Investigating Dusty Plasma of Cometary Coma with NASA Stardust Data

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Introduction:

Dusty plasmas have been studied in lab environments and have been found to exhibit coulomb crystallization under certain conditions. These 'plasma crystals' form when dust particles suspended within the plasma become charged, and their collective inter-particle potential energy overcomes their individual thermal energy. These structures can have varying degrees of ordering from short range, behaving as a 'plasma liquid', to long range, as a 'plasma solid'. [1]

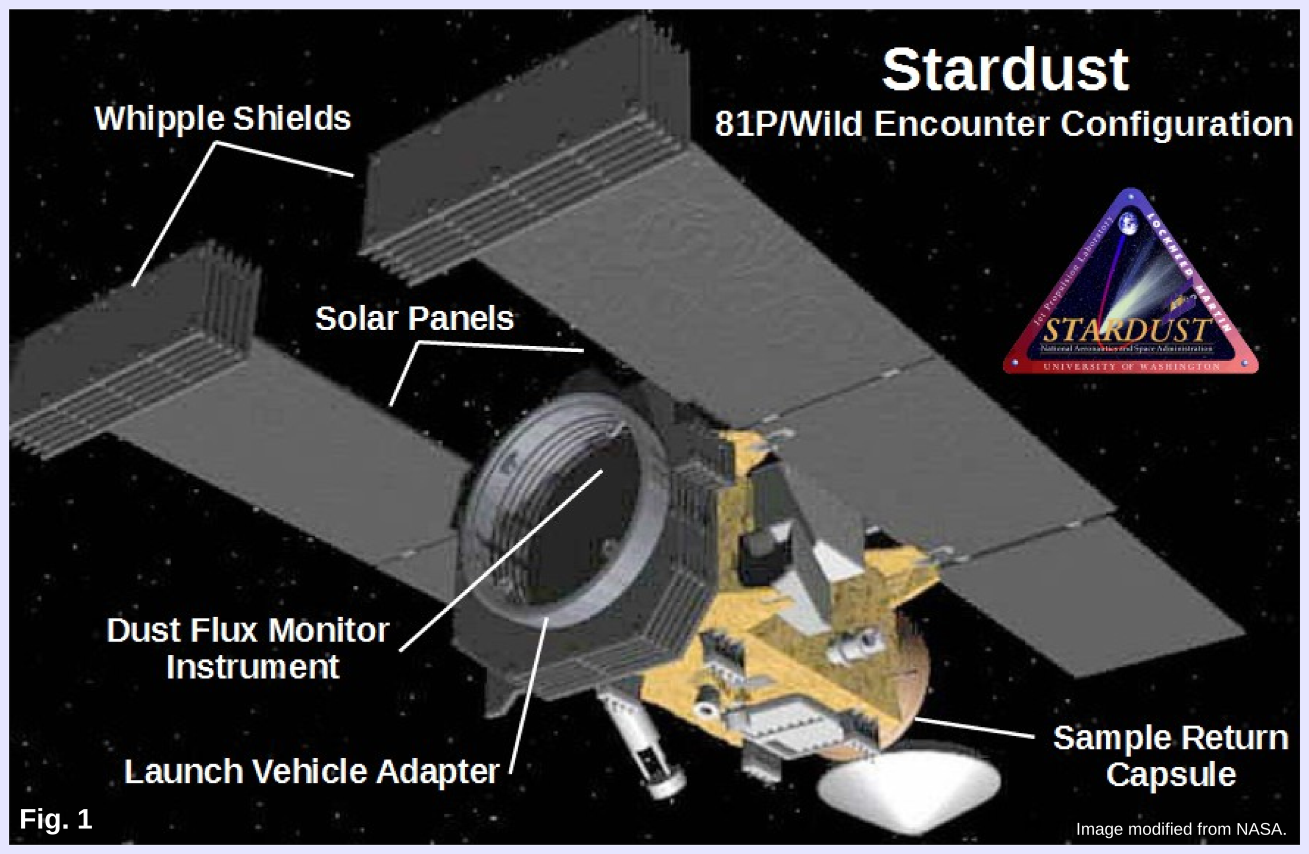

Fig. 1

In 2004, NASA's Stardust spacecraft (Fig. 1) performed a flyby of comet 81P/Wild (Fig. 3), collecting samples and recording data about the particles encountered during the close approach, nearly 200 km from the comet nucleus. These data could shed light on any coulomb crystallization processes occurring within the coma of 81P/Wild.

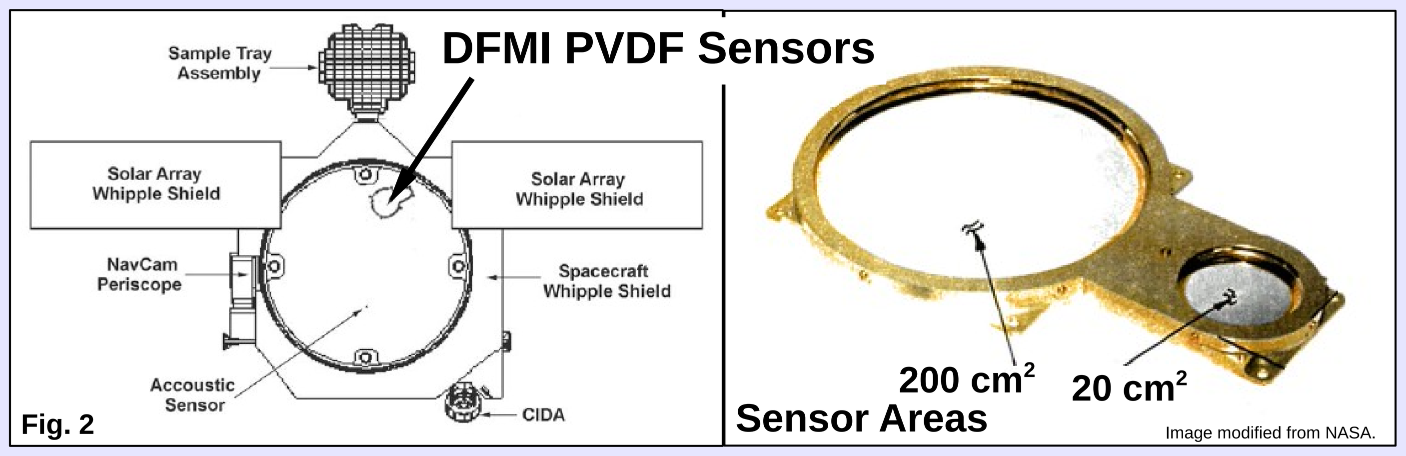

Fig. 2

Motivation:

Investigation of these processes could contribute to the understanding of the space environment surrounding comets and can be compared to future exploration of comets. If found to be a home to plasma crystals, comets could provide a natural environment to study this phenomena beyond the lab.[2]

Methods:

Data from Stardust's Dust Flux Monitor Instrument (DMFI) PVDF (polyvinylidene flouride) sensors (Fig. 2) have been used to develop a profile of dust properties surrounding the nucleus of 81P/Wild, including particle mass (from PVDF sensor thresholds) and spacial distribution.

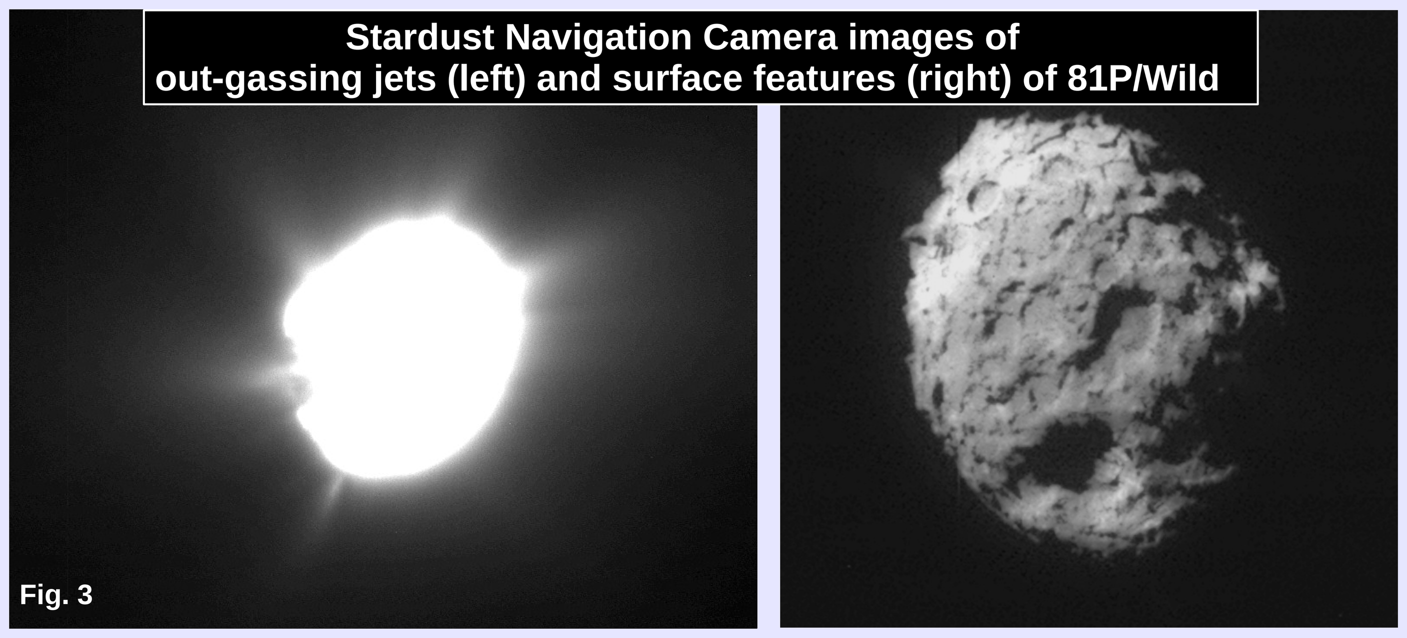

Fig. 3

A basic model of cometary plasma will then be developed, using observed comet jet geometry [3] and the assumption of photoionized products of water ice sublimation [4] dominating the plasma composition [5]. Plasma properties from this model, along with the measured dust properties, will be used to calculate the coulomb coupling parameters for various scenarios around 81P/Wild.

Preliminary Results:

Stardust encountered a series of particle collisions measured by the PVDF sensors as it approached within 1000 km of 81P/Wild (labeled A below). A second cloud of particles (labeled B) was encountered at a distance of approximately 3800 km from 81P/Wild. These two regions exhibit differences in two variables evaluated.

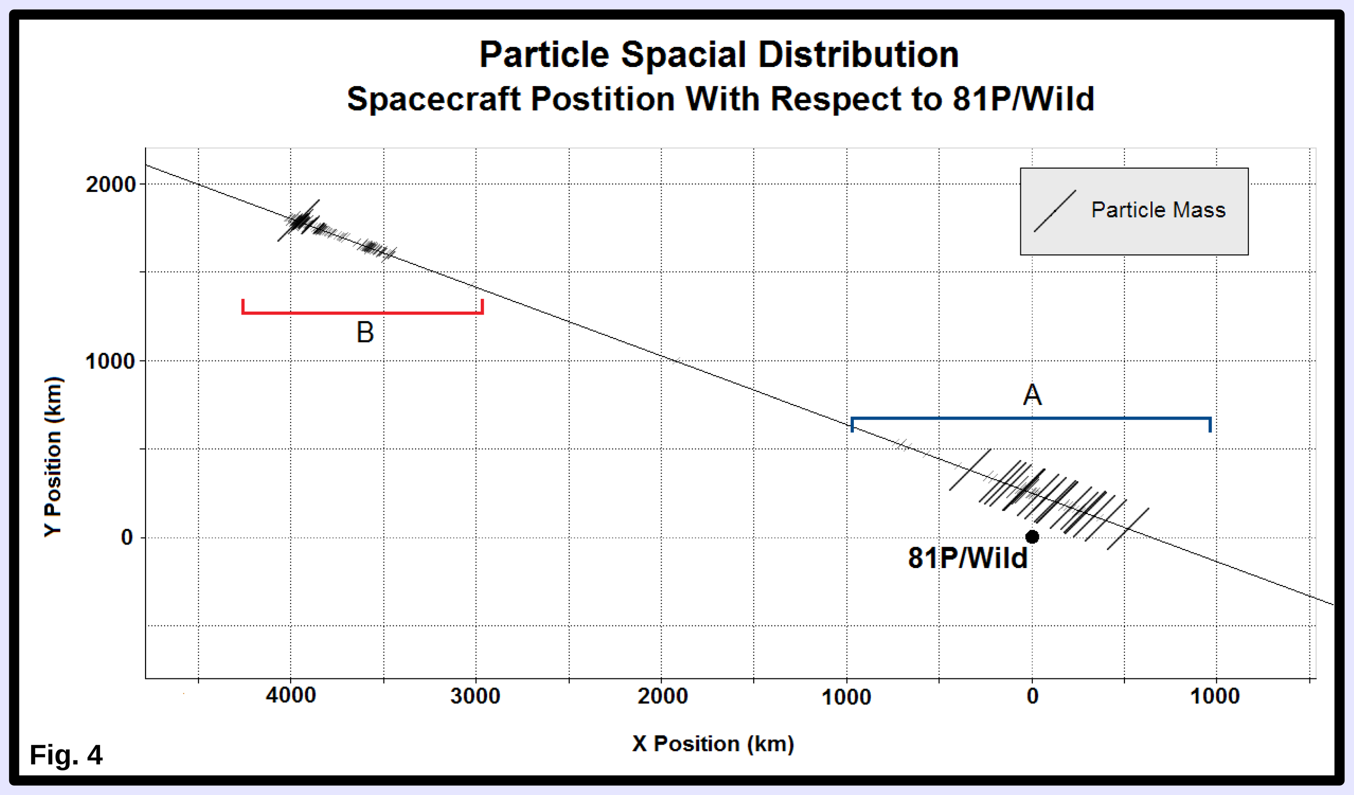

Fig. 4

Region A had a higher average and wider distribution of particle mass, whereas B had a narrower distribution and lower average particle mass (Fig. 4). Region B, however, had a higher number density of particles encountered than A of ~34/m³ (Fig. 5).

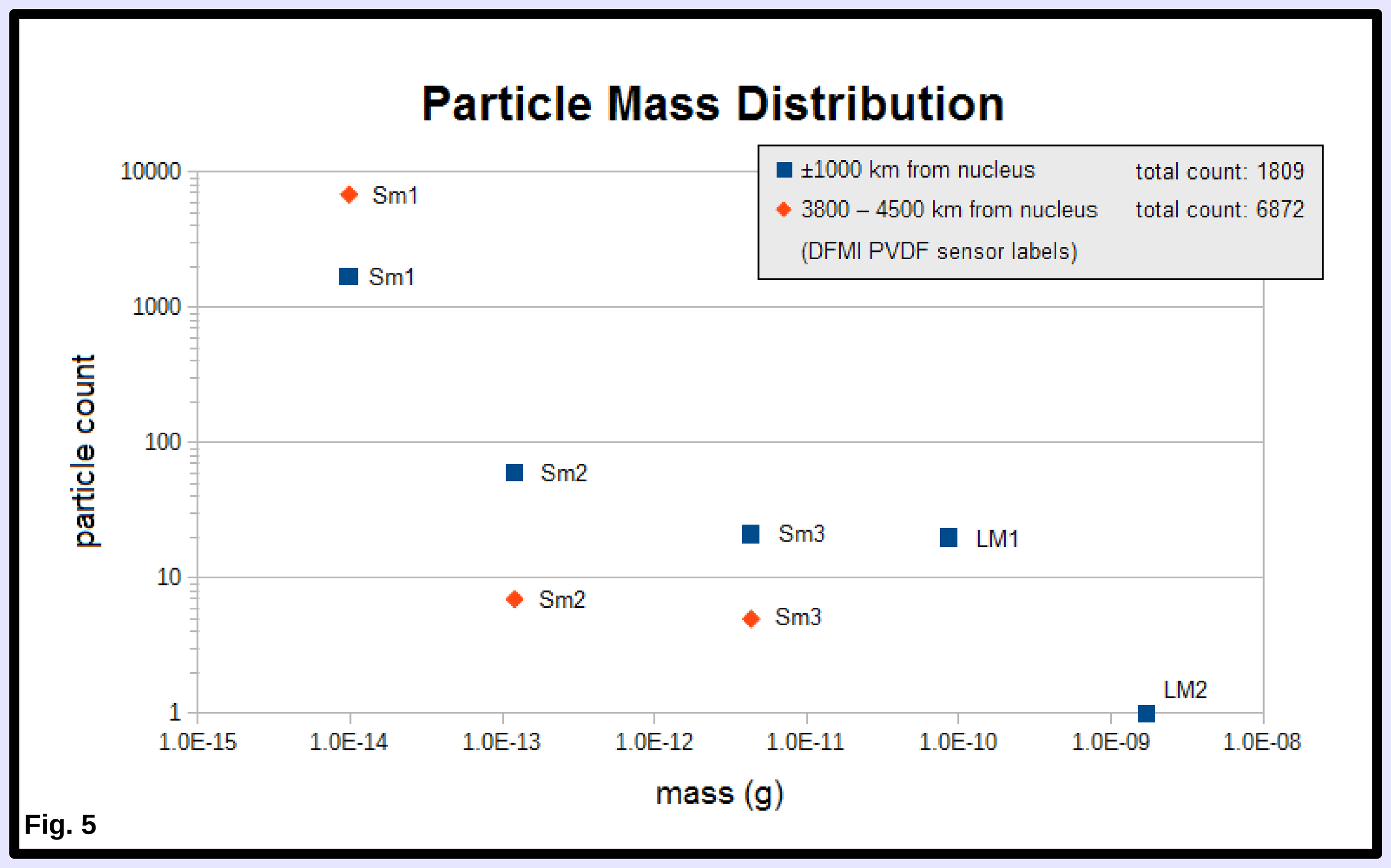

Fig. 5

Conclusion / Next Steps:

It can be expected that the differences in average particle size and spacial density between the two observed regions will translate into distinct dust-plasma interactions for each region. Additionally, each location will exhibit different plasma properties stemming from their respective distances from the source of newly sublimated gasses, the comet's nucleus.

This provides two distinct regions to study and compare coulomb coupling strengths, and their dependence on the previously mentioned parameters.

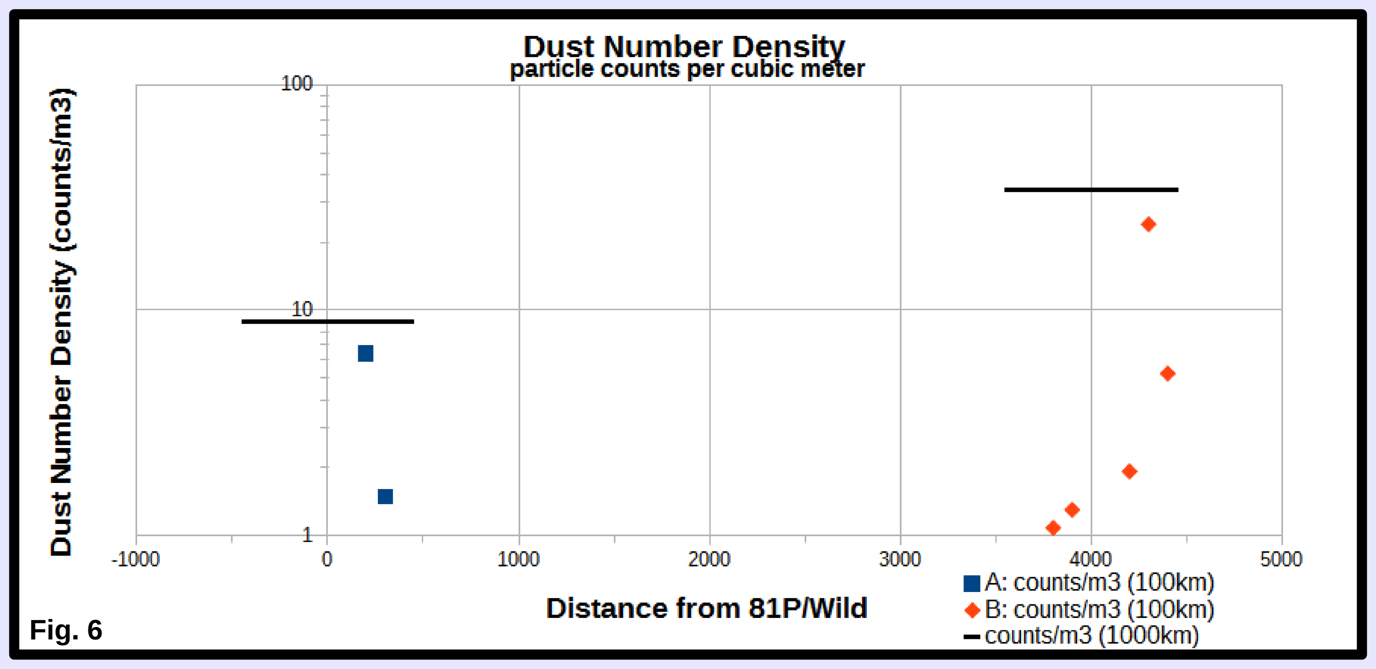

Fig. 6

References:

[1] Vasut, J., Hyde, T.W., Barge, L. (2002) Finite coulomb crystal formation, Advances in Space Research 34: 2396-2401.

[2] Mendis, D.A., and M. Horányi (2013), Dusty Plasma Effects in Comets: Expectations for Rosetta, Reviews of Geophysics, 51, 53–75.

[3] Sekanina, Z., et al. (2004), Modeling the Nucleus and Jets of Comet 81P/Wild 2 Based on the Stardust Encounter Data, Science, 304 (5678): 1769-1774.

[4] Andreas, E. (2007), New estimates for the sublimation rate for ice on the Moon, Icarus, 186: 24-30

[5] Cravens, T.E. (1987), Theory and Observations of Cometary Ionospheres, Adv. Space Research, 7 (12): 147-158