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研究論文 1-1
論文書

天竺木製紙
湯川記念館史料室
I

May 1957 ~

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学
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N151 030

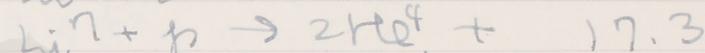
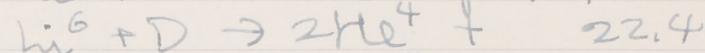
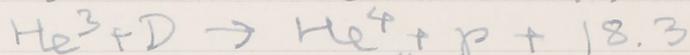
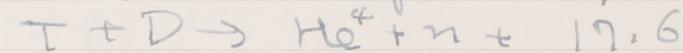
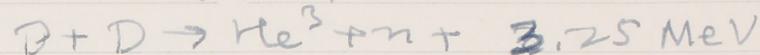
R. F. Post

Controlled Fusion Research.

An Application of the Physics
of High Temperature Plasmas

(R.M.P. 28 (1956, July), 338)

Controlled Fusion Reactor



Reaction power density

$$p_r = 9 \times 10^{-30} n_D^2 \text{ watts/cm}^2$$

for $T = 100 \text{ KeV}$ in the case of D-D.

Effective radiation rate

Minimum temperature for a self-
sustaining fusion reaction

$$p_i/p_r = 1.92 \times 10^4 (T)^{2/6} \exp[-18.76 T^{-1/3}]$$

$$p_i/p_r = 1 \Rightarrow T_c = 35 \text{ kilovolts.}$$

for D-D in hydrogen plasma

Confinement

Pinch effect

Plasma

Hydromagnetic waves

Frisler Approaches

3

3

N151 040

h. Spitzer
 Physics of Fully Ionized Gases

4

N151 050

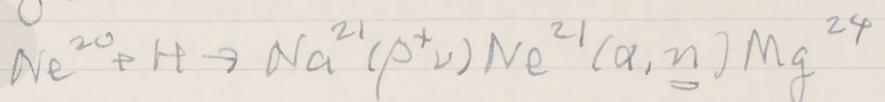
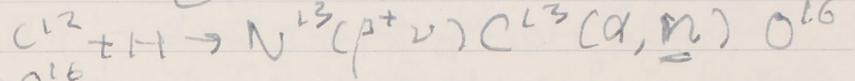
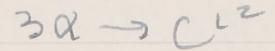
049

物理学的現象の記述

(整理中) Oct. 14, 1957

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1) 核反応: 星の核と元素の起源



$N^{14}(n, p) C^{14}$: N^{14} の n の生成

N^{14} の生成 (C 12 の β^+ の生成)

$C^{13}(p, \gamma) N^{14}$ が起る α と C^{12} の p の

$H/C^{12} = 0.05 \sim 0.20$

Fowler et al.

$22 < A < 50 \quad n/Ne^{21} = 2.2$

$60 < A < 100$

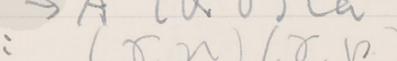
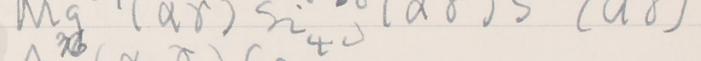
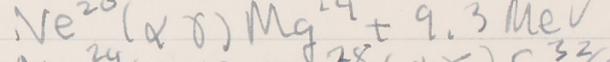
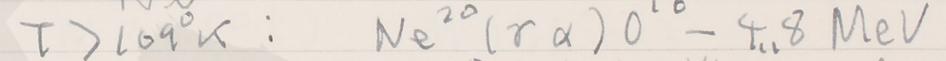
$100 < A$

$6A = \omega n$

n-magic number $N=50, 82, 126$

^{99}Tc $\sigma = 1/10$ abundance $10^{5\%}$
 $2 \times 10^5 y$

^{93}Nb



$T \sim 3 \times 10^9$: $(\sigma, n), (\sigma, p), (n, \sigma), (p, \sigma)$

核反応の平衡状態

Fe peak (V, Cr, Fe, Co, Ni)

$T = 3.8 \times 10^9 \quad \rho \sim 10^5 g/cc$

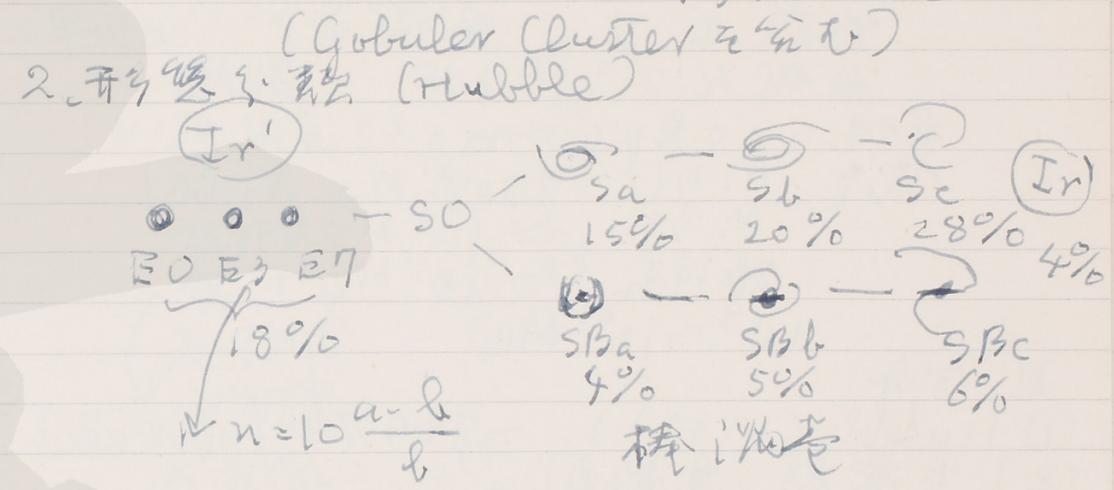
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$\rho = 10^8 \text{ g/cm}^3$, $T = 7.6 \times 10^9, 8.2 \times 10^9 \text{ K}$
 He: Fe^{56} 1:1 50:1 ←
 $\text{Fe} \rightarrow \text{He}$ 富集のI族 ← $1.7 \times 10^{18} \text{ erg}$
 $8 \times 10^9 \text{ K}$ のI族 ← $3 \times 10^{17} \text{ erg}$
 $M > 6.5$ $\rho = 10^8 \text{ g/cm}^3$ 1/5 sec
 Urca
 fast n_{56} capture $^{254}(\rho \text{ decay})$
 $\text{Fe} \rightarrow \text{Cr}$ 100 sec
 $\frac{U^{235}}{U^{238}} \rightarrow 6 \sim 7 \times 10^9 \text{ year}$

太陽系外に54個のUが238
 最も多い 6~7 x 10^9 year
 太陽 5 x 10^9 year
 星の生死
 O族 massive $2 \times 10^6 \text{ y}$
 ↓
 Ⅱ族 Ⅰ族 $6 \times 10^9 \text{ y}$
 恒星の生死

恒星の生死: 恒星
 1. 恒星の生死: 恒星
 系外: $10^8 \sim 10^{11} M_{\odot} \rightarrow \text{galaxy}$, 1. 宇宙
 系外: 恒星の生死
 1784: Messier 10397
 1890~1908: Dreyer 1840 NGC 5386 IC



Hubble-Sandage
 3. 恒星の生死 (Morgan and Mayall)
 (Hamason)
 M31 (SB) M33 (Sc)
 NGC 449 (Ir)
 A system: 恒星の生死
 F 恒星の生死
 K 恒星の生死

4. 恒星の生死
 1. Jeans (1928) →
 2. v. Weizsäcker (1947) ←
 (1951)
 turbulence, friction 恒星の生死

$T \propto R/v$
 宇宙の年齢 $\sim 10^9$ year
 銀河の年齢 1.5×10^9 year

II. 起源

Edwin Hubble
 1929年
 Hubble's Law $v = H_0 d$
 Hubble constant $H_0 = 2.3 \times 10^{-18} \text{ s}^{-1}$
 $\sim 10 \text{ km/sec/Mpc} = 32.6 \text{ l.y.}^{-1}$
 銀河系 $M_{\text{HI}} \sim 2 \times 10^{11} M_{\odot}$
 銀河系 $M_{\text{HI}} \sim 10^9 M_{\odot}$
 銀河系 $10^{11} M_{\odot}$
 $10^8 \sim 10^{11} M_{\odot}$

III. 分布

- (1) Hubble (1914): 一般分布 (overall)
- (2) 星雲群, 星雲団
 1000個以上の星雲.
- (3) Neyman-Scott-Shane (1952~56)
 星雲の分布の一様性.
 Poisson 分布.
- (4) Supergalaxy 宇宙の元々の河川!!!
 $10 \text{ Mpc} \sim 30 \text{ M.l.y.}$
- (5) 宇宙の密度
 $\rho = 1 / \text{Mpc}^3$
 $\rho_{\text{cl.}} = 10^{21} \sim 10^{23} \text{ Mpc}^{-3}$
 星雲の速度 2000 km/sec
 星雲の年齢 $1/2 \times 10^9$ year (Compton cluster)

星雲物質の起源 \rightarrow inter-nebular matter
 IV. 赤色偏位 $v = c \frac{\Delta \lambda}{\lambda}$
 Hubble const. $H = \frac{v}{d} = 176 \text{ km/sec/Mpc}$
 宇宙の年齢 $H^{-1} = 5.4 \times 10^9$ 年
 (Hubble, Mayall, Sandage, 1956)

星雲の起源

星雲の質量
 星雲 3×10^{49}
 星雲 3×10^{48}
 星雲 3×10^{48}
 星雲 10^{48}
 星雲 3×10^{48}
 星雲 $\sim 10^{48}$
 星雲 10^{18} eV

星雲の起源

Shurely Supergalaxy
 Newton の法則

Belgians' paradox
 星雲の起源

Einstein: 1917 static universe
 cosmological constant

$$R_{ij} - \frac{1}{2} g_{ij} R + \lambda g_{ij} = -\kappa T_{ij}$$

(Mach principle: matter determines geometry)



de Sitter

$$T_{ij} = (\rho + p)u_i u_j - p g_{ij}$$

(Λ is in T_{ij} , matter is in $u_i u_j$)
 Friedmann
 Hubble
 Tolman
 Robertson
 non-static

o Milne 1933: Kinematical Rel.
 time scale of arbitrariness

o Hoyle-H. Bondi & T. Gold: Steady State
 (M.N. 108 (1948) 252) theory

Relativistic Cosmology

$$ds^2 = dt^2 - R(t)^2 \left(\frac{dr^2}{1 + \frac{R^2}{4} r^2} + r^2 d\theta^2 + r^2 \sin^2 \theta d\phi^2 \right)$$

$R = 1, 0, -1$
 closed, euclid, open

$H(t) = \dot{R}/R$: Hubble const.

Cosmological Principle

t : cosmic time.

$$\rho(t) = f_0(R, R; \lambda)$$

$$p(t) = f_0(\dots)$$

model of Λ is Λ .

PCP: perfect cosmological principle

Minkowski, Einstein, de Sitter

Red shift: de Sitter

W. H. McCrea (1951)

negative stress $p < 0$
 $\rho = \rho + 3p < 0$ for steady state
 gravit. density inertial density

Report in Progress (1953)

Gold: Vista in Astronomy

o Dirac, Nature 139 (1937)

o P. R. S 165 (1938)

Λ is Λ in T_{ij}

$10^{39}, 10^{2 \times 39}$

$G \sim \frac{1}{t}, (M \sim t^2?)$

Jordan, Schwerkraft u. Weltall

Veblen, Projective Relativity

Gilbert, M.N. 116 (1956), 684

o Eddington, Fundamental Theory
 blank sheet principle

o Newtonian cosmology
 Milne and McCrea (1934)

o Gödel

o Einstein

T_{ij} g_{ij}



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050 フラズマの伝導現象 N151 060

060 基礎: 11月14日, 1957

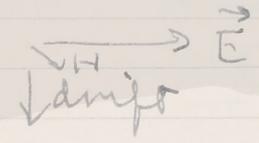
1. フラズマ中の電場の理論と応用
 電場の式: 多電極系
 磁場の式: 磁場の式
 等価系

電場の式: 多電極系
 磁場の式: 多電極系

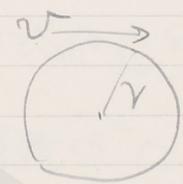
$$\vec{j} = \sigma \vec{E} \quad \vec{v} = \frac{e}{m} \vec{E} \tau$$

$$m \vec{v} = e \vec{E} \quad \tau = \lambda / v$$

$$\frac{ne^2 \lambda}{m} \vec{E} = \sigma \vec{E} \quad \sigma = \frac{ne^2 \lambda}{m}$$



joule heating: $\Delta E = \frac{j^2}{\sigma}$
 recoil energy
 $v \propto \Delta E$



$\frac{e \sqrt{m r^3}}{r^2}$: fluctuation of electric field

Spitzer: Physics of Fully Ionized Gas

Lorentz force: ion velocity \vec{v} in \vec{E} and \vec{B}
 Chew, Goldberger, Low: Ion motion

$$\frac{\partial f}{\partial t} + (\vec{v} \cdot \nabla) f + \frac{e}{m} (\vec{E} + \frac{1}{2} \vec{v} \times \vec{H}) \cdot \nabla_v f = 0$$

drift velocity: $\vec{u} = c \frac{\vec{E} \times \vec{H}}{H^2}$

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13

Radiation の 計算
 電磁波の放射率 $\propto T^2 n_e n_e$
 Maxwell: 放射率 $\propto T^2 n_e n_e$
 螺旋運動 \rightarrow radiation synchrotron
 radiation $\propto T^2 n_e n_e$
 $\frac{dE}{dt} \propto T^2 n_e n_e$
 for $n = 10^{18}$ $T = 10^8$ $\omega = 10^8$

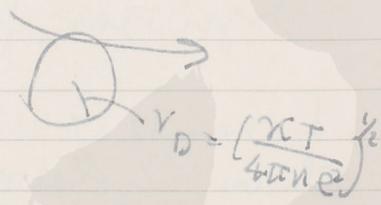
$\approx 10^2$ $\omega = \text{電磁}$
 ≈ 10 2 倍

中長距離力: 電磁相互作用と重力との違い
 long range force
 long range part \rightarrow $\nabla \cdot B$ がおきわたり。
 $\frac{df}{dt} = \mathbf{v} \cdot \nabla_x f + \frac{e}{m} (\mathbf{E} - \frac{1}{c} \mathbf{v} \times \mathbf{B}) \cdot \nabla_v f = \left(\frac{df}{dt} \right)_c$
 $f e n = \int e f d\mathbf{v}$
 $\mathbf{j} = \int e \mathbf{v} d\mathbf{v}$

Chapman-Cowling

$\rho \left(\frac{\partial}{\partial t} + \mathbf{u} \cdot \nabla_x \right) \mathbf{u} = -\nabla_x p + \frac{1}{c} \mathbf{j} \times \mathbf{B}$

Watson



電磁波の放射率

$$\mathbf{j}_\mu(x,t) = \int_{-\infty}^t dt' \int d\mathbf{x}' \mathbf{j}_{\mu\nu}(x-x',t-t') \times \mathbf{E}_\nu(x',t')$$

damping \rightarrow Boltzmann 分布式

本誌: Plasma Dynamics

本誌: Magnetic Decaying Time

$\frac{\partial H}{\partial t} = \text{curl}(\mathbf{v} \times \mathbf{H}) + \eta \nabla^2 \mathbf{H}$

$\tau_{\text{decay}} = \frac{L^2}{\eta} \quad \eta = \frac{1}{4\pi\sigma}$

参考値:

	R_m	η (cm ² /sec)	τ_{decay}	L
Interstellar space			year	cm
H II	10^{40} K	10^{17} 10^8	10^{23}	10^{19}
H I	10^{20} K	10^{14} 10^{11}	$< 10^{20}$	"
太陽圏				
photosphere	6×10^3 K	10^{10} 10^8	$< 10^7$	10^8
AW	1.5×10^7 K	10^{10} 10^2	10^6 y	"
ACR		10 10^4	10^{-2} sec	10
SJ charge	10^{60} K	1 10^5	10^{-3} sec	10

$R_m = \frac{\tau_{\text{decay}}}{\nu_{\text{transp}}} = \frac{L^2}{\eta}$

Pinch effect (Pinch effect)

$v = 0$

$\frac{\partial H_z}{\partial t} = \eta \frac{1}{r} \frac{\partial}{\partial r} (r \frac{\partial H_z}{\partial r})$

$\eta = \frac{c^2}{4\pi\sigma}$

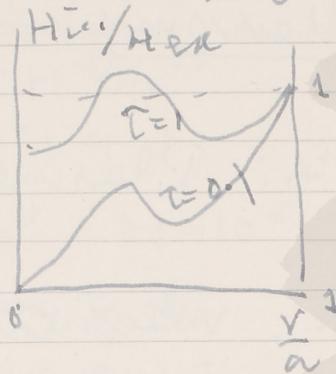
$(H_z)_{r=a} = \alpha t$
 $(H_z)_{t=0} = 0$

$r = \eta t / a^2$

$\tau = 10^{18} t / \sigma$

$\sigma \sim 10^{12} \text{ esu}$

$\tau = 1 \rightarrow t = 10^{-6} \text{ sec}$



Pinch effect
 (thermal pinch)
 (thermal pinch)

1933 Bennett Thermal magnetic pinch
 equilibrium

$P = \frac{B^2}{8\pi\mu}$

$\mu_0 = 0.005 \text{ m.u.t.g} \sim 1 \text{ gauss}$

$r \sim 60 \text{ cm}$

$V \sim 10^5 \text{ V}$

$I_{\text{max}} \sim 10^5 \sim 10^6 \text{ A}$

$dI/dt \sim 10^{11} \text{ A/sec}$

$W_{\text{max}} \approx 4 \times 10^7 \text{ kW}$

$\omega = 0.02 \text{ MHz}$

oscilloscope 250 cm^2/sec (oscilloscope)

I, V

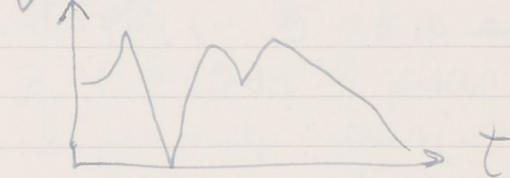
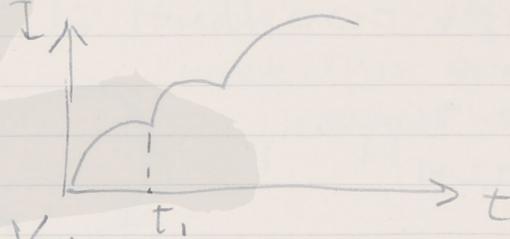
$H \rightarrow j$

n

δ

optical spectrum

Pinch effect



$\Lambda^{n, \delta}$

Pinch effect

$\frac{d}{dt} (\frac{1}{2} M \frac{da}{dt}) = - \frac{I^2}{ac^2} + 2\pi a \bar{P}$

$I = \dot{I} t \quad \dot{I} = \omega r t \quad h_i = \frac{1}{2}$

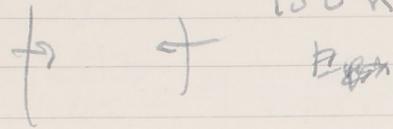
$t_1 = (\frac{1}{2} M)^{1/4} a_0^{1/2} (\frac{1}{2} \dot{I}^{-1/2})$

(Pinch effect)

Allen (Harwell): Proc. Phys. Soc. 20B

shock wave in atmosphere.

100 km/sec.



(内田氏: $v = \frac{d(LI)}{dt} + RI$)

Pinch instability

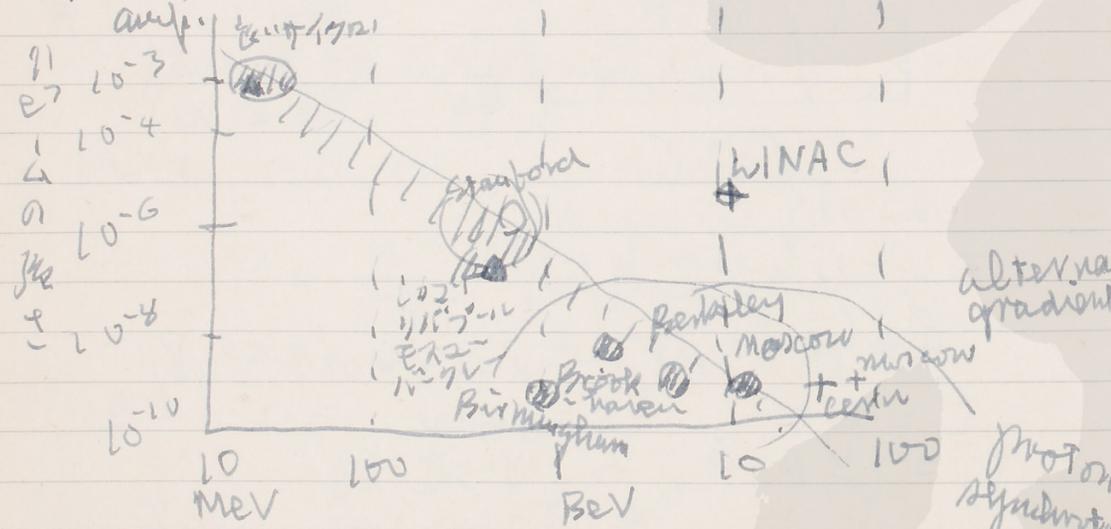
H, $\frac{dH}{dt}$ のおかげで.

Stellarator

Columbus type

Transient process

内田氏: Plasma の 加速 の 過程



内田氏 - 報告: 0.75 BeV el. synch. (1959~1960)

内田氏 + 末吉氏

I. 粒子の Machine の 進歩.
 { linear accel. (principle の 説明)

II. New ideas

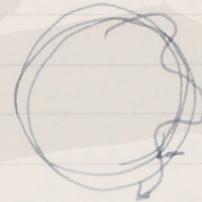
① Veksler 共振の力

共振は plasma frequency
 の近くで plasma の 粒子は
 共振して plasma の 粒子は
 共振して plasma の 粒子は

② Budker 共振

electron の 共振 (plasma)

proton の 共振 (plasma)



本稿: 共振の plasma 共振
 linear dispersion, max velocity
 の 共振, dissipation の 説明

$$P\left(\frac{d\mathbf{v}}{dt}\right) = (-\text{grad } p + \rho \mathbf{g} + \mathbf{F}) + \mathbf{j} \times \mathbf{H}$$

alternating gradient $\mathbf{H}, \mathbf{v} \rightarrow \mathbf{j} \rightarrow \mathbf{E}: \mathbf{j} = \frac{1}{4\pi} \text{curl } \mathbf{H}$

$$\mathbf{j} = \sigma (\mathbf{E} + \mathbf{v} \times \mathbf{H})$$

Turbulence

energy dissipation $\frac{dE}{dt} \propto \frac{1}{L^2}$

$$\frac{H^2}{8\pi} \leq \frac{1}{2} \rho v^2$$

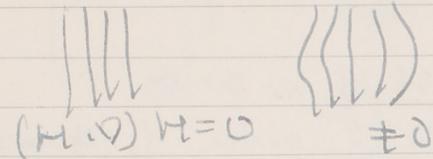
equipartition

dynamo theory of geomagnetism
 sun spot, filament (corona)
 streamer



① 山崎 (1957): 多電子系中のプラズマ

$$P = \frac{1}{8\pi} \frac{dW}{dt} = \text{const.} \quad \text{for } (H.D.) H=0$$



② 山崎: 多電子系中のプラズマ理論

N	ω_p	S	β_{ex}	σ
10^{23}	10^{16}		$(\frac{qE}{4})^{1/3} \frac{1}{v_a}$	
	0.4		~ 1.0	

- ① kinetic theory.
- ② collective motion
- ③ 山崎の論文.

Thermonuclear Research the World Around
 Report of Venice Conference
 (June, 1957) N151 070 21

by H. Reiffel (Nucleonics, August 1957) N151 070

Igor Kurchatov, Lecture at Harwell, April, 1956.

A. Schlüter and R. Hiatt (Göttingen)
 mag. field \perp to \vec{v} , field \parallel to \vec{v} and \vec{v} in the same direction, collision \parallel to field parallel to \vec{v} and a velocity \perp to field
 $\vec{v} \perp$, mag. field \perp to \vec{v} , $\vec{v} \perp$ to field
 $\vec{v} \parallel$, mag. field \parallel to \vec{v} , $\vec{v} \parallel$ to field
 $\vec{v} \perp$, mag. field \parallel to \vec{v} , $\vec{v} \perp$ to field

field \perp to \vec{v} , velocity of a randomization
 to \vec{v} to \vec{v} confine \vec{v} to \vec{v} \vec{v} to \vec{v}

M. Rosenbluth (General Atomics)
 R. J. Taylor (Harwell)

Stability of linear pinch.
 K. Siegbahn (Uppsala), Pinch effect

120 μ sec of 0.5 μ fd condensers at 50 kv. (inductance 5×10^{-9} henries)
 pinch tube: length 60cm; diameter 28cm.
 (electrodes \perp porcelain discs \perp overl, sputtering \perp to \vec{v})

3 bunches of \vec{v} with \vec{v} neutron of \vec{v} \vec{v}
 detect \vec{v} . $\sim 10^6$ neutrons for 300,000 amp, 3- μ sec. (rise time)

S. C. Curran (Aldermaston, England)

080 1017

22

S. A. Colgate, Livermore
 $\sim 10^8$ neutrons per discharge. This amount
agreed with that expected from a true
thermonuclear reaction, but they ~~put~~ it was
proved that the neutrons were produced by
some acceleration mechanism.

S. Chapiro, gross stability of magneto-
hydrodynamic equilibrium configuration

Everyone - including Russians - expressed
the general hope that controlled fusion
research would be declassified within
the year.

22

Controlled Fusion N151 080

A. S. Bishop

Mr. 9 23

(Nucleonics, Sep. 1954, 15, 128)

23



N151 090 Fusion Power

24

R. F. Post, Scientific American

Dec. 1957, 197 Nr. 6. 73.

deuterium gas	Pressure	average energy
room Temp.	1 atm. pres.	~ 2.5 eV
5,000 °C (atoms)	40	~ 1 eV
100,000 (plasma)	1,500	~ 10 eV

100 million	1.5 million	~ 10 keV
-------------	-------------	---------------

100 million kilowatt / liter

350 million

self-sustaining

deuterium gas flow pressure (per liter)

room temp.	pres. atm.
------------	------------

350 million °C	1/100,000
----------------	-----------

heat content 13,500 cal.

(heats a small cup of coffee)

Energy loss

(i) Radiation loss

increase rapidly with density and small amount of impurity energy yield of fusion increases very rapidly with temperature and at small density and overcomes radiation loss at about 370 million degrees for d-d.

(ii) Dissipation of particle energy to the walls. ~~no~~ contact with walls instantly cool the plasma.

24

000 000

25

Magnetic pressure

100 atm	50,000 gauss
10,000 atm	500,000

Fusion reactor could never explode, but collapse!!!

Instability of pinch

of small kink

"sausage" effect

longitudinal mag. field!!!

conducting wall

doughnut-shaped tube

avoids the cooling due to the bumping into a solid surface.

measurement is hard!!!

Tuck, Los Alamos

1951; Perhapsatron

Spitzer, Princeton

1951

Harnwell

2-3 years earlier

York, Livermore

1952

General Atomics

G. E.

USSR, France, Germany, Netherlands, Sweden

25



N151 100

26 第2回 原子力工学の基礎

第3回 原子力工学 (1/2)

基礎知識:

55. 原子力の基礎

超伝導

原子力の歴史

56. 原子力現象と原子力工学の基礎知識

57.

58. Plasma の dispersion formula 導出

110 核融合の基礎

N151 110

27

33年 210 100

10-1: プラズマの基礎知識: 1. 基礎知識

0 Noise

$$\langle \epsilon^2 \rangle_{AV} = 4kT_e R B$$

Probe

0 検電率の基礎: $\epsilon = 1 - \frac{\omega_p^2}{\omega^2}$ $\omega_p^2 = \frac{4\pi N e^2}{m}$

→ 検電率 N が 10²⁰ cm⁻³

0 Ion Temp. $I_i = \frac{1}{4} e N \sqrt{\frac{8kT_i}{\pi m}} S$

$T_e \sim 10^4 \sim 10^5$ K

$T_i \sim 10^3$

pressure \sim 22 eV

$\omega_p \sim 100$ MC

10-3: プラズマ中の波動現象

Stabilization

→ プラズマの安定化

0.05 amp 以下

10-4: (a) 1000V 電圧を印加したときのプラズマの発生と安定化の基礎知識

25 kC (3万C) 電圧を印加したときのプラズマの発生と安定化の基礎知識

25 kC (3万C)

電圧を印加したときのプラズマの発生と安定化の基礎知識

電圧を印加したときのプラズマの発生と安定化の基礎知識

電圧を印加したときのプラズマの発生と安定化の基礎知識



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10-5 空気のプラズマの生成と安定性

Landau Bohm-Pine

10-6 磁場中のプラズマの物理

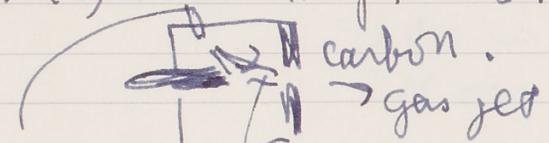
10-7 プラズマの不安定性と磁場の効果

Transient phenomena

Plasmatron

Plasmatron 入力: 70 kW の power

電圧 15 kV, 電流 500 A, 70 Amp, 80 kW



Thermal pinch

10-8 熱的ピンチと磁気ピンチ

100 kW sec 1 sec 以下

面積 1/2
2倍

500 A 以下 50 ~ 100 万 P-imp

pinch 2 mm ~ 3 mm

温度 5000 K ~ 46000 K

600 A 100 万 P-imp ~ 140000 K

2000 A 以下

電圧 10^7 V 以下

(磁場. PPSA 半径 1 mm

I = 1000 Amp

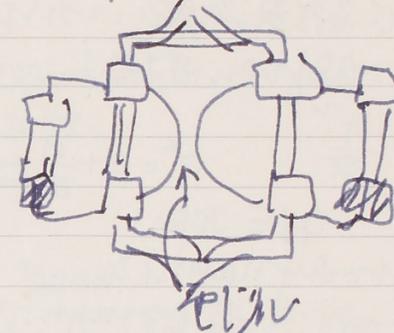
$H^2 = \rho = nKT$ の balance $n = 10^{19} 20$

1000 A: $2 \times 10^{20} / cm^3$

500 A: 1 msec $10^{20} / cm^3$

1 msec

電流: 500 amp x 20 = 10000 amp



10-9 磁気ピンチ (磁場): 磁気ピンチ

10-11 山田 (電法) 磁気ピンチ

10-12 長尾 (東北工): 磁気ピンチの安定現象

三浦 論文

安定現象

附: 山田 (磁気ピンチ)

stability torus

電場ピンチ

磁場ピンチ

10-13 磁気流と地球の磁気: 湯川

地球の磁気 湯川, 磁気流の生成

harmor-Elsasser: self-exciting dynamo
 triadal + dipole



放射能 - 放射: radioactivity

20.

201110: 放射

11-2: 磁場のなかで電荷の加速 (放射)
 放射の電圧を下させる, 磁場のなかで電荷の加速
 magnetic bottle, 磁場のなかで電荷の加速

11-3: 放射: 磁場のなかで電荷の加速の電圧
 放射, Alfvén の速 $c_a^2 = \frac{\mu_0 H^2}{\rho}$

$$\left\{ \begin{aligned} p^* &= p + \frac{H^2}{8\pi} & e^* &= e + \frac{H^2}{8\pi} \quad (\text{energy density}) \end{aligned} \right.$$

$H = \pi p$
 → hydrodynamics $U > c$
 c (magn. = sonic wave vel.)

plasma の hydro-magnetics の
 放射の放射? (放射)

two fluid mixture

11-1: 放射 (放射, 放射) 放射の放射

放射の放射
 300 放射, 30 放射
 放射の放射
 放射の放射
 放射の放射

11-4 放射: 放射の放射
 20 volt, 2 μ F, 1 μ H
 1 MC, 20 μ Ampere \sim 100 放射
 40 volt, 1000 μ Amp.
 (secondary)

11-5. 放射: 放射の放射

interstellar plasma の condensation
 gravitational instability
 magnetic field of condensation
 μ -merson の放射の放射
 dead end $d+d \rightarrow t+p$
 $d+t \rightarrow \alpha+n$

(放射) μ -molecule non-adiabatic
 correction

放射の放射

I. $T > 10^8$ $nt > 10^{16}$
 mass motion \rightarrow heat

a) pinch model i) 放射の放射

ii) slow-plaw

iii) free-particle

$$\left. \begin{aligned} \frac{1}{2} \rho v^2 &= \frac{H^2}{8\pi} \\ E &= \frac{v}{c} H \end{aligned} \right\}$$

$$v^2 = \frac{c^2 E^2}{4\pi p}$$

$$T \sim p^{1/2} E$$

放射の放射

Maxwell perhapsatron \rightarrow 放射の放射

II. (nt) sausage inst. $\frac{l}{v} \sim \mu$ sec

放射の放射 stabilize

skin \rightarrow 放射の放射

diffusion $4\pi \sigma_p r$ $4\pi \sigma_p d$



Marshall $v = 10 \text{ cm}$
 $5 \times 10^{-2} \text{ sec}$
 dimension $\sim 10^8 \text{ cm}$

Non-thermal reaction mechanism

$$\Delta E = 4a \frac{\partial \mathcal{L}}{\partial t}$$

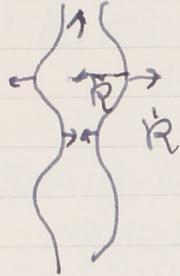
$$ER \sim 8IR$$

$$I \sim 2 \times 10^6 \text{ A}$$

$$R \sim 10^7 \text{ cm/sec}$$

$$ER \sim 16 \text{ keV}$$

$$k = \text{rate} \sim 10^{14} \text{ volt}$$



11-6: 湯川: 宇宙線の加速機構
 $\frac{p^2 \sin^2 \alpha}{H} = \text{const.}$

Fermi I, Statistical

Fermi II 伝導運動

湯川:
 宇宙線: π 伝導 $\sim 10^8 \text{ cm}^2$

湯川: Plasma stability

Sausage:

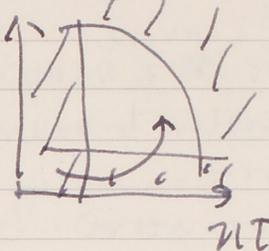
$$p + \frac{B_0^2}{2\mu} = \frac{B_1^2}{2\mu} \quad 2B_0^2 > B_1^2$$

Jayber

湯川: 宇宙線の加速機構

high temp. T
 pulsive

宇宙線の加速機構
 T 上昇



大河: Zeta, Nature Jan. 1958
 Columbus
 Permutation

宇宙線の加速機構

宇宙線の加速機構

40,000,000 (A)

宇宙線の加速機構

8,000,000 (A)

宇宙線の加速機構

5百万 (第一宇宙速度)

宇宙線の加速機構

174
34 N151 141 March 19, 1958

1. 本: 38回
2. 子山: プラズマの測定
 Ti Doppler broadening
 Te X-ray
 n microwave (plasma oscillation)
 neutron
 H
3. 西田: Pinch effect について
 物理学的に
 おおし pinch イオニス joule's heat
 子 pinch 7+4力 mechanical

研究内容

基研: (子山): 電の工学的, 宇宙線の発生
 星の電波の発生機構, 地球電波, プラズマ
 電波の伝播して伝送現象,
 (青島, 15回)

横尾研: (西田): 放射線のプラズマ,
 測定の測定, プラズマ shock wave
 high intensity of ion source

(林): 宇宙線現象, 宇宙空間のプラズマ,
 プラズマ制御

地研(南谷): magneto-hydrodynamics

(嶋海): nuclear reaction

高橋研(山崎): microwave

内田研(山崎): 放射線の測定

富田研: plasma の特性

宇宙物理: 太陽電磁気 (大崎)
 超電導・電子線: 電界プラズマ発生

プラズマ jet による測定の測定
 分岐: 三相電圧: 放電, breakdown

D.C. low pressure breakdown

p = 20.5 mm Hg Argon gas
 longitudinal magnetic field

Te = 10⁴°K

研: B.N.研 (林) magneto-hydro.

工研: 林研 0.2x20 μF condenser
 D.C. A.E. generator
 A.C.



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フラスコ研究

N151 150

587th ~ 15th 1958

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全約 1000:

電圧研究

川崎氏 (1954): 内外の研究の整理.

測定対象

1. 電圧回路の特性

I, V

2. 電圧

中性子

3. probe

全約

小島氏 (1954)

木原氏 (1954): フラスコ理論

8月: 全約

今井氏: 電圧回路

Alfvén (1954)

Counting (1957)

Spitzer (1956)

Landshoff (1957)

Kantrowitz & Pevsner

Syrovatsky (1957) (電圧回路)

Rexler & Sears, Magneto-Aerodynamics

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核融合論文
論文研究費 (33年分) 取り上げ.

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5/19 午の general discussion
会場: resumé
核融合懇話会 機関雑誌.

会場: 現在保蔵中, → 核融合

160
核融合懇話会
5/20, 21, 22 ~ 24

N151 160

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13日 午後 Cgenre 論文発表
会場: (午) (11時)

14日
11:30 Plasma の安定性.

会場: 本館.
水場:

MHD
(Kihara)
Taylor
Bretton

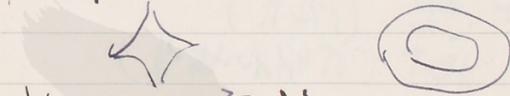
Polignac Eq.
Chandrasekhar

Srbat
theory
Poincaré
-homonore

- i) 安定な configuration の安定性
- ii) 安定性の - 安定条件

会場:

conference の会場.



場の - 安定

位相空間の W と δW (安定性).

$$p \ll \frac{B^2}{8\pi}$$

mean free path が大きい,
plasma は熱平衡状態.

子午:
軌跡
軌跡

本木:

orbit \rightarrow Rutherford \rightarrow MHD

stellarator

100 msec
(diffusion \sim 1 sec)

子午

A, M の物理学的.

本木: linear pinch (1920)

流線型 (1920)

円筒型 (1920)

in jet 型 (1920)

plasma jet (1920)

本木:

plasma jet (1920)

plasma jet (1920)

plasma jet (1920)

子午

子午型 plasma jet (1920)
D-D 反応の外部系

分冊

plasma jet.

plasma-free jet.

流線型 定常流

平行流線型 (confinement)

torus が唯一



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湯川秀樹先生 講演メモ
Jan. 8 ~ 10, 1958

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