Successful Leonid Airborne Mission

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We report on a successful effort to explore the November '98 Leonid shower by a team of 28 scientists with a range of instrumental techniques from two airborne platforms flown out of Okinawa, Japan. The Leonid meteors were observed by a two-beam iron lidar, high-definition intensified TV and other imaging techniques and by UV/Visible slit-less spectroscopy and mid- and near-Infrared spectroscopic techniques.
This paper gives a brief informal report of the 1998 Leonid multi-instrument aircraft campaign just days after the event.

1. Introduction

Meteor observing got a whole new meaning when our wildest dream came true last November. Just in time, all pieces fell in place of what became NASA's first Astrobiology mission: a NASA-sponsored effort to fly two aircraft stacked with instruments and eager scientists to explore what promised to be a highly unusual meteoric event [1].
Scientists and crew shared with amateur observers world-wide the excitement of going out to explore one of nature's most impressive natural phenomena: a meteor storm.
For that purpose, we brought some unusual instrumentation: the University of Illinois at Urbana contributed a two-beam laser-radar called "lidar", and the Aerospace Corporation of California contributed a helium-cooled infrared detector for mid-Infrared spectroscopy, to mention a few. The airborne platforms were supposed to bring the scientists to the best place for studying the event, above clouds, water vapor and aerosols, while the two platforms would make stereoscopic observations possible.
The goal of the mission was to learn about comets and how cometary matter interacts with our atmosphere. A meteor storm results from the most recent comet ejecta and the meteoroid orbits and size distribution can provide information about how comets eject large dust grains. Also, if a meteor storm would occur, we would have a window on our past, 4 billion years ago, when Earth just about started to be a cosy place for life, and meteors rained at hundred times the rate at the present time.
Any molecule detected in the light of the meteors might provide clues to how meteoroids may have contributed molecules that could have played a role in the origin of life on our planet.
Furthermore, ground-based support would be provided at locations one and two timezones further East, where amateur observers of the Dutch Meteor Society teamed up with Chinese astronomers of Nanjing and Beijing Observatories to provide flux measurements and multi-station imaging in case the event happened late in the night. And in Albequerque, New Mexico, a ground-based lidar would probe meteor trains, if any would occur.
At the time of writing, the mission is just behind us and below is a first informal report of events.

2. The mission

The Leonid Multi-Instrument Aircraft Campaign proceeded according to plan, with both the NSF (NCAR) Lockheed Electra and the USAF (452nd FTS) KC-135 FISTA executing their mission from Kadena AFB in Okinawa in the night of November 17 (with strong local support at Kadena AFB).
Both aircraft were able to fly above the cloud cover that prevented ground-based observations at that time. 28 scientists onboard, seven nationalities from Universities, government and private institutions, and a total of 46 including crew and media, witnessed an intense shower of Leonid meteors.
The meteors were probed by lidar, imaging and spectroscopic techniques covering the UV, visible, near-Infrared and mid-Infrared wavelength ranges. All instruments performed as planned and there were no last-minute drop outs.
The Leonid shower returned with a bang. Numerous bright fireballs were reported in the day and a half leading up to our mission. On mission-date itself, rates had decreased slightly, but an intense shower was observed with Zenith Hourly Rates up to about 200. The shower was rich in faint meteors, unlike the prior night, from which we suspect that we did witness the storm component. Especially in the hour before dawn (20-21 UT) rates picked up somewhat, which is likely the most recent debris that we were hoping to detect.
At the time of writing only scant information on the scientific results is available. However, the tally of detections is impressive. Some 30 iron debris trails were detected by lidar, compared to a typical 1-2 trails/night under normal conditions, and excellent HD-TV imaging was obtained in parallel for studies of iron chemistry and

physical processes in the train. One of the two lidar beams was tuned off the iron resonance line in order to detect Rayleigh scattering from potential dust. No strong dust signal was detected, as expected, and such a potential detection awaits further data analysis.

The University of Illinois all-sky airglow imager recorded numerous trails for flux measurements at the bright meteor end.

The intensified cameras mapped the shower flux distribution around the position of the expected storm and they measured the particle size distribution, which was markedly different from that reported one night earlier.

The Mount Allison University intensified cameras recorded many trails at high resolution for studies of meteor ablation and fragmentation properties.

A number of meteors were recorded from both aircraft simultaneously for the measurement of trajectories and orbits. At least one long-lasting persistent train was imaged from both aircraft in high resolution and turbulent motion was for the first time detected. This train was also studied by the near-IR spectrographs and we have good hopes to have obtained the first 1-3 micron spectroscopy of a meteor train from these measurements (and of meteors in general for that matter). The Ames CCD camera recorded six spectra, two of which do show excited atmospheric molecular bands for the study of excitation temperatures in the meteor. And the Czech Ondrejov spectrograph was estimated to have recorded some 50 UV/Visible spectra for main element abundances.

It seems that we achieved some 70% of our science objectives. We were not able to aim the University of East Anglia telescope at a persistent train: none was suitably located, and we do not know yet if the mid-IR spectrometers were successful. We are also in doubt if we have sufficient numbers of meteors to study the mass-dependence of ejection velocities from the flux measurements, but that may still be possible if all video tapes are analysed. Clearly, a meteor storm would have given much more data for all instruments. In hindsight, we could have obtained significantly more data on persistent trains if we would have had the funds and the opportunity (no curfew and no constraints due to crew rest) to do a mission in the night of November 16.

All in all, we are very happy. We did not see a storm, but we did see one of the best showers ever and we obtained a lot of exciting data. And there is hope for the future.

This year's return was almost identical to the return of 1965 when the broad component of bright meteors peaked a little over half a day before nodal passage as it did this year, and a narrow peak of faint meteors was detected just after the time of nodal passage just as in 1965 [2].

This raises hopes that next year will see a return of the storm of November 1966 (although perhaps not as intense). Peak activity is expected over Europe and Africa this time.

3. Ground-based efforts

The airborne campaign provided a strong motivation for ground-based observing efforts in China, the USA and Europe. Several of those ground-based efforts were wildely successful, notably a ground-based lidar of the Univ. of Illinois in an effort directed by Dr. Mike Kelly of Cornell University at Kirtland AFB in New Mexico, and the groundbased effort of multi-station photography in China, performed by the Dutch Meteor Society in collaboration with the Nanjing Observatory (and Beijing Observatory).

Both ground-based teams in China (at Xinlong Station and near Delingha) had clear weather on all important nights and obtained numerous multi-station meteors by two-station photography and intensified video.

These meteors are typically brighter than those recorded by the HD-TV cameras on the aircraft and the results are complimentary for an analysis of radiant dispersions as a function of meteoroid mass.

In addition flux information was obtained that complements the counts made by intensified video techniques from the airborne platforms one and two timezones earlier, respectively.

The ground-based effort to probe meteor persistent trains with a sodium lidar from the Starfire range at Kirtland AFB in New Mexico was wildely successful. The lidar was pointed at several trains, one of which was probed for 20 minutes, another for 30 minutes. These data on meteor trains nicely compliment the lidar detections of the meteors themselves that were obtained from the Electra aircraft.

We are only beginning to sift through the data. There is clearly plenty of material for our post-mission Leonid workshop, tentatively scheduled for April 12-15 at NASA/Ames Research Center, and we have no doubt that some exciting new insight will emerge in the coming months when the data reduction is performed. At this moment, we all need some rest, pay the bills and gloat over the images!

4. Acknowledgements

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dom, the Netherlands and the Czech Repubic.

The two aircraft and much of the logistic support were provided by the U.S. National Science Foundation and the United States Air Force. The aircraft were operated by the National Center for Atmospheric Research (NCAR) Research Aviation Facility in Broomfield, Colorado, and the United States Air Force 452nd Flight Test Squadron (452nd FTS) at Edwards Air Force Base in California. The mission was flown out of Okinawa, Japan, with strong support from Kadena Air Force Base. The Japanese Broadcasting Company provided intensified high-definition TV imaging of the meteors from both platforms and, together with a team of NASA/Ames Research Center, informed the world about our activities. Thank you all.

For next year's mission and first results see our website at:
http://www-space.arc.nasa.gov/~leonid/

References.

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[2] P. Jenniskens, 1996, Meteor stream activity. III. Measurement of the first in a new series of Leonid outburst, Meteoritics & Planetary Science 31, 177-184.