2008 Solar 24 Napa meeting Flare-CME Connection abstract

The Flare/CME Connection

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We present evidence supporting the view that, while many flares are produced by a confined magnetic explosion that does not produce a CME, every CME is produced by an ejective magnetic explosion that also produces a flare. The evidence is that the observed heliocentric angular width of the full-blown CME plasmoid in the outer corona (at 3 to 20 solar radii) is about that predicted by the "standard" model for CME production, from the amount of magnetic flux covered by the co-produced flare arcade. In the standard model, sheared and twisted sigmoidal field in the core of an initially closed magnetic arcade erupts. As it erupts, tether-cutting reconnection, starting between the legs of the erupting sigmoid and continuing between the merging stretched legs of the enveloping arcade, simultaneously produces a growing flare arcade and unleashes the erupting sigmoid and arcade to become the low-beta plasmoid (magnetic bubble) that becomes the CME. The flare arcade is the downward product of the reconnection and the CME plasmoid is the upward product. The unleashed, expanding CME plasmoid is propelled into the outer corona and solar wind by its own magnetic field pushing on the surrounding field in the inner and outer corona. This tether-cutting scenario predicts that the amount of magnetic flux in the full-blown CME plasmoid nearly equals that covered by the full-grown flare arcade. This equality predicts (1) the field strength in the flare region from the ratio of the angular width of the CME in the outer corona to angular width of the full-grown flare arcade, and (2) an upper bound on the angular width of the CME in the outer corona from the total magnetic flux in the active region from which the CME explodes. We show that these predictions are fulfilled by observed CMEs. This agreement validates the standard model. The model explains (1) why most CMEs have much greater angular widths than their co-produced flares, and (2) why the radial path of a CME in the outer corona can be laterally far offset from the co-produced flare.

This work was supported by NASA's Science Mission Directorate through its Heliophysics Guest Investigators Program, Its Living With a Star Targeted Research & Technology Program, and its Solar and Heliospheric Physics Supporting Research & Technology Program; and by NSF through its SHINE Program.

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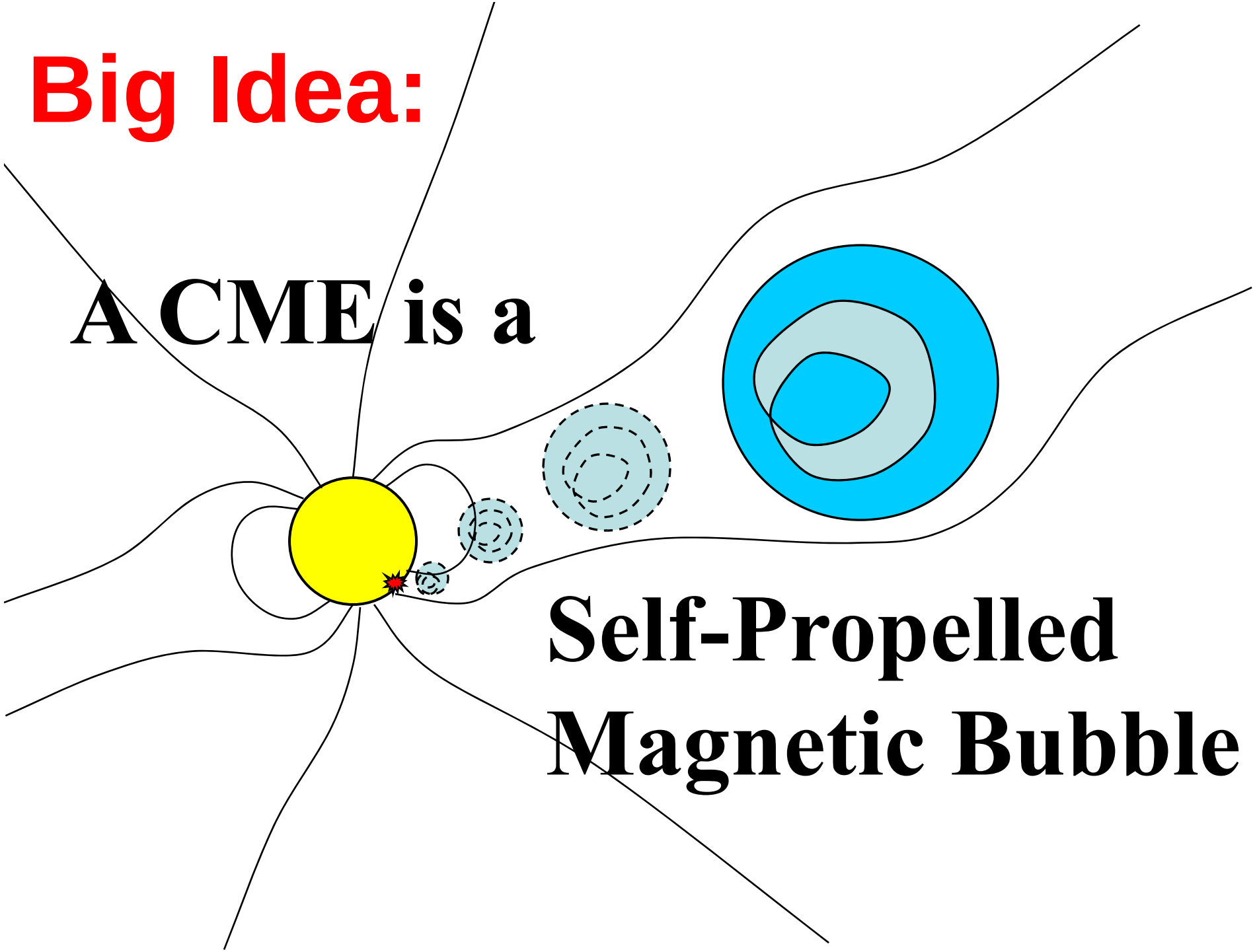
Big Idea:

A CME is a



Self-Propelled Magnetic Bubble

Main Points

- **The "standard model" for CME production is the right physical picture.**
- **A CME is a magnetically inflated (low-beta) "plasmoid with legs."**
- **The CME plasmoid is produced together with a flare by tether-cutting reconnection.**
- **The CME plasmoid propels itself by pushing on the surrounding coronal magnetic field.**
- **The CME plasmoid expands to become much wider than the source-region flare.**
- **The CME can become laterally far offset from the flare.**

Outline

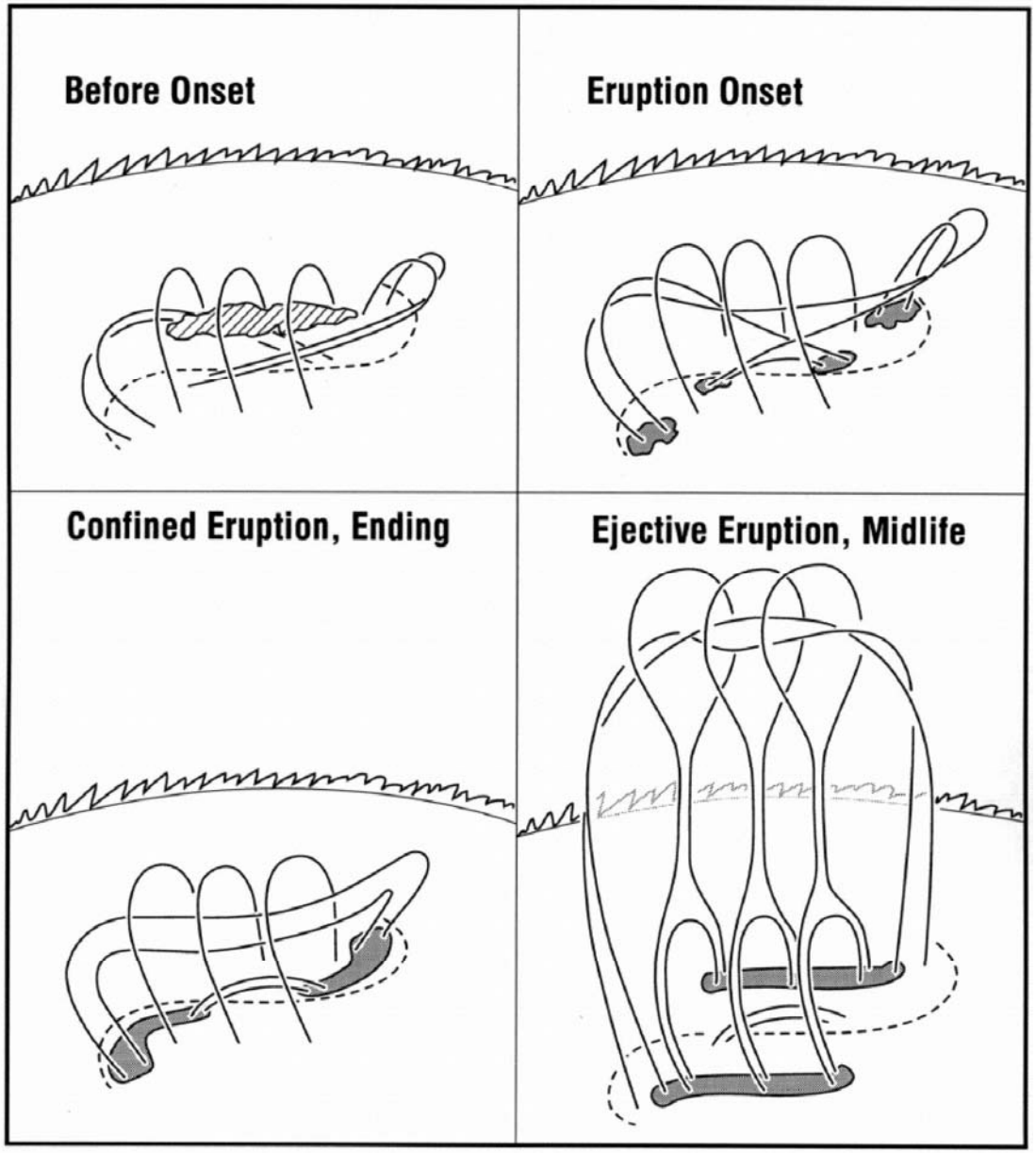
I. Introduction

II. Standard Model for CME Production

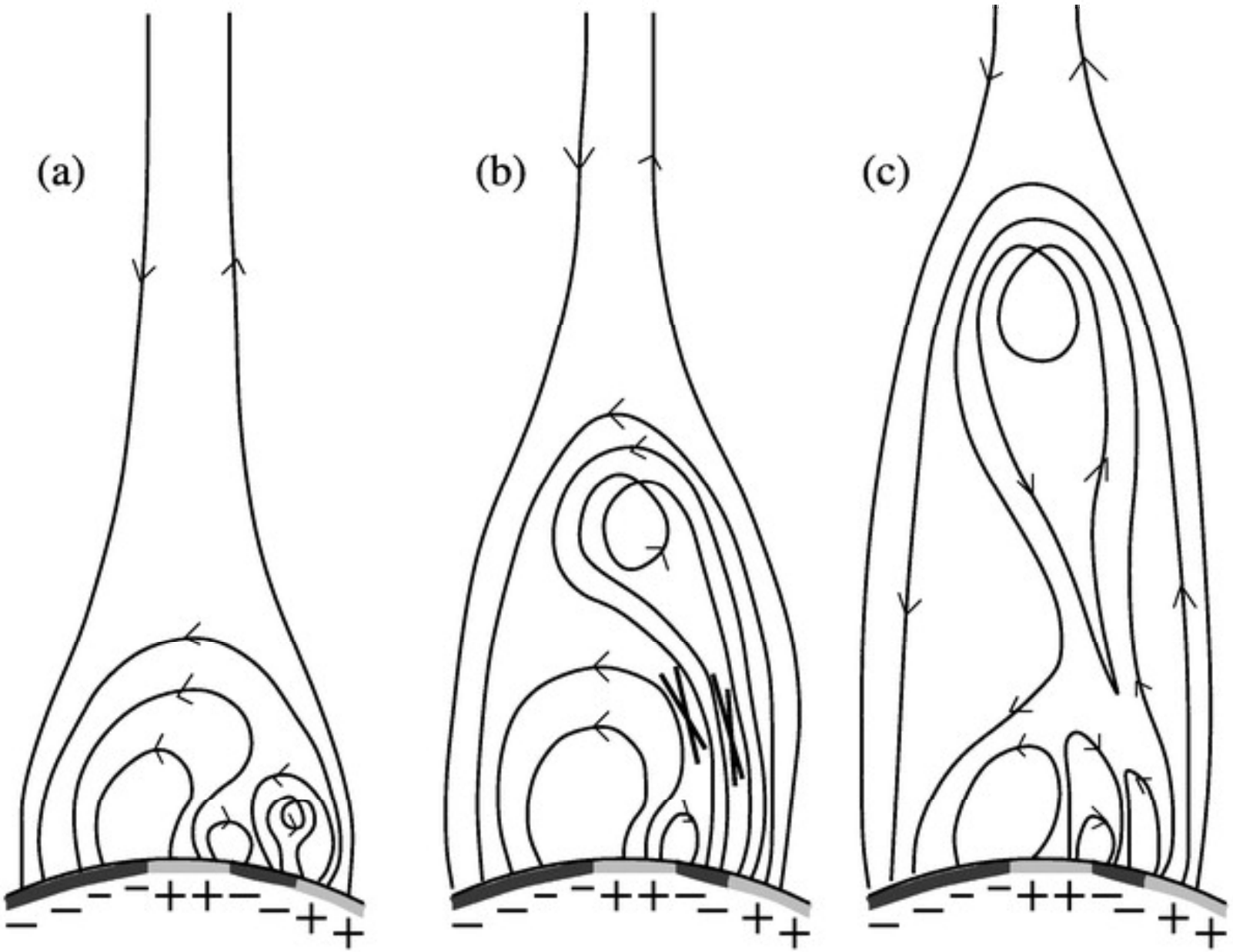
III. Observational Tests

IV. Conclusion

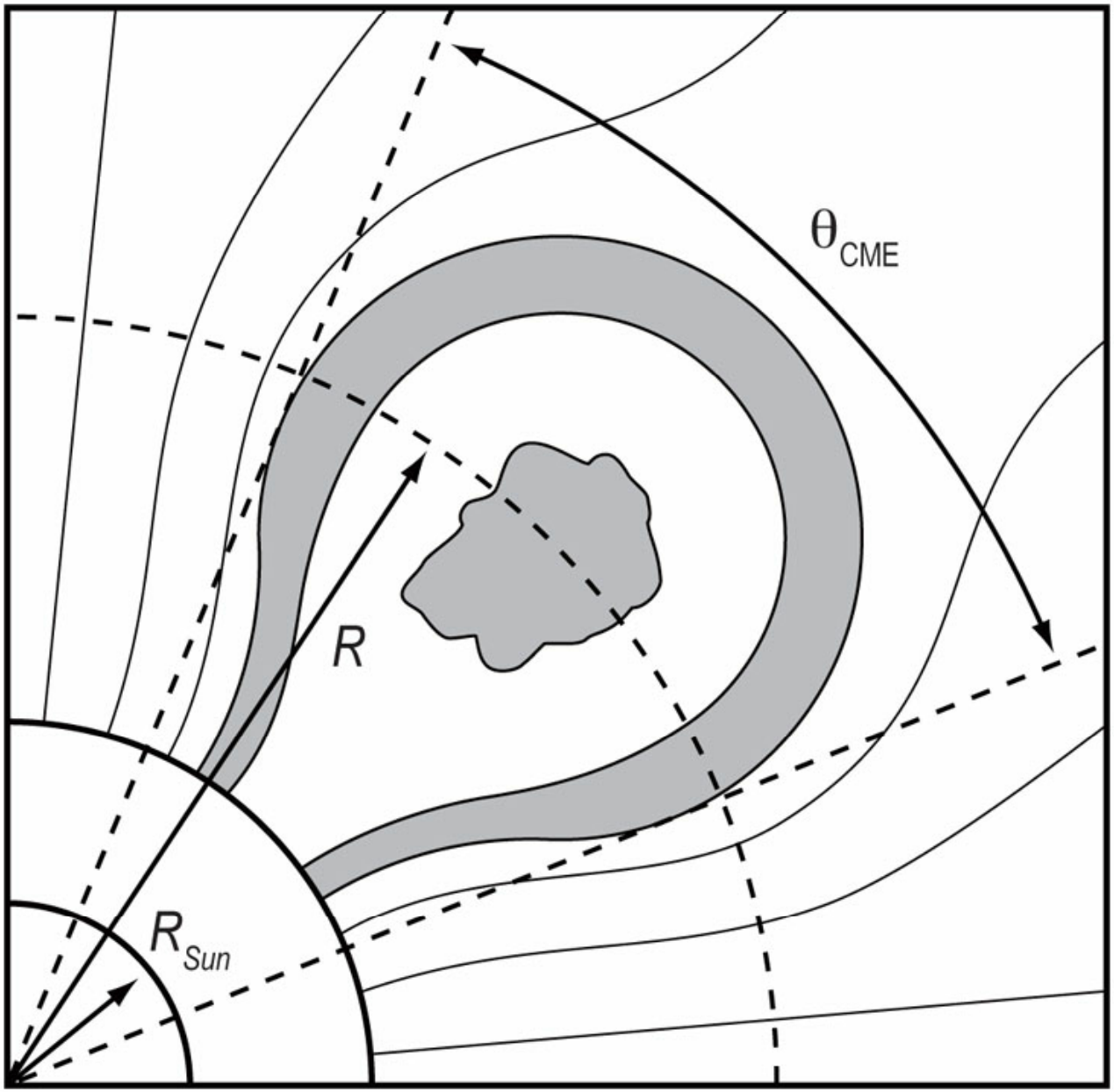
Birth and Release of the CME Plasmoid



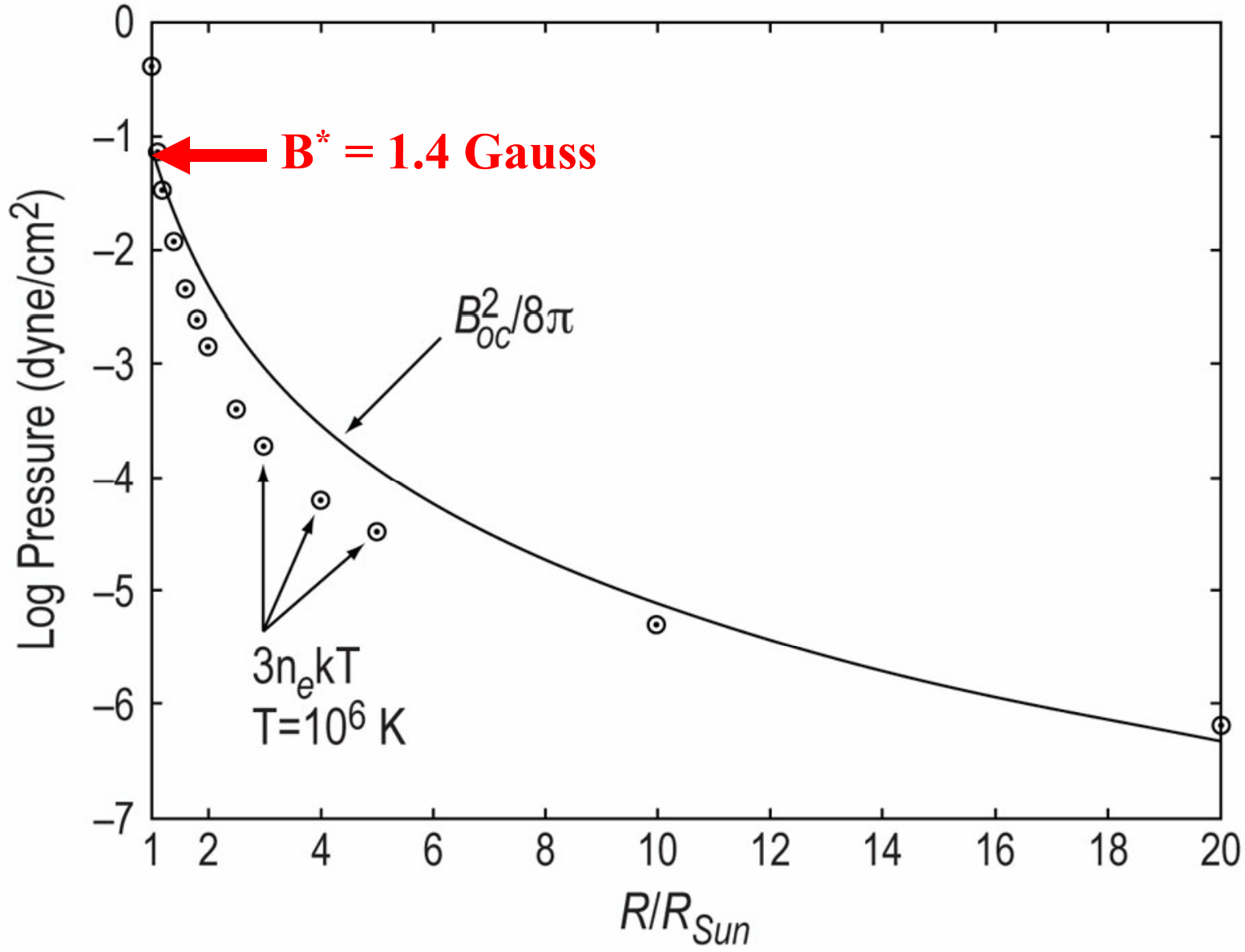
Escape Path Determined by Surrounding Field



Resulting CME in Outer Corona



Lateral Pressure in Outer Corona



Two Testable Predictions of the Standard Model for CME Production:

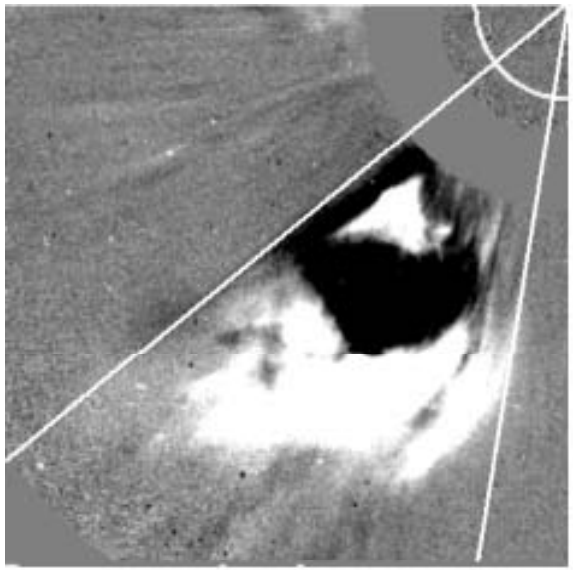
1. $B_{Flare} \approx 1.4(\theta_{CME}/\theta_{Flare})^2$ Gauss

2. $\theta_{CME} \leq (\Phi_{AR}/1.4)^{1/2}(R_{Sun})^{-1}$ radians

Our 3 Test CMEs

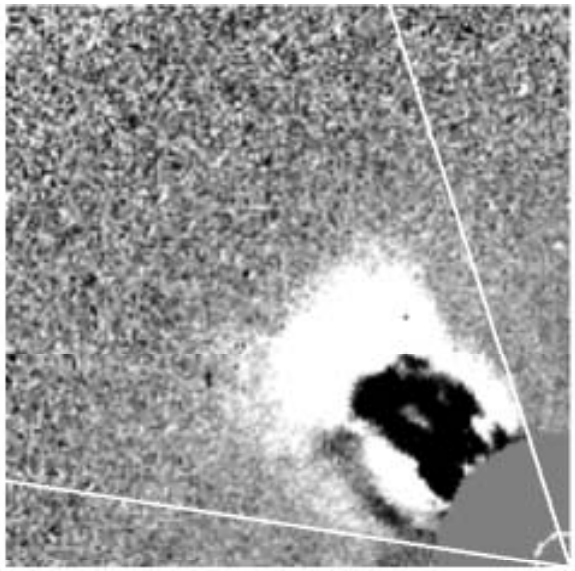
at Final Width in Outer Corona

2002 May 20



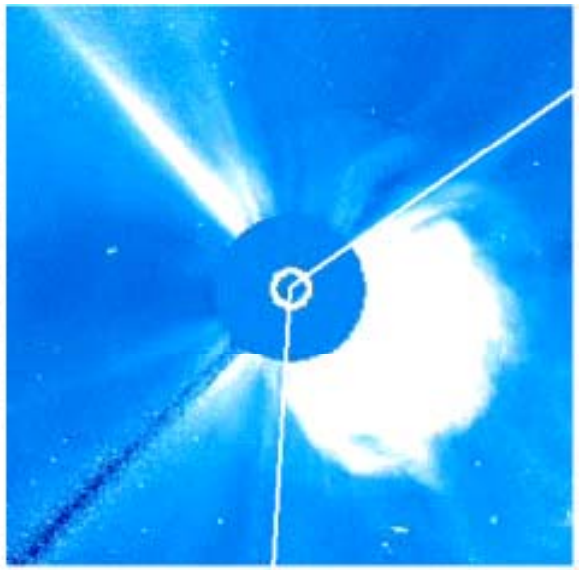
C2 Difference Image

1999 Feb 9



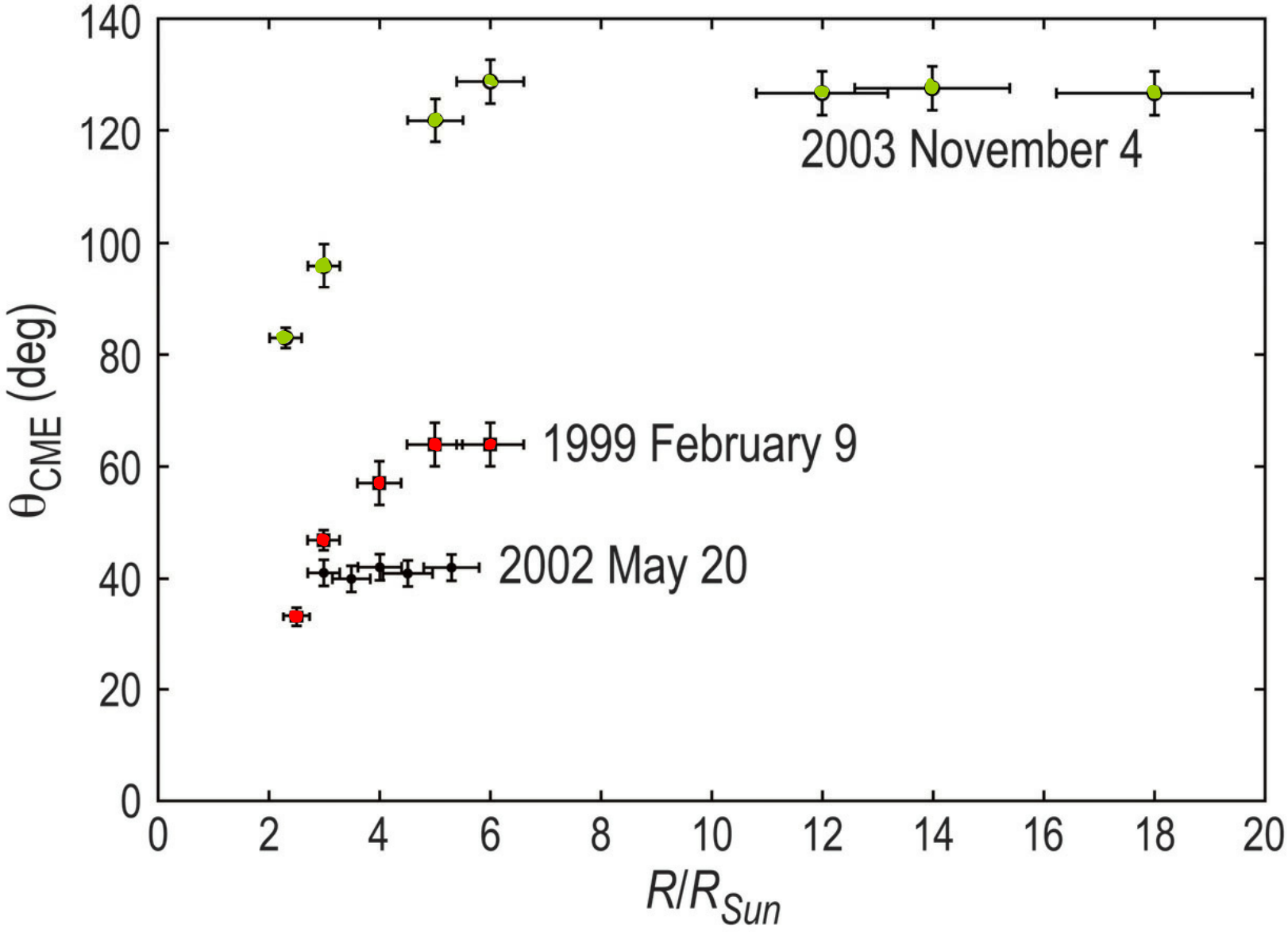
C3 Difference Image

2003 Nov 4

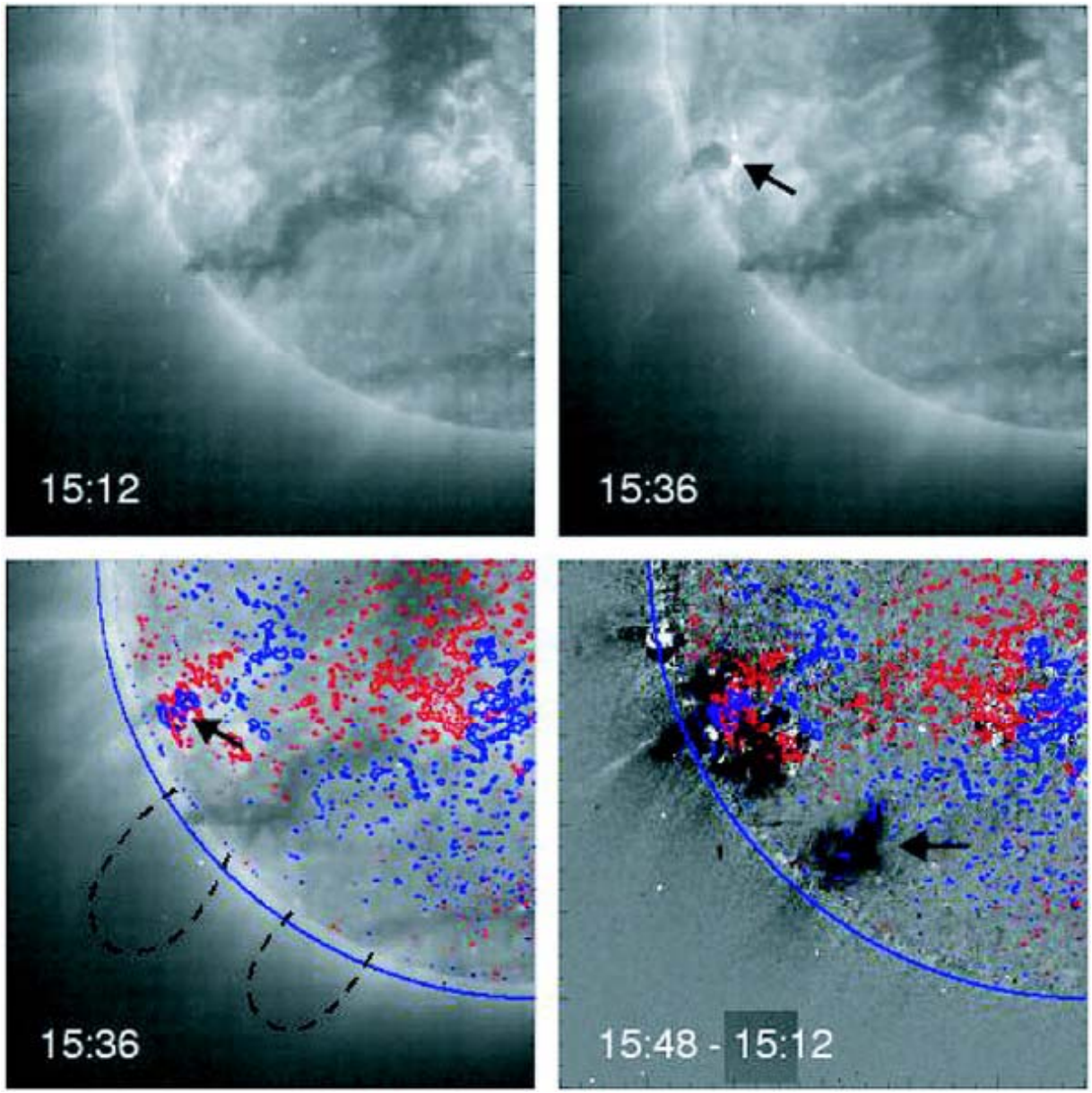


C3 Direct Image

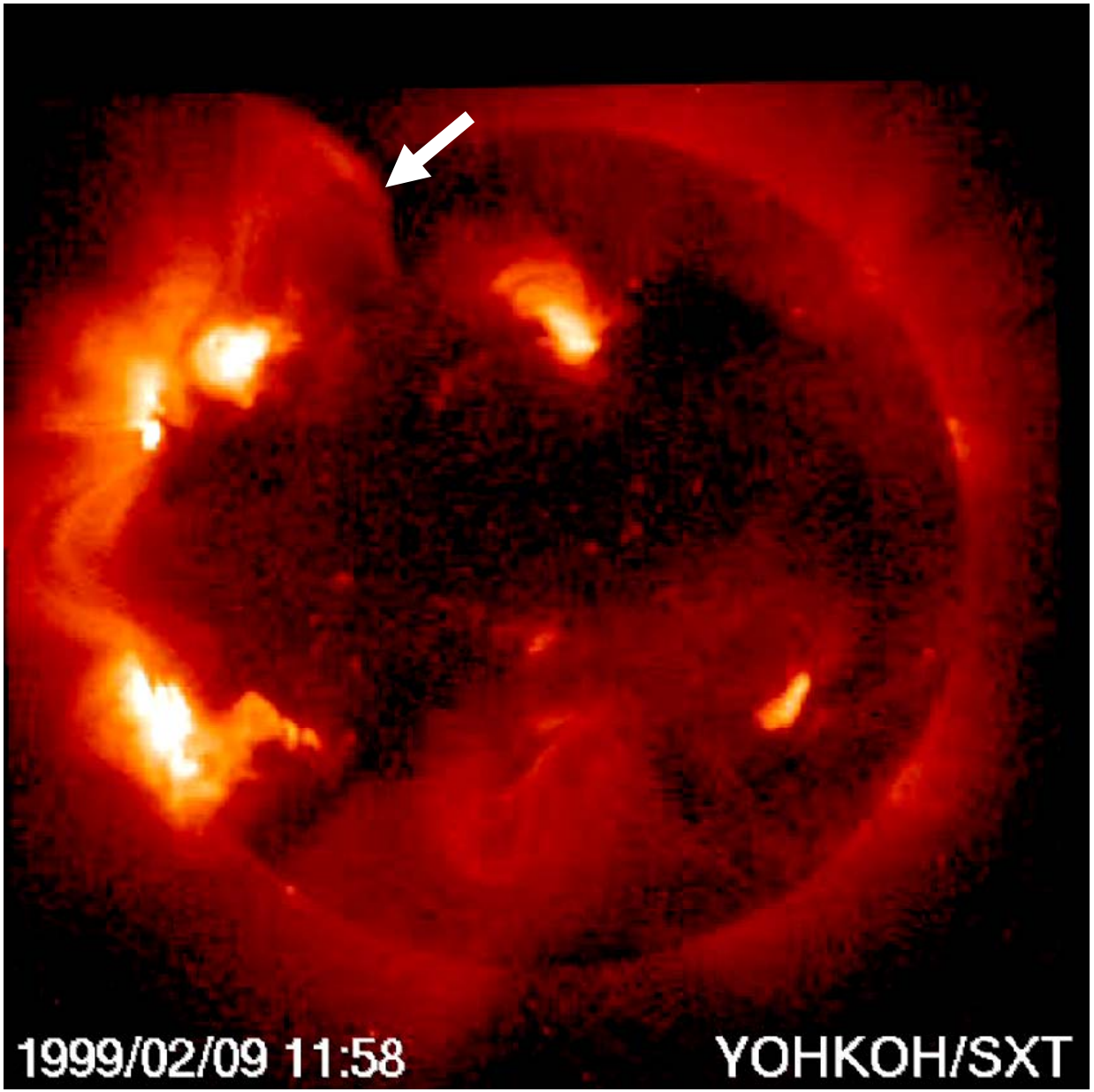
Measured Angular Widths of each CME



Source of the CME of 2002 May 20

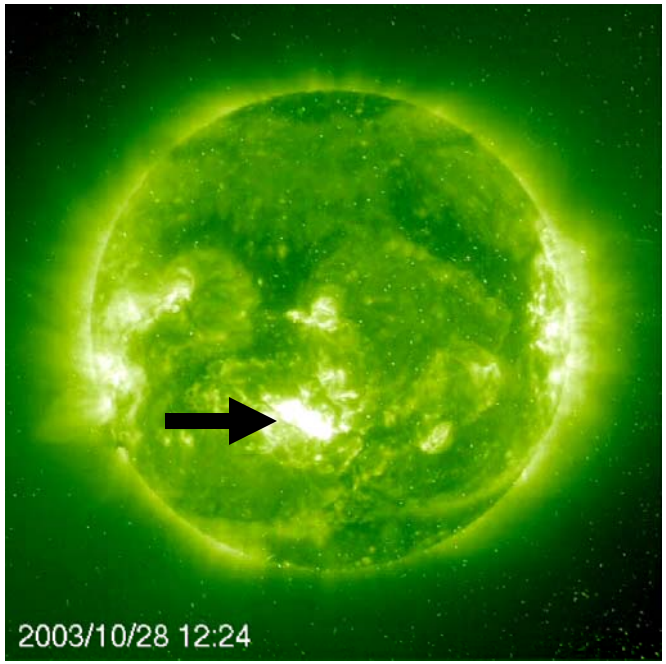


Source of the CME of 1999 Feb 9



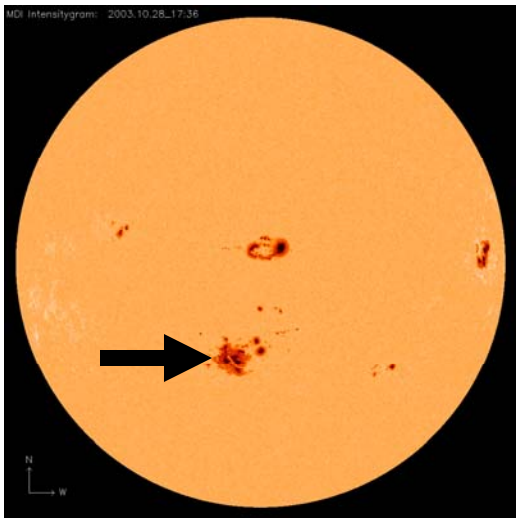
Source of the CME of 2003 Nov 4

Oct 28 X17 Flare Arcade



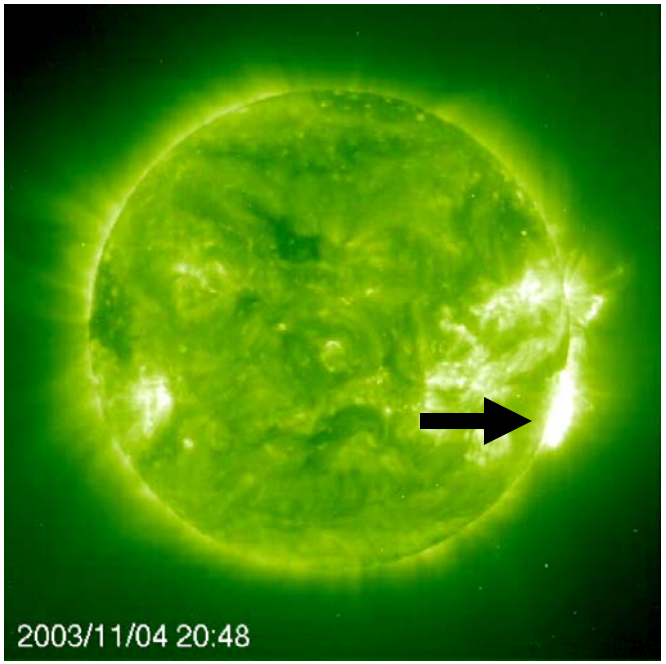
EIT 195 Å Corona

Giant δ Sunspot Centered Under Flare Arcade



MDI Photosphere

Nov 4 X20 Flare Arcade

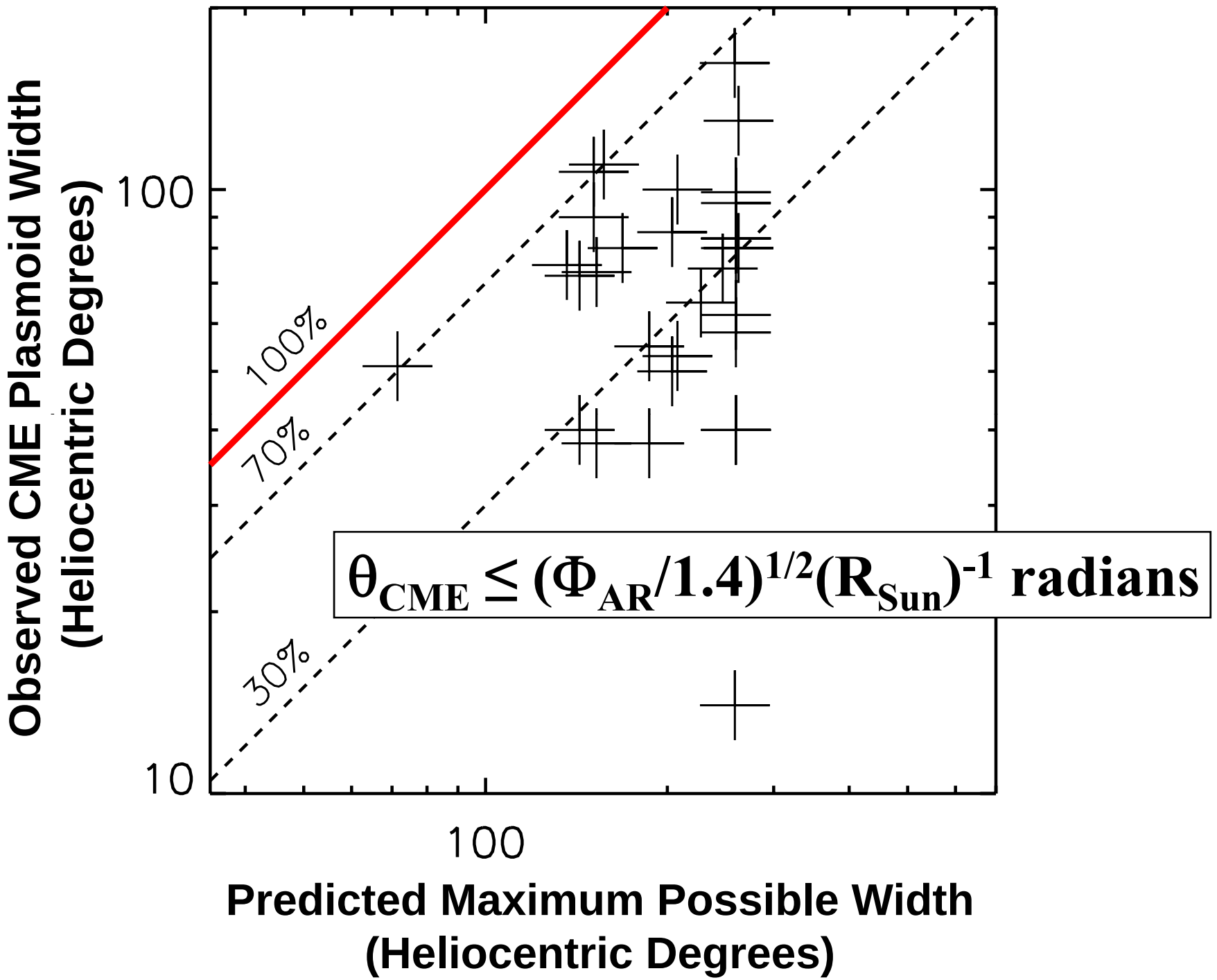


EIT 195 Å Corona

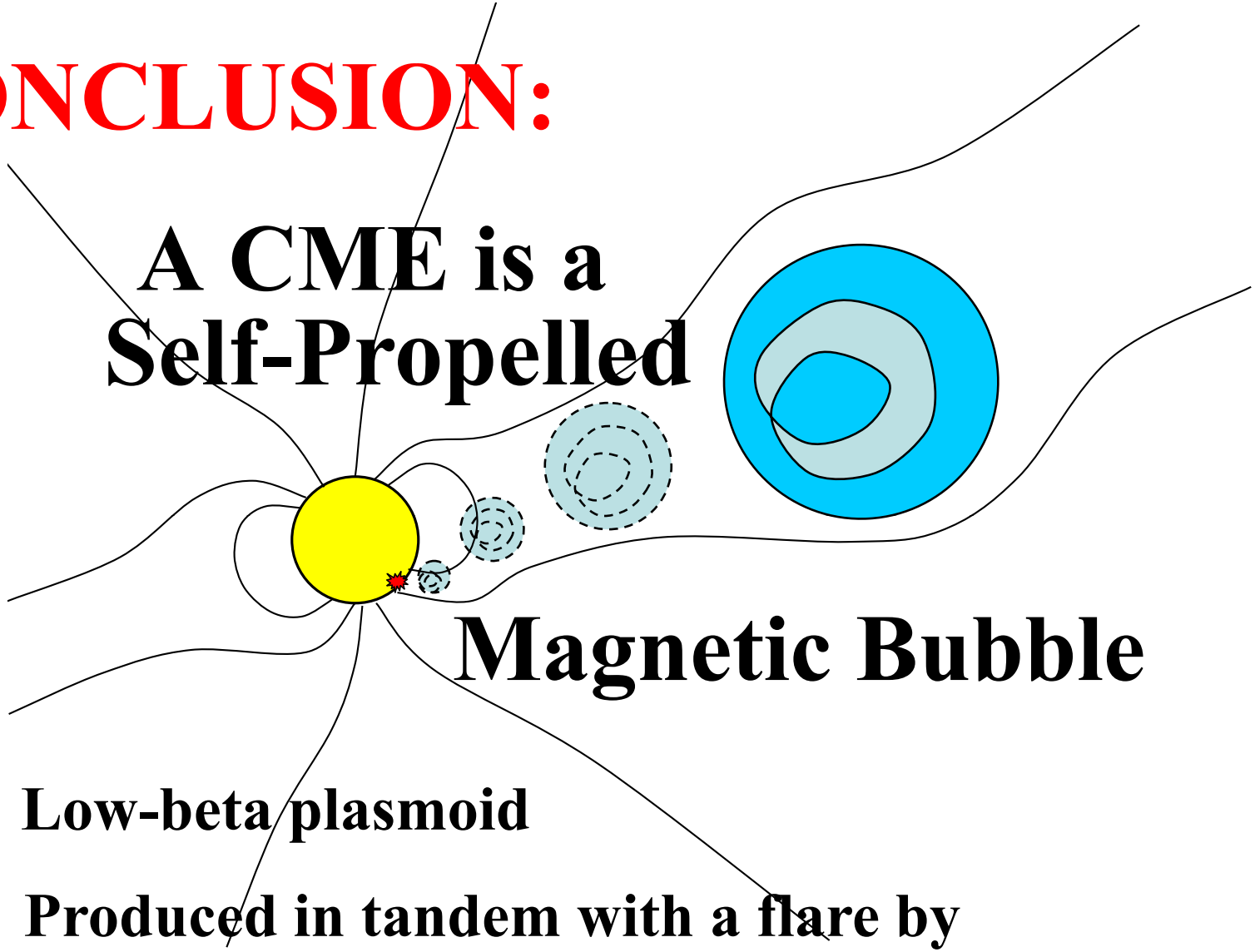
Test Results

CME (date)	Source Region	θ_{CME} (deg)	θ_{Flare} (deg)	Predicted* B_{Flare} (Gauss)	Predicted B_{Flare} Fits Source Region? (Yes/No)
2002 May 20	Centered on small δ spot	41	2.2	≈ 490	Yes
1999 Feb 9	Quiet region filament arcade	64	27	≈ 8	Yes
2003 Nov 4	Centered on giant δ spot	128	8.7	≈ 300	Yes

* Predicted $B_{Flare} \approx 1.4(\theta_{CME}/\theta_{Flare})^2$ Gauss


Observed CME Plasmoid Width
(Heliocentric Degrees)
100
10
100
100%
70%
30%
$\theta_{CME} \leq (\Phi_{AR}/1.4)^{1/2}(R_{Sun})^{-1}$ radians
Predicted Maximum Possible Width
(Heliocentric Degrees)

CONCLUSION:



- Low-beta plasmoid
- Produced in tandem with a flare by tether-cutting reconnection
- Propelled by own magnetic field pushing on surrounding field

Abstract

We present evidence supporting the view that, while many flares are produced by a confined magnetic explosion that does not produce a CME, every CME is produced by an ejective magnetic explosion that also produces a flare. The evidence is that the observed heliocentric angular width of the full-blown CME plasmoid in the outer corona (at 3 t0 20 solar radii) is about that predicted by the "standard" model for CME production, from the amount of magnetic flux covered by the co-produced flare arcade. In the standard model, sheared and twisted sigmoidal field in the core of an initially closed magnetic arcade erupts. As it erupts, tether-cutting reconnection, starting between the legs of the erupting sigmoid and continuing between the merging stretched legs of the enveloping arcade, simultaneously produces a growing flare arcade and builds and unleashes the low-beta plasmoid (magnetic bubble) that escapes to become the CME. The flare arcade is the downward product of the reconnection and the CME plasmoid is the upward product. The unleashed, expanding CME plasmoid is propelled into the outer corona and solar wind by its own magnetic field pushing on the surrounding field in the inner and outer corona. This tether-cutting scenario predicts that the amount of magnetic flux in the full-blown CME plasmoid nearly equals that covered by the full-grown flare arcade. This equality predicts (1) the field strength in the flare region from the ratio of the angular width of the CME in the outer corona to the angular width of the full-grown flare arcade, and (2) an upper bound on the angular width of the CME in the outer corona from the total magnetic flux in the active region from which the CME explodes. We show that these predictions are fulfilled by observed CMEs. This agreement validates the standard model. The model explains (1) why most CMEs have much greater angular widths than their co-produced flares, and (2) why the radial path of a CME in the outer corona can be laterally far offset from the co-produced flare.

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