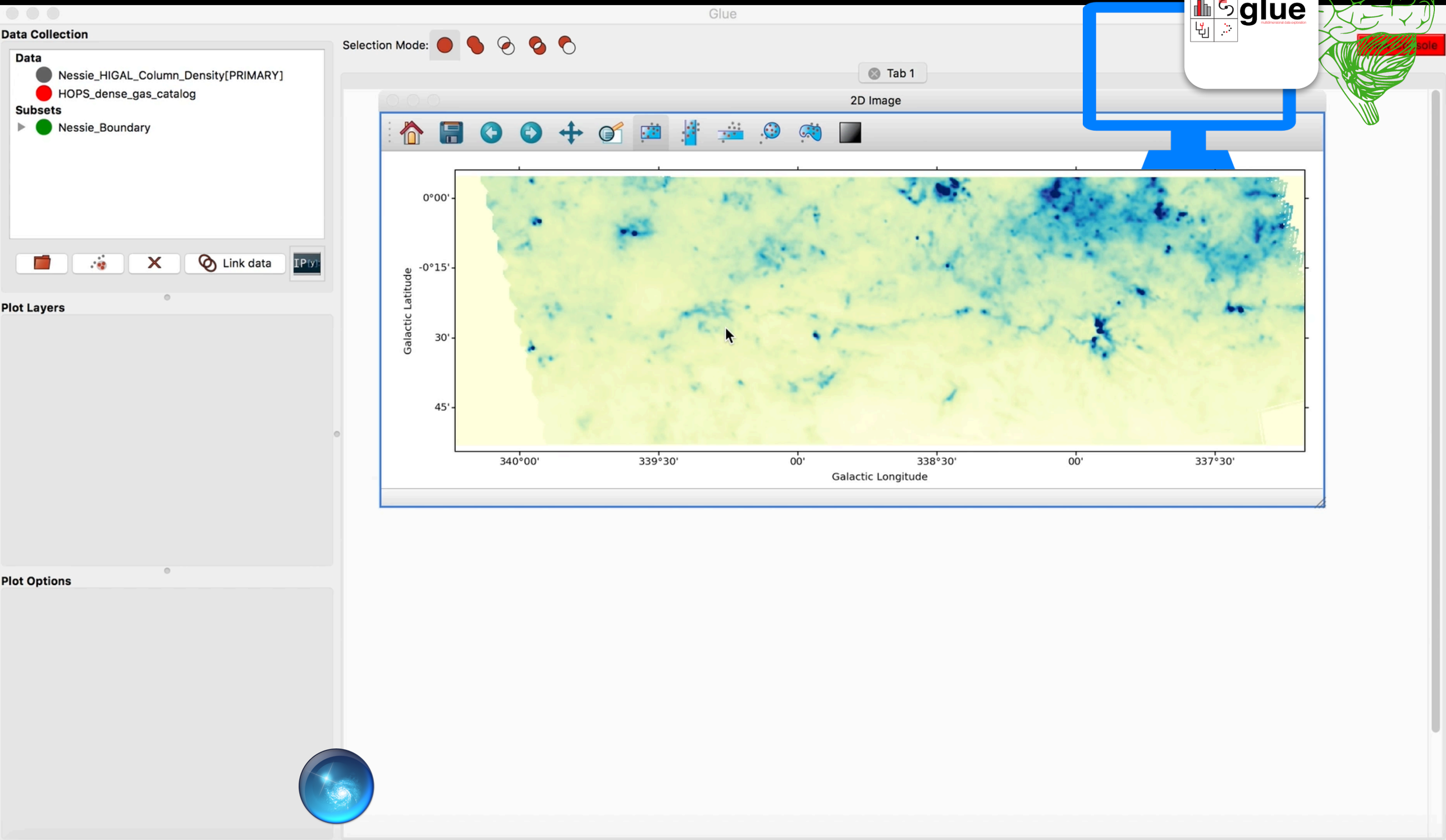


figure, by M. Borkin, reproduced from Goodman 2012, "Principles of High-Dimensional Data Visualization in Astronomy"

NESSIE in glue + WorldWide Telescope



NESSIE in glue + WorldWide Telescope



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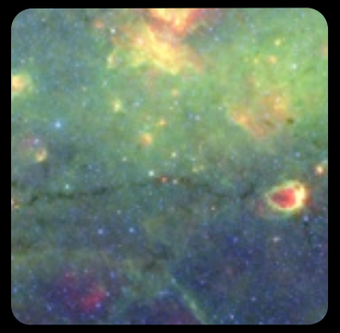

glue
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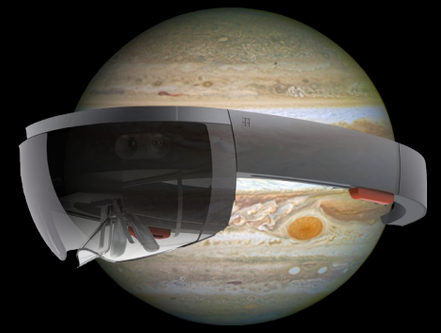
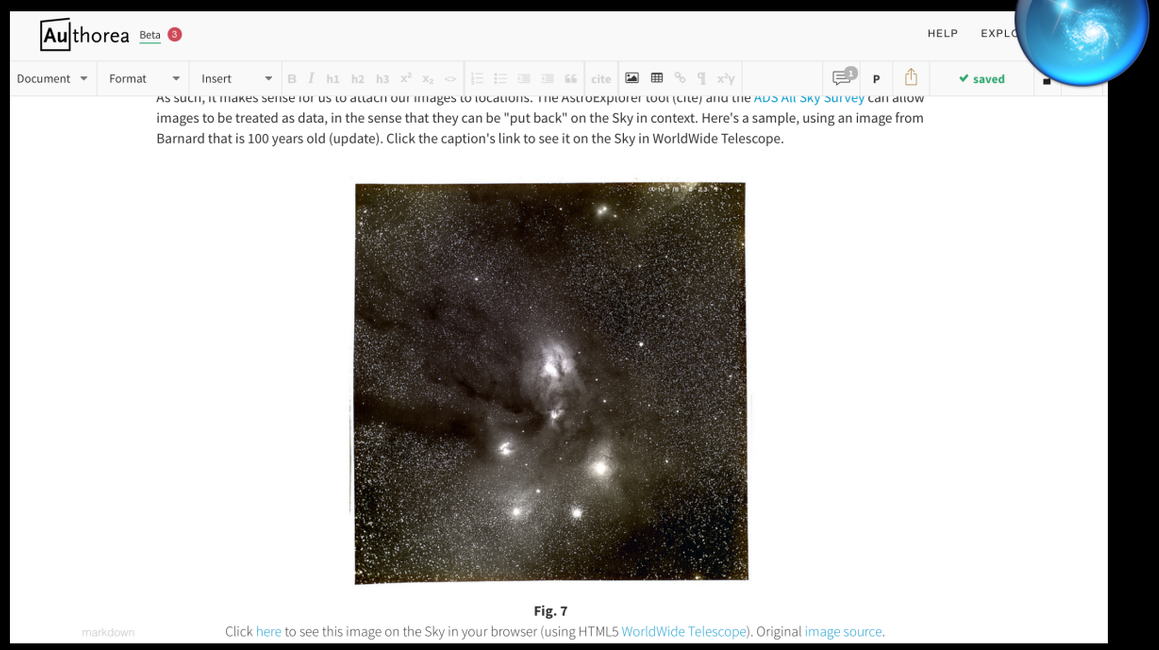
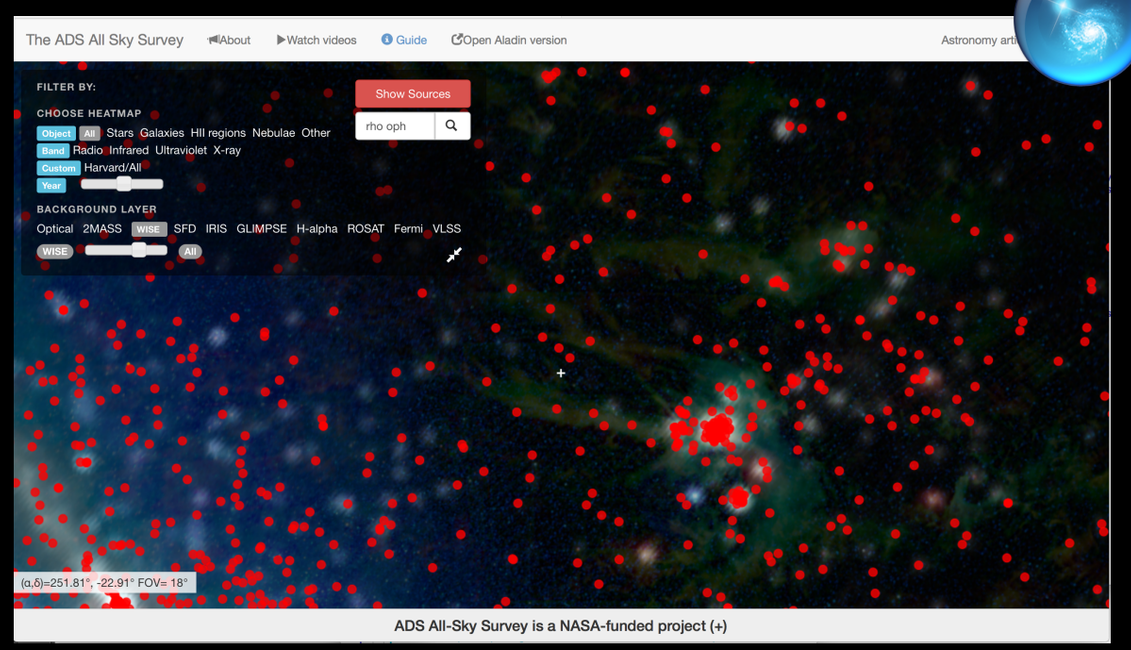


Literature as (a filter for) Data





The Power of a "WorldWide Telescope"

Authorea Beta 3

HELP EXPLORE

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markdown

5.3.3 Putting Images in Context

Most observational astronomy has the unique feature of having a specific space to which the data are attached: the celestial sphere. As such, it makes sense for us to attach our images to locations. The AstroExplorer tool (cite) and the ADS All Sky Survey can allow images to be treated as data, in the sense that they can be "put back" on the Sky in context. Here's a sample, using an image from Barnard that is 100 years old (update). Click the caption's link to see it on the Sky in WorldWide Telescope.

Fig. 7

Click here to see this image on the Sky in your browser (using HTML5 WorldWide Telescope). Original image source.

ADS All-Sky Survey & Astronomy Rewind

"putting articles and images (back) on the Sky"

1. Images Extracted from Journal Articles

ON A GREAT NEBULOUS REGION AND ON THE QUESTION OF ABSORBING MATTER IN SPACE AND THE TRANSPARENCY OF THE NEBULAE

By E. E. BARNARD

While photographing the region of the great nebula of *ρ Ophiuchi* (which I had found with the Willard lens) at the Lick Observatory in 1893, the plates with the small lantern lens (1½ inches diameter, also attached to the Willard mounting) showed a remarkable nebula involving the 4.5 magnitude star *ν Scorpii* (Plate I). It had not been noticed on the Willard lens photograph, where it was very faint and near the edge of the plate. The discovery of this object therefore is due to the small lantern lens.

astrophysics data system

"historical" images

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THE COMPLETE SURVEY OF STAR-FORMING REGIONS: PHASE I DATA

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ABSTRACT

We present an overview of data available for the Ophiuchus and Perseus molecular clouds from Phase I of the COMPLETE Survey of Star-Forming Regions. This survey provides a range of data complementary to the *Spitzer*

astrophysics data system

astronomy image explorer

"recent" images

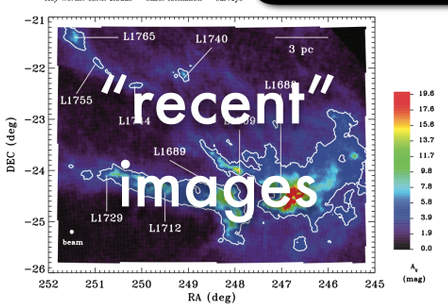

Fig. 3.—Map of extinction in Ophiuchus derived using 2MASS NICER. The contour indicates an A_V of 3 mag and is repeated in subsequent figures for orientation. Note that the small "hole" at the center of the L1688 cluster is an artifact due to the high extinction at that position.

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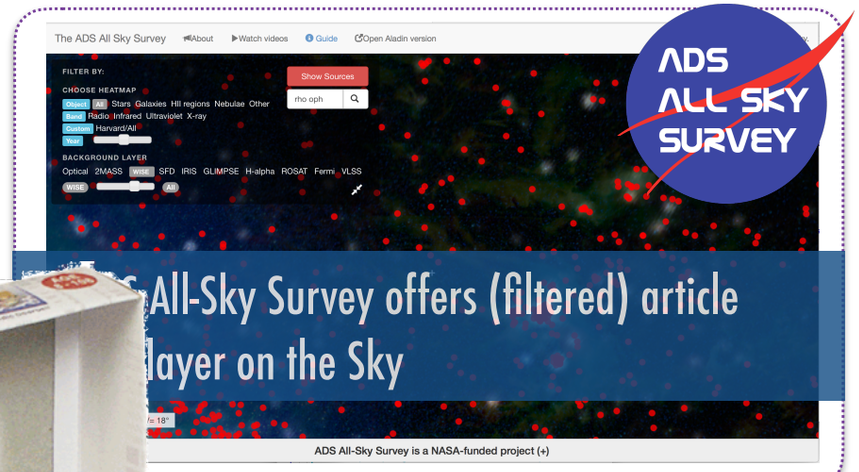
via "Astrono… Science Project…

ZOONIVERSE



ADS ALL SKY SURVEY

…All-Sky Survey offers (filtered) article …layer on the Sky

…returned to ADS & Astronomy Image Explorer

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astronomy image explorer

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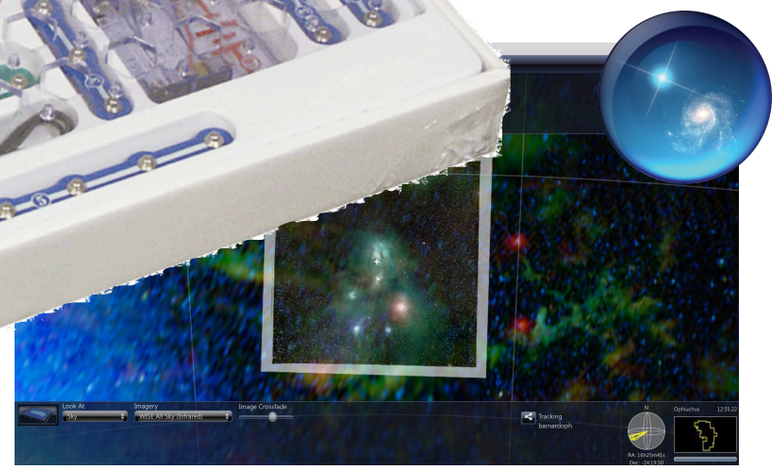

astrophysics data system — ADS — 1992

click entries on the timeline to try out services

WorldWide Telescope — 2008

ZOONIVERSE — Zooniverse — 2009

Astrometry.net — Astrometry.net — 2011

flickr — ADS ALL SKY SURVEY — ADS All Sky Survey — 2014

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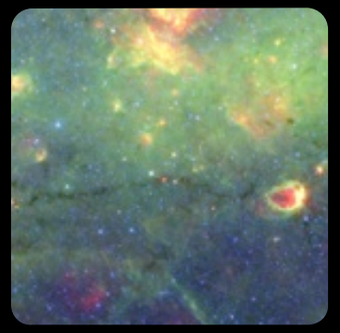
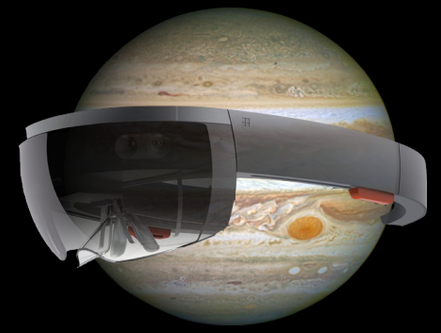


glue
multidimensional data exploration

ADS
ALL SKY
SURVEY



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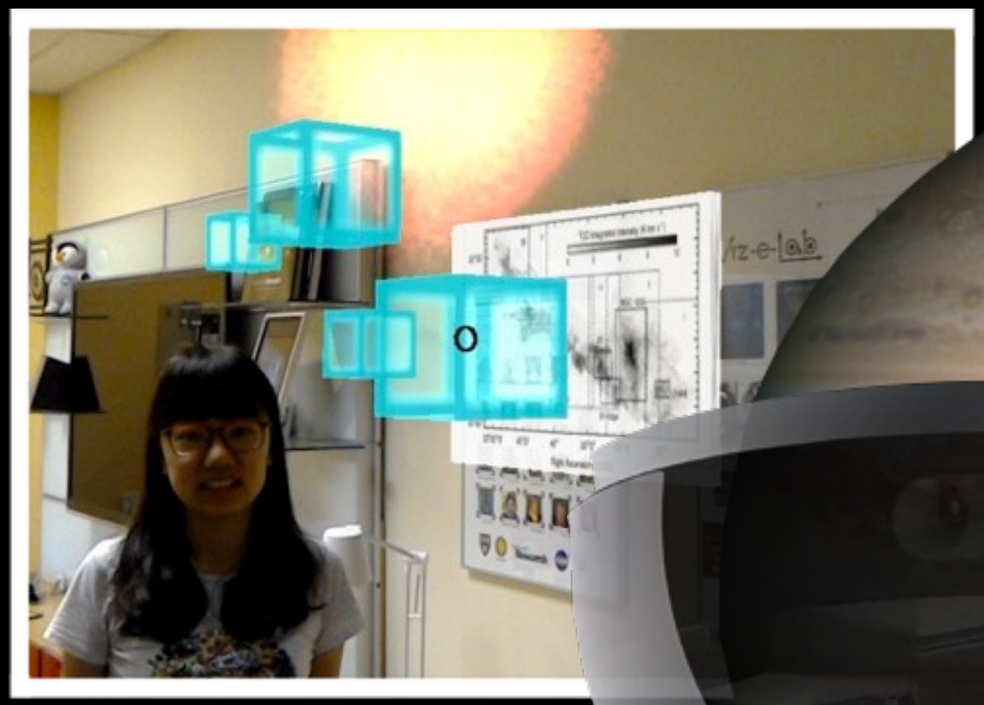
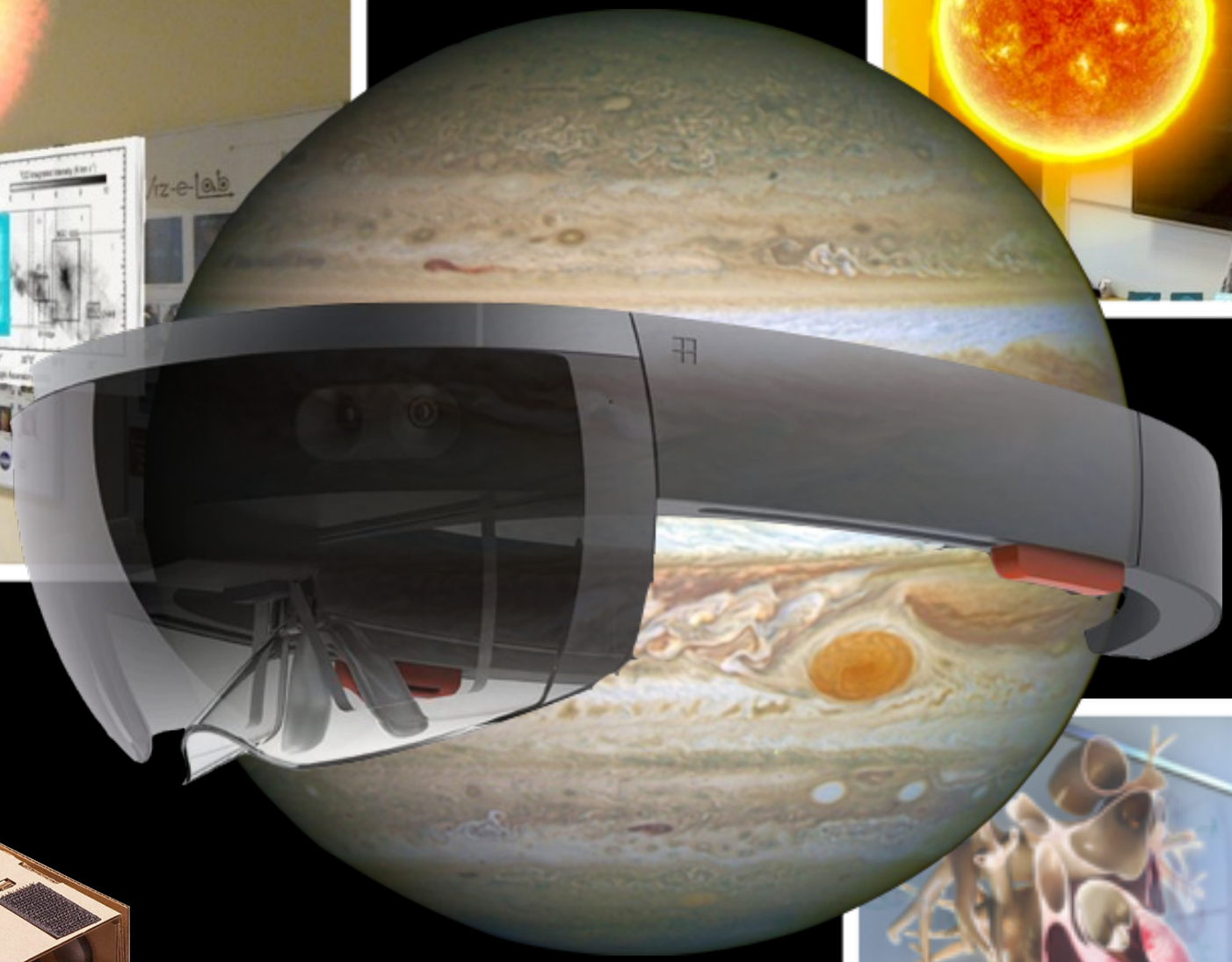
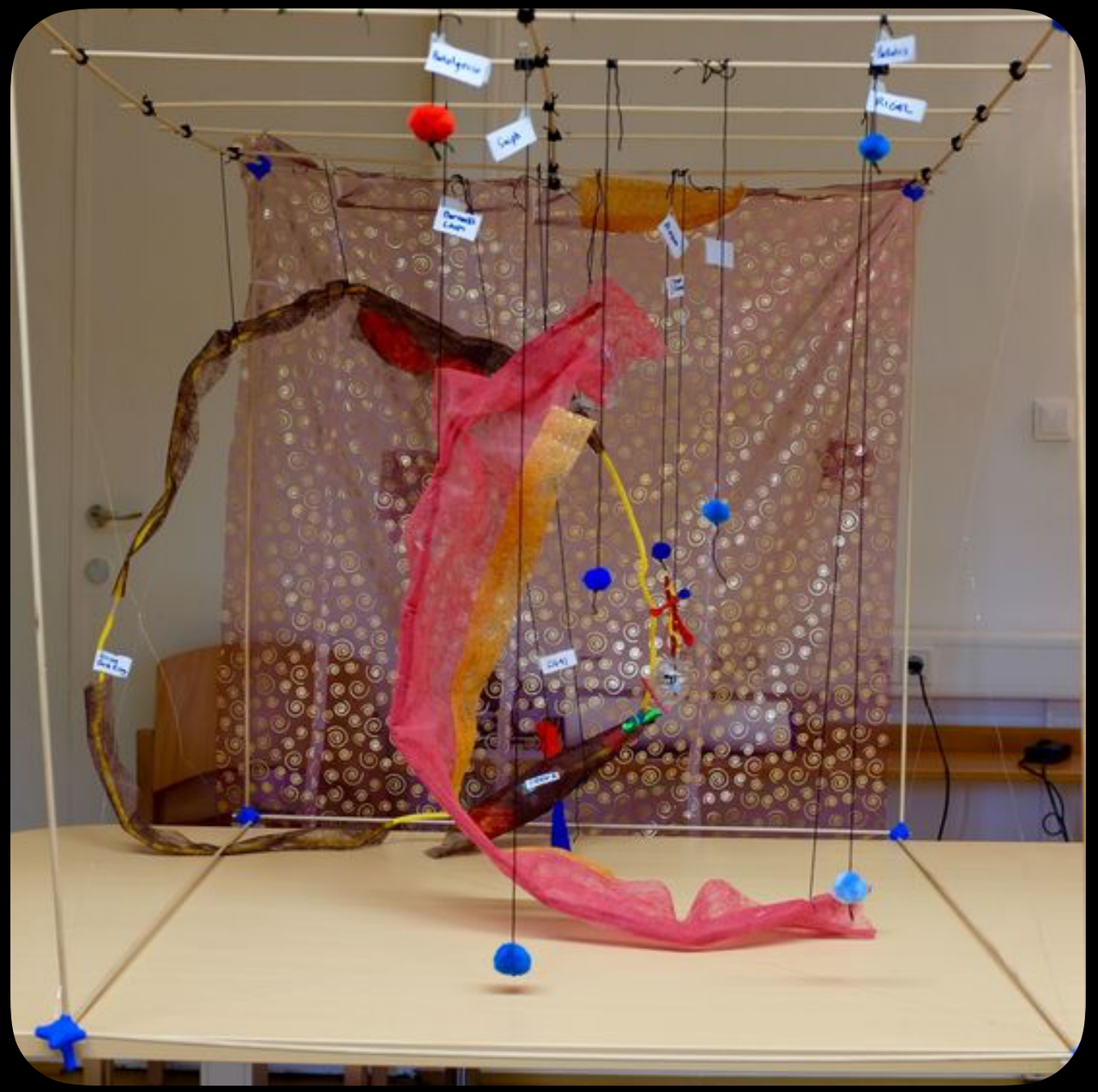




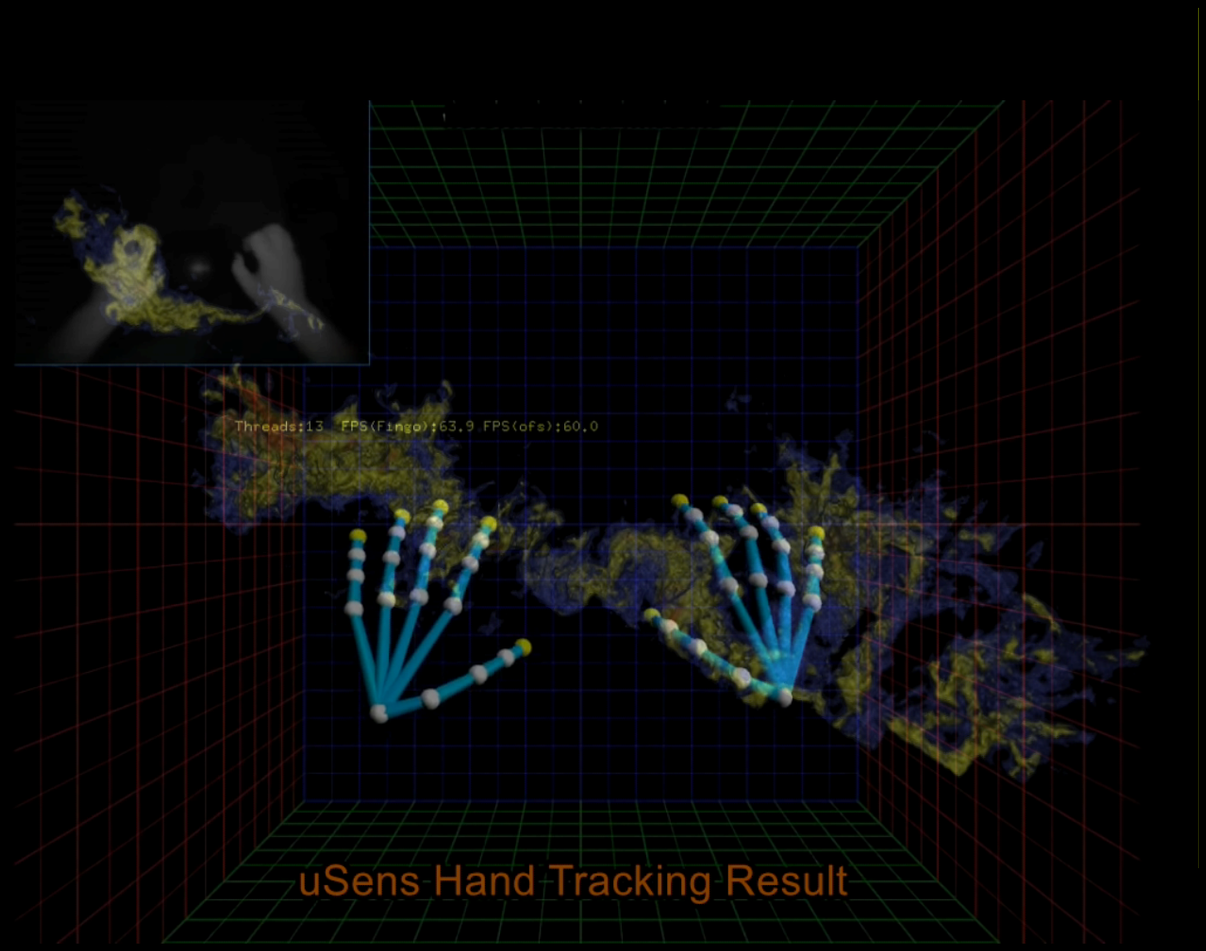
Viz-e-Lab

The challenge of 3D Selection



A state-of-the-art 3D model of the stars & gas near the Orion nebula, created at Orion (un)plugged, Vienna, 2015.
Expert builders (~20 total) include: Joao Alves, John Bally, Alyssa Goodman & Eddie Schlafly. (cf. "Image & Meaning" workshops by Felice Frankel)
YouTube video explanation; WWT Tour

EL FUTURO



uSens Hand Tracking Result

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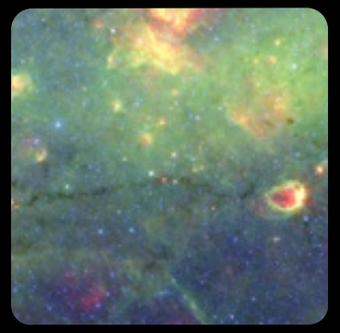

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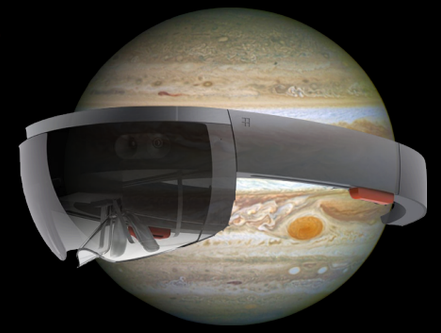

What can humans + computers teach each other about the Universe?

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