JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

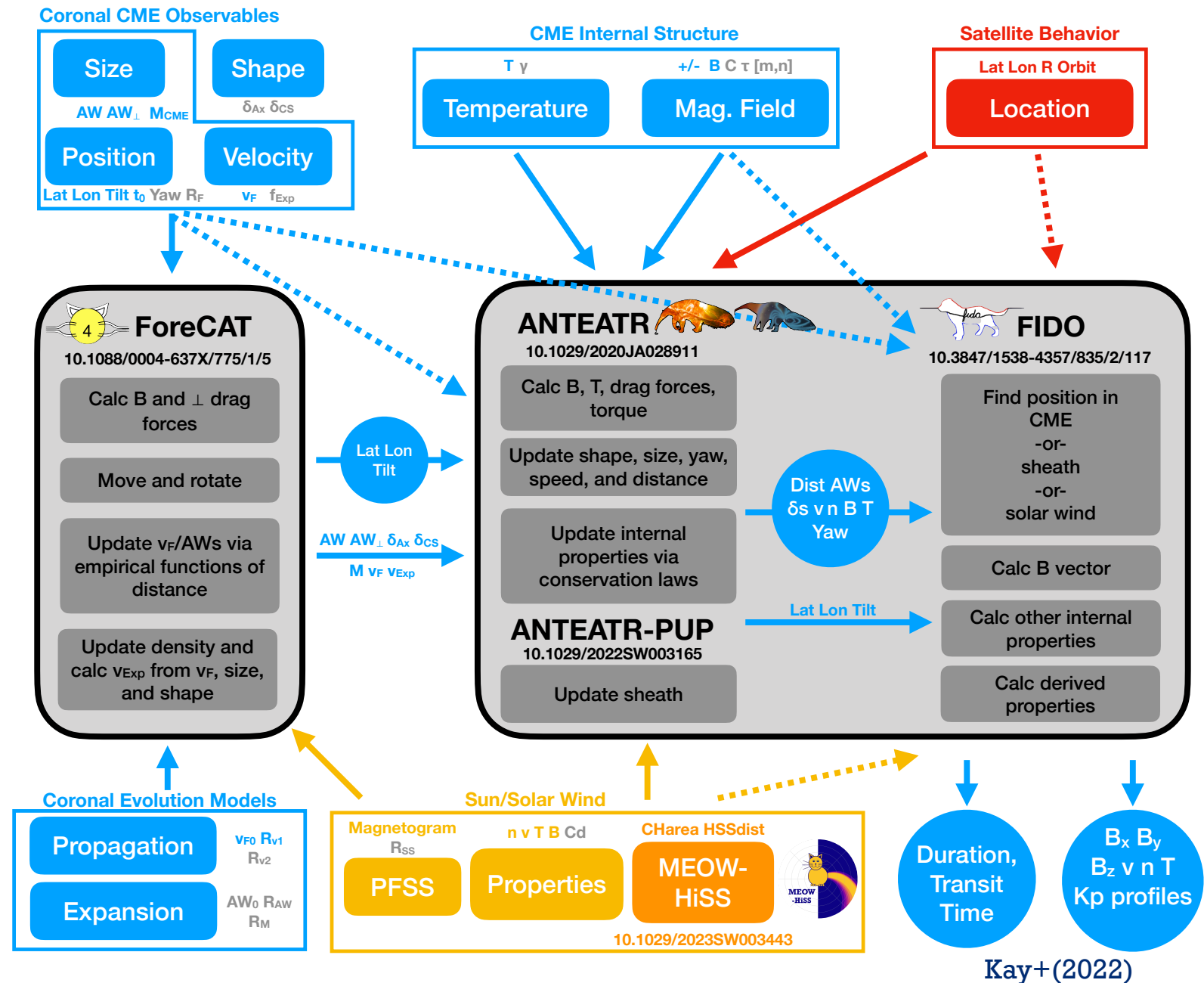# Combining PUNCH Observations with OSPREI Modeling

C. Kay *(Johns Hopkins Applied Physics Laboratory)*
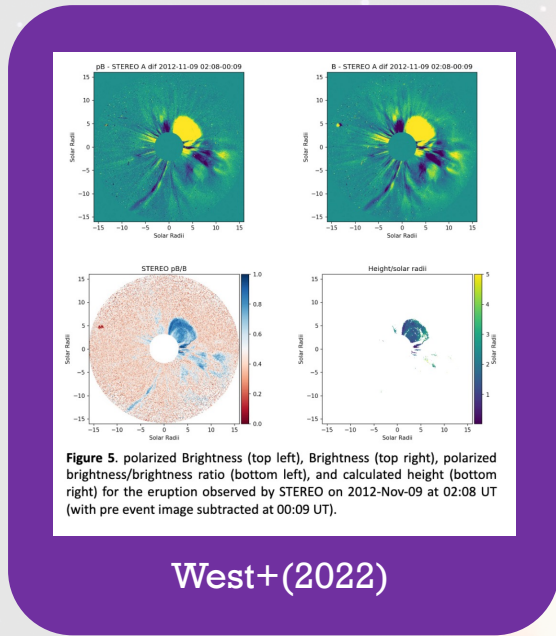
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Punch Workshop 6

OSPREI Model

- Three fully-coupled, user-friendly models for CME evolution with automatically-generated visualizations

- **ForeCAT** – Coronal deflection and rotation of CMEs from background magnetic forces

- **ANTEATR** – IP propagation including drag, CME expansion, deformation, and rotation

- **FIDO** – synthetic in situ profiles (magnetic field and plasma properties)
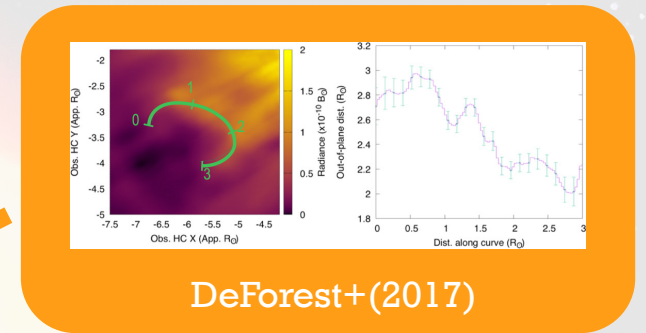
Coronal CME Observables

Size — AW AW$_\perp$ M$_{CME}$
Shape — δ$_{Ax}$ δ$_{CS}$
Position — Lat Lon Tilt t$_0$ Yaw R$_F$
Velocity — v$_F$ f$_{Exp}$

CME Internal Structure

T γ — Temperature
+/- B C τ [m,n] — Mag. Field

Satellite Behavior

Lat Lon R Orbit — Location

ForeCAT
10.1088/0004-637X/775/1/5

Calc B and ⊥ drag forces

Move and rotate

Update v$_F$/AWs via empirical functions of distance

Update density and calc v$_{Exp}$ from v$_F$, size, and shape

Lat Lon Tilt

AW AW$_\perp$ δ$_{Ax}$ δ$_{CS}$
M v$_F$ v$_{Exp}$

ANTEATR
10.1029/2020JA028911

Calc B, T, drag forces, torque

Update shape, size, yaw, speed, and distance

Update internal properties via conservation laws

ANTEATR-PUP
10.1029/2022SW003165

Update sheath

Dist AWs δs v n B T Yaw

Lat Lon Tilt

FIDO
10.3847/1538-4357/835/2/117

Find position in CME
-or-
sheath
-or-
solar wind

Calc B vector

Calc other internal properties

Calc derived properties

Coronal Evolution Models

Propagation — v$_{F0}$ R$_{v1}$ R$_{v2}$
Expansion — AW$_0$ R$_{AW}$ R$_M$

Sun/Solar Wind

Magnetogram R$_{SS}$
n v T B Cd
CHarea HSSdist

PFSS
Properties
MEOW-HiSS

MEOW-HiSS

10.1029/2023SW003443

Duration, Transit Time

B$_x$ B$_y$ B$_z$ v n T Kp profiles

Kay+(2022)

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Coupling with PUNCH

Figure 5. polarized Brightness (top left), Brightness (top right), polarized brightness/brightness ratio (bottom left), and calculated height (bottom right) for the eruption observed by STEREO on 2012-Nov-09 at 02:08 UT (with pre event image subtracted at 00:09 UT).
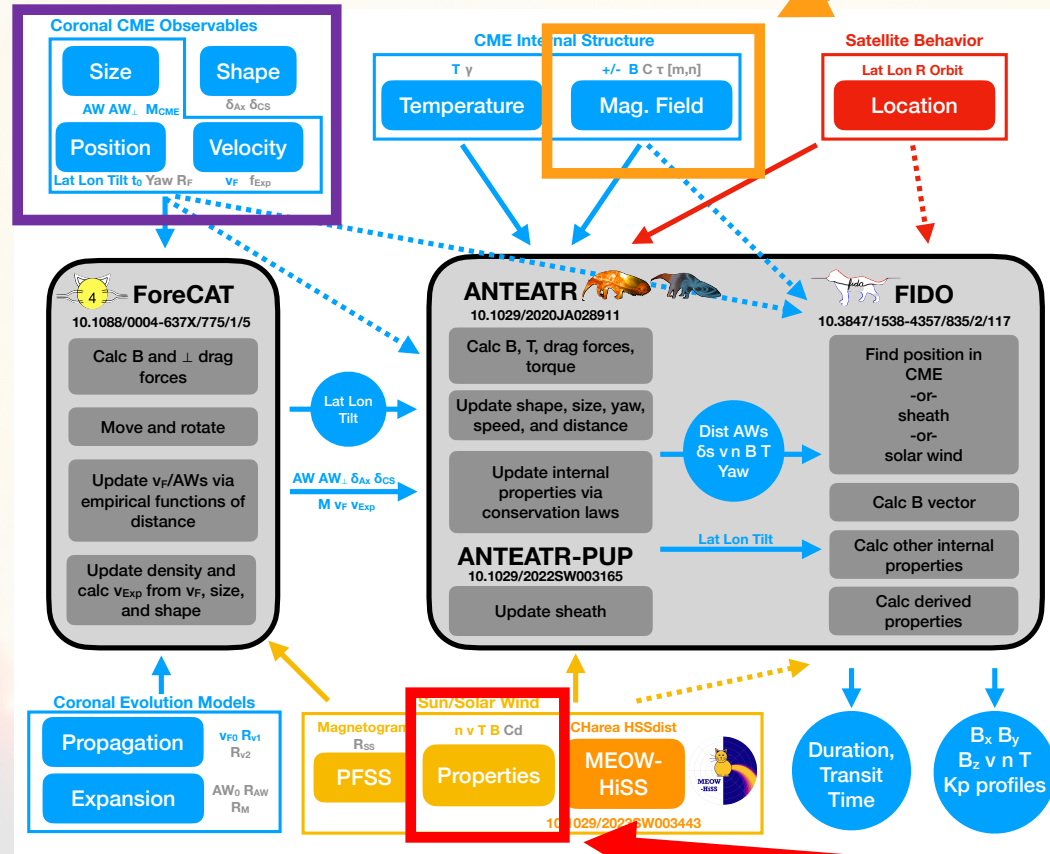
West+(2022)

Better geometry inputs through polarized images

But better for limb events and not as much Earth-directed(?)

DeForest+(2017)

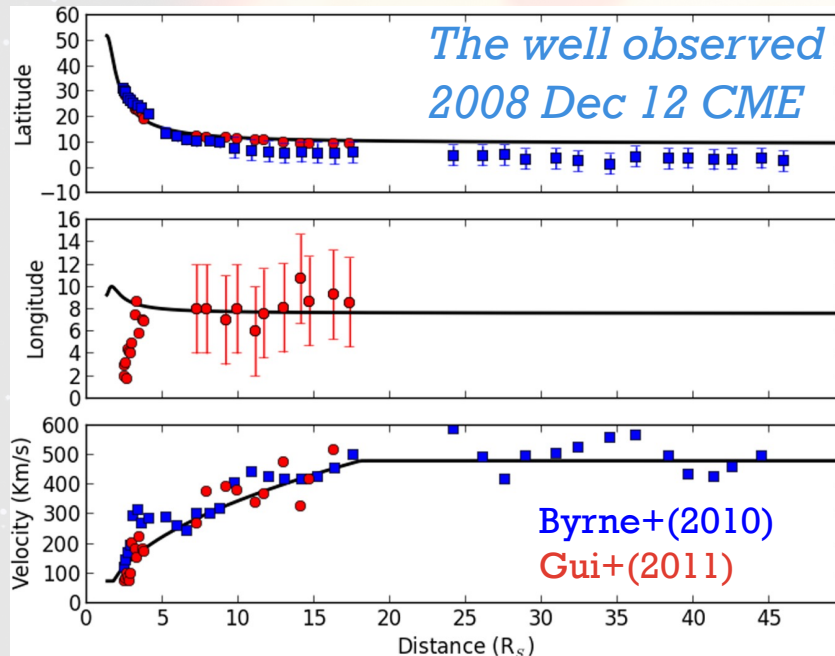Measures of chirality
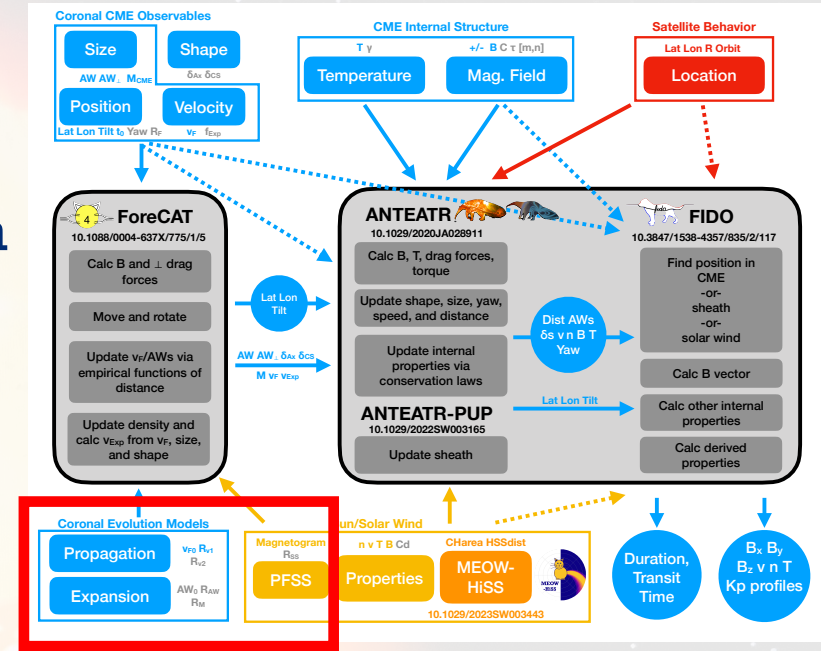
Improved SW backgrounds

Coronal CME Observables

Size	Shape

AW AW⊥ M_CME   δ_Ax δ_CS

Position	Velocity

Lat Lon Tilt t₀ Yaw R_F   v_F f_Exp

CME Internal Structure

T γ   +/- B C τ [m,n]

| Temperature | Mag. Field |

Satellite Behavior

Lat Lon R Orbit

| Location |

ForeCAT
10.1088/0004-637X/775/1/5

Calc B and ⊥ drag forces

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Update v_F/AWs via empirical functions of distance

Update density and calc v_Exp from v_F, size, and shape

Lat Lon Tilt

AW AW⊥ δ_Ax δ_CS

M v_F v_Exp

ANTEATR
10.1029/2020JA028911

Calc B, T, drag forces, torque

Update shape, size, yaw, speed, and distance

Update internal properties via conservation laws

ANTEATR-PUP
10.1029/2022SW003165

Update sheath

Dist AWs δs v n B T Yaw

Lat Lon Tilt

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10.3847/1538-4357/835/2/117

Find position in CME -or- sheath -or- solar wind

Calc B vector

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Coronal Evolution Models

| Propagation | v_F0 R_v1 R_v2 |
| Expansion | AW₀ R_AW R_M |

Magnetogram R_SS

PFSS

Sun/Solar Wind n v T B Cd

Properties

CHarea HSSdist

MEOW-HiSS
10.1029/2022SW003443

Duration, Transit Time

B_x B_y B_z v n T Kp profiles

Figure 2: Deep-field views of the outer solar corona, from STEREO/COR2, reveal fine structure both in space and time[4]. These images show the inner half of the NFI field of view. LEFT: fine structures, laterally confined by the magnetic field, dominate the outer corona. RIGHT: Removing a running average reveals a "riotous torrent" of ejecta at all times and locations. PUNCH uses these ejecta to trace solar wind flow.

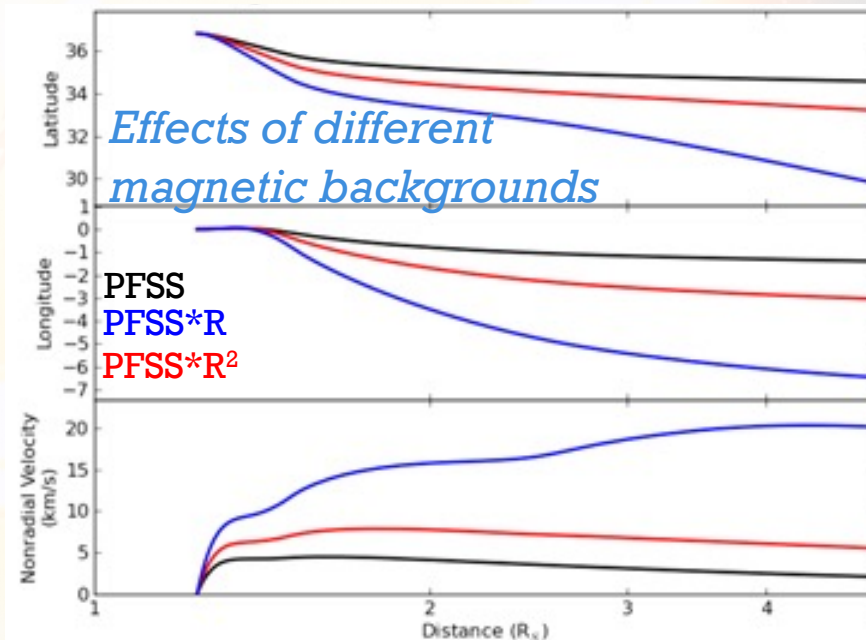DeForest+(2022)

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Science Improvements

- Use empirical models for radial CME propagation in corona
  - Speed through corona and deflection/rotation intrinsically coupled
- Can use improved observations to better constrain both radial and non-radial motions
  - Can potentially back out info about solar magnetic field by tuning deflection/rotation to match observations

The well observed 2008 Dec 12 CME

Byrne+(2010)
Gui+(2011)

Kay+(2015b)

Effects of different magnetic backgrounds

PFSS
PFSS*R
PFSS*R^2

Kay+(2015a)

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