Origin, Development, and Effects of Coronal Mass Ejections (CMEs): Report from the 2nd International CME Workshop at Elmau Castle, Germany, in February 2003

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Abstract

The second of three international workshops on Origin, Development, and Effects of Coronal Mass Ejections (CMEs) was held at Elmau castle with about 50 participants. The aim of the workshop is to interpret the observations from CMEs involving scientists from all different disciplines affected. This includes experimenters, ground observers, modellers, and theorists, remote sensing and in-situ observations, and the environments of the solar photosphere, chromosphere, coronal and the interplanetary space out to the outer heliosphere. The work is done mostly within two sets of 4 working groups meeting in parallel and concentrating on specific aspects of CMEs. To stimulate interdisciplinary cross-fertilisation especially in the second set of working groups participants from different areas using various tools cooperate. The working groups are: Set I: A: Coronal observations, B: Solar wind and magnetic field measurements, C: Energetic particle observations, D: CME theory and models. Set II: E: The pre-CME Sun, F: CME-related coronal phenomena, G: Inner heliosphere, H: Outer heliosphere & high latitudes. Preliminary results from the working groups are presented.

1. Introduction

Coronal Mass Ejections (CMEs) were first studied in detail nearly 30 years ago with Skylab. Their effects were described early by Gosling et al, 1974, and Kahler et al., 1978. The necessity to study CMEs with an interdisciplinary working group arose from observations with unprecedented resolution and sensitivity by the SOHO remote sensing instruments demanding new models and tests.

Two workshops were held in March 2000 and February 2003 at Elmau castle, Germany. About 50 scientists were contributing observations on the solar photosphere and corona, on plasma, magnetic field and particles from SOHO, ULYSSES, HELIOS 1/2, PIONEER 10/11, and VOYAGER 1/2, and from s/c at Earth orbit and presented models and theories. Both 6 day workshops included invited talks (describing the state of knowledge for all participants) and a small number of contributed talks. Most of the time, however, was devoted to working group sessions.

pp. 3671–3674

A first set of four parallel working groups (8–15 participants) led by two co- chairs investigated the aspects of the corona, plasma and fields, energetic particles, and theory and models. Splinter groups were set up by members of individual working groups to discuss specific topics or from different working groups to investigate detailed correlations.

A second set of again four groups contained a mix of specialists from different fields to stimulate collaboration on topics where progress demands cooperation. Topical areas are the pre-CME Sun, CME-related coronal phenomena, effects in the inner heliosphere and in the outer and high latitude heliosphere.

2. Highlights from the Working Groups

2.1. Working Group A: Coronal Observations

Working group A included scientists from SOHO (LASCO, UVCS, EIT), ACE, GOES, YOHKOH, RHESSI, WIND, and TRACE, and from ground based observatories. 2449 CMEs observed with LASCO are the basis for statistical and detailed case studies on the following topics:

- CME mass and kinetic energy transport studies
- Studies of the 3D topology of "structured" CMEs and their source regions
- Statistical evaluations of CMEs over the solar cycle and their correlations with radio bursts. Is there a continuous spectrum of CME properties?
- Analysis of the velocity and acceleration profile of a fast CME
- Observational evidence for reconnection and its actual role
- The interaction between CMEs near the sun and in space
- Shocks from flares and CMEs: evidence for blast waves?

2.2. Working Group B: Solar Wind and Magnetic Field Measurements

Working group B consists of scientists observing magnetic fields, solar wind including composition and radio and plasma waves. Main topics are:

- In-situ signatures of CMEs: Comparison, relevance, reliability, modelling
- Composition: Compared to coronal composition. Spatial variation in CME
- Sheath
- Boundaries
- Comparison of in situ and solar detection of CMEs?
- CME interactions

Interaction with working group C, (Energetic Particles) focussed on:

- Hot flow anomalies: Implications for fast CME-driven shocks?
- Do energetic particles ionise bulk plasma, and so change charge states?
- Energetic particles as probes of magnetic topology and structure
- What can energetic particle flux patchiness tell us about internal structure?

2.3. Working Group C: Energetic Particle Observations

Main topics assigned to this working group are:

- Particle Acceleration: Solar (flare and CME related), heliospheric
- Particle Transport
- Quiet Time Component (e and ions).

In-situ particle analysis has the problem that observed populations are generally a mixture from several effects. Separating the contributions requires powerful models. A major complication is the origin of particles in large SEP events from shock and/or flare acceleration. Observed is often both "flare" material (Fe/O) and in particular 3He, electron acceleration, and multiple CMEs/shocks accelerated material. Several related questions were discussed:

- Comparison of the timing of e and p injection (derived from interplanetary measurements) with the event onsets observed at the Sun.
- Energy dependent ionic charge states: Stripping at low coronal altitudes?
- Evidence for perpendicular transport in large events (decay: Profiles and spectra)

Joint discussions with Working Group D focussed on systematics of changes in composition, ionic charge states, energy spectra, and electrons.

2.4. Working Group D: CME Theory and Models

The working group included theorists and modellers from all fields involved in the workshop. The main topics discussed are:

- CME Initiation
- Models and observational tests: Small flux changes can trigger events
- Complexity of CME sources: Do fast CMEs ever come from bipolar regions?
- Structure of CMEs: Relationship to in situ observations
- Bright outer rim
- Dark cavity Magnetic Cloud
- Bright core (prominence) He +

2.5. Working Group E: The pre-CME Sun

WG E focussed on conditions prior to an eruption. Main topics are:

- Pre-eruption structure, evolution & energy release
- Global issues: helicity, homologous CMEs
- Inputs to CME initiation models

The pre-eruption structures investigated in great detail are sigmoids, flux ropes, guiding streamers, and the pre-eruption evolution.

2.6. Working Group F: CME related coronal phenomena

Major topics discussed are:

- Filament cavity
- Post CME current sheet identification, parameters, physical meaning
- CME acceleration and flare evolution
- Coronal waves, shocks and CMEs
- Electron events: Quantitative model with realistic field configuration needed

2.7. Working Group-G: CMEs in the Inner Heliosphere

This working group covered all aspects of CMEs in interplanetary space between the Sun and 1 AU. In particular:

- Characteristics of CMEs in the solar wind
- Bi-directional electron fluxes: Tracers of magnetic field topologies
- CME interactions: Effects of multiple CMEs
- Bipolar regions as CME source regions

2.8. Working Group H: CMEs in the Outer Heliosphere and at High Latitudes

WG H included observers and modellers of plasma and fields mainly from ULYSSES, PIONEER 10/11 and Voyager 1/2 and covered the topics:

- Detailed observations at moderate heliospheric distances at all latitudes
- Evolution of CMEs at extremely large heliocentric distances
- Global structure of CMEs, modelling and multi-spacecraft observations
- Large transient events and Forbush decreases, GMIR- CME relations

3. Open Questions and Future Work

The working groups collected many action items and open questions and will continue working for another year on these topics. The series of workshops on CMEs will end with a third Workshop at the International Space Science Institute, Bern, in March 2004 with the main emphasis on a comprehensive publication of the workshop results.

4. Acknowledgements

I acknowledge stimulating discussions and professional presentations of all wokshop participants. Parts of this project are supported under grant No. 50 OC 0105 by the German BMBF through DLR.

5. References

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