A Planned Muon Detector for Space Weather Storm Nowcast in Europe

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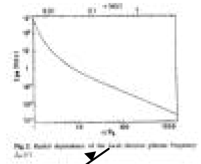
It is foreseen to construct a cosmic ray muon telescope in Greifswald (MTG). The MTG will be able to observe interplanetary shock waves and CMEs in real time from the ground. By means of the MTG in Europe and a world-wide network of muon telescopes (Australian and Japanese muon telescopes) a 24 hour real-time observation is foreseen to give online the arrival of space weather storms at Earth. The data of the MTG should be included in SWENET.

Contemporary situation

❍ **no real time data about interplanetary CMEs and shocks**

contemporary status:

Solar environment
1) - Soho (UV) observations up to 30 solar radius R_S or only about 1/3 Mercury orbit
   - very good: space and near real time, data are used for estimations /simulation of arrival time
2) - radiospectrogaphs on the ground measure up to 1.7 R_S
   - very good: instruments on the ground and real time data



problems:

1) - from 30 R_S to Earth orbit no remote or in-situ real time data

2) - only radiospectrographs for instance on Ulysses and WIND s/c measure the interplanetary propogation of CMEs or shock waves (position is a function of the plasma frequency (Mann, Jansen, MacDowall et al. Astron. Astrophys 348, 614 (1999)), but data are not available in real time (data transfer to Earth about 2 to 5 days later)

Nearby situation: solution by the cosmic ray anisotropies?

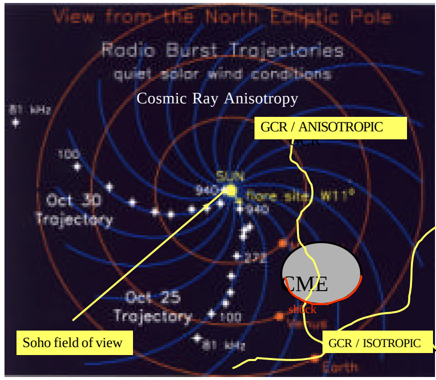
❍ **interplanetary CMEs and shocks are detecable by cosmic ray muons**

possible solution:

-anisotropic galactic cosmic rays due to CMEs measured by:

- Cosmic Ray Telescopes on the ground, insofar a relatively low cost solution with real time data access and forecast and nowcast capability

Sketch for UV, radio and cosmic ray observations of interplanetary CMEs with shock waves



contemporary status
- Soho (UV) observations up to 30 R_S (1/3 Mercury o.) (space, near real time)
- radiospectrogaphs up to 1.7 R_S (ground, real time)

problems:
-from 30R_S to Earth orbit
-radiospectrographs on s/c (Ulysses, WIND) not in real time (2 – 5 days)

possible solution:
-anisotropic galactic CR (GCR) due to CMEs measured by CR – telescopes on ground / real time

Space Weather Related Physics Behind Muon Telescopes on Ground, Part I

1) Ground-level CR detectors scan various directions in space (including to the Sun) as Earth rotates.

2) Daily variations in counting rates on ground reflect anisotropic intensity distribution of CRs in space.

3) Semidiurnal variation due to interactions in the heliosphere of outward moving solar wind and inward diffusing galactic cosmic rays.

4) Semidiurnal variations were observed by neutron monitors, ion chambers and muon telescopes.

5) Detectors observe reduced flux of CR particles moving away from the shock (with small pitch angles), due to CR depleted region behind the shock.

6) CR intensity deficit in the order of 1 % to 2 %.

7) First detection of the shock at a distance of $r \sim 0.1$?$_P$ cos ß
(?$_P$ scattering mean free path of cosmic rays, angle between Sun-Earth line and the mean IMF at Earth)

8) ?$_P$ about 1 AU for 10 GeV CRs (neutron monitor energy range) => 5 hours before shock wave arrival

9) **Muon detectors measure at 50 GeV => ?$_P$ much longer => 24 hours before shock wave arrival !!!**

Space Weather Related Physics Behind Muon Telescopes on Ground, Part II

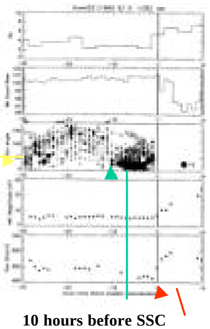
Example: space weather storm on 9th September 1992

Figures right (from top to bottom,
black line is the sudden commencement (SSC))
1) change of Kp index versus time
2) cosmic ray neutron monitor counts versus time
(no hints for changing counts rate before SSC)

3) pitch angle versus time, but with cosmic ray muon telescope data (Nagoya Scintillator Telescope) enhancement of comic ray muon anisotropy into Sun direction (black circles) about 10 hours before SSC

4) change of interplanetary field magnitude
5) change of solar wind velocity

Details see in
Munakata et al. J. of Geophys. Res. 105 (A12) 27457, 2000



10 hours before SSC

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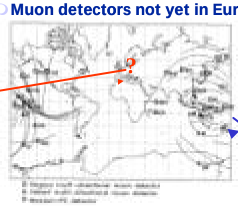
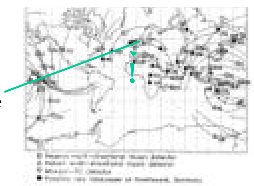
World-Wide Muon Detector Network?

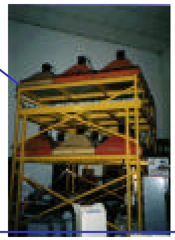
- **Muon detectors not yet in Europe**

Viewing angle of muon telescopes in Australia and Japan: no data from European and Atlantic Ocean regions



Viewing angle with a new telescope in Greifswald, this means also a 24 hour data coverage





Hobart Scintillator Telescope (HST) / Australia

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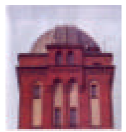
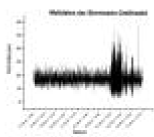
Construction and schedule for the Muon Telescope Greifswald (MTG)

Detection / construction principle:
- two layers of plastic scintillators (PS) with wavelength shifter, lead layer between the PS layers for low energy CR absorption
- high voltage photomultiplier tubes for signal detection and direction determination due to anti-coincidence measurements at different plastic scintillator plates
- electonics and data recording



Tower of the Observatory Greifswald



Data from the Geiger-Müller counter at the Sternwarte Greifswald

Schedule:
- start of construction early 2004
- data available end 2005

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