# Science Goals with the X-Ray Imager

Ed DeLuca
NGXRT Sub Working Group

Spectroscopy tells what is happening, imaging tells you where and why (Golub)

# Coronal Instrumentation

- Grazing Incidence X-Ray Telescope
  - Broad temperature response
  - High sensitivity to coronal plasma
  - Highest resolution 0.5 "/pixel
  - Photon counting would provide temperature and density
  - Minimum temperature ~1MK
- Normal Incidence EUV/UV Telescopes
  - Narrow temperature response
  - Requires large effective area
  - Highest resolution 0.1"/pixel, (0.02"/pixel is possible)
  - Multiple passbands are required see the whole corona
  - Chromospheric and Transitions Region passbands are possible

# NASA Heliophysics Vision

- Open the frontier to space environmental prediction
  - Understand the fundamental physical processes of the space environment - from the sun, to the earth, to other planets and beyond to the interstellar medium.
- Understand the nature of our home in space
  - Understand how human society, technological systems, and the habitatbility of planets are affected by solar variability interacting with planetary magnetic fields and atmospheres
- Safeguard the journey of exploration
  - Maximize the safty and productivity of human and robotic explorers by developing the capability to predict the extreme and dynamic conditions in space.

# Plan-B science goals

- Trace energy flow at natural dynamic solar time scales over a large dynamic range from the photosphere into the corona through small spatial-scale elementary solar structures and determine the resulting large-scale structures (Understand the physics of the beta = 1 region)
- Understand physical processes such as magnetic dissipation and reconnection in astrophysical plasmas, under a wide variety of physical conditions.
- Understand and spatially resolve elementary atmospheric structures over each temperature domain of the atmosphere and determine how they are created and evolve
- Understand how small-scale physical processes initiate large scale dynamic phenomena creating space weather
- Understand how physical processes alter coronal properties such as variations in its composition
- Understand the mechanisms of particle acceleration in space and astrophysical plasmas

# Plan-B Science & HP Roadmap

- Plan B science is closely aligned with the understanding of fundamental physical processes.
- The NASA/Heliophysics strategic mission line that addresses fundamental physics is the Solar-Terrestrial Probe line. Hinode is an S-T Probe. The current Roadmap has the following missions in the S-T Probe line
  - Magnetospheric Multi-Scale Mission (2014)
  - Origins of Near Earth Plasma (2018)
  - Solar Energetic Particle Acceleration and Transport (2021)
  - Ion-Neutral Coupling in the Atmosphere (2025)
- This summer NASA will ask the National Research Council to start a Decadal Survey of HP, it will take about 2-years

# Coronal Science Basis Vectors

- Dynamical - Origins, energetics and plasma diagnostics
  - Waves
  - Flows
  - Particle Acceleration
- Topological - Stability and heating
  - Magnetic Free Energy
  - Helicity
  - Quasi-Separtrix Surfaces
- Thermal - Magnetic, plasma and radiative sources/sinks
  - Heating/Cooling
  - Thermal Instabilities
  - Non-Equlibirum Ionization
  - Elemental Abundances

# Instrumentation Requirements

- Dynamical - Origins, energetics and plasma diagnostics
  - High resolution in space and time - throughput is important.
  - Temperature coverage - we need to see the plasma
  - See non-thermal emission
- Topological - Stability and heating
  - Temperature coverage
  - FOV large enough to understand the magnetic boundary conditions
- Thermal - Magnetic, plasma and radiative sources/sinks
  - Distinguish hot plasma from cold plasma
  - Follow the thermal evolution of the plasma
  - Identify non-thermal plasma

# Jets - A Universal Example

- Dynamical -
  - Have seen flows and waves in jets.
  - What is the contribution of non-thermal particles to the energy budget?
- Topological -
  - Basic topology is understood
  - What is the role of helicity in the energetics?
- Thermal -
  - How does energy flow from the corona to chromosphere?

# Science Flow Down - GI

- The flow of energy from the photosphere into the corona
  - Required measurements
    - High resolution, high sensitivity photospheric and chromospheric magnetograms, combined with high-resolution, high-sensitivity, high-cadence coronal imagery and plasma diagnostics.
  - Example
    - Jets - Define the magnetic structure before the jet: free energy, helicity and topological connections. Observe the reconnection between emerging flux and overlying flux. Measure the plasma energy during the jet, both thermal and kinetic.
  - X-Ray Observations
    - Integrating: 3-4 filters (0.5 - 3.0MK) cadence of 30s
    - Photon counting: morphology image every 30s , spectrum every 1-2 minutes

# Science Flow Down - GI

- Diagnostics of reconnecting plasma
  - Required measurements
    - Time evolution of the hot plasma (possibly in non-ionization equilibrium), evaporated chromospheric plasma, radiative instabilities and cooling plasma.
  - Example
    - Post flare loop arcade
  - X-Ray Observations
    - Photon Counting: 2000 photon spectra with a 30s cadence over 100"x100" FOV (200x200 0.5" pixels).

# Science Flow Down - GI

- Connections to the Heliosphere
  - Required measurements
    - Measure the flow of low density high temperature plasma into the heliosphere. Measure the evolution of the closed and open fields above active regions.
  - Example
    - Non-flare active region at the limb. Coronal hole jets & Plumes
  - X-Ray Observations
    - Photon Counting: 10,000 photon spectra with a 3600s summed exposure over 100"x100" FOV (200x200 0.5" pixels).
    - Integrating: 1-2 filters, summed images at the limb.

# Science Flow Down - GI

- Particle Acceleration
  - Required measurements
    - Image the non-thermal electrons from small reconnection events. Need to be able to distinguish thermal and non-thermal spectra at ~6KeV.
  - Example
    - Active region transiant brightenings. The background plasma temperature is about 3MK. A very common reconnection phenomena.
  - X-Ray Observations
    - Photon Counting: Accumulate spectra with 2000 photons at 30s cadence in 100"x100" fov (200x200 pixels at 0.5"/pixel).

# Science Flow Down - NI

- The flow of energy from the photosphere into the corona
  - Required measurements
    - High resolution, high sensitivity photospheric and chromospheric magnetograms, combined with high-resolution, high-sensitivity, high-cadence coronal imagery and plasma diagnostics.
  - Example
    - Jets - Define the magnetic structure before the jet: free energy, helicity and topological connections. Observe the reconnection between emerging flux and overlying flux. Measure the plasma energy during the jet, both thermal and kinetic.
  - X-Ray Observations
    - Multiple passband observations with emphasis on high sensitivity observations of the high chromosphere, transition region and low corona

# Science Flow Down - NI

- Diagnostics of reconnecting plasma
  - Required measurements
    - Time evolution of the hot plasma (possibly in non-ionization equilibrium), evaporated chromospheric plasma, radiative instabilities and cooling plasma.
  - Example
    - Post flare loop arcade
  - X-Ray Observations
    - Multi-filter observations with emphasis on coronal wavelengths.

# Science Flow Down - NI

- Connections to the Heliosphere
  - Required measurements
    - Observations of outflows along loops connecting to the heliosphere. Observations are needed at multiple temperatures. High sensitivity required to observe low density plasma.
  - Example
    - Active region and coronal hole limb observations
  - X-Ray Observations
    - Take images in 304, 465, 171, 195, 211 at 30s cadence. Flows can be high speed (~100 km/s) but are observed on long loops (~100"). Observe for 2 hours. FOV is 200"x200" (or 2000x2000 pixels at 0.1"/pixel).

# Science Flow Down - NI

- Elementary Structures in the Corona
  - Required measurements
    - High spatial and temporal resolution observations to detect the substruction of coronal loops: braiding, resonant absorptions, islands.
  - Example
    - Non-flare active region loops.
  - X-Ray Observations
    - Multi-wavelength observations - may take high cadence in 1-2 passbands at a time, ~6 passbands needed for full temporature coverage.

# Science Flow Down - NI

- Particle Acceleration
  - Required measurements
    - Footpoint dynamics - UV images at high resolution and high cadence
    - Footpoint depth - determine the depth of energy deposition for different magentic field configurations.
  - Example
    - Flare foot point spreading - indentify the locations of particle impact for joint observations with chromospheric spectrographs.
    - Flare foot point spreading - Simultanious multi-wavelength observations of particle impacts UV and moss brightening.
  - X-Ray Observations
    - Imaging in a single UV passbands
    - Imaging in UV, 171, 304 and 465 passbands, high cadence in each passband is needed.

# Conclusions

- GI Telescope without Photon Counting
  - High Cadence observations of coronal plasmas, broad FOVs
  - Limited temperature resolution
  - Limited spatial resolution
- GI Telescope with Photon Counting
  - Simultaneous imaging and X-ray spectroscopy
  - Technology development may be needed
  - Limited spatial resolution
- NI Telescopes
  - High spatial resolution
  - Need multiple telescopes
  - Need large effective area

# Concerns

- Is the proposed set of Plan-B instruments consistent with the capabilities of the program?
- The resources have not been defined, but the present instrument compliment is vast.
- What are the one or two critical measurements that we need to be able to make for Plan-B to be compelling?