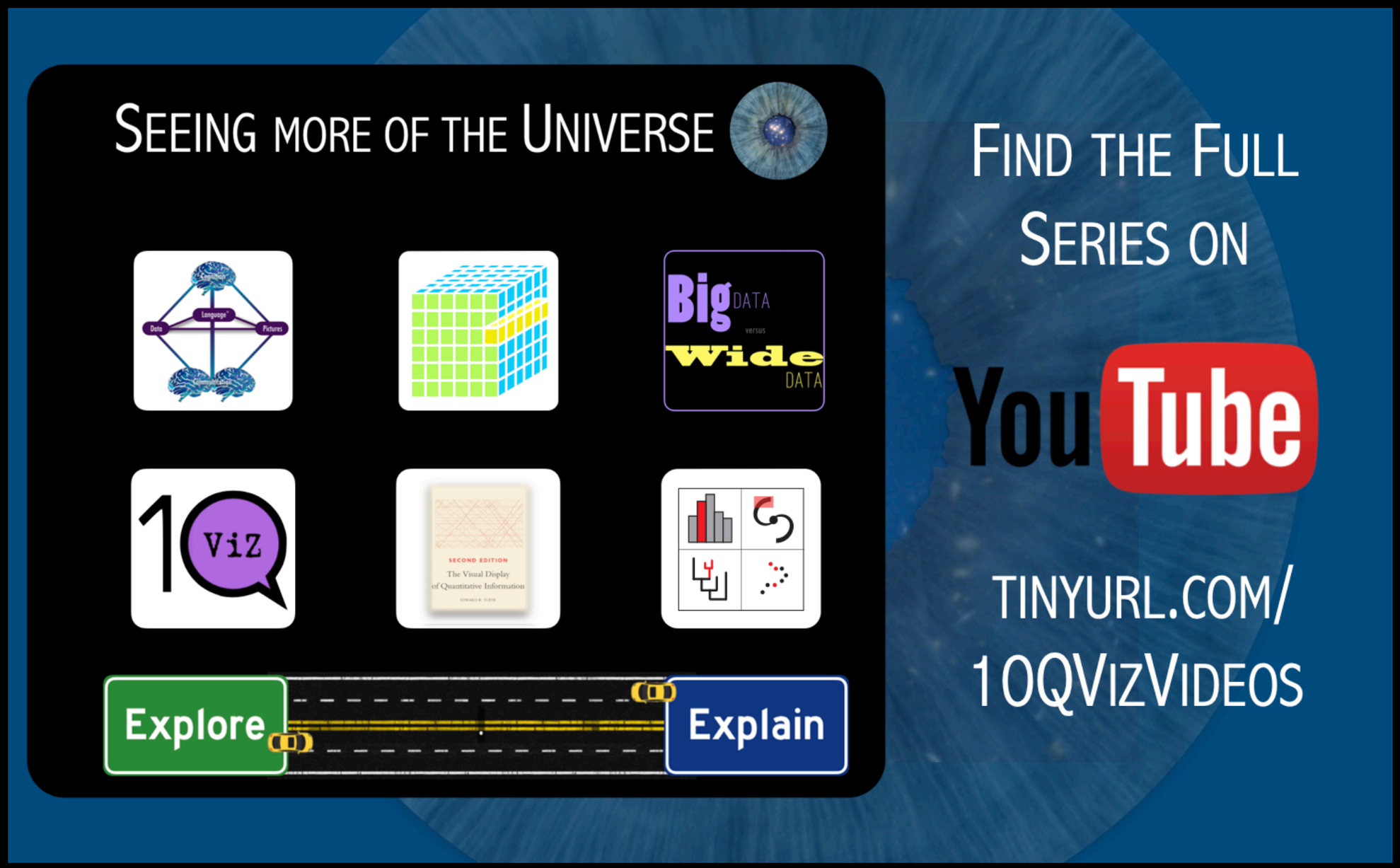
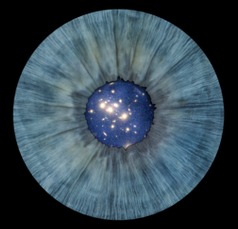
Seeing more of the Universe

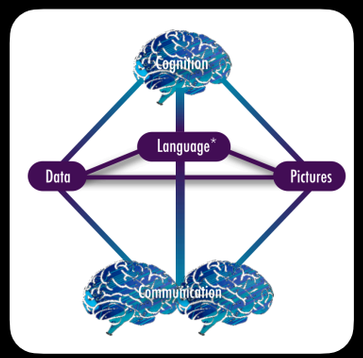


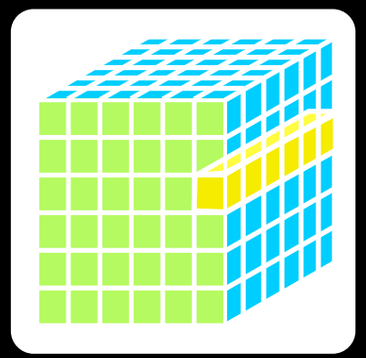
Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics

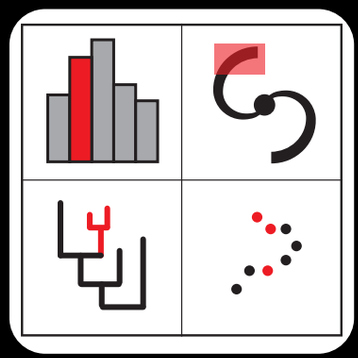
Gordon and Betty Moore Foundation
NASA
NSF

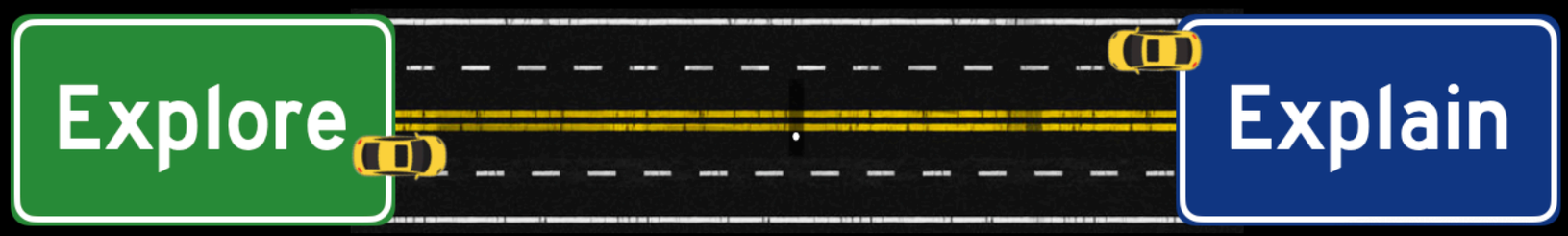
SEEING MORE OF THE UNIVERSE IN 20 MIN

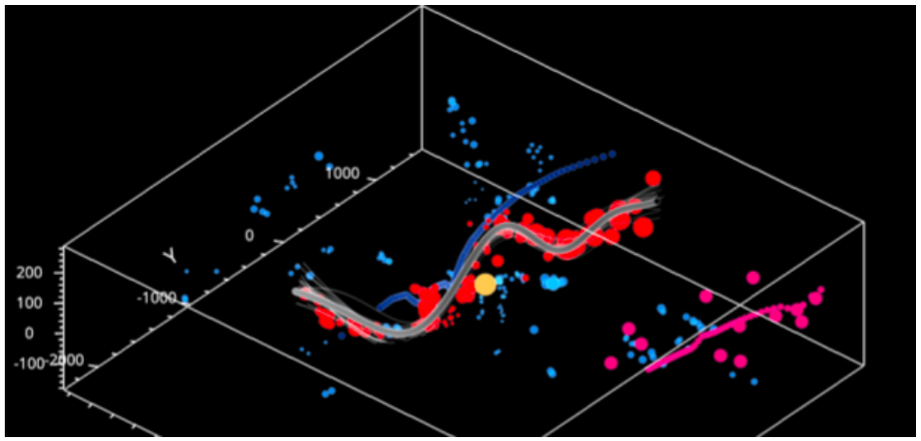


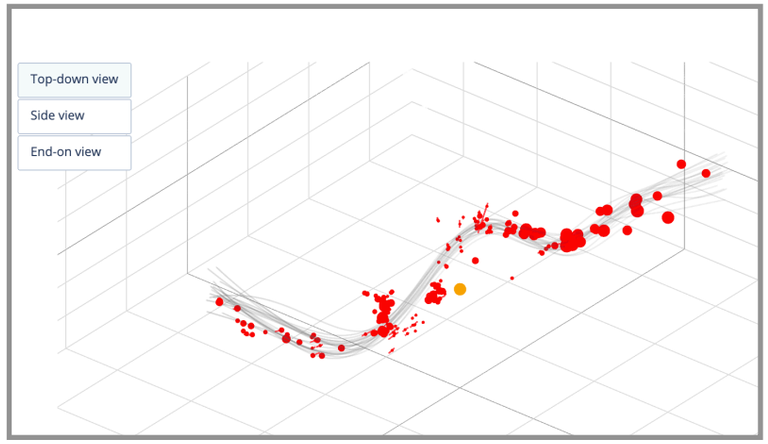


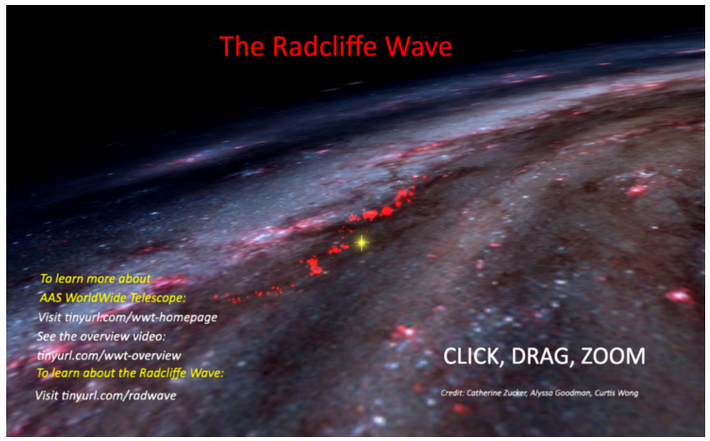












glue
multidimensional data exploration

plotly

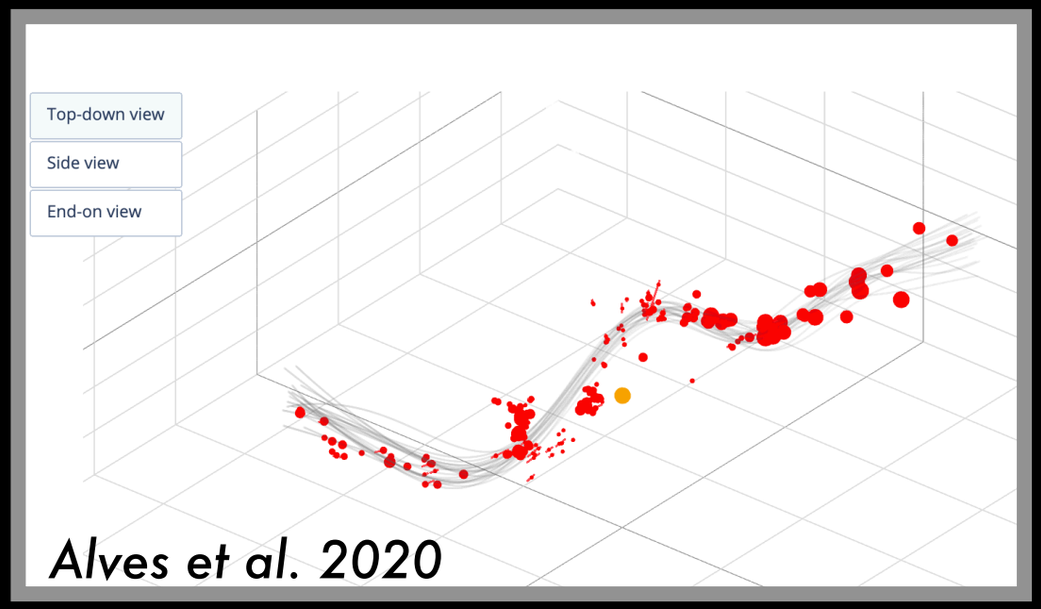
AMERICAN ASTRONOMICAL SOCIETY
WORLDWIDE TELESCOPE

glue multidimensional data exploration

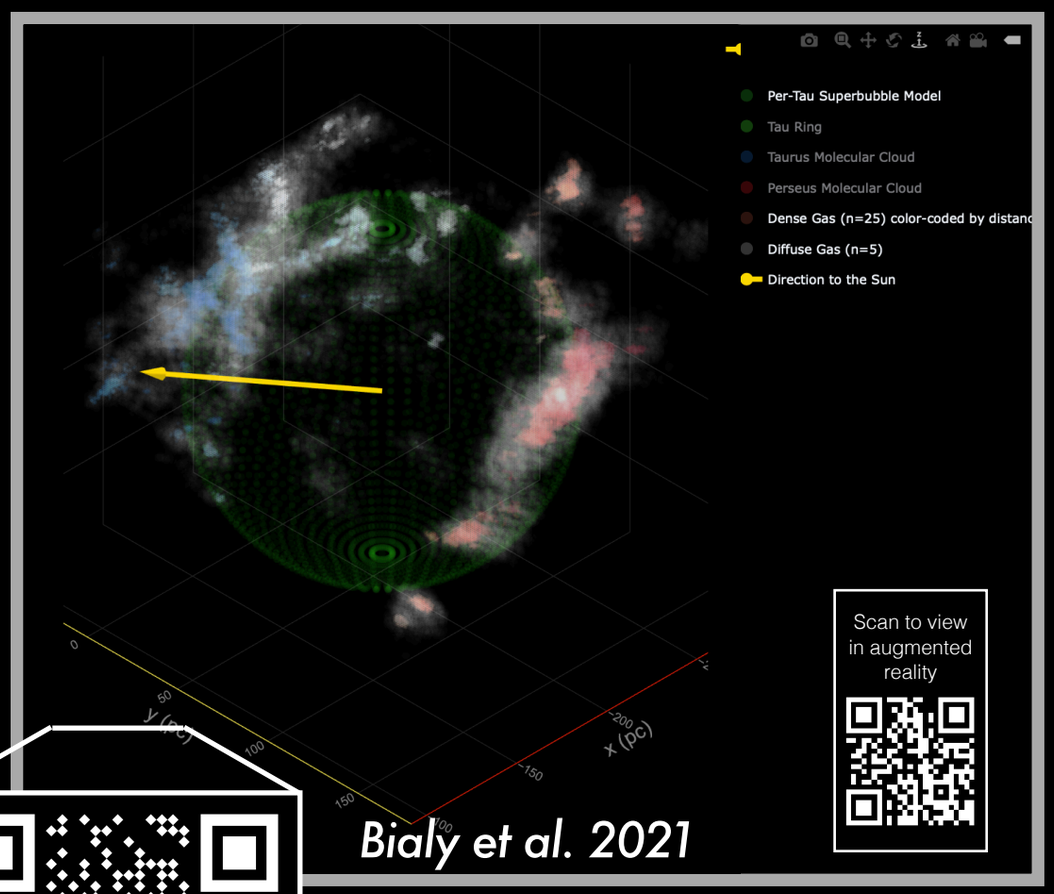
plotly

glupyter multidimensional data exploration

João will show you...



Shmuel showed you



Scan to view in augmented reality

Catherine will show you...

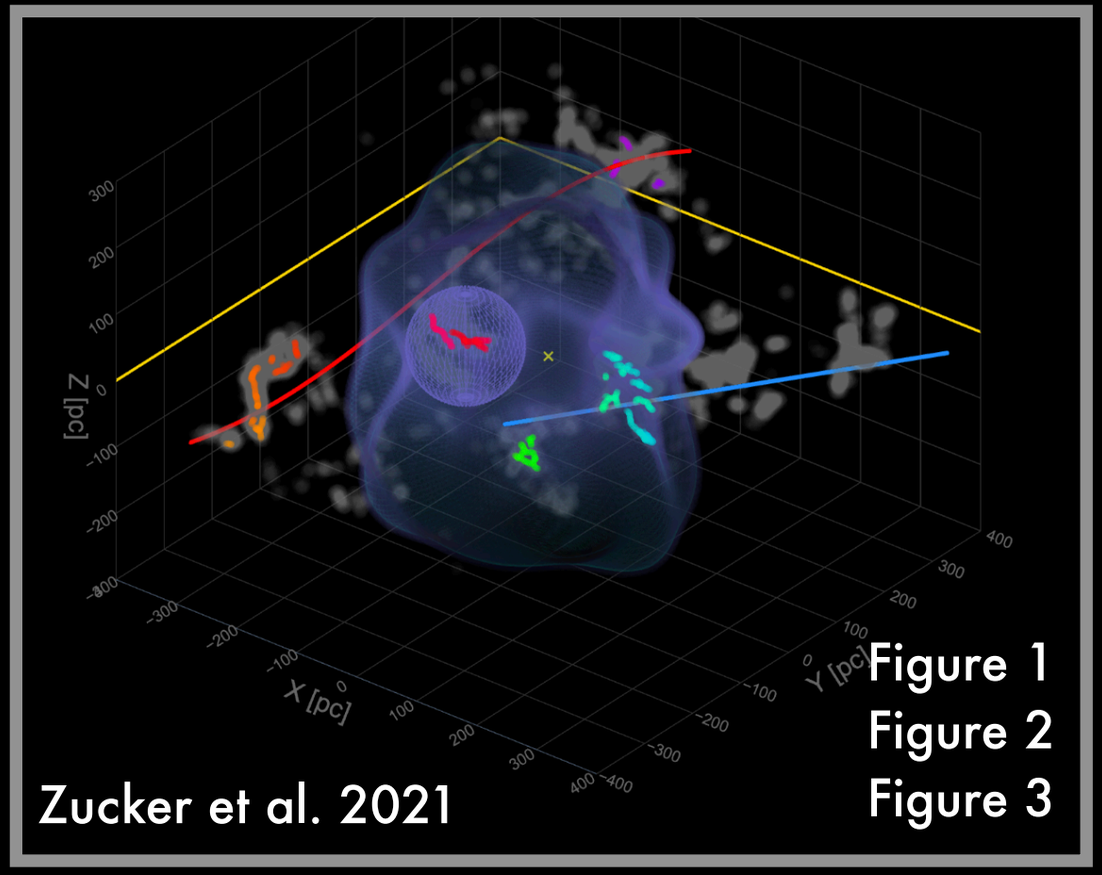
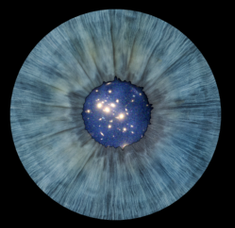
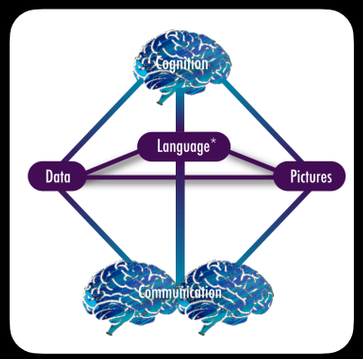


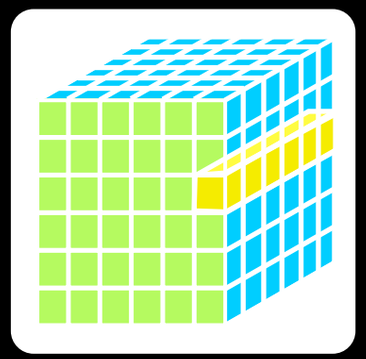
Figure 1
Figure 2
Figure 3

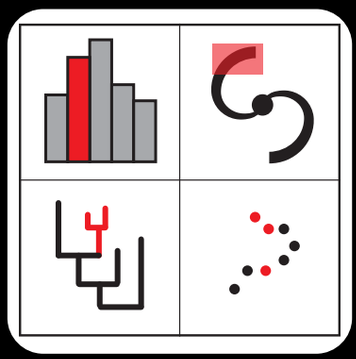
Later: Merge Cube

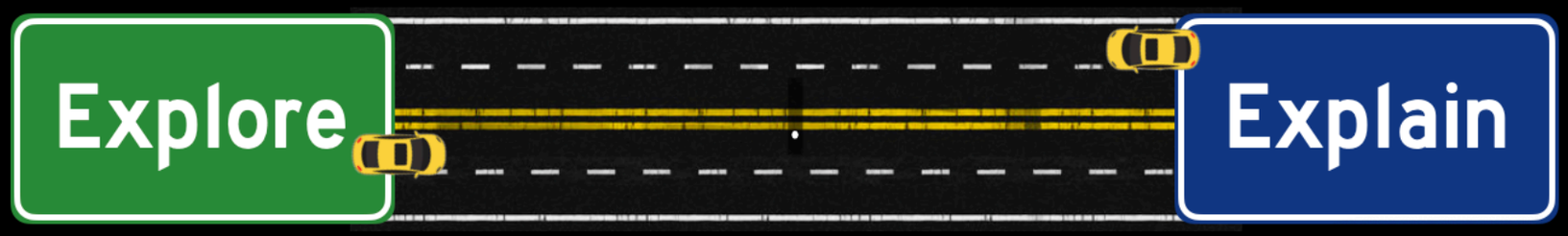
SEEING MORE OF THE UNIVERSE IN 20 MIN











WIDE DATA DISCOVERY: THE RADCLIFFE WAVE

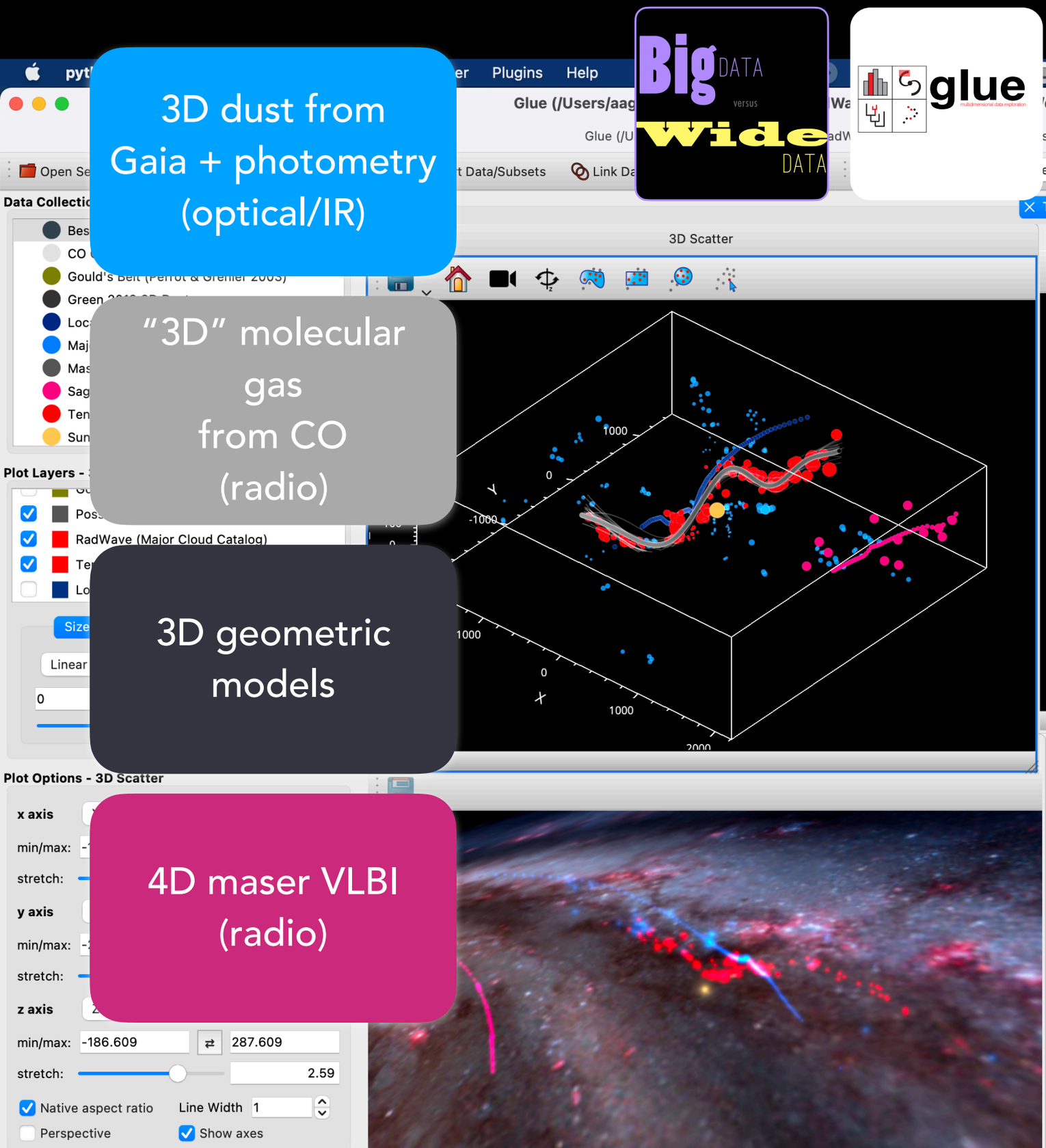
Alves et al. 2020

3D dust from Gaia + photometry (optical/IR)

"3D" molecular gas from CO (radio)

3D geometric models

4D maser VLBI (radio)



glue

multidimensional data exploration

glue-ing data

built-in

standard data loaders

Data File 1

Data File 2

Data File N

define new variables, import/export insights, interactive plots for the web, save state, all from GUI

link data files' attributes

glue-ing plots

standard 1D, 2D & 3D plots

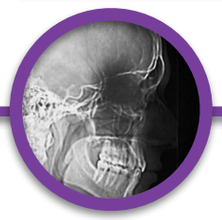
highlight live or algorithmic selections with Boolean logic

custom plots

plug-in

custom data loaders

custom buttons, features



?

glue-ing tools

+options

user config.py file (loaders, colors, plot types, +)

access to all matplotlib functions through built-in IPython terminal

run & interact with glue from Jupyter notebook & other tools

DEMO: 5 steps to revealing a wispy veil in 3D

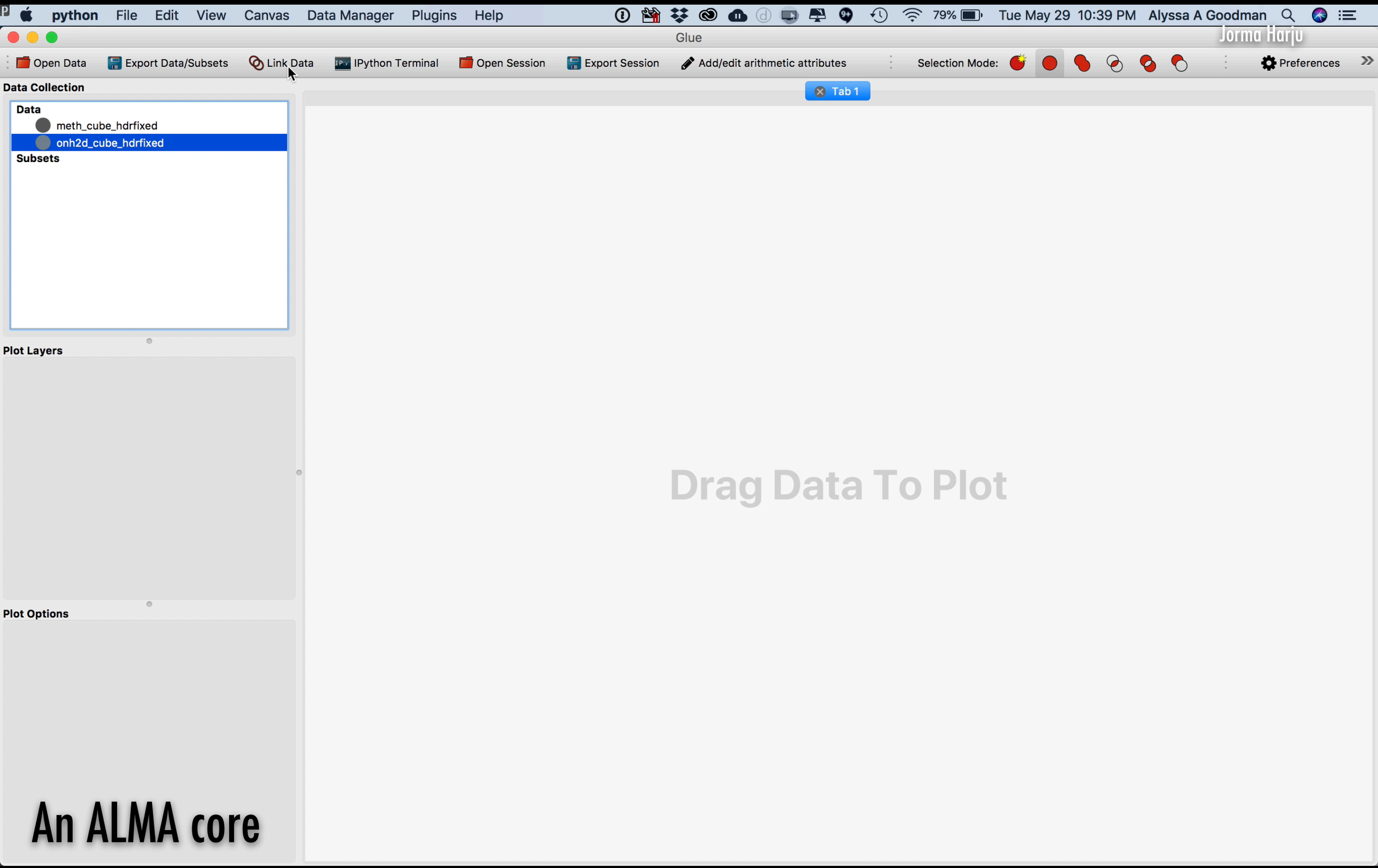
1. "glue" data sets to each other
2. drag data sets to visualize
3. inspect cubes with 2D sliders
4. adjust color
5. inspect cubes as (superimposed) 3D volumes

+ bonus—comparison with traditional views & sliders

sample ALMA (spectral-line) data cubes courtesy of Jorma Harju

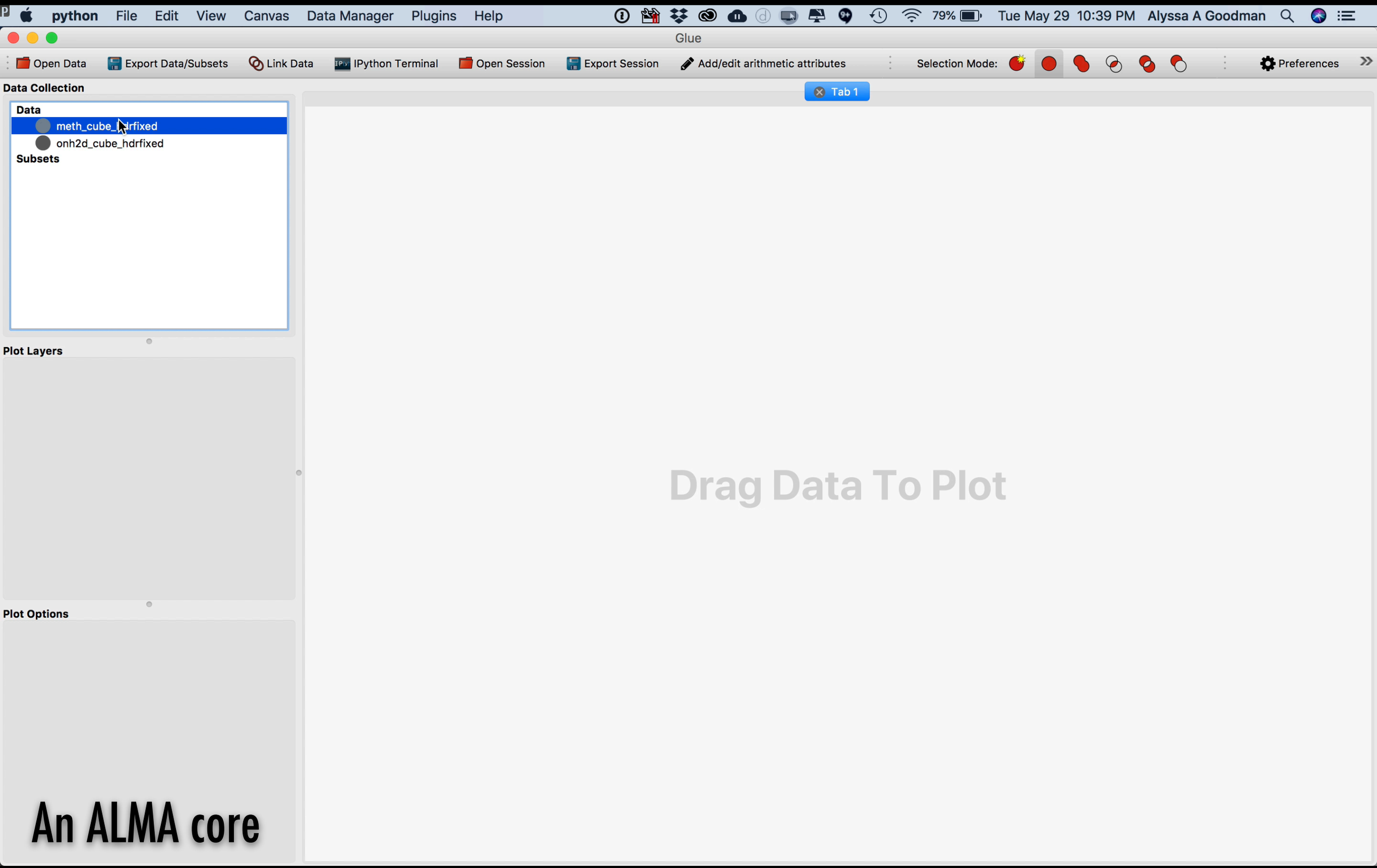
Find out more about glue, and download for free, at glueviz.org

No merging of data sets—just glue them.



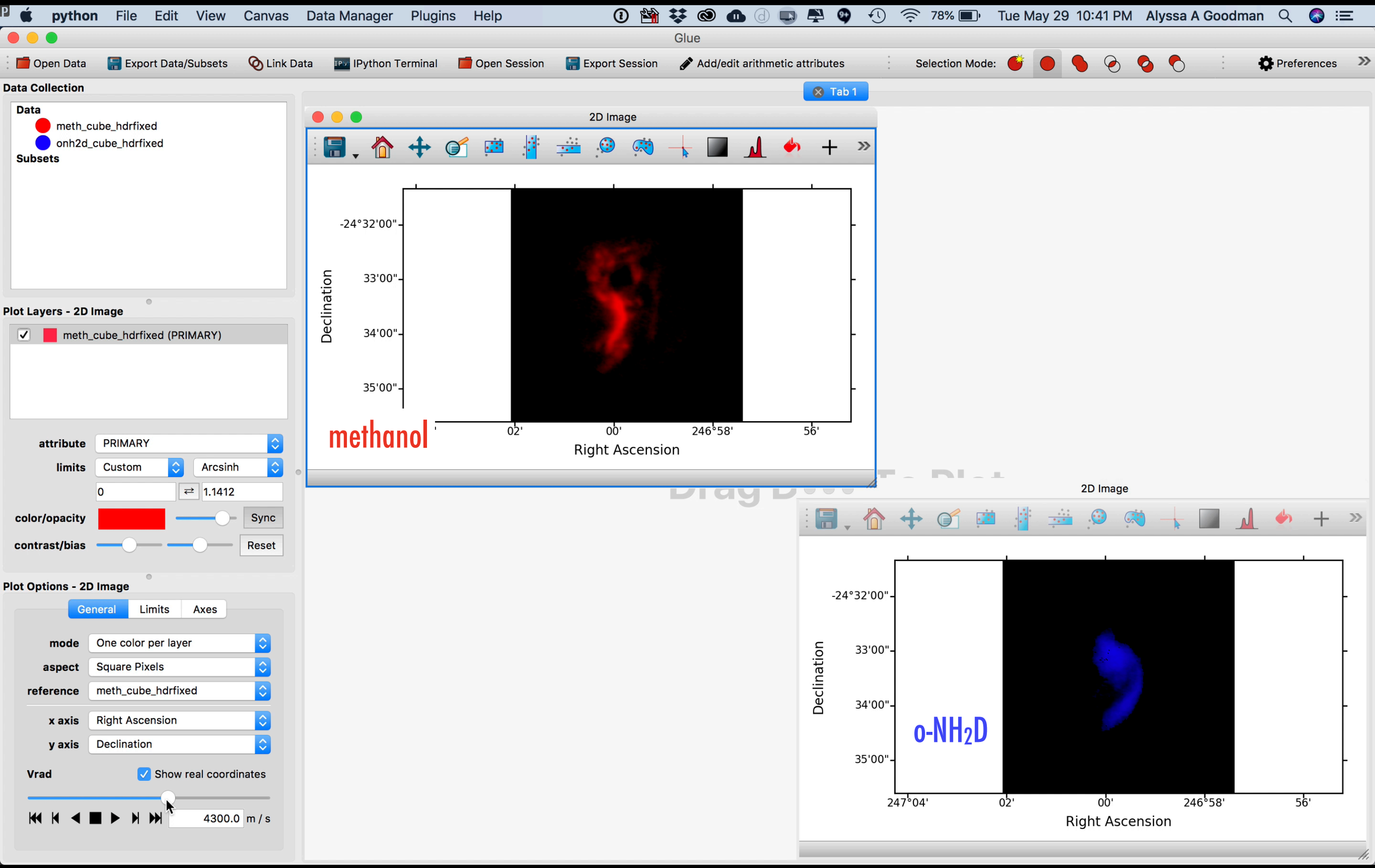
An ALMA core

Just drag to visualize, e.g. series of 2D "channel maps."

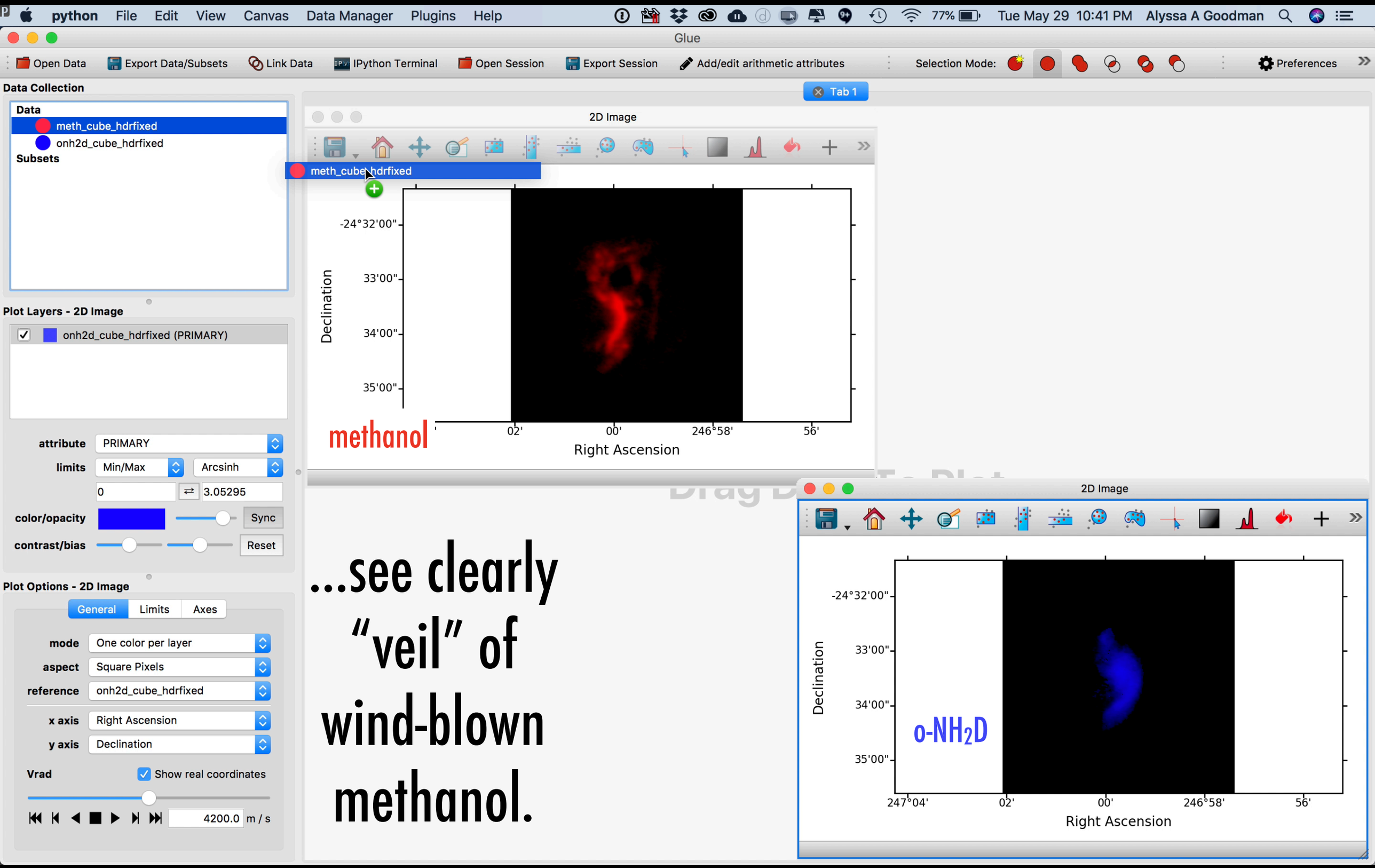


An ALMA core

Adjust so each tracer is a different color.



Create 3D views...

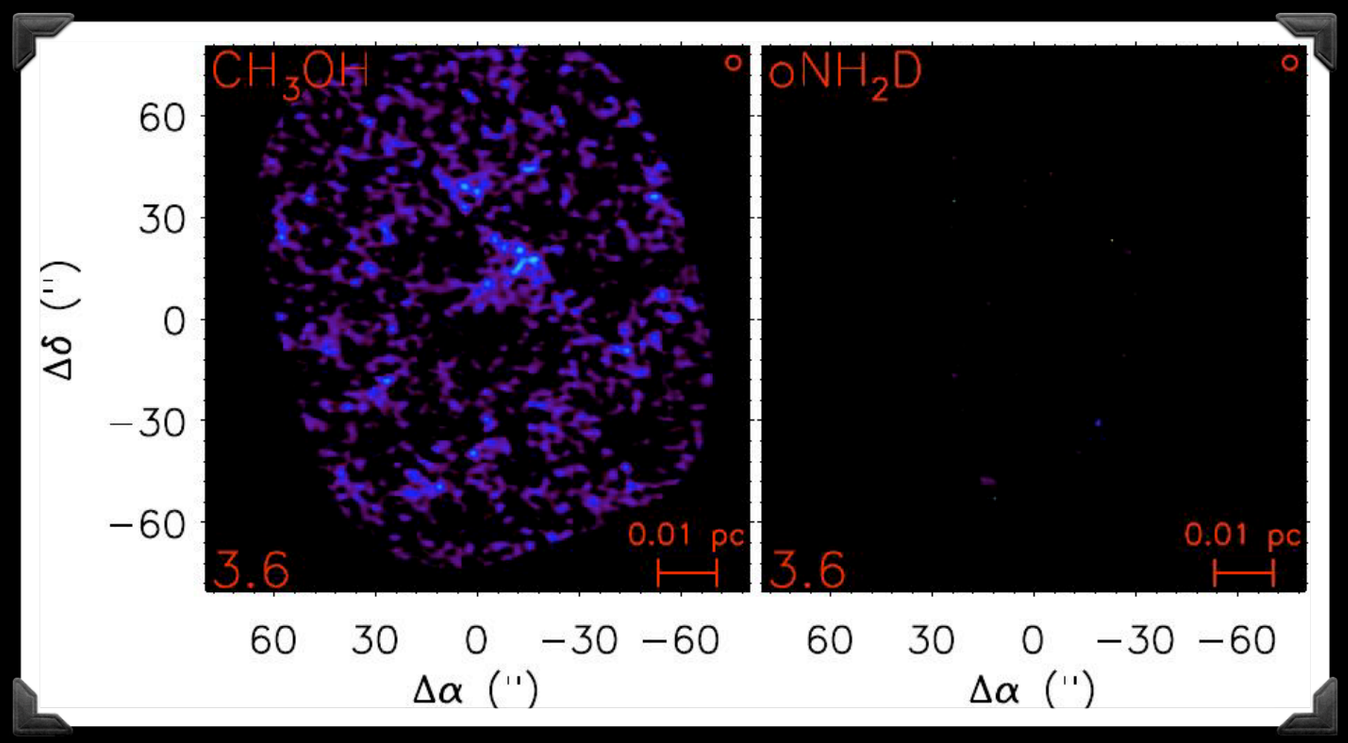


...see clearly "veil" of wind-blown methanol.

COMPARISON

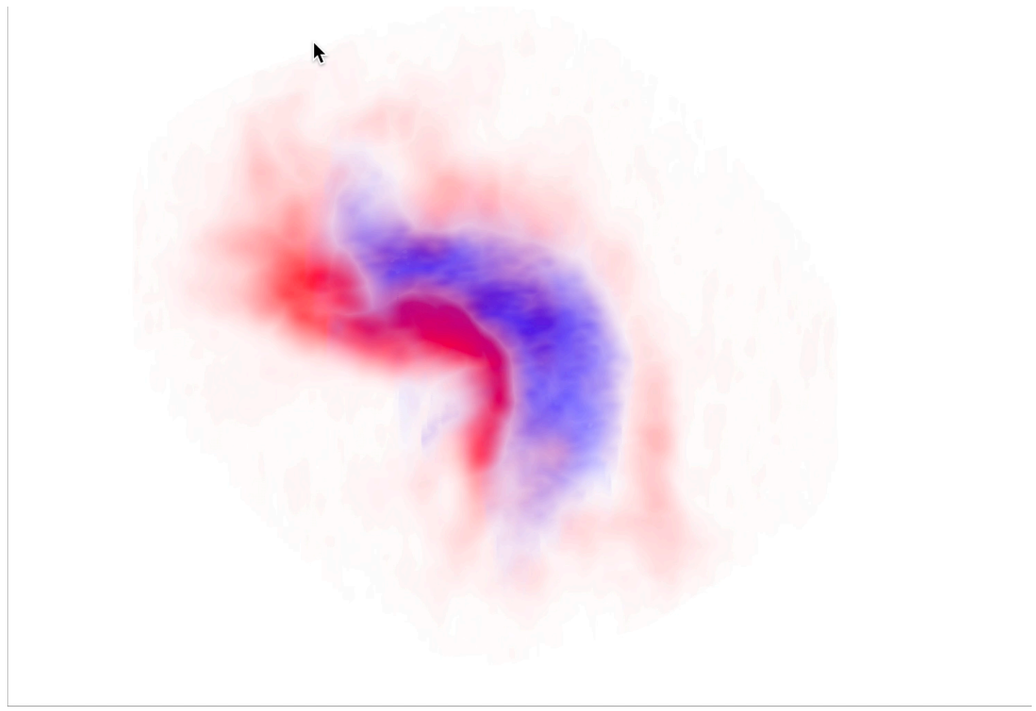
glue

traditional rainbow channel maps

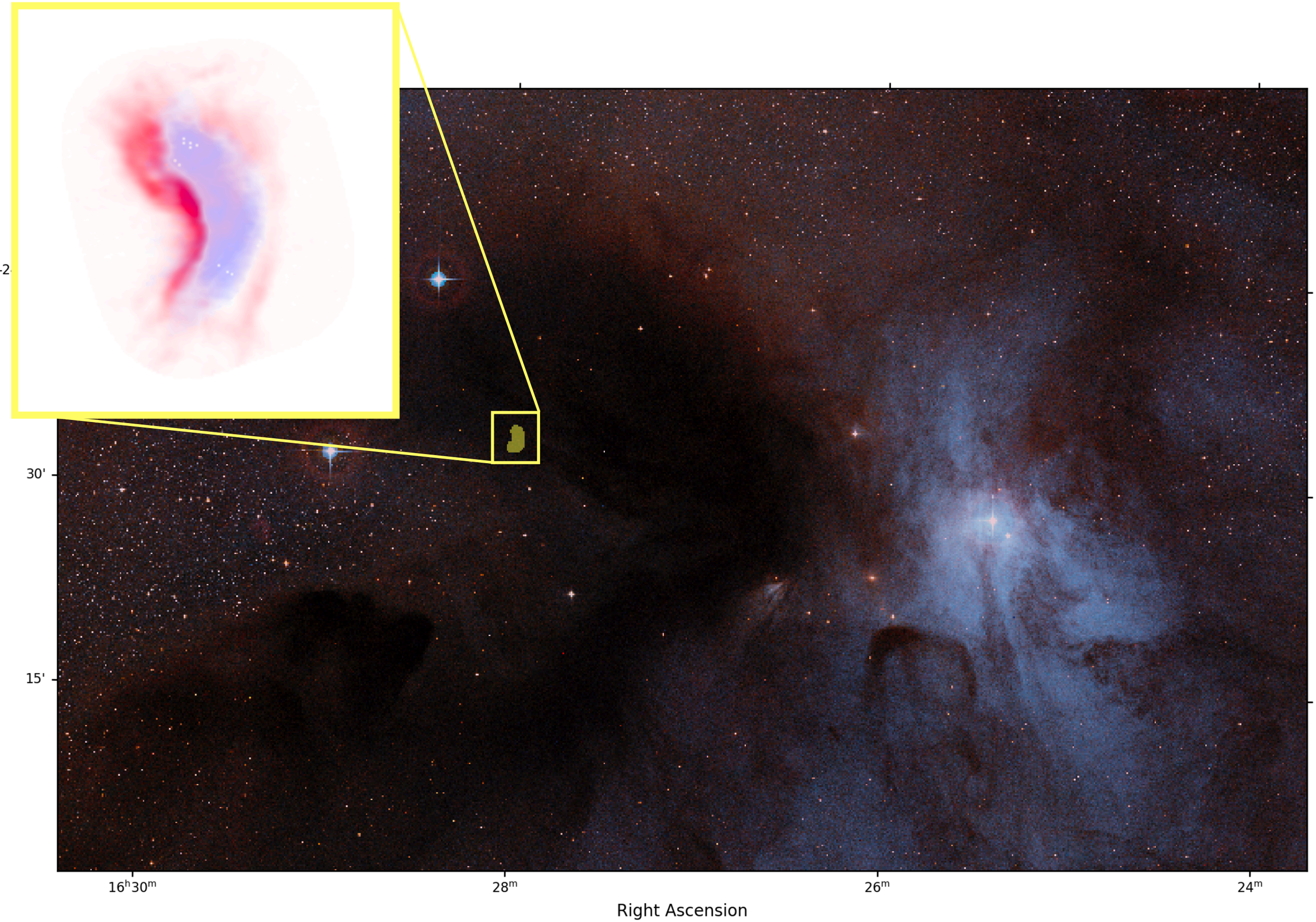


result: happy unicorns

glue volume visualization



result: previously unknown phenomenon (veil of emission) revealed

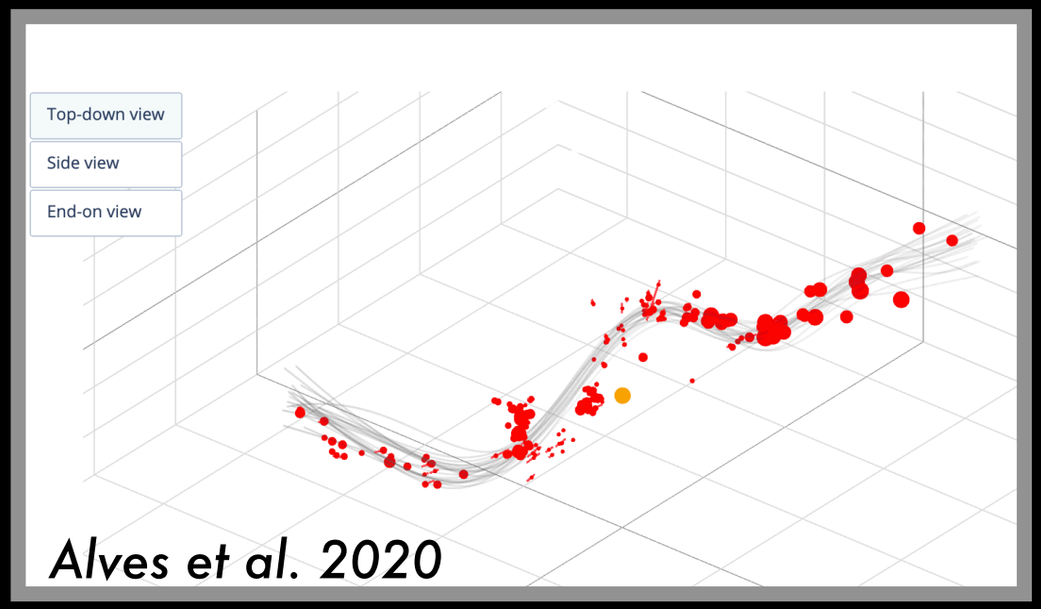

-2
30'
15'
Declination
16h30m
28m
26m
24m
Right Ascension

glue multidimensional data exploration

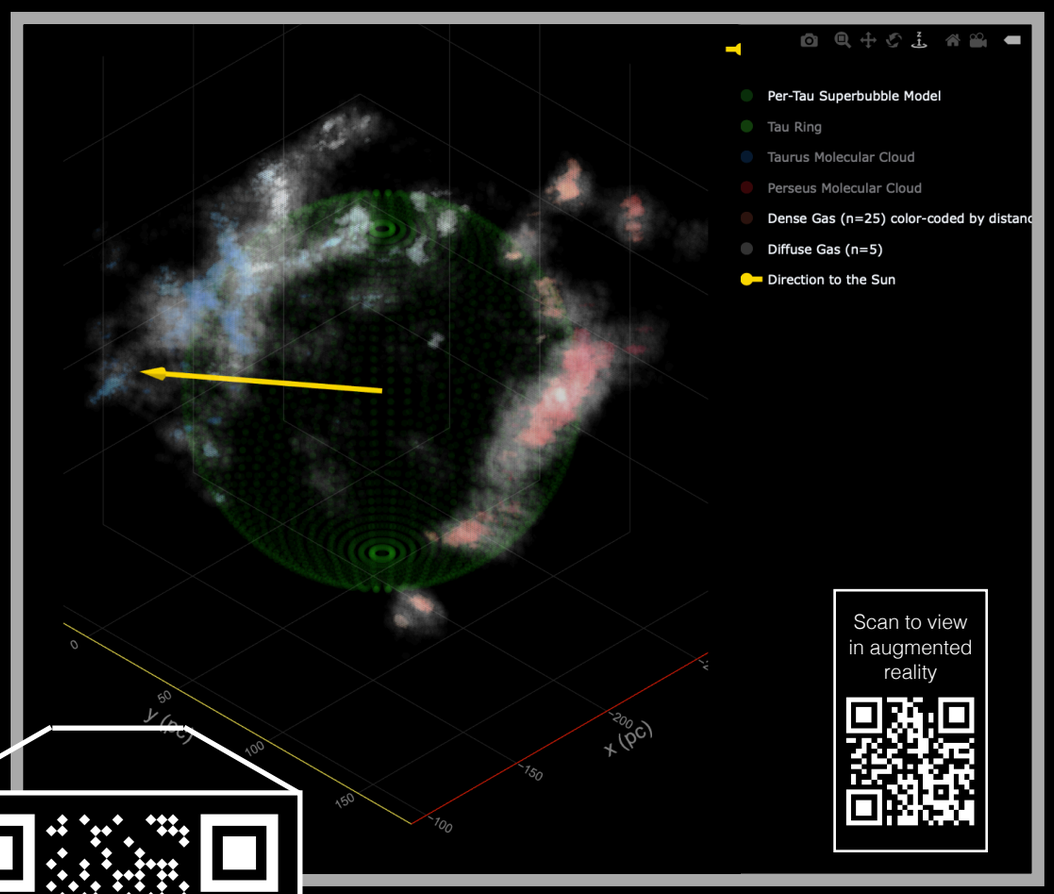
plotly

glupyter multidimensional data exploration

João will show you...

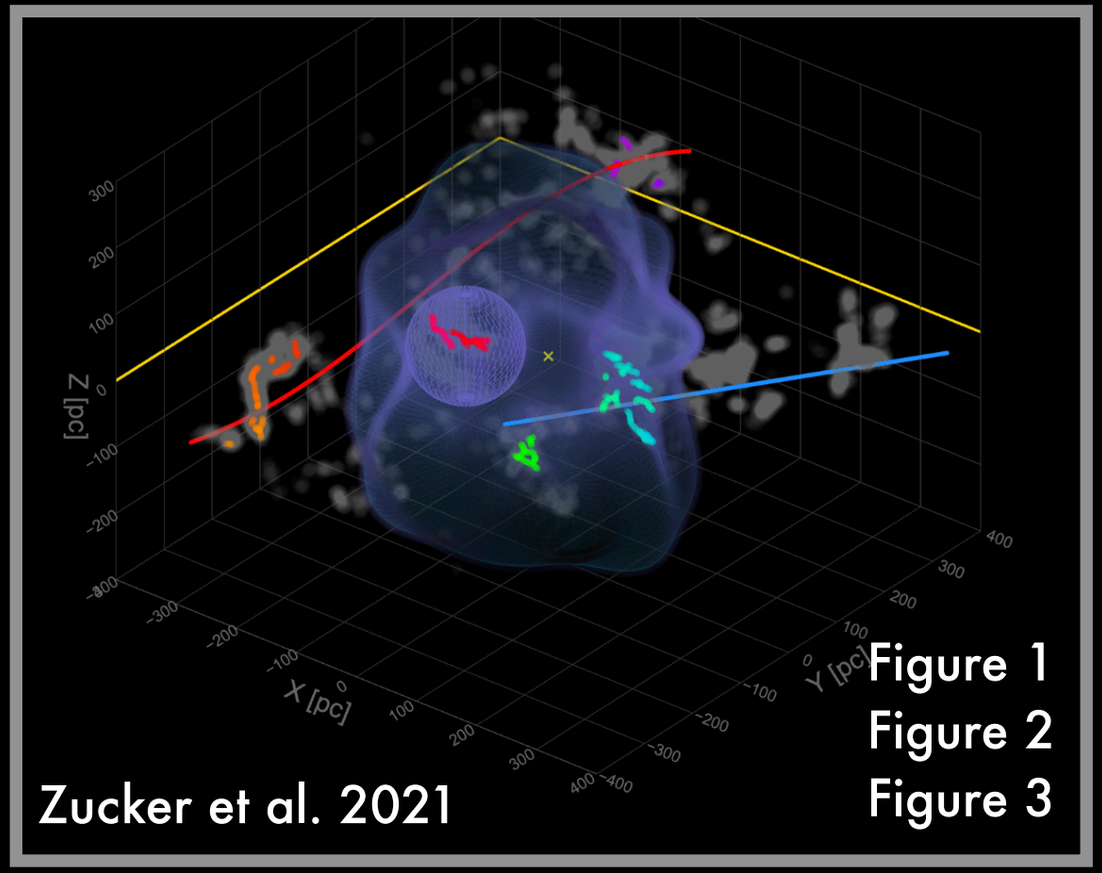


Shmuel showed you



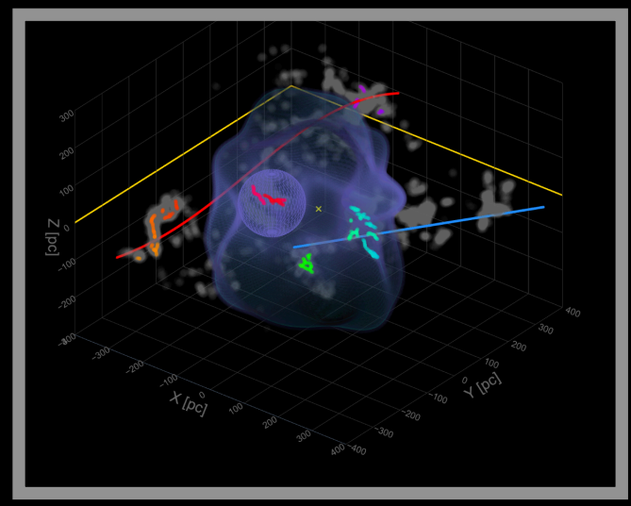
Soon... Merge Cube

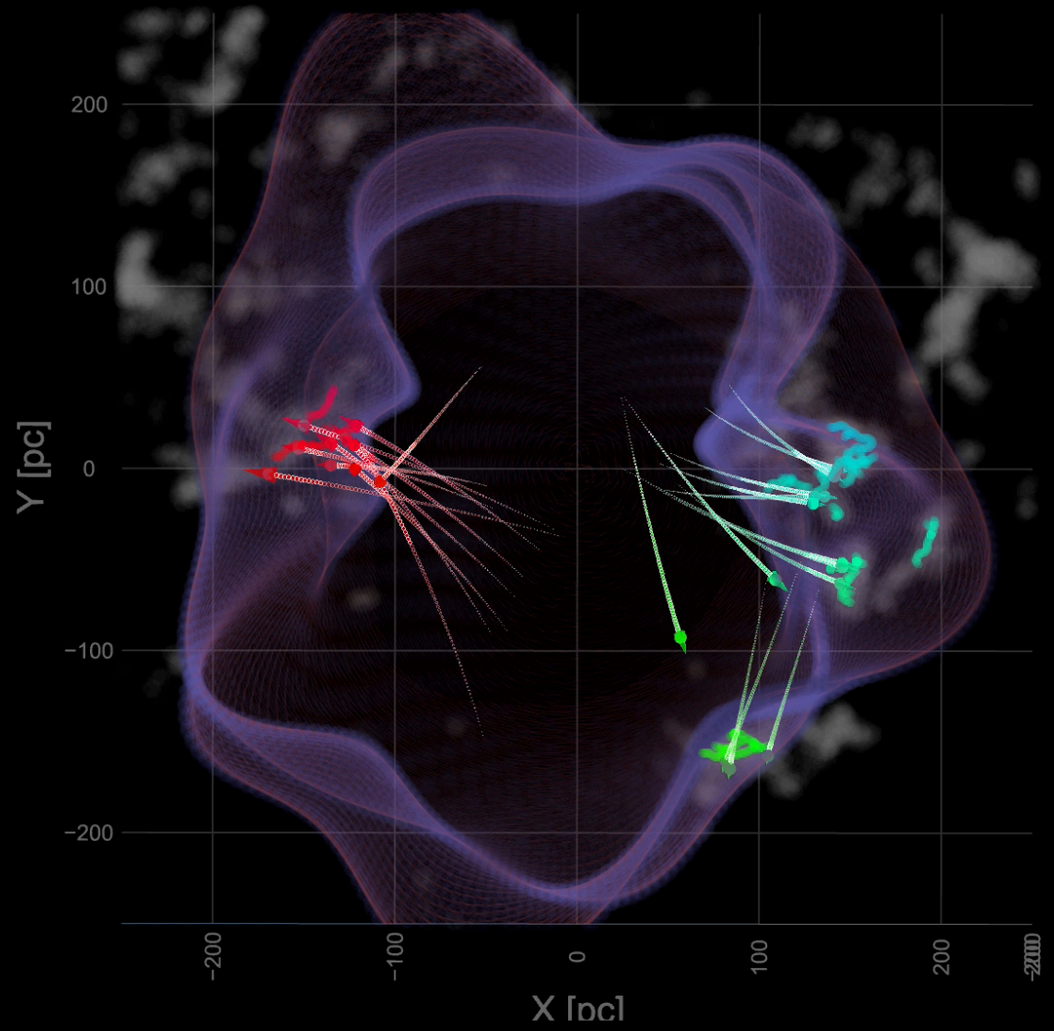
Catherine will show you...



glue
multidimensional data exploration

plotly





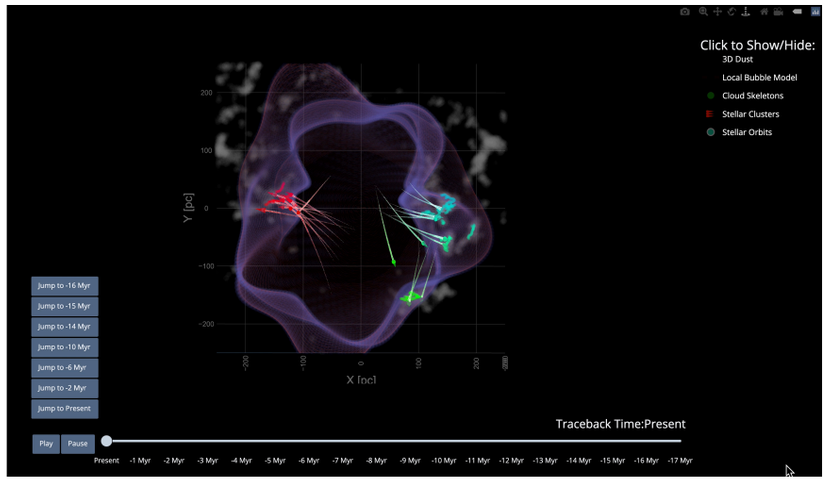
Jump to -16 Myr
Jump to -15 Myr
Jump to -14 Myr
Jump to -10 Myr
Jump to -6 Myr
Jump to -2 Myr
Jump to Present

Traceback Time:Present

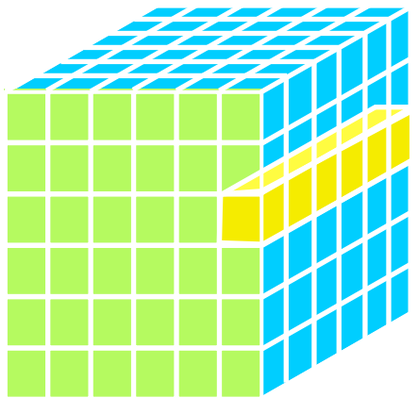
Play Pause

Present -1 Myr -2 Myr -3 Myr -4 Myr -5 Myr -6 Myr -7 Myr -8 Myr -9 Myr -10 Myr -11 Myr -12 Myr -13 Myr -14 Myr -15 Myr -16 Myr -17 Myr

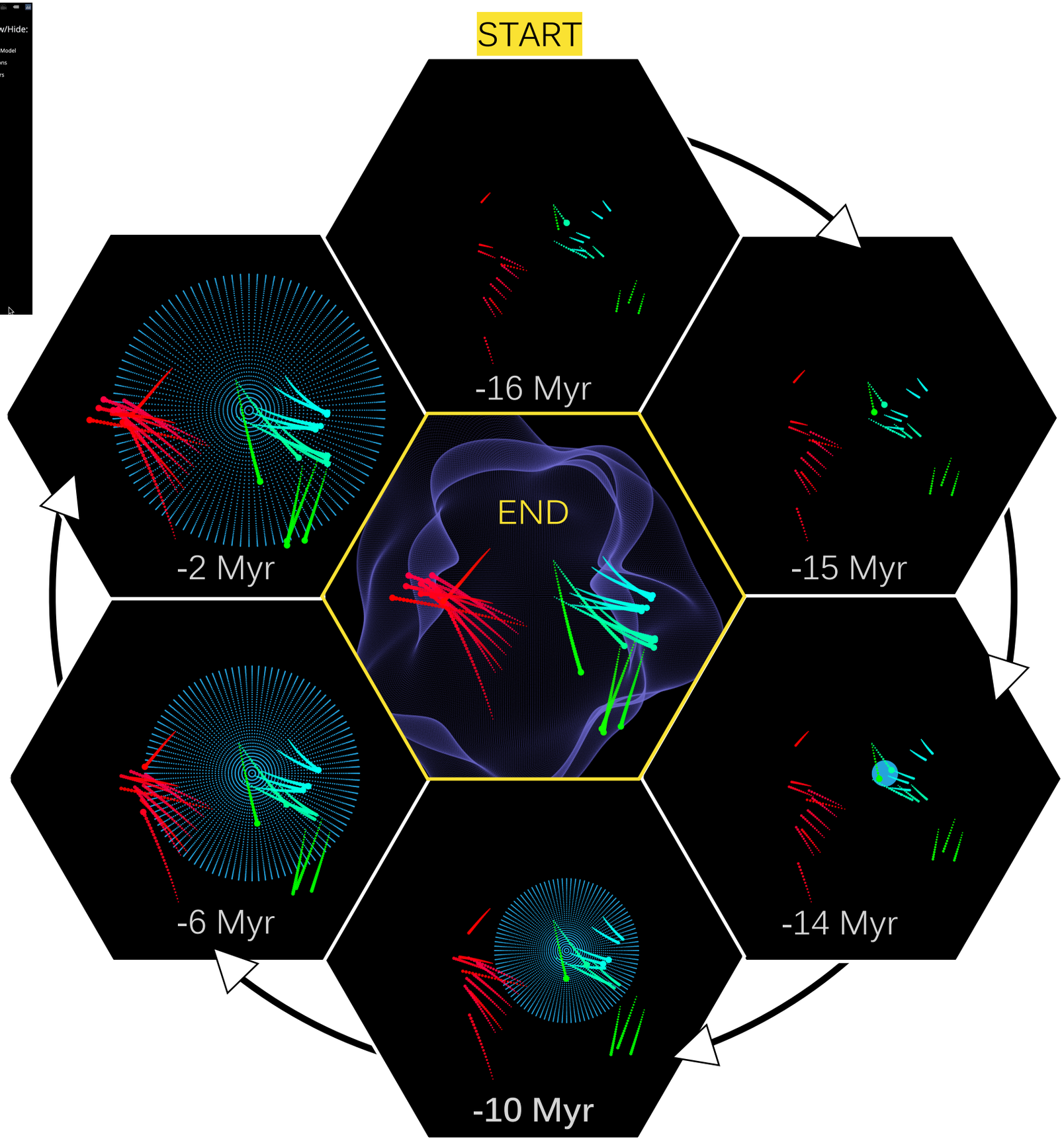
Zucker et al. 2021



"Data-Dimensions-Display"

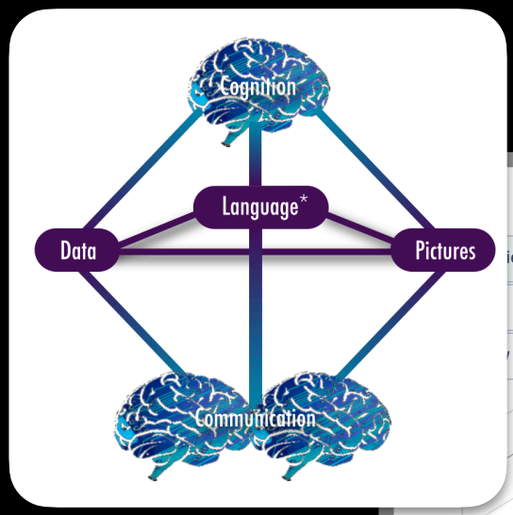


& Publishing...

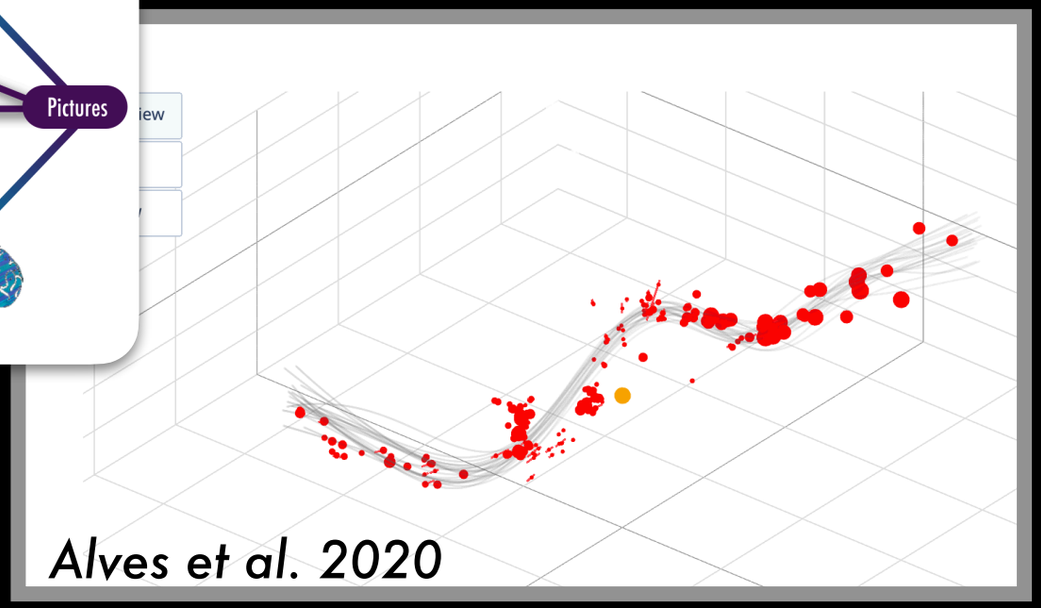


glue
multidimensional data exploration

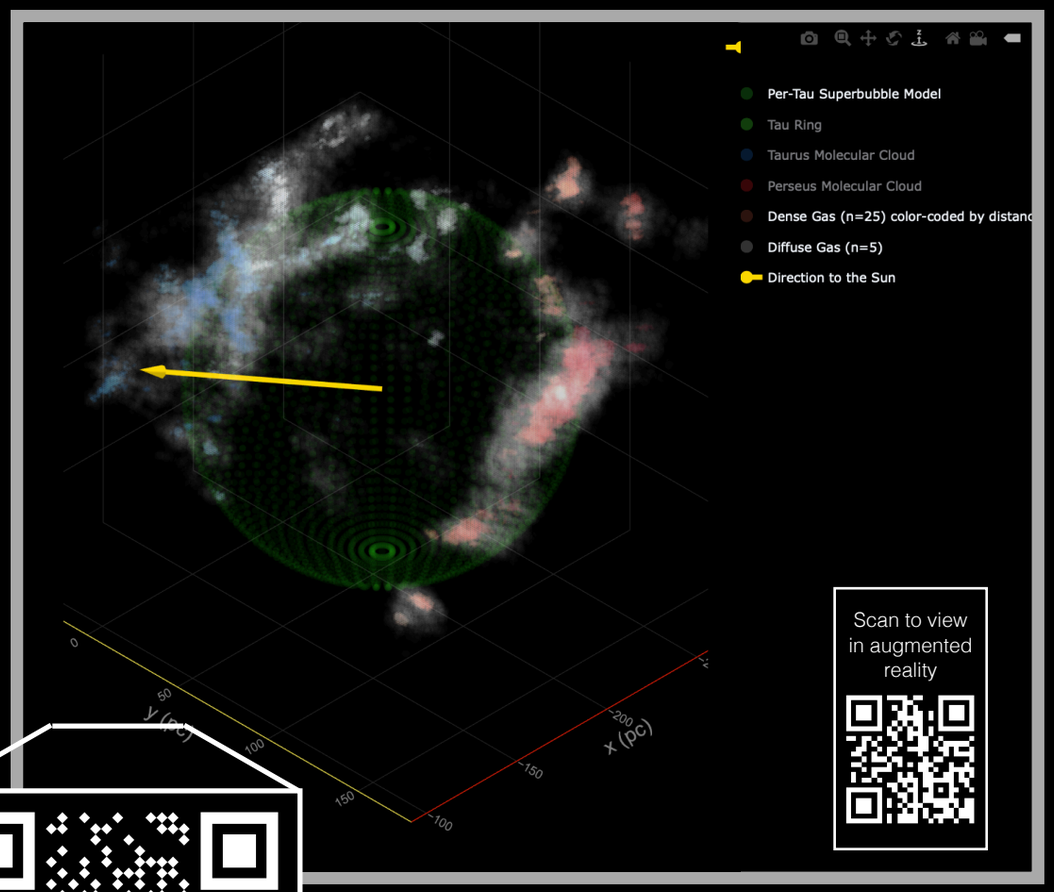
plotly



João will show you...

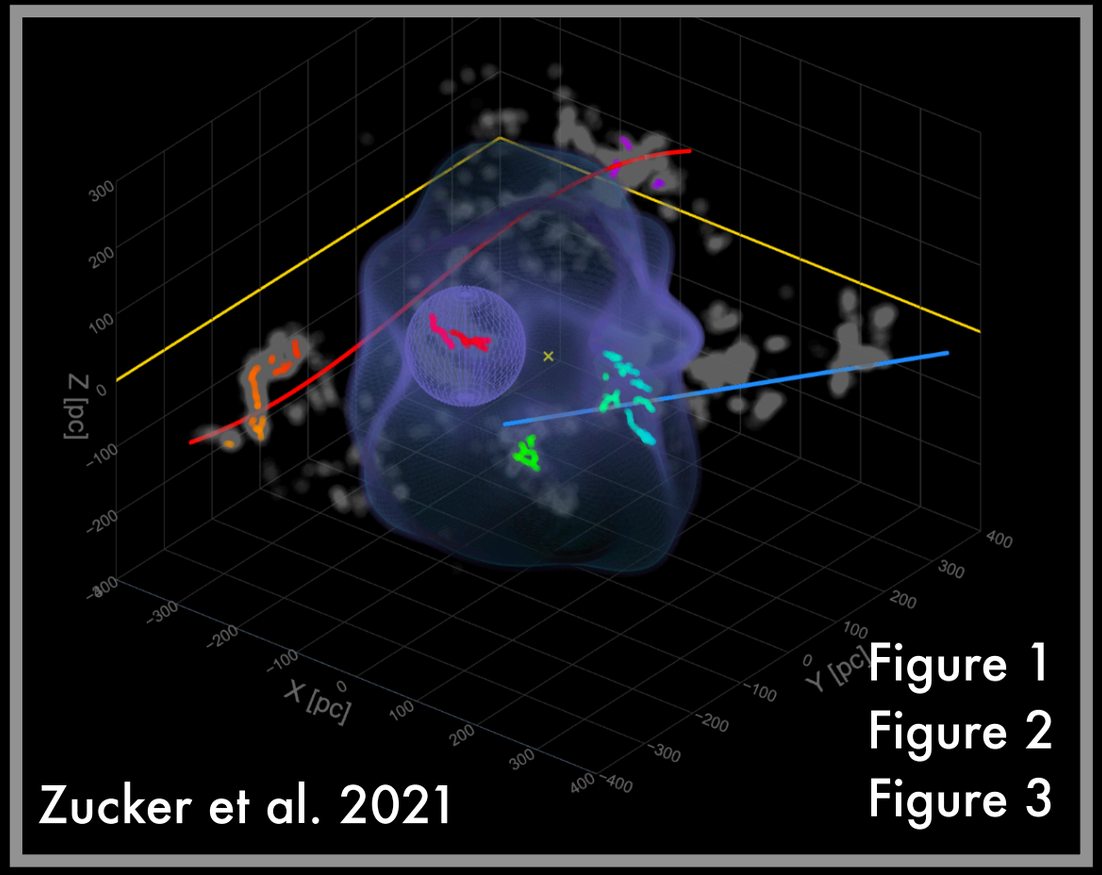


Shmuel showed you

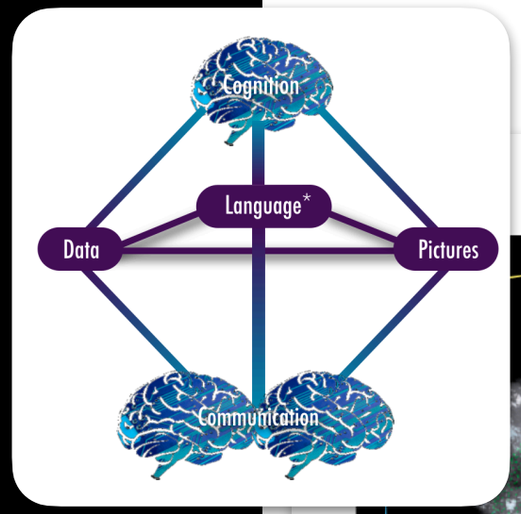


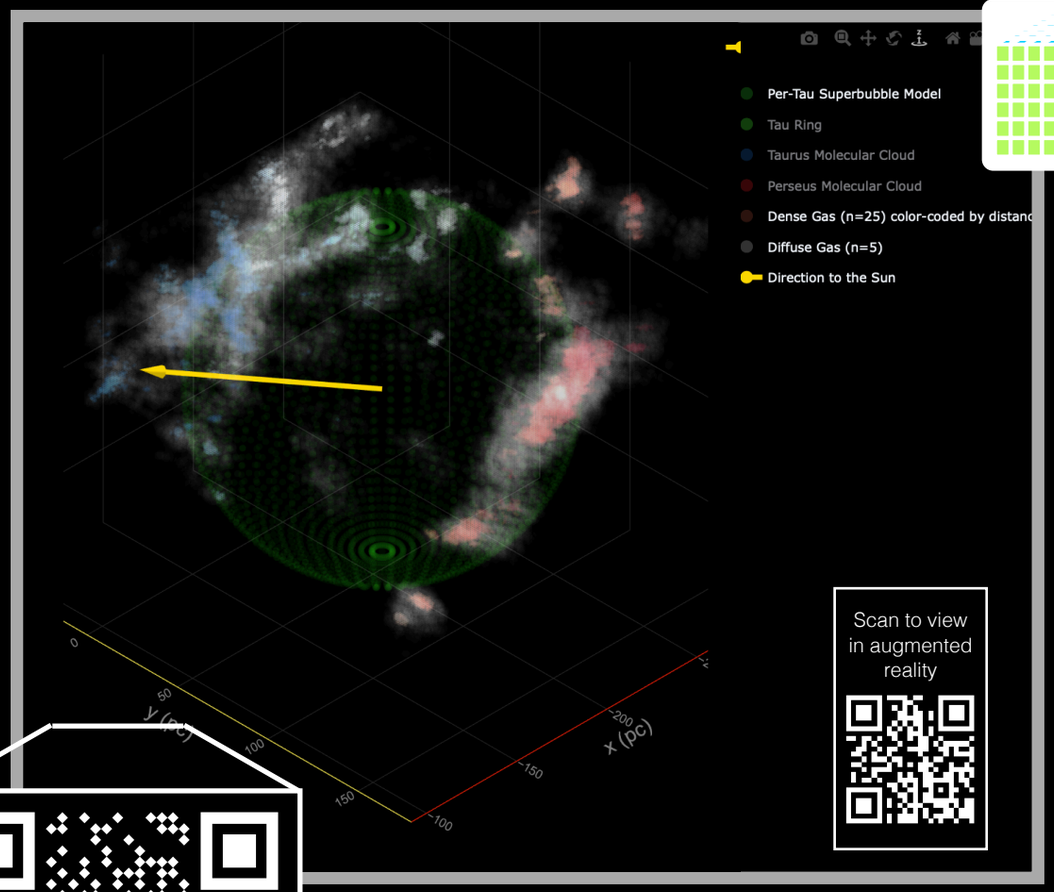
Bonus: Merge Cube

Catherine will show you...

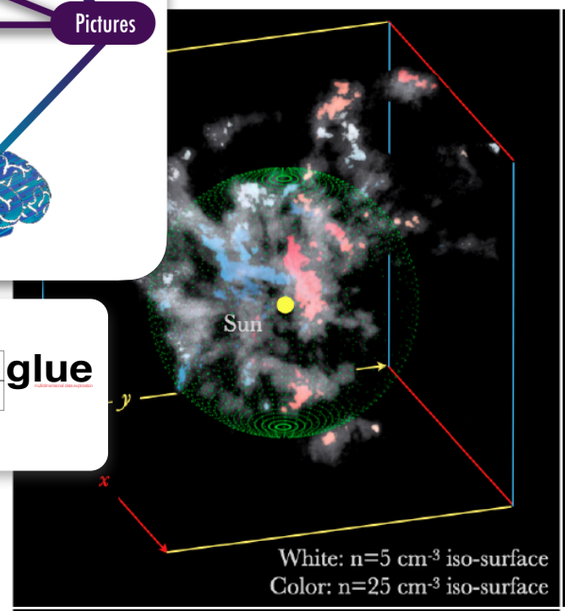


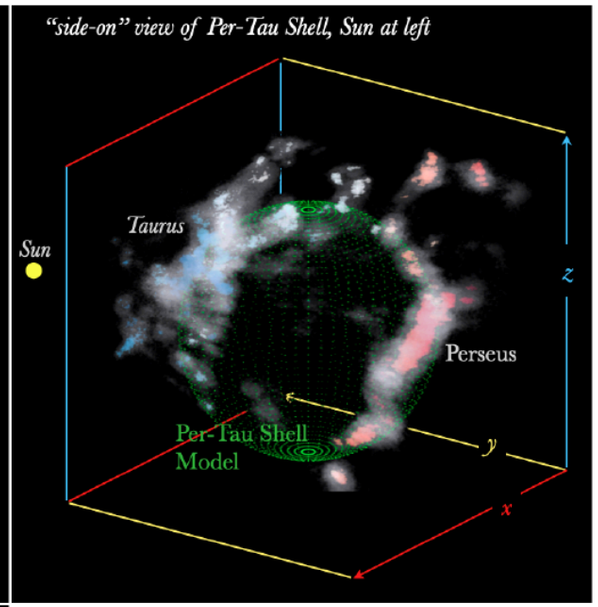
Publishing's interactive Cutting-Edge & (Augmented) Future

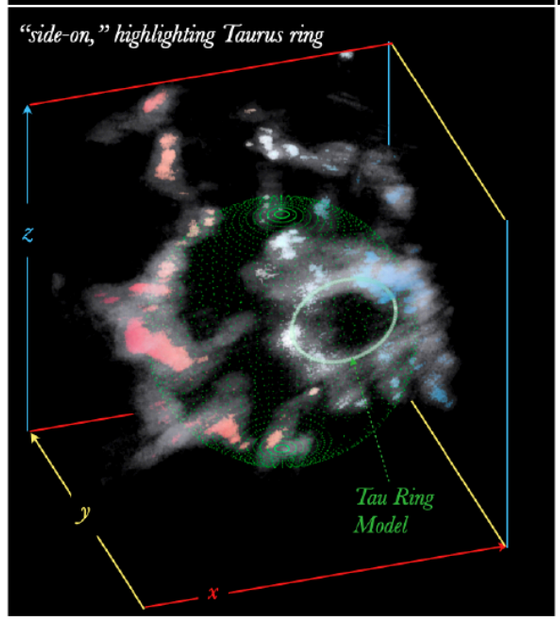




Now: Merge Cube







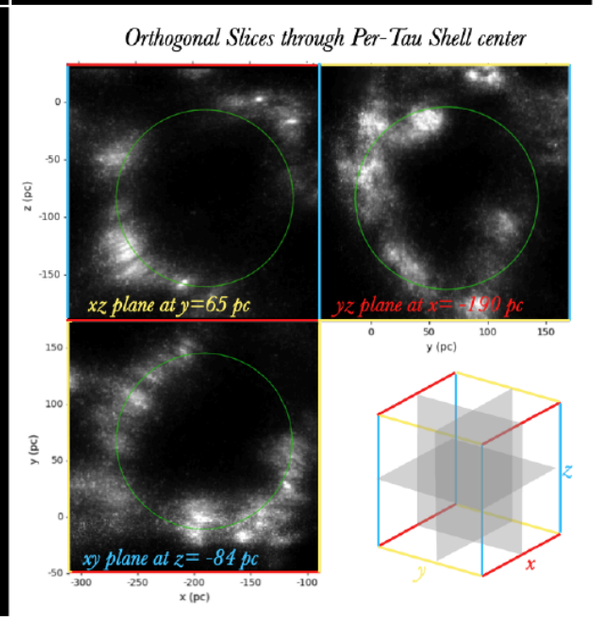


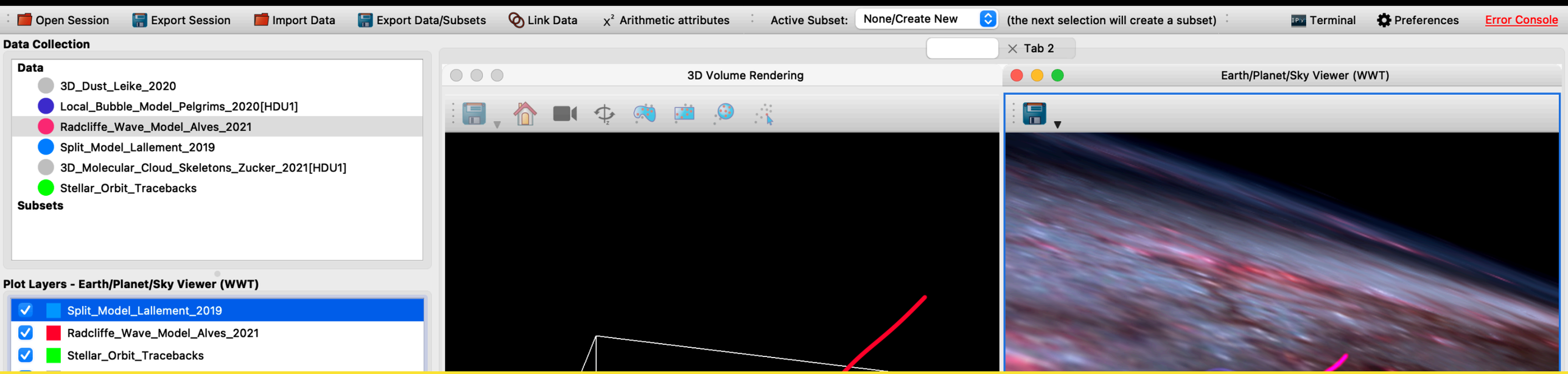
FIG. 2.— 3D[a] [b] views of the Per-Tau shell (see Fig. 5 for more visualizations). Plotted are density iso-surfaces at levels $n = 5$ cm^{-3} (grey) and $n = 25$ cm^{-3} (color), overlaid with our spherical shell model, radius $R_s = 78$ pc, distance from the sun $d = 218$ pc.. The $n = 25$ cm^{-3} surfaces are colored by distance from the sun (blue-to-red). **Upper-left**: View from the sun (compare with Fig. 1). **Upper-right**: A side view of the region. Perseus and Taurus and their diffuse envelopes are arranged on two opposing sides of the Per-Tau shell. **Lower-left**: Another side view emphasizing the Tau Ring. The ellipse is the Tau Ring model (Appendix B). **Lower-right**: 2D density slices along the xy, xz, yz planes. All planes intersect at shell's center. In all panels xyz are the Heliocentric Cartesian Galactic Coordinates.

[a] For an interactive version of this figure visit https://faun.rc.fas.harvard.edu/czucker/Paper_Figures/sbialy/pertau_superbubble.html.

[b] For Augmented Reality (AR), scan the QR code

Bialy et al. 2021

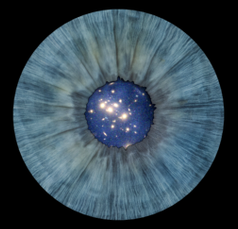
Live demo, using the New Frontier Catherine will explain tomorrow.

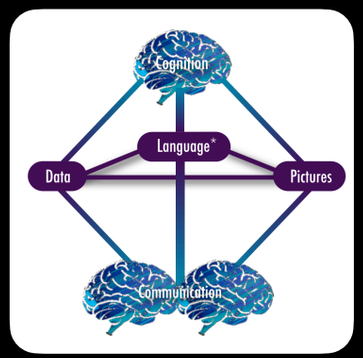


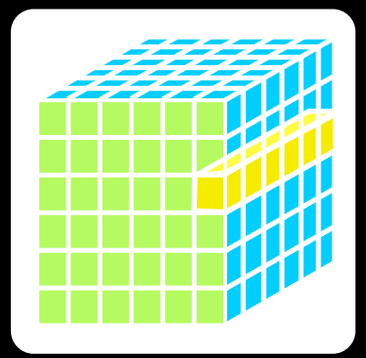
TOP SECRET, REALLY— PLEASE DO NOT SHARE—BEING SUBMITTED TO NATURE in a few days

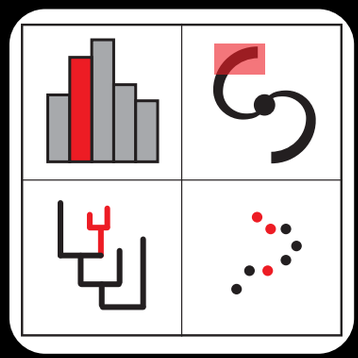
Zucker, Goodman, Alves, Bialy, Foley, Finkbeiner, Speagle, Großschedl, Swiggum , Burkert 2021.

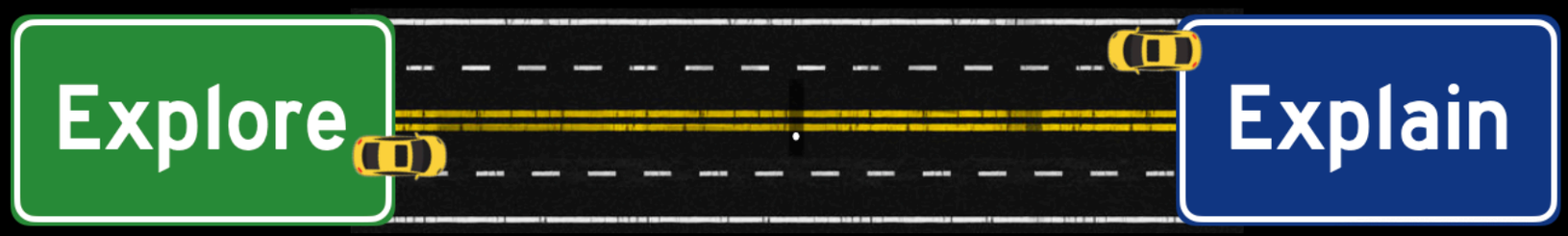
SEEING MORE OF THE UNIVERSE IN 20 MIN

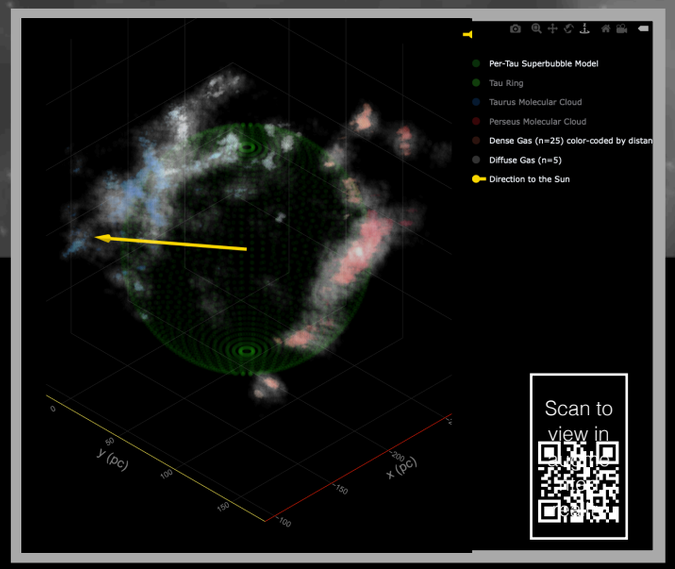






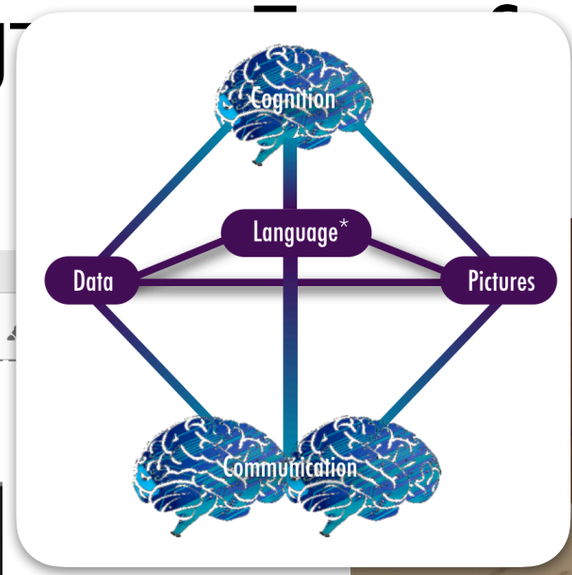






explanatory “Per-Tau Shell” video by Jasen Chambers,
for release with Bialy et al. (ApJL) & Zucker et al. 2021 (ApJ)

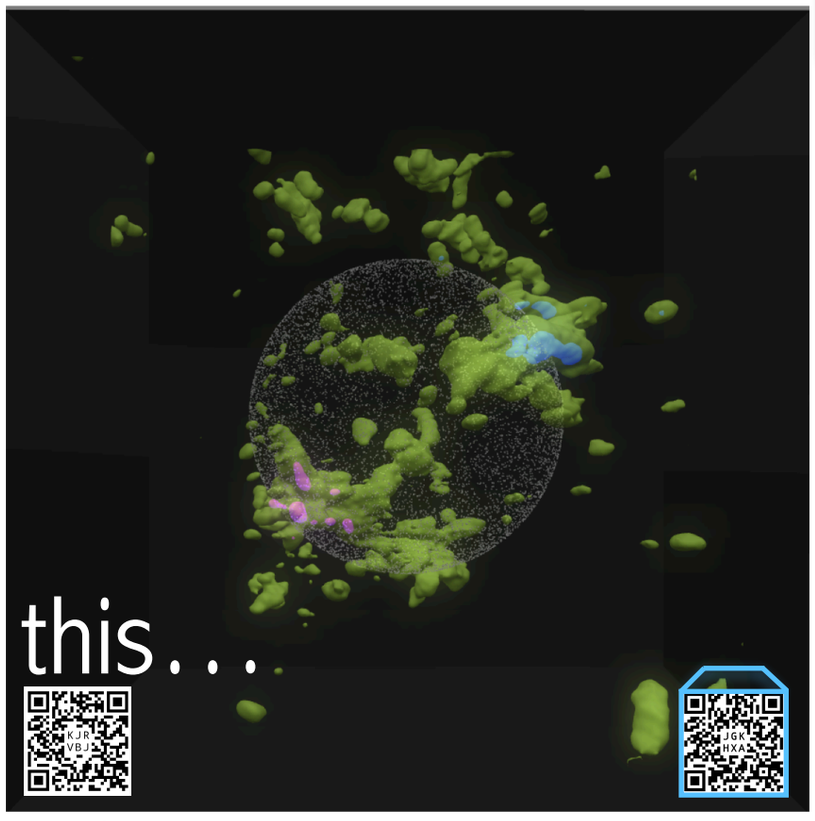
PUBLISHING'S INTERACTIVE CU… (AUGMENTED) FUTURE



main.pdf

2 (2 of 7) 90.4%

2



scan this…

FIG. 1.— Density $n = 5$ cm^{-3} iso-surfaces in the Perseus-Taurus region as derived from 3D-dust extinction observations. The coordinates are the 3D galactic $x-y-z$ coordinates (see footnote 1). Overlaid is our spherical shell model (Eq. 5). The positions of Perseus and Taurus and the sun are indicated.

It is useful to express the results in terms of gas density. We first derive a conversion factor which we use to convert the reported dust opacity density s, into gas Hydrogen nuclei particle density n (units: cm^{-3}). The gas column density and dust extinction are related through the wavelength-dependent extinction curve, $A_\lambda/N_{\rm H}$, where A_λ is the dust extinction at wavelength λ and $N_{\rm H}$ is the H nuclei column density. For the Gaia G-band, $\lambda = 673$ nm (central wavelength), $A_{\rm G}/N_{\rm H} = 4 \times 10^{22}$ mag cm^2 (reference XXX). In terms of the dust opacity $\tau_{\rm G}/N_H = 3.7 \times 10^{-22}$ cm^2. Following the definition of s_x we get

$$\Delta N_{\rm H} = s_x \left(\frac{\tau_{\rm G}}{N_{\rm H}}\right)^{-1} \frac{\Delta L}{\rm pc} \,. \quad (2)$$

Dividing by ΔL we obtain the gas density (averaged over the 1 pc^3 resolution element):

$$n = \frac{\Delta N_{\rm H}}{\Delta L} = 880\, s_x \ {\rm cm}^{-3} \,. \quad (3)$$

tion of the 3D position, (x, y, z).

The gas density obtained via Eq. (3) is approximate as it includes several approximations. First, it assumes an extinction curve $A_\lambda/N_{\rm H}$ that is independent of position. In practice, there may be variations in the dust properties which result in deviation from the canonical extinction curve. Second, it includes uncertainties involved in the derivation of the original 3D dust map of **?**, e.g., their assumptions on the priors, etc. (see **?** for more details XXX). The derived densities are accurate probably to within a factor of 2-3. With these uncertainties in mind, we note that this is a unique opportunity to explore observationally the 3D density structure of the ISM in the solar neighborhood.

3.2. *Characterizing the shell profile*

Radially-averaged mean density: In §4 we explore the 3D density structure in the Perseus-Taurus region, and discuss a large 3D-shell structure, extending from the Taurus

BIALY ET AL. 2021

…see this

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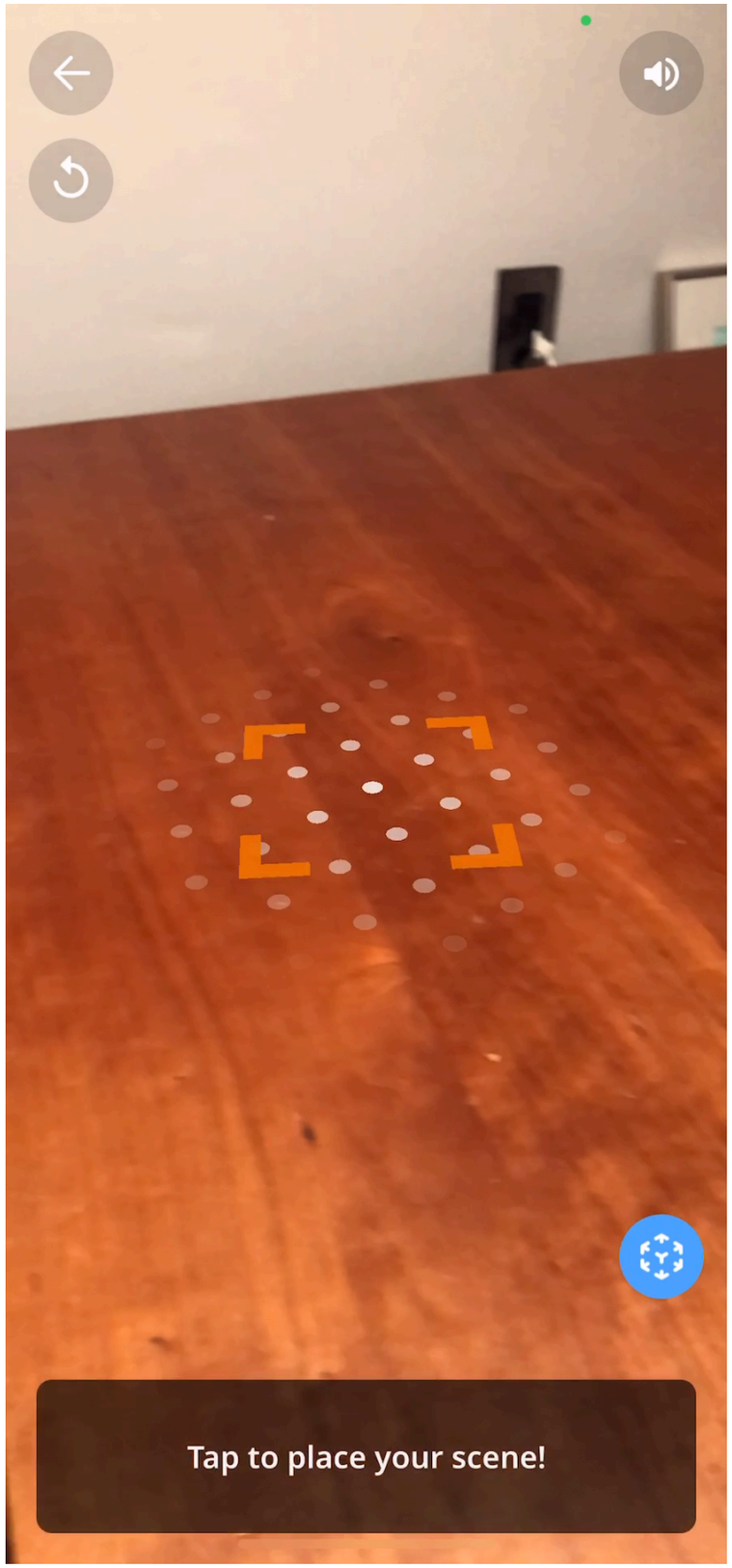

Early Demo of Bialy et al. 2021

DATA,
CODE,
COLLABORATION

DATA-DRIVEN STORYTELLING

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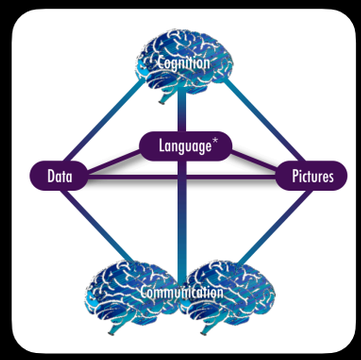
see *"New Thinking on, and with, Data Visualization"*
(Goodman, Borkin & Robitaille arxiv.org/abs/1805.11300)

Learn more in our next episode…
"CONNECTING DATA, LANGUAGE AND PICTURES"



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