

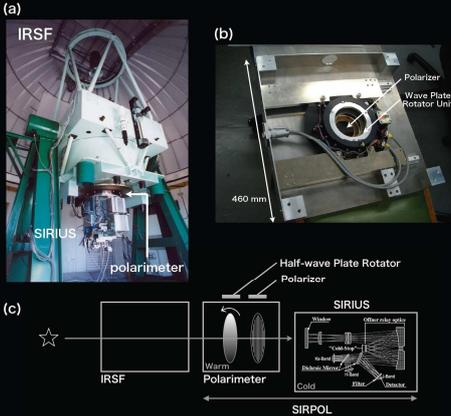
# Wide-field NIR imaging polarimetry of massive star-forming regions with SIRPOL

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## ABSTRACT

We present for the first time wide-field (8'x 8'; ~1 pc) near-infrared polarization images of massive star-forming regions. We discuss the details of polarized Infrared Reflection Nebulae (IRNe) and compare magnetic fields of some regions derived from our near-infrared polarization data and the previous sub-millimeter polarization data.

## 1. IRSF/SIRPOL (First light of polarimetry mode : Dec 2005 -)



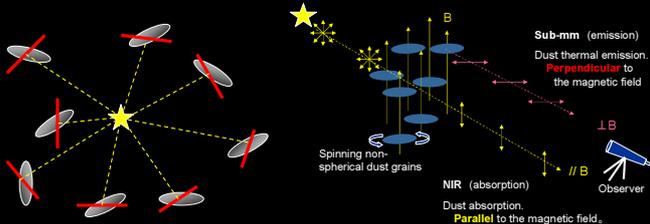
- (a) IRSF 1.4 m telescope with SIRIUS camera in South Africa
- (b) Polarimeter (half waveplate + polarizer) installed upstream of the camera at room temperature
- (c) A schematic illustration of IRSF/SIRPOL

## 2. Performance of SIRPOL

- JHKs-simultaneous imaging polarimetry (linear or circular)
- FoV : 7.7' x 7.7' (1k x 1k x 3 band, 0.45"/pixel)
- Band : J (1.25 micron), H (1.63), Ks (2.14)
- Sensitivity (point source, expos. = 60 min) :
  - Intensity meas.
    - J = 19.2 mag, H = 18.6, Ks = 17.3
  - Polarization meas.
    - J < 16.5 mag, H < 15.7, Ks < 14.5 (dP < 1%)
    - 1% polarimetry can be available for all the 2MASS stars.
    - (dP ~ 0.3% for bright sources)
- Polarization efficiency :
  - J = 95.5%, H = 96.3, Ks = 98.5
- Telescope site :
  - Sutherland, South African Astronomical Observatory
  - Altitude : 1760 m
  - Typical seeing : 0.9 - 1.4" at J

## 3. Science

- Scattered light polarimetry ( $E \perp$  illuminating direction)
  - Determination of IR-nebula's illuminating sources
  - Dust properties
- Background star polarimetry ( $E \parallel B$ )
  - Magnetic field structure in star-forming regions
- Synchrotron radiation ( $E \perp B$ )
  - Magnetic field structure (e.g., SNR)



Scattered light polarization

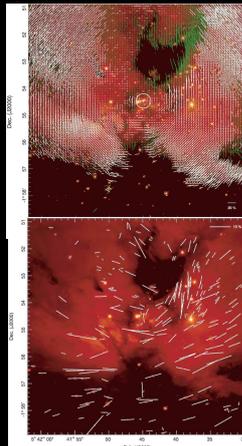
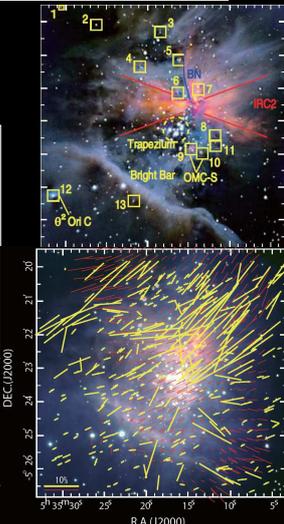
Polarization produced by magnetically aligned dust grains

## 4. NIR polarimetry of massive SF regions with SIRPOL

### OMC-1

- is one of the nearest massive star-forming regions.
- Discovery of a large bipolar IRN associated with IRc2
- Clear revealing of an IRN associated with BN object
- 13 IRNe associated with low- to intermediate-mass YSOs
- Good consistency between NIR and 350  $\mu$ m vectors
- First detection of 10 brown dwarf's polarizations

(Right top: NIR three-color composite images of the Orion Nebula in polarized intensity. Tamura et al. 2006, Right bottom: H band (yellow) and 350  $\mu$ m (red) polarization vectors, overlaid on a JHKs composite color image. Kusakabe et al. 2007 submitted)



### NGC2024

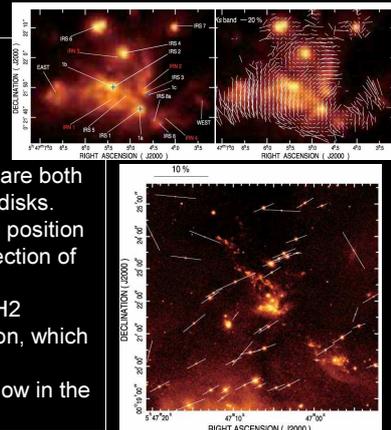
- is a massive star-forming region in the Orion B giant molecular cloud.
- A prominent and extended polarized nebula over NGC 2024
- Five small polarized nebulae associated with YSOs.
- The position angle of projected magnetic field across the region is 110°.
- 64 highly polarized sources and five brown dwarfs as candidates associated with circumstellar material.

(Left top: Polarization vector map on the intensity image at H. Whit plus symbol indicate expected location of the illuminating source of NGC2024. Left bottom: Polarization vector of each stellar source on H intensity image. See, Kandori et al. 2007)

### NGC2071

- star-forming region lies in the northern part of the Orion B molecular cloud.
- There are four IRNe in NGC2071IR.
- The polarized position angle IRS 1 and IRS 3 are both consistent with the orientations of the compact disks.
- The projected magnetic fields are running at a position angle of 120°, which is perpendicular to the direction of the large-scale outflow.
- The dominant knotty nebulae of the shocked H2 emission are polarized due to dichroic absorption, which is consistent with the projected magnetic fields.
- The field strength is too weak to align the outflow in the large-scale field direction via magnetic braking.

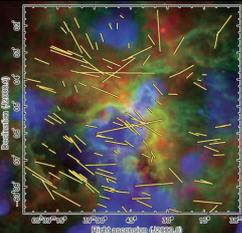
(Right top: Ks band polarization vector map and Ks band identification map of the central NGC 2071IR cluster region superposed on the intensity image. Right bottom: Ks band polarization map of point-like sources superposed on the intensity image. See Tamura et al. 2007)



### 30 Dor

- located in the Large Magellanic Cloud, is the most studied star-forming region outside the Galaxy.
- First NIR polarimetric observation toward a central part of 30 Dor
- A clear association of the magnetic field and an expanding shell structure

(Left: Comparison of the H band polarization vectors with the shell structures toward 30Dor. Fig 15 of Townsley et al. (2006) is underlaid; red = mid-infrared Spitzer IRAC image, green = H  $\alpha$  from the Magellanic Clouds Emission-Line Survey (Smith et al. 2000). Blue = X-ray by Chandra ACIS 900-2300eV. See Nakajima et al. 2007.)



## References

- Tamura, M., et al. 2006, ApJ, 649, L29; Tamura, M., et al. 2007, PASJ, 59, 467; Kandori, R., et al. 2006, Proc. SPIE, 6269, 6262951; Kandori, R., et al. 2007, PASJ, 59, 487; Nakajima, Y., et al. 2007, PASJ, 59, 519; Kusakabe et al. submitted.