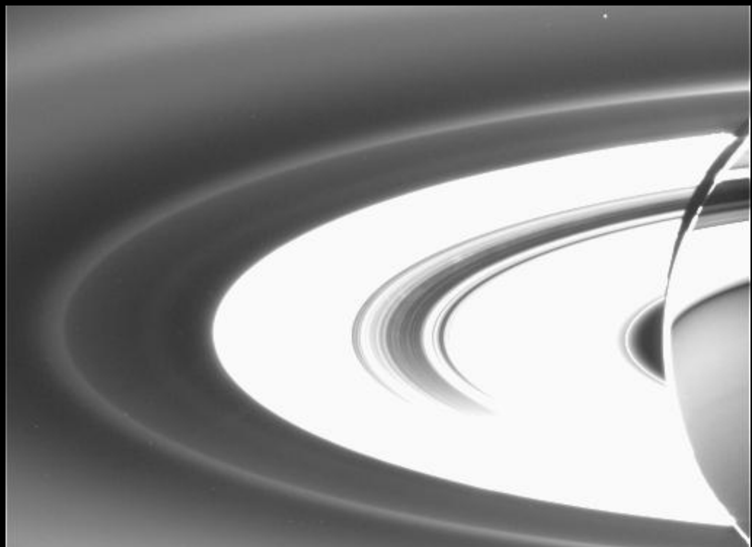


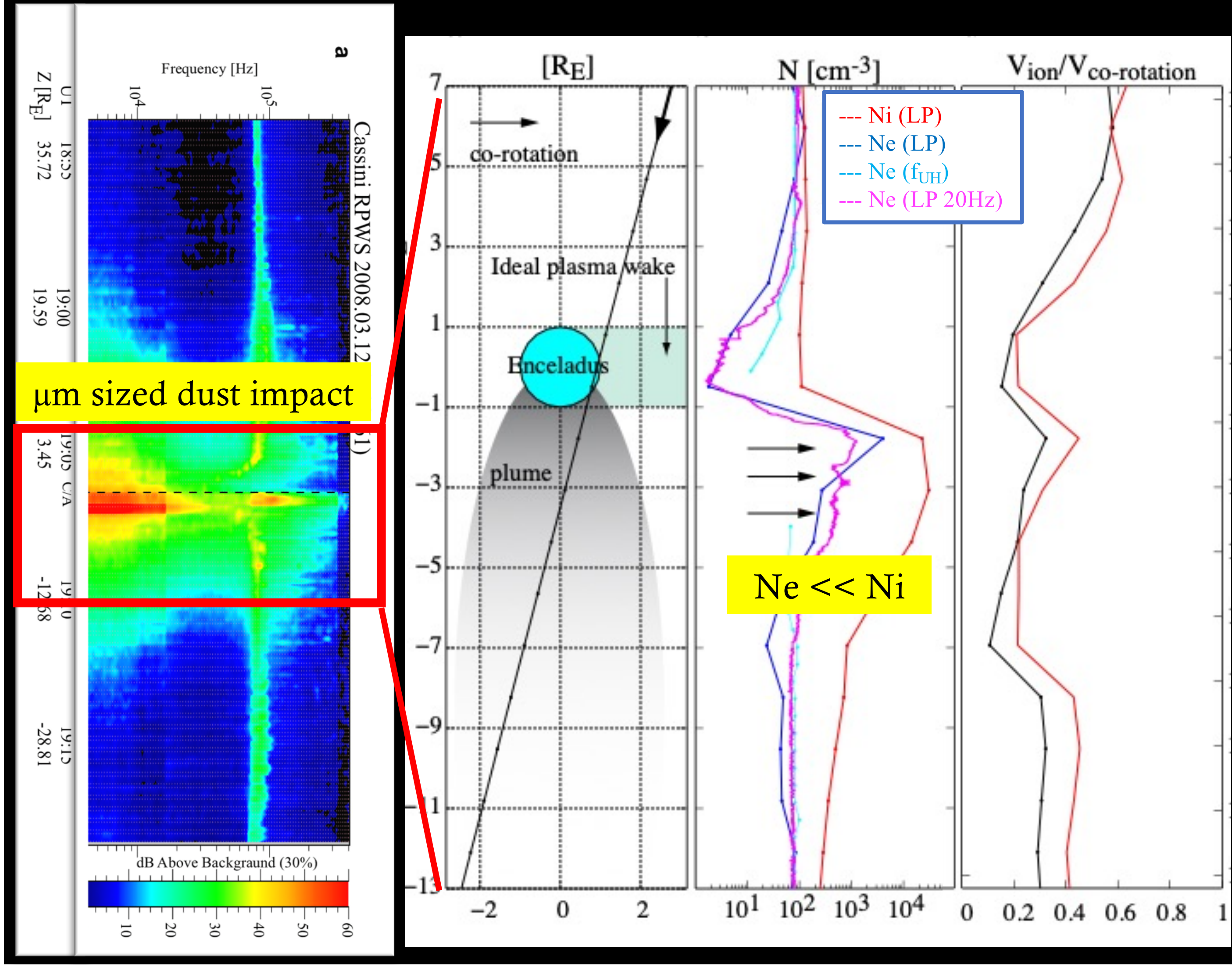
The Langmuir probe observations of the dust and plasma at Enceladus plume and the E-ring

Michiko W. Morooka

The LP observations of the dust and plasma

- Cassini observations revealed the dusty plasma, charged dust takes in place in the charge balance, in many places in the Kroninan system.
- The Langmuir Probe measures the electron and ion densities and provides important parameters for the dusty plasma.
- The LP measurements combining with the other instrument's measurements shows different types of dusty plasma.
- What is the remained problems?
- Expectation to the JUICE observations.

RPWS/LP observation in the Dusty Enceladus plume

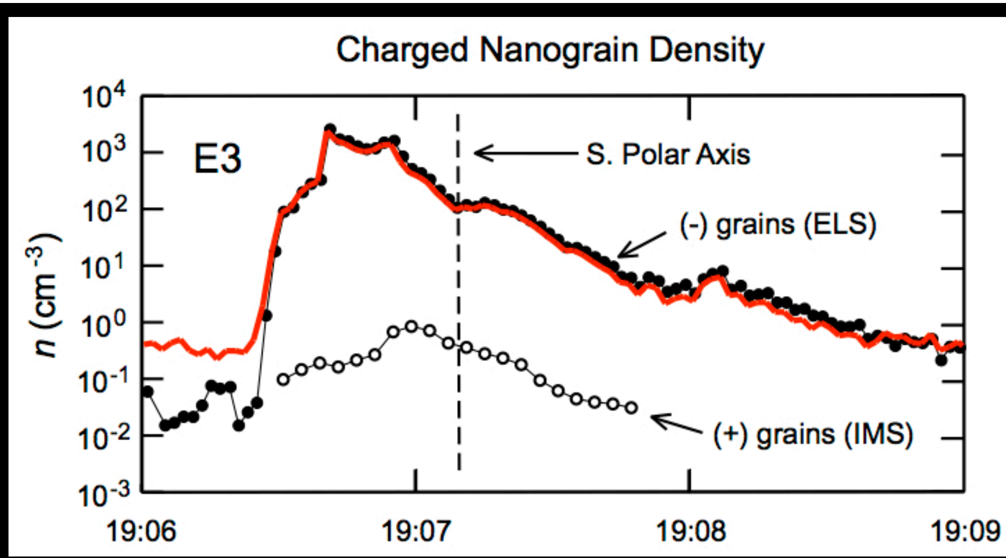


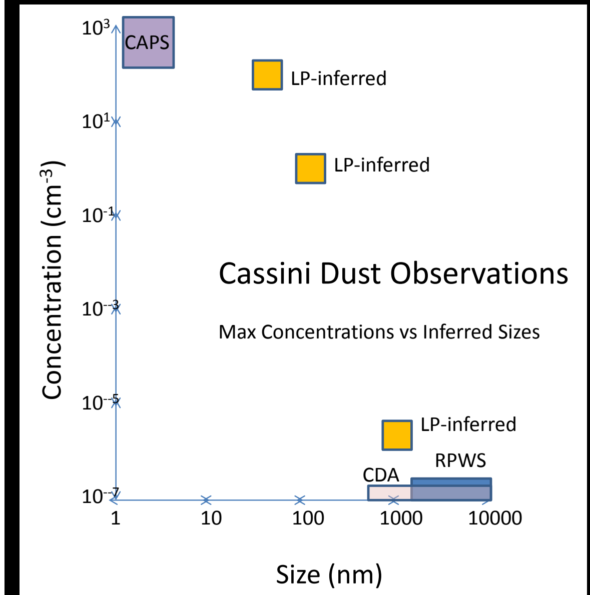
- µm grains signals by RPWS antenna
- LP measures
  - U: LP potential (grain potential)
  - Ne, Te: Electron density and temperature
  - Ni, Vi: Ion density and speed
- Dense plume plasma
  Ni: 2 10^4 cm^{-3}, Ne: 2 10^2 cm^{-3}
- Small N_i/N_e ratio: << 0.1
  Negative charges are on dust grains
- Slow down of the Ion
  - From corotation to Keplerian speed

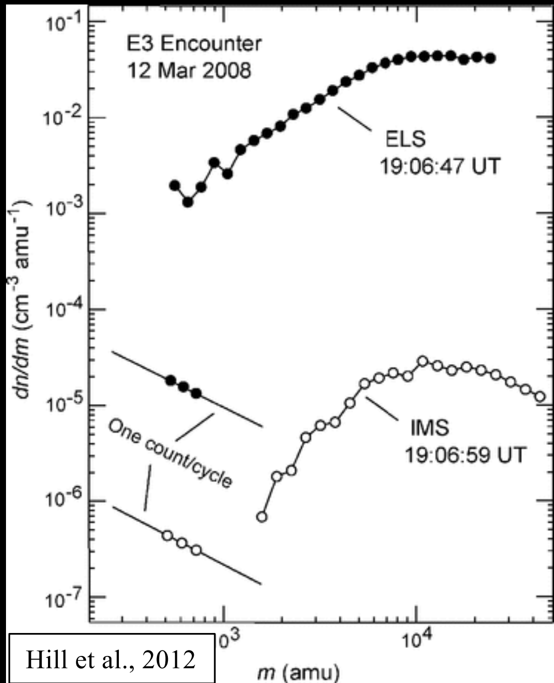
Negative charges are mostly on nm sized grains.

- N^-_{nano} (10^4 cm^{-3}) >> N^+_{nano} (1 cm^{-3})
- Density peak about < 2nm
- Most of the grains are singly charged.
- CAPS and LP densities are consistent.

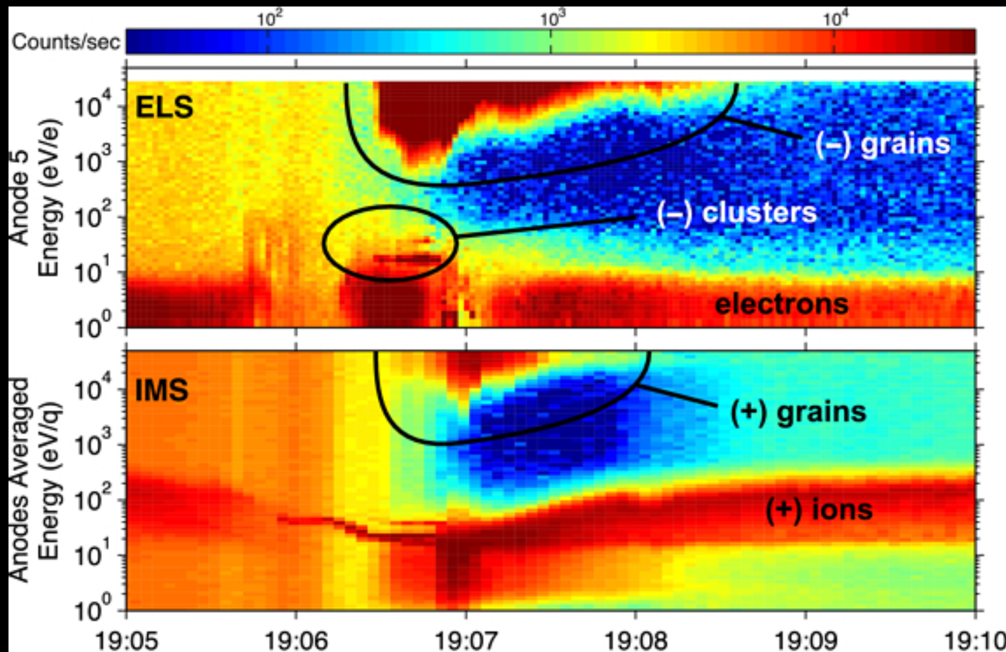
Hill et al., (2012); Dong et al. (2014)







Hill et al., 2012



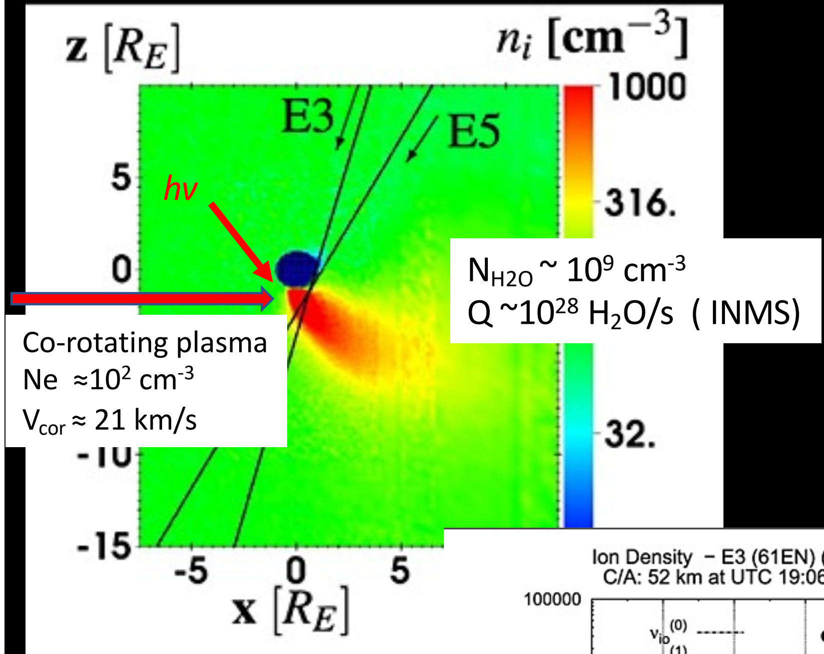
Problem remained: How is the large plasma density (N_i ~10^5 cm^{-3}) generated?

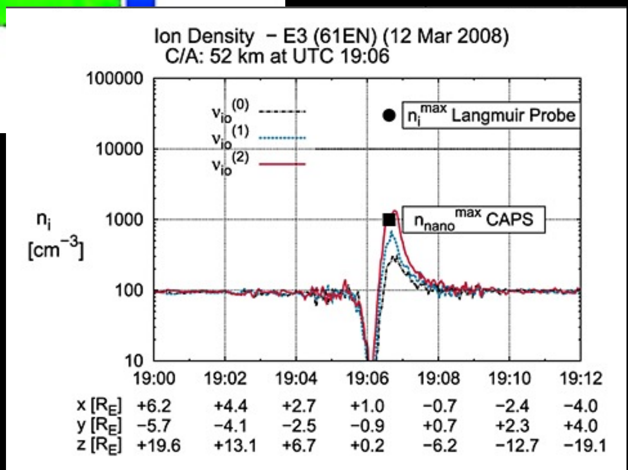
Ionization source is not enough with:

- Ion-Neutral charge exchange
- Electron impact ionization
- Photo ionization

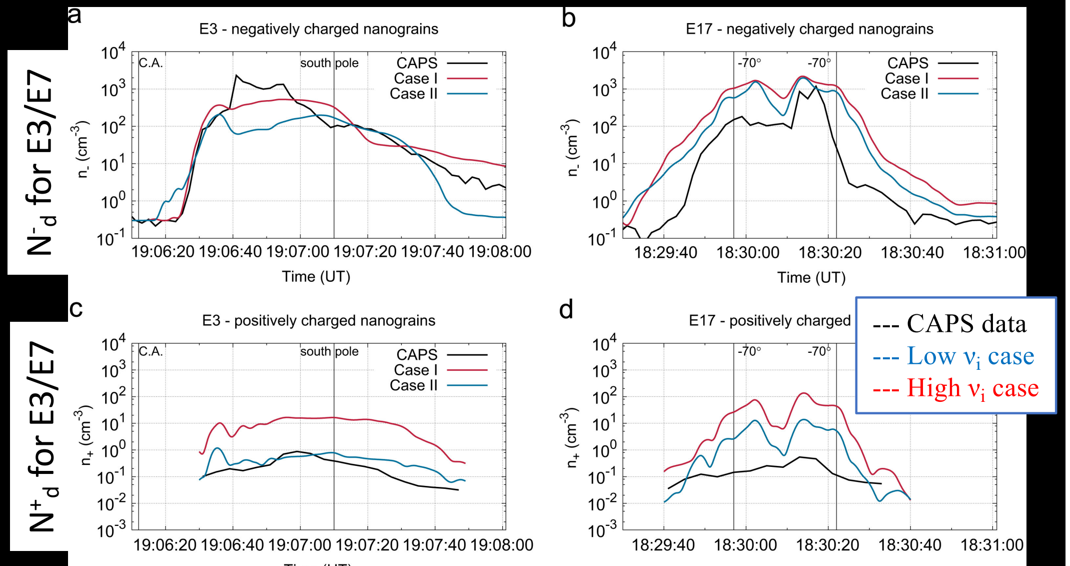
to count on observed ion density. e.g., Kriegel et al., [2014], Sakai et al [2016]

But charged nano dust simulation also shows that a high ionization ratio is required to explain the observed N^-_d /N_d^+ ratio. Meier et al., [2015]





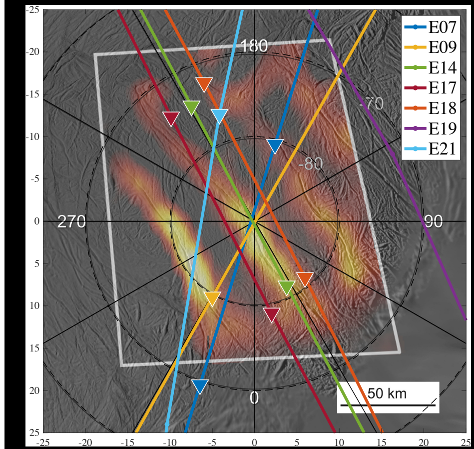
Kriegel et al., [2014]

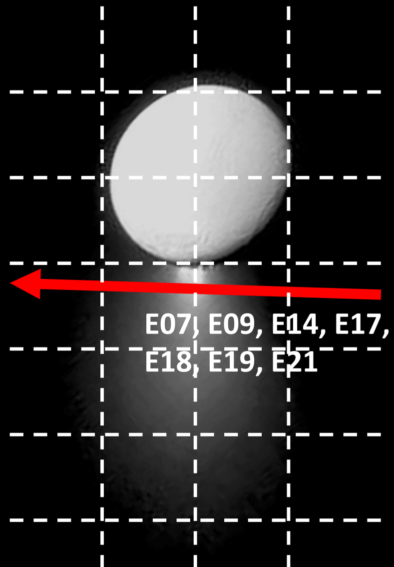


Meier et al., [2015]

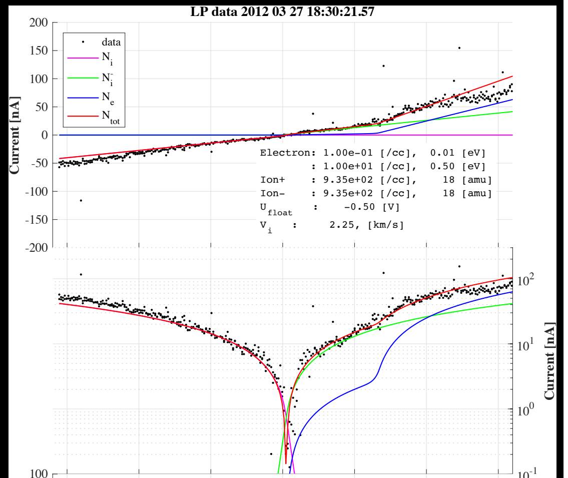
Ion$^+$/Ion$^-$ plasma in the plume

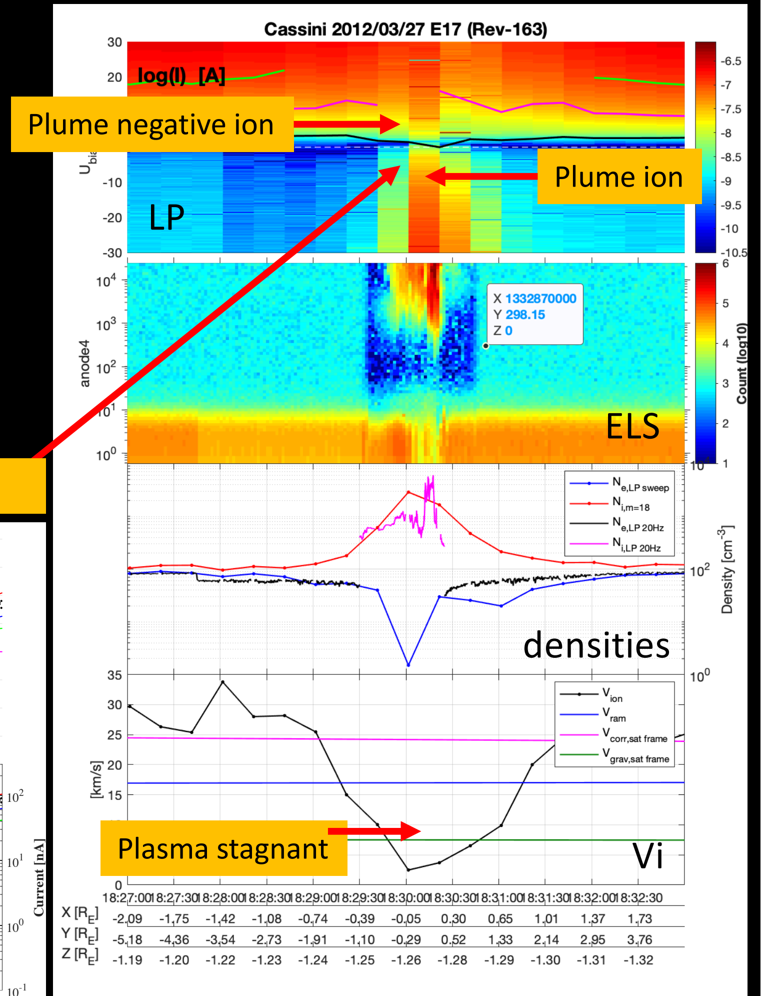
- LP sweep shows negative/positive ions
  N_i^+: 9 10^2 cm^{-3}, N_i^-: 9 10^2 cm^{-3}, N_e: 1 10^1 cm^{-3}
- Tribo-electrical charging or other charging mechanisms?
- A large mass loading results in stagnant plume plasma as be observed by LP.





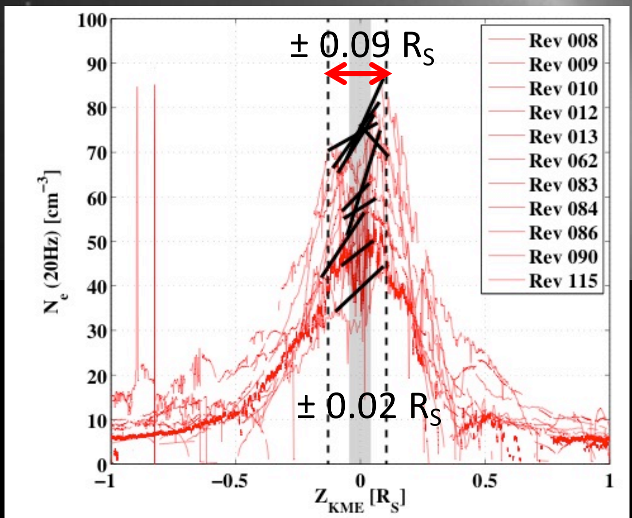
Ion$^+$/Ion$^-$ plasma. Almost no electron.



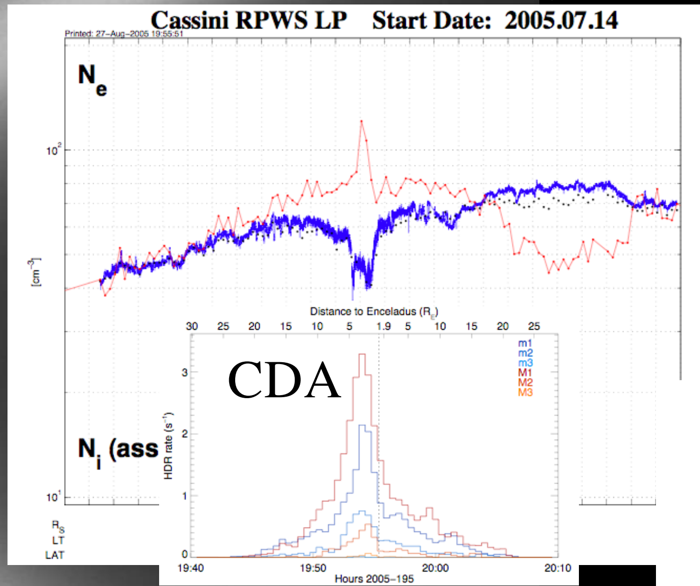


E ring dust

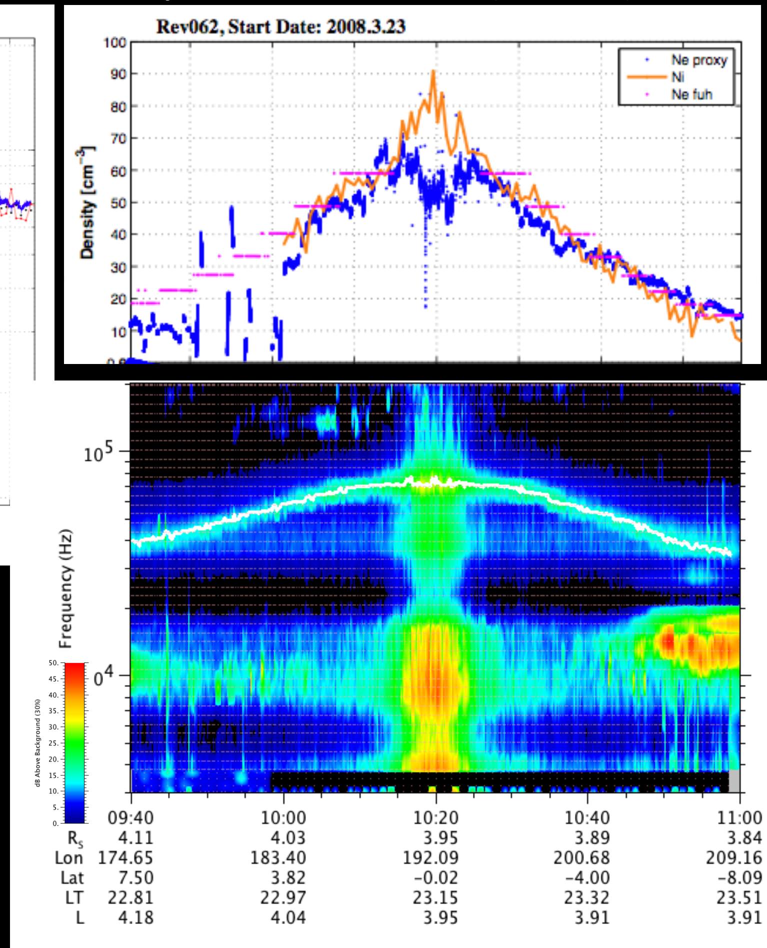
- N_i>>N_e region appears associated with the μm sized dust signals.
- Narrow (<6000km) dusty disk cantered at equator in ±1200km.
- Surrounding plasma has north/south asymmetries.



Near Enceladus (Rev 11, E02)

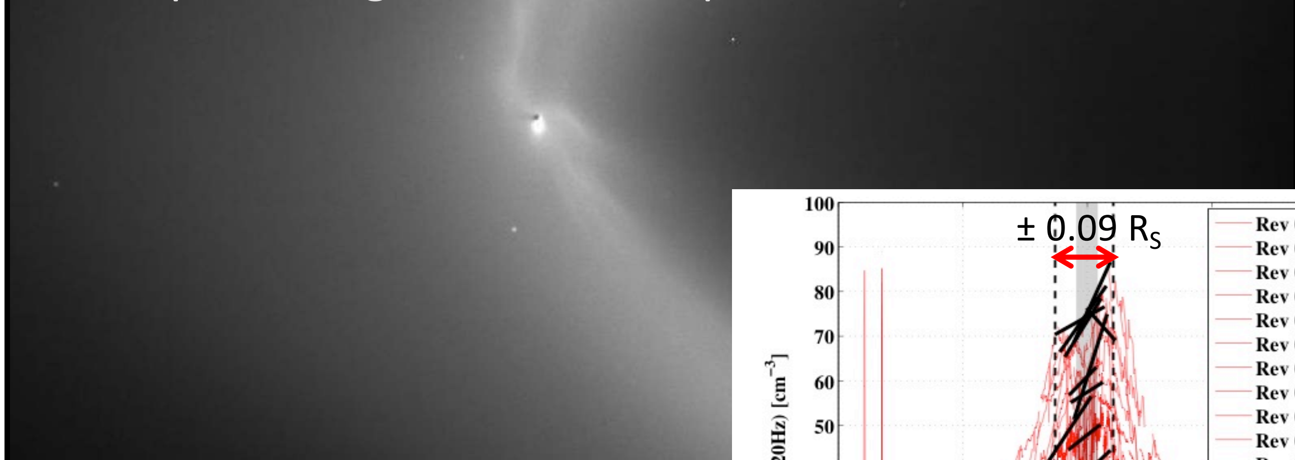


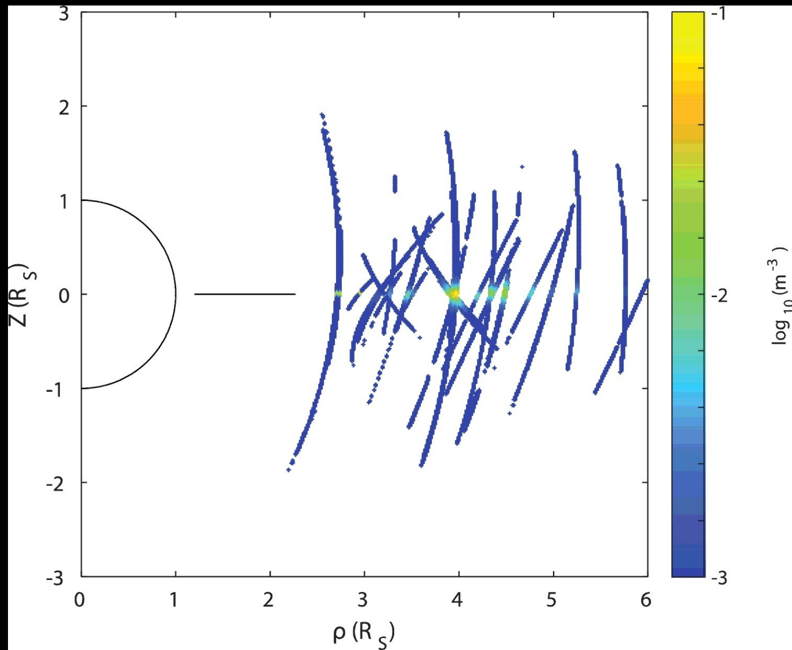
Away from Enceladus (Rev 66)

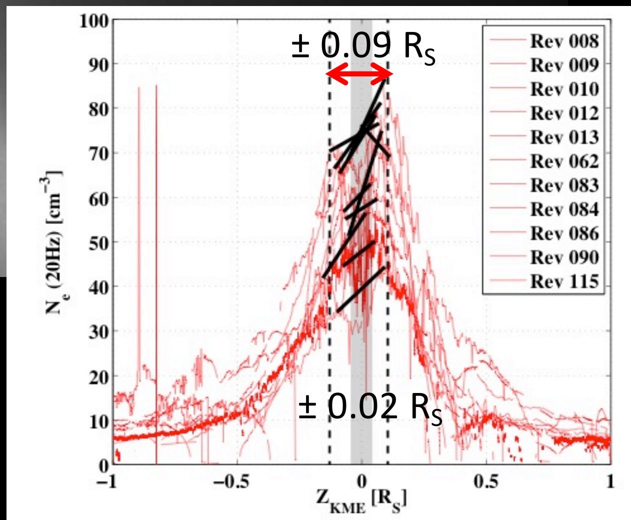


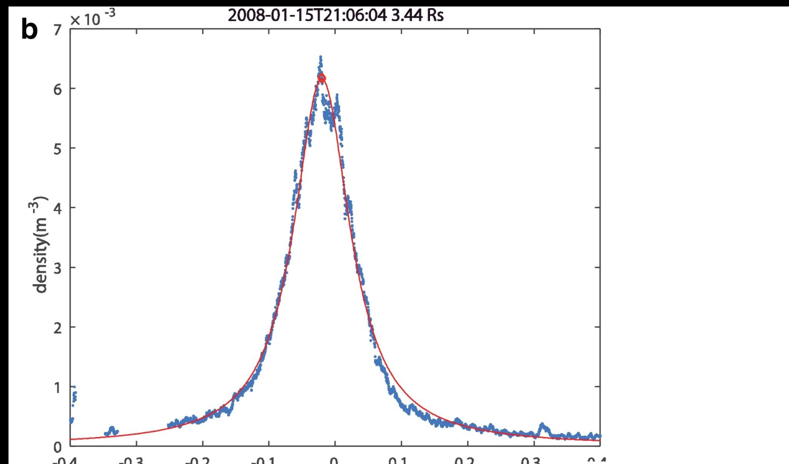
E ring dust

- $N_i >> N_e$ region appears associated with the µm sized dust signals.
- Narrow (<6000km) dusty disk cantered at equator in ±1200km.
- Surrounding plasma has north/south asymmetries.
- Shape is in agreement with µm dust disk.









Ye et al., [2016]

Different type dusty plasma

- Dusty Plasma condition

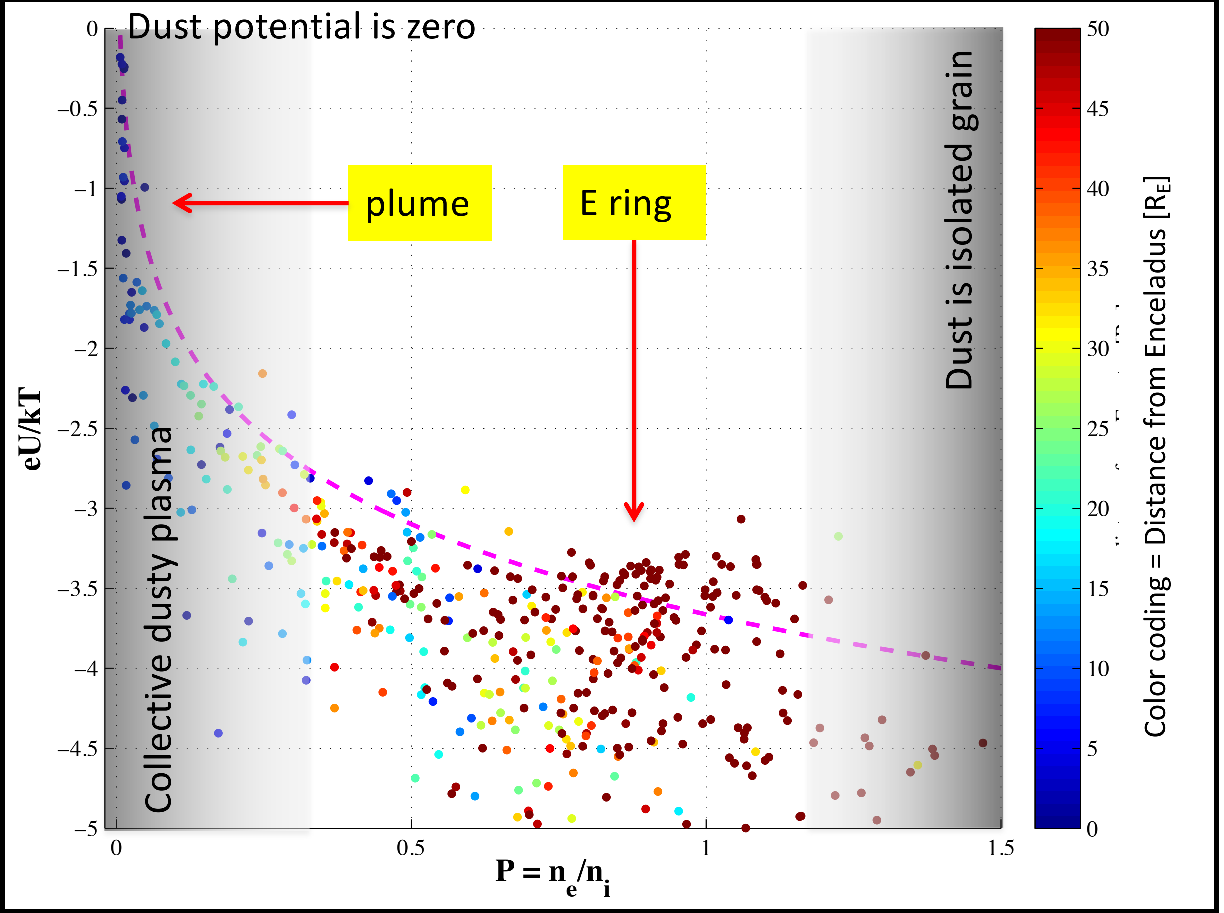
$I_i = I_e$

$$I_i = eN_i\sqrt{\frac{kT}{m_i}}\left(1-\frac{eU}{kT}\right)\pi a^2$$

$$I_e = eN_e\sqrt{\frac{kT}{m_e}}exp\left(\frac{eU}{kT}\right)\pi a^2$$

$$P = \frac{N_e}{N_i} \text{ (modified Havnes parameter)}$$

$$\left(1-\frac{eU}{kT}\right)+P\sqrt{\frac{m_i}{m_e}}exp\left(\frac{eU}{kT}\right)=0$$



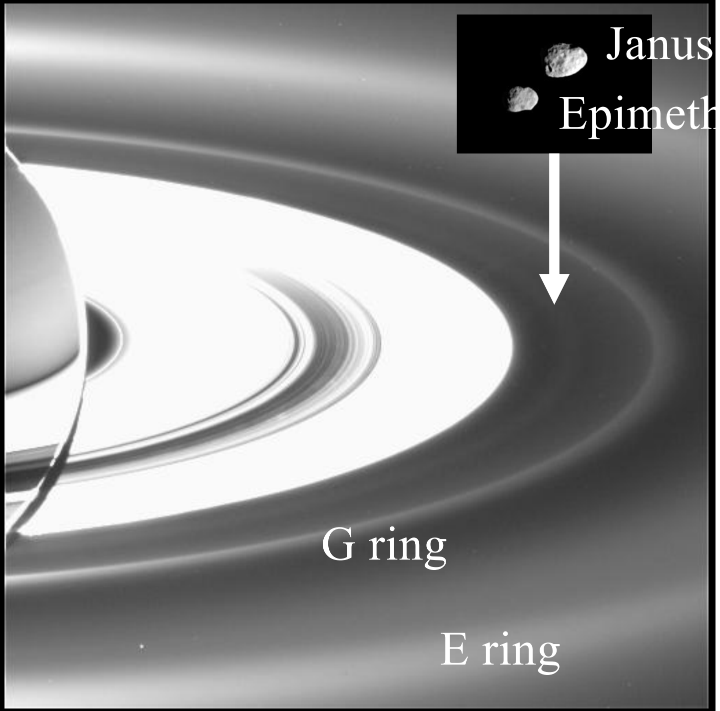
- Enceladus plume:

  Dust and plasma in collective regime

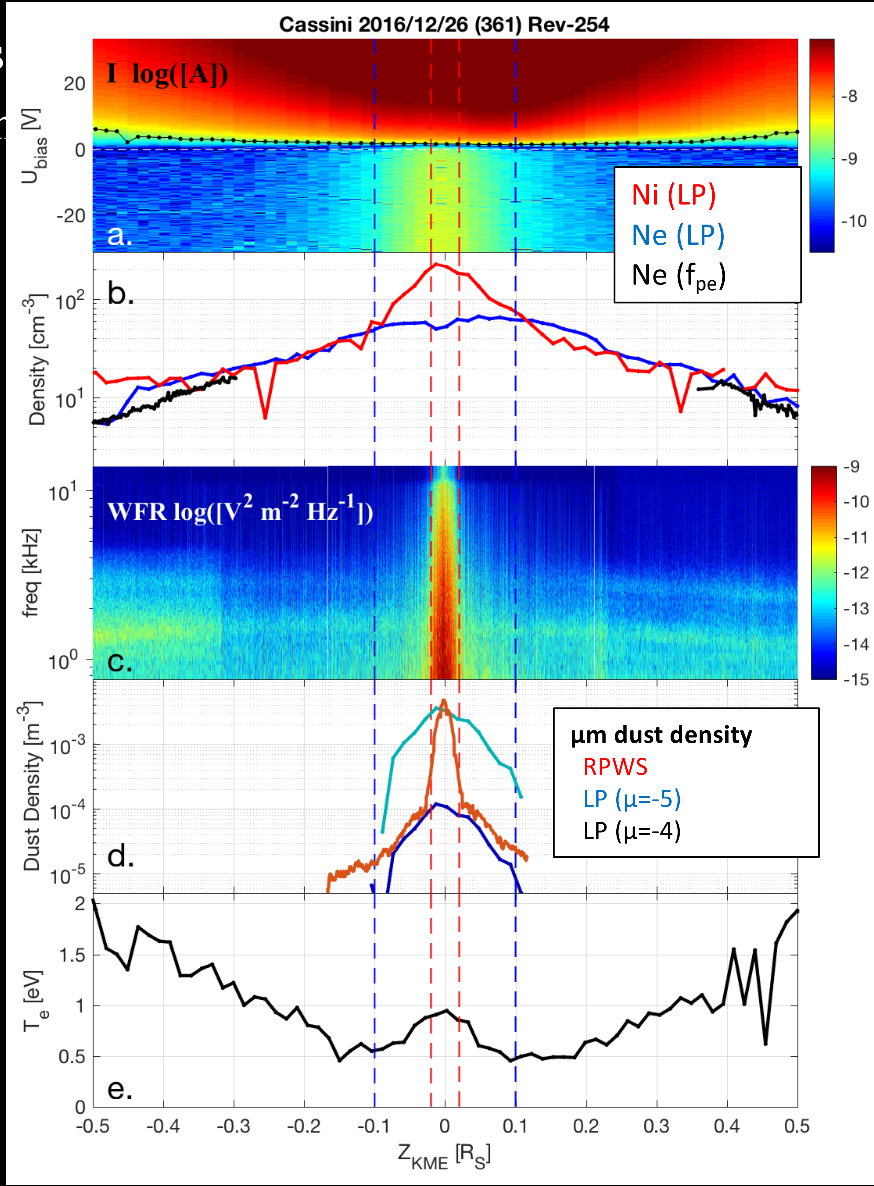
- E ring

  Dust are isolated in plasma.

Dusty F ring



Janus
Epimeth
G ring
E ring



Cassini 2016/12/26 (361) Rev-254
I log([A])
a.
b.
c.
d.
e.
Ni (LP)
Ne (LP)
Ne (fpe)
WFR log([V2 m-2 Hz-1])
μm dust density
RPWS
LP (μ=-5)
LP (μ=-4)
Ubias [V]
Density [cm-3]
freq [kHz]
Dust Density [m-3]
Te [eV]
ZKME [RS]

Dusty F ring

N_i/N_e>1 has found at the ring.

- Extra Ni increasing at $|Z|<0.1R_S$
- µm size dust appears at $|Z| < 0.02R_S$ (RPWS)

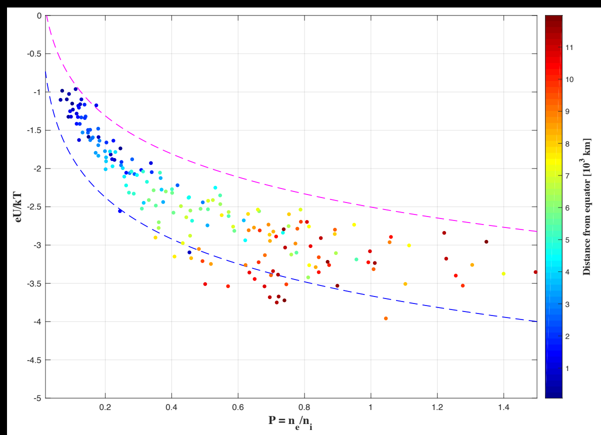
More µm grains close to center.

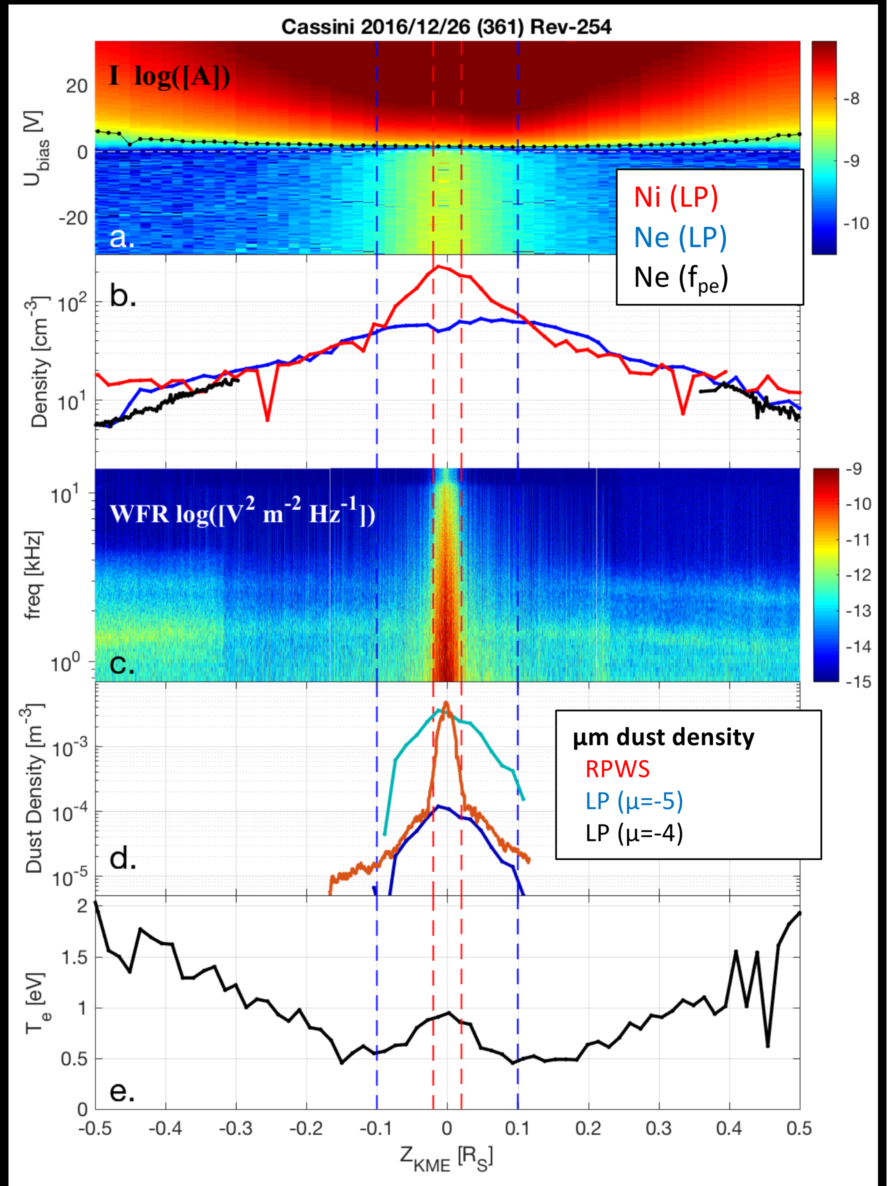
But most of the negative charges are on nm grains.

Dust size distribution sharper close to ring center.

$$N_d = \int K a^{\mu} da$$

Havnes parameter plot indicates dust-plasma collective near center.





The LP observations of the dust and plasma

- The dusty plasma environment have be found in many places in the Kroninan system.
  - Enceladus plume, E ring, F ring
  - Saturn ionosphere and Titan ionosphere as well
- The Langmuir Probe provides important parameters for the dusty plasma.
- Dust-Plasma interaction differs depending on the dust characteristics.
- Similar dust-plasma environment can be expected at:
  - Europa plume, Europa torus, Ganymede ionosphere.
- We can do a better observations in the Jupiter system by JUICE.
  - With better data points and more parameter including E-field.