The Physics and Numerical Modelling of Coronal Mass Ejections

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Abstract

Our current understanding of the basic physical processes that lead to large-scale solar eruptions is reviewed. These events include coronal mass ejections (CMEs), the accompanying flare, and often an erupting filament (or prominence). The eruptions appear follow an evolution in four phases: (1) the quasi-static evolution through a series of force-free coronal magnetic equilibria with increasing free magnetic energy, (2) the activation, which is often seen as a slow rise of a filament, (3) the main acceleration of the CME (and filament if present), accompanied by the flare, and (4) the propagation phase with only very gradually changing speed through the outer corona and interplanetary space. It is not yet clear whether the first two are indeed distinct. Substantial progress in the understanding of the main physical processes involved has been achieved in the recent two decades, based on both analytical work and a large body of numerical modelling. CME models generally focus on the main acceleration phase: what determines its onset; which magnetic topology is given at the onset and through this phase; what causes the acceleration (is it an ideal-MHD process or reconnection, or both)? The currently competing models will be reviewed and put in a common framework, which allows a straightforward characterization of their overlap and differences. The instability or catastrophe of a flux rope, facilitated by reconnection in a flare current sheet, emerge as the key physical elements. The state of the art of computational studies that address these processes and of studies that attempt to reproduce certain well observed events will be illustrated. The modelling of the activation phase, which is far less developed and relies largely on numerical experiments, will also be reviewed. The triggering of eruptions by the emergence of new flux, as well as by flux cancellation, have been in the focus here. Some aspects of the propagation phase will be briefly addressed.

Recommended reading:

T. G. Forbes, J. Geophys. Res. 105, 23153 (2000)
J. A. Klimchuk, in Space Weather (Geophys. Monogr. 125), ed. P. Song et al., (Washington: AGU), p. 143 (2001)
G. Aulanier et al., ApJ 708, 314 (2010)

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CV Dr. Bernhard Kliem (as of 29 September 2010)

Professional Preparation:
Humboldt University Berlin, Germany: Physics Diploma 1974
GDR Academy of Sciences, Berlin, Germany: PhD in Plasma Physics 1987

Appointments:
Central Institute for Solar-Terrestrial Physics, Potsdam, Germany, 1974-1983: Research Assistant
Central Institute for Astrophysics, Potsdam, Germany, 1984-1991: Research Assistant/Associate
Astrophysical Institute Potsdam, Germany, 1992-1997: Senior Research Associate
University of Potsdam, Department of Physics, Germany, 1997: Senior Research Associate
Astrophysical Institute Potsdam, Germany, 1998-2007: Senior Research Associate
Kiepenheuer Institute for Solar Physics, Freiburg i.Br., Germany, 2007: Senior Research Associate
University College London, Mullard Space Science Laboratory, UK, 2008-present: Senior Research Associate
University of Potsdam, Institute of Physics and Astronomy, Potsdam, 2010-present: Senior Research Associate

Visiting Positions:
Nobeyama Radio Observatory, Japan: 09-12/2002: Visiting Professor
University of St Andrews, UK: 03-06/2004: Visiting Research Associate
George Mason University, Fairfax, VA, USA: 2008-2011: Visiting Research Associate
Naval Research Laboratory, Washington, DC, USA: 2008-2011: Visiting Research Associate

Scientific Experience:
1) Solar and stellar physics:
- Solar eruptions (CMEs, flares, prominence/filament eruptions)
- Coronal magnetic field
- Solar radio emission
- Stellar radio flares

2) Plasma physics:
- MHD instabilities
- Magnetic reconnection
- Particle acceleration
- Kinetic waves and instabilities