The persistence of apparent non-magnetohydrostatic equilibrium in NOAA 11035

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made possible by The Thomas Metcalf SPD Travel Award MONTANA STATE UNIVERSITY

IAU Symposium 305 ~ Punta Leona ~ 2014 Dec 1

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NOAA 11035

 Rapid emergence starting **Observed with:** 14-15 Dec 2009 171 Å TRACE Very early cycle, high Whitelight latitude, large tilt Ni I 6767 Å SOHO MDI Ca II H 3968 Å Hinode SOT/FG Highly sheared configuration Na I 5896 Å H I 6563 Å Fe I 6302 Å Hinode SOT/SP Produced several small flares Fe I 6302 Å **DST/FIRS** He I 10830 Å Fe I 15650 Å Decays as it reaches the • Ca II 8542 Å **DST/IBIS** limb on Dec 20-21

Overview of evolution



Overview of evolution





Photospheric magnetic fields

2009-12-17 13:30 - 13:54

Hinode SOT/SP Fe I 6302 I Merlin



Photospheric magnetic fields

2009-12-17 13:30 - 13:54



Chromospheric structure



Chromospheric structure



Problem ?

- In General:
 - Magnetic fields are:
 - strong and vertical in the umbra
 - weak and horizontal in the penumbra
 - Strong horizontal fields cannot be maintained because of buoyancy
- For magnetic pressure balance we must be seeing something at an equivalent pressure of at least

 $(3800 \text{ G})^2/8\pi = 5.7 \times 10^5 \text{ dyn/cm}^2$

 $z \sim 375$ km below **T** [500nm] = 1 in the Spruit convective model (Spruit 1974 Sol. Phys.)

Say we have a horizontal magnetic tube



$$P_{out} = P_{in} + \frac{1}{8\pi} \left(B_z^2(r, z) + F_c(r, z) \right)$$

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and assuming

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and assuming

$$P_{out} = P_{in}$$

then

$$-B_z^2(r,z) = F_c(r,z) = 2 \int_r^a B_z(r',z) \frac{\partial B_r(r',z)}{\partial z} dr'$$

assume a functional form with no radial dependence



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then at z where Bz = max(Bz), r=0

$$-B_z^2 = F_c = 2B_z(z)\frac{\Delta B_r(z)}{\Delta z}a$$

assume a functional form with no radial dependence



then at z where Bz = max(Bz), r=0

$$-B_z^2 = F_c = 2B_z(z)\frac{\Delta B_r(z)}{\Delta z}a$$

say

 $a \sim \Delta z/2$

assume a functional form with no radial dependence



then at z where Bz = max(Bz), r=0

$$-B_z^2 = F_c = 2B_z(z)\frac{\Delta B_r(z)}{\Delta z}a$$

say then
$$a\sim \Delta z/2 \qquad -B_z\sim \Delta B_r$$

assume a functional form with no radial dependence



then at z where Bz = max(Bz), r=0

$$-B_z^2 = F_c = 2B_z(z)\frac{\Delta B_r(z)}{\Delta z}a$$

say then $a\sim \Delta z/2$ $-B_z\sim \Delta B_r$



Are the inversion results accurate?

2CMO inversion code

- "2 Component Magneto-Optical" inversion code
- Milne-Eddington inversion code with model options (QS, 1M, 1M+QS, 1M+SL, 2M, 2M+SL)
- comparable to MERLIN

B ₀	source function
	Magnetic Component
B ₁	source function gradient
λ	wavelength
Δλ	doppler width
а	damping parameter
η₀	line to continuum absorption ratio
В	magnetic field strength
γ	magnetic field inclination
φ	magnetic field azimuth
	Non-Magnetic Component
B ₁	source function gradient
λ	wavelength
Δλ	doppler width
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2CMO inversion code

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Non-Magnetic Component		
B ₁	source function gradient	
λ	wavelength	
Δλ	doppler width	
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no	line to continuum absorption ratio	

Inversion results



Suspicious Profiles

fit with 1 magnetic, 1 nonmagnetic components Hinode SOT/SP

B > 3000 G

14

12

10

+



Suspicious Profiles

fit with 2 magnetic, 0 nonmagnetic components Hinode SOT/SP

B > 3000 G

14

12

10

+



Results

- Magnetic field is 3600 G strong in 2C inversion, 3800 G strong in 1C inversion
- Complexity in profiles is obvious
 - Component 1: Material in the photosphere is flowing up at ~4 km/s along vertical field lines
 - Component 2: Small Doppler velocities and horizontal field
- There is optically thick, filamentary structure above the pore in the chromosphere















Contracting loops, flux pile-up

Conclusions

- Slow, continuous reconnection is happening in the photosphere
- Magnetic tension force on the contracting loops is significant
 - This can be verified in detail because the horizontal gradient is known

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