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Hydromagnetic Taylor-Couette Experiments in Liquid Sodium

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Turbulent shear flow + restoring force can lead to an instability…

$$\text{N-S} + \frac{N}{R_m}(\vec{\nabla} \times \vec{B}) \times \vec{B}$$

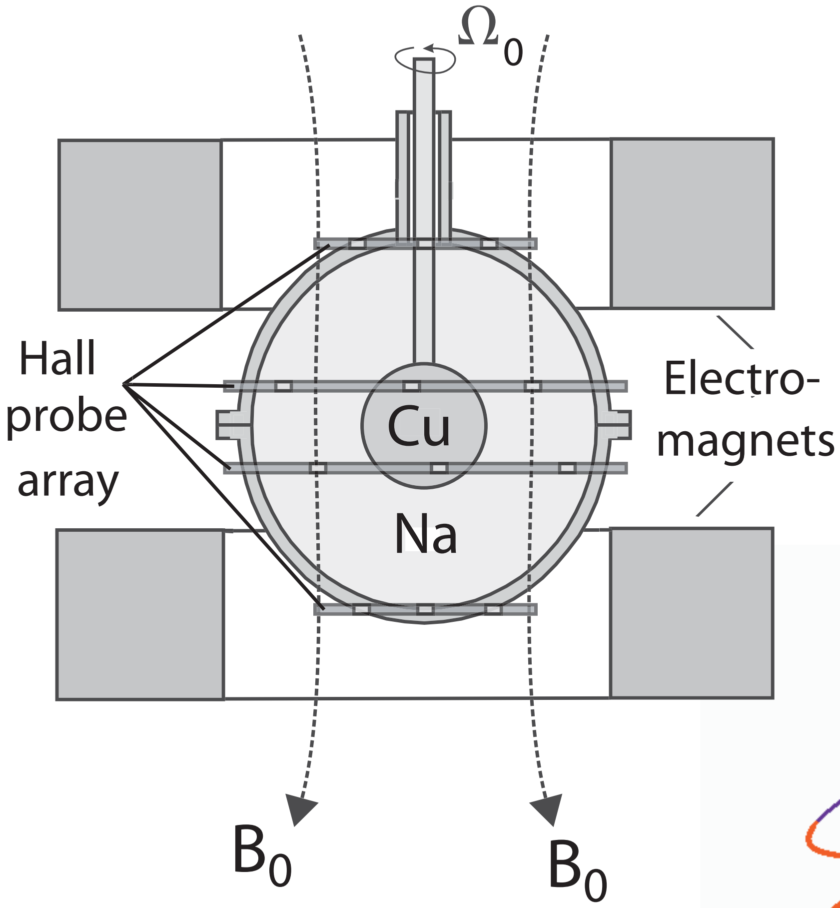
$$N = \frac{B_0^2 L}{\rho \mu_0 \eta \Omega r_i}$$ Magnetic Interaction Parameter (Stuart Number) — Strength of Lorentz Force

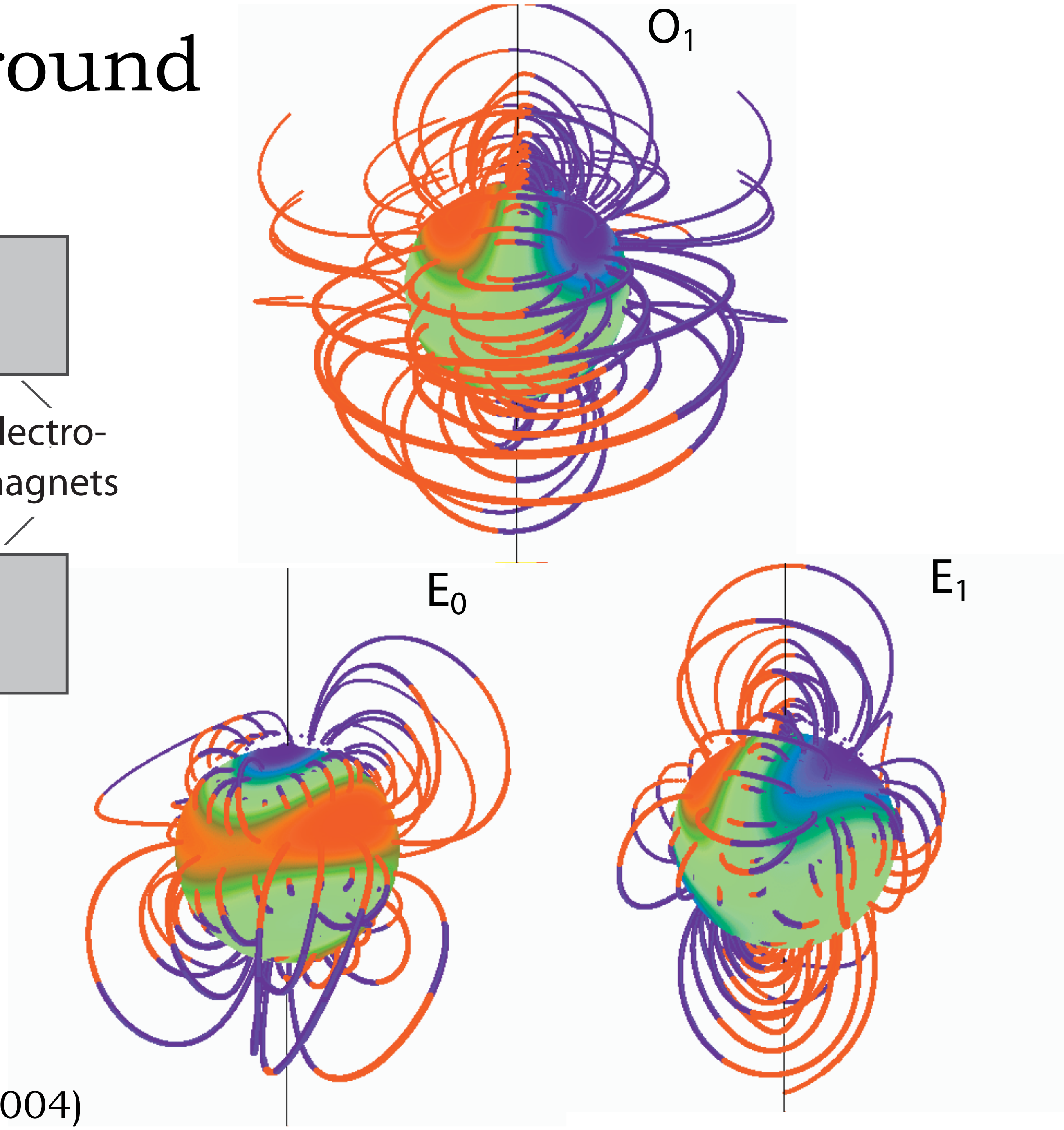
$$R_m = \frac{\Omega r_i L_{gap}}{\eta}$$ Magnetic Reynolds Number — Strength of Magnetic Advection

$$S = \frac{B_0 L_{gap}}{\sqrt{\rho \mu_0} \eta}$$ Lundquist Number — Dimensionless applied field (Rm for Alfven)

$$Re = \frac{\Omega r_i^2}{\nu}$$ Reynolds Number

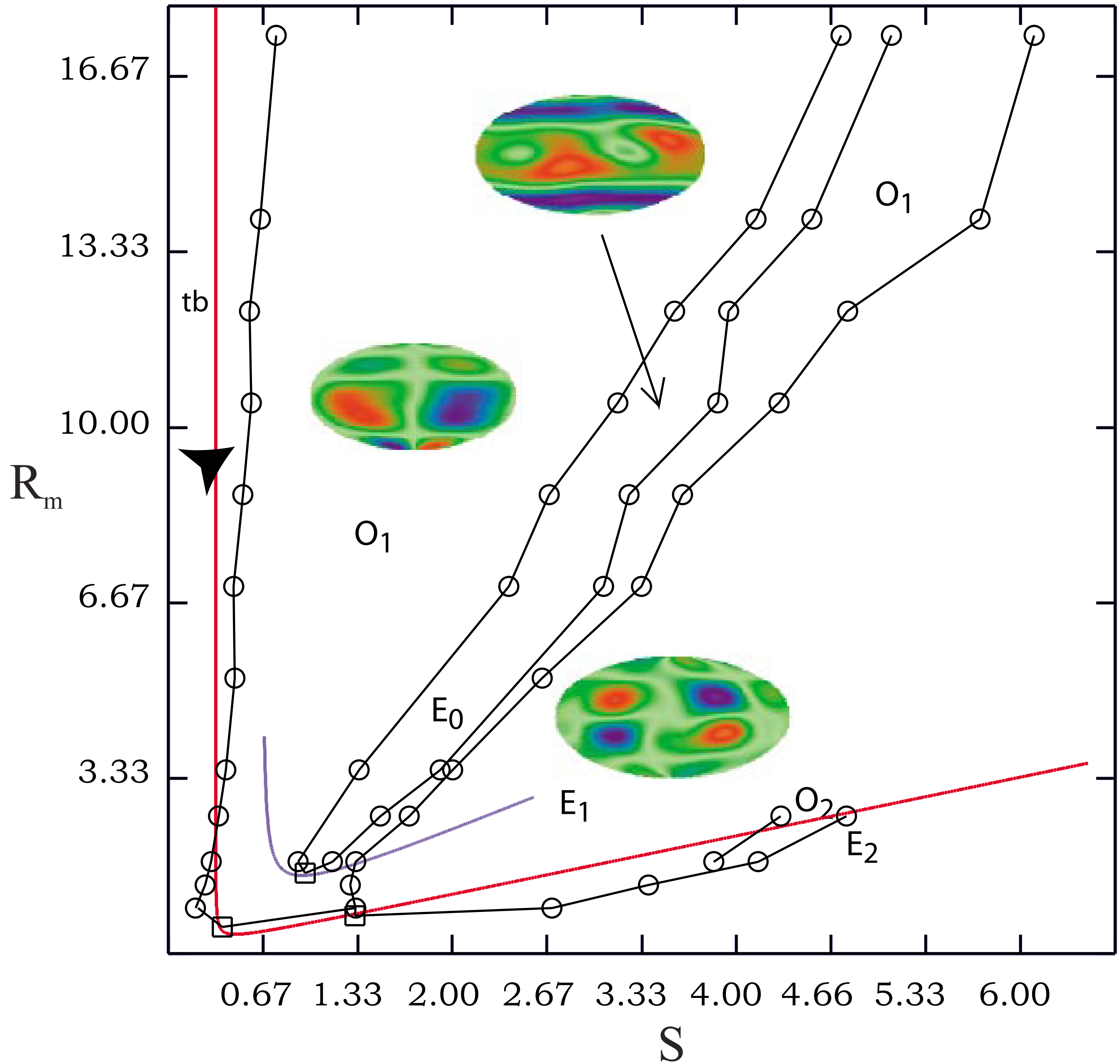
Magnetorotational Instability From A Turbulent Background





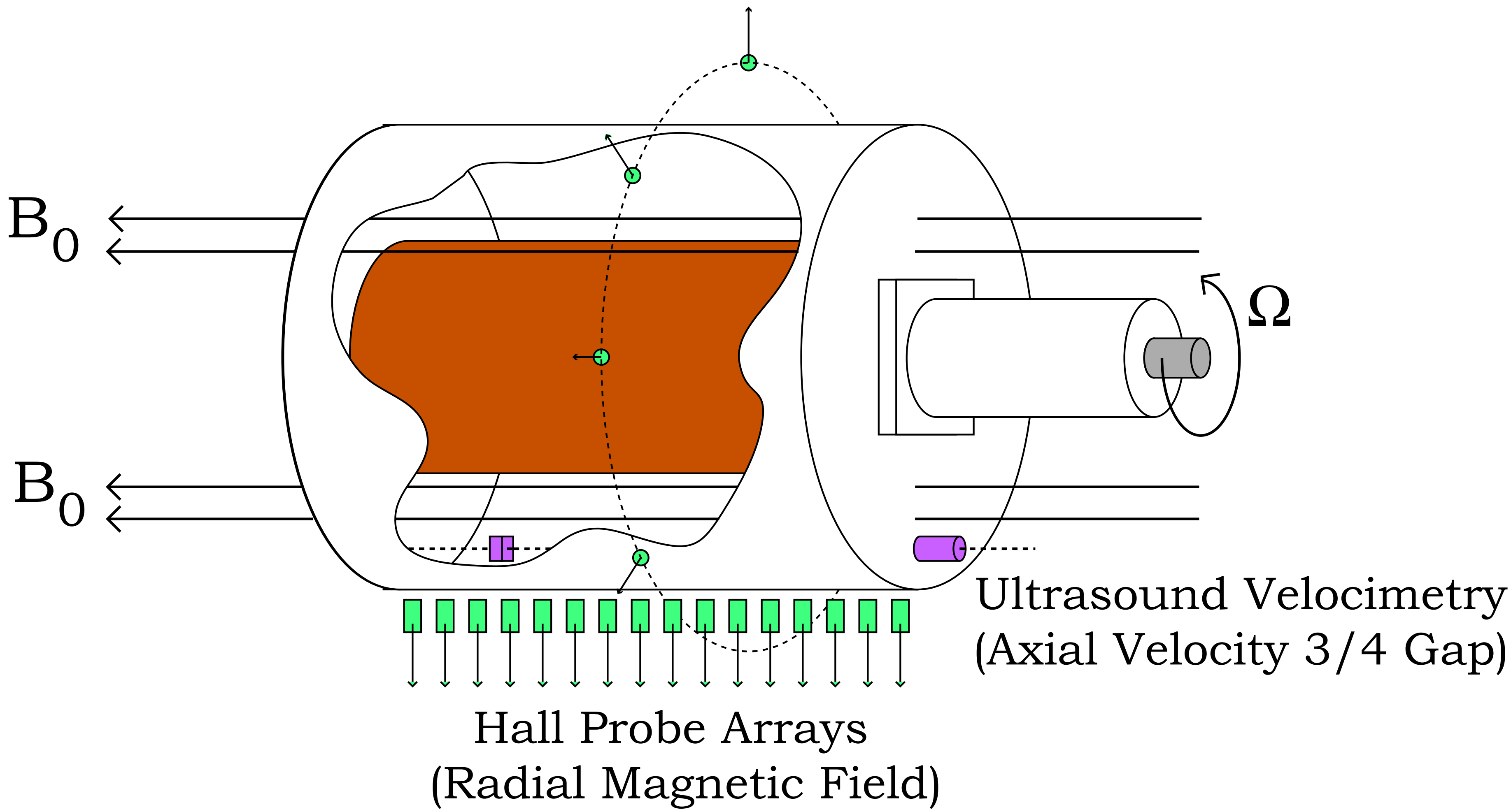
Sisan et. al Phys. Rev. Lett. 93 (2004)

Onset of Organized Patterns



Magnetic
Field
Threshold

Results motivate new geometry...



N ~ 0.05-30

R_m ~3-14

Re $>10^5$

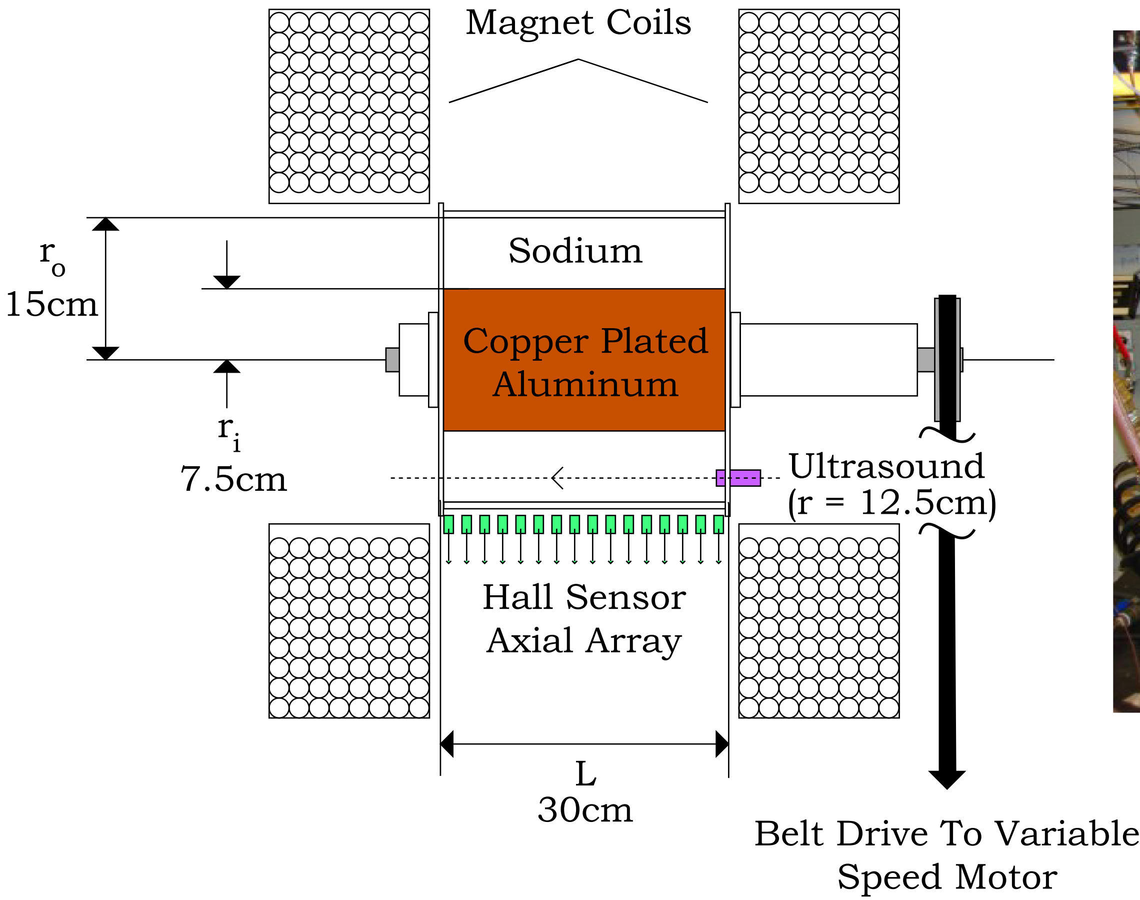
Radius Ratio = 1/2

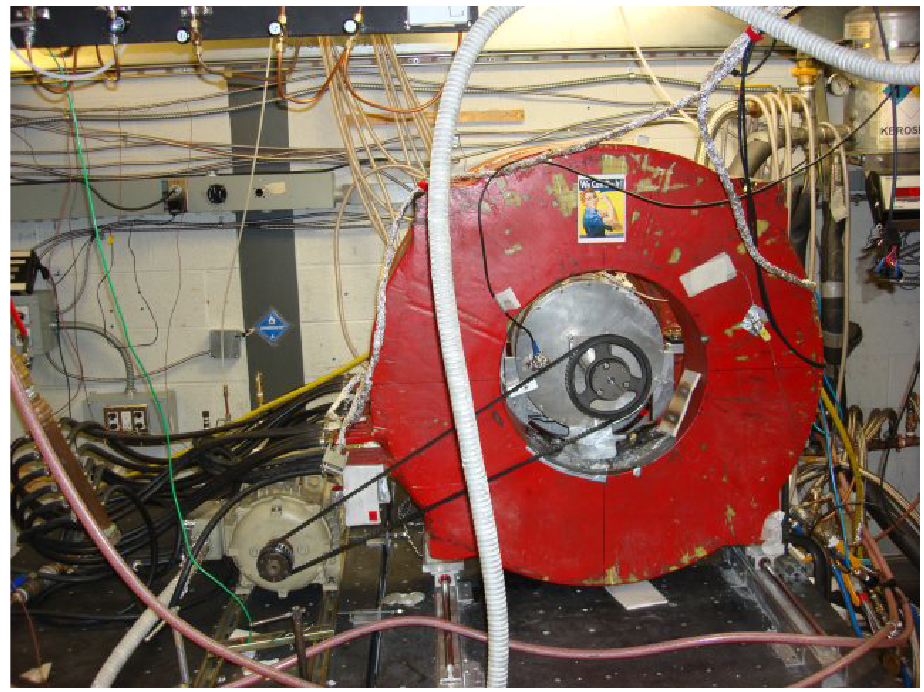
Aspect Ratio = 4

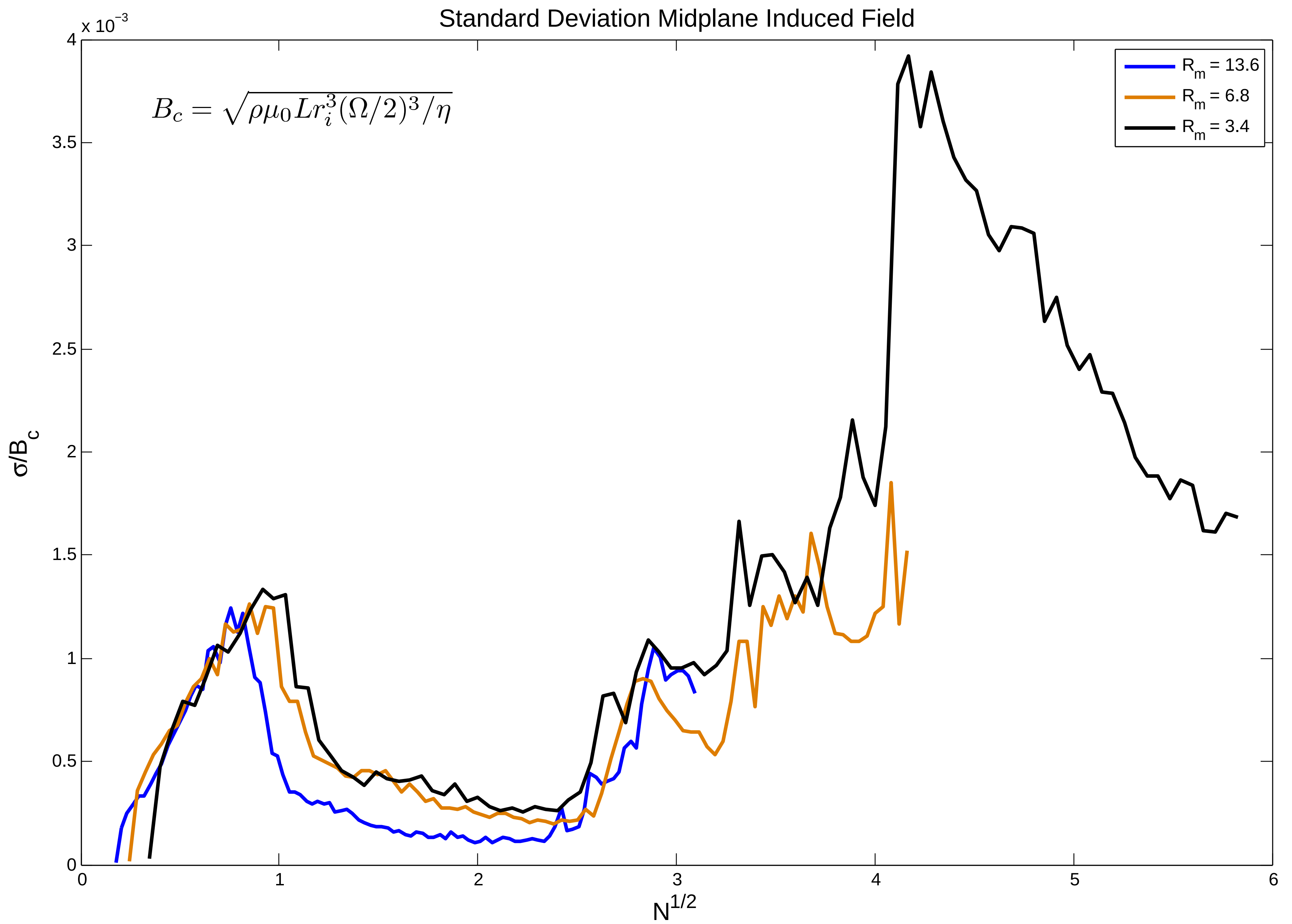
Units and experimental realities…

~1400 gauss (140mT)

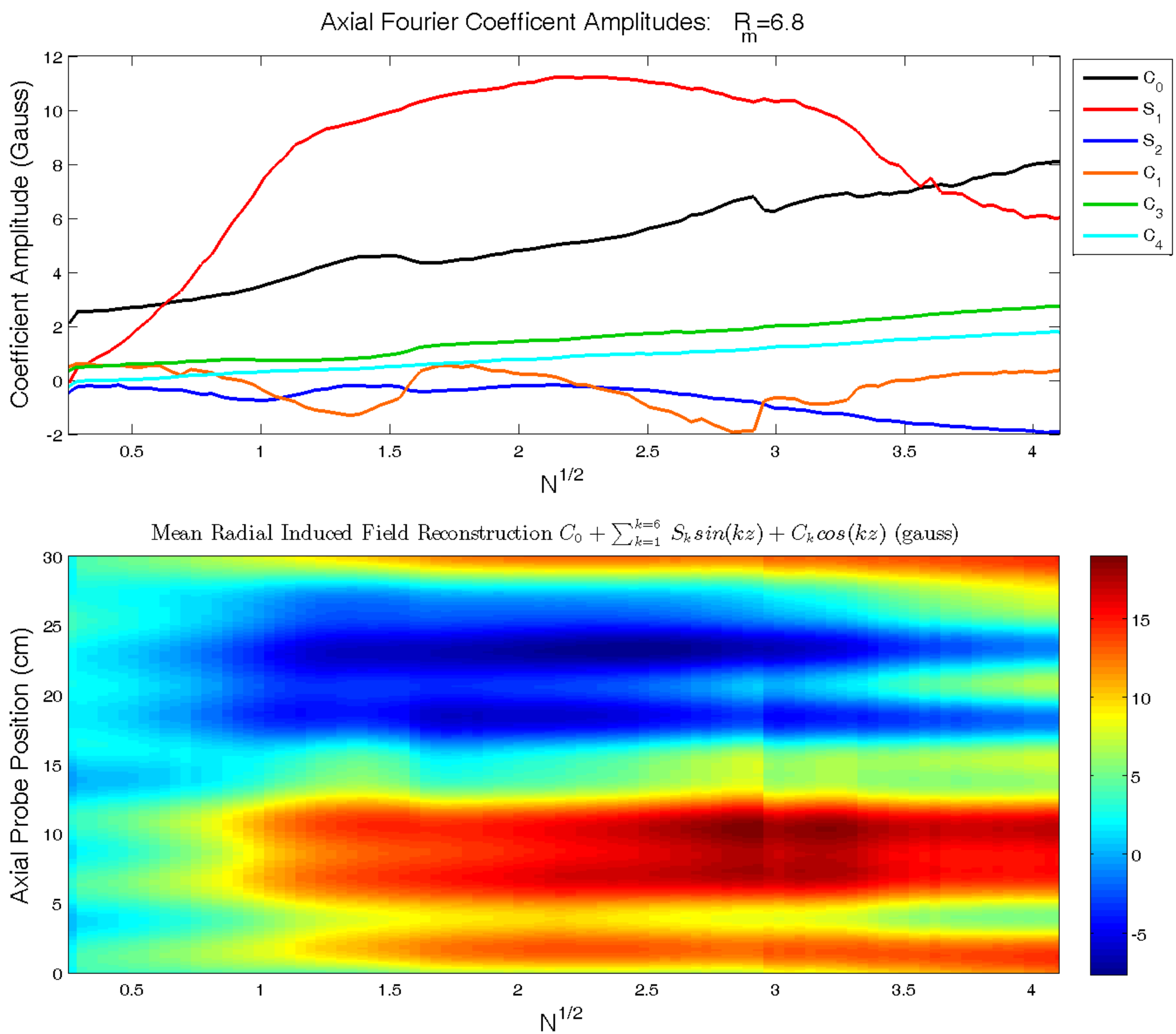
~32 Hz Maximum Rotation Rate



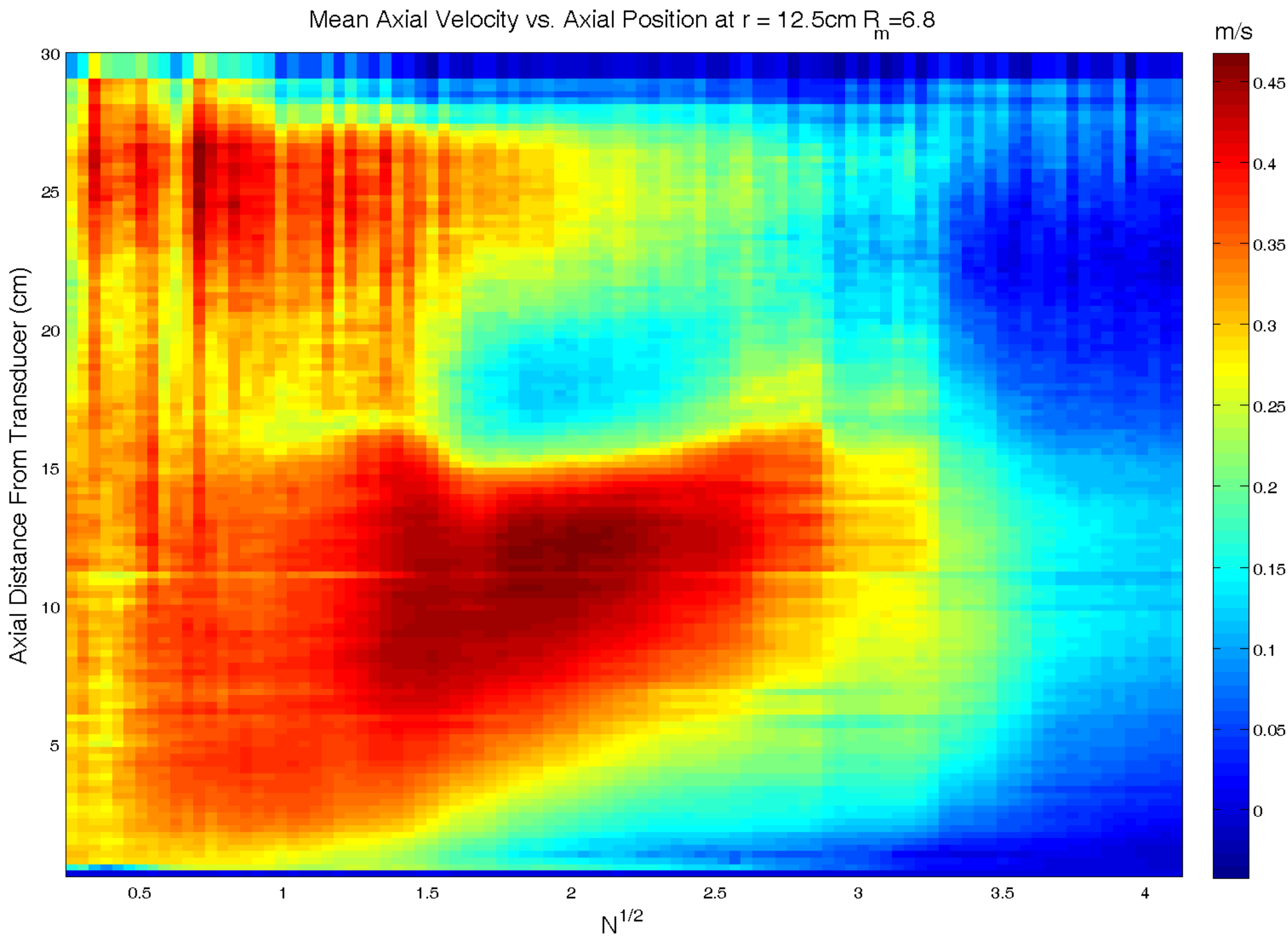




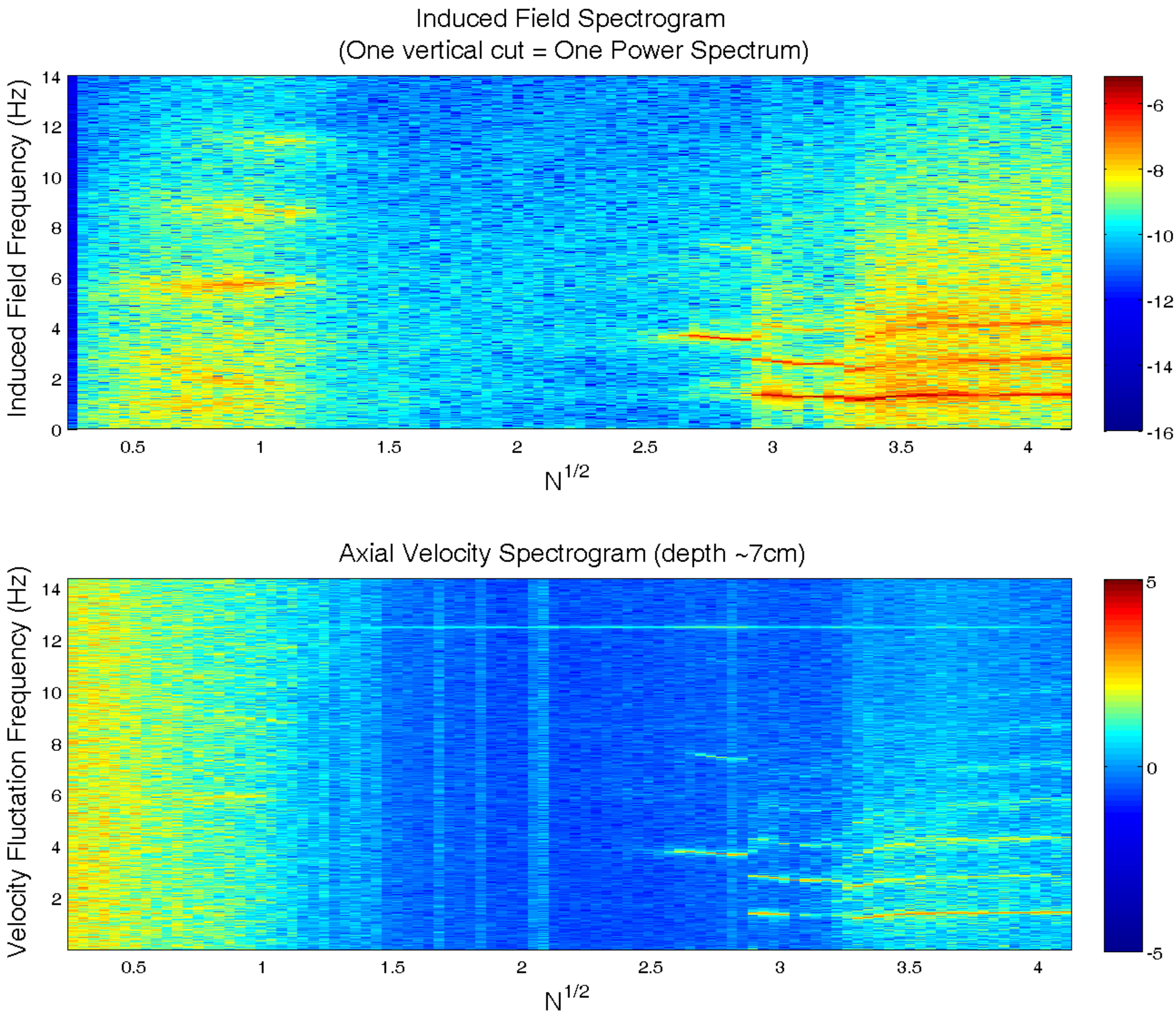
Standard Deviation Midplane Induced Field
x 10^-3
$B_c = \sqrt{\rho \mu_0 L r_i^3 (\Omega/2)^3/\eta}$
R_m = 13.6
R_m = 6.8
R_m = 3.4
σ/B_c
N^1/2
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6



Axial Fourier Coefficent Amplitudes: R_m=6.8
Coefficient Amplitude (Gauss)
$N^{1/2}$
C_0
S_1
S_2
C_1
C_3
C_4
Mean Radial Induced Field Reconstruction $C_0 + \sum_{k=1}^{k=6} S_k sin(kz) + C_k cos(kz)$ (gauss)
Axial Probe Position (cm)
$N^{1/2}$

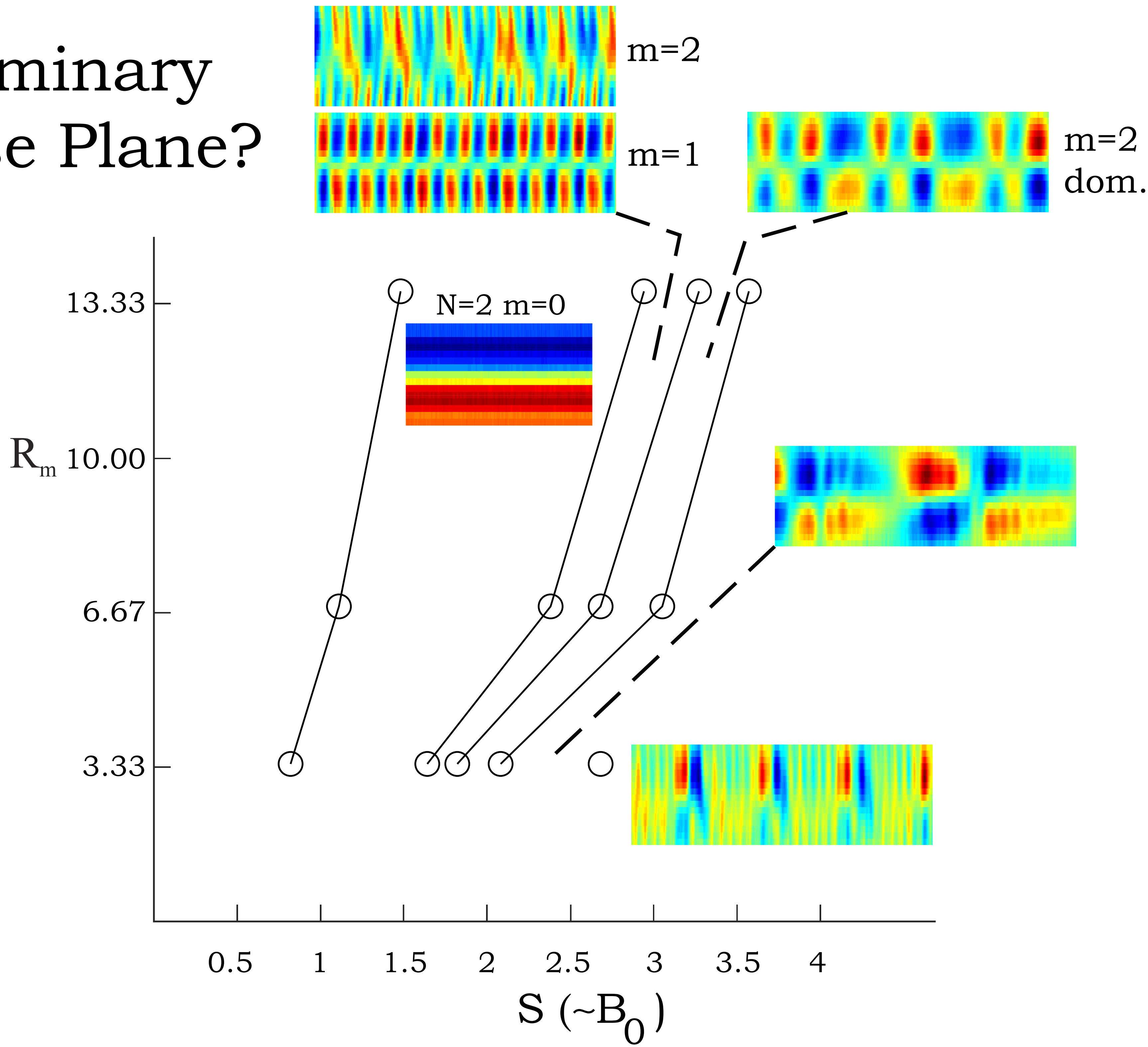


Mean Axial Velocity vs. Axial Position at r = 12.5cm R_m=6.8
m/s
Axial Distance From Transducer (cm)
$N^{1/2}$
30
25
20
15
10
5
0.5
1
1.5
2
2.5
3
3.5
4
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

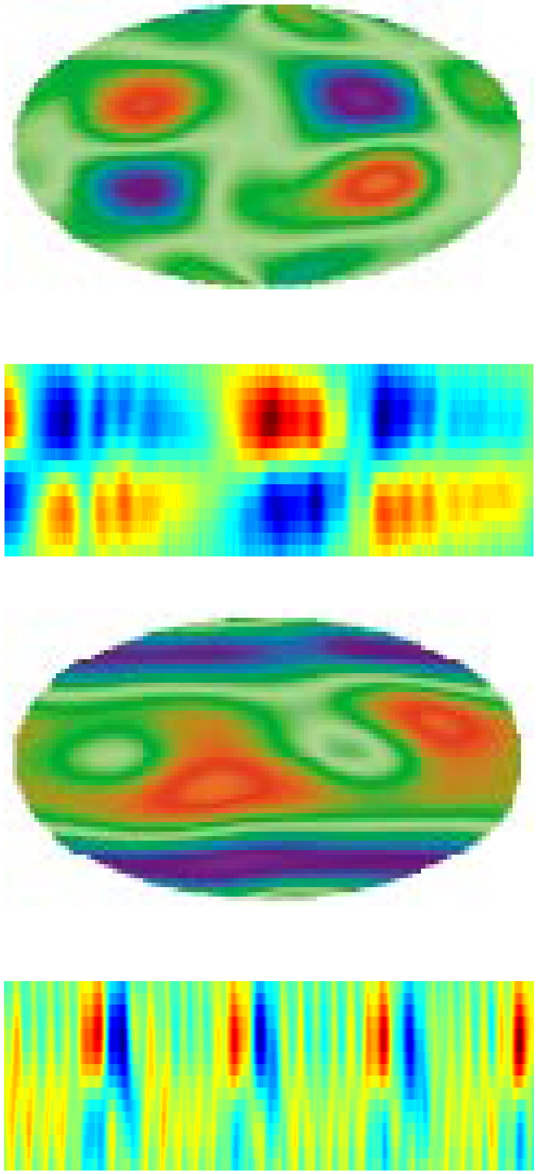


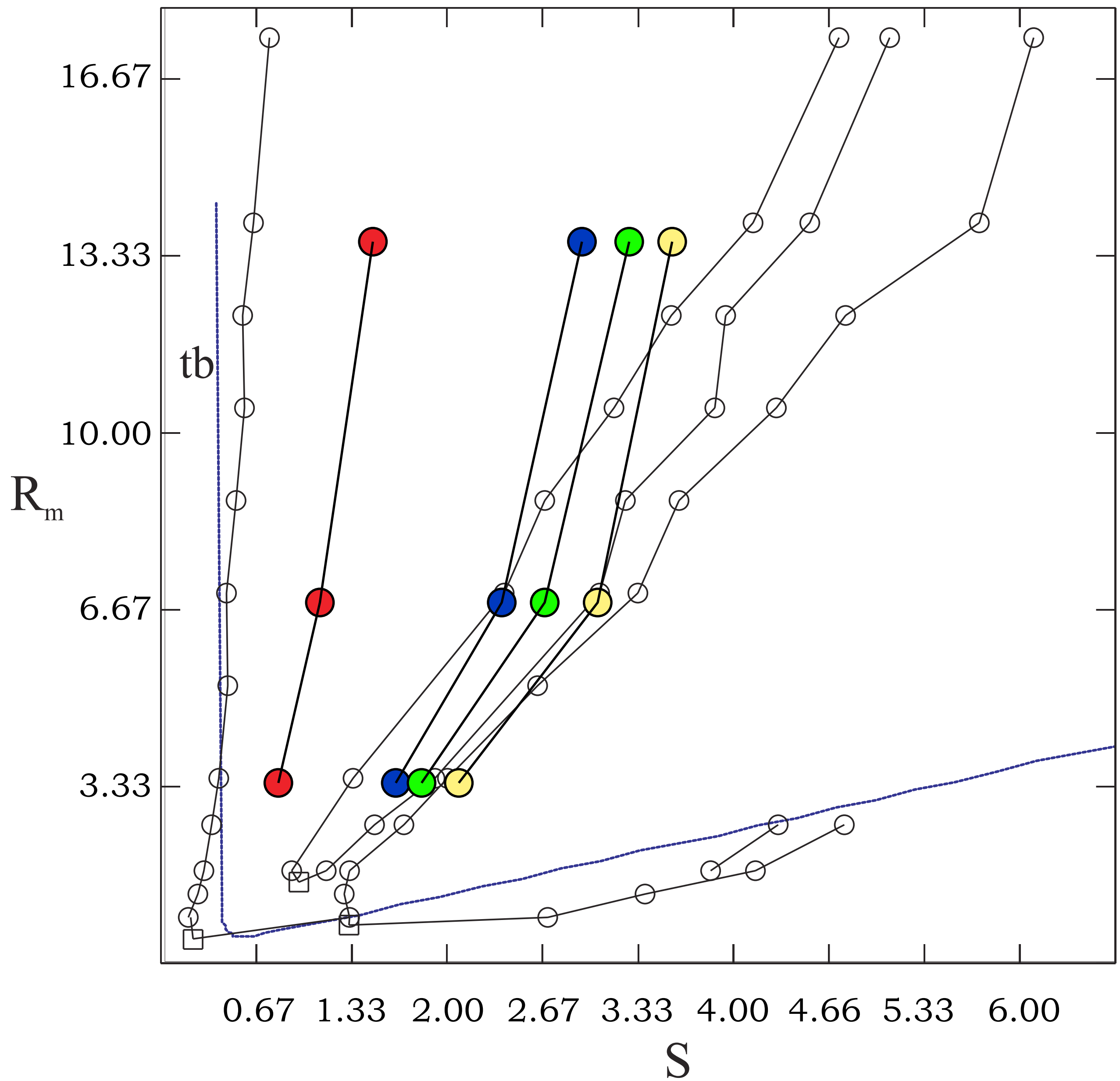
Induced Field Spectrogram
(One vertical cut = One Power Spectrum)
Induced Field Frequency (Hz)
14
12
10
8
6
4
2
0
0.5
1
1.5
2
2.5
3
3.5
4
$N^{1/2}$
-6
-8
-10
-12
-14
-16
Axial Velocity Spectrogram (depth ~7cm)
Velocity Fluctation Frequency (Hz)
14
12
10
8
6
4
2
0.5
1
1.5
2
2.5
3
3.5
4
$N^{1/2}$
5
0
-5

Preliminary Phase Plane?



Comparison With Sisan et. al





A rich region of parameter space...

In conclusion:

Liquid Sodium Taylor-Couette shows significant effect of applied magnetic field on the flow beginning at a well defined value of N and shows instability to organized oscillatory states as N is further increased, all starting from a base state of fully developed hydrodynamic turbulence.

This behavior occurs in the same region of parameter space where instabilities to rotating patterns were observed in a spherical Couette flow.

And further on:

Properly characterize oscillatory states and fill out phase plane
Investigate angular momentum transport (torque!)