Study of the Galactic Center Region and the Super Massive Black Hole Sgr A* with Near-Infrared Polarimetry

近赤外線偏光観測で探る銀河系中心部と巨大ブラックホールSgr A*

Tetsuya Nagata (Dept Astronomy)

長田哲也（宇宙物理学教室）

Outline :

1. What is Sgr A*?

2. Sgr A* Flare Polarimetry

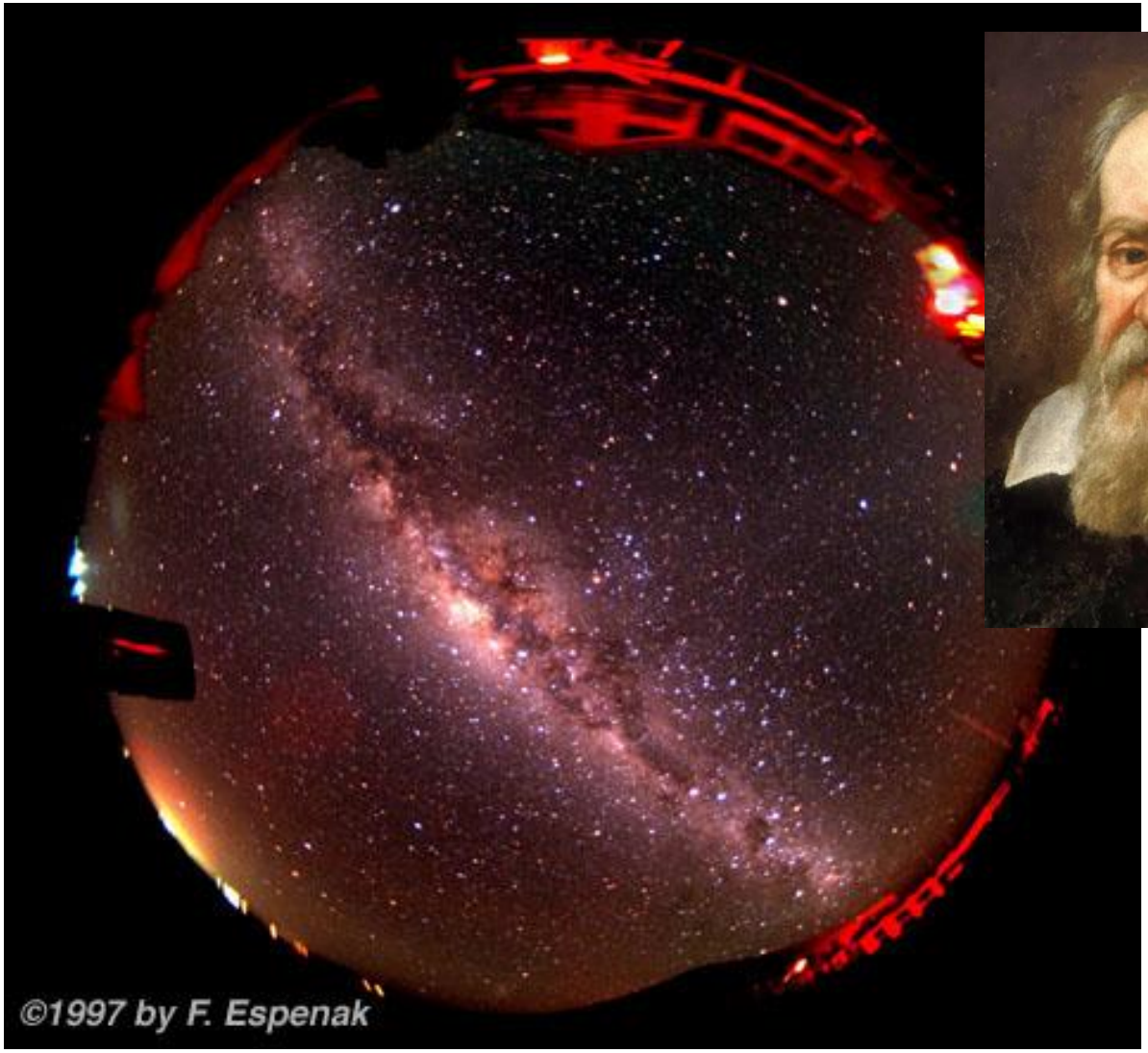
   Nishiyama et al. 2009 ApJ 702 L56

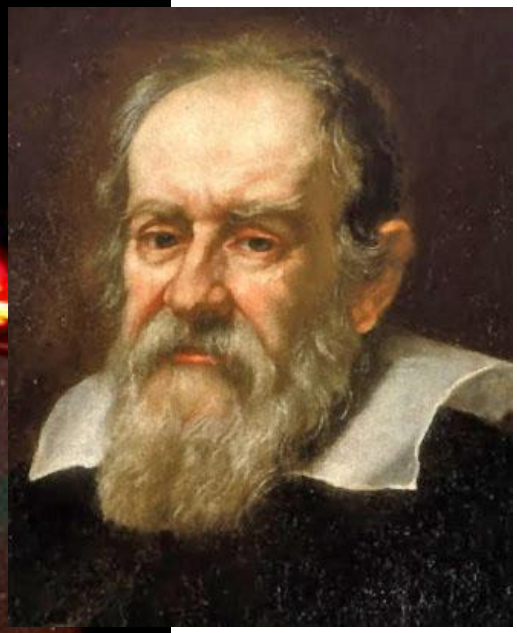
   Poster 68

3. Galactic Center Magnetic Field

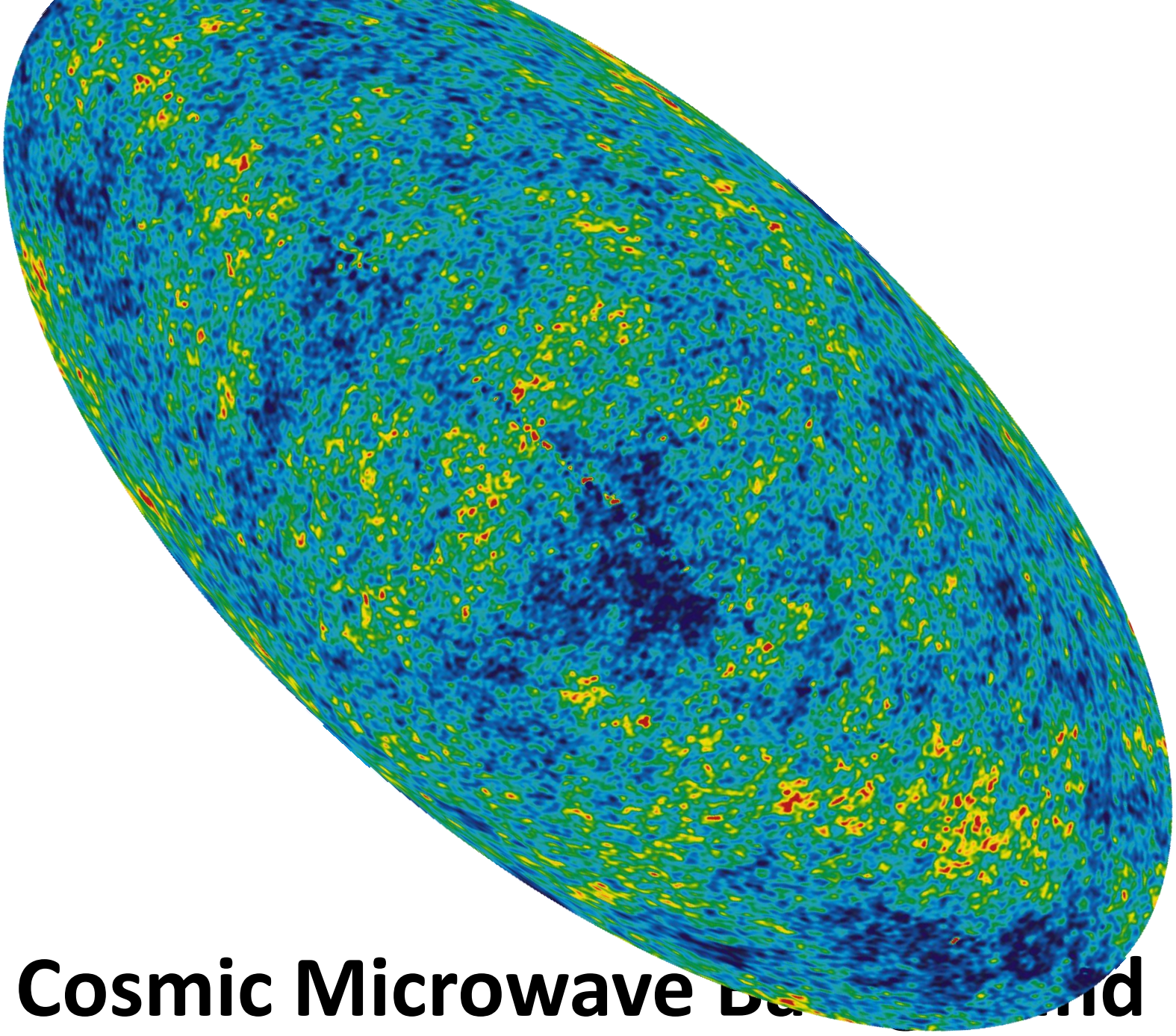
   Nishiyama et al. in prep

Looking up at the sky,

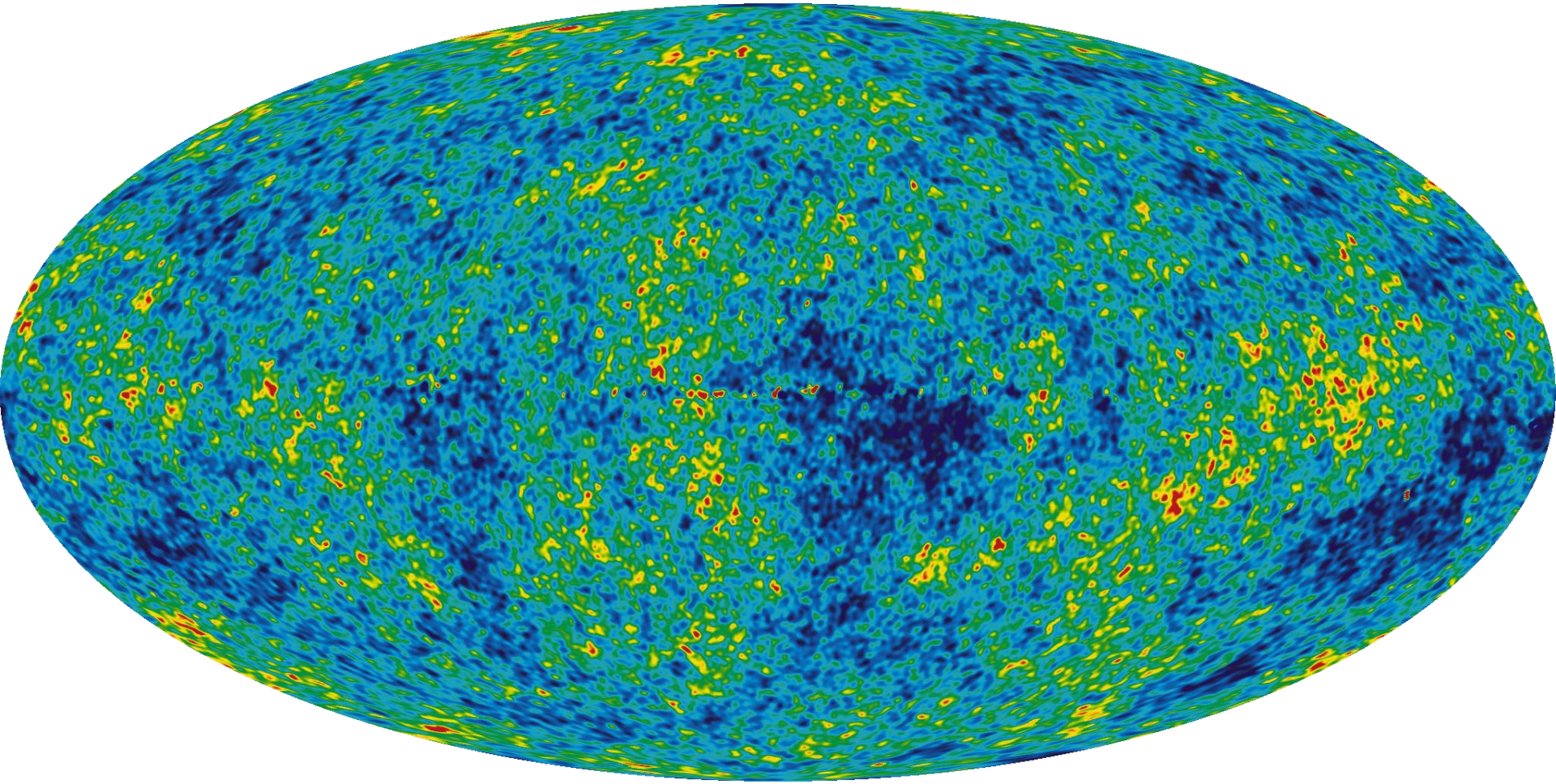




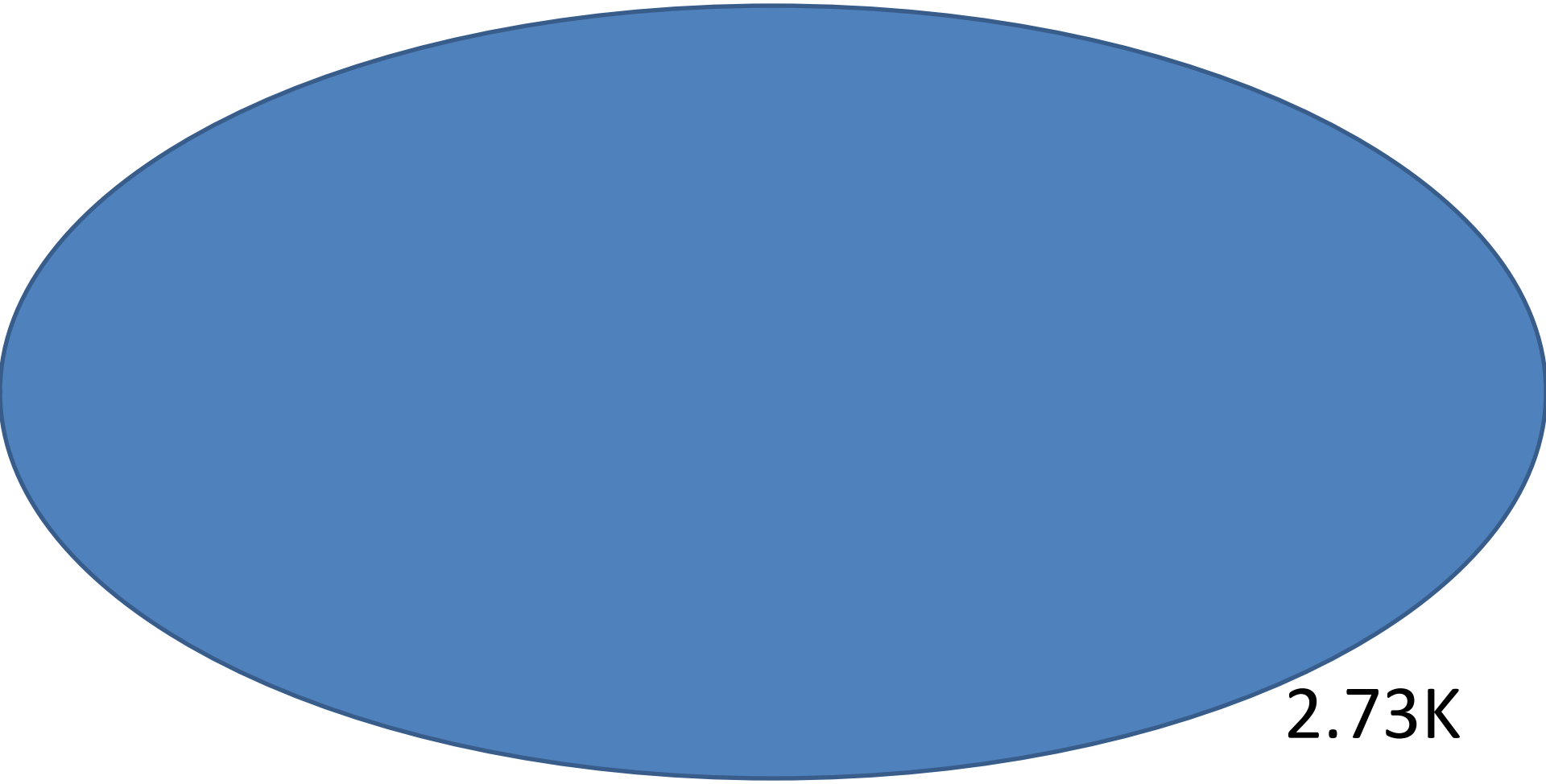
All sky image **from Southern hemisphere**



Cosmic Microwave Ba nd



Cosmic Microwave Background



Cosmic Microwave Background

Cosmic Microwave Background

(Cover Page, **Physics Today 1992) COBE DMR**

http://lambda.gsfc.nasa.gov/product/cobe/dmr_image.cfm

Dipole Component

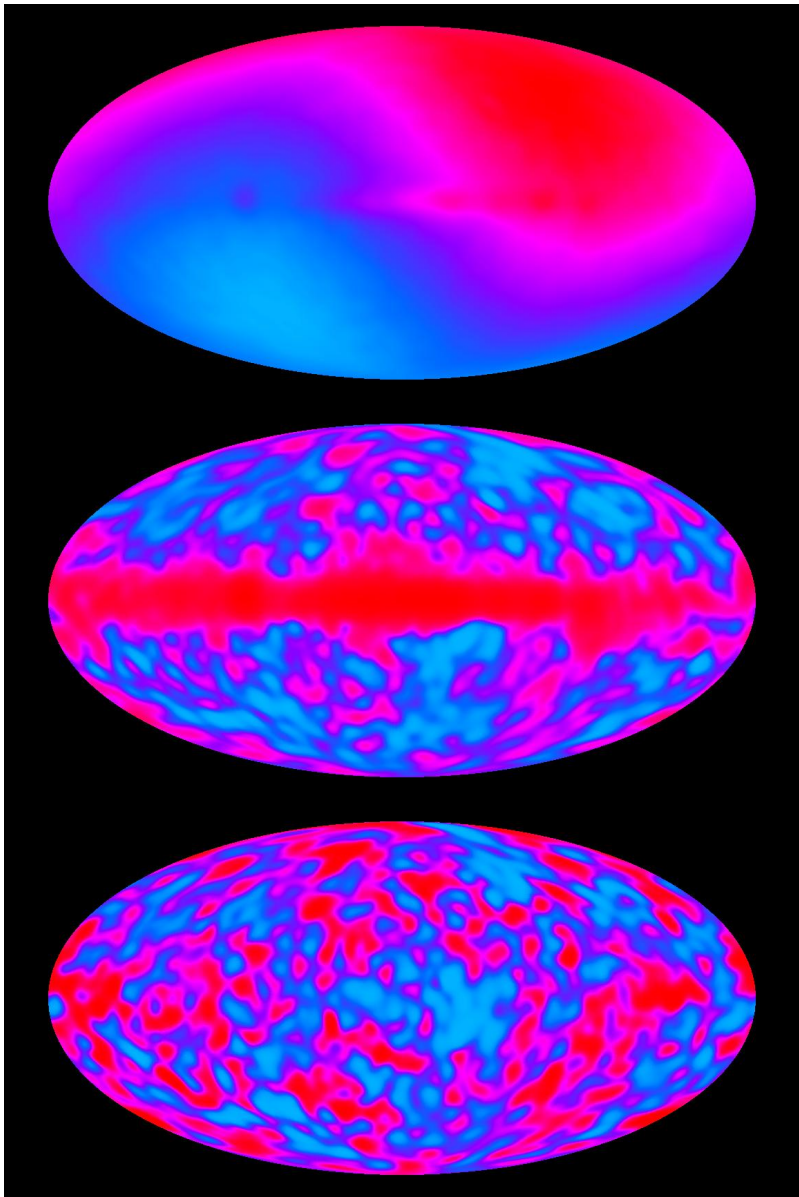
10^{-3}

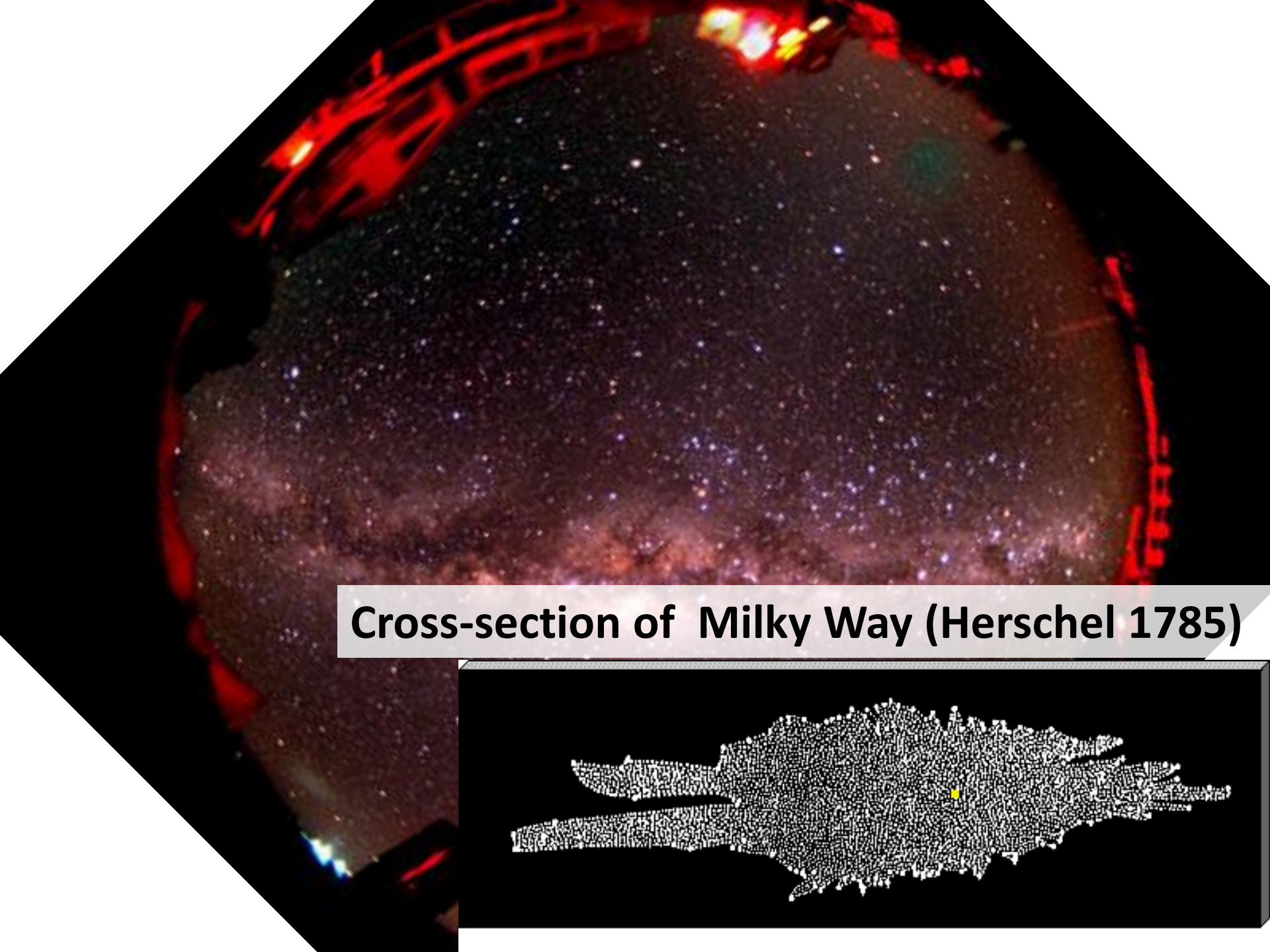
With Galactic Component

10^{-5}

Without Galactic Component

10^{-5}





Cross-section of Milky Way (Herschel 1785)

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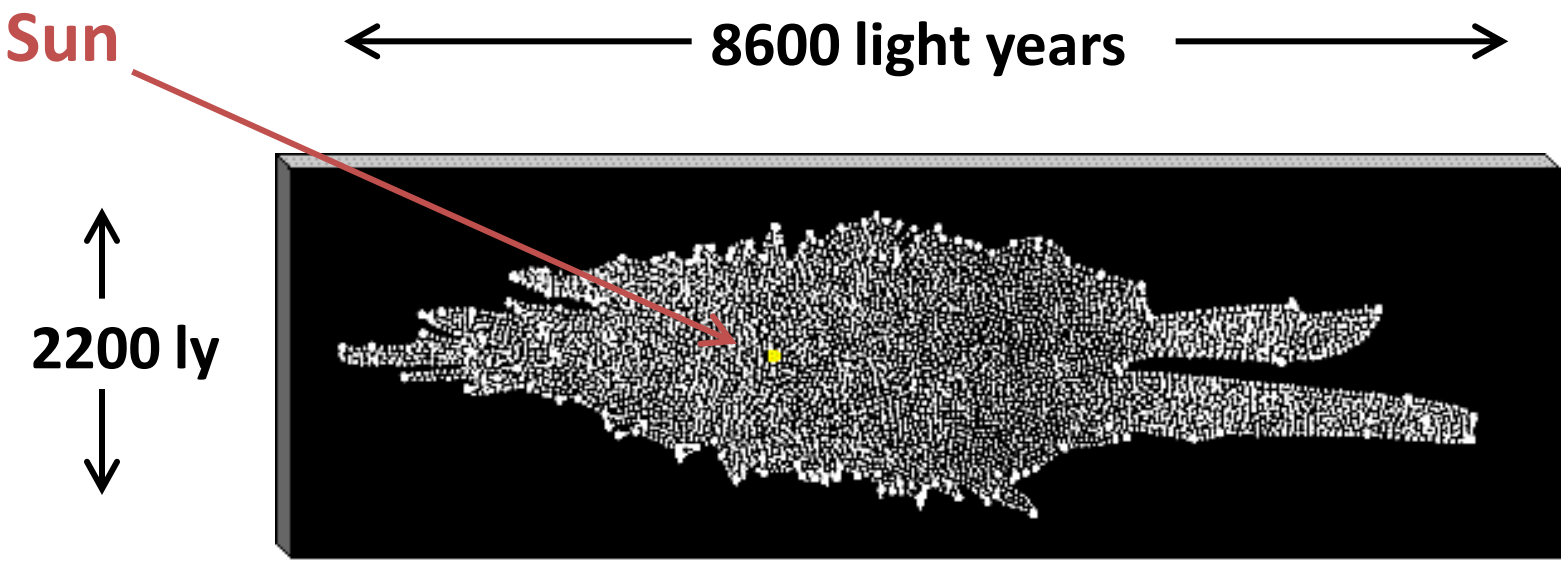
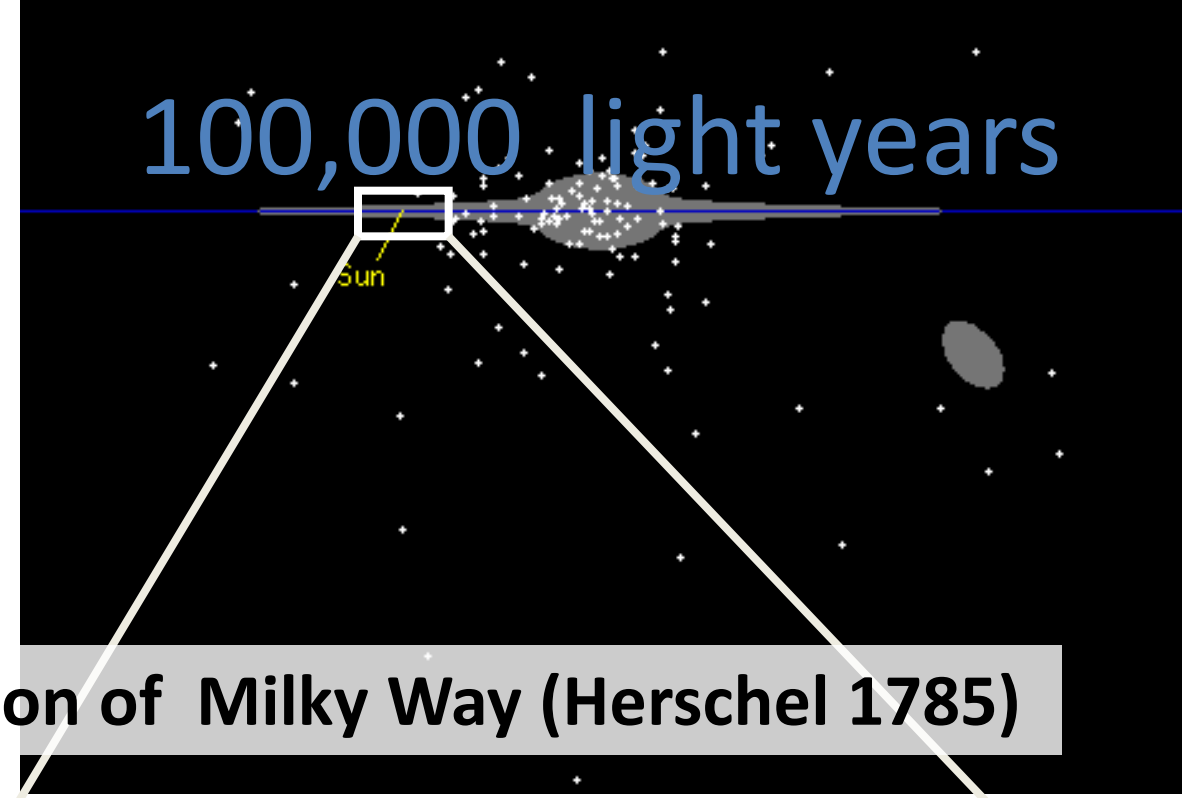
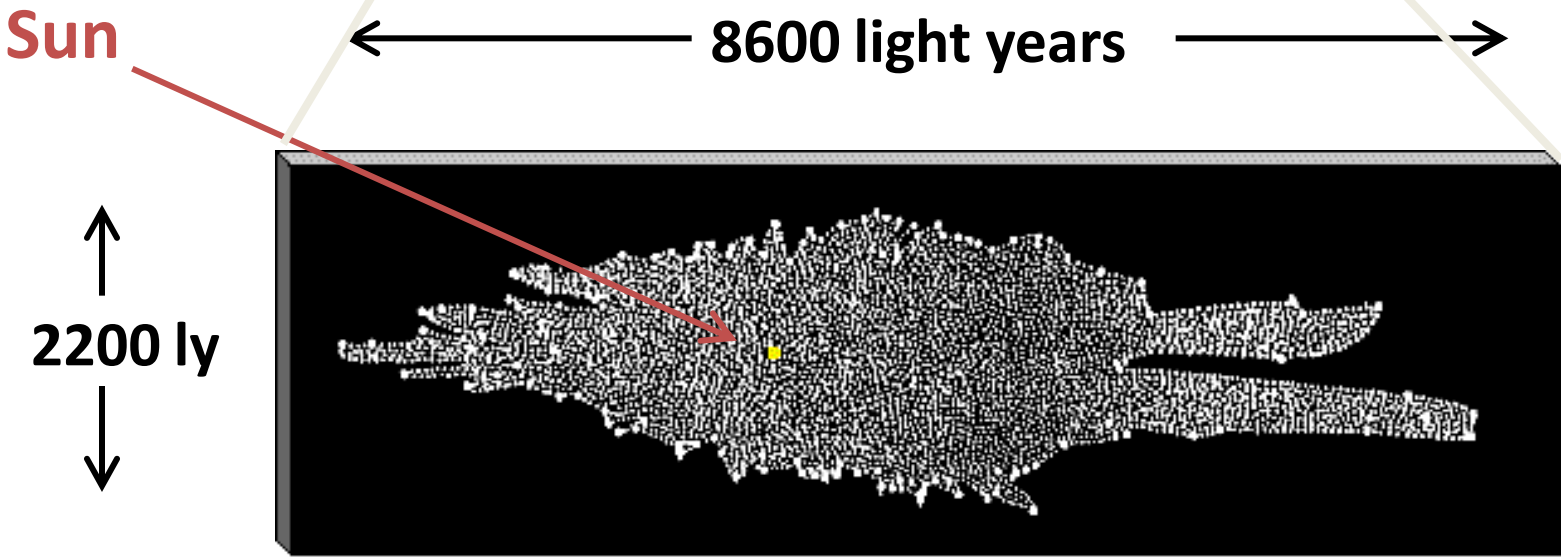
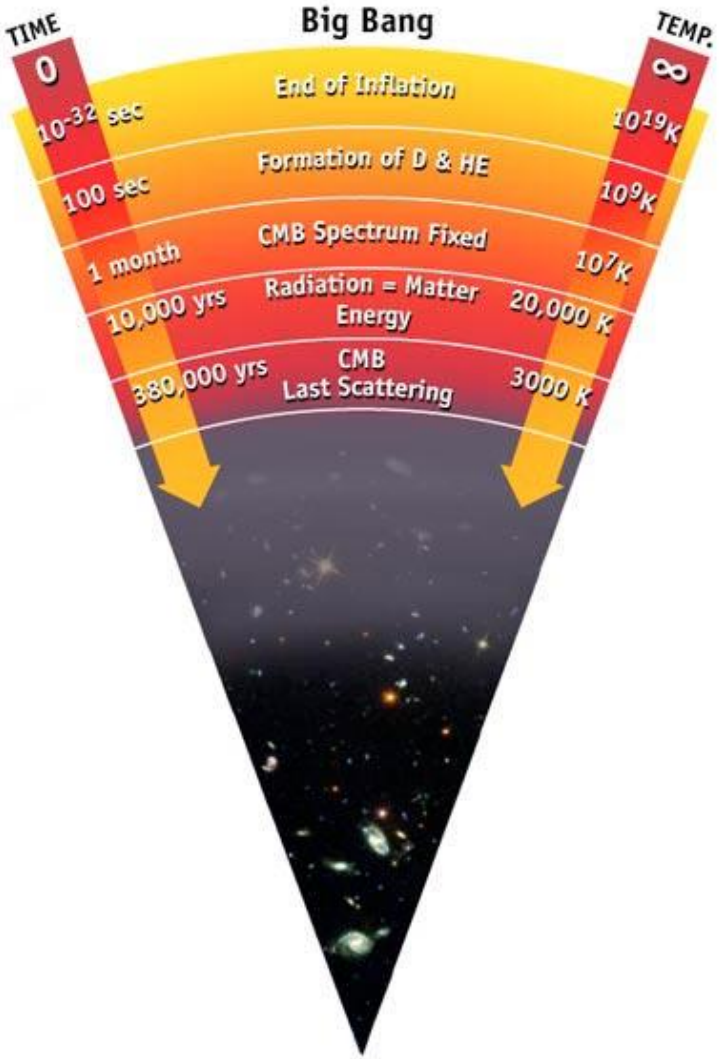


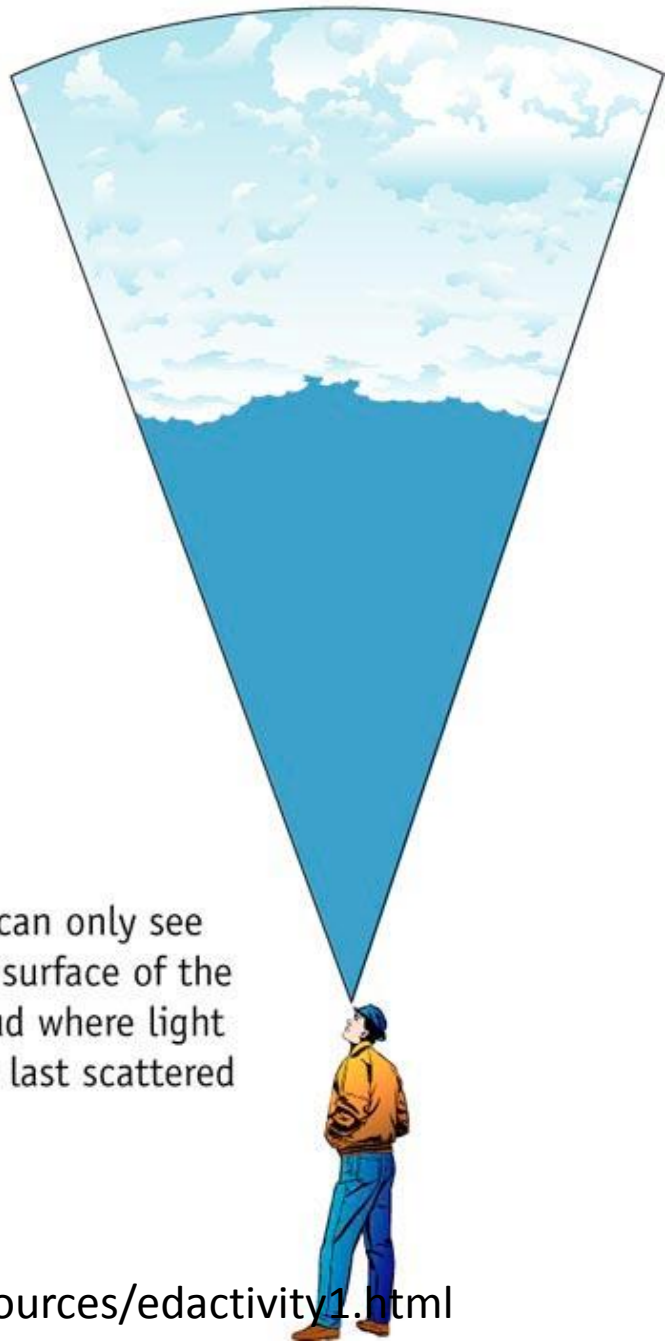
Real Milky Way



Cross-section of Milky Way (Herschel 1785)



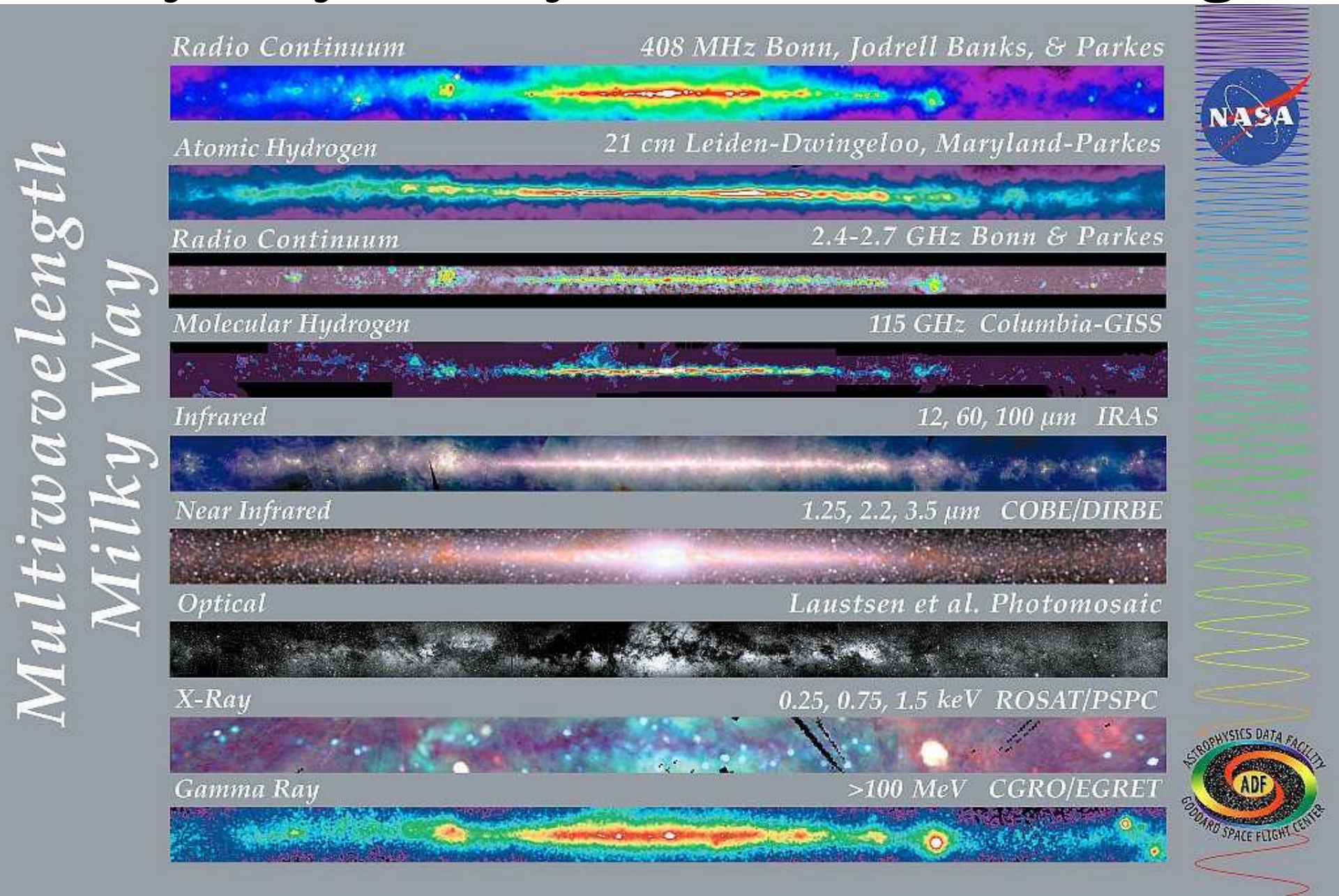




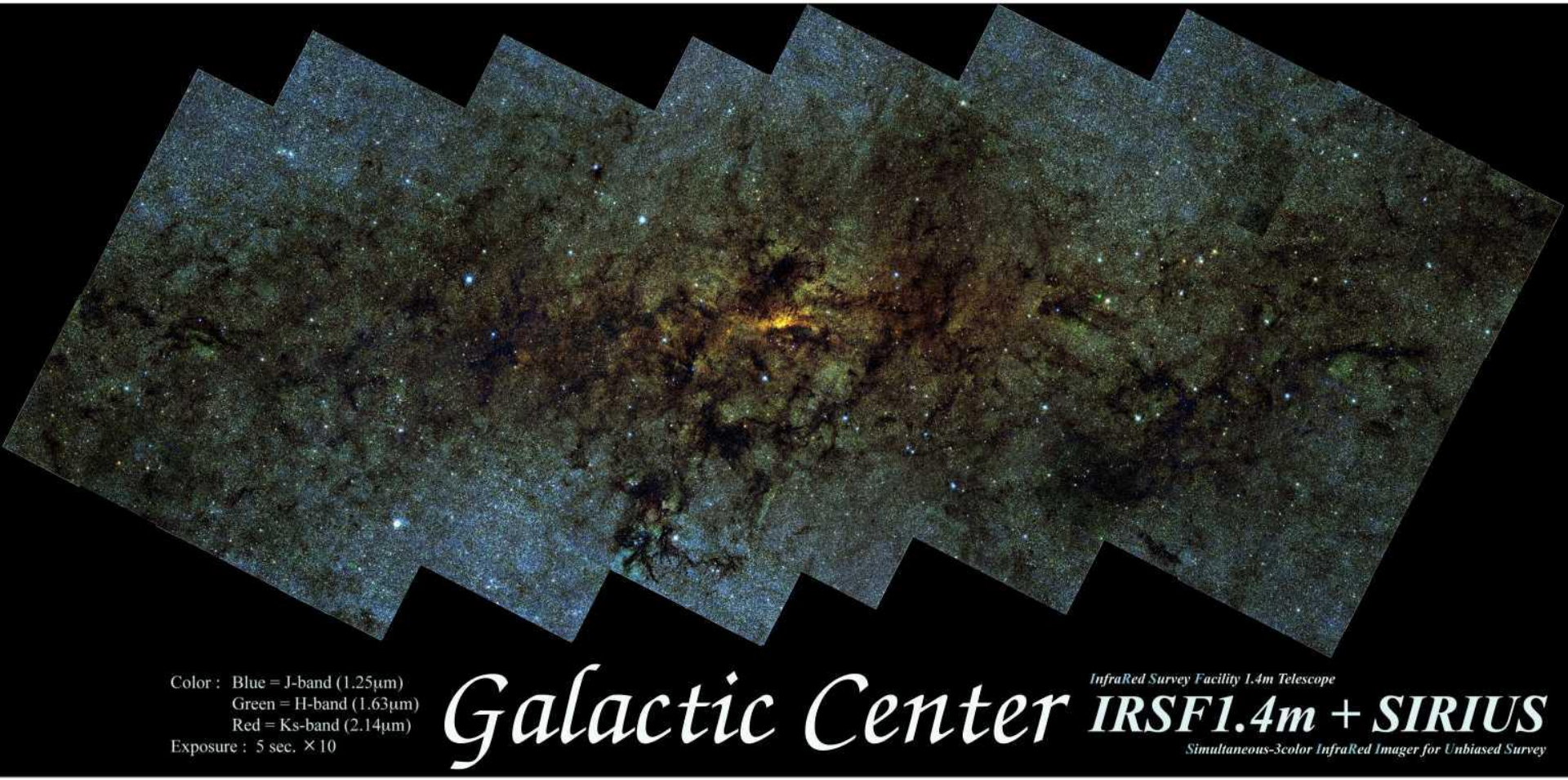
The cosmic microwave background Radiation's "surface of last scatter" is analogous to the light coming through the clouds to our eye on a cloudy day.

http://map.gsfc.nasa.gov/resources/edactivity1.html

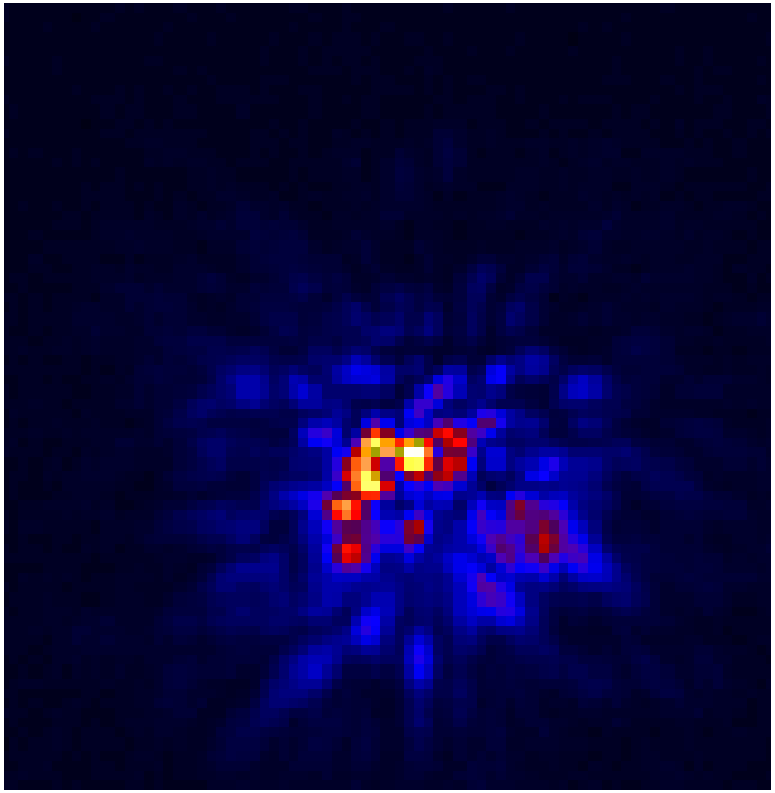
Milky Way Galaxy at Various Wavelength



Stars at Galactic Center (λ=1-2.5μm)



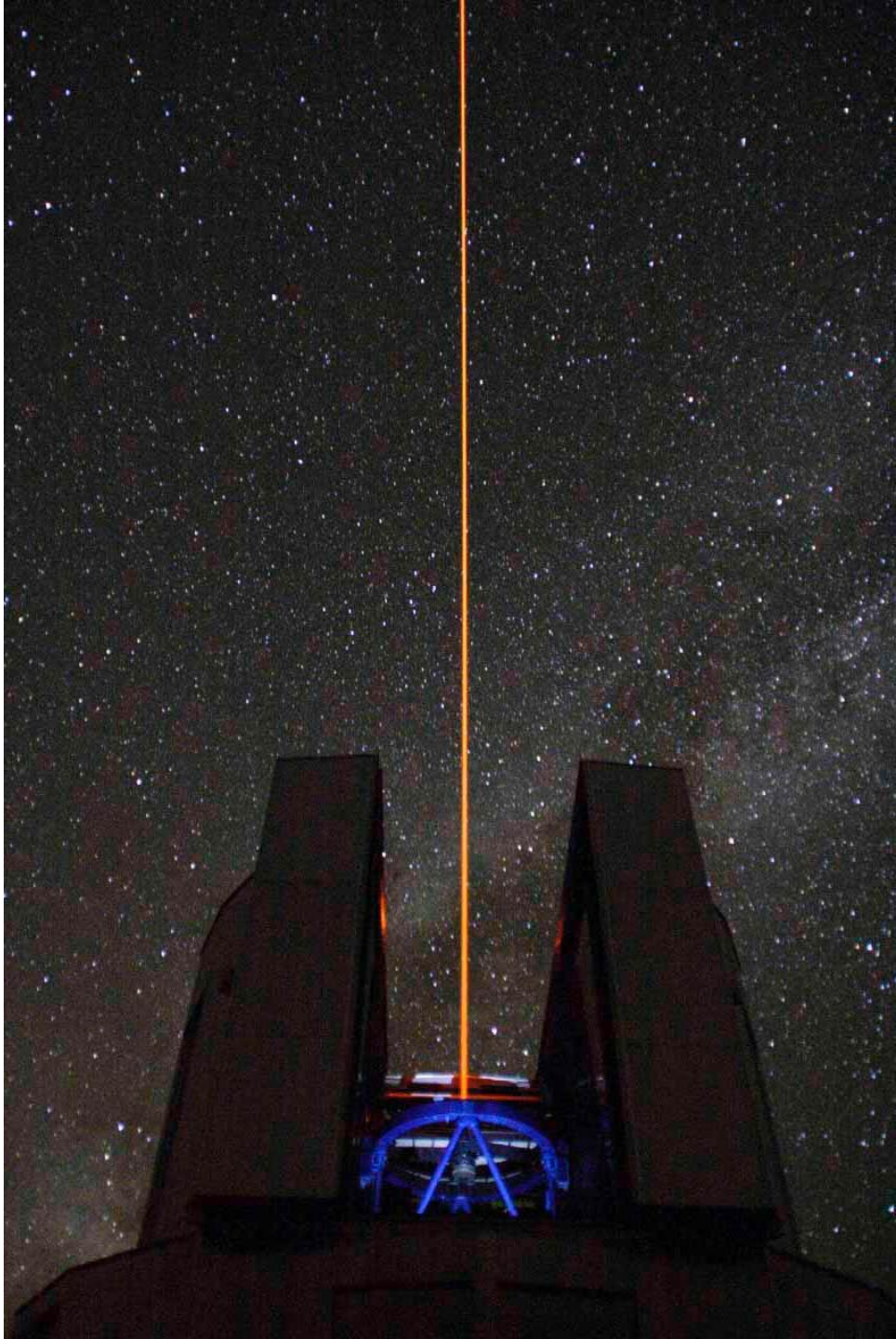
Atmospheric Turbulence



Red Supergiant Star “GC IRS7”

(Should be a Point Source)

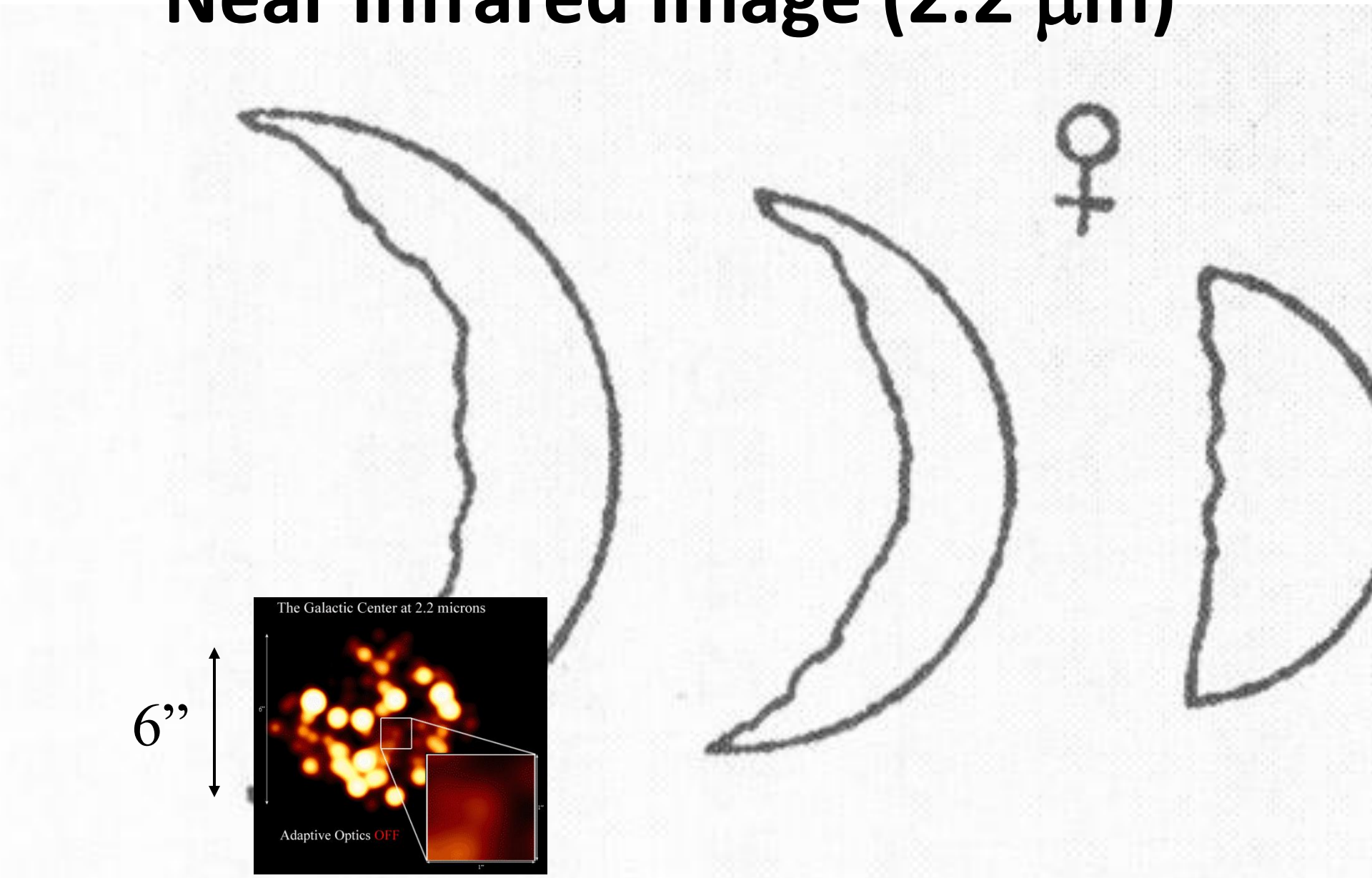
Subaru Telescope and Laser Guide Technique



補償光学 Adaptive Optics

http://subarutelescope.org/Pressrelease/2006/11/20/j_index.html

Near Infrared Image (2.2 μm)



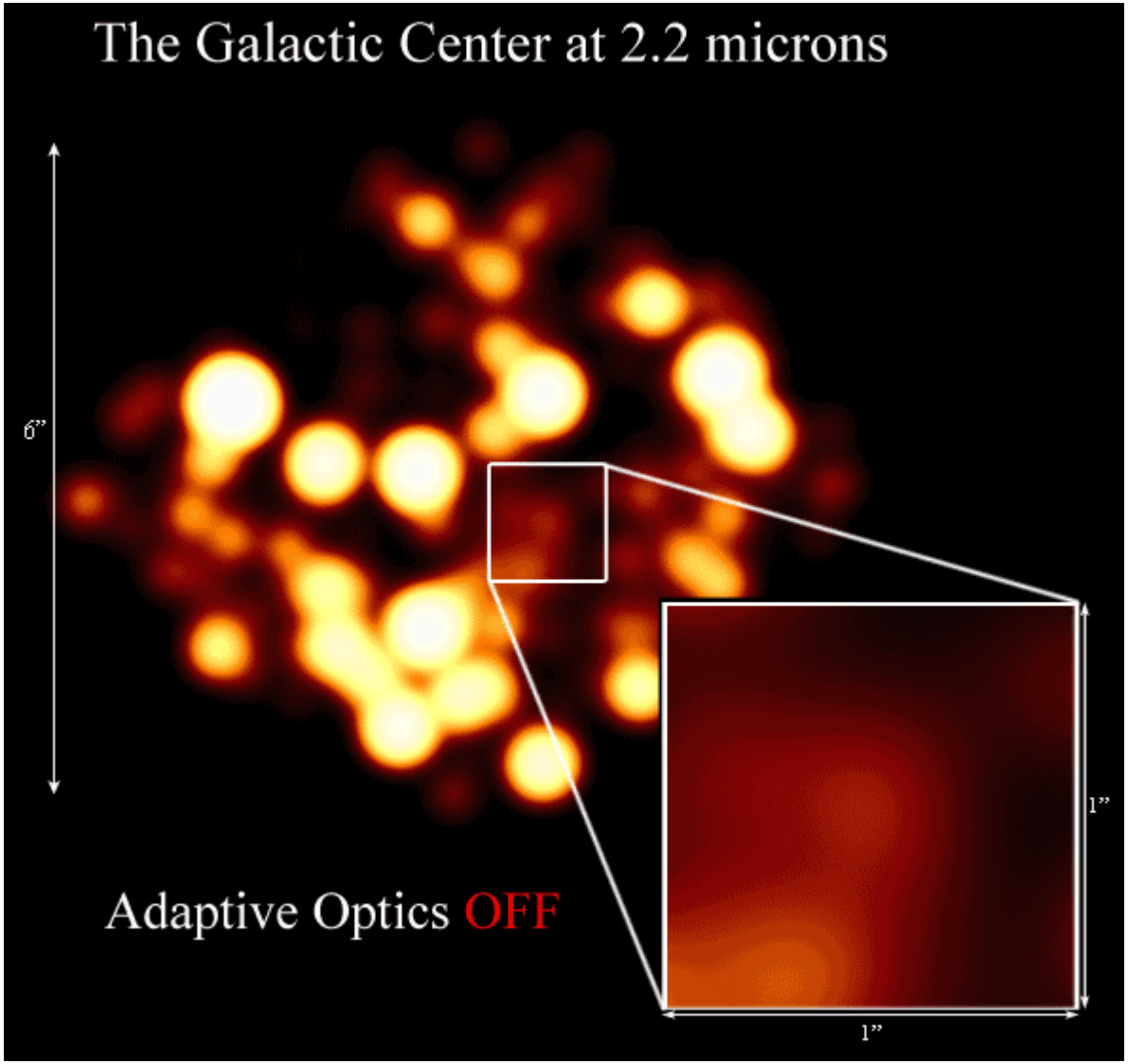
http://www.astro.ucla.edu/~ghezgroup/gc/

Near Infrared Image (2.2 μm)

6”

(1 l.y.)

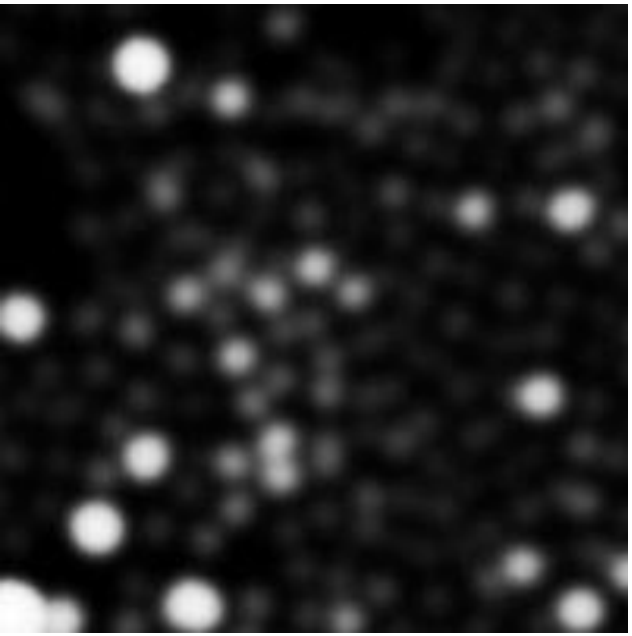
(0.3pc)

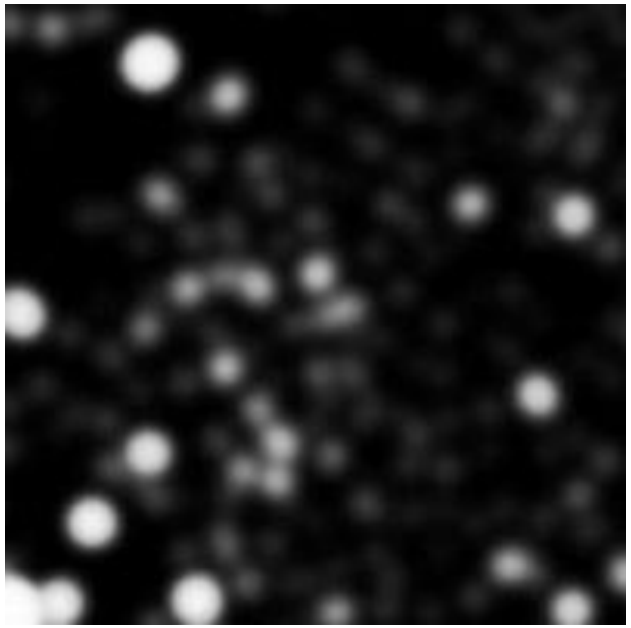


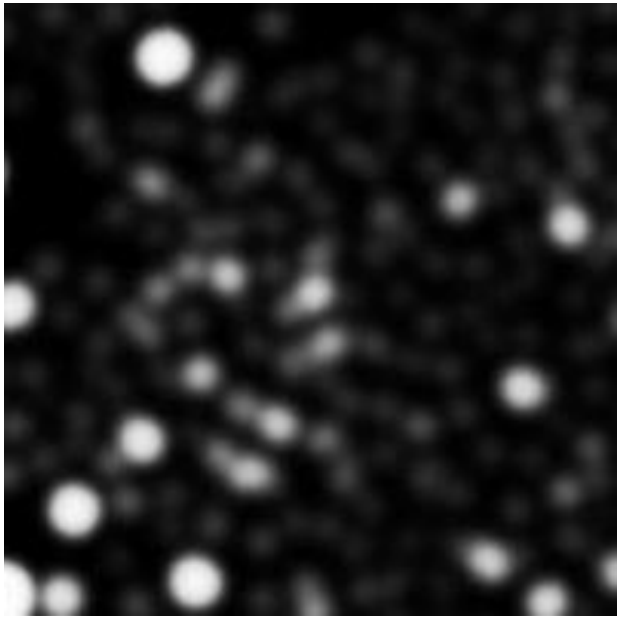
http://www.astro.ucla.edu/~ghezgroup/gc/

Infrared Image of Galactic Center

3 arcsec
Field of View





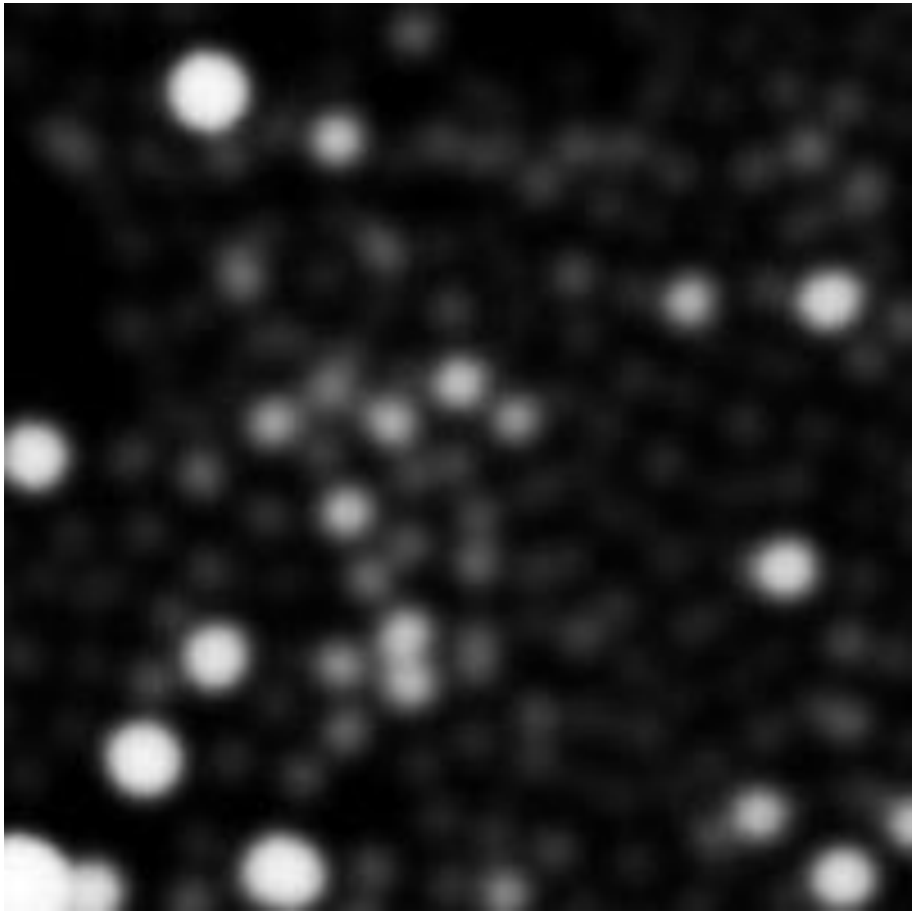


1994 1996 2000

http://www.mpe.mpg.de/ir/GC/res_mass.php?lang=en

銀河系の中心の赤外線像

3秒角
視野



1994

http://www.mpe.mpg.de/ir/GC/res_mass.php?lang=en

銀河系の中心の赤外線像

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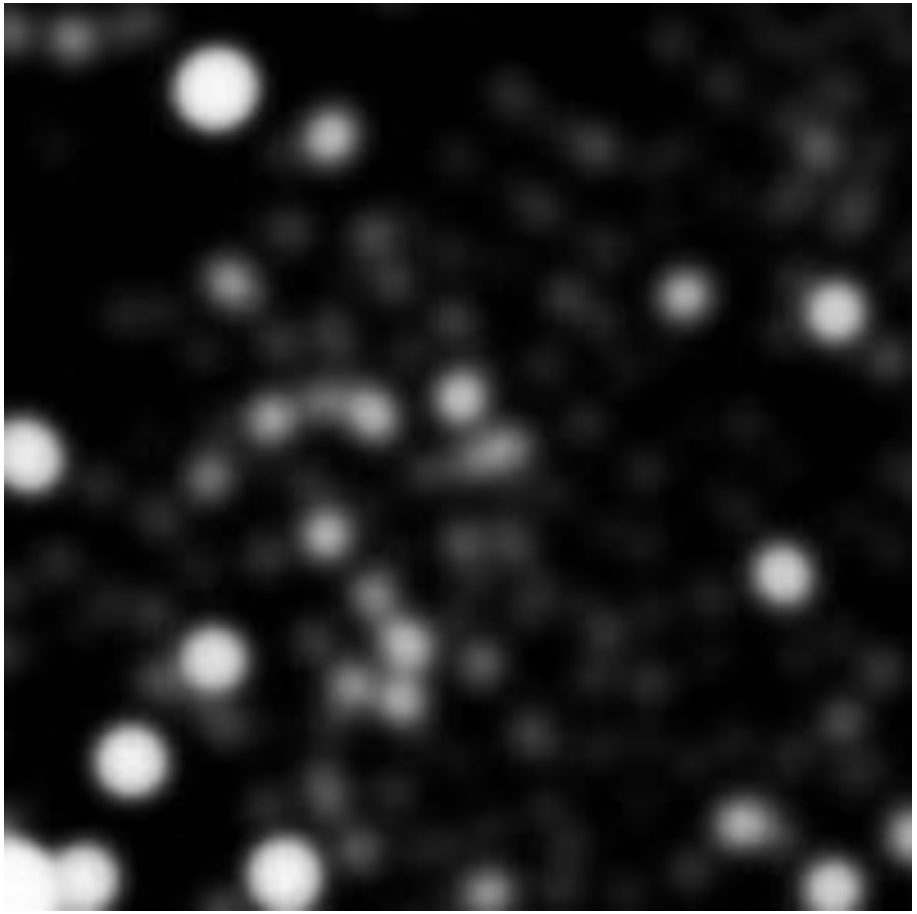
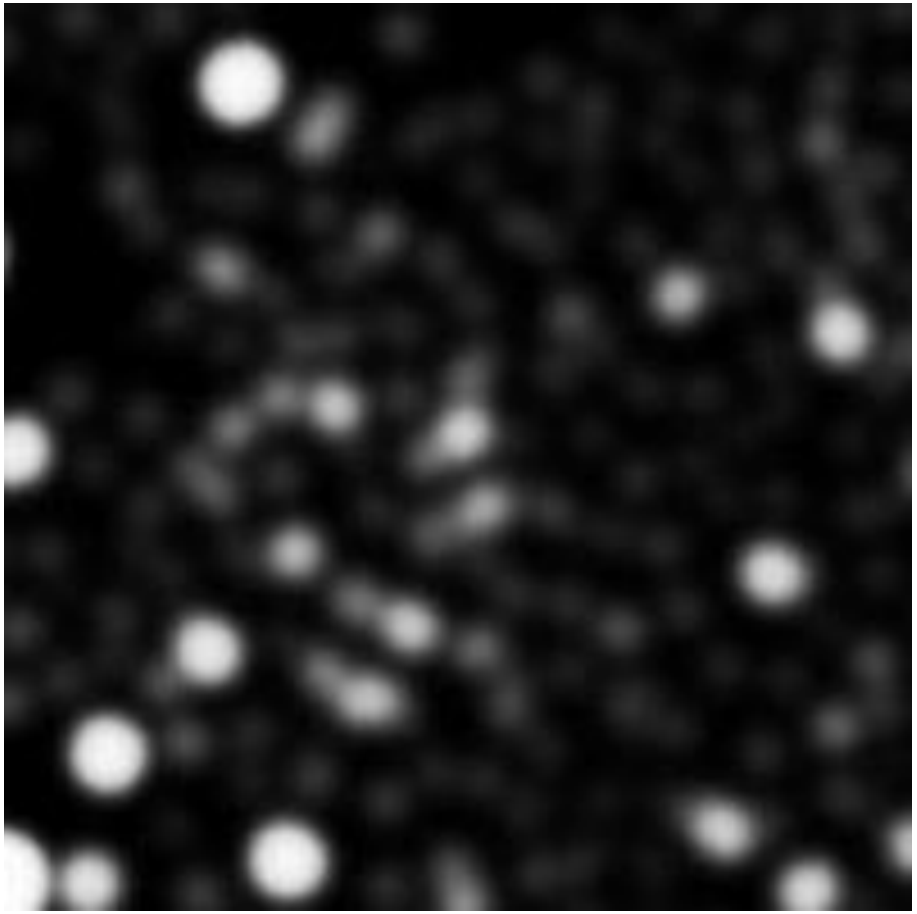


1996

銀河系の中心の赤外線像

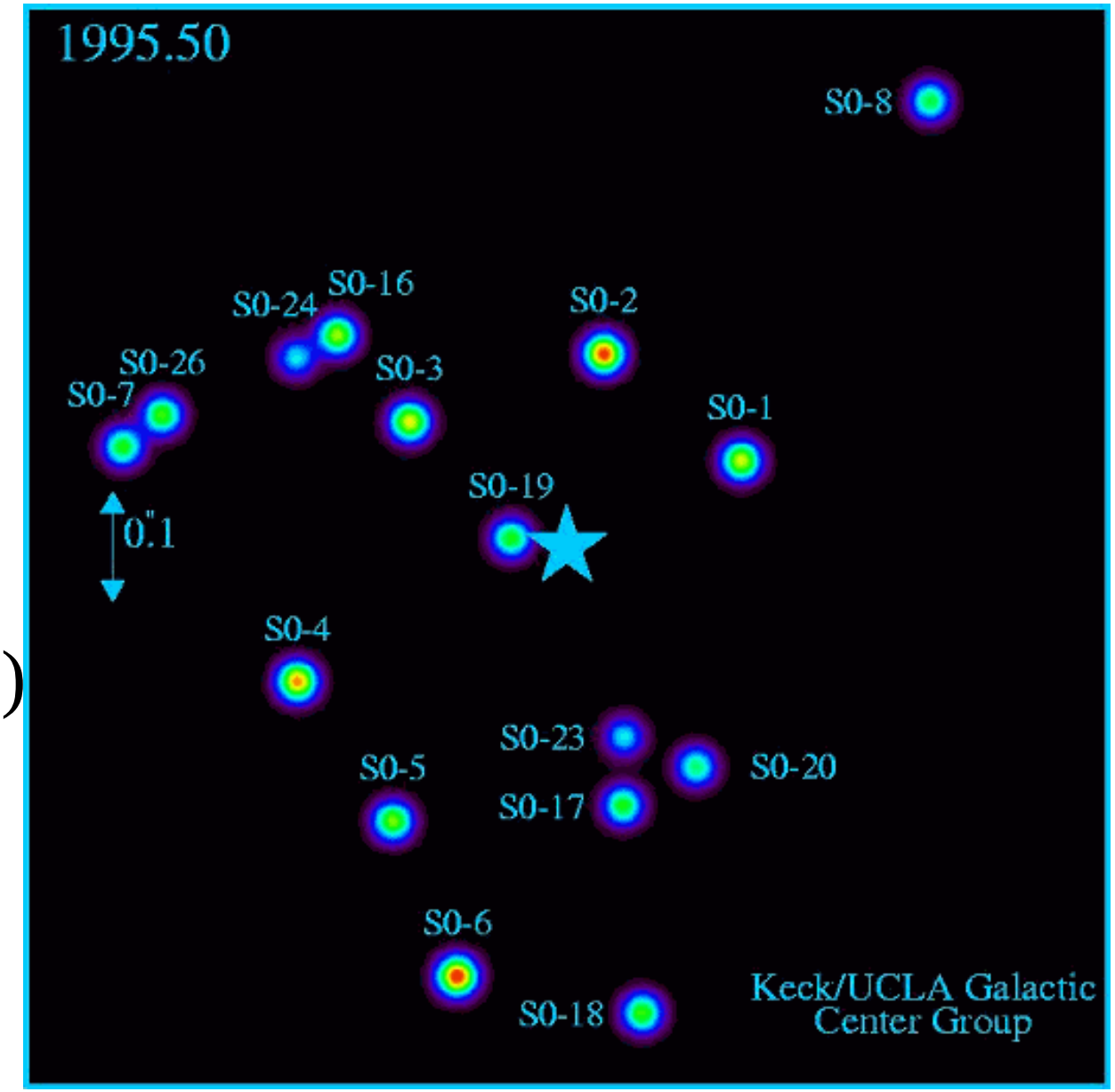
3秒角
視野



2000

Infrared Image of Galactic Center

1995-2006
Data

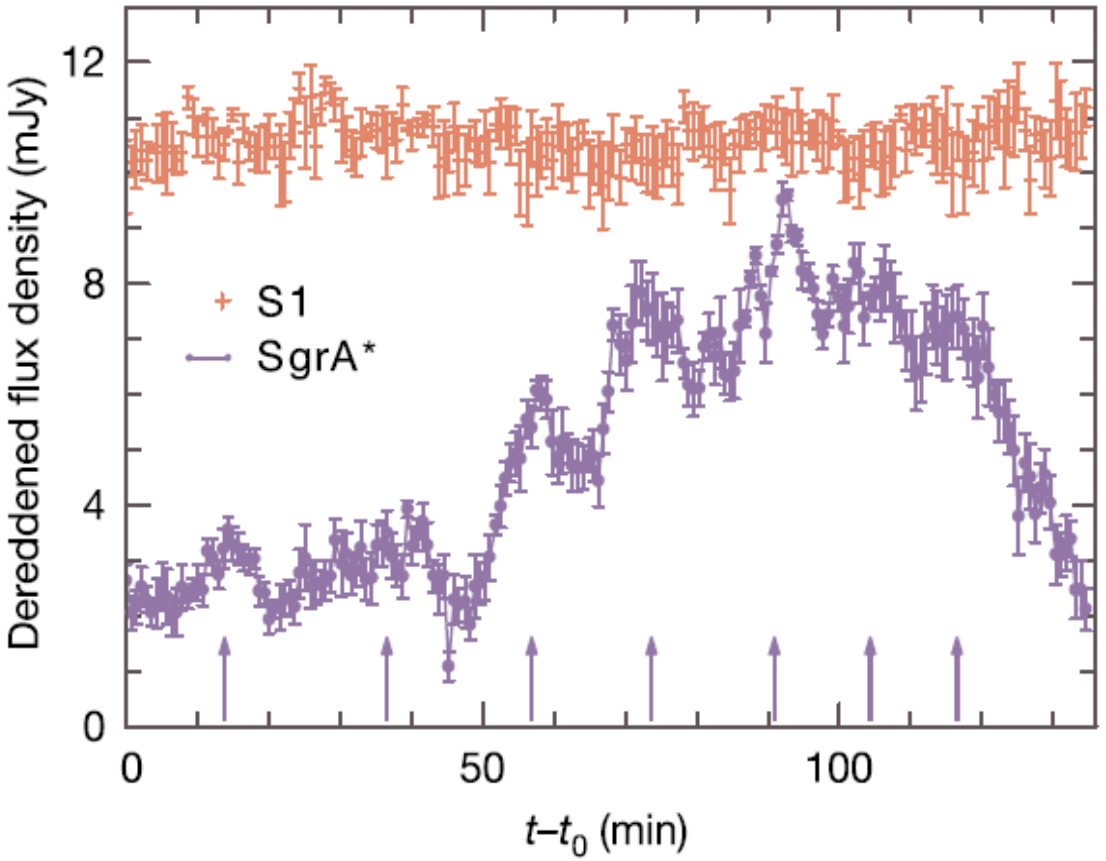


0.1arcsec

(0.015 l.y.)

Sgr A* : Super Massive Black Hole at the Center of our Galaxy

- Closest SMBH : ~8 kpc (25,000 light years)
- Mass : ~4×10^6 M_{sun}

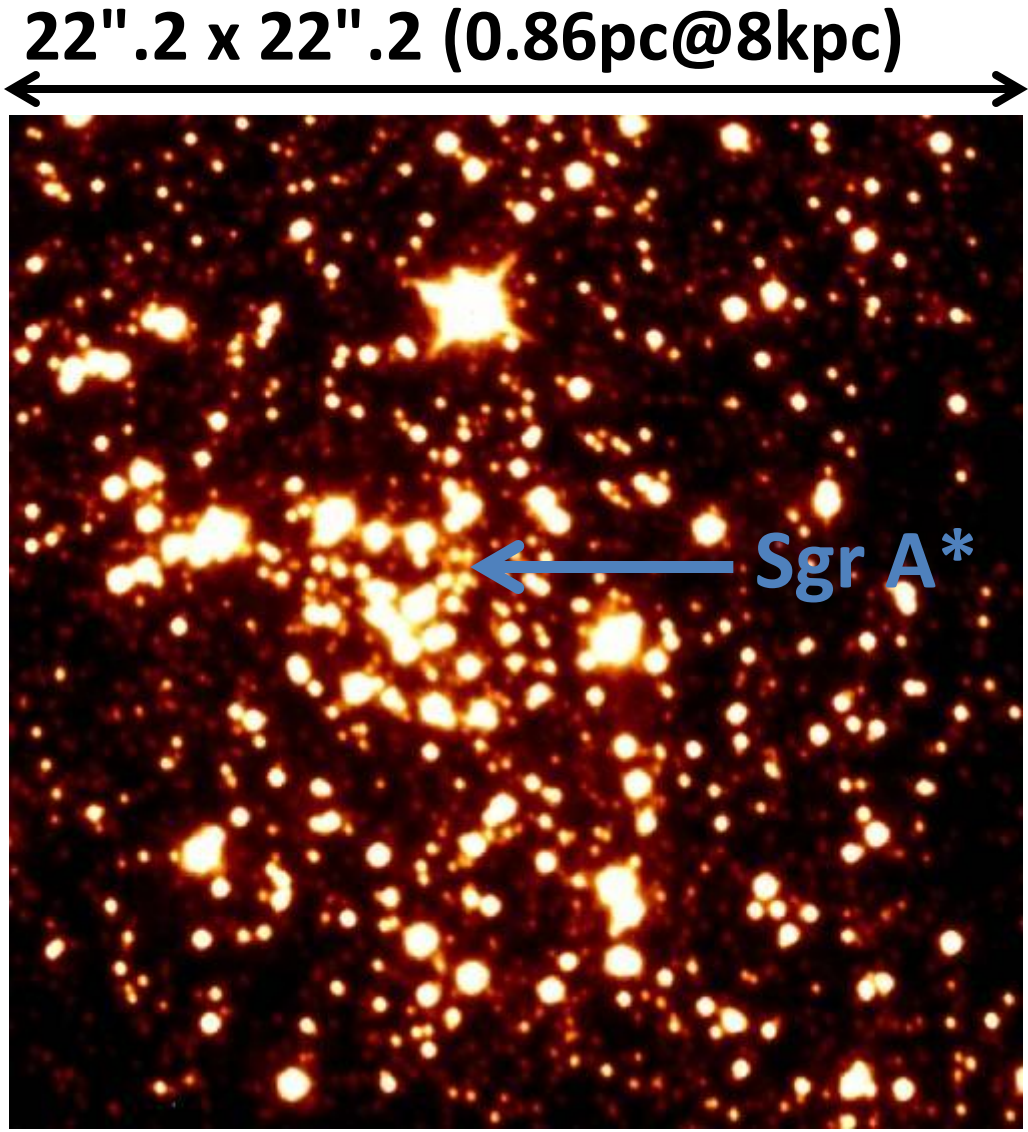


- Since 2000, many X/NIR flares

(Genzel et al. 2003)

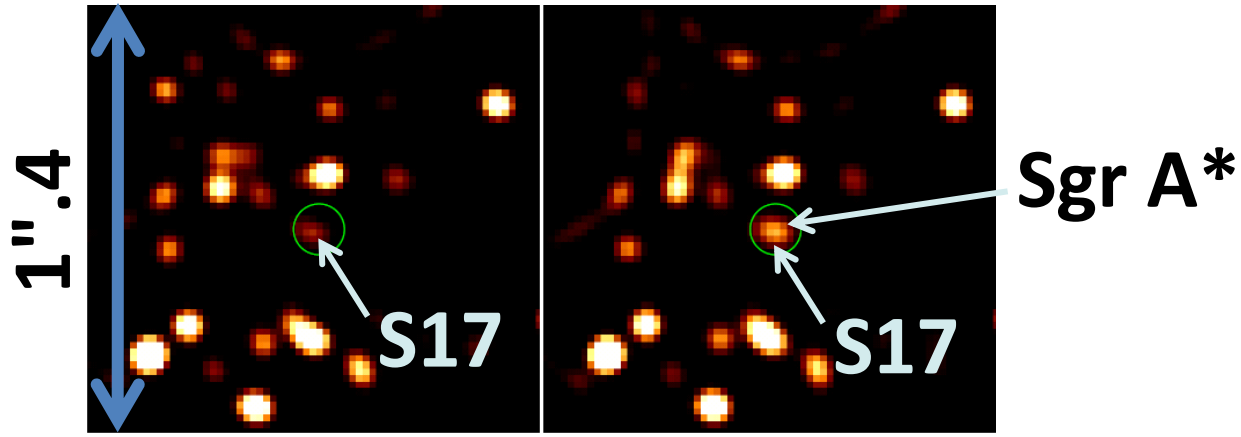
Sgr A* Observations with Subaru/CIAO

- 2008/5/28
- Subaru/CIAO/AO36
- AO guide star :
  USNO0600-28577051
  (*R* = 13.7, ～20")
- *Ks* polarimetry
  20sec exposure
  at 4 wave plate angles



→ polarimetry every ～3.3min

Sgr A* Observations with Subaru/CIAO



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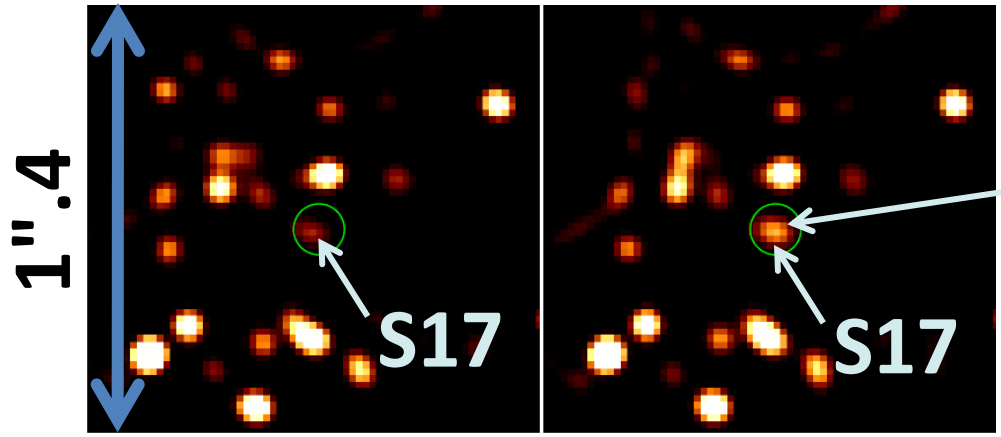
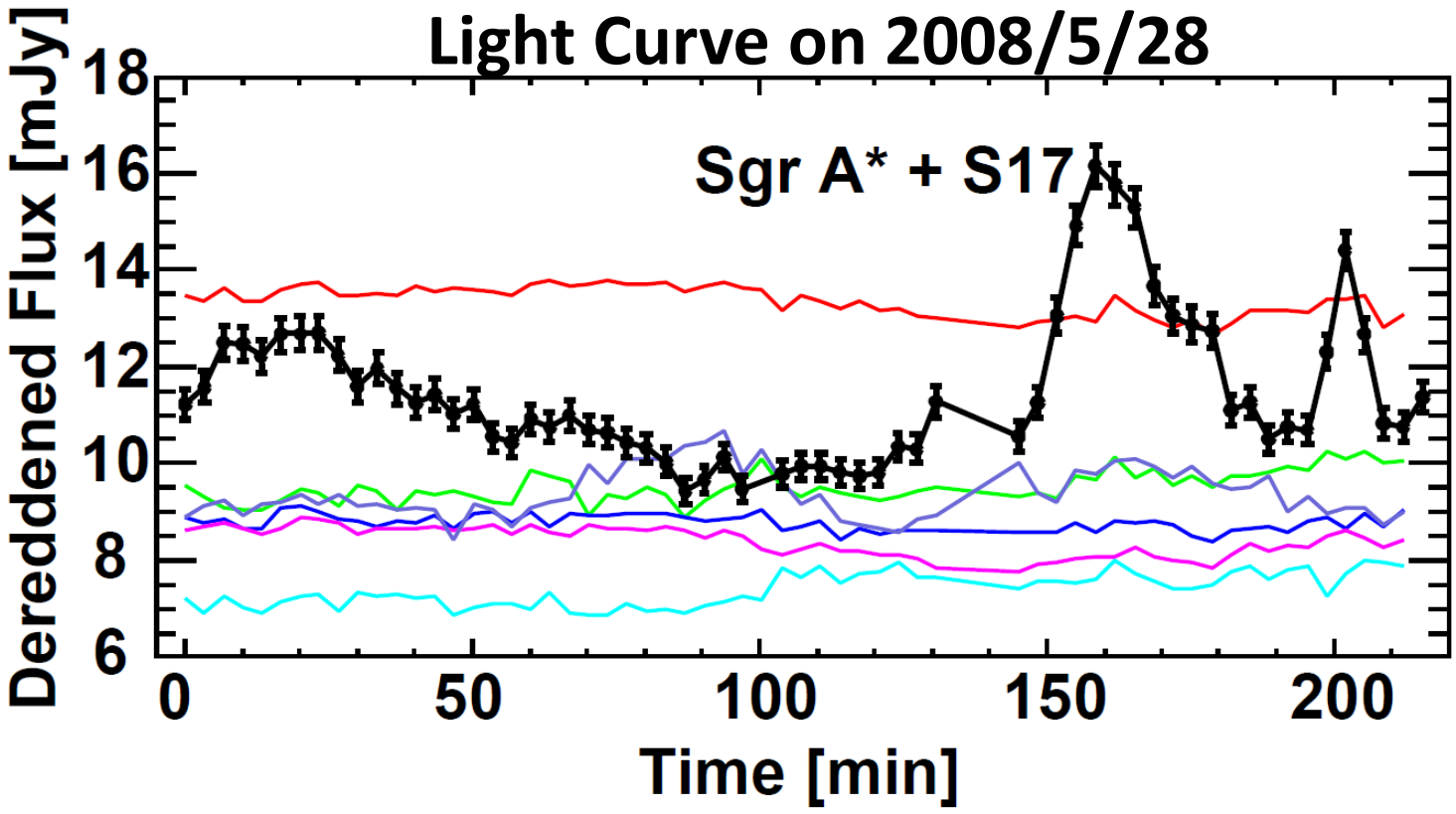
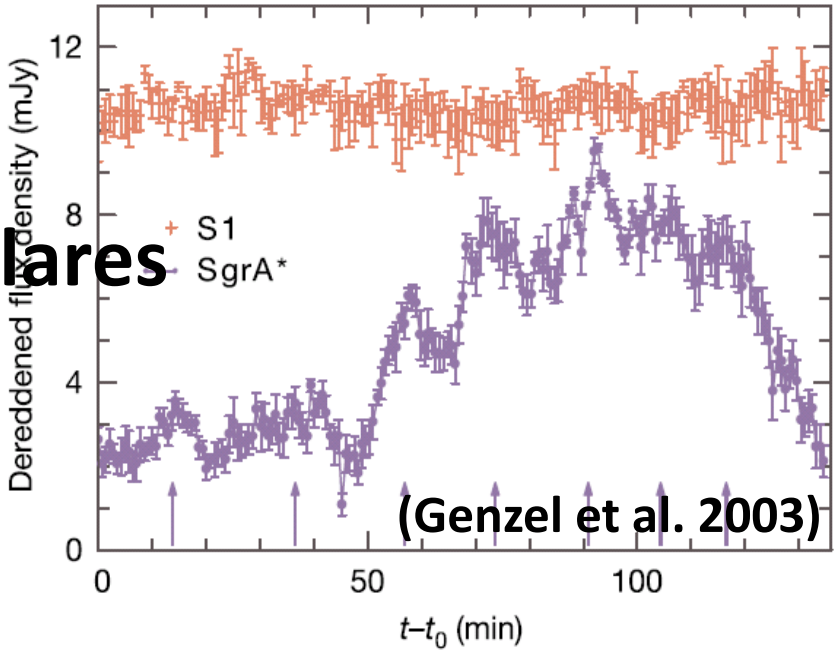




Sgr A* … SMBH at the Galactic Center

Sgr A* : Supermassive black hole (SMBH) at the center of our Galaxy

- **Closest SMBH : ~8 kpc**
- **Mass : ~4x10^6 M_{sun}**
- **Since 2000, many X/NIR flares**



(Genzel et al. 2003)

NIR Polarimetry

- **High spatial resolution**
- **Short timescale variability**

→ **phenomenon close to SMBH (<10r_s)**

- **High flare rate → large samples**
- **Additional information with polarimetry**

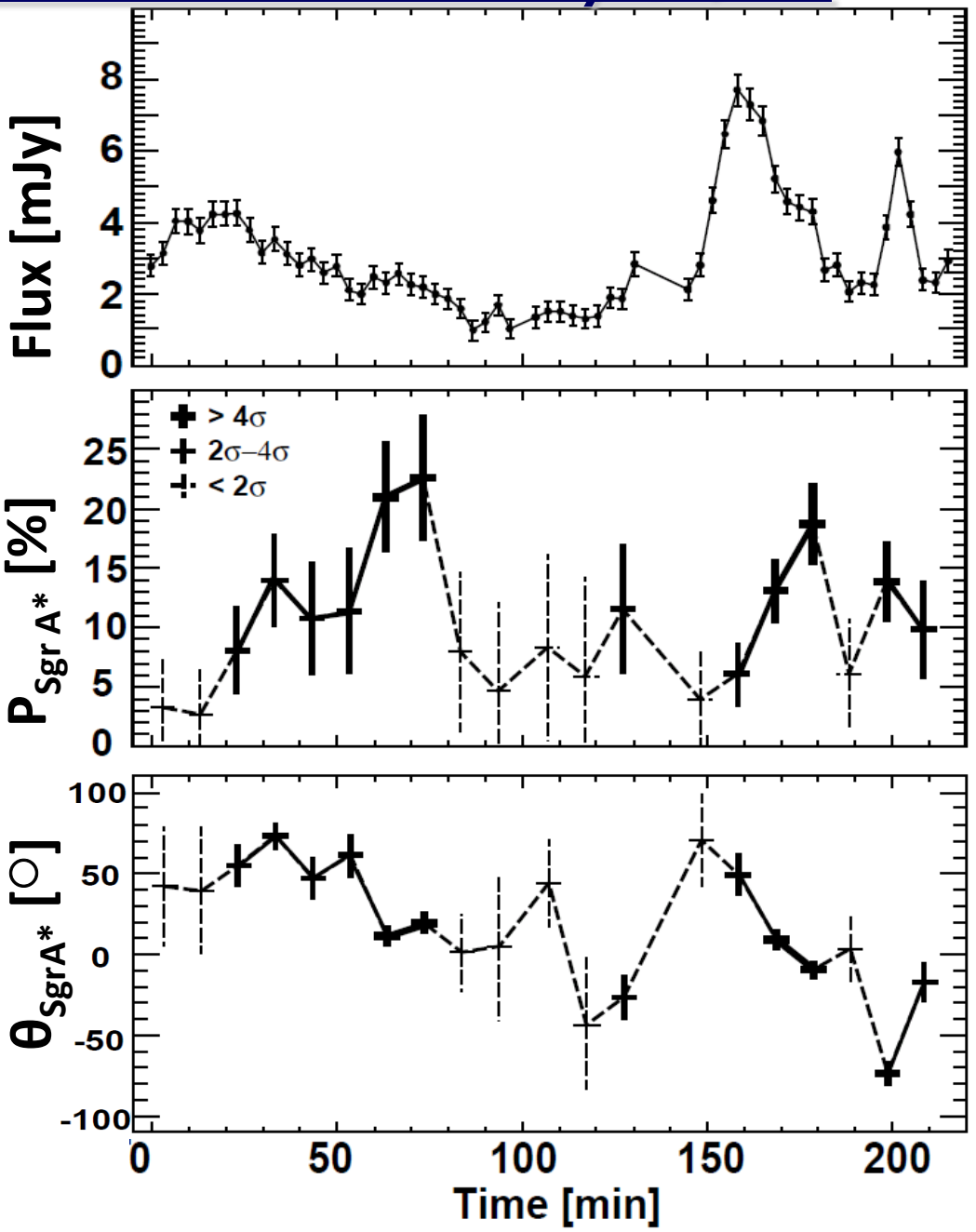
(mag. field geometry、orientation of disk, etc.)

Sgr A* Observations with Subaru/CIAO

Light curve (contribution of S17 is subtracted)

Degree of polarization

Position angle



Sgr A* Observations with Subaru/CIAO

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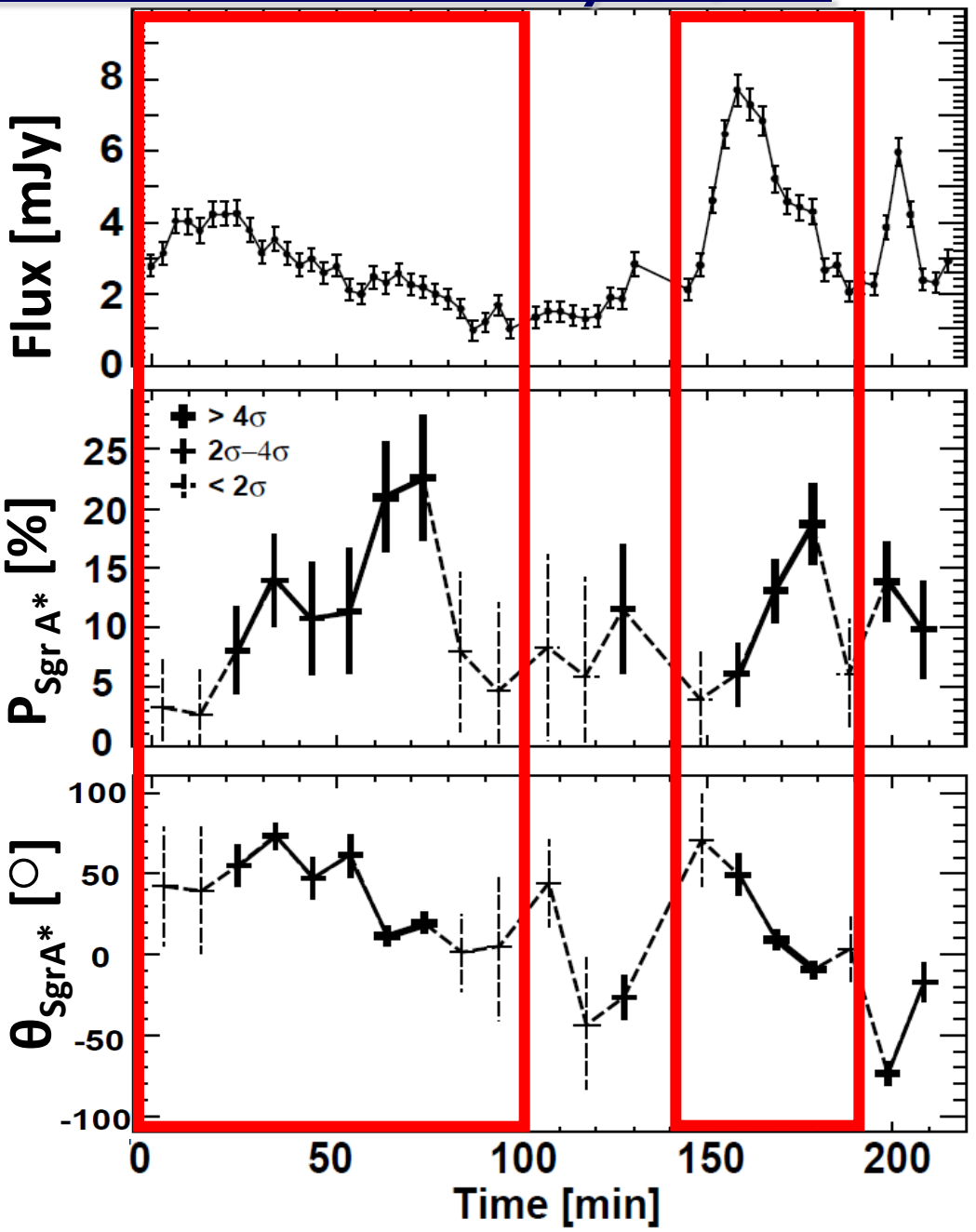
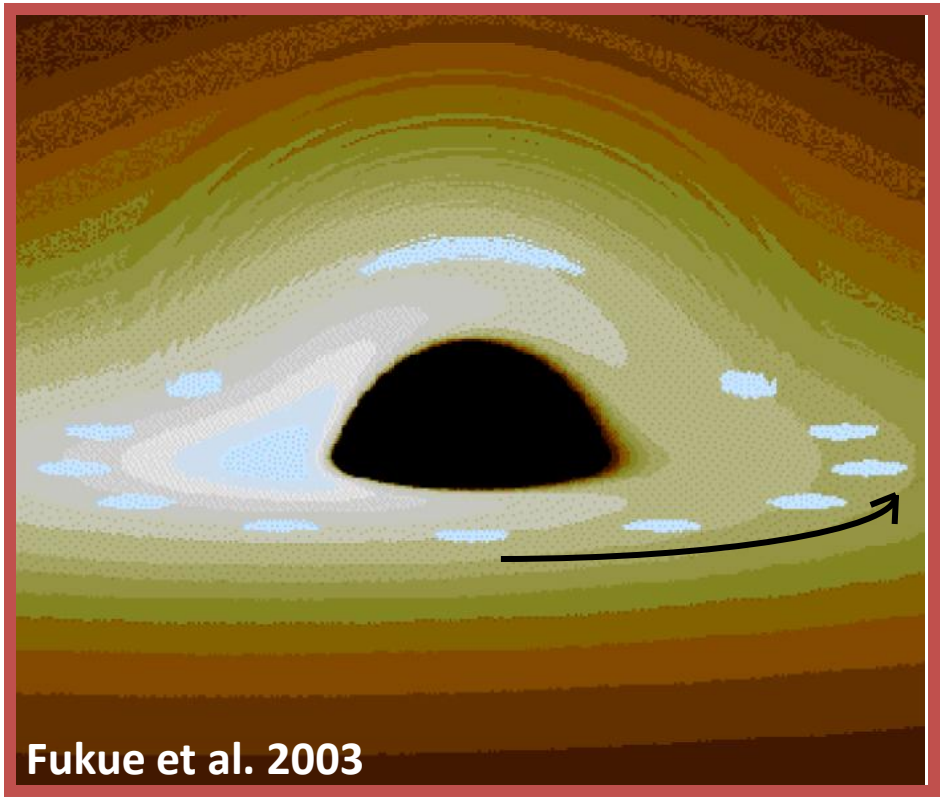


Discussion: Hotspot Model



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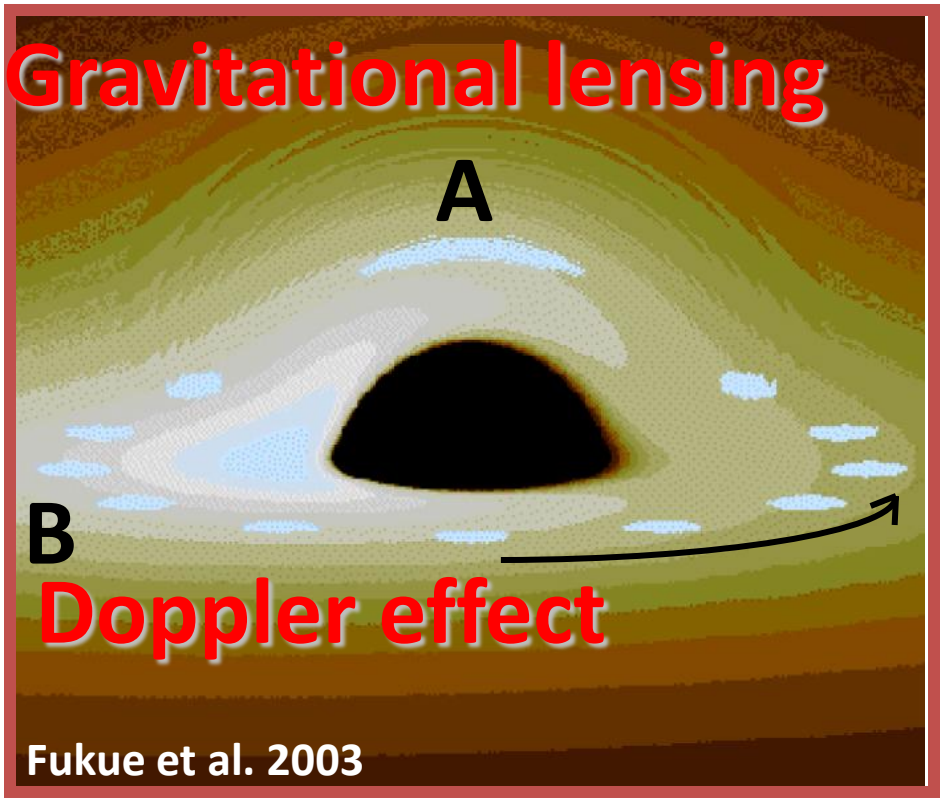
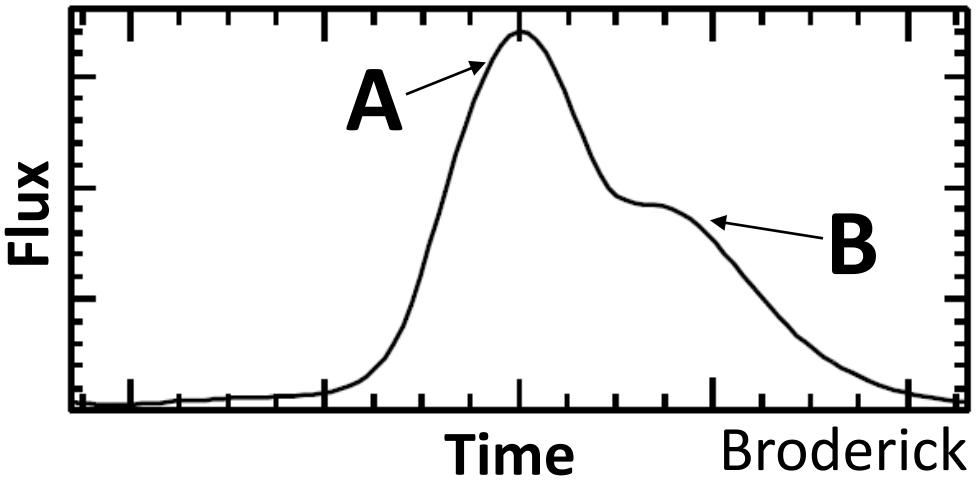
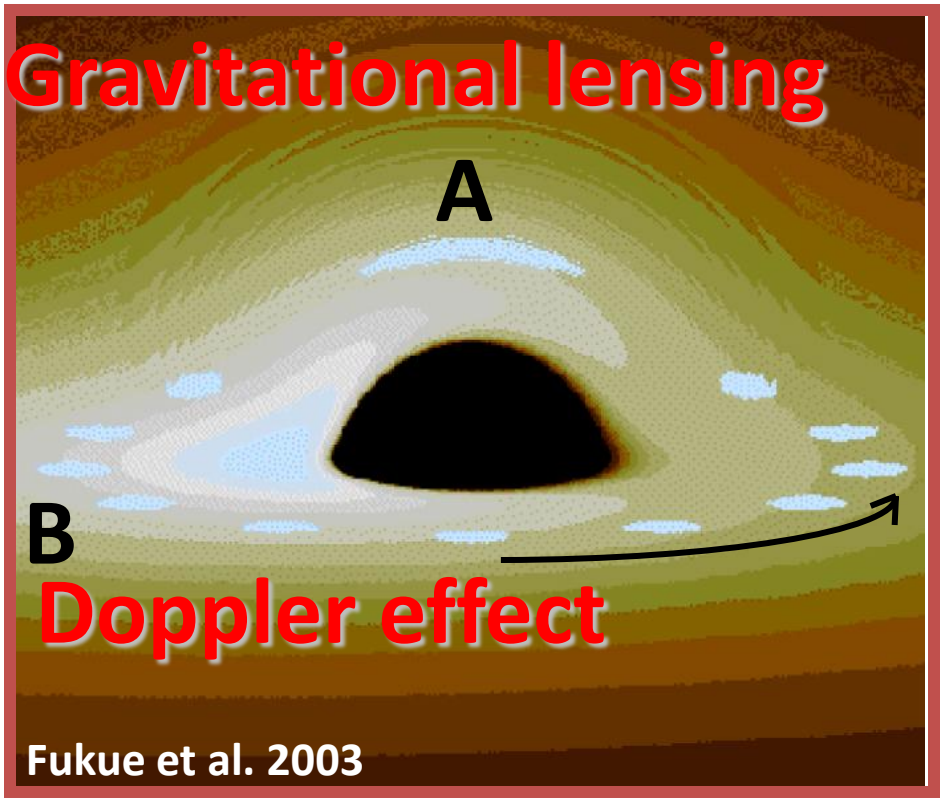
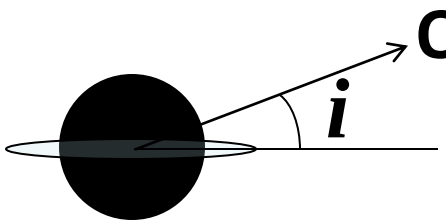


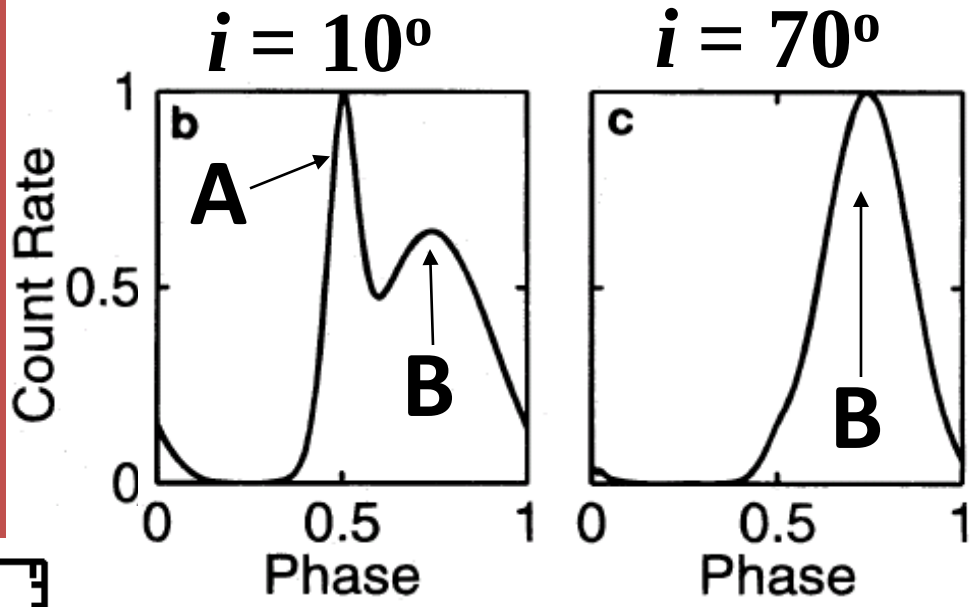


Broderick & Loeb (2006)

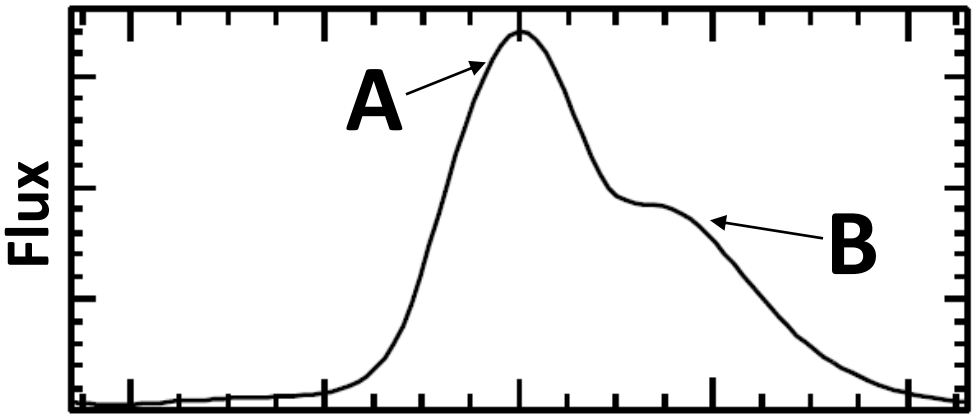
Discussion: Hotspot Model







Karas (1996)



Broderick & Loeb (2006)

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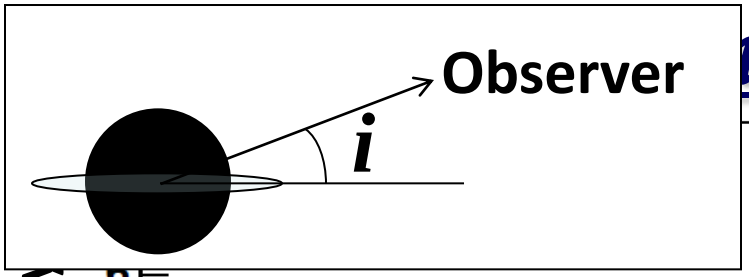
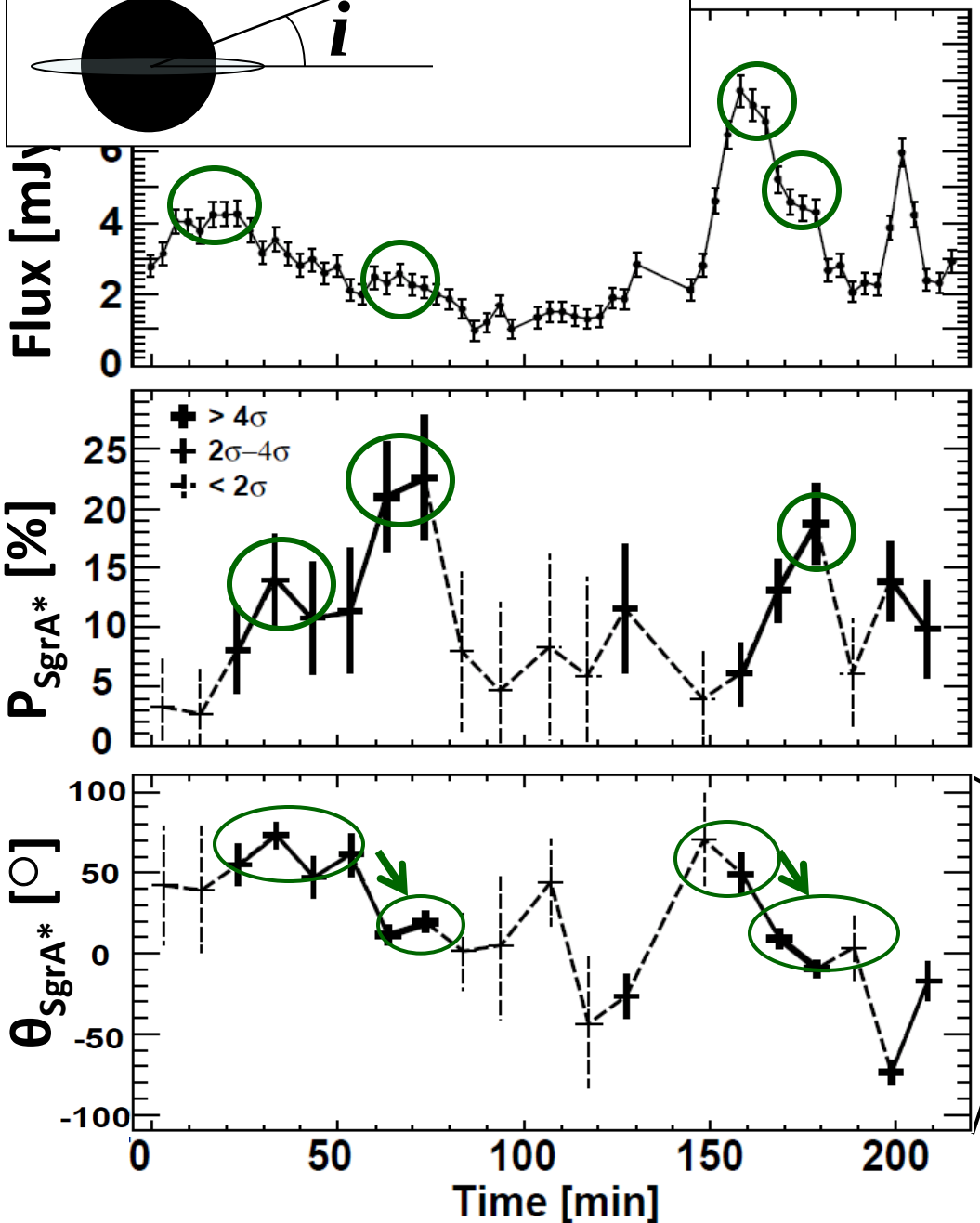
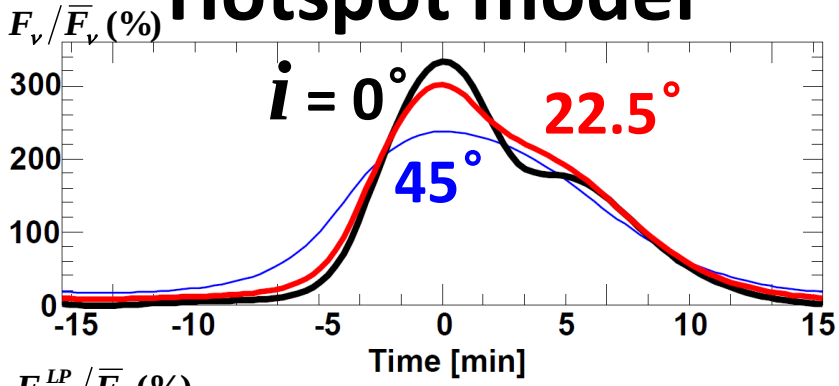
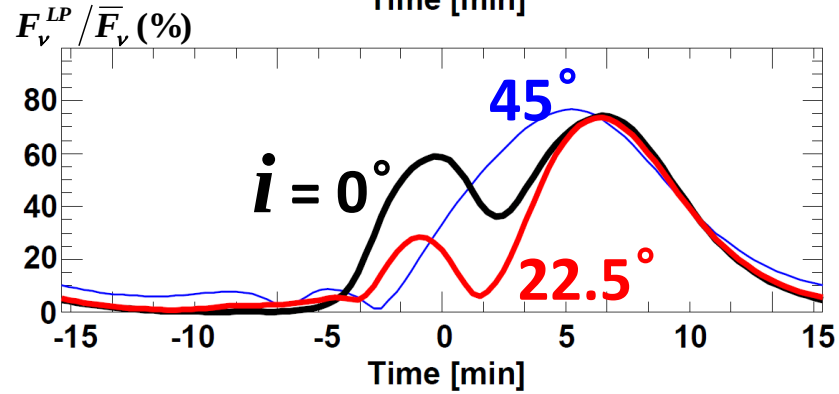
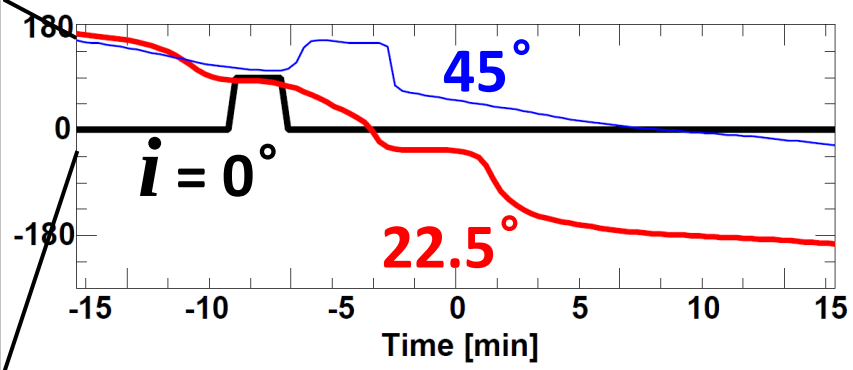




Hotspot model

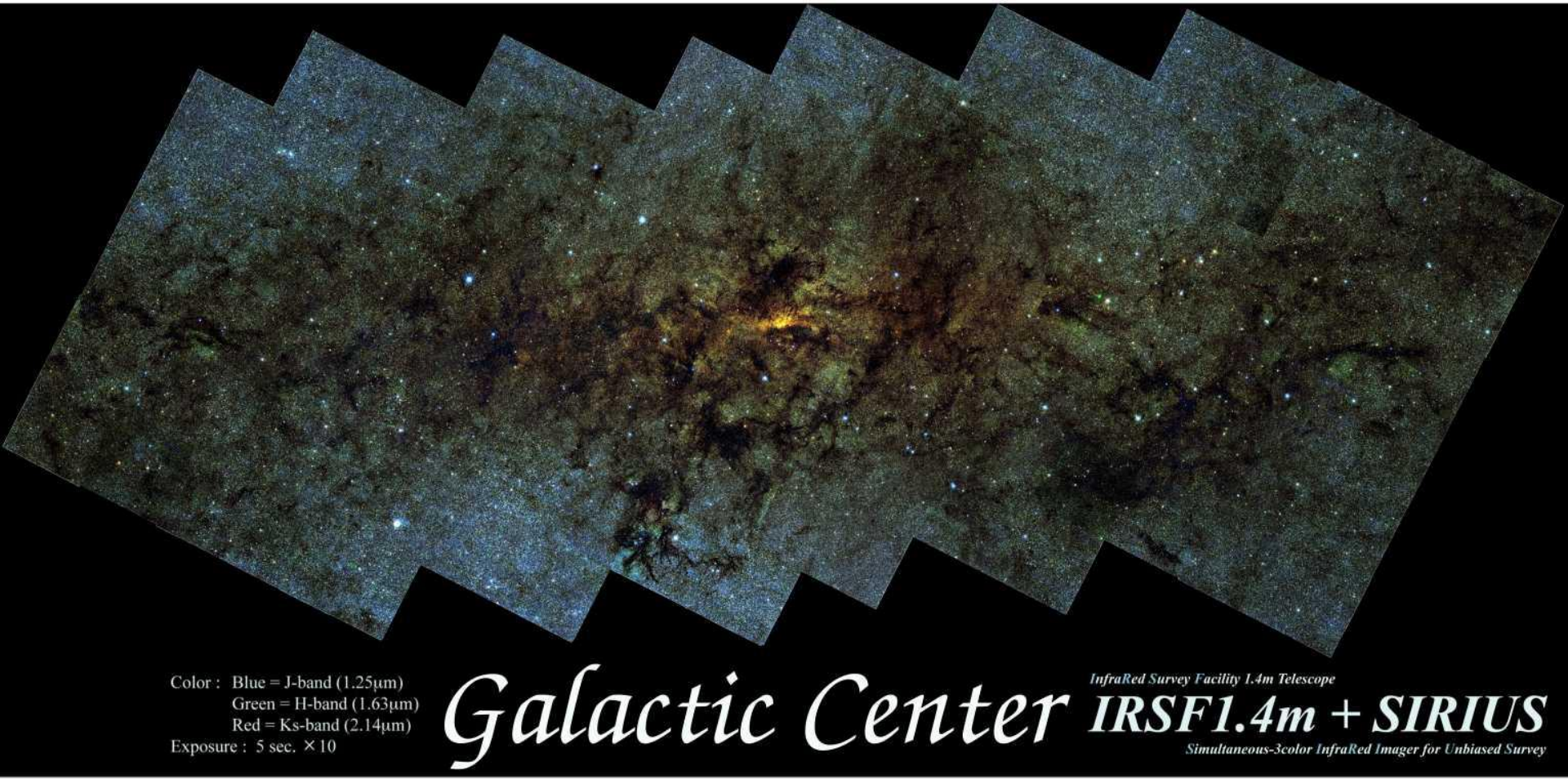






Broderick & Loeb (2006)

Stars at Galactic Center (λ=1-2.5μm)



$2^\circ \times 2^\circ$ (300 pc 1000 ly)

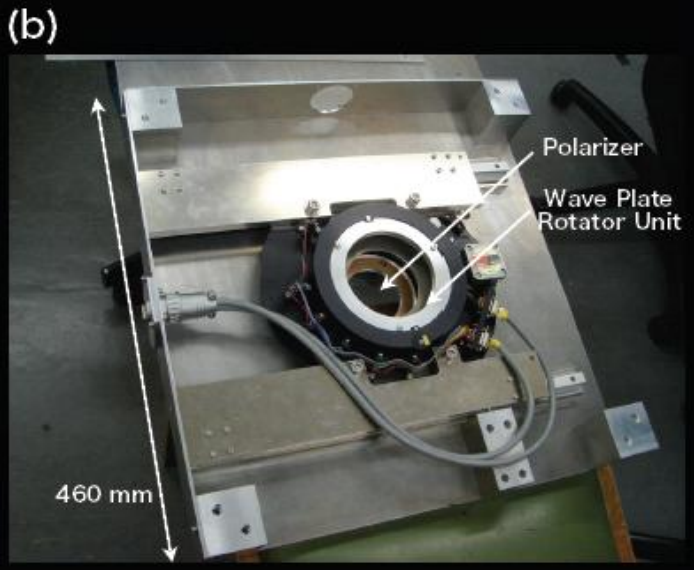
IRSF 1.4-m Telescope South Africa

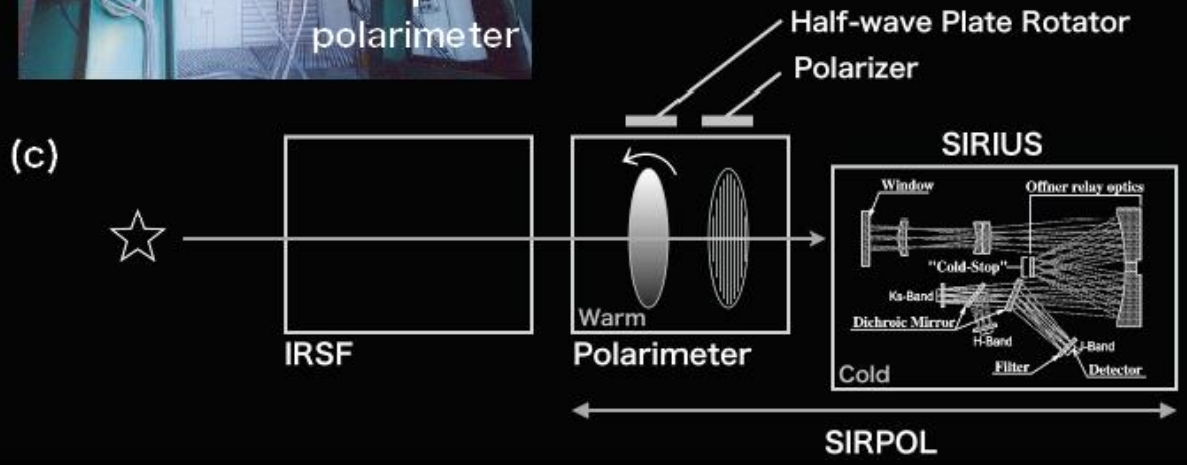
Kyoto Univ, Nagoya Univ,
Natl Astr Obs Jpn, ……

Astronomical Herald 2005.3 Cover

Observation

1.4m IRSF + SIRPOL





- Near IR (J,H,Ks)

  Polarized Images

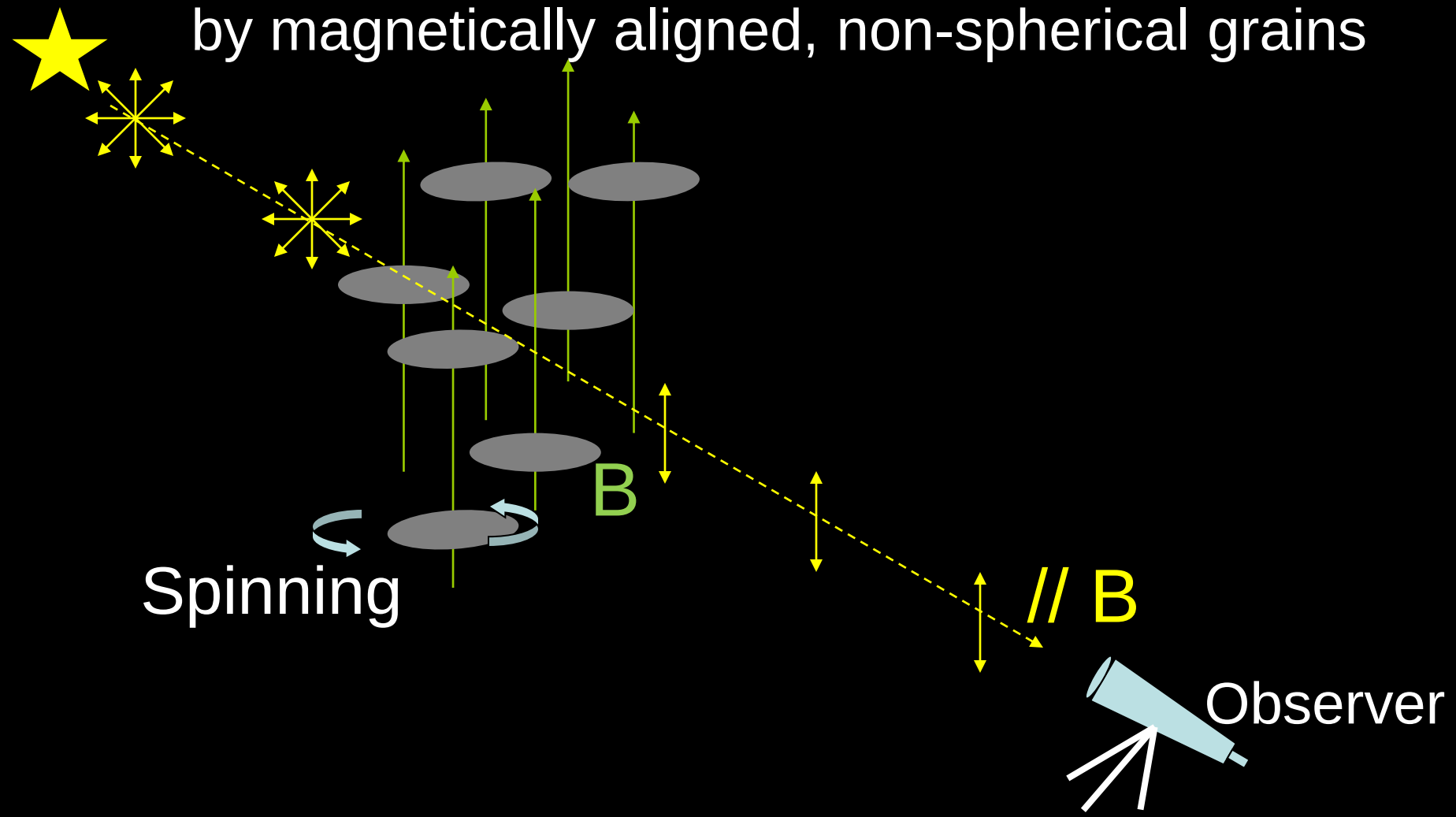
- Field of View: 7.7’×7.7’

Kandori et al. (2006)

Interstellar Polarization

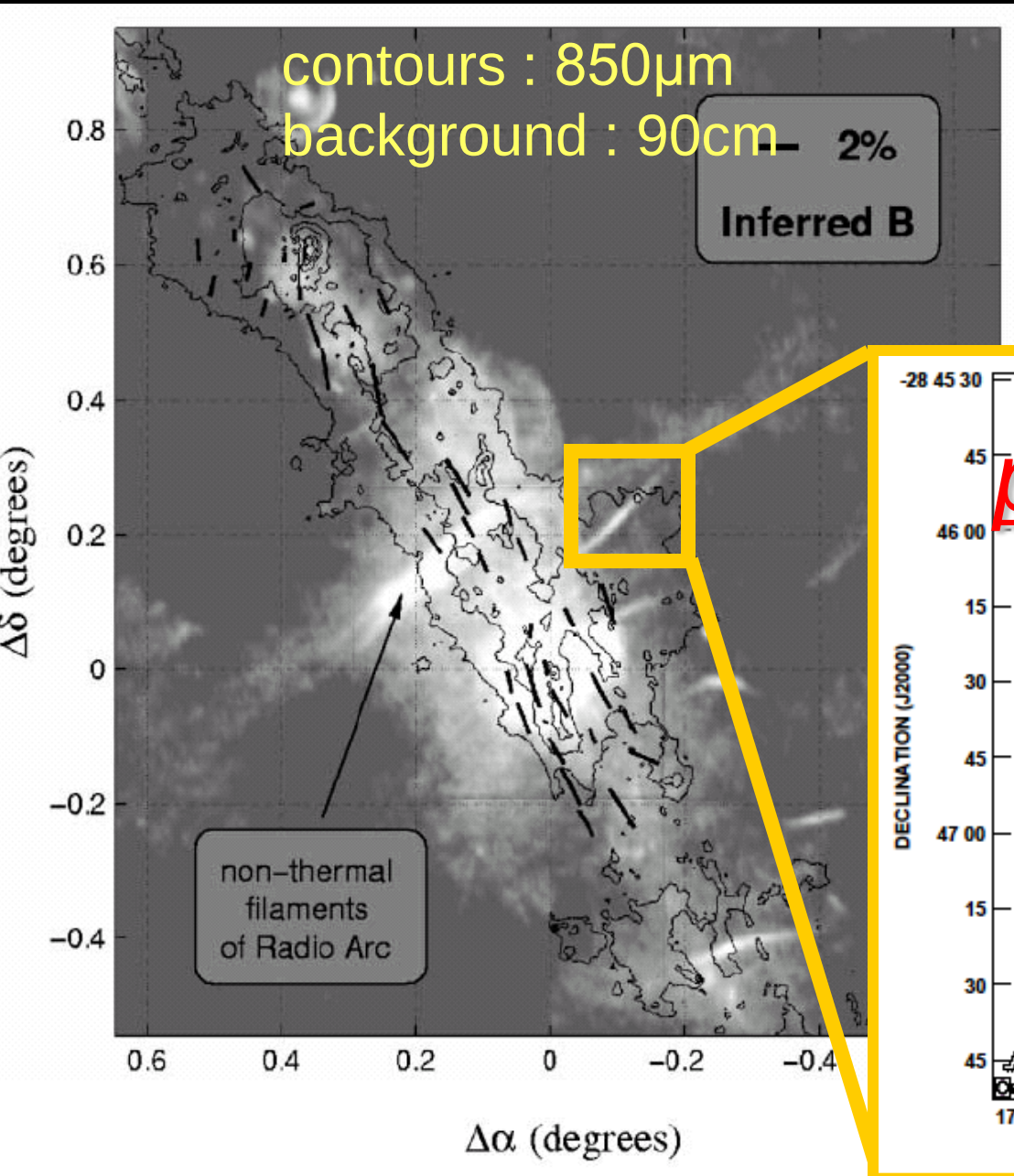
Dichroic polarization

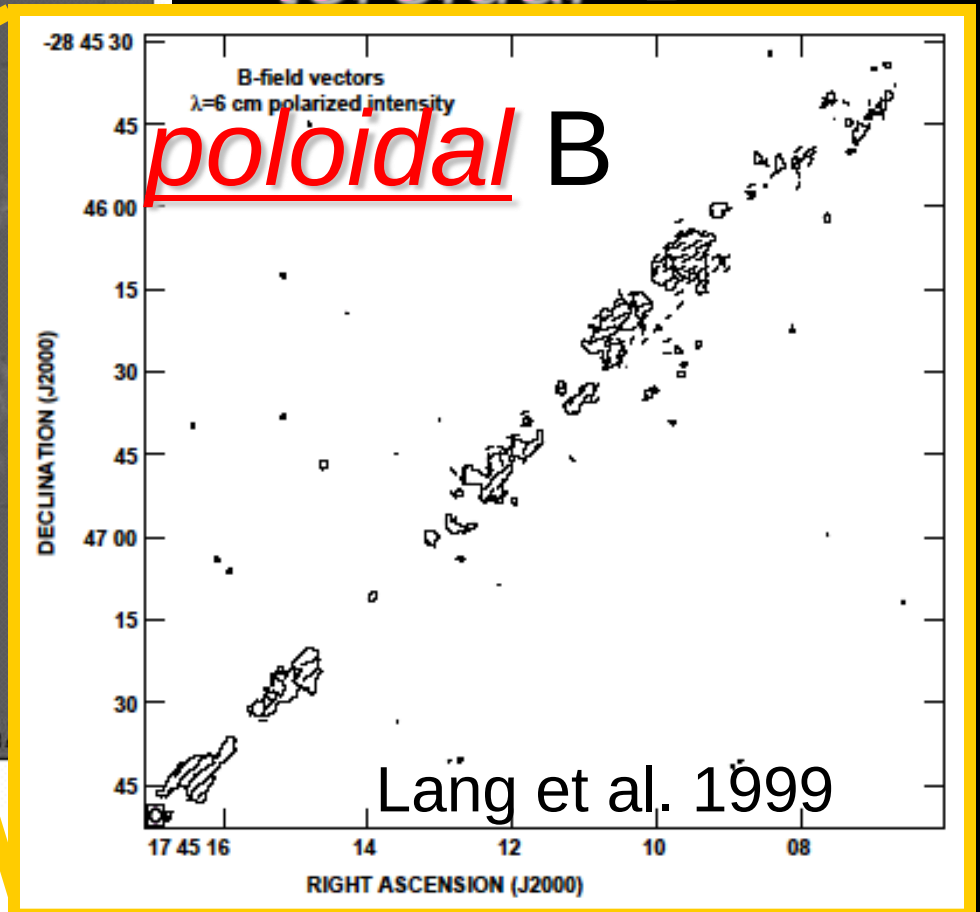
by magnetically aligned, non-spherical grains



450μm Polarization Map (Novak et al. 2003)

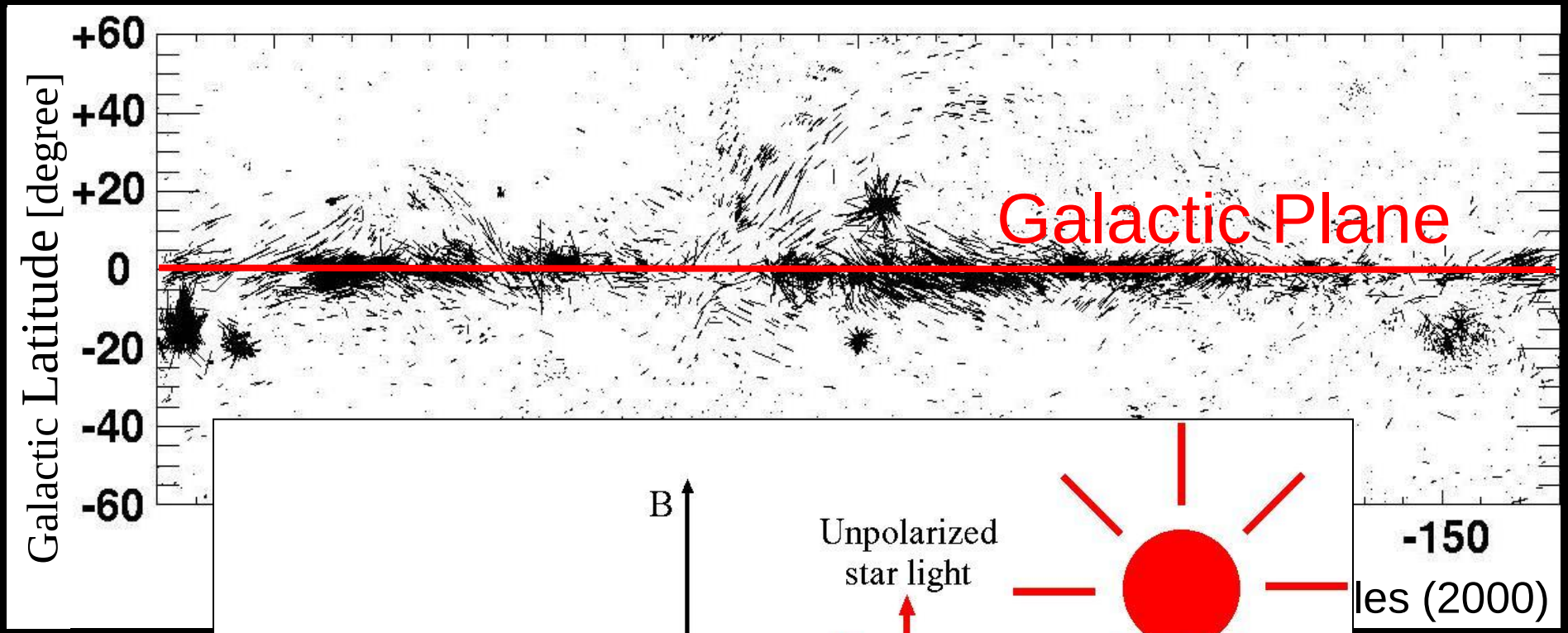
→*toroidal* B

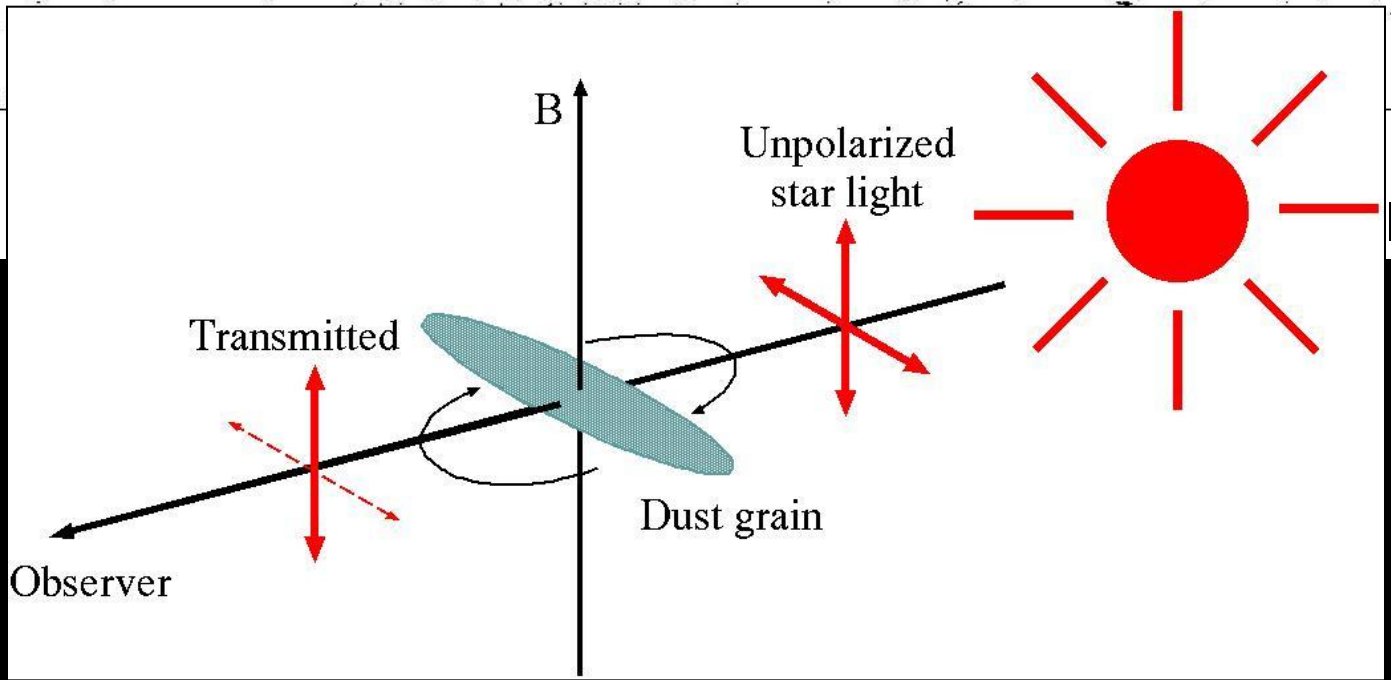




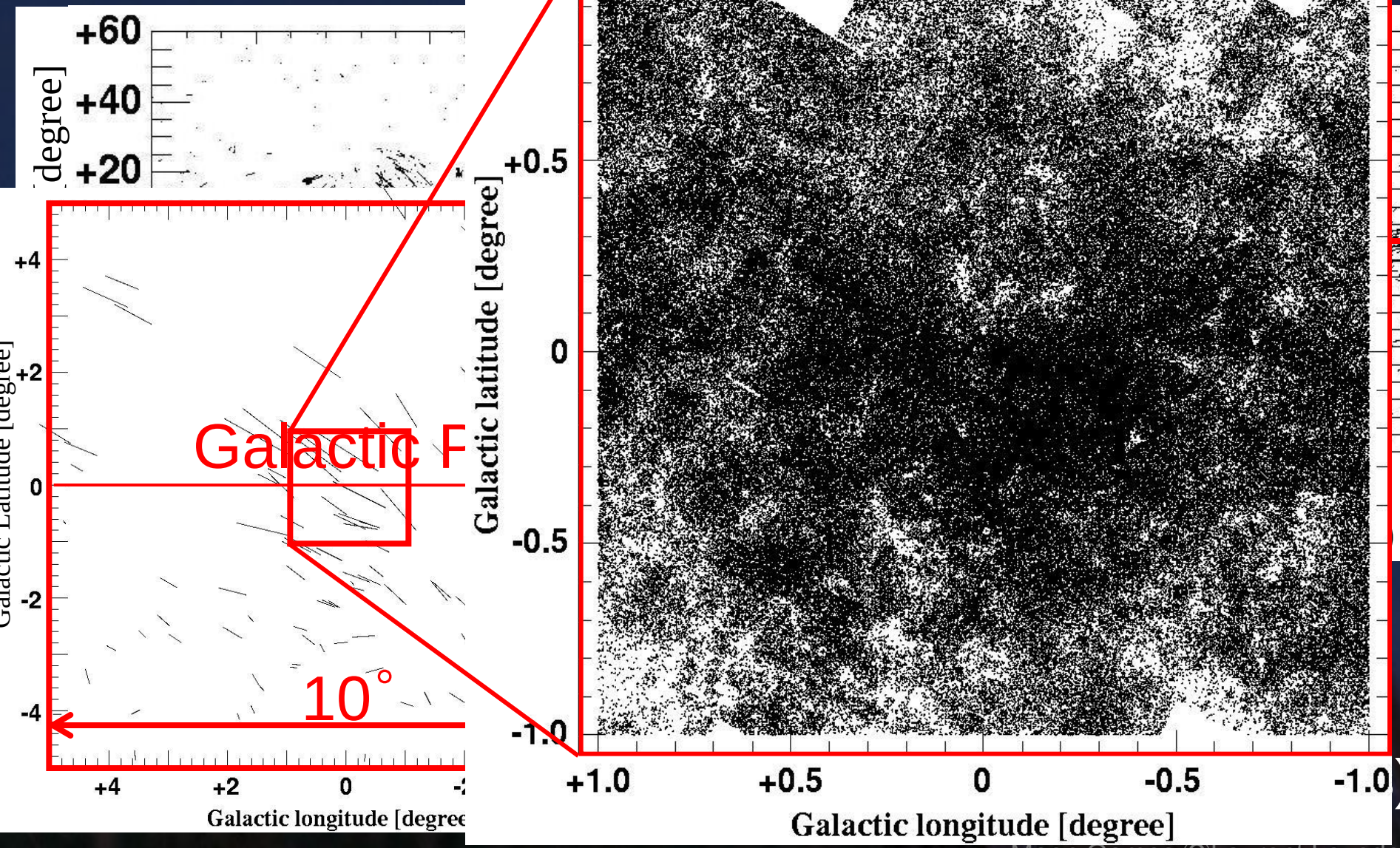
Starlight Polarization

Optical Data (～9000 Stars@*Blue*)





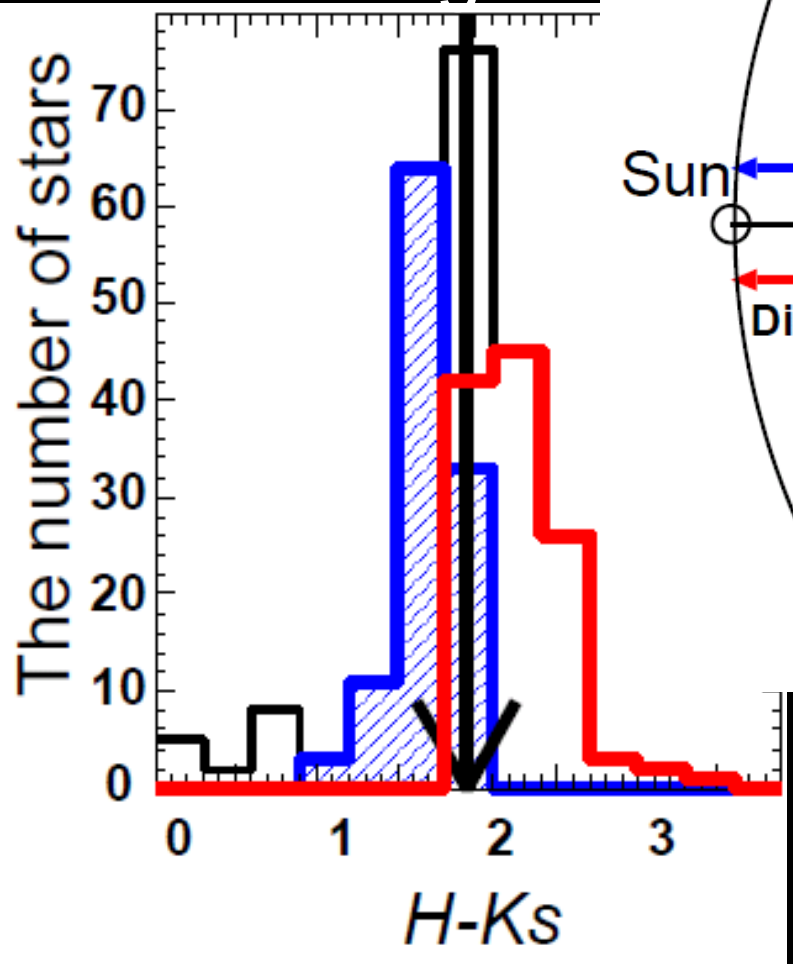
Starlight Polarization

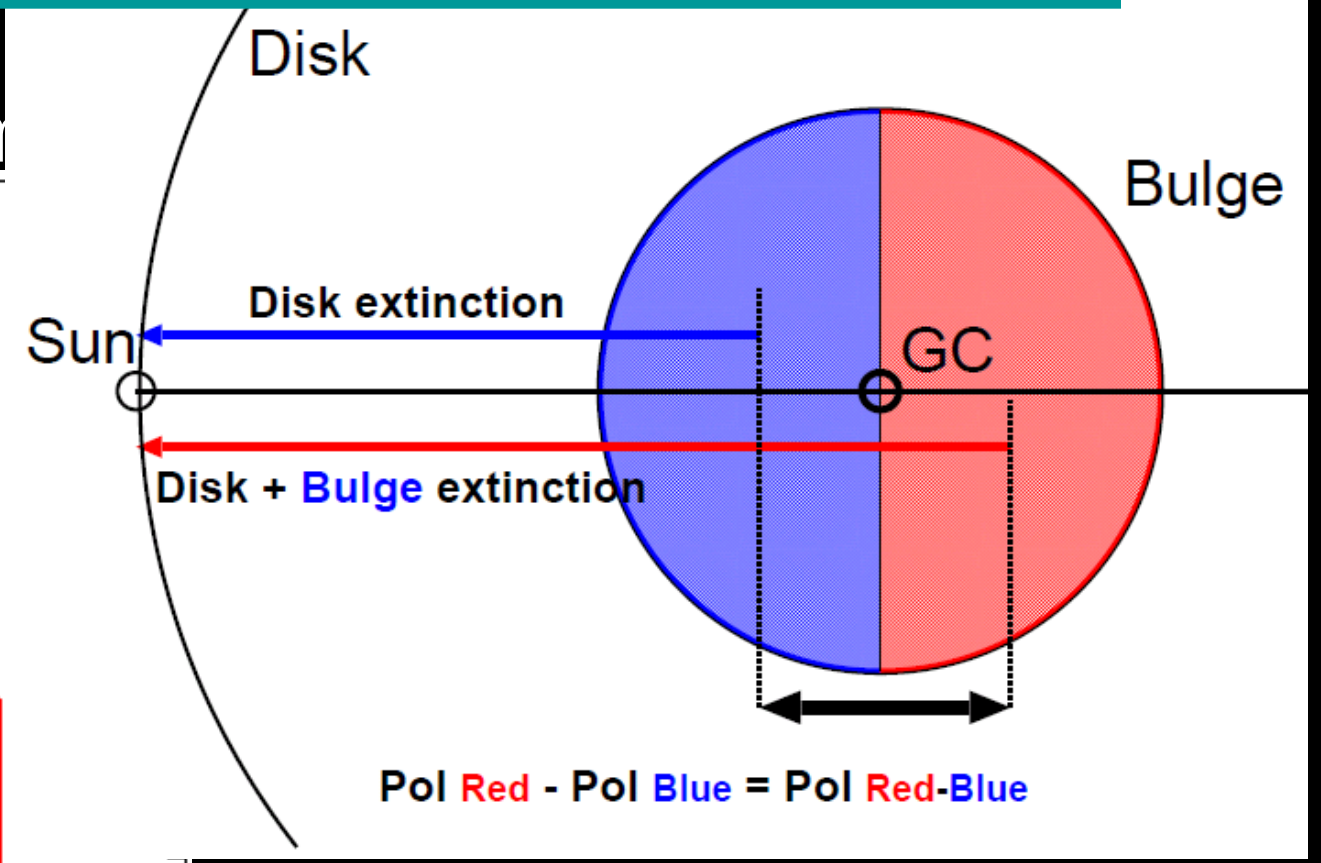


NIR Polarization at the GC

B at the ”Center“ of the Galaxy

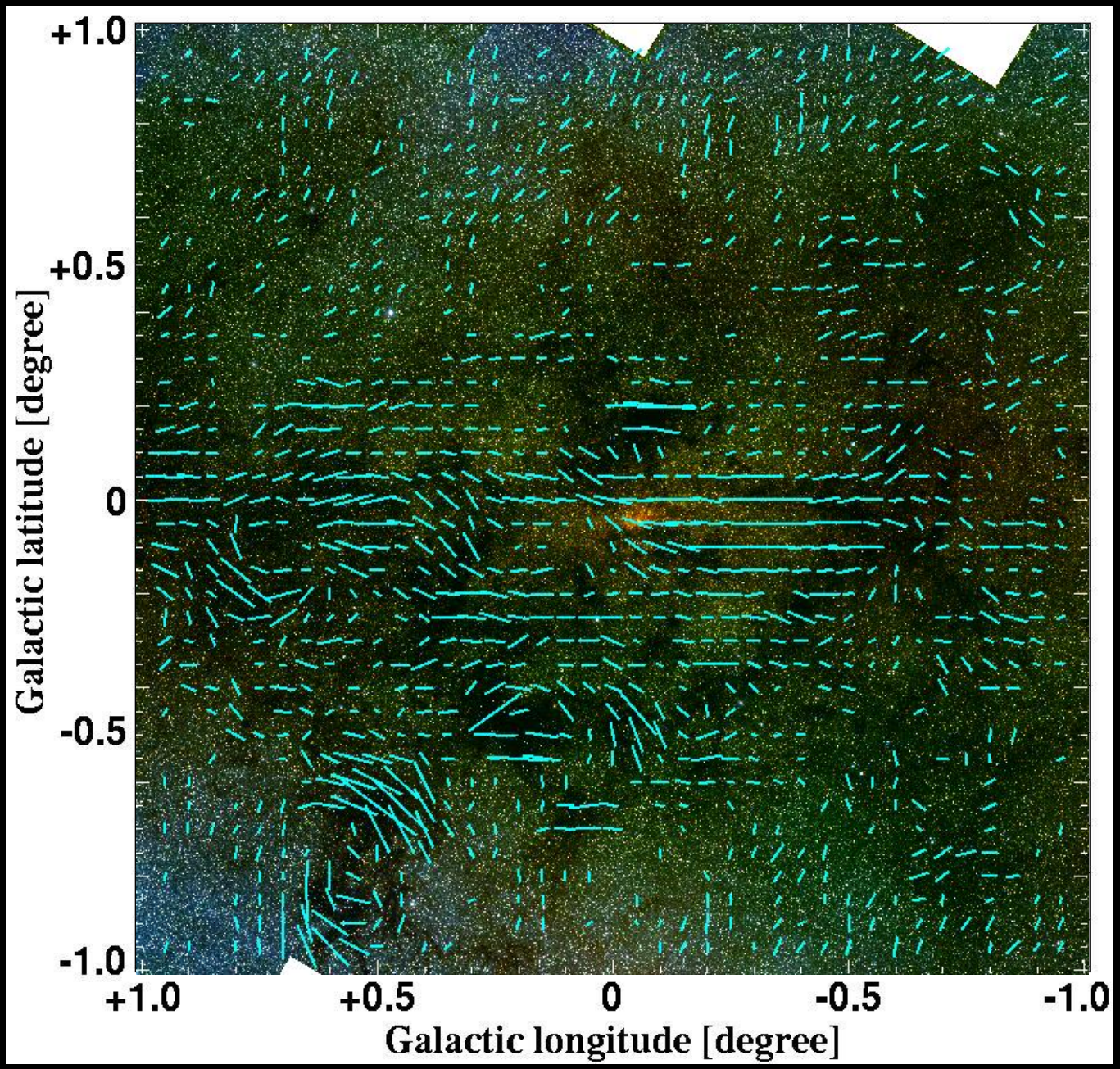
H-Ks Histogram





Nishiyama et al. 2009
ApJ, 690, 1648

NIR Polarization at the GC



B Structure at G.C.
(2.0˚x2.0˚
Ks band
P/Pe>2.0)

IRSF/SIRIUS
J/*H*/*Ks*