Small debris is all over our solar system
The Kuiper Belt = remnants of planet formation
Debris disks, a.k.a. “Exo-Kuiper Belts”

- **Protoplanetary/primordial disk** — gas/dust, optically thick
  - ~2-10 Myr

- **Transitional disk** — gaps start forming
  - ~1-2 Myr

- **Debris disks** — optically thin, mostly dust (can be replenished by collisions)
  - >5 Myr
Debris disks are...

Rings of dust around young(-ish) stars

**Key** to understanding *how* different system architectures are created!
High-contrast imaging has resolved many examples

Esposito et al.; ESO/Lagrange; Muller et al.; Arriaga et al.; Lewis et al. in prep
The Kuiper Belt’s largest inhabitant: Pluto
Pluto, Before *New Horizons*

*DISCOVERY OF THE PLANET PLUTO*

January 23, 1930

January 29, 1930
Pluto, Before New Horizons

Pluto System • February 15, 2006
Hubble Space Telescope • ACS/HRC

Pluto
Charon
Nix
Hydra

Pluto
Hubble Space Telescope • Faint Object Camera

NASA, ESA, H. Weaver, A. Stern
Pluto, Before New Horizons
PLUTO
and New Horizons
PLUTO
and New Horizons
New Horizons was revolutionary

- Flyby of Pluto system in 2015
- First detailed information on a Kuiper Belt Object! (Now we’ve got 2 – MU69)
- Multiple instruments: images, spectra, dust counting, and more
NH gathered images + spectra

- **LEISA** — Linear Etalon Imaging Spectral Array (1.25-2.5 micron, R~240, 6-7 km/pix)
  - Spectral info -> composition!

- **MVIC** — Multispectral Imaging Camera, even higher resolution image data sets!
  - Other maps, like albedo and elevation!
Pluto’s geology is varied
Topographic extremes -5 to 5 km

Image adapted from Schenk et al. 2018
Orienting ourselves on this map

Topographic Map of Pluto’s Surface

- **Cthulu Regio**
- **Sputnik Planitia**

Image adapted from Schenk et al. 2018
Pluto is moving into Northern Summer

1 Pluto orbit = 248 Earth years

Passed equinox and perihelion in ~1989 (moving from Northern spring to Northern summer)
Pluto’s ice transport is driven by sublimation
4 main components: $\text{H}_2\text{O}$, $\text{CH}_4$, $\text{N}_2$, CO
2 methods of mapping composition

Spectral fitting (Hapke Modeling)

Integrated band depth measurements

Protopapa et al. 2017; Schmitt et al. 2017; Lewis et al. 2021
Missing coverage on half of globe

Protopapa et al. 2017; Lewis et al. 2021

No data at regions south of -38 degrees

Low-res data here, LORRI only
Goal = Relate $N_2$ (mapped by New Horizons) to geology, topography, and global trends

Why? To get a detailed snapshot of Pluto’s seasonal/climatic state, informing both model predictions & historical climate studies
Conclusion #1: Ice moves to low places

- Frost at lower elevation feels higher atmospheric pressure
- Must maintain vapor pressure equilibrium
- Preferentially deposits at low elevation because of pressure differential

A different way of moving ice!

Figure from Stansberry et al. in prep; Lewis et al. 2021
We see evidence of this transport in the current ice distribution!

“Topographic” transport could have filled Sputnik Planitia
Other ices on Pluto like methane and CO also trace this distribution. In fact, some of the methane follows the nitrogen!
Conclusion #2: Latitudinal trends match climate models
Conclusion #3: Pluto is “Triton-Like”

- Albedo: ~0.8
- Emissivity: 0.5–0.9

Lewis et al. 2021; Adapted from Buratti et al. 2017
Looking to the future...

- People are proposing missions to return to Pluto! (Buie et al. 2021)

- *JWST* observations of both KBOs and Debris Disks (PIs Stansberry, Chen, Lellouch, Hinkley, and many more)
  - Looking at KBO composition (including Pluto)
  - Measuring solid-state reflectance spectra of debris disks

- Improvements in tech for ground-based high-contrast imaging (AO, GPI 2.0, data processing, ELTs, and more) (Guyon 2018, Chilcote et al. 2018, Lewis et al. in prep)
WRITING
in Physics & Astro
“Writing is not a special language owned by the English teacher. Writing is thinking on paper...Writing, demystified, is just another way for scientists to transmit what they know.”

—William Zinsser, author
How do astronomers learn to write?

You tell me!

In the chat, tell us how you learned to write about science.
How do astronomers learn to write?

- First year composition classes in undergrad — assuming skills will transfer
- One-on-one mentorship and “on-the-job” practice
- One-off workshops or conference sessions
- Feedback from peers
- Few astronomers report structured learning for writing within the discipline
Why writing in physics/astro classes

- Scientists need to communicate well
  - for the public!
  - for other scientists!

- Better research paper writing = more accessible field, serving DEI goals and furthering science

- Writing can help improve understanding (writing-to-learn)
Why writing in physics/astro classes

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Writing well in a discipline is a learned and practiced skill, and we should treat it that way.
How writing in physics/astro classes

- Incorporate it into your existing curricula / courses! [e.g. quick writes, writing-to-learn, small assignments]
- More structured guidance + real-world tasks in lab classes
- Dedicated science communication and technical writing courses
- ...and more!
Writing in intro science courses

- Writing can also be useful in introductory / non-major courses
- Building science literacy
- Increasing confidence to engage with scientific research
- Currently investigating how practicing writing about science influences student attitudes towards science in my class
Astrobites as a model for science writing education

The (new) April Fools Peer Review Process
by Astrobites | Apr 2, 2022
There is a tradition in Astronomy to post silly science papers to the

Meteors Ahead! Does Kuiper Belt Dust Affect Titan's Atmosphere?
by Lili Alderson | Apr 2, 2022
Impacts might have been a disaster for the Titanic, but on

Life, Death, and Robots
by Katya Goiman | Mar 31, 2022
Looking for aliens? Searching for signs of technology might prove just as fruitful as searching for
Astrobites as a model for science writing education

150+ authors
Astrobites as a model for science writing education

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Astrobites as a model for science writing education

150+ authors

600k+ yearly views

3000+ articles

Worldwide readership

Khullar et al. 2019, Lewis et al. in prep
Astrobites as a model for science writing education

Come see us at AAS 240!
Conclusions

Pluto is geologically active, interesting, and great place for in-depth study of the outer solar system.

Observations of both our own solar system’s small bodies and debris disks can provide complementary insight into planet formation.

Writing is a key part of the skill set of a modern astronomer, and should be taught as such.
THANK YOU

Any questions?
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Briley Lewis