"To understand is to perceive patterns"

http://sidc.be/nemo

NEMO

A software package for 'Novel EIT wave Machine Observing'

On-Disk Eruption Measure Tool

Elena Podladchikova, David Berghmans, Judith de Patoul

SECCHI / ROB

Outline

- **Motivation**
  - NEMO in the context of Space Weather & SOHO
  - Technological challenges

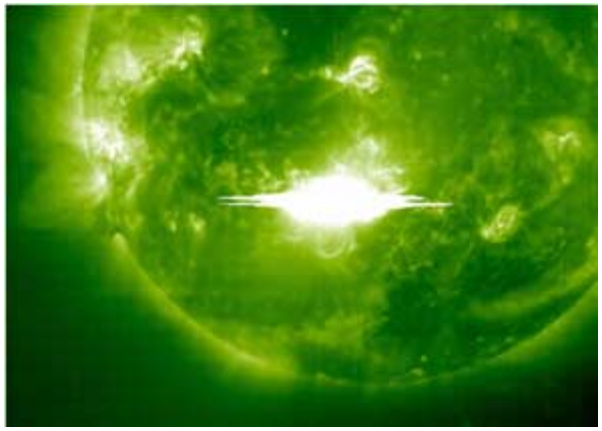
- **Skeleton of NEMO software**
  - Architecture
  - Recognition & Diagnostic,
  - Catalogues,
    in real time

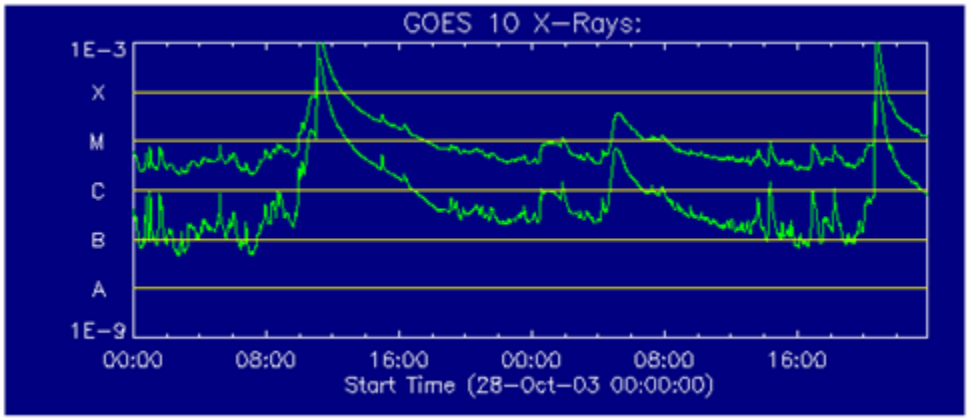
- **Some new features / understanding**

- **Discussion**
  - STEREO WAVES
  - New quasi-circular waves!

Solar Eruptions in Real time

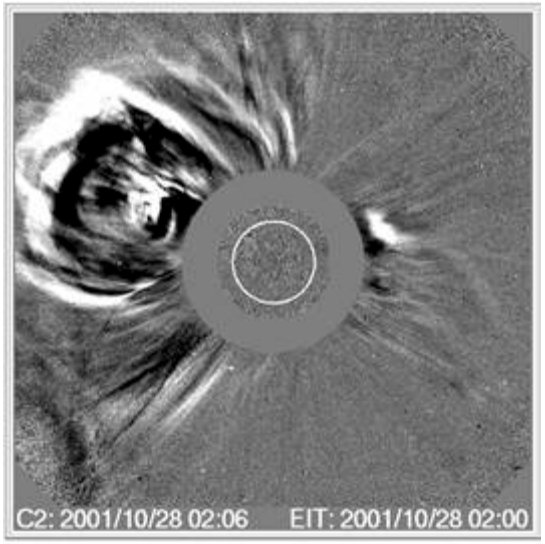
- **Flares**





- ***SEC events at NOAA, SXI***
- ***SolarSoft events***
- ***B2Xflare***

- **CMEs**

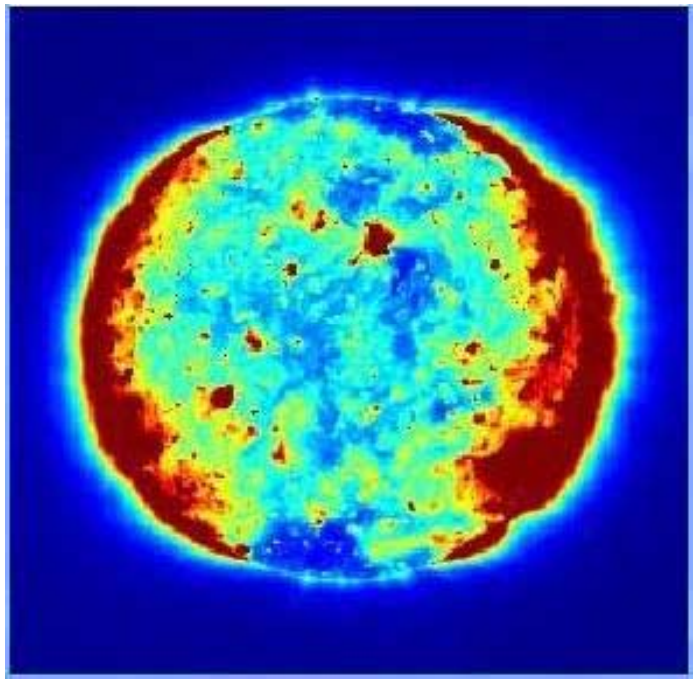


- ***"Gopalswamy" list***
- ***http:/sidc.be/cactus***

How does Eruption look like in EUV?

precursor

- **"EIT wave"**



Original Image

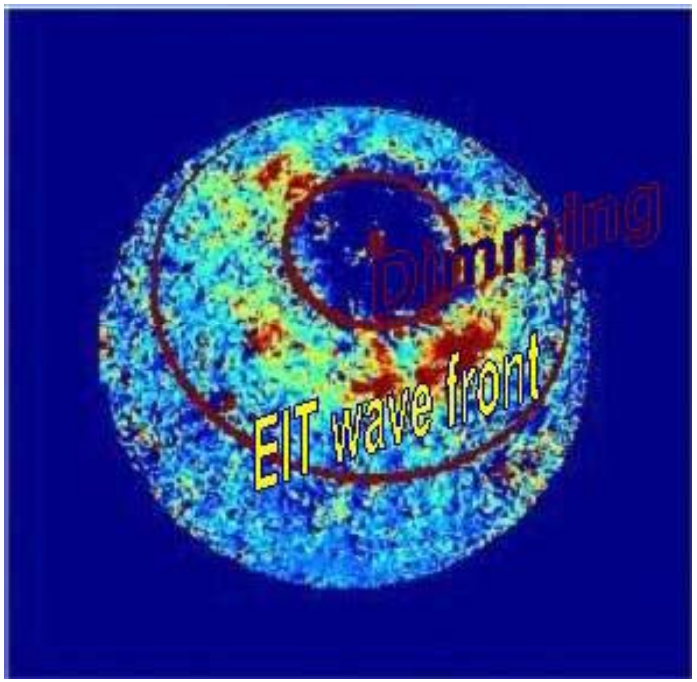


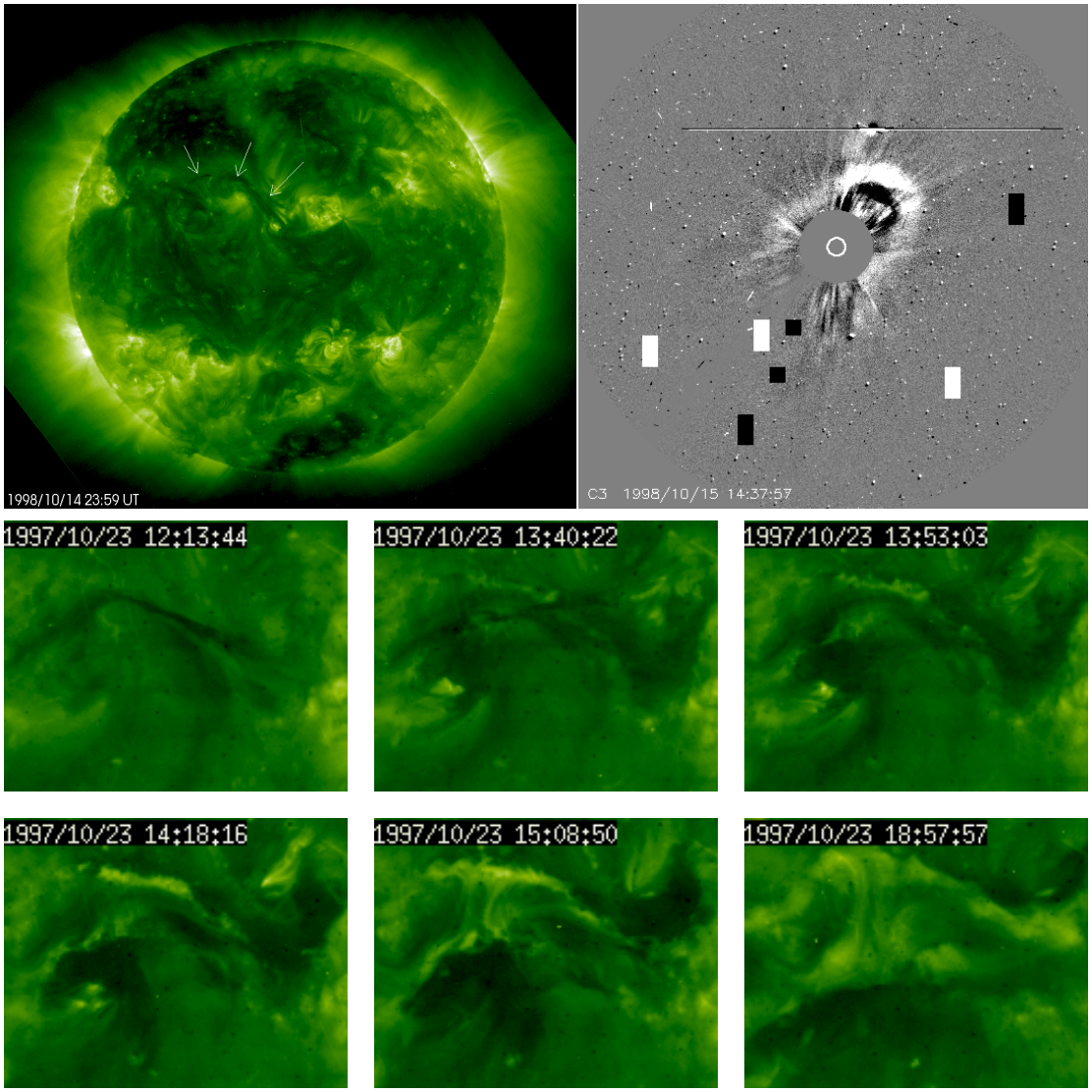
Image substructed from prevrious one

Discovery: ***Thompson et al, 1998;*** **On disk CME signatures:** ***Biesecker & Thompson, 2002***

New EUV features (1/2)

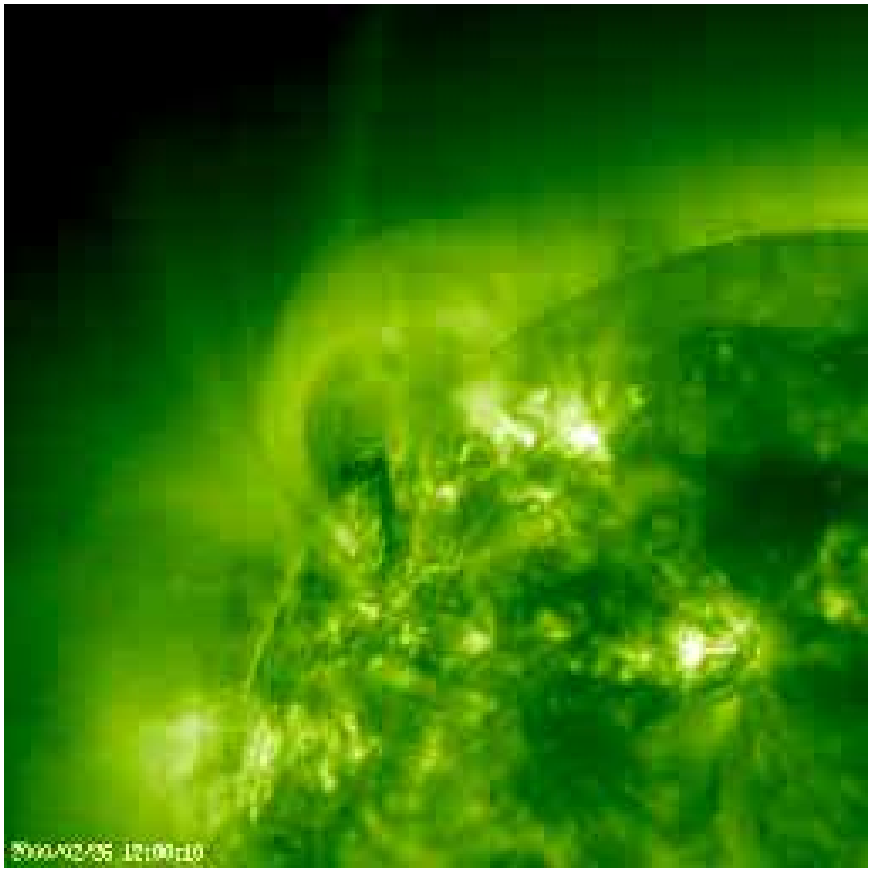
- **Filament Eruption (on-disk) evolution on solar disk EIT (FeXII)**

2 h later CME is detected.



New features (2/2)

- **Filament Eruption (off-disk)**



before eruption

- **Source situated far from all Active Regions**
- **No X-Ray jumps asscoiated (no GOES detection et al)**

To extract such a signal from noise

- **Requires an advanced technological approach**
  - Huge phenomenological diversity of events
  - Signal weakness on top of dynamical backgrounds
- **Requires a new pattern recognition approach**
  - methods for tracking solid objects do not apply,
  - regular properties of EIT waves classification -> to develop specifically tailored method.

New Solar features (summary)

- EIT waves,
- Dimmings,
- Filament Eruption,
- Gradual Solar Flares,
- Loop Opening

have one important common characteristic: Those events strongly affect PDF of pixels distributions (more structures with pixels >> std.dev).

What is higher-order Moments (1/2)?

- Centered moment of order *k:*
  - experimental: $\mu_k = \frac{1}{n}\sum_{i=1}^{n}(x_i - \langle x \rangle)^k$
  - theoretical: $\mu_k = \int x^k \overbrace{p(x)}^{\text{PDF}(x_i)}\, dx$

- Measure of PDF
  - asymmetry: $\gamma_1 = \frac{\mu_3}{\mu_2^{3/2}}$ **- Skewness**
  - flatness: $\gamma_2 = \frac{\mu_4}{\mu_2^2} - 3$ **- Kurtosis**

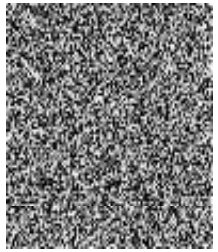
- ***γ1, γ2 >> 0*** computed for pixels distribution of EUV image could be indicators of large scale coherent structures:

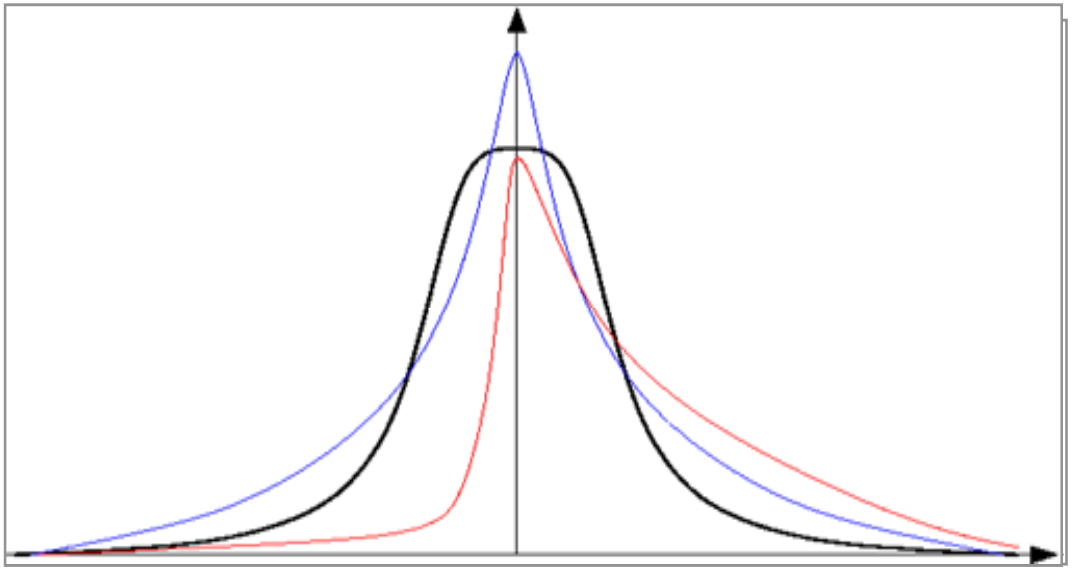
for a Gaussian distribution *γ1=γ2 = 0*

used in structure recognition

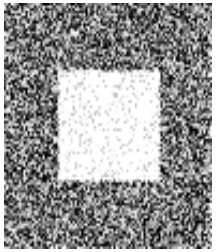
Examples (moments and the form of PDF) (2/2)

Gaussian: $\gamma_1=\gamma_2=0$

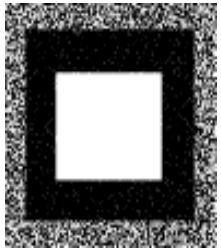




$\gamma_1=0,\ \gamma_2>0$



$\gamma_1>0,\ \gamma_2>0$



- **Skewnes = kurtosis = 0**
- **Skewnes =0, kurtosis >0**
- **Skewness >0, kutosis >0**

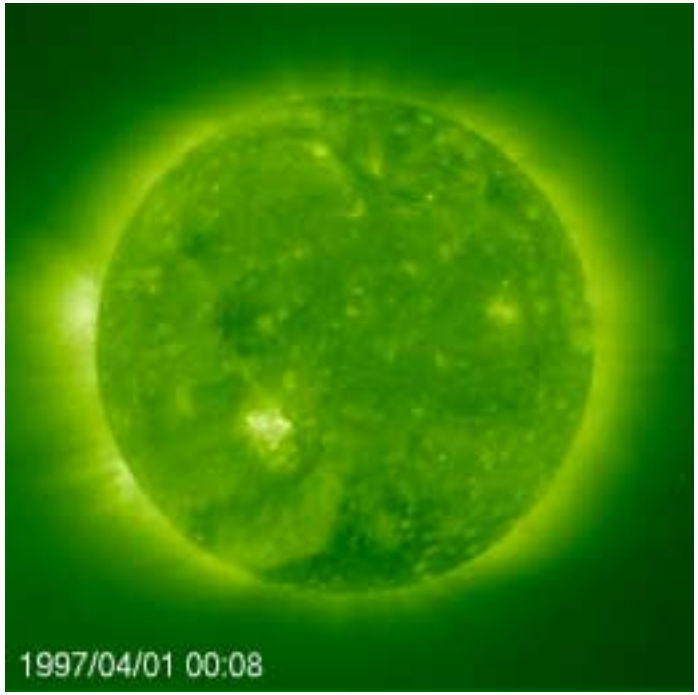
Moments of 1st and 2nd order define average value and width of distribution

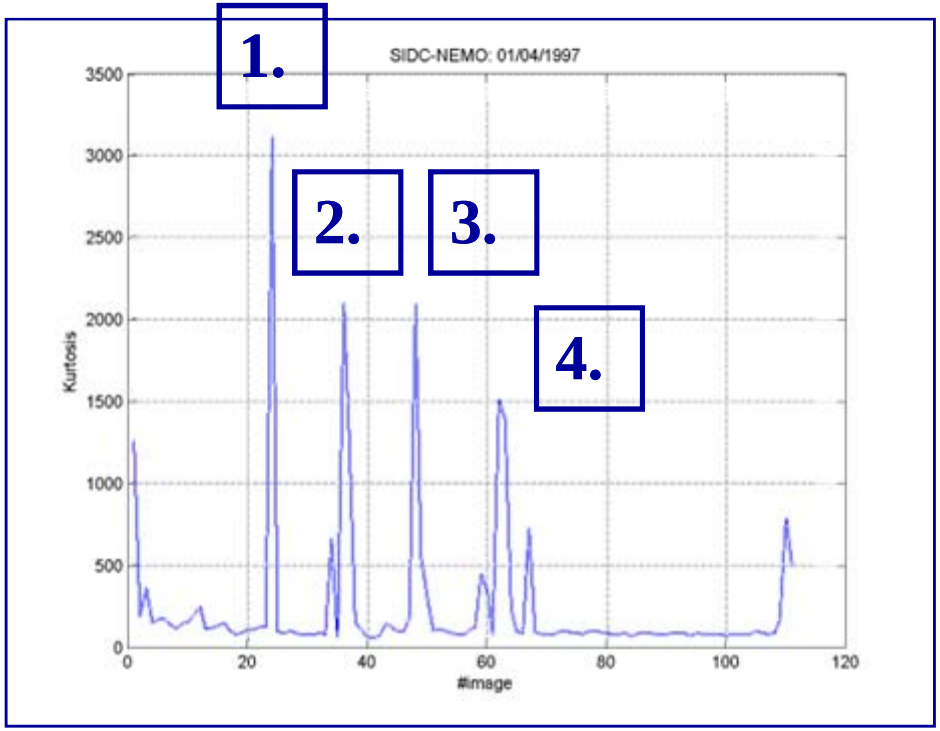
1. Detection

LASCO CME

1.	1997/04/01	06:22:00
2.	1997/04/01	09:24:33
3.	1997/04/01	12:05:23
4.	1997/04/01	15:18:38

WHERE?

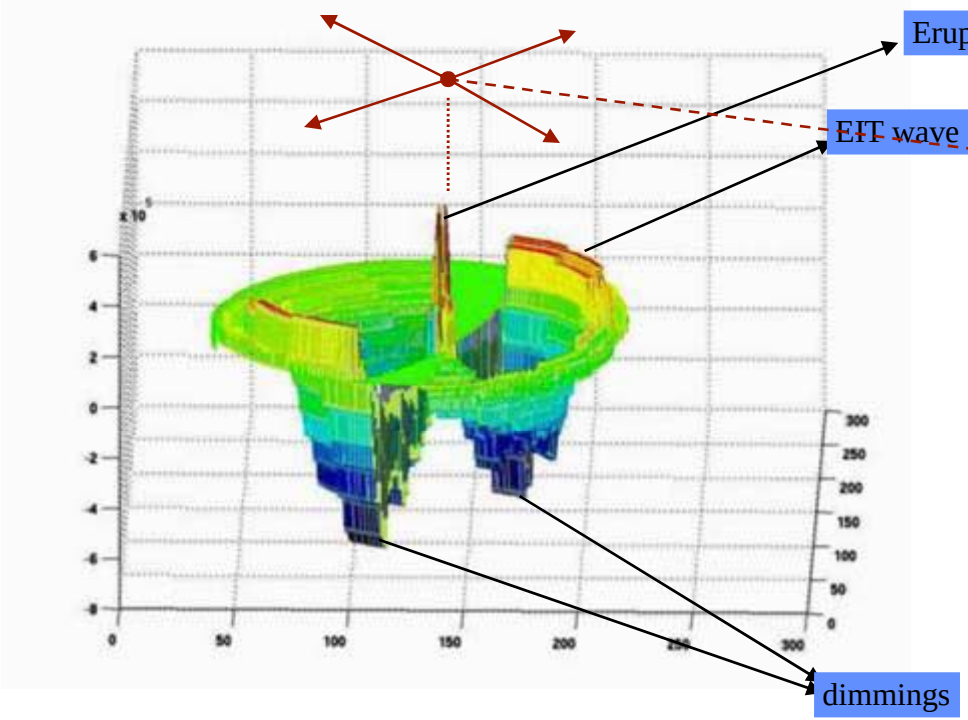


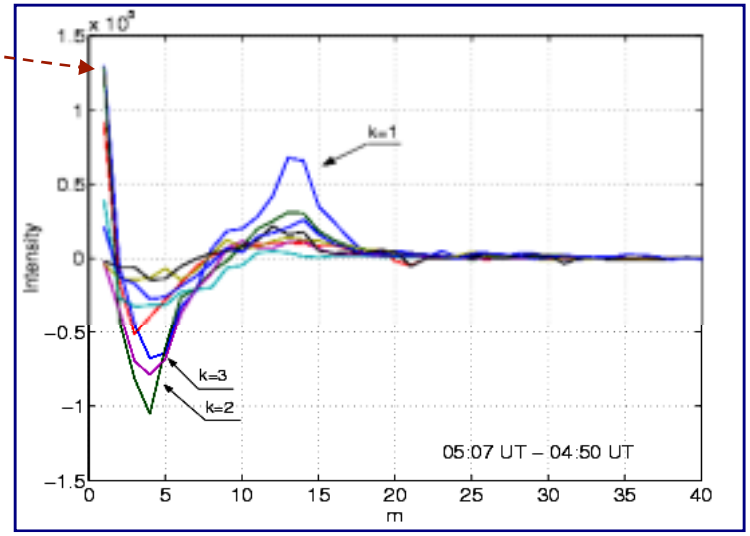


< - On-DISK ERUPTION MEASURE

2. Geometrical Extraction (1/2)

CROSS-SECTION procedure

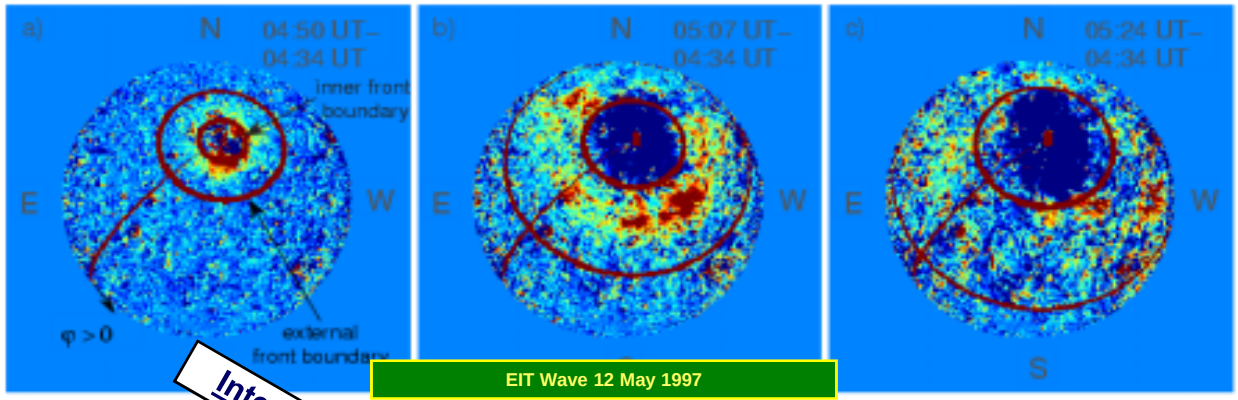




1. Solar hemisphere projected on the plane during an EIT wave event

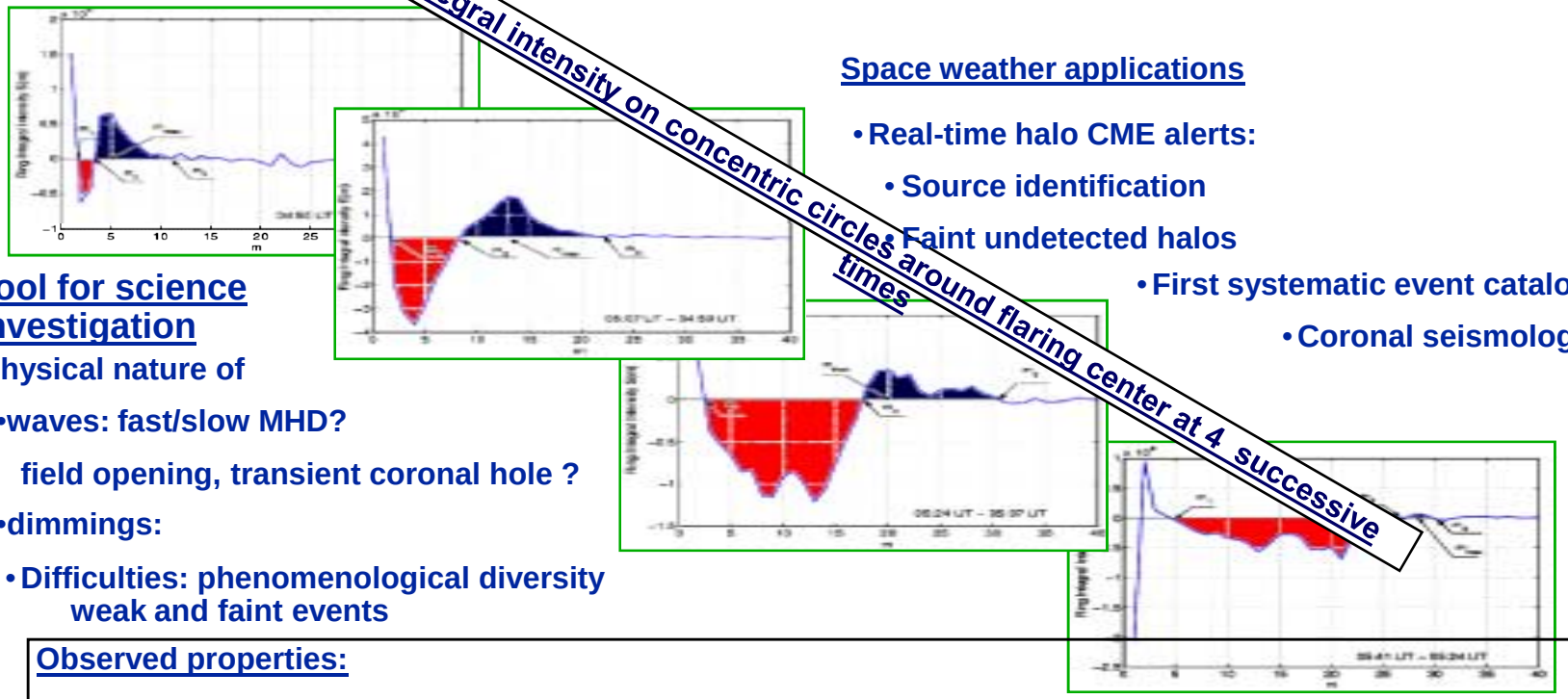
2. 8 vertical cross-section from EC, radially

Extraction (2/2) (slide prepared by F. Clette)



EIT Wave 12 May 1997

Integral intensity on concentric circles around flaring center at 4 successive times



Space weather applications

- Real-time halo CME alerts:
  - Source identification
  - Faint undetected halos
- First systematic event catalog
- Coronal seismology

Tool for science investigation

- Physical nature of
  - waves: fast/slow MHD?
    field opening, transient coronal hole ?
  - dimmings:
- Difficulties: phenomenological diversity
  weak and faint events

Observed properties:

- Width of the wavefront grows quasi quadratically in time
- Dimming boundary contiguous to inner wavefront edge
- Correlation of wave structure with associated dimming
- Energy supply to EIT wave fronts comes from dimmings

Rotataion (1/3)

- **SIDC new space weather product (sidc.be/nemo)**
  - **Real-time catalog**
  - **Monthly scan**

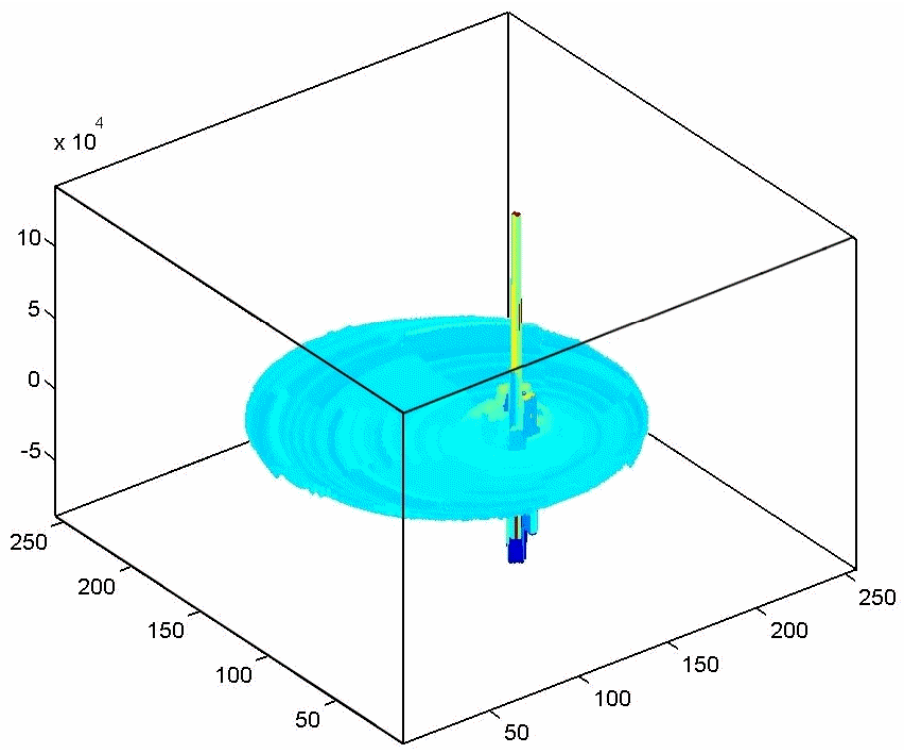
- **Global Waves in 3D for SECHHI/STEREO in Jan. 2007 :**

Under condition of free propagation

rotation of EIT wave fronts

Is often observed

STEREO WAVES

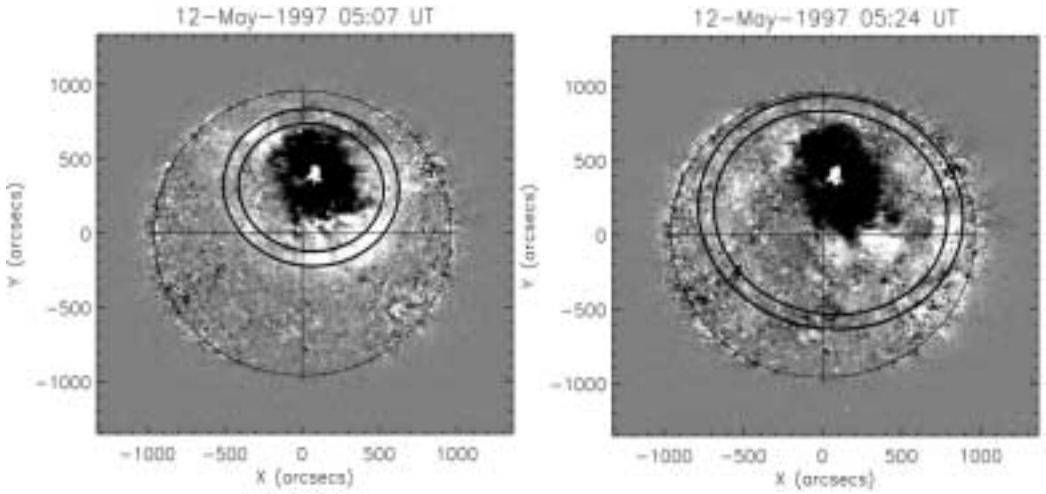


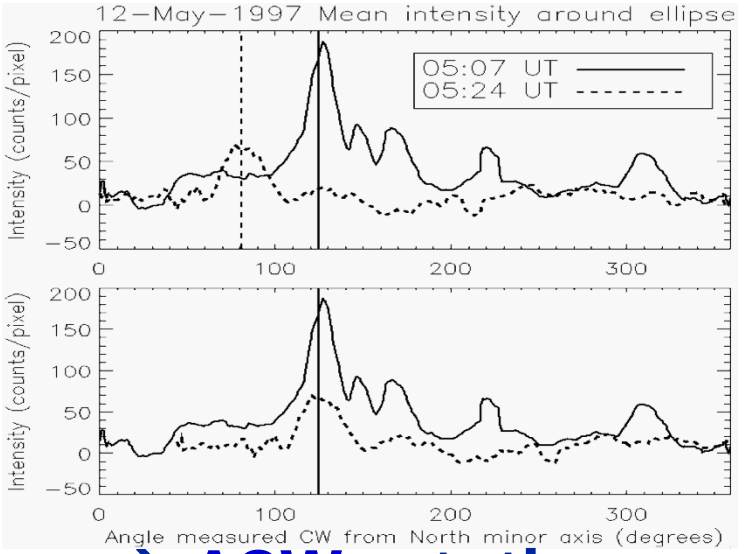
Solar hemisphere projected on the plane in 3D view

May 1997 event

Rotataion (2/3)

Intensity around bright front:

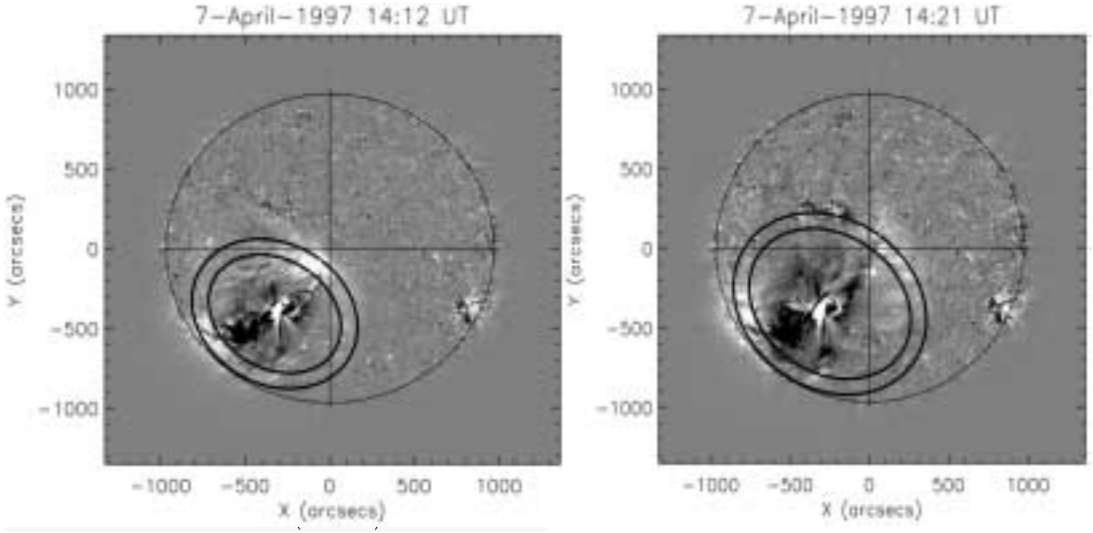


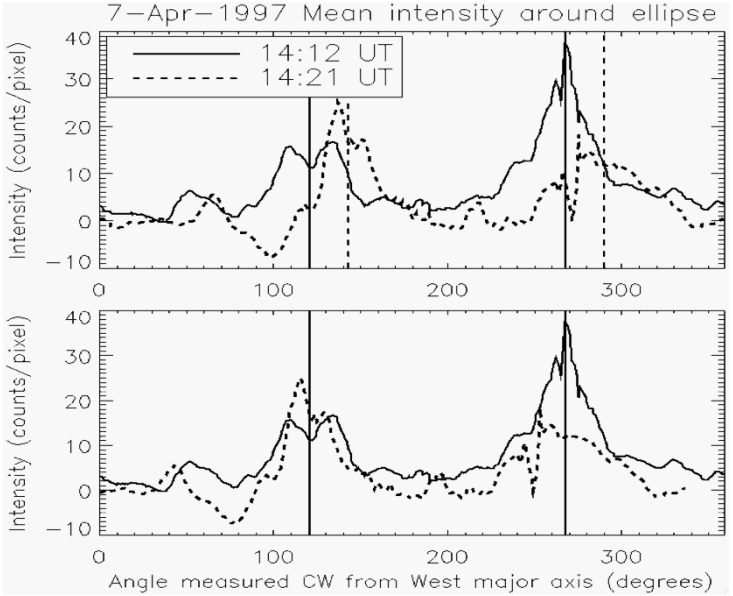


Confirms somewhat controversial result of Podladchikova & Berghmans (2005)

→ ACW rotation

7th April 1997 event





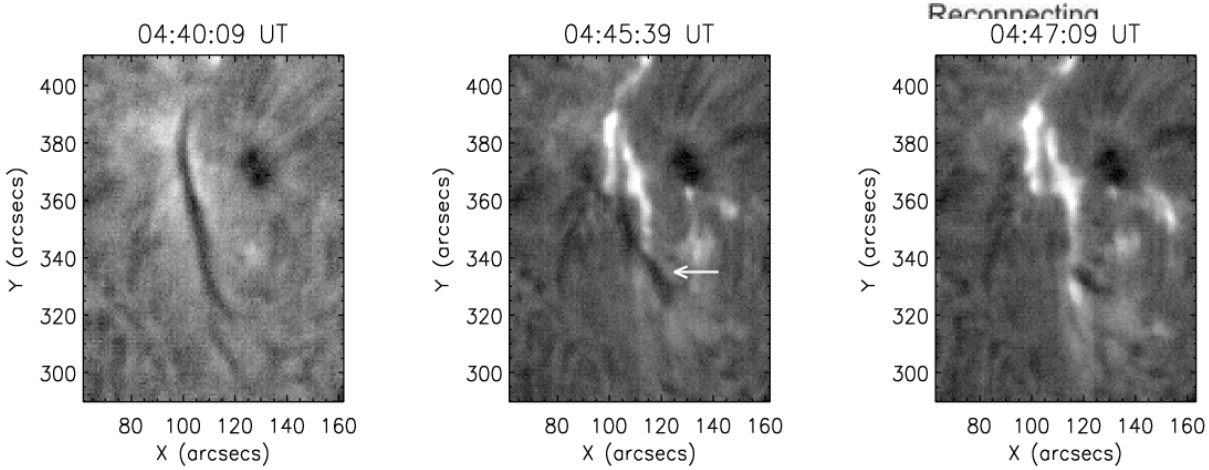
→ CW rotation

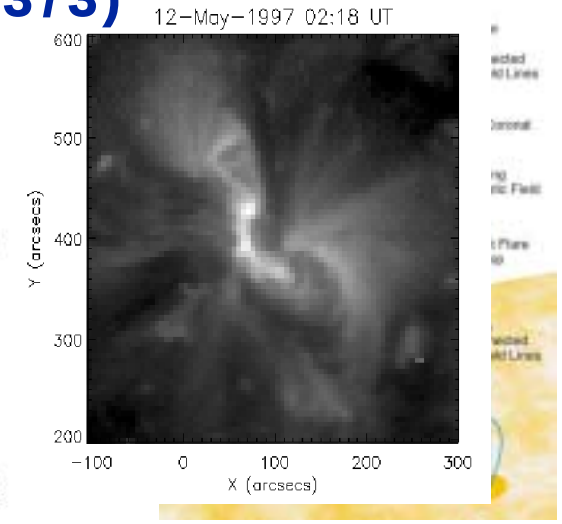
Courtesy of G. Attril et al., (Attrill G., 2007 APJL)

Standard" Model for eruptive flares (Sturrock, 1966; Shibata et al. 1995)

12th May 1997 ACW event

Rotataion (3/3)

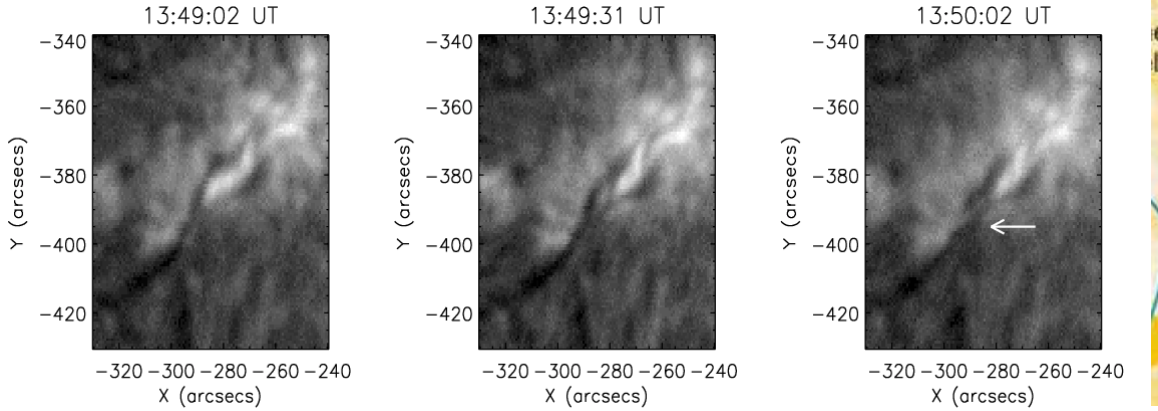


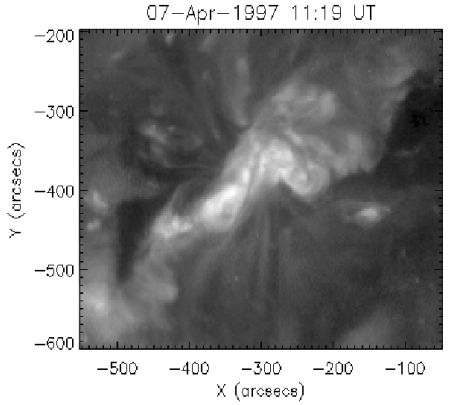


Reverse "S" sigmoid

→ ACW rotation → Negative Helicity

7th April 1997 CW event





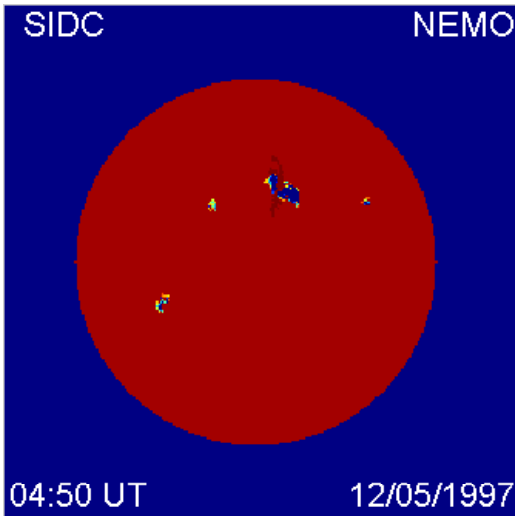
Forward "S" Sigmoid

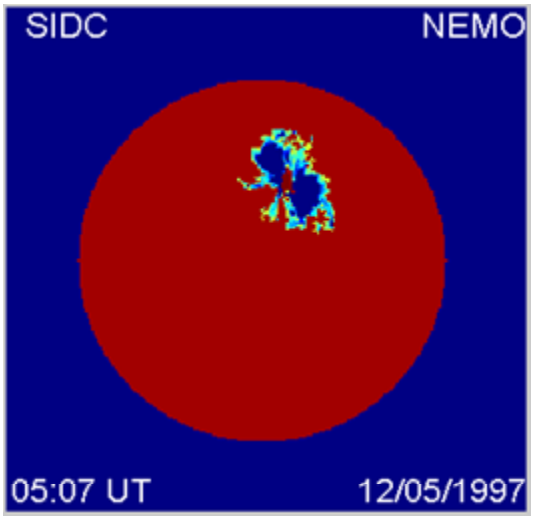
Courtesy of G. Attril et al.

→ CW rotation → Positive Helicity

Geometrical Extraction (3/3)

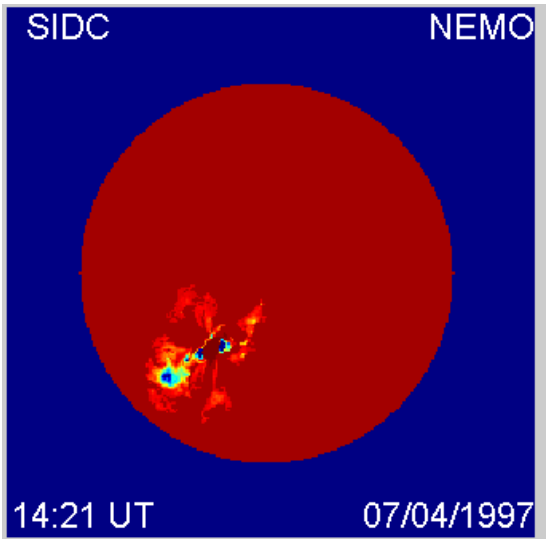
- **Dimmings evolution and ICME**





dipolar

quadrupolar



Dimmings are the coronal footpoints of interplanetary flux rope

Webb & Hudson, 2000

Attrill et al, 2006

Dimming regions: Magnetic flux II

Region	Positive Flux (Mx)	Negative Flux (Mx)	Absolute Flux (Mx)	Net Flux (Mx)
1	2×10^{20}	-11×10^{20}	13×10^{20}	-9×10^{20}
2	24×10^{20}	-3×10^{20}	27×10^{20}	21×10^{20}

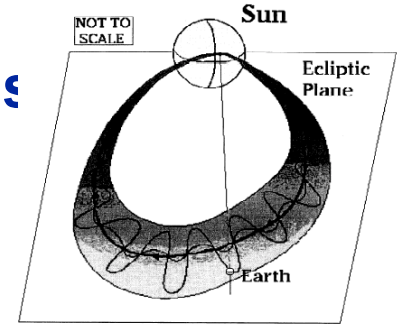
Uncertainty in magnetic flux measurements = ± 7×10^{20} Mx

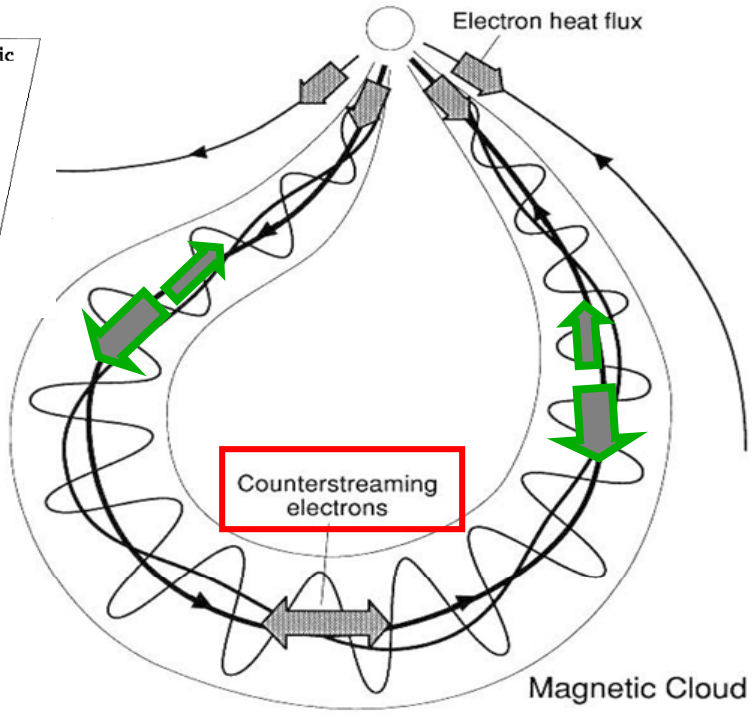
Since the majority of small-scale mixed polarities close in their direct vicinity, the Net Flux provides an estimate of the amount of magnetic flux that is potentially free for connection with magnetic flux outside of the selected region.

from Attrill G., 2006 Sol.Phys.

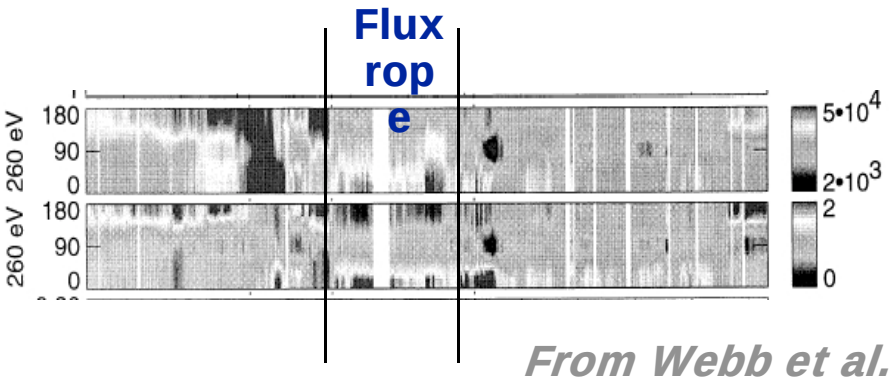
From: Webb et al., 2000

- **"Twin" dimming regions**
- **Dimming regions mark footpoints of erupted flux rope**
- **Magnetic flux in dimmings is twice larger than magnetic flux in the magnetic cloud**





- **No bidirectional electron streaming in magnetic cloud**
- **→ Authors question the correspondence between bi-directional flows & solar ejecta**

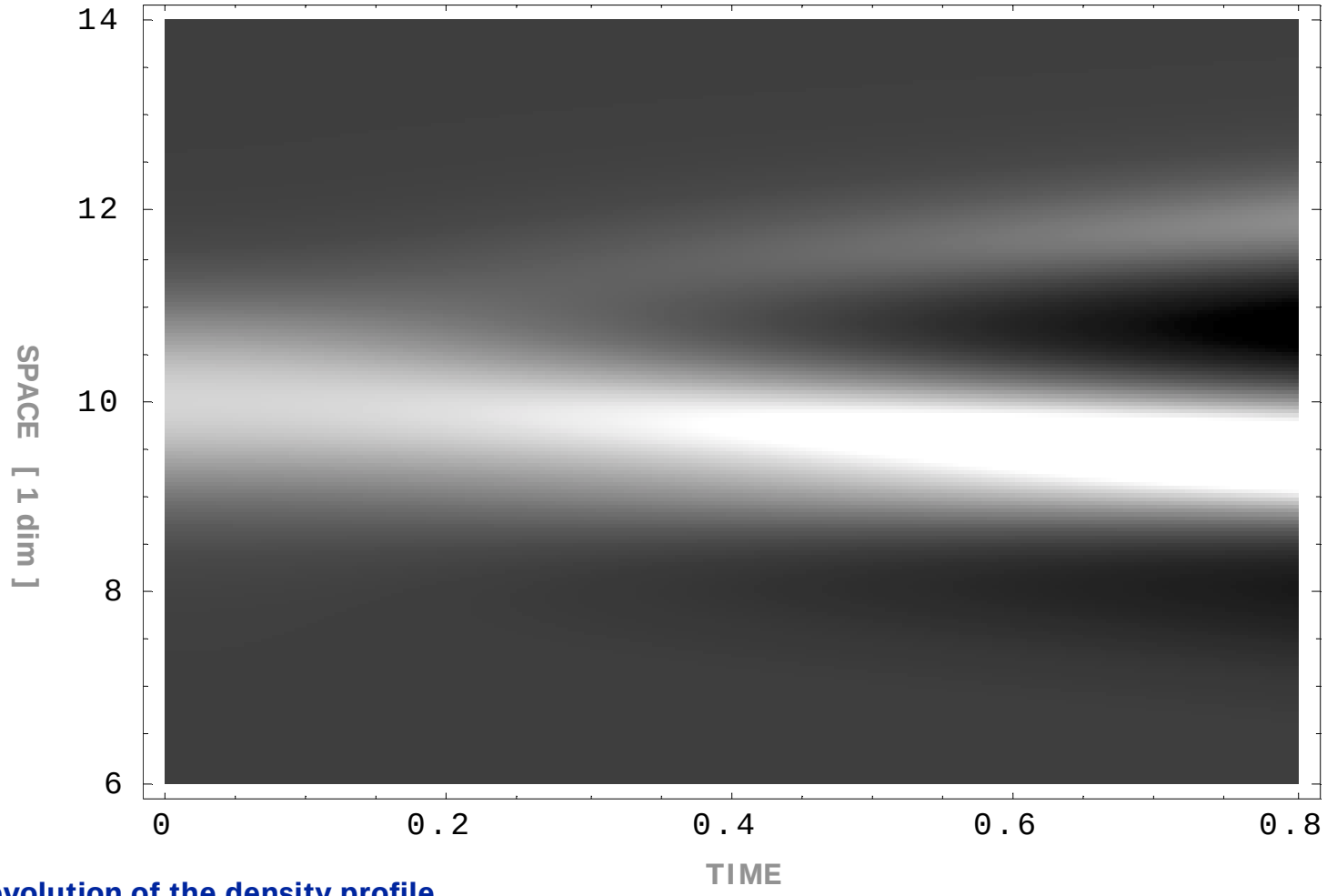


From Webb et al., (2000)

from Attrill G., 2006 Sol.Phys.

3. Validation

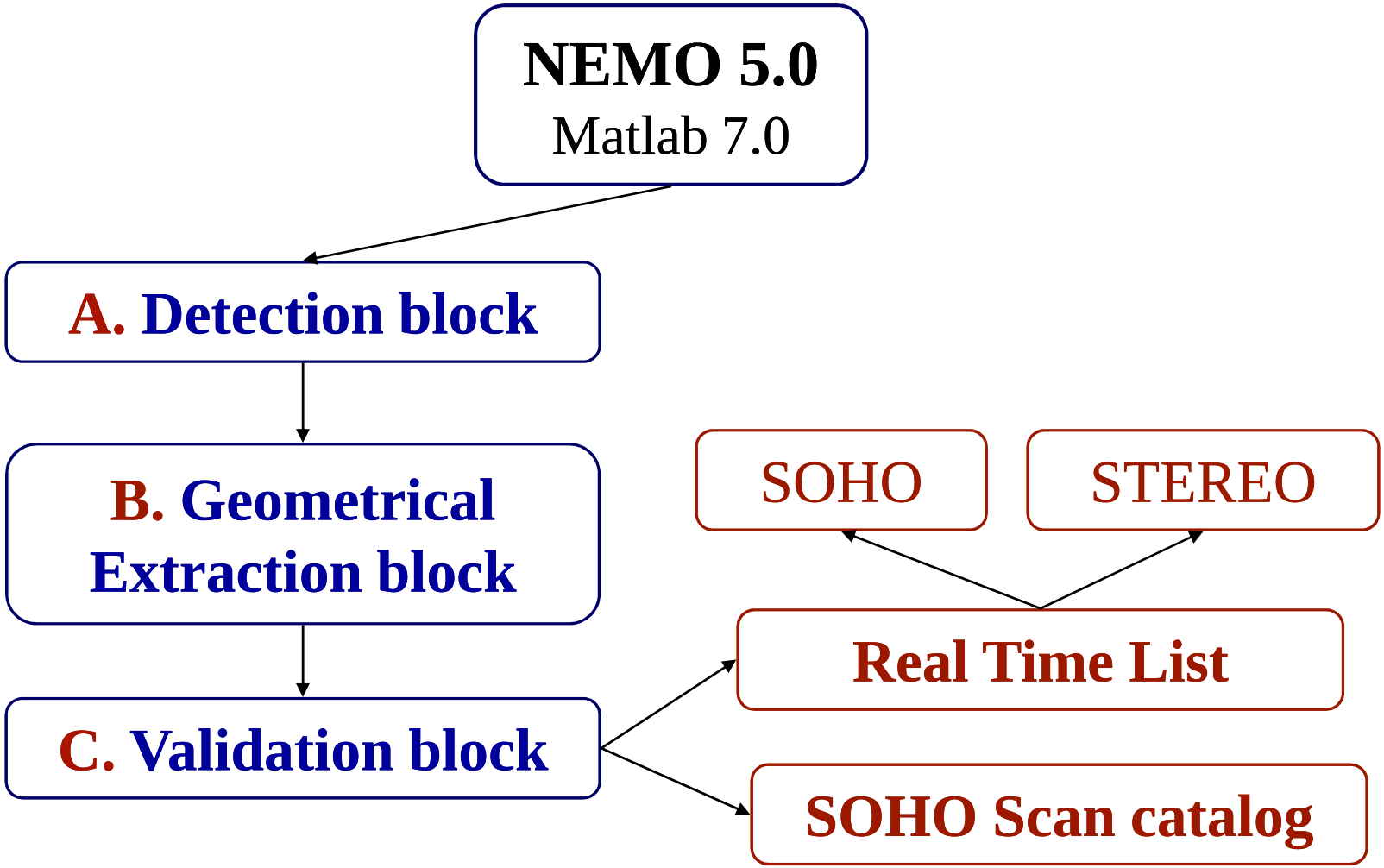
- **MHD BLAST WAVES FROM POINT AND CYLINDRICAL SOURCES:**



Time evolution of the density profile

Fast mode moving upwards and slow downwards

Architecture



NEMO Basic Classification

of Eruptive EUV Dimmings :

- **on magnetic topology**
  - dipolar
  - quadrupolar
  - free shape

- **on morphology**

Type	Area	Intensity
1	Small	High
2	Large	Weak

of EIT waves :

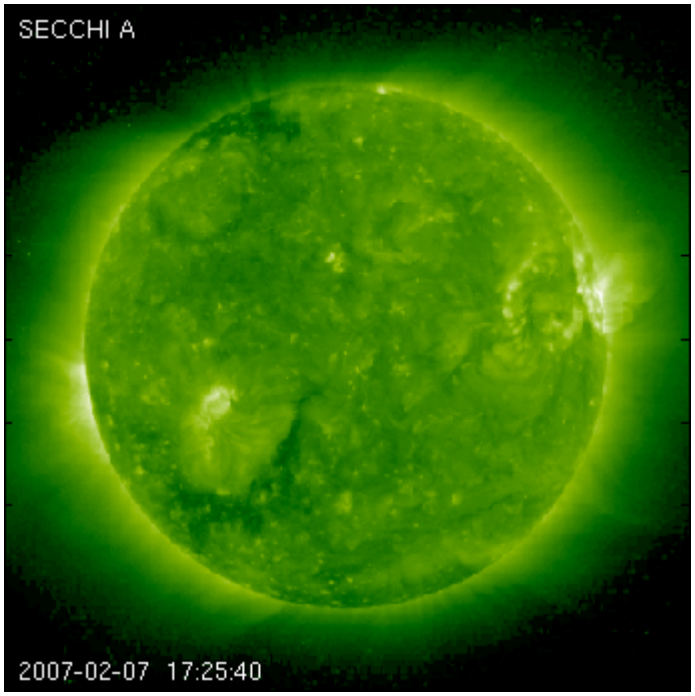
- **on type**
  - Slow
  - Fast

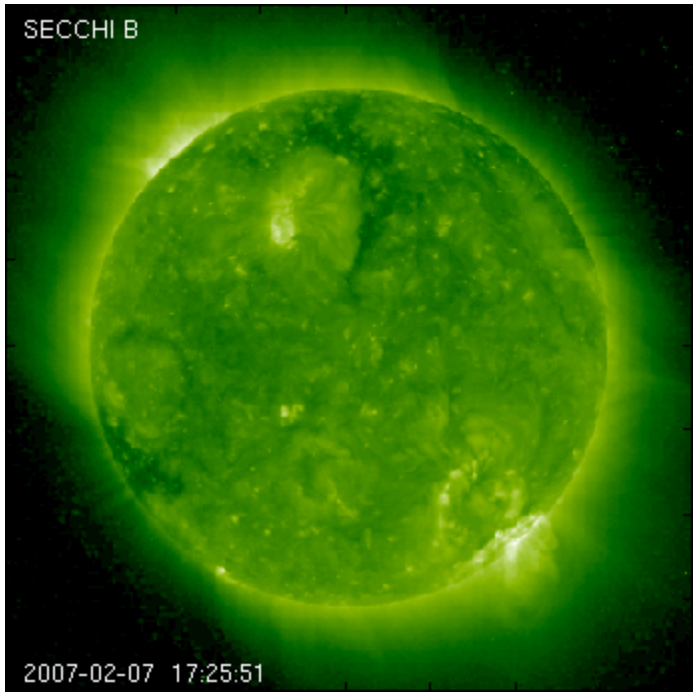
- **on morphology**

Type	Geometry	Solar Condition
1	Assymmetrical/symmetrical	Freely propagating
2	Assymmetrical/symmetrical	Interacting with ARs

Dimming classification concerns only eruption accompanying EUV dimmings, detected by NEMO and extracted from SOHO/EIT data.

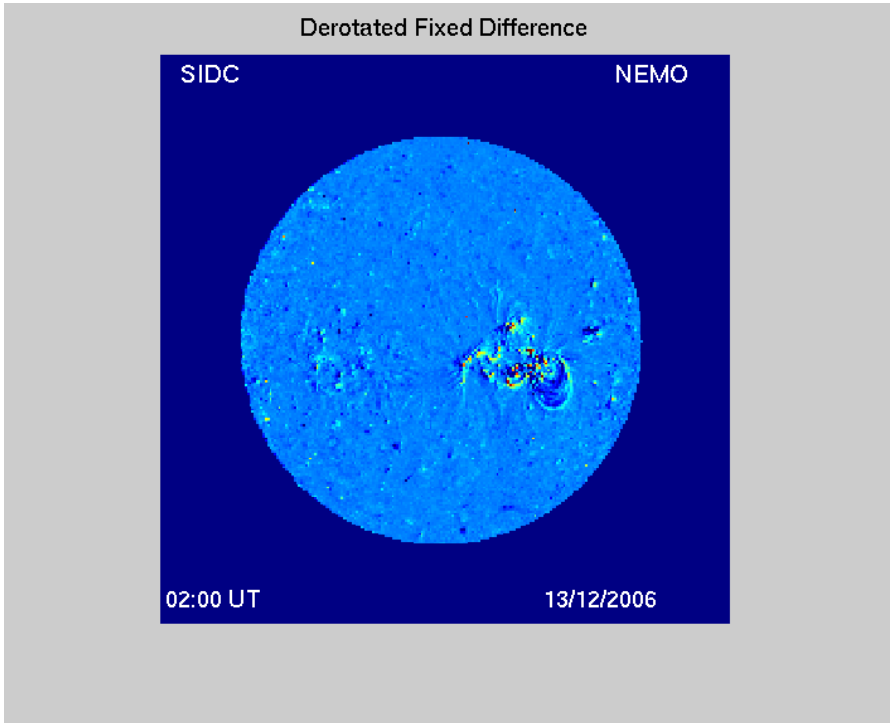
SECCHI EUV WAVES

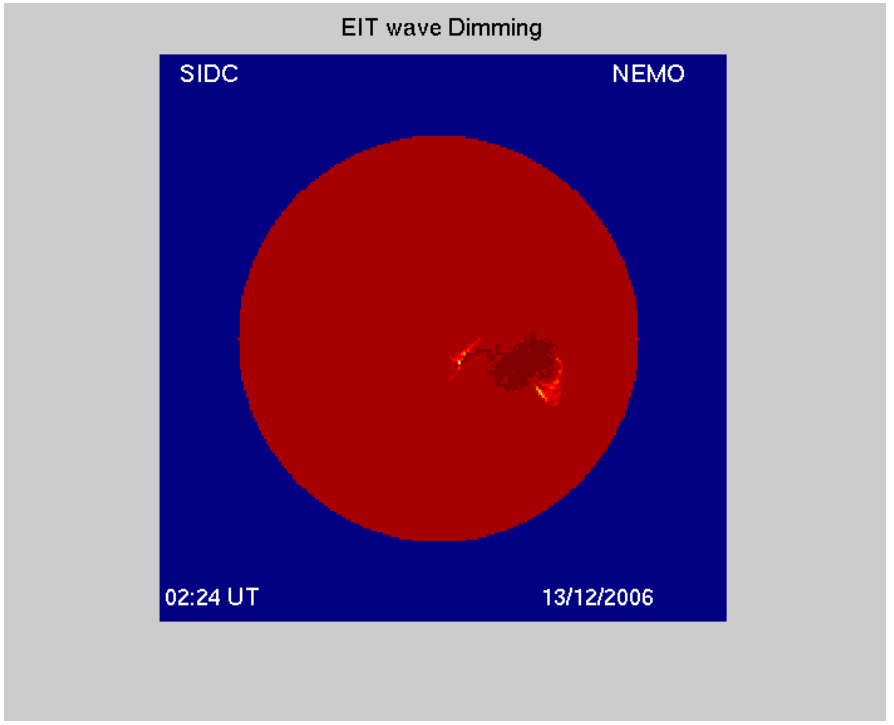




Well observed in 4 wavelenghts. The morphology is slightly different in 304 A.

23-24 Solar Minimum Events





Conclusion

NEMO:

- **detects only eruptions, not flares.**
- **can build on-disk SP.W. event catalog with SECCHI.**
- **extraction technique brings new insight on events.**
- **is able to sort out modern dataflows TBs/day (i.e. SoL.Orb. or SDO)**
- **On-board recognition perspective for telemetry optimisation**

Thanks

- to Barbara Thompson for 1997-1998 EIT wave catalog
- to SIDC preview web, Cactus, B2X teams
- LPCE-Orleans, Obsrevatoire de Meudon
- to SECCHI/STEREO, BELSPO, ESA, NASA

"And you are telling me
you work in pattern recognition!"