Overview of recent and future complex plasma research on the International Space Station

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Why Research under Microgravity Conditions?

• Gravity strongly influences the complex plasma (especially bigger particles)

- 2D studies
- 3D studies with smaller particles (< 1 µm)
- 3D studies in thermophoresis
- large homogeneous particle clouds
- weaker forces become important

4 OF 5 ISS PARTNERS (NASA, JAXA, ROSCOSMOS AND ESA) INCLUDED COMPLEX (DUSTY) PLASMA INTO THEIR ISS PROGRAMME

- complements research on ground
- opens up new possibilities
PK-3 Plus - The Plasma Chamber
Research Topics under μg

• Basic studies to cover a broad parameter range
  – particle sizes from 1.5 to 15 µm, particle density, rf power, argon and neon pressure, etc.)
  – decharging of particles in the afterglow
• Crystallisation and melting of large 3-D plasma crystals
  – homogeneous and heterogeneous nucleation (including 3-D analysis)
• use complex plasma as a model system to study generic processes in physics at the most fundamental, the kinetic level of individual particles
  – Dispersion relation (externally excited)
• Basic experiments with mixtures
  – Boundaries between different particle sizes
  – Phase separation in binary mixtures
• Instabilities occurring at high \( n_D \) and low plasma power
  – Heart-beat
  – Filamentary mode
• Investigations at high \( n_D \) and high plasma power
  – Search for critical phenomena
• occasionally big particles are accelerated into the cloud. Depending on their velocity:
  – they push away the neighboring particles or
  – they produce Mach cones
• mach cone relation:

\[ \sin \theta = \frac{c}{v} \]

\[ c \sim 28 \text{ mm/s} \]
Penetration of two clouds of different particles leads to:
Lane Formation - Parameter Study

- size of particles (stable and penetrating particles)
- number of particles
- successive penetrations
- lane formation → phase separation

Sütterlin et al., PRL (2009)
Du et al., to be published in NJP
Lane Formation → Banding → Phase Separation

- Small particle cloud forms a honeycomb like structure, in which big particles can be effectively caged.
- Big particles closer to the wings of small particle cloud are quickly expelled.
- Close to center of chamber, honeycomb structure shrinks and there is a change in the laning mode from a free lane formation to a banding mode and finally to phase separation.
The next ISS Laboratories
PK-4 launch 2014 – Task: Fluid Physics at the "atomistic" level

PlasmaLab – launch 2018 – Task: "atomistic" studies with designed particle potentials
The near Future – PK-4

DC plasma chamber (glass tube, 45 cm long, 3 cm diameter) with cylindrical electrodes.

Manipulation possibilities:
- polarity switching (kHz)
- rf-coils
- IR-laser (20W)
- electric manipulator (pulses)
- thermal manipulator
- gas flow

Setup is specially suited for the investigation of liquid complex plasmas. E.g. the transition from laminar to turbulent flow, phase separation, cloud collisions, waves, etc.
The chamber will be driven by 12 independent rf-generators that can be individually shifted in phase, with different programmable output power as well as an arbitrary DC-offset – everything software controlled (>10kHz).
The most important point is that in future it will be possible to "design" the binary interaction potential between the microparticles and to study different physical processes at the "atomistic" level for the first time using "realistic" potentials.

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Electrorheological Plasma in PK-4

MD simulation (by Glenn Joyce †)  

P = 60 Pa (M_T ~ 0.4)

TUNING OF INTERACTION POTENTIAL IN 1D

Ivlev et al, PRL 2011
back to the roots:
• cylindrical rf discharge

but:
• larger electrodes
  (different electrode systems are possible)
• flexible distance between electrodes and guard ring
• covers a much broader exp. parameter range
Future Research Topics under $\mu g$

- plasma physics and complex plasma processes
  - individual particle interaction
  - cloud or cluster collisions
  - wave phenomena
- fundamental generic processes
  - non-linear phase transitions
  - phase separation in binary mixtures
  - critical point studies
  - transition to turbulence
  - glass transition
  - design of isotropic and anisotropic interaction potentials
µg-Research in Complex Plasmas

THANK YOU

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