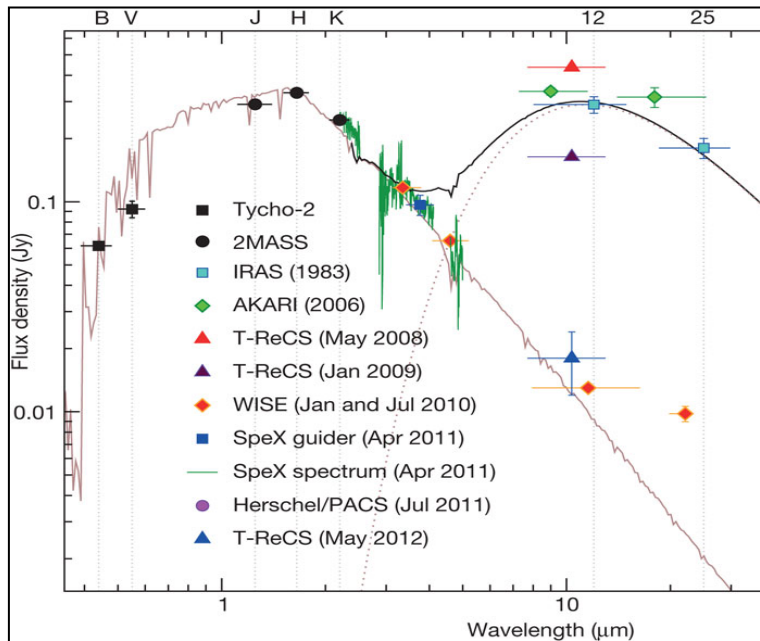


forming dwarf planets  
- clues from observing Pluto

Jane Greaves  
SUPA, St Andrews

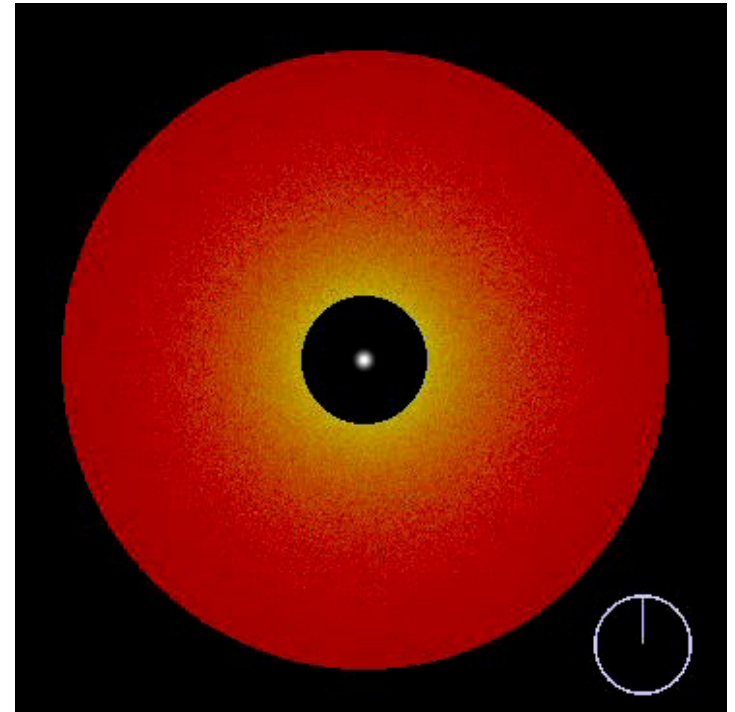
# why Plutos?

- can detect dust and planets... but not scales in between, for exo-systems?



Melis et al. 2012

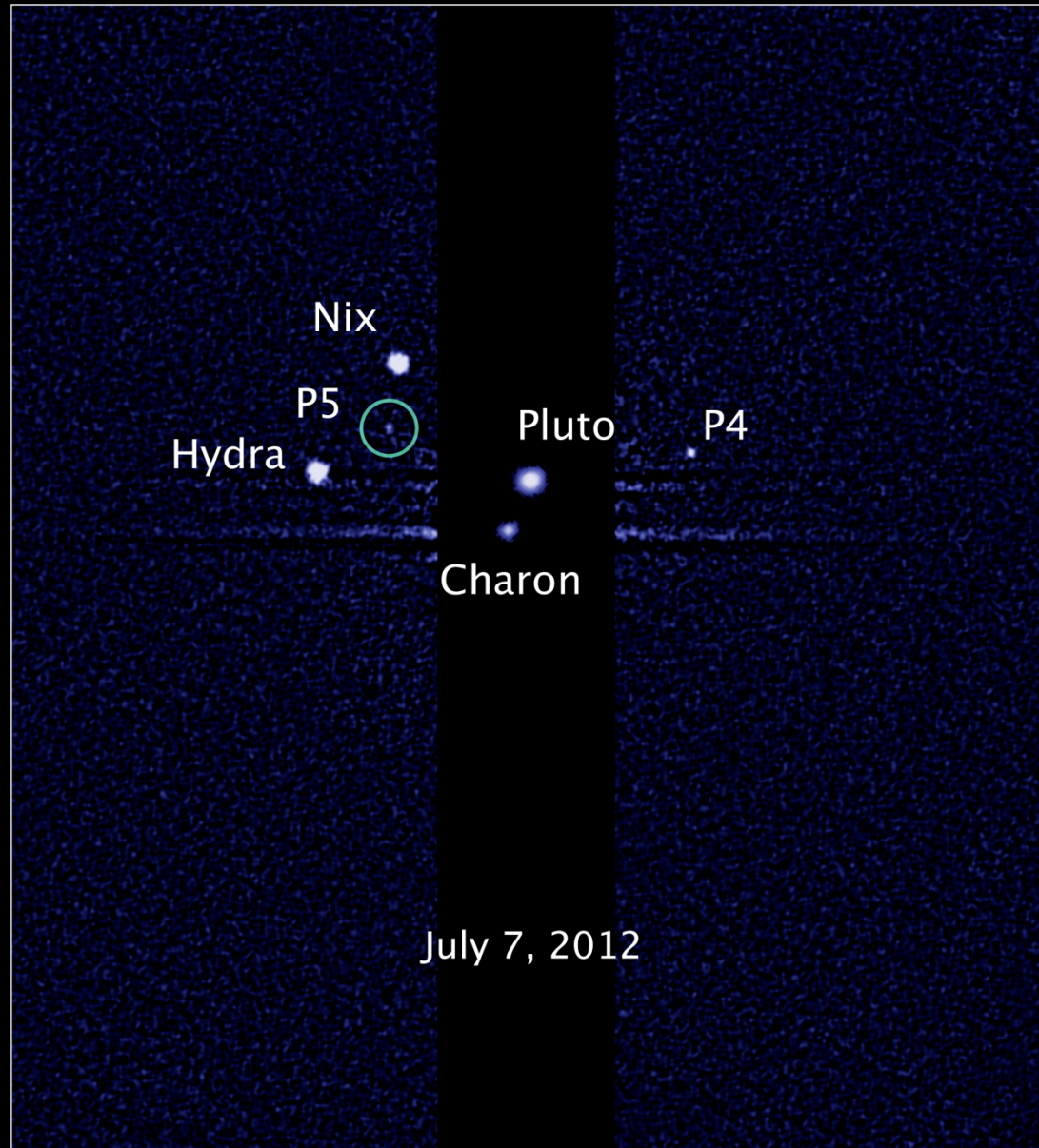
Kenyon & Bromley 2002



- want clues for the stages of growth to planets!

how did  
the Pluto  
system  
form?

how do  
these  
bodies  
evolve  
and  
interact?



**Pluto System**  
*Hubble Space Telescope • WFC3/UVIS*

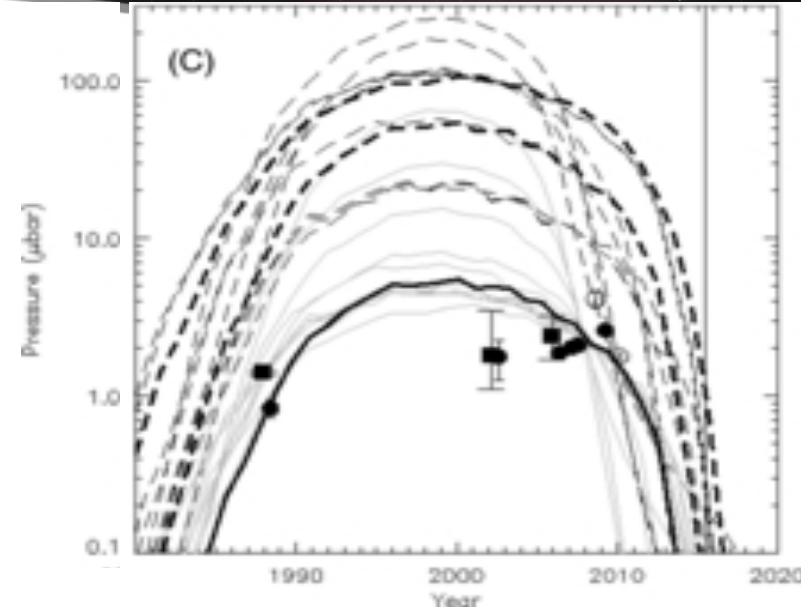
# Pluto in the submillimetre

- (Pluto – Charon – Nix – Hydra - ???...)
- bright submm target: ALMA calibrator!
  - but, how *constant* is the flux?
- search for atmospheric gases since atmosphere found by occultation
  - submm: high layers, exosphere?

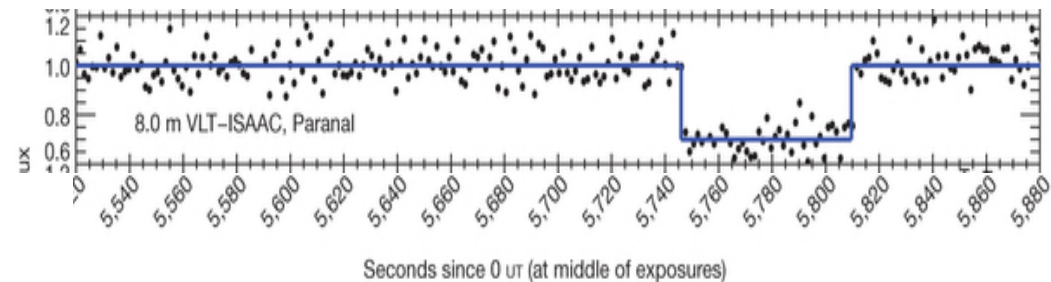
# expectations

Young 2013  
(early-collapse model run)

- as a large icy KBO, Pluto should still retain some frozen volatiles, and a tenuous atmosphere can result from surface ice sublimation



- is this seasonal?
- is it stable?
- does it happen elsewhere?
  - not for Eris, Makemake...



Ortiz et al. 2012;  
Sicardy et al. 2011

# N<sub>2</sub>, CH<sub>4</sub>, CO...?

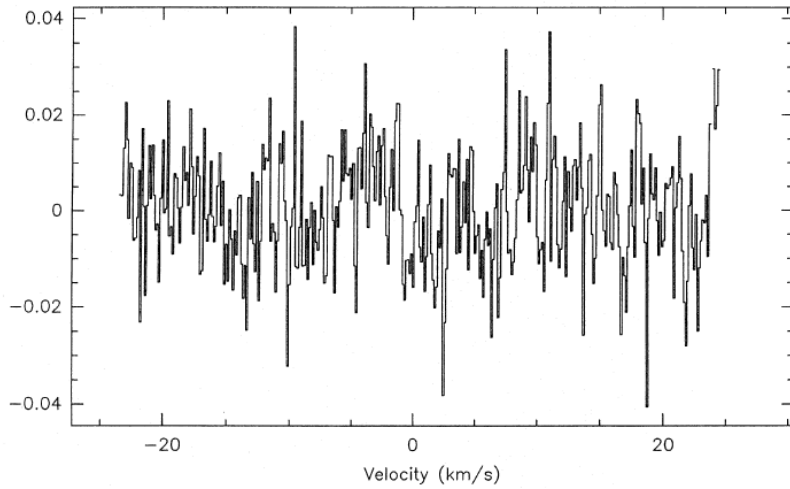
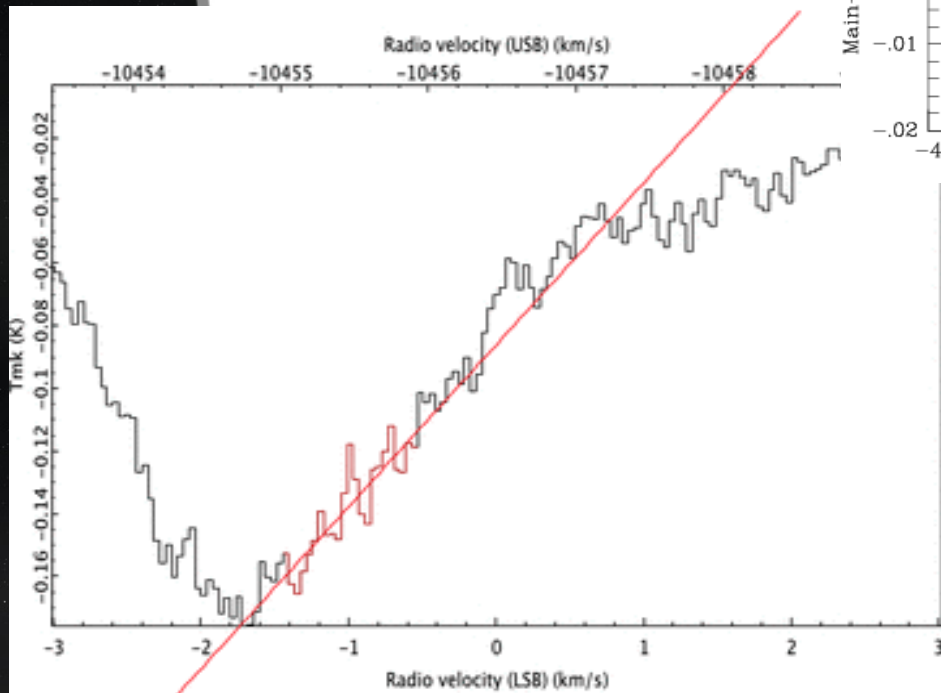
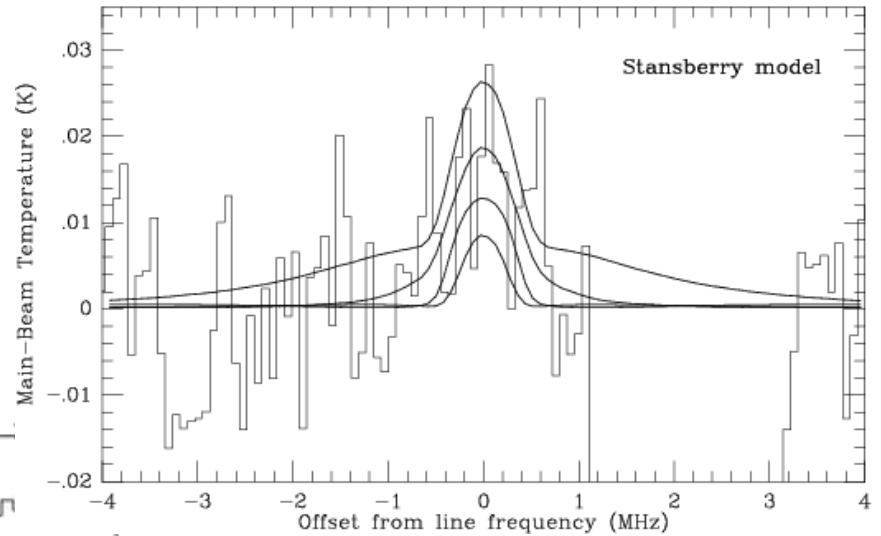


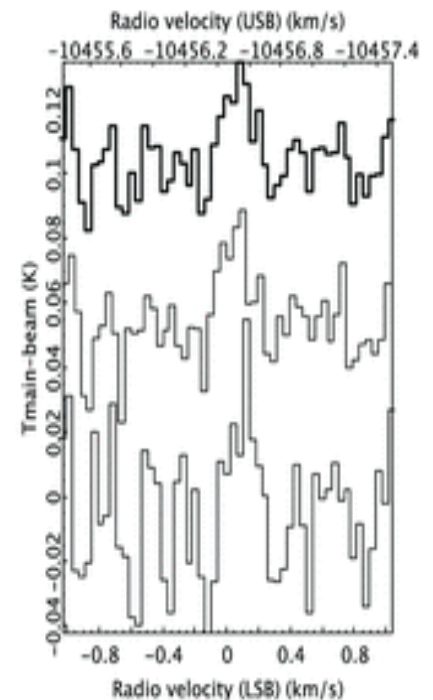
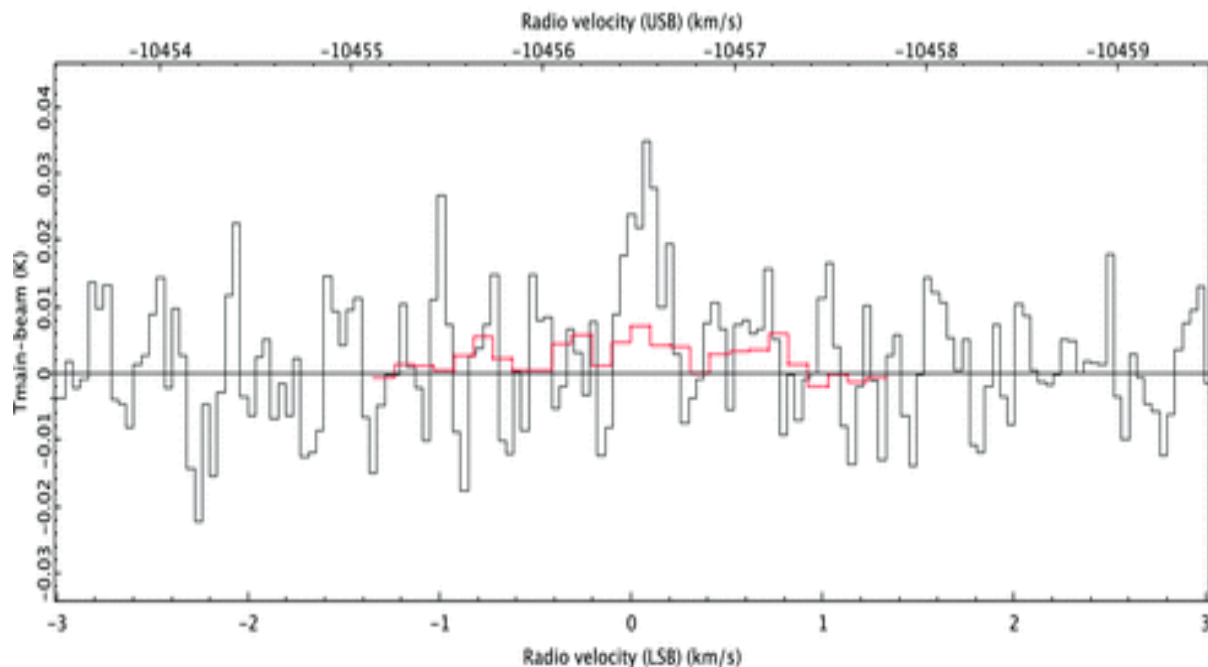
FIG. 1. Final spectrum from Haystack  $J=1-0$  observations. This represents 31.4 h of integration time at a mean system temperature of 600 K for an rms noise level  $\sim 12$  mK. The temperature scale is in units of  $T_{\text{MB}}$  (K). This spectrum is a slightly smoothed version of the final averaged spectrum.

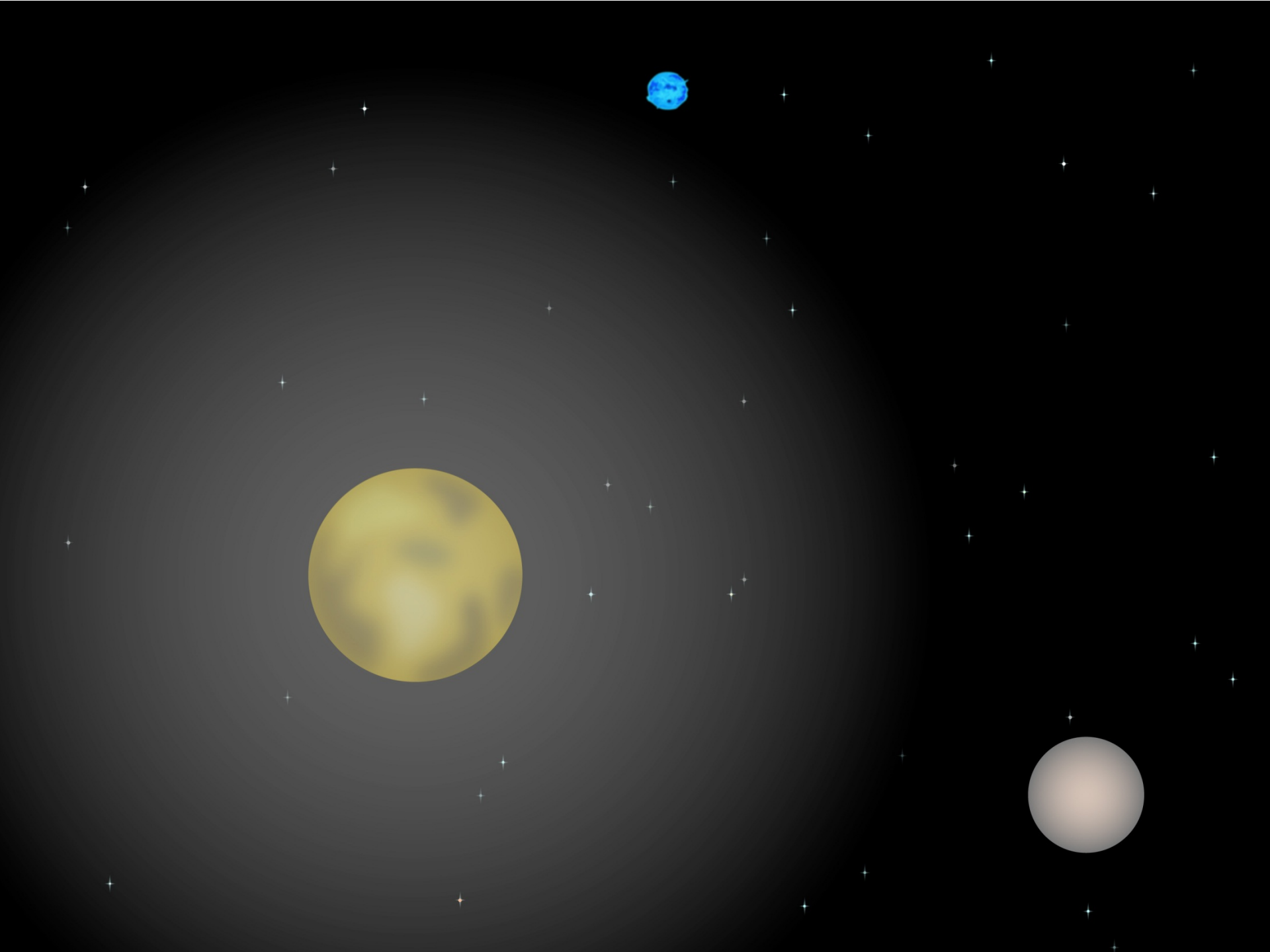


Barnes 1993;  
Bockelee-Morvan et al. 2001;  
Greaves, Helling & Friberg 2011  
lower-atmosphere IR spectra:  
Lellouch et al. 2011

# JCMT-15m results

- CO 2-1 line ( $6.5\sigma$ ) is reproducible over 2009, 2010... but much brighter than the tentative IRAM-30m detection from 2000



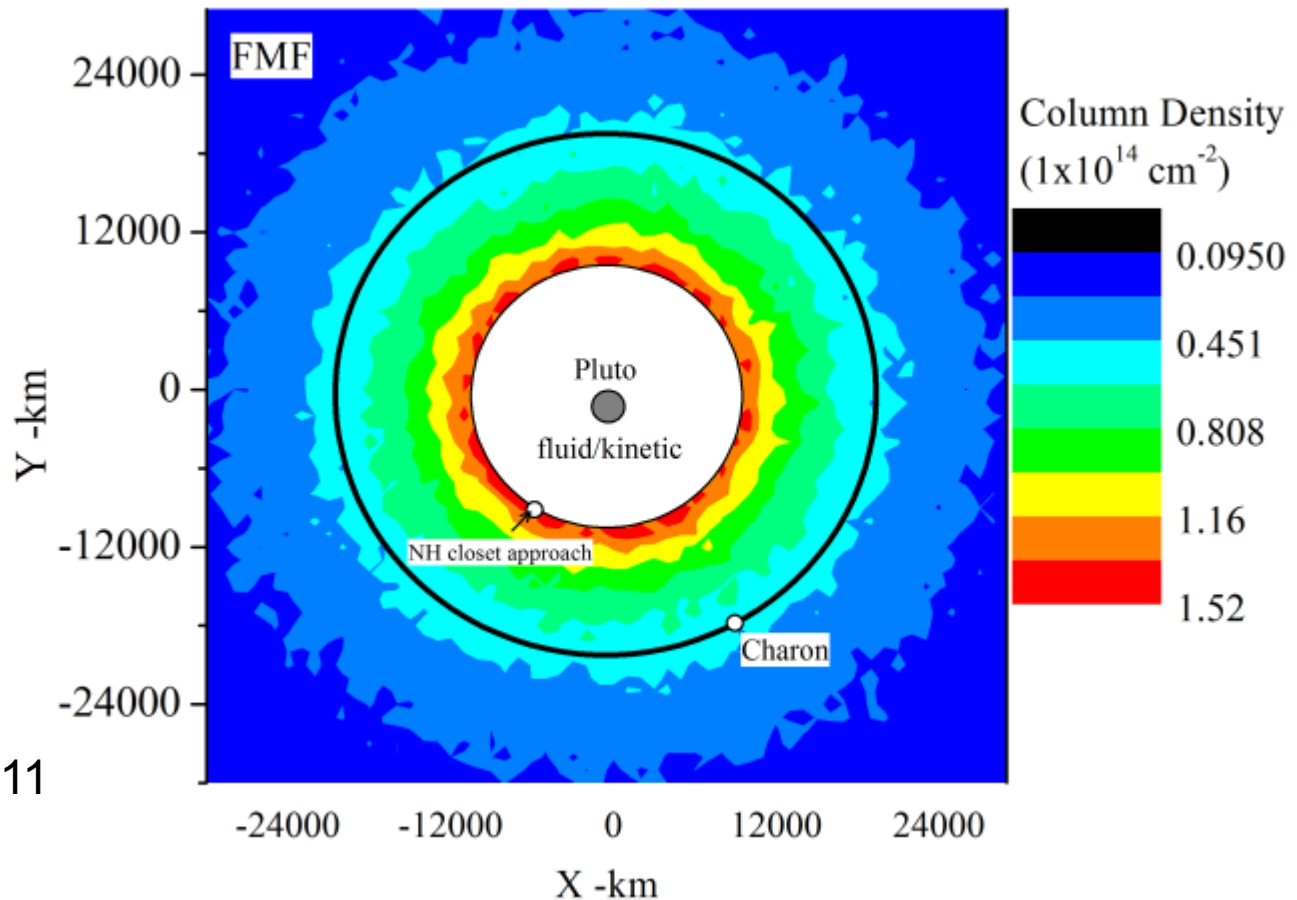




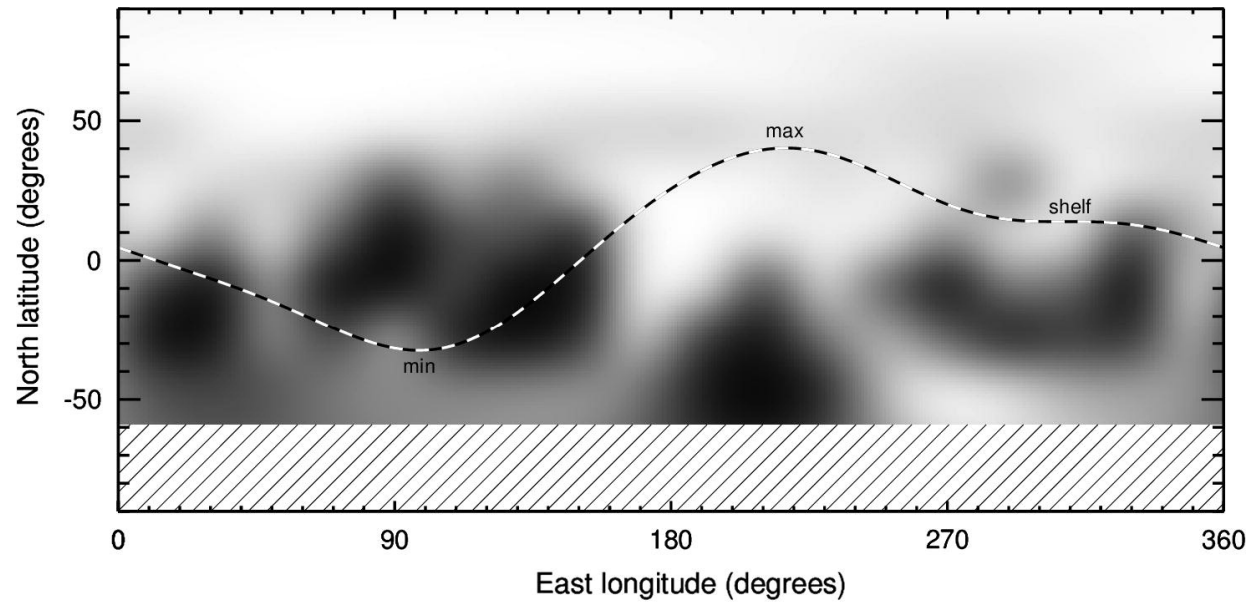
# model updates

- fluid/kinetic approach raises the atmospheric heights, and has sub-sonic outflow

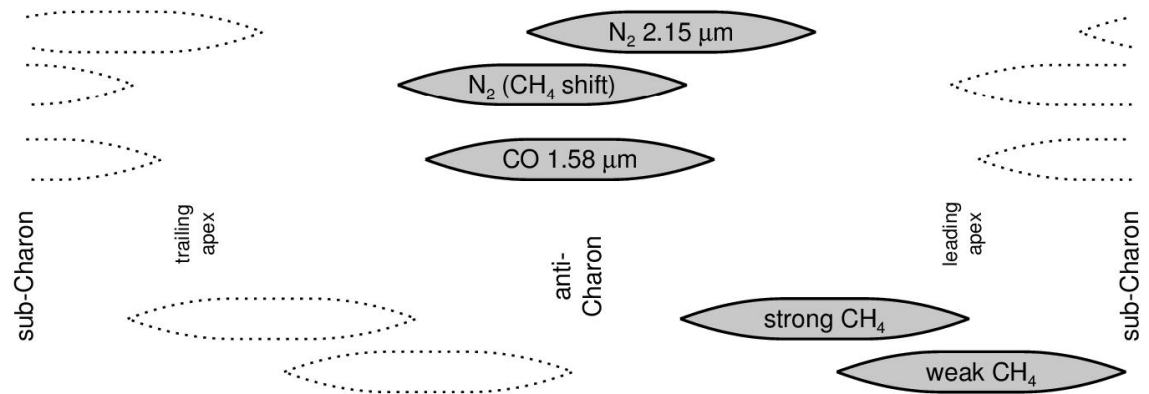
Tucker et al. 2011



Grundy  
et al.  
2013



what  
is the  
surface  
doing?

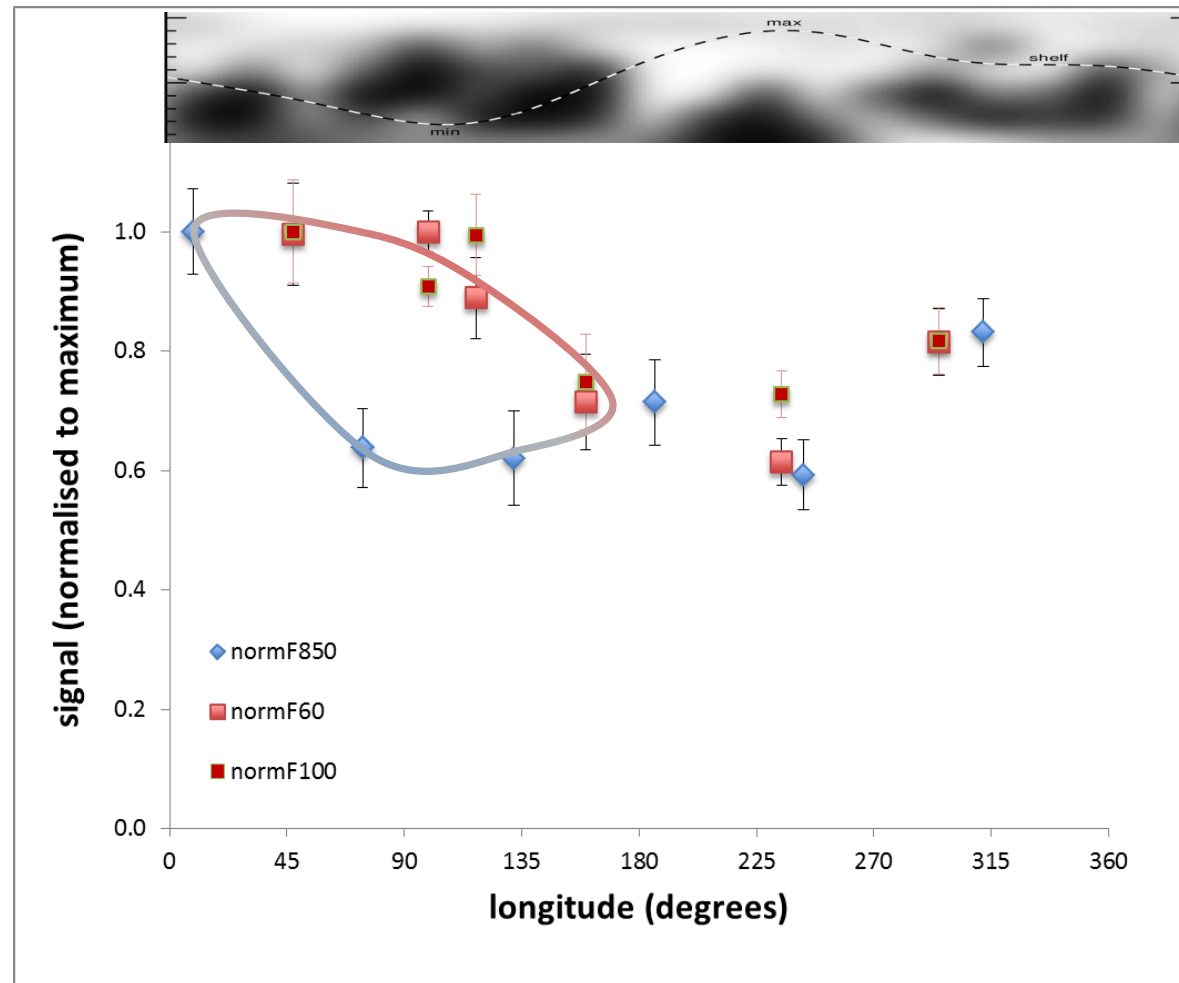


– over 2001-2012, CH<sub>4</sub> ice absorption has increased while N<sub>2</sub> and CO have decreased

# thermal properties (1997)

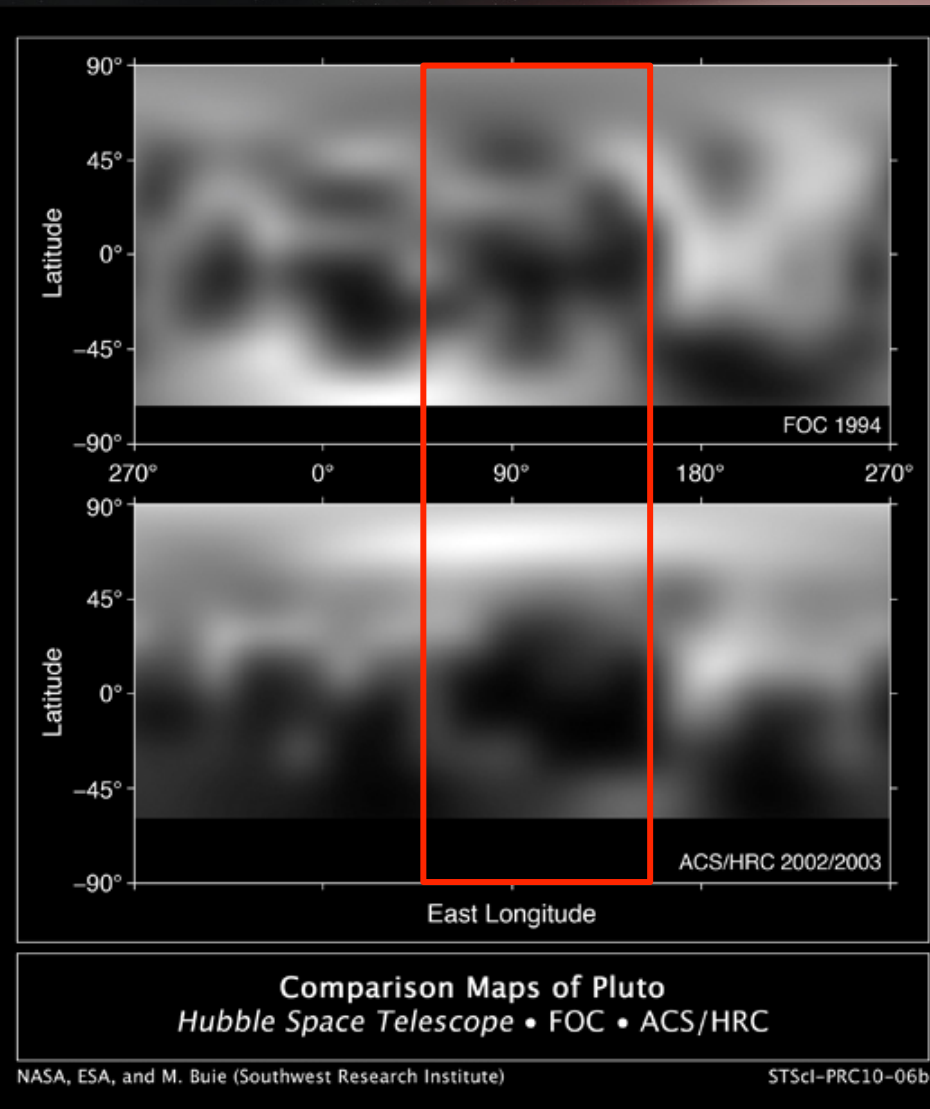
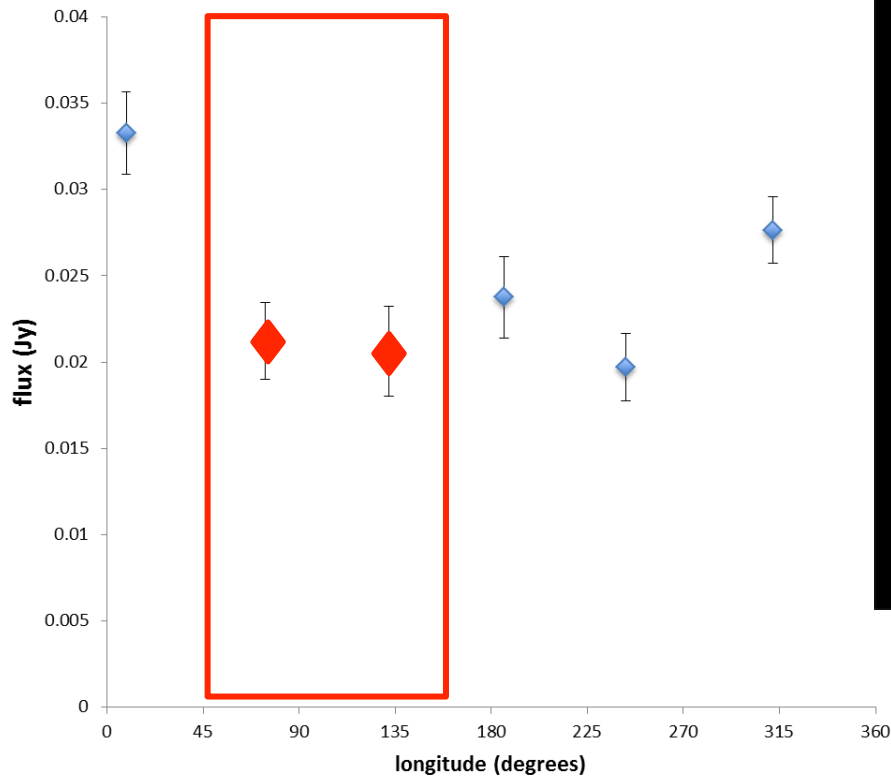
- from archival JCMT/SCUBA data plus ISOPHOT in same year

Whitelaw & Greaves;  
Lellouch et al. 2000



Pluto was then becoming redder, and brighter in the north

850 micron flux versus Pluto longitude  
(from sub-Charon point)



Buie et al. 2010

# what next?

- image the CO atmosphere
- monitor the surface as *New Horizons* approaches (2015)



ALMA (res. for Band 7 @ 1 km)

