The Mission

The Submillimeter Wave Astronomy Satellite (SWAS) is the first space-based, radio observatory sensitive to radiation at submillimeter wavelengths. SWAS is a NASA Small Explorer (SMEX) mission designed to: (1) study how clouds cool as they collapse to form stars and planets; and (2) provide heretofore missing information key to understanding interstellar chemistry. Specifically, SWAS seeks to address such questions as:

1) Where is the oxygen hiding?

After hydrogen and helium, oxygen is the most abundant element in the Universe. However, the sum of observed oxygen atoms and oxygen-containing molecules falls short of accounting for the total oxygen abundance. H_2O and O_2 have long been predicted to be the "missing" reservoirs of oxygen.

2) How do interstellar gas clouds cool as they collapse to form stars and planets?

As clouds collapse to form stars, the gas temperature rises. Unless this heat is shed, increasing thermal pressure will eventually stop the gravitational collapse, preventing a star from forming. H_2O is believed to be a dominant cloud coolant but this prediction has not been tested.

3) What is the structure of interstellar gas clouds?

Astronomers know that stars and planets form within molecular clouds. However, the structure - i.e., the density, temperature, and uniformity - of these parental clouds remains poorly known. The strength and spatial distribution of the atomic carbon and isotopic carbon monoxide emission are useful probes of cloud structure.

4) Do the molecules of life originate in space?

H_2O and O_2 are critical to life on Earth. SWAS observations are providing clues linking these molecules to their formation in interstellar space.

To answer these questions, SWAS observes:

H_2O	$H_2{}^{18}O$	O_2	CI	^{13}CO
Water	Isotopic Water	Molecular Oxygen	Atomic Carbon	Isotopic Carbon Monoxide
Wavelength (in millimeters):				
0.539	0.547	0.626	0.610	0.545

Unfortunately, the high abundance of H_2O and O_2 in the Earth's atmosphere interferes with all attempts to detect emission from astronomical sources of H_2O and O_2 using ground-based or even airborne telescopes. Thus, **the only way to detect interstellar H_2O and O_2 is from a space-based radio telescope.**

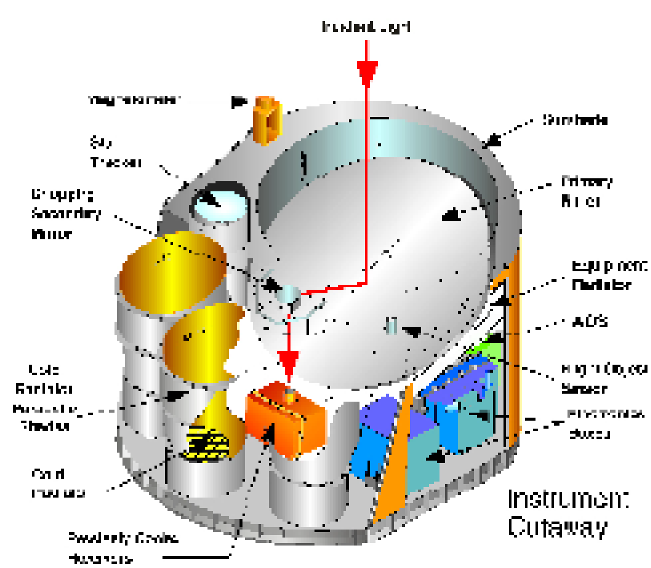
• SWAS was launched on Dec 5, 1998.

• To date, SWAS has operated flawlessly and has observed over 100 targets including regions forming Sun-like stars and larger, supernova remnants, evolved stars, and solar system objects (Mars, Jupiter, Saturn, Comets).

• For more about SWAS and its results see:
http://cfa-www.harvard.edu/cfa/oir/Research/swas.html

The Instrument

SWAS's 68 x 54 cm diameter aperture results in a spatial resolution of approximately 3.5 x 4.8 arcminutes. An optical star tracker permits the telescope to point within 5 arcseconds of any desired target. The sensitivity of SWAS's two radio receivers improves with decreasing temperature. A stable detector temperature of 170 K (-150 F) is achieved *passively* (i.e., without cryogens, like liquid nitrogen) by adopting spacecraft attitudes that maintain a view of cold space for the cold radiators (at the base of the parabolic shades).



SWAS Education and Public Outreach

We have used SWAS, in collaboration with the *Cooperative Satellite Learning Project* (CSLP) to teach high school students the basics of radio astronomy, star formation, and independent scientific research. The CSLP is a unique, successful, and award-winning partnership in education joining Honeywell Technology Solutions Inc. and NASA with schools nationwide. It is designed to motivate K - 12 students to to pursue the study of science, engineering, math, and the space industry through hands-on involvement in a NASA mission. For more on the CSLP program see: http://joy.gsfc.nasa.gov/CSLP/home.html

SWAS has formed an extremely successful partnership with *Keystone Oaks High School* in Pittsburgh, PA. Since 1998, students at Keystone Oaks have been provided with data directly from SWAS and, under the guidance of Astronomers at the *Smithsonian Astrophysical Observatory* (SAO), have produced scientifically meaningful projects. As of January 2001, this collaboration has yielded numerous awards and two publications (one in the Astrophysical Journal and one in the conference proceedings of the Astronomical Society of the Pacific) in which the students at Keystone Oaks are listed as co-authors. For more information on the CSLP program at Keystone Oaks High School, see: http://www.cslp.net/index2.html

• High school-level classroom materials (student handbooks with questions as well as a teacher's edition and viewgraphs) related to the topics of SWAS, radio astronomy, and star formation have been created by scientists at SAO and are available at:

http://cfa-www.harvard.edu/~rplume/vhs/vhs.html

This URL also provides links to other related material on the web.

• For more information on the SWAS E&PO program, and on how your school can participate, contact: Dr. Rene' Plume at the Smithsonian Astrophysical Observatory (rplume@cfa.harvard.edu).

The figure below shows SWAS spectra superimposed on a Hubble Space Telescope image of the Trapezium cluster in the Orion Nebula.

By learning how to interpret the data from SWAS, it is possible to infer the conditions at the center of the Orion nebula (a region that is currently forming a cluster of hot, massive stars). For example, the peak intensity and broad width of the H_2O line indicate that the source of the water emission line is in warm gas associated with outflows emanating from young stars at the heart of the nebula. Moreover, the model that best reproduces the SWAS (and other) data suggests that within this region water is being chemically formed at a rate ***sufficient to replenish the Earth's oceans every 24 minutes!!!***