Welcome to Caltech Submillimeter Observatory

- The Caltech Submillimeter Observatory (CSO) is a cutting-edge facility for astronomical research and instrumentation development. It is simultaneously one of the world’s premier submillimeter telescopes and one of the easiest to use. It consists of a 10.4-meter diameter Leighton radio dish situated in a compact dome near the summit of Mauna Kea, Hawaii. The telescope is operated by Caltech under a contract from the National Science Foundation and has been operating on a regular basis since 1988. It is open to the astronomical community, with most of the observing time available for non-Caltech observers.

What is Submillimeter wavelength?
- The ‘submillimeter’ region of the electromagnetic spectrum is at the border between the far infrared and the short-wavelength radio regions. As such, it borrows technologies from both regimes: bolometers from the infrared, heterodyne receivers from the radio.
- Wavelength: 300 microns to 1 millimeter
  - cf. human hair diameter: 20 – 180 microns
- Frequency: 300 Gigahertz to 1 Terahertz
- In practice, the atmosphere is the greatest problem faced by submillimeter astronomers, which, combined with the lack of high-performance instrumentation, explain why the submillimeter region of the spectrum is currently the least well studied. Submillimeter astronomy can only be done in the submillimeter at sites with extremely dry atmosphere, such as the tops of mountains and the antarctic.

Why Submillimeter Astronomy?
- With this wavelengths, cold dust and cold/hot gas can be traced efficiently.
- Combining dust and gas information, one can investigate the distribution of medium as well as the kinematics of detected astronomical objects.

Instruments at CSO
- Heterodyne receivers (covers 180 – 950 GHz) with wide band spectrometer (up to 4 GHz band width)
- Dish Surface Optimization System (DSOS)
  - Our DSOS is used when observing so that the telescope can have very high efficiency.
- SHARP: 350/450/850 micron
- Balcom: (1100/2000 micron)
- Hertz: the 350 micron polarimeter developed by Dr. Roger Hildebrand at University of Chicago
- SHARP: SHARCII Polarimeter led by Dr. G. Novak (Northwestern University) and Dr. C.D. Dowell (JPL/Caltech)

Colliding Galaxies
- Line Surveys at CSO
  - Line Forest towards Orion
  - HsI Image (Whitmore et al. ’99)
  - CO Gas (Contour, Wilson et al. ’00)
  - Dust (SHARCII image, Dowell et al. in prep)

The Observatory
- The Observatory
  - Nasmyth Focus
  - Nasmyth Focus AOS Room
  - Nasmyth Focus Receiver Lab
  - Nasmyth Focus Mechanical Workshop
- Electronic Lab
- Kinematics of the Gas
- Gas Distribution
- Evolved Star Helix Nebula

Evoluted Star Helix Nebula
- 350 micron (850 GHz) Line Survey
  - Young et al. ’99

CSO in World Wide
- CSO is the observatory that provides opportunities to make highest submillimeter bands (up to 300 micron/950 GHz) observation with high angular resolution efficiently in the world.
- CSO-JCMT-SMA interferometer will be the most powerful interferometer of extraterrestrial science with large interferometer array.
- Many students and postdoctoral scholars graduated from CSO.
- CSO has been used by many researchers at Caltech, University of Hawaii, JPL, the University of Texas Austin, and other users worldwide (e.g., Europe, Asia, North/South America) to carry out cutting edge science.
- CSO is led by Prof. Tom Phillips group, in the Physics department at Caltech.
- Other similar examples: Mt. Fuji Submillimeter-wave Telescope (Yamamoto Group at the University of Tokyo) (350/450/809 GHz)
  - Diameter: 1.2m; Completely remote observation; Open to public
- CSO has relatively small number of people among the observatories at Mauna Kea.
  - 10 people dedicated for the observatory locally.
  - CSO-JCMT-SMA interferometer will be the most powerful interferometer of extraterrestrial science with large interferometer array.

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Deuterium Fractionation

- Deuterated molecules observed in interstellar medium (e.g., C2D, C3D, CD3C, CD3H, HD, HD2, HD3, HD4, HD5, HD6)
- Fractionation Process:
  - It's difficult to distinguish between these two processes and the models are still struggling to explain the observed abundances.
  - Nevertheless, the inclusion of the more abundant deuterated species in the models has recently been able to explain observed abundance.

- Their abundances are much larger than the cosmic (D/H) ratio of 1.5 x 10^-5 (Linsky et al. 1998).
- How is it possible? Deuterium can't be created, and is only destroyed by nuclear reaction inside stars. Surprisingly even tiny deuterated molecules are detected.

Triply Deuterated Ammonia

- This is a long, elongated filament, over 5 pc (10^6 AU), in the northern portion of the Orion A molecular cloud. It is one of the active sites of massive star formation, at a distance of 500 pc. It is associated with the Orion Nebula and the Trapezium Cluster of about 1000 young stars. The filament contains the OMC1 and OMC2 complex. The filament contains several thousand young stars in the past few million years and contains dozens of embedded young stellar objects that posses dozens of molecular outflows. Young stars are found up to 150 AU from the filament axis. The filament is expanding in a direction perpendicular to the plane of the sky at a speed of about 10 km/s. A group of dense cores can be found at the center of the filament, and a number of embedded protostars are found in the dense cores.

Low/Intermediate Star Formation

- In 2004, two monitoring campaigns were carried out in Dowell and Yusef-Zadeh in coordination with many other facilities observing at X-ray through radio wavelengths (Dowell et al. '05). The first submillimeter/far-infrared spectrometer, during this relatively new field of research, was the SHARCII and the Bolocam.
Stars produce all of the elements that are needed to create things such as planets and even your body. Much of the stellar debris exists in the form of small dust particles which absorb light from nearby hot stars and re-emit it as infrared (IR) light. The dust temperature in these regions is high enough to be detectable by sensitive IR instruments. Using cameras that are sensitive to the infrared light this heated dust produces, we can probe where in a galaxy that stars are being actively formed. In the above image, we show four galaxies viewed with the SHARC-II camera. The background image is an optical picture, and the black outline shows the area that SHARC-II studied. The white contours show where dust, and hence regions of vigorous star formation, was detected.

The images presented here show selected star-forming regions in very distant galaxies that are billions of light years away from the Earth. The dust-dust interaction in these galaxies is important for understanding how galaxies evolve. The sample was compiled from cross-correlation of the faint-IRAS catalog and the FIRST 21cm radio catalog. The sources are ULIRG's lying within the redshift range of 0.1 and 1; near infrared morphologies of these objects reveal they tend to be interacting systems. Far infrared/submillimeter fluxes were obtained for the first time on these targets, so were SED fits in the FIR (Yang et al. '05).

This is a map of a tenth of a square degree made at a wavelength of 1.1 mm with Bolocam at CSO. At 1.1 mm, our observations are sensitive to dust in distant galaxies heated by stars forming deep within clouds of molecular gas. The bright white spots with dark circles around them are galaxies that we detected. They do not appear as galaxies in visible-light images because we cannot resolve them at the long 1.1 mm wavelength: because of their great distance, the galaxies appear about 30 times smaller than the smallest structures we can resolve with the CSO.