Title: Explorations in Numerical Relativity - Lecture 10

Date: Apr 15, 2011 09:00 AM

URL: http://pirsa.org/11040051

Abstract:

Pirsa: 11040051 Page 1/151

Critical Phen. Type II Type I dP = - (8+P) (m+ 4nr'P) MaH ST a -oly P-PO In MBH = X len /P-F

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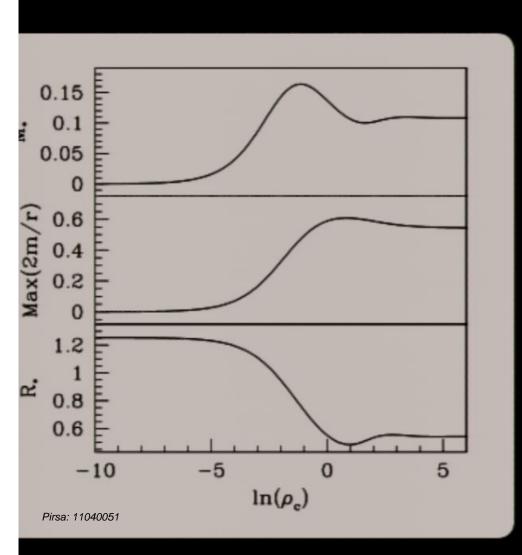
Page 2/151

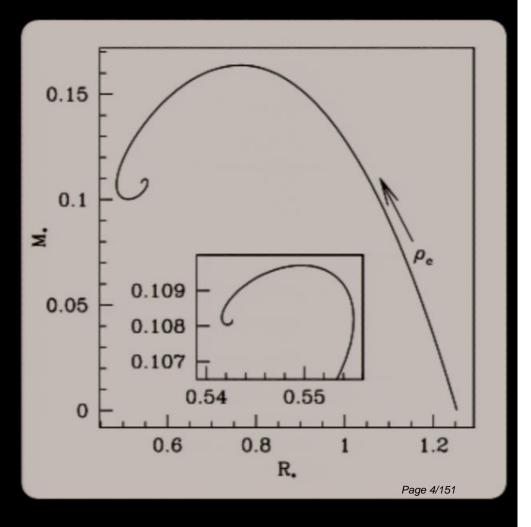
Critical Phen. Type II Type I dP = (8+P)(m+4nr3P) MBH ST a -oly P-PE In MBH = X lulp-P*

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Page 3/151

TOV Solutions





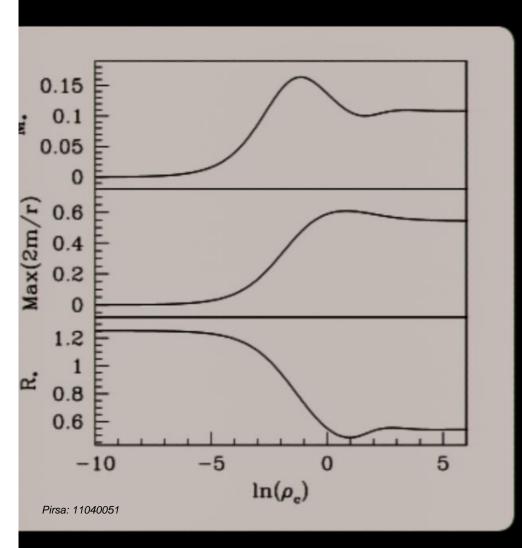
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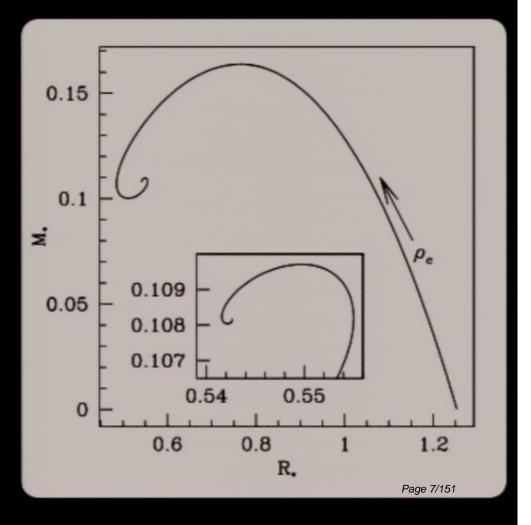
Critical Phen. Type II Type I MBH 8+P)(m+4111 P) ba. ST a -ohilp-pt ln MBH = X ln /P-P*

Page 6/151

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TOV Solutions

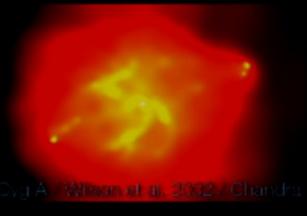




The Exciting World of Relativistic Plasma



Dynamics!

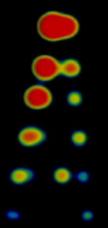


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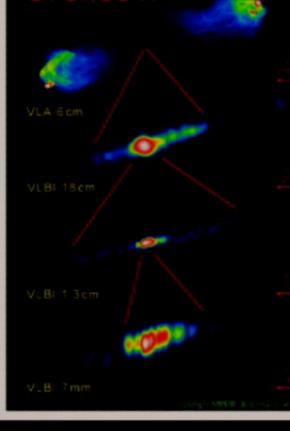
XRBs!!

Core of Galaxy NGC 4261

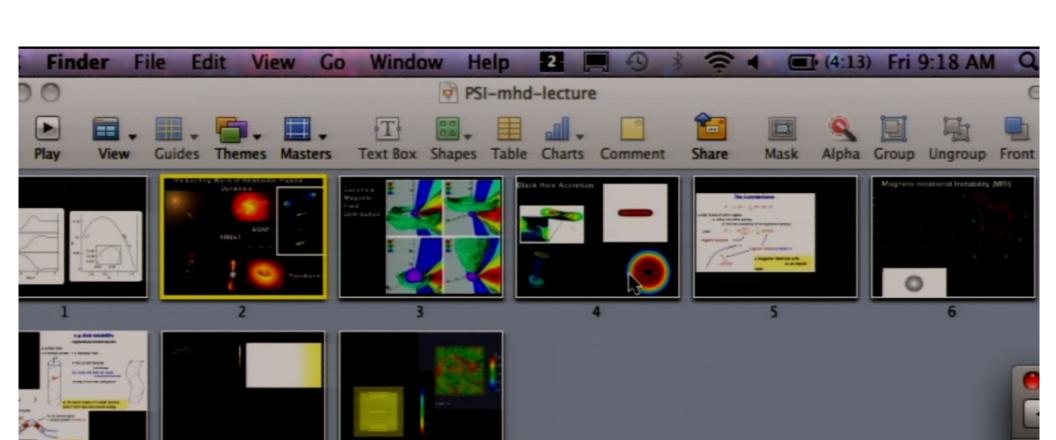
Hubble Space Telescope
Wide Field Planetary Camera



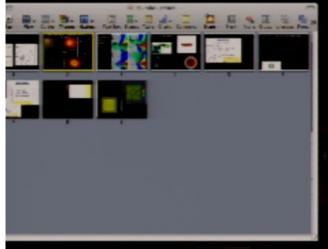




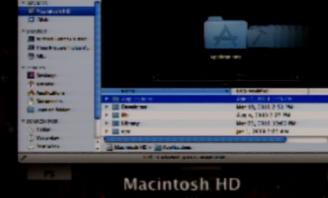
Feedback!



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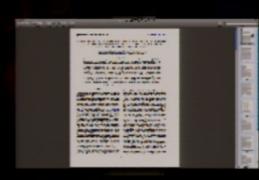
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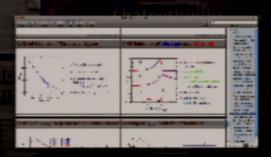
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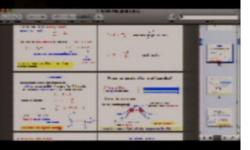
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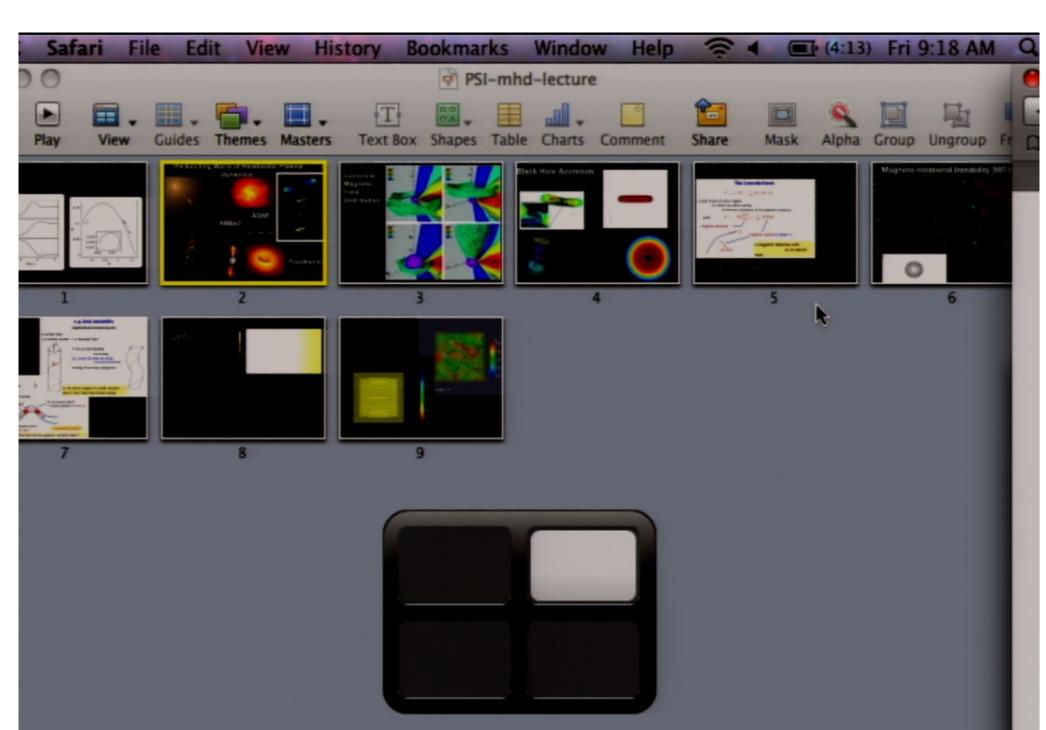
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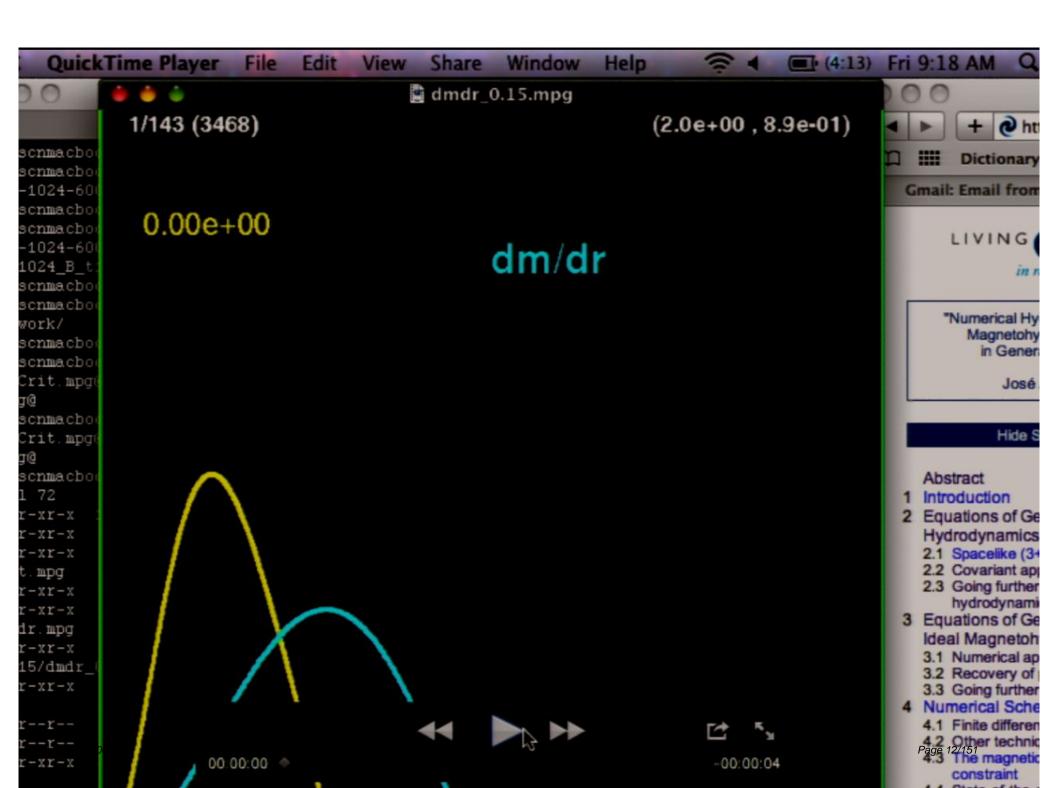
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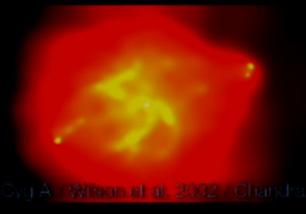
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The Exciting World of Relativistic Plasma



Dynamics!

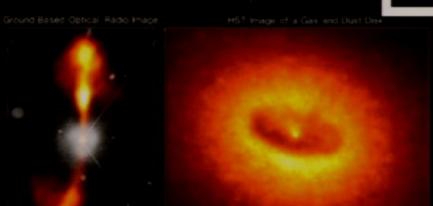


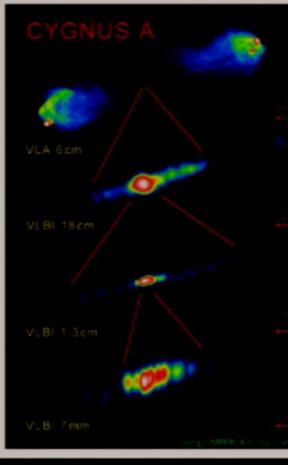
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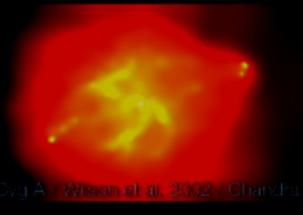


Feedback!

The Exciting World of Relativistic Plasma



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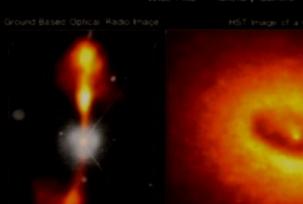


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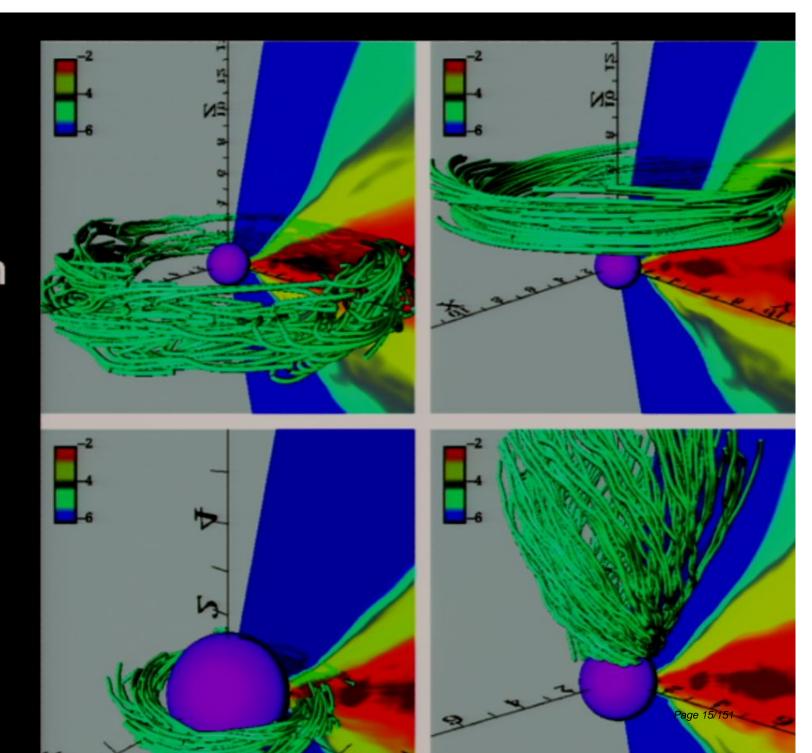
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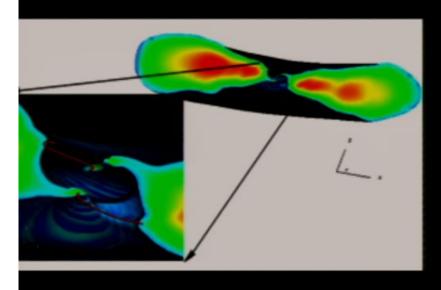


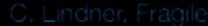
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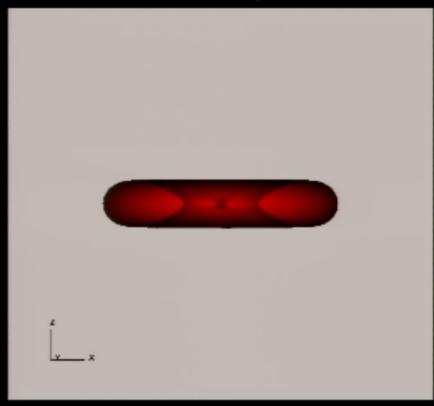
Feedback!

Canonical Magnetic Field Distribution

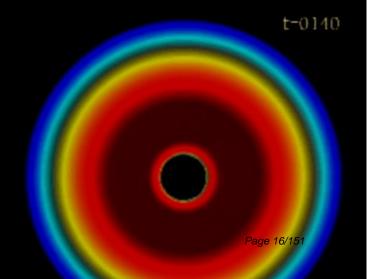


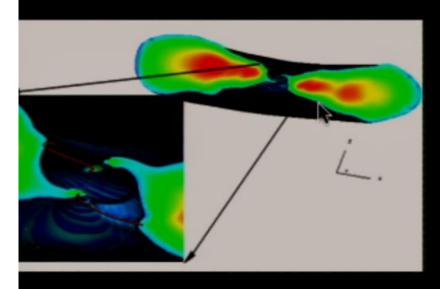


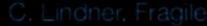


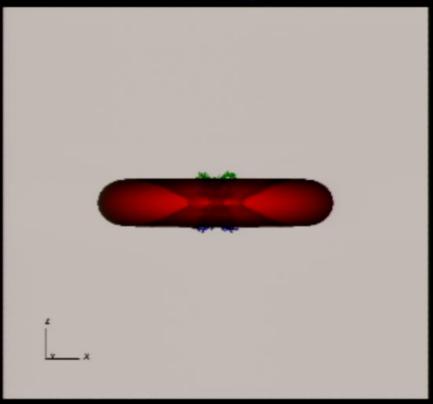




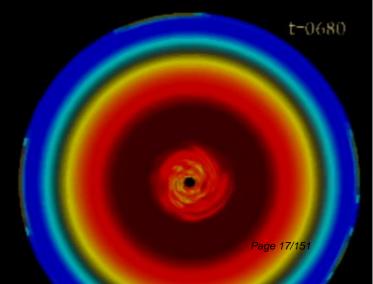


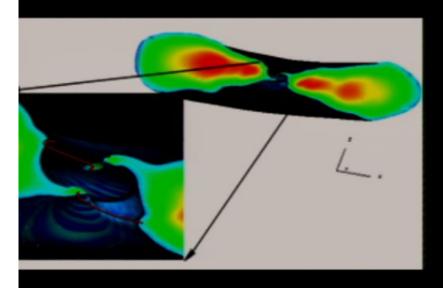


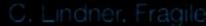


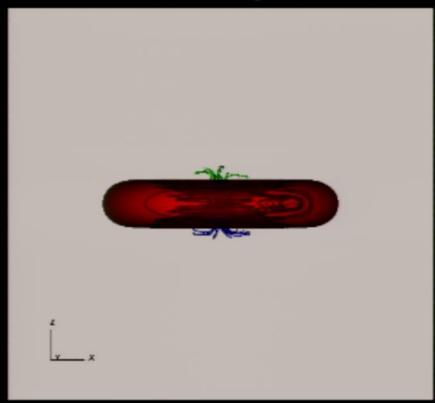




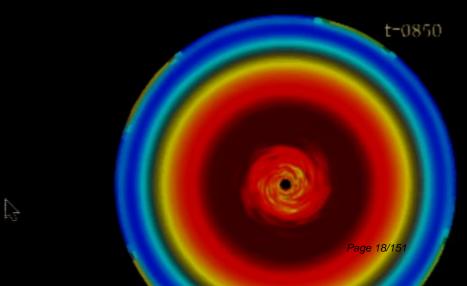


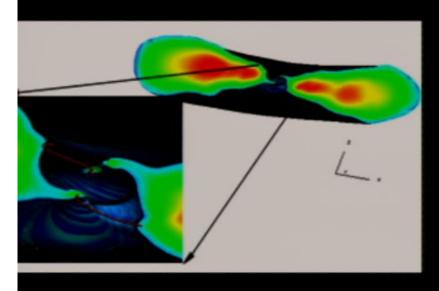




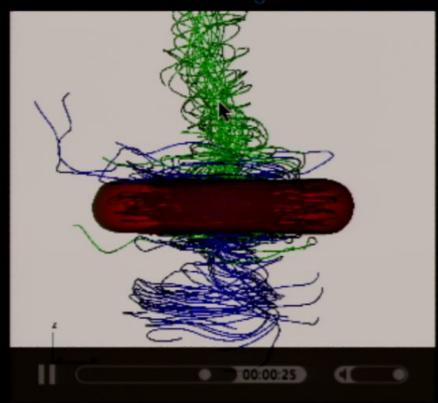




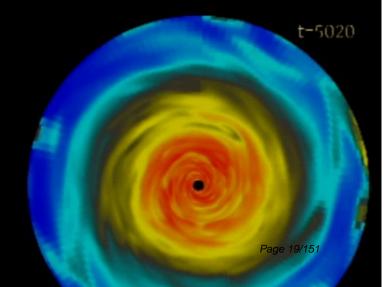












Flux Freezing

The Lorentz force

$$\vec{F} = \vec{j} \times \vec{B} = \frac{1}{4\pi} (\vec{\nabla} \times \vec{B}) \times \vec{B}$$

small miracle of vector algebra,

... or rather: the subtle working

of the inner consistency of the equations of physics,

gives:
$$\vec{F} = -\vec{\nabla}\left(\frac{B^2}{8\pi}\right) + \frac{1}{4\pi}\,(\vec{B}\,\vec{\nabla})\vec{B}$$
 magnetic pressure

magnetic tension (a tensor!)

a magnetic field line acts as an elastic

rope

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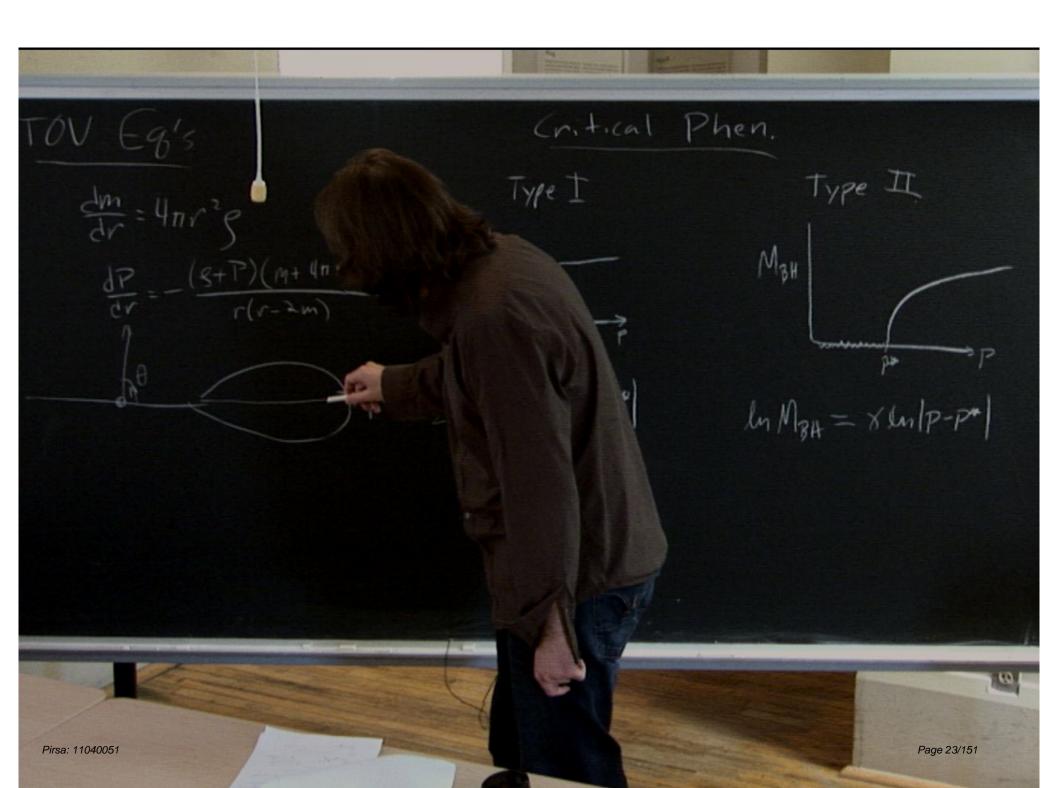
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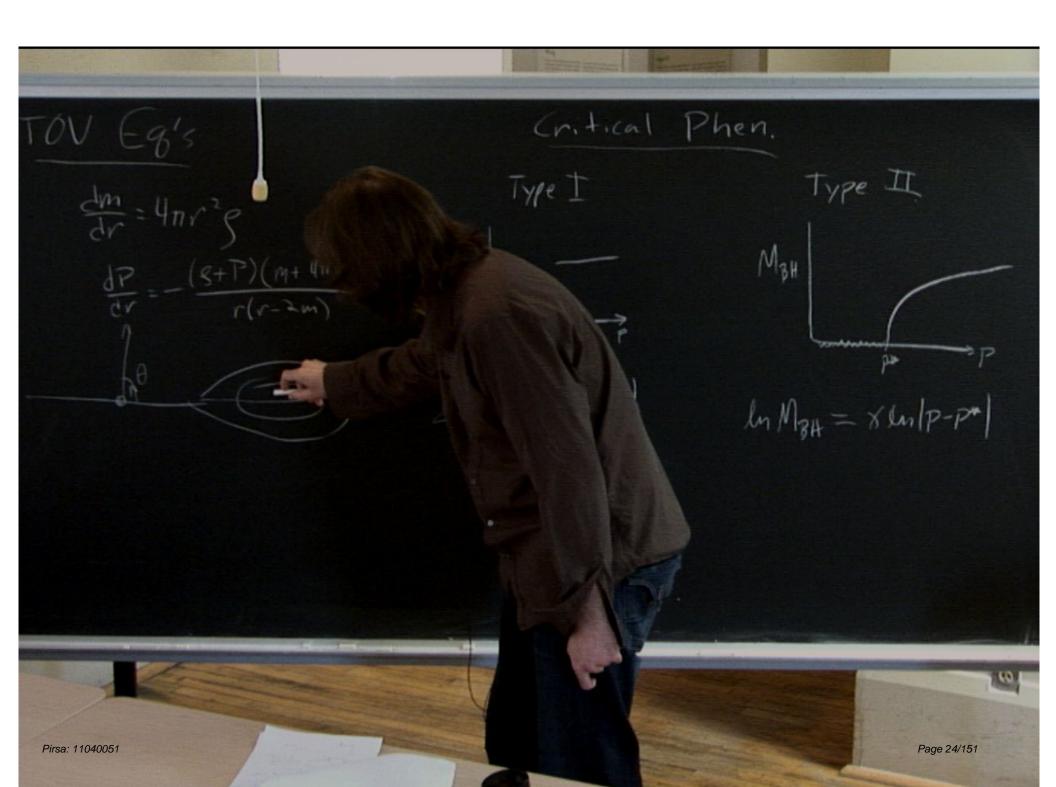
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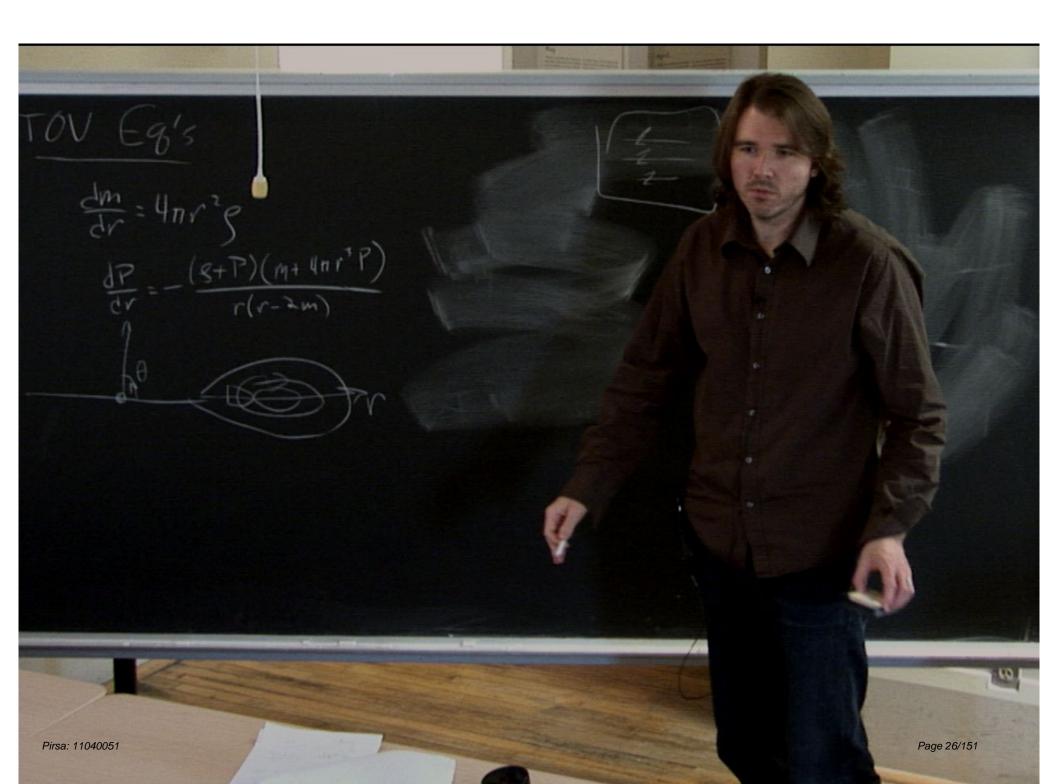
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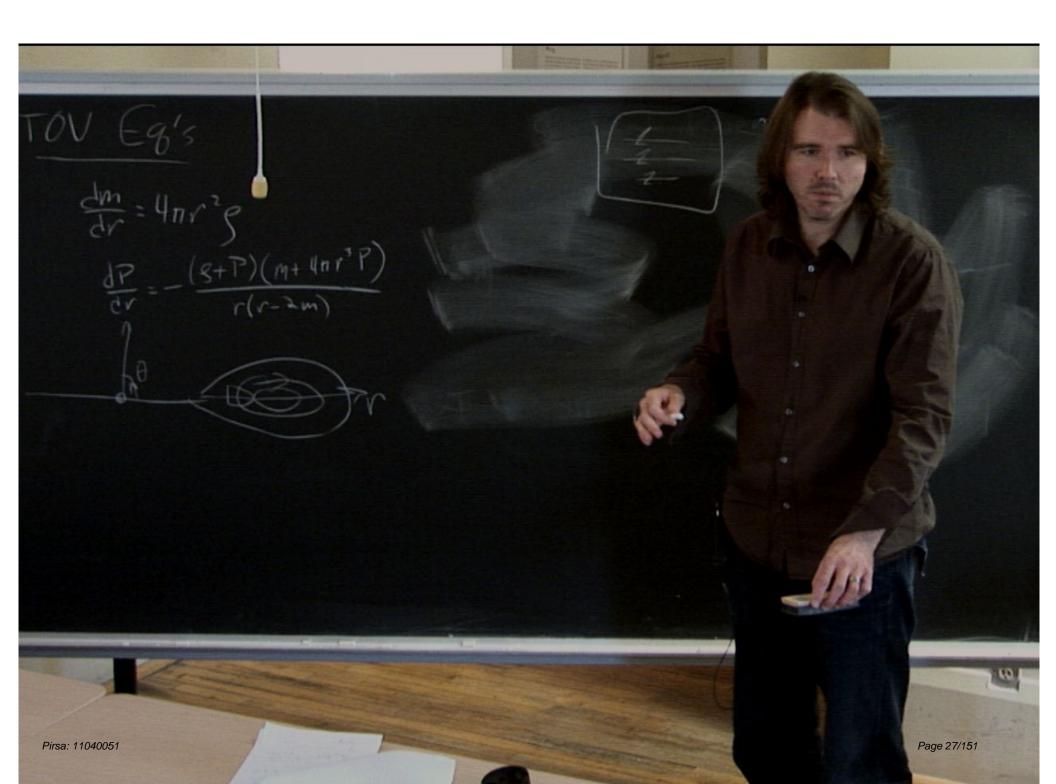
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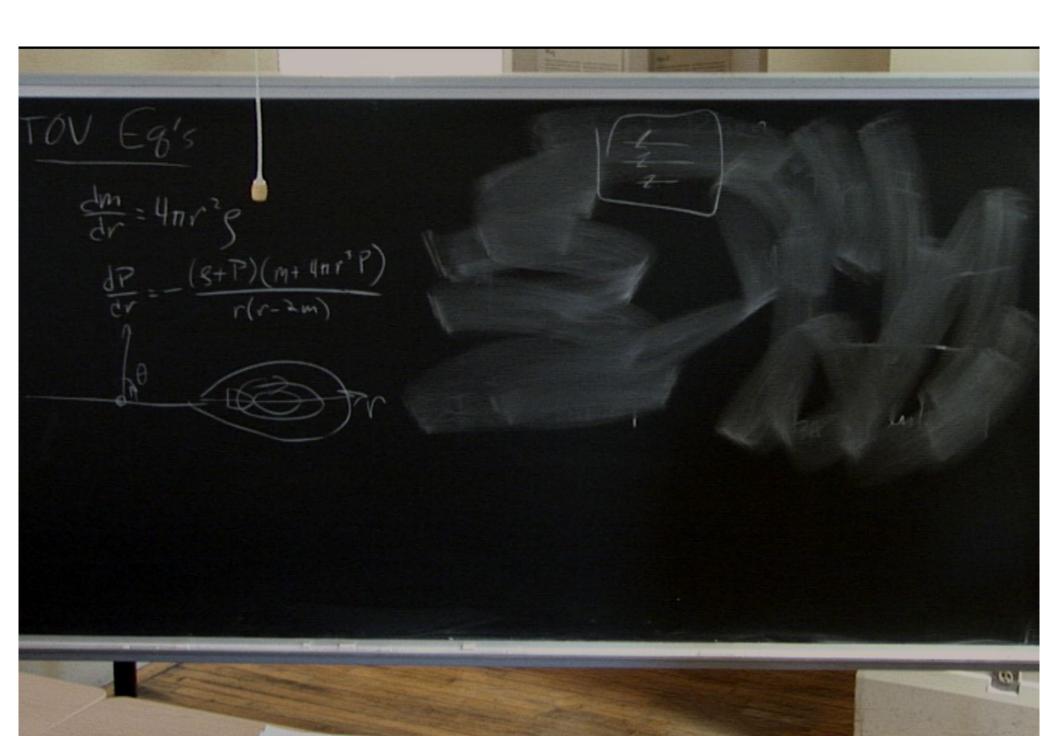




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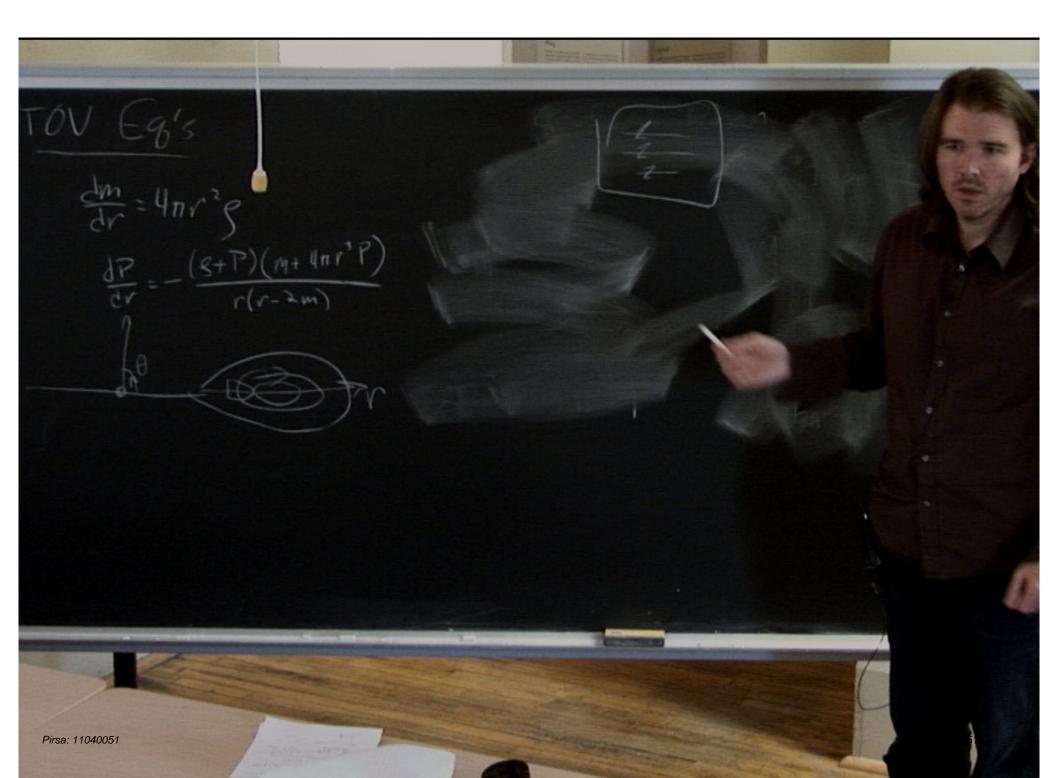






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Page 28/151



Velikhov (1959)

Chandrasekhar (1960)

Balbus & Hawley (1991)

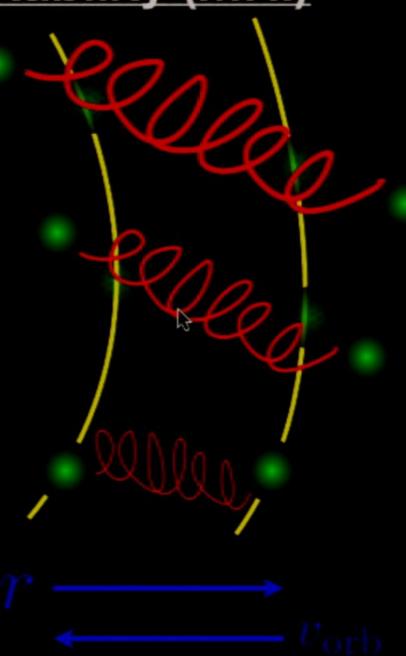
Growth on orbital time scale.

IRI develops from weak initial field --- relevant or any (partially) ionized gas.

Magnetic coupling over different radii is not well lescribed by local viscosity.

Can explain high accretion rates where lydrodynamic viscosity cannot.





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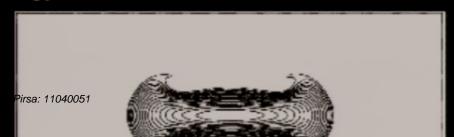
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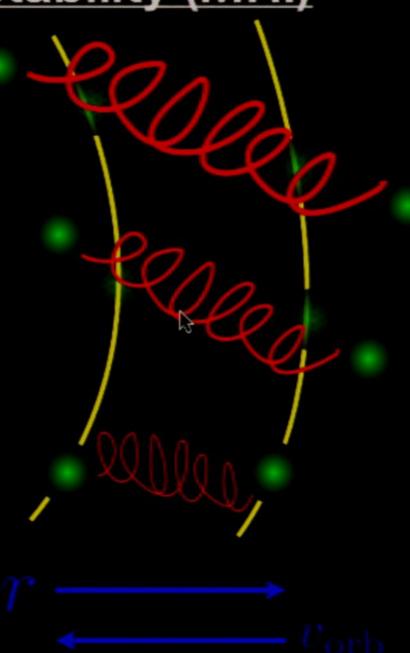
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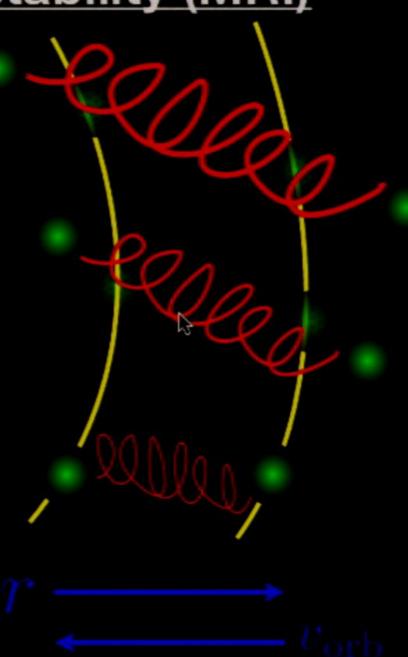
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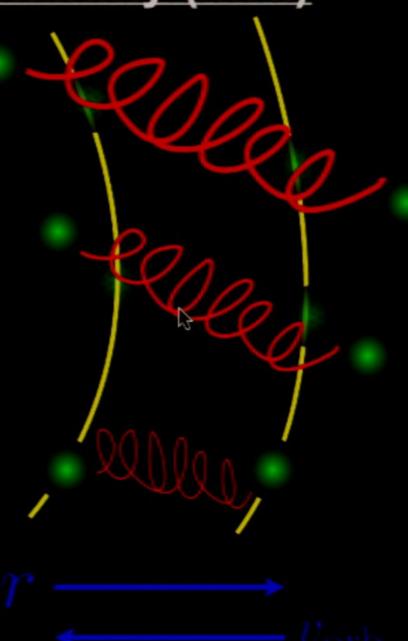
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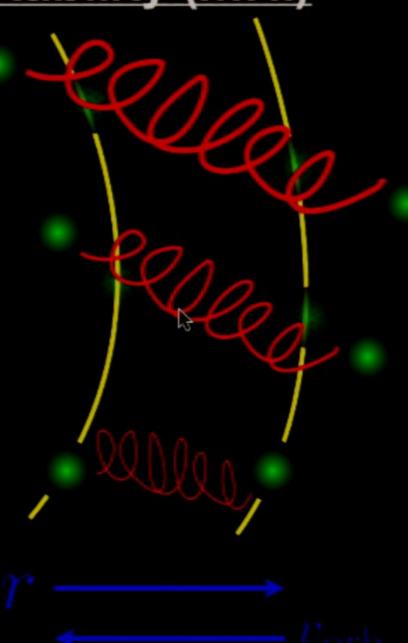
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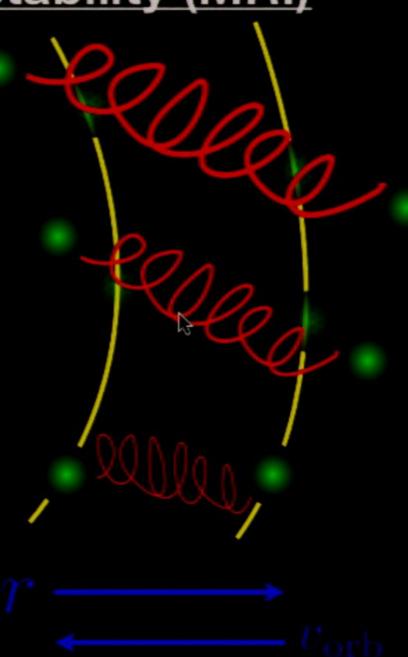
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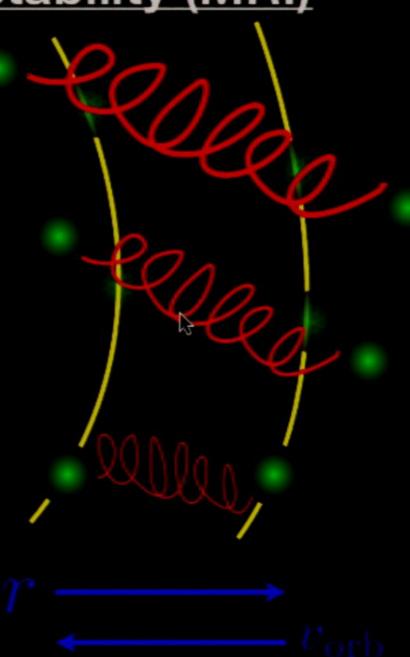
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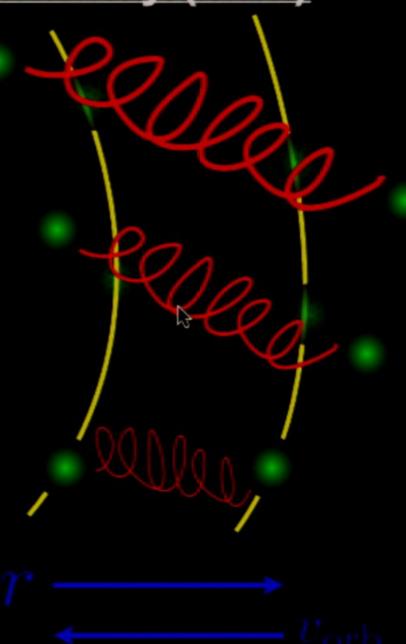
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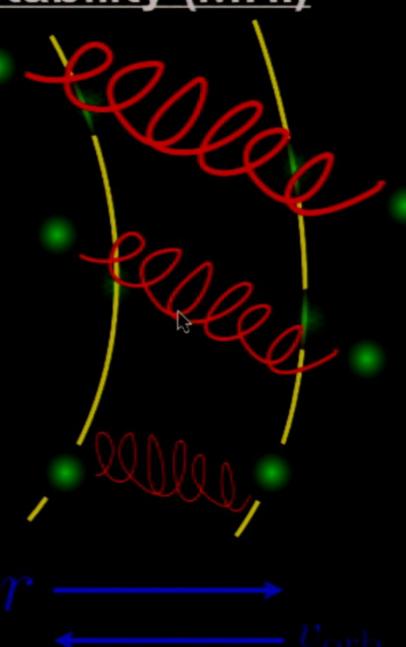
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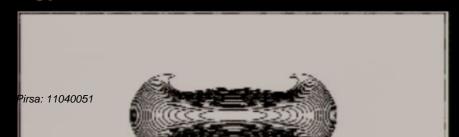
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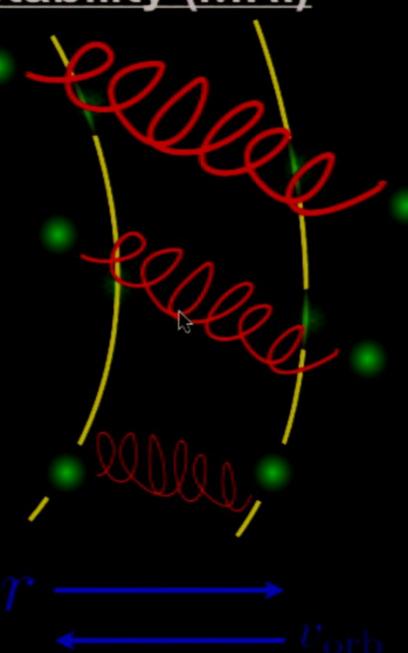
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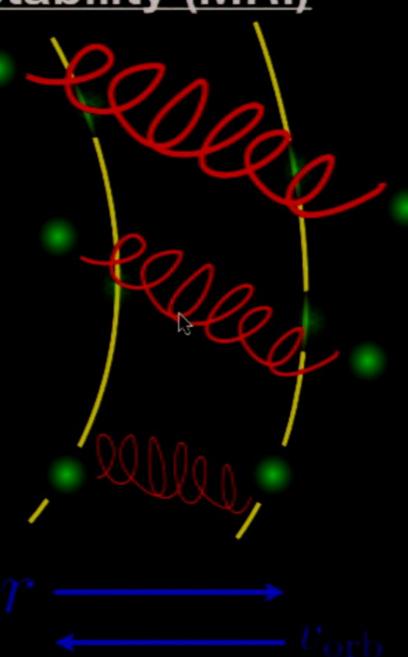
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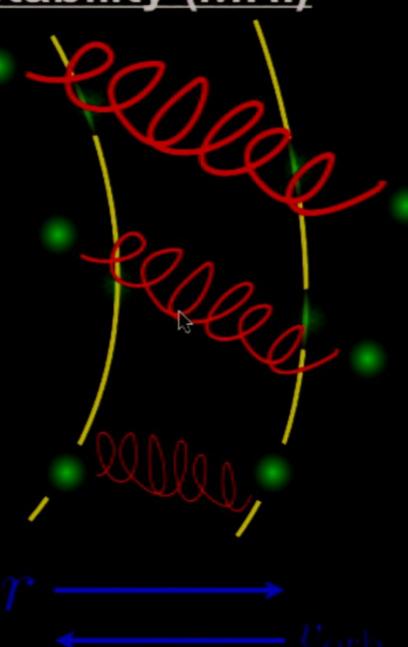
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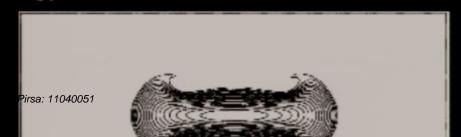
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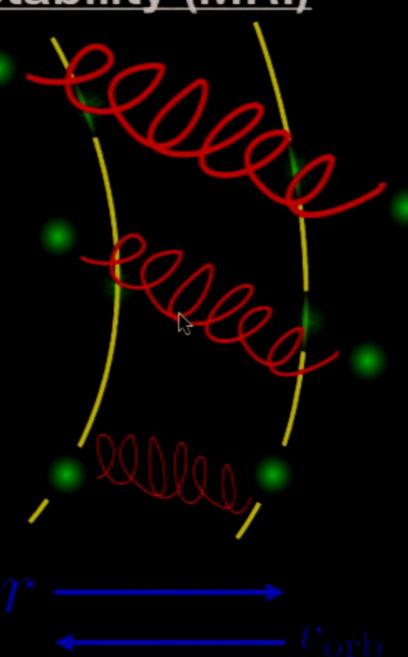
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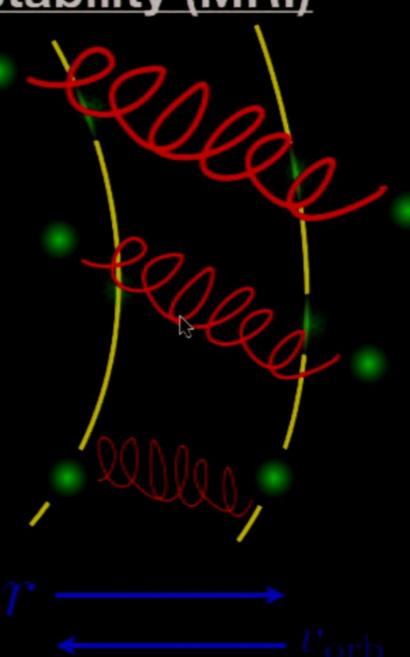
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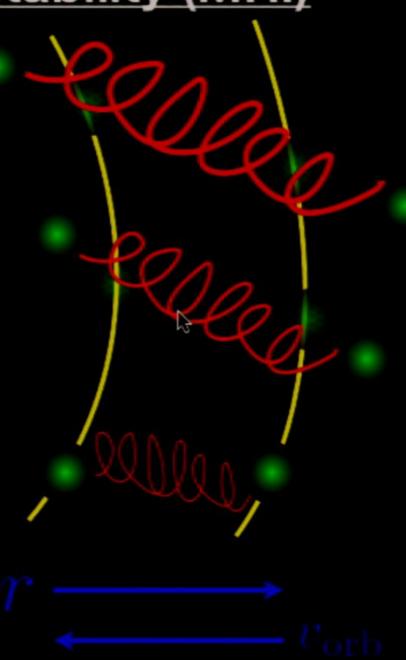
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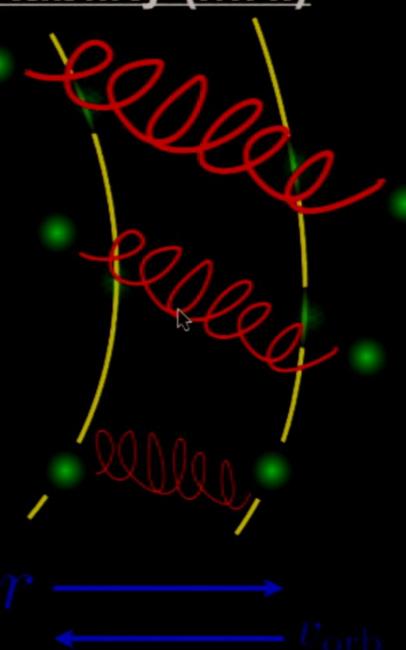
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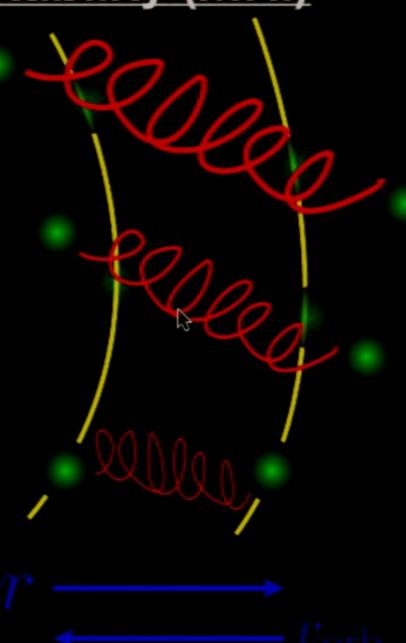
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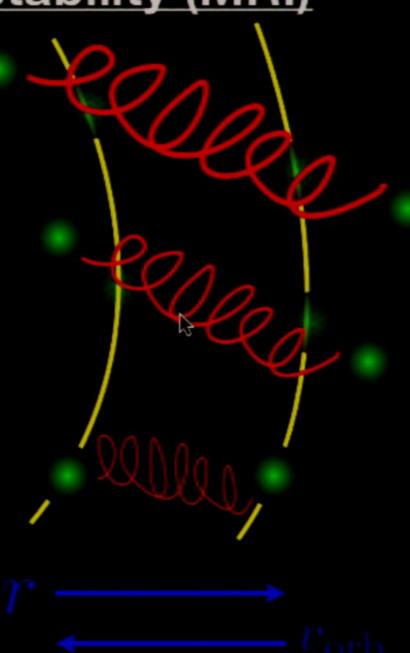
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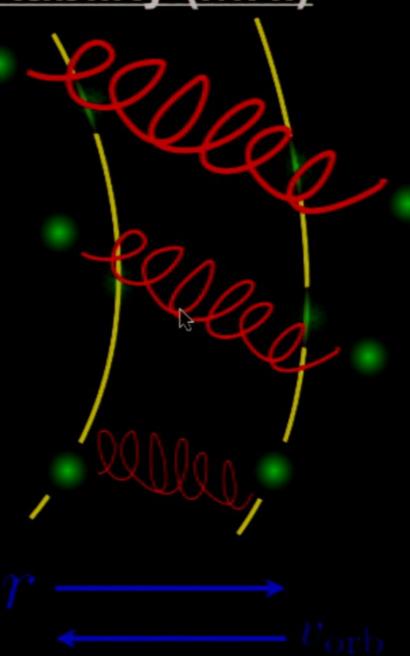
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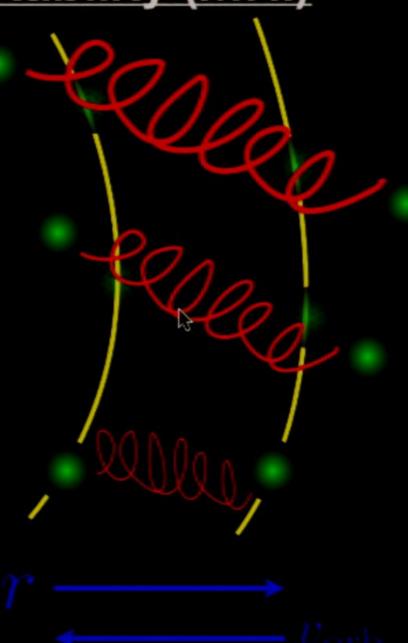
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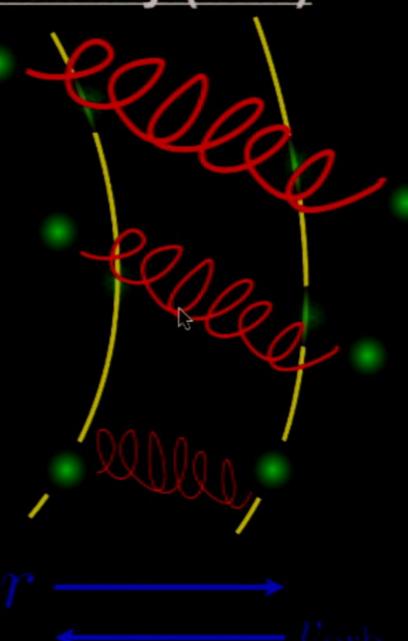
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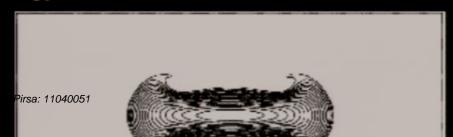
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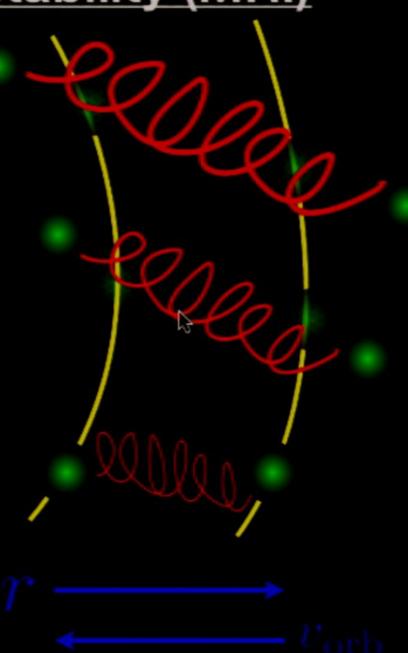
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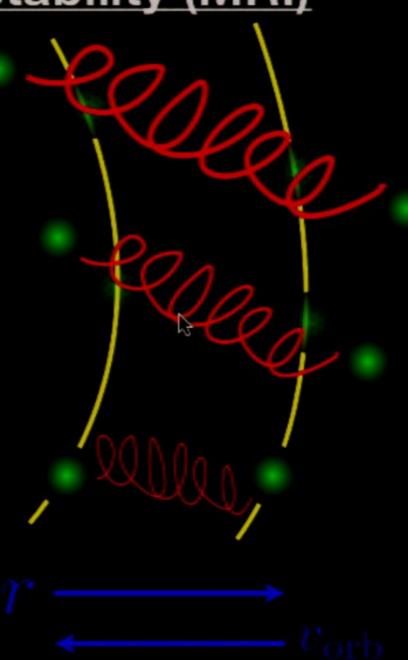
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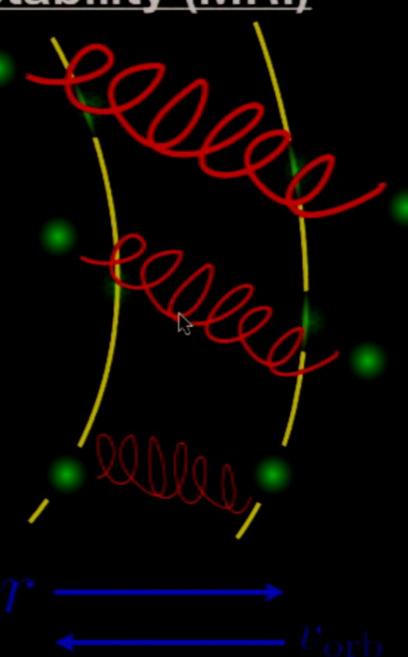
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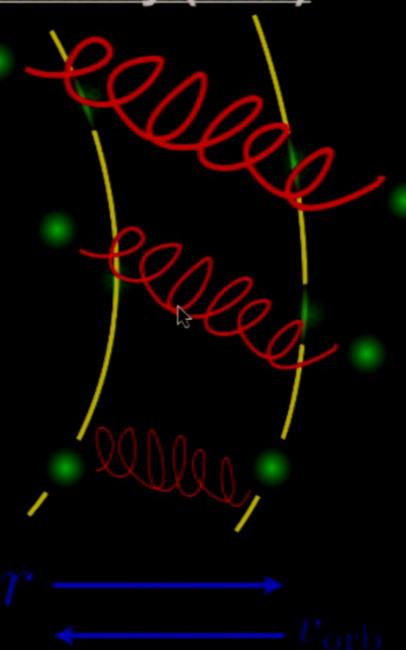
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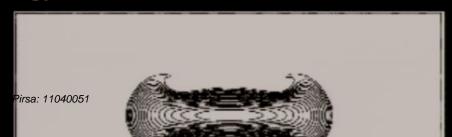
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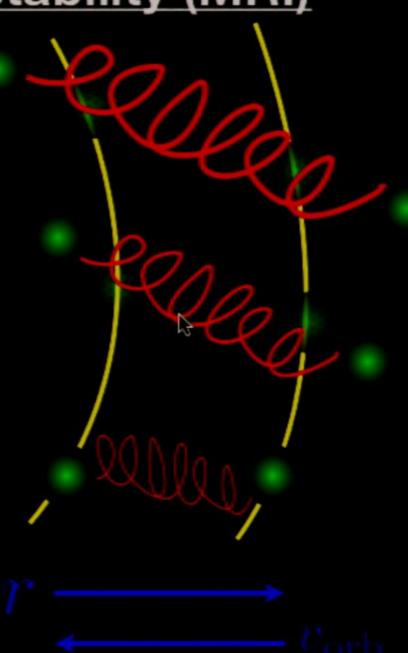
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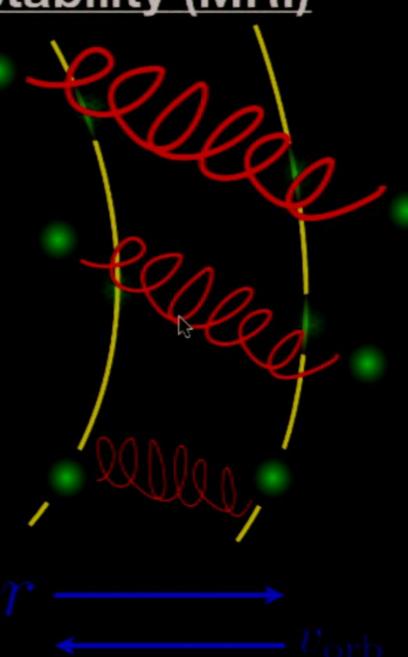
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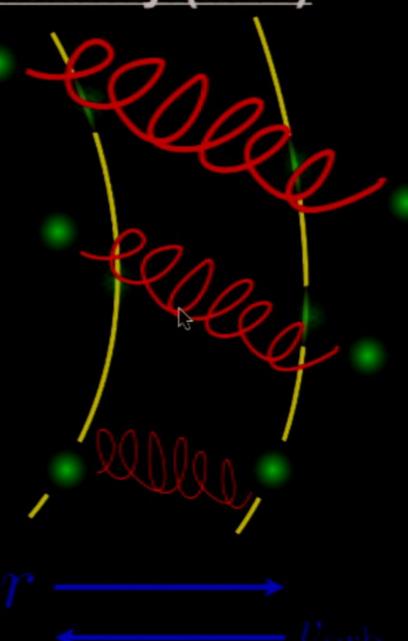
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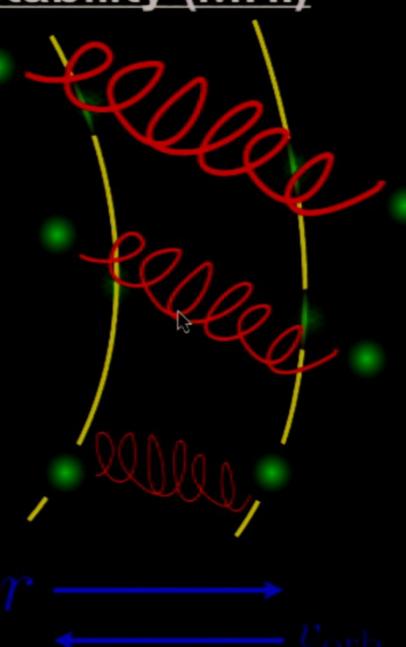
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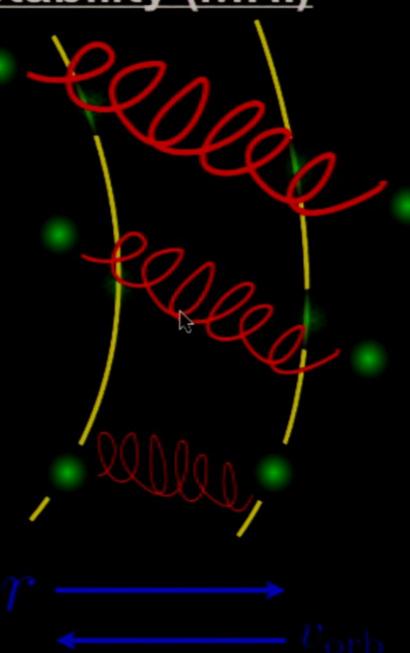
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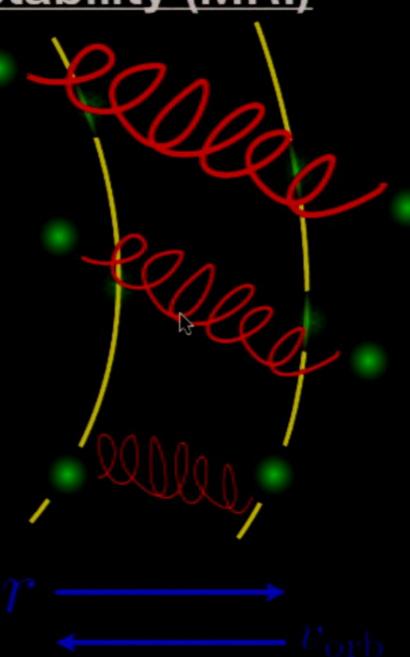
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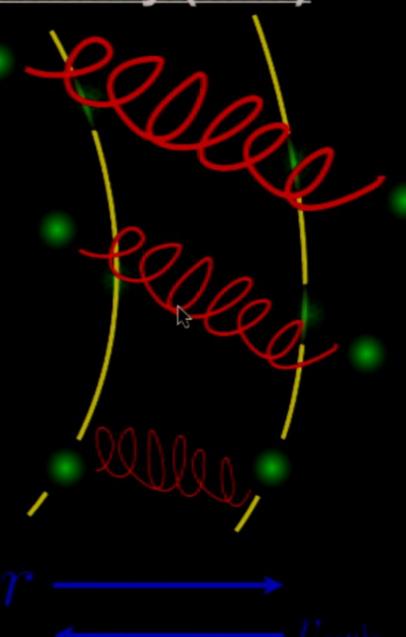
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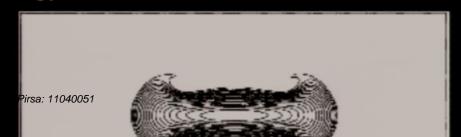
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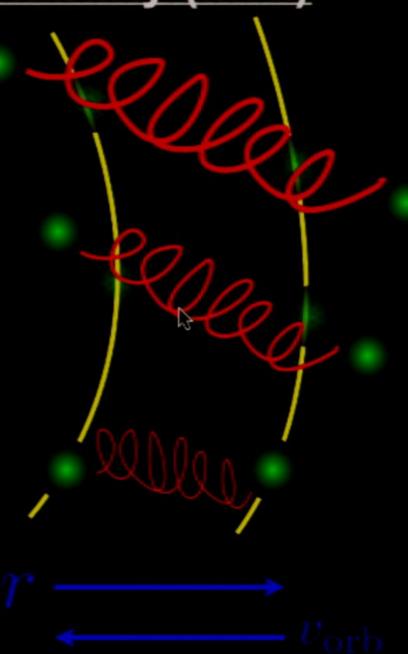
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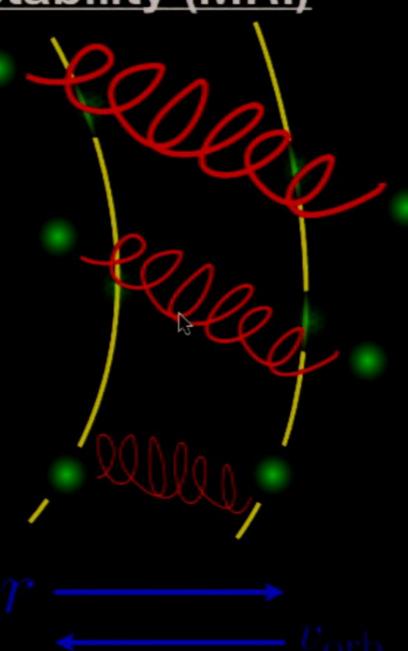
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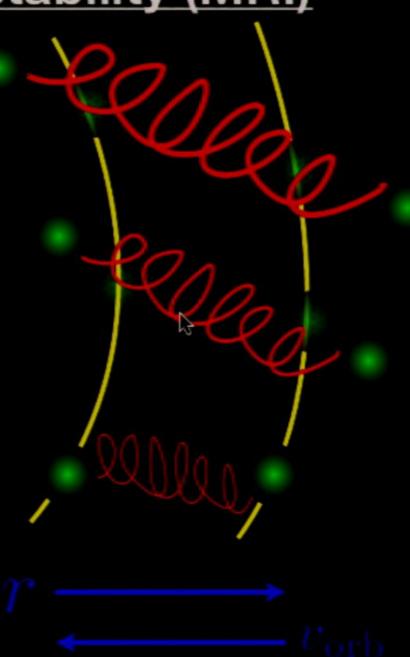
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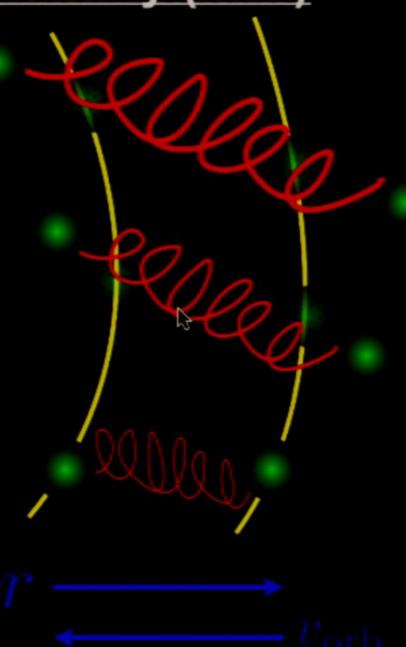
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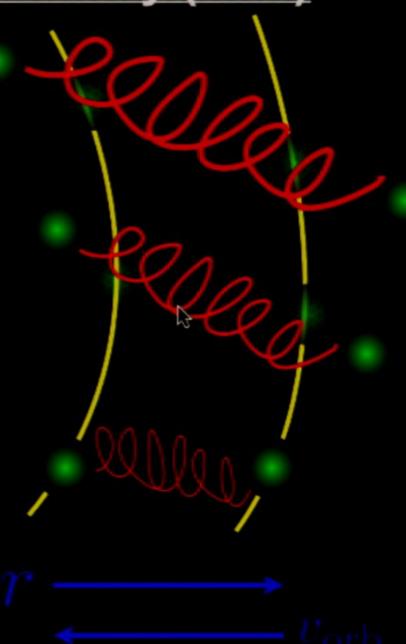
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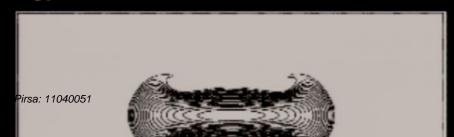
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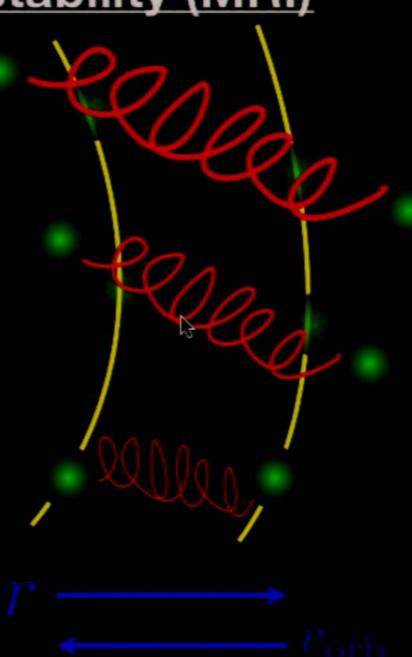
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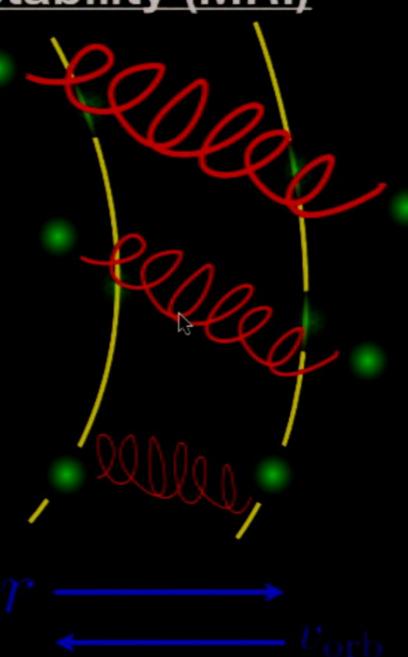
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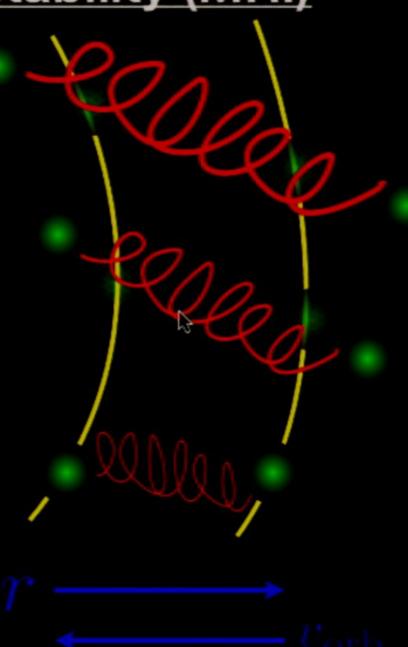
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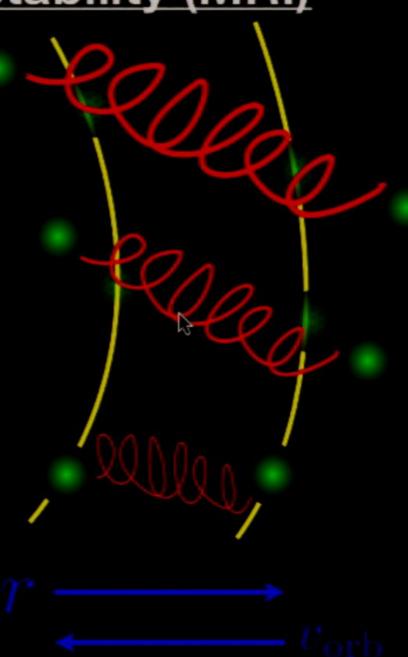
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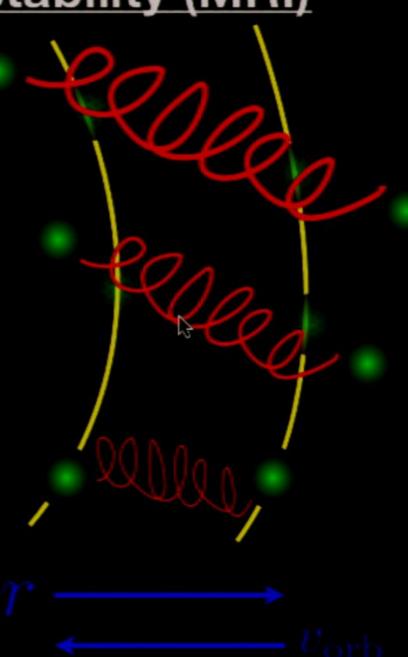
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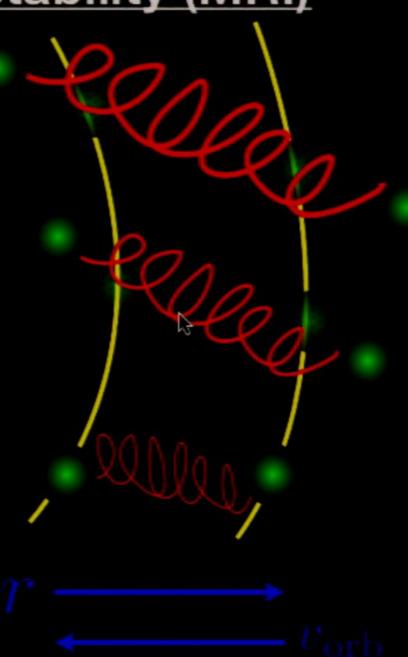
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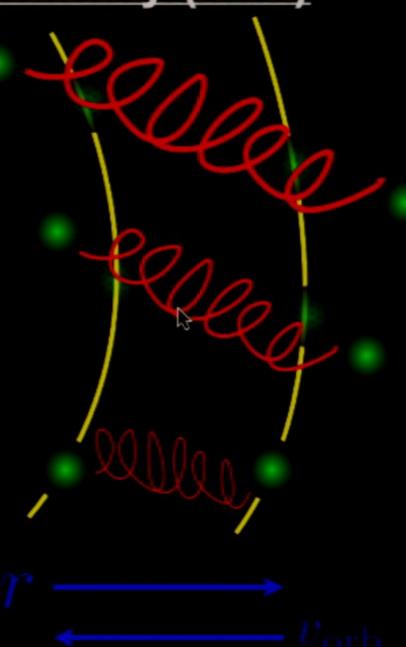
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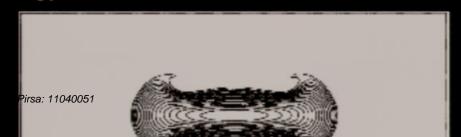
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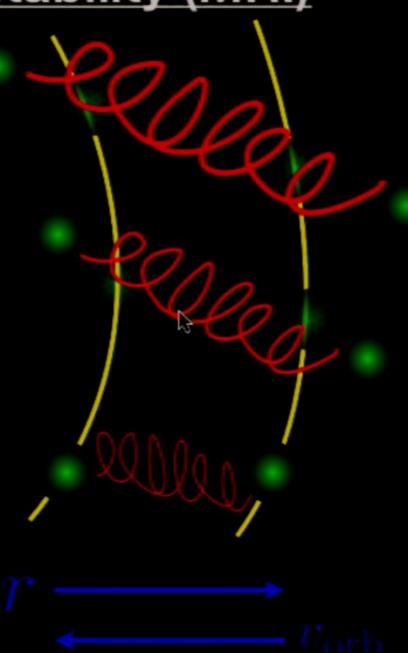
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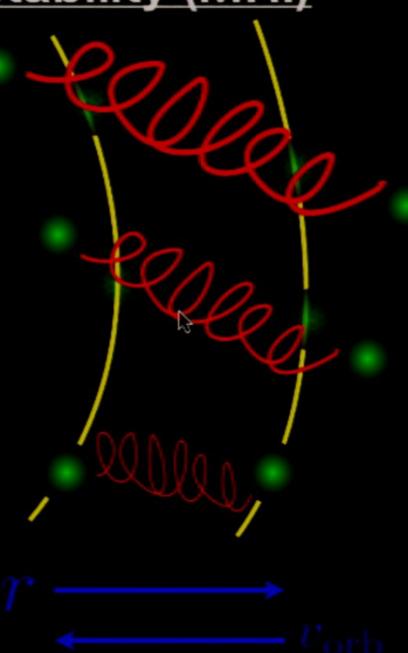
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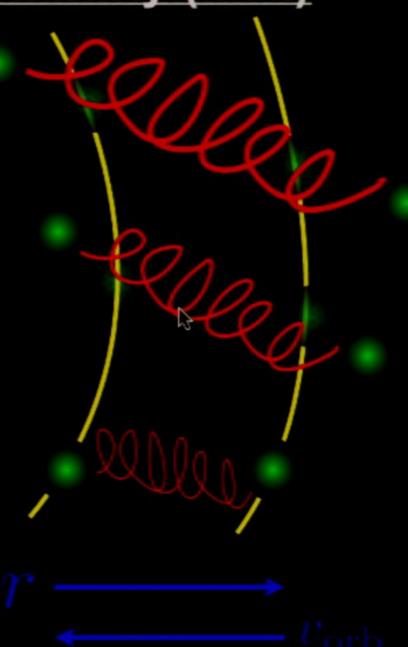
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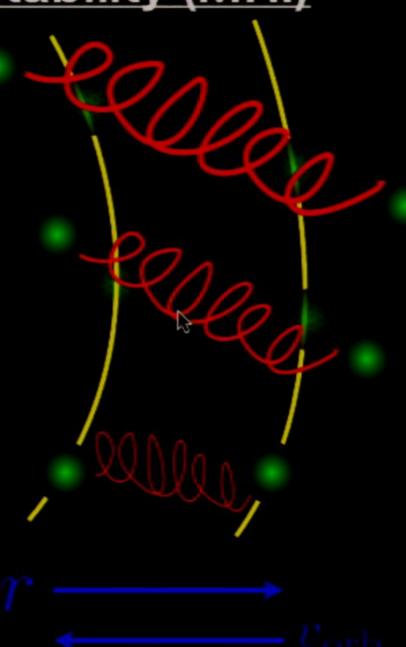
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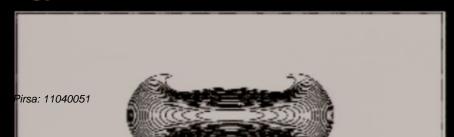
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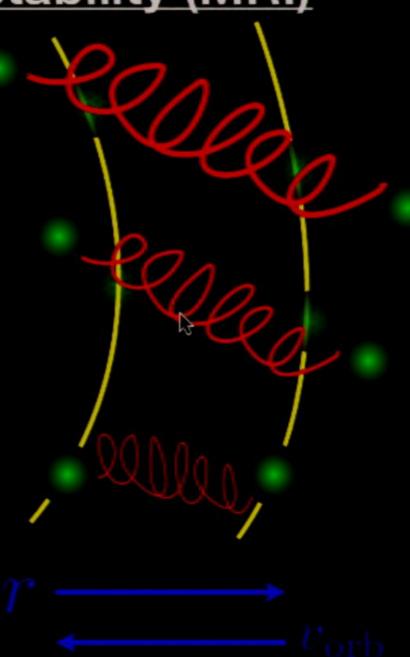
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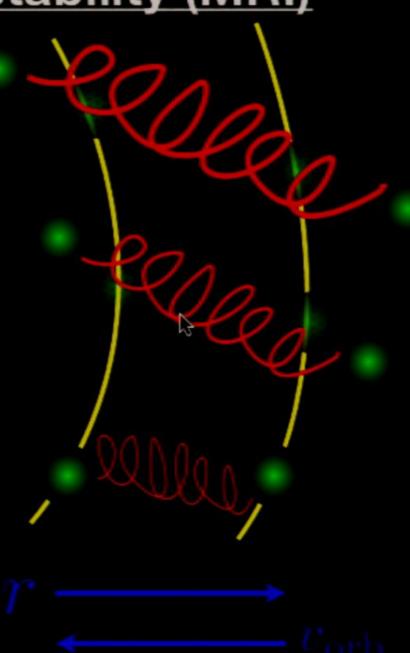
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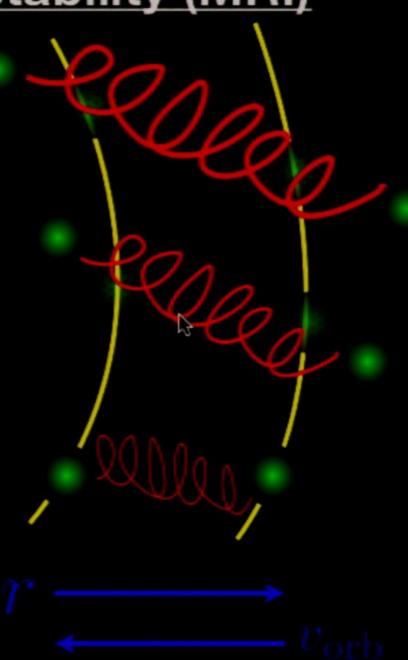
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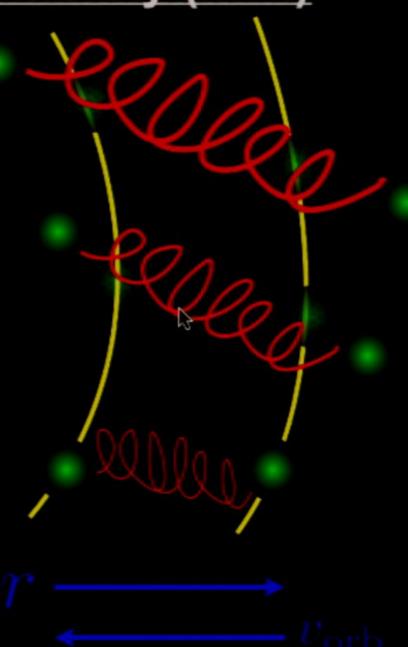
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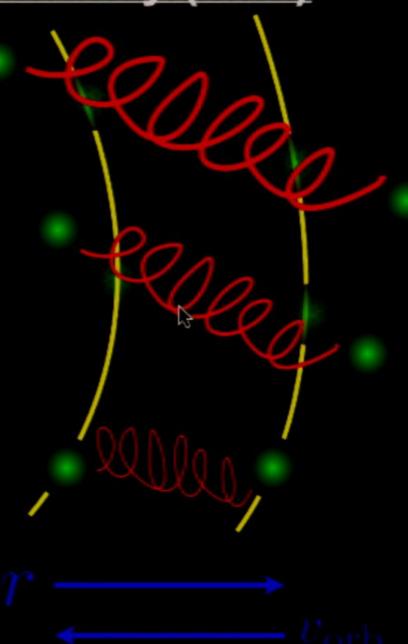
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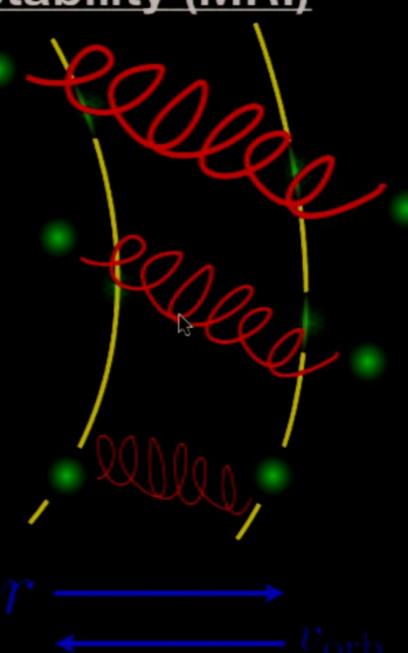
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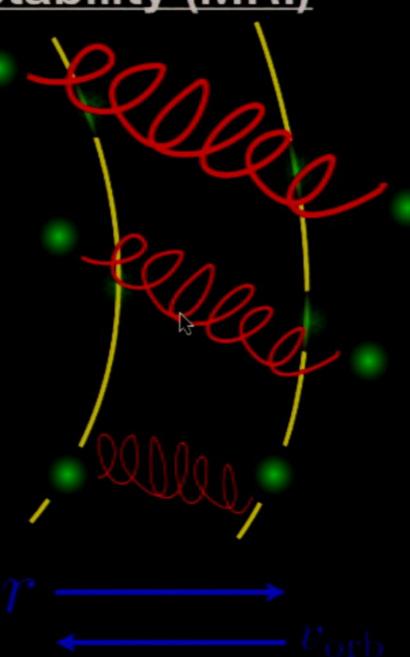
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Other MHD nstabilities

Parker instability

n a stratified, magnetized medium

if a flux tube starts to buckle

the top becomes lighter starts sliding down along B -> buoyancy pushes it further up Pirsa: 1104005 the bottom becomes heavier

e.g. kink instability

(applications to knots in jets)

a vertical field

+ a vertical current -> a helicoidal field



if the current becomes

too strong

(i.e. winds the field too much)

twisting of the whole configuration

as the elastic engine of a model airplane, when it can't take more torsion energy

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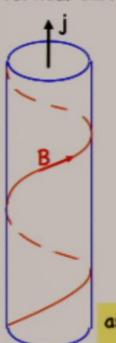
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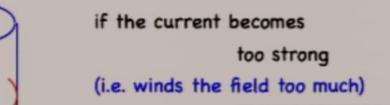
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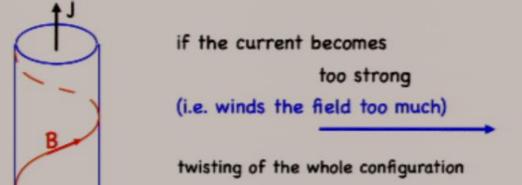
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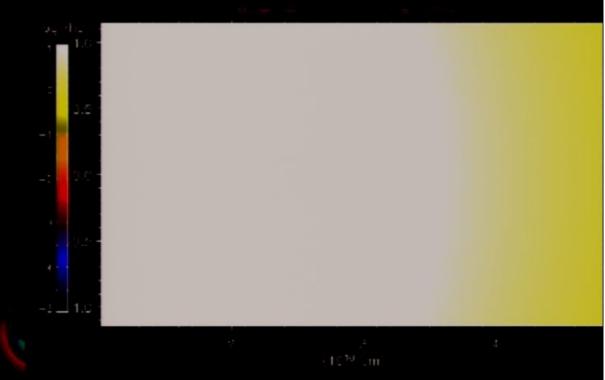
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5 3 Special Relativistic Hydro 5 mulation of Collapsin Jensey & A. Piger

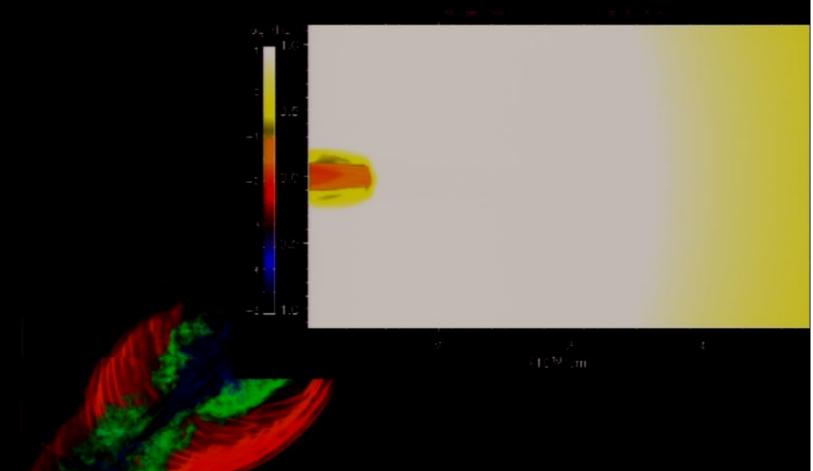


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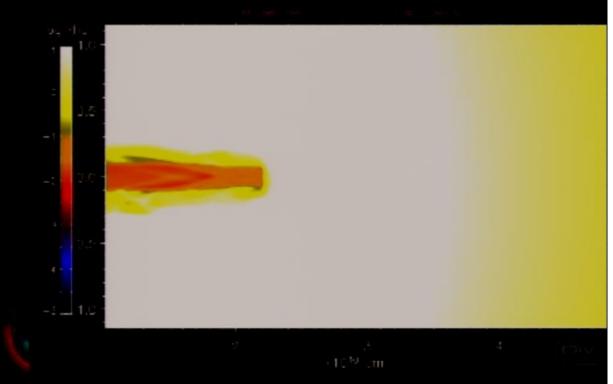
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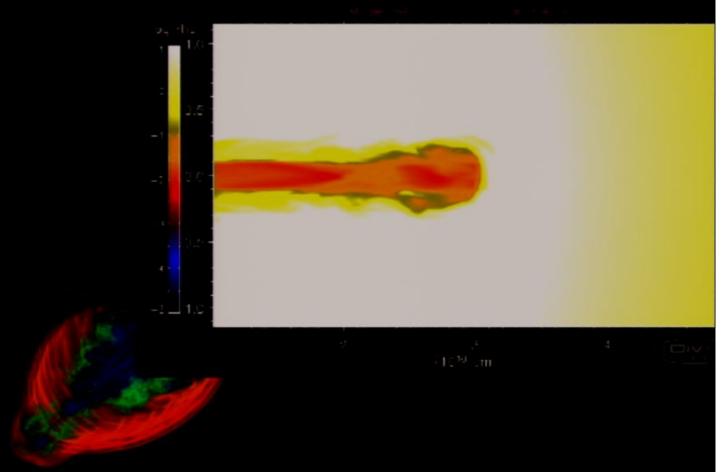


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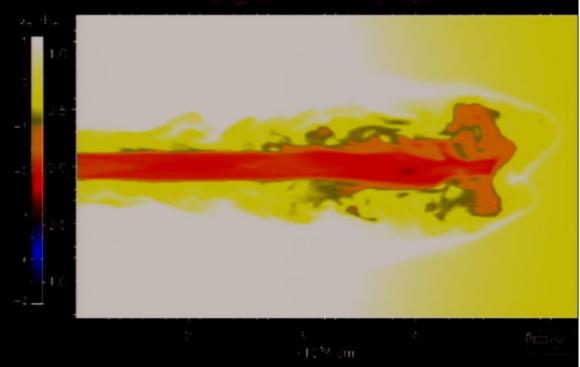
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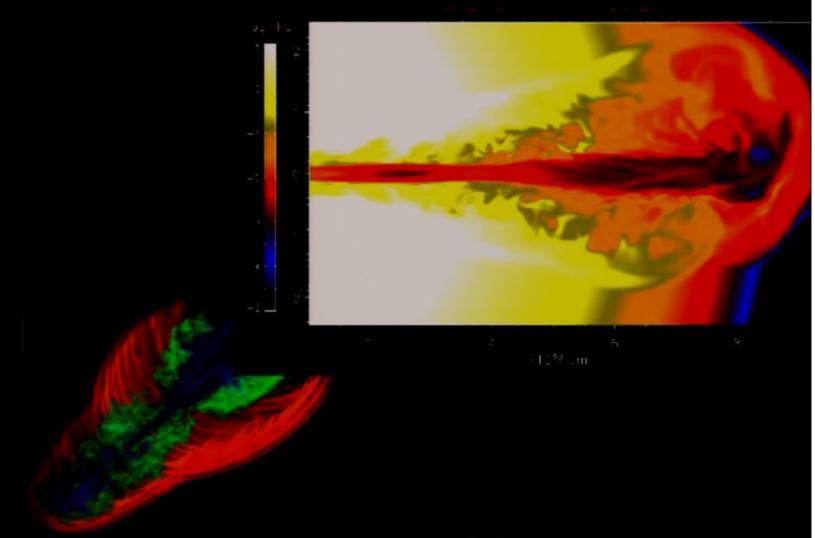


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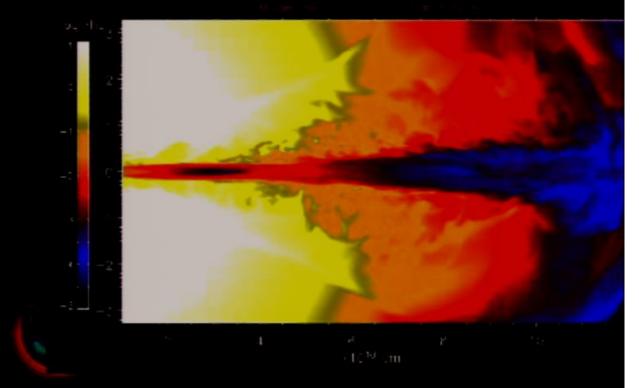
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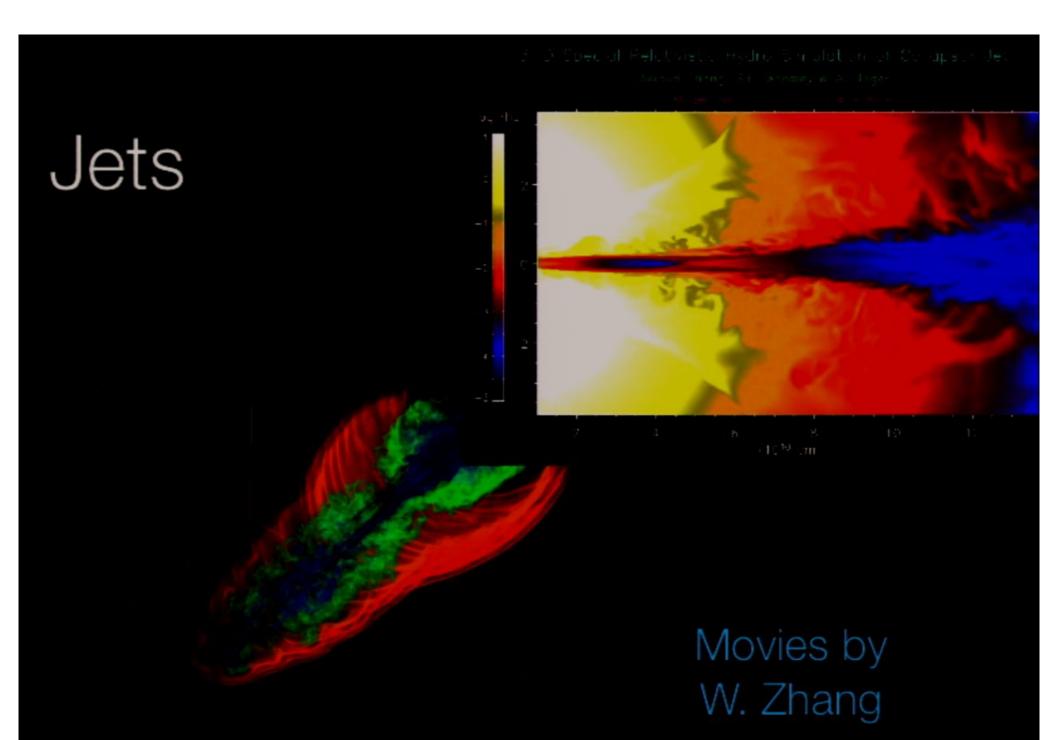


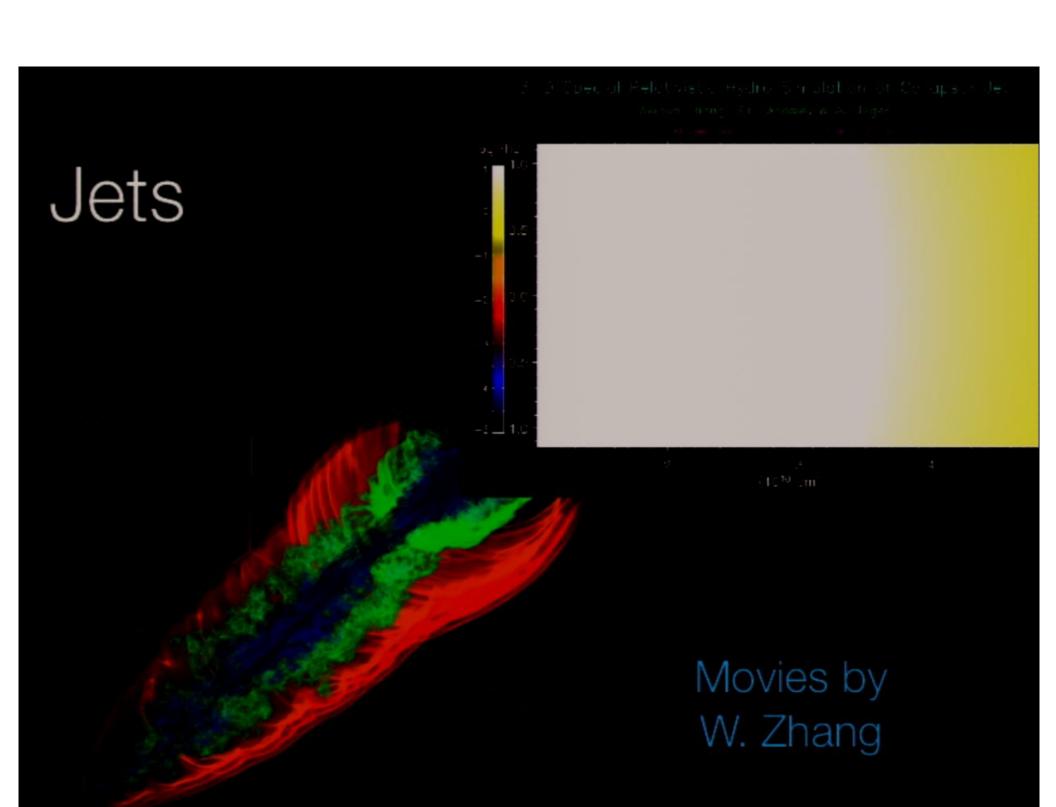
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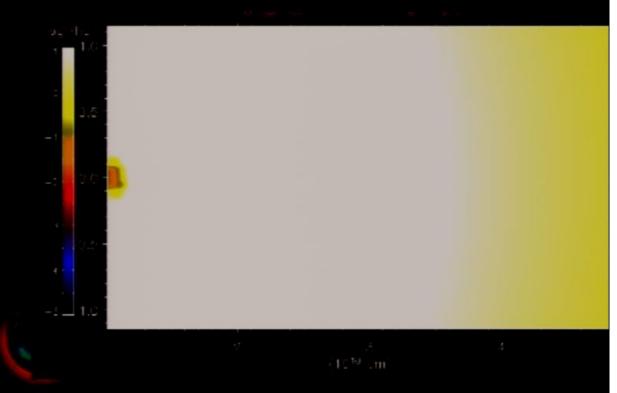
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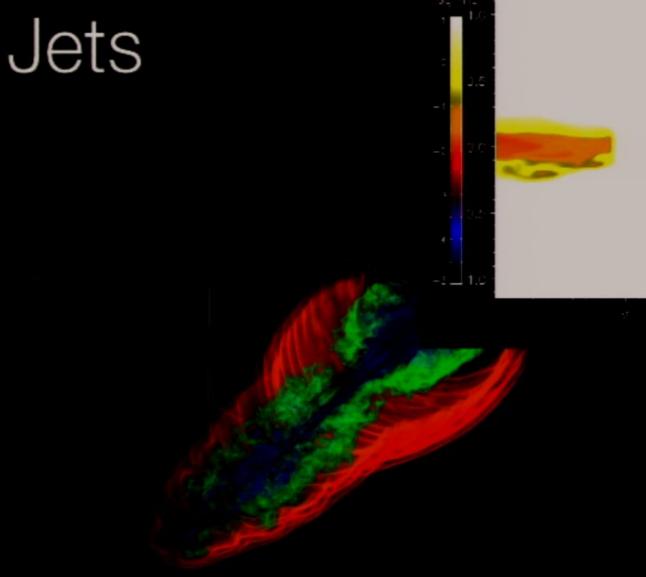
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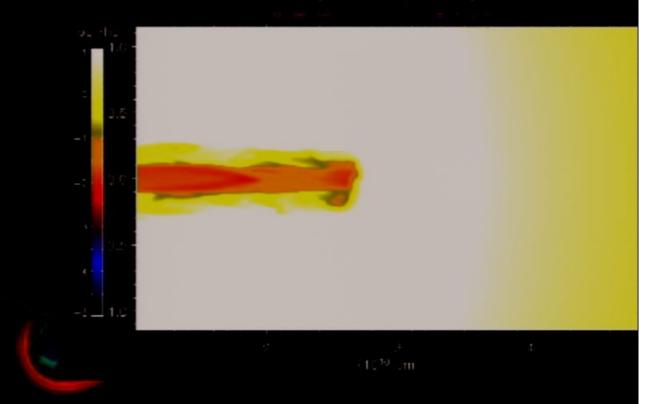
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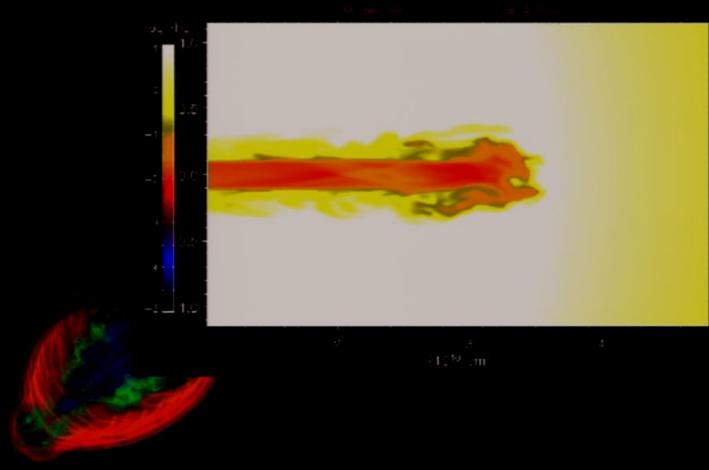
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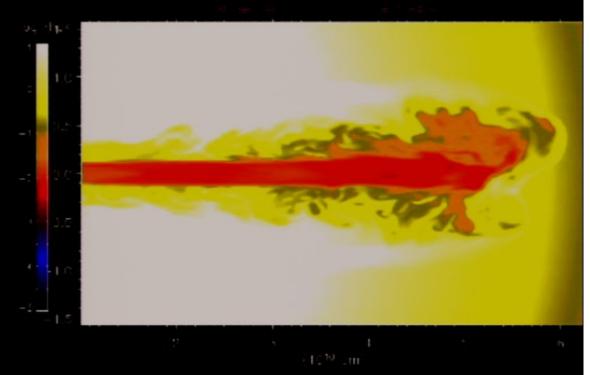
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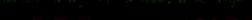


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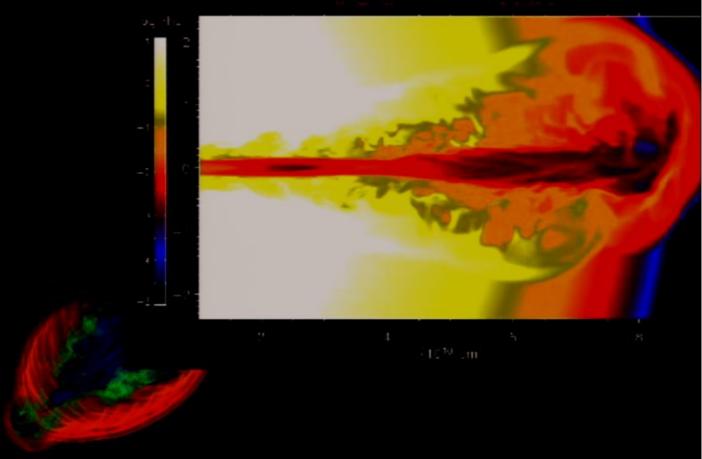
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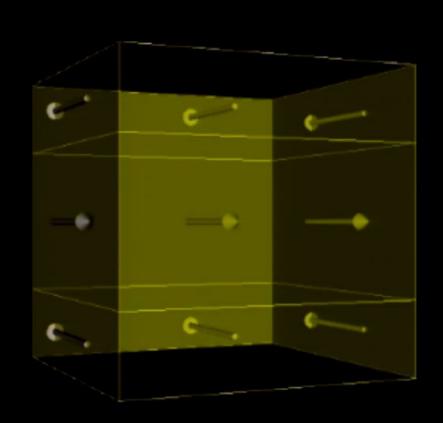
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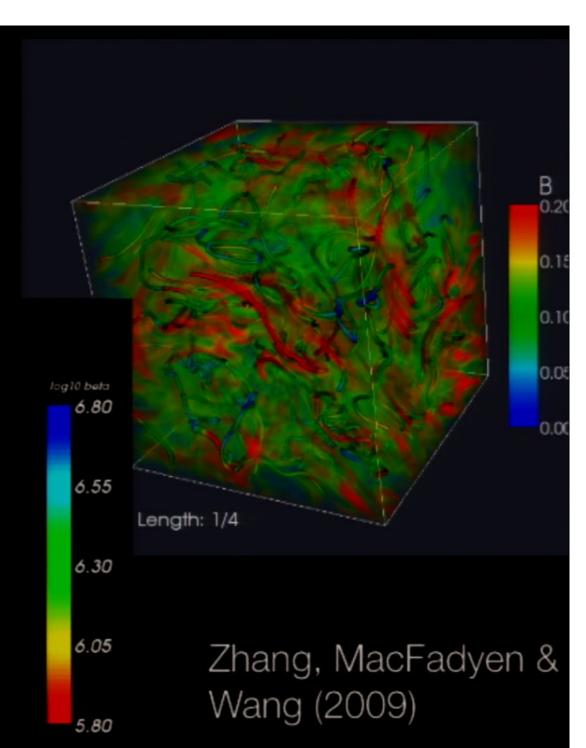


Jets

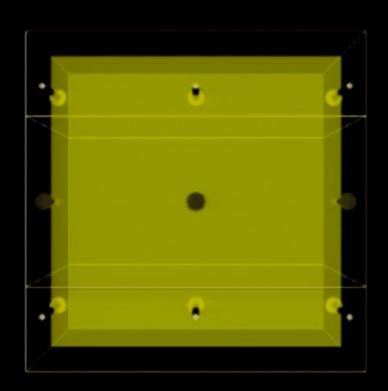


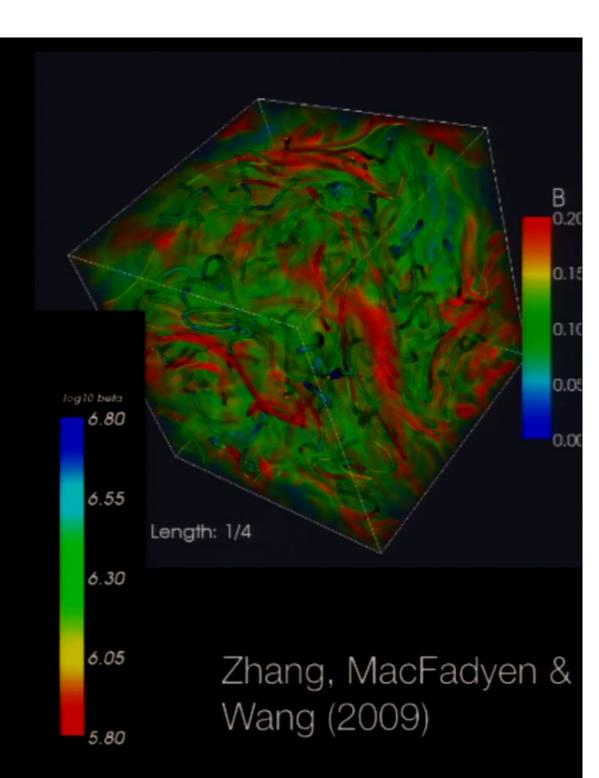
ielvin-Helmholtz Istability



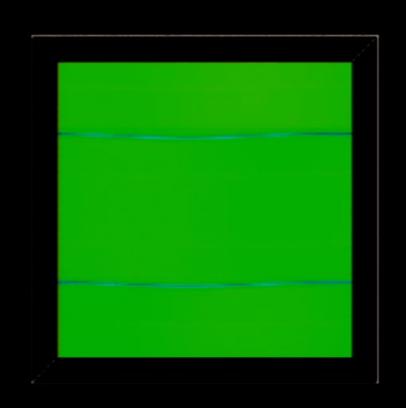


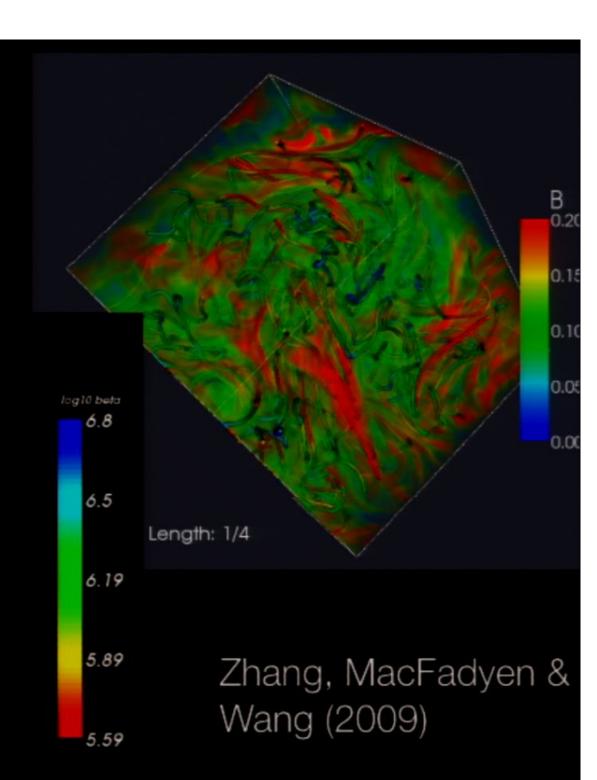
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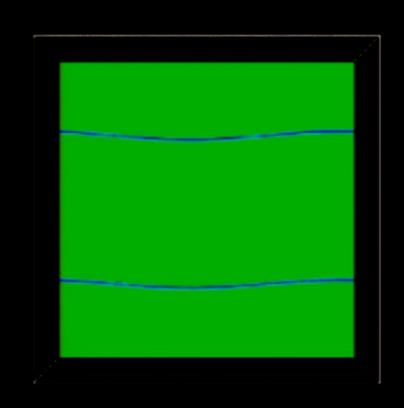


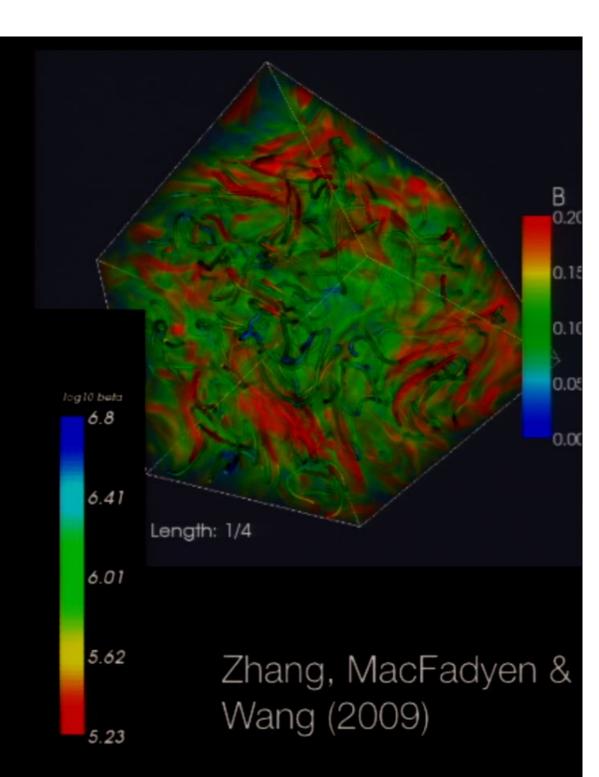
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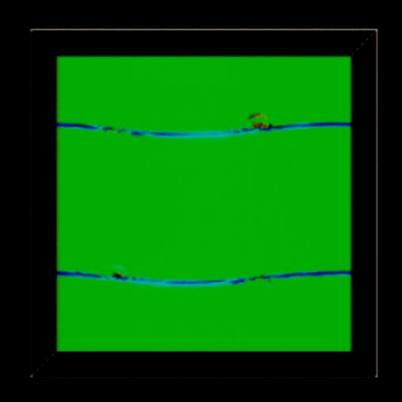


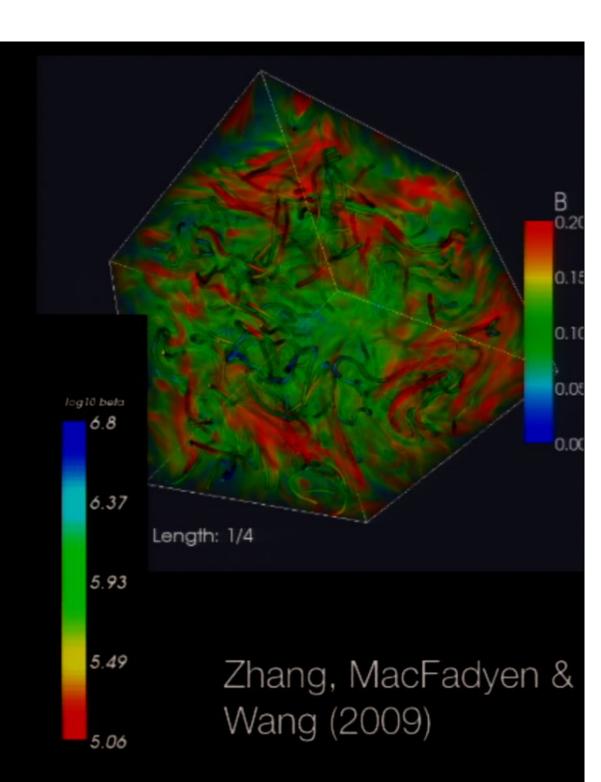
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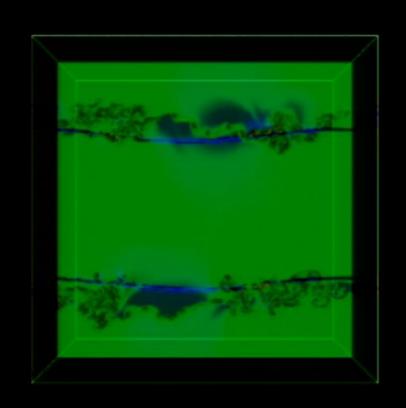


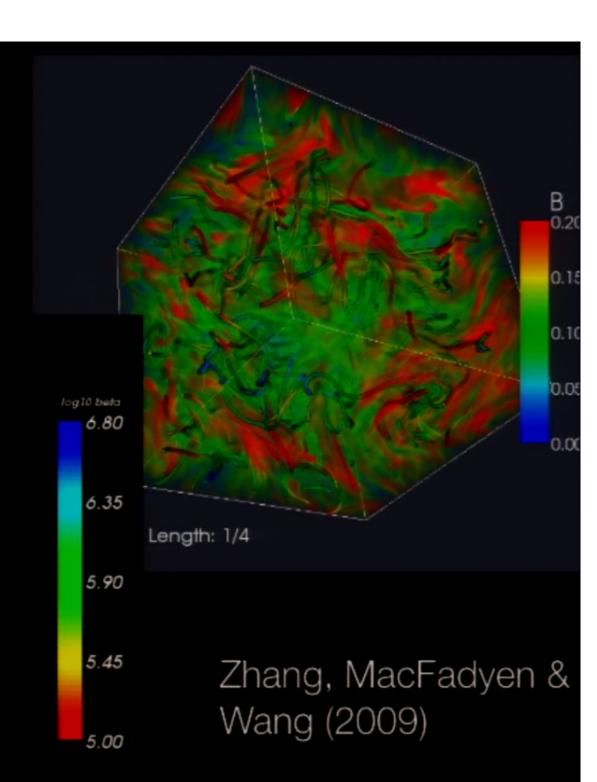
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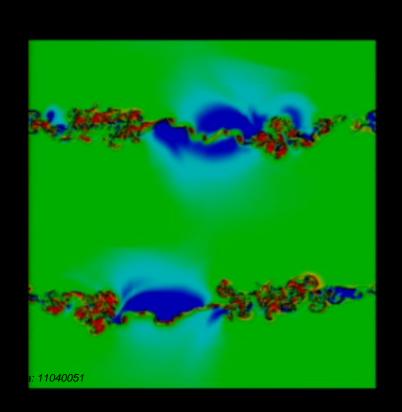


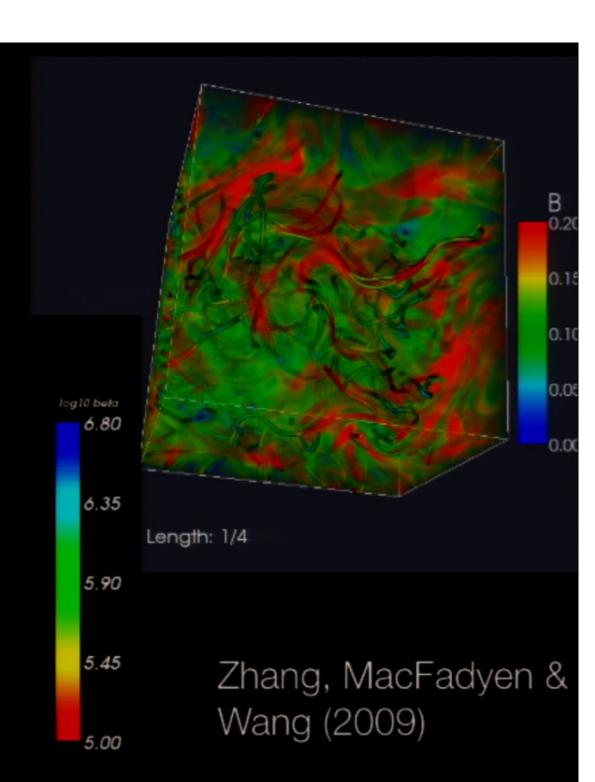
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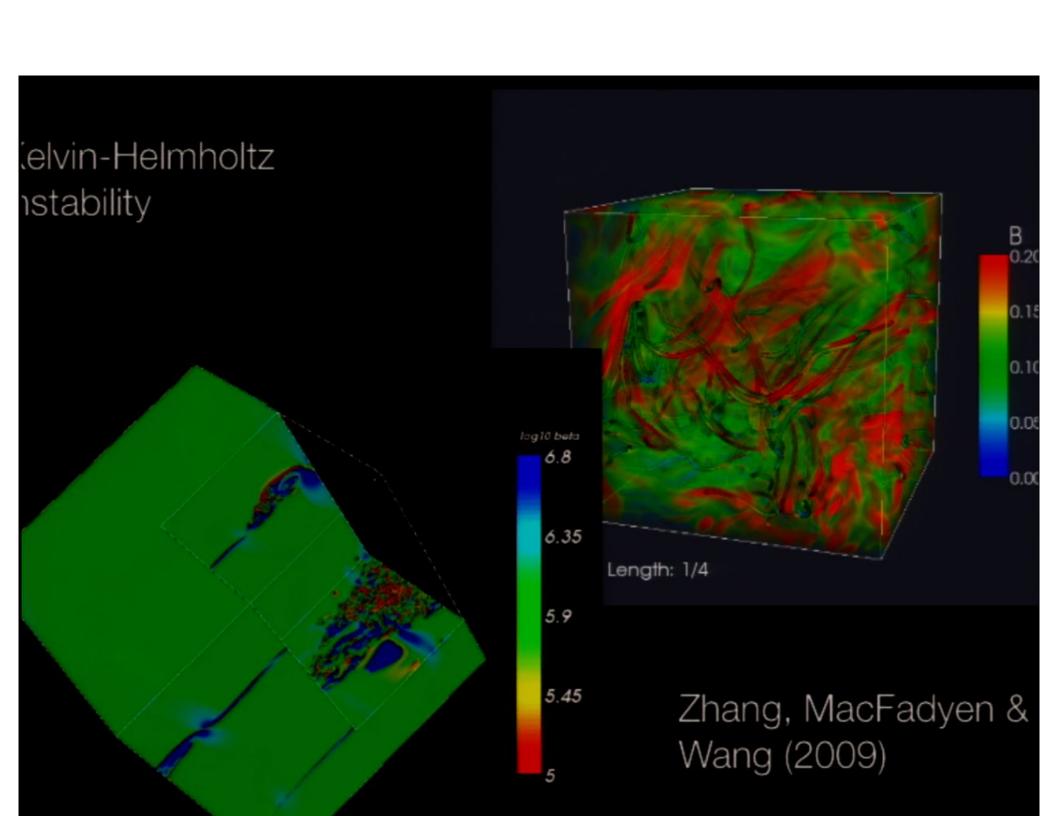


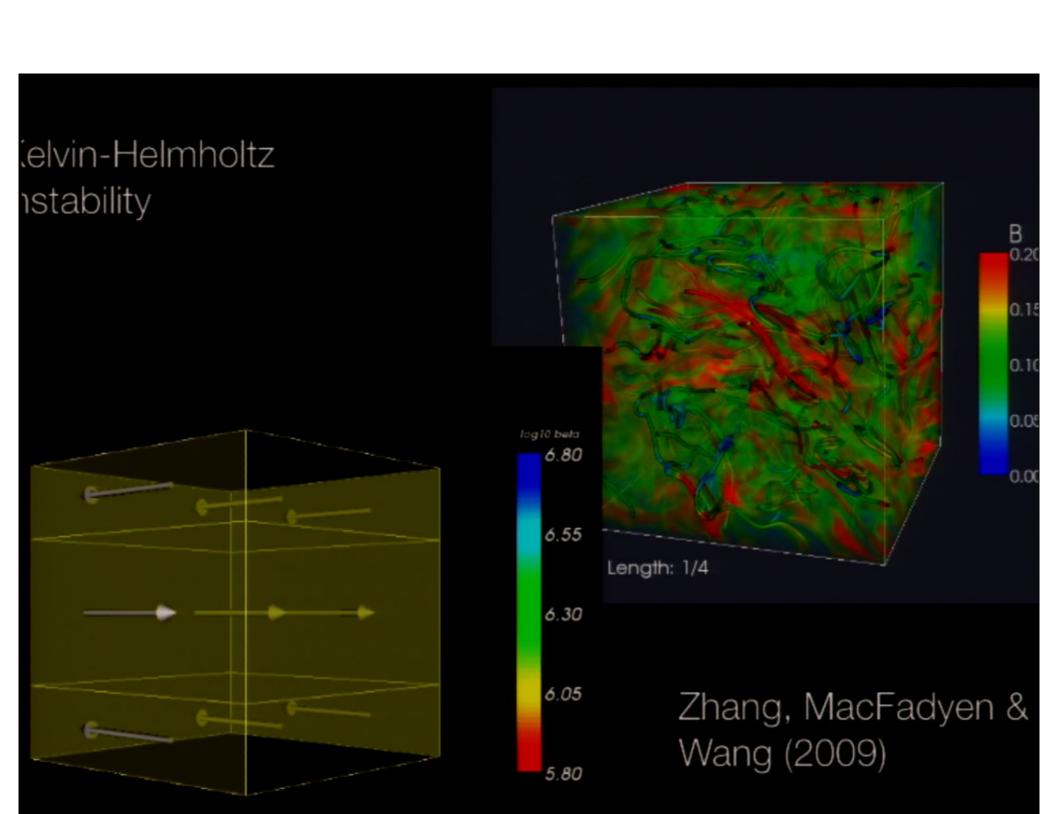


Celvin-Helmholtz Instability

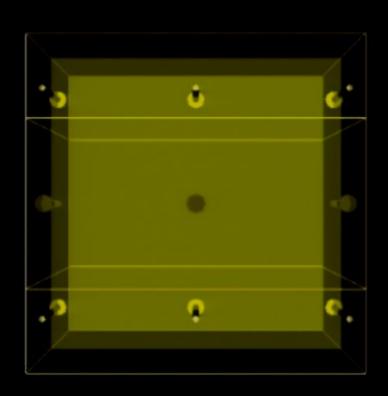


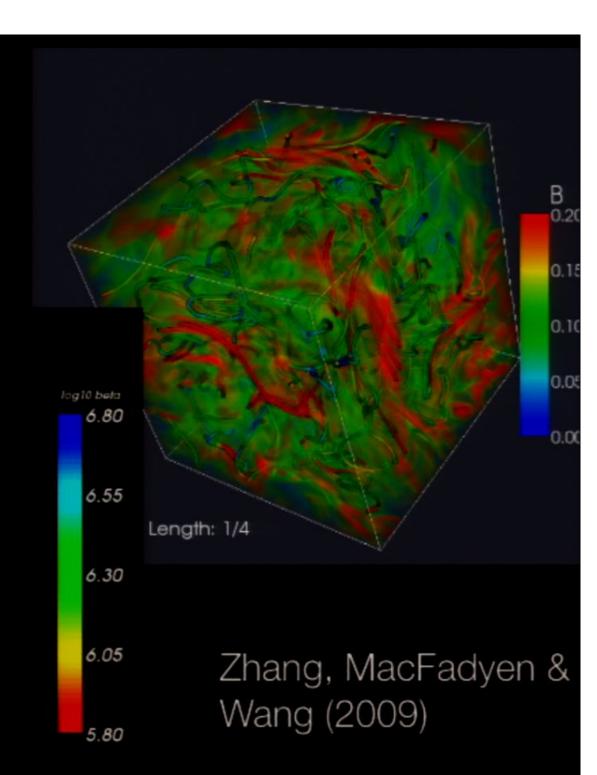




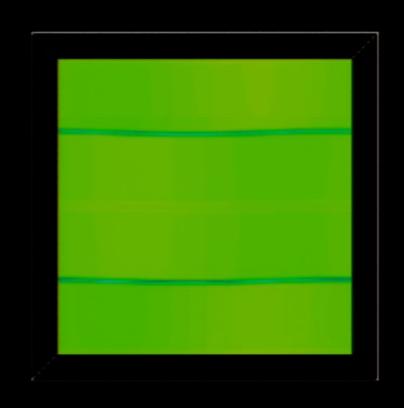


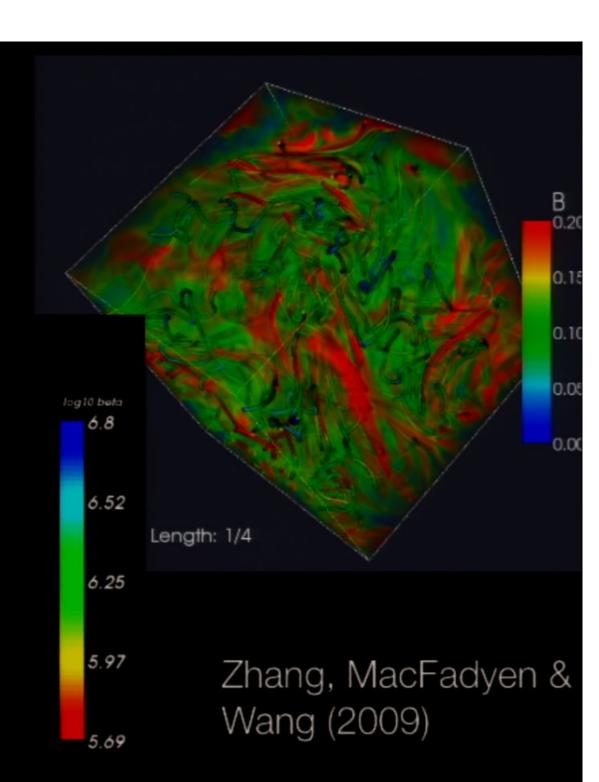
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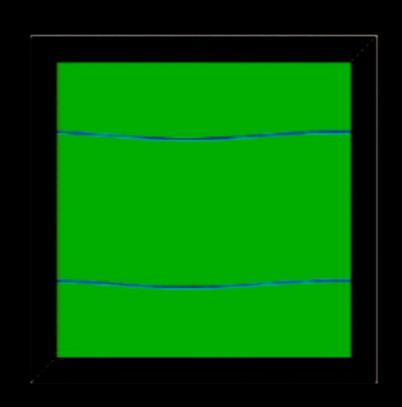


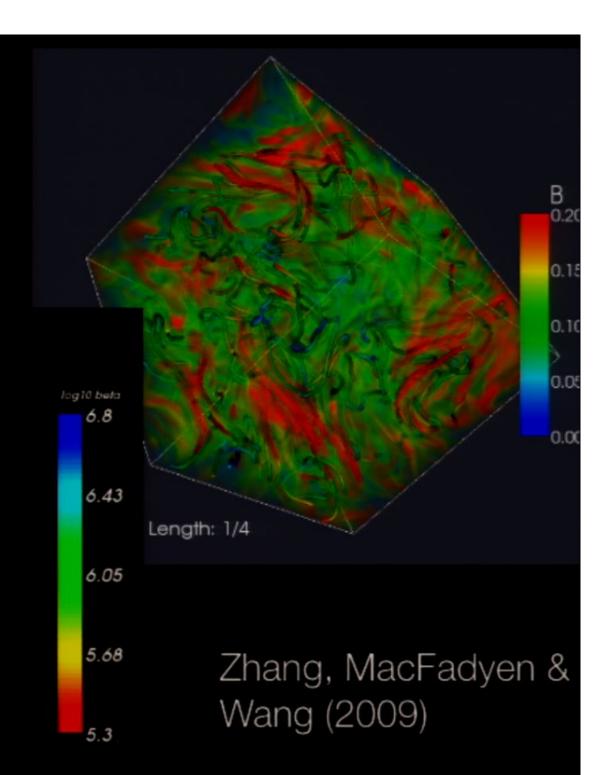
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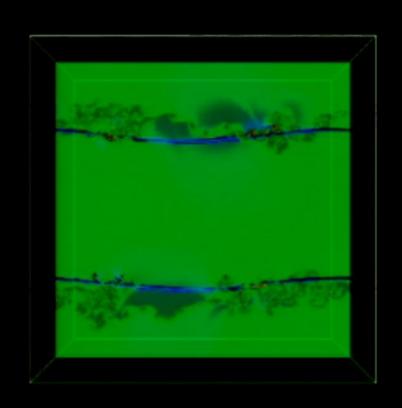


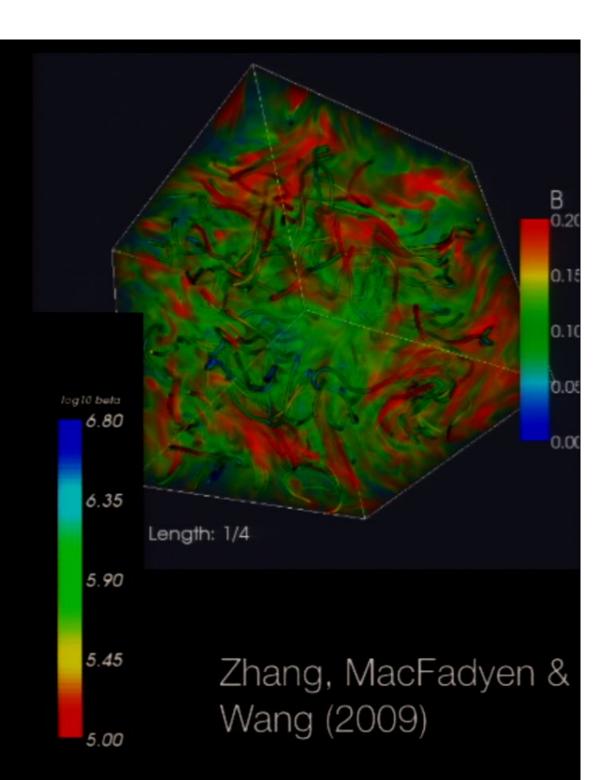
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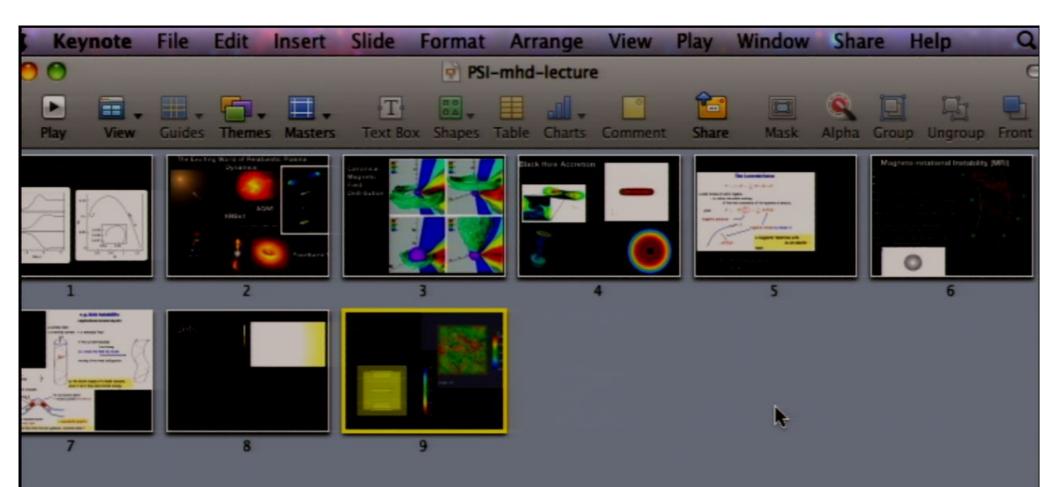




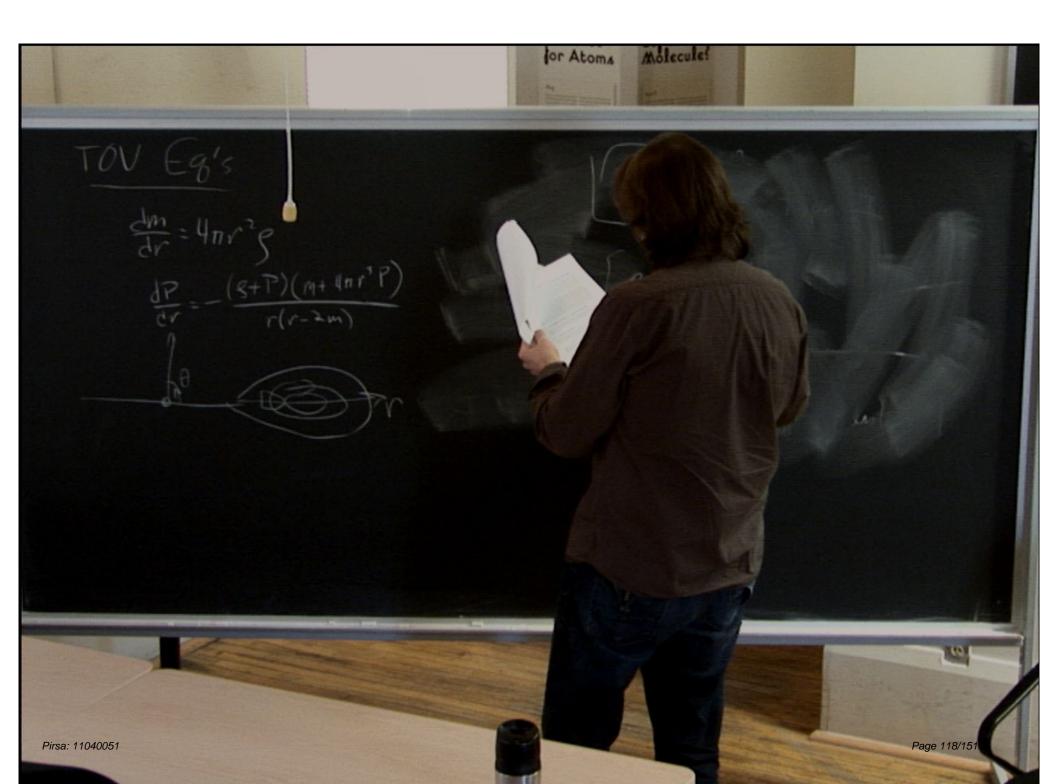
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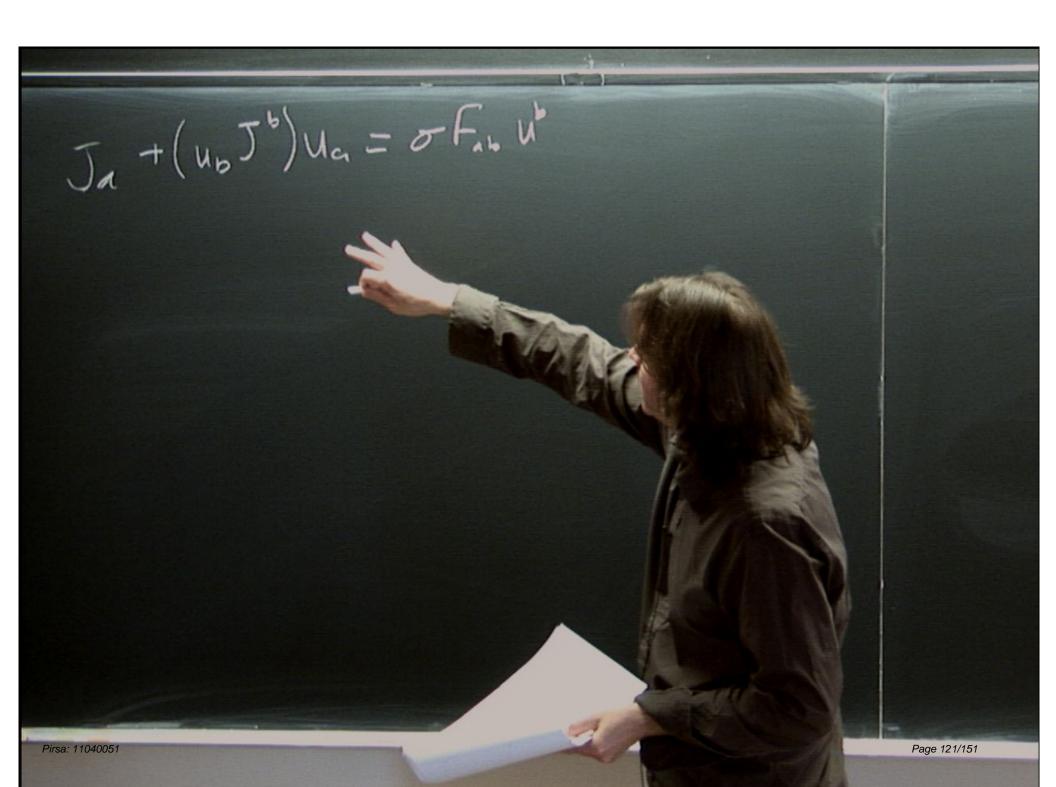


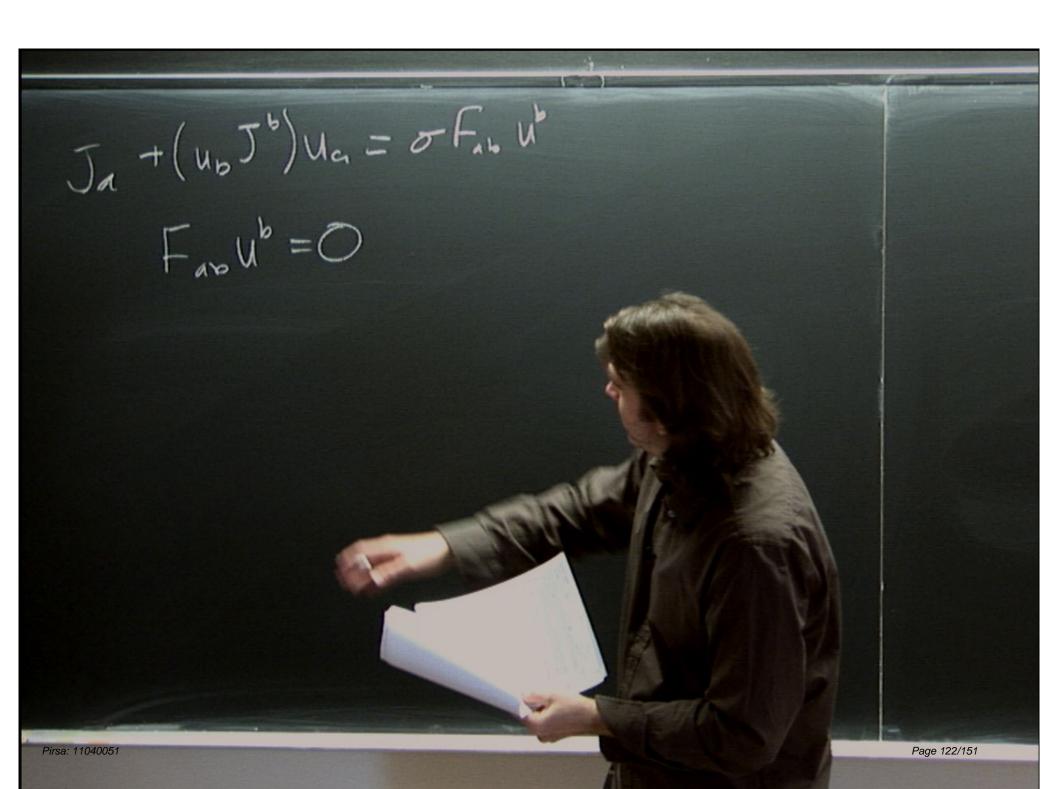
Pirsa: 11040051 Page 117/151

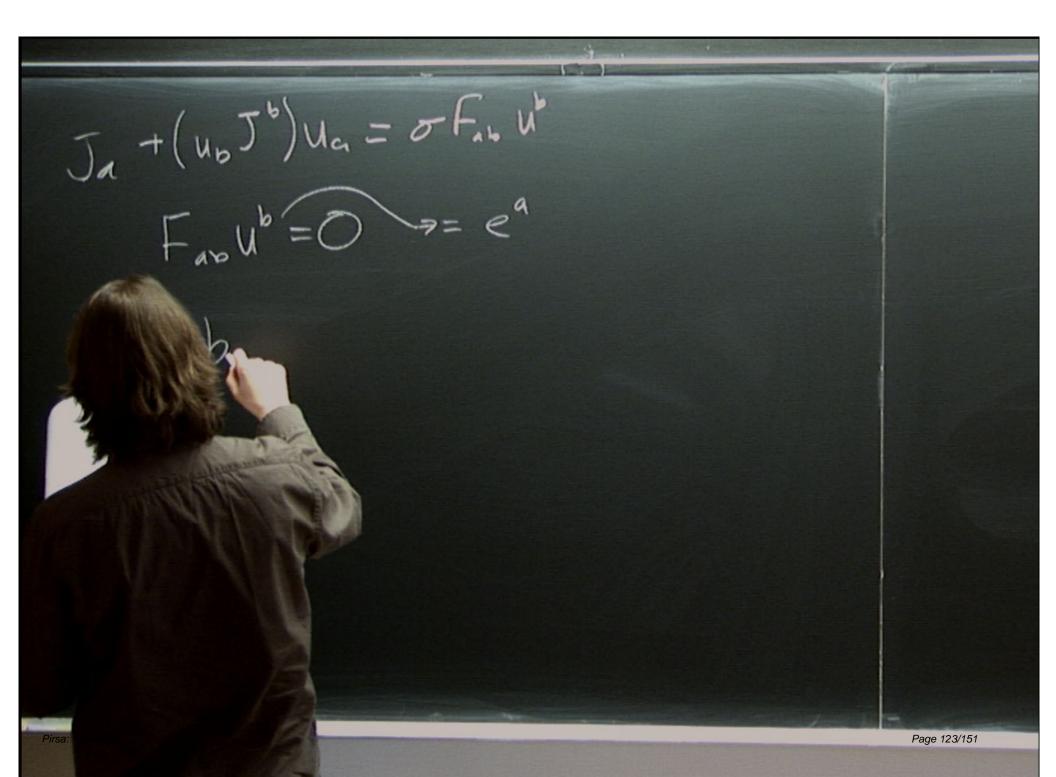


or Atoma Pirsa: 11040051 Page 119/151

or Atoms Molecules Pirsa: 11040051







$$\int_{A} + (u_{b}J^{b})u_{a} = \sigma F_{ab}u^{b}$$

$$F_{ab}u^{b} = 0 \Rightarrow = e^{a} f_{ab} = 0$$

$$F_{ab}u^{b} = 0$$

$$F^{ab}u_{b}$$

$$F^{ab}u_{b} = 0$$

$$F^{ab}u_{b} = 0$$

$$F^{ab}u_{b} = 0$$

 $J_{a} + (u_{b}J^{b})u_{a} = \sigma F_{ab}u^{b}$ $F_{ab}u^{b} = 0$ $F_$

Ja + (ub Jb) Ua = o Fab ut Trans-trans Tan = uau, [e,e" + b,b] + = 90 [e,e" + b,b"] - eaen Tob = Way, [3.(1+2)+P+ b] + [P+36]56

Pirsa: 11040051

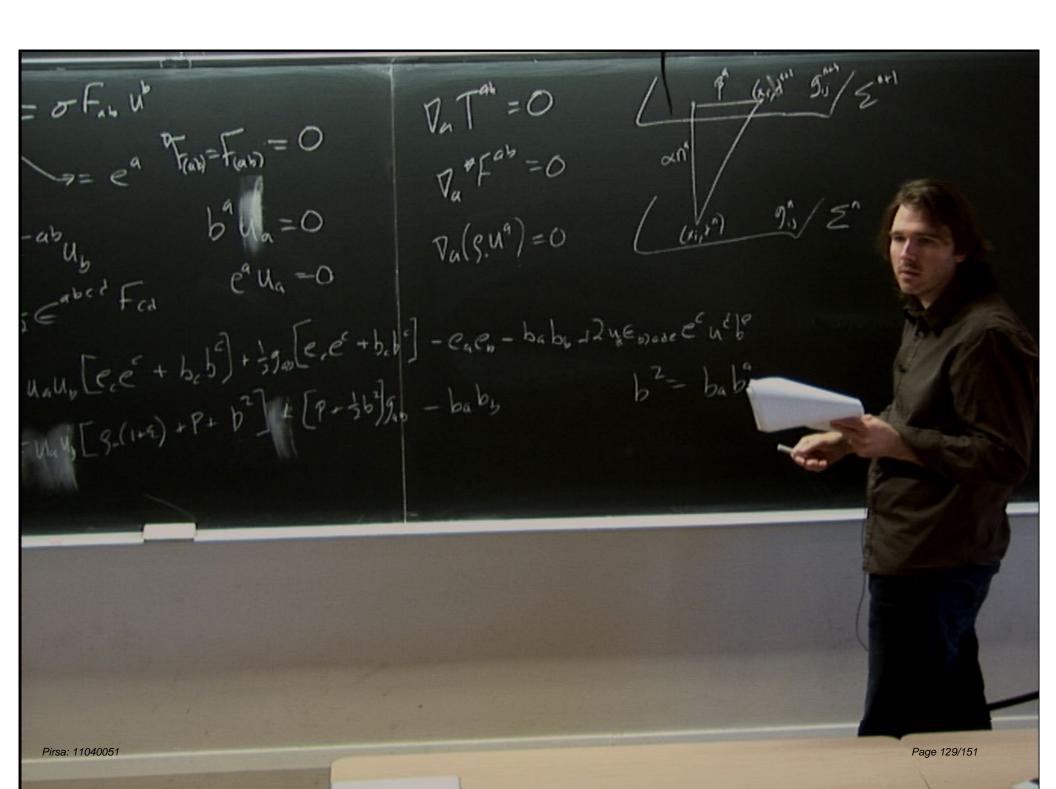
Page 126/151

Ja + (ub Jb) Ua = o Fab ut Fable = 0 = ea Fan=Fan=0 ba = Fabus balla = 0

Prov = [= abcd Fcd equa - 0 Tob = 444, [ee + beb] + 390[e, e + beb] - eaen - baby 22 yencee e u'b Tay = Way, [3.(1+2) +P+ b2] + [P-36]9, - bab, b2- bab

Pirsa: 11040051

Ja + (ub Jb) Ua = o Fab ut VaTa = 0 Fabub =0 == ea Fran-Fran = 0 1 + Fab = 0 b"= F" ub b" ua = 0 DEON = [Eaper Fed eq Ma -0 Tob = 444, [ee + beb] + 390 [ee + beb] - eaen - baby 22 ye more en Tab = Ulay, [9-(1+2)+P+ b] + [P+36]90 - baby



\$ 60 m VaTa = 0 == ea Fran-Fran = 0 Va(9.49) = 0 uau, [e,e+b,b]+=90[e,e+b,b]-eaen-baby 12 yenovee utb 1445 [3-(1+2)+P+ b] + [P-36]5, - baby

VaTa = 0 ea Fran-Fran = 0 Va(8.49) = 0 Ually [ee + beb] + 390[e,e+beb] - eaen - baby 12 yenove e nib 144 [3-(1+2)+P+ b] +[P-36]5, - baby

Pa(9.49)=0 hab = gab + Mally beb - each - baby - 2 ye made e nobe

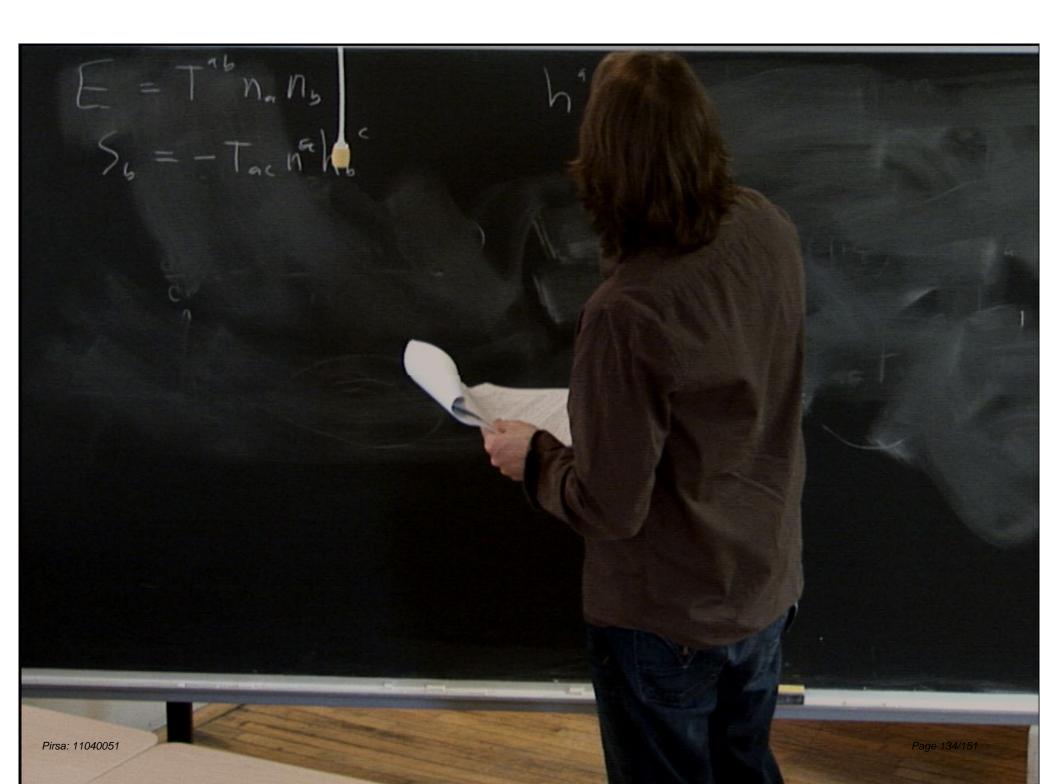
Page 1

Pirsa: 11040051

na==[-0,0,0] 7a(g.u9)=0 hab = Jab + Ma Mb beb - each - baby - 2 ye brade e nob b2- bab

Pirsa: 11040051

Page 133/15



h'b = 5% + n9n,

Pirsa: 11040051

E = Tacnalo n 6 = 5 % + 1 n n, (IT) = Tasha, h's Pirsa: 11040051

 $E = T^{a} h_{a} n_{b}$ $S_{6} = -T_{ac} h_{b}^{a} h_{c}^{a}$ $= [g + P, b^{2}]W^{2} - [P + b^{2}] - [g + P, b^{2}]W^{2} - [P + b^{2}] - [g + P, b^{2}]W^{2}$ $= [g + P, b^{2}]W^{2} - [P + b^{2}]W^{2}$

n'b = S''b + n''n $= [g + P, b^2]W^2 - [P, 3b^2] - (n_ab^2)^2$ $W = -n''u_a$) = Tabhaha Page 138/15 11040051

n'b = S''b + n''n, $= [g + p, b^2]W^2 - [p, -b^2] - (n_a b)^2$ $V = -n''u_a$ $V^a - \frac{1}{W}(1u)^a$ The = Tabhehas Page 139/151 11040051

1 b = 5 b + n n, - 1 n. n. W=-nqua V=-1(14)9 The = Tabhaha 1 x) = h b x Page 140/151 11040051

7 b = 5" b + m" n. [9+P.L2]W"-[P.-16]-(n.1)2 [p+P+6] W + (n.6") (16)4 Page 14 11040051

[3+P.b]W'-[P.3b]-(n.b) n'h = 5" b + n"n, n. No = [g+P+6] Wv, + (n.b")(Lb), [V=-n"un
[V"-],(1u) The = Tabhaha = [9+P+b2] W'V, V2 + Page 142/151 11040051

n'b = 5" b + n'n, [3+P. 6] W2-[P. 36]-(na,6)2) = [g+P+6] WV,+(n.60)(16); The = Tabhahis = [9+P+b2] W2V, V. + of Pib had Page 143/151 11040051

n'b = 5" b + n'h, [3+P. 6] W'-[P. - [b]-(n. 5)2) = [p+P+6] WV,+ (n.6")(Lb), The = Tanhaha = [q+P+b2] W2 V2 V2 + +[P'16] hed - (16) (16) 1040051

[3+P.6]W'-[P.36]-(n.5)2 [g+P+6] Wi,+(n.5")(16), les = Tanhahis = [9+P+b2] W2V2+ +[P1+ b]hed - (1 b) (16) Page 145/151 11040051

[3+P.b]W'-[P.]b]-(n,b)2 = [9+P+6] WV, + (nob")(1b), [N=-n"un
V=-12], 1211 The = Tabhaha = [9+P+62] W'V, Vet +[P1/2]hed - (15) (16) Page 146/151 1040051

Page 147/151 Pirsa: 11040051

Pirsa: 11040051

B9 + 40 (14) Bb a = W Edabe Ne UBS Pirsa: 11040051

B9 + 40°(14) Bb a = W Edabe Ne UBS Balla = banh Pirsa: 11040051

na= [-0,0,0] (x1, xn) = gab + Na Nb Page 151/151