### 7-8 March 2012: a "busy" period in the geospace



#### **Solar sources of the disturbances**



NOAA AR # 11429 (N18,E31)

Two eruptive X-class flares on early 7-March 2012 within 1 hours leading to 2 ultra-fast (>2000 km/s) CMEs (CME1 &CME2)



### **Major Questions**

□ What is the magnetic seed structure which erupted with CME1 & CME2 ?

□ Which event(s) gave rise to the protons?

□ Which CME was associated w/ the ICME and geomagnetic-storm?

### A synergistic effort is required to tackle these questions



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Naval Research Lab University of St Andrews

More than 30 people involved

Funding from Greek & EU sources



Ευρωπαϊκή Ένωση Ευρωπαϊκό Κοινωνικό Ταμείο

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης



http://proteus.space.noa.gr/~hnswrn/

#### Sun-to-Earth Analysis of a Major Geoeffective Solar Eruption within the

#### Framework of the

**Hellenic National Space Weather Research Network** 

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### Photospheric magnetic field & motions in SR





HMI Bz  $\rightarrow$  complexity (multiple & strong PILs)

> **Required elements for FR formation via reconnection**

Vectors of horizontal
B-field ontop of Bz
→ shearing and rotating motions along and around PIL

Chintzoglou

### **Coronal activities leading to the 7 March events**

Transient activities around the PIL during the 6<sup>th</sup> leading to flux-rope like features

# NOT resulting into an impulsive CME

#### 8-12 MK 100 0 100 200 300 400 500 600 600 600

#### DEM image for 8-12 MK ~ 13:30 on 06/03/2012

Hot FR-like structures ←Reconnection-related?



AIA 131 A movie

### **Connecting photospheric and coronal activities**



#### **Georgoulis & Tziotziou**

#### Gradual increase of self Em & heating episodes in the corona

### **NLFF B-field extrapolations & FRs**

Bz: photosphere



#### AIA (131): hot corona

NLFF b-extrapolation around 23:45 UT (before First X-class flare)



Low-lying FR "finger-prints" that may have erupted with CME1 & CME2

#### Chintzoglou

### SEPs during 7 March 2012



prompt particle rise at STB
gradual & delayed rise at L1
weak enhancement at STA

release time @ Sun-STB field-line: 00:35 +- 1 min → the first event is responsible for the particles seen in STB (second event peaks after 01:00)

Kouloumvakos

### Example of coronagraphic observations of the WL CMEs and shock



#### **COR2A: FOV 2-15 Rs**

#### Example of 3-ple SC WL shock & CME fitting

Shock  $\rightarrow$  spheroid (ellipse with revolution) model (h,d,s)

 $CME \rightarrow Graduated Cylindrical Shell (GCS)$ model (= 2 conical legs + tubular section) Thernisien et al. 2006



COR2B





### **Evolution of WL shock longitudinal extend**



Immediate contact w/ Sun-STB b-field line

Not contact w/ Sun-L1 b-line line →

consistent w/ delayed particles at L1

#### Explaining the longitudinal SEP properties



### **CCMC/ENLIL MHD simulations**

2012-03-05T09:00

2012-03-04T00 +1.37 days

🗢 Earth



 ▶ launch a hydrodynamic pressure pulse at 20 Rs constrained by the shock fittings (speed, angular extend) → evolve MHD to 1 AU

### **ENLIL at Earth**



### Which CME is Earth-directed?

CME1  $\rightarrow$  NE

#### L1 views of the best-fit CMEs



CME2 → SW heading towards Earth

### ICME & MC



SC is within the ICME for longer time > B-bield rotation interval (MC) → crossing flank

## **MC fitting results**

□ Fit the MC b-field data w/ the Hidalgo & Nieves-Chinchilla (2012) (allowing for non-force-free & non-circular MCs)



 $local \rightarrow global$ 

MC axis away from the Sun-L1 line (flank-impact)
 MC tilt of ~ -58 degrees wrt to NS

#### **Nieves-Chinchilla**

## Putting WL FR & MC together



Simulated WL view of the FR at 200 Rs from above the ecliptic Similar tilts for FR & MC axis  $\rightarrow$ & ~ EW orientation  $\rightarrow$  $\Phi$ poloidal mainly interacts w/ magnetosphere

View	from	above	the	ecliptic			
					to	Earth	

### **Estimating Opoloidal due to reconnection**



MHD model of Lin et al. 2004  $\rightarrow$ Poloidal flux added by reconnection during CME = $\Phi$ poloidal=f( $\lambda$ ,p,q,h,R,B\_0)

Deduce free params from CME fitting & b-field extrap (Chintzoglou & Nindos)

**Φpoloidal ~ 8.1e20 Mx** 

### **Major Conclusions**

□ First steps of a **synergistic effort** into understanding & combining a complex stream of solar & heliospheric data **asssociated with extreme Space Weather conditions** 

**Both CMEs involved FRs** formed via confined recconnection several hours before the eruptions

**Driven shock from CME1** consistent with particles at STB

**CME2** is Earth-directed

ICME flank impact at Earth: consistent orientations of FR and MC

## **Future work**

- Determine particle injection time for L1 & compare with shock extend in the heliosphere (HI1 & H12); which shock(s) accelerate L1 particles?
- Bflux + Helicity budgets at the Sun (extrapolations & magnetic connectivity) *before eruption during eruption* (Φpoloidal; reconnection) and *at 1 AU* (MC fitting)
- □ Tie remote-sensing constraints (FR orientation, size, length, speed, momentum, magnetic flux) w/ magnetospheric response
- □ Investigate multiple ejection and shock scenario