

CORHEL at the CCMC

COMMUNITY COORDINATED MODELING CENTER

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CORHEL at CCMC

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 - MAS Polytropic Parameters
- Heliospheric Boundary Conditions
 - Input Source
 - Input Parameters
- Heliospheric Model
 - ENLIL Parameters
- Summary
 - Run Summary

Date (MM/DD/YYYY): / /

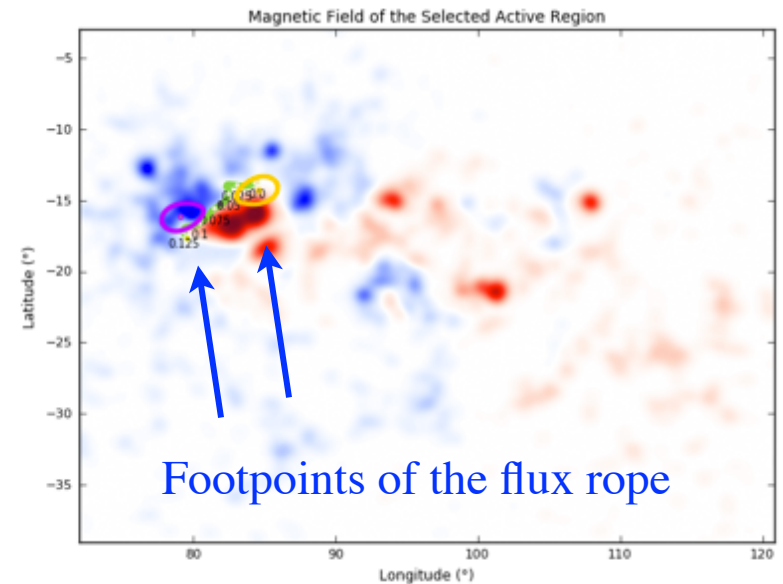
Carrington rotation number:

Resolution: Low Medium

Corona model: MAS Polytropic (101x101x128) MAS Thermodynamic (201x181x281) MSA (101x92x182) None

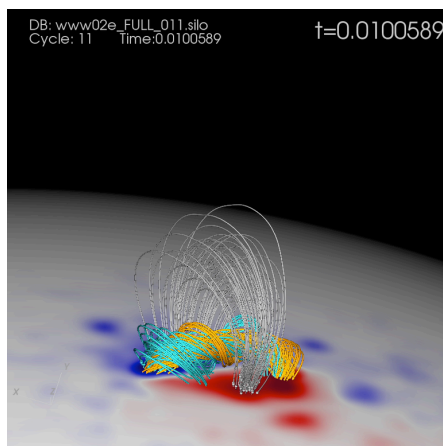
Heliospheric model: ENLIL (320x60x180) ENLIL with Cone Model (320x60x180) MAS Interplanetary (141x111x128) None

Next

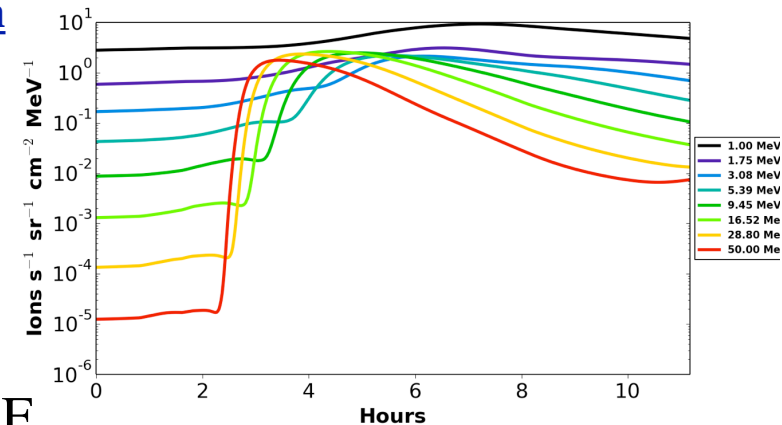


Jon Linker, Cooper Downs, Tibor Torok, Viacheslav Titov, Zoran Mikic, Pete Riley, Roberto Lionello, Ron Caplan, & Janvier Wijaya

Predictive Science, Inc. (PSI), San Diego, CA, USA



<http://www.predsci.com>



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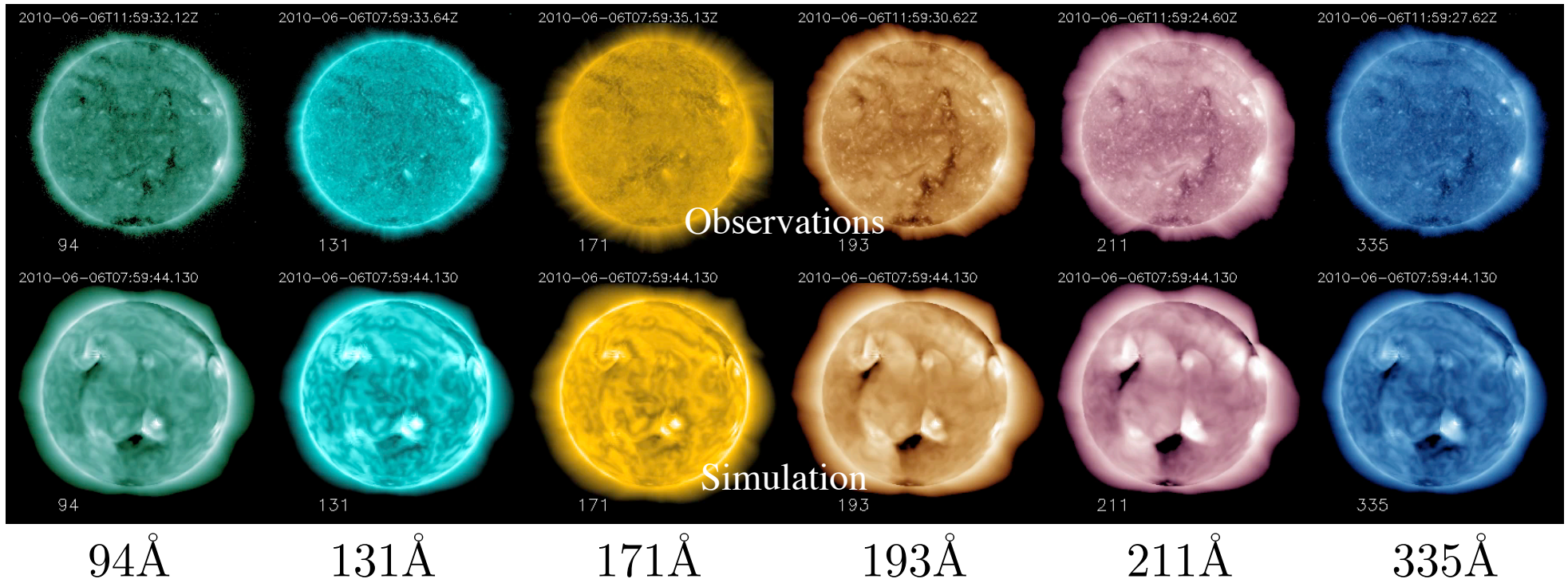
What is CORHEL?

- CORHEL - “Corona-Heliosphere”
- A coupled set of models and tools for quantitatively modeling the ambient solar corona and solar wind
- The principal observational input to CORHEL are maps of the radial magnetic field at the photosphere, derived from solar magnetograms
- CORHEL provides coronal solutions using 3 approximations:
 - WSA model (numerical potential solver)
 - Polytropic MHD (MAS Code)
 - Thermodynamic MHD (MAS code)
- CORHEL provides two different heliospheric codes: Enlil & MAS
- CORHEL outputs plasma and magnetic field quantities in 3D space
- It also outputs observable quantities for validation
- CORHEL has been delivered to AFRL, CCMC, and CISM



Thermodynamic MHD Models

June 6 - July 3, 2010: Simulated and Observed Emission Lines



- To accurately simulate plasma density, a more sophisticated energy treatment is required (coronal heating, radiative cooling, thermal conduction)



What's Next for CORHEL?

- CORHEL presently provides time-integrated solutions that describe the quasi-steady solar corona and inner heliosphere.
- We are engaged in two projects that will provide community models that describe Coronal Mass Ejections (CMEs) and Solar Energetic Particles (SEPs)
- CORHEL-CG (CORHEL with CME Generation)
 - Primarily supported by AFOSR BRI on CMEs
- STAT - Solar particle event (SPE) Threat Assessment Tool
 - NASA STTR program
 - Joint effort between Predictive Science Inc (PSI) and University of New Hampshire (UNH)
 - Couples PSI CME simulations (MAS/CORHEL) with UNH simulations of SEP acceleration and transport (EMMREM)
- I will briefly describe these today



CORHEL-CG

- Our goal is to develop a community tool for simulating CMEs in realistic coronal/solar wind solutions
- At the present time, coronal CME simulations are primarily performed by experts and are typically very manpower intensive
- CORHEL-CG utilizes modified Titov-Demoulin (TDm) flux ropes - Titov et al. 2014
 - Allows user to develop stable equilibrium with embedded flux rope(s)
 - Destabilize configuration to initiate CME
- PSI is developing the interface
 - An intuitive interface requires deep knowledge of the model
 - We developed the CORHEL interface presently implemented at the CCMC
- We used this approach to model the Bastille Day (7/14/2000) flare/CME



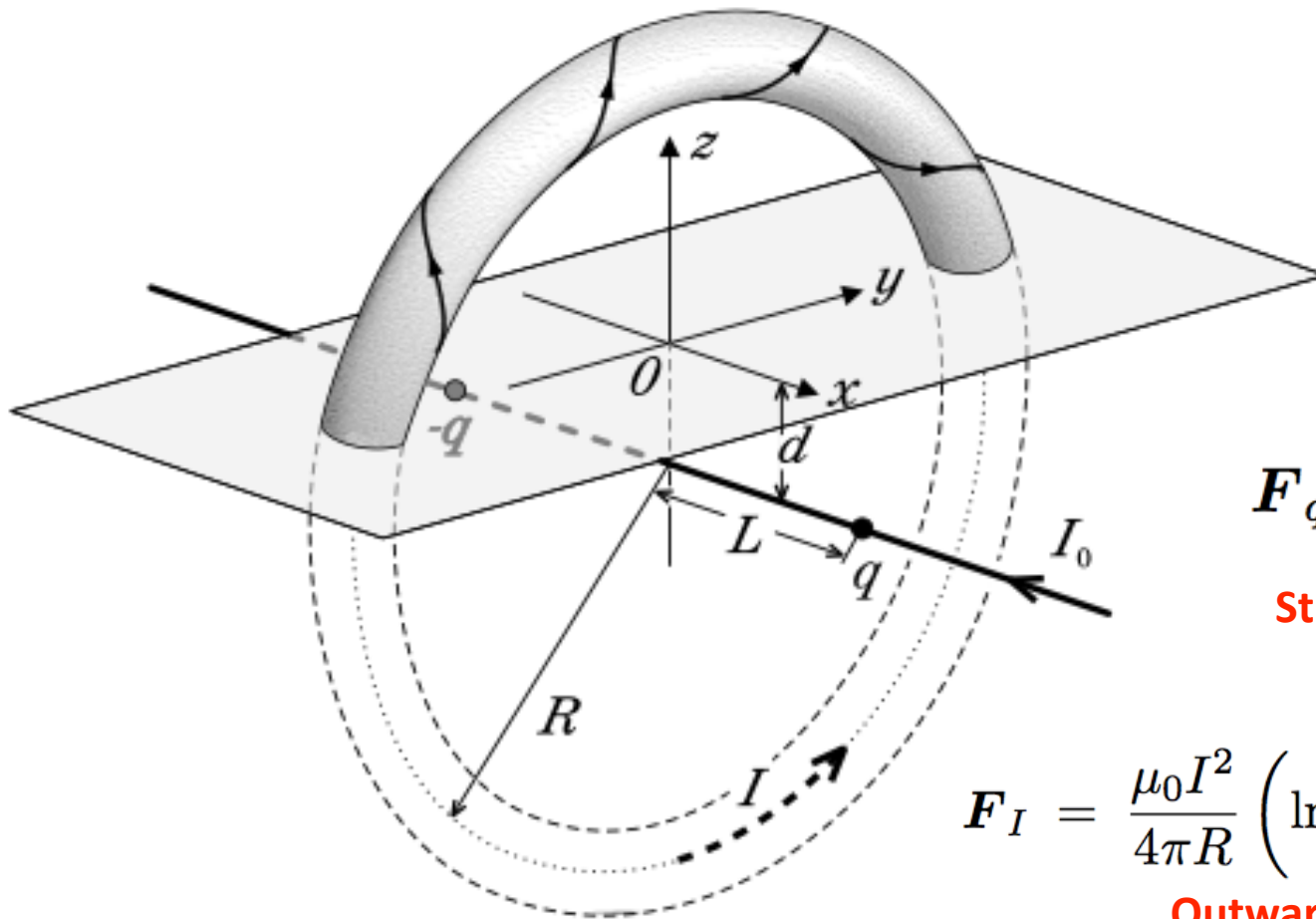
Why is Starting from Equilibrium Important?

- Non-equilibrium solutions can have any energy and expand at any speed.
- Solar active regions can store only a finite amount of energy - this bounds the size of the eruption.
 - Bounds on energy storage are well described by Aly-Sturrock theorem
- Solar eruptions often show rotation of the erupting flux rope:
 - Strongly out-of-equilibrium flux ropes don't display this property
 - This has can have important consequence for geo-effectiveness
- We want the equilibrium flux rope(s) to disturb the background as little as possible:
 - CME at 1 AU is a combination of initial eruption and overlying fields
- We first study in zero-beta, prior to inserting in full thermodynamic MHD



TD Flux Rope

Titov & Démoulin 1999



$$F_q = -\frac{2qLI\mathbf{n}}{(R^2 + L^2)^{3/2}},$$

Strapping force from charges

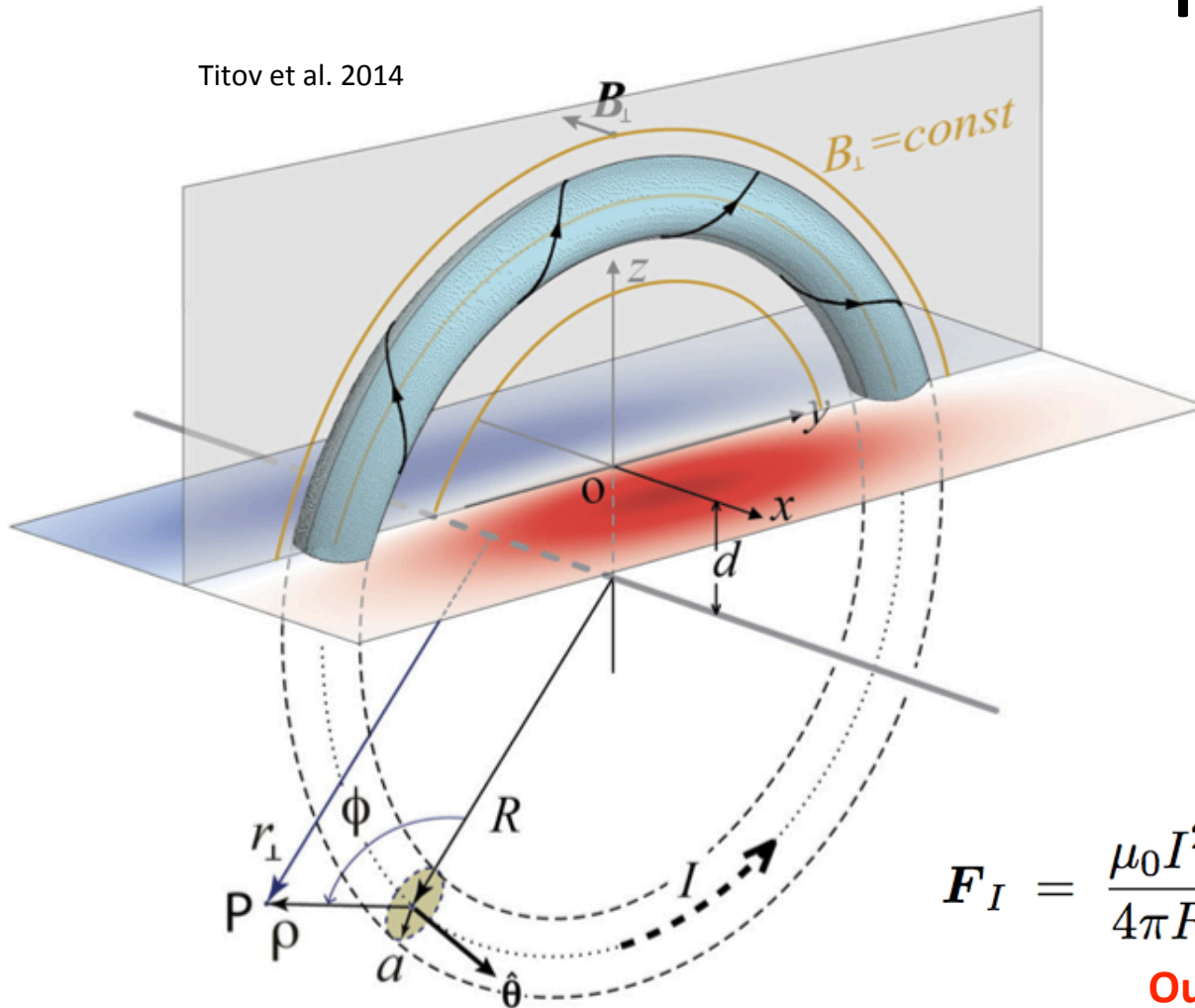
$$F_I = \frac{\mu_0 I^2}{4\pi R} \left(\ln \frac{R}{a} + \ln 8 - 3/2 + l_i/2 \right) \mathbf{n}$$

Outward force of the Rope

- Analytic model of circular flux rope as current carrying ring + axial field
- Hoop force of the flux rope is known
- This force is balanced by a strapping field

TDm Flux Rope

Titov et al. 2014



Instead you can use the arcade of the AR you want to study

~~$$F_q = - \frac{2qLI\mathbf{n}}{(R^2 + L^2)^{3/2}},$$~~

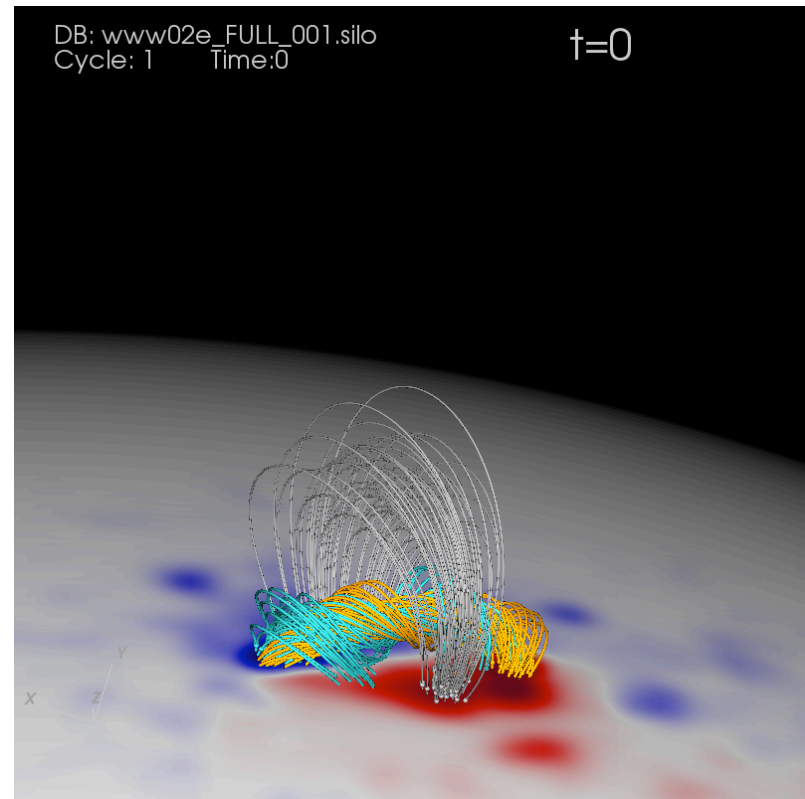
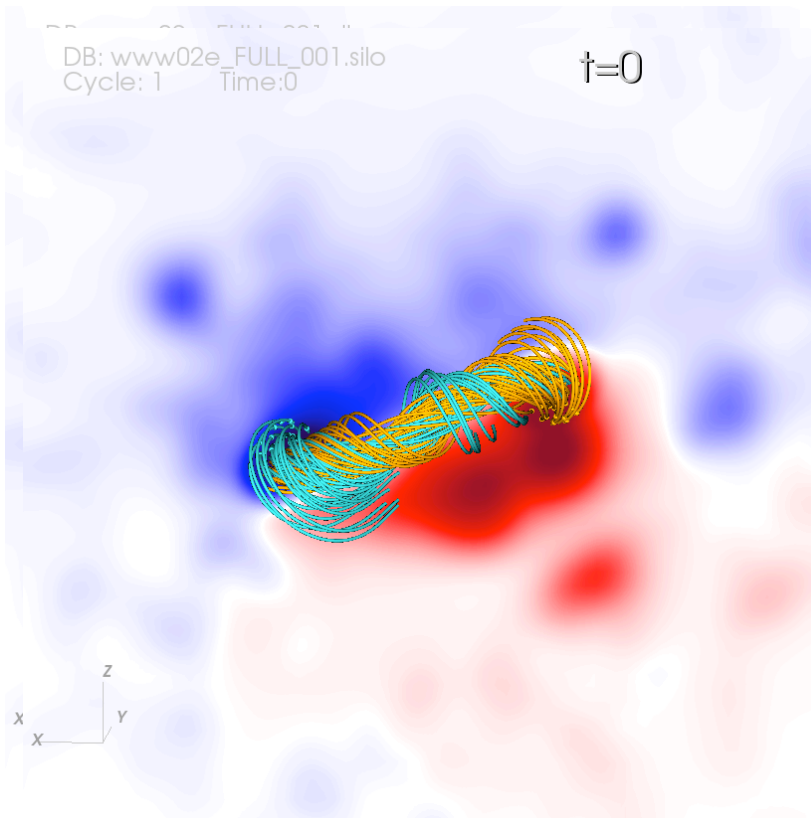
~~Strapping force from charges~~

$$F_I = \frac{\mu_0 I^2}{4\pi R} \left(\ln \frac{R}{a} + \ln 8 - 3/2 + l_i/2 \right) \mathbf{n}$$

Outward force of the Rope

- Complete expression for rope vector potentials given in Titov et. al 2014.
- Two types of volumetric current profiles considered (hollow core, parabolic)
- This model is implemented in the MAS code and can be inserted into any configuration

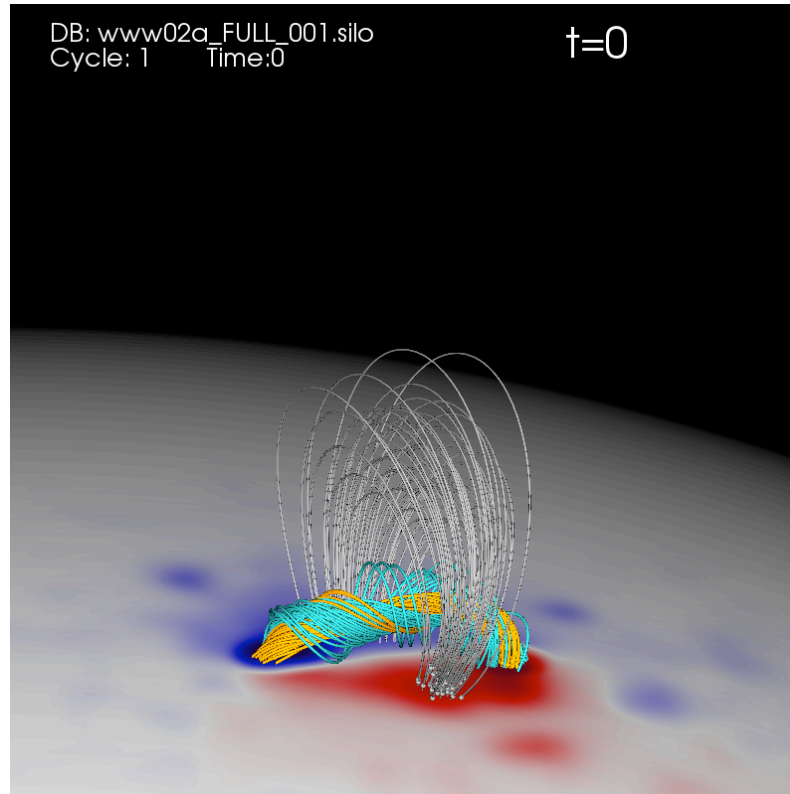
Test Stability with Trial Runs in Zero-Beta



- Zero-beta runs can be performed in minutes on a few hundred processors
- Example of a stable flux rope



Test Stability with Trial Runs in Zero-Beta

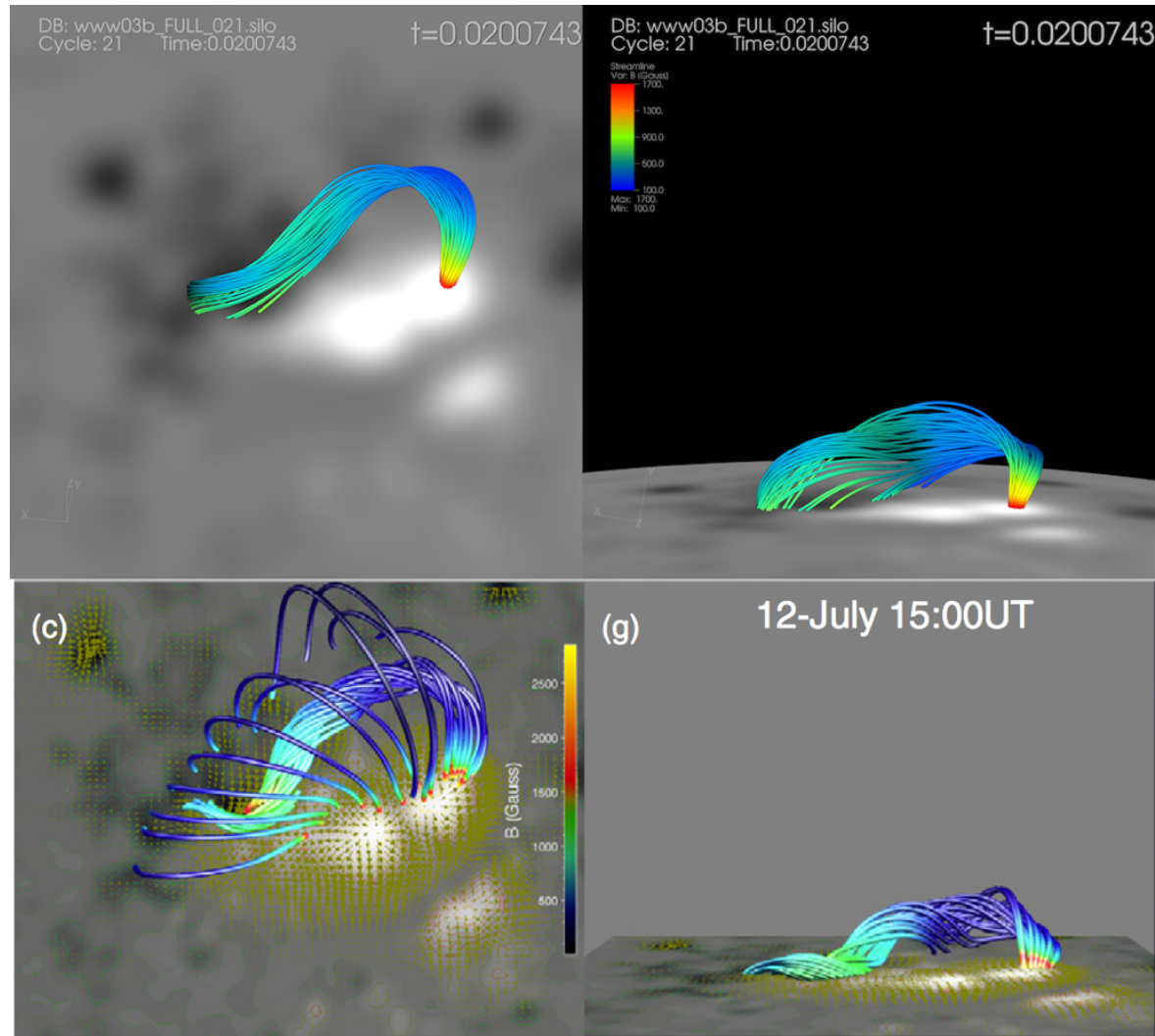


- Eruption - choosing B_p above stability limit
- Also via flux cancellation



Comparison of TDm Flux Rope with NLFF Model

TDm Flux Rope



Cheng et al. 2012
NLFF model



Coupled CME-SEP Simulations with CORHEL-EPREM

CORHEL EPREM

[Run Registration](#) >

[Run Parameters](#) >

[Run Summary](#) >

Run Registration

First name

Bugs

Last name

Bunny

Email

bbunny@wbros.com

Daily request

1

Next

EPREM solves Focused Transport Equation
for particles embedded in MHD electric & magnetic fields



Coupled CME-SEP Simulations with CORHEL-EPREM

CORHEL EPREM

Run Registration



Run Parameters

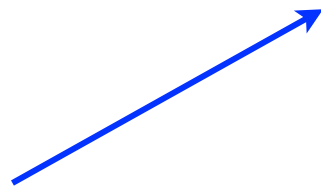
Run Parameters



Run Summary



Select CME run



MAS run

Bastille Day

Start sequence

1

Start MAS time

164.000168273287

Start date and time

2000-07-14 10:00



Relaxation time

0.25

days

Minimum energy

1.0

MeV/nucleon

Maximum energy

50.0

MeV/nucleon

Mean-free-path

1.0

AU



Use particle drift



Use perpendicular diffusion

$K_{\text{perpendicular}} / K_{\text{parallel}}$

0.01

Next

Select EPREM parameters



Coupled CME-SEP Simulations with CORHEL-EPREM

CORHEL EPREM

- [Run Registration](#) >
- [Run Parameters](#) >
- [Run Summary](#) >

Run Summary

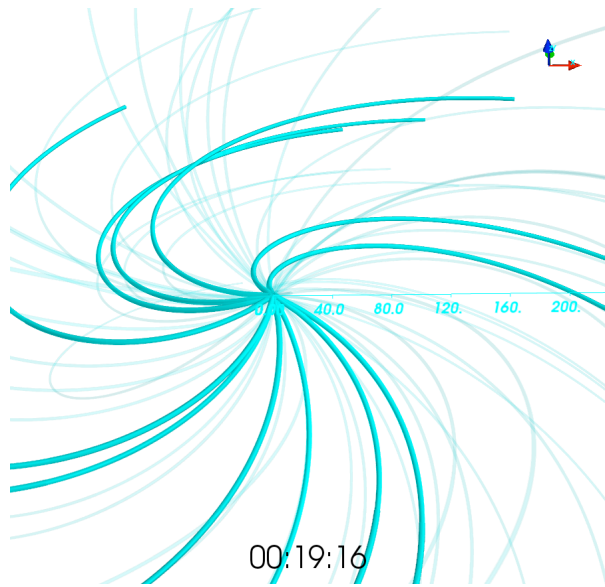
First name	Bugs
Last name	Bunny
Email	bbunny@wbros.com
Daily request	1
MAS run	Bastille Day
Start date and time	2000-07-14 10:00 UT
Relaxation time	0.25 days
Minimum energy	1.00 MeV/nucleon
Maximum energy	50.00 MeV/nucleon
Mean-free-path	1.00 AU
Use particle drift	Yes
Use perpendicular diffusion	Yes
$K_{\text{perpendicular}} / K_{\text{parallel}}$	0.01

[Download Input File](#)

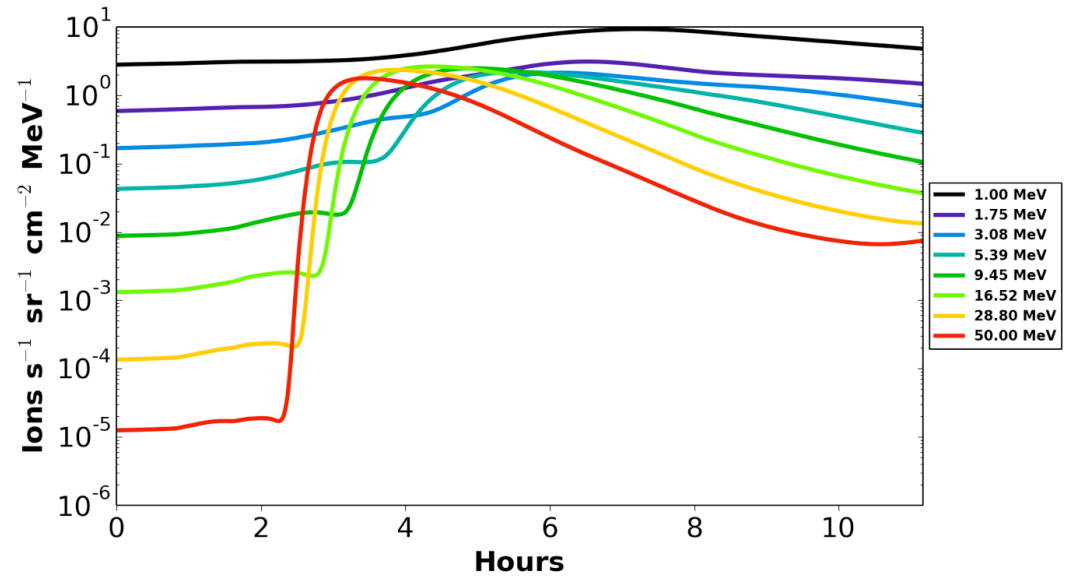
[Submit Run Request](#)



Coupled CME-SEP Simulations with CORHEL-EPREM



EPREM streams



Simulated SEP flux at 1 AU

- Example - (very preliminary) simulation of Bastille Day Event (July 14, 2000)



Summary

- Today I've described the extension of CORHEL into modeling of CMEs and consequent SEP production.
- CORHEL-CG will provide an approach to modeling CMEs starting from equilibrium configurations
 - Our AFOSR-supported project promises delivery to AFRL Kirtland
 - We welcome the opportunity to provide this capability to the CCMC
 - Presently investigating with zero-beta, eventually provide full thermodynamic MHD
- SPE Threat Assessment Tool (STAT)
 - Coupled CORHEL-EPREM Simulations
 - Presently focused on low-coronal response
 - Can also investigate energetic storm particles

