Blobs in Space: An introduction to space weather and satellite engineering

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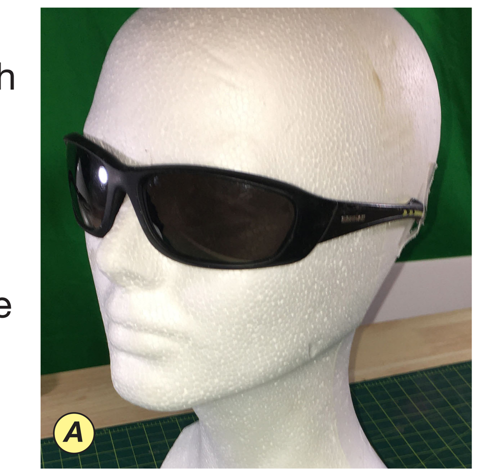
Blobs in Space uses a faux sci-fi movie poster and a foam head (A) wearing sunglasses to draw learners to a serious challenge: the power and communications grids that make modern society possible are increasingly vulnerable to blobs — coronal mass ejections and other space weather events — from the Sun.

The *Blobs* hands-on activity connects STEM concepts to the Polarimetry to UNify the Corona and Heliosphere (PUNCH) mission. At its heart are polarizing filters, the special "sunglasses" that will let scientists observe how blobs evolve so we can improve space weather predictions.

Three major components can be presented standalone or as an integrated sequence. Each has been tested and well-received at STEM events. *Blobs* is designed with blind/visually impaired (BVI) students in mind. Facilitator guides include instructions on making components from low-cost craft materials. The guides also address misperceptions such as space being empty or satellites having to fire thrusters to stay in orbit.



This multi-disciplinary approach complements grade 1–5 Next Generation Science Standards, including:

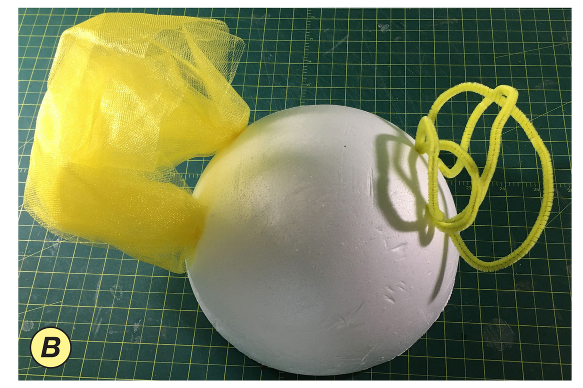
- PS4 Waves and their Applications,
- PS1 Matter and its Interactions,
- ESS1 Earth's Place in the Universe,
- ESS2 Earth's Systems,
- ESS3 Earth and Human Activity,
- PS2 Motion and Stability,
- PS3 Energy, and
- ETS1 Engineering Design.

To get Blobs:

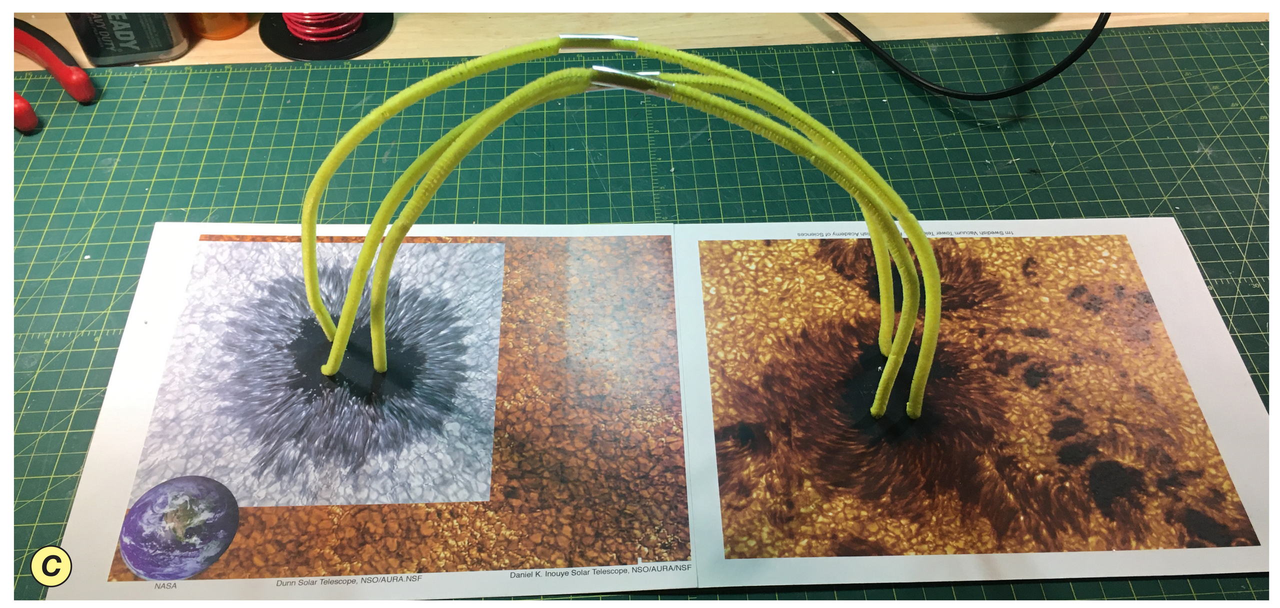
"Touch" space weather

Although PUNCH does not observe them, basic solar features serve as a familiar starting point to introduce the sources of solar storms.

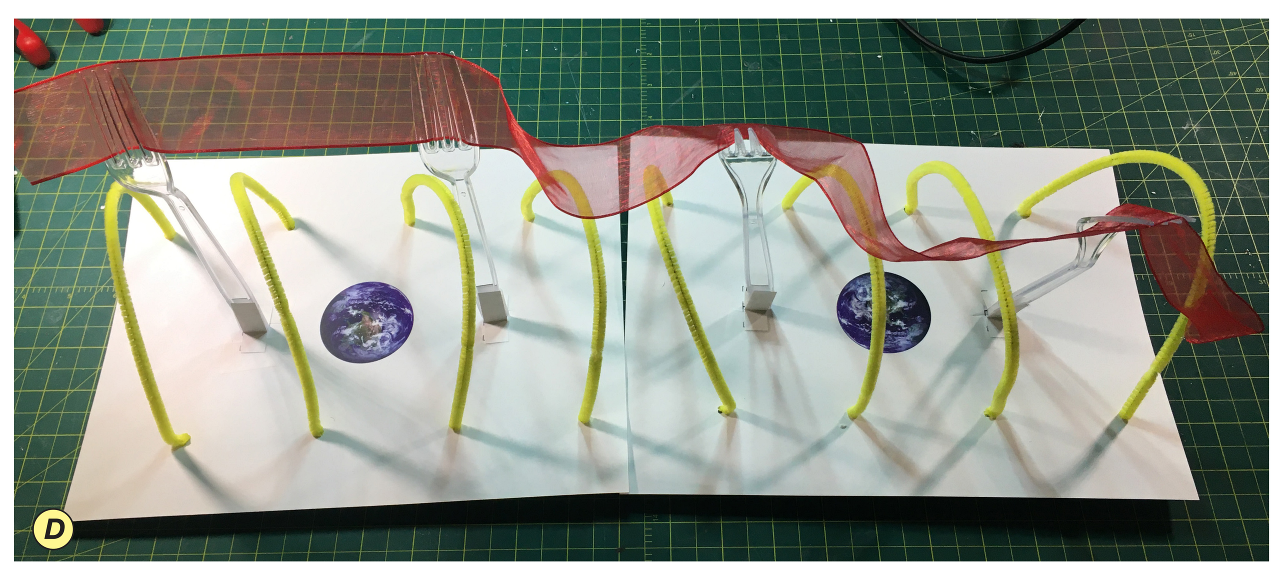
Loops vs. Veils: Chenille sticks and tulle fabric on a smoothfoam ball (B) represent coronal loops as we once perceived them and as Dr. Anna Malanushenko's now interprets them.



Connect the Dots: Chenille sticks and printouts mimic sunspots and their magnetic fields (C). This model and the next are scaled so a 5cm (0.5") ball represents Earth (1:250 million). For additional "Wow!" scale, Earth is in the *Blobs* poster at the exclamation mark.



Solar Ribbons: A ribbon atop a chenille stick arcade represents a solar prominence (D). Learners handle and twist a Slinky to mimic magnetic reconnection.

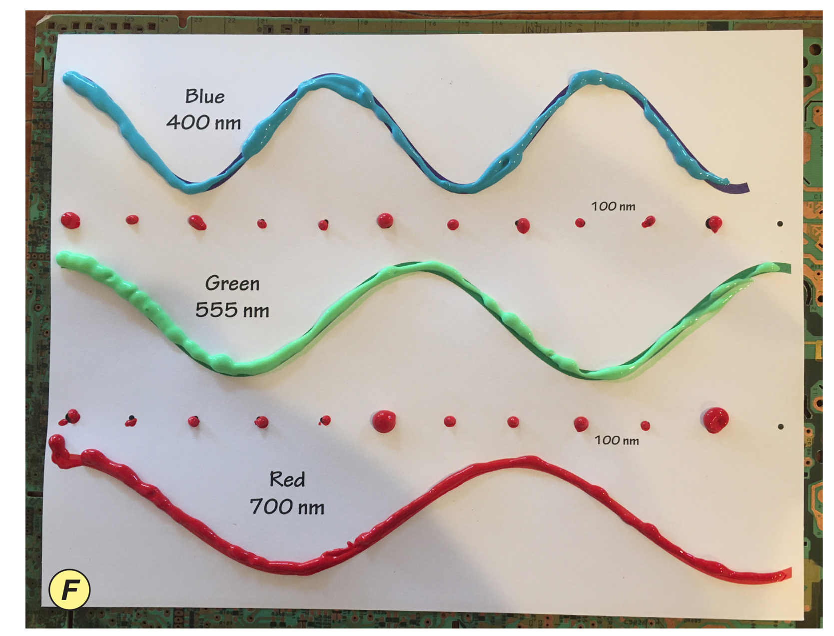


Twisting the lights: A high-strength magnet twists plasma (in a shielded UV germicidal lamp) and mimics the aurora (the scan pattern in an old monochrome monitor, E). Finally, a dancer's veil waved across a 5cm foam ball (Earth) illustrates the relative scale of a CME sweeping over the magnetosphere (this connects with PUNCH's *Dancing Up a Solar Storm*).

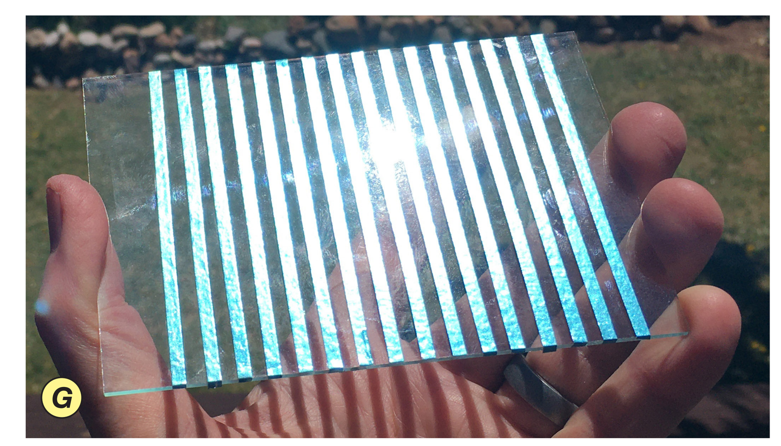
See the solar wind

The basics of light, waves, and polarization show how scientists see the otherwise invisible solar wind.

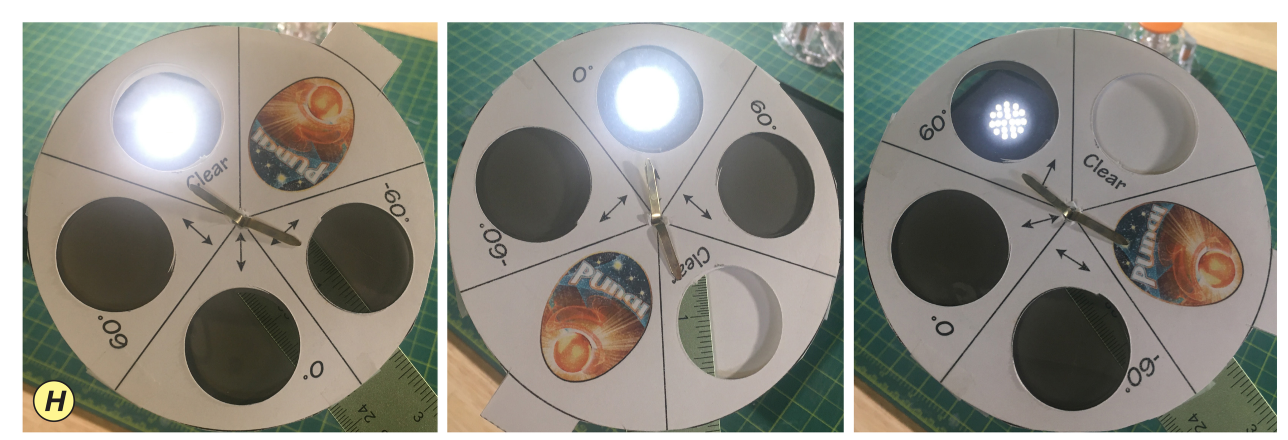
Light waves: A raised sine wave (Puffy Paint on cardstock) illustrates the wave nature of light and plane polarization of the electric vector (depicted by mounting the wave on cardstock). Another card (F) has wavelengths scaled to depict red, green, and blue light. Craft sticks mimic the conventional — though incorrect — model of polarizing filters.



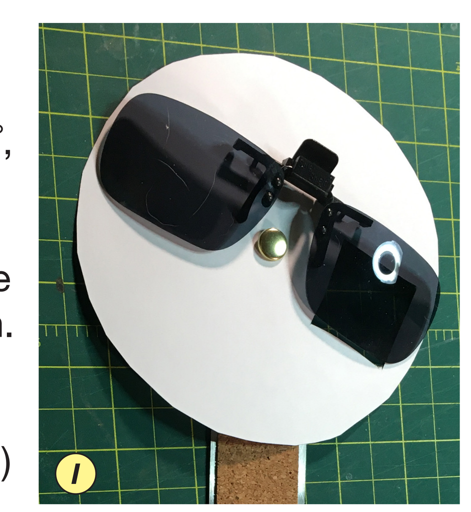
Sunglasses and glare: Learners observe reflection from overhead lights in small sheets of glass (4x5 picture frames backed with matte black paper). Sunglasses show how reflection is polarized and how that depends on the angle of incidence, the heart of observing electrons in the solar wind.



Polarization filter wheel: Aluminum tape strips on glass (G) are a 300,000x model of the PUNCH nanogrid filters. Where polarized sunglasses absorb waves that are in-plane with iodine crystals, the nanogrid filters reflect waves that are in-plane and pass those that are transverse.

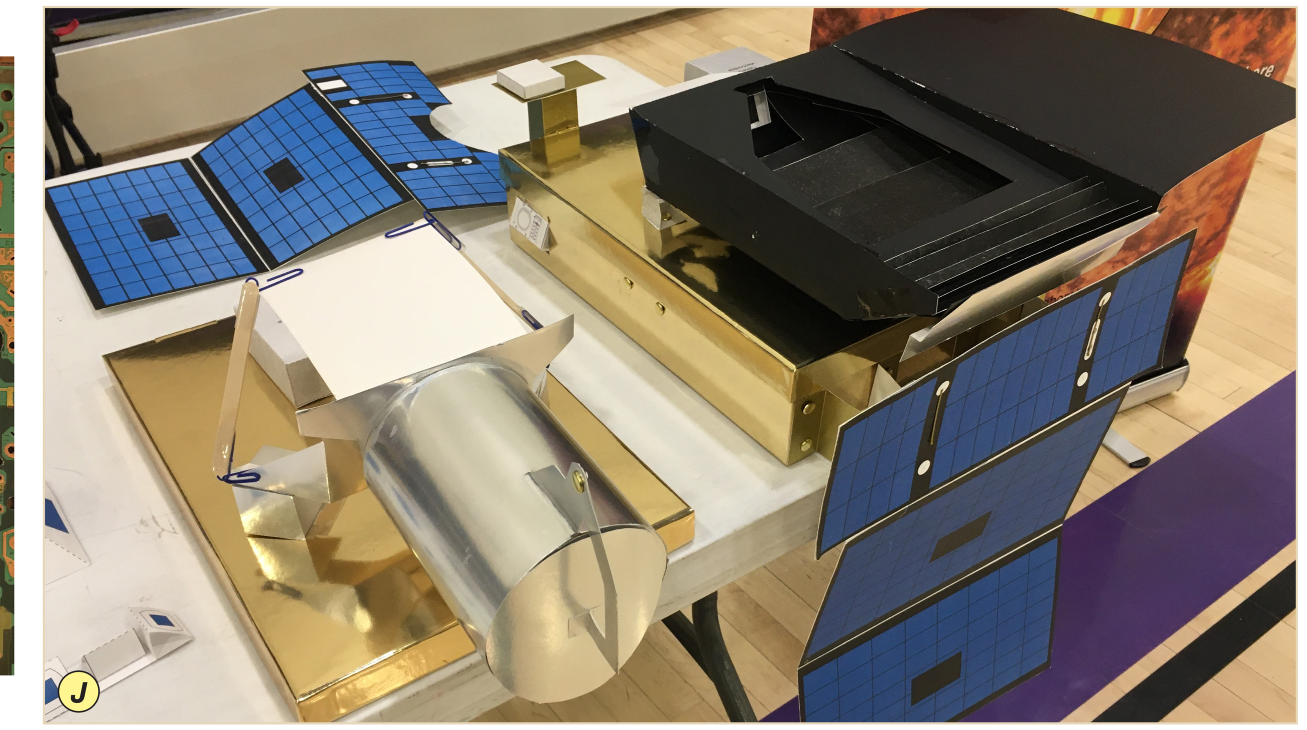


Getting to the heart of PUNCH, a full-size (127 mm) model (H) of the polarization filter wheel demonstrates how different filter angles — -60°, 0°, and +60° — produce differing brightness. By comparing these with unfiltered brightness, scientists can estimate the density and distance of blobs ands whether they are headed to Earth. (For easier assembly, the filter arrangement differs from the actual design. A low-cost version can be made with clip-on sunglasses, I.)

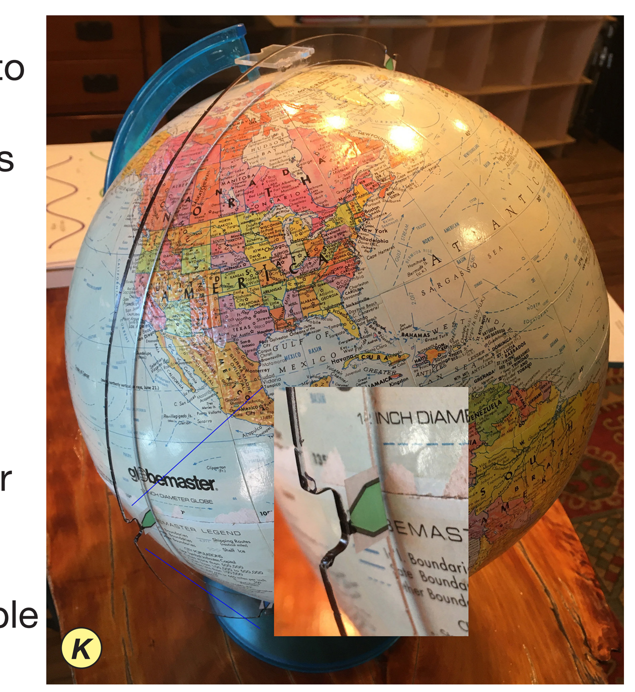


Dissect a satellite

Crafted like a biology class where students dissect a specimen to learn how the whole works, learners disassemble a half-scale model of PUNCH (J).



A backwards orbit: A 30cm (12") classroom globe holds a ring scaled to the PUNCH orbit and depicting their spacing (K). We discuss how satellites stay in orbit (objects in motion; not continuously firing rockets) and how Earth's irregular gravity produces sun-synchronous orbits. This leads to why the PUNCH spacecraft have their particular design, including why a constellation of four satellites rather than one.



Inner workings: Learners disassemble half-scale models (L) based on CAD plans for the actual spacecraft and implemented with available materials ranging from a gift box to poster boards. Opening the top reveals components, which are removed as learners discuss how they think each is used. For example, four reaction wheels (represented by wooden wheels) control attitude using the same twist/counter-twist of a power drill. An LED bulb viewed between two pencils shows how bright light diffraction could obscure our view of the solar wind and is eliminated by baffles in front of the camera. Thumbtacks in a plastic cup of salt water atop a 9-volt battery electrolyze water, much as HYDROS-C will generate fuel to adjust spacecraft orbits.

The conclusion unites the parts with an animation of the CAD model and images of the flight hardware.