The Binarity, Compositions (and a few Sizes) of Kuiper Belt Objects: Revealing the Solar System's Formation

Wes Fraser

Queen's University, Belfast

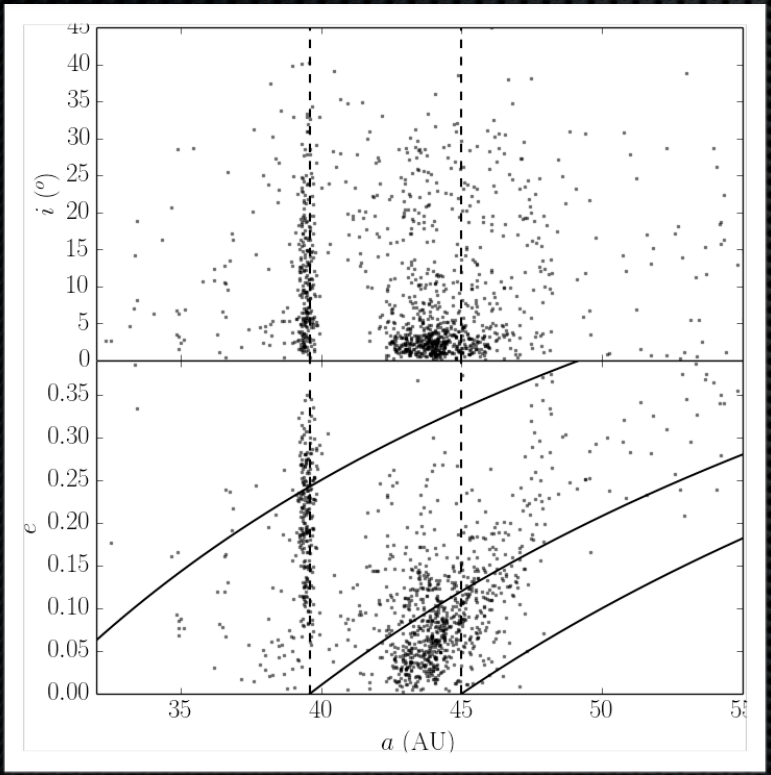
“We understand if it breaks, then Wide Field (Planetary Camera 2) stays in”

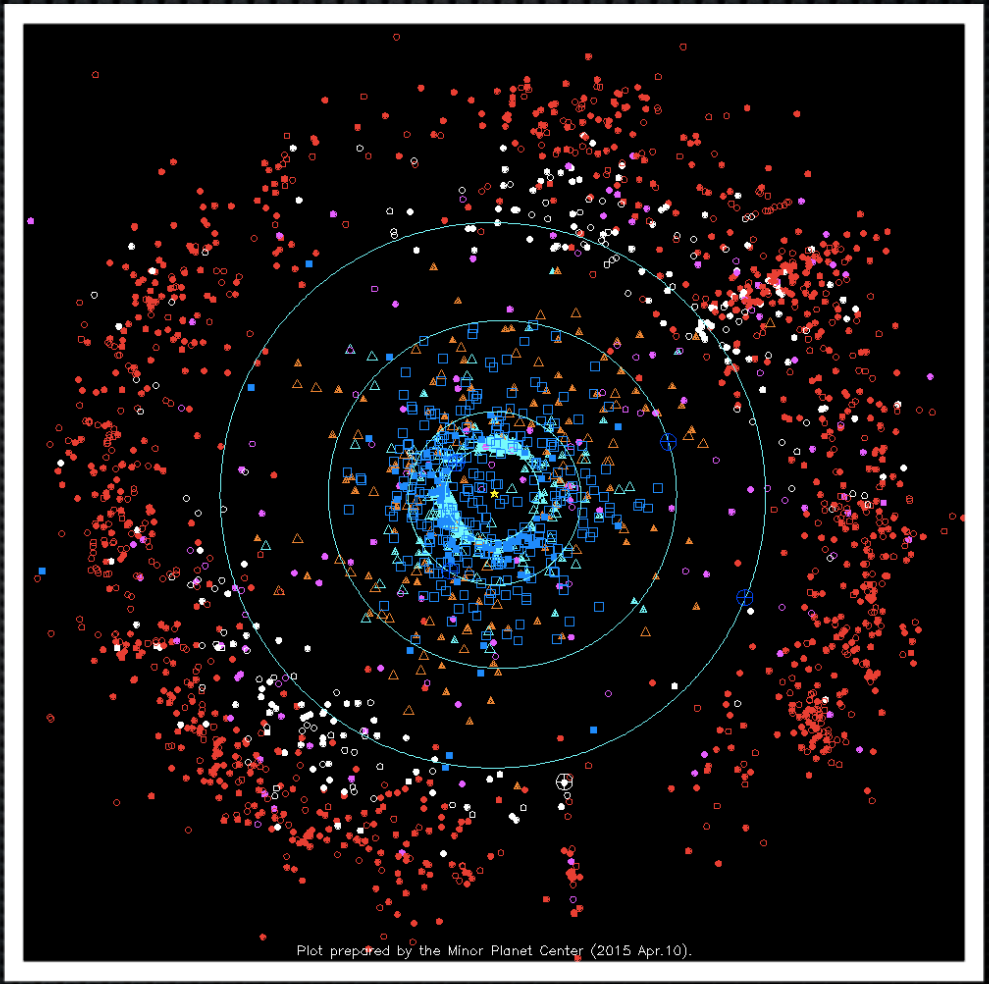
- John Grunsfeld

The Kuiper Belt

2016

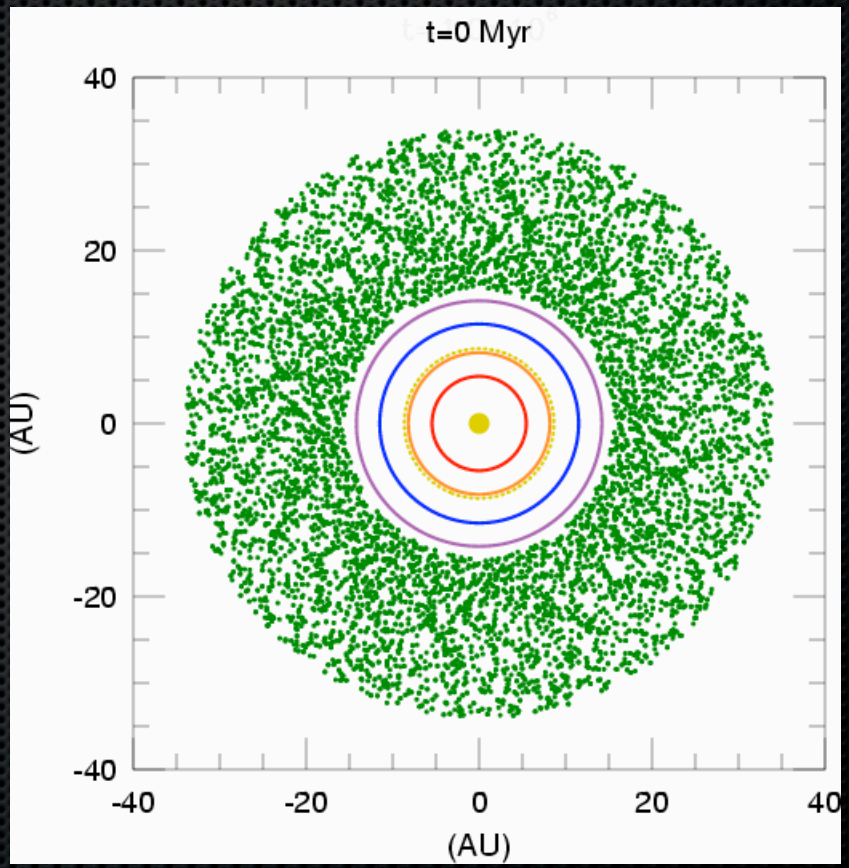
The Kuiper Belt





Formation Mechanisms

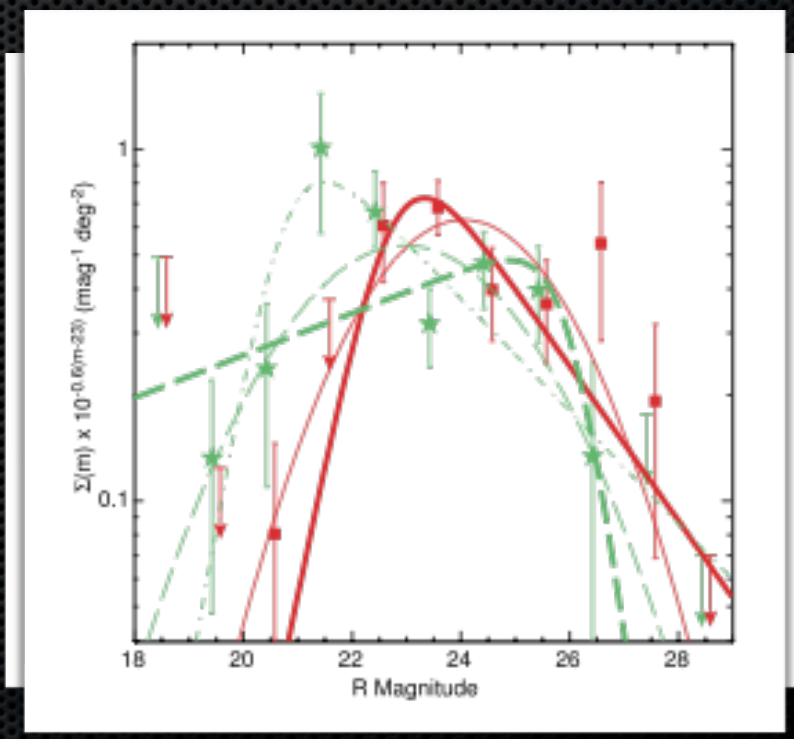
- some “push-out” mechanism was required
- depletion of 90-99.9% of initial mass
- produced majority of KBO dynamical structure



Courtesy of Rodney Gomes

HST: The TNO Size Distribution

- Bernstein et al. (2004)
- Fuentes et al. (2010)
- Schlichting et al. (2009/2013)
- Parker and the New Horizons Team (LPSC 2015)



Bernstein et al. (2004)

The Nice Model is Basically Correct

And so was Bernstein

- Size Distribution is a broken power-law
- Hot component matches the Jupiter Trojans

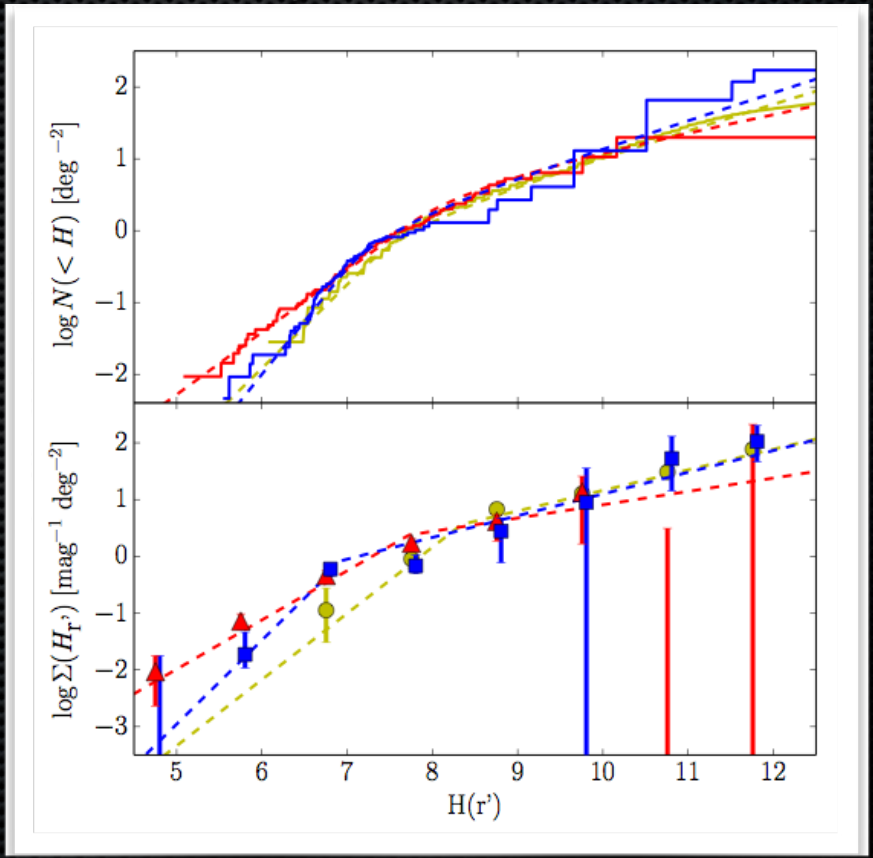
HST:

- 73 hours (100 orbits) = 3 detections
- 37 hours (60 orbits, Parker) = 3 detections

JWST:

- prediction of Levison et al. (2008), Morbidelli et al. (2009)
- 4 hours = 8 detections

$$H = K - 2.5 \log\left(\left(\frac{D}{100\ \mathrm{km}}\right)\rho\right)$$



Fraser et al. (2014)

New Horizons: Hubble to the Rescue!

- New Horizons launched on the premise that a second fly-by target would be found
- but galactic plane
- 160 orbit HST search for the next NH target
- images courtesy of Alex Parker and the NH team

The Nice Model is Basically Correct

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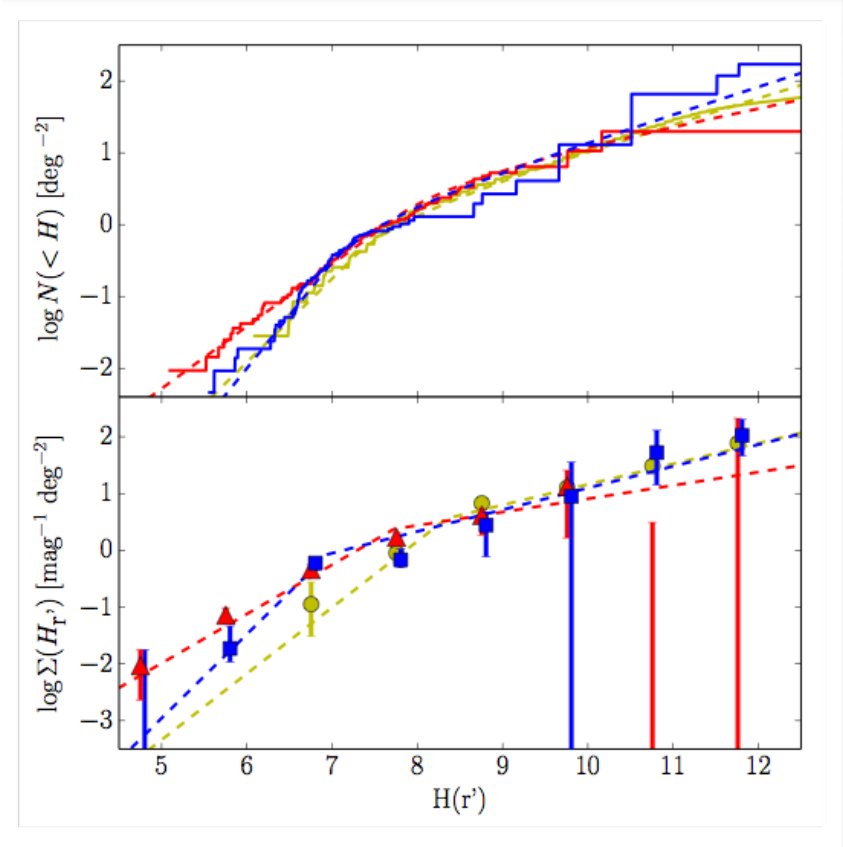
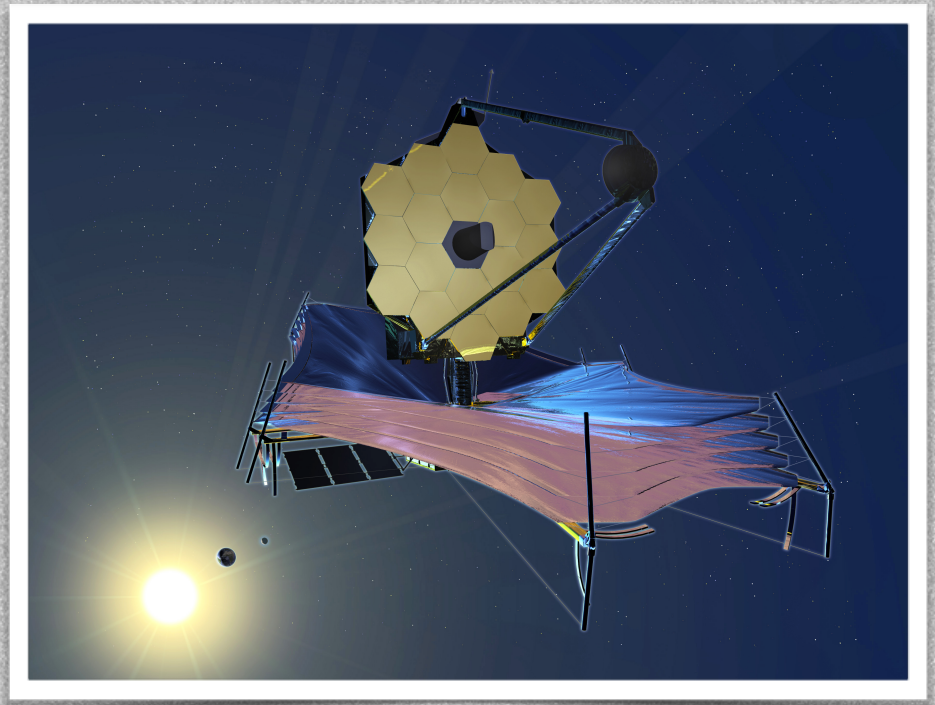
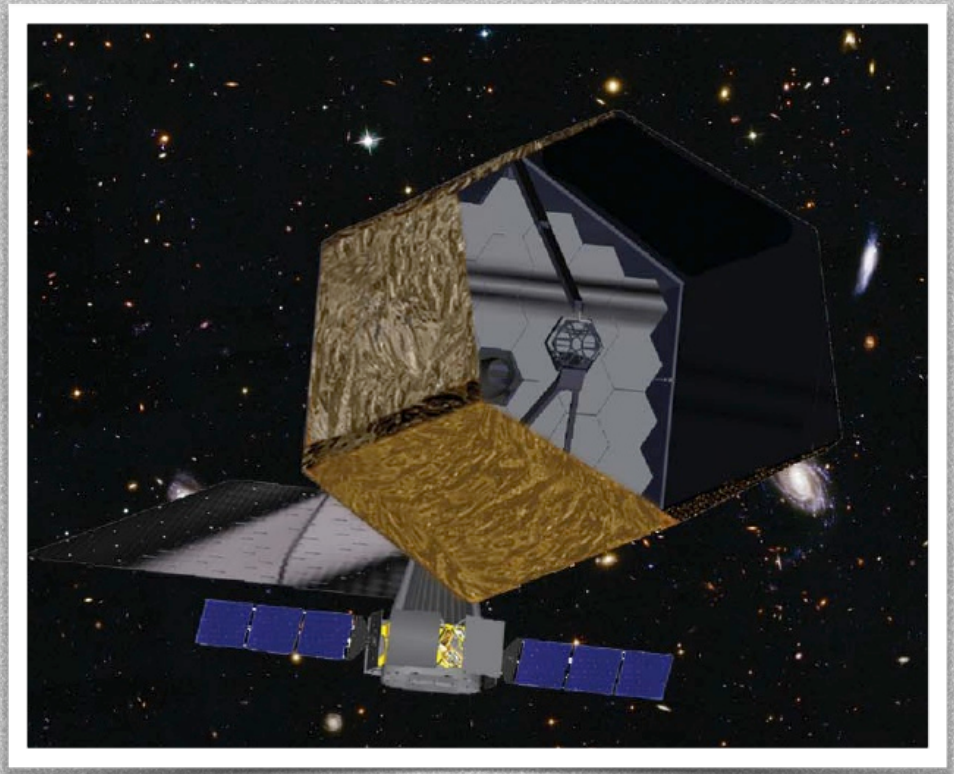


Fraser et al. (2014)

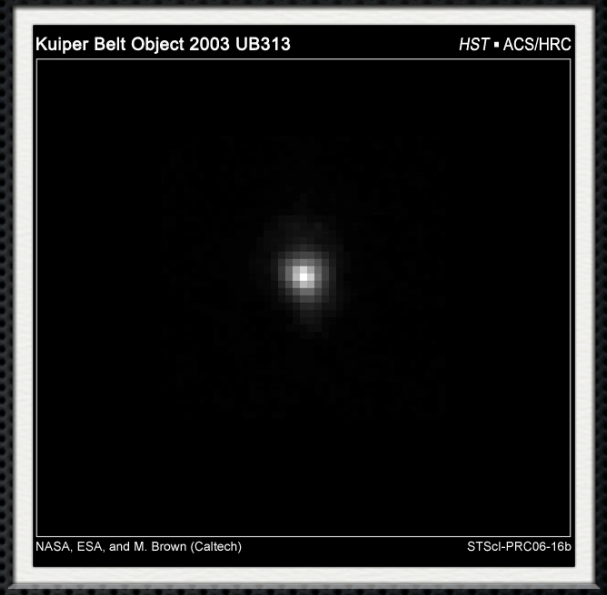


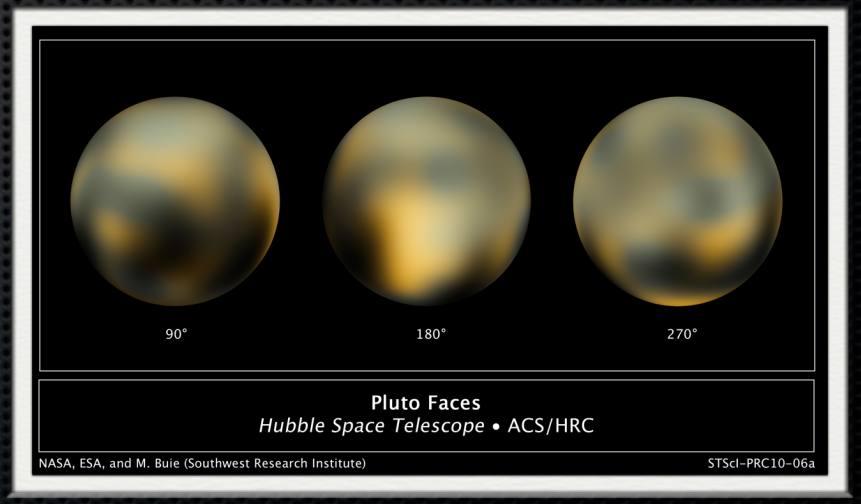


HST: Resolving[ish] Dwarf Planets

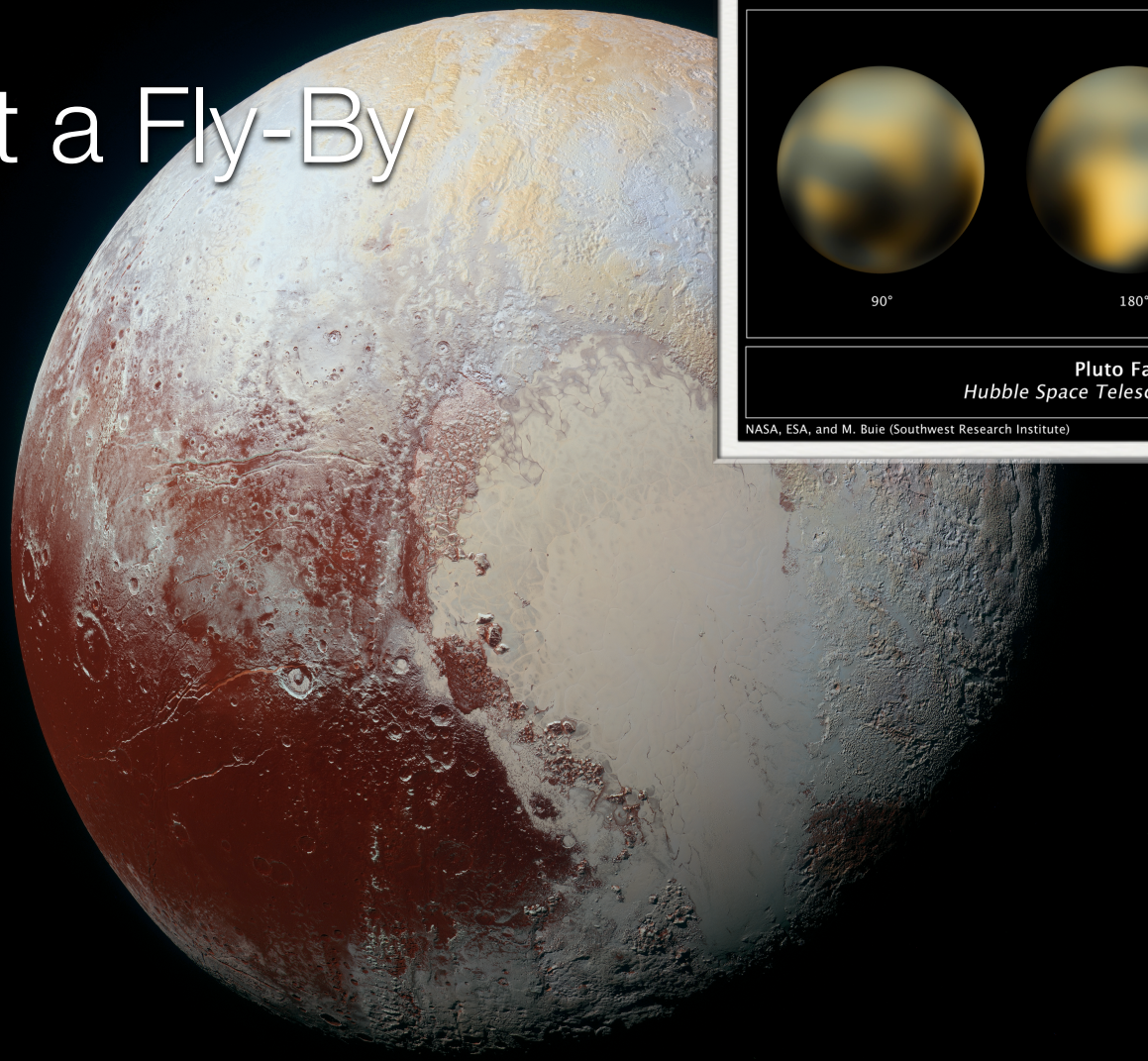
Sizes:

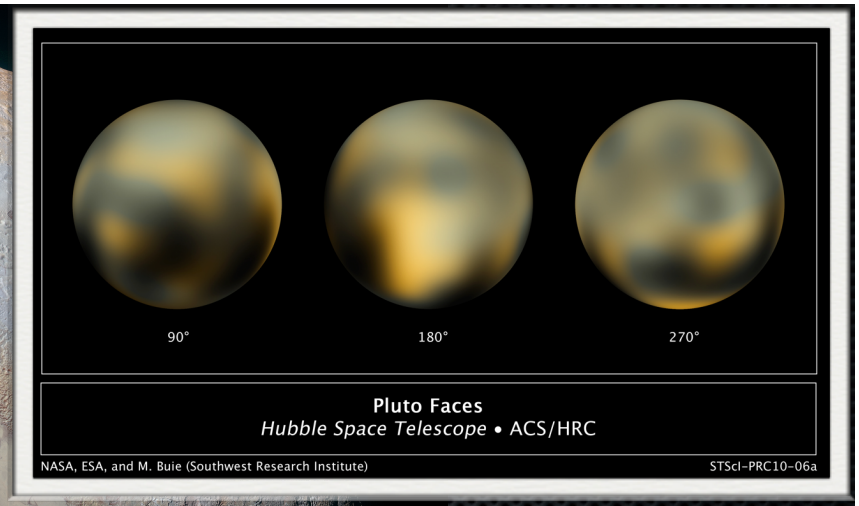
- Eris - Brown et al. (2006)
- Pluto - Buie et al. (2010)
- Quaoar - Brown and Trujillo (2004)



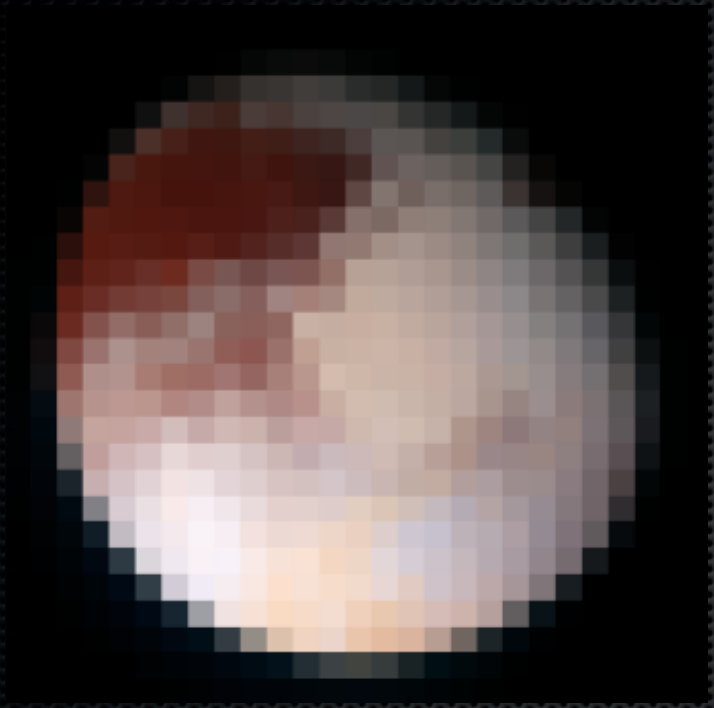


Can’t Beat a Fly-By





But you can do pretty darned well!



Pluto, 0.08”

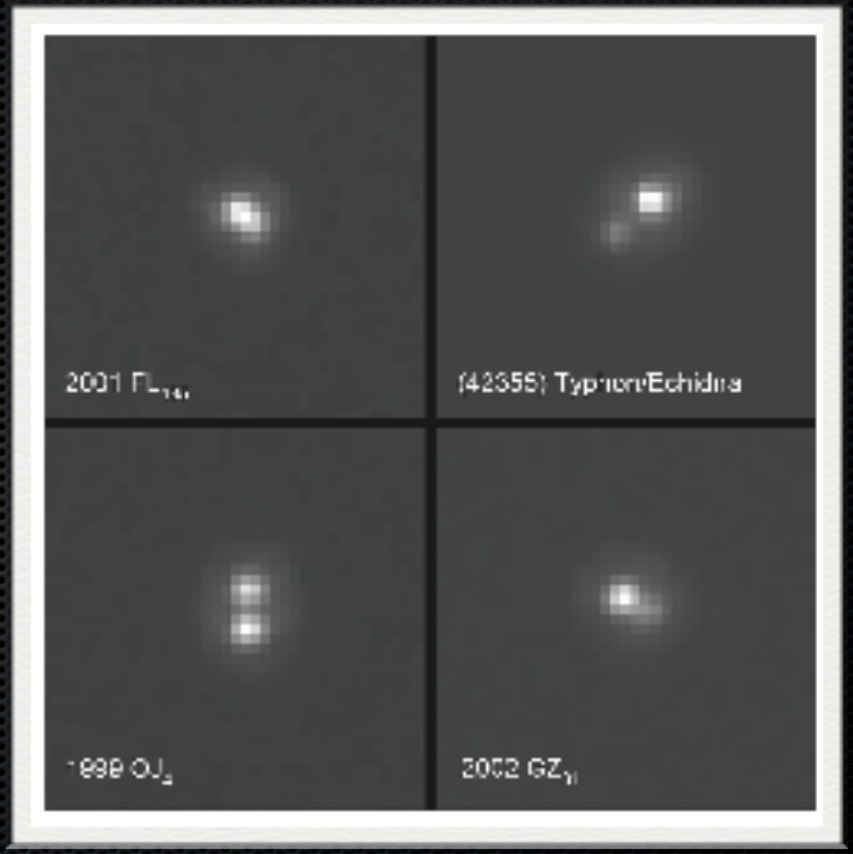
Eris, 0.03”

Makemake, 0.036”

Orcus, 0.027”

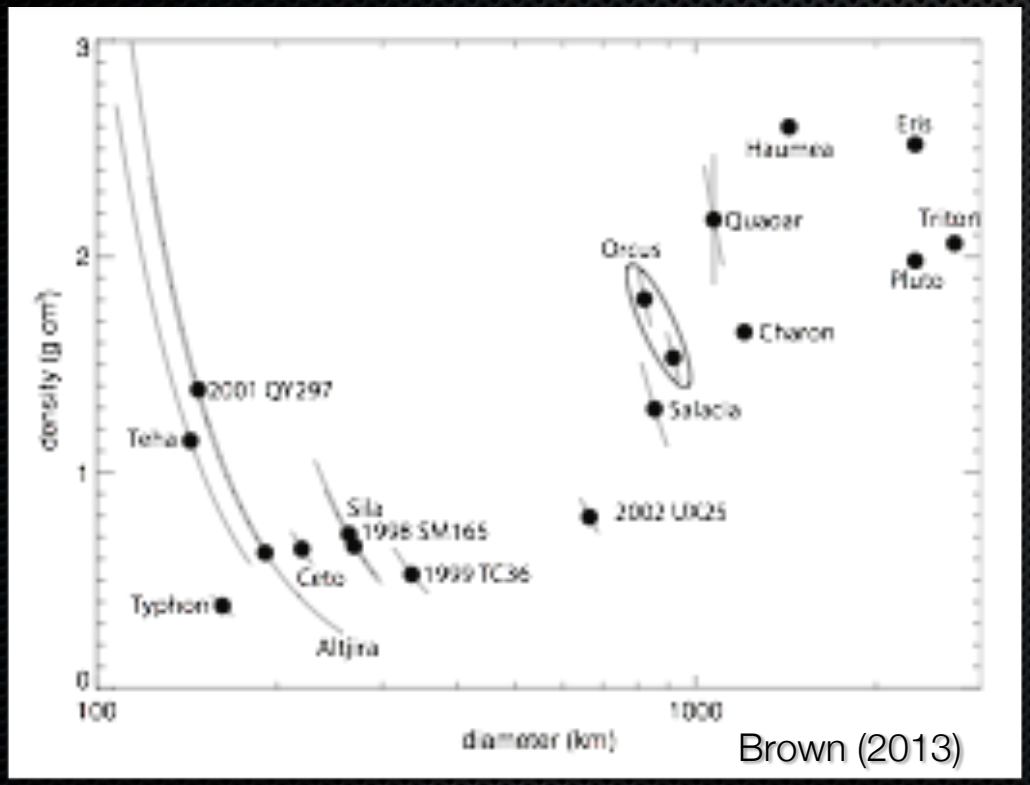
KBO Multiplicity

- Brown and Trujillo (2002 ab)
- Noll et al. (2003, 2006 abcdef)
- Stephens and Noll (2006)
- Benecchi et al. (2008,2010)
- Grundy et al. (2009)

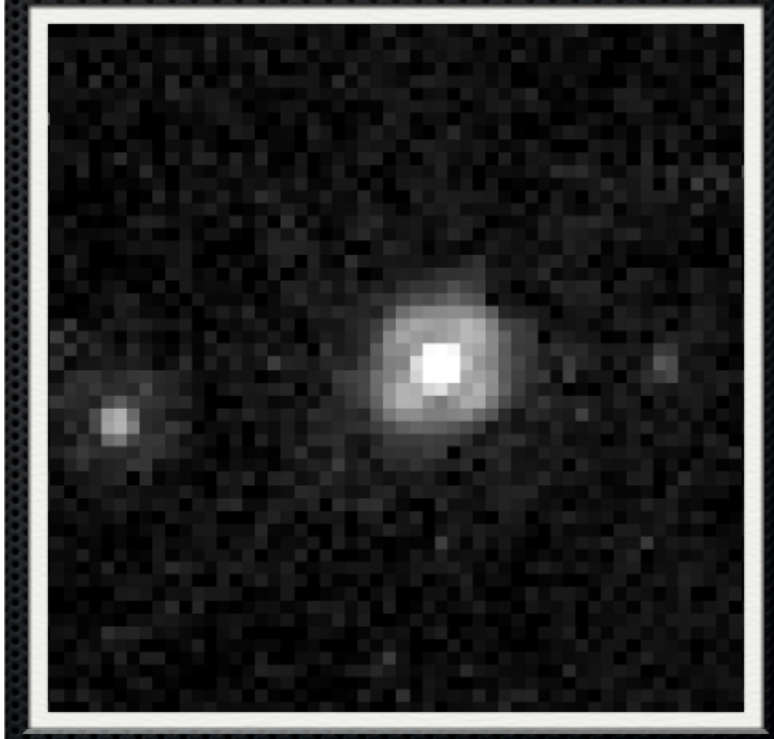


Noll et al. 2008, SSBN Review

Weighing the Dwarf Planets



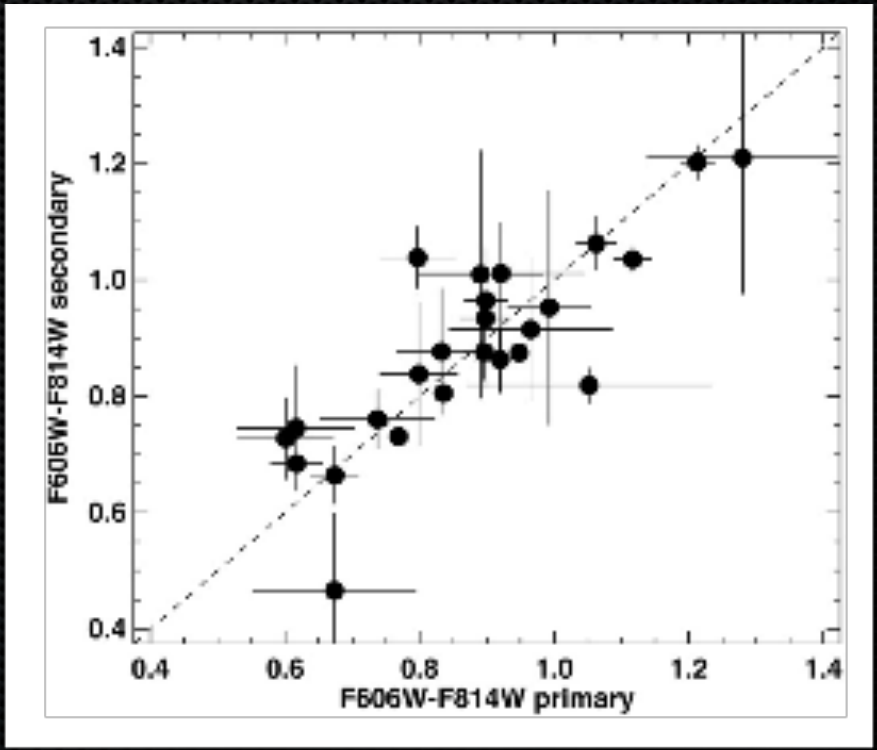
Brown (2013)



Ragozzine et al. (2009)

Binaries: Formation Conditions

- probes of early disk conditions
  - small body density (eg. Goldreich et al. 2002)
  - bulk dynamics (Parker et al. 2010)
  - disk compositional structure (Benecchi et al. 2008)



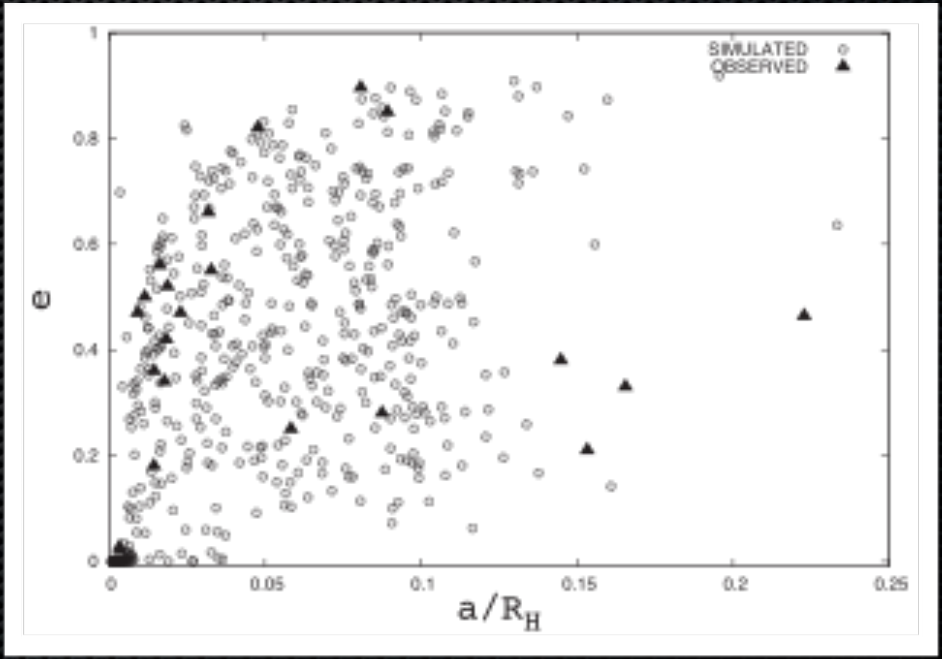
Benecchi et al. 2008

Binaries: Evolution

Binaries: Evolution

UVOIR Binary Detection

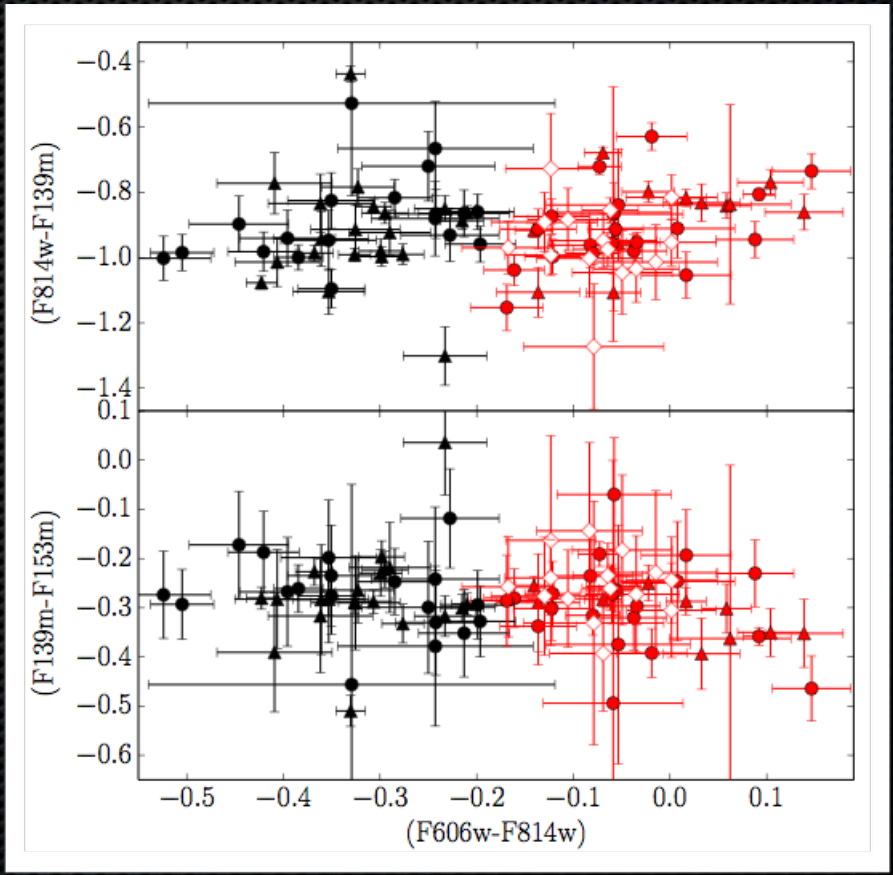
- with HST binary detection is only resolution limited
- huge parameter space left to probe



Bruini and Zanardi (2016)

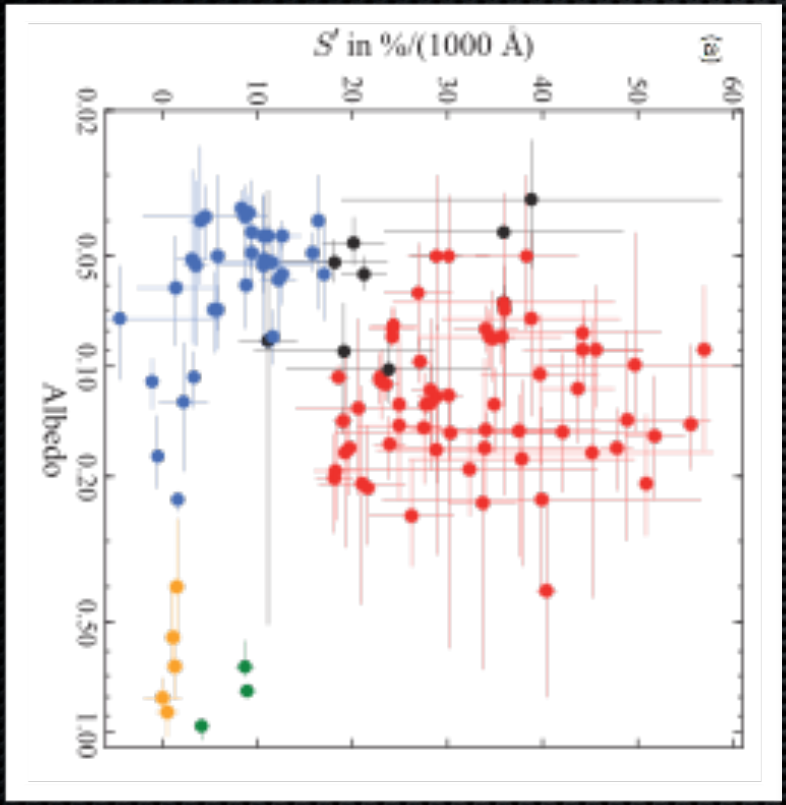
KBO Compositions

- First Taxonomy: Barucci et al. (2005)
- Bimodal Colours: Tegler and Romanishin (2003)
- Bimodal Albedos: Stansberry et al. (2008)
- Compositional Classes: Fraser and Brown (2012), **H/WTSOSS**

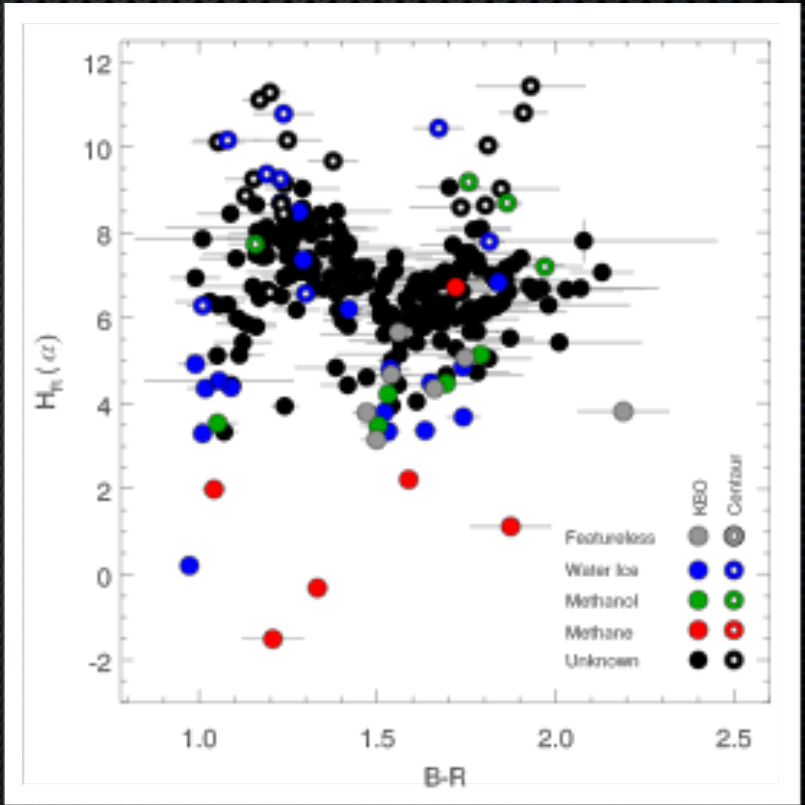


Fraser and Brown (2012)

Two Types of Small KBO



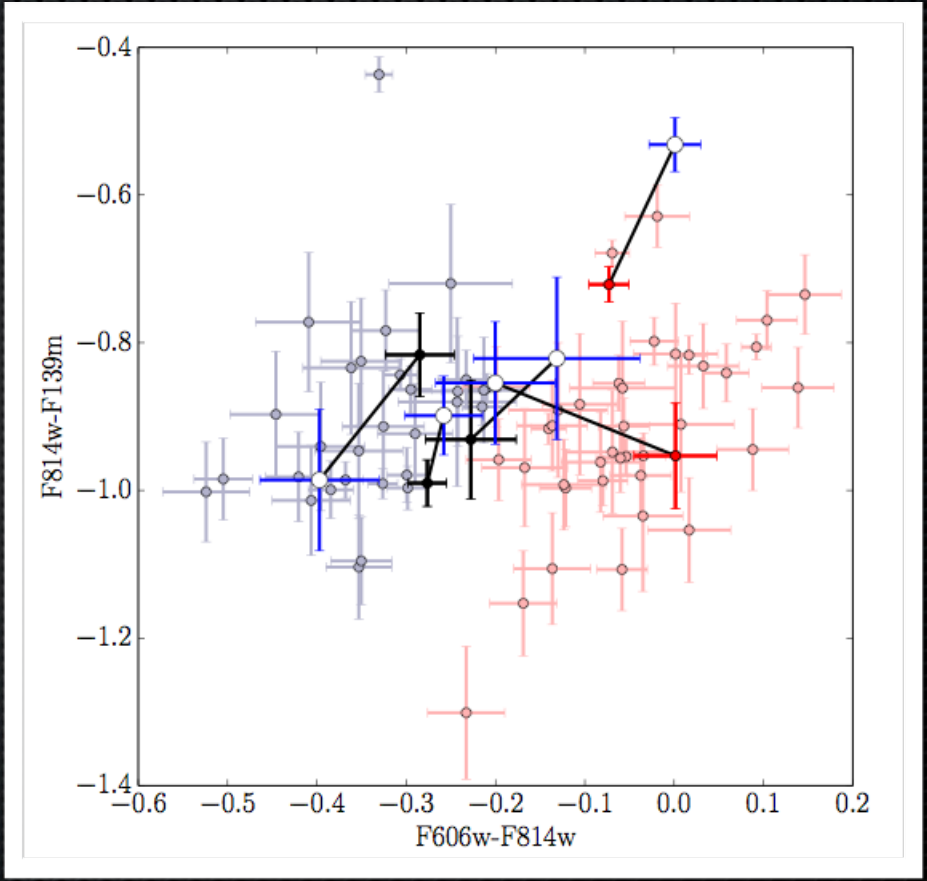
Lacerda et al. (2015)



Peixinho et al. (2012)

KBO Compositions

- spectral variability suggests there are truly only two surface classes
- implies a homogenous disk
- post-formation volatile loss is a good candidate for different classes



Fraser et al. (2015)

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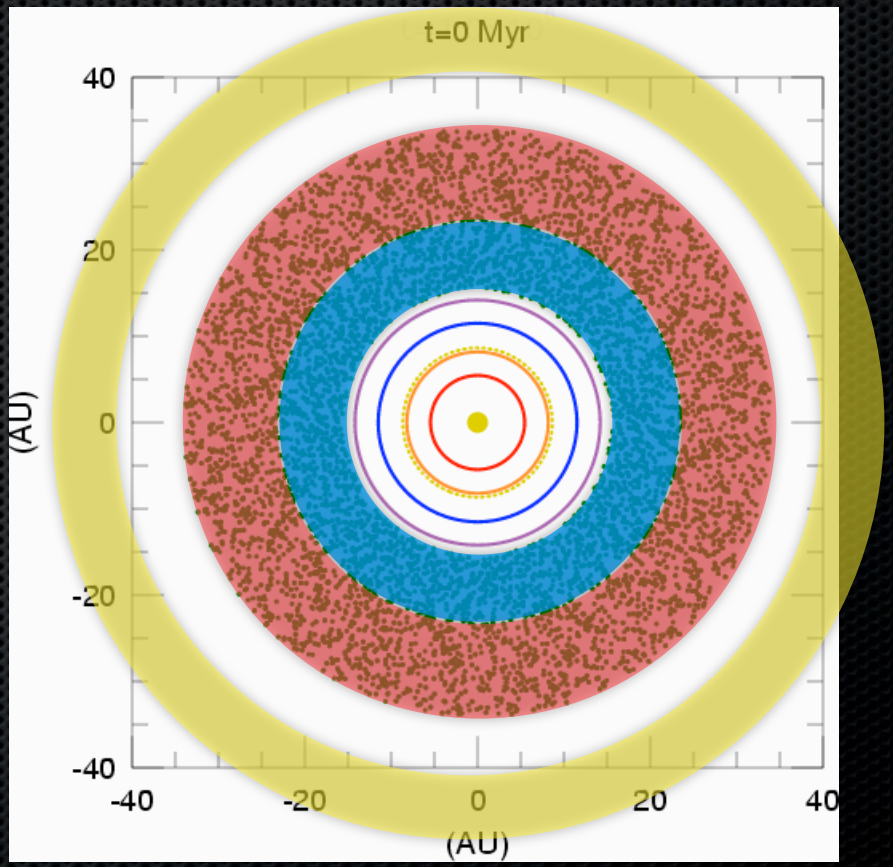
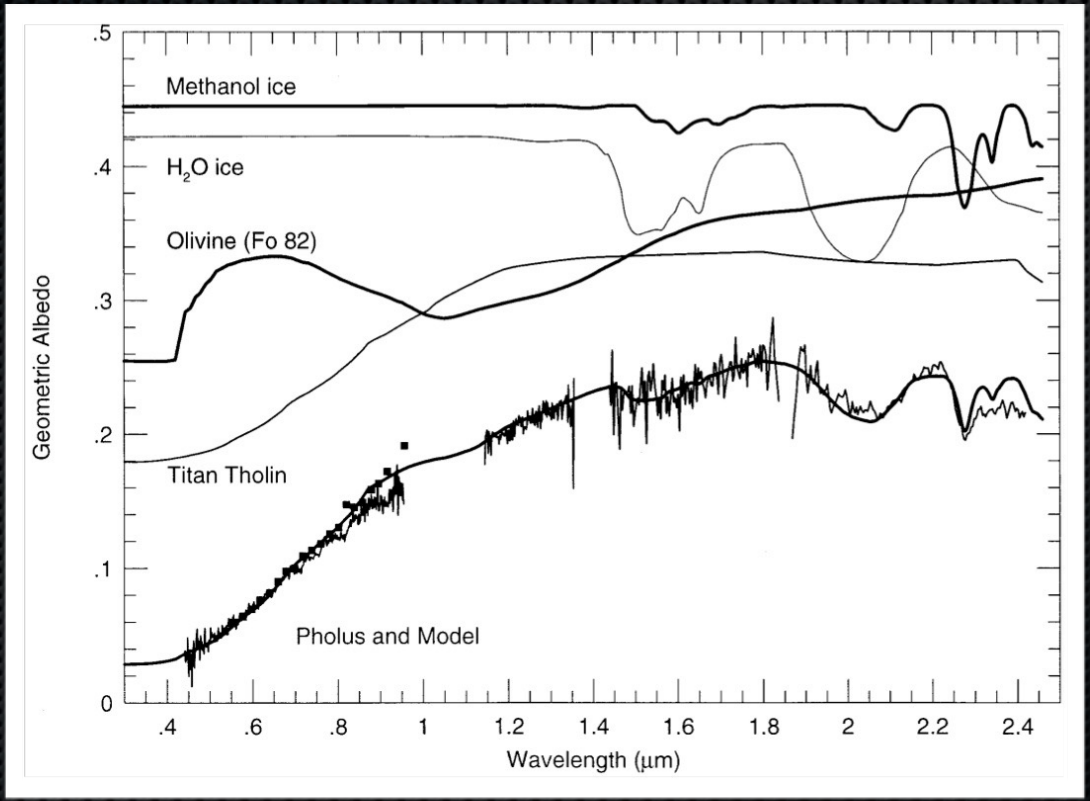
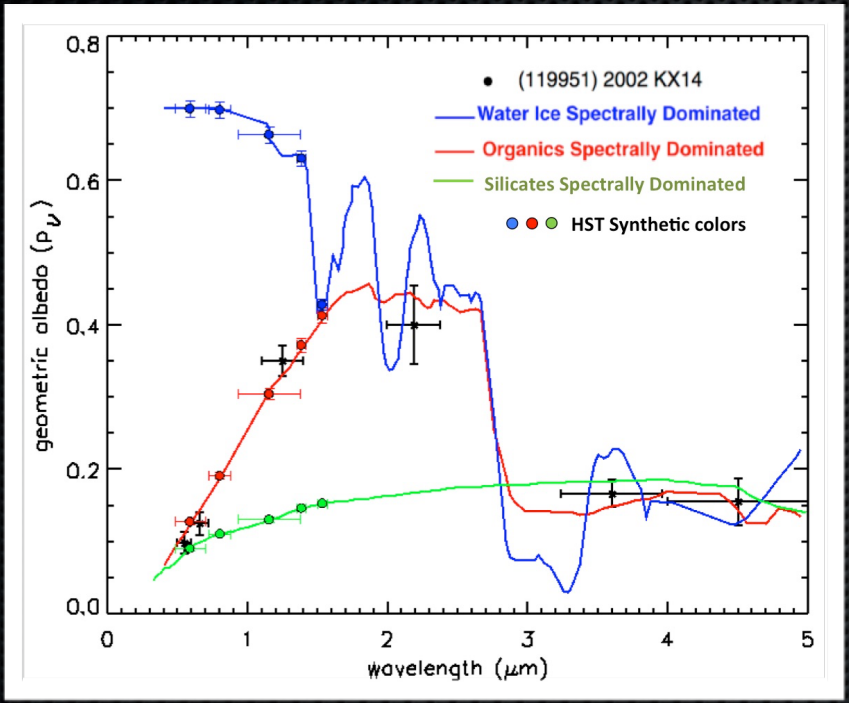


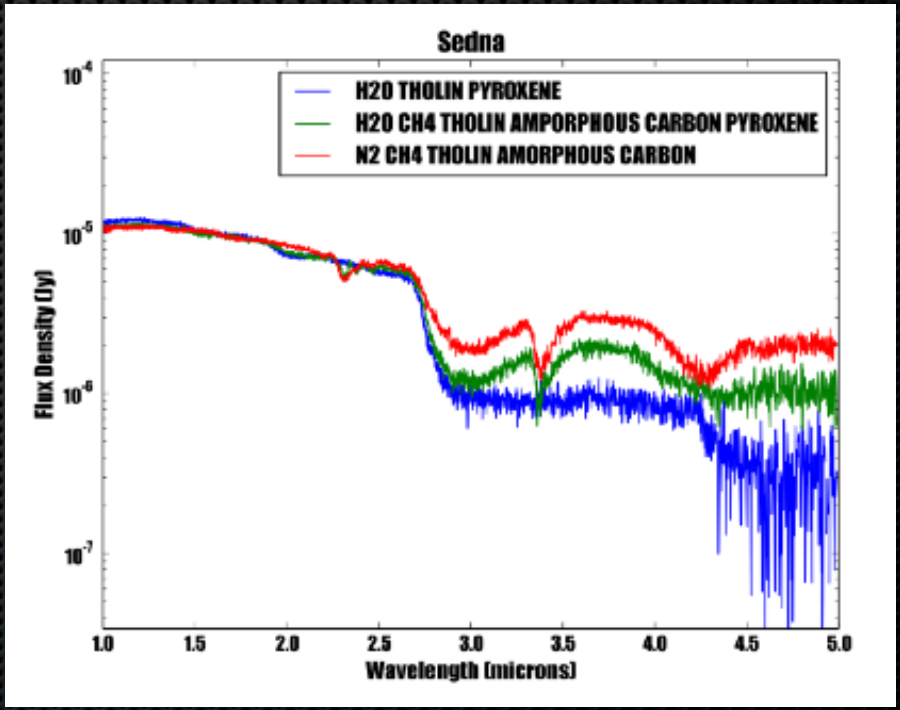
Typical Small KBO Spectrum



Cruikshank et al. (1998)

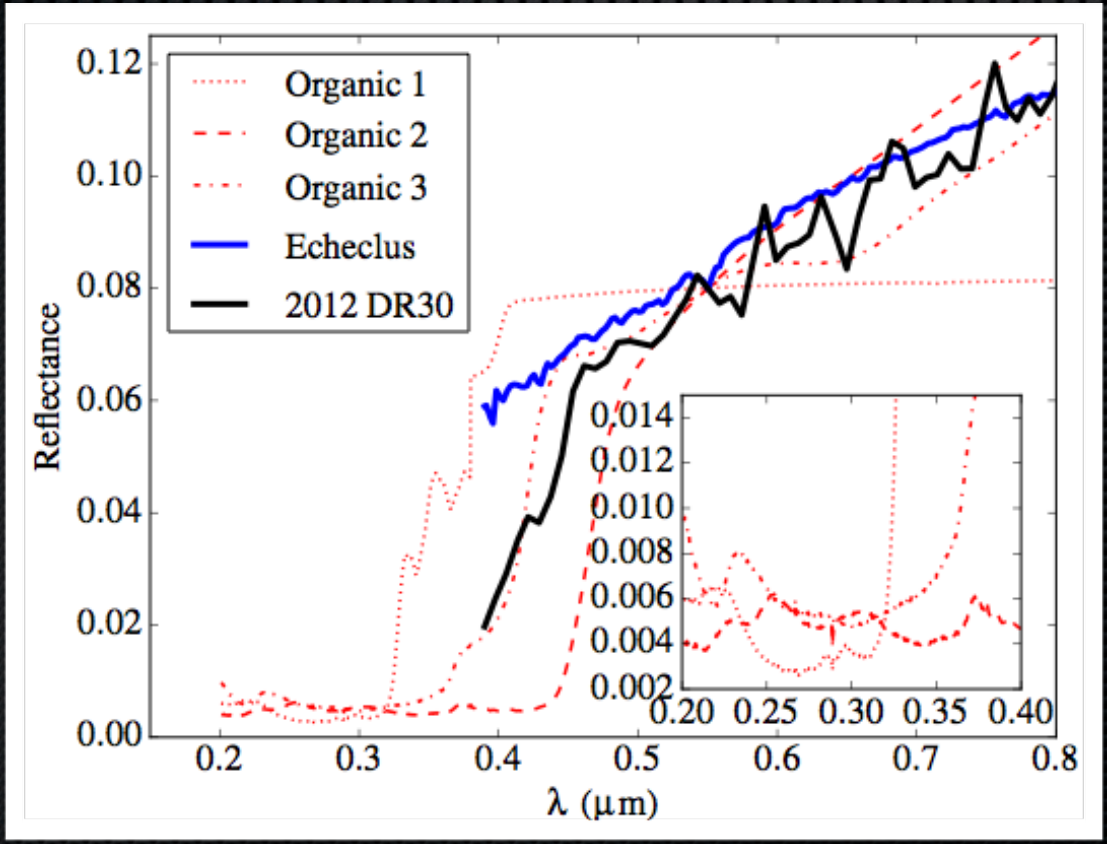
HST and JWST: the Compositions Machine



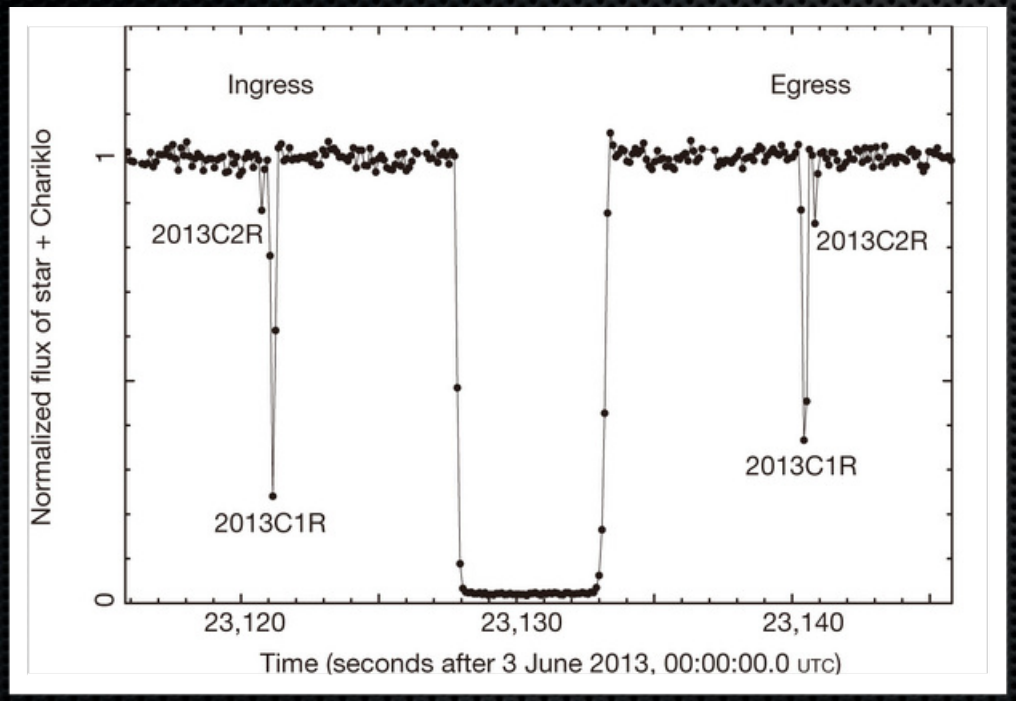


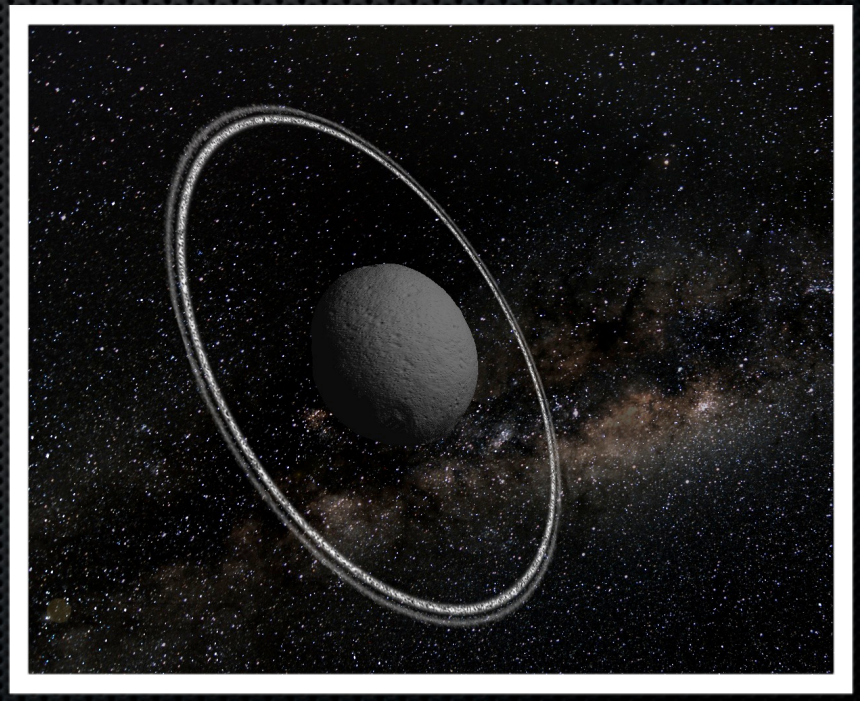
Plots Courtesy of Noemi Pinilla-Alonso

2012 DR30: Small and Organic Rich?



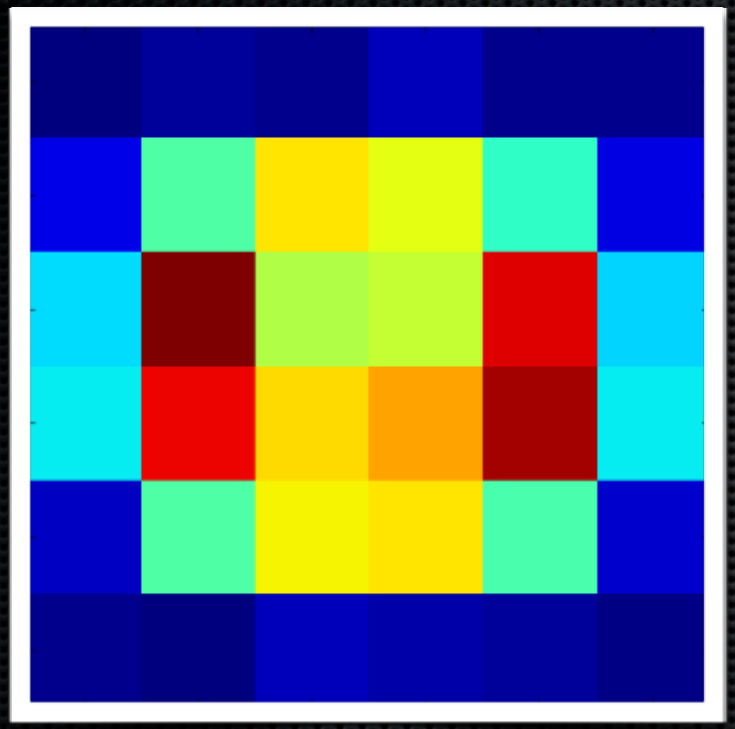
For Fun: Resolving Centaur Rings

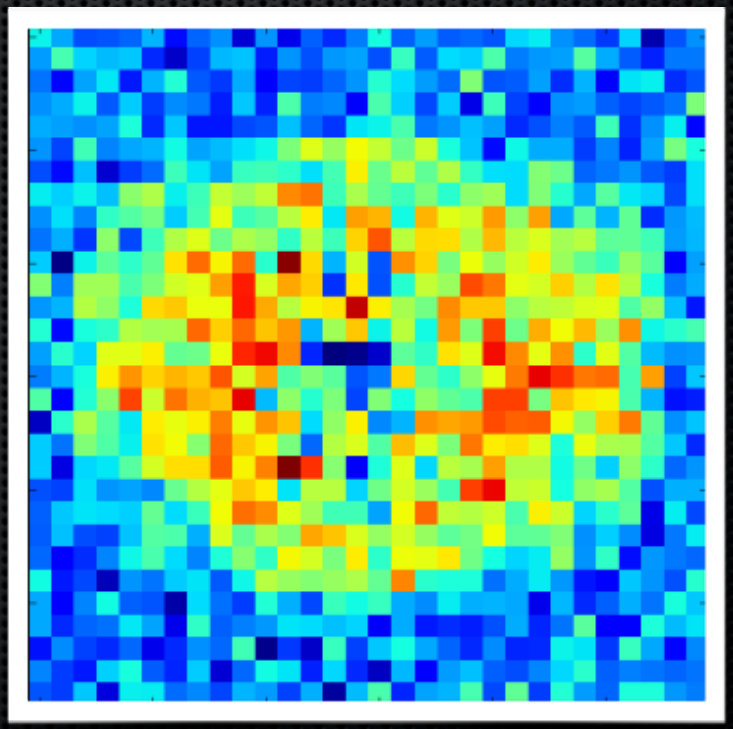




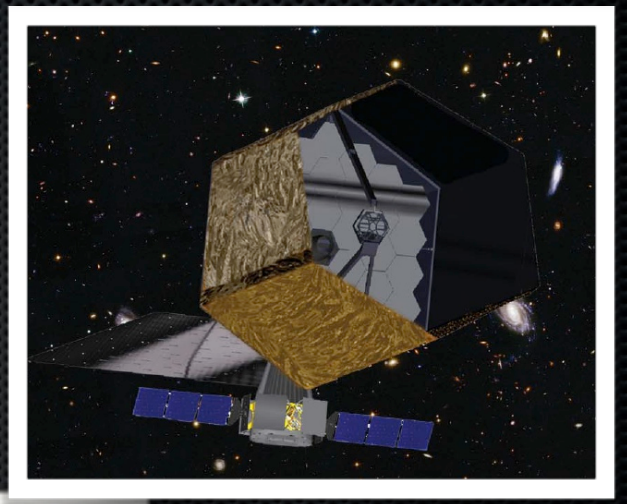
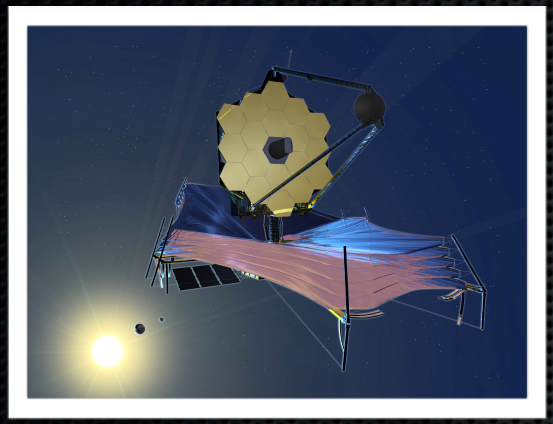
Sicardy et al. (2014)

Chariklo's Rings: JWST and HDST





Nowhere near done with the HST!

- centaur activity monitoring
- collision watch from LSST
- characterized binary search
- mass measurements for newly discovered binaries
- resolved binary spectroscopy
- D=10 TNO colour measurements and lightcurves
- low resolution spectroscopy
- mutual event observations
- ...

Space Telescopes: Worth Every Freaking Penny