Retarding Potential Analyzers

In the ionosphere, mount along ram velocity, measure species densities

- Ram speed (7.5km/s) is high or supersonic relative to ion thermal speed or motion
- Spacecraft charging is negative and small relative to motional energy
- I-V curve has steps at $qV_{\text{ret}} = \frac{1}{2}m(V_{sr}+V_r)^2 - q\psi_s$ ; where: $\psi_s$ = sensor potential relative to plasma, $V_{sr}$ = ram speed
- Homework #1 Show that the thermal width of the steps is $m V_{sr} V_{th}$, where $V_{th}$ is the ion species thermal speed. Show that for sensor potential of $-0.8V$, the step functions are at 1.1V for $H^+$ and 6V for $O^+$.

- Ions can be further differentiated with mass spectrograph behind RPA
  - See: Chappell et al., The retarding ion mass spectrometer on DE-1, Space Sci. Instr. 4, 477, 1981

Heelis and Hanson, 1998

ESS 265 Low Energy Particle Instruments 1
RPA/Ion Drift Meters

Heelis and Hanson, 1998

- In the ionosphere, mounted along ram velocity, measure species velocity
  - G2 retards lower energy H⁺, but allows higher energy O⁺ through
  - Collimated beam comes through and falls asymmetrically on collectors
  - G6 suppresses electrons, G3-5 are grounded to remove distortions
  - Homework #2: Determine transverse velocity $V_t$ as function of ram speed, $W$, $D$.

- Issues: $V_t$ error can be significant when ram direction angle is large

- Further reading:

ESS 265 Low Energy Particle Instruments 2
Magnetic Spectrographs

For low energy particles (left):
- post-acceleration $V_{pa}$ behind an RPA provides $V$, $T$ and $m/q$
- Homework #3 Show that in LIMS: $m/q = (Brc)^2/(2V_{pa})$, where $B$ is magnetic field, $r_c$ magnet curvature

For higher energy particles (right):
- Broom magnet clears electrons
- High field bends high energy ions
- Ions that were not bent assumed neutrals (ENAs)

Further reading:
Electrostatic Analyzers

- Electrostatic deflection analyzes velocity distribution
  - Analyzer constant, $K = R_1 / \Delta$, where $\Delta = R_2 - R_1$; Outer shell is at 0 Volts, inner shell at potential $V$.
  - Electrostatic deflection at entrance aperture can measure incoming ions from different directions if spacecraft non-spinning
  - Homework #4 Show that the energy $E$ of the particles of charge $q$, incident on the MCP is $E = -KqV/2$

- Further reading:
  - McFadden et al., The THEMIS ESA plasma instrument and in-flight calibration, Space Sci. Rev., in press
Time of Flight

- Electrostatic deflection \( \Rightarrow \) energy per charge: \( E/Q \). Time of flight, \( \tau \), \( \Rightarrow \) energy per mass \( E/M \)
  - Post-acceleration \( U_{\text{ACC}} \) provides sufficient energy for optimal McP operation and timing electrons at foil
  - Electrons generated at carbon foil result in energy loss \( \alpha \)
  - Homework #5. Show \( M/Q = 2(E/Q + qU_{\text{ACC}})/(d/t)^2 \alpha \)

- Further reading: