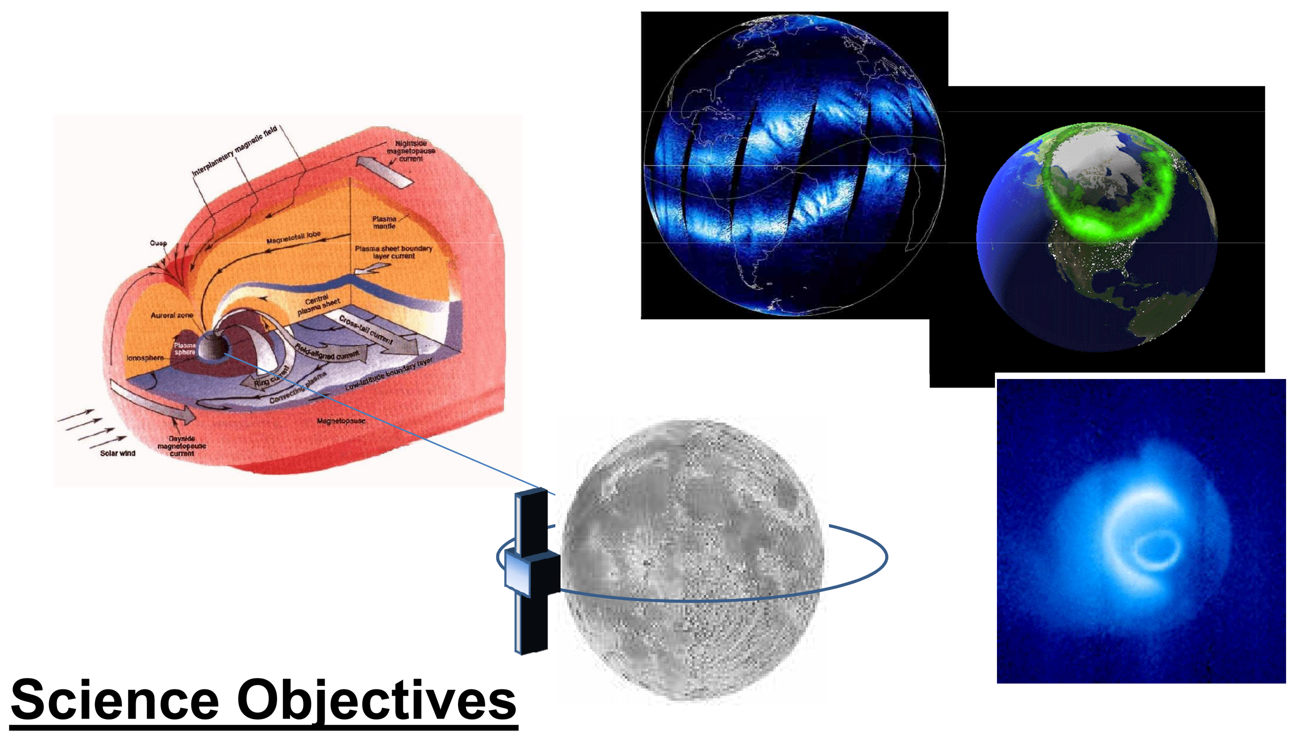
GEOSPACE OBSERVATION FROM LARGE DISTANCE (GOLD)

Joseph M. Davila, Nelson Reginald, John Sigwarth, Tom Moore , Michael Collier, O. C. St. Cyr, Barbara Thompson (Goddard Space Flight Center), James Spann, and Dennis Gallagher (Marshall Space Flight Center)

TIMED, IMAGE, Polar, and Dynamics Explorer have provided breathtaking views of the ionosphere and plasmasphere. The Heliospheric Imager (HI) onboard the Solar Terrestrial Relations Observatory (STEREO) has produced similarly stunning images of CMEs and CIRs in the interplanetary medium (IPM). We present a new mission concept combining these techniques to simultaneously image global structures in geospace. Instruments optimized to image the magnetosphere, the plasmasphere, and the ionosphere simultaneously provide unprecedented new information on the evolution of geospace, its interaction with the solar wind, and the upper atmosphere of Earth. A magnetosphere imaging instrument with an advanced active pixel detector, which provides individually addressable detector pixels, could be used to observe all of these regions in a single combined image, or images of the magnetospheres of other planets in the solar system, like Jupiter and Saturn with moons or rings in the field-of-view. Potentially this technique can also be used to obtain images of the interaction between the solar wind and comets.



Science Objectives

1. Understand the dynamic coupling of the magnetospheric system to solar UV, and solar wind variations, plasma sources, dayside reconnection and storm dynamics,
2. Understand the global evolution of the ionosphere in response to the magnetospheric drivers
3. Understand critical global solar wind/magnetosphere/ionosphere parameters and dynamics that drive physical prediction models

Associated RFAs

F1. Understand the role of plasma and neutral interactions in nonlinear coupling of regions throughout the solar system.
H2. Determine changes in the Earth's magnetosphere, ionosphere, and upper atmosphere to enable specification, prediction, and mitigation of their effects.
J1. Characterize the variability, extremes, and boundary conditions of the space environments that will be encountered by human and robotic explorers.

Measurement Strategy

Thomson scatter, visible light images of the global magnetosphere, EUV images of the plasmasphere, and UV images of the ionosphere. All are obtained at a sufficient resolution and cadence to reveal global magnetospheric structure, and it's evolution in response to solar wind drivers.

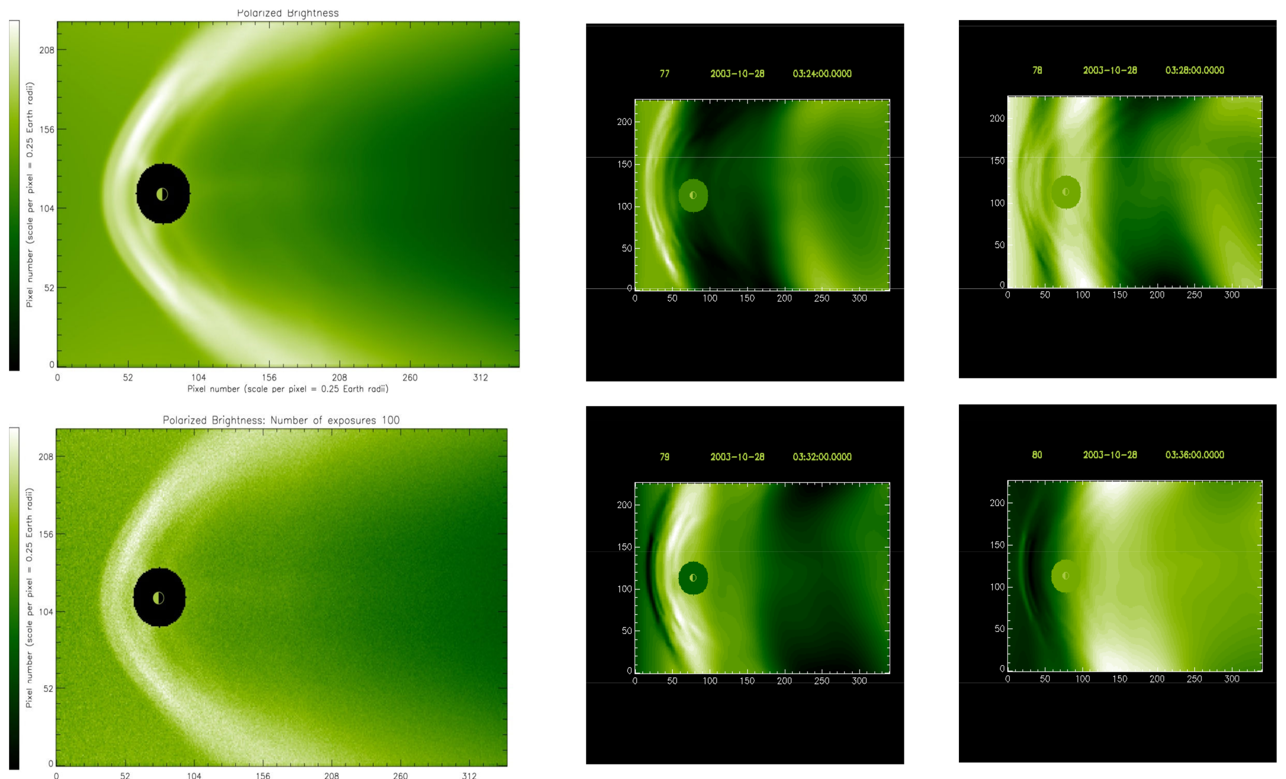


Figure 1: Simulated images of the magnetosphere from the side using the electron density modeled by BATSRUS for the Halloween storm period 2003. Single image with no noise (UL), single image with noise from solar wind emission added (LL), a series of consecutive 4-minute running difference images demonstrating the rapid temporal evolution. All images are 227 (V) x 341 (H) pixels with a resolution of 0.25 R_E/pixel. A 5 RE region is blocked by the occulter, this allows imaging of the fainter outer portions of the magnetosphere.

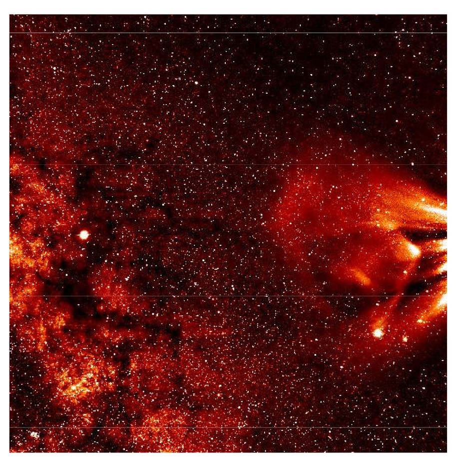
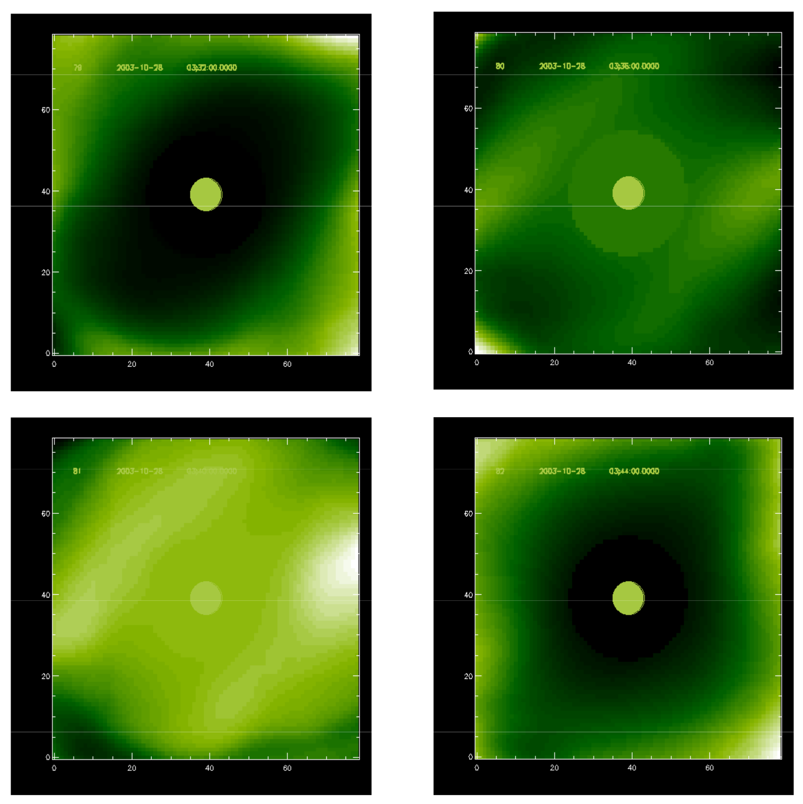


Figure 3: The Heliospheric Imager on STEREO has provided the first views of CMEs and CIRs in the interplanetary medium.

Mission Implementation Description

Single 3-axis spacecraft of moderate size in lunar orbit is required. Estimated Payload resources required (100 kg / 80 W / 250 kbps). Spacecraft must be far enough away from Earth to allow a global view, but not so far that the image intensity is too low. For all of the simulations presented, a lunar distance was assumed. Other possibilities include L1, heliocentric Earth-synchronous orbit. Detailed instrument parameters depend on the distance, but there has been no study of these alternative orbits.

For a SC in lunar orbit, different views of the magnetosphere at different times during the lunar month are obtained. Side views for 2 weeks, front view for 1 week, and when the moon is in the tail (full) the instrument will be sunward pointed and only EUV imaging is possible.



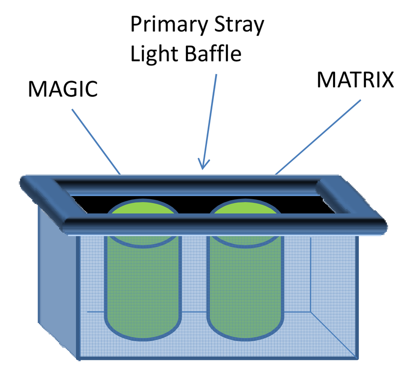


Figure 2: Front side views showing 4-minute running difference images. The B_y component in the solar wind magnetic field initiates non-axisymmetric evolution. All images are 79 x 79 pixels with a resolution of 0.25 R_E/pixel (L). Schematic showing MAGIC and MATRIX configurations (L).

Why is this possible now?

The imaging of sources this faint is possible because of 3 significant developments:

1. STEREO/Heliospheric Imager (HI) and the Solar Mass Ejection Imager (SMEI) have imaged sources of similar brightness
2. Demonstrated advancements in baffle designs (See Figure 4)
3. Development of methods for background subtraction of zodiacal light, stars, planets, and emission from the solar wind

Need to validate designs with Earthshine at various angles.

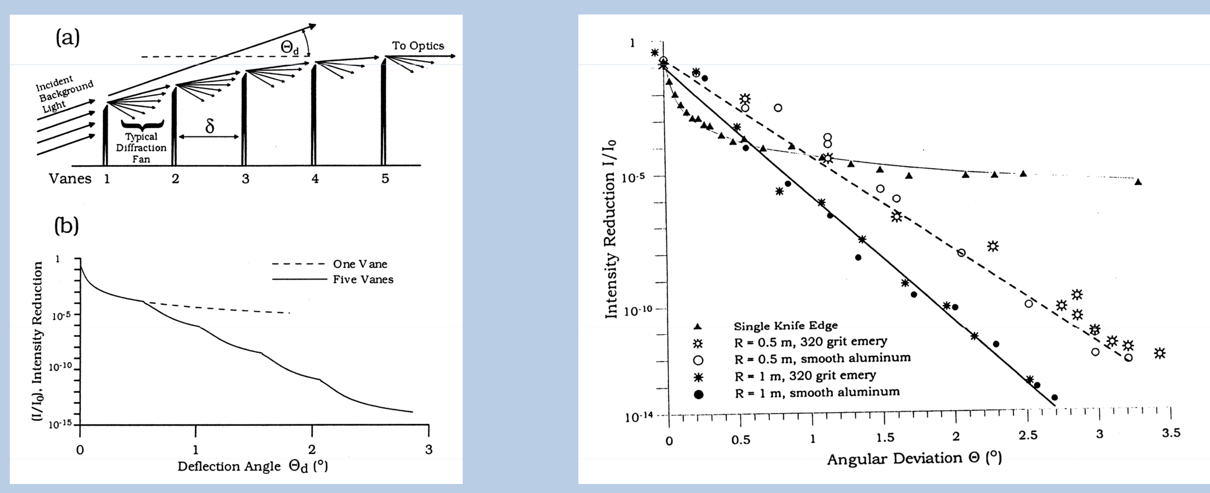


Figure 4: The STEREO/HI imager uses a series of knife-edge baffles to reduce the stray light to 10^{-12} B_{sun} (L), laboratory test of a continuous baffle shows stray light level of 10^{-14} B_{sun} (R). Either of these approaches satisfies the MAGIC requirement. (Figures from Buffington 2000)

MAGIC			EXISTING CORONAGRAPHS	
Moon	L1	0.1 AU	C3	COR1
4.4	2.44	0.24	3.2	0.6
44.1	24.43	2.44	18.5	2.1
0.14	0.08	0.008	0.02	0.002

Table 1: For three different orbits the FOV of MAGIC is compared to existing C3 and COR1 coronagraphs. The requirements for MAGIC are similar to C3 or COR1 depending on distance. Larger apertures are required to satisfy the 1 min time resolution requirement.

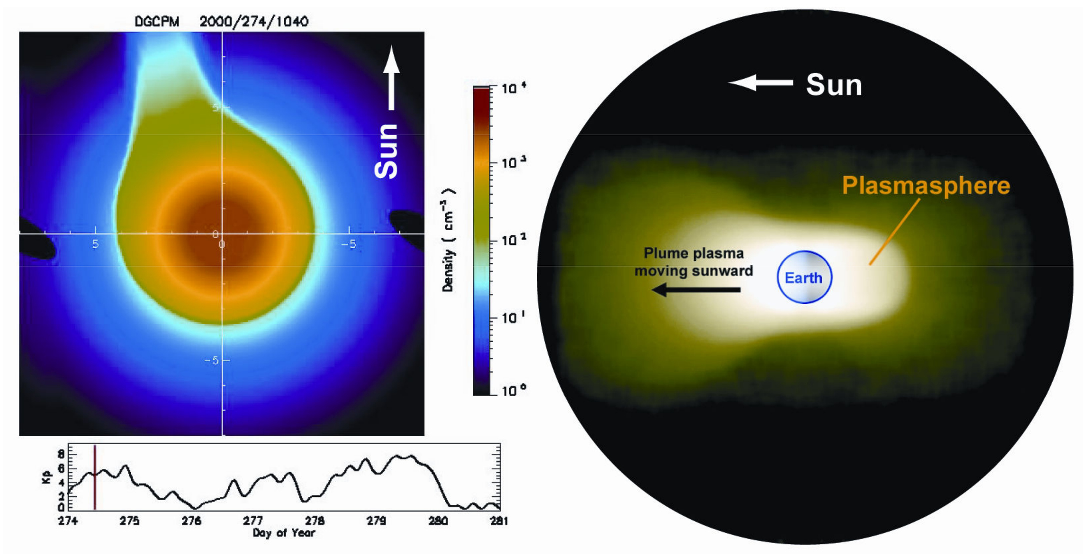


Figure 4: A modeled thermal density distribution is shown on the left for a storm in October 2000. A simulated lunar image in 30.4nm light is shown on the right for this density distribution. The image is for a 10-minute integration time, 14 degree FOV, for 100-times the sensitivity and 0.6 R_E resolution.

Instrument Descriptions

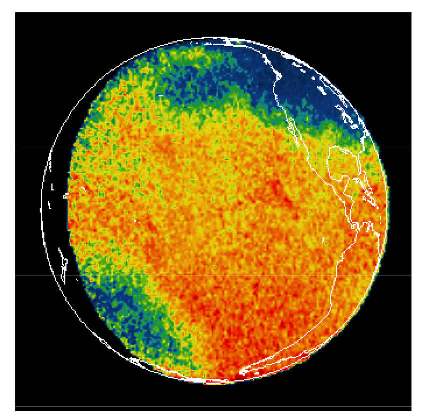
GOLD benefits from imagers that have an extensive history of flights on NASA missions including Dynamics Explorer, Polar, IMAGE, and TIMED. The Ionospheric Imager is designed to observe the atmospheric and ionospheric response to magnetospheric changes including the aurora, effects on dayside thermospheric composition of total column atomic oxygen and molecular nitrogen, and nighttime ionospheric density and recombination. The Plasmaspheric Imaging Experiment has flight heritage from the EUV instrument on IMAGE, along with new capabilities.

Plamaspheric Imaging Experiment (PIXI)

Resolution: 640 km (0.1 R_E)
FOV: 14°
Image Size: 144 x 144 pixels
Aperture Area: 87.2 cm^2
Exposure Time: 500 s
Temporal Res: 500 s
Wavelength: He II 30.4, O II 83.4 nm
Sensitivity: 1 counts/R-s

Ionospheric Imager (II)

Resolution: 28 km/pixel (15 arcsec)
FOV: 2° x 2°
Image Size: 512 x 512 pixels
Aperture Size: 200 mm
Exposure Time: 15 s
Temporal Res: 15 s
Wavelength Bands: O I 135.6 nm, N_2 LBH 140-160 nm
Sensitivity: 26 counts/kR-pixel



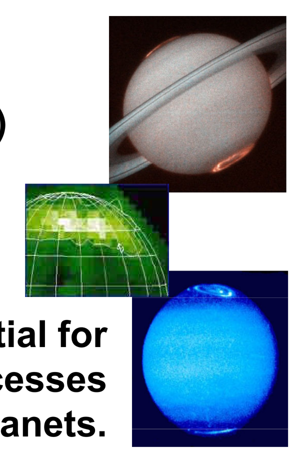
Dayside column O/N_2 density ratio.

Magnetosphere Imaging Coronagraph (MAGIC)

Resolution: 1000 km/pixel = 0.157 R_E/pixel
Outer FOV: 50 R_E
Occulter Radius: 5 R_E
Image Size: 640 x 640 pixels
Aperture size: 207 mm (8.15 in)
Exposure Time: 0.6 s
Temporal Res: 1 min (100 images summed)
Scattered light: $<10^{-19}$ B_{sun}

Magnetotail Reconnection Imaging Experiment (MATRIX)

Resolution: 1000 km/pixel = 0.157 R_E/pixel
Outer FOV: 30-80 R_E Tailward
50 R_E North-south
Occulter Radius: Linear
Image Size: 640 x 640 pixels
Aperture size: 207 mm (8.15 in)
Exposure Time: 0.6 s
Temporal Res: 1 min (100 images summed)
Stray light: $<10^{-19}$ B_{sun}
Baffle: $<10^{-13}$ B_{sun}



This technique also has potential for observing magnetospheric processes on other planets.