

"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

Olena Podladchikova & David Berghmans

ROB



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Outline

● Introduction

- NEMO in the context of Space Weather Services
- Technological challenges

● Bare Bones of NEMO software

- Architecture
- Recognition & Diagnostic,
- Catalogue
in real time

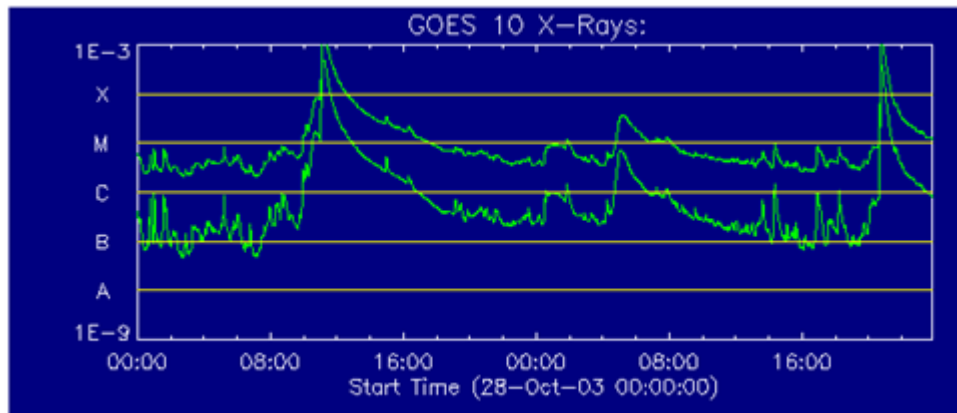
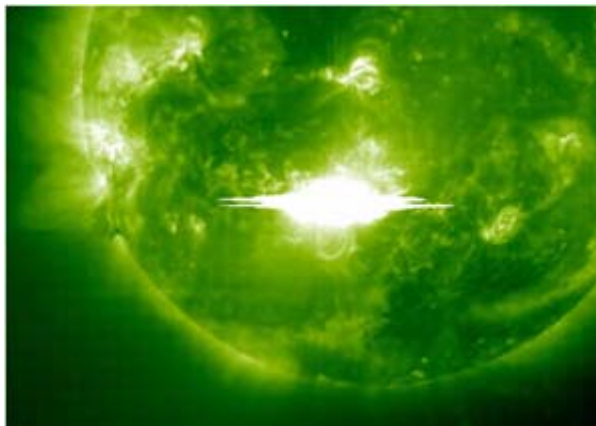
● Discussion

- Event classification,
- hidden properties.
- Perspectives

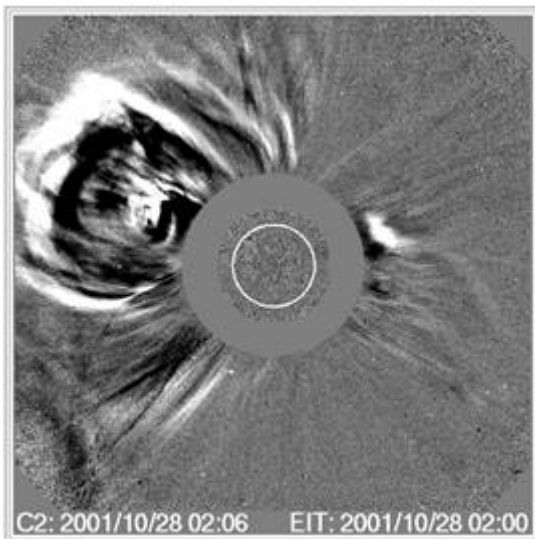


Solar Eruptions in Real time

Flares



CMEs



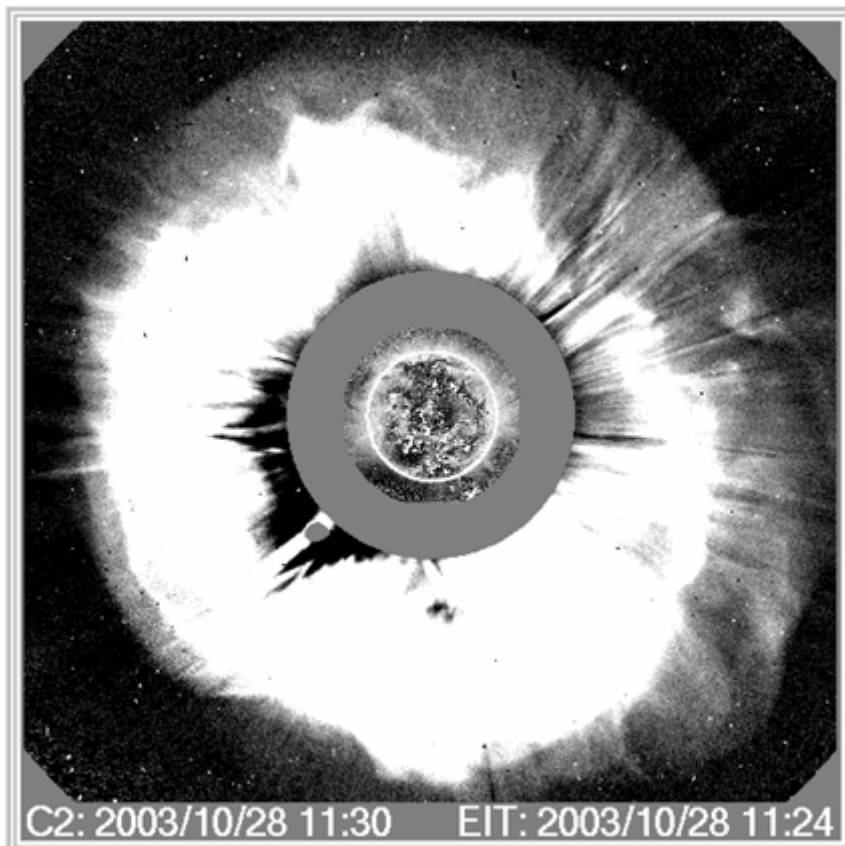
- *SEC events at NOAA, SXI*
- *SolarSoft events*
- *B2Xflare*

- *“Gopalswamy” list*
- *<http://sidc.be/cactus>*

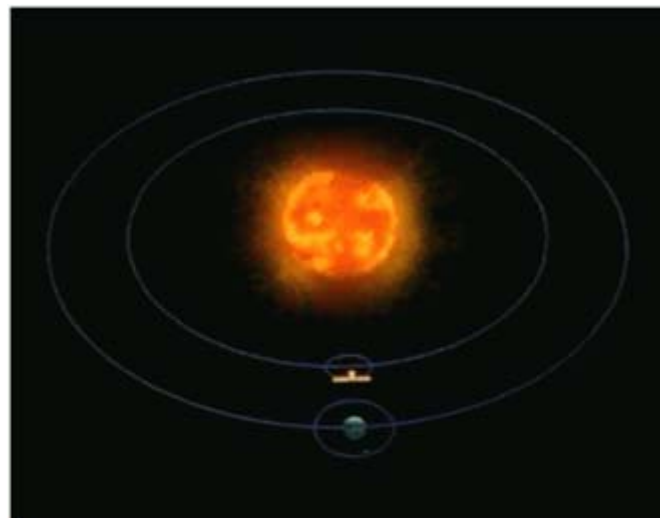


Importance of On-Disk Eruptions

geoeffectivity



SOHO profits continuous view of the Sun.



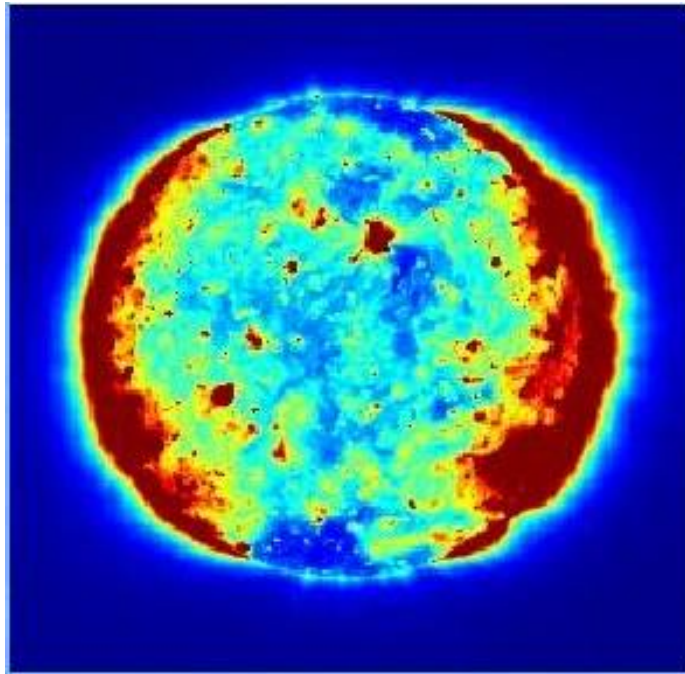
SOHO is in the L1 Lagrange point
in the Solar-Terrestrial System,
and goes around the Sun simultaneously
with the Earth.



How does Eruption look like in EUV?

precursor

● "EIT wave"



Original Image

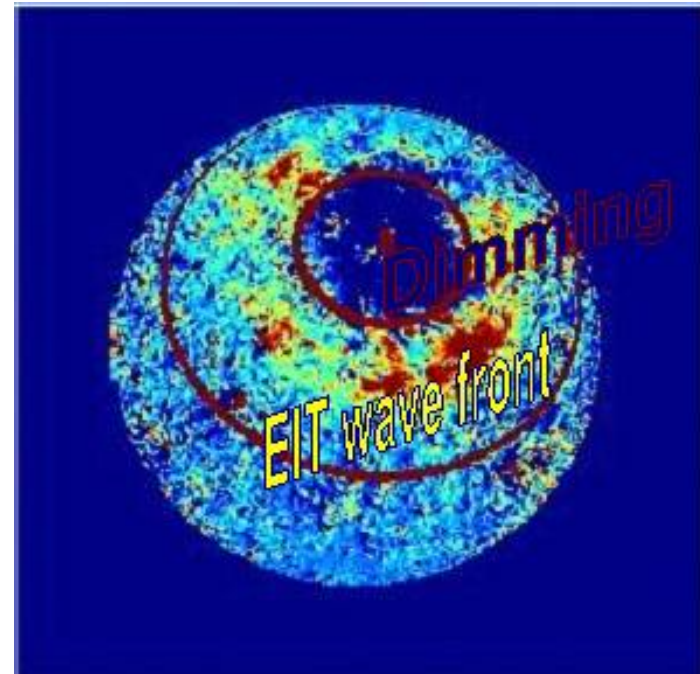


Image substracted from previous one

Discovery: *Thompson et al, 1998;*

On disk CME signatures: *Biesecker & Thompson, 2002*



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**

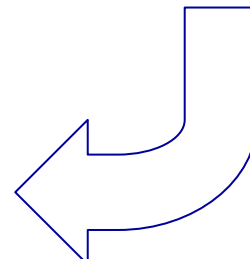
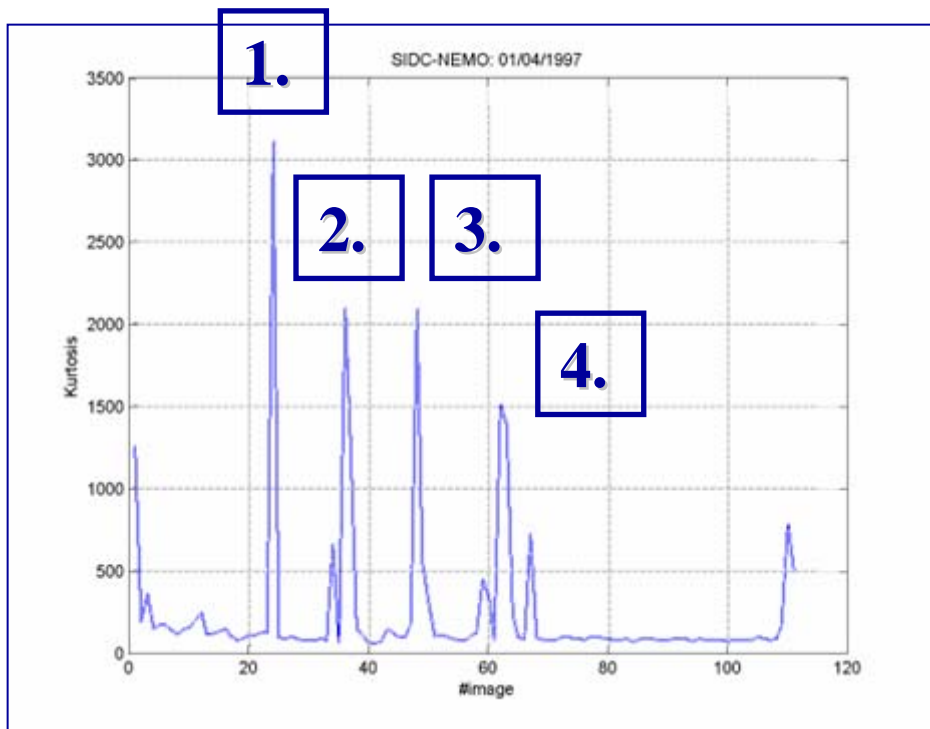
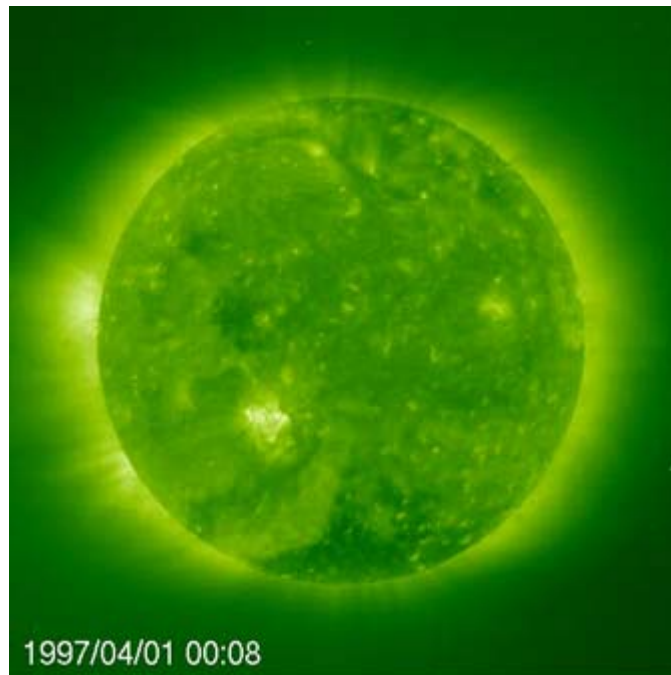
- methods for tracking solid objects do not apply,
- regular properties of EIT waves classification -> to develop specifically tailored method.



A. 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



On-DISK ERUPTION MEASURE



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:

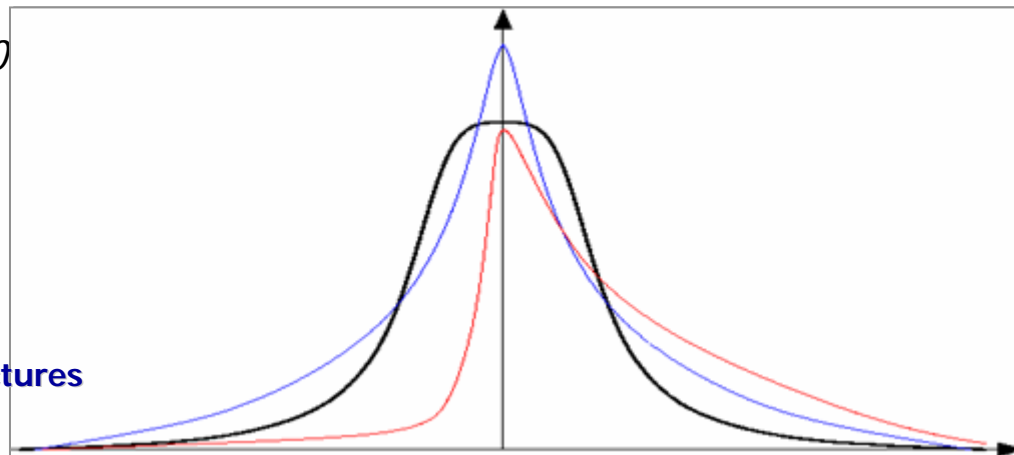
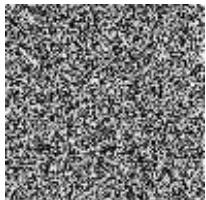
$$\gamma_2 = \frac{\mu_4}{\mu_2^2} - 3$$

- Kurtosis

$\gamma_1, \gamma_2 \gg 0$ computed for pixels distribution of EUV image could be indicators of large scale coherent structures:

for a Gaussian distribution $\gamma_1 = \gamma_2 = 0$

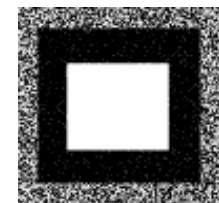
Gaussian: $\gamma_1 = \gamma_2 = 0$



$\gamma_1 = 0, \gamma_2 > 0$



$\gamma_1 > 0, \gamma_2 > 0$

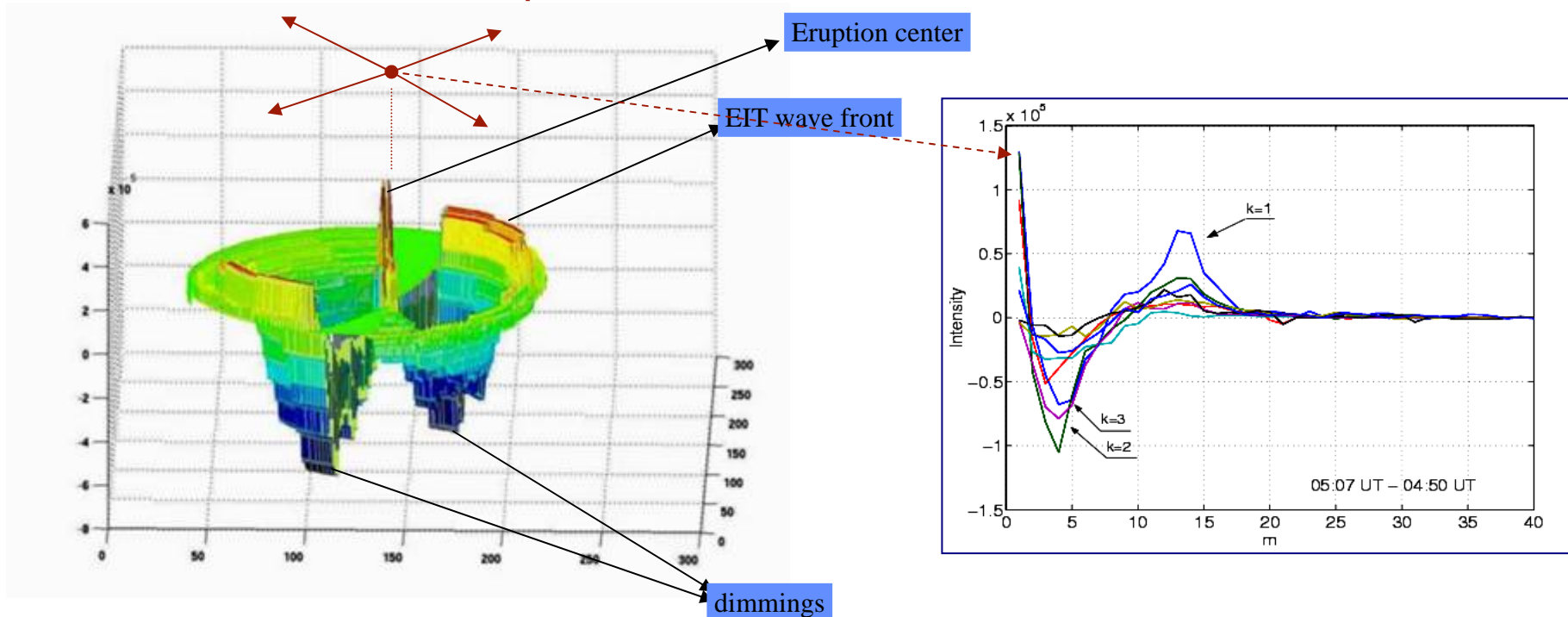


Indicator of large scale structures



2. Geometrical Extraction (1/3)

CROSS-SECTION procedure



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

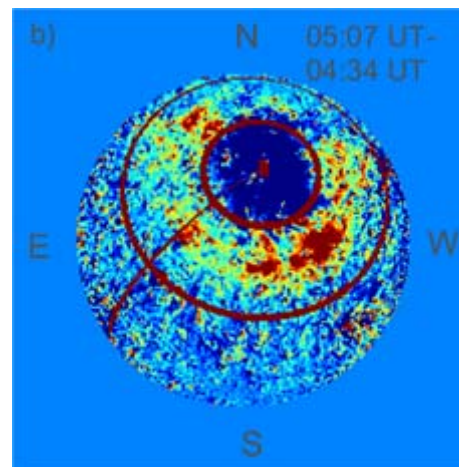
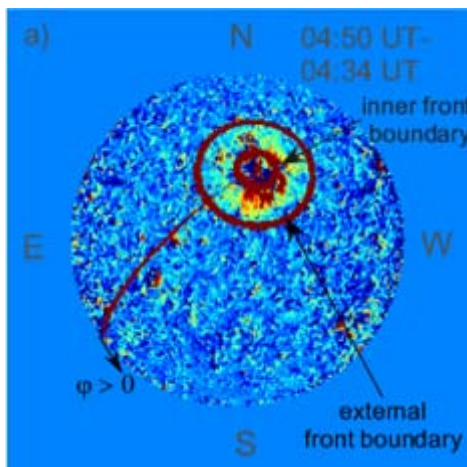
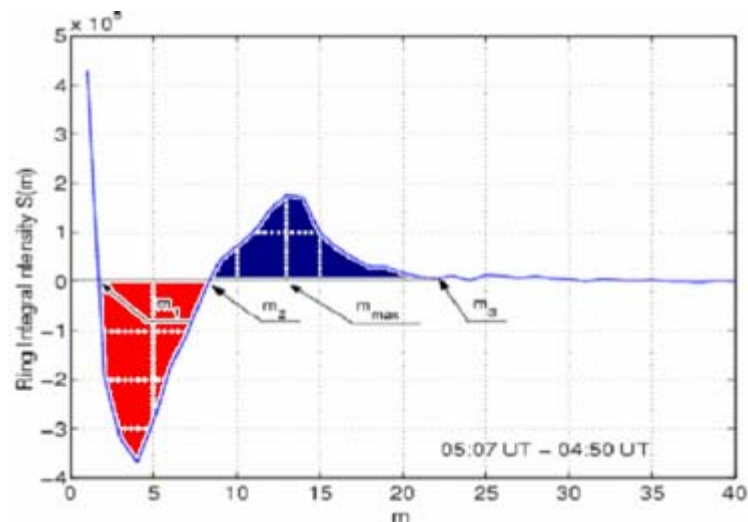
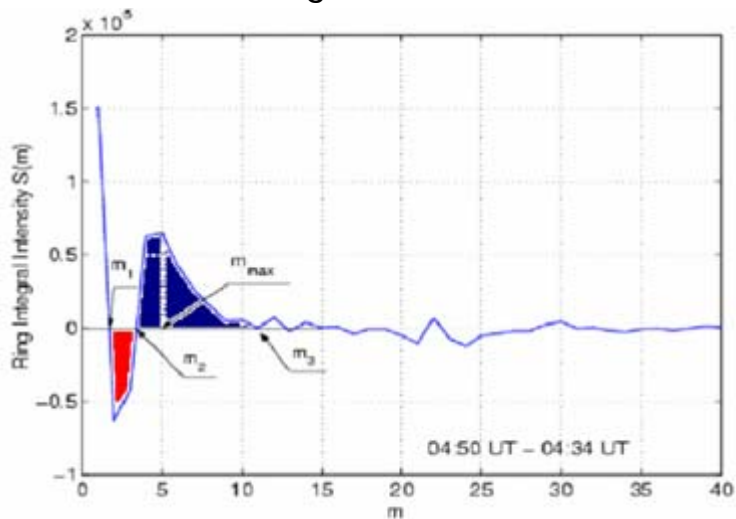
2. 8 vertical cross-section from EC, radially



Geometrical Extraction (2/3)

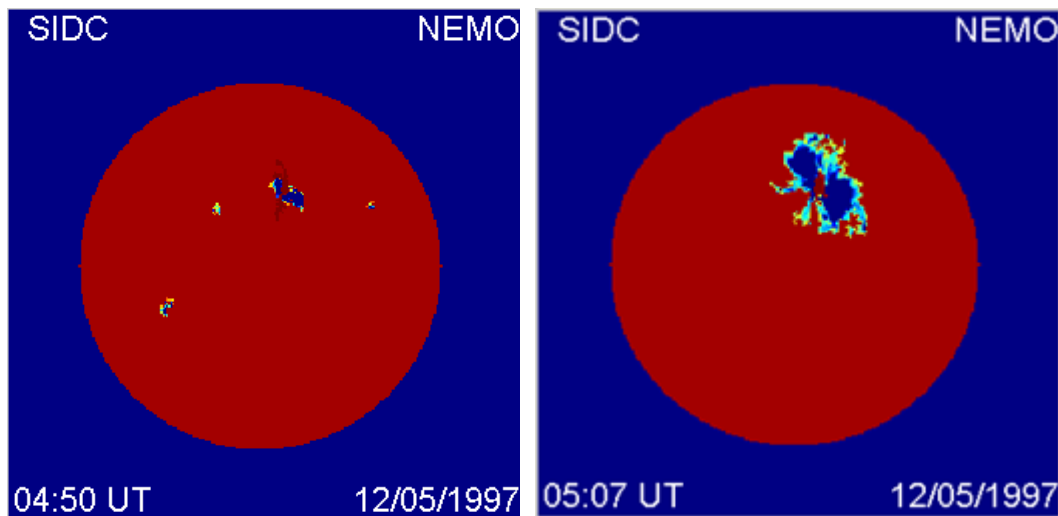
From Podladchikova & Berghmans, 2005

The integrated positive intensity of the front balances the integrated negative intensity of the dimmings.

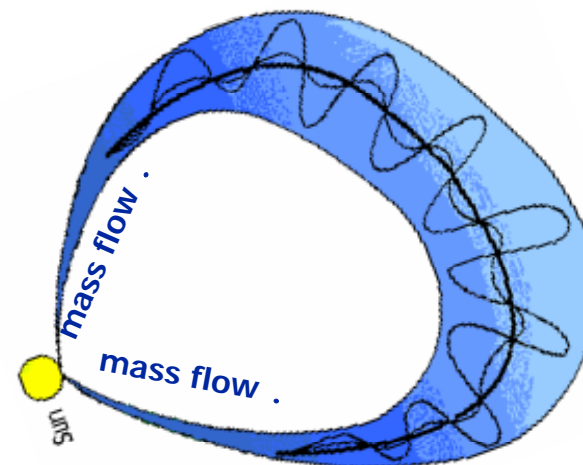


Geometrical Extraction (3/3)

Dimmings evolution and ICME



dipolar

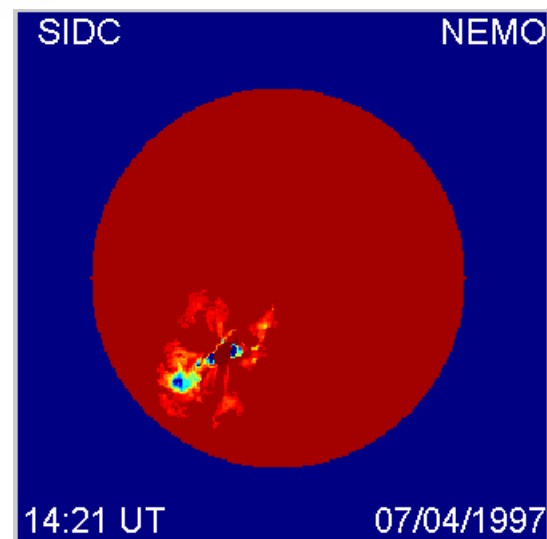


quadrupolar

Dimmings are the coronal footpoints of interplanetary flux rope

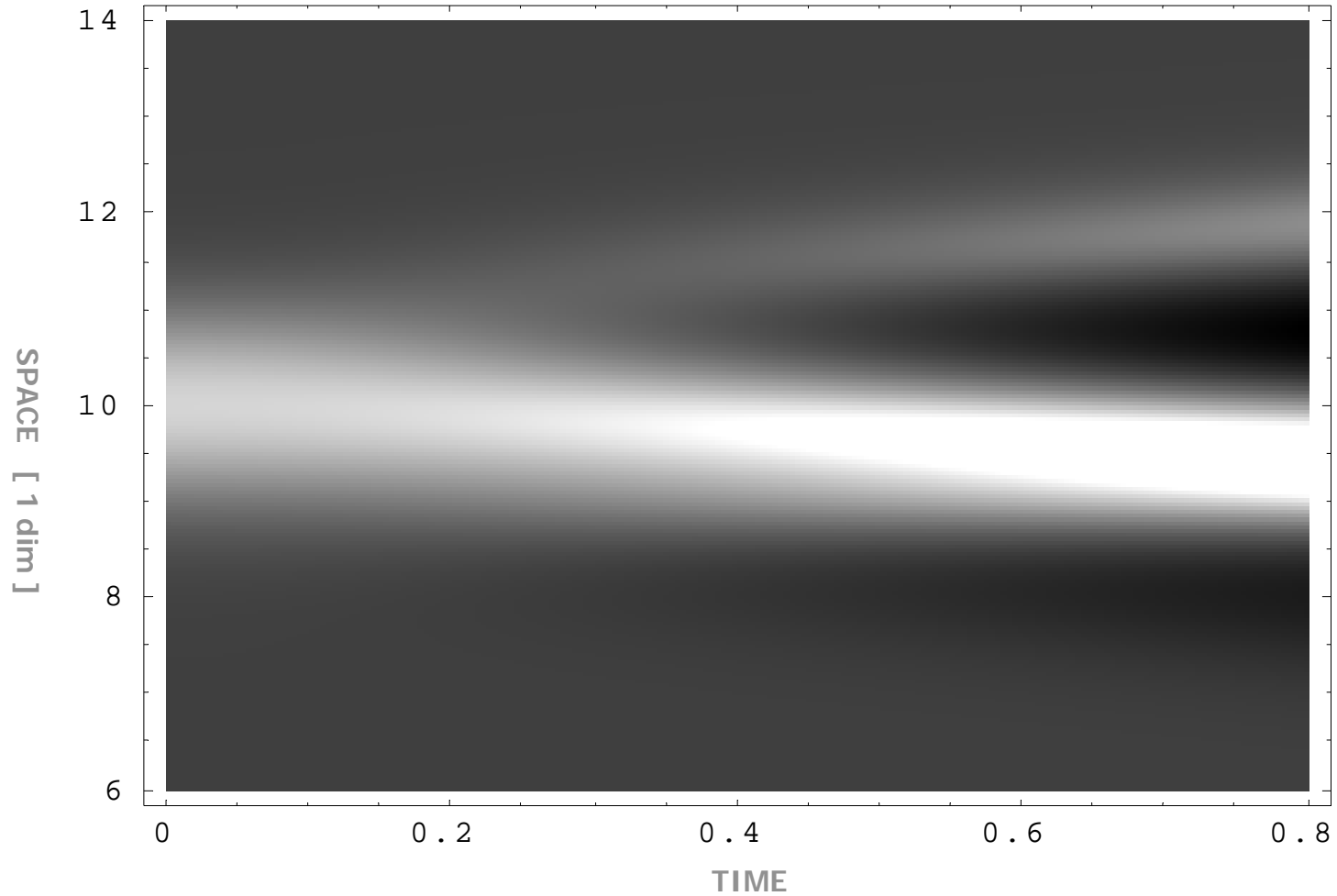
Webb & Hudson, 2000

Attrill et al, 2006

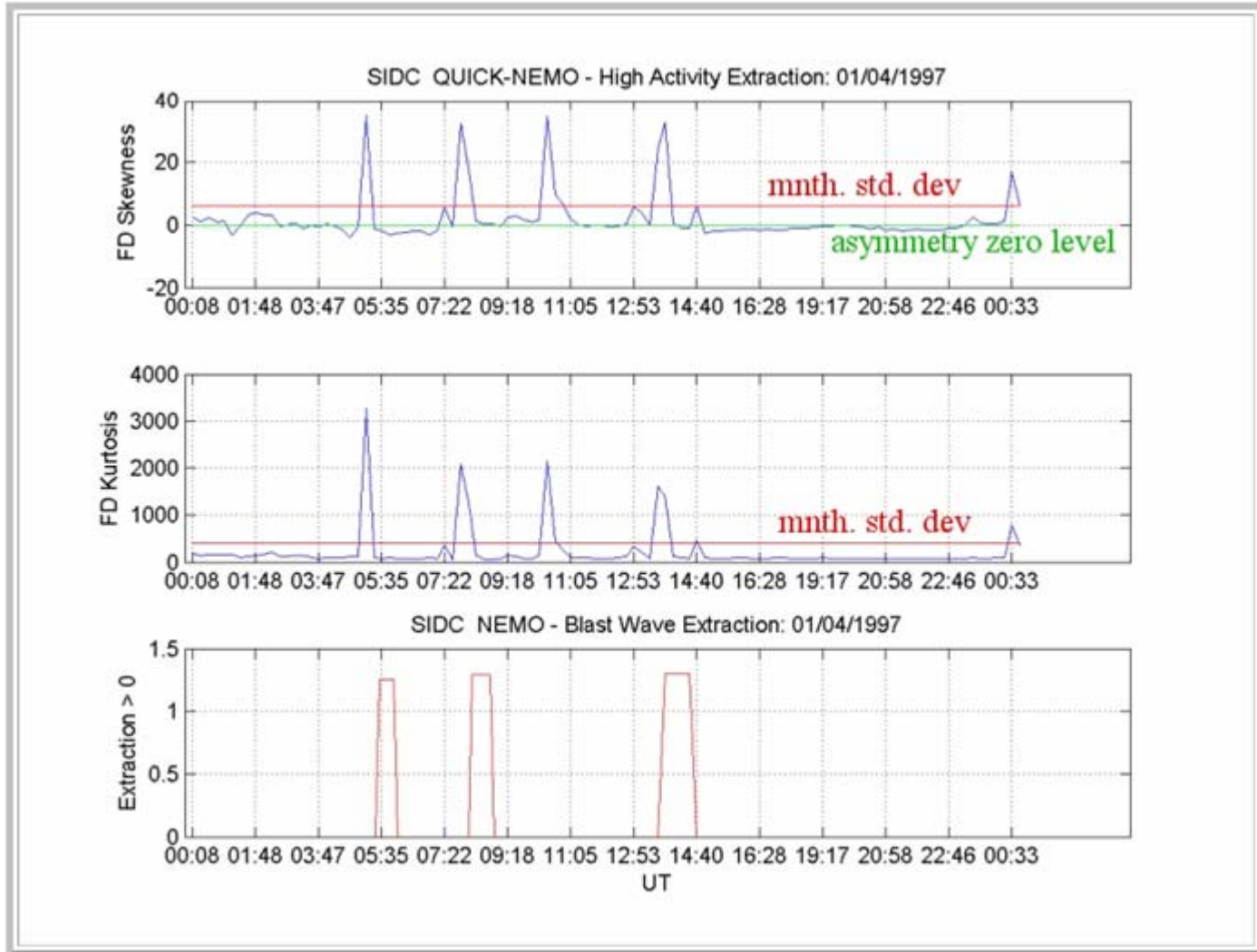


3. Validation (1/2)

● Density profile after cylindrical source explosion



3. Validation (2/2)



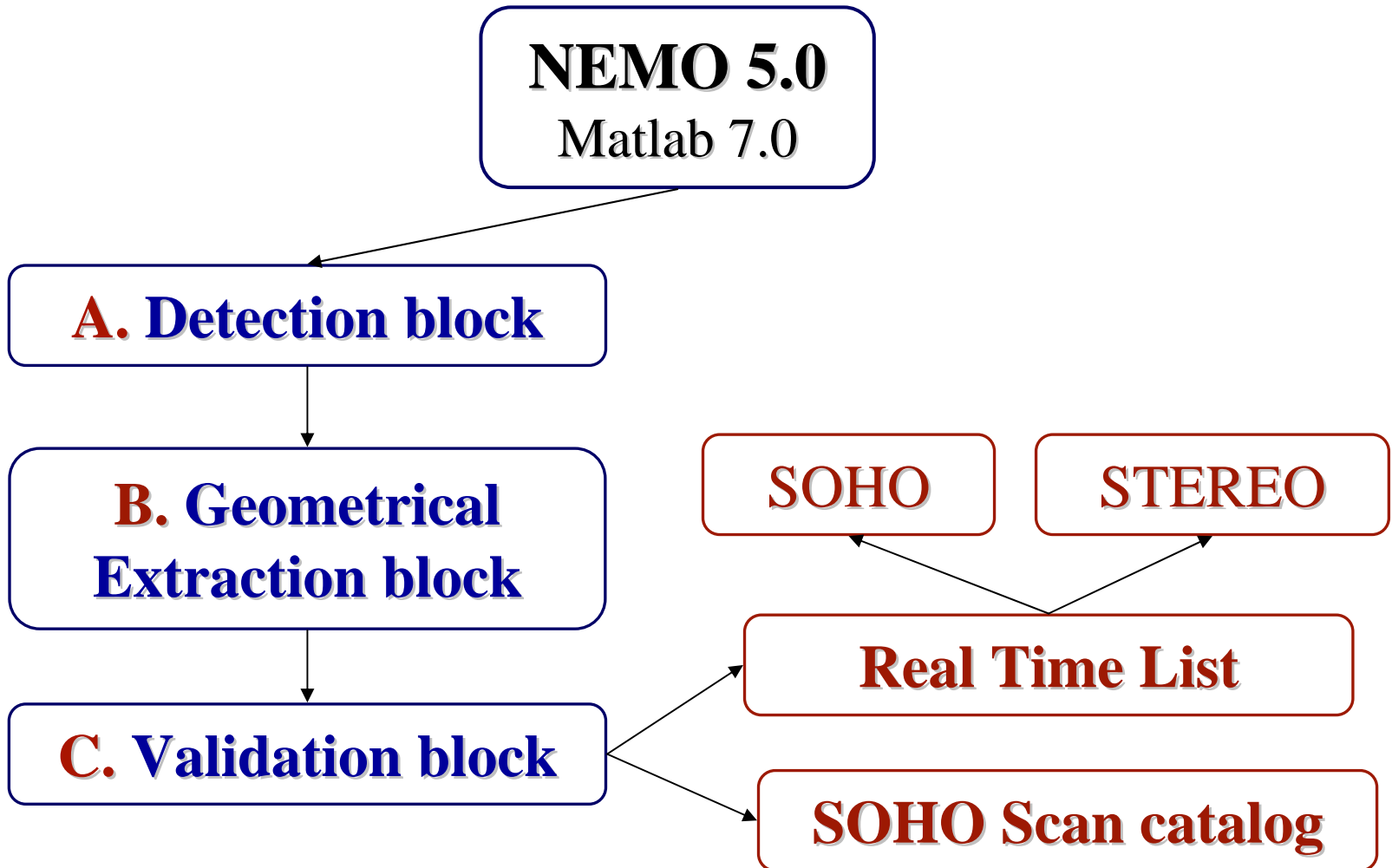
Example of Daily List

Daily list of SOHO/EIT waves. Royal Observatory of Belgium-SIDC.

#EIT wave	Date	Time	<u>Var</u> test	HOM <u>test</u>	<u>MHDw</u> test	<u>DimAr</u> [pxl]
-	-	-	-	-	-	-
-	01/04	00:41 UT	yes	-	-	-
-	01/04	00:58 UT	yes	-	-	-
# 1 START	01/04	01:10 UT	-	-	yes	193
# 1 END	01/04	01:19 UT	-	-	yes	197
-	-	-	-	-	-	-
# 2 START	01/04	02:09 UT	-	yes	<u>yes</u>	280
-	01/04	02:22 UT	-	yes	<u>yes</u>	311
# 2 END	01/04	02:41 UT	-	-	yes	315
-	-	-	-	-	-	-
-	01/04	09:09 UT	-	yes	-	-
-	01/04	09:18 UT	-	yes	-	-
-	-	-	-	-	-	-
-	01/04	10:03 UT	-	yes	-	-
-	01/04	10:12 UT	yes	<u>yes</u>	-	-
-	01/04	10:25 UT	yes	<u>yes</u>	-	-
-	-	-	-	-	-	-
-	01/04	12:31 UT	-	yes	-	-
-	01/04	12:44 UT	-	yes	-	-
-	01/04	12:53 UT	-	yes	-	-
-	-	-	-	-	-	-
-	01/04	13:37 UT	yes	-	-	-
# 3 START	01/04	13:46 UT	yes	-	yes	135
-	01/04	14:00 UT	-	-	yes	251
-	01/04	14:18 UT	-	-	yes	489
# 3 END	01/04	14:31 UT	-	-	yes	441
-	-	-	-	-	-	-
-	02/04	00:01 UT	-	yes	-	-
-	02/04	00:14 UT	-	yes	-	-
-	02/04	00:33 UT	-	yes	-	-



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.



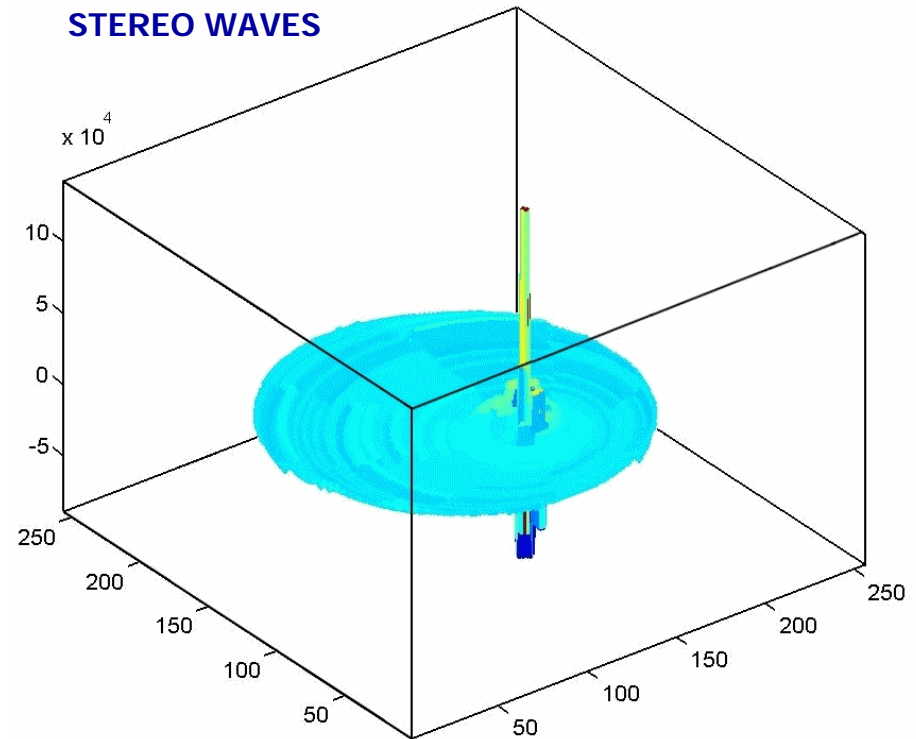
Conclusion (1/2)

- **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 observed regulary



Solar hemisphere projected on the plane in 3D view



Conclusion (2/2)

NEMO:

- detects only eruptions, not flares.
- can build on-disk SP.W. event catalog with SWAP and 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, Observatoire de Meudon
- to SECCHI/STEREO, BELSPO, ESA, NASA





“And you are telling me
you work in pattern recognition!”