

SGMAP project

Search for Galactic Magnetic field by
All-sky Polarization survey

Michitoshi Yoshida (吉田道利)

Hiroshima Astrophysical Science Center

(広島大学・宇宙科学センター)

全天偏光サーバイによる銀河磁場構造の解明

平成26年度～31年度：9.8億円

- SGMAP プロジェクト -

事業の目的

大規模な全天偏光サーバイを実施、他の追随を許さない歴史的な天体偏光データベースを構築し、天の川銀河系の磁場構造を解明し、銀河系の構造形成史に迫る。広島大学は、このプロジェクトにより学術分野の世界的な研究拠点を形成する。

科学的重要性・緊急性

●銀河系磁場の詳細構造の解明は世界的に急務

1. 磁場は天の川銀河系の構造形成のカギ
2. 銀河系外天体の光の偏光に影響
3. 星間空間の宇宙線の伝搬を支配

→しかし、銀河系磁場の詳細は未だ不明

→全天の偏光観測によってのみ、磁場を知ることができる！

●全天偏光サーバイは世界の天文学のエアポケット状態

→今こそ歴史的データを世界に発信できるチャンス

最先端天文学進展のボトルネック

なぜ広島大学が取り組むのか

●広島大学・宇宙科学センターの持つ優れた研究実績、人材、環境を生かして発展させる→世界的な研究拠点の形成

1. かなた望遠鏡を駆使した天体偏光観測の研究実績
2. 世界最高性能の天体偏光観測装置の開発実績
3. 天体偏光観測分野における世界的研究者（川端、植村）
4. 日本における最良の天体観測サイト、大学キャンパスから至近

全天偏光サーバイをやれるのは広島大学しかない！

ねらい

●天体偏光観測で随一の実績を持つ広島大学が中心となり、新しい目=偏光で宇宙を探る

- 日本発の大規模かつ歴史に残る偏光データベースを世界に提供。天の川銀河系の磁場の詳細測定、銀河系構造形成史を解明
- 国立天文台や他大学と連携して、国内に天体偏光の世界的な研究教育拠点を形成
- 良好な立地条件を生かし、最先端の研究現場をフルに活用して社会連携活動を展開

特定の新しいサイエンスの集中展開
→大学だからこそできる

事業内容

全天偏光サーバイ

2年間で施設整備
4年間で集中観測

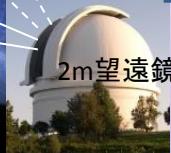
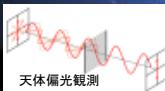
天の川銀河系の大半をカバーする
超広域天体偏光データ

天の川銀河系

本事業のサーバイ範囲

これまで偏光で
探査された領域

10倍遠くまで見通して、
他の追随を許さない系統的、大規模な天体偏光データを得る



期待される成果

天体偏光に関する歴史的データベース・偏光マップを作成、世界に発信

天の川銀河系の磁場構造の詳細を解明

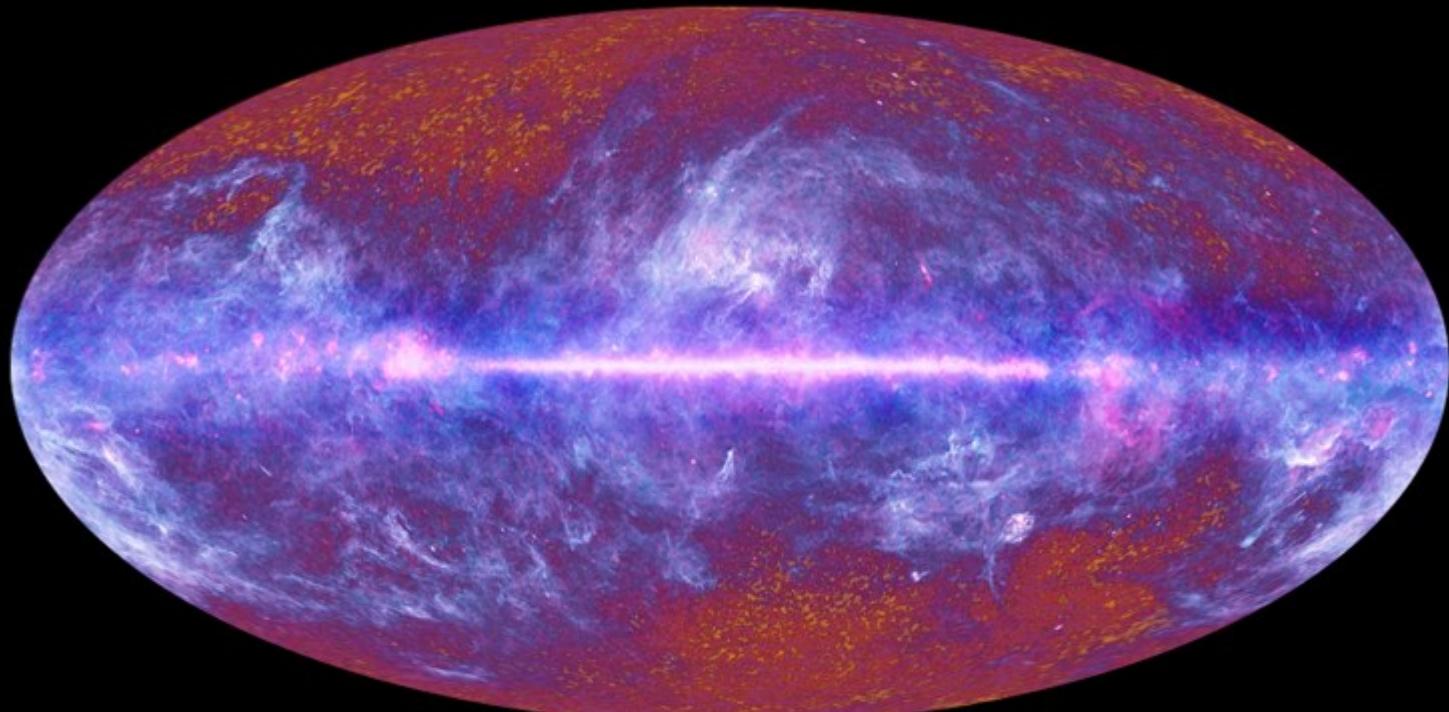
天の川銀河系の構造形成、太陽系の誕生過程の解明

研究拠点：広島大学宇宙科学総合研究機構

Introduction

- Mechanisms that originate optical radiation and light
 - Dust scattering
 - Interstellar medium
 - Circumstellar disks
 - Electron acceleration
 - Synchrotron radiation
 - Inverse Compton scattering and AGNs
 - Synchrotron radiation
 - Active Galactic Nuclei (blazars)
 - Gamma-Ray Bursts
- However, not yet well explored !!

Galactic Dust Emission

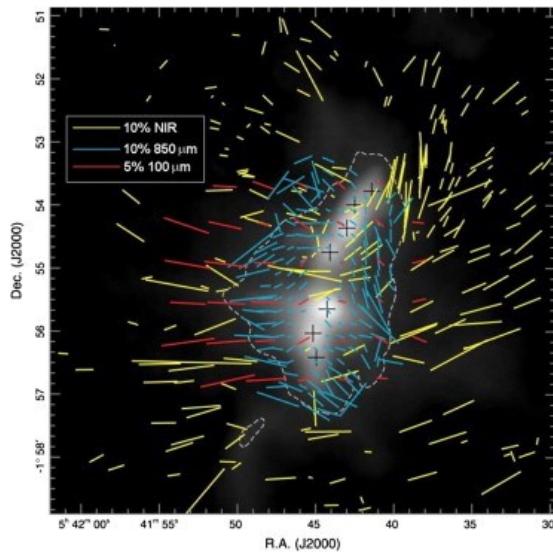
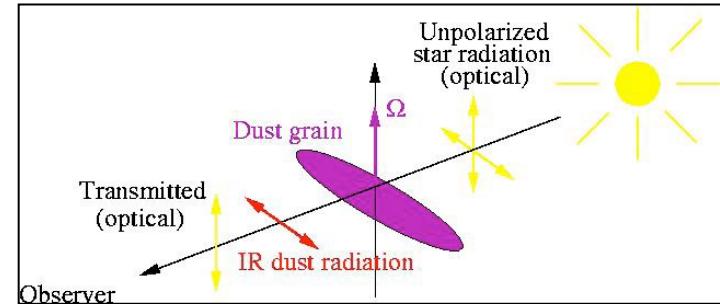


The Planck one-year all-sky survey

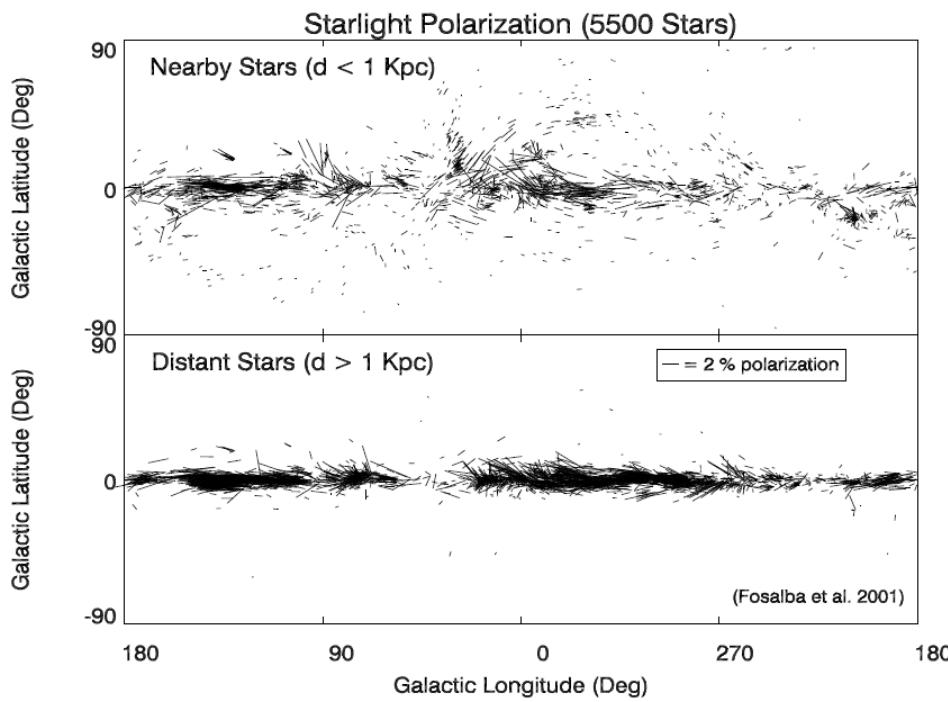


(c) ESA, HFI and LFI consortia, July 2010

- Optical starlight polarization arises from dust grains aligned by interstellar magnetic field
- Starlight Polarization → dust properties & interstellar magnetic field
(B vector projected on the sky)



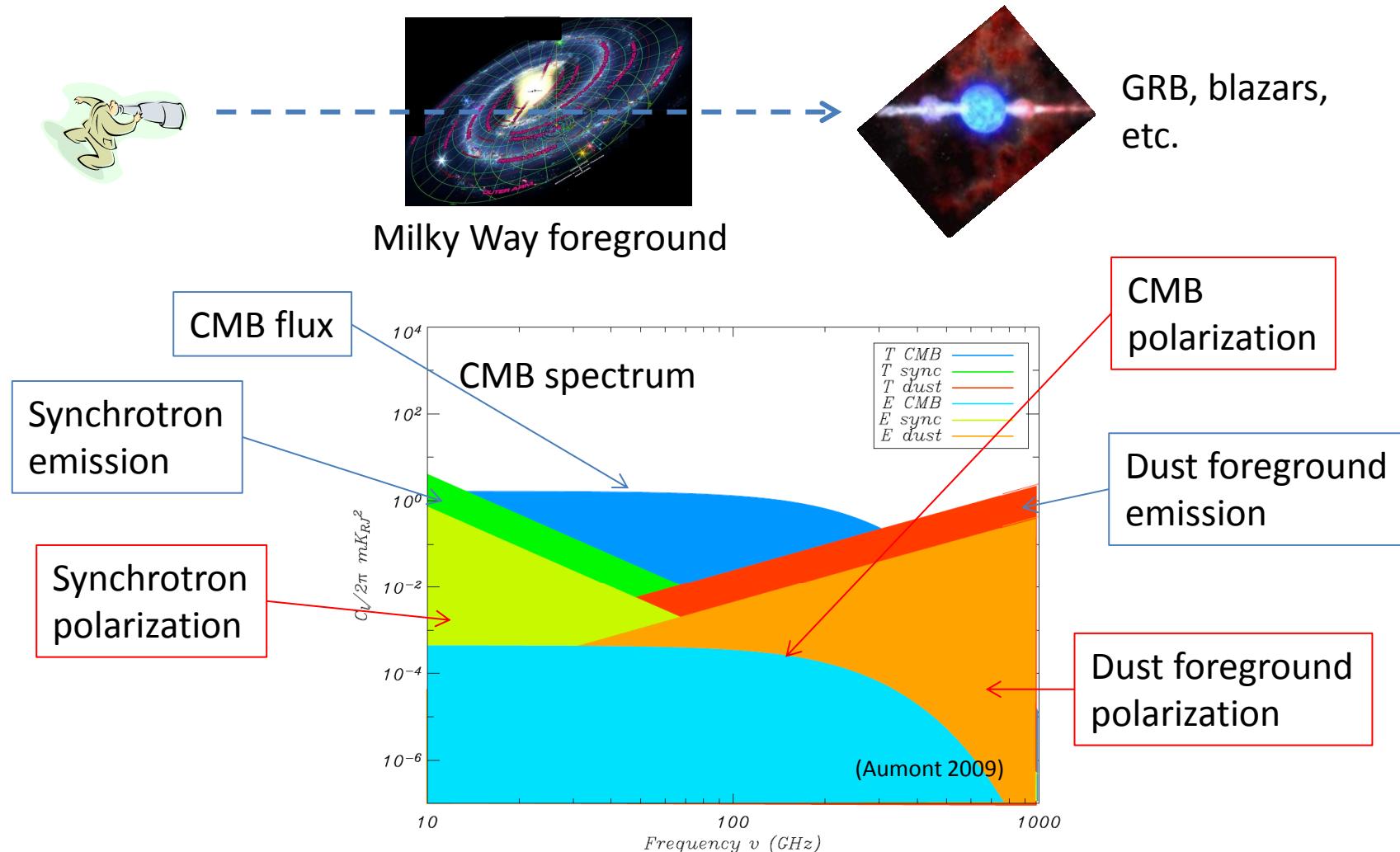
Star-forming
Region
NGC 2024
Kandori+ 2004



Problems for extra-galactic polarization study

- No accurate, high spatial resolution, and uniform Galactic interstellar polarization data

➔ Serious problems for foreground polarization correction



Polarized light

→ magnetic field, dust properties, circum-stellar structure, gas distribution, foreground correction

- No all-sky polarization survey in optical/NIR bands
 - The current catalog (Heiles 2000; 9286 stars) is quite heterogeneous and shallow (< 9mag.) at only one band (V).
↓
- 2m telescope + multi-color polarimeter
 - 0.1% polarimetric accuracy with 90s exposure at $m_V < 14\text{mag}$
 - More than 1,000,000 stars in the northern sky
 - 100 times deeper than the existing database
 - Optical three color
- Collaboration with GAIA
 - Three dimensional structure of Galactic magnetic field

Legacy database of polarized objects

SGMAP project

Search for Galactic Magnetic field by All-sky Polarization survey

- **Optical polarization survey of northern sky**
- Survey area:
 - R1: $-30 < b < +30$, $0 < l < 220$ $12,600 \text{ deg}^2$
 - R2: $+30 < b < 90$, $0 < l < 360$ $10,300 \text{ deg}^2$
- Sensitivity:
 - Polarimetric accuracy 0.1% at $m_v \sim 13$ mag.
- Three (or Four) color simultaneous polarimetry
 - 3 (or 4) broad bands: (B), V, R, I

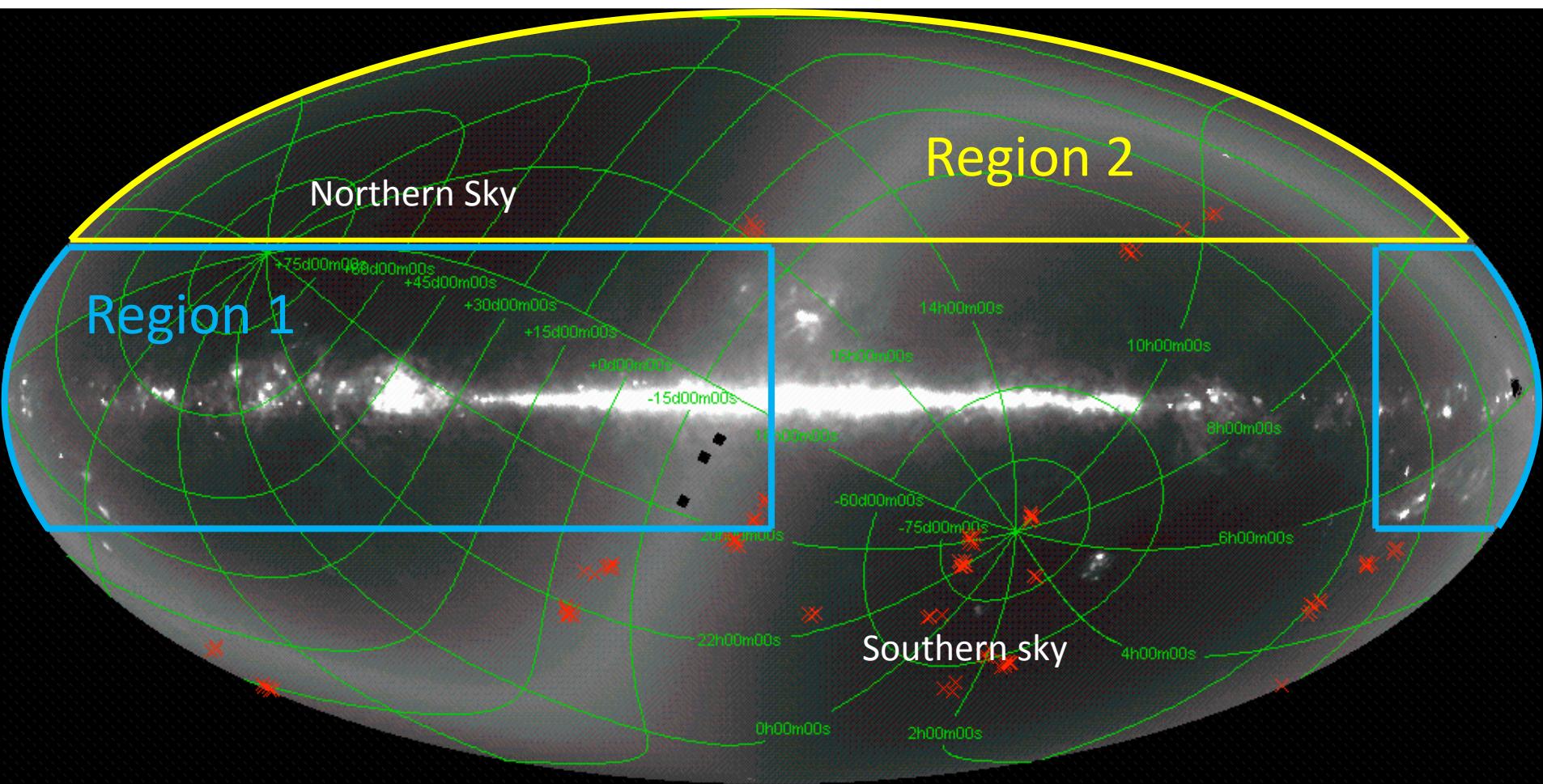
Method

- MAGNUM 2m telescope (Univ. Tokyo -> Hiroshima Univ.)
- Three color wide-field polarimeter
 - 3 (or 4) x 4K CCD $0''.49/\text{pix}$
 $\text{FoV} = 33'\phi$
 - Rotatable waveplate + Wollaston prism + 2 dichroic mirrors → 3 (or 4) color polarimetry
- Survey strategy
 - 158sec x 4 exposure for each field → polarimetric accuracy < 0.3% at $m_V = 15$.
 - Survey area:
 - R1: $-30 < b < +30, 0 < l < 220$ $12,600 \text{ deg}^2$
 - R2: $+30 < b < 90, 0 < l < 360$ $10,300 \text{ deg}^2$

Polarimetric accuracy achievable at 158sec exposure

m_V	accuracy
13	0.1%
14	0.2%
15	0.3%
16	0.6%
17	1.1%
18	2.4%

Survey Area



We explore the anti-center disk and the high latitude of the Milky-Way Galaxy.

Survey Speed

- FOV
 - 33.3 arcmin ϕ , 15% overlap
- Observation parameters
 - Seeing 1.8 arcsec FWHM
 - Atm. Extinction (mag) B: 0.75, V: 0.55, R: 0.40, I: 0.20
 - Sky brightness (mag/arcsec²) B: 19.0, V: 19.0, R: 18.8, I: 18.0
 - System efficiency B: 0.14, V: 0.25, R: 0.29, I: 0.31
- Observation time and Limiting magnitude
 - V=13.0mag G5 star (158s exp + 15s read) * 4 + overhead 60s = 278s
 - B: 0.21%, V: 0.10%, R: 0.04%, I: 0.04% for 13.0mag G5 star
- Survey speed
 - 0.2056 deg² per 1 set exposure
 - Region 1 : 12605/0.2056=61308 sets -> 595 nights -> x 3 → 1786 nights
 - Region 2 : 10313/0.2056=50161 sets -> 487 nights -> x 3 → 1461 nights

MAGNUM 2m telescope (Univ. of Tokyo)



Dismantled and
back to Japan
In 2009



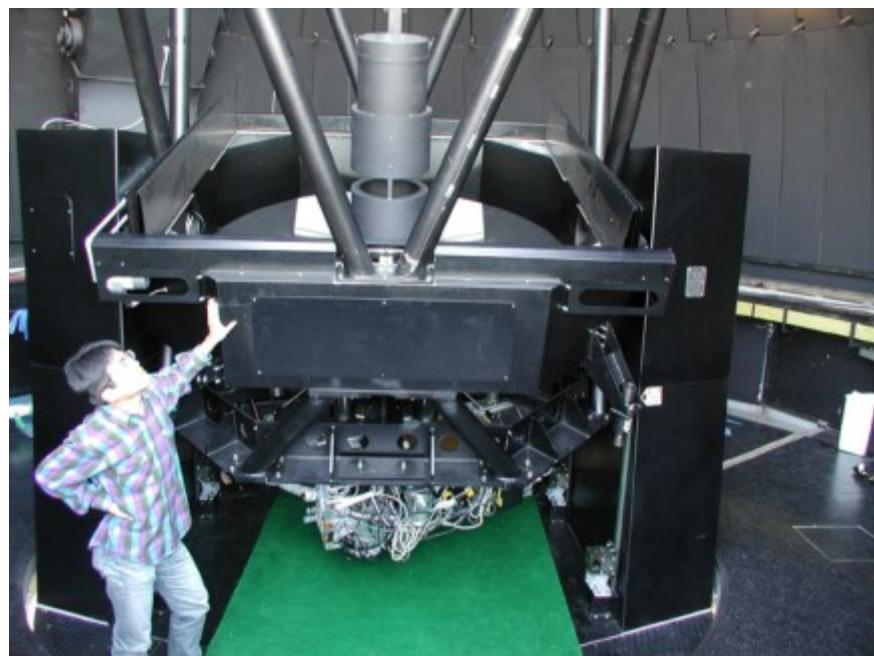
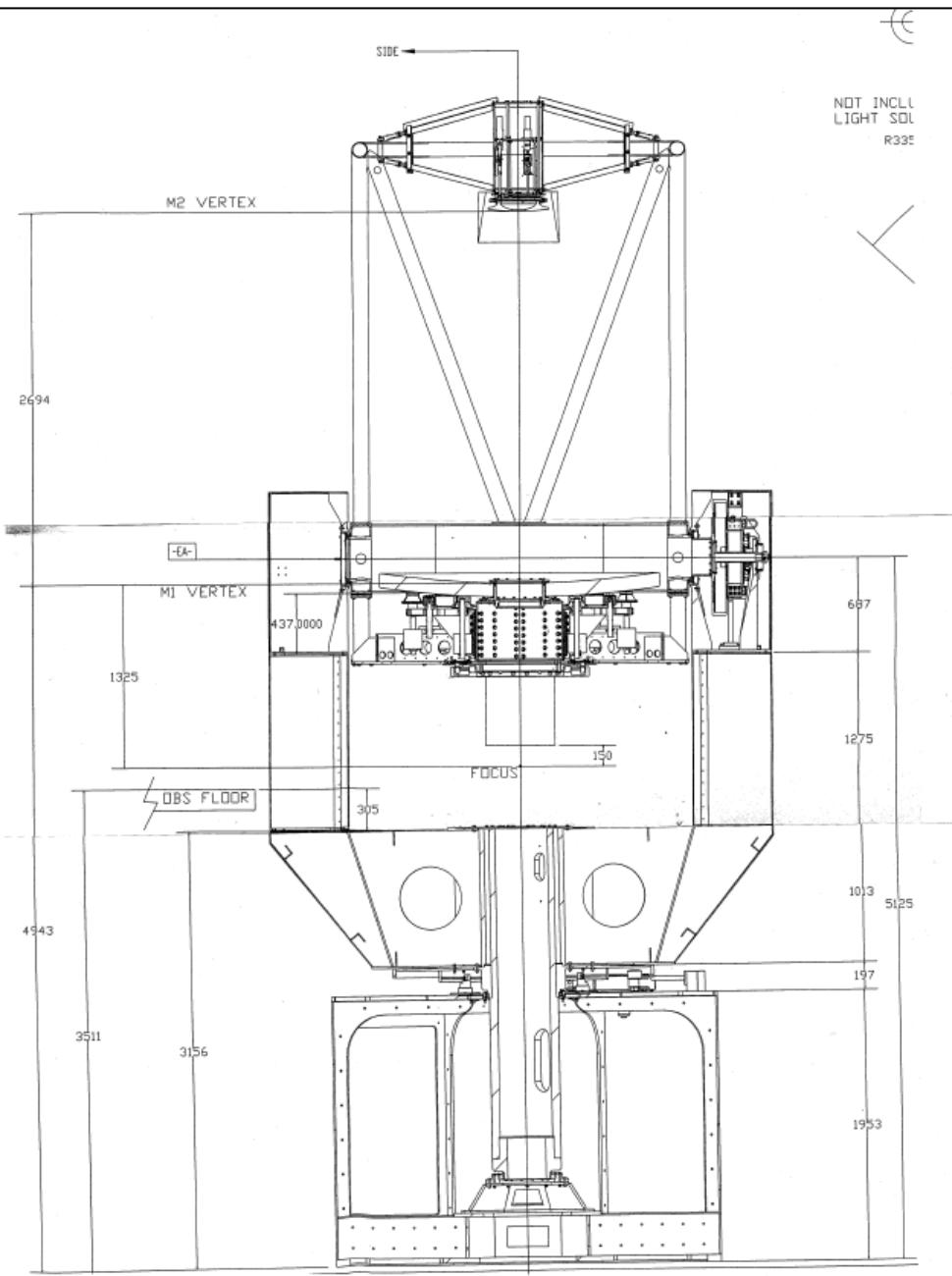
Move to
our observatory

MAGNUM was operated atop
Haleakala from 2000 to 2008



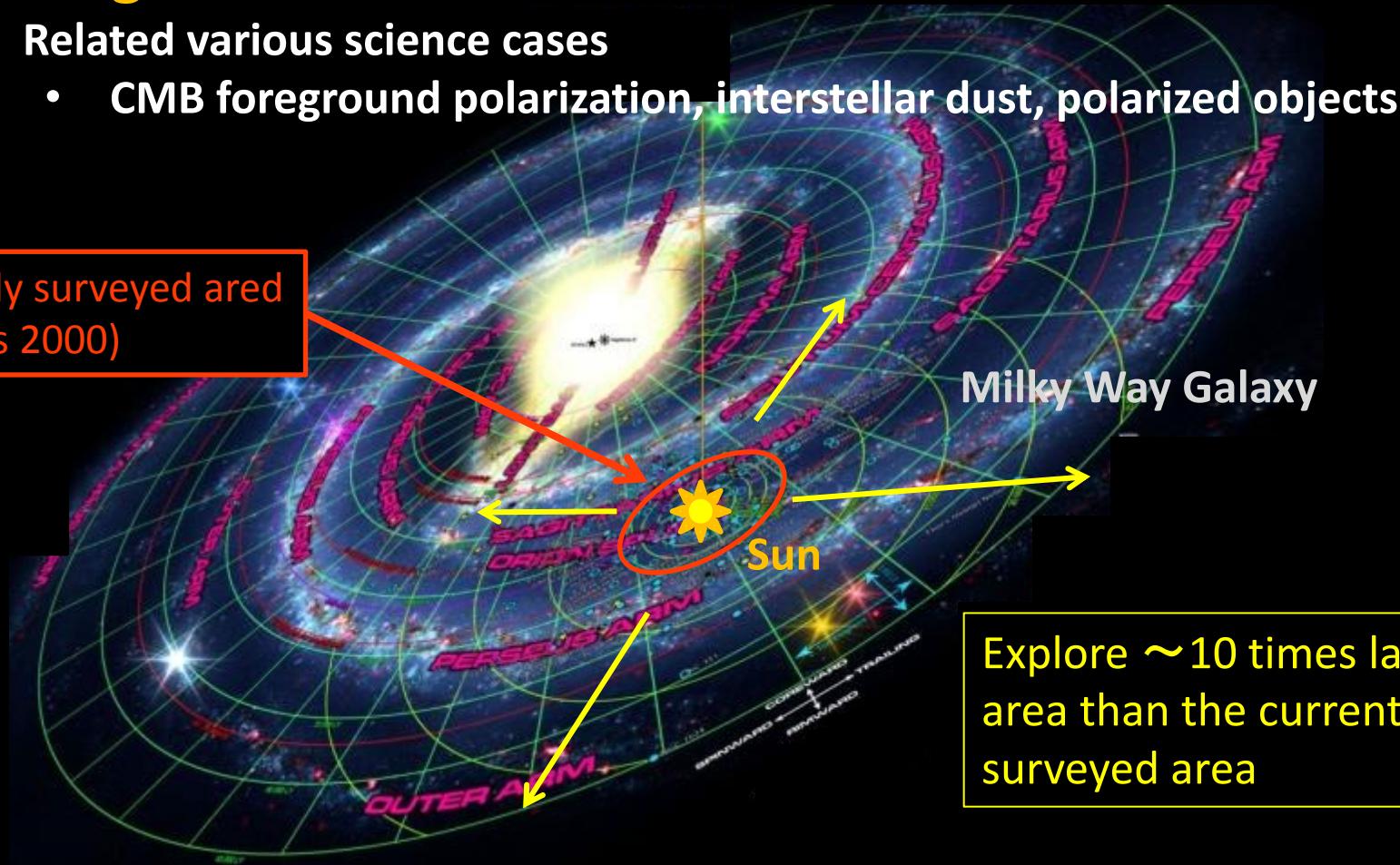
Low cost, quick construction,
and quick start of observation

MAGNUM 2m telescope

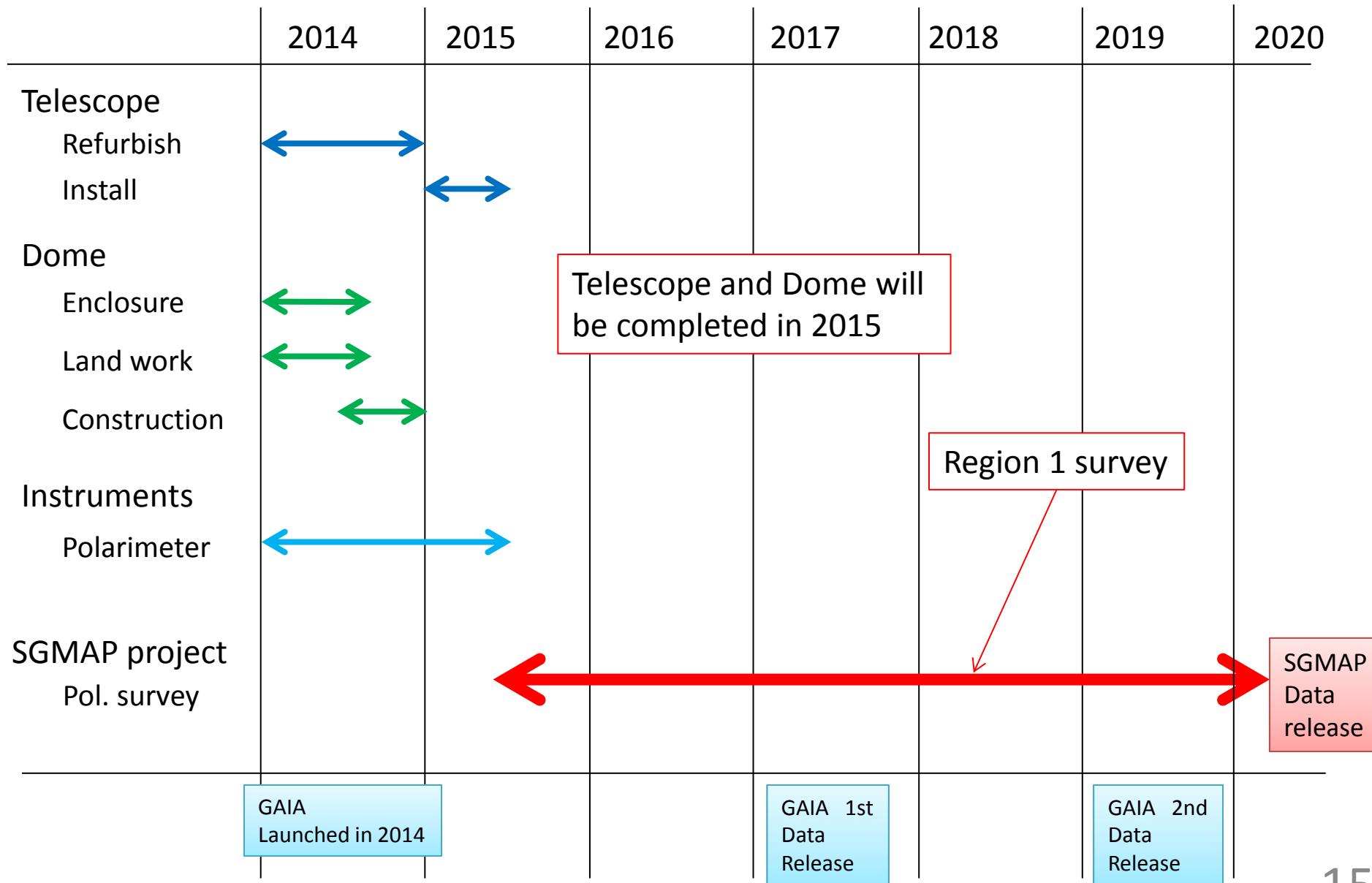


• What we want to do

- Large area survey of optical polarimetry of northern sky
→ huge database of polarized sky → Galactic magnetic field
- Related various science cases
 - CMB foreground polarization, interstellar dust, polarized objects



SGMAP ROADMAP



Polarization Mapping for Southern Sky

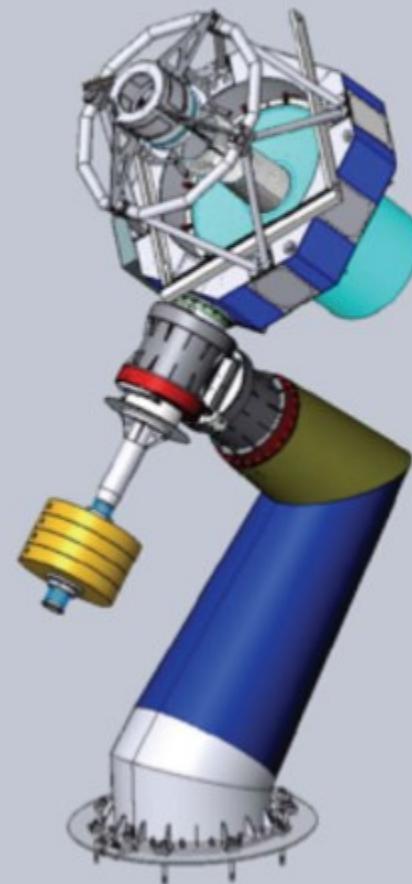
SOUTH POL

- **T80S Robotic Telescope**
 - FAPESP, PI: C. M. de Oliveira,
 - To be installed in 2013 @ CTIO
 - support for J-PAS (B. Ascaso's talk)

Table 1: Summary of the performance of the T80 design

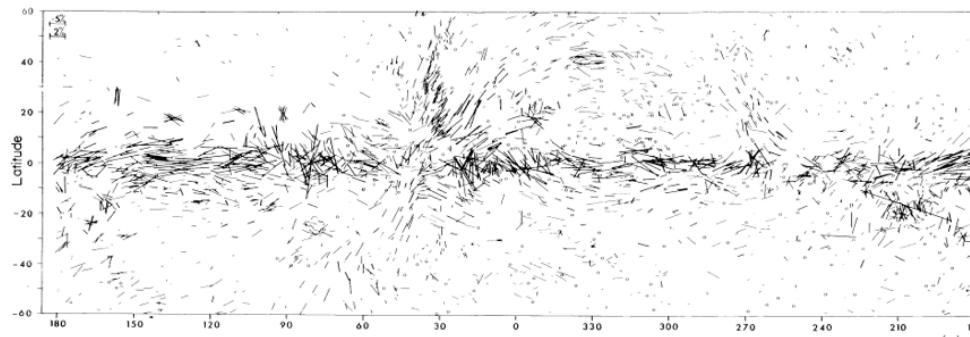
Performances of design	
Aperture	0.840 m diameter
Plate scale	55.56 arcsec/mm
Focal length	3712 mm
Field of view	110 mm (1.7°) with optimized image quality 155 nm (2.4°) with limited performances
Image Quality	50% EE = $5 \mu\text{m} / 0.28 \text{ arcsec}$ (diameter) 80% EE = $13 \mu\text{m} / 0.72 \text{ arcsec}$ (diameter)
Distortion	0.6%

- CCD:
 - EEV, 9k x 9k, 92mm
 - 2.0 deg^2 (!)



Science Impact

- **Galactic Astronomy**
 - **Interstellar Polarization**
 - SGMAP should provide $\sim 10^2$ more objects
 - Deeper, more precise and accurate
 - **Combination of SGMAP (+SOUTH POL) and GAIA**
 - **→ 3-D Mapping of ISM Magnetic Field!**
 - **Magnetic Field topology across Molecular Clouds**
 - From less dense regions (optical, SGMAP, SOUTH POL)
 - to denser regions (sub-mm: Planck, ALMA, APEX)



Science Impact

- **Extragalactic Astronomy**
 - **Many blazars will probably be discovered**
 - EGRET & FERMI sources with $V \sim 18$ will be identified
 - Identification of EGRET sources
 - highly polarized blazars
 - (polarization variability)
 - Identification of FERMI sources
 - $\sim 1,000$ sources (Abdo et al. 2010)
 - **Study of known blazars**
 - 500 Blazars with $R < 19$ exist in $dec > -15^\circ$ (Massaro et al. (2009))
 - $R_{\text{median}} \sim 17$

Science Impact

- **Stellar Astrophysics**
 - ToO polarization observation → Time evolution of explosive phenomena
 - Gamma Ray Bursts
 - Supernovae
 - Novae
 - Study of circumstellar environments
 - Young stellar objects
 - Evolved objects

Summary

- **SGMAP**
 - Measure polarized northern sky
 - With three (or four) optical colors simultaneously
 - Accuracy of $\sim 0.1\%$ at $m_V = 13$ mag.
- **Optical/NIR Pol Surveys are unprecedented**
 - Scientifically opportune
 - Synergy with Planck, ALMA & GAIA
 - Complementary with radio polarization survey
- **The data will impact various research fields**
 - from Cosmology to Solar System studies



MAGNUM for
SGMAP

Kanata