# Dust in the solar system and the Galactic plane

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# Outline

- About PRL facilities for Astronomy at Mount Abu
- About the Himalayan Chandra Telescope of IIAp at Hanle
- Dust in the Solar System and the Milky Way


INDIA
Optical / infrared
Observatories in India
HCT
DOT
MIRO
USO
PRL
Girawali
IIA
VBO
TAJIKISTAN
AFGHANISTAN
PAKISTAN
CHINA
(Tibet)
NEPAL
BHUTAN
BANGLADESH
MYANMAR
(BURMA)
SRI LANKA
Arabian Sea
Bay of Bengal
INDIAN OCEAN
Andaman Sea
NEW DELHI
Mumbai
Hyderabad
Bengaluru
Chennai
Kolkata
Thiruvananthapuram
Kanyakumari
LEGEND
Country Boundary
Major Road
Major River
Major City
Other City
Major Sea Port
Country Capital
Major Airport
Major National Park
Point of Interest
Major Mt. Peak
Map not to scale
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# About PRL's observatory at Mount Abu

## Mount Abu Infrared Observatory

72°46'47.5"E, 24°39'08.8"N, 1680 m

# Astronomy and Astrophysics Division

## Optical & Infrared Astronomy

1.2 m Infrared Telescope at Gurushikhar, Mt. Abu

Instrumentation

Infrared camera/spectrographs
2 Channel IR Fast Photometer
Fabry-Perot Spectrometer
LN2 cooled CCD camera
Optical Polarimeters
High resolution Echelle Spectrograph

0.5 m Telescope with EMCCD Camera

Science Topics

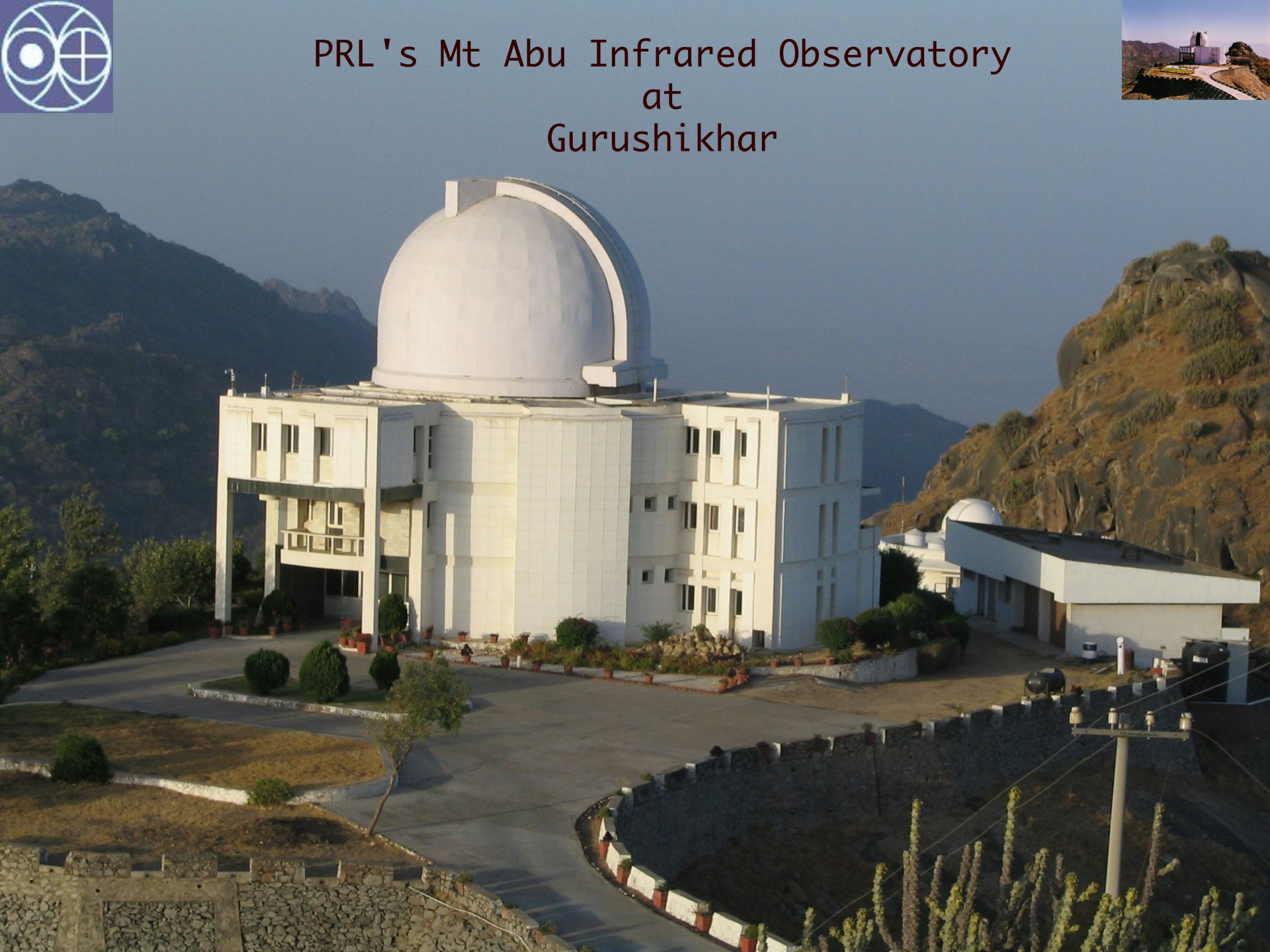
Solar System Objects
Extra-solar planets
Stellar Evolution
Interstellar Matter and Star formation
Milky Way as a galaxy
Starburst galaxies and Active Galactic Nuclei

# Imaging facilities on PRL telescopes

- 2K x 2K CCD from Andor
  - available with UBVRI, Sloan and Hale-Bopp filters
  - 6’ x 6’ field of view on 1.2m telescope
  - 26’ x 26’ field of view on 50cm telescope
- 1K x 1K EMCCD available on both telescopes
  - field of view on 50cm : 13’ x 13’
  - UBVRI filters (also with polarization capability)
- 1K x 1K near infrared camera + spectrograph on 1.2m
  - J,H,Ks filters (and some narrow band)

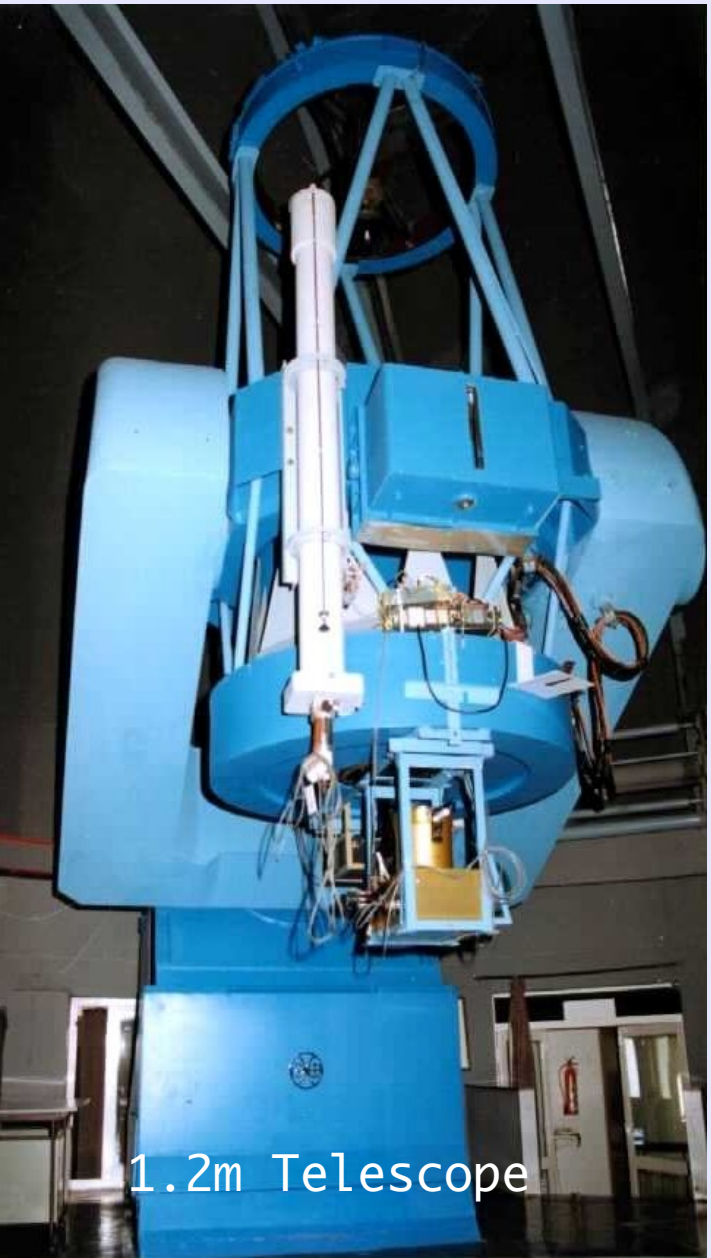
# PRL's Mt Abu Infrared Observatory
# at
# Gurushikhar

# PRL's Mt Abu Infrared Observatory at Gurushikhar



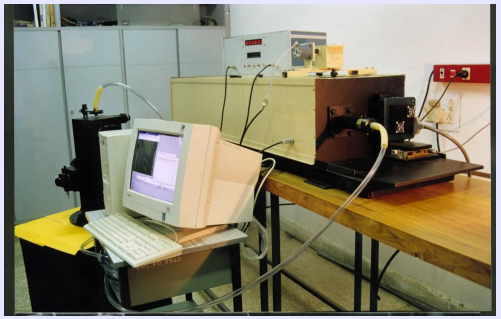
1.2mt Telescope

# PRL's Mt Abu Infrared Observatory

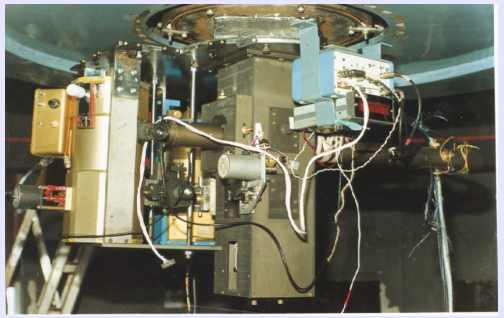


1.2m Telescope

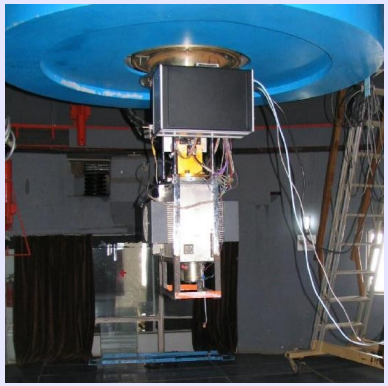
## Focal plane instruments



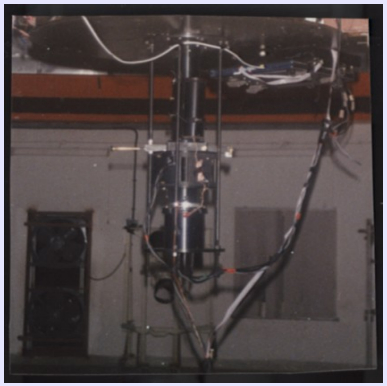
Fibre-linked Grating Spect.



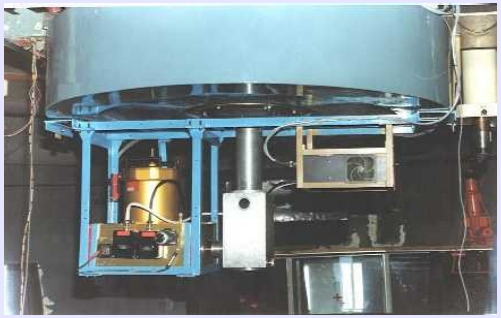
2-channel IR photometer



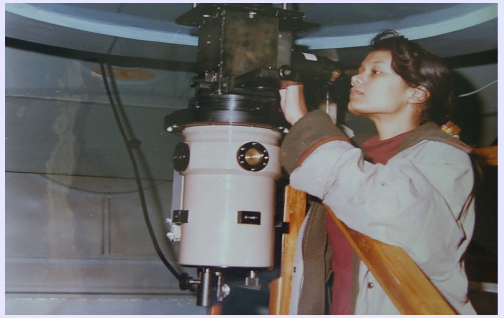
Optical polarimeter



Imaging Fabry Perot spect.



NICMOS Imaging-spect.



Cooled CCD camera

# Facilities at Mt. Abu Infrared Observatory

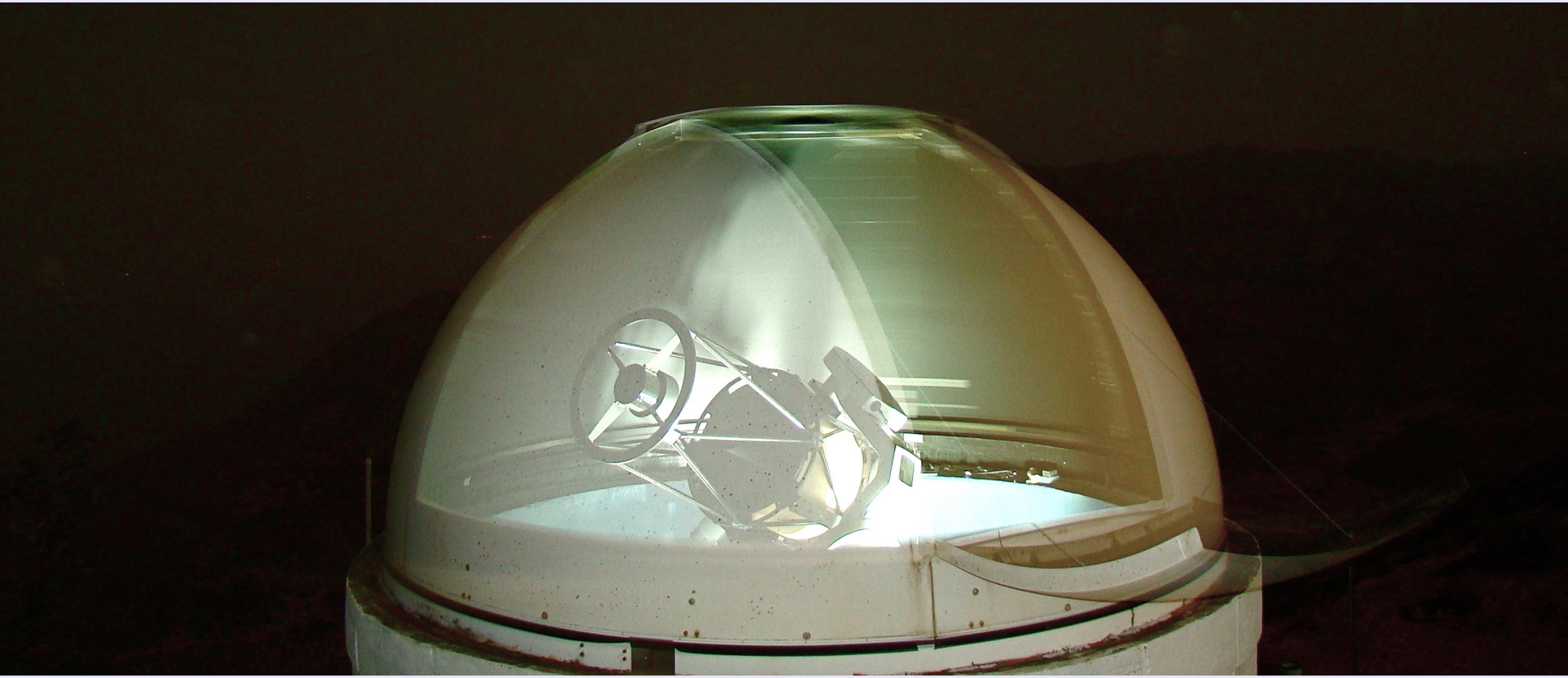
Aluminising Plant at Mt. Abu Observatory

Aluminised 1.2m dia Mirror

Other facilities include a workshop and a $LN_2$ plant

# 0.5m Telescope at Gurushikhar, Mt. Abu

# 0.5m Telescope at Gurushikhar, Mt. Abu



# 0.5m Telescope at Gurushikhar, Mt. Abu

With last year's summer trainee

# About IIA's observatory at Hanle

Indian Institute of Astrophysics, Bangalore

2m Telescope in the Himalayas at Hanle, near Leh, Ladakh

| | |
|---|---|
| Latitude | 32d46m46s N |
| Longitude | 78d57m51s E |
| Altitude | 4500 meters above msl |

Wind Speed Median 2.2 m/s (8 kmph) at night
Annual precipitation of rain & snow < 7 cm
Precipitable water vapour < 2 mm between October and April

Number of spectroscopic nights ~ 260 per year
Number of photometric nights ~ 190 per year

Median seeing < 1 arcsec

Calls for proposals with deadlines on

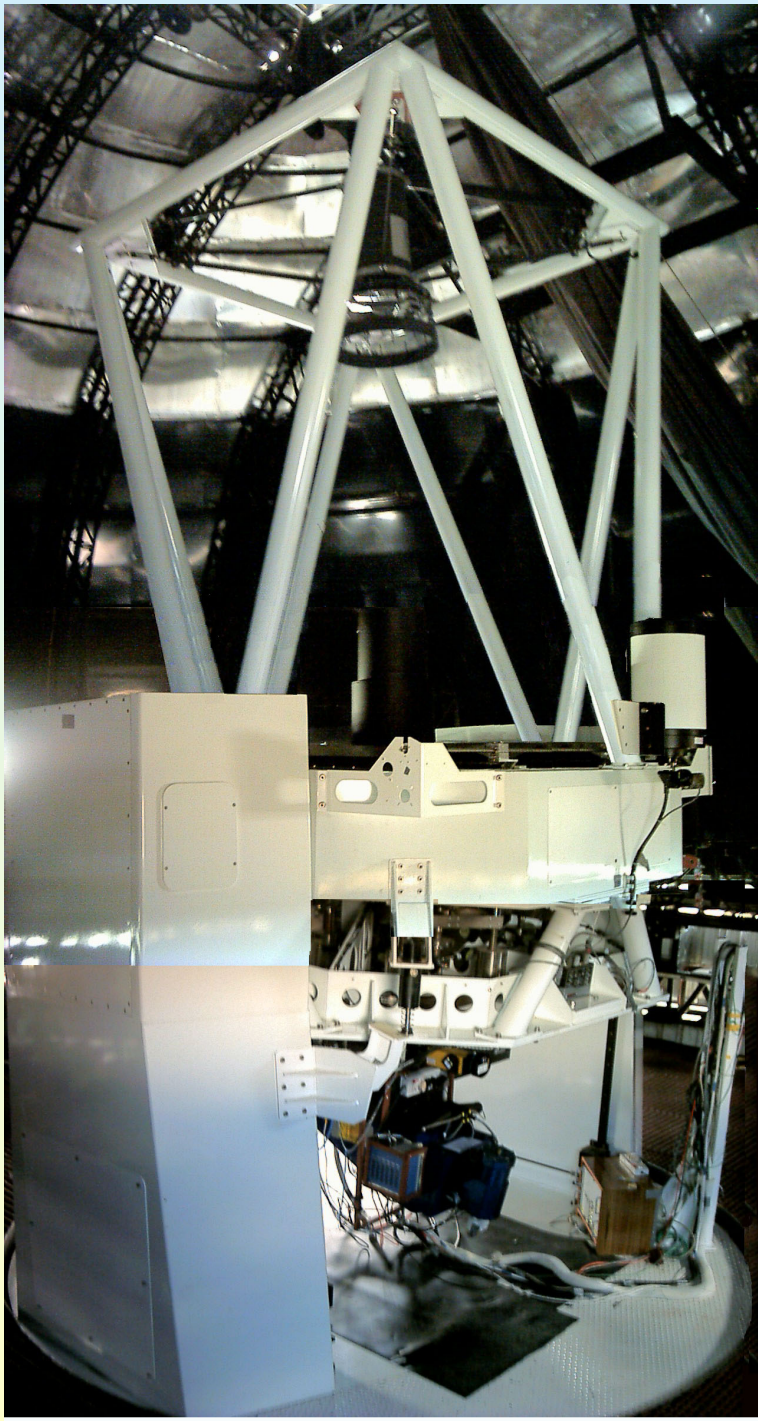
| | |
|---|---|
| January-April (YYYY_Cycle1) | November 1 |
| May-August (YYYY_Cycle2) | March 1 |
| September-December (YYYY_Cycle3) | July 1 |

# Dome for 2-m Himalayan Chandra Telescope & Last Qt. Moon

# Himalayan Chandra Telescope

2-m aperture modern technology telescope

- F/9 Cassegrain configuration
- Pointing accuracy 2 arcsec
- Open loop tracking accuracy 1 arcsec in 10 min
- Controlled remotely from CREST, Hosakote near Bangalore
- Instruments remotely selectable from CREST, Hosakote
  - HFOSC - Himalayan Faint Object Spectrograph Camera (optical imaging and spectroscopy)
  - TIRSPEC (imaging and spectrosocpy)
  - Optical imager
  - HESP - Hanle Echelle SPectrometer



# Hanle Echelle SPectrometer (HESP)

- The 2m Himalayan Chandra Telescope (HCT) achieved a major milestone with the installation of the 2nd Generation instrument, HESP, a Fibre-fed, high resolution spectrograph.

- Built by – Callaghan Innovation, New Zealand

- Instrument control interface was developed by IIA.

- Project was funded by DST, India

- Spectral Resolution - 30,000 and 60,000
- Wavelength coverage - 3600 – 9600 A (without any gap)
- Detector is a 4K x 4K CCD

# Hanle Echelle SPectrometer (HESP)

Spectral resolution
R = 30000 (unsliced fiber)
R = 60000 (with image slicer)

Continuous wavelength coverage:
350-1000nm in single exposure with 4Kx4K detector format of 15μm square pixel Mechanical stability 200 m/s

Radial velocity accuracy 20m/s (ThAr reference mode)

Total system Efficiency > 20% (including telescope and detector in the range 400-700nm)

Double fiber mode to record the star and calibration/sky spectra simultaneously for high precision RV measurements

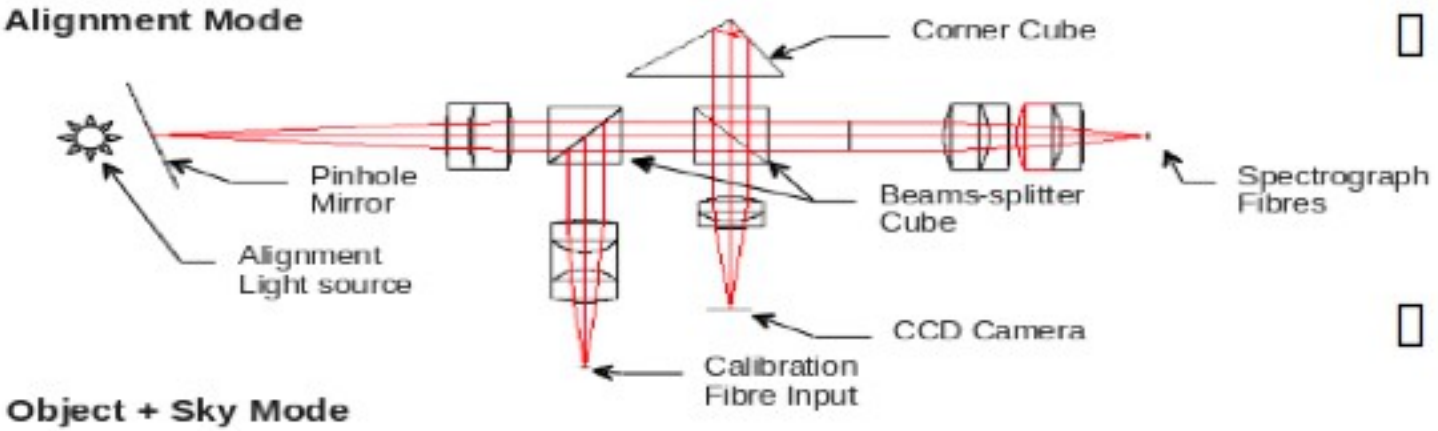
A minimum inter-order separation of 400 μm on the detector
Faintest limit ~12mag (@R=60000 S/N ~15)

- The pre-shipment acceptance test of the spectrograph was completed in New Zealand during May 2015.

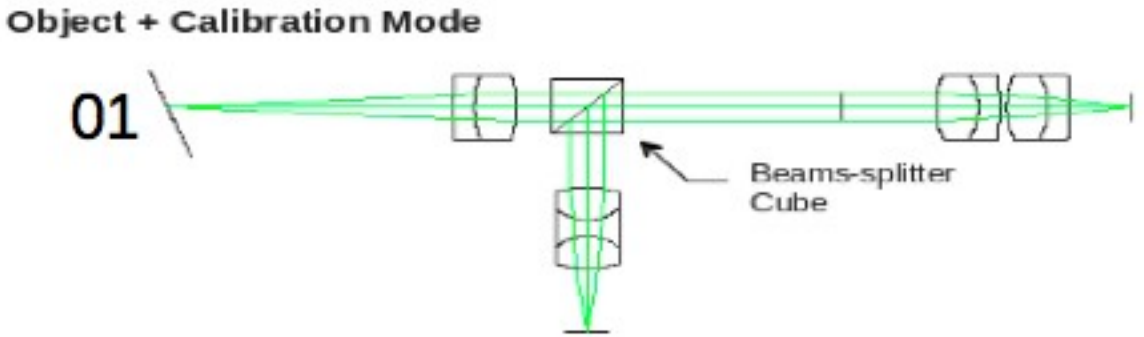
- HESP was installed at the telescope during September, 2015
- The on sky commissioning was performed at IAO Hanle.
- Remote observations of HESP were tested from CREST.
- HESP was released for observations in January 2017

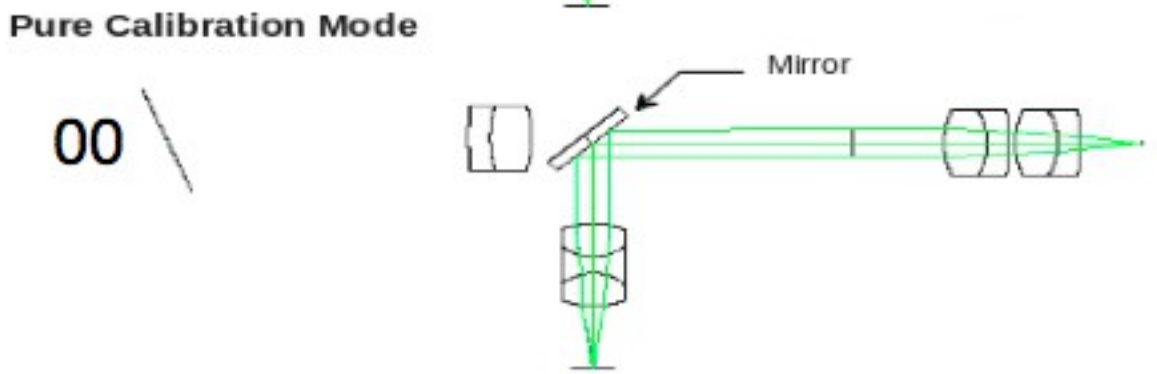
- The Cassegrain interface is mounted on one of the side ports of the instrument cube; the main spectrograph is located in the ground floor of the dome in a temperature controlled enclosure.

# HESP operating modes



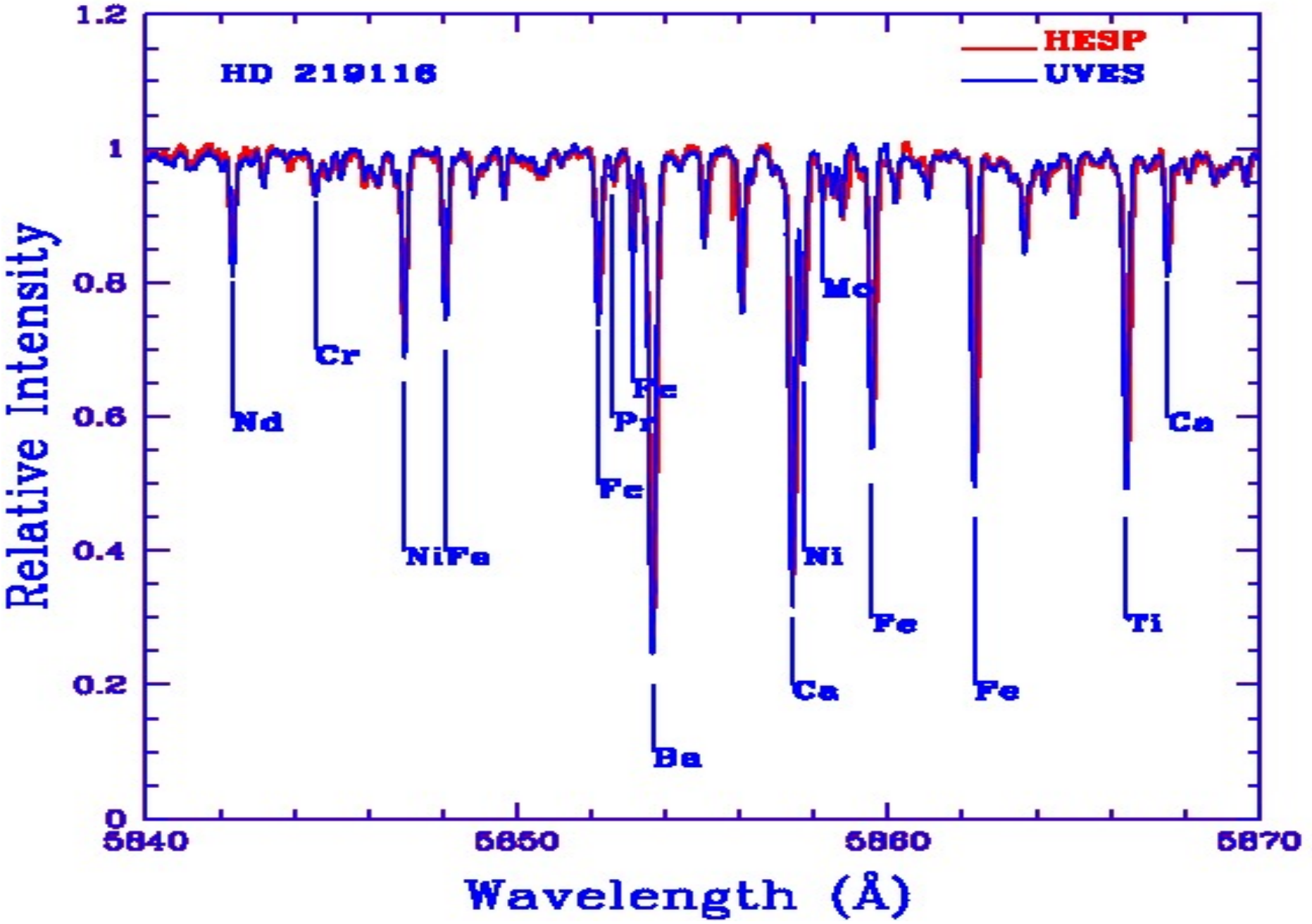





- Alignment mode allows pinholes, calibration and science fibres to be precisely aligned.
- Object and Sky mode is for pure observation.
- Object and Calibration mode is for simultaneous recording of object and calibration spectra for precision.
- Pure calibration mode is for calibration exposures between observations.
- Calibration fibre outputs will be at f/3.6.

Shutter behind Pinhole selects Fiber
00: Calib-Calib
01: Object-Calib / 10: Calib – Object
11: Object - Sky




A HESP sample spectrum HD 219116 compared with UVES spectrum

# Dust in the Solar system and the Milky Way

# Dust in the Solar system : comets

*Comet Hale-Bopp C/1995 O1*

Evening twilight next to the dome of the 1.2m telescope at MIRO

# Dust in the Solar system : comets

Instrumentation driven science

Optical Polarimeter on 1.2m telescope

LISA Spectrograph on 50cm telescope

Some of the results – 1985-2017

# Dust in the Solar system : comets

Optical Polarimetry at PRL (since mid 1980s)

Pioneering instrument in the country

Asoke Sen, U C Joshi, M R Deshpande : some of the earliest members involved in this work

Earlier observations (for Comet Halley) from Kavalur (VBO)
May 1990 onwards are from Mount Abu

Sunlight scattered by cometary dust is polarized
The observed polarization is a function of
- *Wavelength*
- *Phase angle of observation*
- *Refractive index of the particles*
- *Size distribution of the dust grains*

# Dust in the Solar system : comets

Optical Polarimetry on 1.2m telescope (since 1990)

**Current status:**
Instrument available for observations. All electronics modernized and all mechanical controls automated. Can now be used remotely

**Imaging polarimeter developed with an EMCCD as a detector**

# Dust in the Solar system : comets

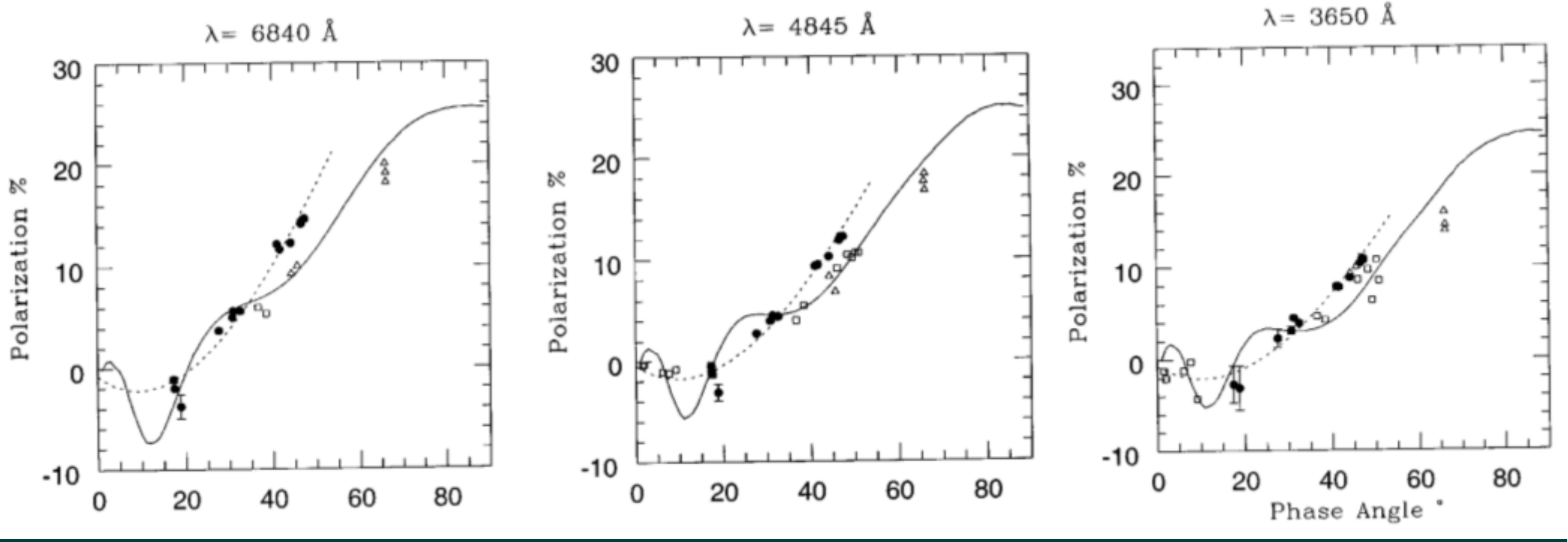
Comets studied using PRL instruments

1P/Halley
17P/Holmes
49P/Arend-Rigaux
C/1989 C1 (Austin)
C/1995 O1 (Hale-Bopp)
C/1996 B2 (Hyakutake)
C/2000 WM1 (LINEAR)
C/2001 Q4 (NEAT)
C/2007 N3 (Lulin)
C/2014 Q2 (Lovejoy)

C/2009 P1 (Garradd)
C/2012 S1 (ISON)
C/2013 A1 (SidingSpring)
C/2013 R1 (Lovejoy)
C/2010 S1 (LINEAR)
C/2012 L2 (LINEAR)
C/2012 K5 (LINEAR)
C/2012 J1 (Catalina)
246P NEAT
C/2017 O1 (ASAS-SN)

# Dust in the Solar system : comets

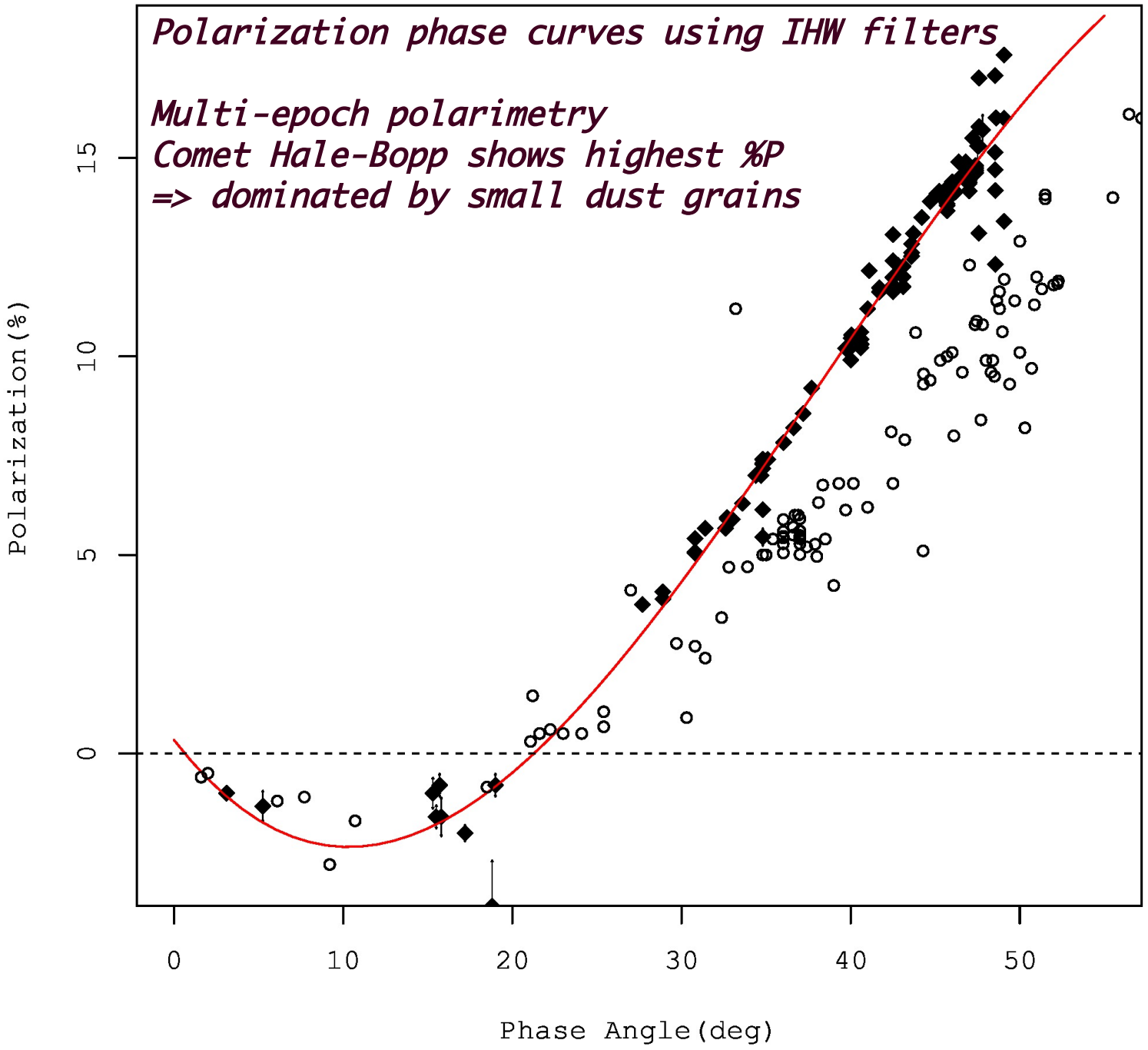
*Hale-Bopp polarization phase curves using IHW filters*




*S. Ganesh et al., A&AS 1998*

Multi-epoch polarimetry
Largest polarization observed for any comet so far
Much stronger wavelength dependence than Comet Halley

# Dust in the Solar system : comets



# Dust in the Milky Way Galaxy

## Dust in the Milky Way Galaxy

We are in the plane of the Galaxy - difficult to understand the structure due to uncertain extinction and distance ambiguity – effect of the dust clouds in the line of sight.

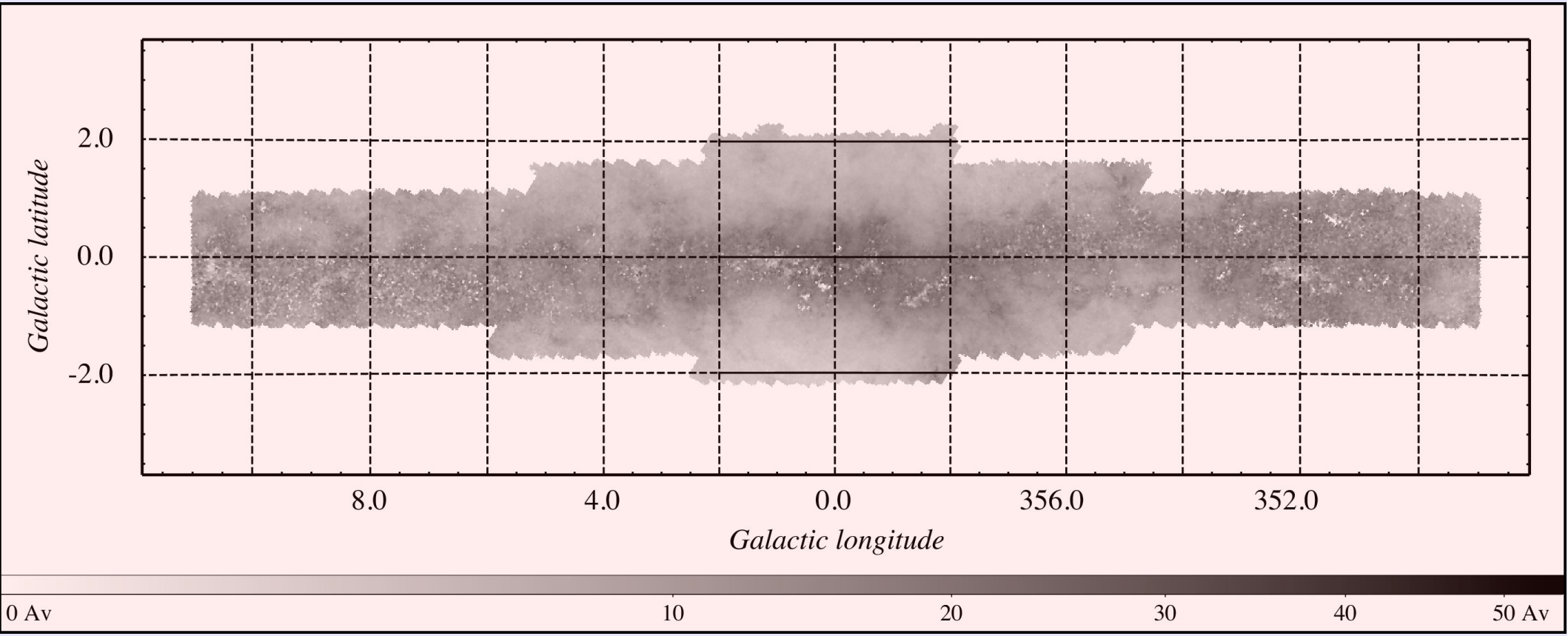
Make use of large scale, broad band, infrared surveys

- e.g. DENIS, 2MASS, etc
- Mid-infrared using observations from ISO (ISOGAL) and Spitzer (GLIMPSEs/GALCEN)

Trace the Red Clump stars in the field ...

# Inner bulge extinction map with 2MASS near IR photometry

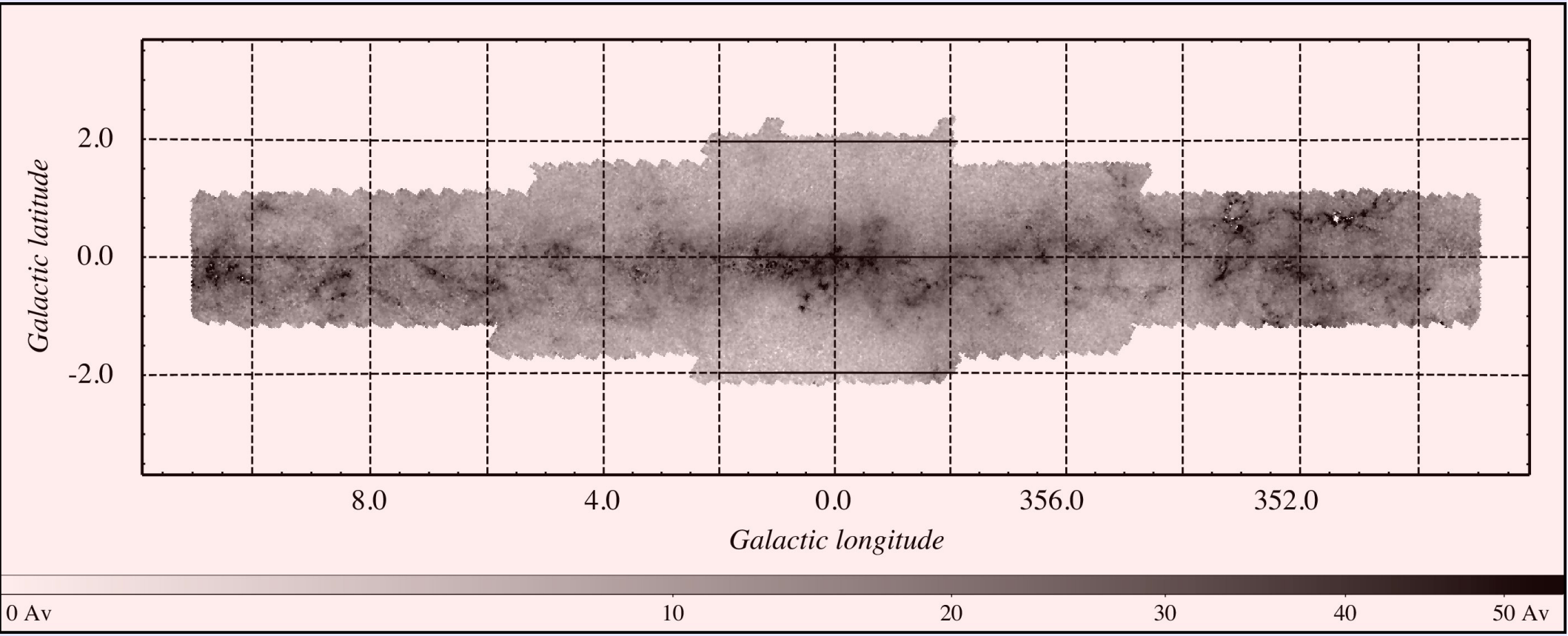
## Extinction map using J, Ks data and RGB isochrones




Extinction < 40Av only probed in NIR
(e.g. Schultheis, Ganesh, Simon et al., A&A 1999 – DENIS map)

# Inner bulge extinction map with Spitzer GLIMPSE-II & GALCEN

## Using MIR photometry + MIR RGB isochrones

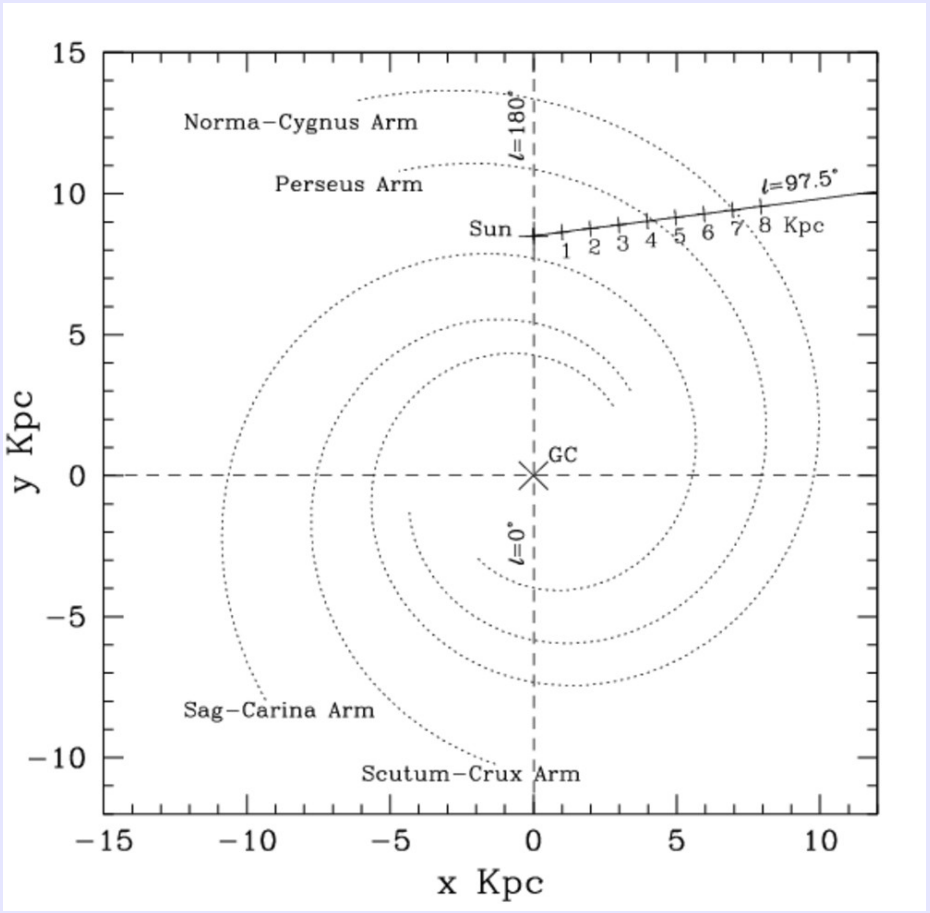



Extinction > 50Av

in some areas it is > 80Av

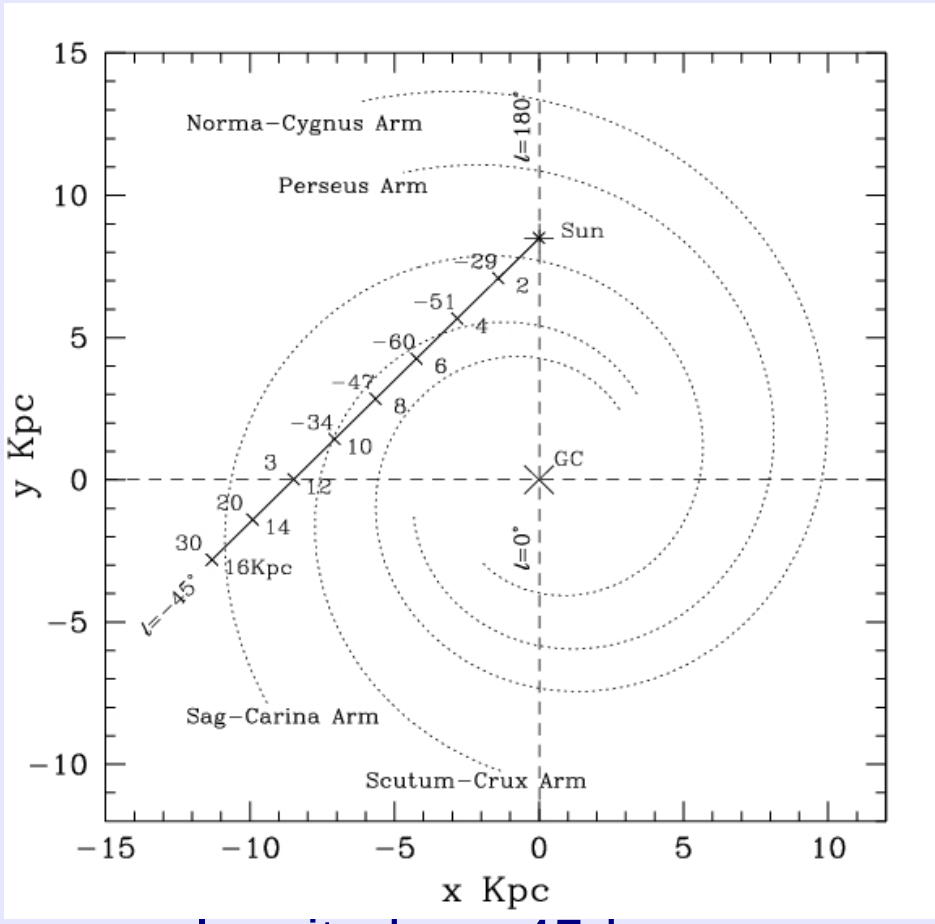
# Introduction

## Two directions in the Galactic plane (disk)




Galactic longitude = 97deg

Northern sky

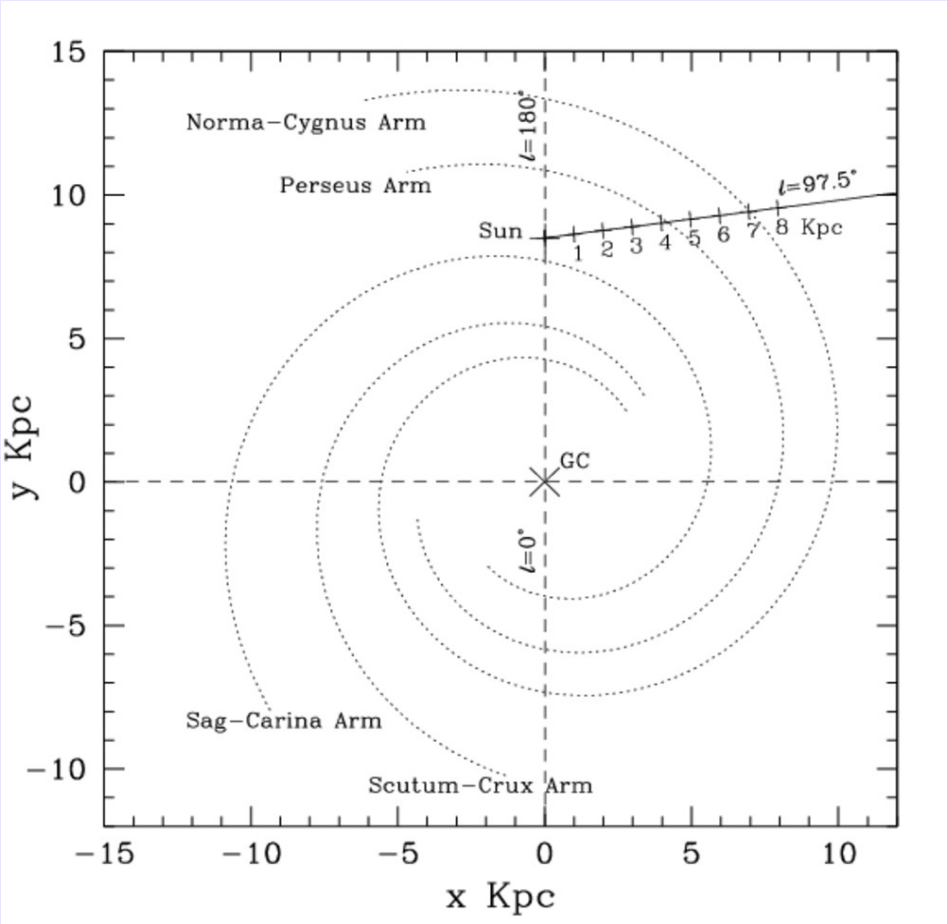



longitude = -45deg

Southern sky

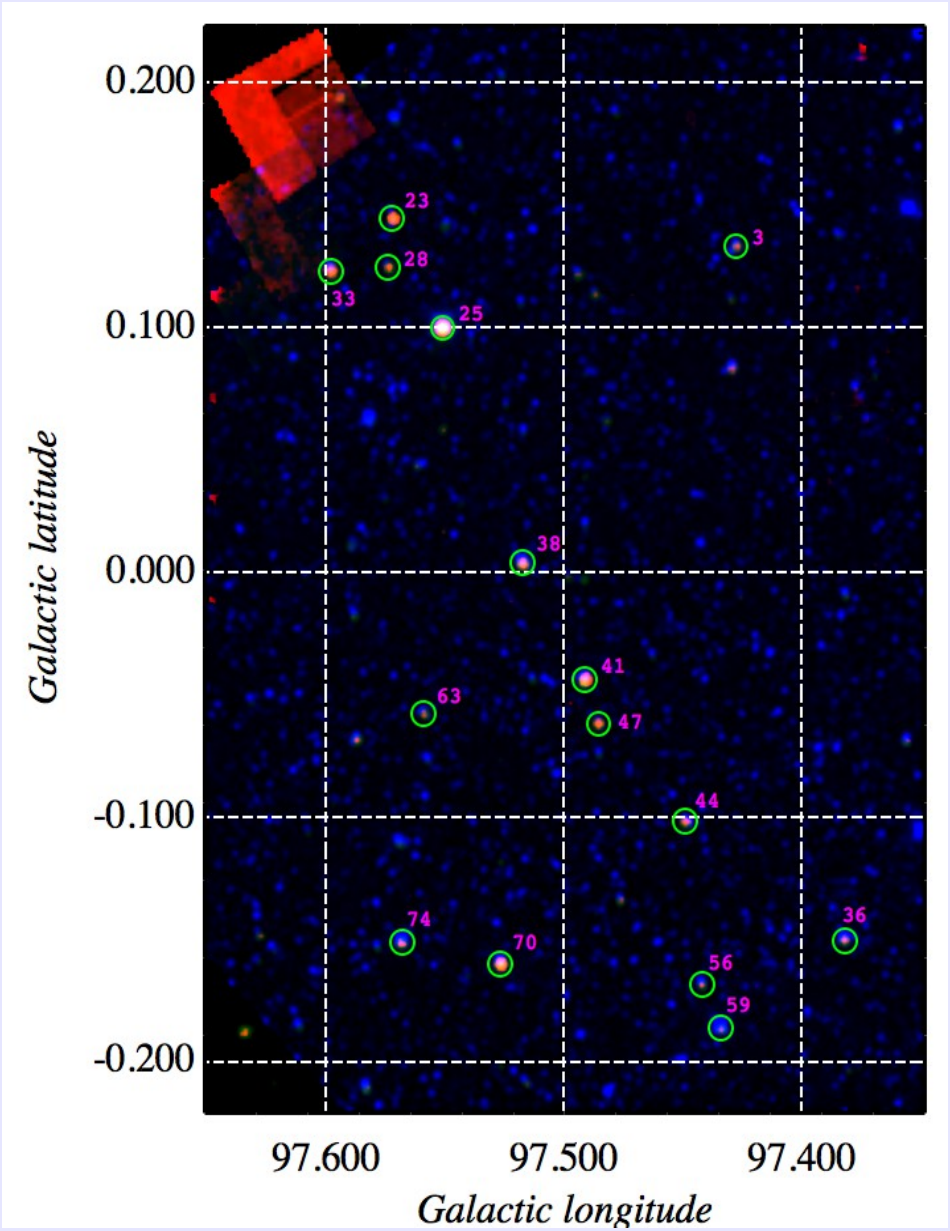
... bulge

# Interstellar extinction and polarisation in L97 field

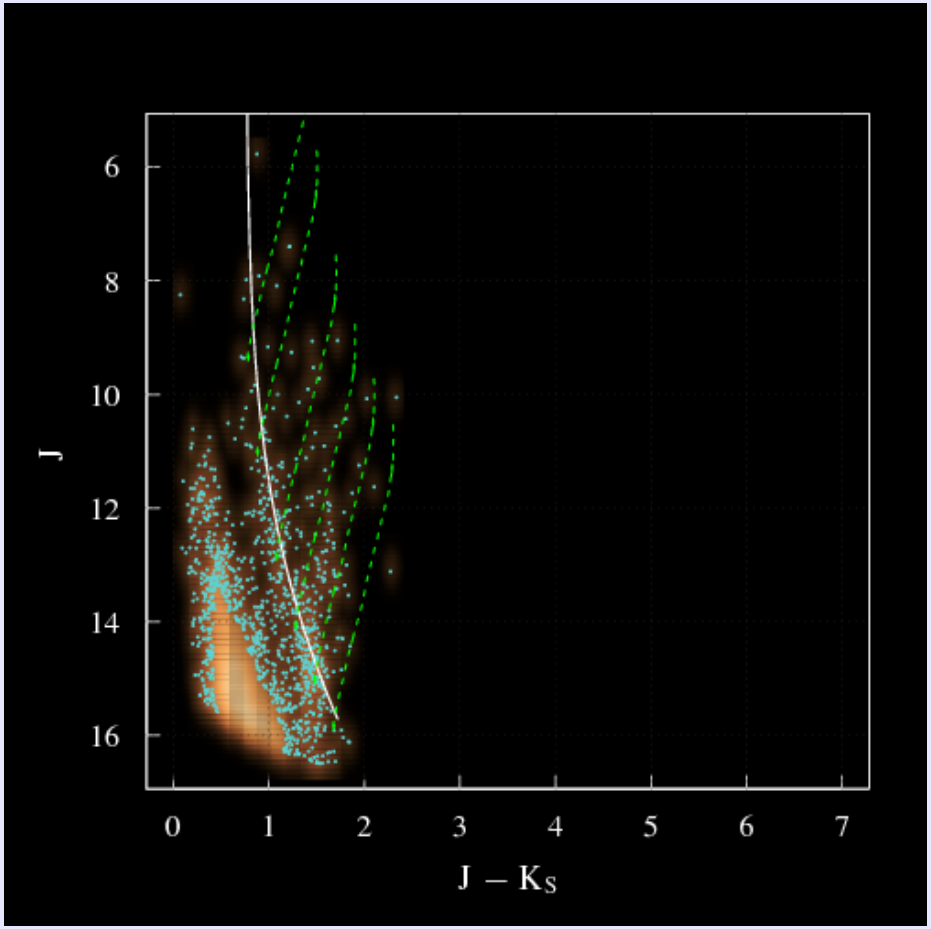



The L97 direction

*(Ganesh et al., in prep)*



# Interstellar extinction and polarisation in L97 field




Full CMD

$$J = M_J + 5\log(d/10) + c_J(d/1000)$$
$$J - K_S = M_J - M_{K_S} + (c_J - c_{K_S})(d/1000)$$

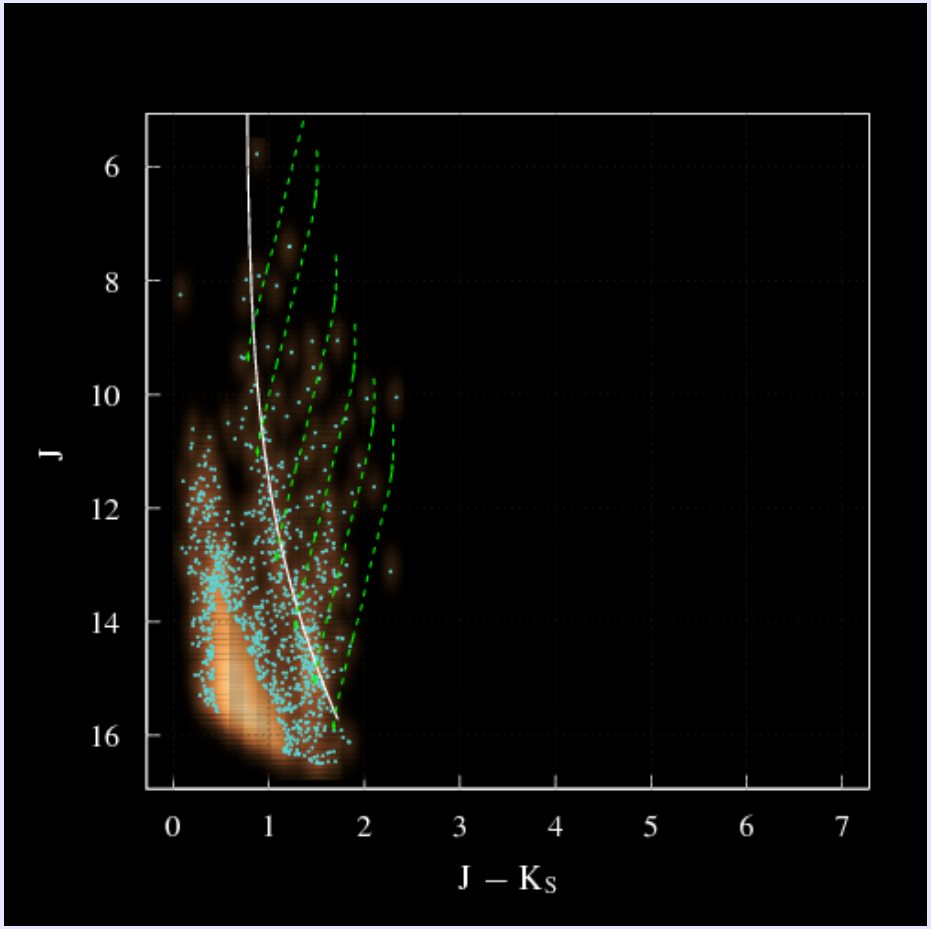
For red clump stars (K2 giants)

$M_J$ = -0.95 and $M_{Ks}$ = -1.65 mag

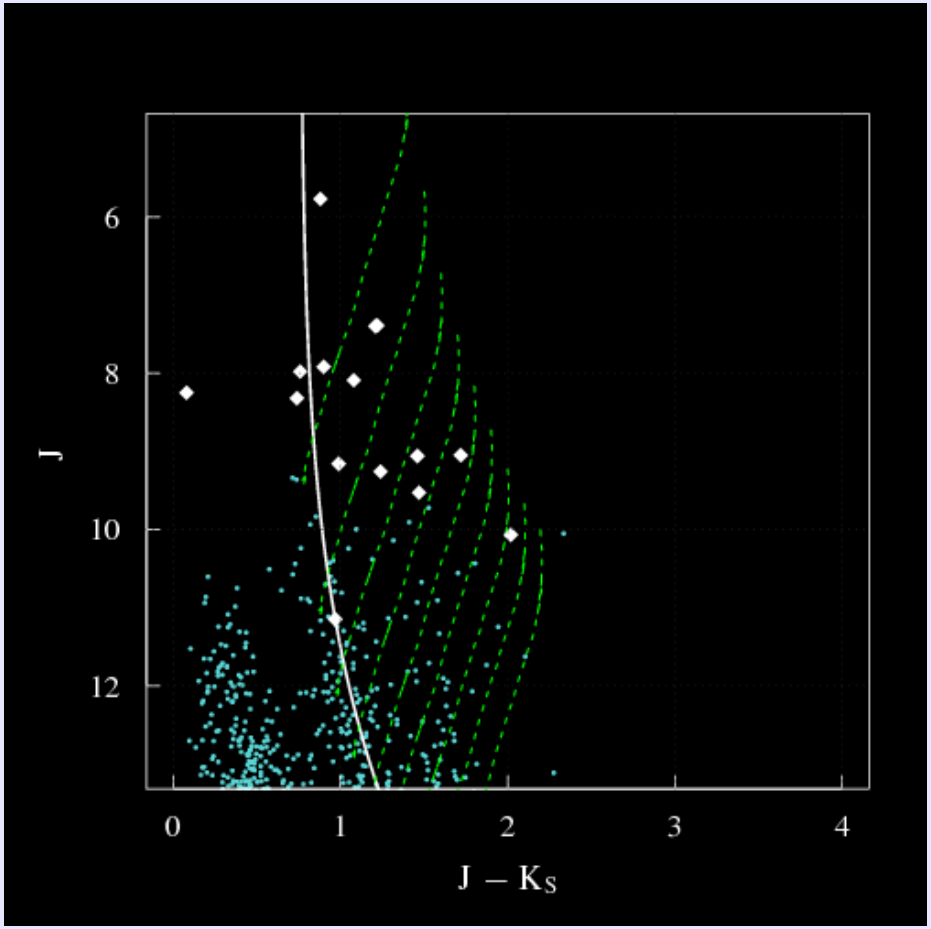
white curve : RC locus

green dotted curves : RGB isochrones

# Interstellar extinction and polarisation in L97 field

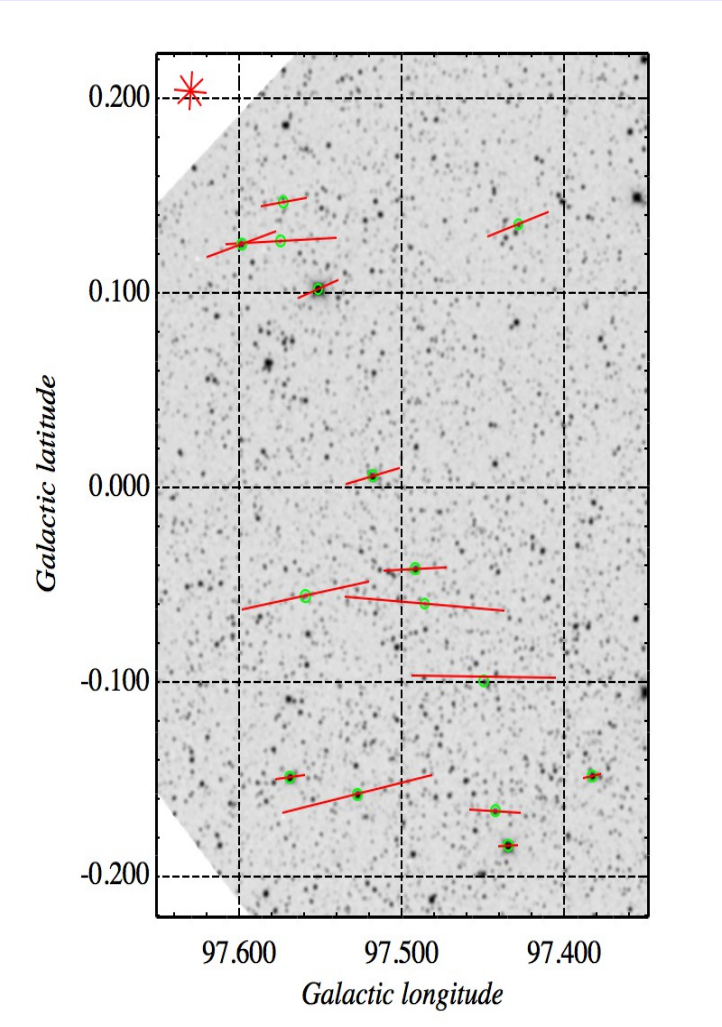



Full CMD

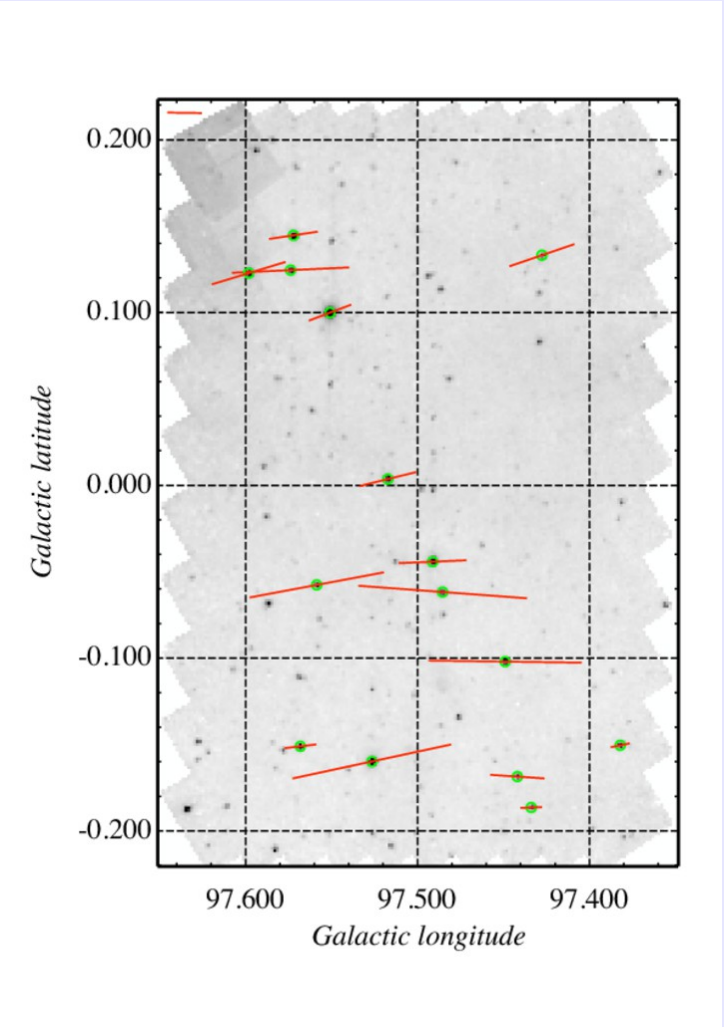



Observed for polarisation
in optical bands (large dots)

# Interstellar extinction and polarisation in L97 field

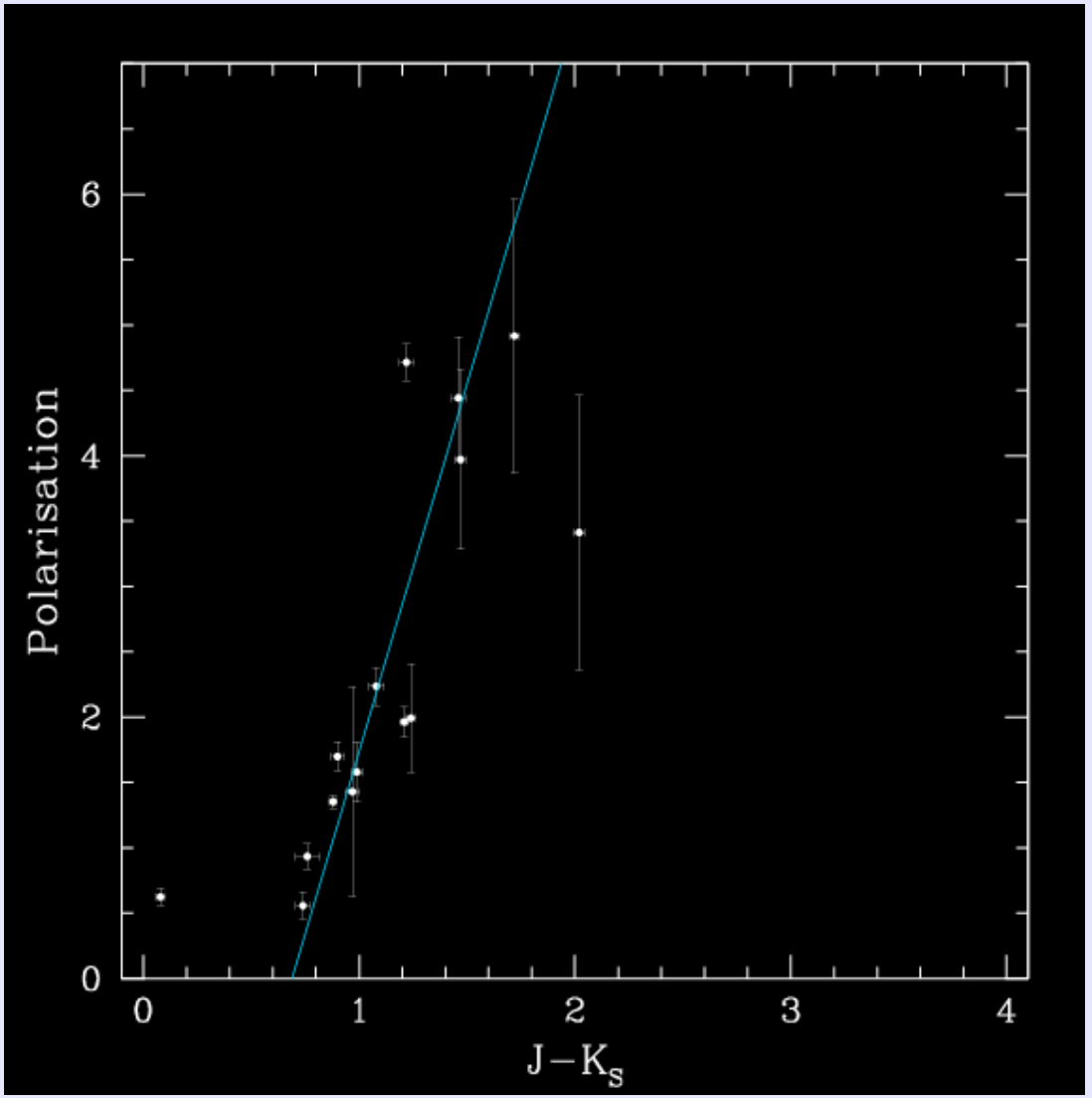



DSS image



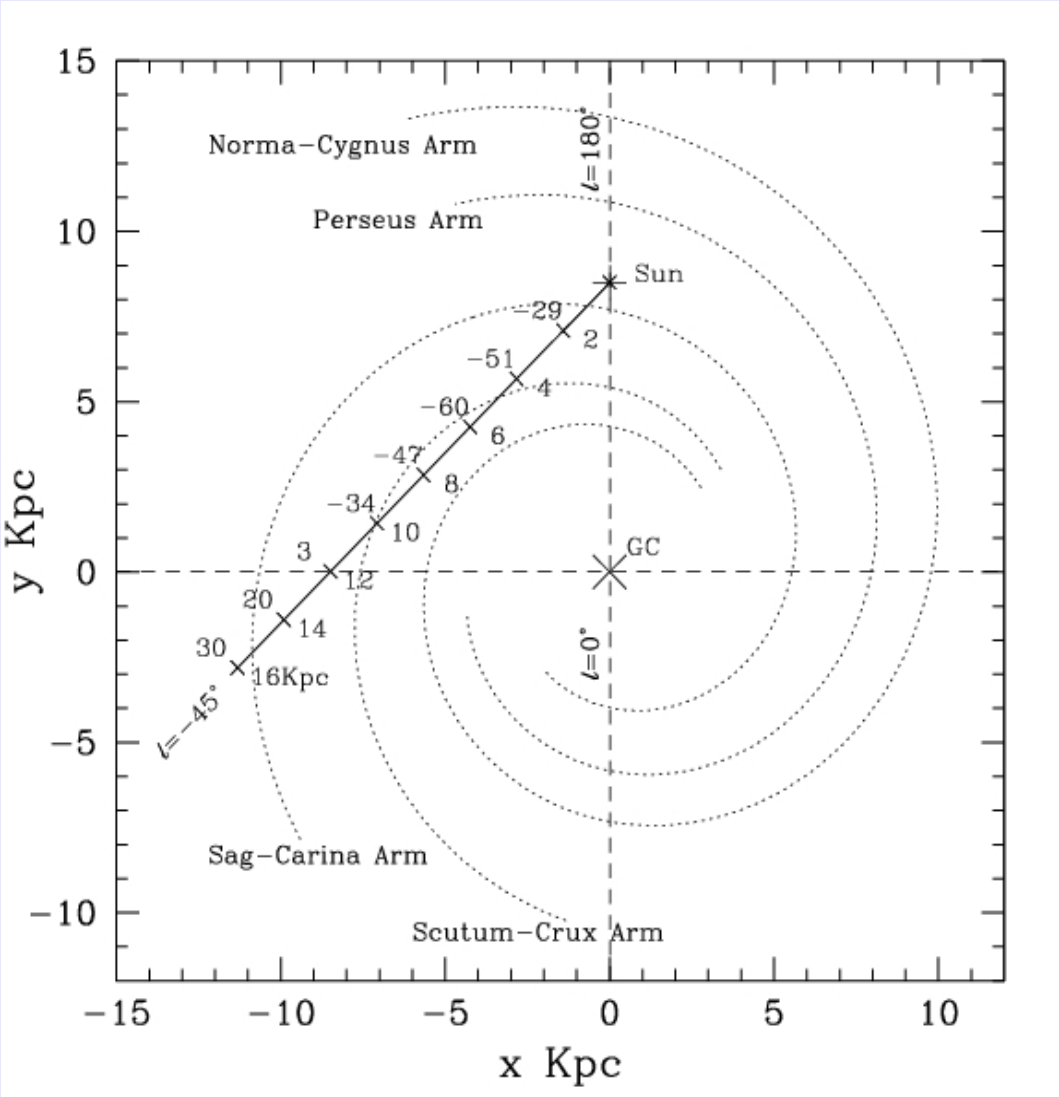

ISOGAL 7 micron

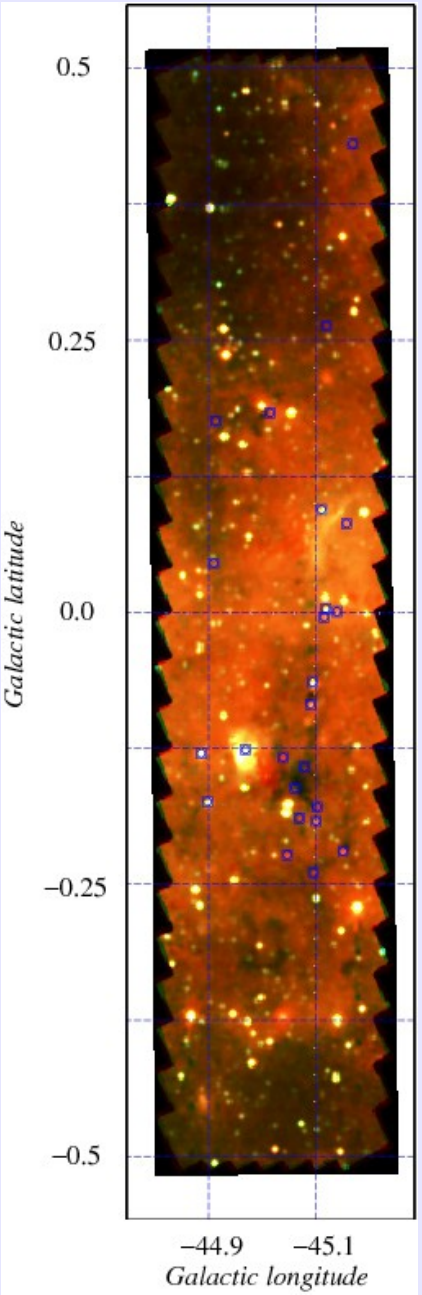
# Interstellar extinction and polarisation in L97 field




R band Polarisation vs near-infrared colour

# Stellar populations in an ISOGAL field in the galactic disc

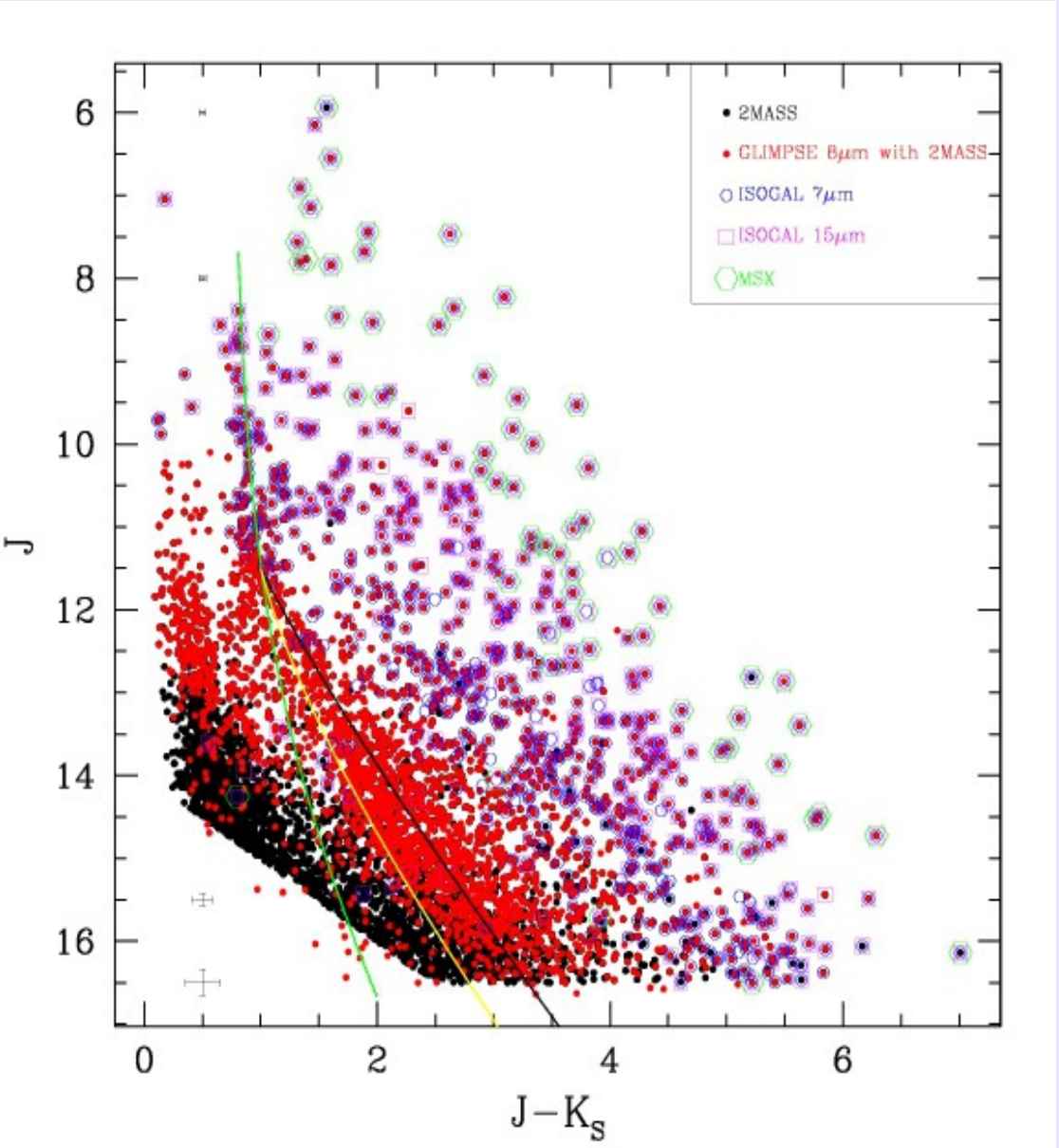



## The LN45 direction

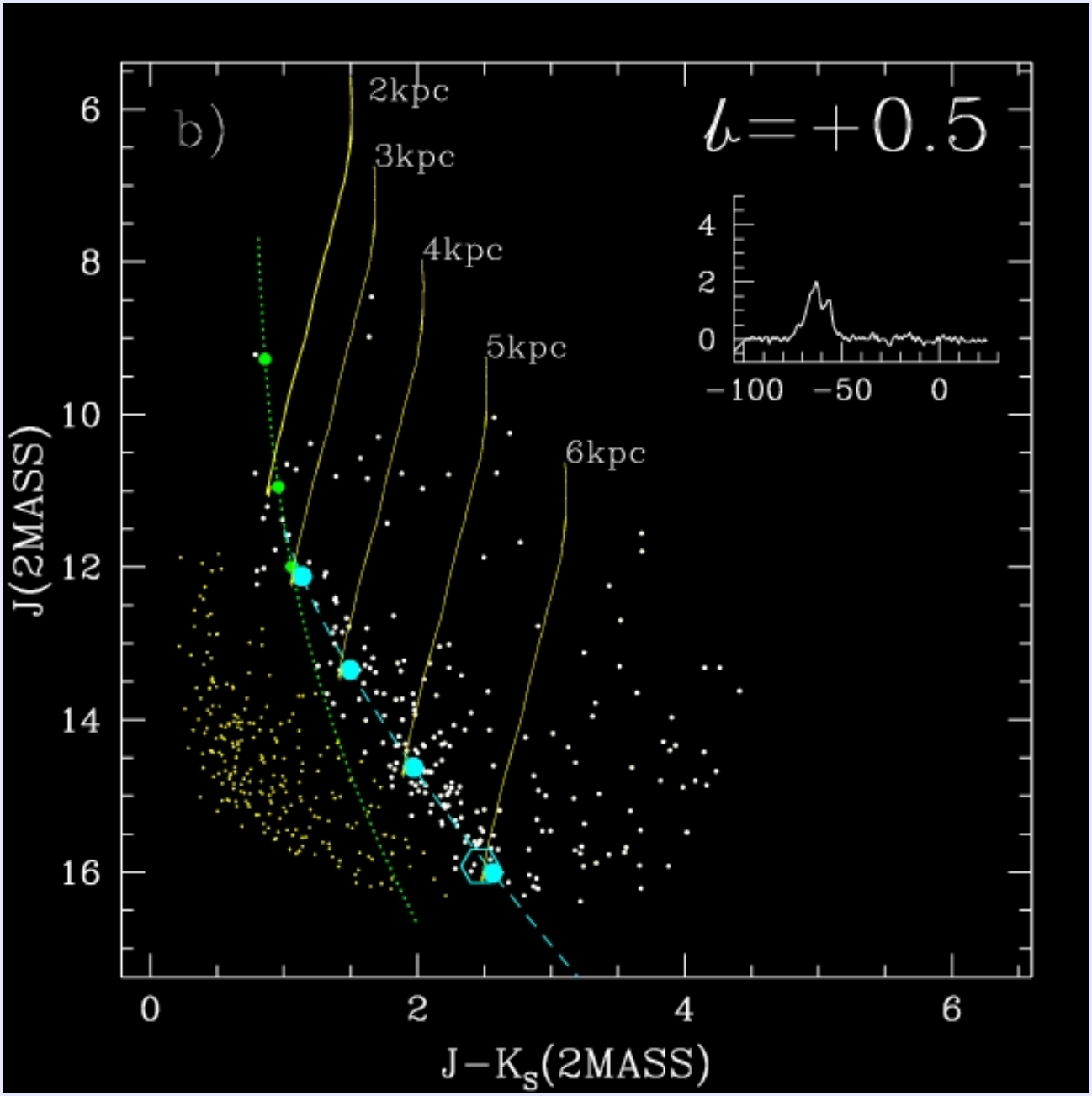
*(Ganesh, Omont, Joshi et al., A&A 2009)*

# Stellar populations in an ISOGAL field in the galactic disc

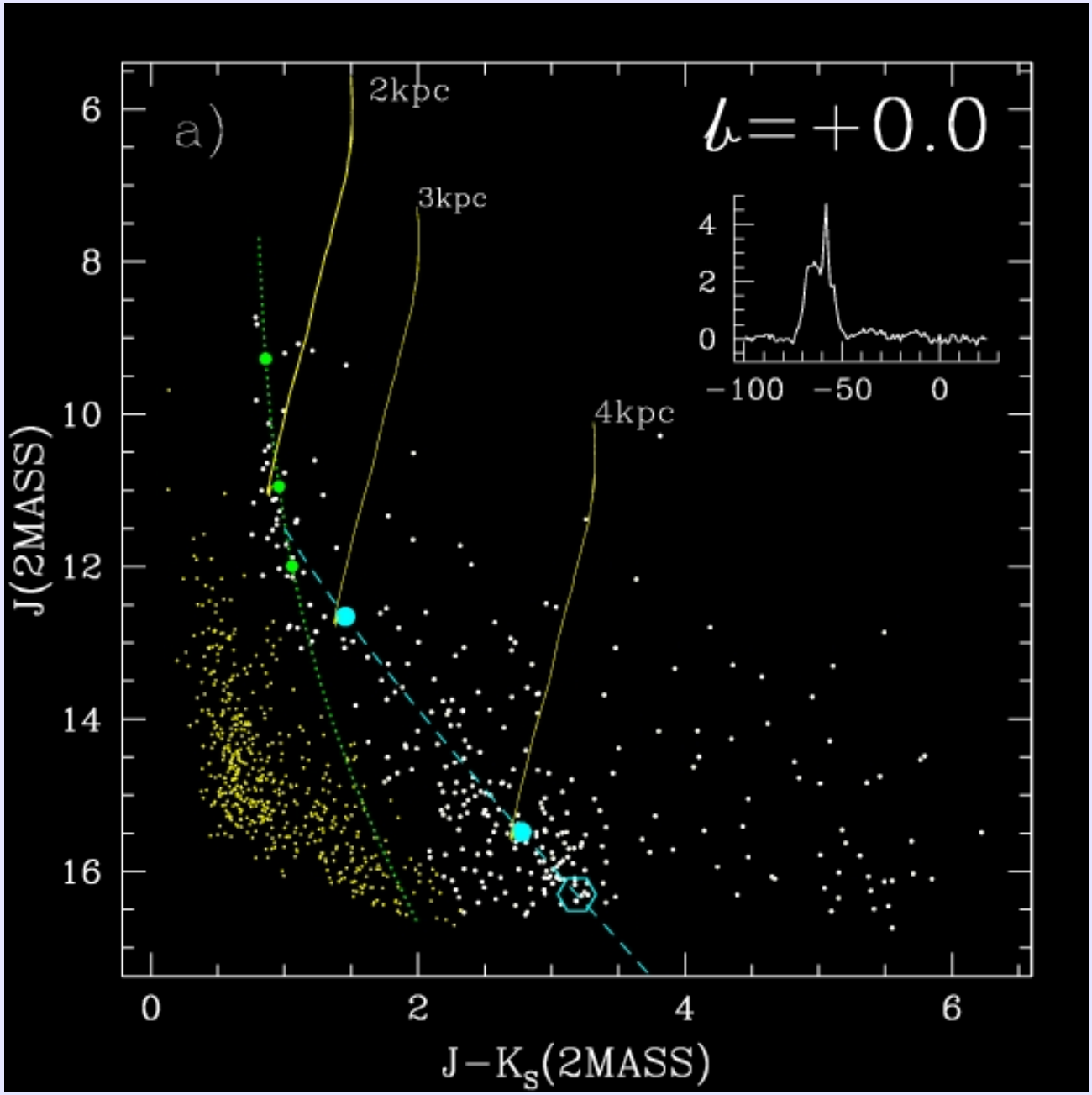



2MASS CMD with detections in various surveys

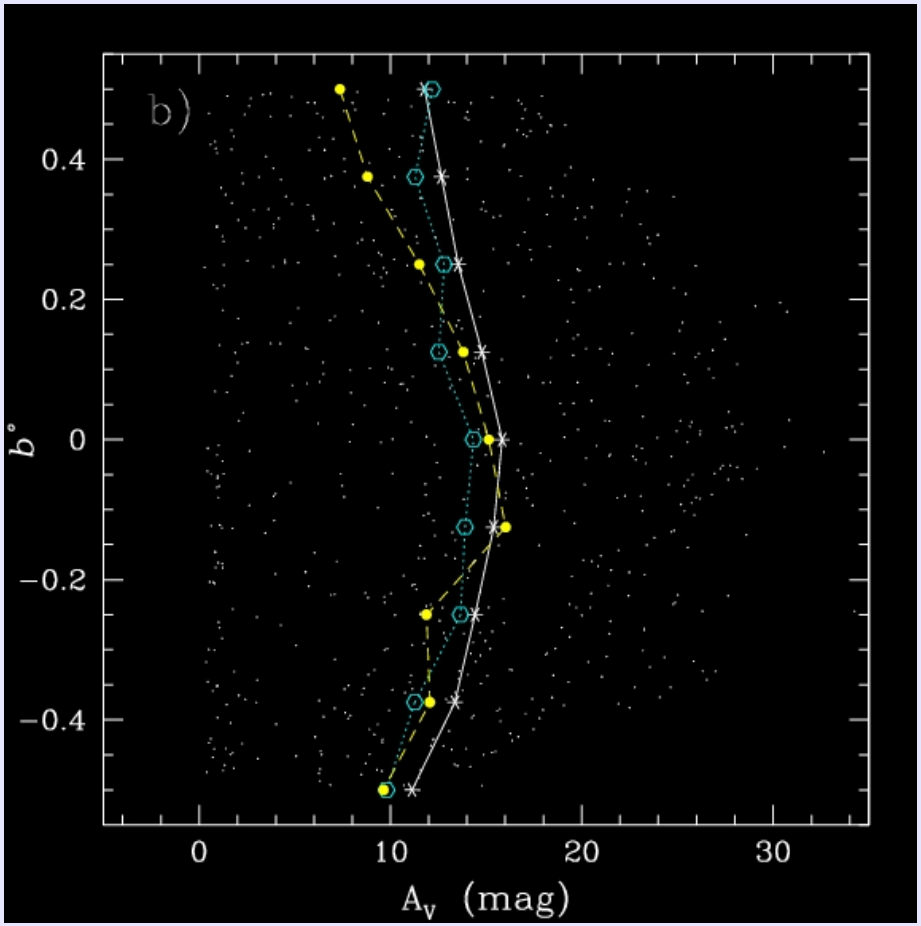
# Stellar populations in an ISOGAL field in the Galactic disc

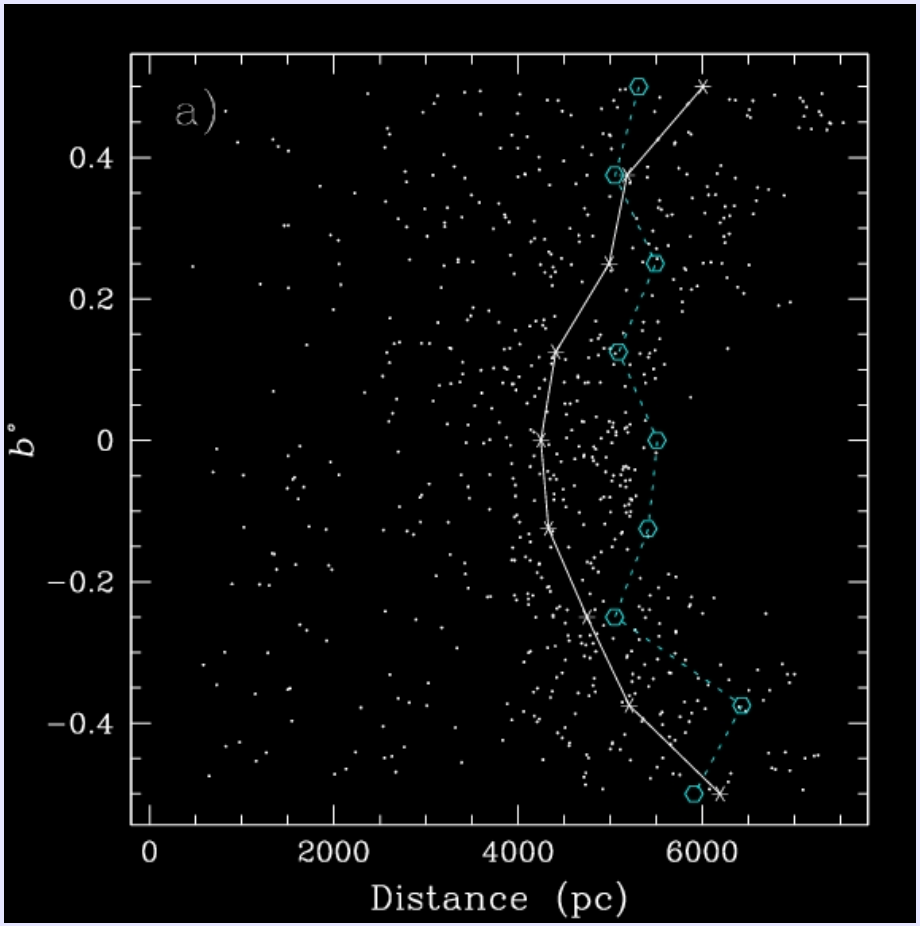


# Stellar populations in an ISOGAL field in the Galactic disc



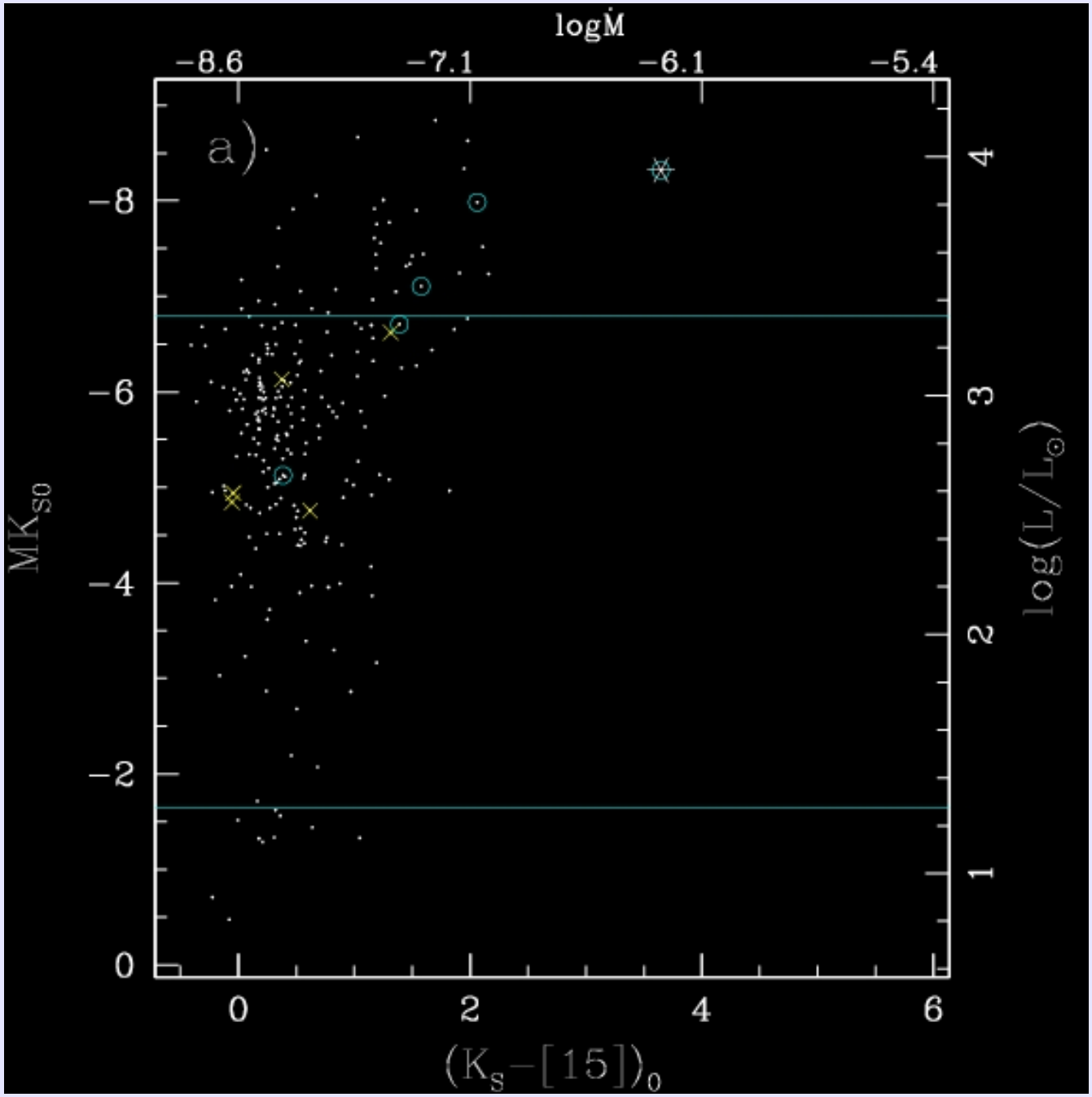
# Stellar populations in an ISOGAL field in the Galactic disc




The LN45 direction : Av and distance with latitude leading edge of the Scutum-Crux spiral arm (4kpc)

# Stellar populations in an ISOGAL field in the Galactic disc



## Summary

- Extinction (~80mag Av) mapped towards inner bulge (2' resolution)
- Estimate distance, extinction for stars in a field towards l=97, b=0
- Optical polarisation measured for mid-infrared selected stars in this field – found to have linear relation with infrared colours
- Estimate distance, extinction for stars in a large field at l=-45
- Towards l = -45, $c_J$ varies with distance and latitude
- In this field the AGB stars found to have ~ small mass-loss rates
- Large scale NIR surveys not deep enough to probe beyond the edge of first spiral arm in line of sight in directions with large extinction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