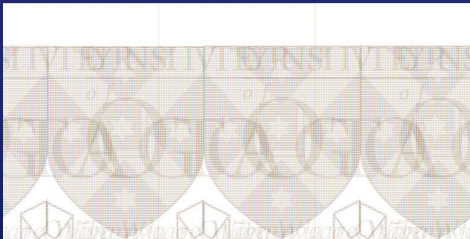


Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN)

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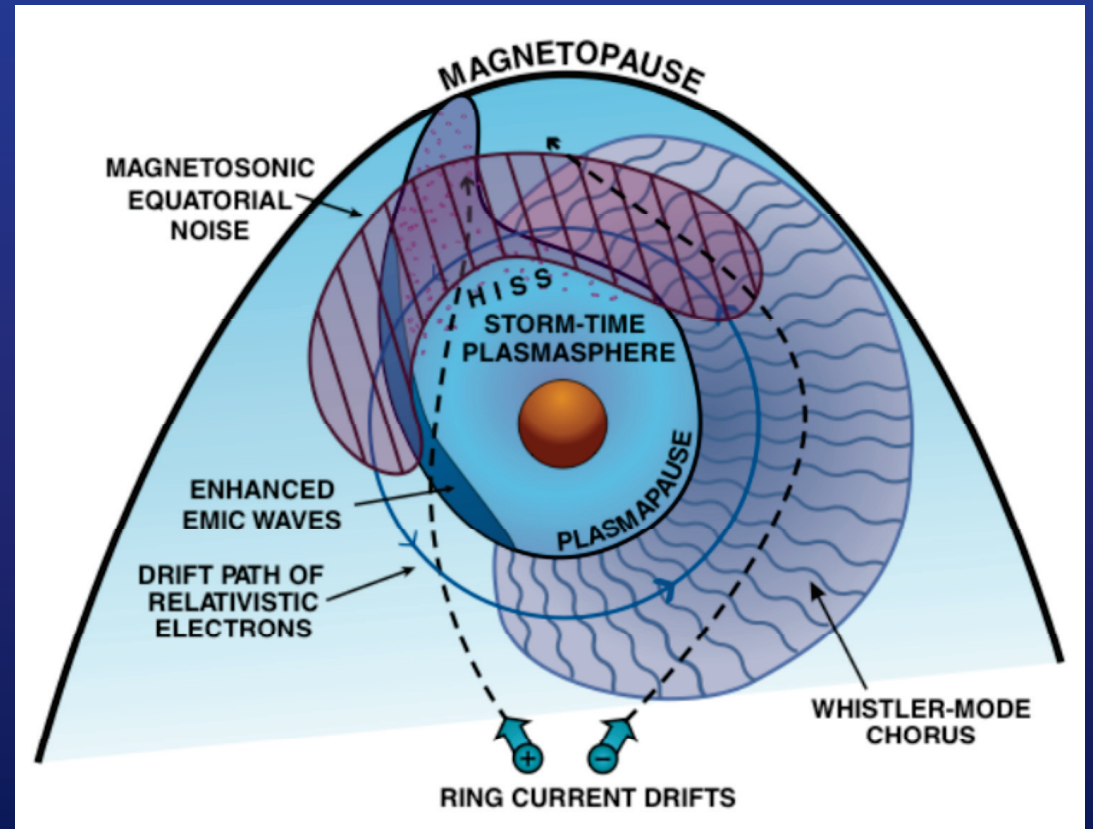
NEW ZEALAND

CAWSES-II Symposium
Invited Presentation PA3a-5; Panel 3
14:30-14:45 Friday 22 November 2013
Nagoya, Japan

SPeCIMEN Objective

Prediction and specification of the Earth's inner magnetospheric environment

1. To high accuracy,
2. Based on inputs from the Sun and solar wind,
3. Employing a combination of physical and statistical predictive modeling.



Thorne [2011] GRL
“frontiers” review

SCOSTEP's SPeCIMEN Project

2014-2018 in VarSITI SUMMARY

Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN)

Goals and objectives: The quantitative prediction and specification of the Earth's inner magnetospheric environment based on Sun/solar wind driving inputs.

Questions: How does the inner magnetosphere respond as a coupled system to Sun/solar-wind driving?

Data/theory/modelling: A combination of physical and statistical (machine learning) modelling, theory, and observations from various platforms – both satellite & ground.

Anticipated outcome: A series of coupled, related models that quantitatively predict the dynamical evolution of the inner magnetospheric state (radiation belts, ring current, cold plasma distribution, plasmashet, convection electric field, and so on).



Co-Leaders:

Jacob Bortnik
(UCLA, USA)

Craig J. Rodger
(U. Otago, New Zealand)

In just 10-years (the "Dst mistake")

Reeves et al. (2003),
Geophys. Res. Lett.,
30(10), DOI: 10.1029/
/2002GL016513.

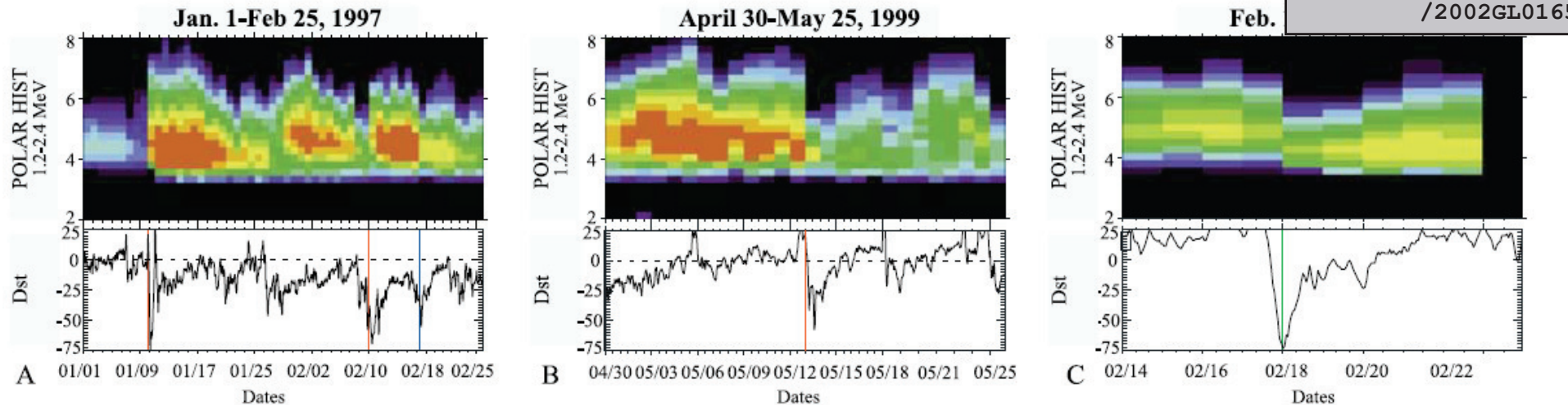


Figure 2. Details of three types of responses. (A) A strong increase of relativistic electron fluxes in response to the January 1997 geomagnetic storm. (B) A dramatic and permanent loss of electrons throughout the outer belt in May 1999. (C) A -100 nT storm in February 1998 with peak fluxes after the storm very similar to peak fluxes after the storm.

Not so long ago the community was struggling to understand or predict what happened to radiation belt fluxes after big storms.

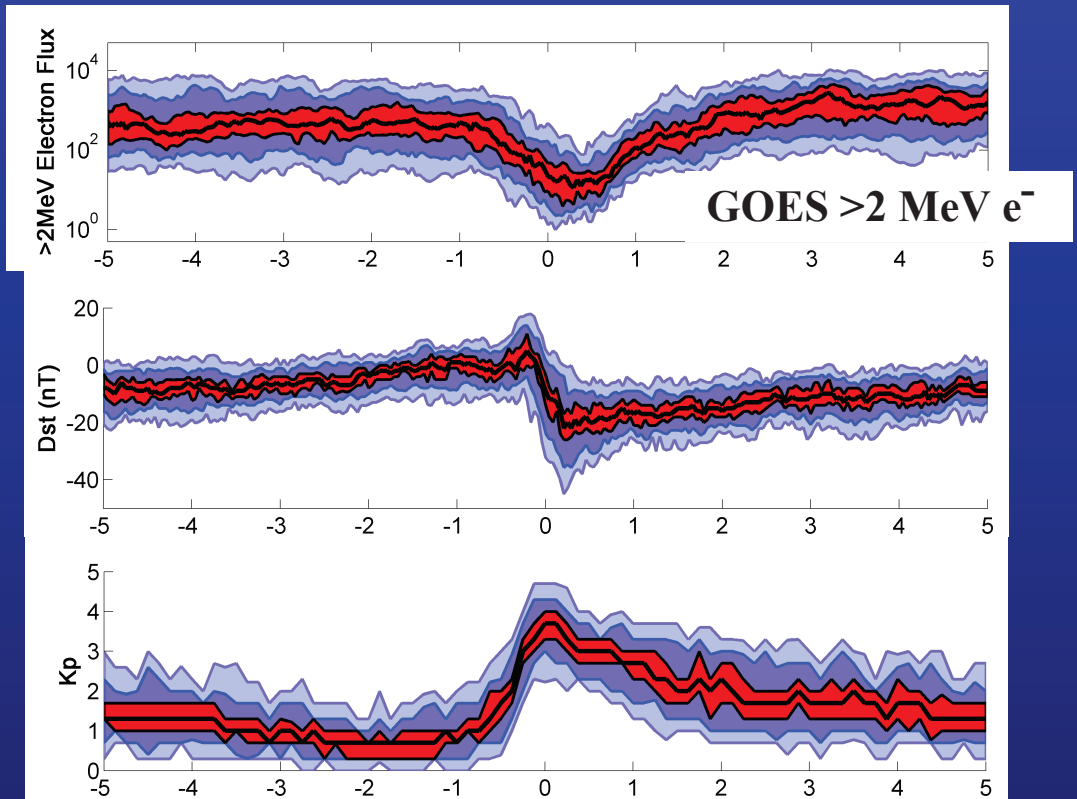
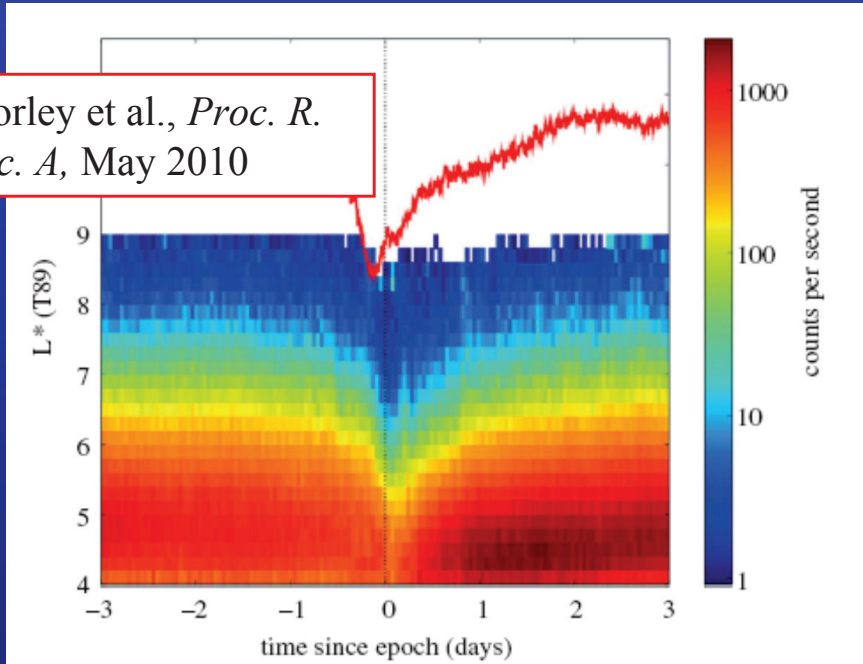
Ten years ago Geoff Reeves (LANL) looked at measurements after big storms ($Dst < -50$ nT) and found a lot of different behaviour after these storms.

Half led to increases in flux, 20% to decreases, and 30% to no-change.

A view was developing that "if you had seen one storm" you had only seen one storm - they were each unique (like a snow-flake). This made it hard to understand the detailed physics in each event, or build predictive models, as there was no consistent response.

But that was then (now, after the "Dst mistake")

Morley et al., *Proc. R. Soc. A*, May 2010



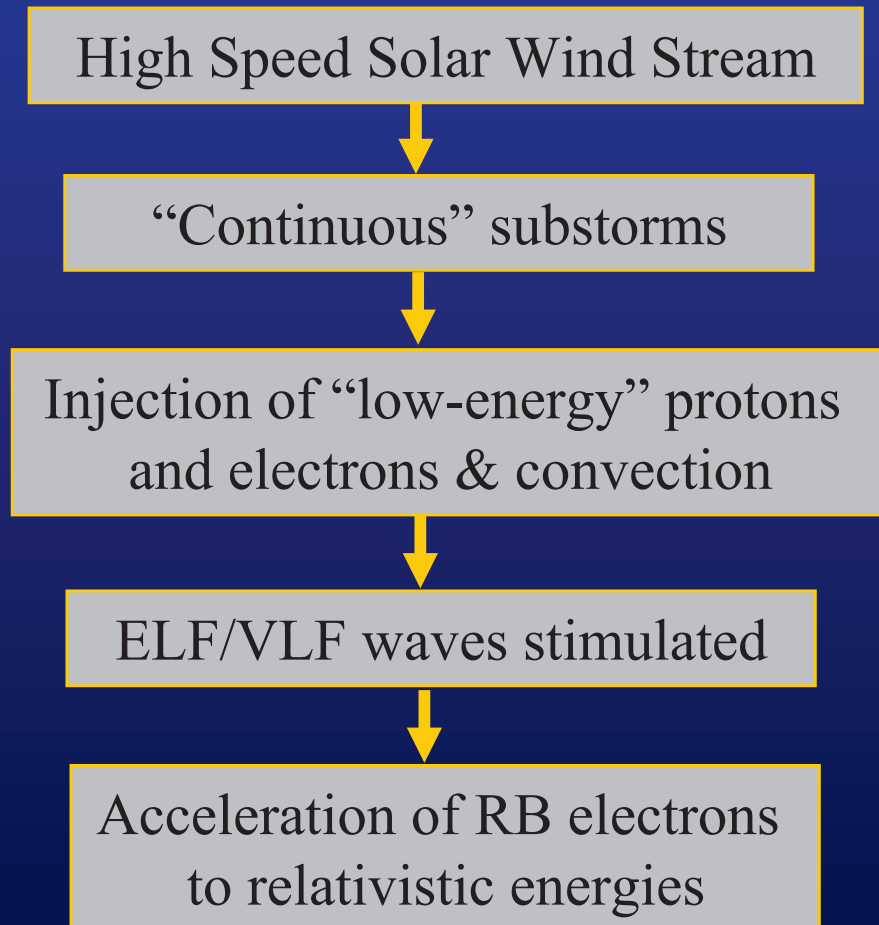
By 2007 (or so) the community was coming to realise that continued classification of geomagnetically disturbed intervals by Dst alone did not work so well, and one could find examples of consistent physical processes occurring storm after storm. This initially started by looking at changes around high speed solar wind stream interfaces and smaller geomagnetic storms (which consistently led to large radiation belt increases).

If you saw one of these storms, you could describe the others!!

Example from Steve Morley of dropouts after high speed solar wind streams followed by an enhancement in fluxes - a process which is highly repeatable.

What's the Physics here?

There is now growing understanding of the linkages which are taking place, and how the inner magnetosphere responds, consistently. **It appears that the same physics occurs around each one of these events (at least to first order).** Various people have been explaining the physical thinking here. One example is that below:



I want to give credit to **Yoshi Miyoshi (STELAB, University of Nagoya)** who gave a particularly clear set of talks at the Japan Geosciences Union meeting in 2012 – he laid out this process, and provided experimental and/or theoretical evidence for the steps. This helped my understanding a great deal.

The improving physical understanding puts us in a good position to be able to **specify** and then **predict** the evolution inside the **Inner Magnetosphere (SPeCIMEN)**.

Why now?

1. Space weather- lots of expensive/
critical space assets.

(it should be done)

2. Lots of data: Recent RBSP mission
launched, and more to come (plus the
ground).

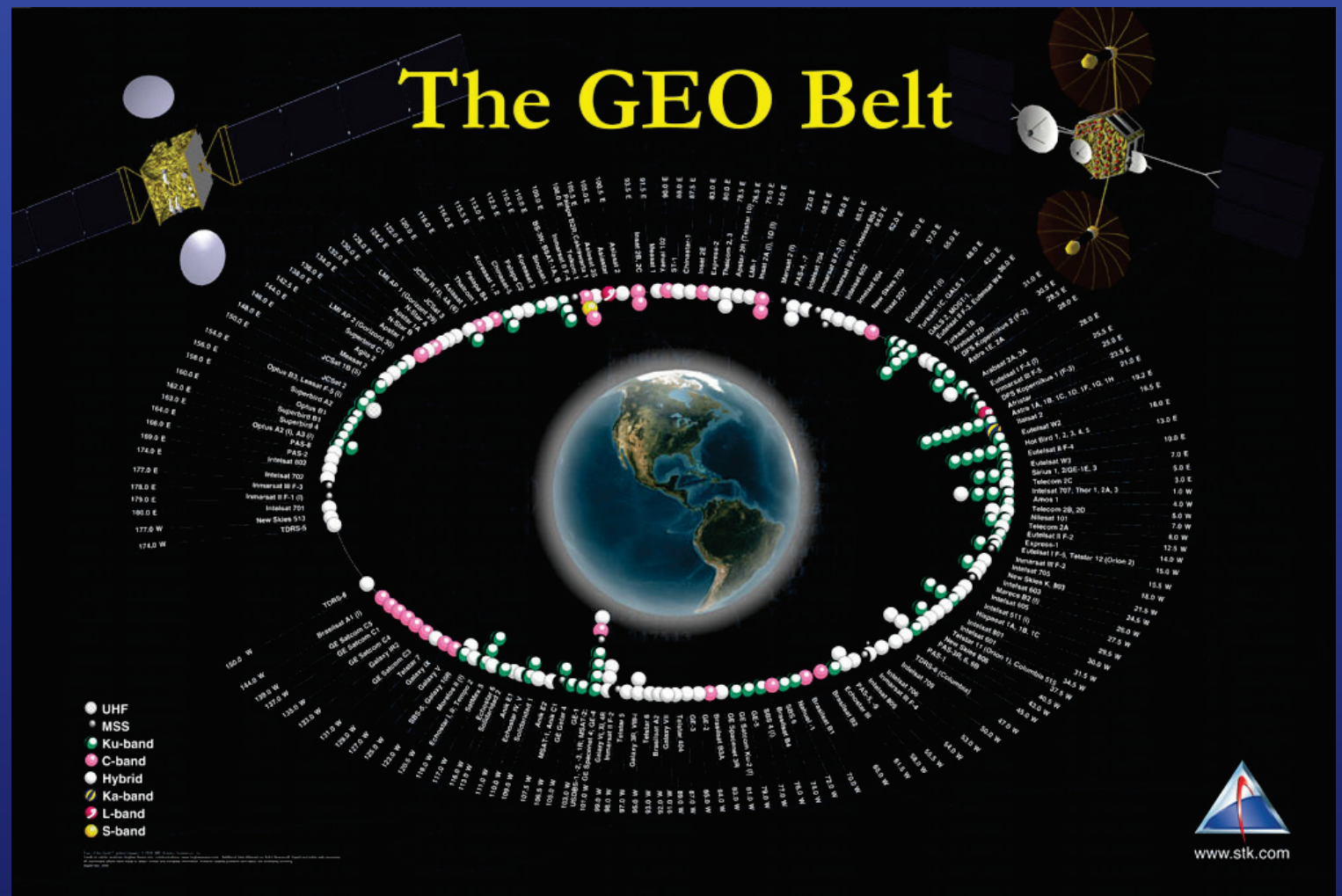
(we have lots of observations)

3. Theoretical tools, numerical
techniques and computational power.

(we have the tools needed)

Space weather

Roughly 450 operational satellites in GEO.



MeV electrons: internal charging; 0.1-100keV: surface charging; MeV ions: SEU

3/4 satellite designers said that internal charging is now their most serious problem, 2001 ESA study [*Horne, 2001*]

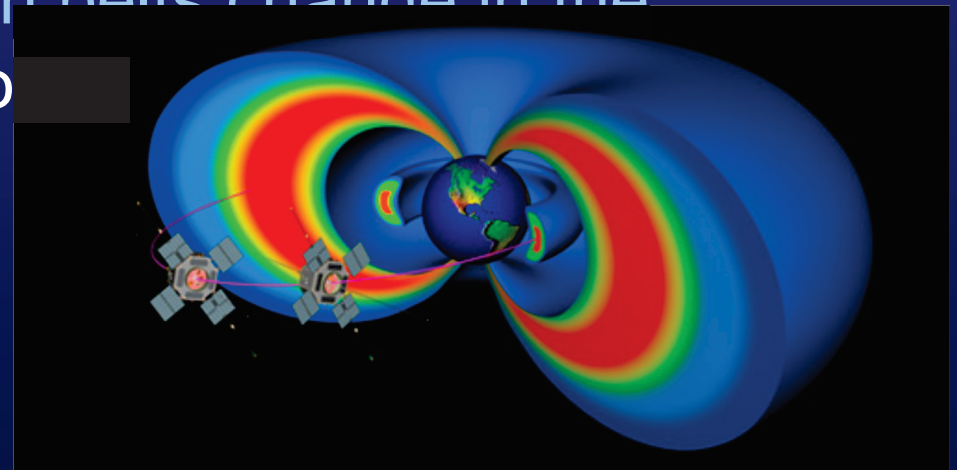
Examples: Intelsat K, Anik E1 & E2, Telstar 401, Galaxy-4, Galaxy-15

Costs: ~\$200M build, ~\$100M launch to GEO, 3%-5%/yr to insure; e.g., in 1998 \$1.6B in claims, but \$850M in premiums

Data: Van Allen Probes/RBSP

1. Discover which processes, singly or in combination, accelerate and transport radiation belt electrons and ions and under what conditions.
2. Understand and quantify the loss of radiation belt electrons and determine the balance between competing acceleration and loss processes.
3. Understand how the radiation belts change in the context of geomagnetic storms

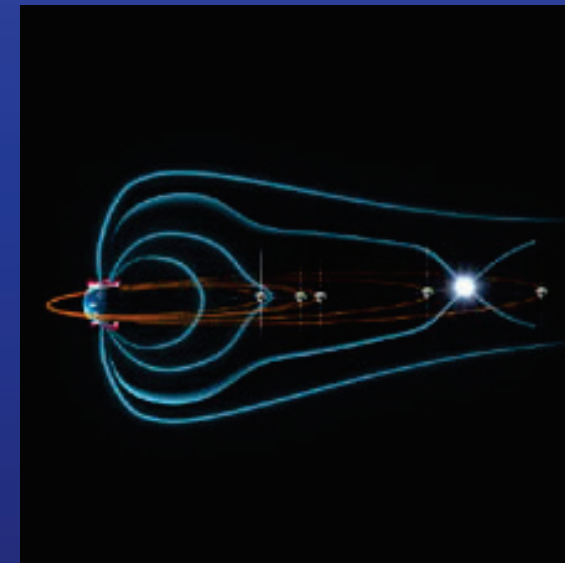
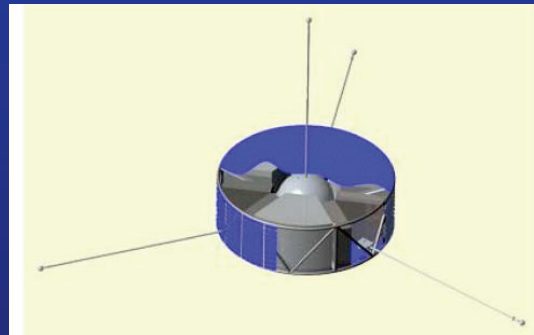
- NASA Living With a Star
- Launched 30 August 2012
- 2 probes, <1500 kg for both
- ~10° inclination, 9 hr orbits



Yet More Relevant Missions (just a few)

RESONANCE (Russia)

Launch ~2014, 4-spacecraft Orbit:
1800×30,000km, ~63° incl.



THEMIS (NASA)

Launch Feb 17, 2007
5 identical probes (now 3)

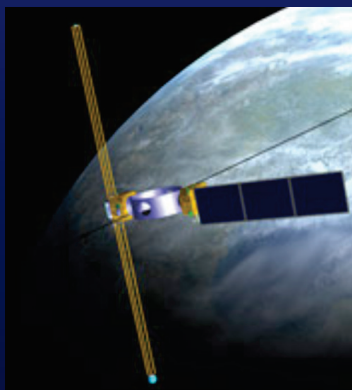
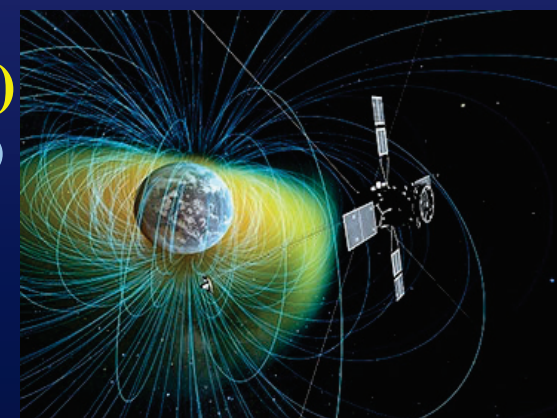


BARREL (NASA)

Launch 2012/13 & 2013/14
2 campaigns, ~20 balloons each

ERG (Japan)

Launch ~2015, GTO



DSX (US AFRL)

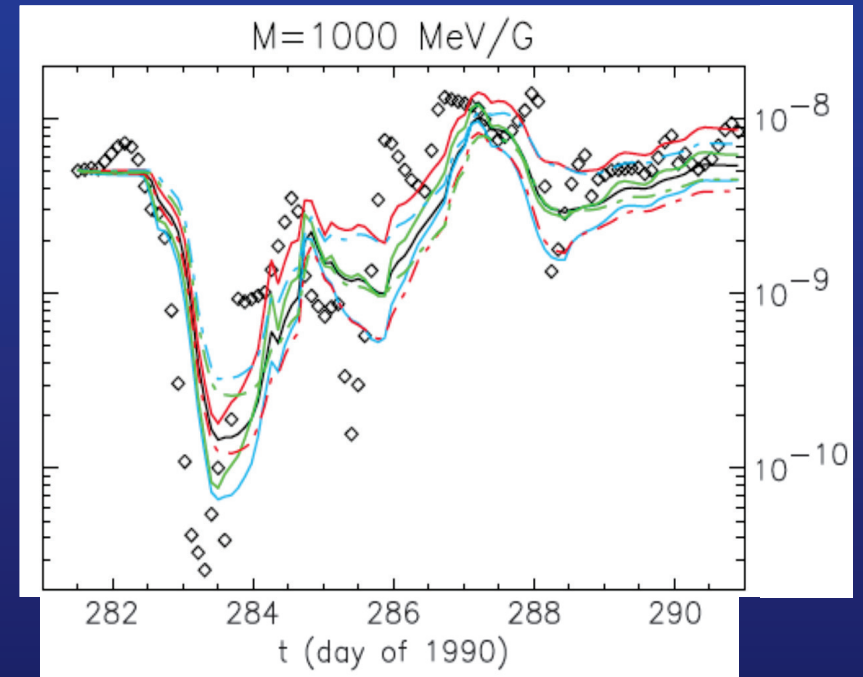
Launch ~2014-2015
MEO, wave/particle

Theoretical tools

A large number of theoretical tools have become available in the past decade. These provide physical insight, but its hard to capture all physics.

Diffusion modeling
(theory: cross-terms, 3D diffusion matrix)

Test-particle based modeling (nonlinear phenomena in wave-

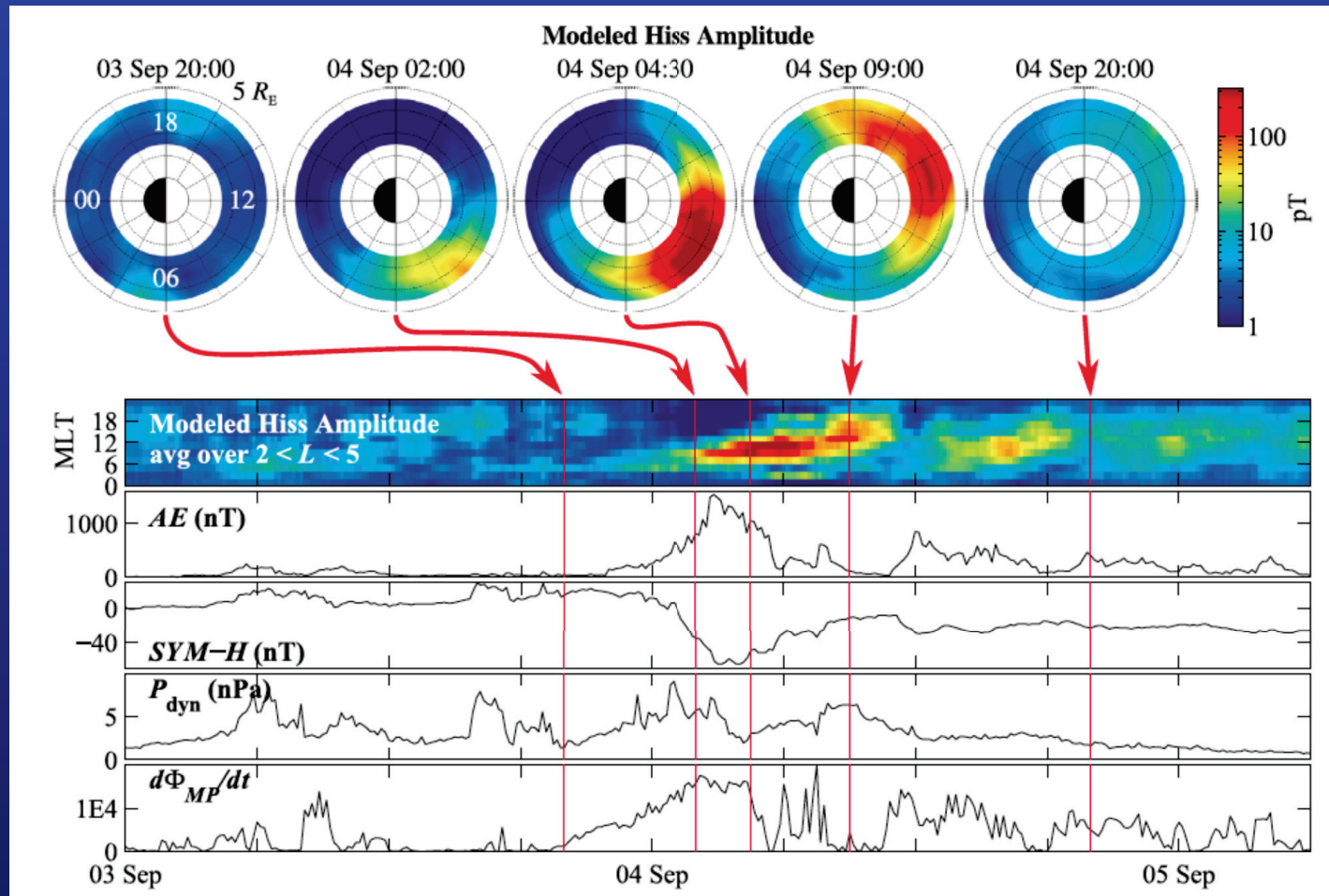


$$\frac{\partial f}{\partial t} = \frac{1}{G} \frac{\partial}{\partial \alpha_0} G \left(\frac{D_{\alpha_0 \alpha_0}}{p^2} \frac{\partial f}{\partial \alpha_0} + \frac{D_{\alpha_0 p}}{p} \frac{\partial f}{\partial p} \right) + \frac{1}{G} \frac{\partial}{\partial p} G \left(\frac{D_{\alpha_0 p}}{p} \frac{\partial f}{\partial \alpha_0} + D_{pp} \frac{\partial f}{\partial p} \right) + L^2 \frac{\partial}{\partial L} \frac{D_{LL}}{L^2} \frac{\partial f}{\partial L},$$

Albert et al. [2009] 3D modeling

3.2 Numerical techniques

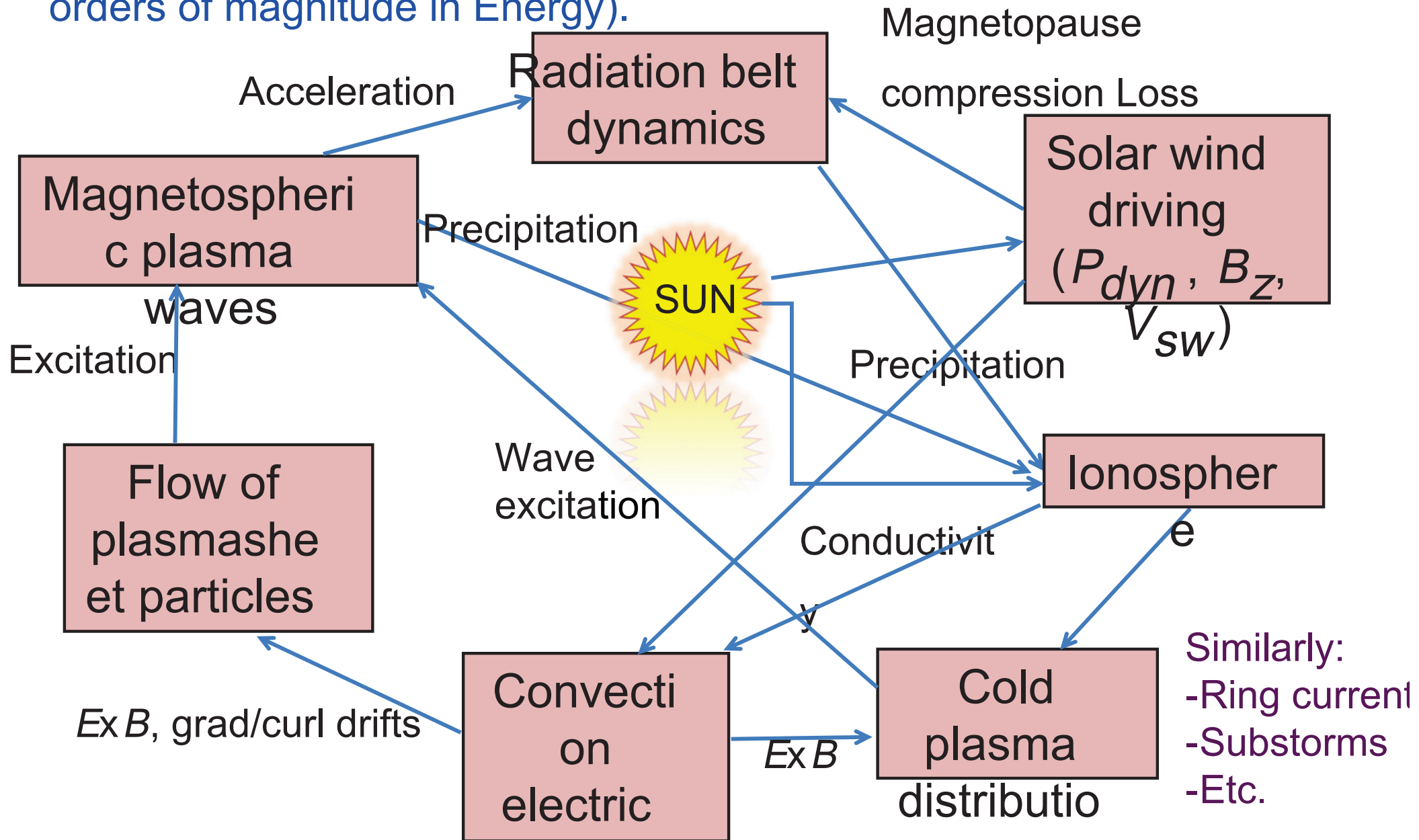
Golden et al.
[2012]
Multiple linear
regression



Numerical “learning” models: capture details, but no physical insight
Multiple linear regression; data assimilative; NARMAX; “mutual information and cumulant based cost”

It's a complex system!

And understanding it will require a lot of people with different knowledge and different backgrounds (remember, we span ~6-orders of magnitude in Energy).



SPeCIMEN Approach

Large scale collaboration between physical modelers, predictive modelers, and observationalists.

Four temporal phases (spanning roughly the 4-5 year project).

1. Improvement of predictive models & further development of theoretical models, with a view to integration

2. Fusion of predictive and physical models

3. First generation 'complete' model development, comparison with multiple data streams

4. Feedback and refinement

All of these phases must be informed by observations! Tools are being developed to help share and visualise experimental observations.

White paper team - from proposal stage

Jacob Bortnik (USA)

Craig Rodger (NZ)

Richard Thorne
(USA)

Mark Clilverd (UK)

Richard Horne (UK)

Yoshi Miyoshi
(Japan)

David Shklyar
(Russia)

Ian Mann (Canada)

Eric Donovan

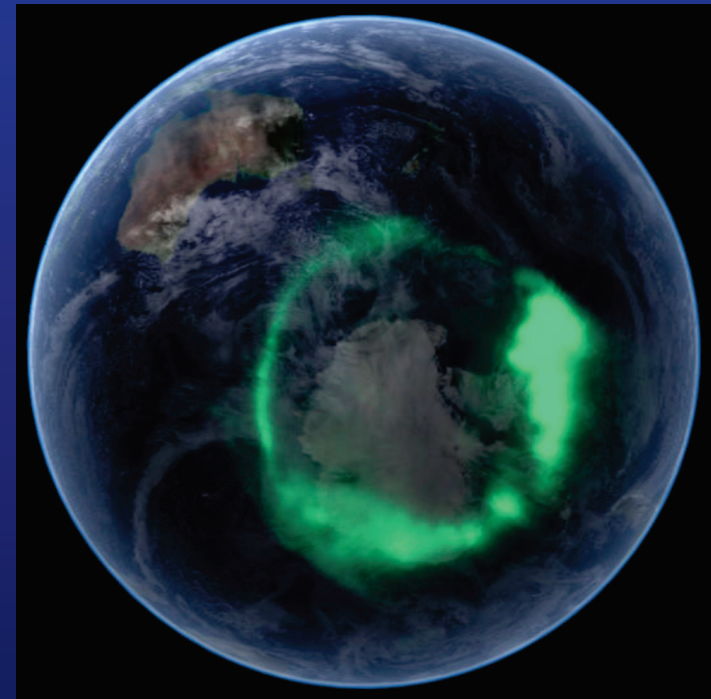


IMAGE satellite,
11 Sep 2005

SCOSTEP's SPeCIMEN Project 2014-2018 in VarSITI SUMMARY

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Schedule outline: We will aim to have 2 in-person meetings per year for the duration of the SPeCIMEN scientific program, 2014-2018. One meeting will be a dedicated project meeting, and the other will be attached to an already existing meeting, that a large proportion of the SPeCIMEN team is already planning to attend.

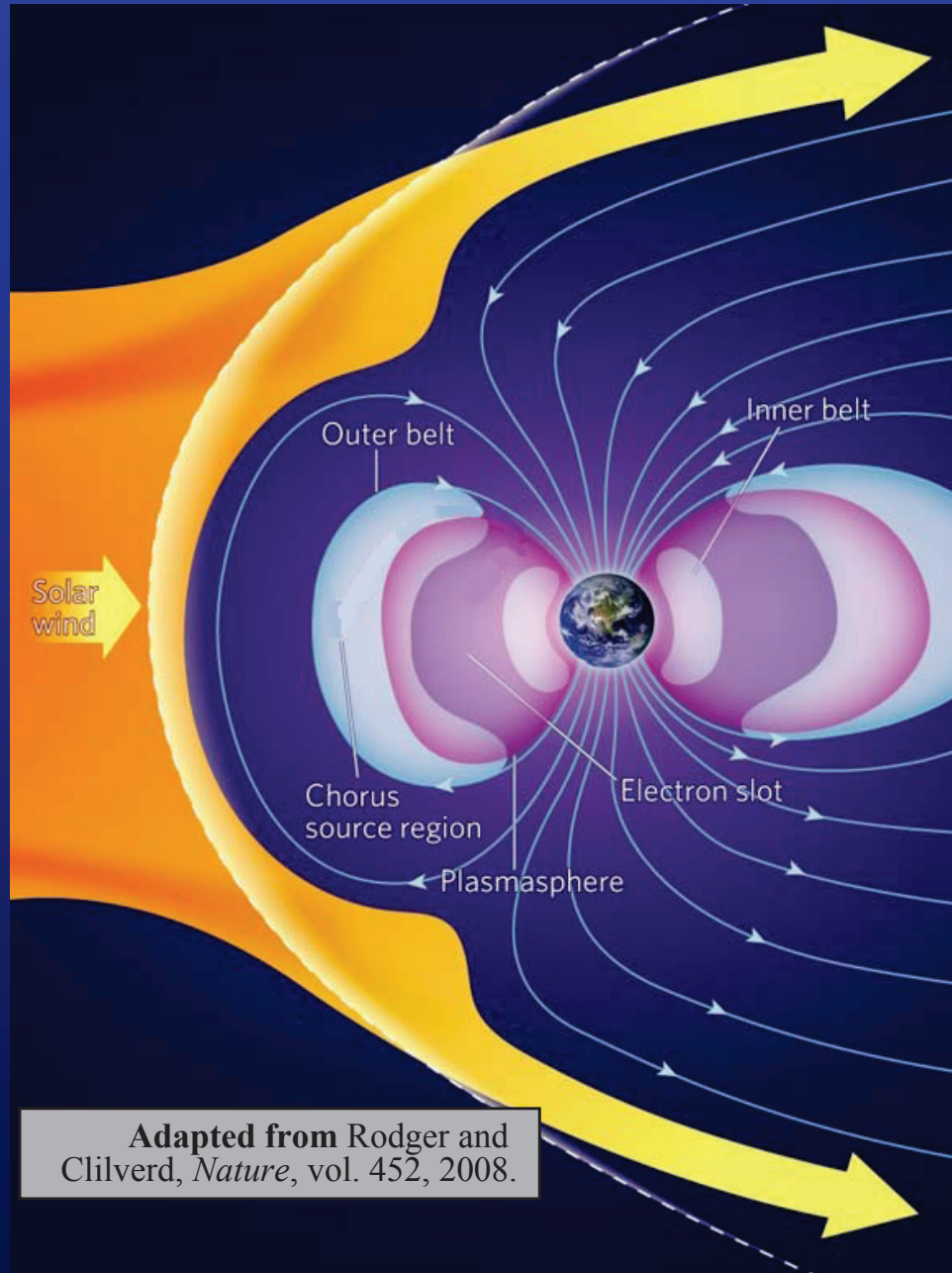
2014

- session at **Geospace Environment Modeling (GEM) workshop** in Portsmouth, Virginia, USA (15-20 June 2014)
- two sessions at the **URSI General Assembly and Scientific Symposium** in Beijing, China (16-23 August 2013)
- **Geospace Revisited Conference** in Rhodes, Greece (15-20 September 2014)



We are preparing an e-mail discussion list to send out announcements!

At the "Dawn of the Space Age"



In 1958 the first US satellites were launched into orbit carrying Geiger counters. *Explorer I* and *Explorer III* discovered the Van Allen radiation belts.



Explorer 1 – post launch press briefing.

At the "Dawn of the Space Age"



Explorer 1 – post launch
press briefing.

The original discovery of the Radiation Belts, right at the start of the Space Age, was an example of research undertaken by international scientists from different background.

SPeCIMEN seeks to create a new international research project under SCOSTEP to produce new understanding and give us predictive power in the inner magnetosphere.

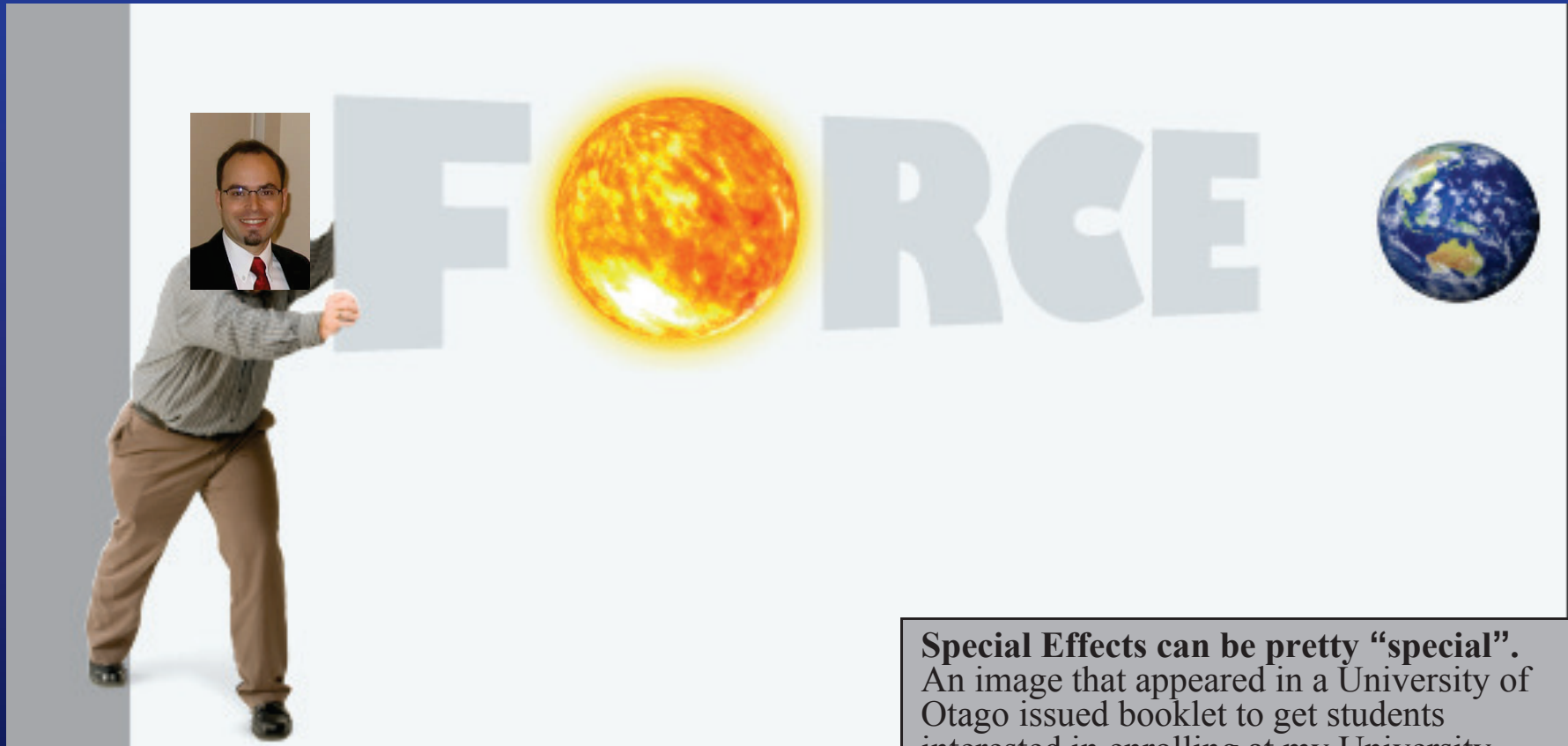
SPeCIMEN - Specification and Prediction of the Coupled Inner-Magnetospheric Environment

Through SPeCIMEN we seek to produce a frame-work where international scientists can work collaboratively on inner magnetospheric physics.

Think about joining us.



Acknowledgement: The research leading to these results has received funding from the European Union Seventh Framework Programme [FP7/2007-2013] under grant agreement n°263218.



Special Effects can be pretty “special”.
An image that appeared in a University of Otago issued booklet to get students interested in enrolling at my University.

SPeCIMEN - Specification and Prediction of the Coupled Inner-Magnetospheric Environment

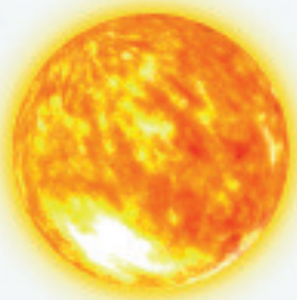


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Thankyou!