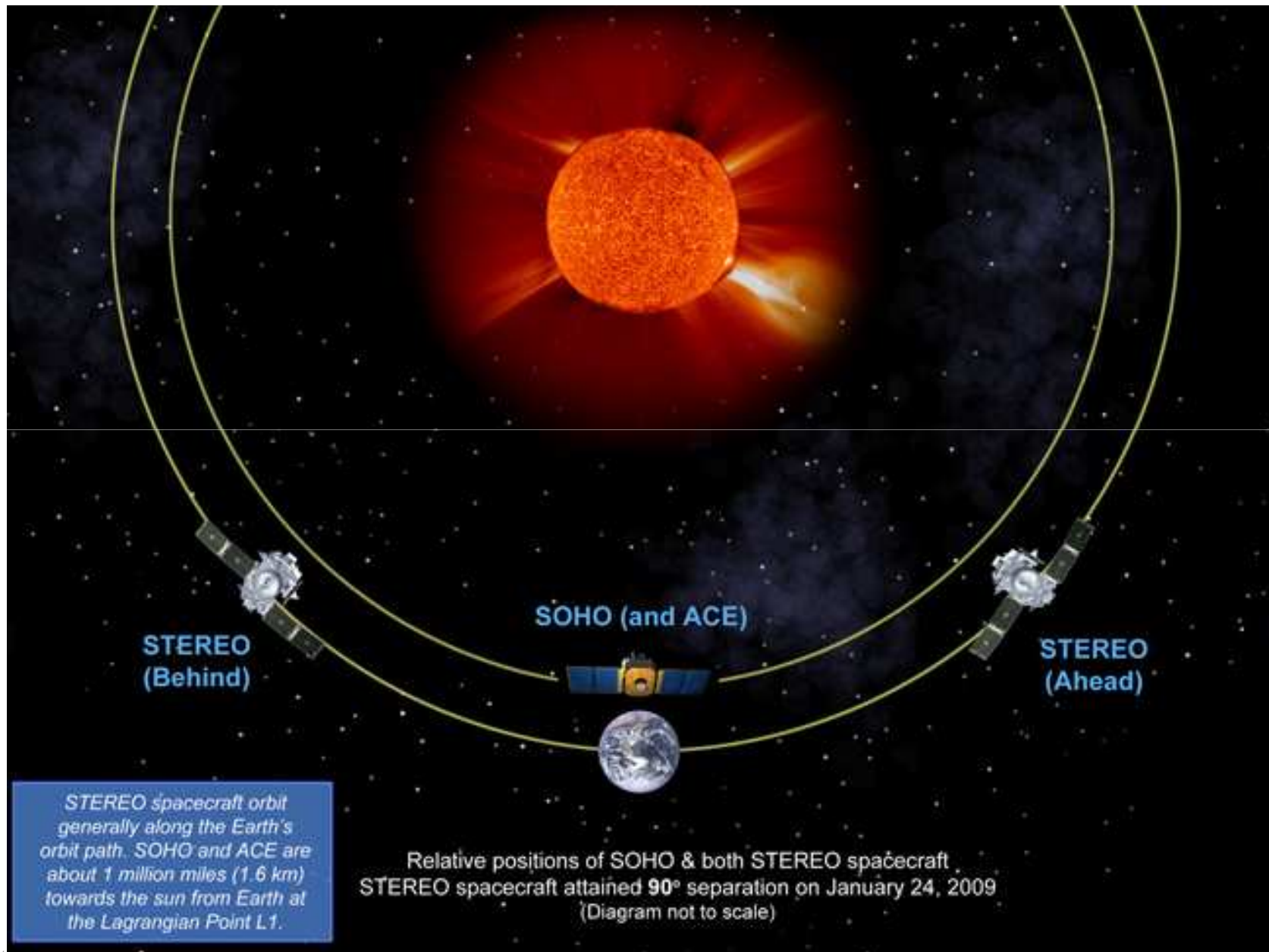


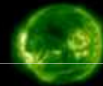
Hurrikans im Sonnenwind

Christian Möstl

Institut für Weltraumforschung, ÖAW, Graz

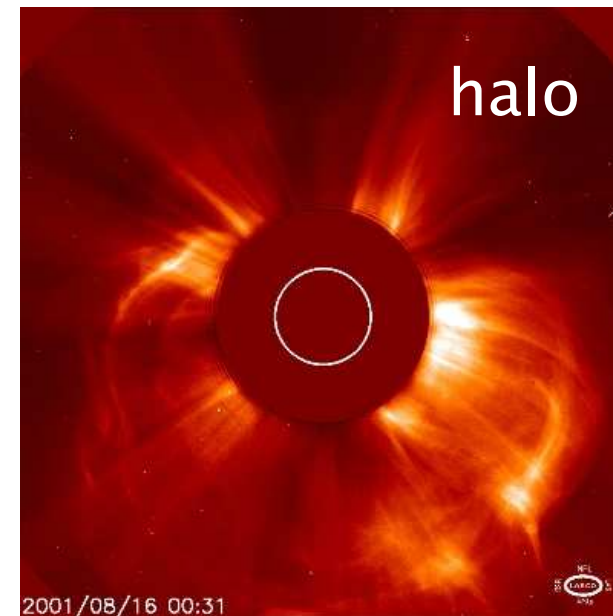
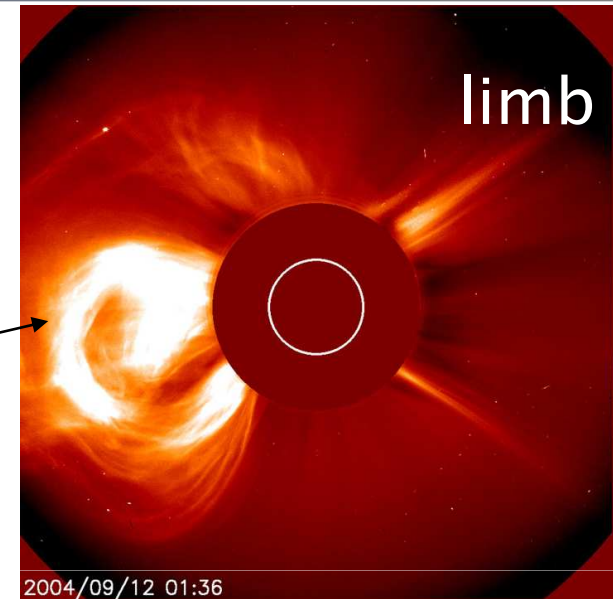
Graz in Space 2010

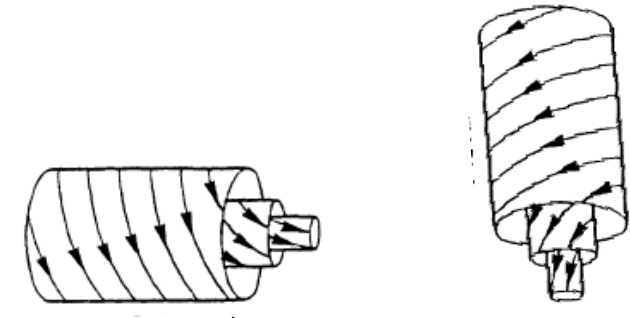
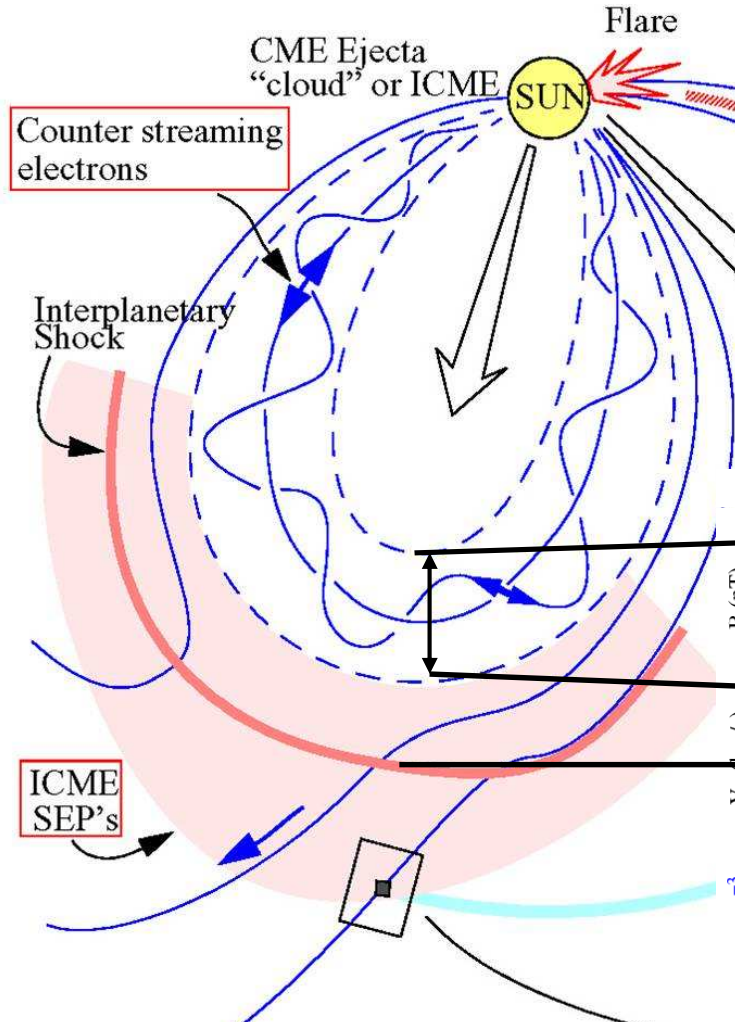




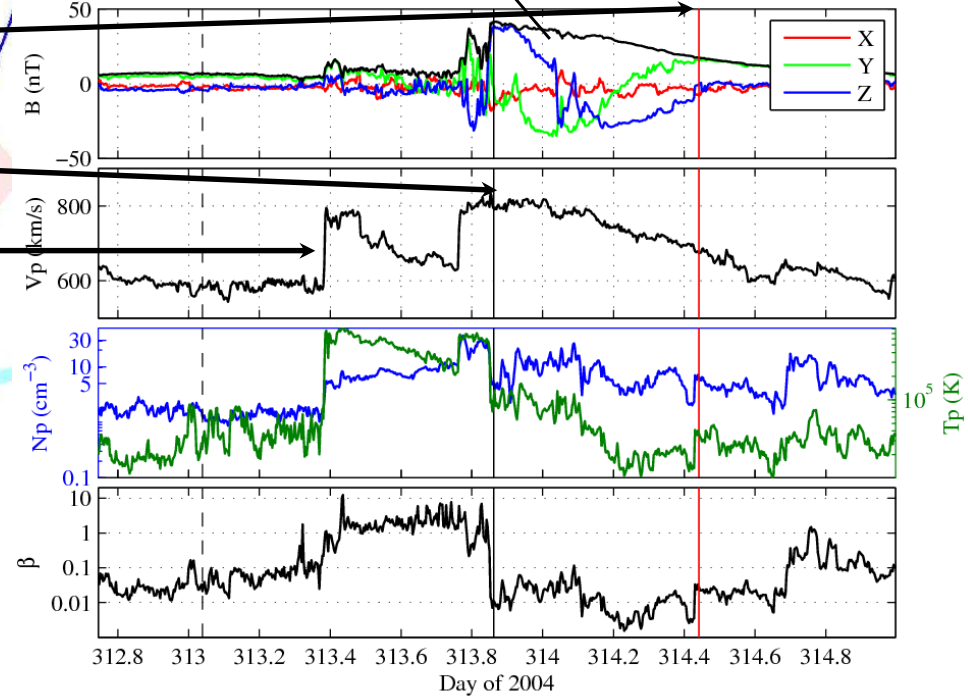
2003 Oct 25 00:00:12

- Koronale Masseauswürfe – *Coronal mass ejections (CMEs)*
- 1971 entdeckt (OSO-7)
- Die grössten Stürme im Sonnenwind (deswegen Hurrikans...)
- 3 teilige Struktur (leading edge, core, void)
- Größe: Sonne: $\sim R_s$ 1 AU: bis 0.4 AU
- Masse $\sim 10^{12}$ kg
- Energie: bis 10^{25} J
- B: bei 1 AU: < 60 nT
- V: 200 – 3000 km/s
- Sonne–Erde: 14 h – 5 Tage
- Stosswelle verursacht energiereiche Teilchen



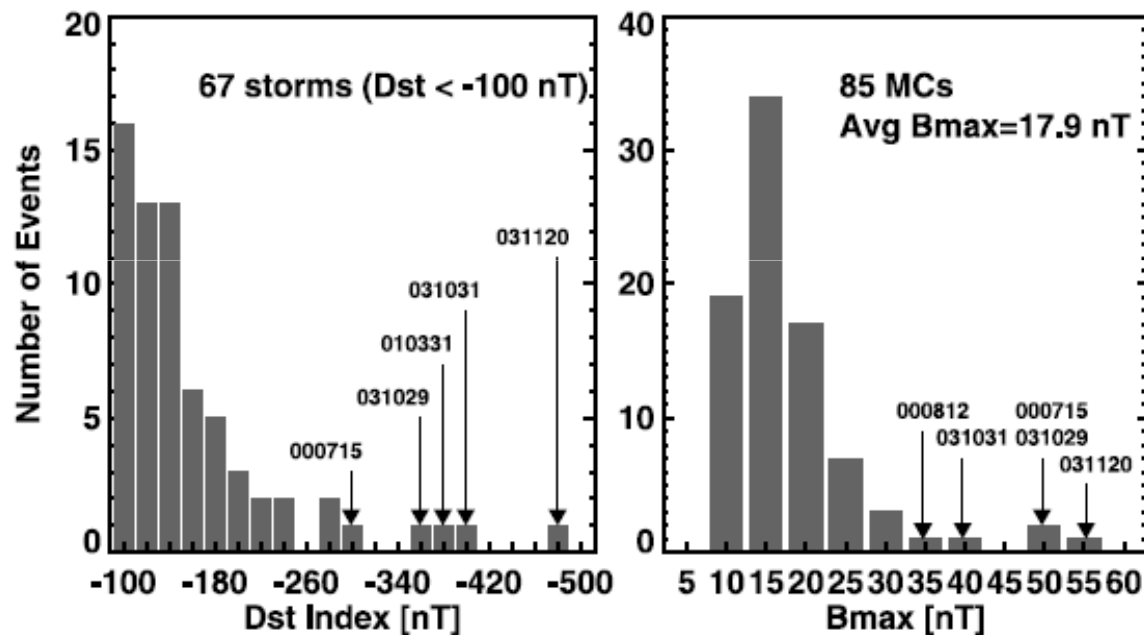


ACE 11/9/2004 20:40:0–11/10/2004 10:36:0 $\Delta t = 4$ min

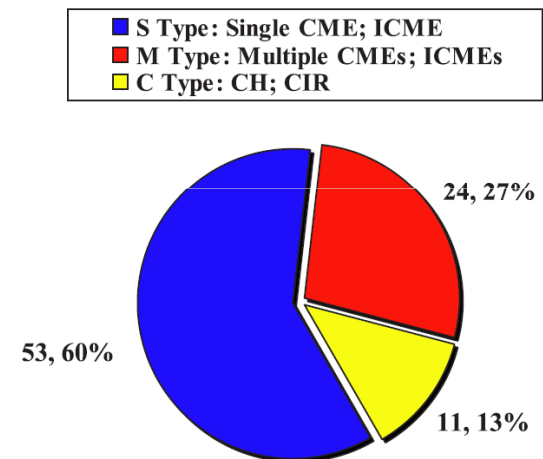


„Interplanetary coronal mass ejection“
 „Magnetic cloud“

- CMEs lösen die stärksten geomagnetischen Stürme aus



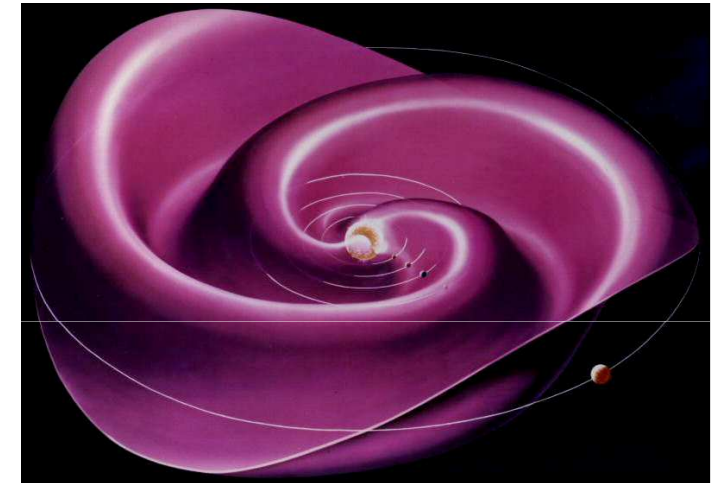
Solar-IP Sources of 88 Major Geomagnetic Storms



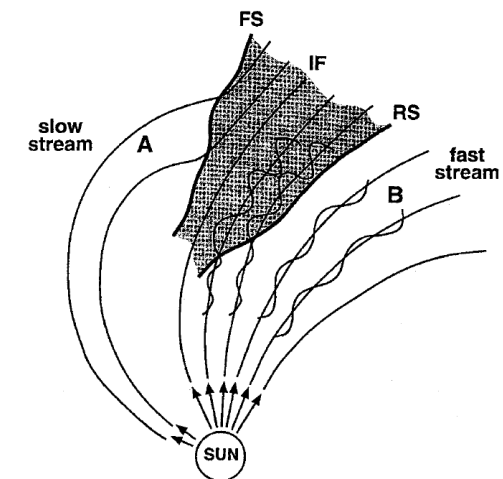
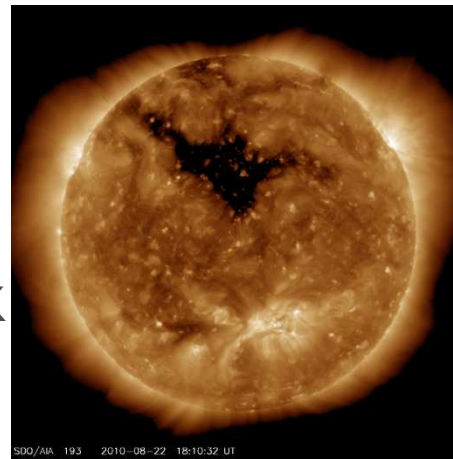
Zhang et al., 2007, JGR

Gopalswamy et al., 2005, GRL

- L. Biermann 1951: Unterschiedliche Kometenschweife
- Parker 1958: Sonnenatmosphäre ist so heiß dass sie mit Überschall abströmt, „Parkerspirale“
- Existenz Bestätigt von Luna 1 1959, Mariner 2 1963
- Ungelöst bis heute:
zu starke und zu frühe Beschleunigung



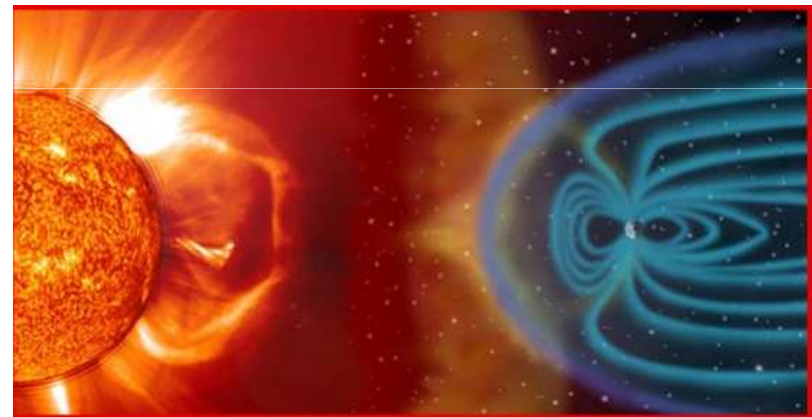
- **Plasma**
300–800 km/s
3–10 Teilchen pro ccm^3
95% p, 4% He+,
e- sodass neutral
Magnetfeld: 4 nT
Tp~40 000 K, Te ~150 000 K



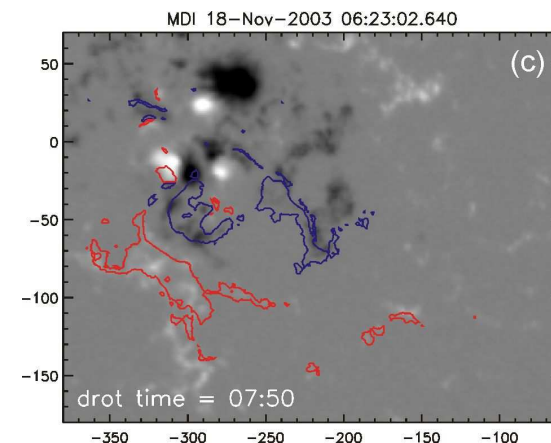
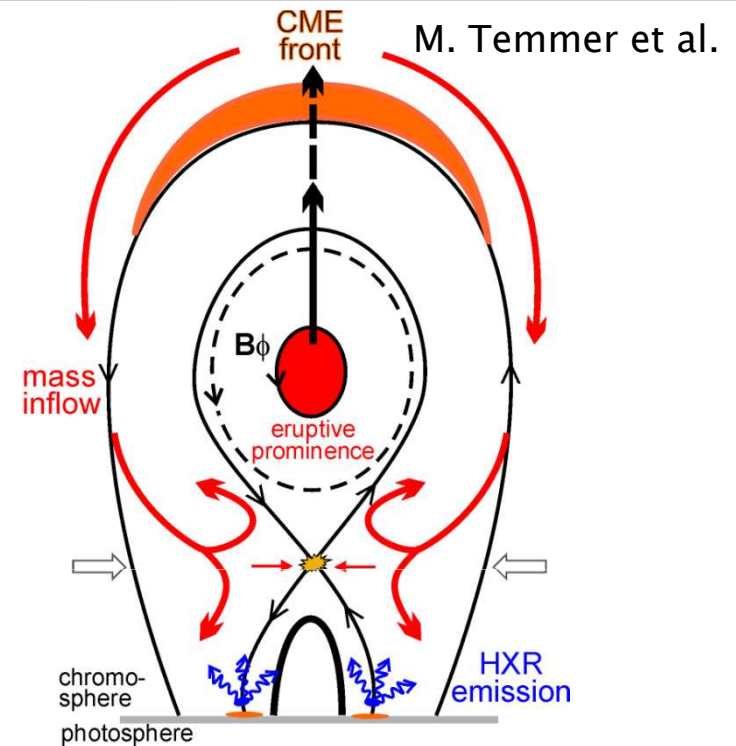
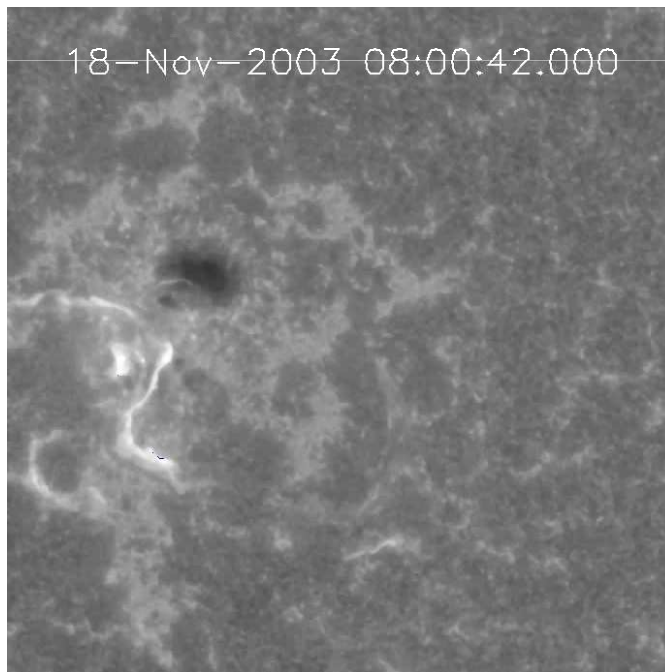
- **Verknüpfung der unterschiedlichen Beobachtungen (Koronograph + in situ)**
 - > Sind alle CMEs gleich aufgebaut?
 - > Wie sehen sie in Erdnähe aus?
- **Ausbreitung im Sonnenwind**

Schnelle werden abgebremst, langsame beschleunigt

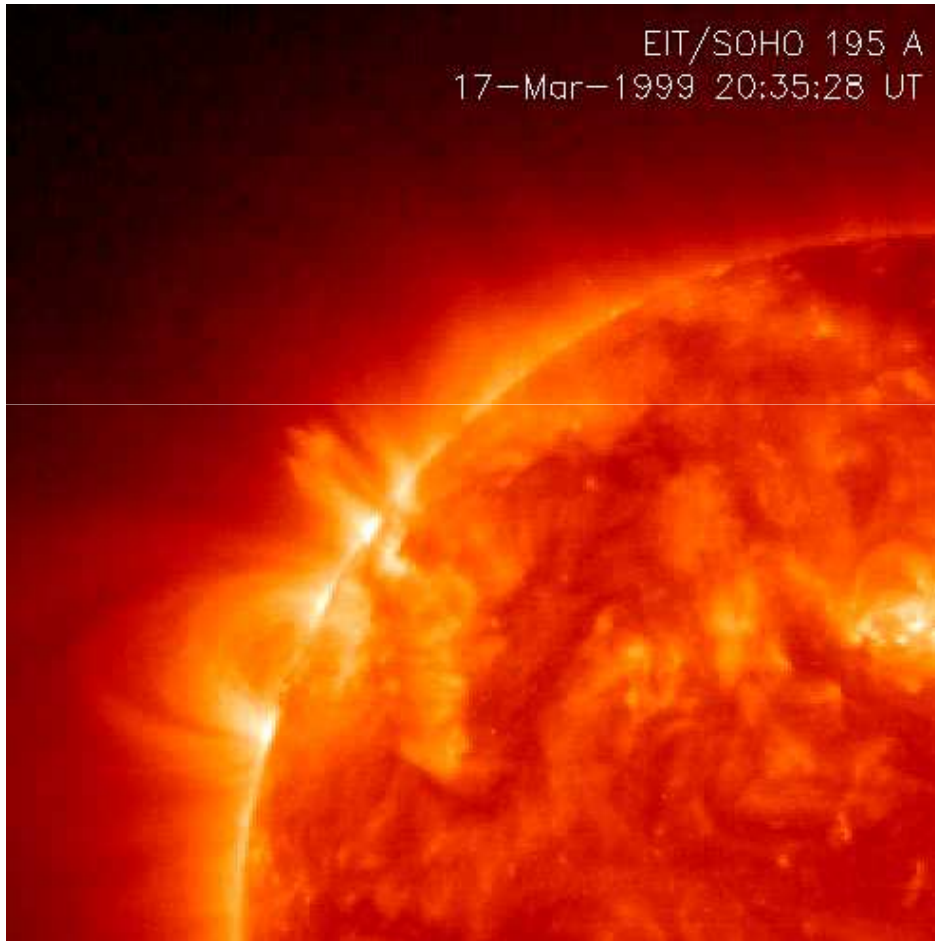
 - > Berechnung der Ankunftszeit
(zur Zeit Fehler +/- 1 Tag)
- **Wird Erde getroffen oder nicht?**
 - > Richtungsberechnung
 - > Magnetfeld im inneren?
- **Wie funktioniert eine CME?**
 - > was ist der Auslöser?
 - > Entstehung einer Flussröhre während oder vor der Eruption?
 - > Ausbruchzeitpunkt vorhersagbar?



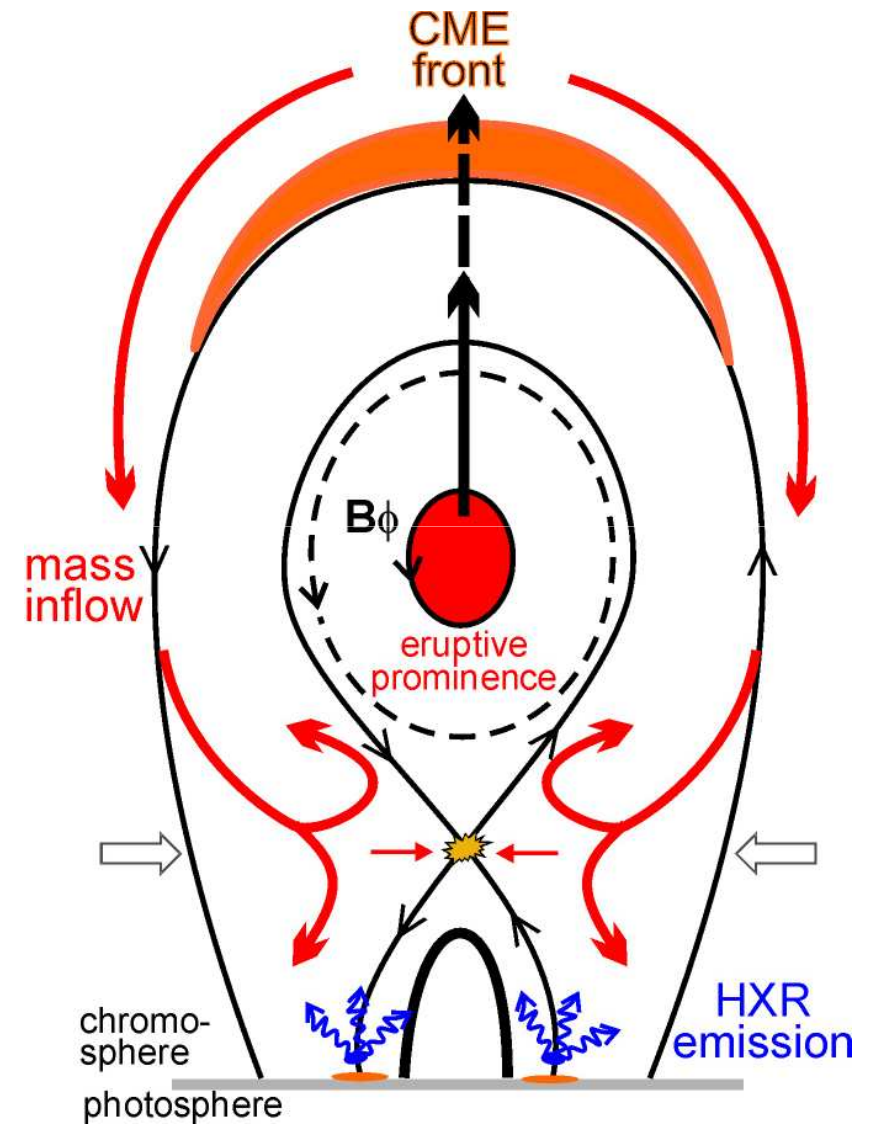
- Filament bewegt sich nach oben
- *Magnetische Rekonnexion*
Energie im **Magnetfeld** staut sich auf und wird plötzlich in kinetische und thermische Energie umgewandelt
- *Flare ribbons*



Miklenic et al. (2007)

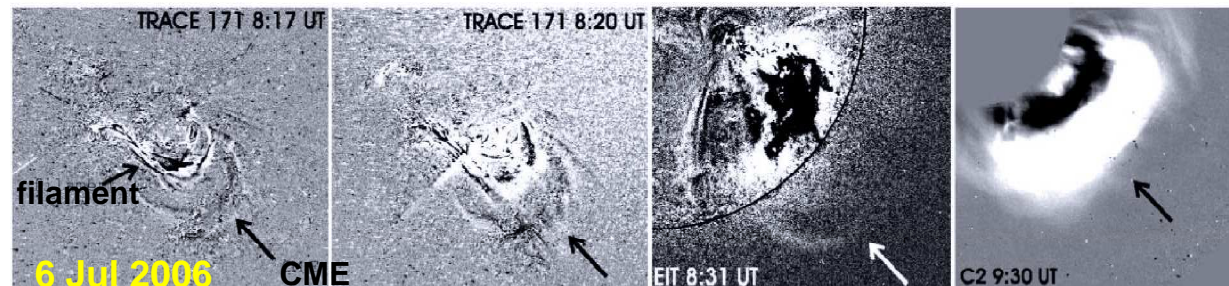


Post flare loops

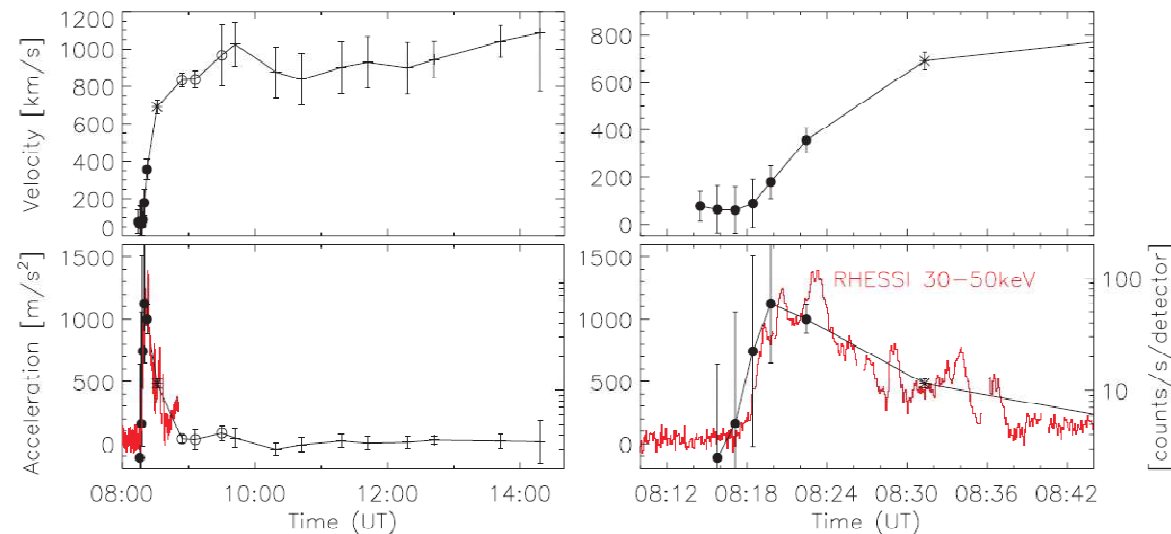


- Nicht jedes flare ist mit einer CME verknüpft und umgekehrt-
- Ursache und Wirkung nur schwer zu unterscheiden
- “Timing” ist ein guter Test für das Standardmodell

Synchron:
CME Beschleunigung
+ Röntgen Emission



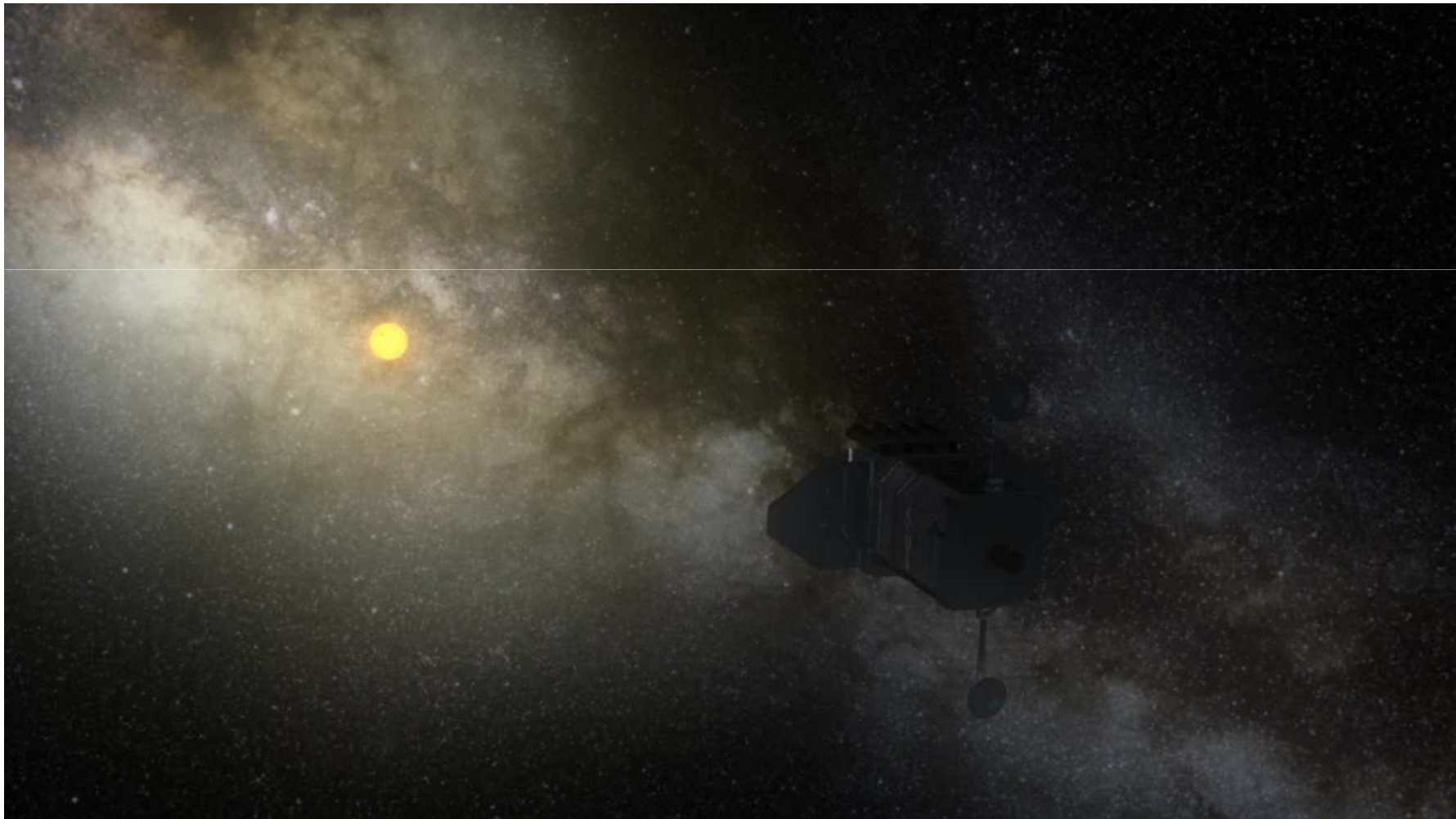
Temmer et al. 2008
*The Astrophysical
Journal Letters*





Launched 11 February 2010

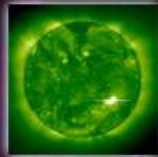
- e.g.: AIA: 4 EUV telescopes / 10s / 4096x4096 -> daily 1,5 TB



Relative Image Resolution



480 Standard
Definition TV



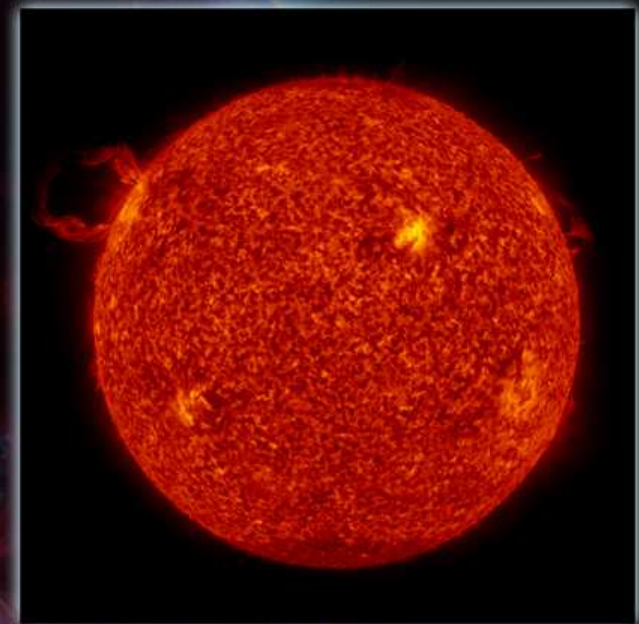
SOHO



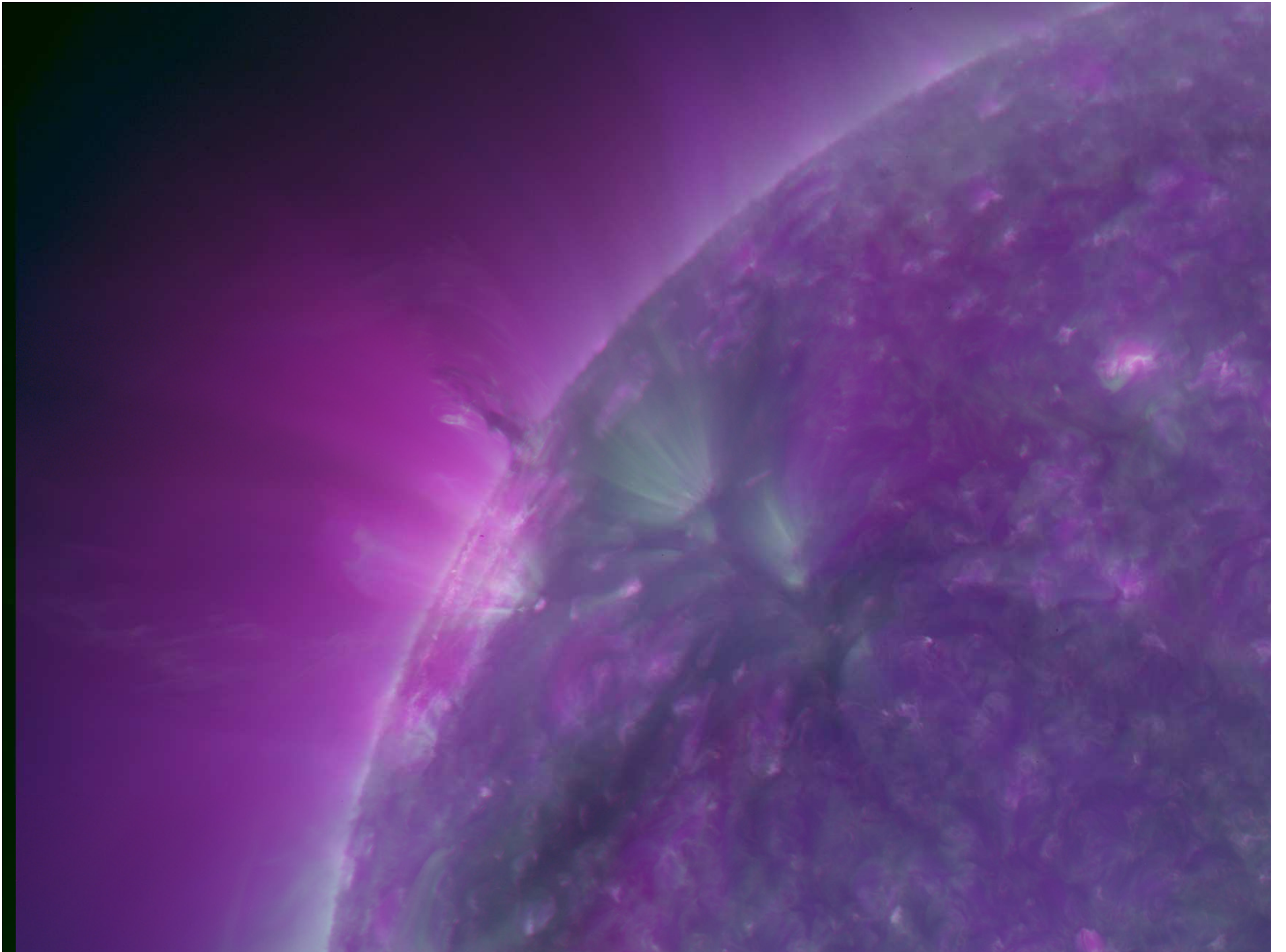
1080 High Definition TV

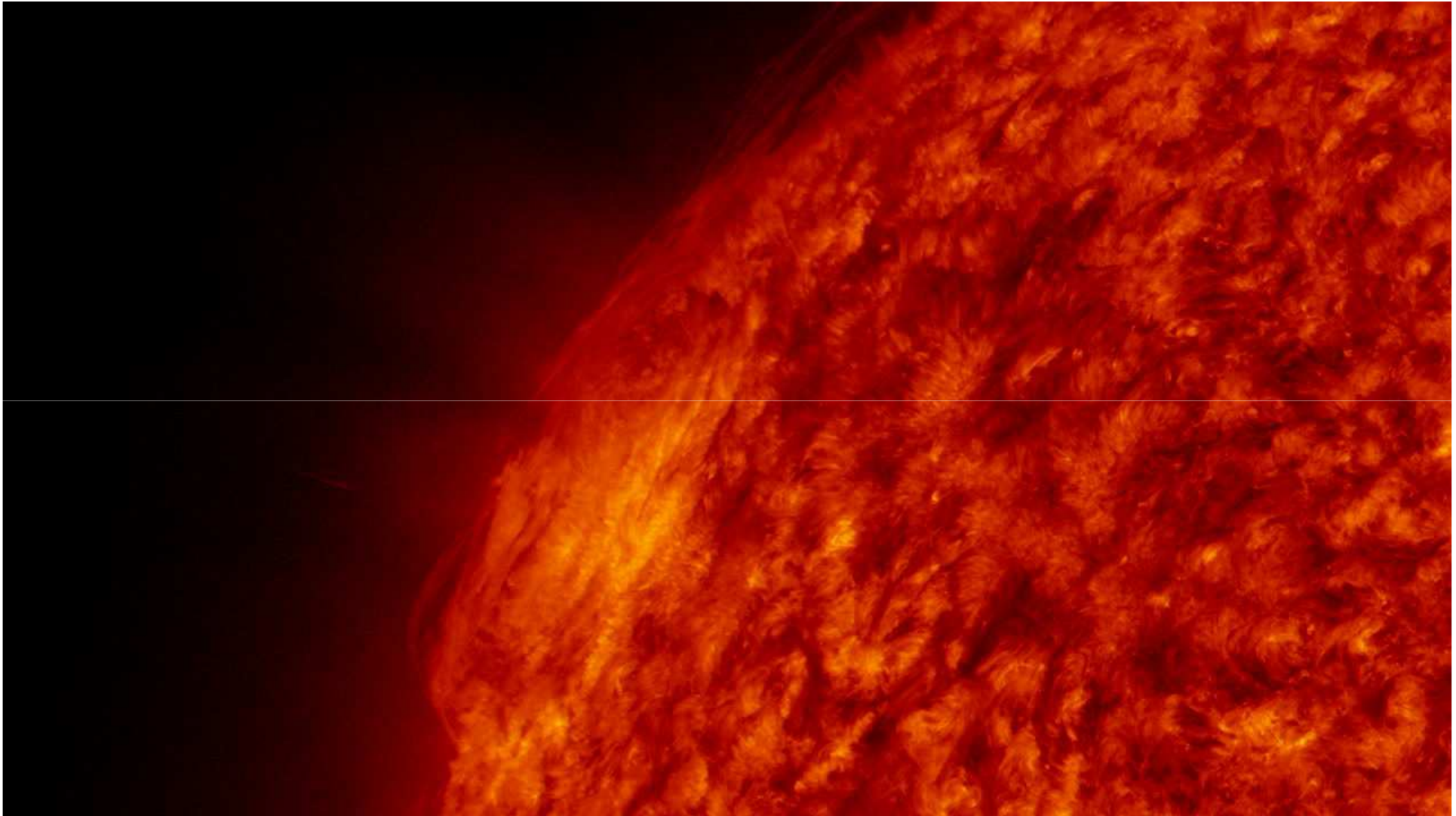


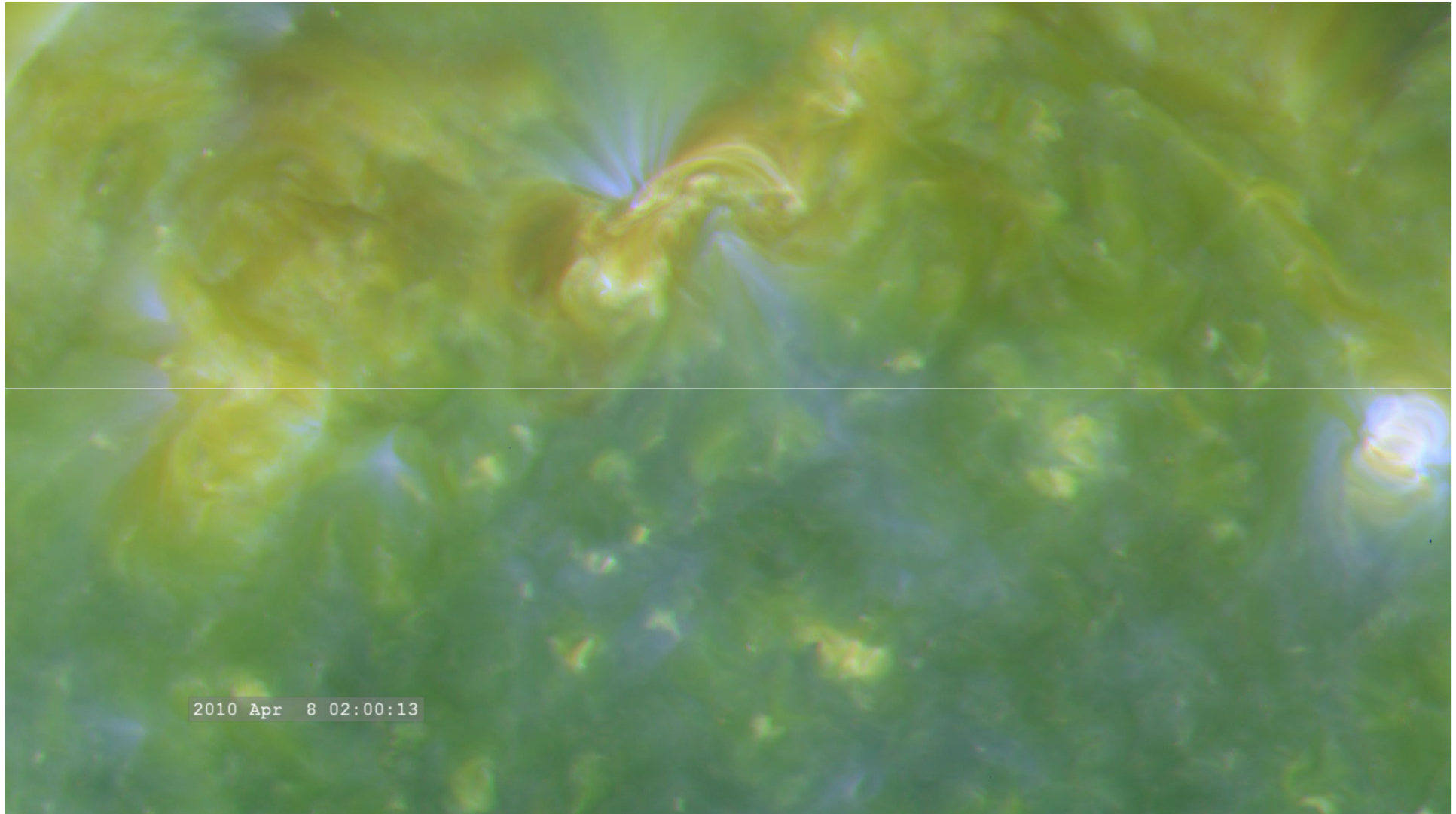
STEREO

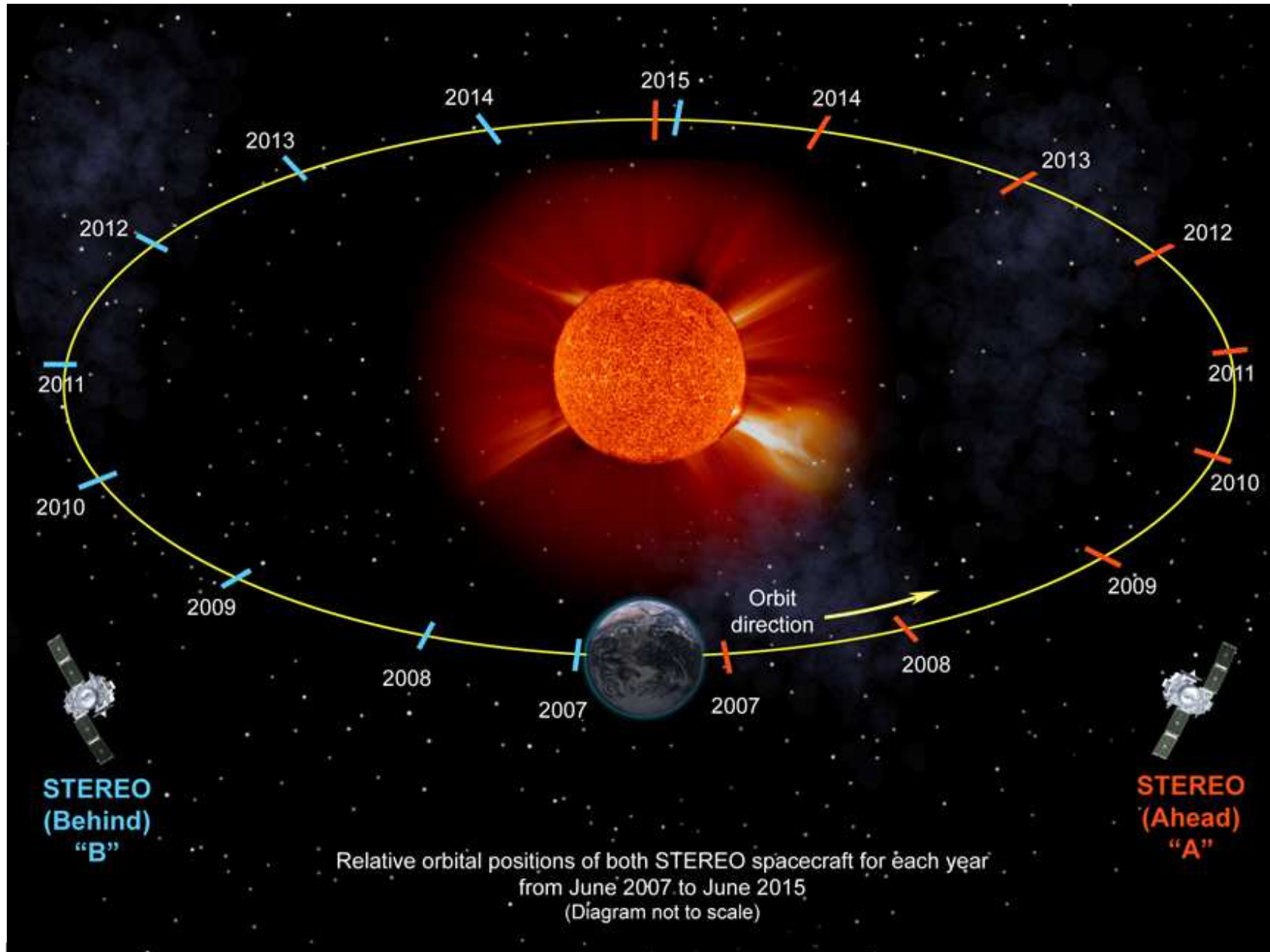


SDO

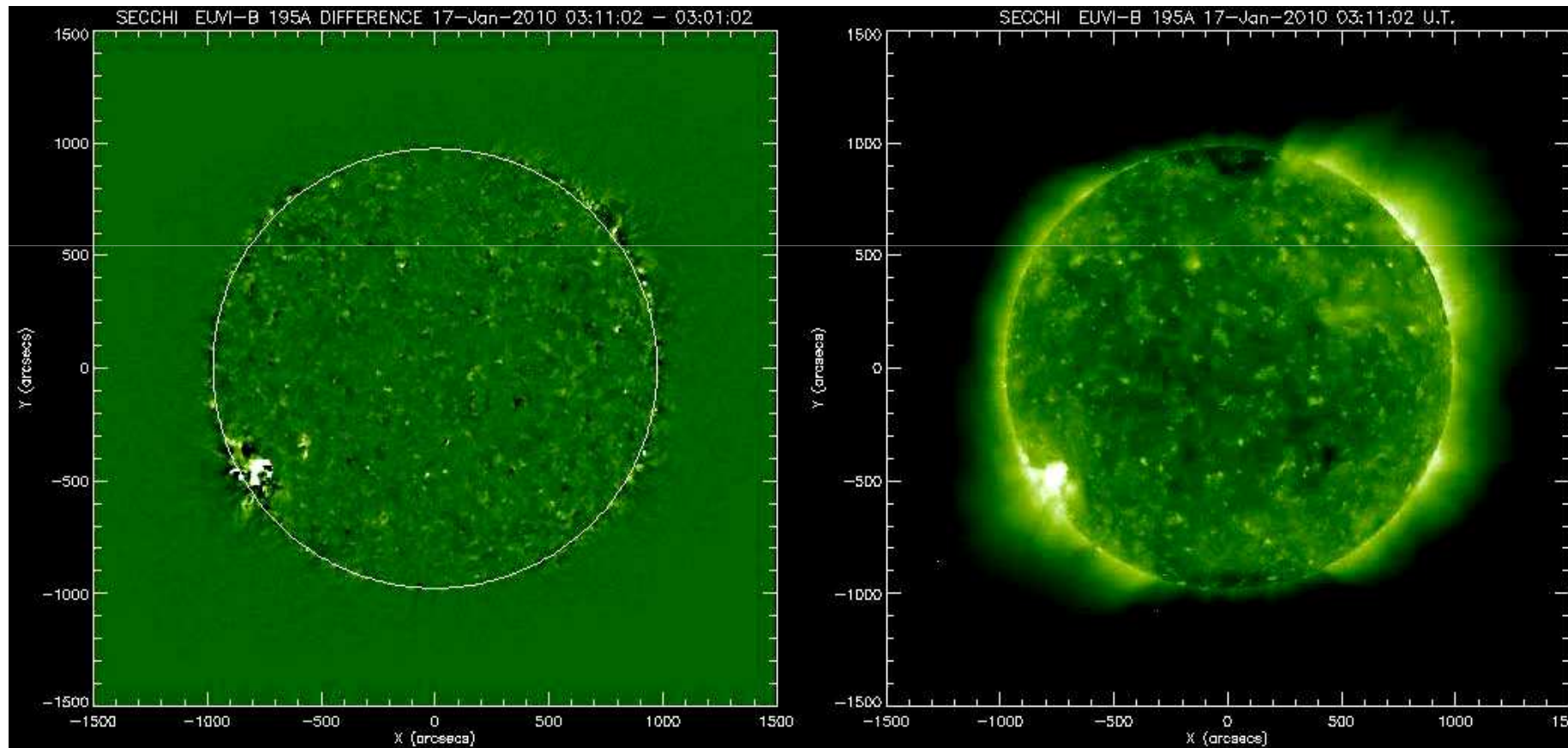




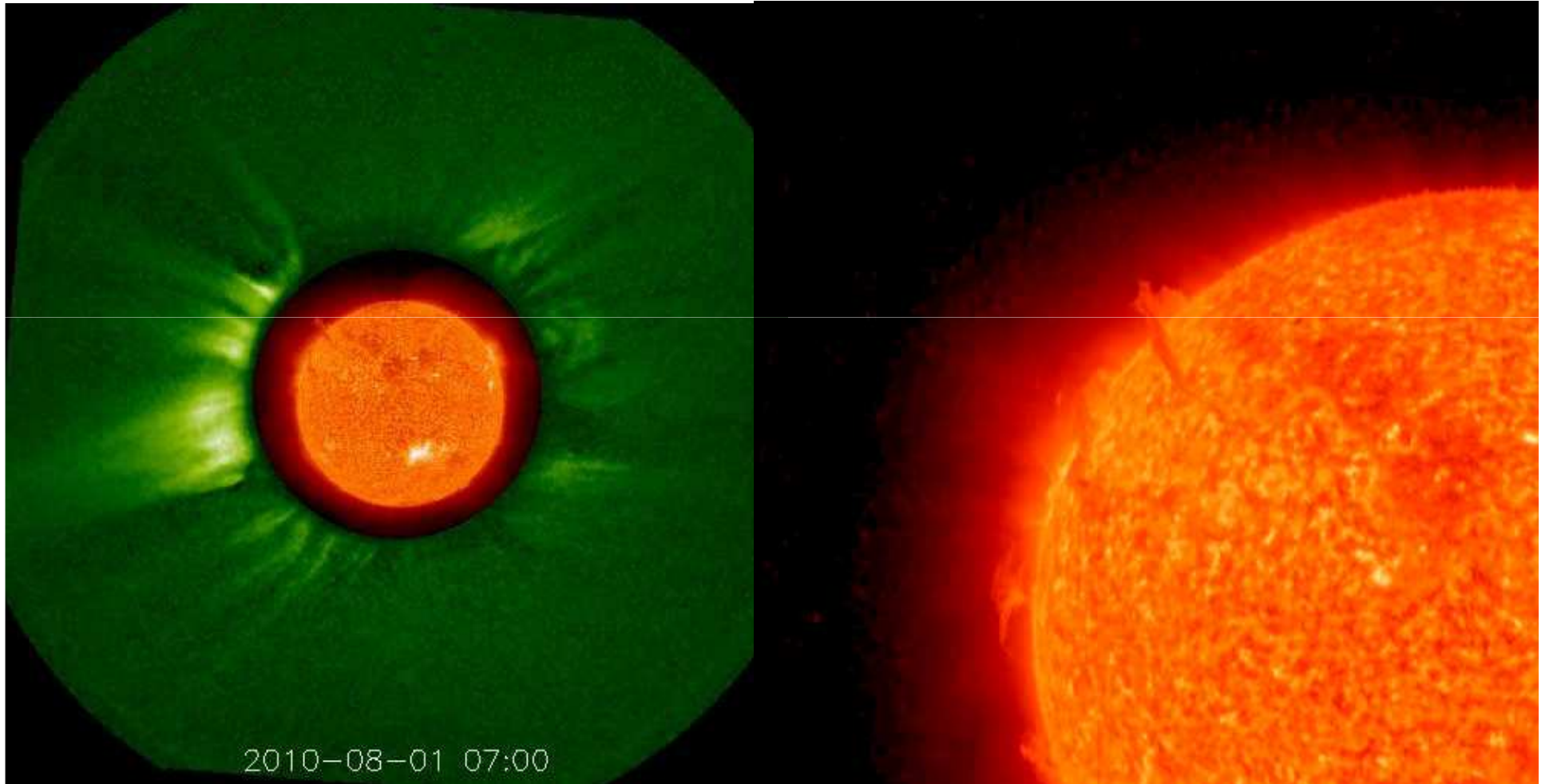


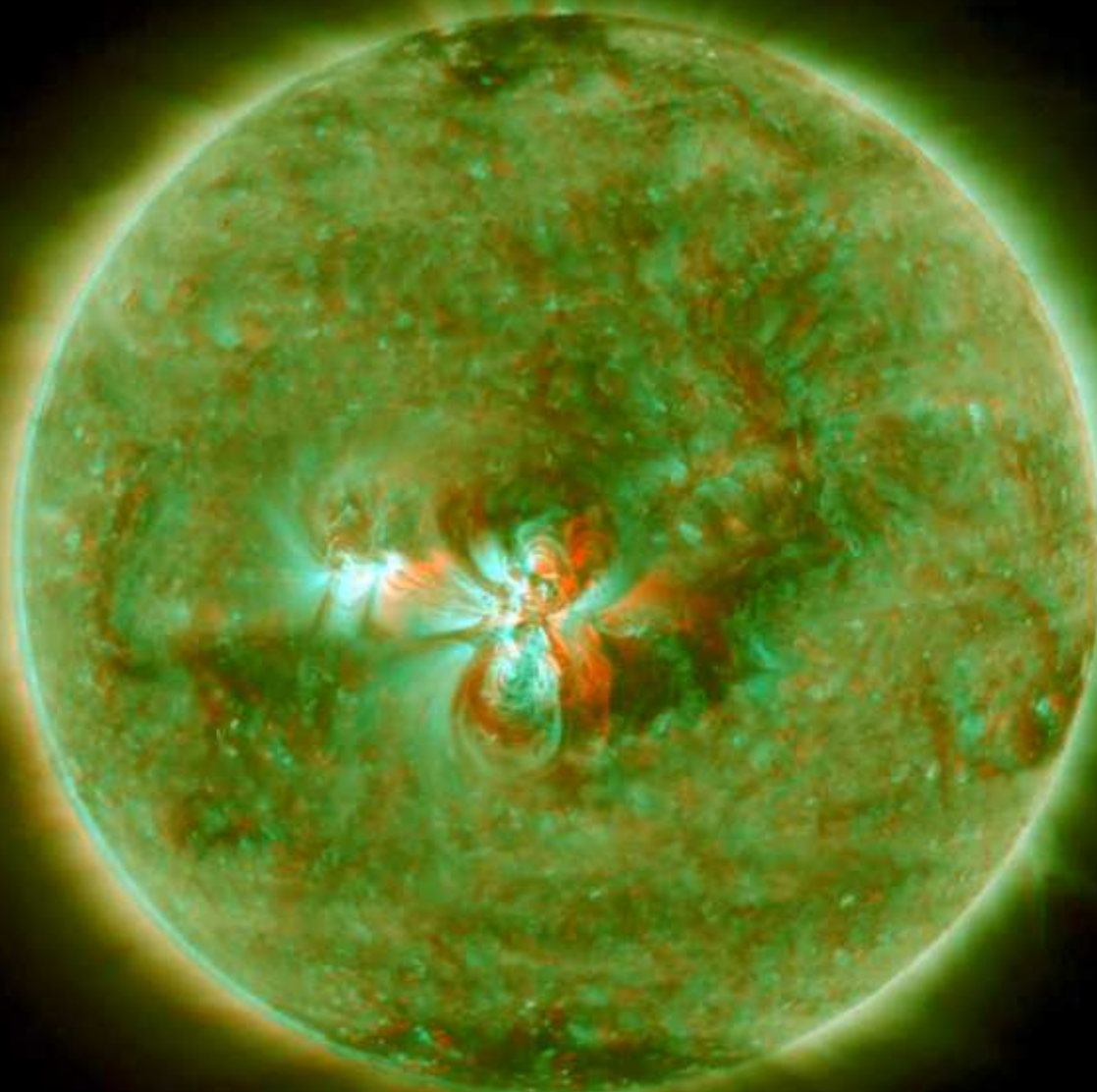


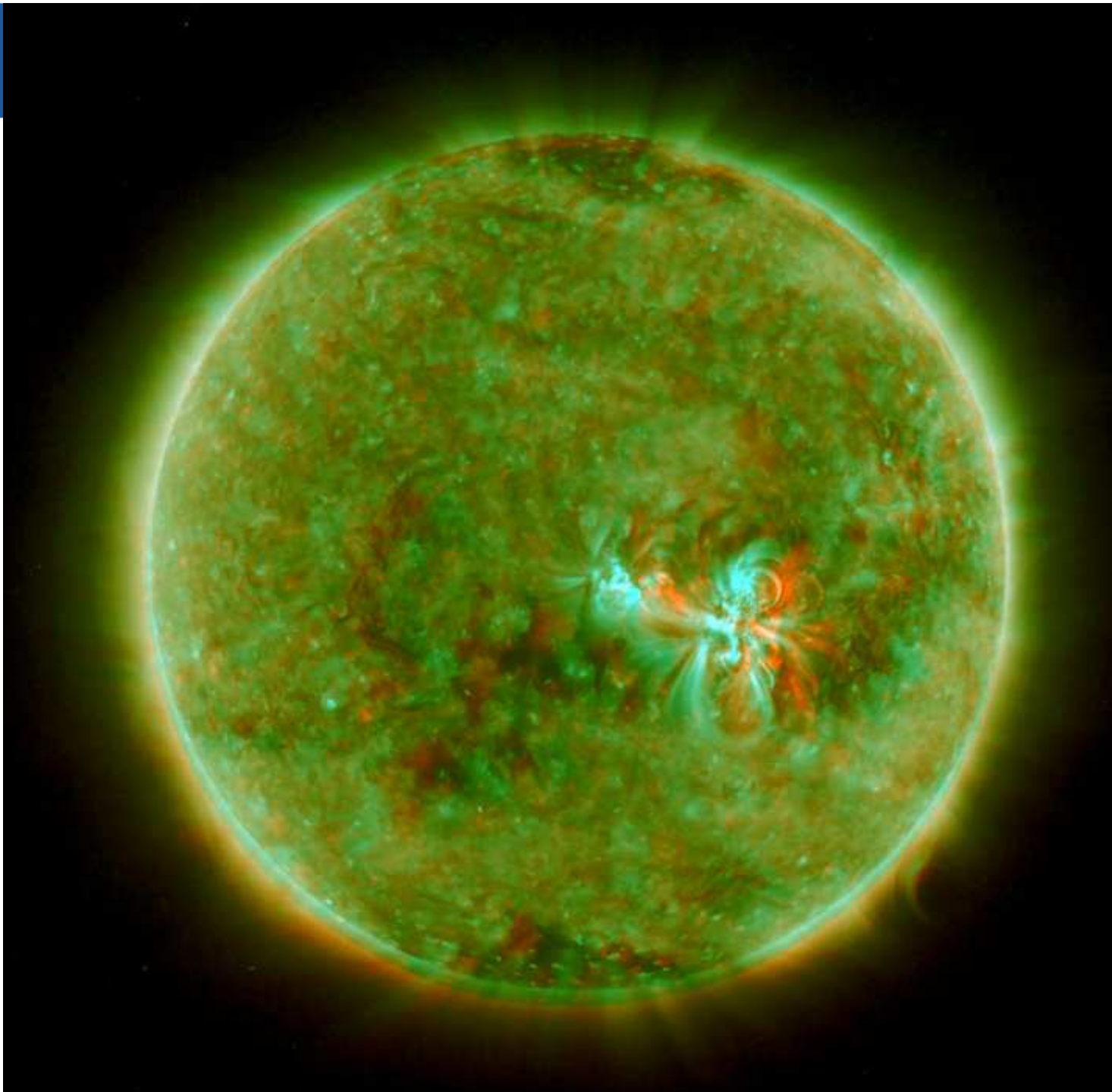
- bei Eruption einer CME breiten sich globale Wellen in der Korona aus
- Diese Welle wird „angestoßen“ von der CME (lange unklar)
- $V \sim 300$ km/s: ident mit V von schnellen MHD Wellen

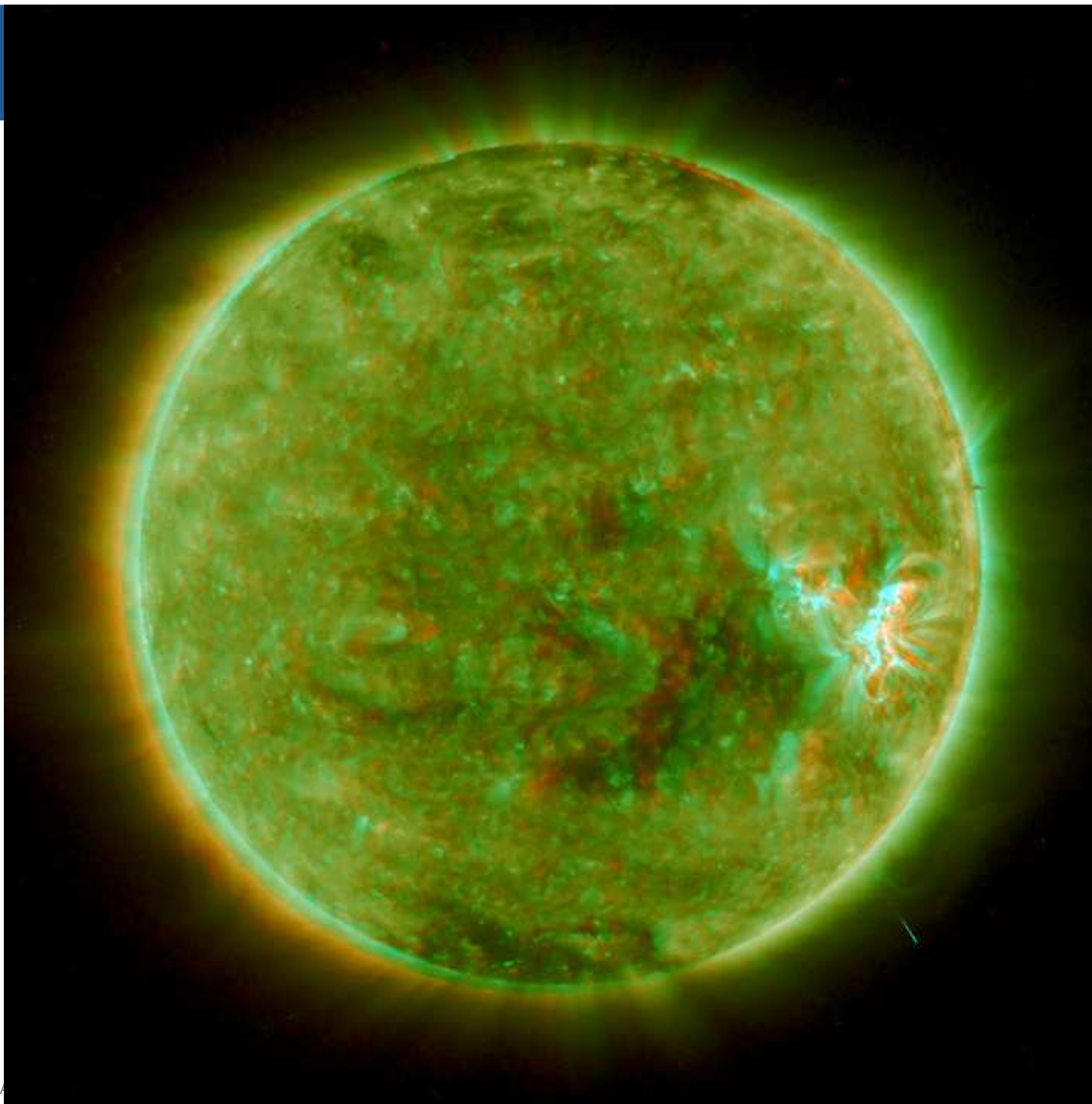


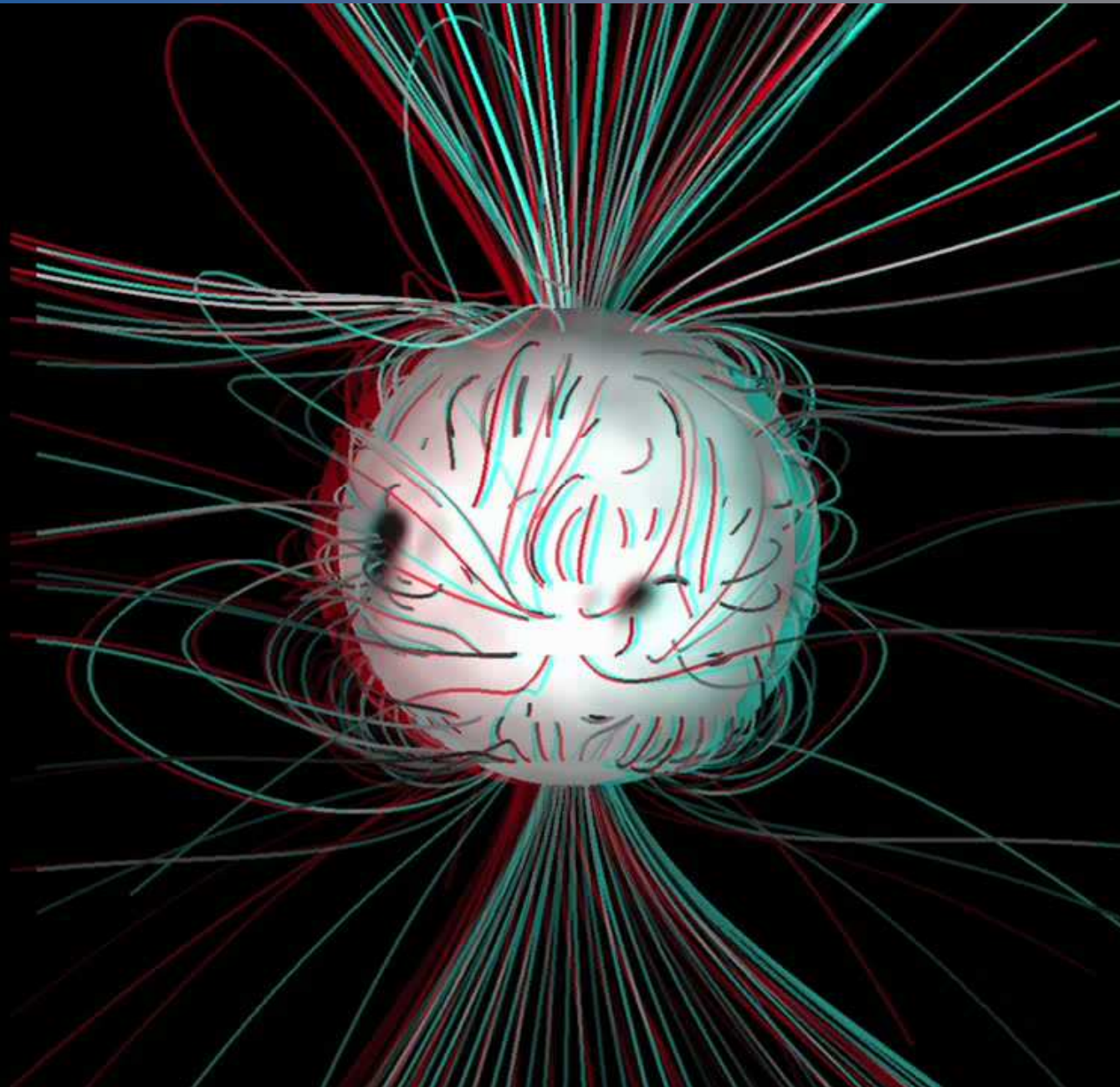
Veronig et al. 2010, *The Astrophysical Journal Letters*

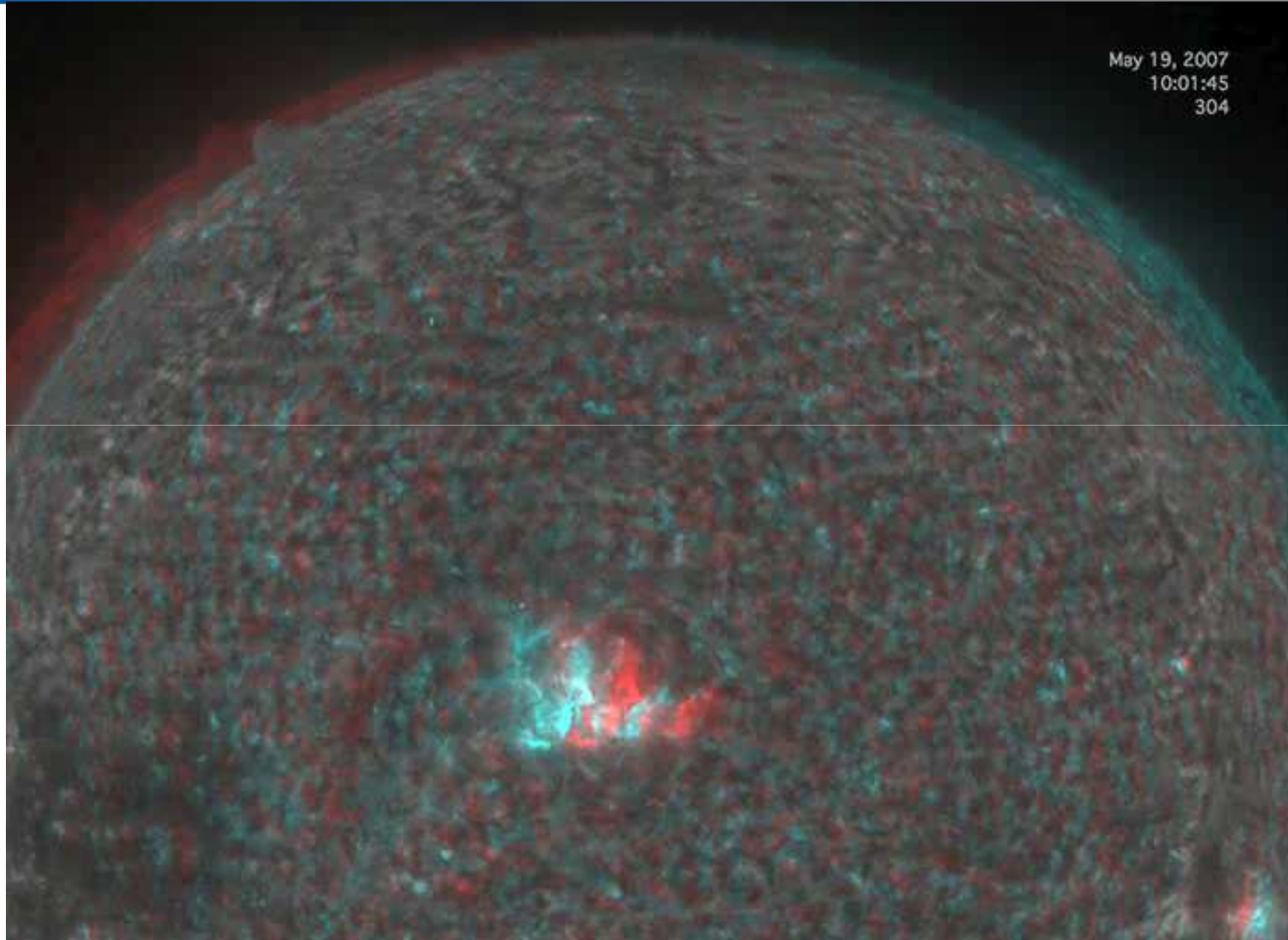


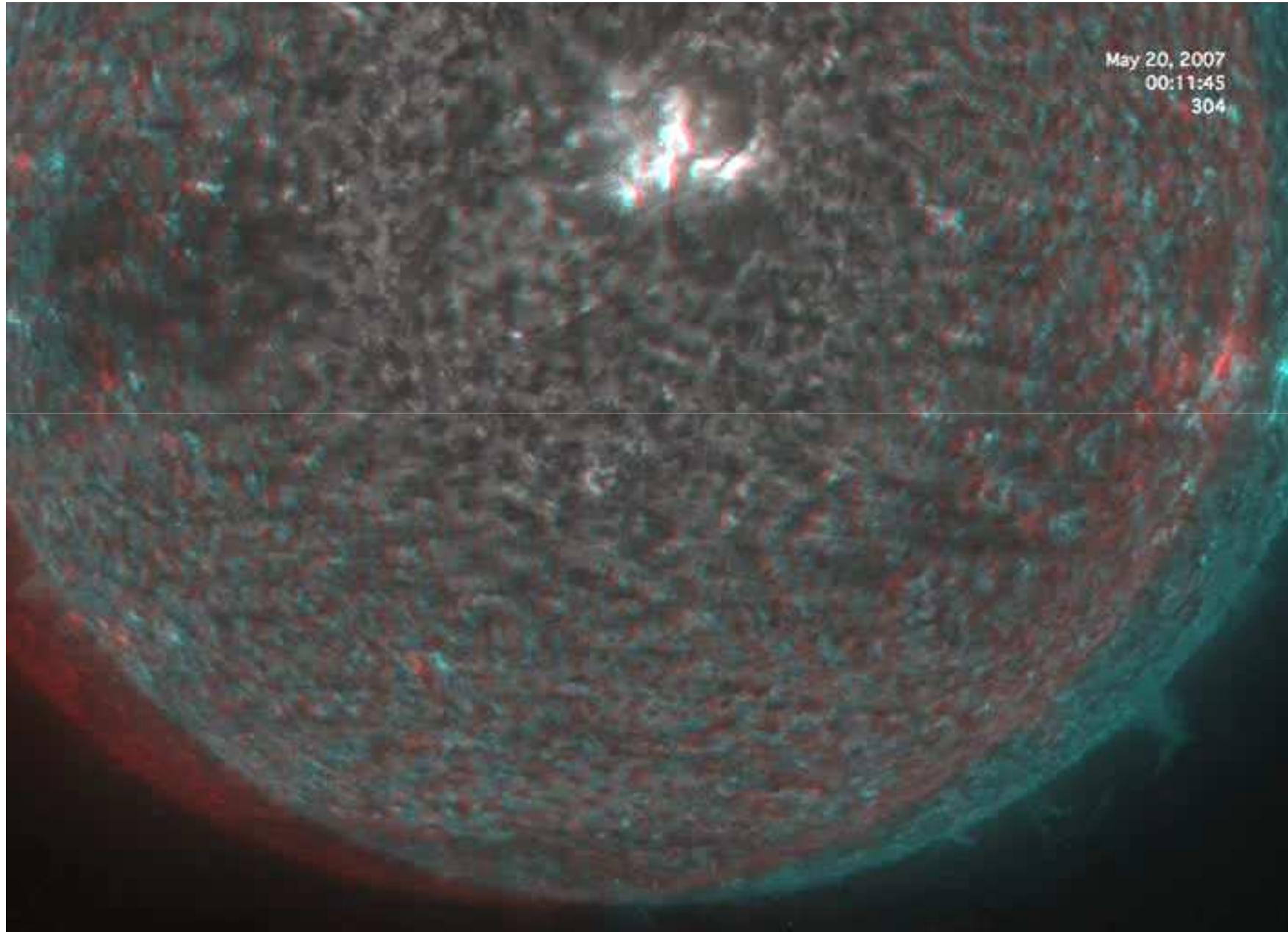




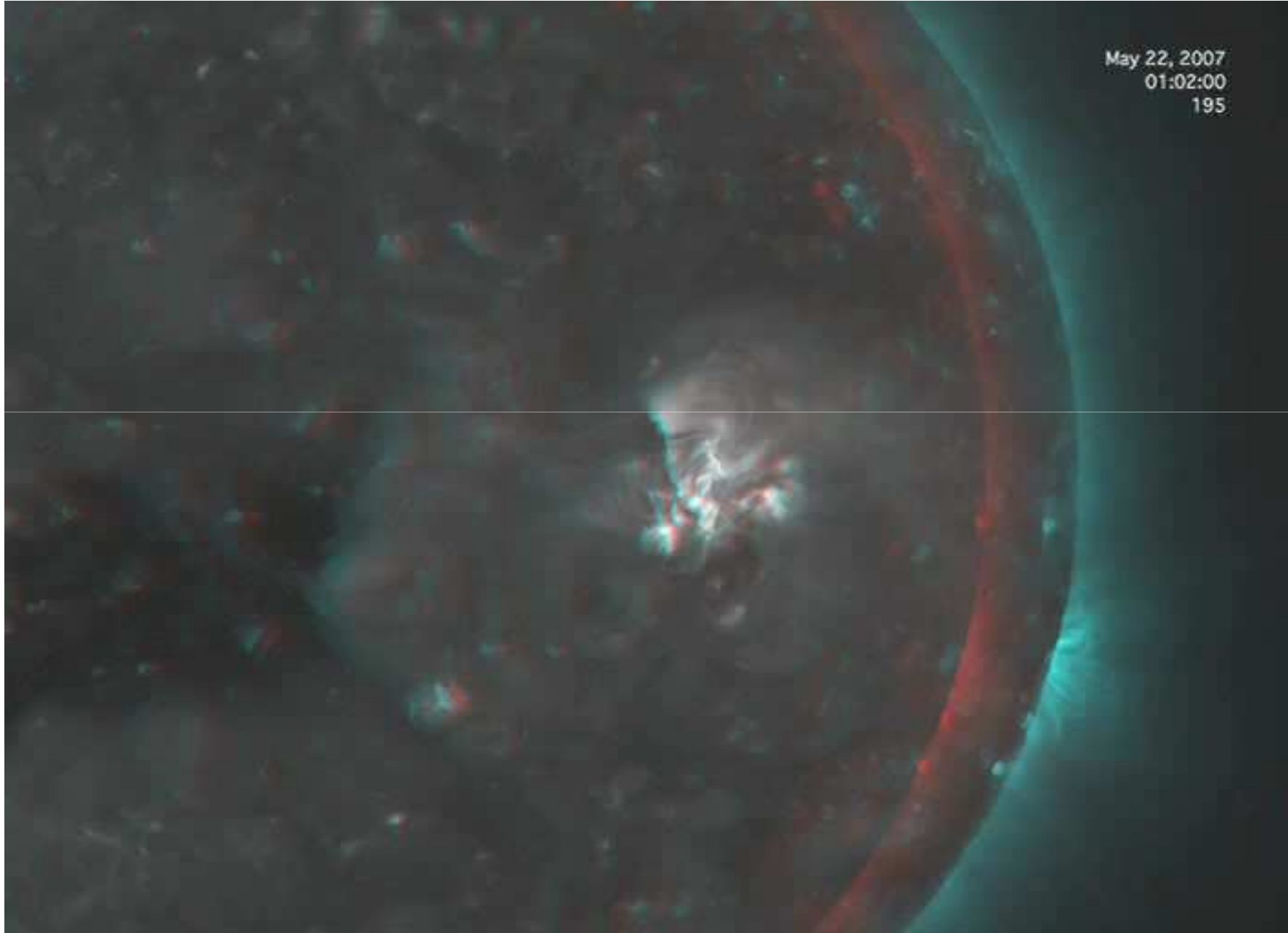


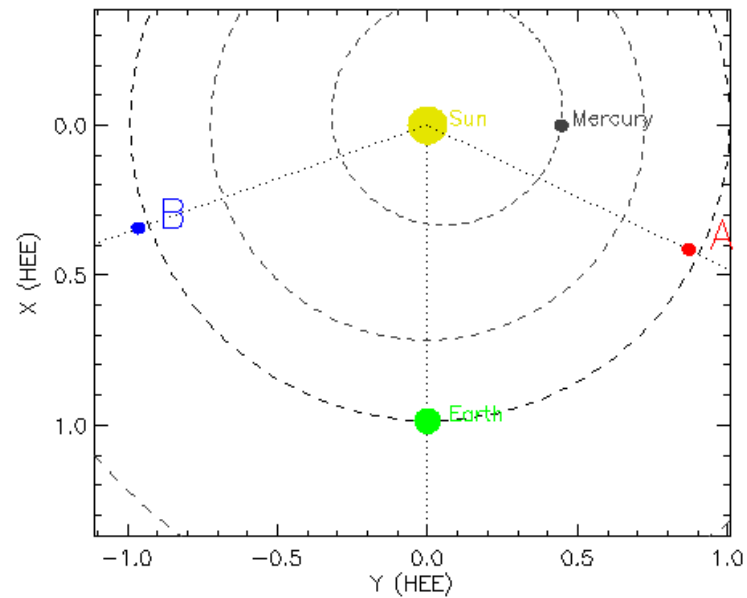
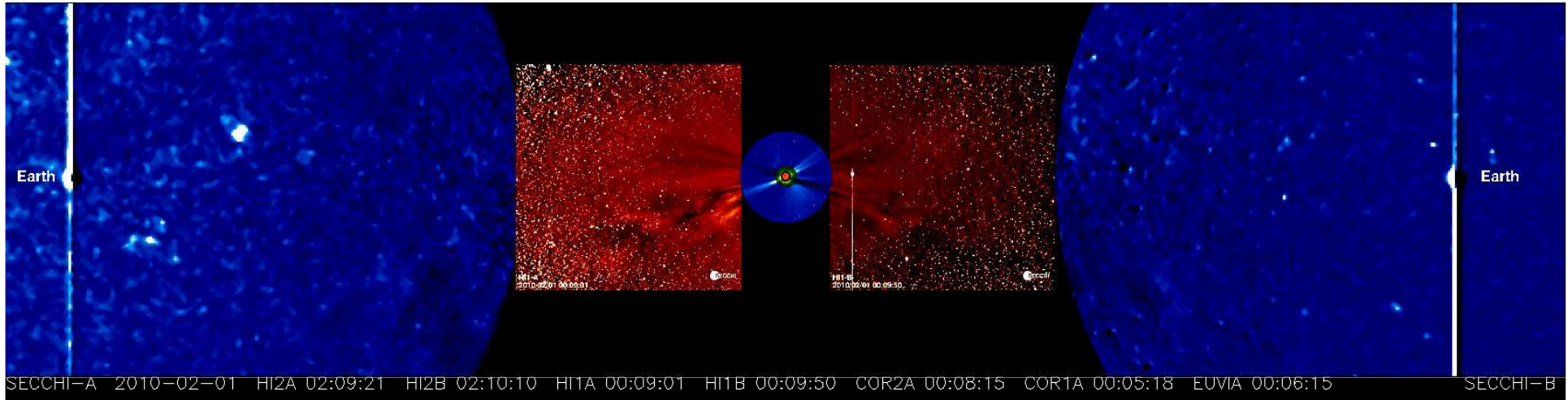






May 22, 2007
01:02:00
195

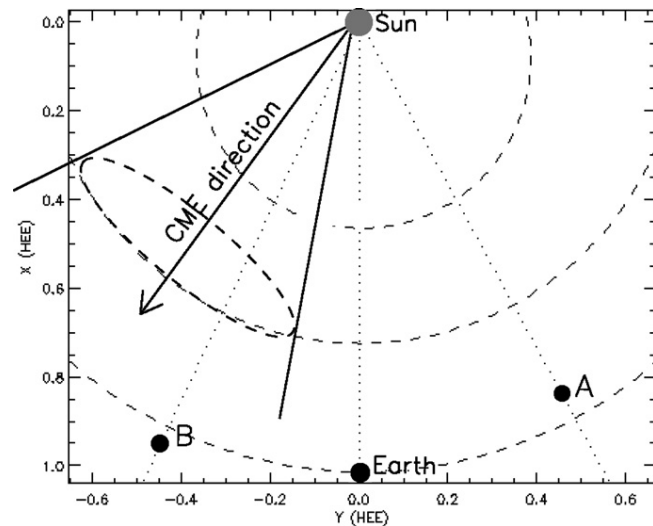
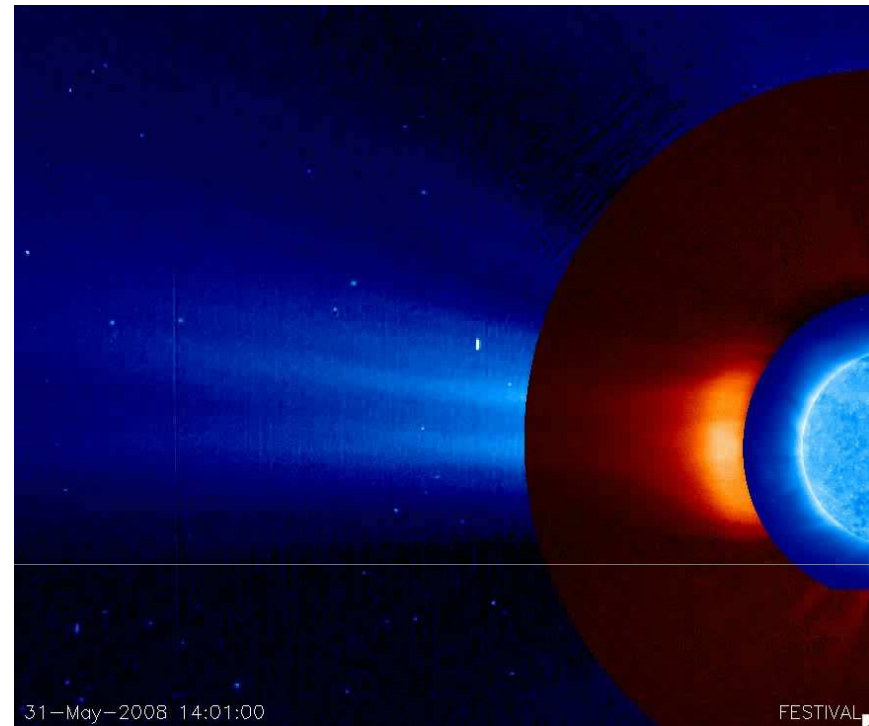




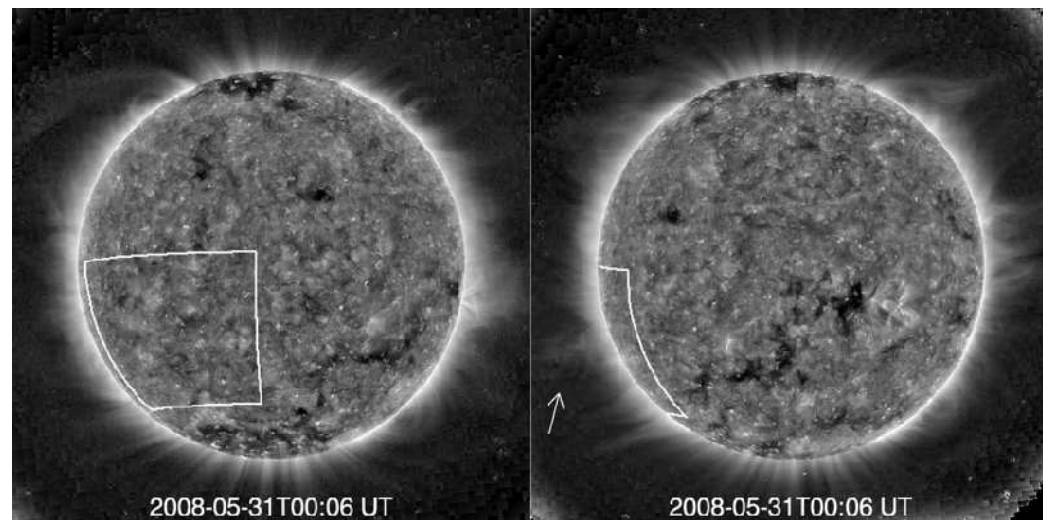
- Robbrecht et al. 2009 ApJ:
Eine CME ohne signaturen
in der Korona oder Oberfläche
(filament, flare, dimming, EUV wave)

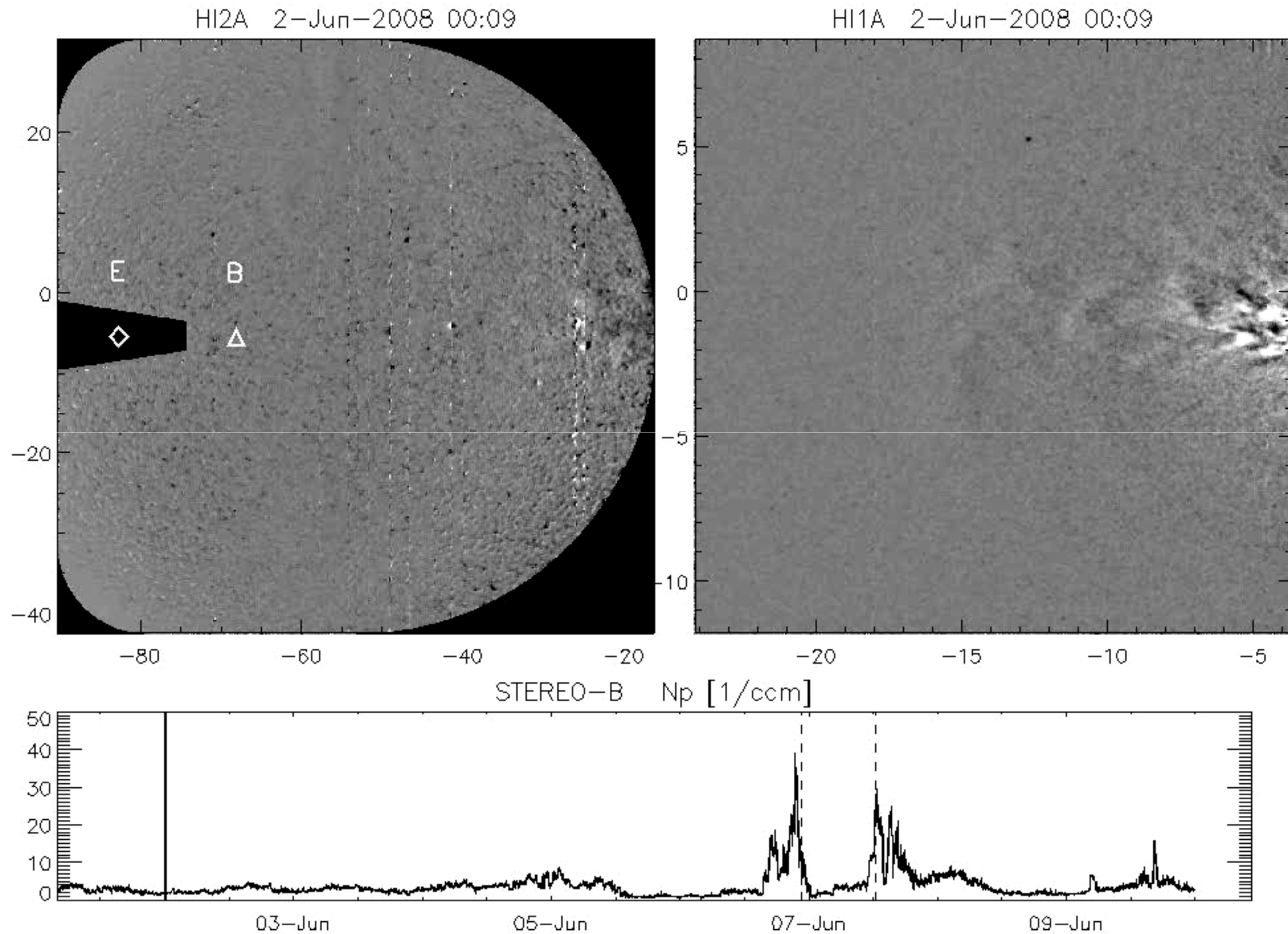
→ „stealth CMEs“

erklärt Stürme ohne „Vorwarnung“



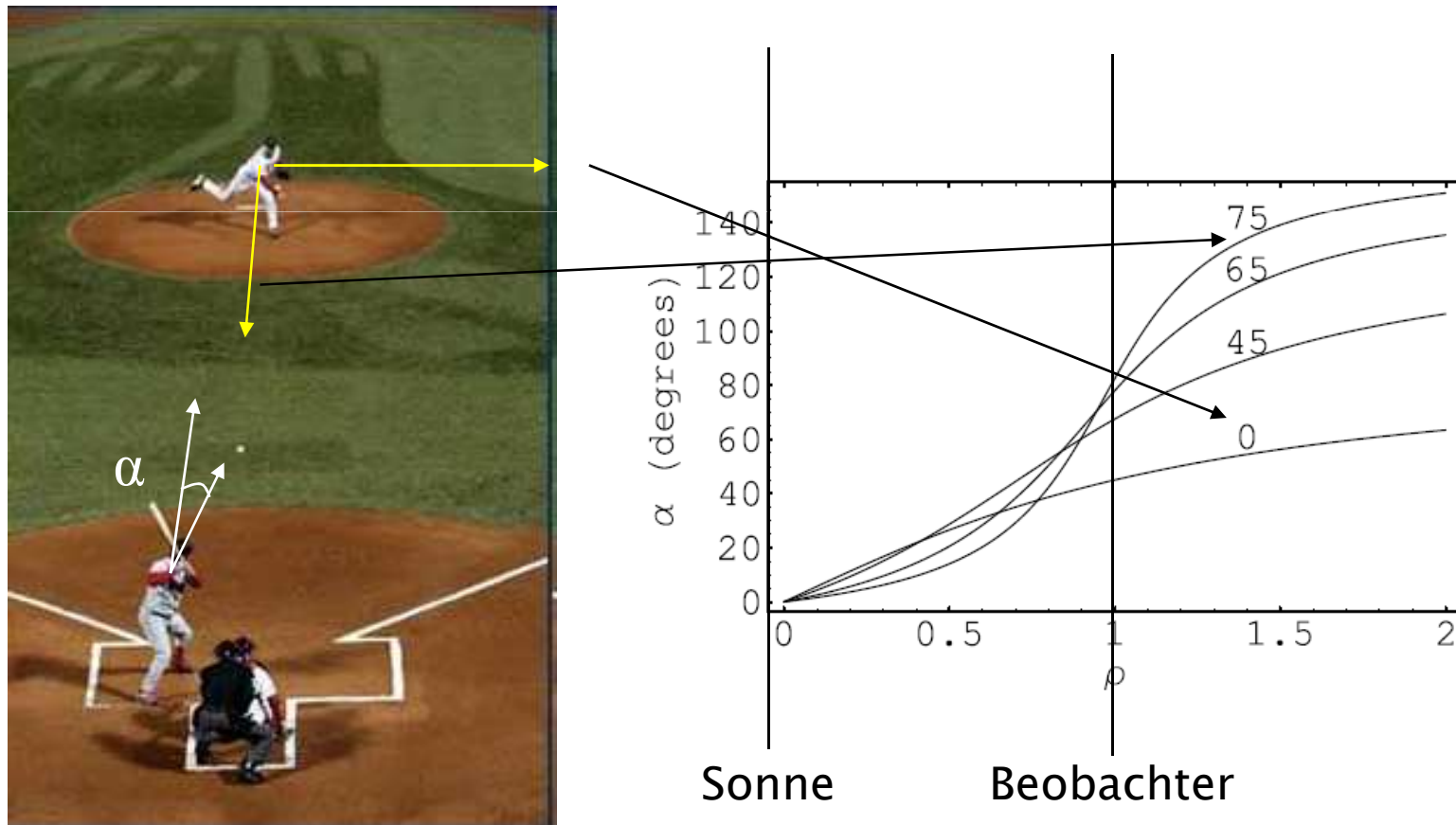
IWF/ÖAW GRAZ

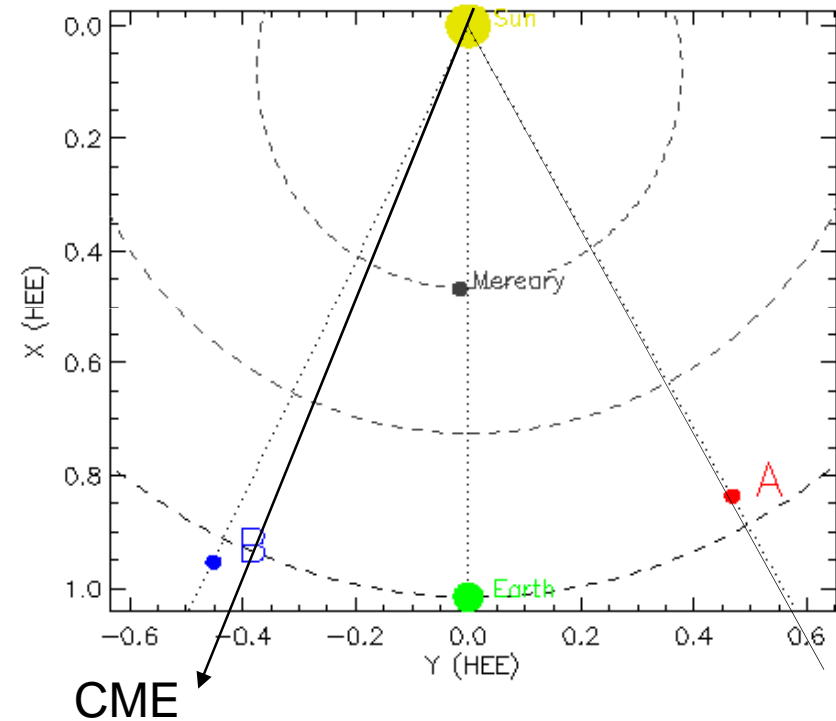
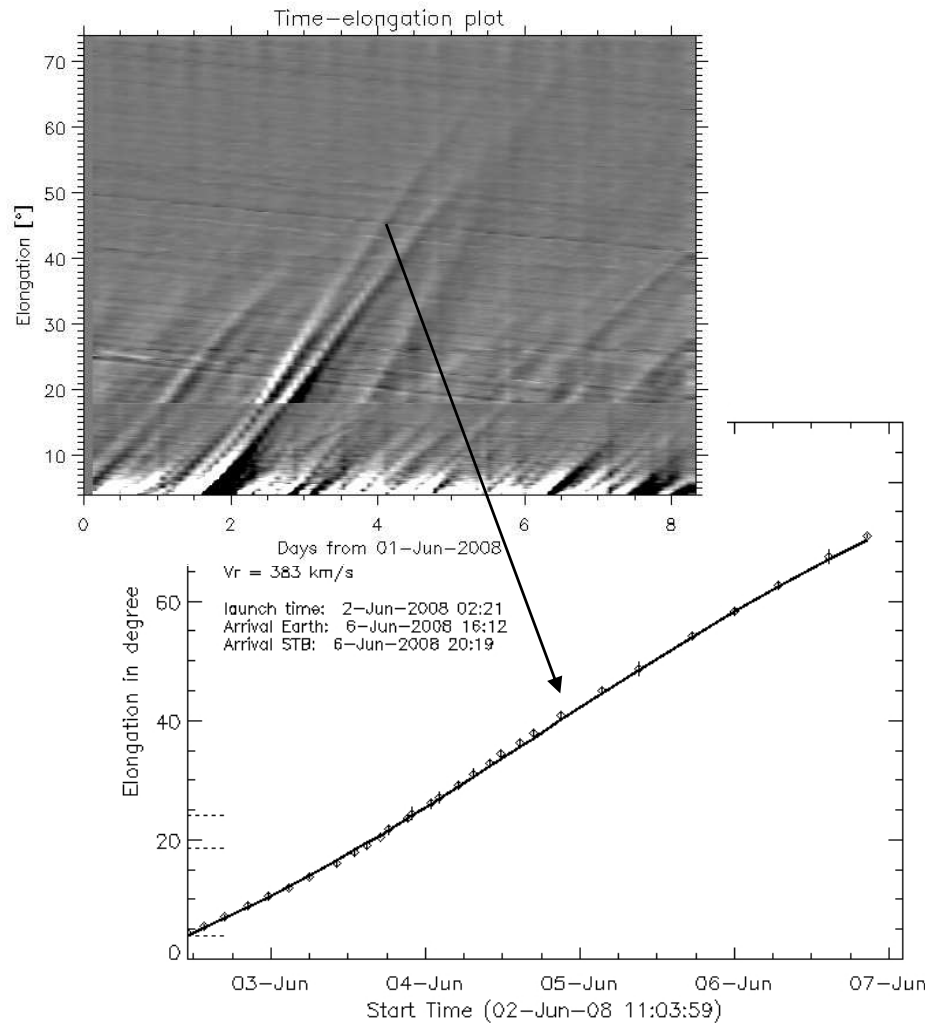




Geometrischer Effekt:

Bewegt sich eine (kleine) CME mit konstanter Geschwindigkeit entlang einer konstanten Richtung relativ zum Beobachter, sieht dieser *scheinbare Beschleunigungen*



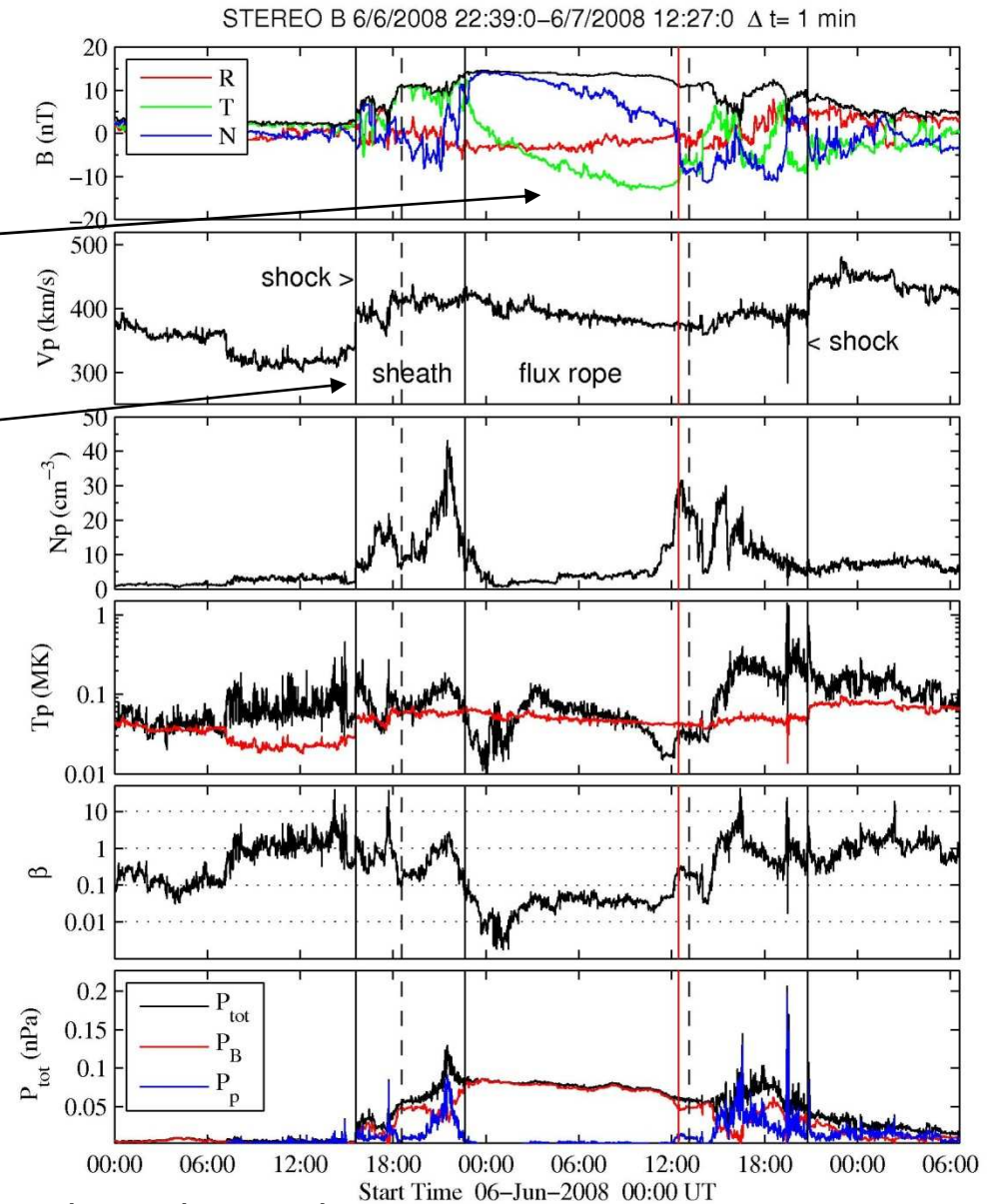


$V = 383 \text{ km/s}$ / Richtung -50° / Ankunftszeit

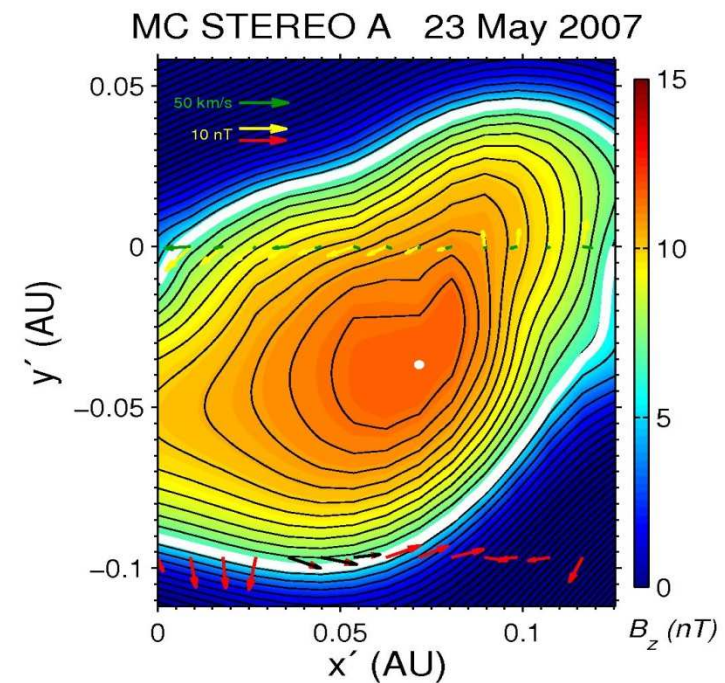
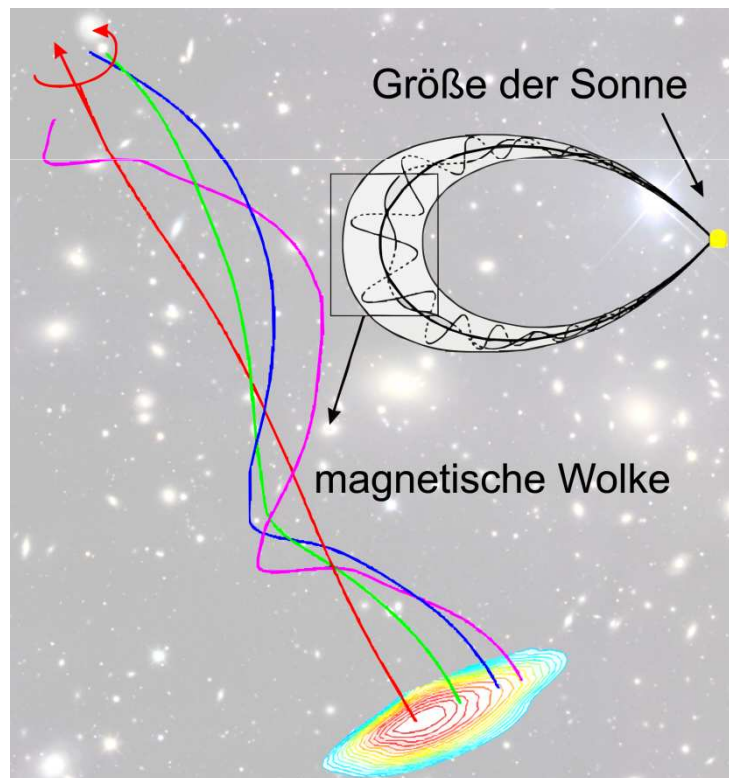
- „Magnetische Wolke“

- Stosswelle

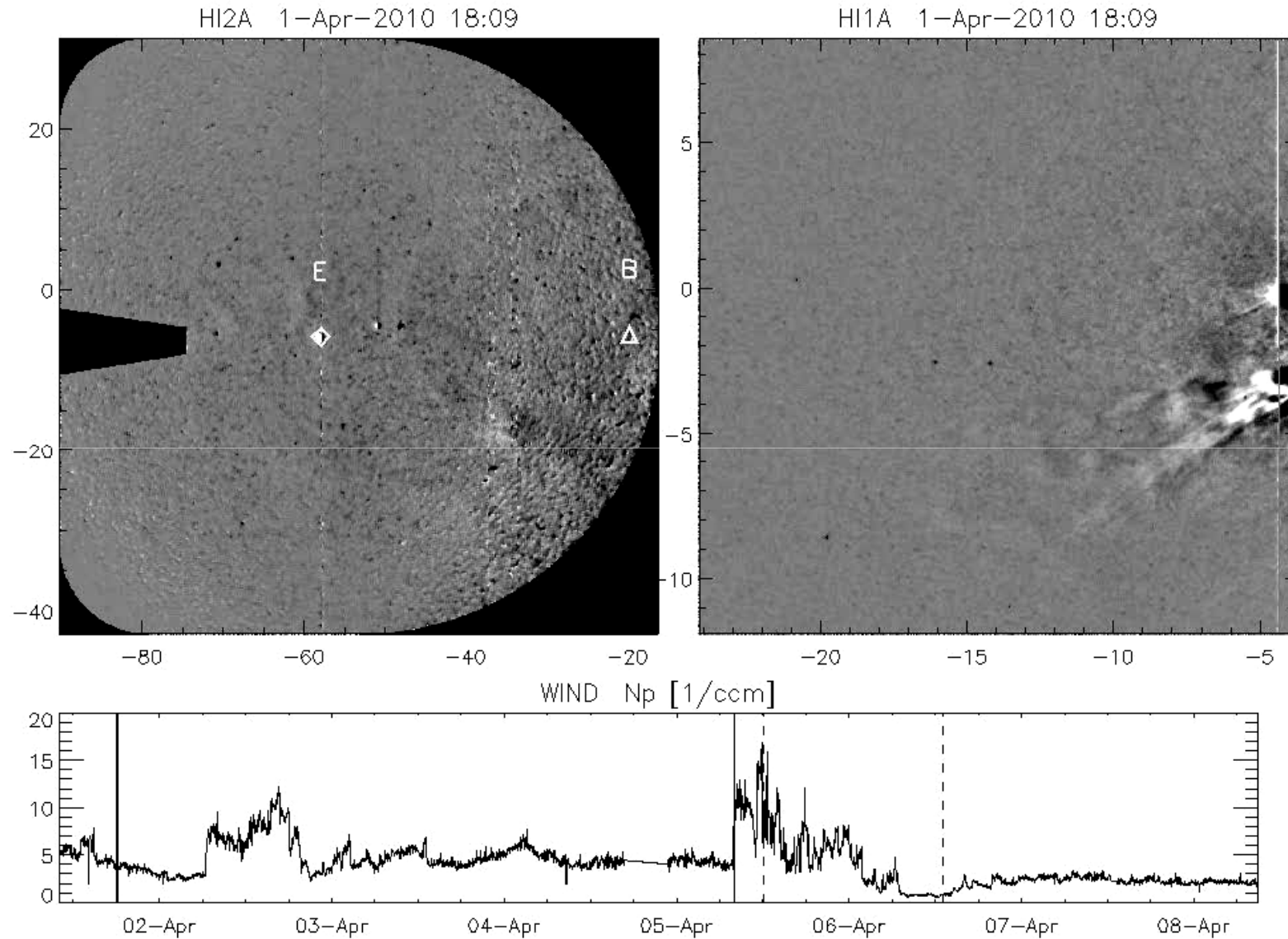
- Zwei deutliche Dichtesprünge



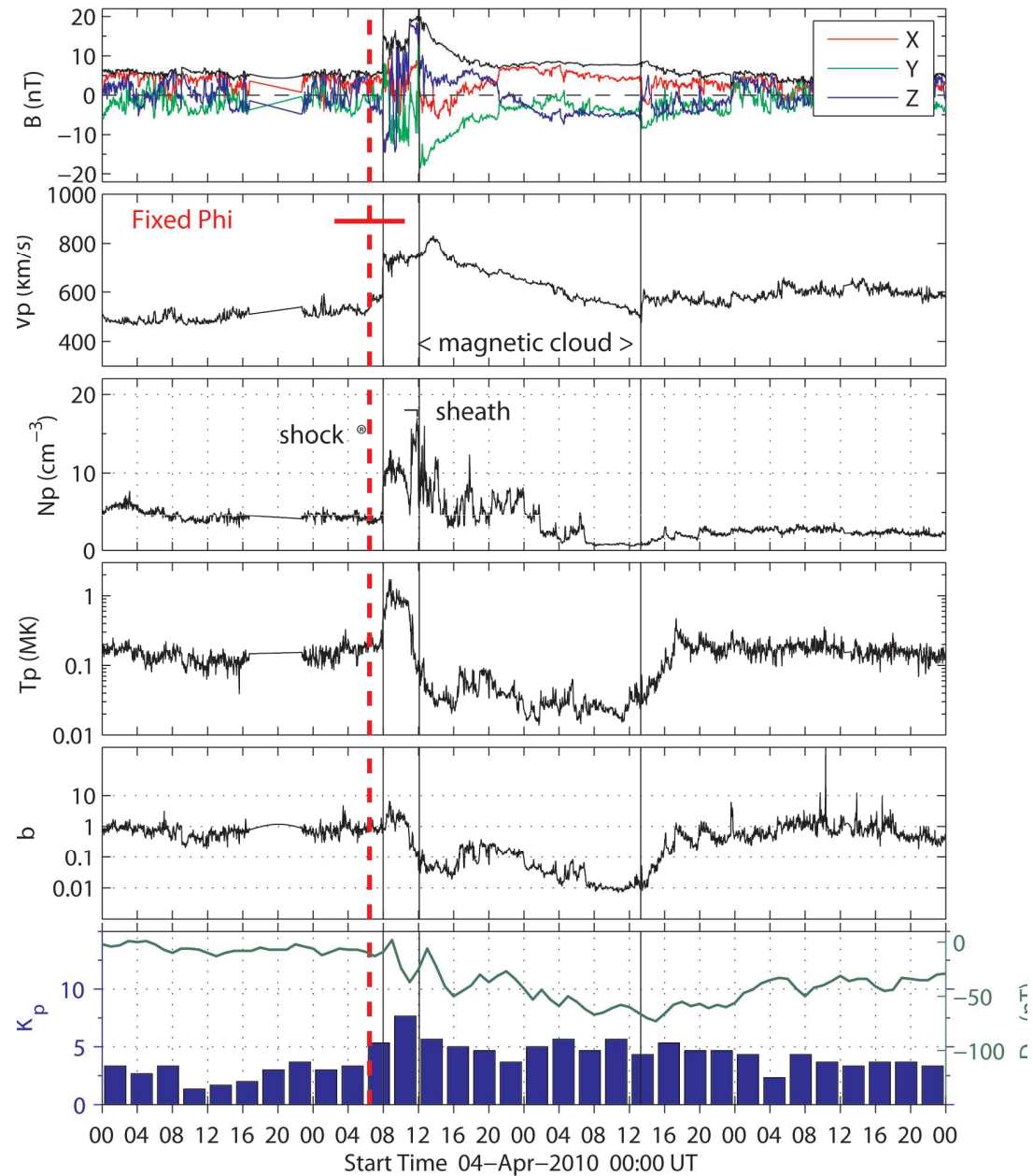
- Magnetische Wolke = „Kern“ einer CME in situ gemessen
- Helikale Magnetfeldlinien (\sim DNA)
- Ausrichtung und Stärke entscheidet über geo-magnetischen Sturm (über die südwärtsgerichtete Magnetfeld Komponente)



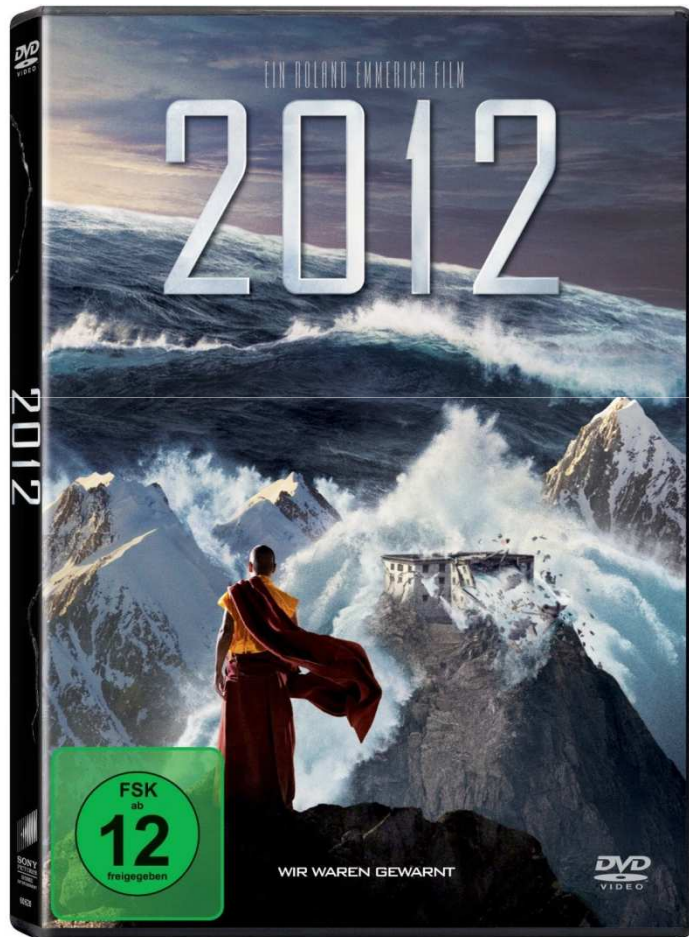
Möstl et al., 2009, Solar physics



Möstl et al. 2010, *Geophysical Research Letters*, submitted



but not this (at least not yet..)



- On April 5th, 2010 Intelsat lost control of the Orbital Sciences built Galaxy 15 satellite and has been unable to regain it's correct position in orbit The bird itself is floating around with its transponders still active. Now for the really fun part: the satellite is moving out of its assigned orbital slot and is about to enter in to range of another satellite: AMC-11. ..

(Wikipedia)

MSNBC



Space [msnbc.com](#)

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Frustrating zombie satellite still adrift in space

Engineers keep eye on wayward satellite as it nears two other spacecraft

By Denise Chow
SPACE
updated 7/8/2010 3:18:04 PM ET

The so-called Galaxy 15 zombie satellite that lost contact with ground controllers on Earth in April is still adrift in space, with engineers keeping a close eye on the wayward satellite as it approaches two other spacecraft this month.

The Galaxy 15 satellite is currently drifting along a stable and predictable path, according to its communications satellite fleet operator Intelsat. The main focus now is preventing Galaxy 15 from interfering with other nearby satellites, including two of Intelsat's own, though no collisions are expected.



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GIZMODO

The Attack of the Zombie Satellite

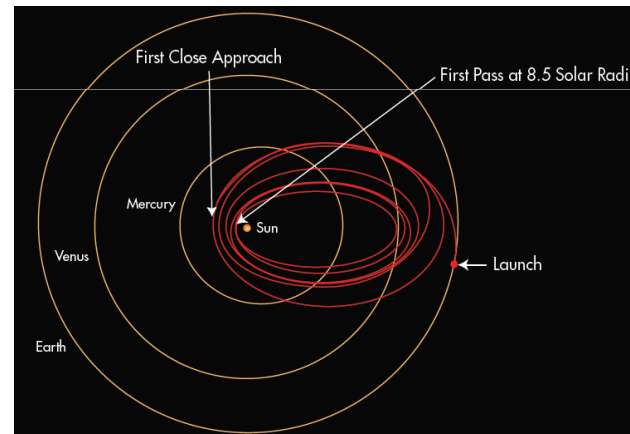
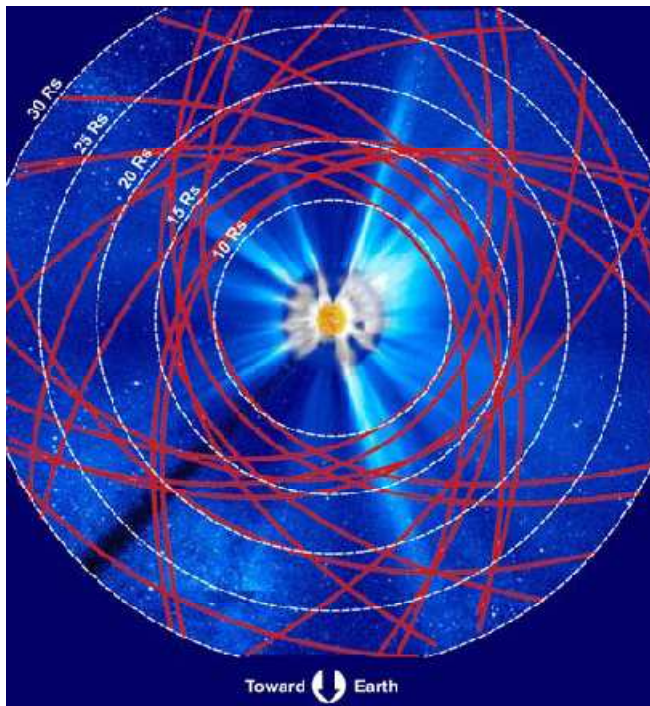


There has been a zombie satellite in space for the last few days. Apparently, the sun's radiation—or space Gremlins—turned it into a rogue spacecraft. Since then, Galaxy 15 has been threatening other cable TV satellites, like MTV's:

While ground control hasn't been able to disconnect Galaxy 15, they have been able to force some intricate evasive maneuvers to avoid interference with the communication satellites in the vicinity. So rest, my fellow humans, because Lady Gaga will continue to blast her inane music from space, with no *zombiesats* threatening the continuous spew of bits and bytes zoomed into your TVs. The Earth is safe again. [Space]

- Solar orbiter (ESA) (Chance 66%)
- 2017-? Bis 48 Rs (0.23 AU), Orbit bis 30° aus der Ekliptik

Imager, in situ, X-rays



Solar Probe + (NASA)

Launch 2018, first close approach 2024
"For the first time, we'll be able to 'touch, taste and smell' the sun."

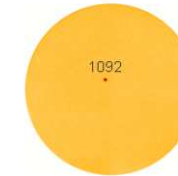
8.5 Rs; Heliospheric imaging, In situ, SEPs
(diese Woche ausgewählt)

- www.spaceweather.com
- App: <http://3dsun.org/>
- Facebook: The Sun Today...

SPACE WEATHER
Current conditions
Solar wind
speed: **592.1** km/sec
density: **7.7** protons/cm³
[explanation](#) | [more data](#)
Updated: Today at 23:45 UT

X-ray Solar Flares
6-hr max: **B1** 2300 UT Aug03
24-hr: **B4** 1145 UT Aug03
[explanation](#) | [more data](#)
Updated: Today at: 23:40 UT

Daily Sun: 03 Aug 10



Sunspot 1092 is facing almost directly toward our planet. Any eruptions from this active region will be Earth-directed. Credit: SDO/HMI
Resolutions: [4096](#), [1024](#), [512](#)

Sunspot number: 17
[What is the sunspot number?](#)
Updated 02 Aug 2010

Spotless Days
Current Stretch: 0 days
2010 total: 36 days (16%)
2009 total: 260 days (71%)
Since 2004: 803 days
Typical Solar Min: 486 days
[explanation](#) | [more info](#)
Updated 02 Aug 2010

The Radio Sun
10.7 cm flux: **79** sfu

What's up in Space

August 3, 2010



ANDROID FLYBYS: Our field-tested satellite tracker is now available for Android phones. Features: Global predictions and flyby alarms! [Learn more.](#)

CME IMPACT! The first of possibly two incoming CMEs hit Earth's magnetic field today at approximately 1730 UT (1:30 pm EDT). As a result of the impact, a polar geomagnetic storm is brewing. High-latitude sky watchers should [be alert for auroras](#) after nightfall.

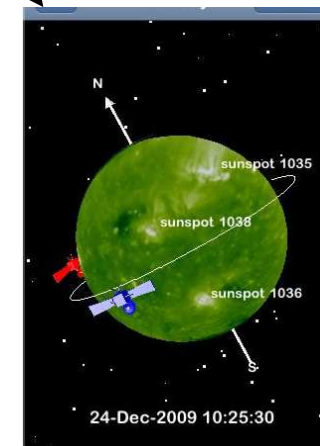
UPDATE: Northern Lights are being sighted now in Europe. Jesper Grønne sends this picture from Denmark (latitude +56 degrees):



Rob Stammes sends this report from Laukvik, Lofoten, Norway: "At 17:40 UT, electrical currents began to flow through the ground outside my laboratory. [data](#). This indicated the arrival of the CME. Three hours later a geomagnetic storm is active, strong enough for auroras."

COMPLEX ERUPTION ON THE SUN: On August 1st, the entire Earth-facing side of the sun erupted in a tumult of activity. There was a C3-class solar flare, a solar tsunami, multiple filaments of magnetism lifting off the stellar surface, large-scale shaking of the solar corona, radio bursts, a coronal mass ejection and more. Click on the image to view just a fraction of the action.

The screenshot shows the Facebook interface for the page 'The Sun Today: Solar Facts and Space Weather'. The page features a cover photo of the sun, a search bar, and navigation tabs for 'Pinnwand', 'Info', 'The Sun Now', 'About Us', 'Fotos', and 'YouTube'. A post from 5 hours ago is visible, titled 'The Sun Today: Solar Facts and Space Weather About 5 hours ago SDO observed a Small! C-Class Solar Flare! Here we show it in 4 different wavelengths. Enjoy!'. The post includes a video player and a text description of the solar flare event. Below the post, there are comments and likes from other users.



The screenshot shows the 'STEREO News' page. It features a navigation bar with 'info' and 'STEREO News'. The main content area is titled 'Today:' and contains a news item: 'Signs of Life on the Sun Dec. 24'. The text reads: 'The sun is peppered with Solar Cycle 24 active regions. The biggest, sunspot 1035, is about to enter STEREO's blind spot.' Below this, there is a section for 'Past active days:' with an item titled 'Great Prominence Sept. 25'. The text for this item reads: 'For the first time, the two STEREO spacecraft have observed an enormous...'.



Danke!

Diese Arbeit wird vom FWF
(Projekt P20145) unterstützt!