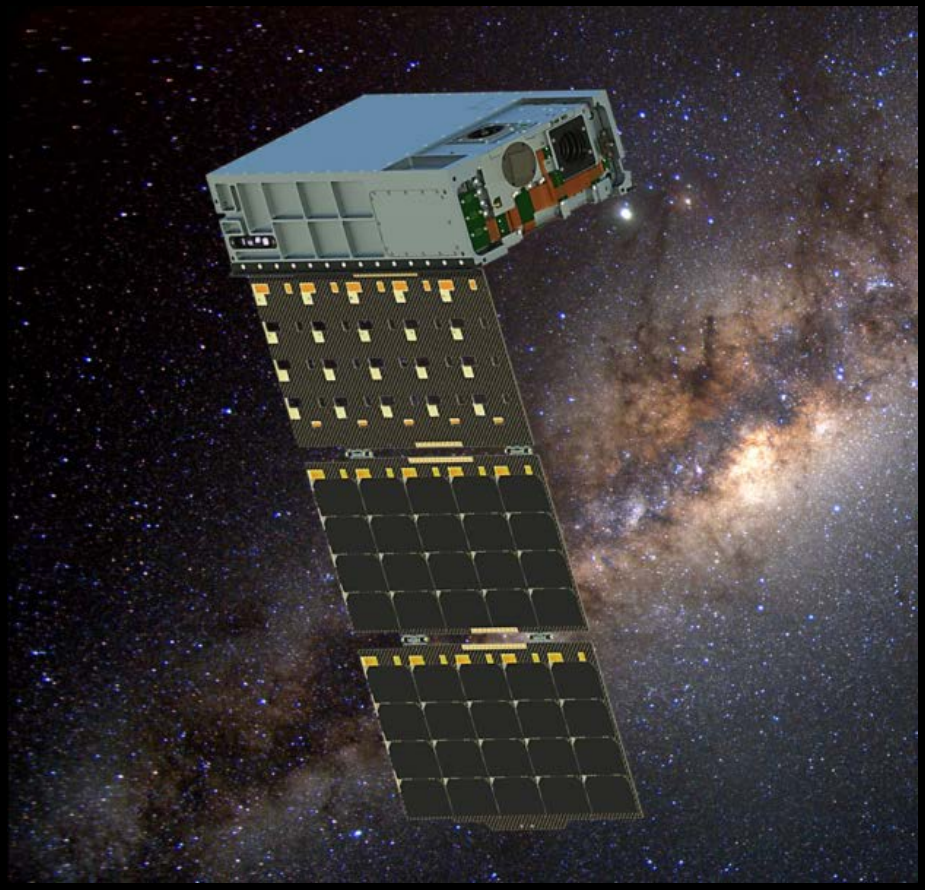
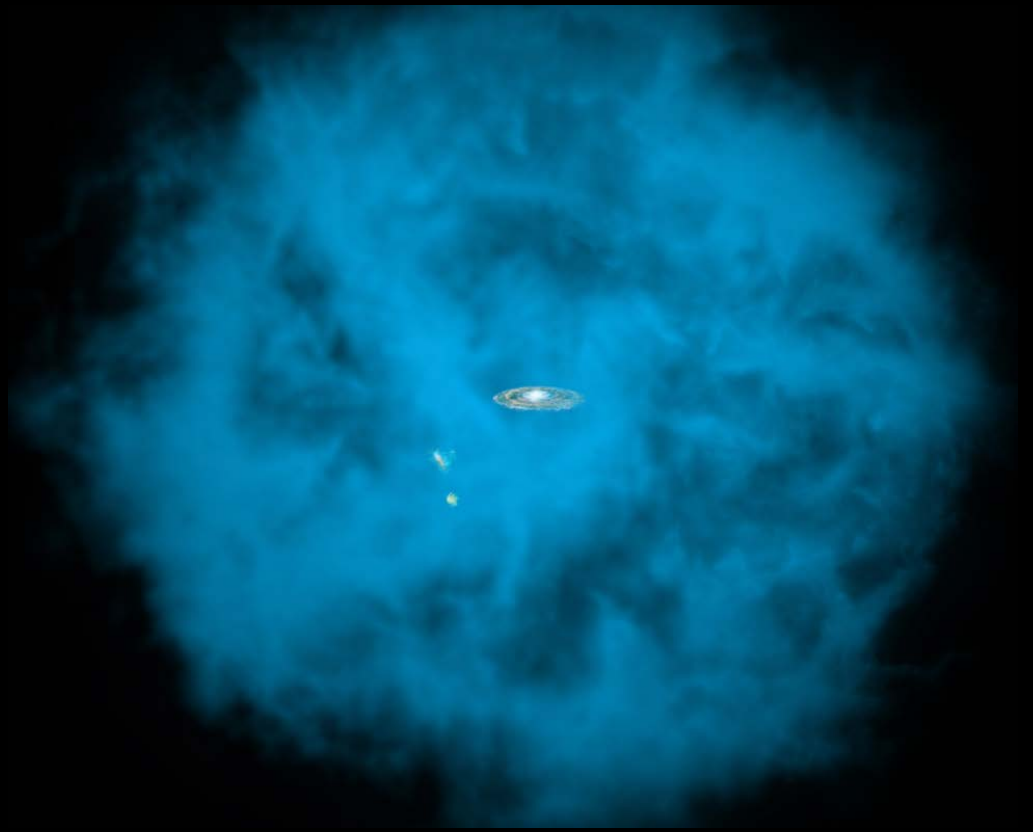
Doing Astronomy with CubeSats

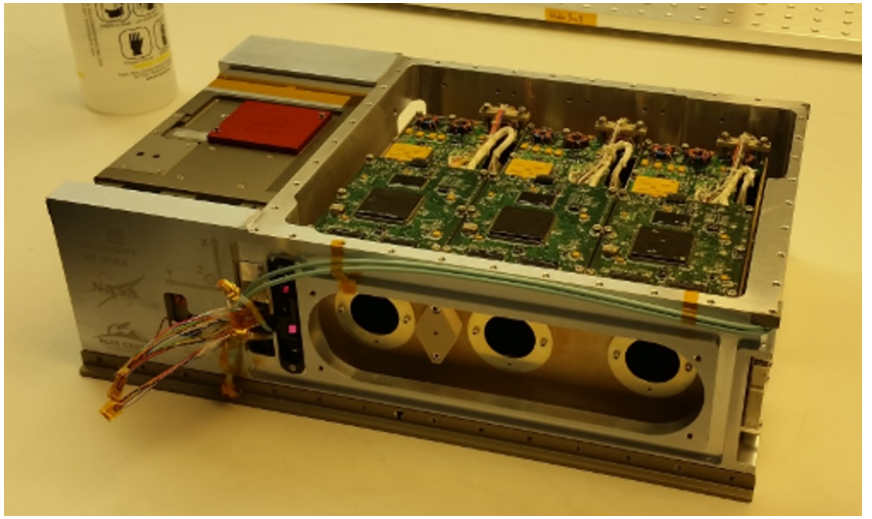
Philip Kaaret (University of Iowa)



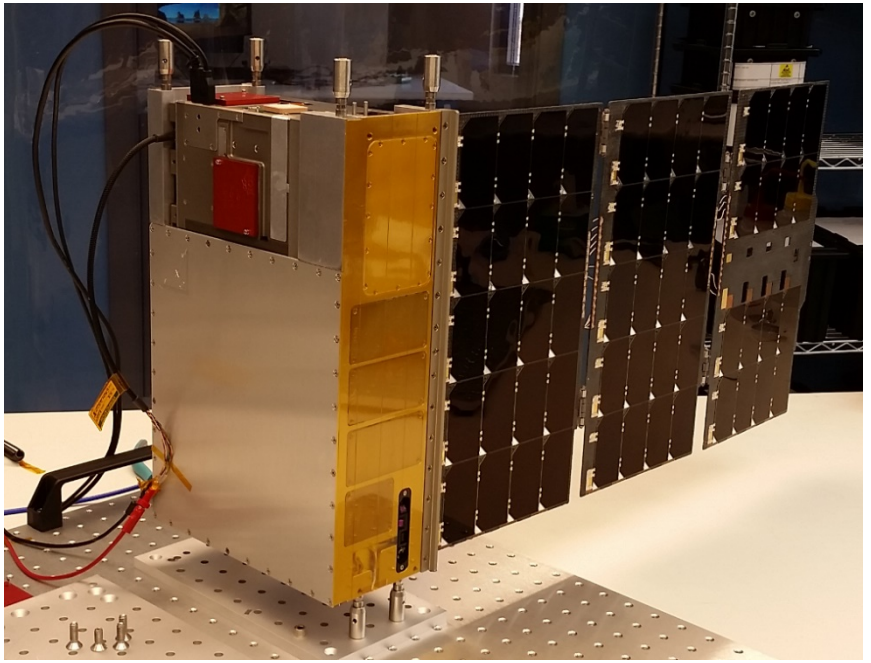


What is the platform?

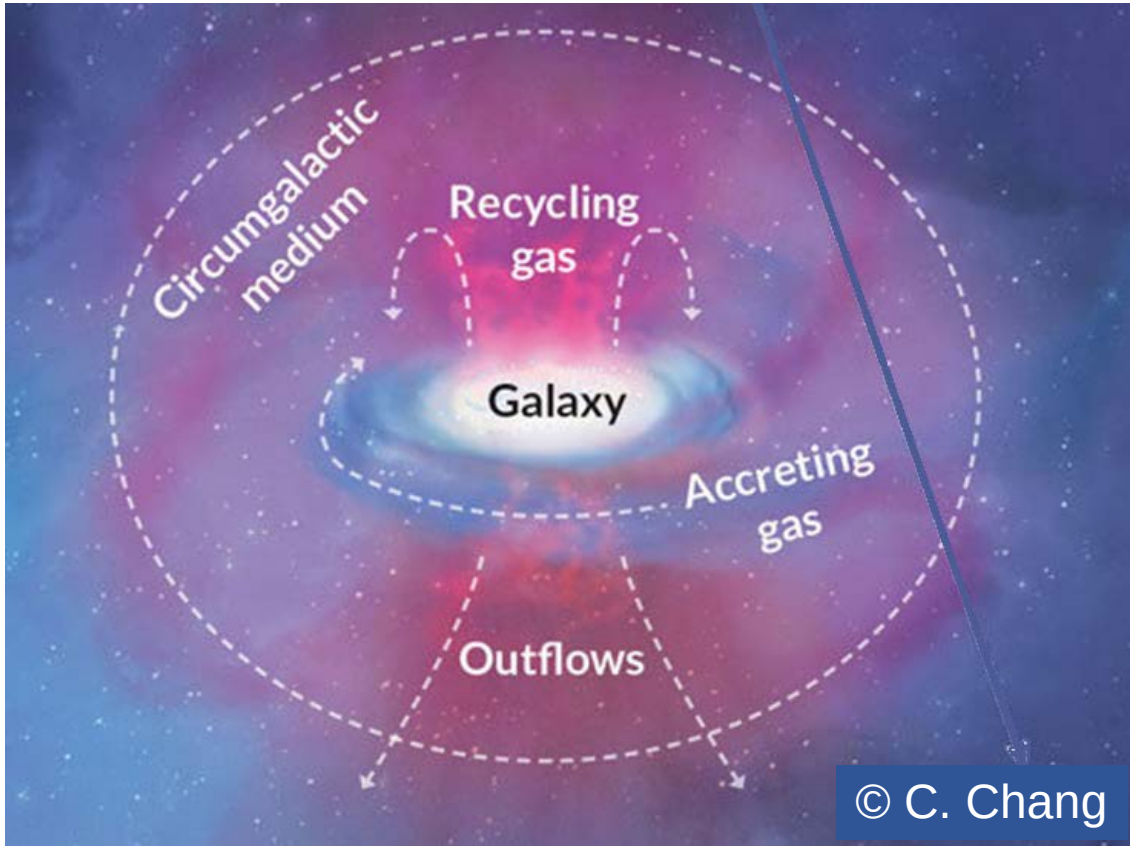
- CubeSats 1 Unit = 10×10×10 cm^3
- NASA supports up to 12U.
- University-built science instrument with commercially provided ‘bus’.
- Bus provides power, communications, pointing (10”)



- Photos are of HaloSat which is in the 6U format with 4U for the instrument.



What new scientific opportunities are enabled?



Study of the hot (~10^6 K) component of the circumgalactic medium by mapping soft X-ray emission from highly ionized oxygen.

Science questions:

- Does the CGM have enough baryons to solve the missing baryon problem?
- How CGM fed and energized?

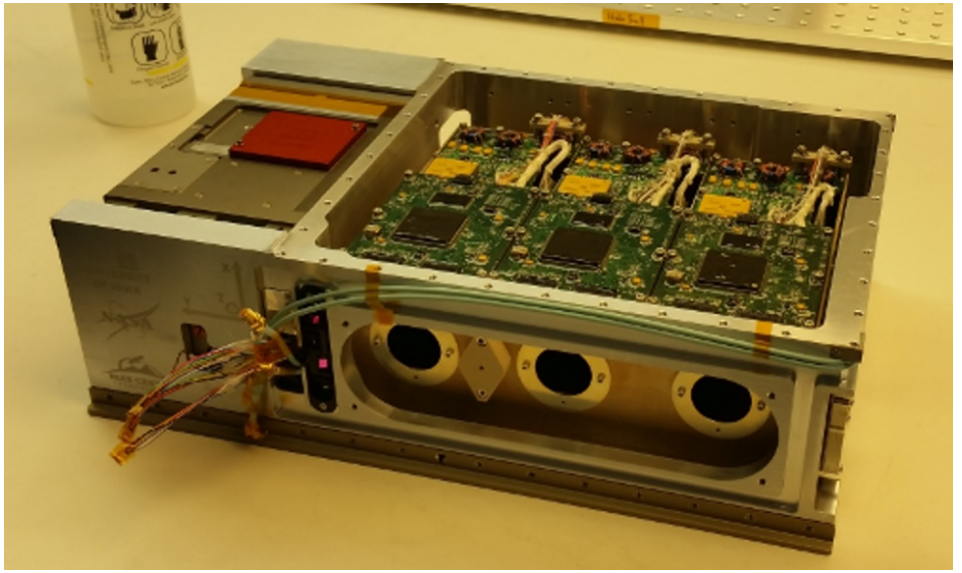
There are very few X-ray (and UV) observatories, mainly due to their cost. CubeSats enable us to build cheap space-based telescopes.

Observational question:

- Is the CGM smooth with a spherical geometry or anisotropic and clumpy?

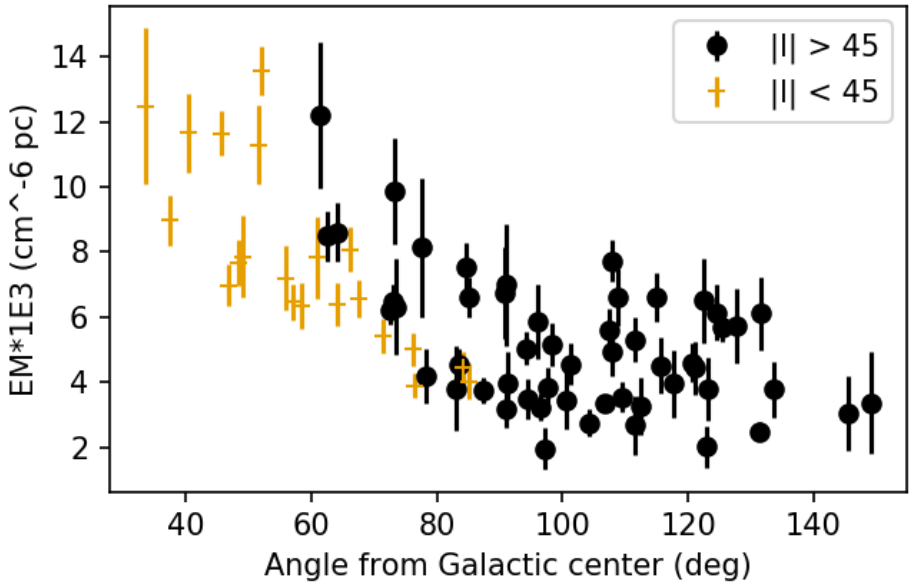
HaloSat is Competitive with Major Missions

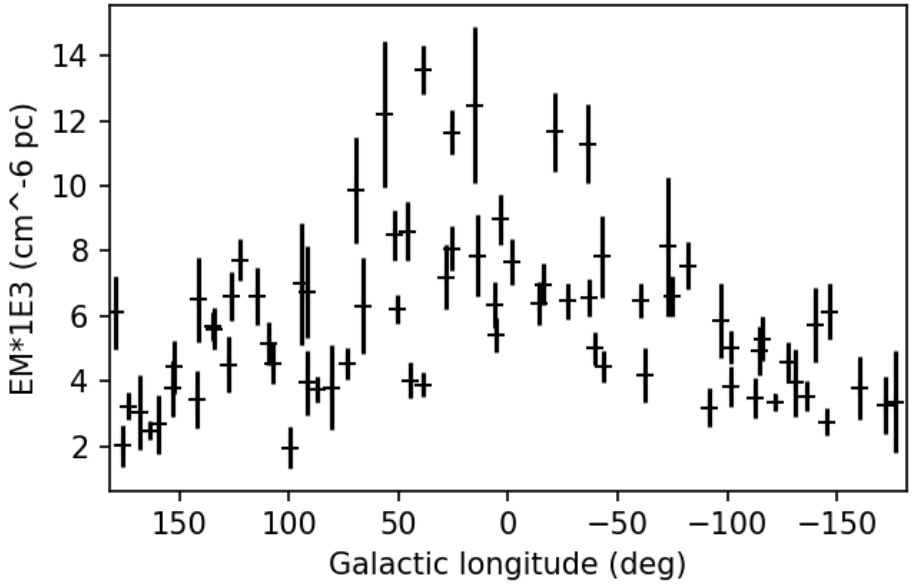
- Lines of highly ionized oxygen are best way to measure 10^6 K gas.
- Lines are in the soft X-ray band, need to do from space.
- Figure of merit for diffuse emission is 'grasp' = product of telescope area and field of view. HaloSat has three small detectors each with a large field of view (10°), grasp is competitive with major missions.



Mission	Grasp (cm^2 deg^2)
HaloSat	17.6
Chandra	8.7
XMM-Newton	73.0

Morphology of Southern CGM





Emission measure (EM) ndicates the brightness of field, proportional to integral of square of density of ionized matter along line of sight.

In spherical geometry, EM decreases with increasing angle from the Galactic center.

- Seen in inner quadrant.
- Not seen in outer quadrants.

→ CGM is concentrated toward inner galaxy.

- Strong longitude variations

→ Inconsistent with uniform disk-like CGM.

- Large EM variations

→ CGM is clumpy.

- Some fields have very low EM

→ Places limits on extended, uniform halo.

Role of the platform in technology development

CubeSats enable long duration (months to years) testing of new technologies. Much longer than possible with sounding rockets.

New technologies on Astrophysics CubeSats

- Novel telescope and spectrograph for NUV at 255-330 nm (CUTE)
- delta-doped CCD, UV dichroic (SPARCS)
- Silicon photomultipliers (BurstCube)
- New UV coatings, advanced microchannel plates (SPRITE)
- CMOS X-ray detectors (BlackCat)

Role of the platform in training

People are excited to work on hardware that will go into space.

Trained on HaloSat:

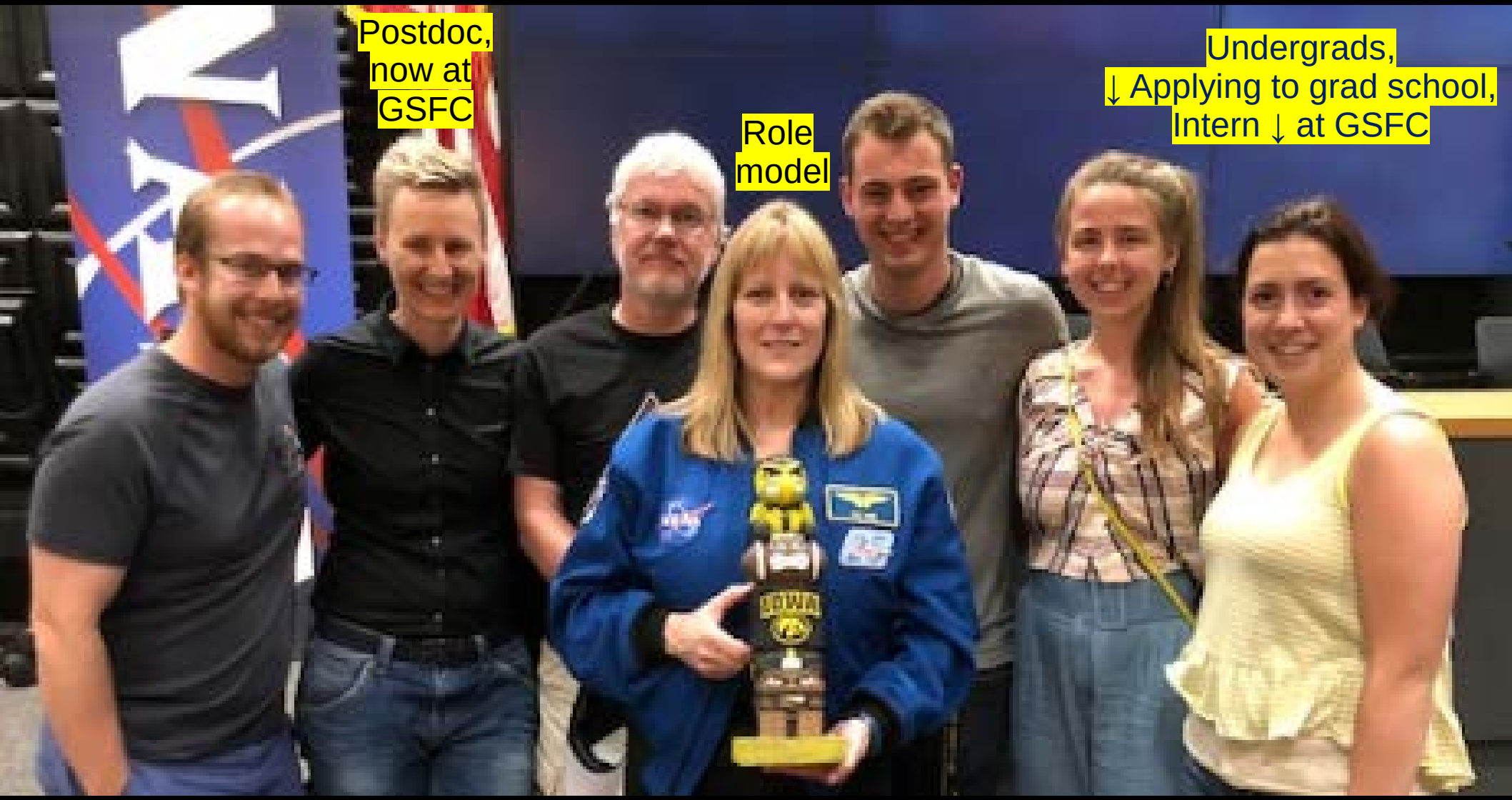
- 2 postdocs – one now at NASA/GSFC
- 3 graduate students – one will be a postdoc at Penn State in the Fall
- 6 physics undergraduates – 2 in graduate school
- 4 engineering undergraduates – 1 in NASA internship

Special opportunities:

- Use NASA environmental test facilities and interact with engineers
- Mentoring by NASA engineers (mechanical, systems)
- Reviews in front of engineers from NASA and industry

Training young scientists and engineers is best on programs classified as 'Research Activity'. Even "tailored class D" is restrictive for student involvement.

Are we training a diverse set of scientists and engineers?



Also one Hispanic engineering student not pictured.

What are the challenges in exploiting the platform's capabilities?

CubeSat PIs must manage the whole project.

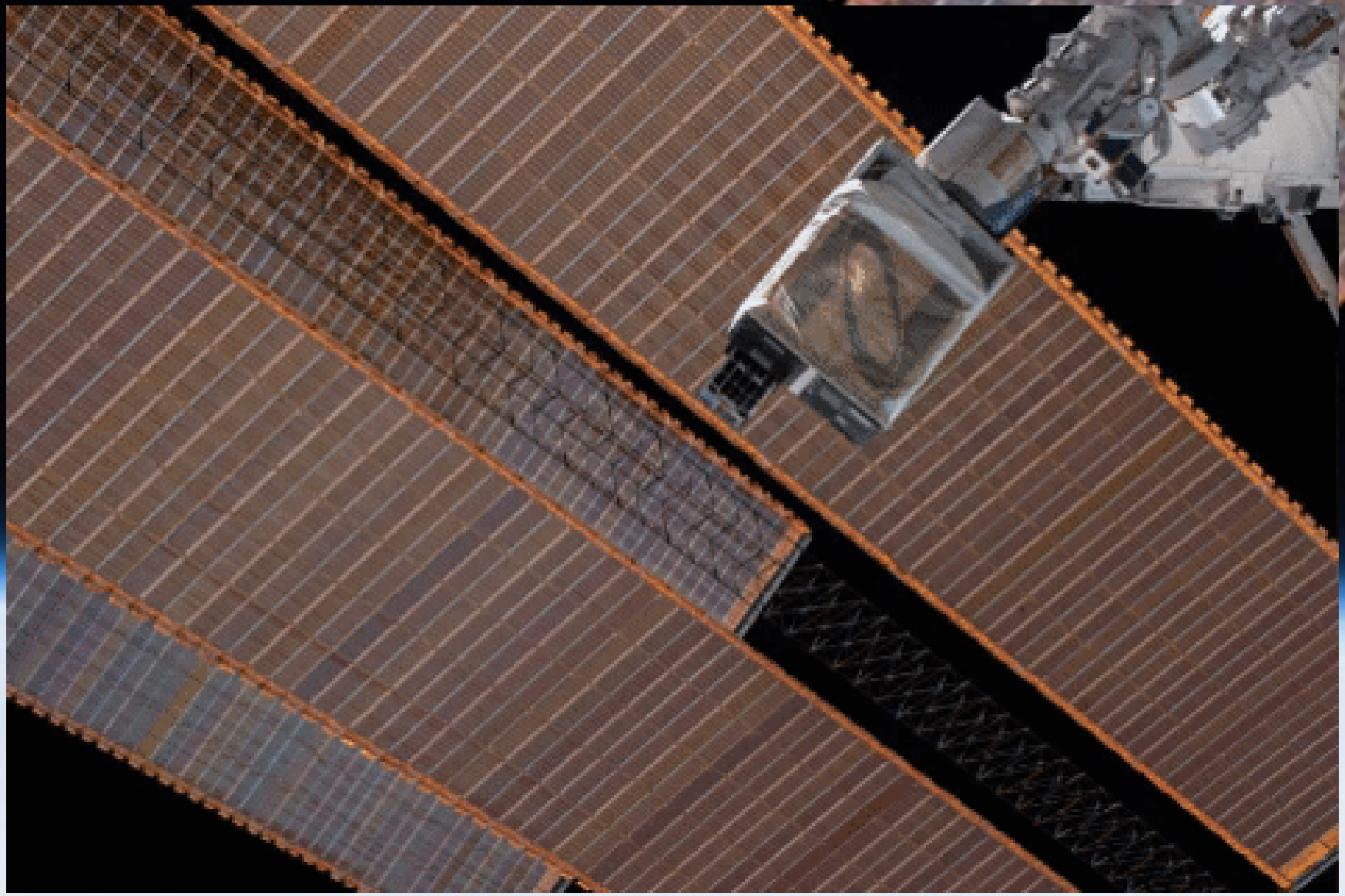
- Creates barriers to entry.
- Requires time on many tasks that are tangential to science.
- Increases risk.

A better way would be to adopt a standard 'bus' that includes spacecraft *and* mission operations (and integration, radio licensings, etc.). This could be provided by industry or NASA. There could be a few options.

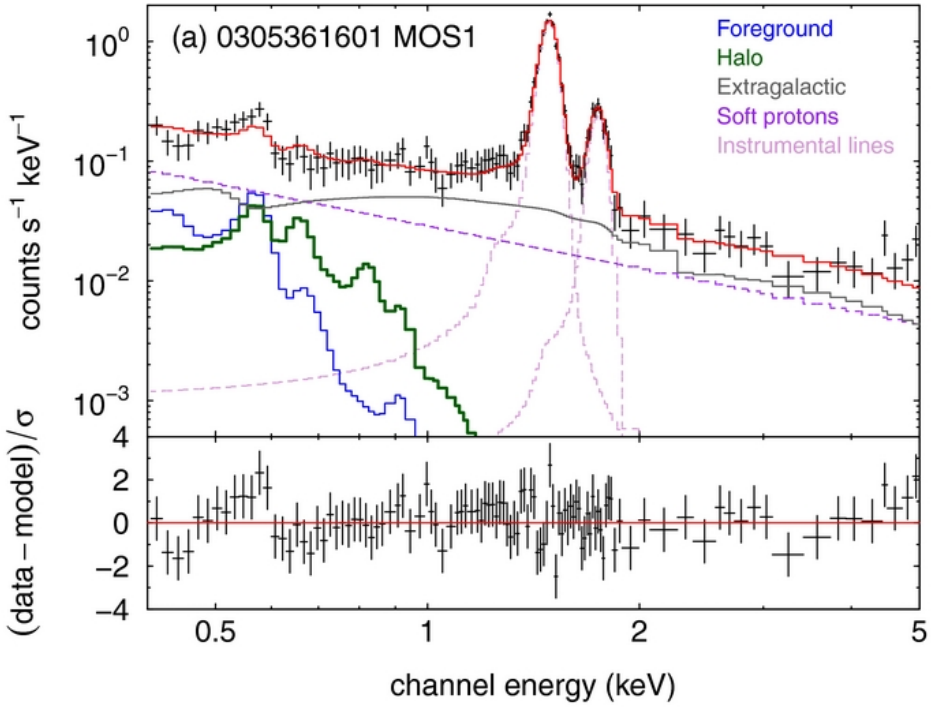
Advantages:

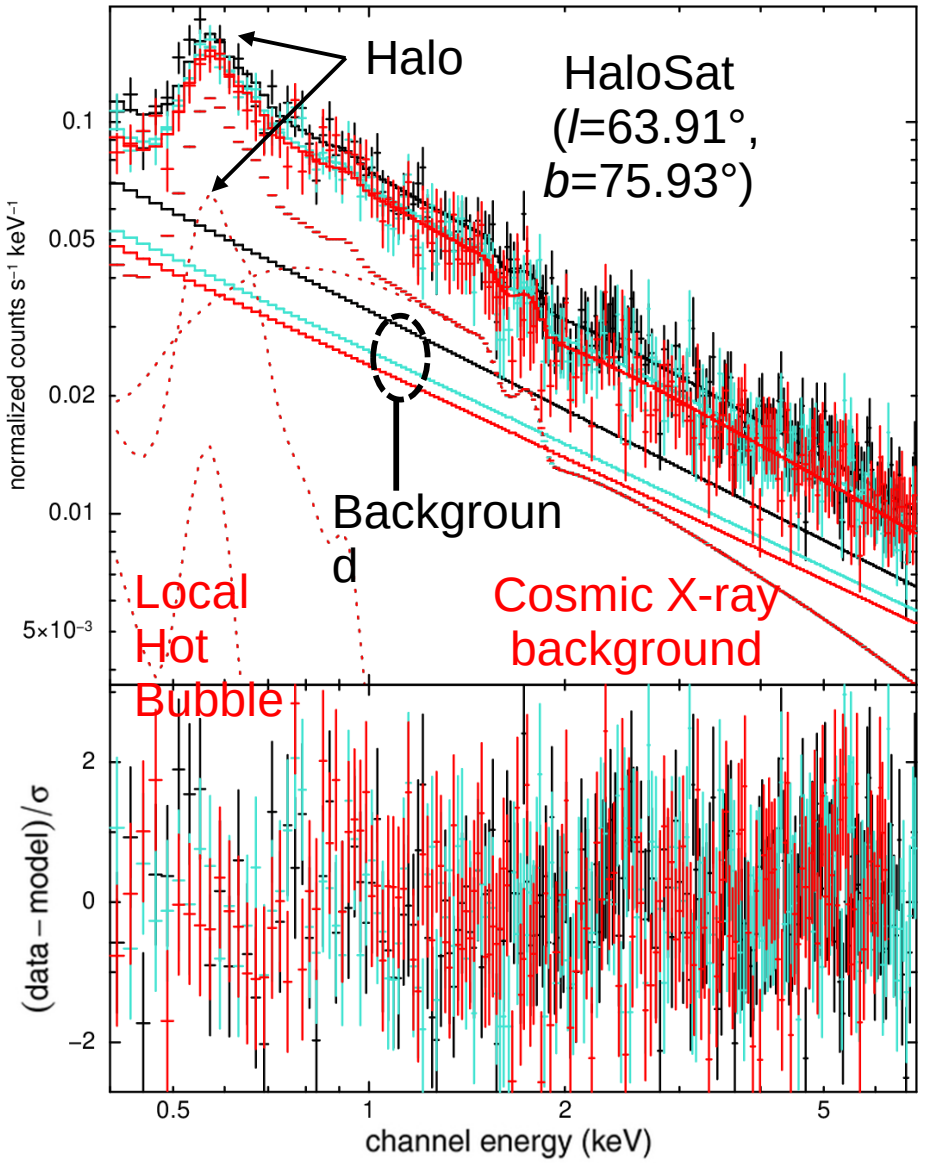
- Allow PIs to concentrate on their unique skills: building science instruments, planning science missions, analyzing data.
- Reduce barriers to entry (may help increase diversity of institutions).
- Decrease risk and cost by sharing engineering time and lessons learned across many missions.
- Decouple instrument development from selection for flight.

HaloSat Deployment – July 13 at 3:05 am



Halo Spectra





- XMM-Newton spectrum of field at (*l*=73.74°, *b*=79.31°) from Henley & Shelton (2013).
- **HaloSat has superior signal to noise for halo emission.**

Results on Southern CGM

Emission measure (EM) indicates the brightness of each field, proportional to integral of square of density of ionized matter along line of sight.

Structure in emission measure map:

- EM's are correlated on angular scales of 10s of degrees.
- Inner quadrant towards Galactic center is brighter.
- Large range in EM, factor ~10.