Effects of galactic cosmic ray ionisation on cloud droplet behaviour on Venus

M W Airey, R G Harrison, K L Aplin, C Pfrang

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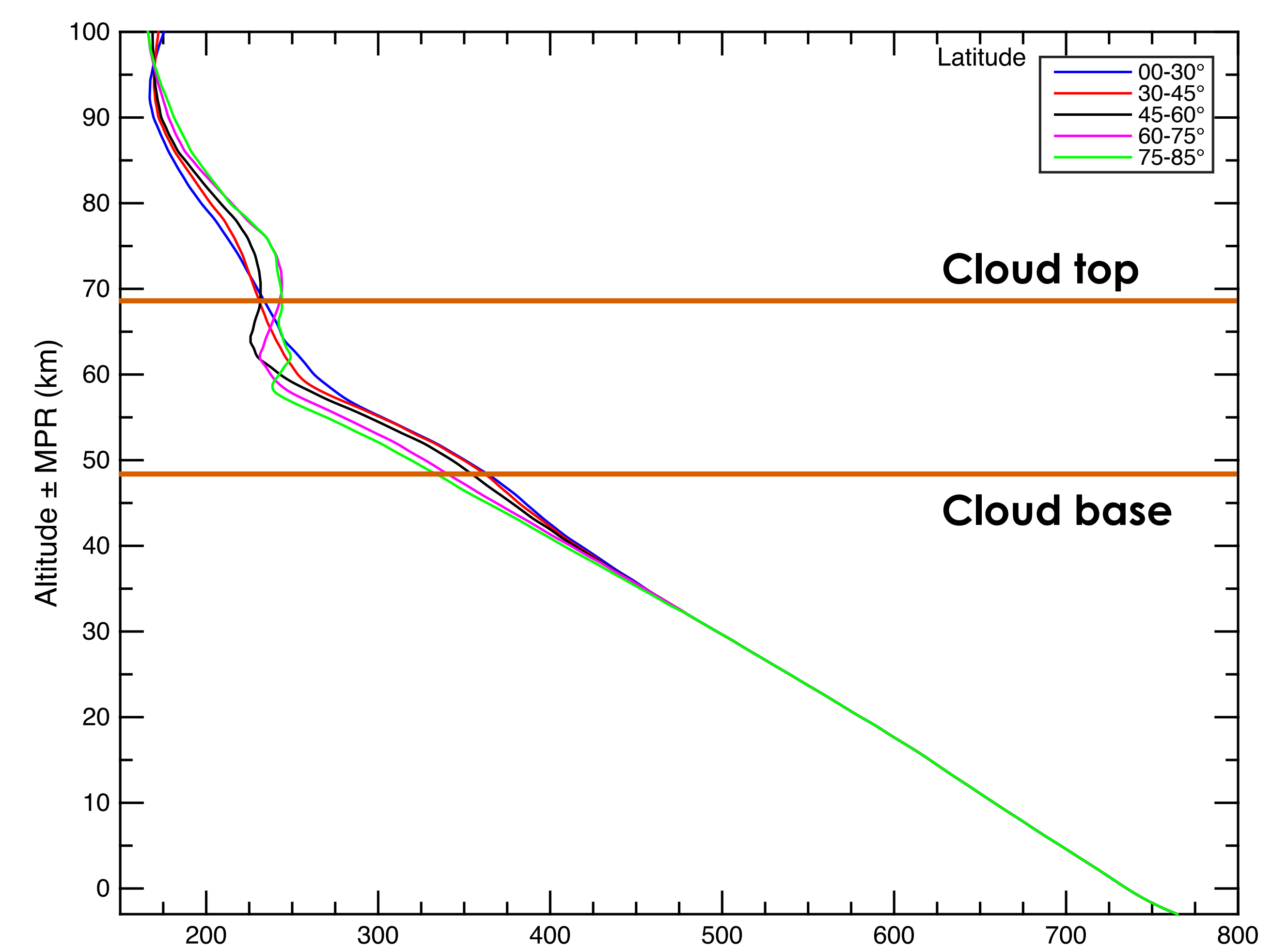
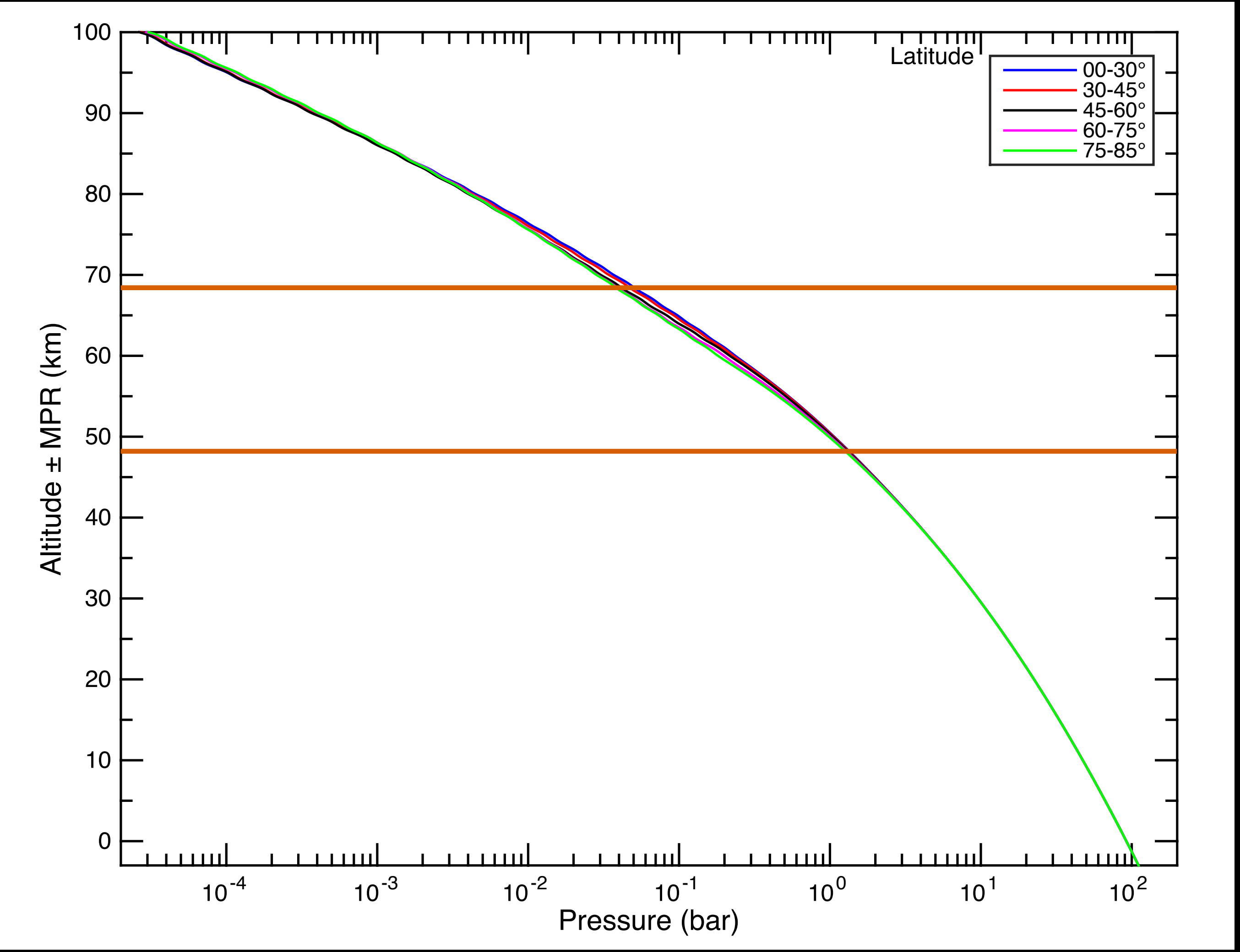
Introduction

Atmosphere and clouds of Venus:

- 96.5% CO_2, 3.5% N_2, traces Ar, H_2O, SO_2, O_2, CO, Ne
- Photo-assited reactions form H_2SO_4 clouds at ~70 km
- Persist to thermal decomposition at ~48 km
- Ionisation principally via Galactic Cosmic Rays below ~100 km
- Other sources may inc. dust tribo, radioactive decay, ash fracto



VIRA data: Kliore et al., 1986



Cosmic rays

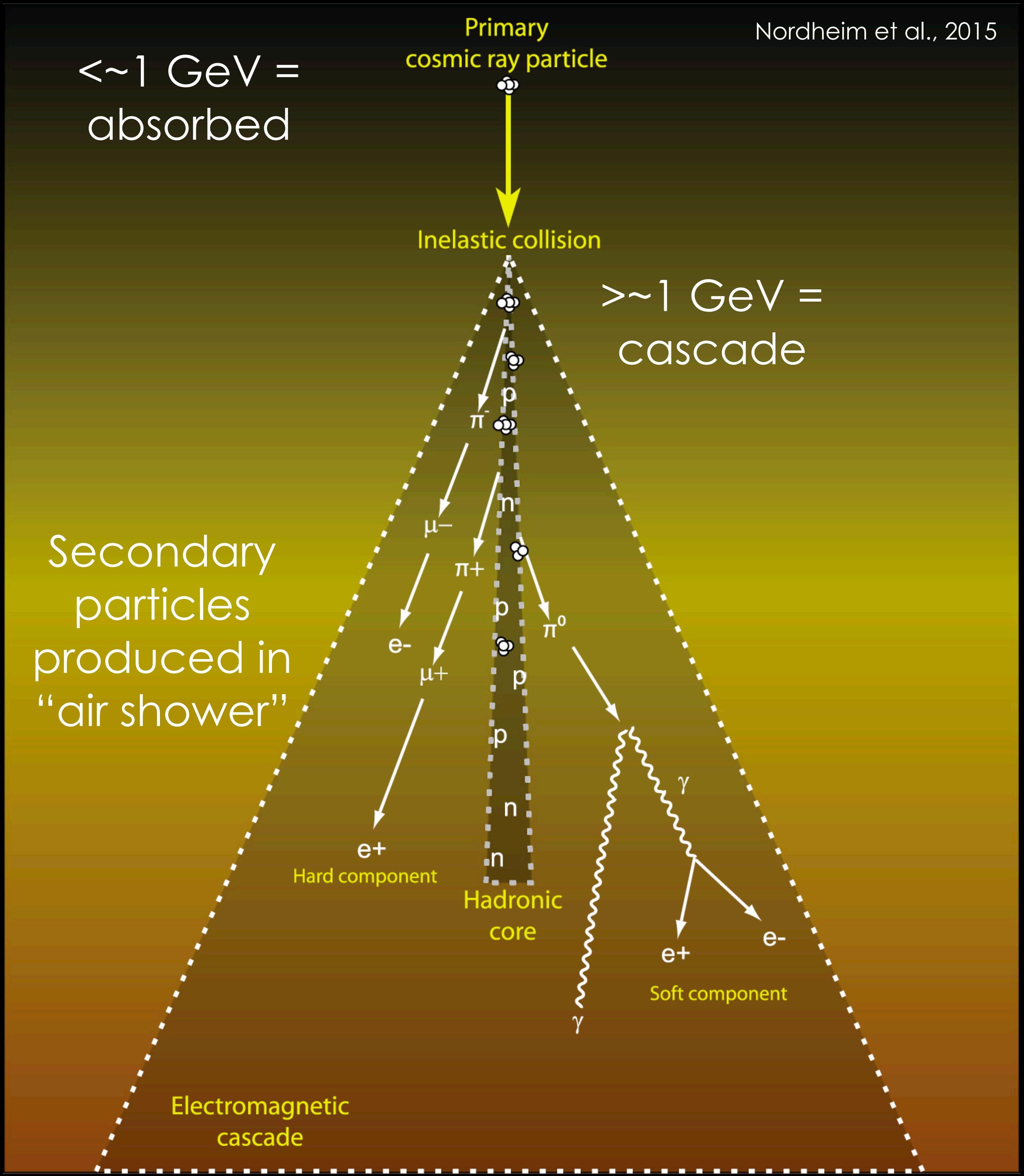
Total cosmic rays comprises galactic cosmic rays (GCRs) and solar energetic particles (SEPs)

GCRs are energetic atomic nuclei:

- Mostly protons (H)
- ~10% alpha particles (He)
- ~1% electrons
- ~1% heavier nuclei

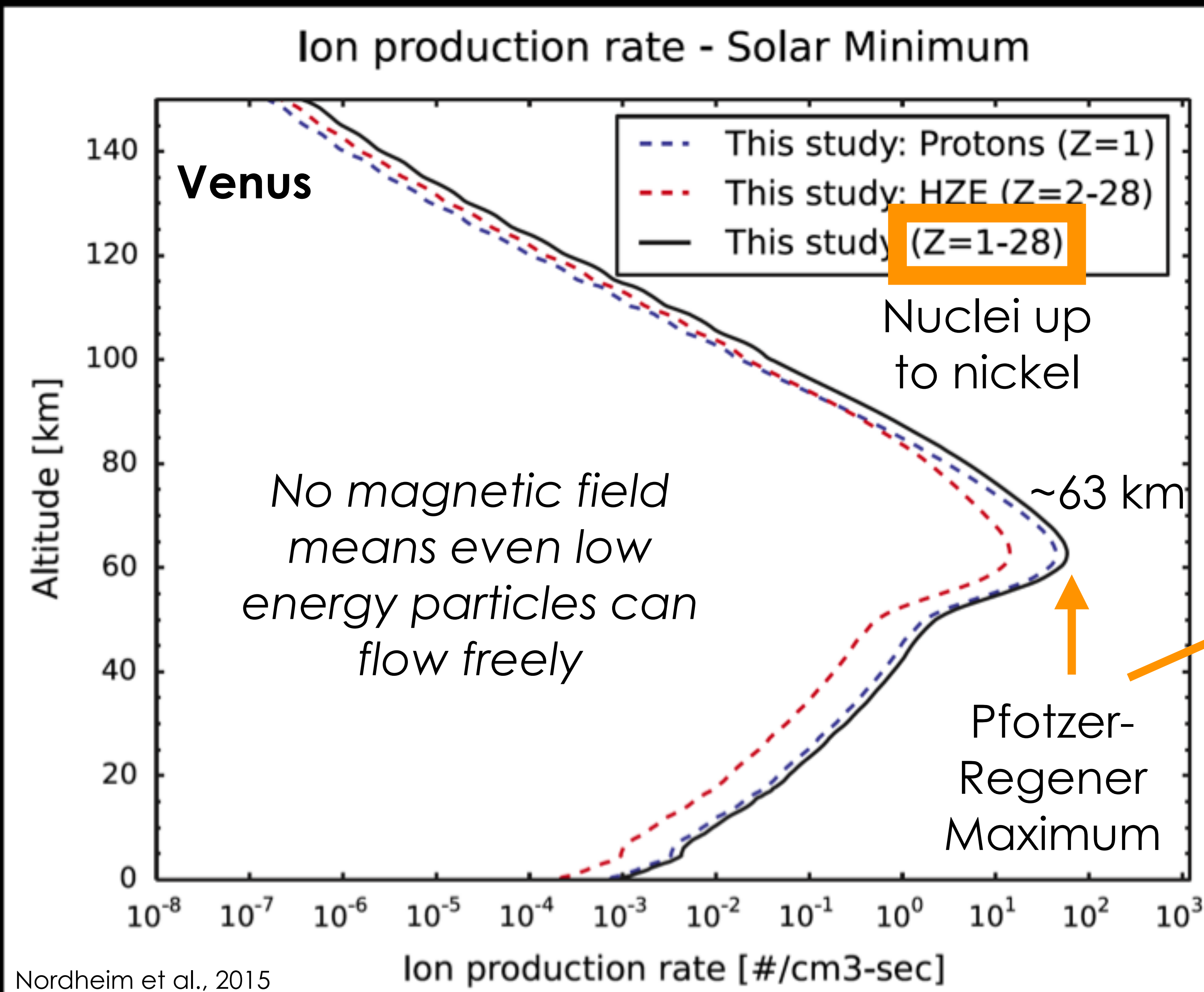
Range from:

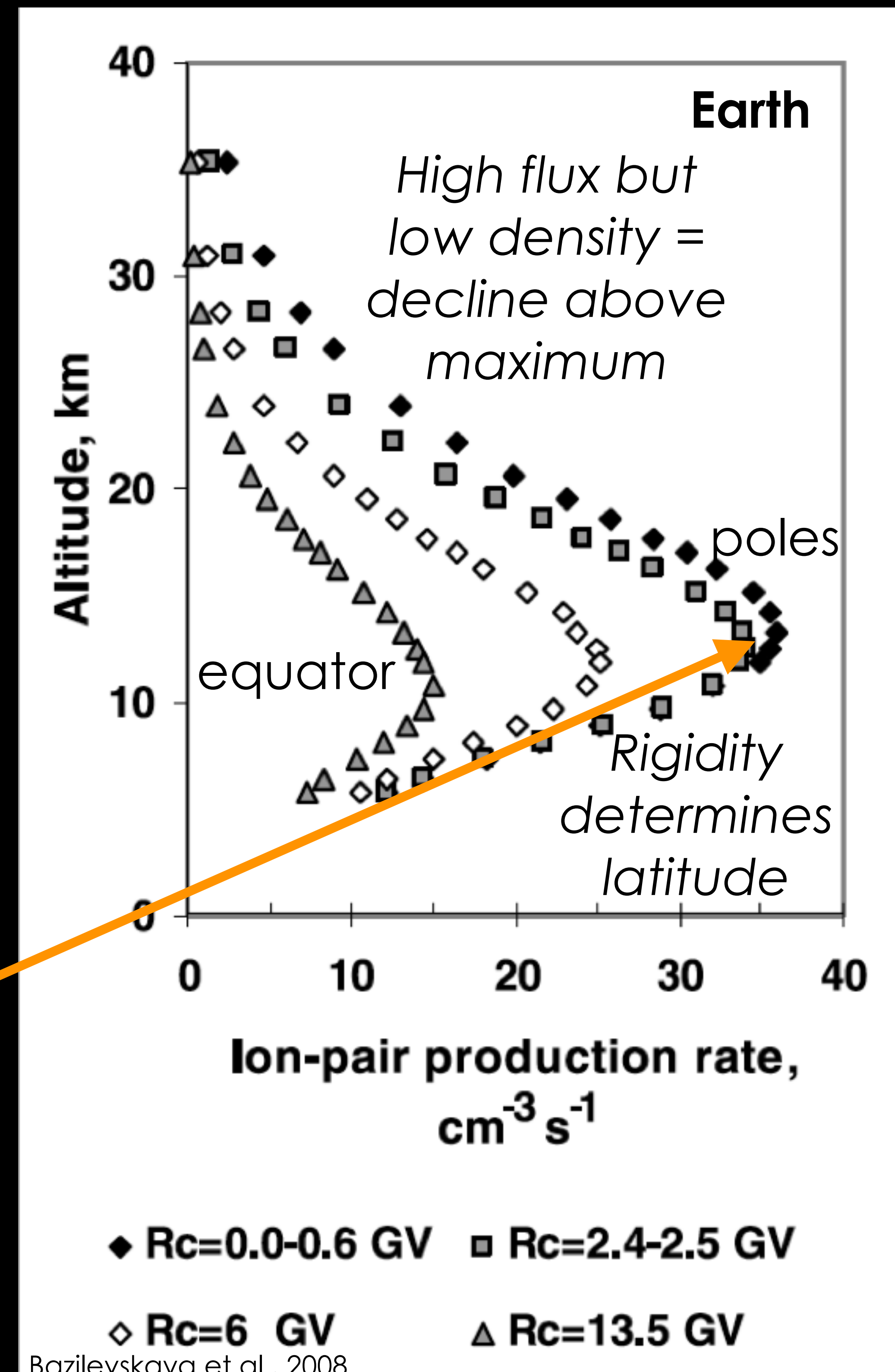
- 1 MeV to 5×10^{13} MeV



Cosmic rays: Earth vs. Venus

- Secondary particle intensity (in terms of *q*) has a distinctive profile for Venus and Earth
- Geomagnetic field prevents particles below a rigidity threshold



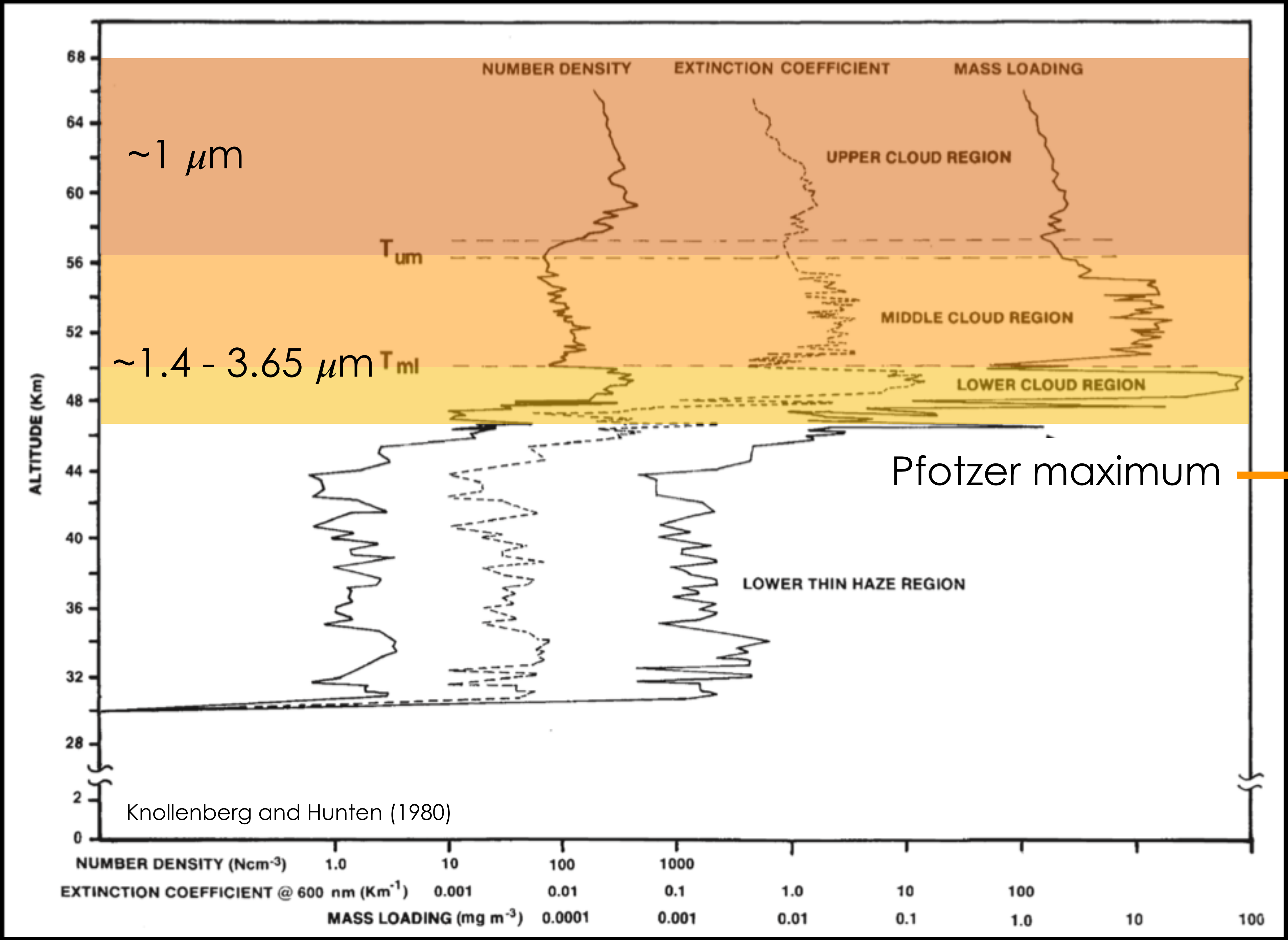


Cloud structure

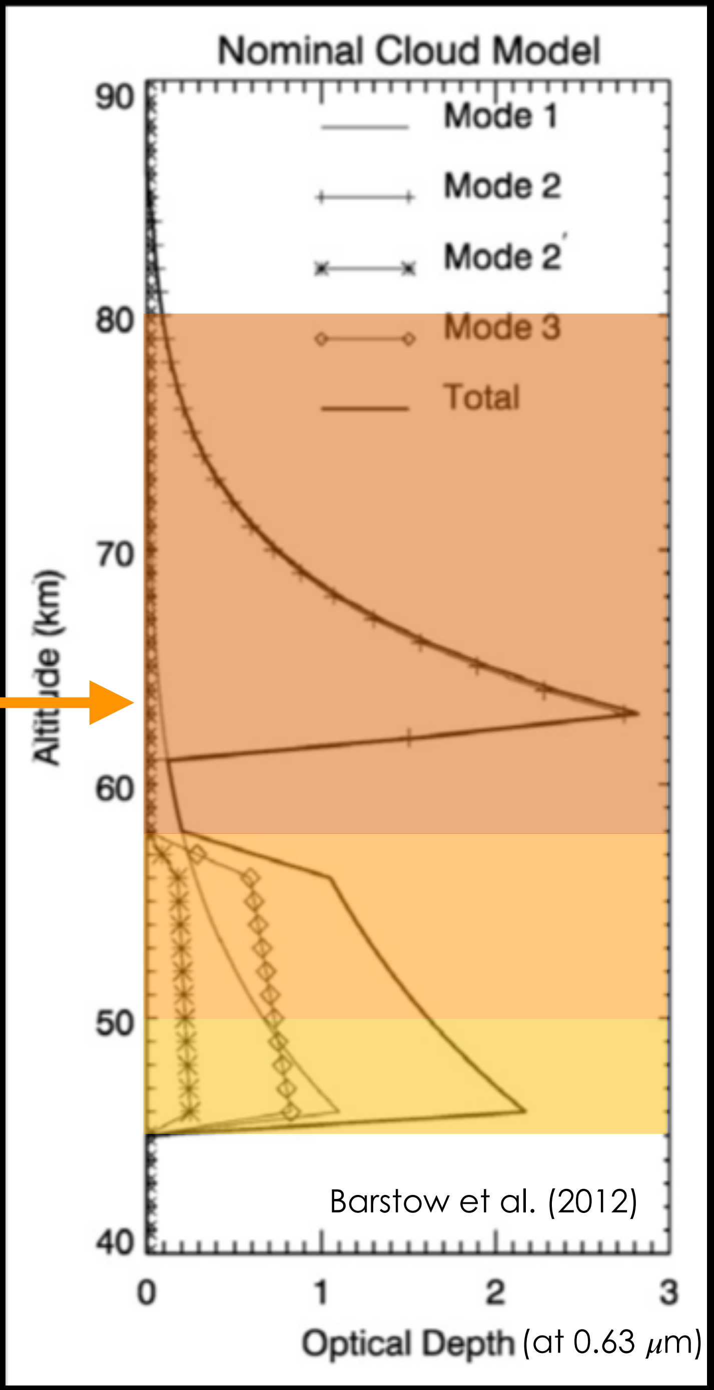
Well known characteristic 'modes' in cloud layers measured from orbiting spectrometers (PVO - VEx)

Table 1
Aerosol particle size distribution as used in this work, which are the same as those used by Pollack et al. (1993). All size distributions are log-normal: $n(r) \propto r^{-1} \exp[-(\ln r - \ln \bar{r})^2/(2\sigma^2)]$, where $\bar{r}$ is the mean radius.

Mode	Effective radius (μm)	σ
Mode 1	0.30	0.44
Mode 2	1.00	0.25
Mode 2′	1.40	0.21
Mode 3	3.65	0.25

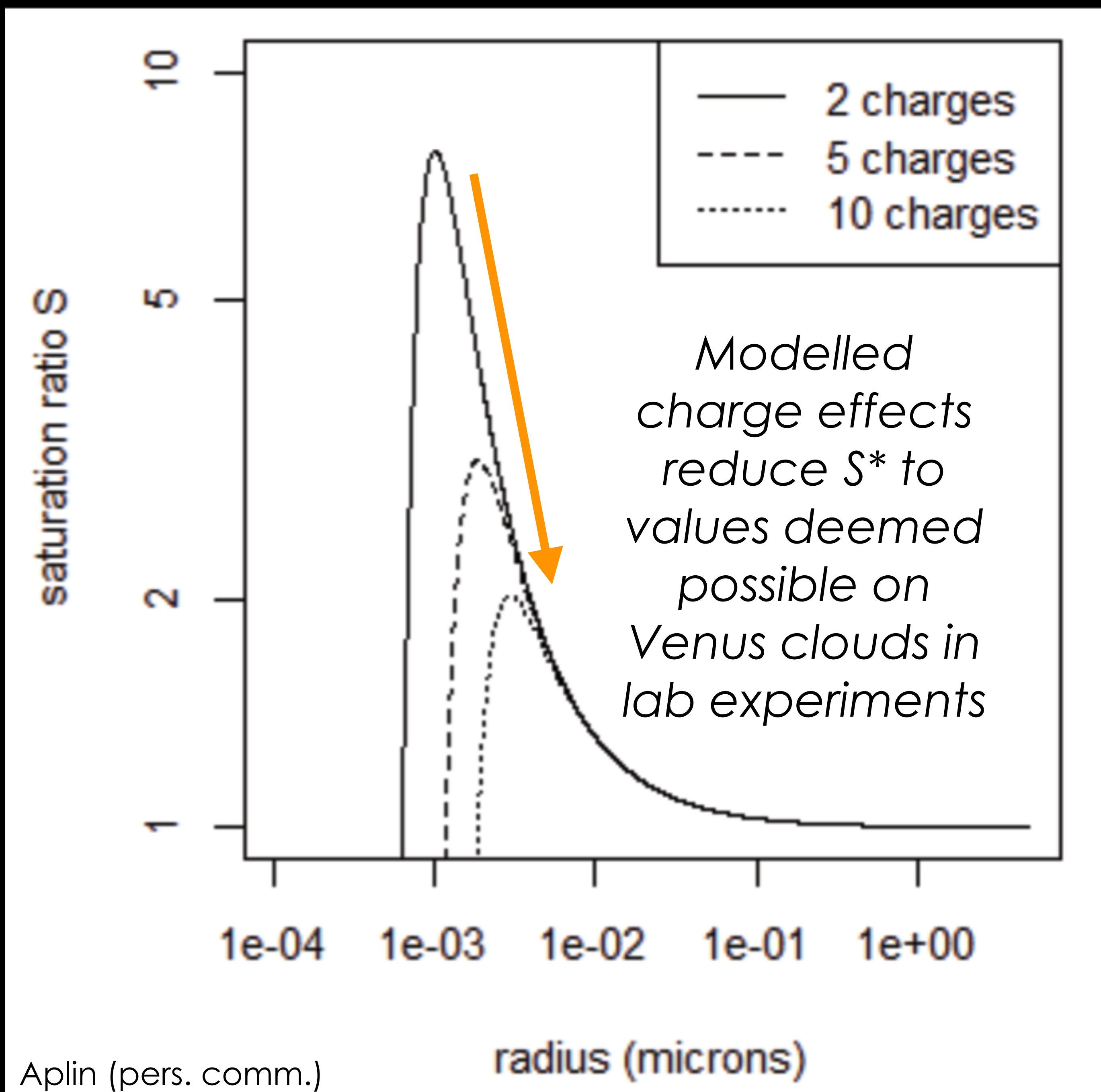


Pfotzer maximum



Cloud droplet charging

Charging of the cloud deck would allow larger droplets to be stable at lower saturation ratios



When charged, Rayleigh effect reduces vapour pressure around droplet (extra energy required for evaporation)

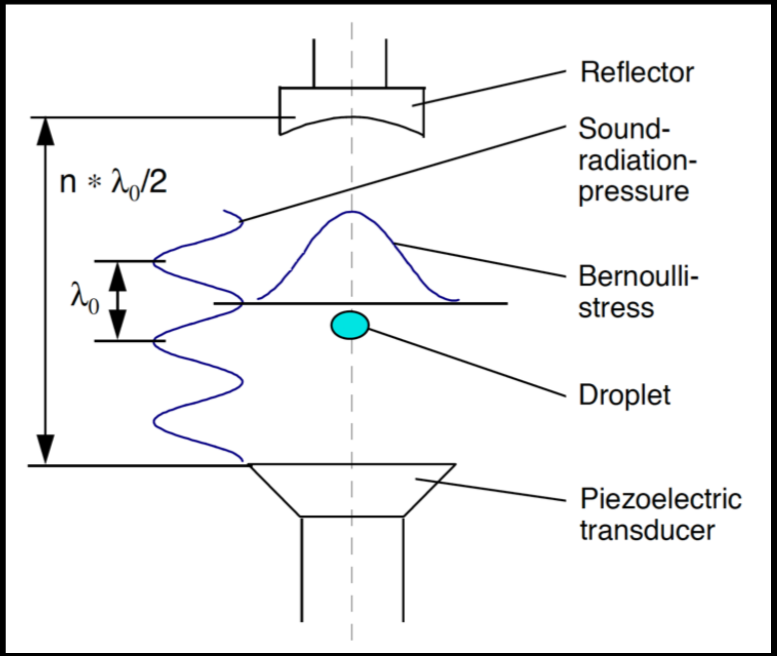
Venus Atmosphere thought to be supersaturated with respect to H_2SO_4 (S>2) (Kolodner and Steffes, 1998)

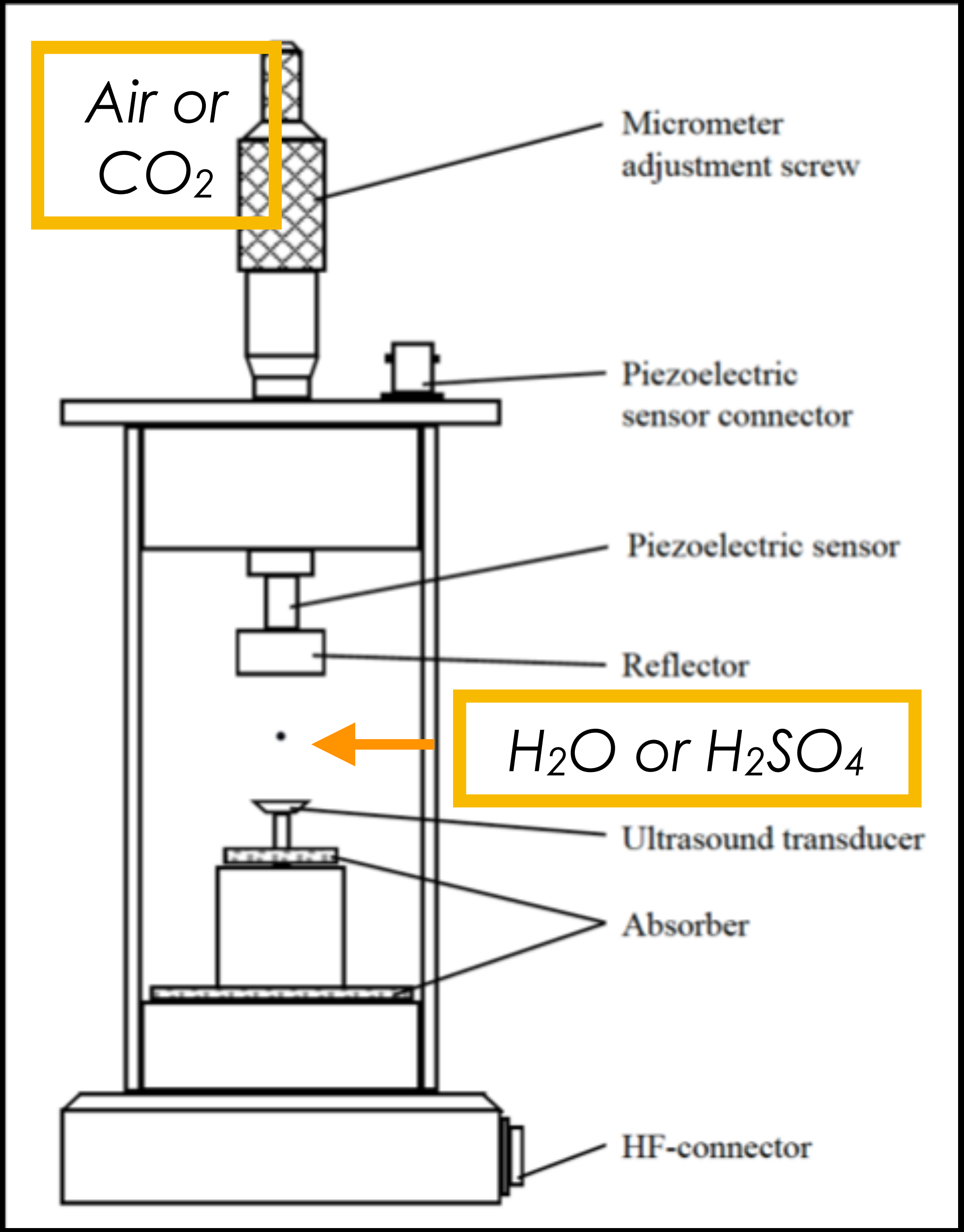
At sufficient saturation, gases may condense directly onto ions, which could lead to cloud formation

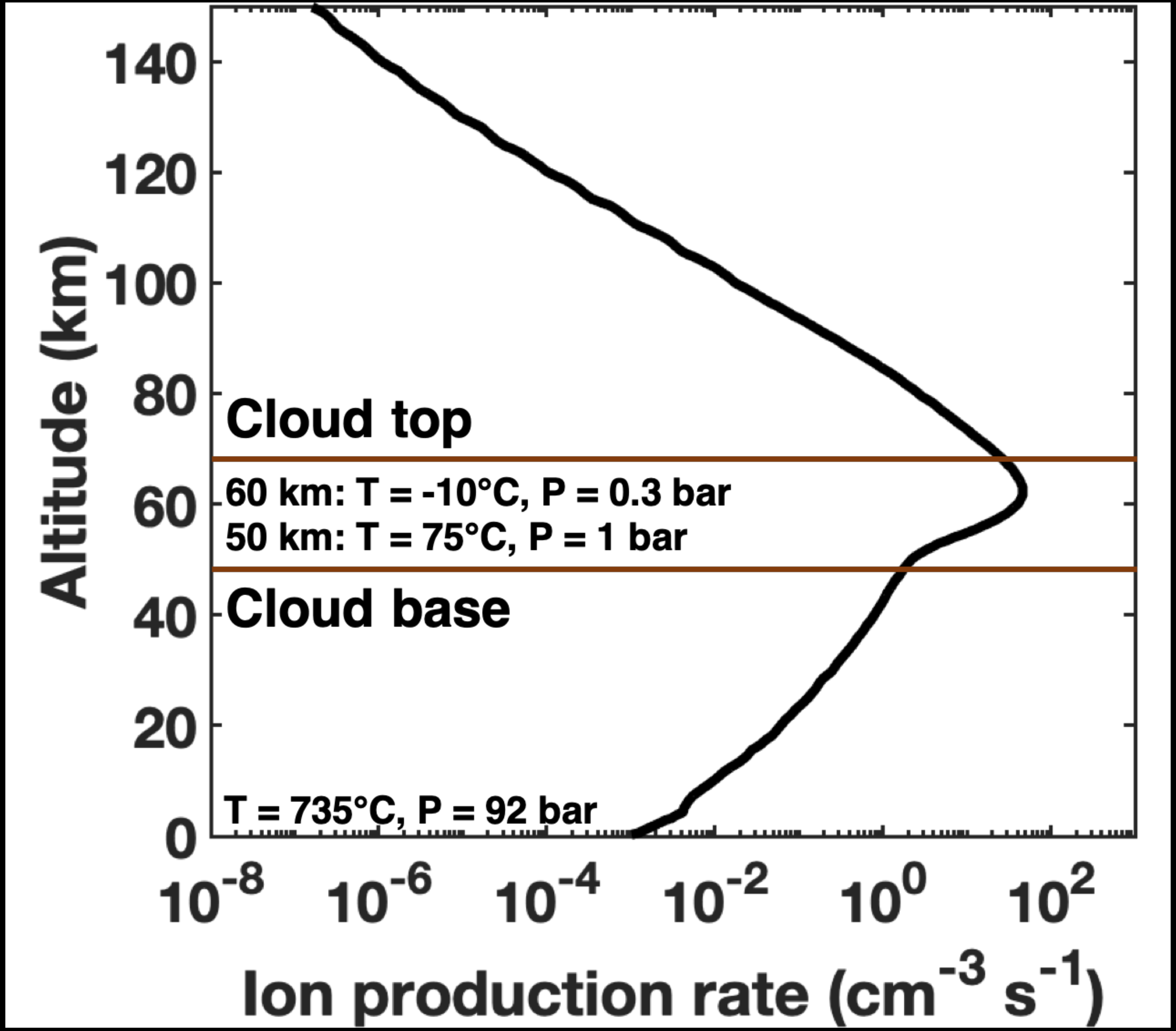
VENI project

Are cosmic rays and SEPs important for Venus' clouds?

"Cloud" droplets are levitated in an acoustic wave

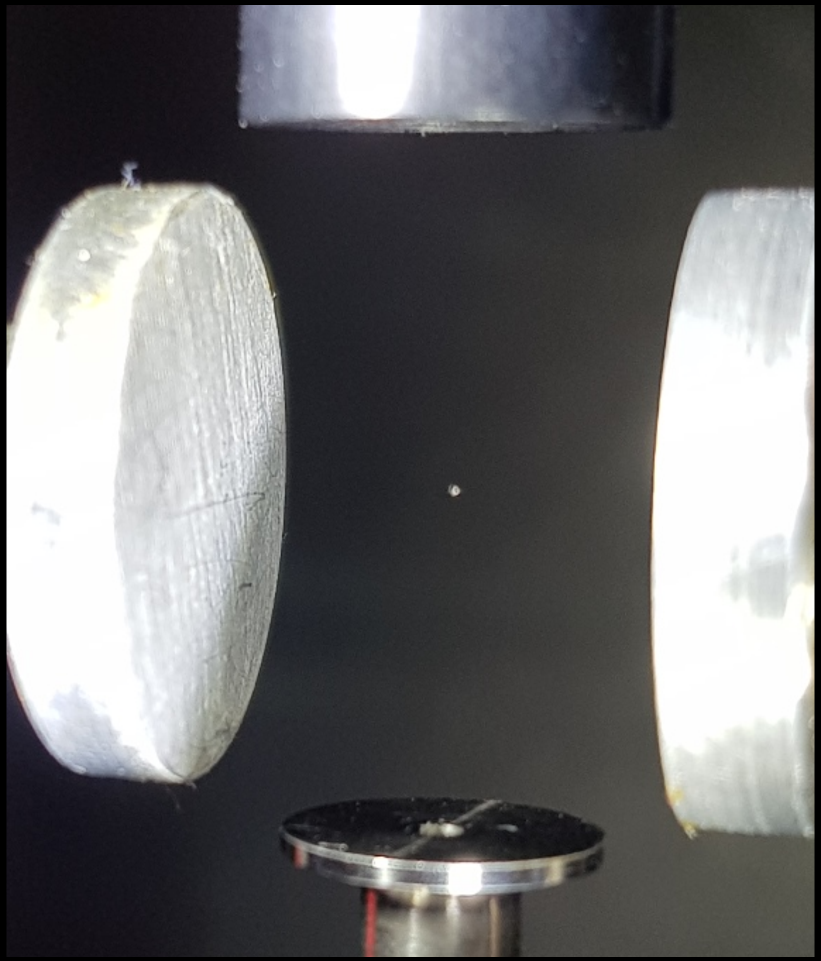


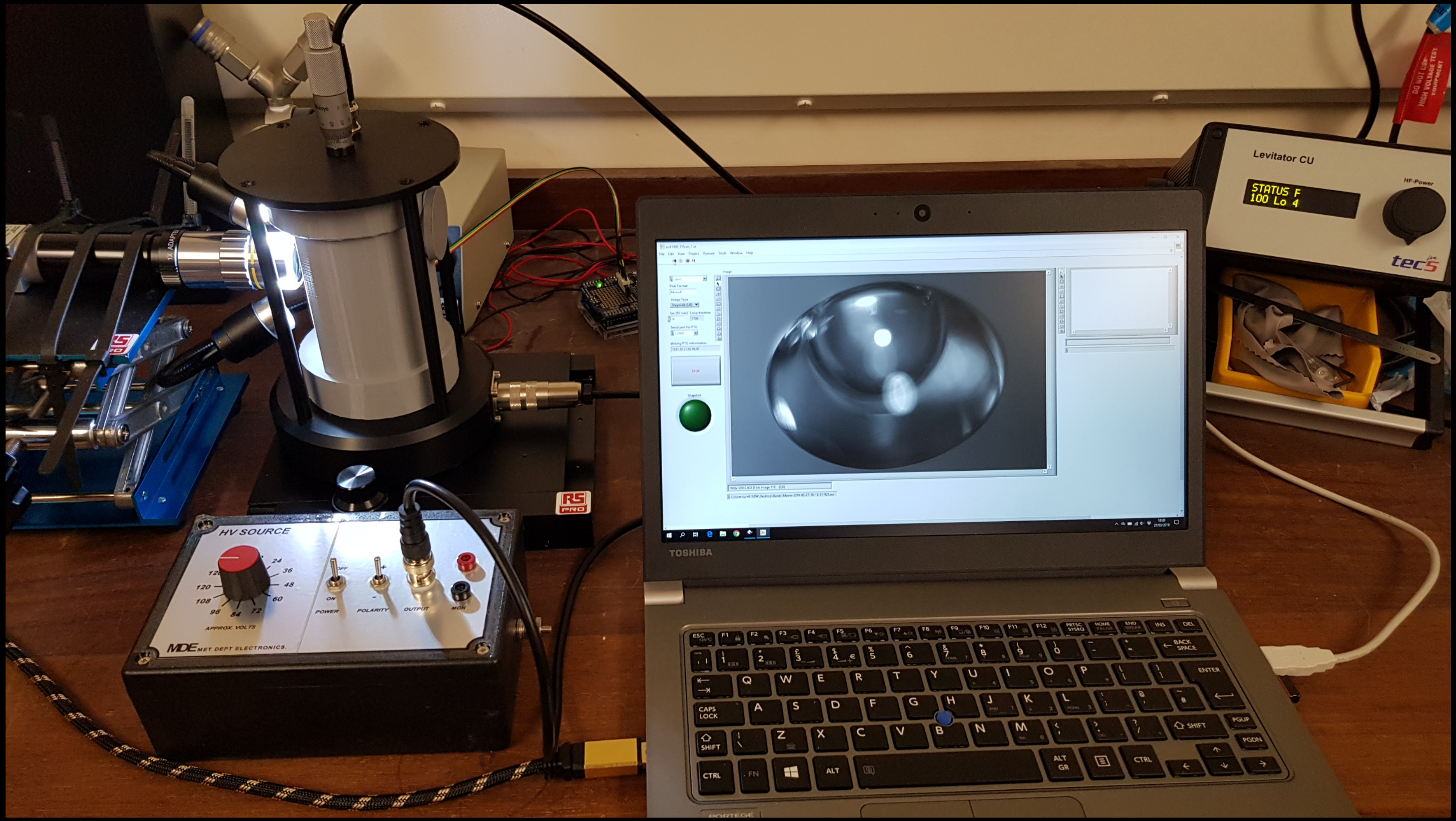




VENI project

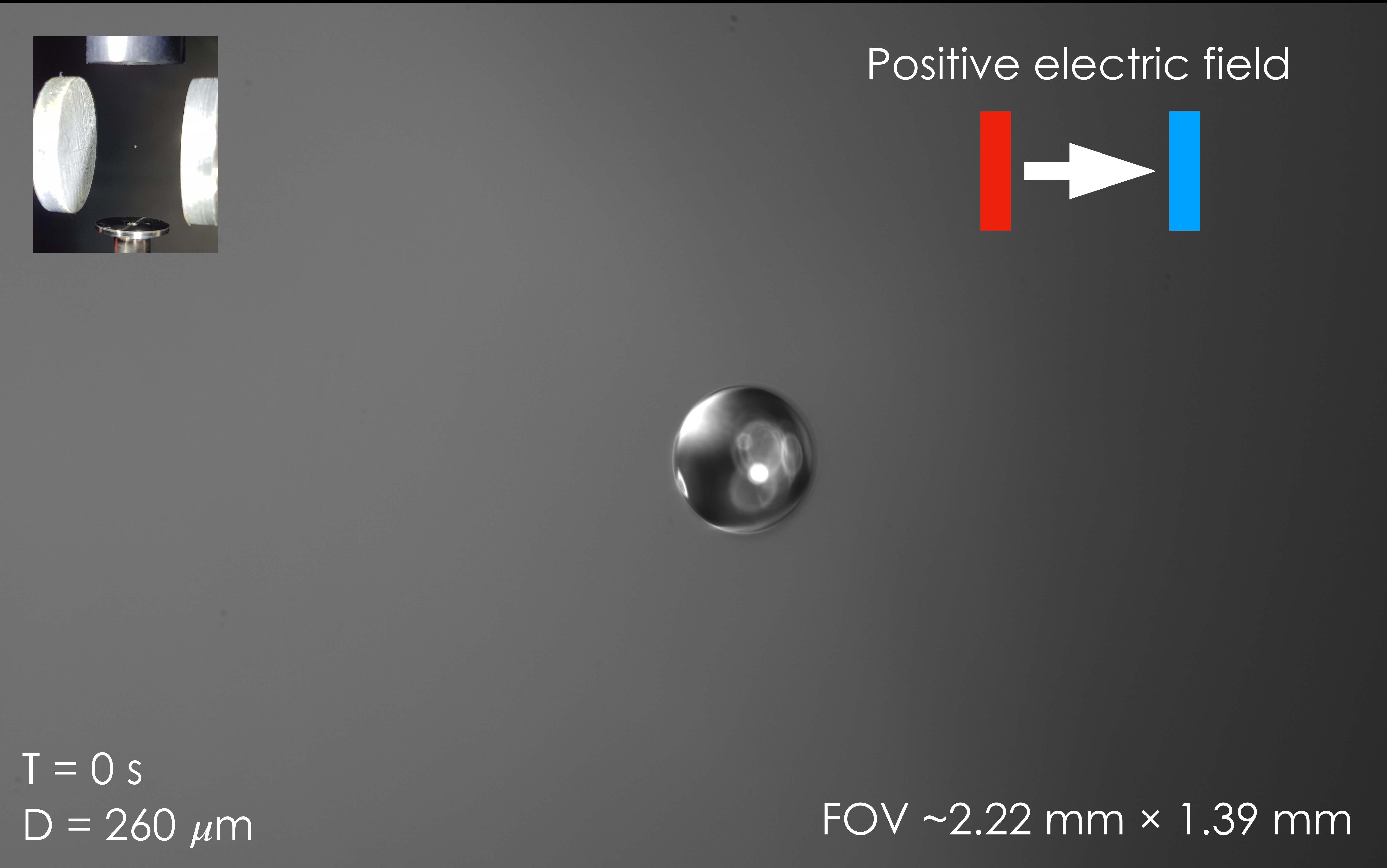
Droplets held in a reversible 10 kV m^{-1} electric field
Charge on droplet causes deflection in the electric field





Droplet monitored as it evaporates and deflections recorded in snapshots

VENI project



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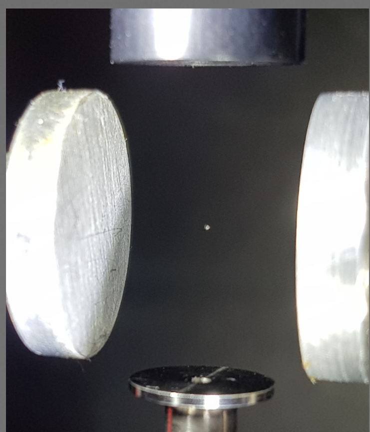
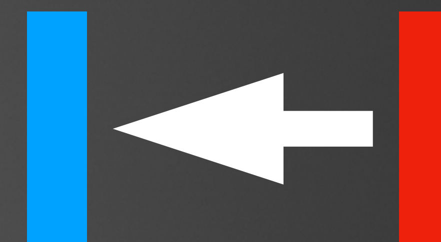
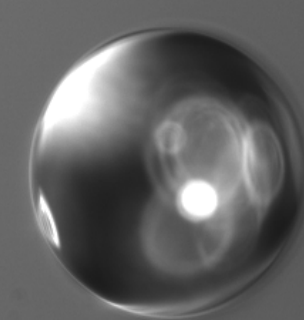


Negative electric field



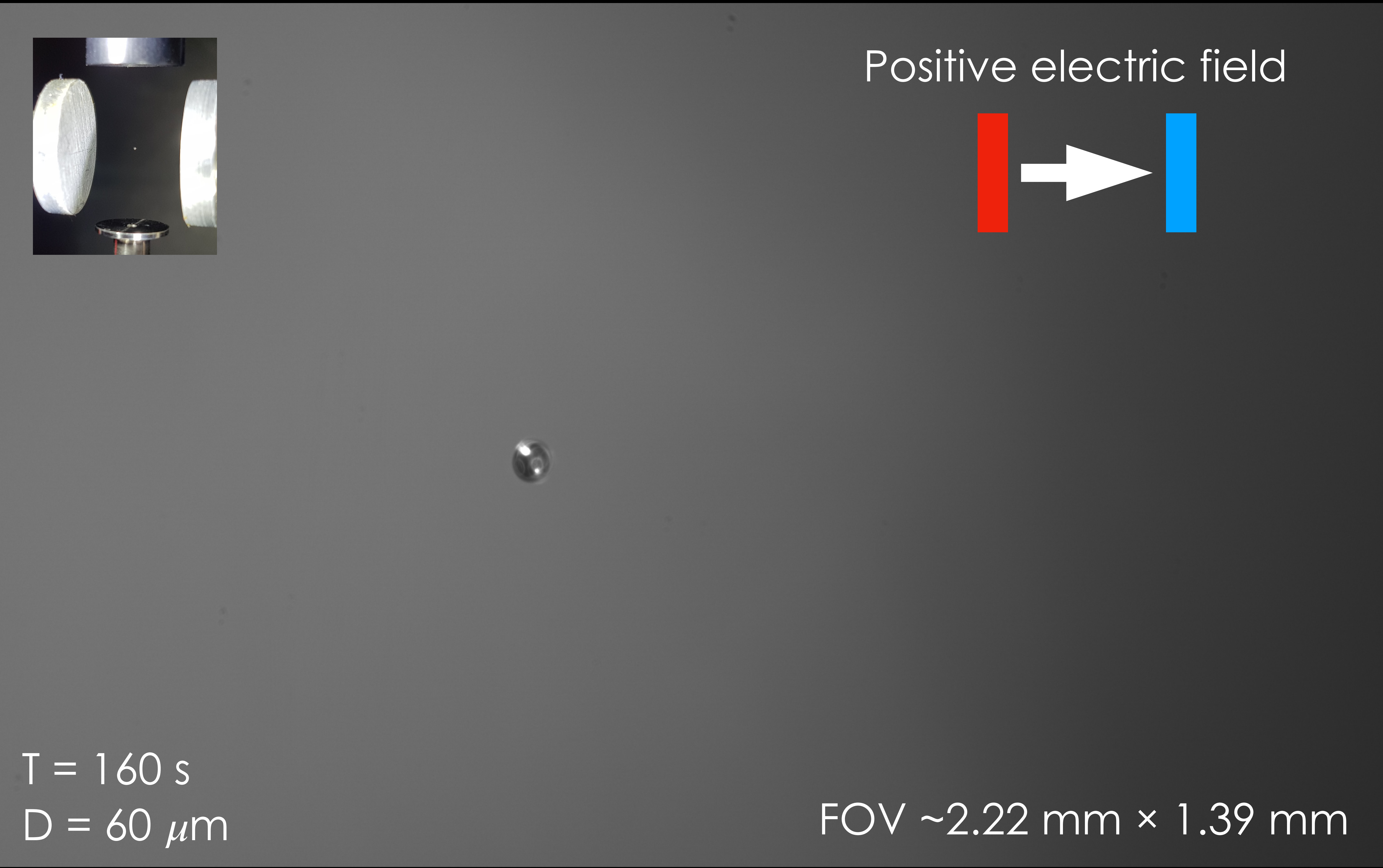


T = 0 s

D = 260 μm

FOV ~2.22 mm × 1.39 mm

VENI project



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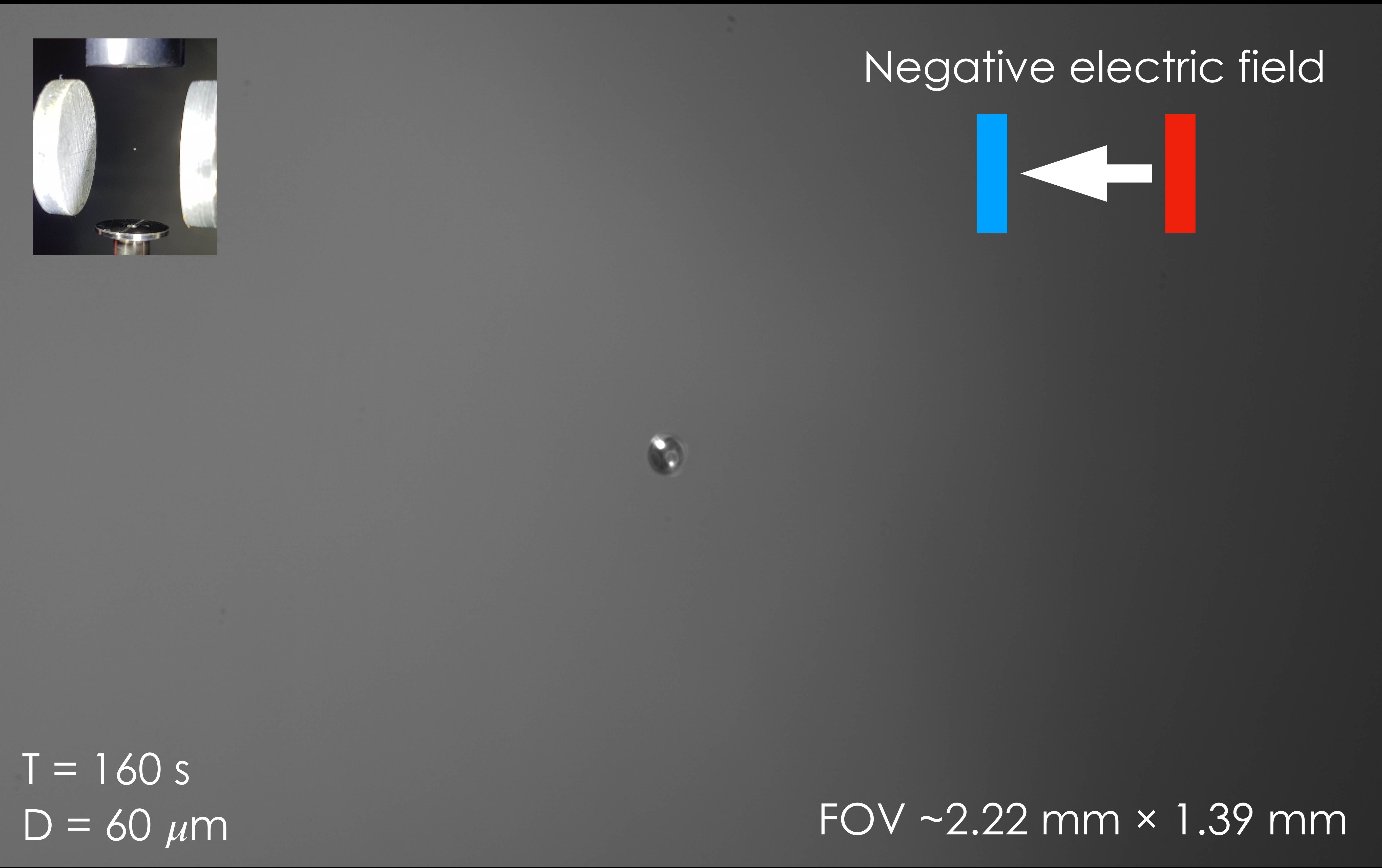
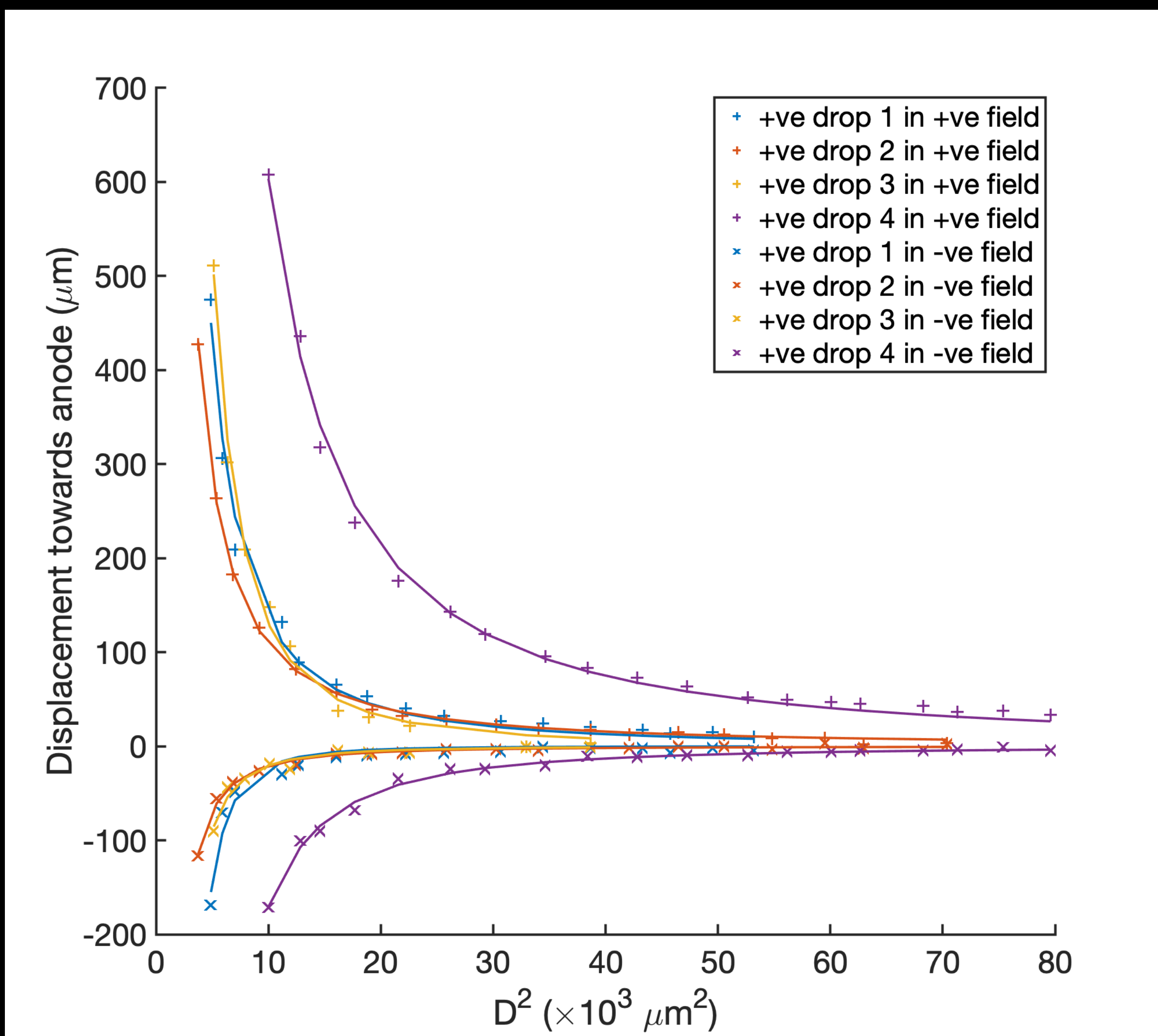


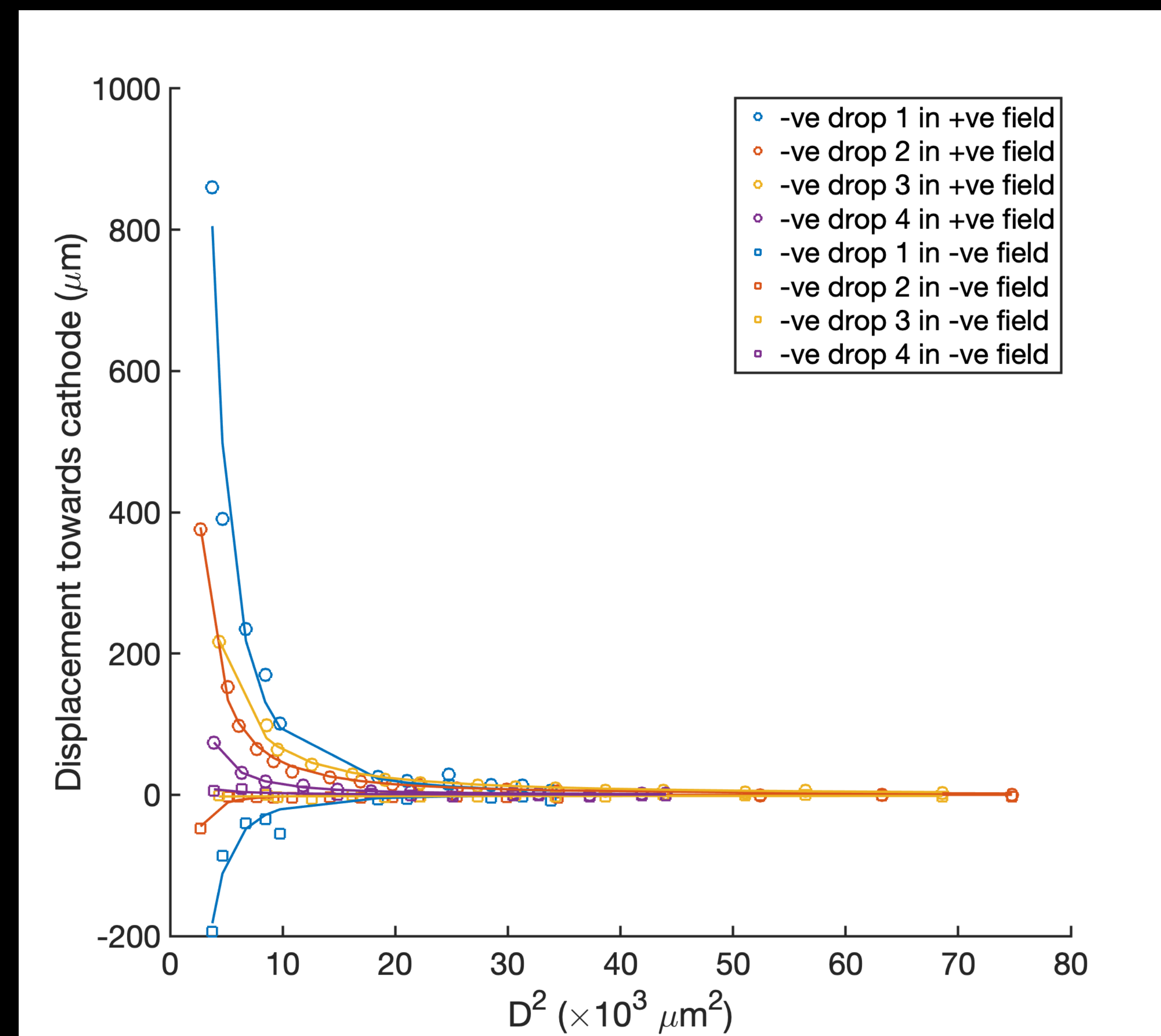
Droplet charge

Selection of eight droplets recorded
Curve characteristic of charge magnitude
Exponent of this curve taken as charge parameter

Positive droplets



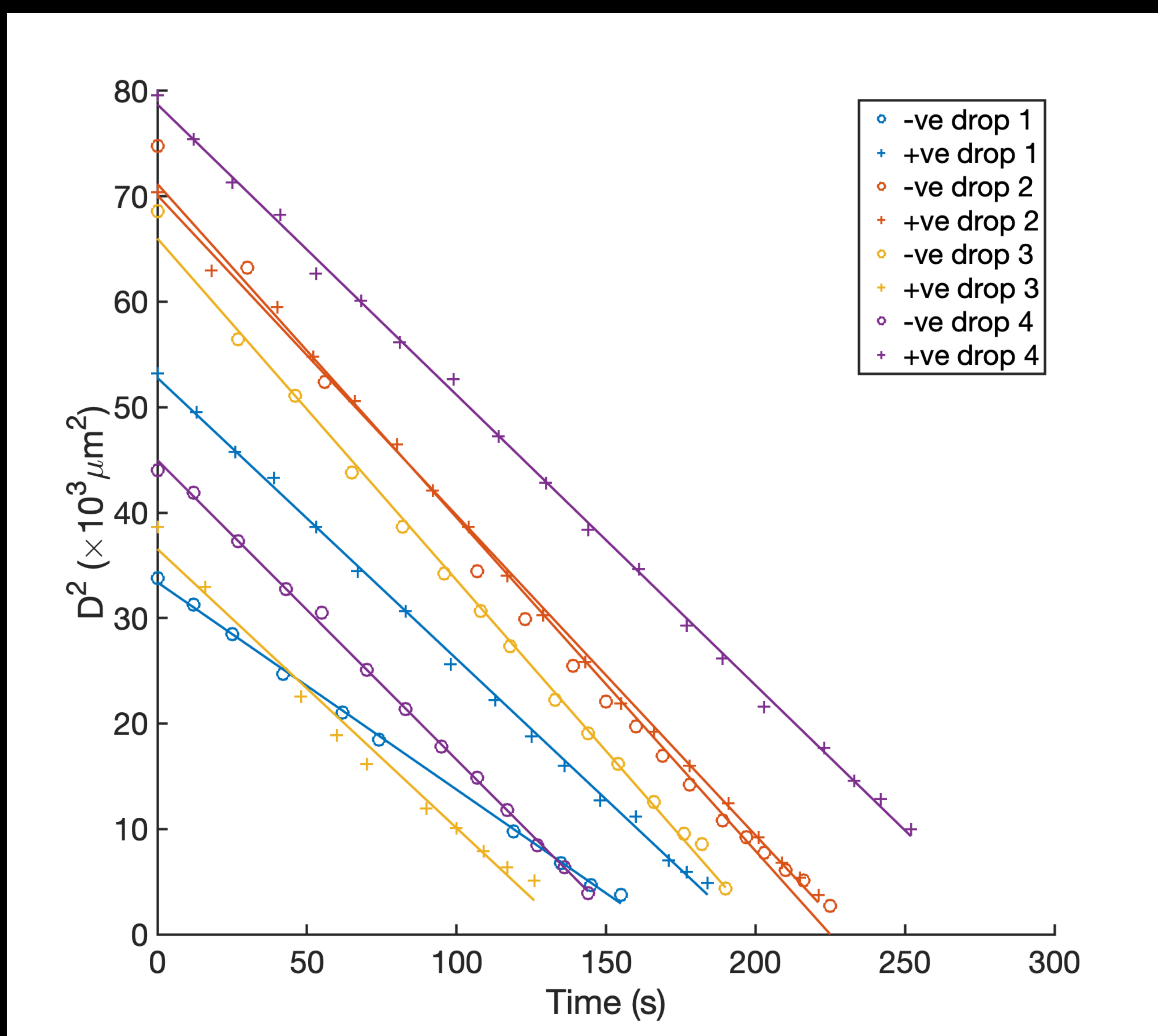
Negative droplets



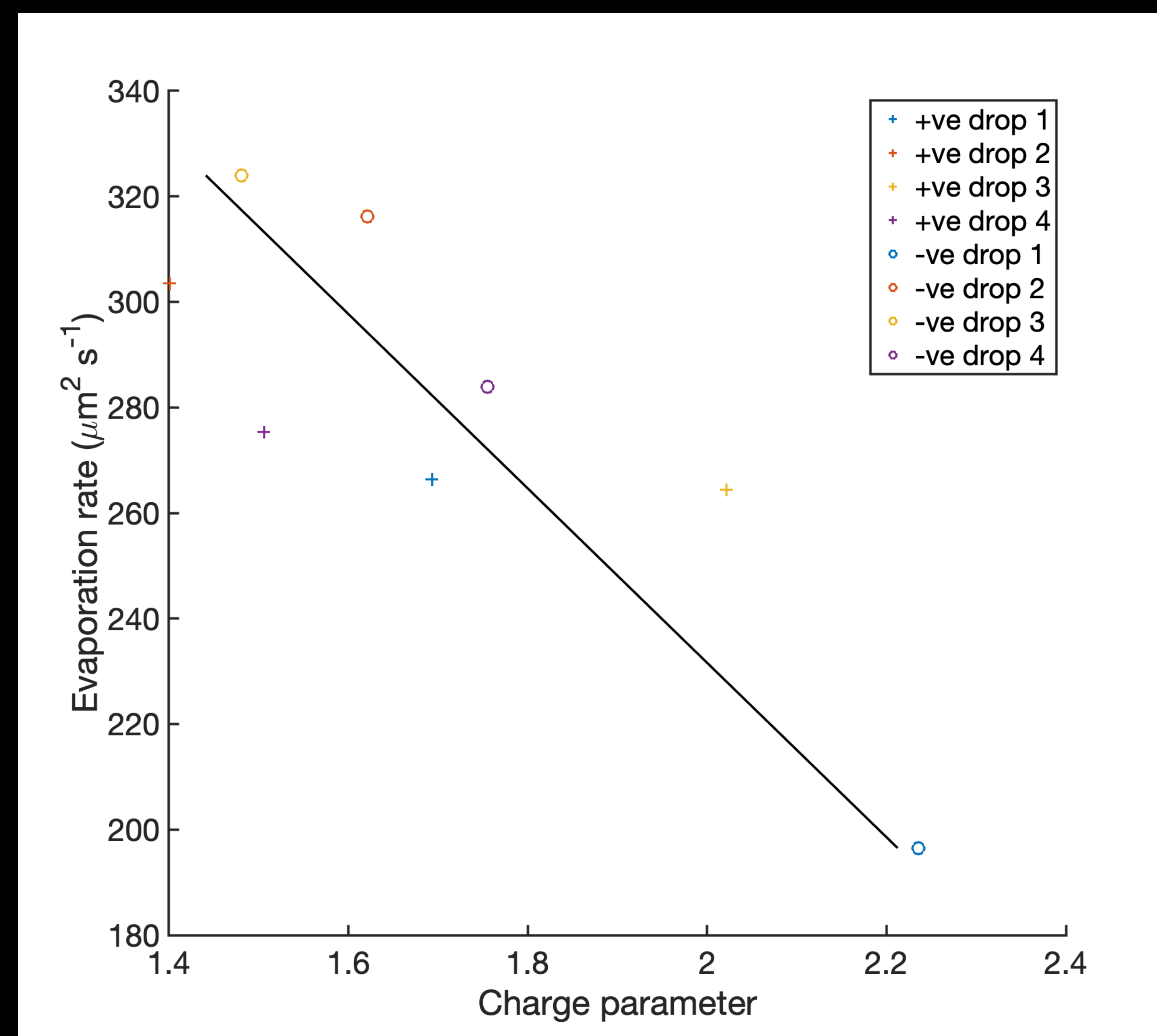
Evaporation timescales

Evaporation rate linear with D^2
Gradient represents stability of droplet
Correlation between stability and charge magnitude

Evaporation rates



Evap. rate vs. charge

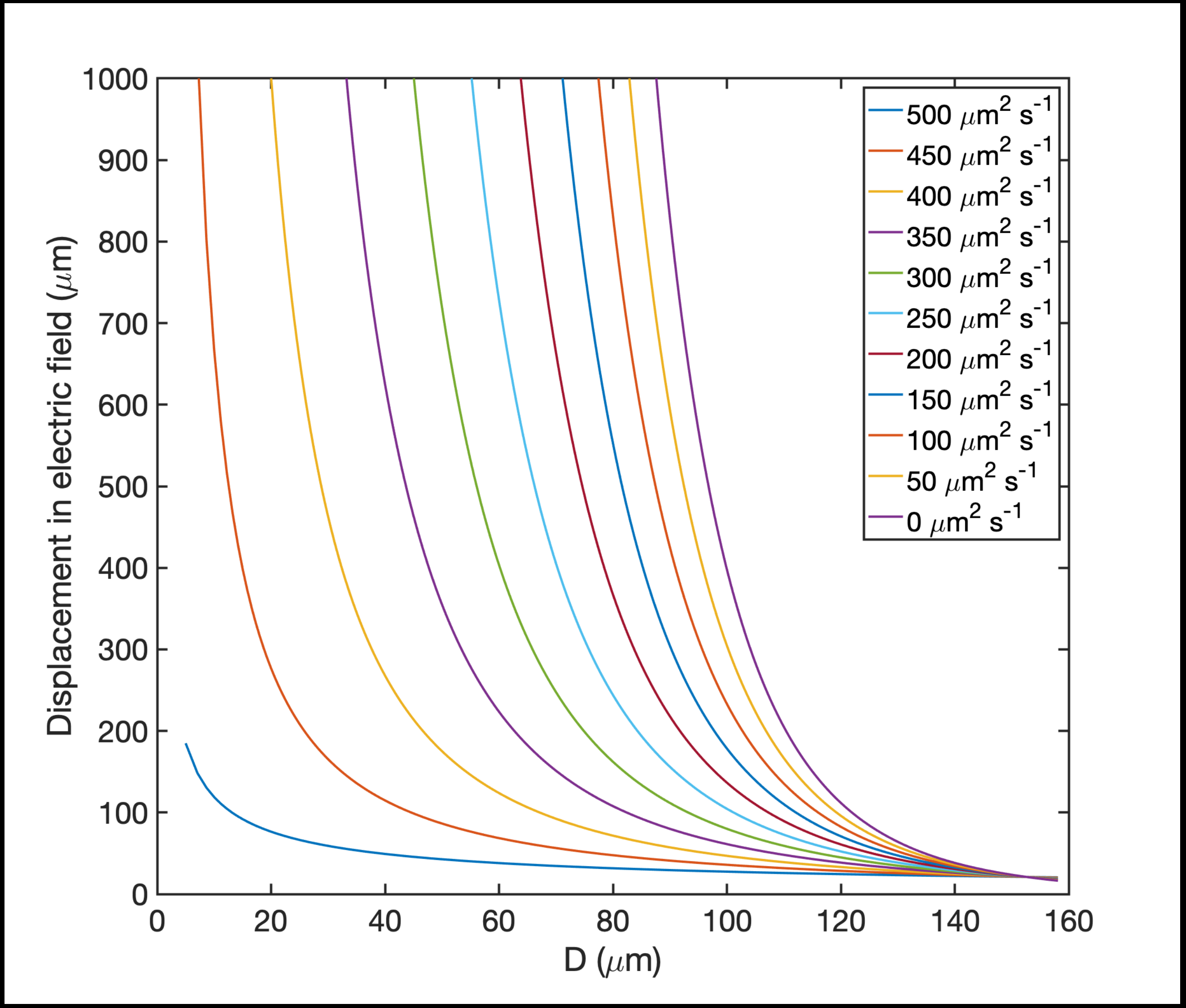


Droplet lifetime

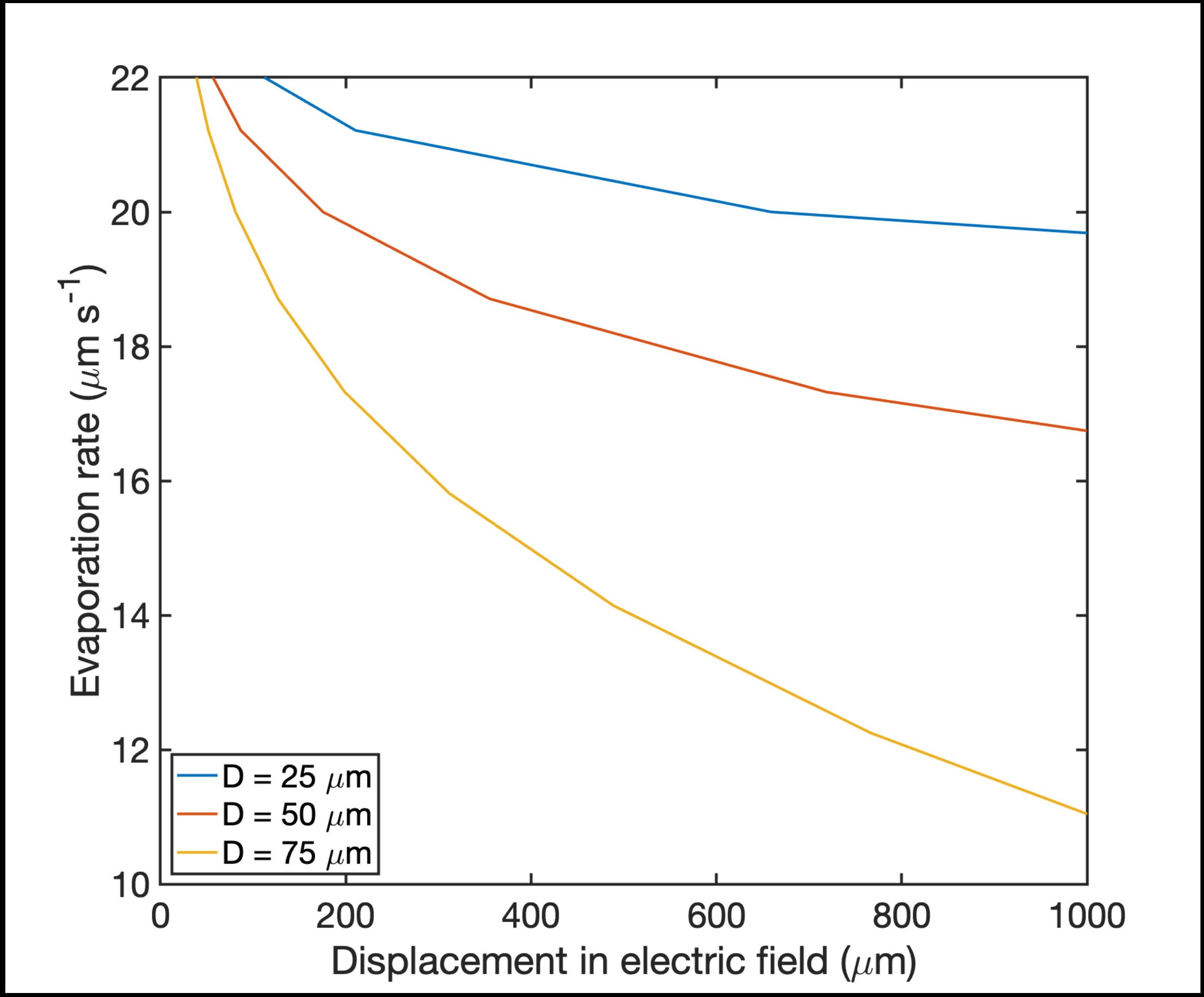
Standardised displacement curves can be used to predict droplet lifetime if the charge is known

For a given droplet size, the more charged it is the slower it evaporates

Modelled displacement



Evap. rate by droplet size



Summary

- Ion production rate (*q*) due to GCRs peaks in the Venusian cloud deck
- High-*q* may enhance ionisation and charging of cloud droplets
- Evaporation rate correlated with droplet charge
- GCR ionisation may be responsible for enhancing droplet persistence and growth
- Additional work will actively charge region and take absolute charge measurements in a simulated Venusian environment