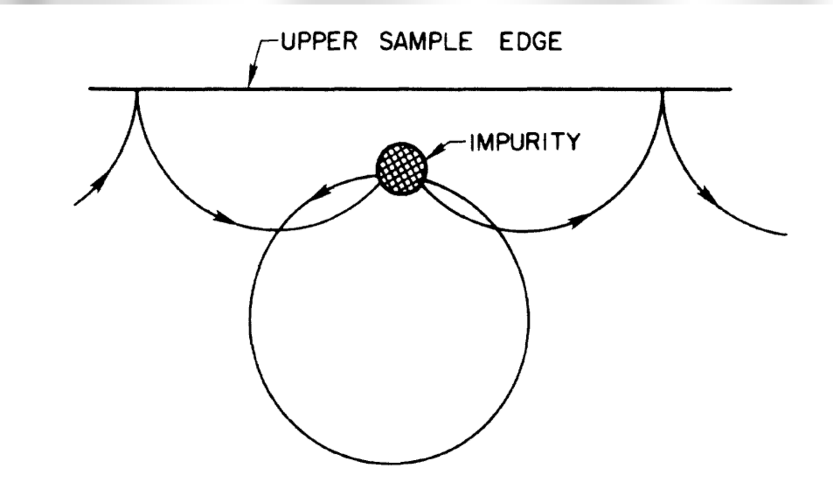
Edge states in 2D conductors.

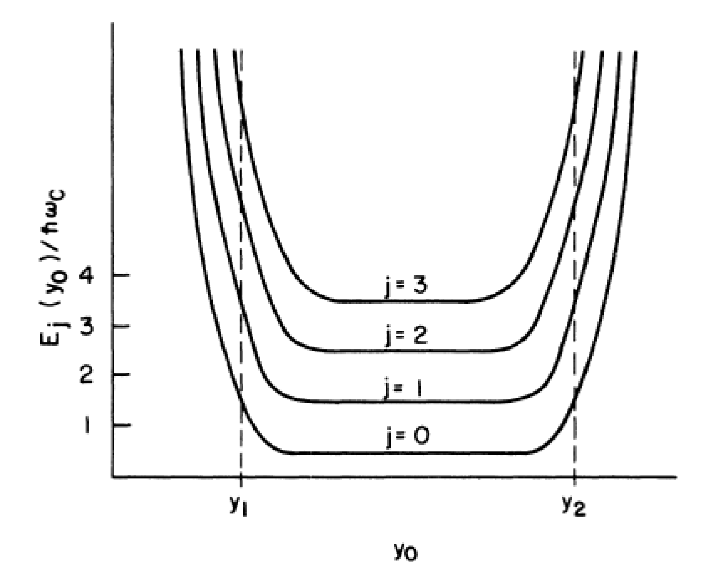
V.Shikin, S.Nazin
ISSP RAS, Chernogolovka

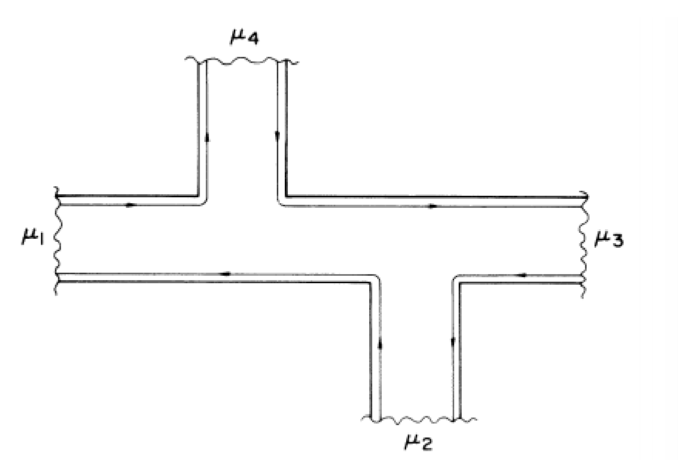
Outline:

- 1. Introduction.
- 2. Existing structure of edge electron states : “ES”.
- 3. Some kind of instability for “ES” structure.
- 4. Relatively stable soft edge electron states: “SES”.
- 5. Exp. possibilities for SES investigation.

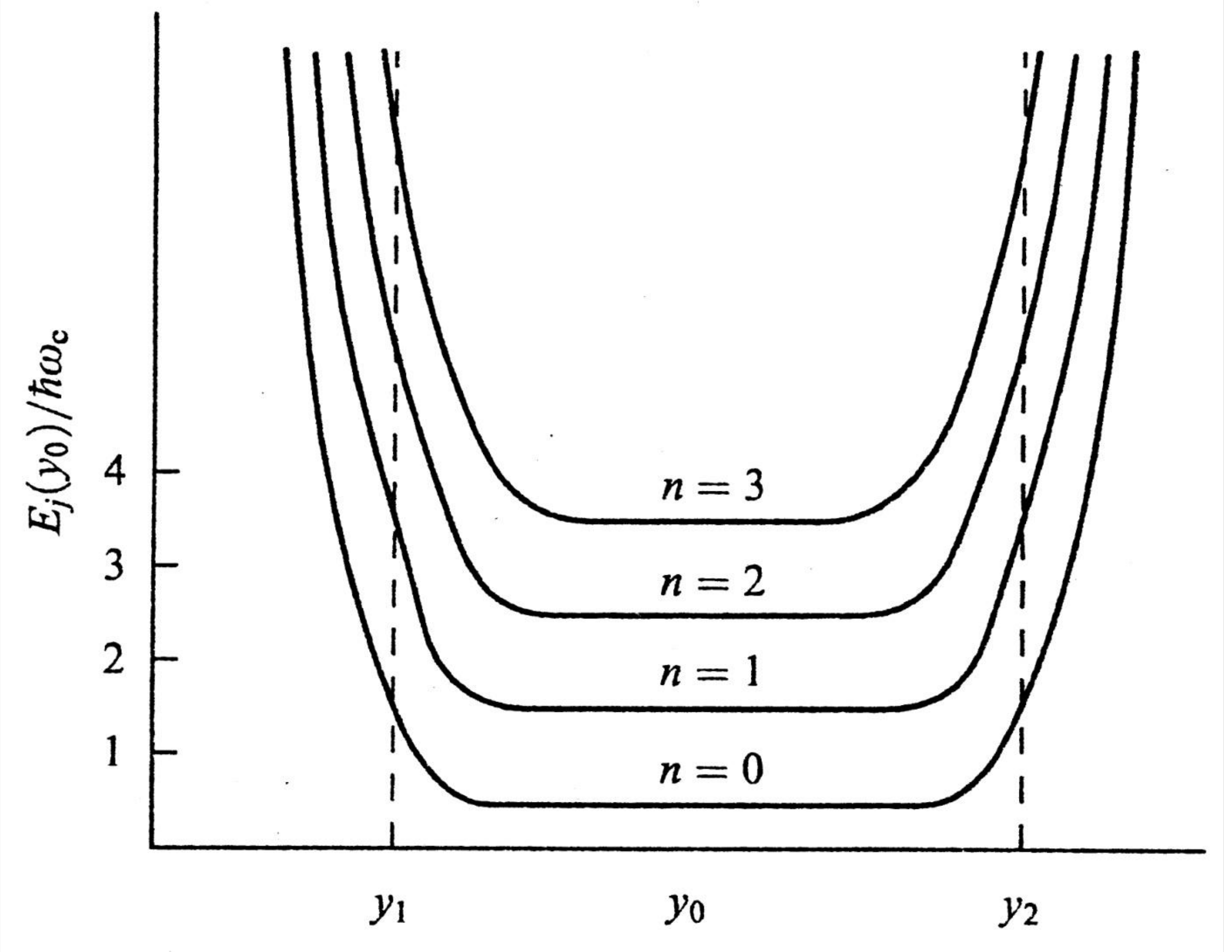
Conventional skipping states in magnetic field



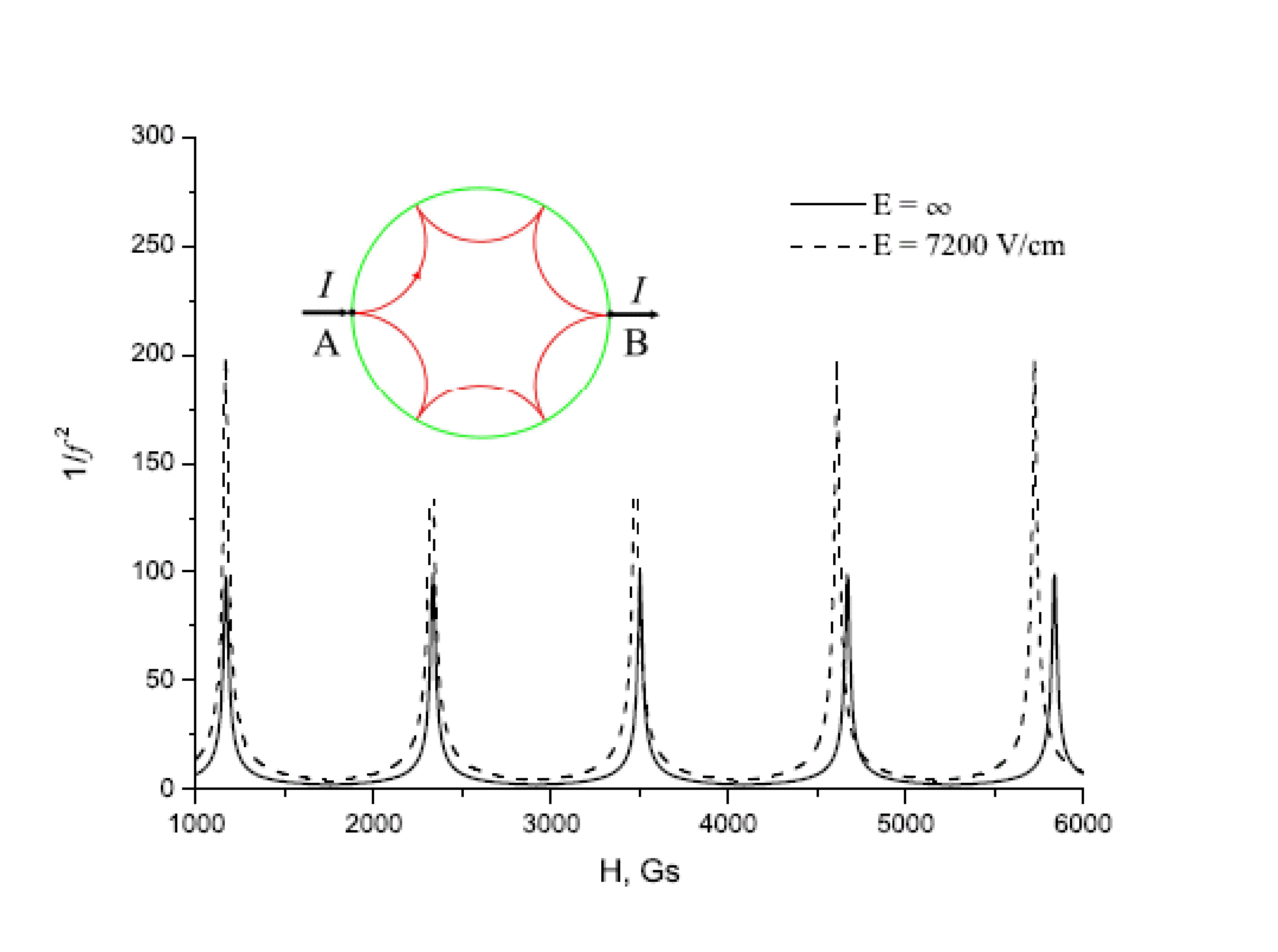


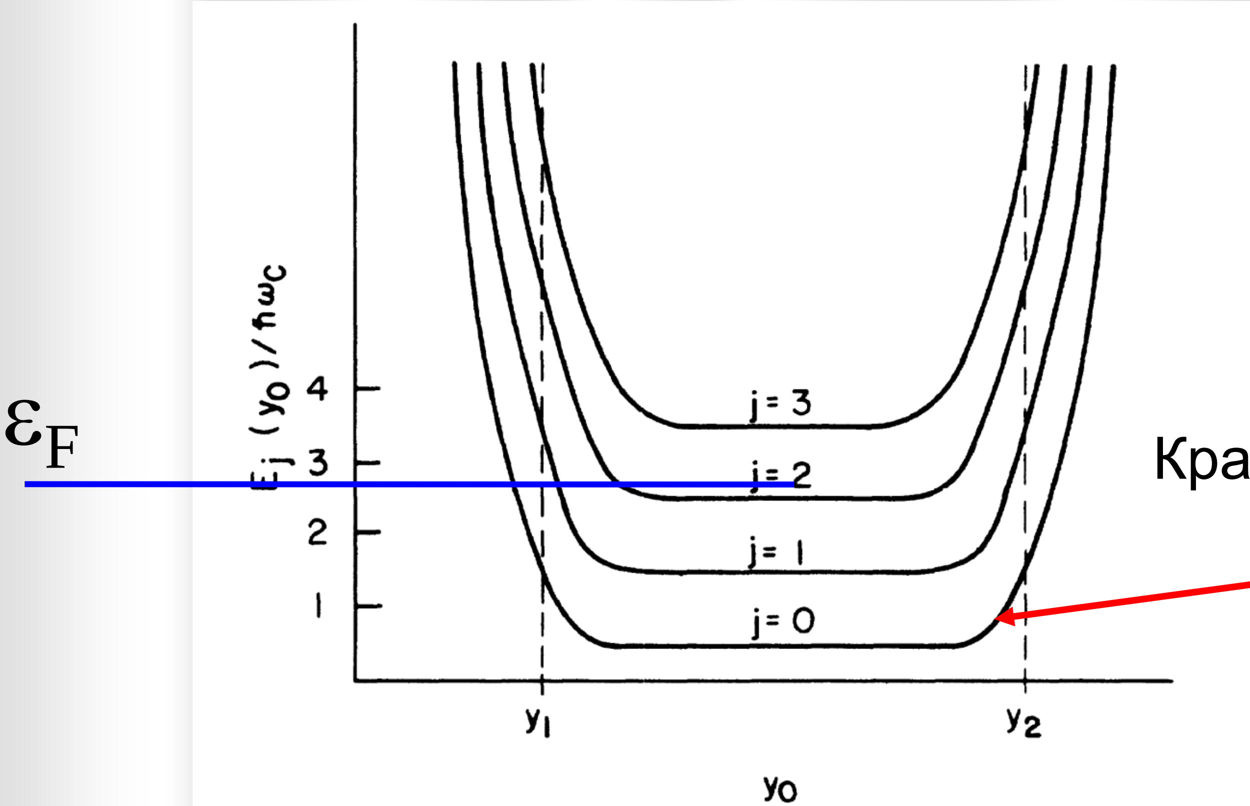


Khaikin's resonances



Magnetic focusing





Краевые состояния.
(edge states)

Edge picture of QEH; Halperin, PRB **25**, 2185 (1982)

$$I=\int_{y_1}^{y_2} j\,\mathrm{d}y=-\int_{k_1}^{k_2} j\,l_{\mathrm{H}}^2\,\mathrm{d}k=$$

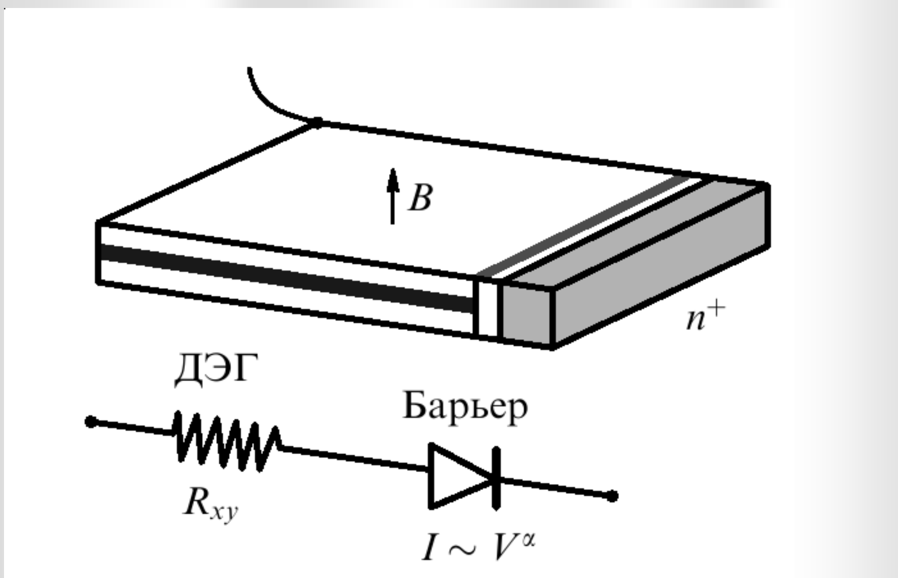
$$=\frac{e}{h}\int_{k_1}^{k_2}\frac{\partial E}{\partial k}\,\mathrm{d}k=\frac{e}{h}\int_{\mu_1}^{\mu_2}\mathrm{d}E=\frac{e}{h}(\mu_1-\mu_2)\,.$$

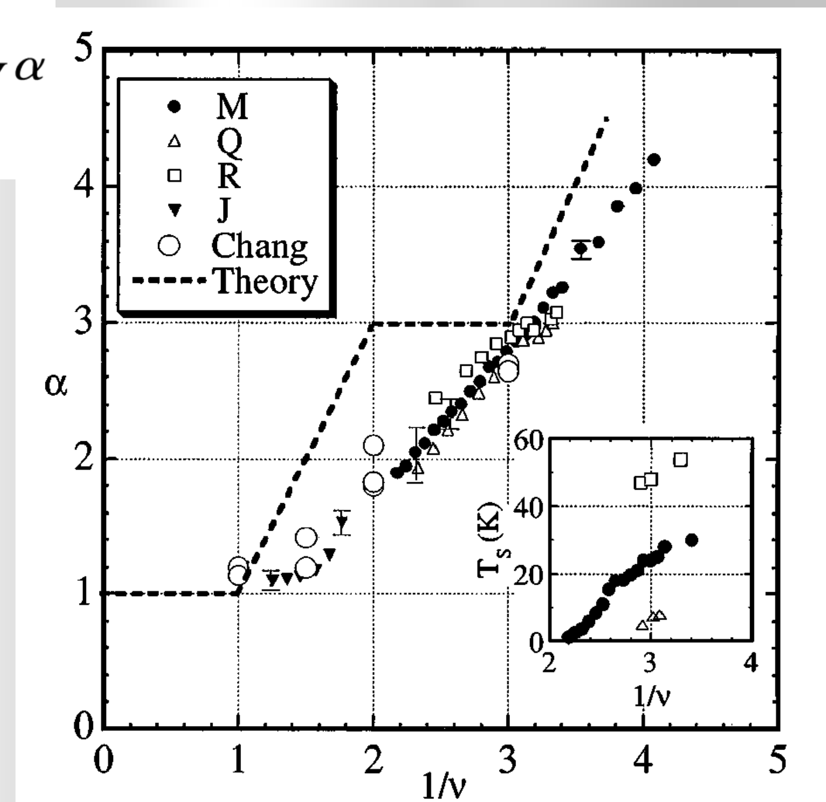
Cleavage (skipping) I-V scenario

$$g = 1/\nu \qquad \rho(E) \sim E^{(1/g)-1}.$$

X. Wen, PRB 43 (1991)

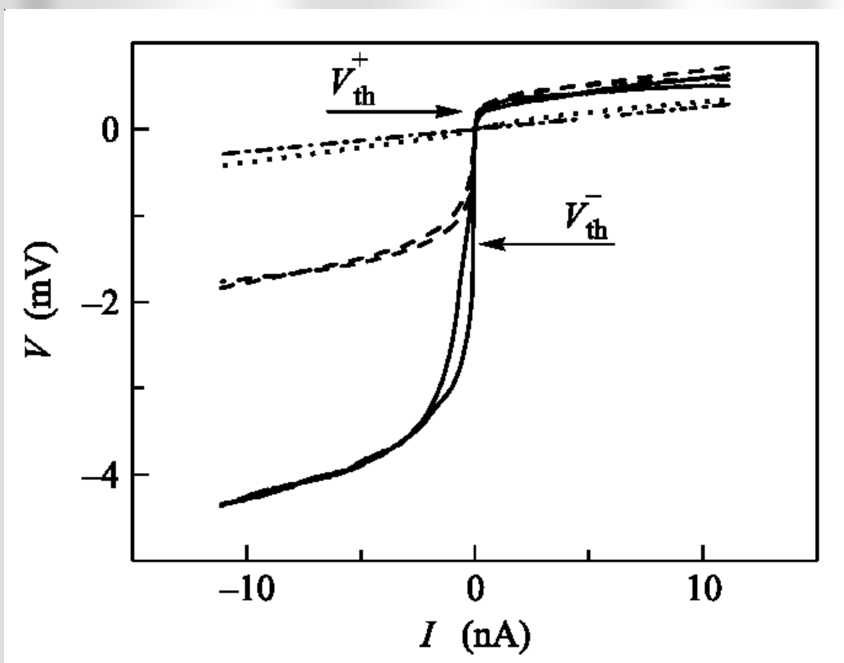
$$I \sim \int \rho(eV)\,dV \sim V^{1/g} \sim V^{\alpha}$$

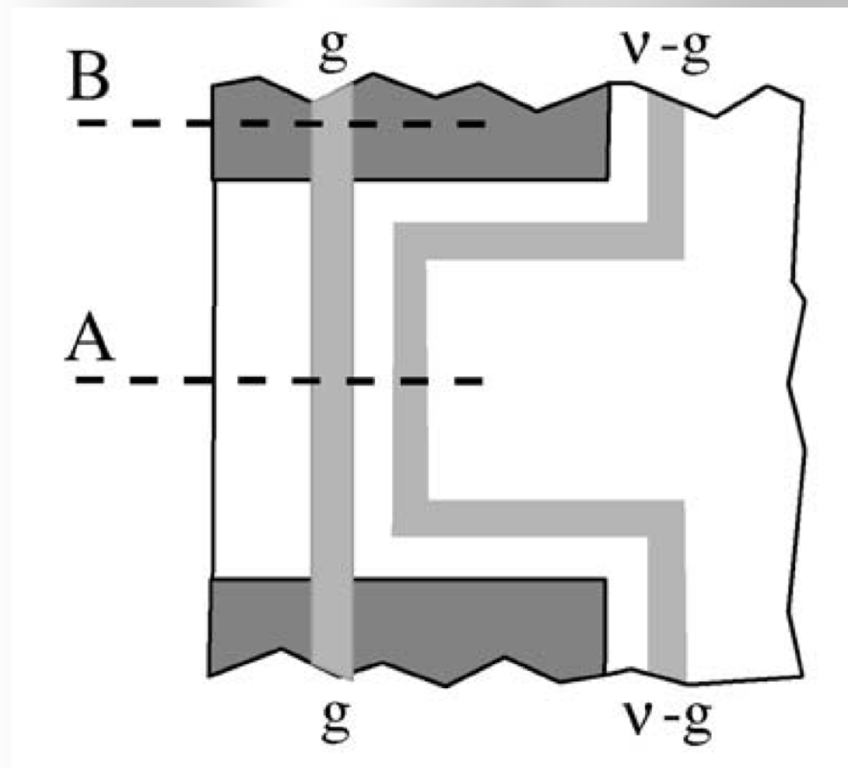




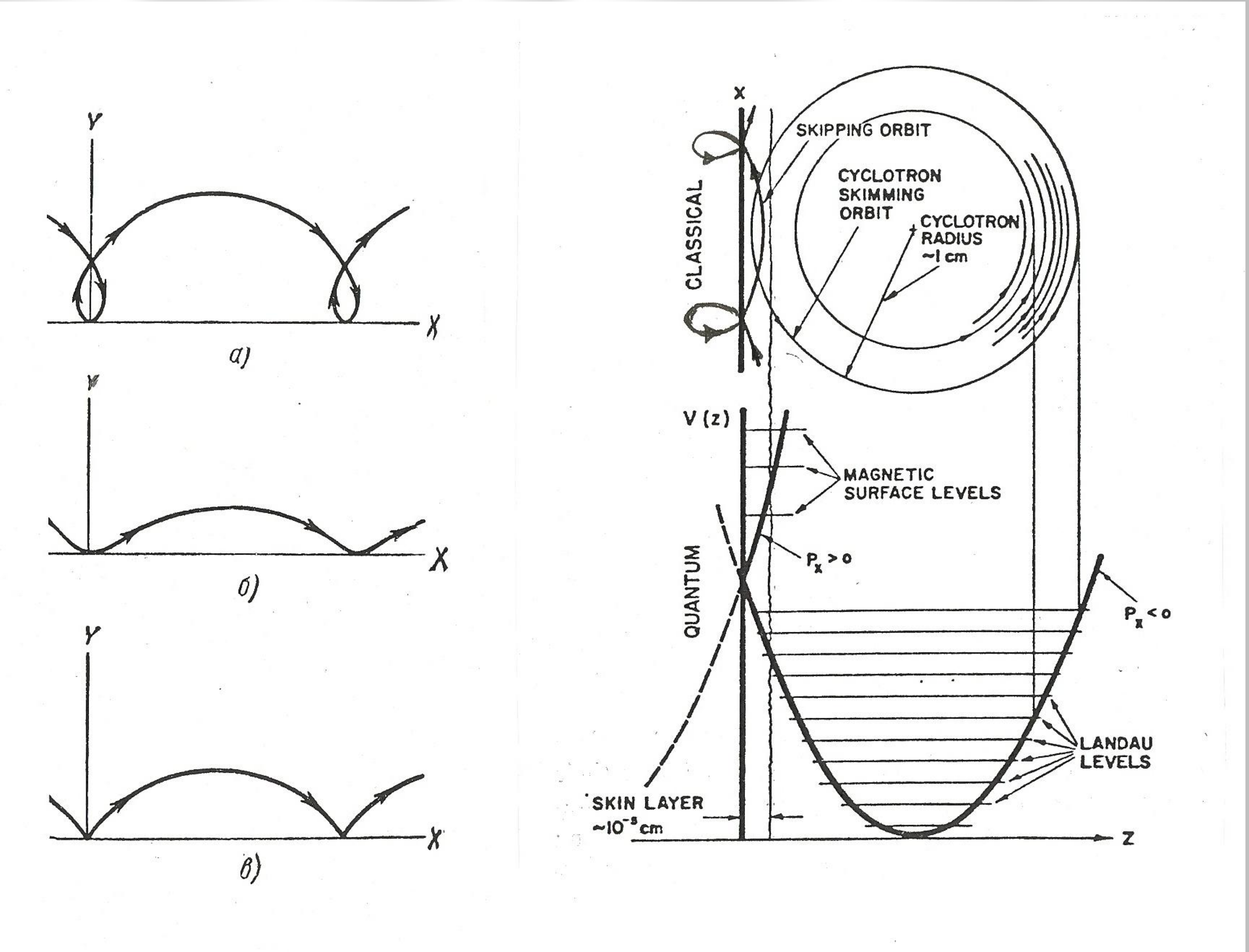
M. Grayson, PRL 80 (1998)

I-V for the integer channel

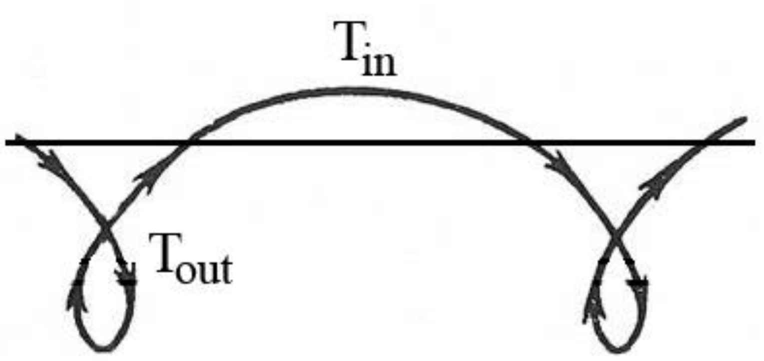




ES and SES structures.



Soft edge electron state (SES)



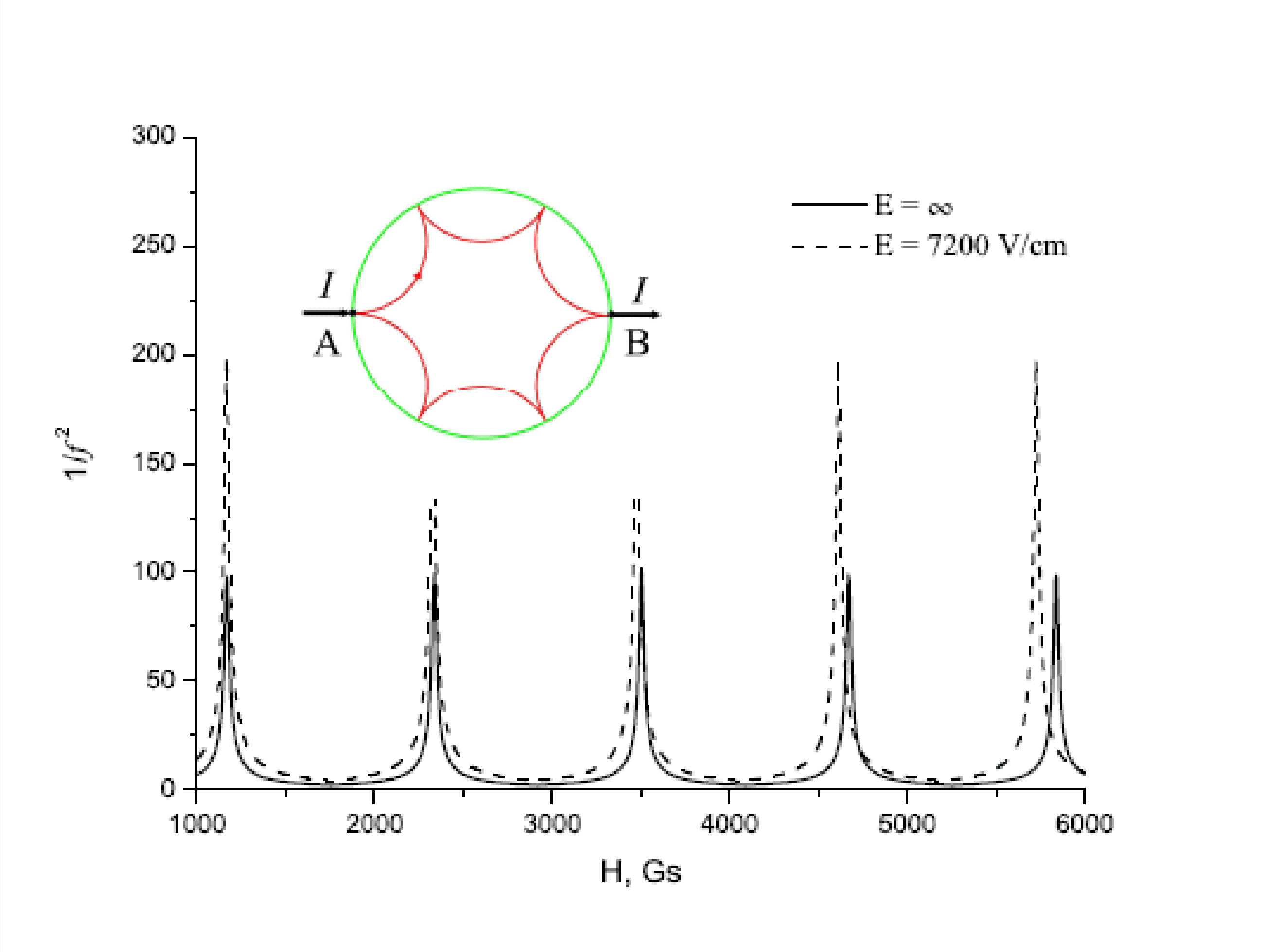
$$T = T_{in} + T_{out}$$

$$T_{in} = \frac{\varphi}{\Omega} = \frac{2}{\Omega}\arctan(\frac{v_y}{v_x}),$$

$$cos(\Omega T_{out}) + \tan(\alpha) sin(\Omega T_{out}) = 1$$

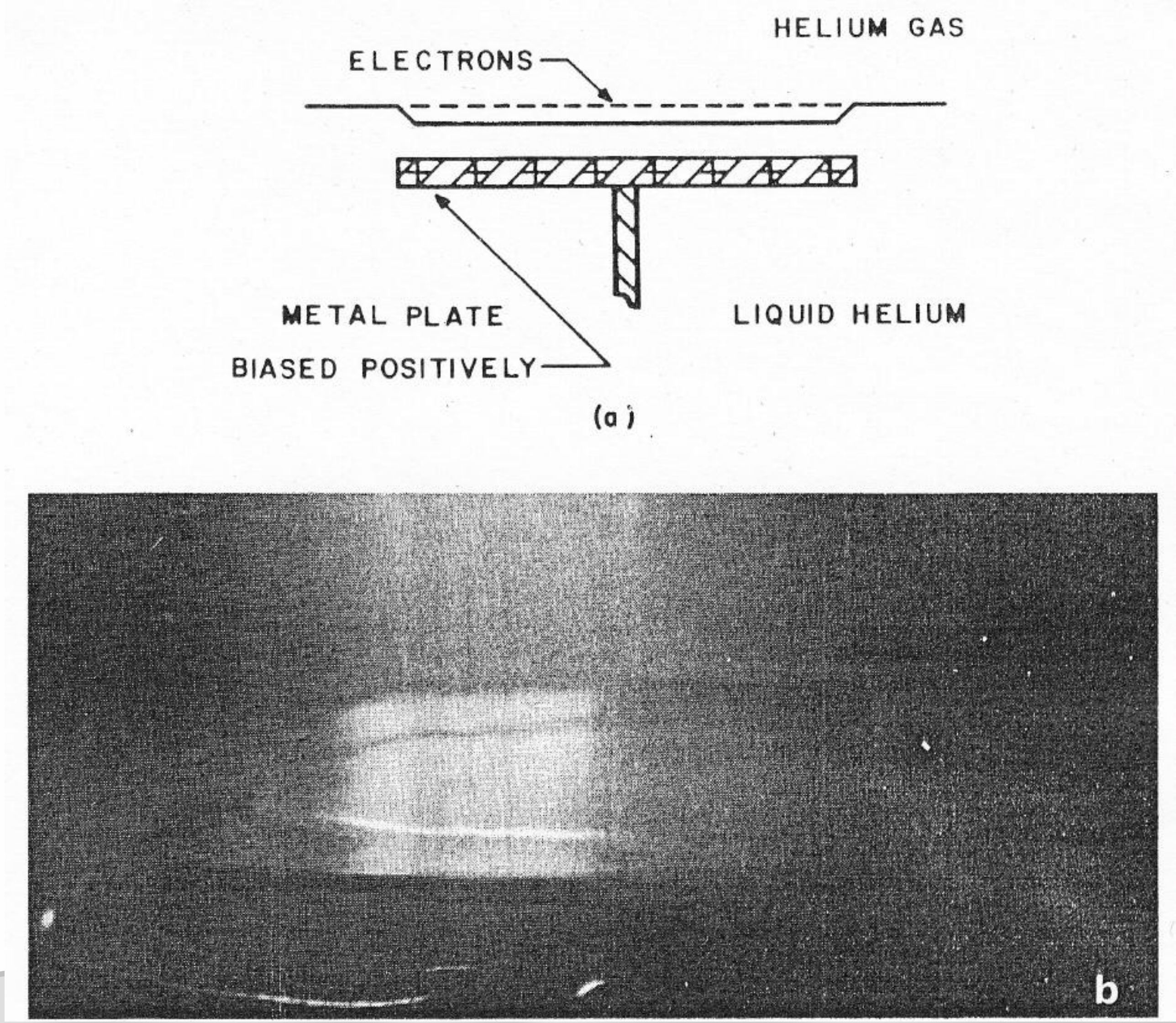
$$\cot\alpha = \frac{v_x}{v_y} - \frac{cE_y}{Hv_y}.$$

Relative ES and SES I-V peaks versus of magnetic field



$$\Delta X = \operatorname{arctg}\left(\frac{u_y}{1-u_x}\right) - u_y \frac{|1-u_x|}{1-u_x}.$$

2D electrons on helium



Edge structure for 2D electron system on helium

$$n_d = const, \quad z = -d, \quad -w \leq x \leq +w$$

$$e\varphi_1(x,z) + e\varphi_2(x,z) = const \quad z = +d, \quad -b \leq x \leq +b,$$

$$\varphi_1'(x,z) = \frac{2e}{\kappa}\int_{-b}^{+b} \frac{(x-s)n_0(s)}{(x-s)^2 + (z-d)^2} ds,$$

$$\varphi_2'(x,z) = -\frac{2e}{\kappa}\int_{-w}^{+w} \frac{(x-s)n_d}{(x-s)^2 + (z+d)^2} ds,$$

$$N = \int_{-b}^{+b} n_0(x)dx = 2wn_d,$$

Relative electron distribution on helium

$$\frac{e^2}{\kappa} n_0(x) = -\frac{1}{\pi^2}\sqrt{b^2 - x^2}\int_{-b}^{+b} \frac{\Phi'(s)ds}{\sqrt{b^2 - s^2}(s - x)},$$

$$\Phi(x) = \ln\frac{w + x}{w - x} - \ln\sqrt{\frac{(w + x)^2 + 4d^2}{(w - x)^2 + 4d^2}},$$

$$2b \neq 2w$$

Two types of electric skin-layer around 2D limited charged system

$$e\varphi_1(x,z) + e\varphi_2(x,z) - T\ln\frac{n(o)}{n(x)} = const,$$

$$\int_{-\infty}^{+\infty} n(x)dx = N, \quad -\infty \leq x \leq +\infty.$$

$$e\varphi_1(x,d) + e\varphi_2(x,d) + \frac{\hbar^2}{2m}n(x) = const,$$

$$\int_{-c}^{+c} n(x)dx = N, \quad -c \leq x \leq +c.$$

Explicit skin-layer field structure in 2D degenerated system

$$U(x) = e\varphi_1(x, +d) + e\varphi_2(x, +d) \neq 0$$

$$U(x) = \begin{cases} = const, & |x| \geq c \\ = const - \hbar^2 n(x)/2m, & |x| \leq c. \end{cases}$$

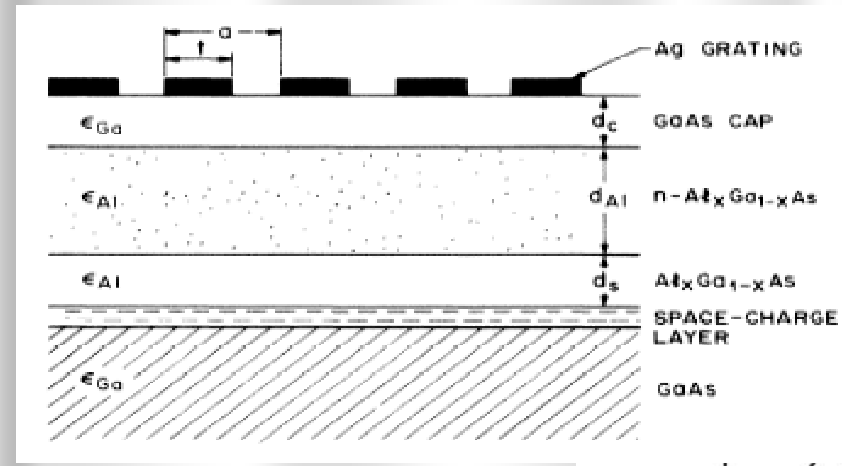
SES structure.

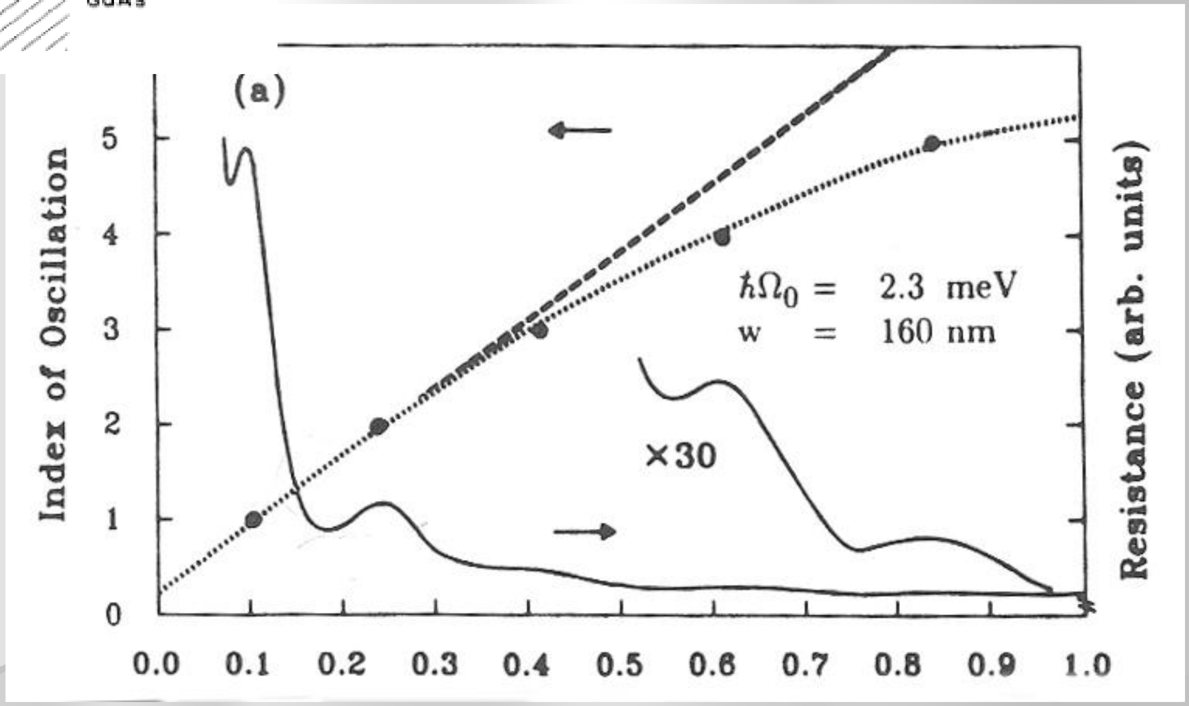
$$\epsilon_l(p_y) \simeq \hbar\omega_c(l + \frac{1}{2}) + U(x_0),$$

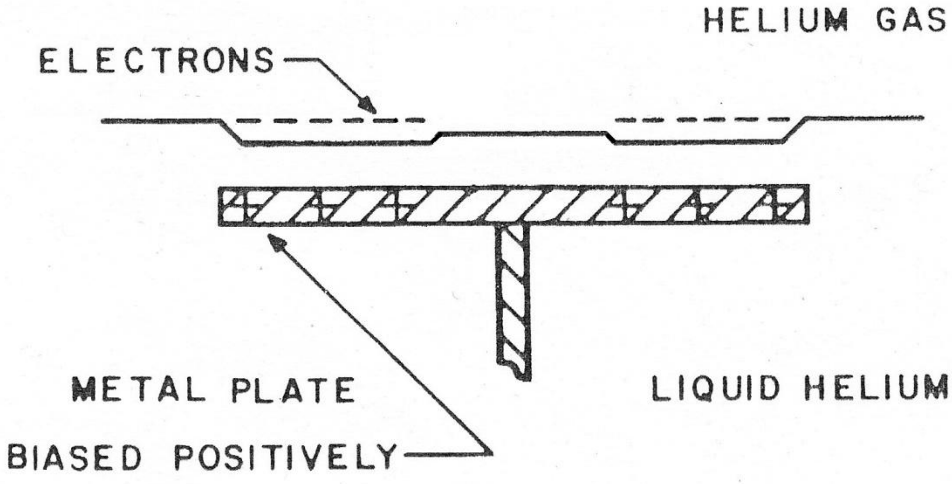
$$U(x) = e\varphi_1(x, +d) + e\varphi_2(x, +d)$$

$$x_0 = -l_H^2 q_y, \quad p_y = \hbar q_y,$$

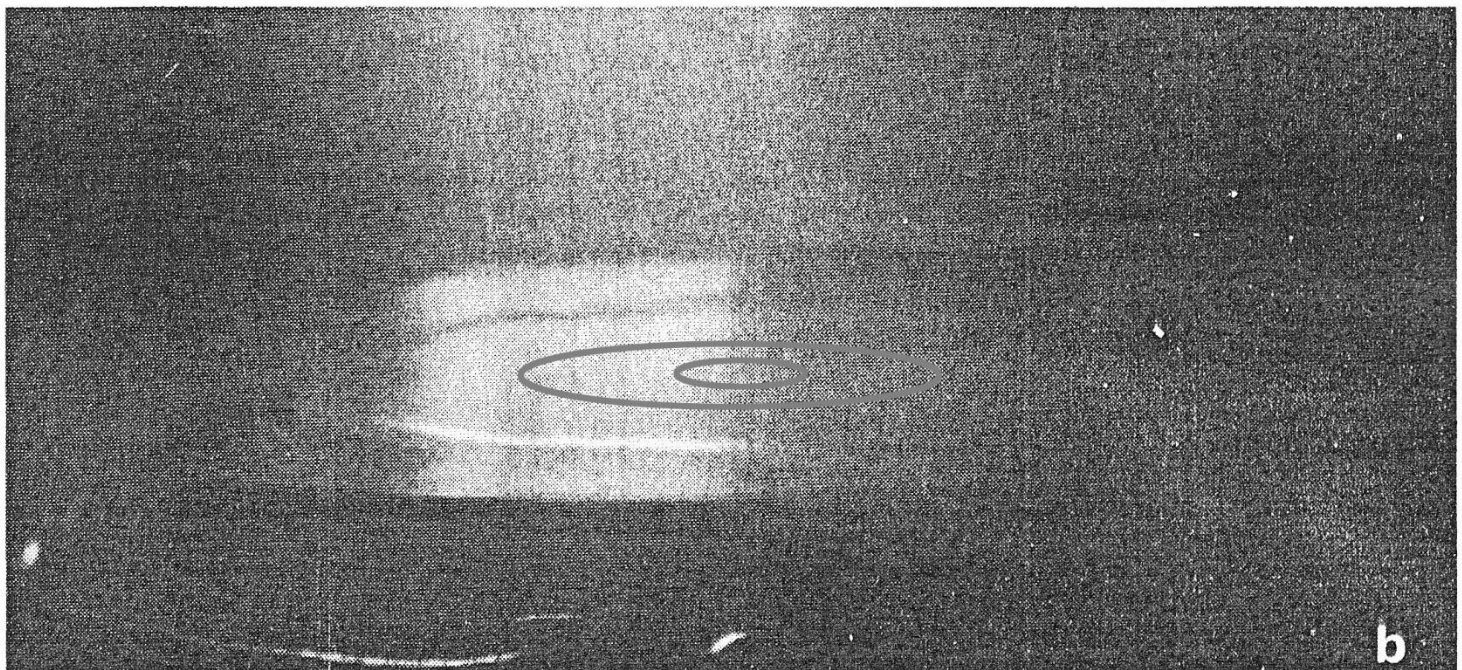
Hall resistance of narrow channels






HELIUM GAS
ELECTRONS
METAL PLATE
BIASED POSITIVELY
LIQUID HELIUM

a



b

Conclusions:

- 1. Existence of 2D soft edge electron states (SES) is predicted.
- 2. Evidence of SES in 2D degenerated systems is demonstrated.
- 3. Some possibilities for SES investigation in 2D classic systems are discussed.