Himalayan Chandra Telescope

Indian Astronomical Observatory
Indian Institute of Astrophysics
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Himalayan Chandra Telescope

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Front Cover : The Indian Astronomical Observatory, Mt. Saraswati, Hanle, Ladakh
Back Cover : Remote control and data acquisition centre of HCT, CREST, Hosakote

Indian Institute of Astrophysics

The Indian Institute of Astrophysics (IIA) traces its origins to a small private observatory set up in 1786 in Nugambakkam, Chennai, which led to the establishment of the Solar Observatory in Kodaikanal in 1899. In 1971, the Kodaikanal Observatory was transformed into an autonomous academic institute for the study of astronomy, astrophysics and allied topics in physics. The Institute has its headquarters at Bangalore and operates observatories at Kodaikanal, Kavalur and Gauribidanur. During the last decade, the Institute developed a superlative site for astronomy in the trans-Himalayan region of Ladakh and established the Indian Astronomical Observatory. The Centre for Research and Education in Science and Technology (CREST) campus at Hosakote has the remote control and data acquisition centre. The Institute has further expanded its horizons into space astronomy through the UltraViolet Imaging Telescope (UVIT), a payload onboard Indian Space Research Organisation's proposed astronomy satellite, ASTROSAT and the Indo-Israeli TAUVEX payload. The Institute has also entered the area of ground-based gamma-ray astronomy in collaboration with the Tata Institute of Fundamental Research (TIFR), Mumbai and the Bhabha Atomic Research Centre (BARC), Mumbai.

INDIAN ASTRONOMICAL OBSERVATORY

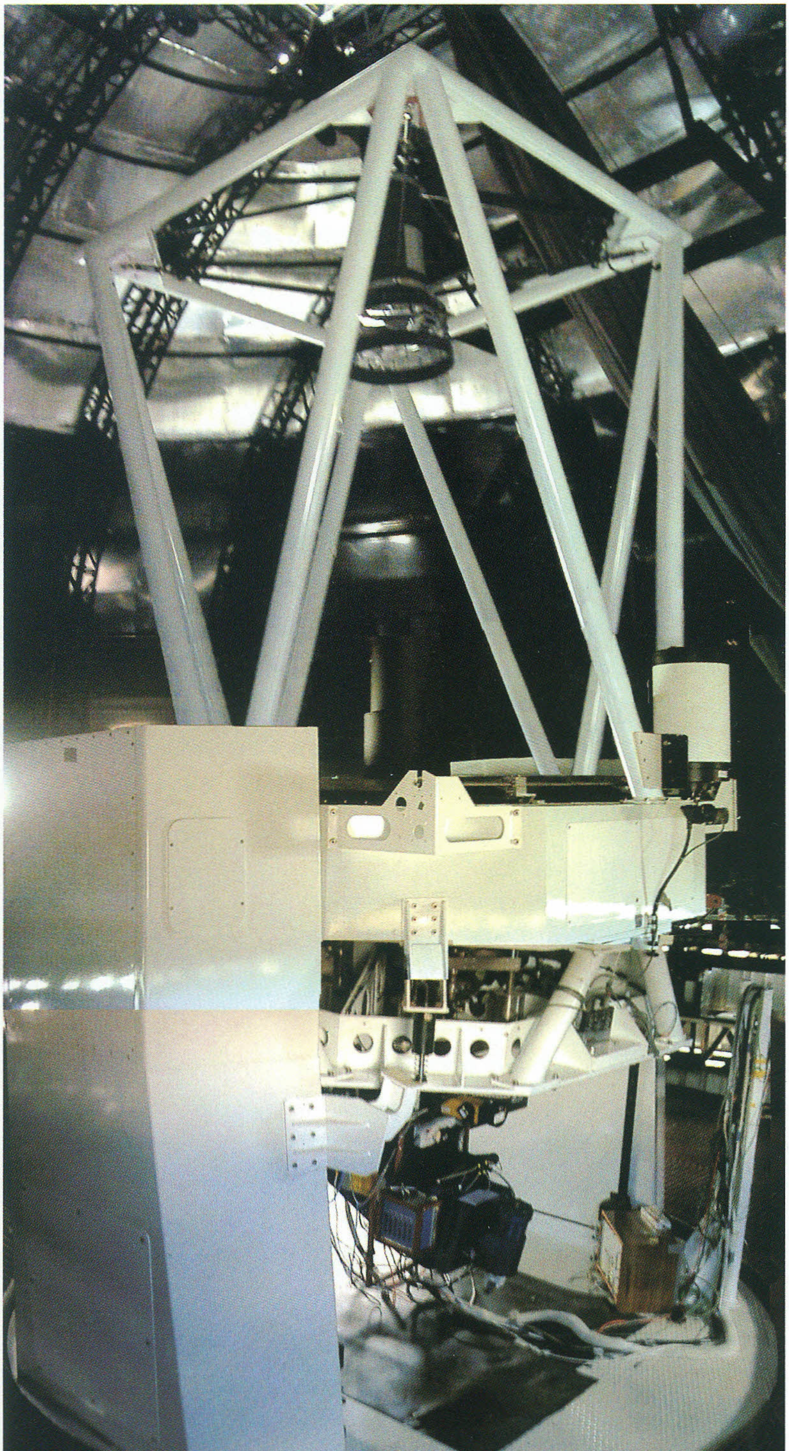
Hanle was identified as a world-class astronomical site for the national large optical telescope, following the recommendations of a committee chaired by Prof. B.V. Sreekantan, on behalf of the Department of Science and Technology, Government of India. Following the identification and characterization of the site, a committee chaired by Dr Kasturirangan suggested the development of the site as a two step process: (1) development of infrastructure and remote operation capability with a 2-m class telescope; (2) development of a large infrared-optical telescope utilizing this infrastructure and experience gained.

Introduction

The 2-m diameter Himalayan Chandra Telescope (HCT) is situated at the Indian Astronomical Observatory (IAO), Mt. Saraswati (longitude 75°57′51′′ E, latitude 32°41′41′′N, altitude 4500 m above mean sea level), Hanle, Ladakh, India. It was installed by the Indian Institute of Astrophysics (IIA), Bangalore, in August 2000, and dedicated to the nation in August 2001 when the telescope and dome were fully automated and remotely operated from Bangalore using a dedicated satellite communication link. It was equipped with the state of the art instruments for optical and near-infrared imaging, and optical spectroscopy during 2002-03 and the regular allotment of telescope time began in May 2003. Due to its location in the high-altitude, cold, desert in the trans-Himalayan Changthang Ladakh region with a large number of clear nights, and ease of operation from Bangalore, it has become highly productive in the intervening years.

HCT was installed at IAO as a first step towards developing a large national infrared-optical telescope at the exceptional site. The infrastructure developed during this process, and the capabilities developed towards remote operation are proving useful, as expected, in further developments at the site. The facility has already attracted other investments in the areas of ground-based gamma-ray astronomy, as well as geophysical and atmospheric sciences. The human resources developed during the process have paved way for the larger infrared-optical facilities.

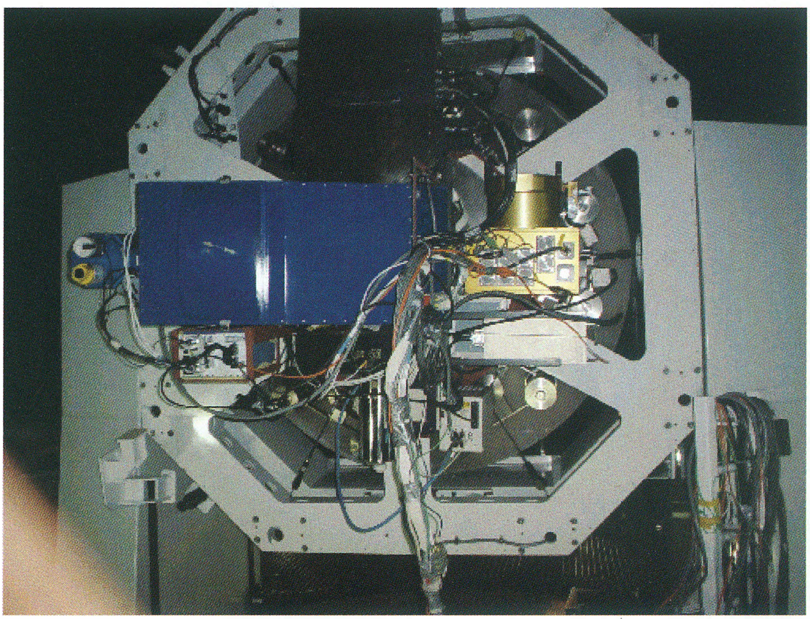
HCT time is allotted based purely on the scientific merit of the proposal by the HCT Time Allocation Committee (HTAC), and priorities decided from time to time. Information on the site, the telescope and focal plane instrumentation, and guidelines for applying for the telescope time, are described in http://www.iiap.res.in/iao/iao.html and links therein. The current user community of HCT includes over 60 astronomers in different institutions and universities in the country and over 60 astronomers from over 14 countries outside India



The Himalayan Chandra Telescope

HCT is of Ritchey-Chrètien design with f/1.75 primary and infrared-optimized secondary, fabricated by M/s EOS Technologies Inc, Tucson, USA, on behalf of their principals, M/s Electro-Optics Systems Pty Ltd, Queanbeyan, Australia. The Cassegrain focal ratio is *f/*9 providing an image scale of 11 arcsec/mm. The primary is made of Corning ultra-low expansion (ULE) coefficient glass ceramic with an aspect ratio of 1:20. The secondary focus and tip-tilt are computer controlled to keep the optical alignment fixed at all orientations and temperatures. Pointing model corrections made online provide a blind pointing accuracy of 2.5 arcsec (rms) and good open-loop tracking. An autoguider built by the Copenhagen University Observatory, Denmark, provides accurate tracking of the telescope for long integrations.

The focal plane instruments are mounted on the Cassegrain instrument-mounting cube fixed to the instrument rotator that corrects for image rotation in the alt-azimuth telescope. A mirror turret reflects the light to the desired side port of the cube, or permits the light path to the axial port. The autoguider assembly is fixed to one of the side ports, and the Shack-Hartmann wavefront sensor used for fine-tuning of the primary mirror warping harness is fixed to another. Thus two side ports and one axial port are available for focal plane instruments. The Cassegrain mirror turret is computer controlled and permits a choice of instruments in about one minute of time.



The focal plane instruments of HCT: The HFOSC (blue) on the axial port and NIRCAM (gold) on the side port to the right, and the CCD imager (steel) on the side port at the bottom. The autoguider assembly (black) is at the top. The Shack-Hartmann sensor is on the side port to the left, hidden by the HFOSC.

INSTRUMENTS

The Himalaya Faint Object Spectrograph (HFOSC), built by the Copenhagen University Observatory, is mounted on the axial port. This is used for optical imaging and spectroscopy. A standby CCD imager is mounted on one of the side ports. The NIR Camera used for broad and narrow band imaging in the 1-2.5 ìm wavelength region is mounted on another side port. This instrument was fabricated by the Infrared Laboratories Tucson, USA, and the control system as well as the user interface was developed by IIA.

Specifications of Himalayan Faint Object Spectrograph:

Wavelength range	350-900 nm
Detector	2048 x 4096 pixels CCD with pixel size 15 x 15 microns (0.3 arcsec x 0.3 arcsec in the image plane)
Collimator focal length	252 mm
Camera focal length	147 mm
Reduction factor	0.58
Spectral resolutions	R~150 to R~4500 using a set of 11 grisms
FOV	10 x 10 arcmin; (unvignetted)
Filters	Bessell UBVRI 372.7(10), 486.1(10), 500.7(10), 656.3(10), 672.4(10)
Performance (not necessarily limiting)	Imaging: R = 22.2, err = 0.18 mag, exp time = 1200s 2-sigma detection of ~23.0 mag/arcsec^2 in 40 minutes (H-alpha filter) Spectroscopy: V = 18.5, Resln = 300; S/N = 22 for 20 min exposure time

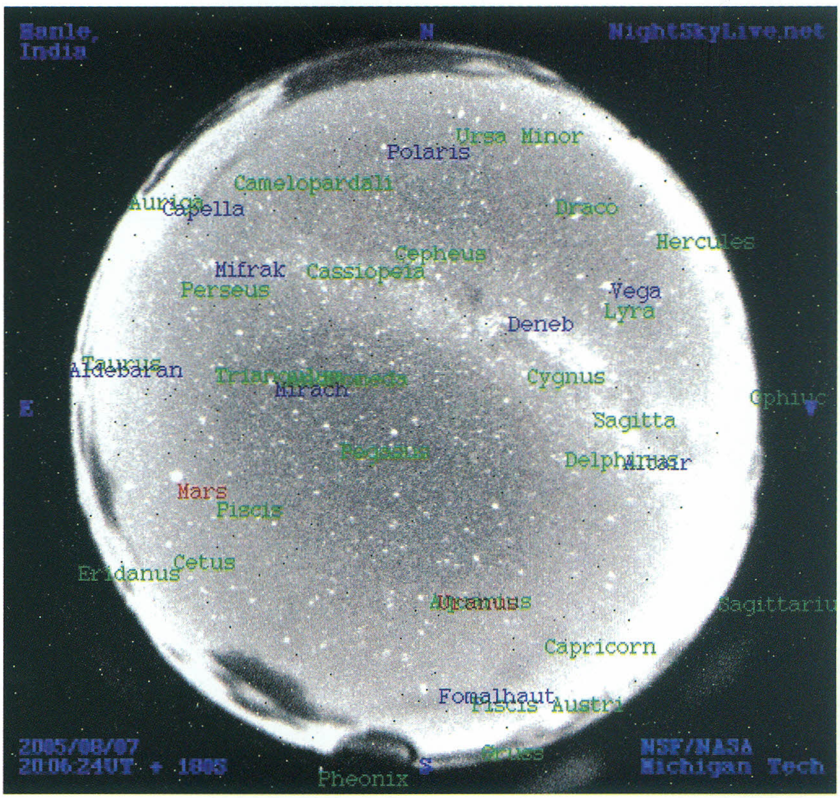
Specifications of the near-infrared camera:

Wavelength range	0.8-2.5 microns
Detector	18 micron pixel, 512 x 512 format HgCdTe array
Image Scale	0.21 arcsec/pixel (Camera-A) 0.4 arcsec/pixel (Camera-B)
FOV	1.8 x 1.8 arcmin (Camera-A) 3.6 x 3.6 arcmin (Camera-B)
Filters	JHK, K_{long}, H_2, CO, Br-γ [FeII] (line & continuum), K-continuum and CVF

A small team of astronomers in Bangalore and engineers in Leh maintain the HCT with a high degree of reliability and ensure trouble-free operation with the help of a small team of support staff in Hanle and the remote control station at the CREST campus.

An automated weather station with weather server software provides online information of ambient temperature, relative humidity, pressure, wind speed, wind direction and detection of precipitation. This information, and an all-sky night-viewing camera (CONCAM) provided by the Michigan Technological University, USA (http://nightskylive.net/ha) support the remote observer through the weather related information. An online webcamera is available to view the telescope enclosure and part of the day time sky (http://www.crest.ernet.in/webcam/webcam.html). The webpage at CREST also provides links to satellite images.

The HCT data archive is under development with the Inter-University Centre for Astronomy and Astrophysics (IUCAA)-Persistent System Ltd., Pune, collaboration of Virtual Observatory India (VO-India).



The image of night sky at Hanle on 2005 August 8, 01:36:24 IST, recorded with CONCAM, and shown with an automatic overlay labeling the bright stars, planets and constellations. Milky Way is prominently seen at top of centre and right. A few dark clouds are seen towards horizon.

Science with the HCT

Beginning with May 2003, HCT time is allocated to astronomers in cycles of 4 months each. During the cycles 1-9 ending April 2006, an average of 25 proposals are received for each cycle. The astronomical community that has utilized the HCT consists of over 60 Indian astronomers and 60 astronomers abroad. The fields of investigation cover a wide range of topics from the solar system objects to cosmology. Some of the results obtained are described in the following.

Extragalactic Astronomy

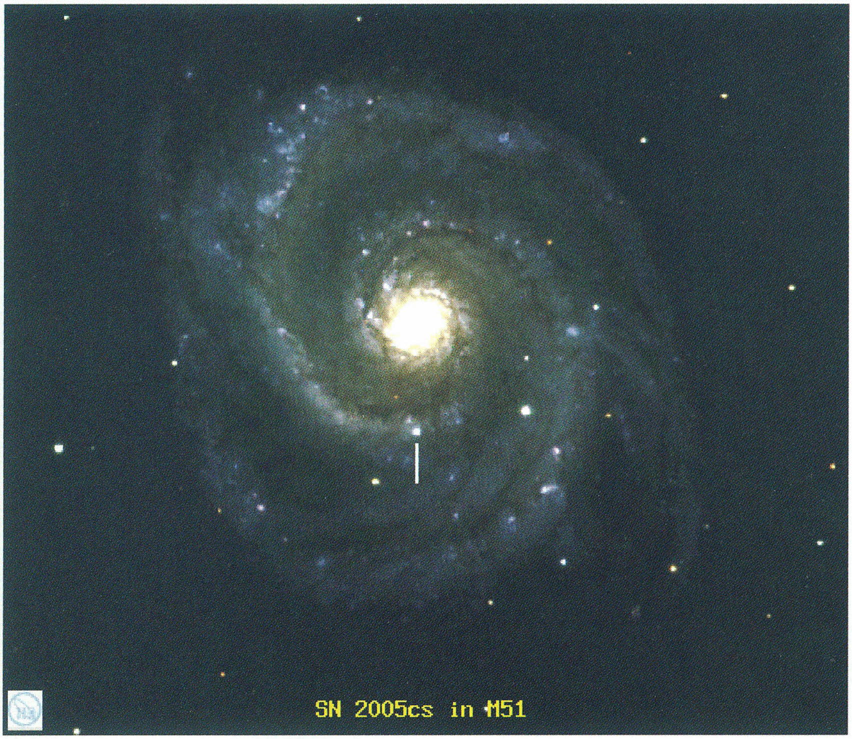
Supernovae

Supernovae of type Ia have been traditionally used as cosmological standard candles. This requires good calibrations, which can be obtained only through a detailed study of nearby supernovae. The diversity of supernovae also excites an interest in the study of the phenomenon itself and the nature of the progenitors. With these motivating factors, extragalactic supernovae are being monitored with HCT as a Target of Opportunity programme. While the type Ia are observed to study the diversity in this class, the core collapse supenovae are observed with an aim to understand the progenitors.

Crab Nebula, the remnant of a Galactic supernova that exploded in 1054 AD.

The first objects to be observed during the science verification phase were the type Ic SN 2002ap (Pandey et al. 2003a), and type Ia SN 2002hu (Sahu, Anupama & Prabhu 2005). Several other supernovae have been observed since Cycle 1. The most interesting object was the type Ib SN 2005bf, which was found to be the end state of a massive star with a trace of the hydrogen envelope in the progenitor before the supernova explosion (Anupama et al. 2005a, Tominaga et al. 2005). Type Ia supernovae studied include, amogst others, SN 2003du (Anupama, Sahu & Jose 2005) and the peculiar SN 2005hk. Several supernovae of type Ib, Ic, II-P and II-n, such as SN 2004et and SN 2005cs are also under investigation.

Type Ia supernova SN 2004 as in the galaxy Holmberg 254B. The Spiral Galaxy to the right of centre is KUG 1122+230.

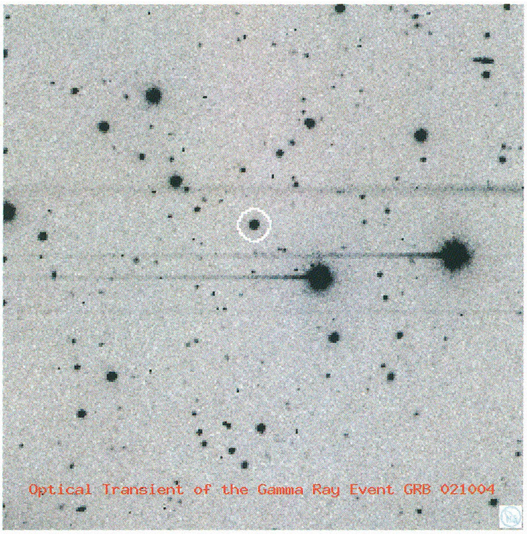


Type IIp supernova SN 2005cs in the spiral galaxy M51.

Optical afterglows of gamma-ray burst sources

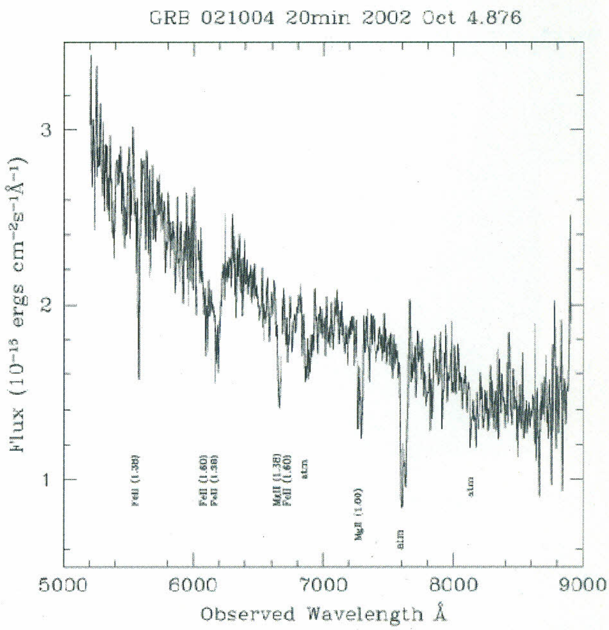
Gamma-ray bursts (GRBs) are the most energetic events in the universe, rivaling the supernovae that held this rank prior to the discovery of the extragalactic nature of the GRB sources. Long duration GRBs with soft spectrum often exhibit an optical afterglow that fades over timescales of days. The phenomenon is akin to supernovae, and some of the GRBs are associated with type Ic supernovae.

Optical monitoring of GRB sources is an observatory project of IAO and is coordinated as a national collaboration between astronomers of IIA, ARIES, Nainital, and RRI, Bangalore. GRB afterglows monitored in detail include GRB 010222 (Cowsik et al. 2001), GRB 021004 (Pandey et al. 2003b), GRB 021211 (Pandey et al. 2003c), GRB 030226 (Pandey et al. 2004), GRB 030329 (Resmi et al. 2005) all observed during the science verification phase. Subsequent to regular allotment of time, monitoring the GRB afterglows is conducted as a Target of Opportunity programme and observers with time already



The optical afterglow of GRB 021004.

allotted to other programmes are strongly persuaded to surrender part of their time to this proposal. The afterglows studied in detail during this period include GRB 050525 and GRB 050820 on which papers are in preparation, whereas limited data obtained on GRB 050502b, GRB 050330, GRB 050803, GRB 051021, and 051028 are communicated to *GCN Circulars (3346, 3774, 3775,4278, 4294)*.

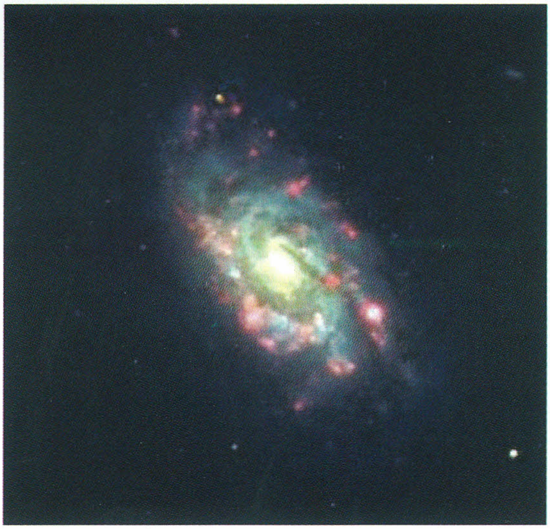


Spectrum of GRB 021004 obtained with HFOSC.

Galaxies and Cosmology

Apart from the studies of supernovae and gamma-ray burst sources, HCT is also being used for several other studies in the area of Galaxies and Cosmology. Notable amongst these studies are the study of star formation in blue compact dwarf galaxies, the study of dust formation in early type galaxies and the study of the nature of extragalactic ultraluminous X-ray sources. The study of variability over various timescales in the Active Galactic Nuclei forms another important component of extragalactic astronomy pursued with the HCT (cf. Raiteri et al. 2005). The telescope is also used for multi-site monitoring of selected gravitationally lensed objects with a view to estimating the Hubble constant at all epochs.

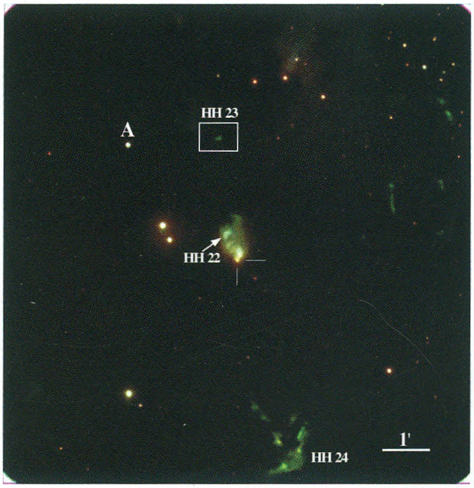
The nuclear starburst galaxy NGC 925



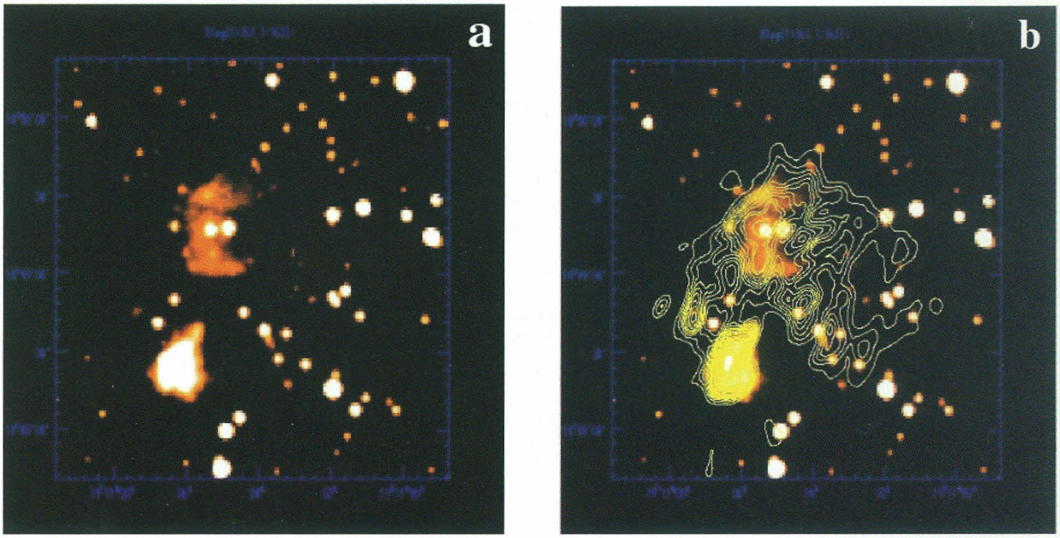
B, V, H-alpha combined image of the starburst galaxy NGC 1084

Galactic Astronomy

Galactic astronomy with the HCT ranges from the study of star formation to that of the late type stars and clusters of stars.



V, H-alpha, I composite image of McNeil nebula and neighbouring Herbig-Haro objects. The location of the young stellar object is marked by lines in the centre.



Br-γ line + continuum image of the region around IRAS I 9111+1048. Contours (right panel) represent the 1280 MHz observed from GMRT.

Star formation studies includes the studies of star forming regions and young stellar objects such as the T Tauri stars and Herbig Haro objects.

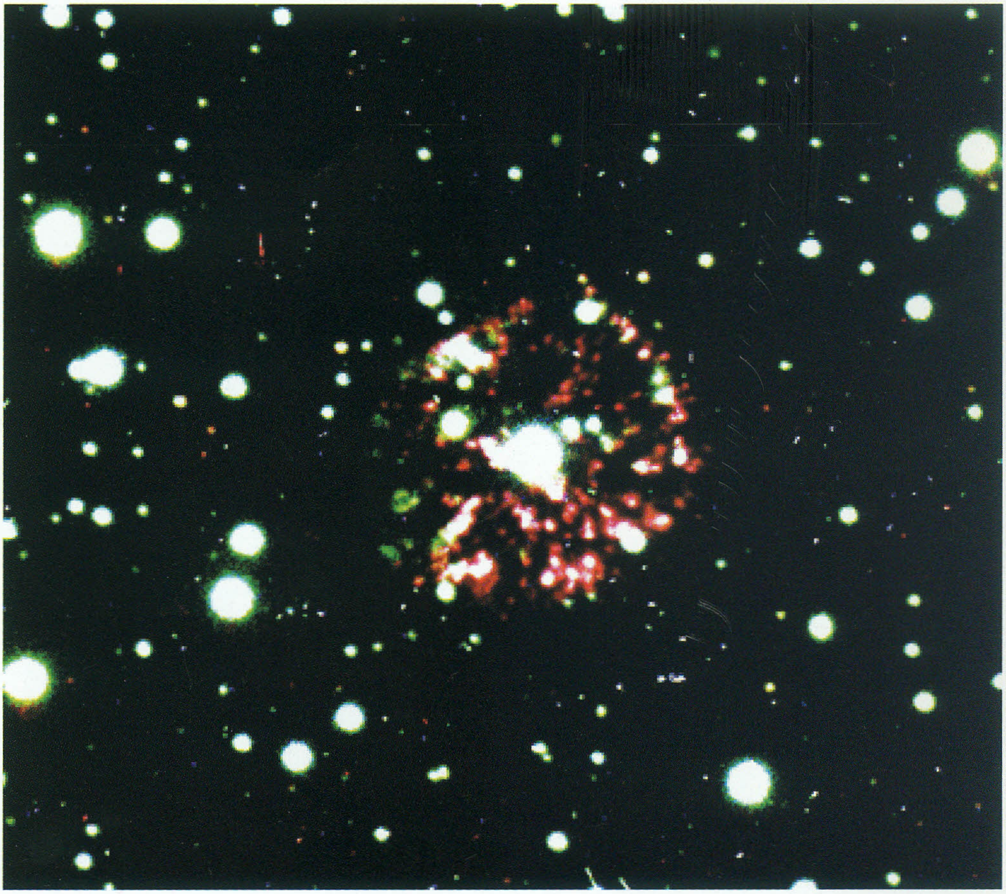
Brown dwarfs, the missing links between stars and gas-rich giant planets like Jupiter, are also being studied with the HCT (Maiti et al. 2005).

Metal-poor, carbon rich stars can provide direct information on the role of low-to intermediate-mass stars of Galactic halo in early chemical evolution. Goswami (2005) observed a large number of candidate stars with HCT, and identified several CH-giant stars, a lesser studied subgroup of this class.

HCT is also used to study stellar oscillations in stages such as RR Lyrae stars (Ferro et al. 2004), white dwarfs, and subluminous B type stars.

The brown dwarf 2MASSW J0036+18.

Classical and recurrent novae as well as symbiotic stars and other nova-like systems are another area of fruitful activity with the HCT. Anupama & Kantharia (2005) have used both the HCT data as well as radio observations from the GMRT to study the nature and evolution of the diffuse remnant of the old nova GK Persei 1901. They find significant similarities between this remnant and the young supernova remnant Cassiopeia A. Banerjee & Ashok (2004) used HCT to study the nova-like variable V4332 Sagittarii and found that it did not conform to the known class of novae. Galactic microquasars and X-ray binaries are other objects that are studied with the HCT.



Shell of nova GK Persei. The red regions depict emission in the lines of Há + [N II] whereas the green regions depict emission in the lines of [O III] (Anupama & Kantharia 2005).

Several groups are also studying open clusters with a view to obtaining accurate photometry of clusters that are not well-studied so far. Variable stars are being identified and followed up in order to understand the evolutionary stage of the cluster. Subramanian et al. (2005) studied the young open cluster NGC 146 and discovered several pre-main sequence stars and one Herbig Be star.

I band image of the poorly studied galactic open star cluster Be 52.

HCT is also used for studies of solar system objects such as asteroids, comets, clouds in the atmosphere of Venus, and space debris in our immediate environment.

Human Resource Development

HCT has contributed significantly to human resource development in the field of optical-infrared astronomy. Several students are using HCT data towards their Ph.D. studies, and several students have undertaken short-term projects related to site characterization, instrumentation, and astronomical studies using the telescope. There is scope for much larger involvement of students of science and technology in future.

The Future

HCT has proven the Indian capabilities of development and utilization through satellite communication link, astronomical facilities at the exceptional astronomical site at Hanle. The Indian Astronomical Observatory is now ready to host additional facilities including a large infrared-optical telescope.

Publications:

Research Publications based on HCT data

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