Langmuir Probe

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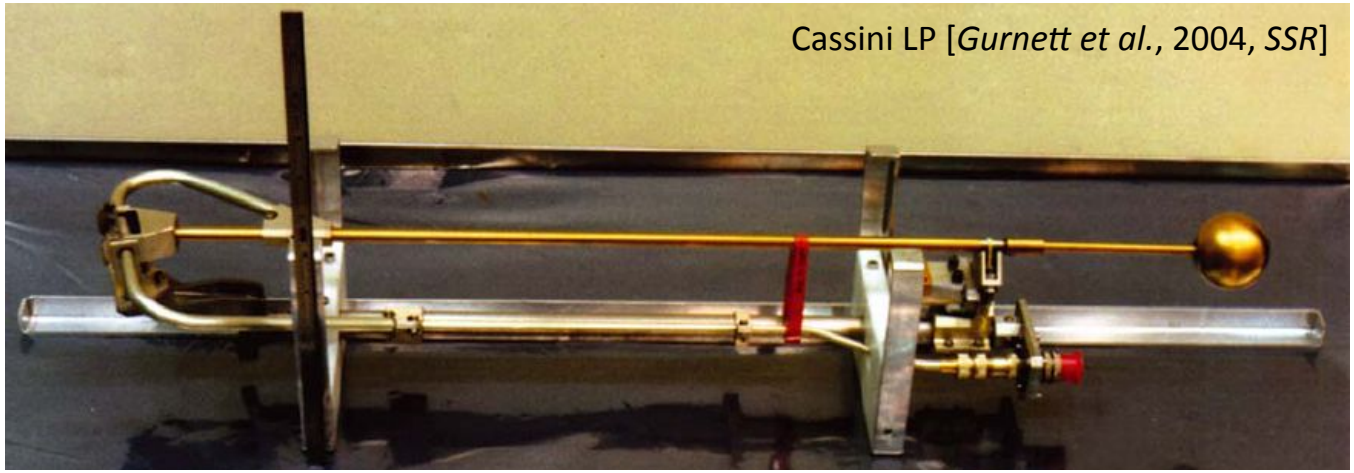
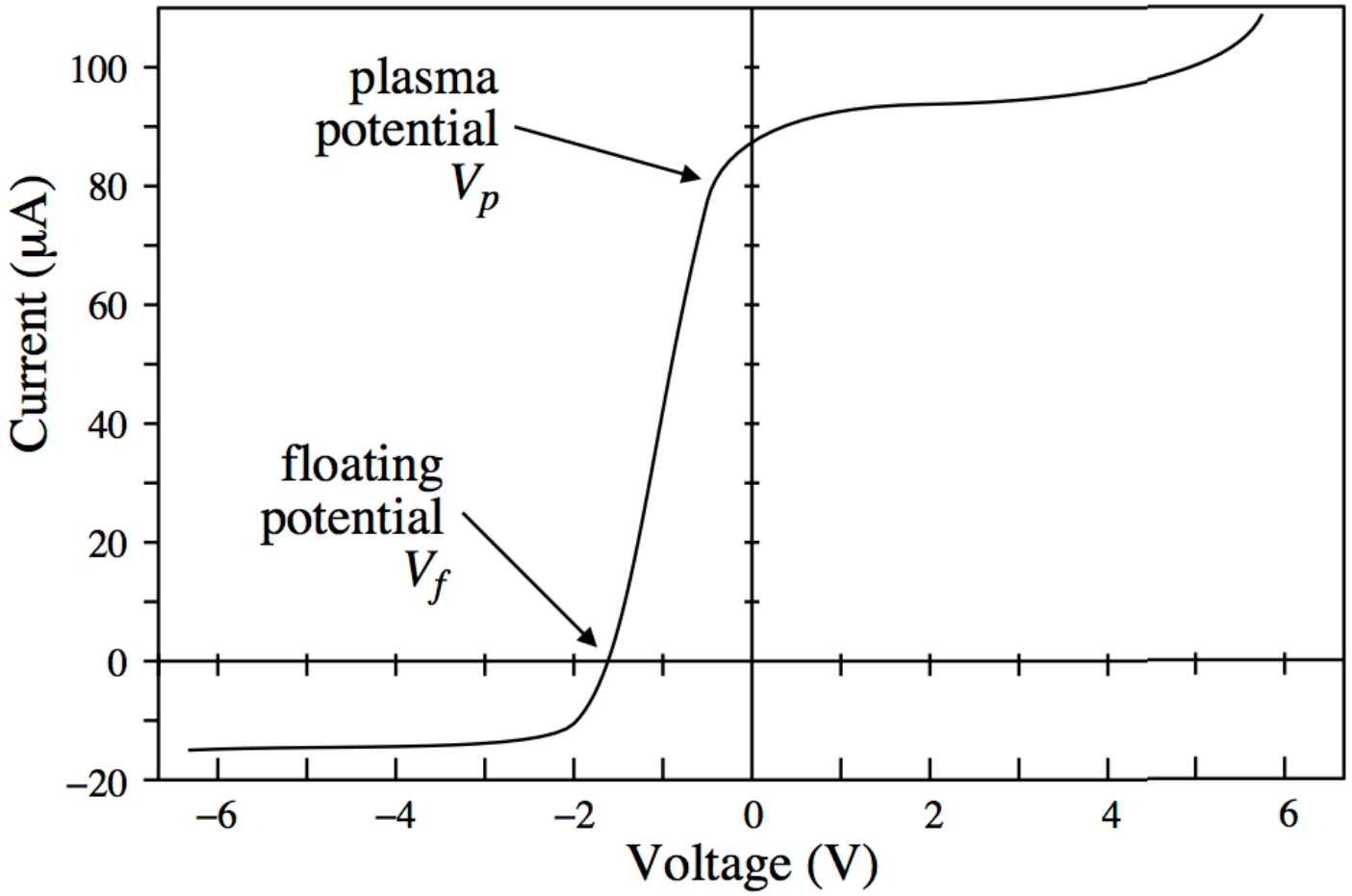
General LP Theory

- Langmuir probe method
  1. Put the probe in plasma
  2. Add the voltage from negative to positive
  3. Find I-V characteristics from current flowing on the probe
  4. Estimate the density, temperature, plasma potential and floating potential



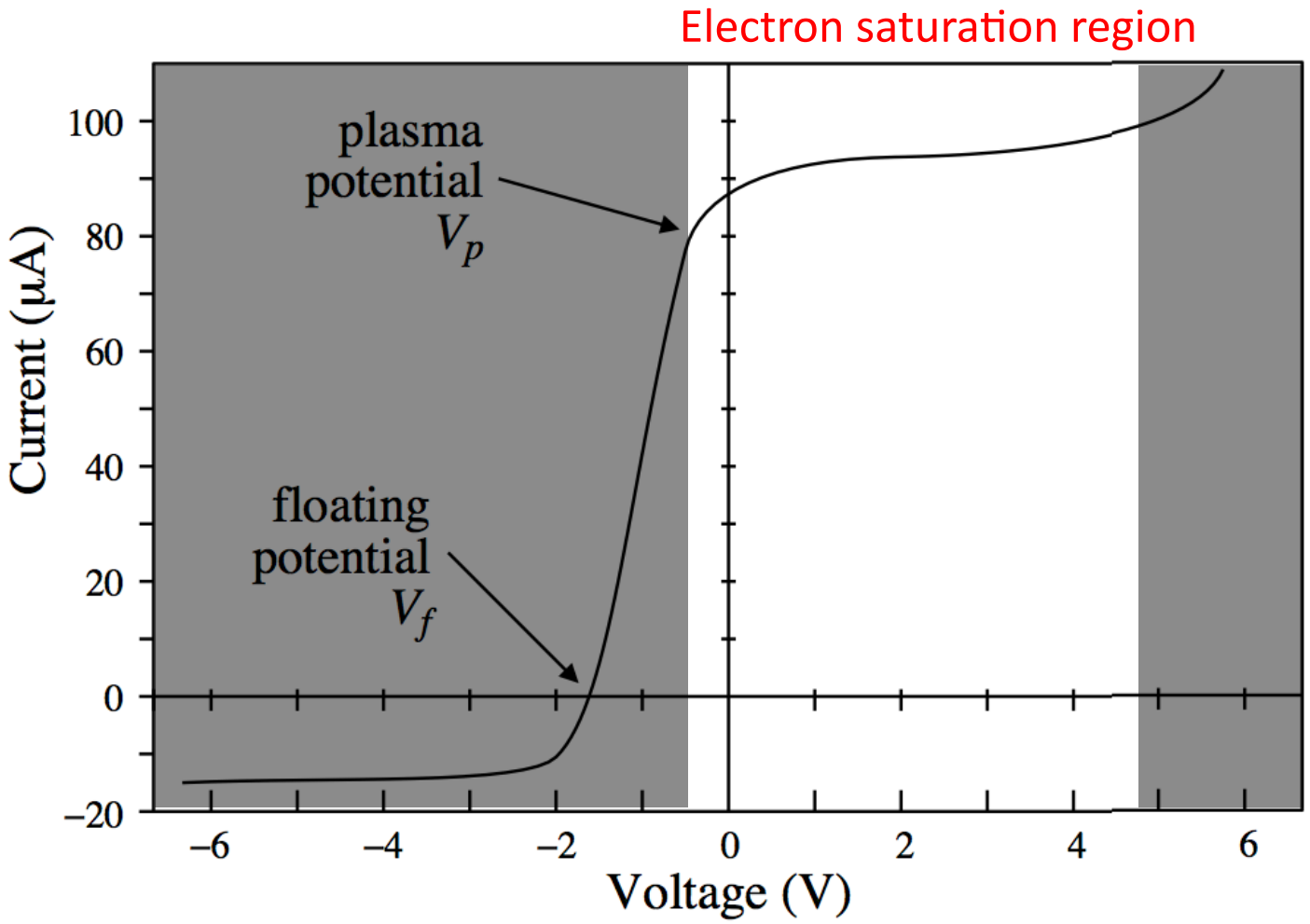
Cassini LP [*Gurnett et al.*, 2004, *SSR*]

General LP Theory



Kirkman, T., A class of College of Saint Benedict Saint John's University, http://www.physics.csbsju.edu/370/langmuir_probe.pdf

General LP Theory: $V > V_p$



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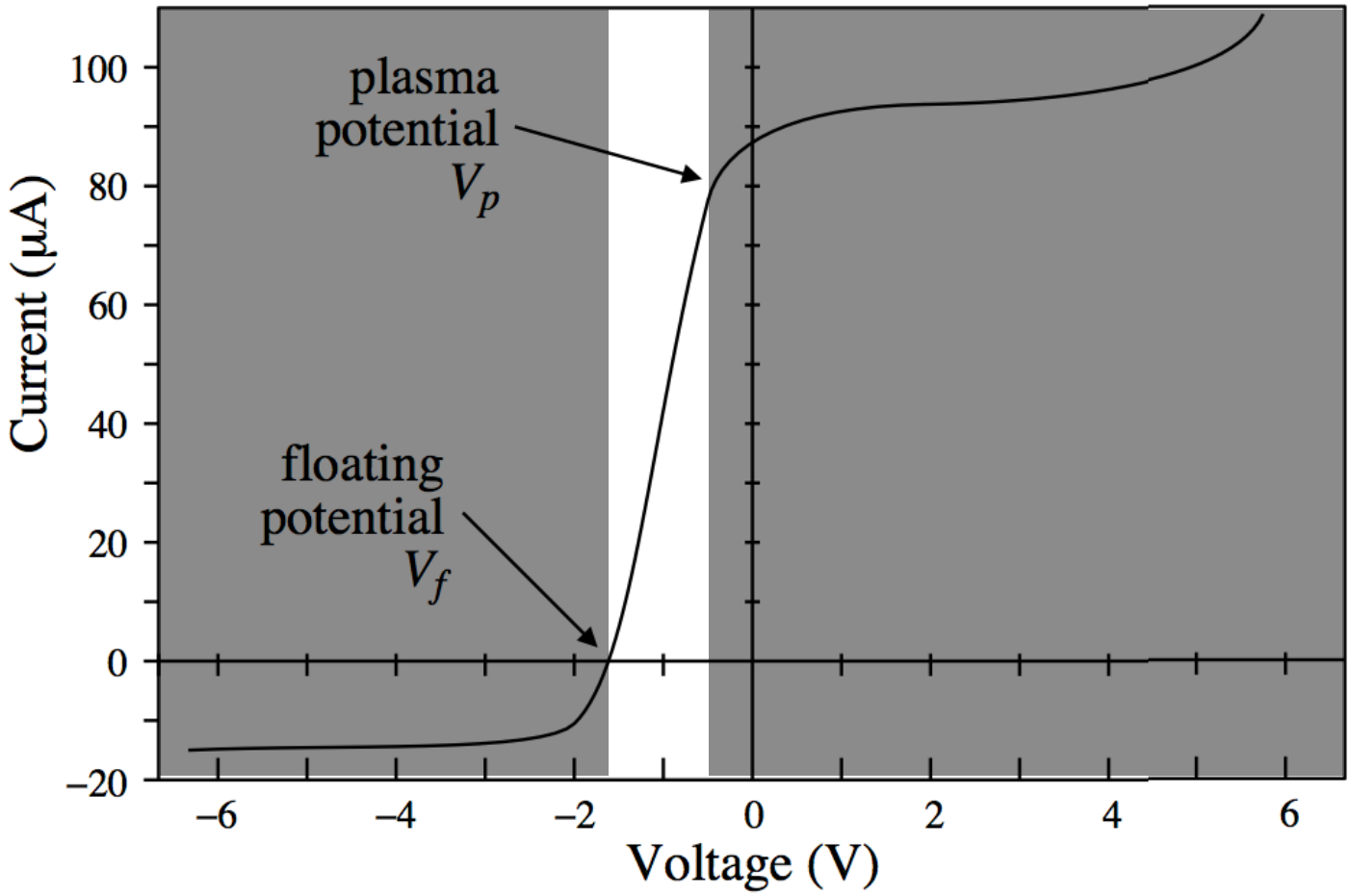
General LP Theory: $V > V_p$

- Electron saturation region
  - Only electron current
    - Ion can't inflow because of almost positive V.

$$I_e = \frac{1}{4} A e n_e v_{eth} = \frac{1}{4} A e n_e \sqrt{\frac{8 k_B T_e}{\pi m_e}}$$

General LP Theory: $V_f < V < V_p$

Transition region



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General LP Theory: $V_f < V < V_p$

- Transition region
  - Electron current and ion current

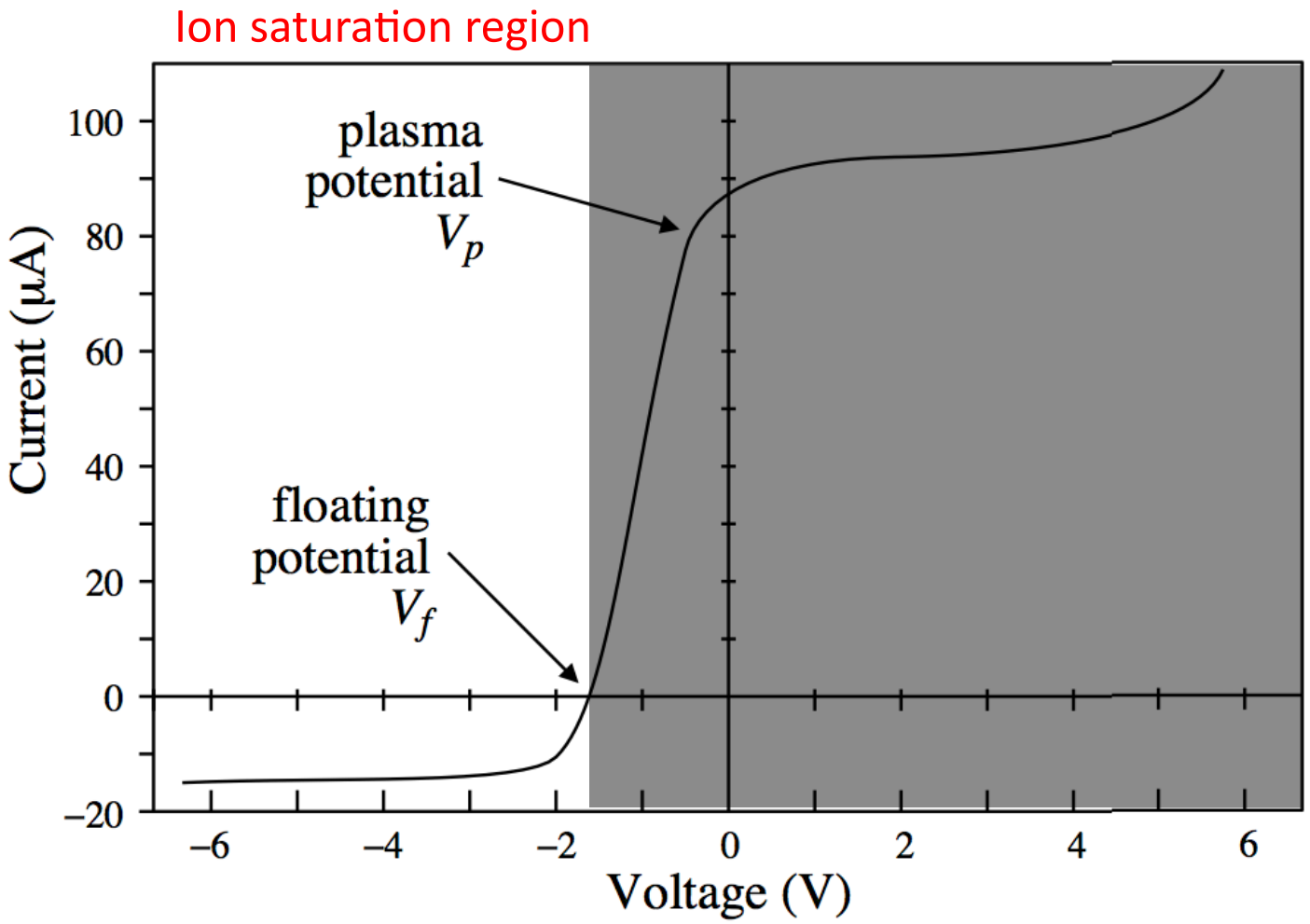
$$I = I_e + I_i$$

$$= \frac{1}{4} A e n_e \sqrt{\frac{8 k_B T_e}{\pi m_e}} \exp\left[\frac{e\left(V - V_p\right)}{k T_e}\right] - \frac{1}{2} A e n_i \sqrt{\frac{k_B T_i}{m_i}}$$

$$\sim \frac{1}{4} A e n_e \sqrt{\frac{8 k_B T_e}{\pi m_e}} \exp\left[\frac{e\left(V - V_p\right)}{k T_e}\right]$$

  - Ion current is neglected.

General LP Theory: $V < V_f$



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General LP Theory: $V < V_f$

- Ion saturation region
  - Only ion current

$$I = I_i = -\frac{1}{2} A e n_i \sqrt{\frac{k_B T_i}{m_i}}$$

How to estimate parameters

- Temperature, T_e

$$I = I_e + I_i$$

$$= \frac{1}{4} A e n_e \sqrt{\frac{8 k_B T_e}{\pi m_e}} \exp\left[\frac{e\left(V - V_p\right)}{k T_e}\right] - \frac{1}{2} A e n_i \sqrt{\frac{k_B T_i}{m_i}}$$

$$= \frac{1}{2} A e n \sqrt{\frac{k_B T_i}{m_i}} \left\{-1 + \sqrt{\frac{2 m_i}{\pi m_e}} \exp\left[-\frac{e\left(V_p - V\right)}{k_B T_e}\right]\right\}$$

$$V = V_f \rightarrow I = 0$$

$$0 = \frac{1}{2} A e n \sqrt{\frac{k_B T_i}{m_i}} \left\{-1 + \sqrt{\frac{2 m_i}{\pi m_e}} \exp\left[-\frac{e\left(V_p - V_f\right)}{k_B T_e}\right]\right\}$$

$$1 = \sqrt{\frac{2 m_i}{\pi m_e}} \exp\left[-\frac{e\left(V_p - V_f\right)}{k_B T_e}\right]$$

$$0 = \frac{1}{2} \ln\left(\frac{2 m_i}{\pi m_e}\right) - \frac{e\left(V_p - V_f\right)}{k_B T_e}$$

$$\frac{k_B T_e}{e} = \frac{2\left(V_p - V_f\right)}{\ln\left(\frac{2 m_i}{\pi m_e}\right)}$$

How to estimate parameters

- Density
  - Electron density
  - Ion density

$$I_e = \frac{1}{4} A e n_e \sqrt{\frac{8 k_B T_e}{\pi m_e}}$$

$$\rightarrow n_e = \frac{4 I_e}{A e} \sqrt{\frac{\pi m_e}{8 k_B T_e}}$$

$$I_i = -\frac{1}{2} A Z e n_i \sqrt{\frac{k_B T_i}{m_i}}$$

$$\rightarrow n_i = -\frac{2 I_i}{A Z e} \sqrt{\frac{m_i}{k_B T_i}}$$