Working Group 2 – Theory

Summary

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WG 2: Overview

• **Objective**: To understand the structure and evolution of CMEs as well as their origin and their magnetic rope structure. Specifically:
  • What is the origin of Bz and how can it be modeled?
  • Are CMEs deflected in the heliosphere?
  • How do ambient conditions affect CME structure, propagation, and dynamics?
  • How long does the Lorentz force dominate over aerodynamic drag?
  • How can we estimate the drag parameter and/or dimensionless drag coefficient?

• **Approach**: Compare results from different analytic and numerical models with measurements, such as transit time to 1AU, kinematics, impact speed, impact magnetic field, etc.
Main progresses where theoretical aspects were included:

1. Drag effect related issues
   - DBM applied to events from the “ISEST list”
   - Comparison of analytic (DBM) and numerical (ENLIL) model (e.g., Vršnak et al., ApJS 213, 21, 2014)
   - Estimation of CME “true” mass (e.g., Bein et al., ApJ, 768, 31, 2013; Feng et al., JGR, in revision, 2014)

2. CME deflection/rotation
   - Deflection --- Observational evidence and kinetic model (Wang et al., JGR, 119, 5117, 2014)
   - 3-D evolution revealing rotation (Isavnin et al., SoPh, 2013; 2014)
Main progresses where theoretical aspects were included (continue):

3. Interacting structures
   - Shock-CME interactions (RAL/Oxford workshop)

4. MC fitting technique and related
   - Investigating plasma motion of magnetic clouds at 1 AU through a velocity-modified cylindrical force-free flux rope model (Wang et al., JGR, 2015)
Main progresses where theoretical aspects were included (continued):

5. Background solar wind
   - Spatially/temporally variable solar wind environment (e.g., Rollett et al., ApJL 790, 6, 2014)
   - On the role played by magnetic expansion factor in the prediction of solar wind speed
Main objectives/topics to be pursued:

• Drag effect related issues
  • Comparisons with MHD solutions?
• CME deflection/rotation
• Interacting structures
• MC fitting technique and related
• Background solar wind

Start research on: How to model Bz ?!

➤ Theory/numerical modelling
➤ Laboratory experiments for some topics
Recent progress: Example

- HELIOSPHERIC PROPAGATION OF CORONAL MASS EJECTIONS: DRAG-BASED MODEL FITTING by Zic et al.

\[ F = F_L - F_g + F_d. \]
\[ F_d = -c_d A \rho (v - w) |v - w| \]
\[ a_d = -\gamma (v - w) |v - w| \]
\[ \gamma = c_d \frac{A \rho}{M} \quad \gamma(R) = \gamma_\infty \frac{w_\infty}{w(R)} \]

\[ E(\Gamma, w_\infty; R_0, v_0) = \sum_{i=0}^{N} [v_i - v(\{\Gamma, w_\infty; R_0, v_0\}, R_i)]^2 \]

\[ v(R) \frac{dv(R)}{dR} = -\gamma(R) [v(R) - w(R)] |v(R) - w(R)| \]
WG2 presentations

- How to Predict Bz? (Pete Riley)
WG2 presentations


![Graph showing ICME speed versus distance for four models.](https://example.com/graph.png)

**FIGURE 6.20** - ICME speed versus distance for the four models analyzed in this work. a) laminar regime considering variability in ICME radius (Eq. 4.9) and $\mu = 0.175 \text{ g/cm} \cdot \text{s}$ (dashed line). b) turbulent regime considering variability in ICME radius (Eq. 4.10) and $C_d = 5 \times 10^4$ (dot-dashed line). c) laminar regime considering variability in ICME radius and SW density (Eq. 4.16) and $\rho = 8.75 \times 10^{20} \text{ cm}^3 / \text{s}$ (continuous line), and d) turbulent regime considering variability in ICME radius and SW density (Eq. 4.13) and $C_d = 1.1 \times 10^5$ (dot line).
WG2 presentations

• Balance of Energy in a CME (Héctor J. Durand Manterola)
WG2 presentations

- Plasma Interaction Processes That Lead to Viscous Forces in the Solar Wind (Héctor Pérez de Tejada)

CONTENTS

Viscous forces suitable for particle-particle (coulombian) and wave-particle (magnetic turbulent) interactions in the solar wind.

The solar wind interaction with planetary ionospheres

I - Transport of solar wind momentum to the Venus upper ionosphere (discussion of measurements and their interpretation).

II - Calculation of viscous forces at the region of interaction between the solar wind and the Venus ionosphere (wave-particle interactions in the solar wind, and particle-particle collisions in the Venus upper ionosphere).
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- We developed an **analytical method** to approximate:
  1) **arrival of shocks** associated with halo CMEs, and
  2) **in-situ transit** profiles (synthetic transits) of plasma sheath

- All the method's inputs are initial data from the event, save the quotient between initial densities of CMEs and ambient solar wind.

- This is an experimental tool of SCiESMEX for space weather forecasting.
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- Dynamics of Coronal Mass Ejections in the Interplanetary Medium in Two Dimensions (Juan Carlos González Marin)

2) Elliptical form for the leading edge of the CME and profiles for the position and the speed for any point of it.
WG2 presentations

- How to Predict Bz? (Pete Riley)
WG2 presentations

- **Study of the Transport of Heat in the Solar Corona** (Diana Gamborino Uzcanga*, J. Martinell Benito, D. del Castillo Negrete)
Abstract

- Solar Corona heating mechanisms still not clear.

- Energy released mainly in AR - propagated to other regions - maintain Corona at observed T.

- Global heat transport influenced by complex $\vec{B}$ geometry that couples distant regions of Corona.

- Produce nonlocal effects in the transport.

- EUV images - AIA/SDO. Three cases: (a) following an explosive event, (b) five hours before the explosive event, same AR and (c) Quiet Sun region.

- SolarSoft - T Maps - full solar disk.

- Regions of interest - selected and analyzed with POD methods.

- (1) Topos-Chronos: Energy cascade process determined - subdiffusion.

- (2) GLRAM: $w \sim t^\gamma$. $W$ found $\gamma < 1$ - subdiffusion.
Summary

- WG2 has made good progress on the goals set at the previous workshop
- Aerodynamic drag continues to be a focus point for study
- Modeling and theory complementary and overlapping concepts – perhaps the distinction is that WG2 shouldn’t focus on complex 3-D models, but rely on more idealized approaches to “explain” phenomena
- More work needs to be done regarding the relative contribution of the drag force and other forces as the CME leaves the Sun
- A crucial question for this group could be: What are the underlying physical processes (kinetic) in the solar wind that give rise to the drag force?

Prediction of Bz remains an overarching goal for WG2