**Research Opportunities from Sounding Rockets at Johns Hopkins University**


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## 1. Research Opportunities from Sounding Rockets at Johns Hopkins University

It is T-1 minute to launch. The all-systems-go has been given and Johns Hopkins University graduate student Kevin France is feeling the pressure. The final hurdle in the preparation for launch of NASA/JHU sounding rocket number 36.198 UG from Launch Complex 36 at White Sands Missile Range, New Mexico has been passed. Now all that remains is to carry out the mission, a spectroscopic study of the far ultraviolet scattering properties of interstellar dust in the reflection nebula IC 405.

Kevin hopes that this observation will reveal clues into what keeps this cloud from forming into stars by studying the interplay between the far-ultraviolet radiation field, and the dust, molecules and atoms that comprise the cloud. It is a feedback system that operates much like a thermostat regulating the release of energy generated as the cloud of gas and dust attempts to collapse into protostars. This cloud seems to be devoid of star formation and he wants to understand why.

The elapsed time for the mission will be 900 seconds and the events are tightly scripted. The first stage Terrier booster will burn for 6 seconds lifting the rocket to an altitude of 3 kilometers. Then the second stage Black Brant will kick in, propelling the payload to an altitude of 60 kilometers and a velocity of Mach 7. At this point the half ton payload and Black Brant motor will separate and the payload will follow a ballistic trajectory to an apogee of 300 kilometers under the coarse pointing control of the onboard guidance and navigation system that will use cold gas jets to steer the telescope to acquire the target nebula.

Between separation and acquisition several events will occur: The telescope door opens, the nebula viewing camera turns on, the spectrograph slit door is opened and the high voltage to the spectrograph detector is activated. All these events will be monitored on the ground via a real-time telemetry stream. The target will be acquired at T+150 seconds at which point the final job, the precision pointing of the telescope, will be handed over to Kevin. He will stand in front of a control panel showing a real-time image of the nebula and perform maneuvers with pitch, yaw and roll controls, not unlike those on your typical computer game. For 350 seconds his job will be to steer selected portions of the nebula into the spectrograph slit, a mere 1/3 of a millimeter wide and 6 millimeters high, and hold it there. The pointing will be overseen by his advisor whose job is to provide a real-time assessment of the spectrograph countrate, keep track of the remaining time, and offer advice on where else to point within the nebula.

This ultimate task is the big payoff, the acquisition of the primary science data, which will become a topic of analysis for his Ph.D. thesis. It has been made possible by months of preparation and attention to a myriad of tasks all of which must be completed successfully by the launch provider and payload teams. There has been no room for error, which is why Kevin is now feeling the pressure. He is the final link in the process and he is determined not to be the weakest.

Founded in 1961 by G. H. Dieke and W. G. Fastie under support from NASA, the sounding rocket program at JHU has provided many graduate students, like Kevin, the opportunity to use sounding rocket-borne telescopes and spectrographs to make unique astronomical and atmospheric observations. The group specializes in the development of spectroscopic instrumentation; a natural outgrowth from the legacy of diffraction grating research led by Professor Henry A. Rowland of JHU at the end of the nineteenth century. Most of the JHU's current suite of rocket-borne spectrographs work in the 900-2000 Angstrom wavelength range where the earth's atmosphere is strongly attenuating and observations can only be made by sounding rockets or orbiting telescopes. Past missions include observations of earth's aurorae, several comets including Hale-Bopp and Halley, Jupiter, Venus, Io's plasma torus, a number of hot stars and nebulae, and the first ultraviolet spectrum of the quasar 3C273.

In the process of designing these experiments the graduate students receive hands-on training in optics, mechanics, electronics and flight support systems, in addition to learning the scientific concepts of their chosen discipline. The JHU payload team includes a project engineer and Ph.D. project scientist who provide experience, direction and corporate memory to the student. Participation in the program also includes undergraduates, who assist the graduate student, engineer and project scientist with the preflight payload assembly and calibration efforts.

The suborbital program is unique in allowing participation in all phases of a space mission, from concept to final analysis of the data, on a time scale commensurate with the length of a graduate education. Over the course of the program's existence at JHU there have been 72 rocket launches, and 31 Ph.D. dissertations have been based wholly or partly on work done under this program. Graduate and undergraduate students who have participated in past sounding rocket projects are highly prized by the space-flight community, and historically have been highly sought after by national laboratories, industry and academia for the development of the next generation of astronomical and atmospheric space missions. The JHU sounding rocket program has been intimately involved with supporting a number of related NASA programs, including the Apollo 17 Ultraviolet Spectrometer Experiment, the International Ultraviolet Explorer, the Hopkins Ultraviolet Telescope, the Hubble Space Telescope, and the Far Ultraviolet Spectroscopic Explorer. It is in support of projects like these where the worth of the sounding rocket program exceeds the short term science return of an individual mission.

Sounding rocket flights are used to validate new instrumental concepts and to develop to a state of flight readiness instrumentation destined to be flown on future long duration free-flyer missions like the launch opportunities offered by NASA's Explorer program. Announcements of Opportunity for Medium and Small Explorers occur at a rate of about one every year, with typically two missions selected for eventual flight. The competition for these launch opportunities involves the writing of proposals with compelling science goals and a clearly defined technical and management plan. Such work requires a highly trained workforce, knowledgeable in the ways of translating high level science goals into realistic mission requirements. The skill mix required by this workforce is well matched by students trained in the ways of rocketry, many of whom go on to propose missions of their own devising.

But let us get back to Kevin. The count proceeds and the payload is launched. All systems perform nominally and the target is acquired on schedule. Kevin manages to observe three different regions in the nebula within his allotted 350 seconds. The doors close, the parachute opens and at about T+900 seconds the loss of signal occurs, indicating the payload has touched down below the horizon at a point some 80 kilometers up-range. There it will sit until the helicopters come to pick it off the desert floor and return it to the payload processing area. The crew is ecstatic. There is much rejoicing. Playbacks of the primary science data goes on into the night, curtailed only by the weariness of the ground station crew (who have seen it all before) and the need to get a little sleep before the helicopter arrives to take the payload recovery team to the landing site. Everyone sleeps soundly, for the first time in months, and at first light Kevin climbs aboard the Huey that takes him and select members of the team out on recovery. Everything is in good shape; in fact, the telescope is still under vacuum when it arrives back at the processing area. Now begins the process of packing up the ton of support equipment for shipment back to Baltimore where Kevin will engage in post-flight calibrations and analysis of his data.

Kevin is not sure of what the analysis will tell him, but he knows one thing after scanning the playbacks – the dust was blue. One hundred times bluer than the dust observed by the same instrument in a dust cloud rife with star formation. Maybe this is the key. Only time will tell.

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Dr. Stephan R. McCandliss is a Research Scientist with the Henry A. Rowland Department of Physics and Astronomy at the Johns Hopkins University. He a Co-Investigator with the JHU Sounding Rocket group, responsible for the design, procurement, fabrication, calibration, and integration of spectroscopic telescope experiments into sounding rocket delivery systems provided by the NASA Sounding Rocket Operations Contractor (NSROC) at the Wallops Flight Facility, Virginia. For more information can be found at http://www.pha.jhu.edu/groups/rocket/ and by following the links therein.

## 2. Picture Caption

Right to left, JHU graduate student Kevin France, JHU project engineer Russ Pelton, NSROC mechanical engineer Robert Ryan, and NSROC mechanical technician Larry Lockhart.

Picture information.
NAWCWD WS-SCN-01-0607-013
Terrier Black Brant
Recovery Operations Terrier Black-Brant Impact Site

Photo Date: 02/10/2001
Photographer R. Vance
U.S. Army Photograph
White Sands Missile Range, N.M. 88002
Publication or commercial use of this material requires release by the U.S. ARMY Public Affairs Officer. (Go to http://www.wsmr.army.mil/paopage/pao.htm for further information on securing picture publication release.)
Credit: U.S. Army

## 3. Nugget

Aimee – Whenever we get a nice result NASA HQ likes to hear about it. On the next page is a little mini poster I put together attempting to describe our result to them succinctly. It's a little technical. I don't know if it is of any use to you.

# Blue Dust in IC 405 Detected by JHU Sounding Rocket


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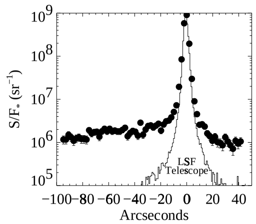
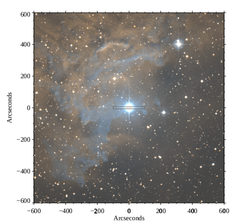
### IC 405 Scattered Light: Spatial

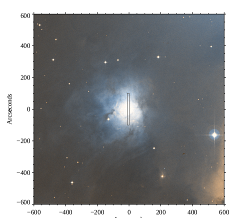



### DSS Blue and Red Plate Composites

IC 405

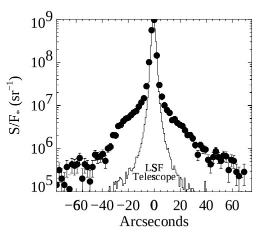


NGC 2023



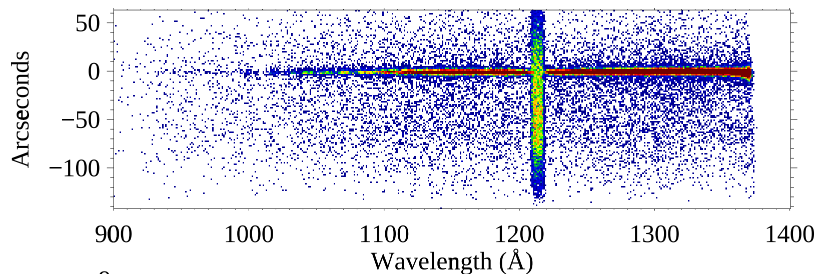


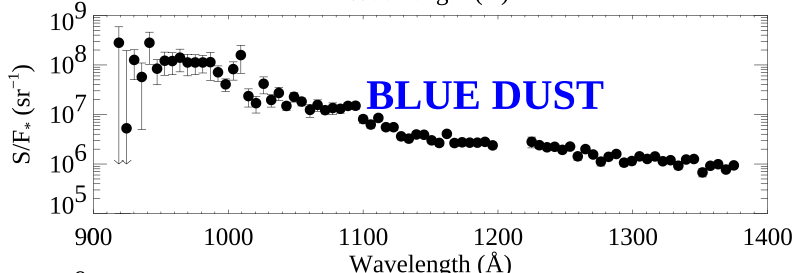
### NGC 2023 Scattered Light: Spatial

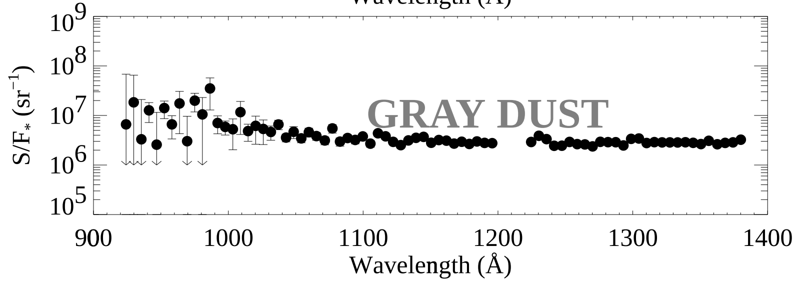



### Far-UV Longslit Nebular Spectra and Surface Brightness to Stellar Flux Spectral Ratios

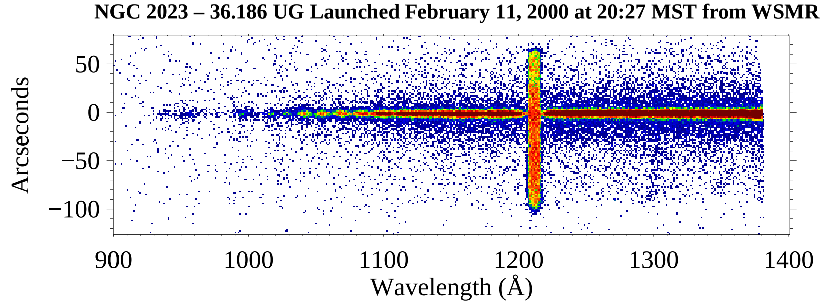
**IC 405 – 36.198 UG Launched February 09, 2001 at 21:00 MST from WSMR**




**NGC 2023 – 36.186 UG Launched February 11, 2000 at 20:27 MST from WSMR**




### Blue Dust

A recent NASA sounding rocket, flown from White Sands Missile Range in NM, on a mission to observe the reflection nebula IC 405 and its exciting star AE Aur (HD 34078), found an extremely blue dust surface brightness to starlight ratio. In contrast, an observation of NGC 2023, a reflection nebula in Orion, revealed a gray ratio. AE Aur is a runaway star that left the Orion constellation approximately 2.5 million years ago and is now entering a region that is relatively devoid of star formation activity. The central star in NGC 2023 (HD 37903) is still embedded within the the nebula from which it formed. This result is exciting because we have found different dust properties in nebulae with dissimilar star formation histories. This has important implications for the role dust plays in star formation. Dust regulates the far-UV radiation field, which effects the formation and destruction of molecules. Molecules are key coolants in the stellar formation process, providing a means for gas to radiate away excessive gravitational energy released by the collapse of interstellar clouds. In future work, we will seek to correlate the different dust properties with the molecular gas content of these two nebulae.

### Figure Descriptions and Credits

The color figures shown at the top and bottom of the middle panel are longslit spectrograms. They are in effect long thin pictures of the nebulae smeared into their component colors by the spectrograph dispersion. The orientations of the slit on the nebulae are overlaid on the Digital Sky Survey two color composites shown at the left. Note how the region around the slit is much bluer in IC 405 than it is in NGC 2023. Within the spectrograms: the vertical stripe at 1216 Å is the geo-coronal Lyman-α line emitted by hydrogen atoms at the top of the earth's atmosphere (it marks the extent of the slit on the detector), the horizontal stripe is the continuous spectrum of the nebula's exciting star, and the diffuse emission surrounding the stellar spectrum is the stellar light scattered by the nebular dust. At the top and bottom left, the variation of the scattered light along the slit is overlaid with the measured line spread function (LSF), showing the measured scattering is indeed much higher than can be attributed to the optics alone. The two graphs in the center of the middle panel are the dust surface brightness to stellar flux ratio. Note the very steep rise, **by two orders of magnitude,** toward shorter wavelengths in IC 405, top center, as compared to NGC 2023, bottom center.

The payload was designed by members of the Johns Hopkins University sounding rocket group under the direction of Professor Paul D. Feldman with funding provided by NASA grant NAG5-5122. Launch services were provided through the NASA Sounding Rocket Operations Contract (NSROC) based at Wallops Island Flight Facility in VA.

NASA-Nugget layout and text by SRM using Brian Wolven's LaTeX Poster macros v2.1, figures by EBB.