

# Triton and the Kuiper belt connection

Michele Bannister  
@astrokiwi

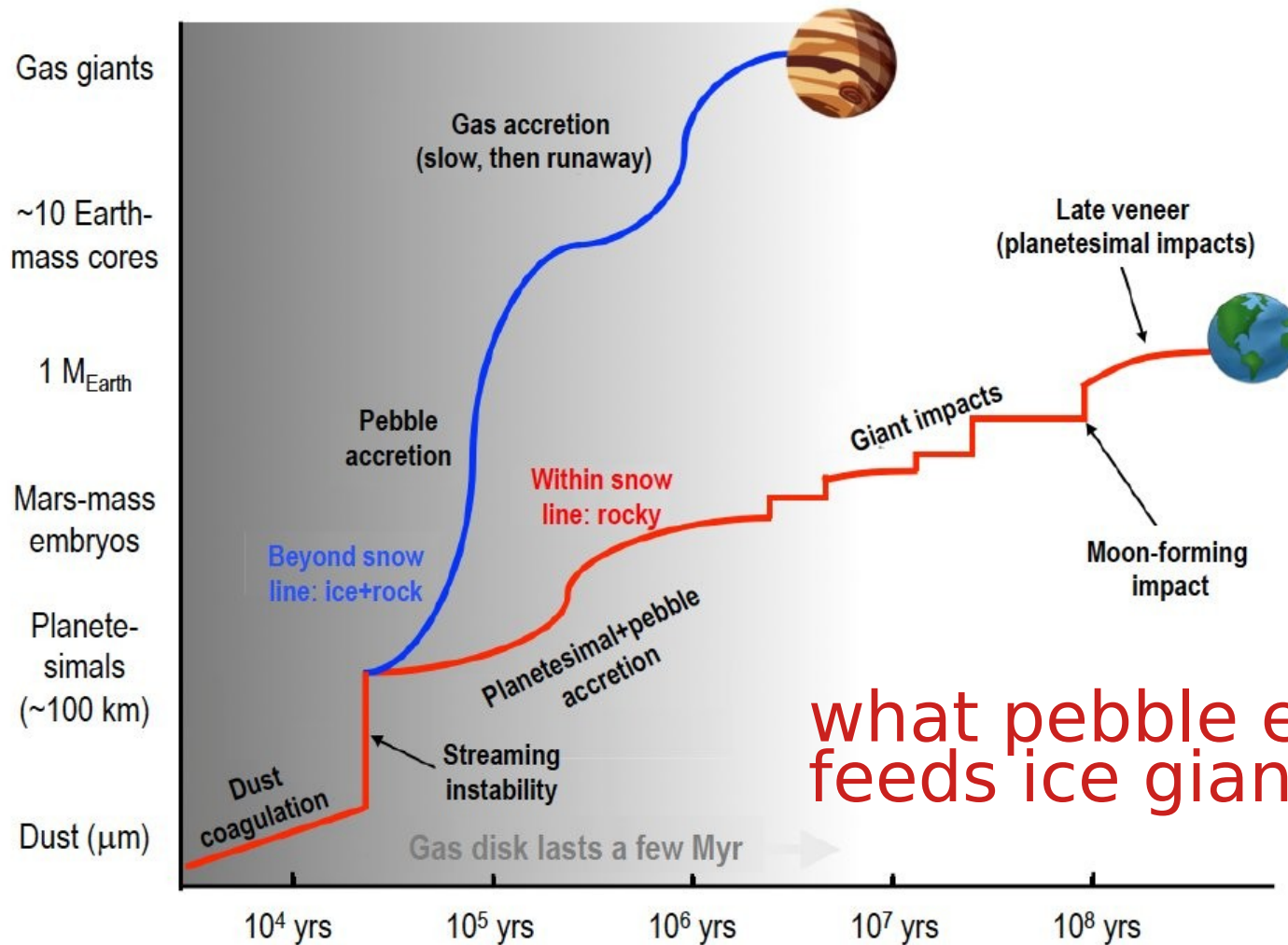


QUEEN'S  
UNIVERSITY  
BELFAST

environment

migration

acquisition

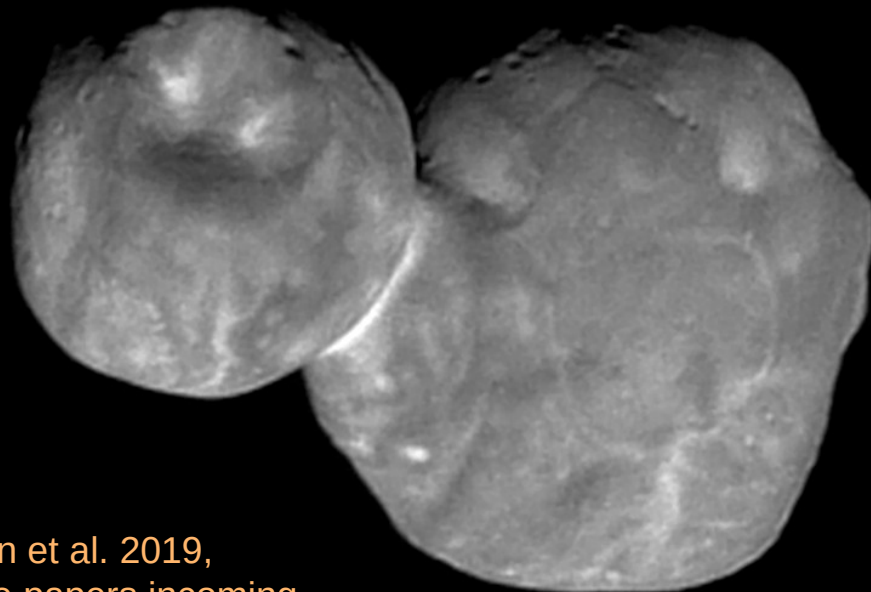


what pebble environment feeds ice giant accretion?

# What is the accretion environment of the ice giants?

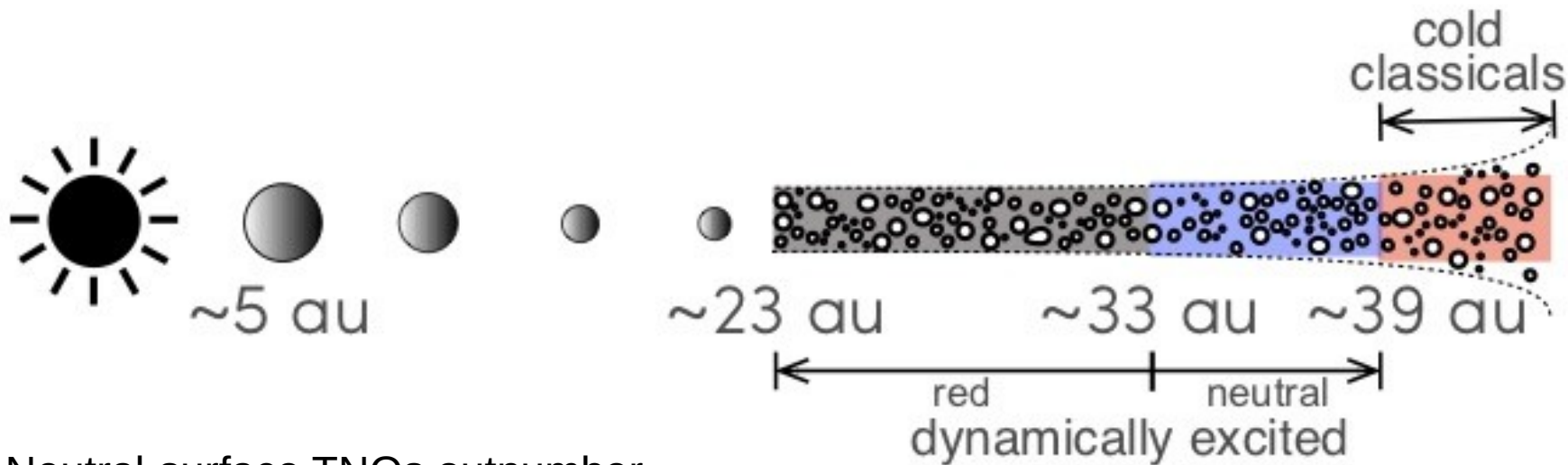
Independent constraints on the ice-to-rock balance in the source planetesimals

- NH flyby: Pluto/Charon (evolved), Arrokoth (primordial?)
- Constraints on disk composition from ground-based observation



Stern et al. 2019,  
more papers incoming

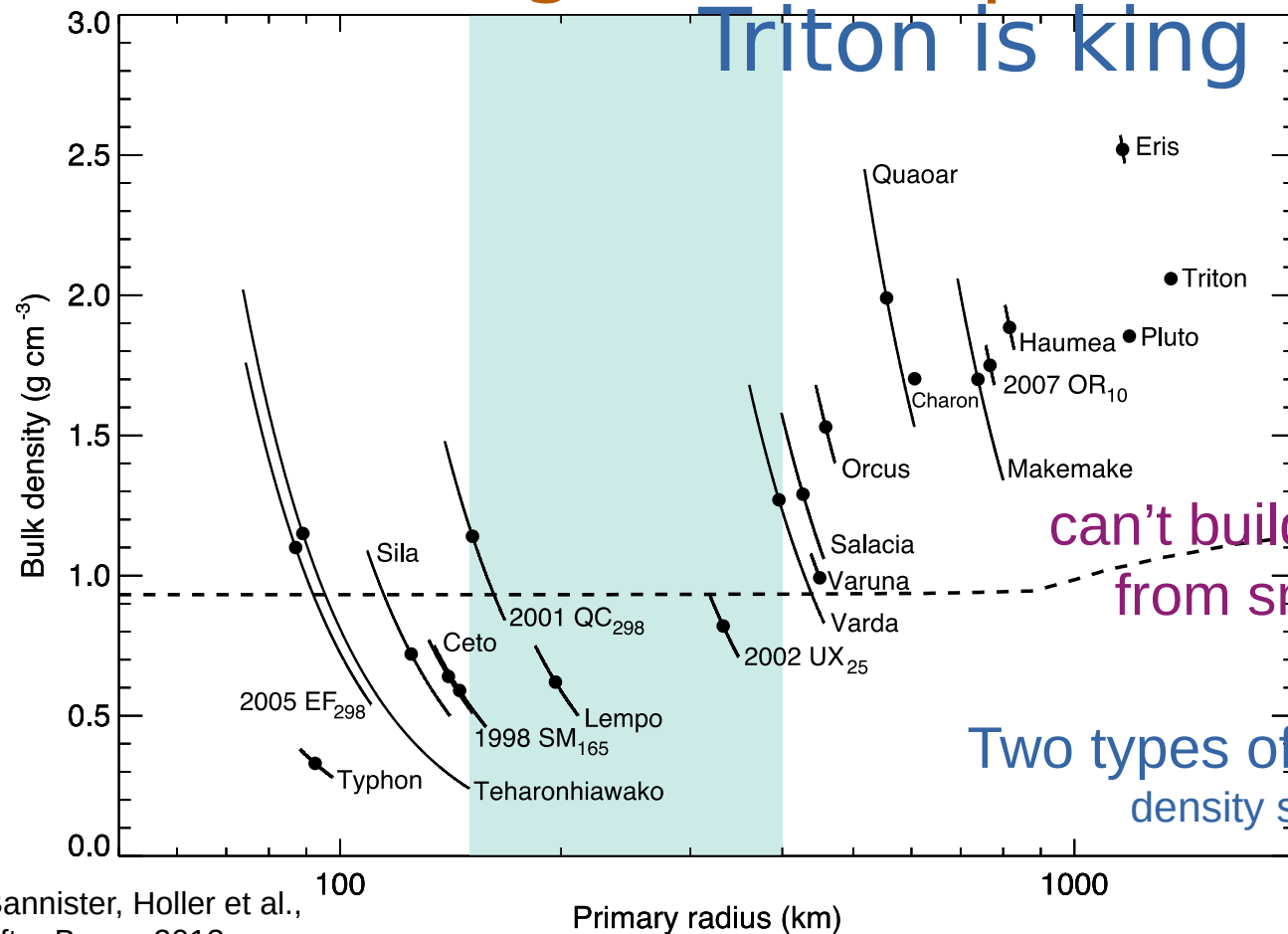
# Observations of colours for precise dynamical population sample: **infer disk composition**



Neutral-surface TNOs outnumber  
red-surface TNOs

Colours of OSSOS ---  
Schwamb, Fraser, Bannister et al. 2019  
arXiv: 1809.08501

# Among trans-Neptunian worlds, Triton is king



Sky surveys have  
completed the dwarf  
planet inventory to  
 $m_r \sim 21.5$

can't build big rock-rich worlds  
from small rock-poor worlds

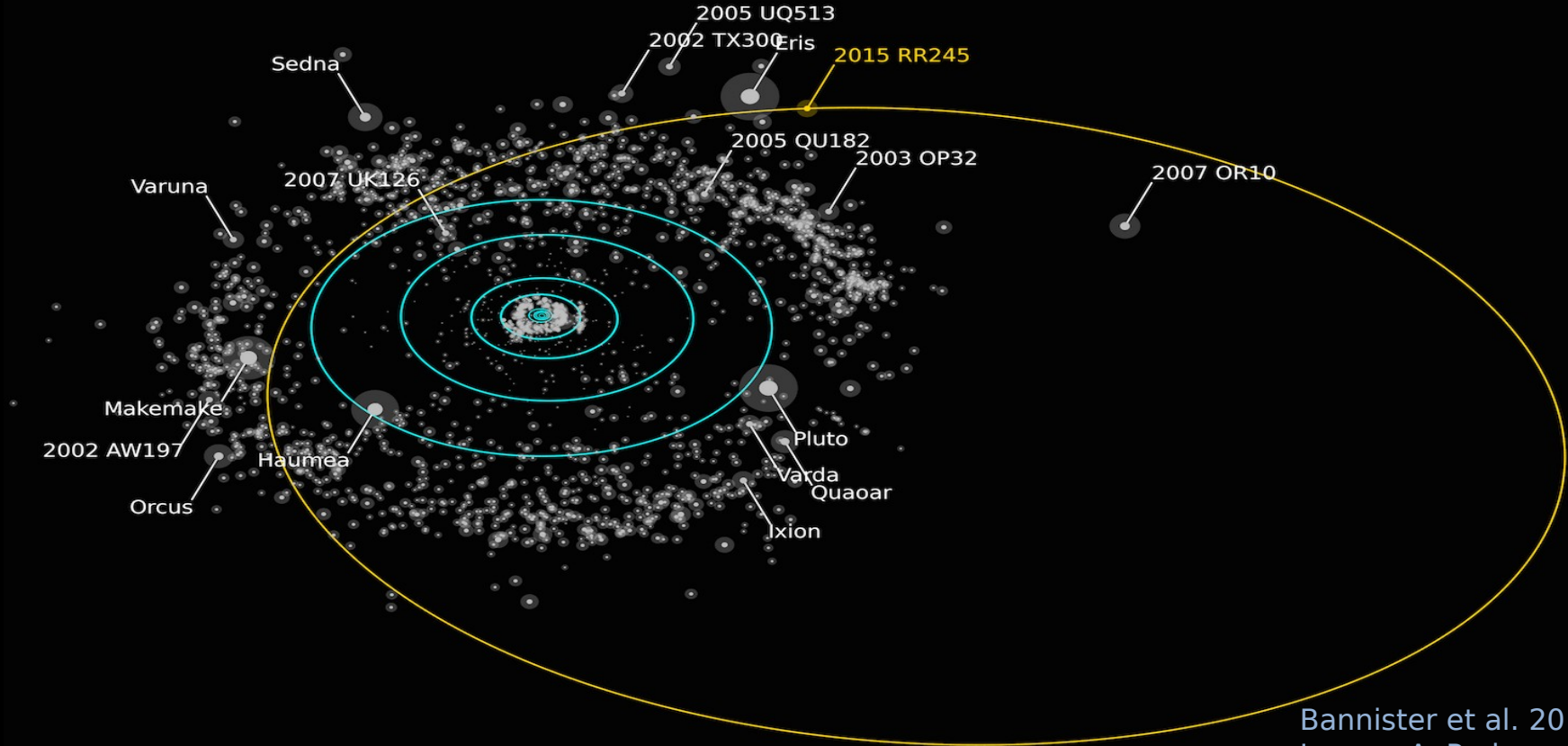
Brown 2013

Two types of collisional histories?  
density similar to Uranian satellites...

Barr & Schwamb 2016

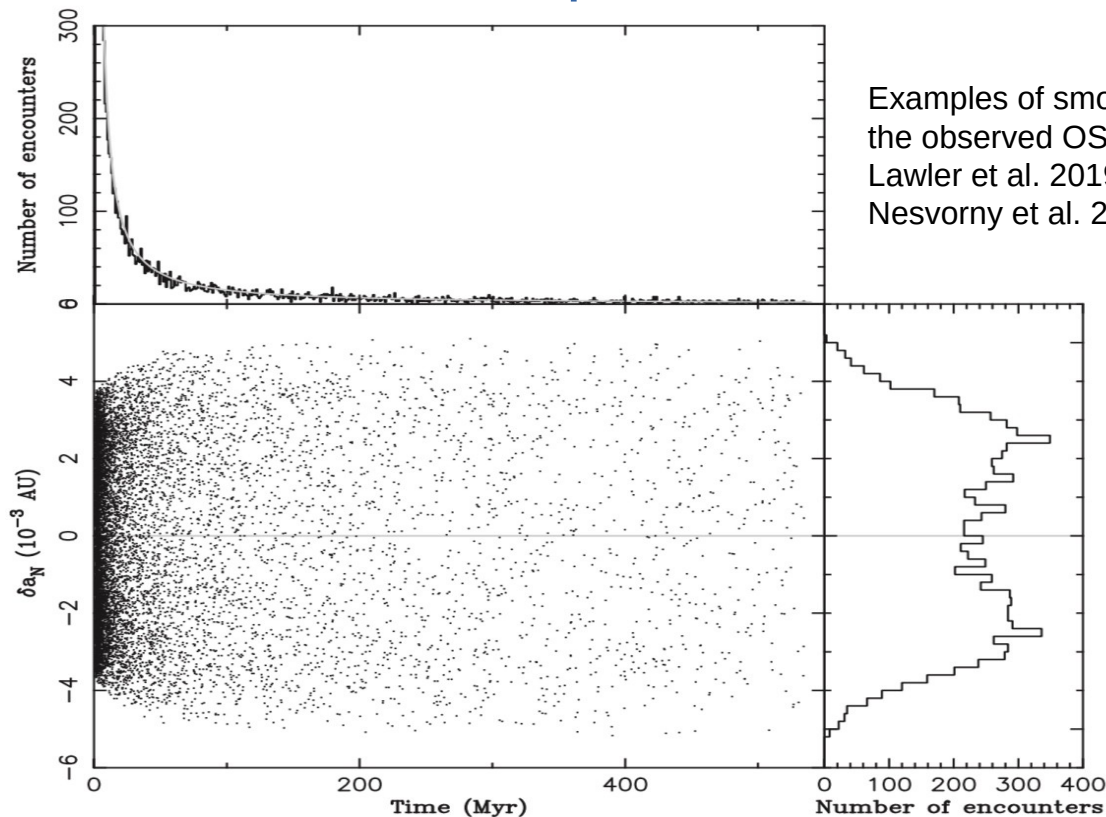
# How many Tritons?

migration emplaced many distant dwarf planets



# Neptune's smooth migration needs to be “grainy” from dwarf planets

Neptune goes  
'bounce' every  
time it comes  
near a dwarf  
planet



Examples of smooth migration matching  
the observed OSSOS TNOs:  
Lawler et al. 2019  
Nesvorný et al. 2019

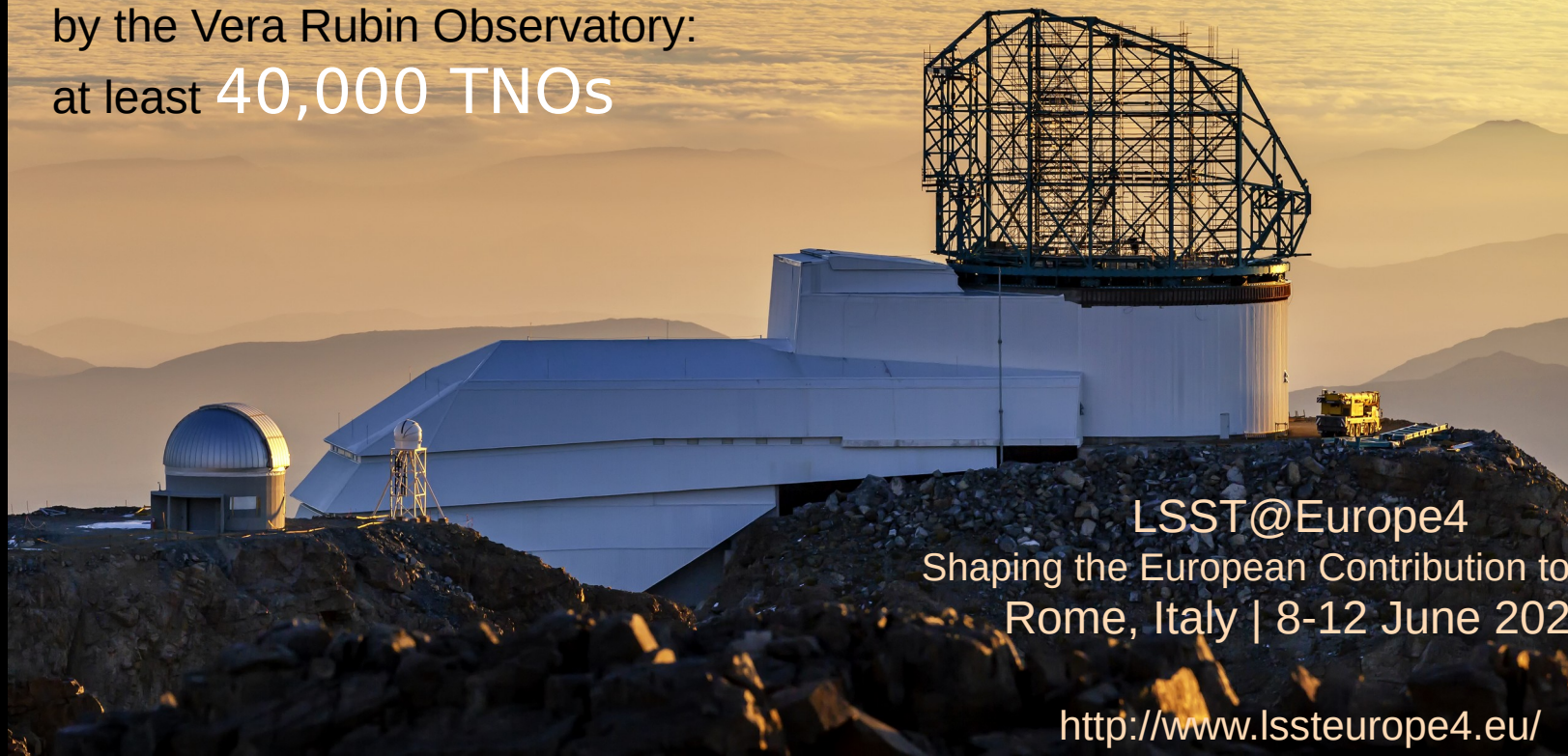


# How many Tritons? sky surveys constrain the original dwarf planet population

- ~100 H ~4 TNOs exist
- “Retention efficiency” over the entire outer Solar System is ~1%  
(Duncan & Levison 1997; Nesvorny & Vokrouhlicky 2016)
- There would have been ~10,000 such objects present when the giant planets began to clear the region.
- In line with primordial estimates of ~1000 Plutos  
(Stern 1991; Stern & Colwell 1997)

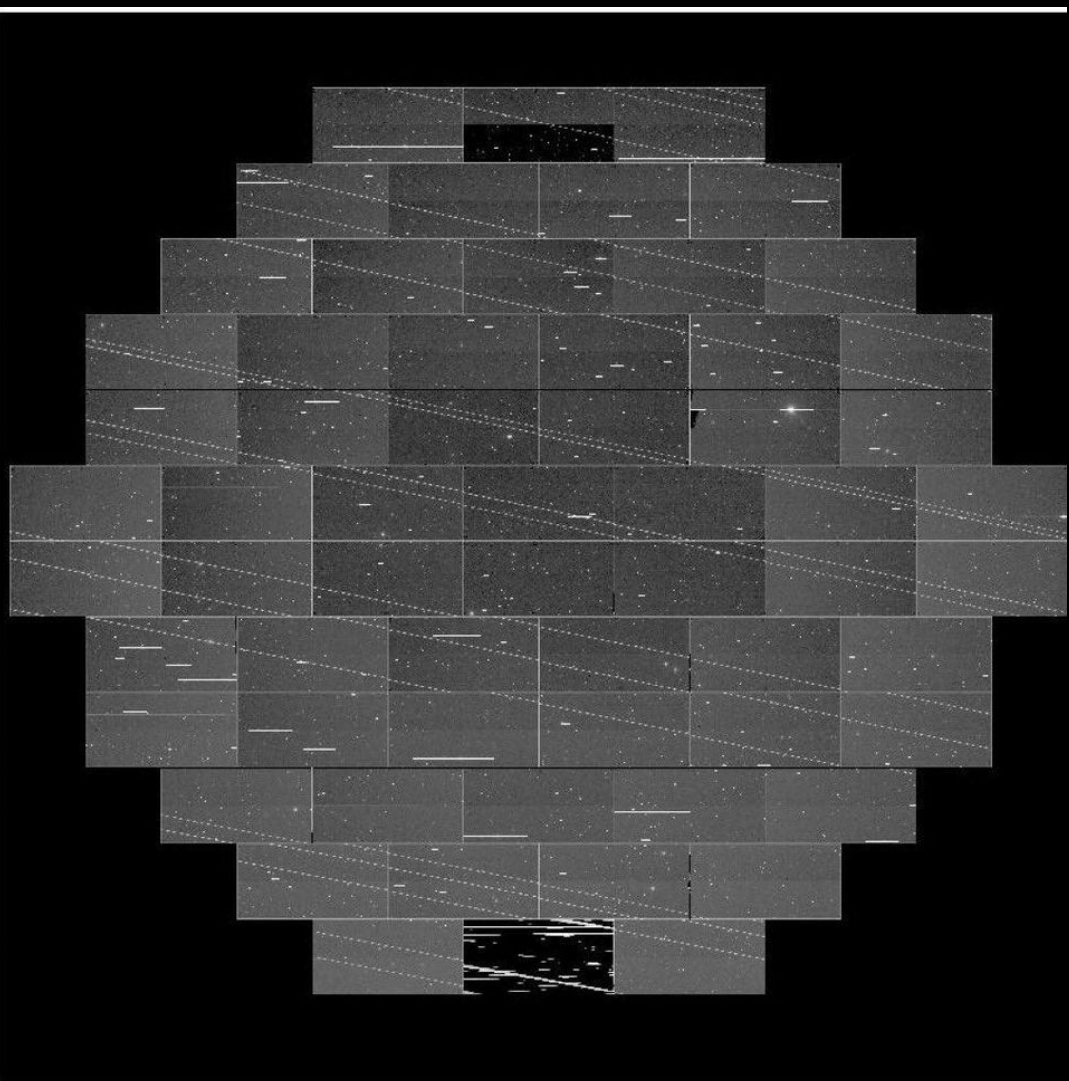
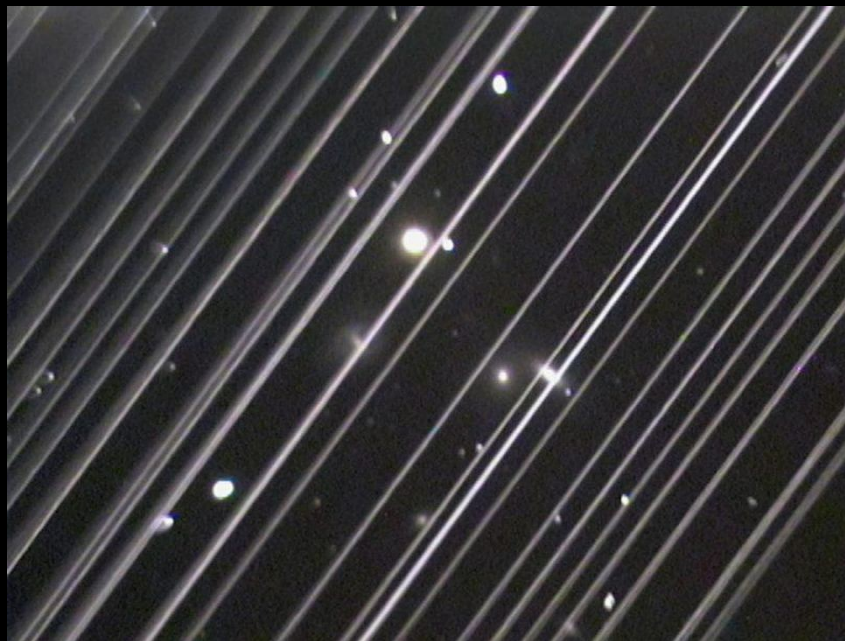


by the Vera Rubin Observatory:  
at least 40,000 TNOs



LSST@Europe4  
Shaping the European Contribution to LSST  
Rome, Italy | 8-12 June 2020

<http://www.lssteurope4.eu/>



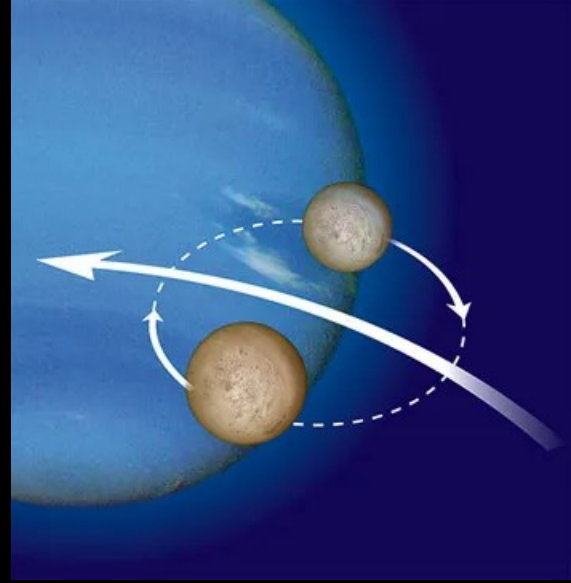


# Triton:

retrograde orbit means a captured TNO

McCord (1966), McKinnon (1984)

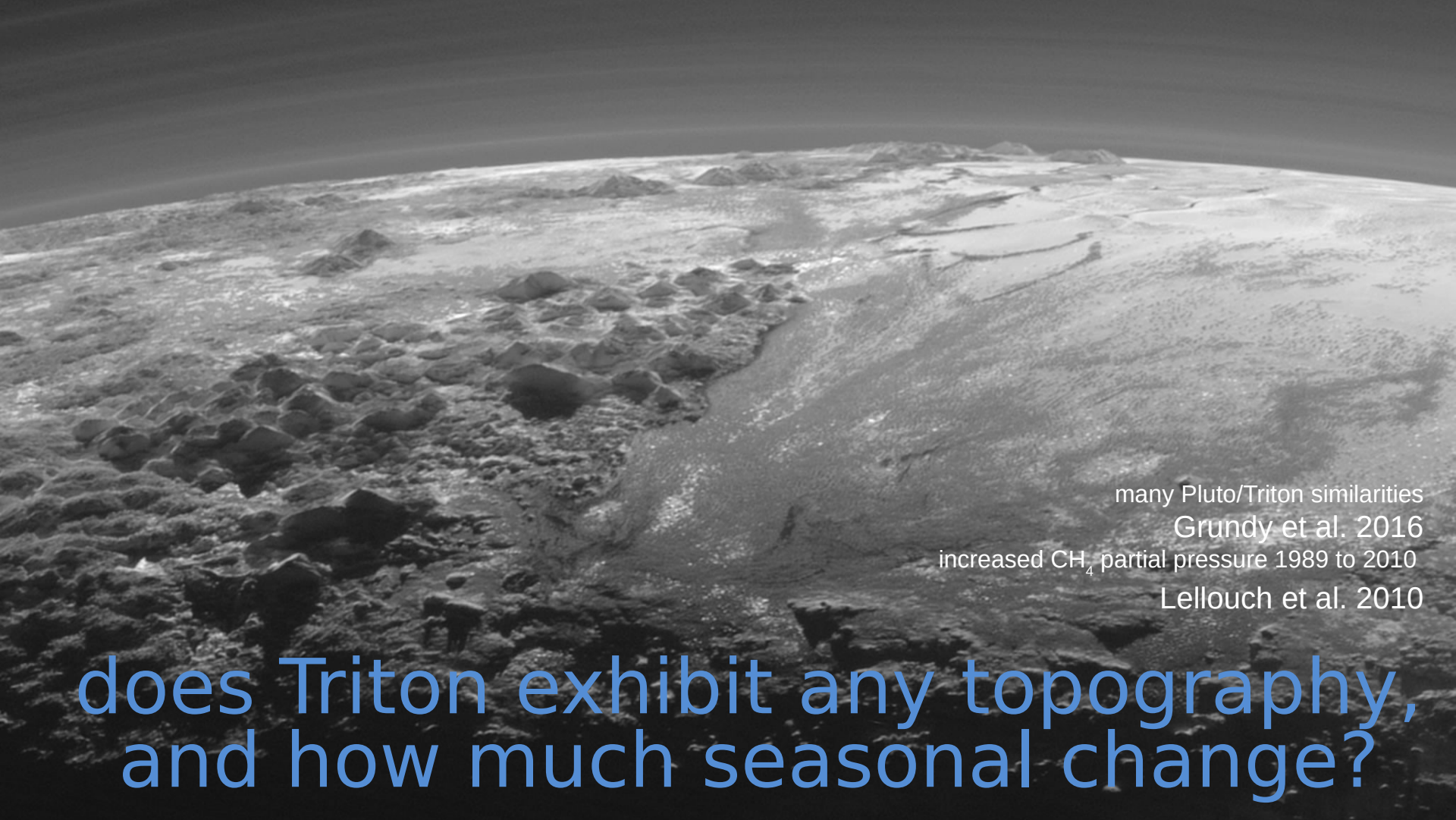
needs to be a binary! Agnor & Hamilton (2006)



# Is Triton also frozen yet young at heart?



Ongoing tidal stresses?  
Nimmo and Spencer 2015  
Ocean crystallisation event?  
Husmann et al. 2006  
Enhanced heat flux?  
Martin-Herrero et al. 2018



many Pluto/Triton similarities

Grundy et al. 2016

increased  $\text{CH}_4$  partial pressure 1989 to 2010

Lellouch et al. 2010

does Triton exhibit any topography,  
and how much seasonal change?



# How active can Triton be?

~100 Ma surface

Stern and McKinnon 2000

Curvilinear features

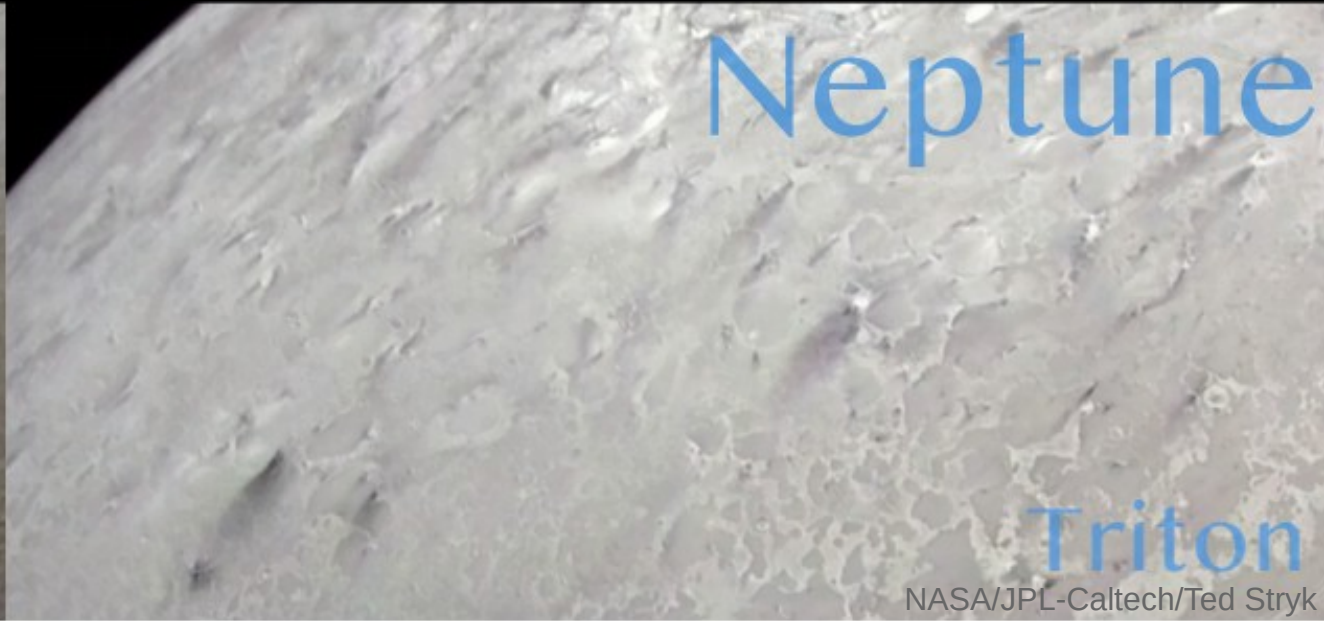
Prockter et al. 2005

active nitrogen gas geysers in the south polar terrains

CO, N<sub>2</sub> intimately mixed ices; complex organics

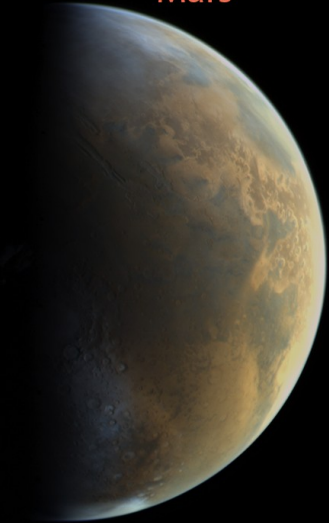
Soderblom et al. 1990

Tegler et al. 2019; Thompson and Sagan 1990



# How common are Tritons in the wider universe?

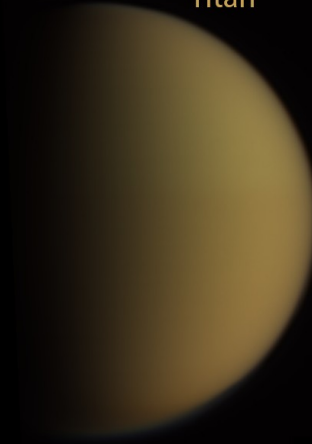
Mars



Ganymede



Titan



Mercury



Callisto



Eris



Pluto



Triton



Europa



Moon



Io





# Open questions

Our planetary system formed **thousands** of dwarf planets.  
How collisionally evolved were those the ice giants ate?

Triton:  
similar yet different from other dwarf planets  
an ocean?  
**ongoing activity?**

example for an exoplanet-common type of ocean world?