

“Relativistic geophysics” and X-ray astronomy

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**probably graduating within a year*

Physics 205, 2/3/14

Physical mechanisms of radiation production from 1 keV – 100 MeV:

Bremsstrahlung

Inverse Compton of low-energy photons off high-energy electrons

Synchrotron radiation

Positron annihilation

Nuclear decay

Nuclear de-excitation

Natural contexts:

Earth's atmosphere

(radiation belt precipitation; cosmic-ray collisions;
particle acceleration in thunderstorms)

Solar flares

Cosmic-ray interaction with rocky planets

Accreting black holes and neutron stars (disk and jets)

Explosions (novae, supernovae, cosmic gamma-ray bursts)

Cosmic-ray interactions with interstellar gas

Pulsar magnetospheres

Observing platforms: Satellites, balloons (> 20 keV), aircraft and ground (lightning only)

Relativistic runaway: gamma-rays from lightning

Millisecond flashes of gamma rays up to 30 MeV are associated with intracloud lightning and perhaps other forms as well.

Data sets from orbit: BATSE (1990s), RHESSI (2002-), Fermi (2008-), AGILE (2008-).
Our group has access to BATSE, RHESSI, Fermi data sets.

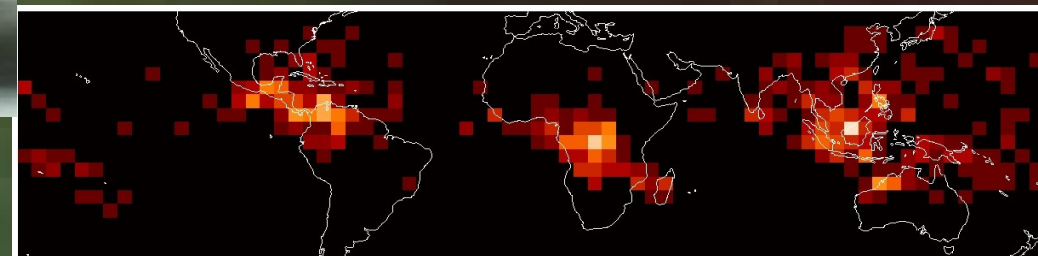
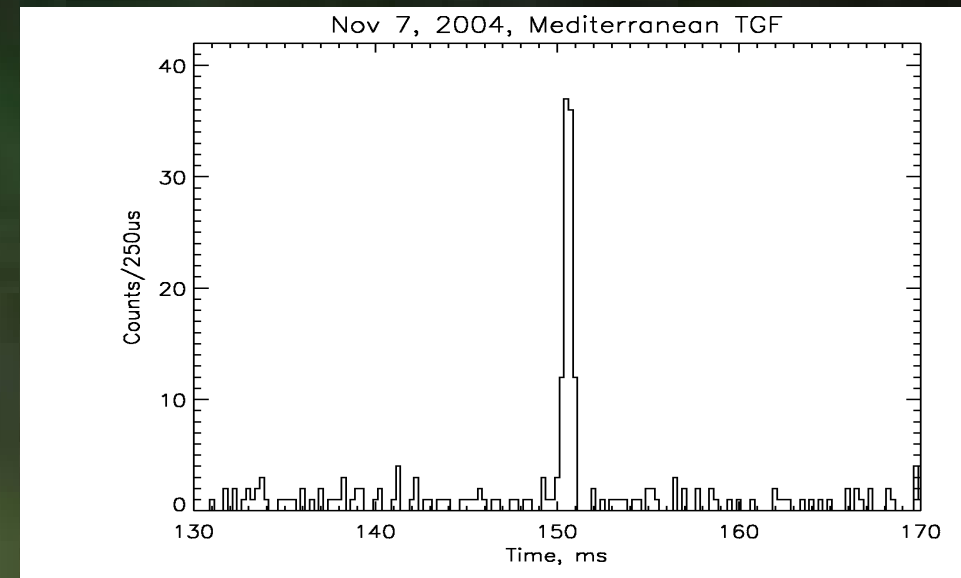
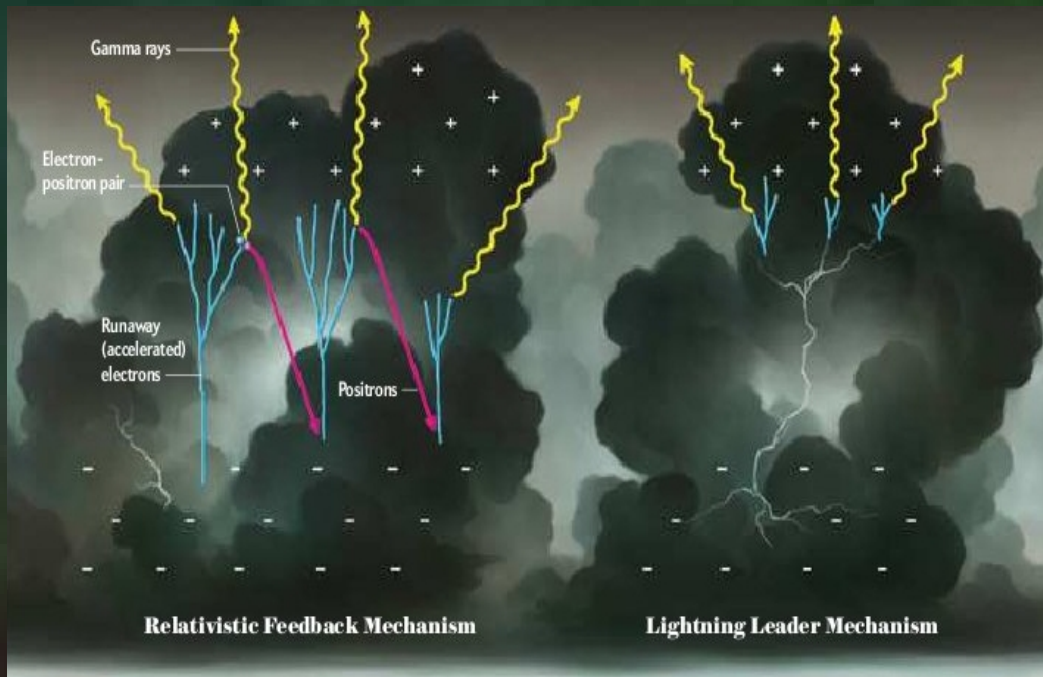
Outstanding questions:

Is the TGF the cause (trigger) of lightning discharges, or a side effect afterwards?

When and how do TGFs occur?

What is the TGF total energy and contribution to atmospheric ionization?

Is there a risk to airline passengers?



TGF map
(RHESSI)



Airborne
Detector for
Energetic **L**ightning **E**missions

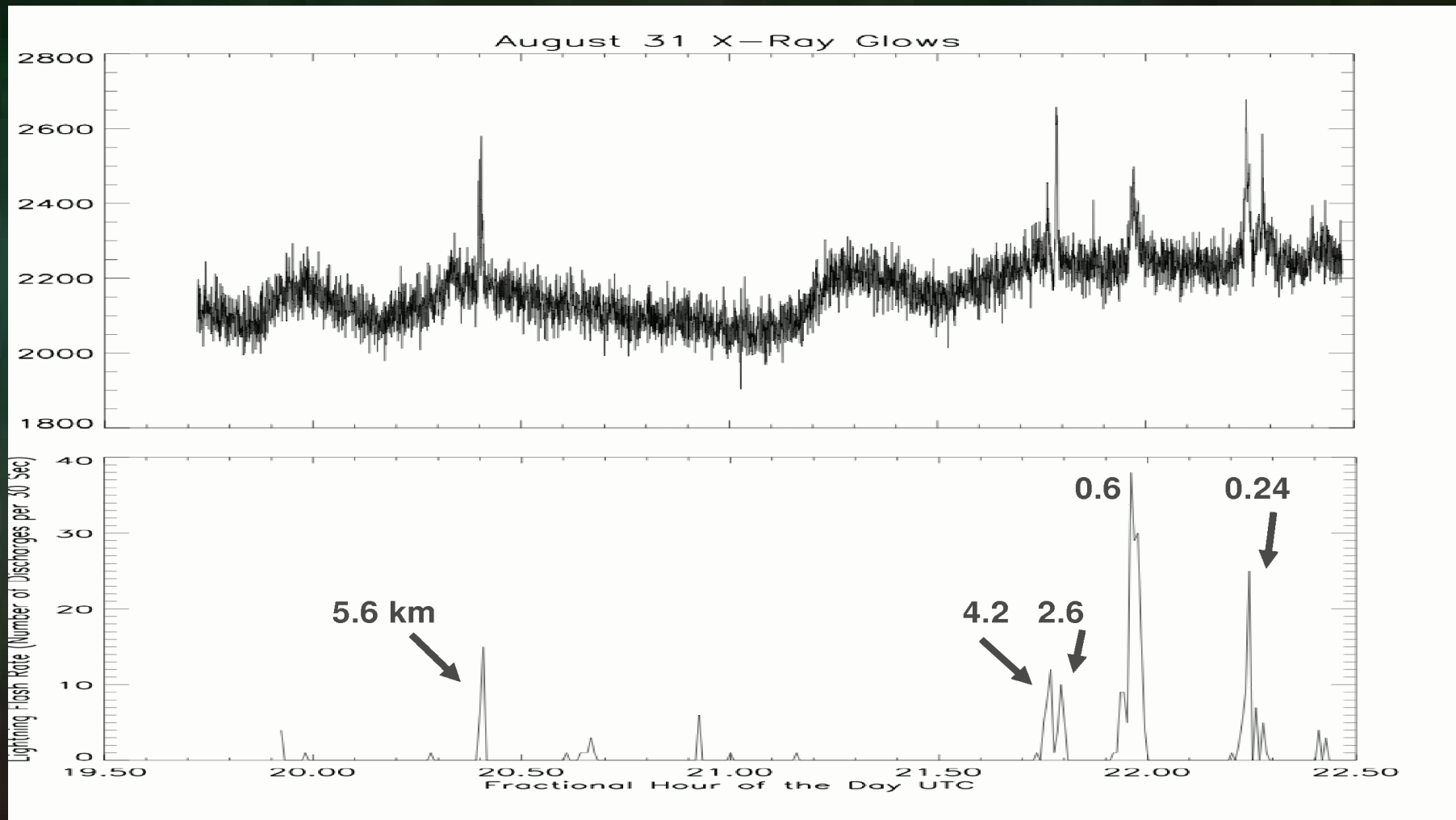


First results from ADELE:

First TGF seen from a plane (10km distance)

TGFs are RARE (< 1% of all lightning)

“Glows” are COMMON – relativistic runaway occurs in many or most storm cells making lightning



Other projects in the pipeline:

ADELE on NOAA Hurricane Hunters

Cellphone app for crowdsourcing airborne
detection (with Image Insight, Inc.)

Micropayloads for sounding balloons/dropsondes

Japanese winter thunderstorms

NSF A10 Warthog

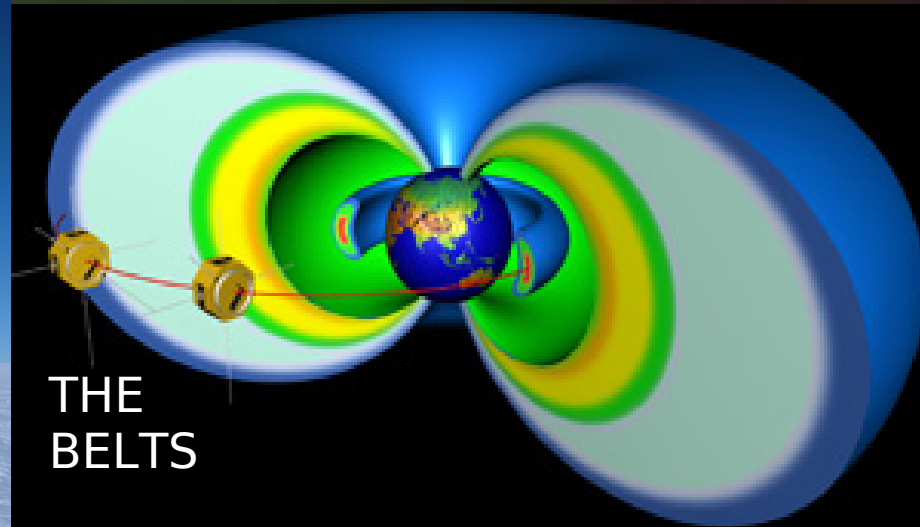
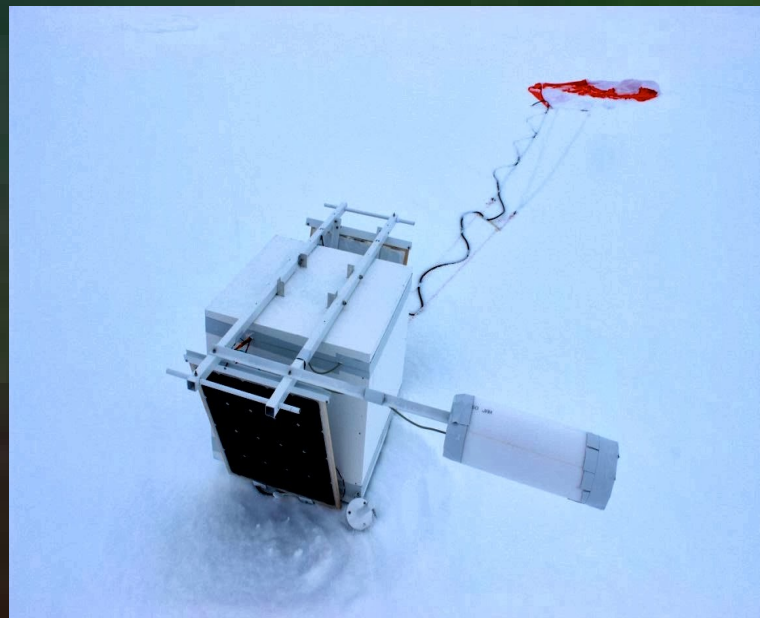


Loss of Relativistic Electrons from the Outer Van Allen Belt

The outer belt (4 to 7 Earth radii at the equator) contains a population of MeV electrons that can vary by factors of thousands over days. Acceleration and loss mechanisms are equally important in understanding and predicting this population, which is a hazard to satellites. The belts are a laboratory for plasma physics in astrophysical environments.

BARREL is a NASA program of 40 balloon flights completing now to study e- losses by observing bremsstrahlung produced when the electrons enter the atmosphere.

BARREL will observe electron losses while the Radiation Belt Storm Probes (RBSP) satellite observes conditions at the equator along the same field line.



UCSC is responsible for the operations center, telemetry, data and software management, and the secondary instrument on each payload - DC magnetometers.

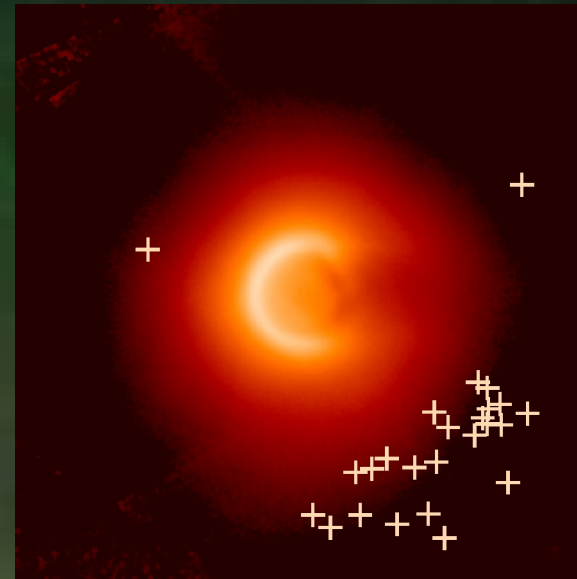
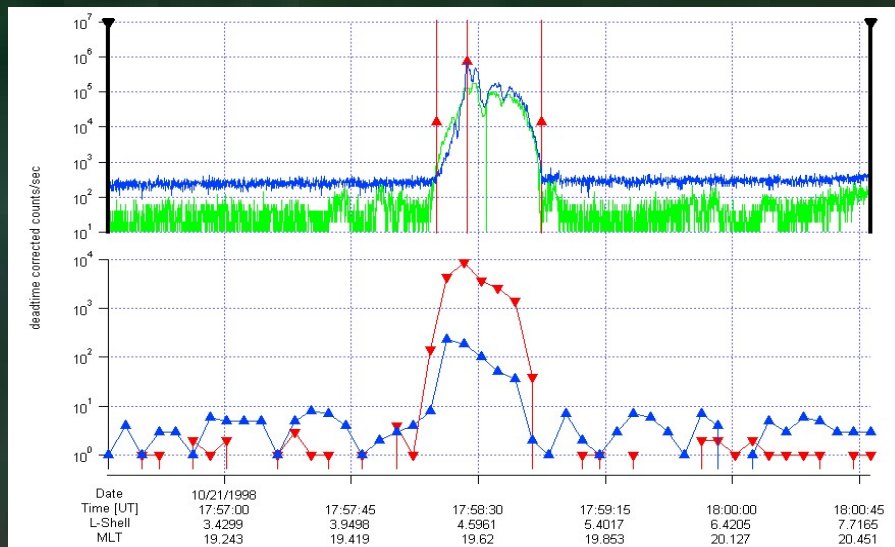
The balloons will be launched at two Antarctic stations, communicating with UCSC via the Iridium satellite network.



In upcoming years:

BARREL data analysis

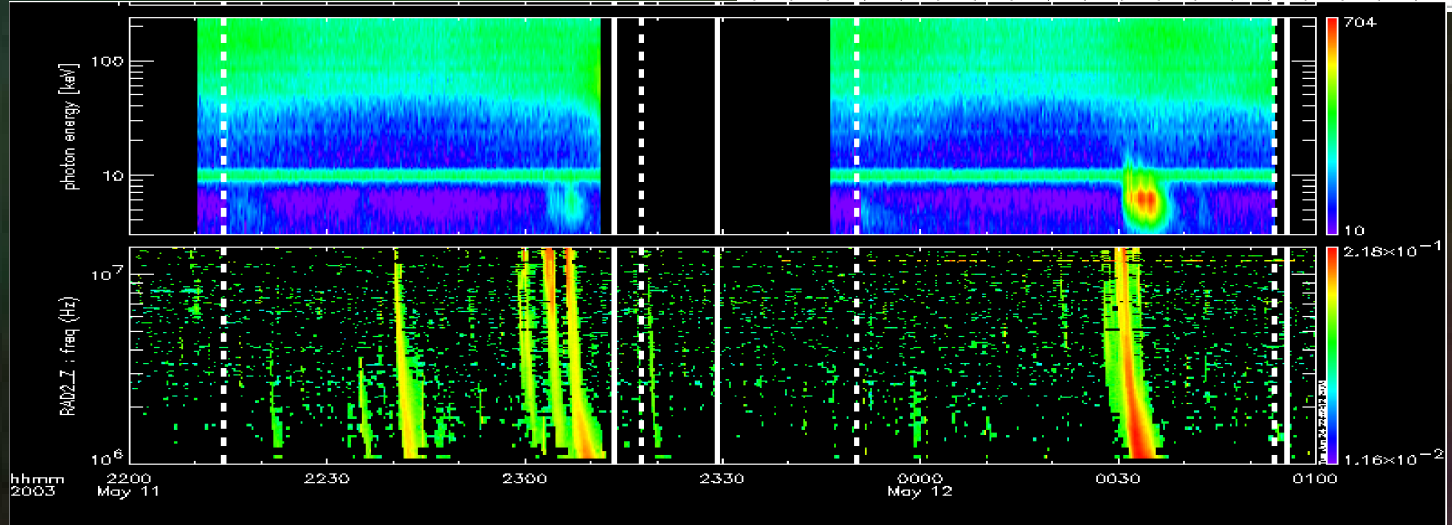
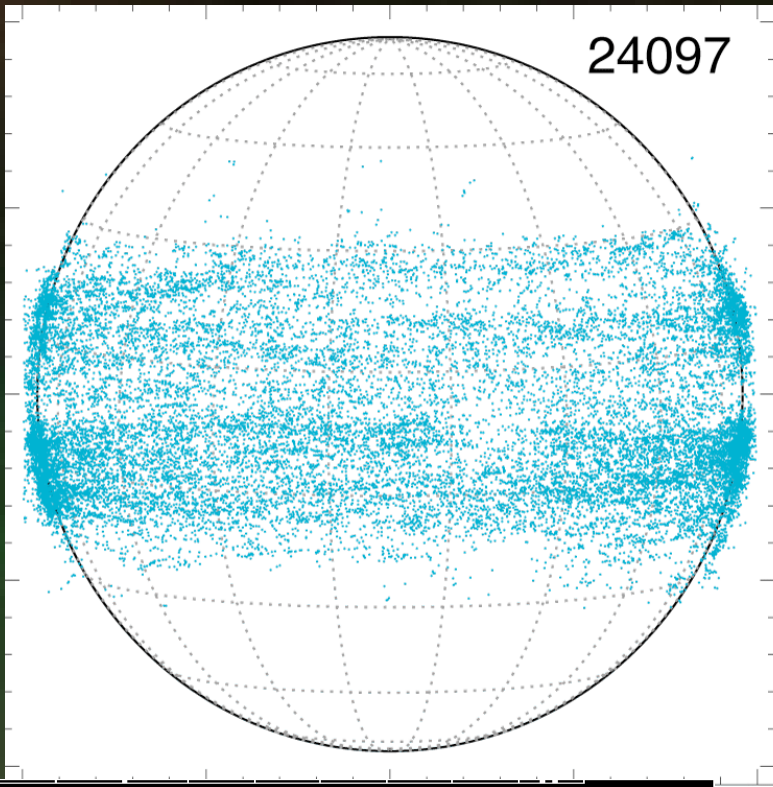
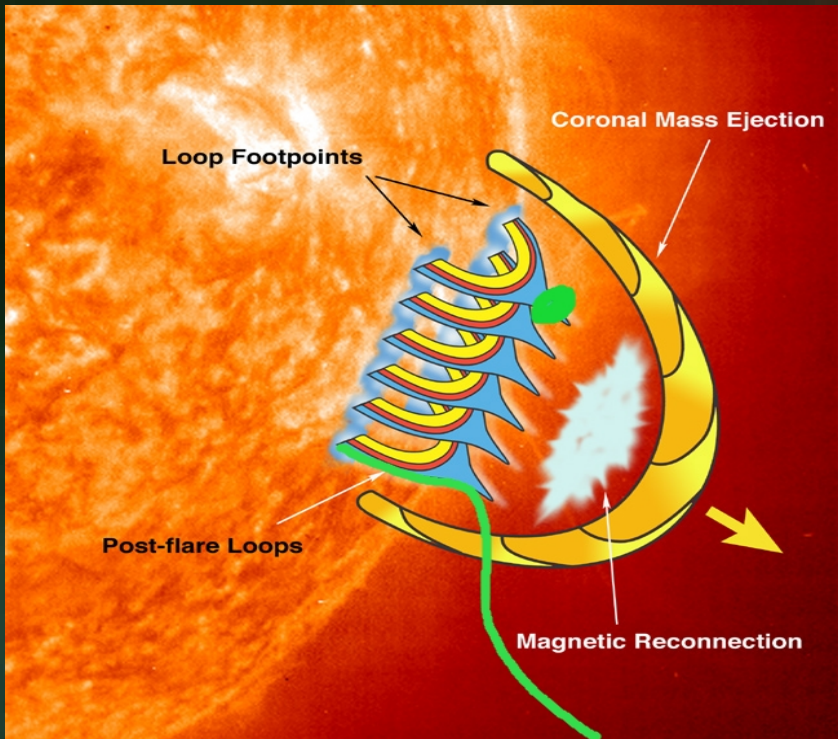
Continued analysis of a larger database from the SAMPEX satellite (scientifically rich, currently unfunded)



Possible further BARREL(ish) launch opportunities

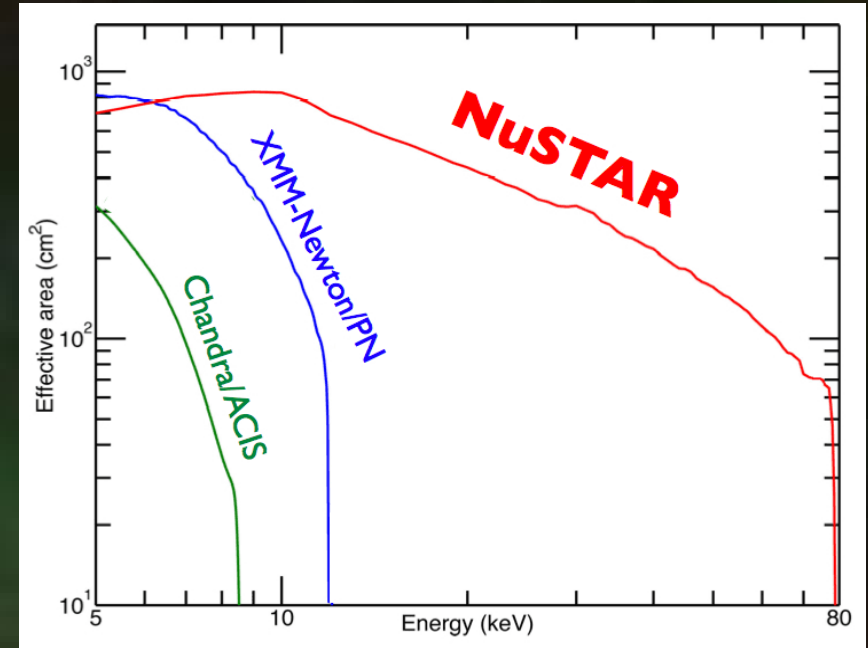
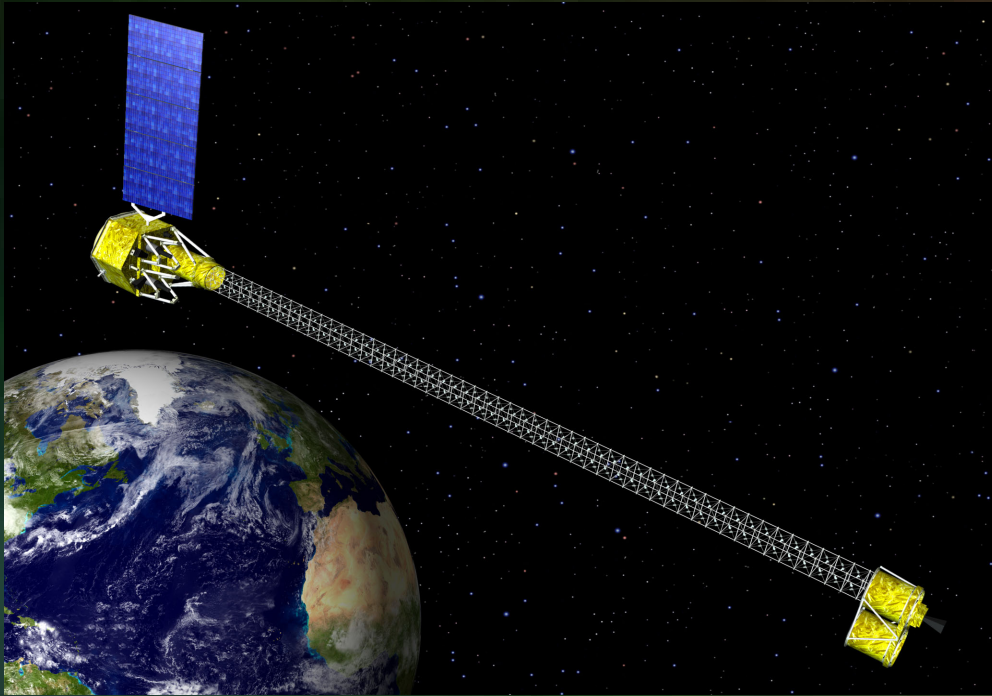
High-Energy solar physics

Particle acceleration during magnetic reconnection in the corona



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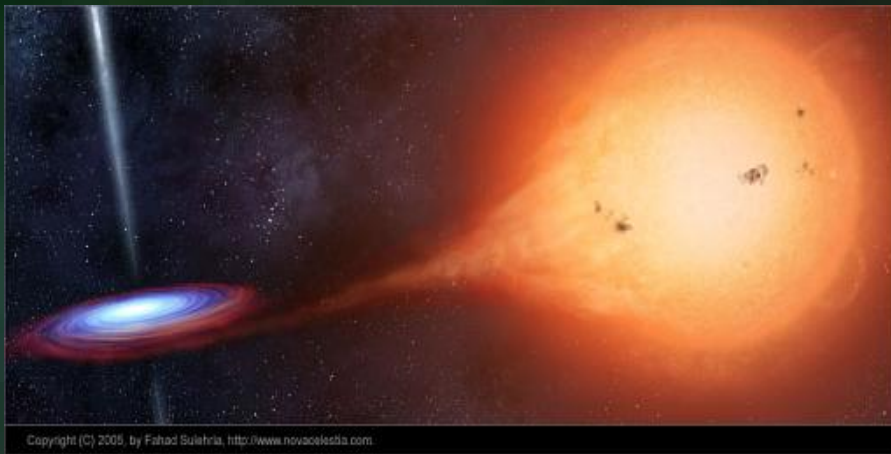
NuSTAR (data start later this year):

First true images of nonthermal x-rays in the solar corona -- very high sensitivity to “nanoflares”, jets escaping the corona – solar observation science lead

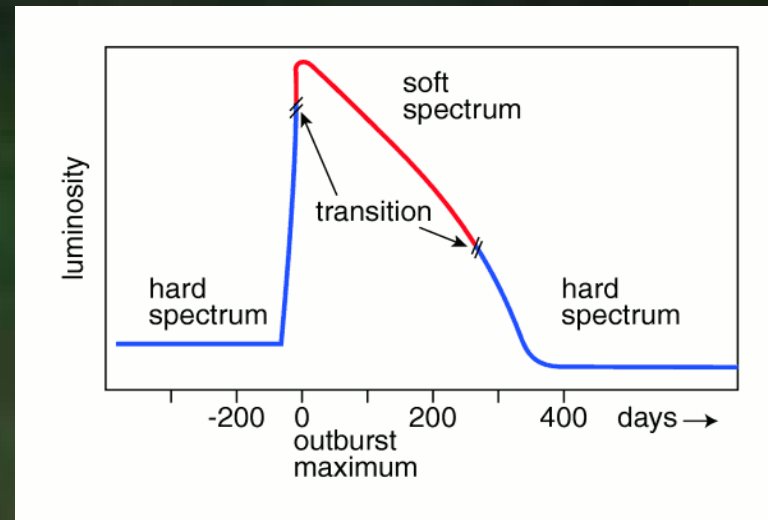
X-ray studies of accretion in neutron star and black hole binaries (satellite data, currently unfunded)

What physics determines transient outbursts vs persistent x-ray luminosity?

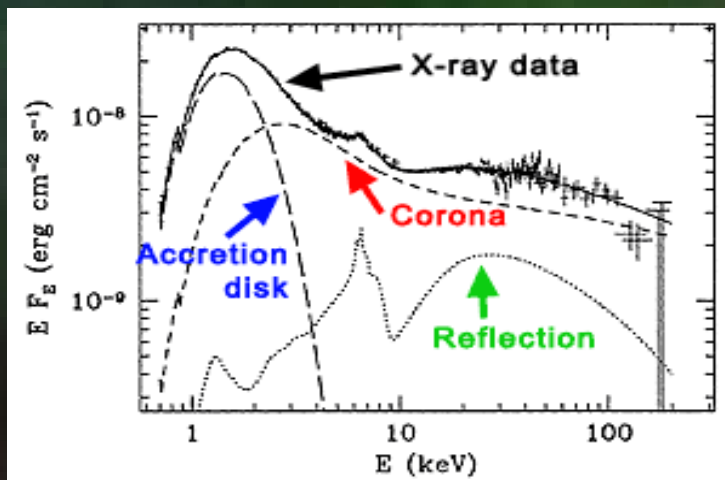
What physics drives the pattern of changes in luminosity and x-ray spectral “hardness”?



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Canonical transient accreting black hole (F. Meyer)



Gierlinski et al. 1999

LMC X-3

