8. Infrared Sky Surveys and Space Missions

Digital sky surveys are now a large part of modern astronomy and the trend is toward ever larger sky surveys. This due to great technical advances in array detectors (optical and IR) and even greater advances in computing and data storage.

Sky surveys are needed to attack problems in cosmology and to identify transient objects. A great example of the latter is the recent identification of the gravitational wave source GW170817.

I will discuss sky surveys and space missions that have surveyed the sky at IR wavelengths as well provided pointed observations.
8.1 Infrared sky surveys from the ground.

- **2 Micron All Sky Survey (2MASS).** The entire sky was surveyed at J, H, and Ks between 1997 and 2001 (Skrutskie et al. 2006). The uniformity, accessibility, and quality of the data has made it an indispensable resource for observing and research especially in regions that are highly obscured by interstellar extinction. The 2MASS near-IR images are available through the NASA/IPAC Infrared Science Archive (IRSA). Home page:

  https://www.ipac.caltech.edu/project/irs
Notes: Infrared Processing and Analysis Center (IPAC). IPAC was founded to process IRAS data and has been expanded to other space observatories.

http://irsa.ipac.caltech.edu/index.html also provides access to an extensive set of databases, including IRAS, ISO, Akari, Midcourse Space Experiment (MSX), Spitzer, WISE, Herschel, and Planck.

References:
Notes: Infrared Processing and Analysis Center (IPAC). Started processing data from the IRAS mission.

http://irsa.ipac.caltech.edu/index.html also provides access to an extensive set of databases, including IRAS, ISO, Akari, Midcourse Space Experiment (MSX), Spitzer, WISE, Herschel, and Planck.

References:


8.1 Sky surveys from the ground (continued)

- UKIRT Infrared Deep Sky Survey (UKIDSS). Started in 2005 and consists of five filters: Z, Y, J, H, and K. The JHK filters are identical to the MKO near-IR filter set (Hewett et al. 2006). The UKIDSS photometric system was established using the 2MASS photometry (Hodgkin et al. 2009). Images from this this survey can be found at: [http://www.ukidss.org/](http://www.ukidss.org/)

- Visible and Infrared Survey Telescope for Astronomy (VISTA). It consists of a dedicated wide-field telescope with a 67 million pixel IR camera. It has a set of filters similar to that used by UKIDSS. The survey programs started in 2010 (Emerson and Sutherland 2010). Information on VISTA: [http://www.eso.org/public/teles-instr/paranal-observatory/surveytelescopes/vista/](http://www.eso.org/public/teles-instr/paranal-observatory/surveytelescopes/vista/)
The science archive for VISTA is at: [http://vsa.roe.ac.uk/](http://vsa.roe.ac.uk/)

Notes:
http://irsa.ipac.caltech.edu/index.html also provides access to an extensive set of databases, including IRAS, ISO, Akari, Midcourse Space Experiment (MSX), Spitzer, WISE, Herschel, and Planck.

References:
Notes: http://irsa.ipac.caltech.edu/index.html also provides access to an extensive set of databases, including IRAS, ISO, Akari, Midcourse Space Experiment (MSX), Spitzer, WISE, Herschel, and Planck.

References:
8.2 Sky surveys from space.

IRAS (Infrared Astronomical Satellite)

The first all sky survey in the IR was accomplished with IRAS in 1983.

Imaging was accomplished in 4 bands: 12, 25, 60, 100 μm as shown to the left. The filters are very broad, and so the effective wavelength of the filters depends on the spectral energy distribution of the source. **Color corrections have to applied depending on whether you have a hot or cold source.**


Webpage: http://irsa.ipac.caltech.edu/Missions/iras.html

Archive: http://irsa.ipac.caltech.edu/Missions/iras.html

References:
False color map with the 12 µm image as blue and 100 µm image as red. The comet Temple 2 dust trail is seen across the top half of the image. The light blue emission is from the zodiacal light at 12 µm along the ecliptic plane. The complex structure is emission from cold dust in the Galaxy at 100 µm.

MSX (Midcourse Space Experiment)

Operated from 1996-1997 at 4.29, 4.35, 8.28 \( \mu \text{m} \), 12.13 \( \mu \text{m} \), 14.65 \( \mu \text{m} \), and 21.3 \( \mu \text{m} \) and it mapped the galactic plane as well as areas of the sky missed by IRAS. One focus of this telescope was to provide an absolute calibration of standard stars in the IR (Cohen et al. 2000; Cohen et al. 2001). The absolute calibration of Akari and the Spitzer Space Telescope is based on this work.

![False-color Midcourse Space Experiment (MSX) composite with the 8.28 \( \mu \text{m} \) band (blue), 12.13 \( \mu \text{m} \) band and 14.65 \( \mu \text{m} \) band (green), and 21.3 \( \mu \text{m} \) band (red). Covers about 4.5 x 4.5 degrees.](image)

From: 
http://coolcosmos.ipac.caltech.edu/image_galleries/MSX/hourglass_nebula.html

Notes:
Webpage: http://irsa.ipac.caltech.edu/Missions/msx.html
Archive: http://irsa.ipac.caltech.edu/Missions/msx.html

References:


More detailed info on the filters used: http://irsa.ipac.caltech.edu/applications/MSX/MSX/imageDescriptions.htm
Spitzer Space Telescope (SST)

Operated from 2003 to the present, Spitzer has provided a wealth of new discoveries.

The Infrared Array Camera (IRAC) is a 4-channel camera operating at 3.6, 4.5, 5.8, and 8.0 μm (Fazio et al. 2004). When the cryogens ran out in 2009, the observatory was operated using only the near-IR instrument at 3.6 and 4.5 μm.

Figure shows the scaled spectra an A dwarf and a K giant star compared to the normalized spectral response of the 4 IRAC channels. InSb arrays were used for 3.6 and 4.5 μm and a Si:As arrays for 5.8 and 8.0 μm.

Notes:
http://www.spitzer.caltech.edu/

Archive: http://irsa.ipac.caltech.edu/Missions/spitzer.html

References:


The Multiband Imaging Photometer for Spitzer (MIPS) had three camera modes and one spectrometer mode (Rieke et al. 2004).

Figure shows the filters used for MIPS. Three types of detectors were used: a Si:As impurity band conduction array at 24 µm (Rieke et al. 2008), a Ge:Ga photoconductor array at 70 µm (Gordon et al. 2007), and a stressed Ge:Ga array at 160 µm (Stansberry et al. 2007).

Notes:
http://www.spitzer.caltech.edu/

References:
Some science highlights from Spitzer:

This Spitzer image shows that the Sombrero galaxy is composed of an elliptical component and a thin disk galaxy embedded within. The starlight detected at 3.5 and 4.6 μm is shown as a blue-green color while the dust detected at 8.0 μm is shown in red.

Notes:
From: http://www.spitzer.caltech.edu/search/image_set/20?by_type=astronomical&tabs=hidden
Spitzer observations of a system of seven planets orbiting TRAPPIST-1, an ultracool dwarf star located only 40 light years from the Earth. The transits were observed over a period of 21 days. Seven rocky planets were found, including three in the habitable zone where liquid water might be found. All of the planets are probably tidally locked to the star.

Notes:
From: http://www.spitzer.caltech.edu/search/image_set/20?by_type=astronomical&tabs=hidden
AKARI

AKARI was launched in 2006 by JAXA (Murakami et al. 2007). The liquid helium ran out in Aug. 2007 after 1.5 years of observations. The near-IR camera could still operate due to a mechanical cryo-cooler and observations continued with a “warm mission” until May 2011 when problems with the satellite power supply caused the end of the mission.

The figures show the filters for the Infrared Camera (IRC) on AKARI (Onaka et al. 2007) and the filters for the Far-Infrared Surveyor (FIS; Kawada et al. 2007).

Notes:
Webpage: http://www.ir.isas.jaxa.jp/AKARI/
Data archive: http://darts.jaxa.jp/astro/akari/
Three-color composite images of eight supernova remnants in the Large Magellanic Cloud composed of images taken at 7 (blue), 11 (green) and 15 (red) micrometers, with the near- and mid-infrared Camera (IRC) onboard Akari. Contours indicate the intensity of the X-ray emission observed by the NASA's Chandra X-ray observatory. The line at the bottom of each image indicates a distance of 20 light-years. This study quantified the dust production in the metal poor galaxy.

Notes:
http://m.esa.int/spaceinimages/Images/2008/11/Supernova_remnants_in_the_Large_Magellanic_Cloud
Wide-field Infrared Survey Explorer (WISE)

WISE was launched in 2009 and it performed an all-sky survey at 3.4, 4.6, 12 and 22 μm (Wright et al. 2010). At the end of the survey the telescope was put into hibernation and then reactivated in 2013 to conduct a search for near-Earth objects (NEOs). This new program is called NEOWISE and it was actually started before the hibernation of the spacecraft.

Normalized relative system response curves on a log scale. The absolute calibration is based on the Spitzer calibration (Cohen 2007).

Notes:
NEOWISE webpage: https://neowise.ipac.caltech.edu/
Data archive: https://www.ipac.caltech.edu/project/irsa

Discovered the object WISE 1828+2650, one of the coolest object yet discovered with a temperature of about 300 K. It is classified as a Y brown dwarf. The image shows three of WISE's four infrared channels, color-coded blue, green and red, with blue showing the shortest infrared wavelengths and red, the longest.

It is about 14 pc from the sun and has a mass of about 3-6 times the mass of Jupiter.
Herschel Space Observatory (Herschel)

Herschel was launched in 2009 by ESA and had a 3.5-m primary mirror that made it the largest infrared telescope launched at that time. The mission ended when the liquid helium ran out. It had three instruments:

- PACS - imaging at 120-210 μm, spectroscopy at 55-210 μm.
- SPIRE - imaging at 208-583 μm, spectroscopy at 200-570 μm.
- HIFI - high resolution spectroscopy at 480-1910 GHz (257-625 μm).

PACS AND SPIRE filters for imaging. The calibration of PACS is based on stars (Balog et al. 2014) while that for SPIRE is based on Neptune (Bendo et al. 2013). Figure is from Marston & Puga (2012).

Notes:
Webpage: https://www.cosmos.esa.int/web/herschel
Archive: http://archives.esac.esa.int/hsa/whsa/

References:
Herschel observations of hot molecular gas within 1 light year of the black hole at the center of the Galaxy. The black hole (known as Sgr A*) has a mass of 4 million solar masses. The temperature of the gas is as high as 1,300 K, much hotter than typical interstellar clouds with temperatures of about 20K. The high temperatures arise from heating by uv radiation and shocks in colliding material.

Notes:
http://m.esa.int/Our_Activities/Space_Science/Herschel/Herschel_finds_hot_gas_on_the_menu_for_Milky_Way_s_black_hole
PLANCK

The Planck spacecraft was launched in 2009 and operated until 2013. The primary was 1.9m x 1.5m and this provided the highest resolution image of the Cosmic Microwave Background. The primary goal was to map the intensity and polarization of the CMB. It had two instruments, the Low Frequency Instrument (LFI) operating in three bands at 28 to 70 GHz and the High Frequency Instrument (HFI) operating at 100 to 857 GHz.

<table>
<thead>
<tr>
<th>Instrument Characteristic</th>
<th>LFI</th>
<th>HFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>28.4</td>
<td>44.1</td>
</tr>
<tr>
<td>FWHM (arcmin)</td>
<td>32.3</td>
<td>27.0</td>
</tr>
<tr>
<td>Bandwidth (%)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Sensitivity (μK_CMB deg)</td>
<td>2.5</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Table 1. Planck instrument performance. Figures taken from the 2015 full mission data release [29]. * The sensitivity values for the 545 and 857 GHz channels, which are not sensitive to the CMB, are given in kly sr⁻¹.

Table is from Clements (2017).

Notes:
Webpage: https://www.cosmos.esa.int/web/planck
Archive: https://www.cosmos.esa.int/web/planck/pla

References:
Planck detector bandpasses (grey) compared to the Cosmic Microwave Background (CMB), Galactic Dust emission, Cosmic Infrared Background (CIB), non-thermal emission, and CO line emission. The CIB dominates away from the plane of the Galaxy and originates from faint galaxies.

From Clements (2017).
The panels show 10 deg x 10 deg maps of the cosmic microwave background. COBE was launched in 1989, WMAP in 2001, and Planck in 2009. The spatial resolution of Planck map is about 0.08 degree.

Notes:
Webpage:

References: