

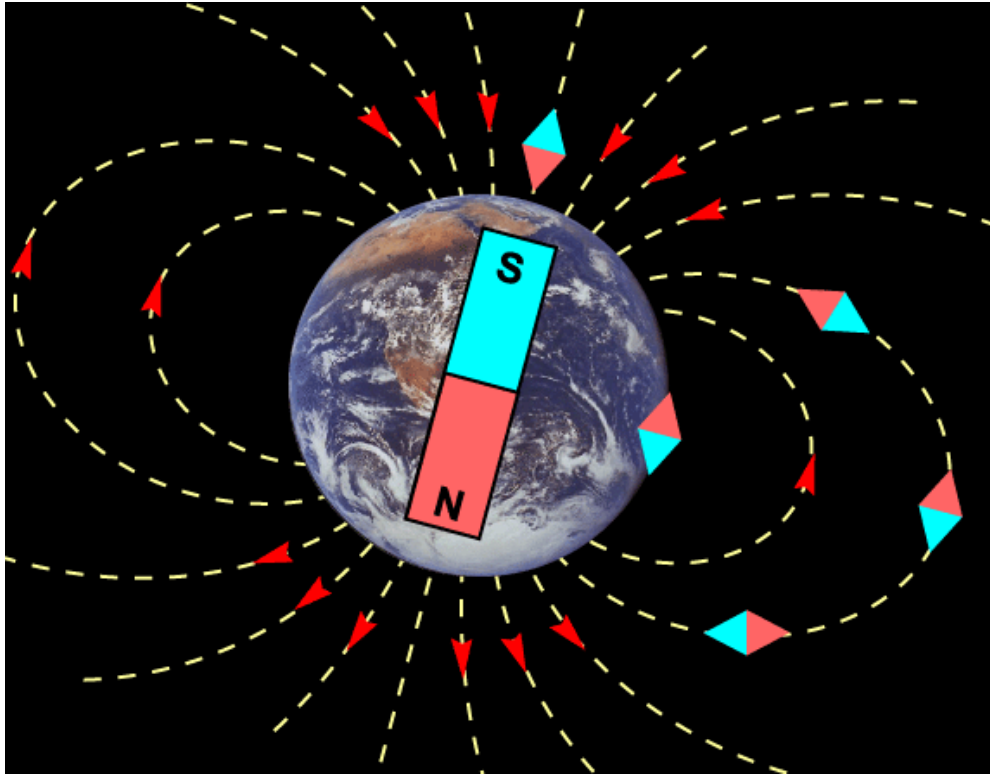
# **Study of Cosmic Magnetic Fields with Square Kilometer Array**

Keitaro Takahashi

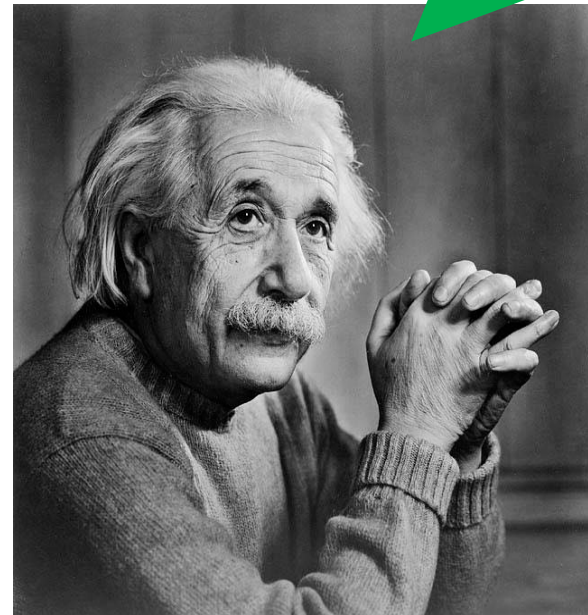
Nagoya University

Sep/24/2010 @ AP-RASC 2010

# Origin of Magnetic Fields

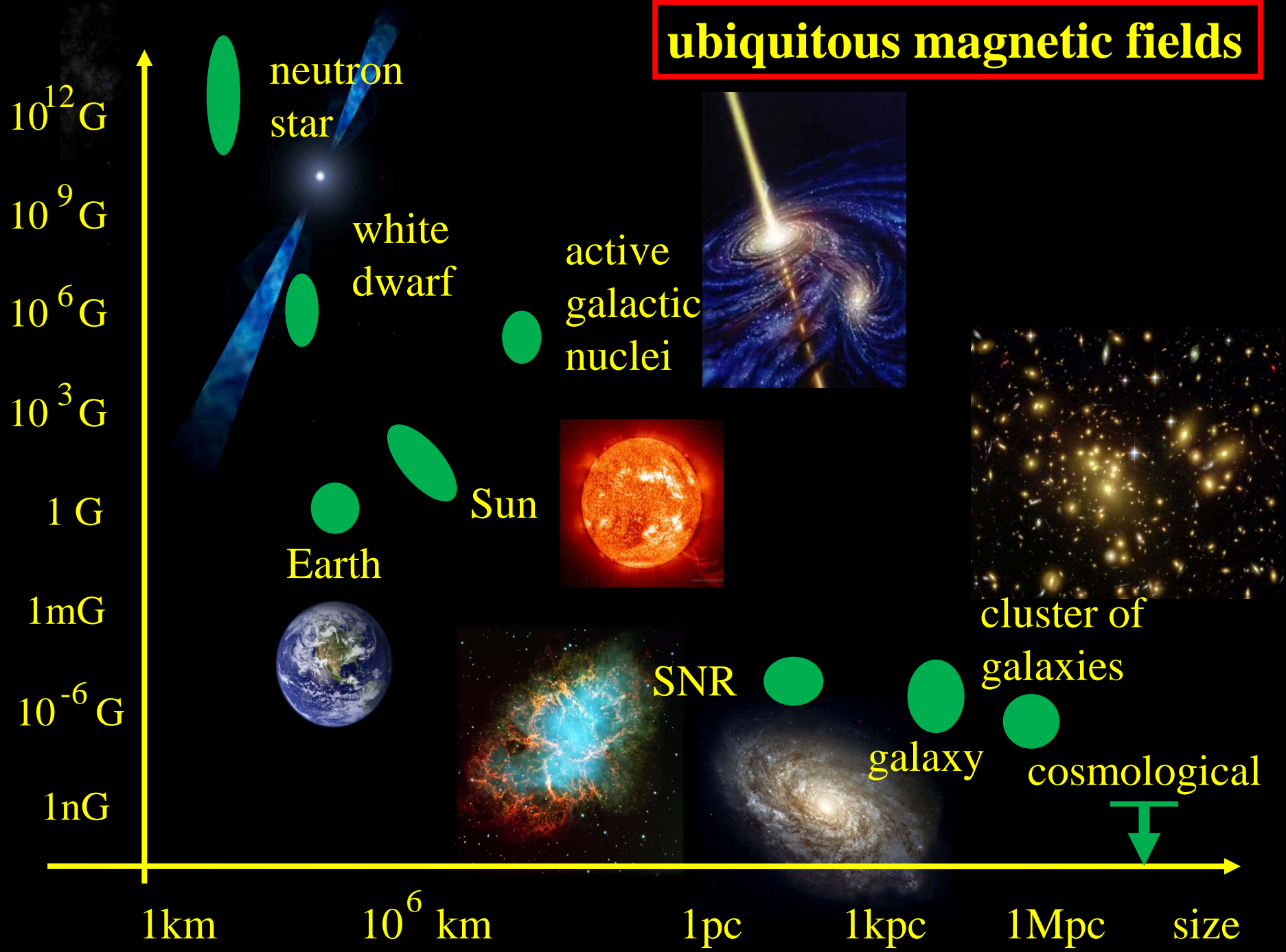


Origin of magnetic fields of the earth is one of the greatest mystery in modern physics.



We now know various astronomical objects have their own magnetic fields.

# ubiquitous magnetic fields



# Origin of Magnetic Fields (Extended)

## Extended Einstein's Question

1. Earth => astronomical object
  - galaxies
  - clusters of galaxies
2. cosmological fields?
  - magnetic fields not associated with any objects
  - only an upper bound  $\sim 0.1\text{nG}$

# Observation of Magnetic Fields

1. synchrotron radiation
2. Faraday rotation  
polarization angle

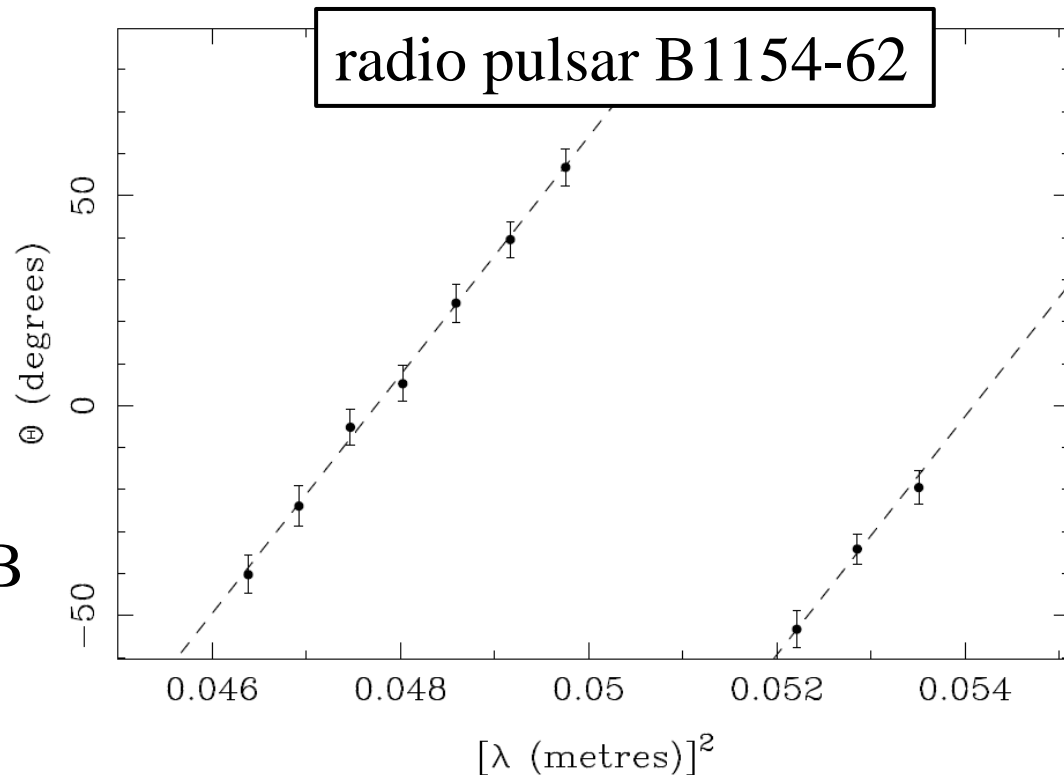
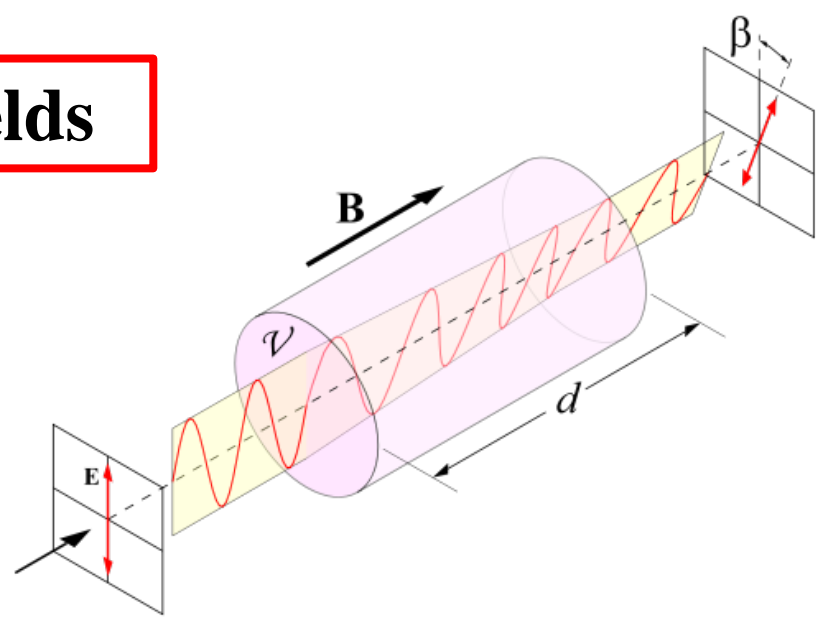
$$\Theta = \Theta_0 + \text{RM} \lambda^2$$

rotation measure

$$\text{RM} = K \int n_e B_{\parallel} dl$$

integration  
from the source  
to the observer

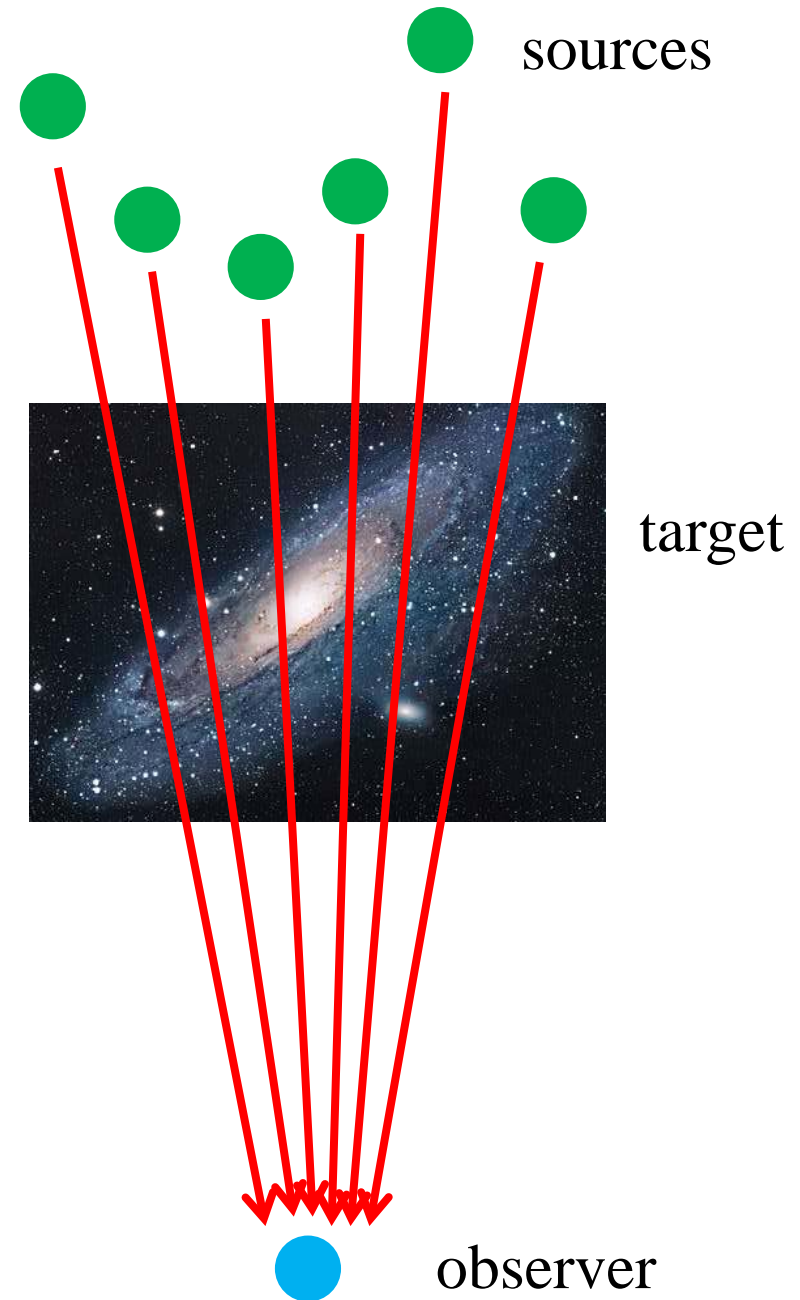
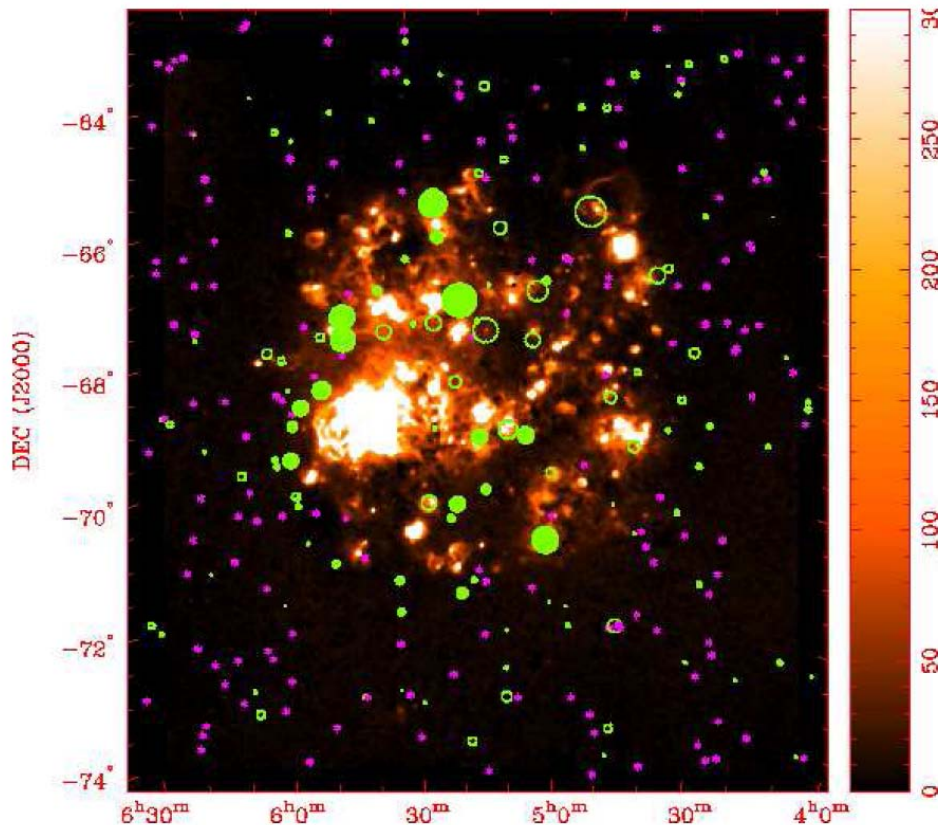
Information on  $B$   
can be obtained  
from the slope.



# Application

We can probe target's magnetic fields by observing a lot of sources behind the target.

292 sources behind LMC



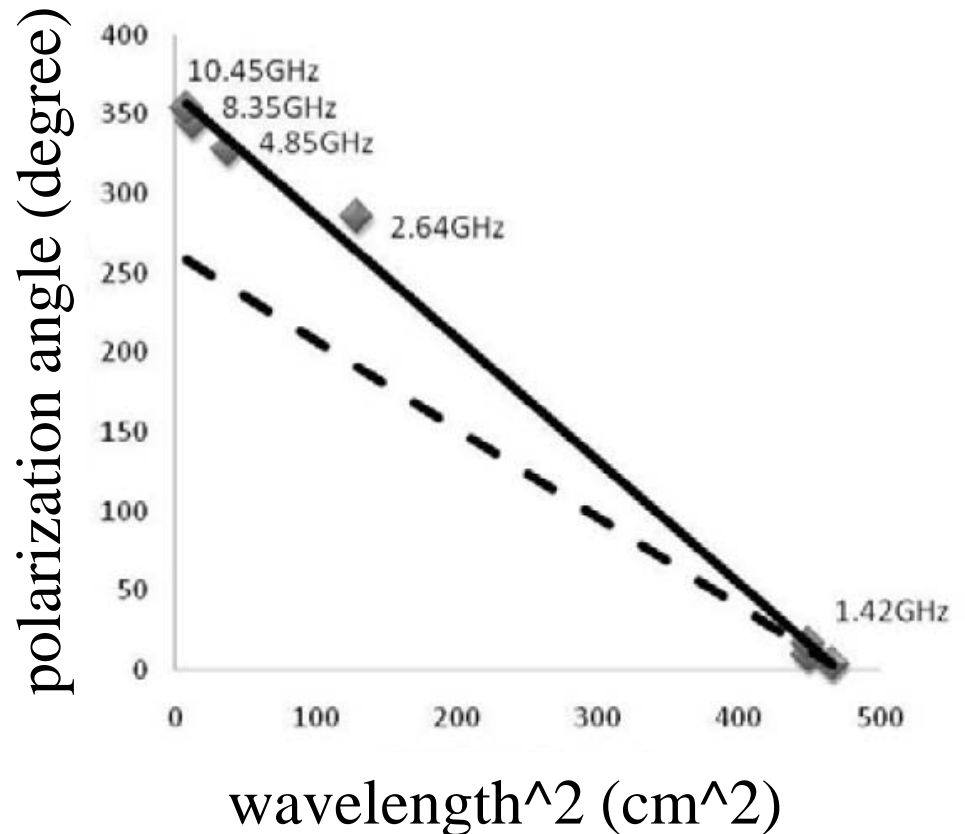
Gaensler et al., Science (2005)



# Importance of Wideband

Rotation measures have often been determined by very narrow band observations (1.365 – 1.435GHz).  
=> very large error

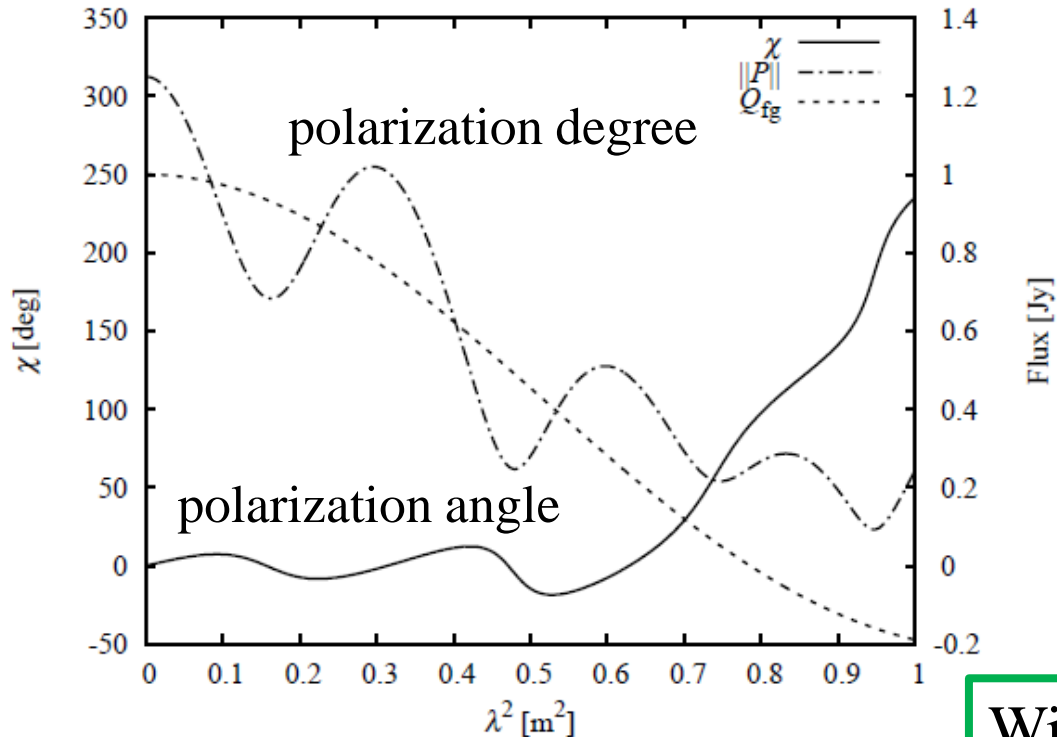
Wideband observation is important for precise determination of rotation measure.



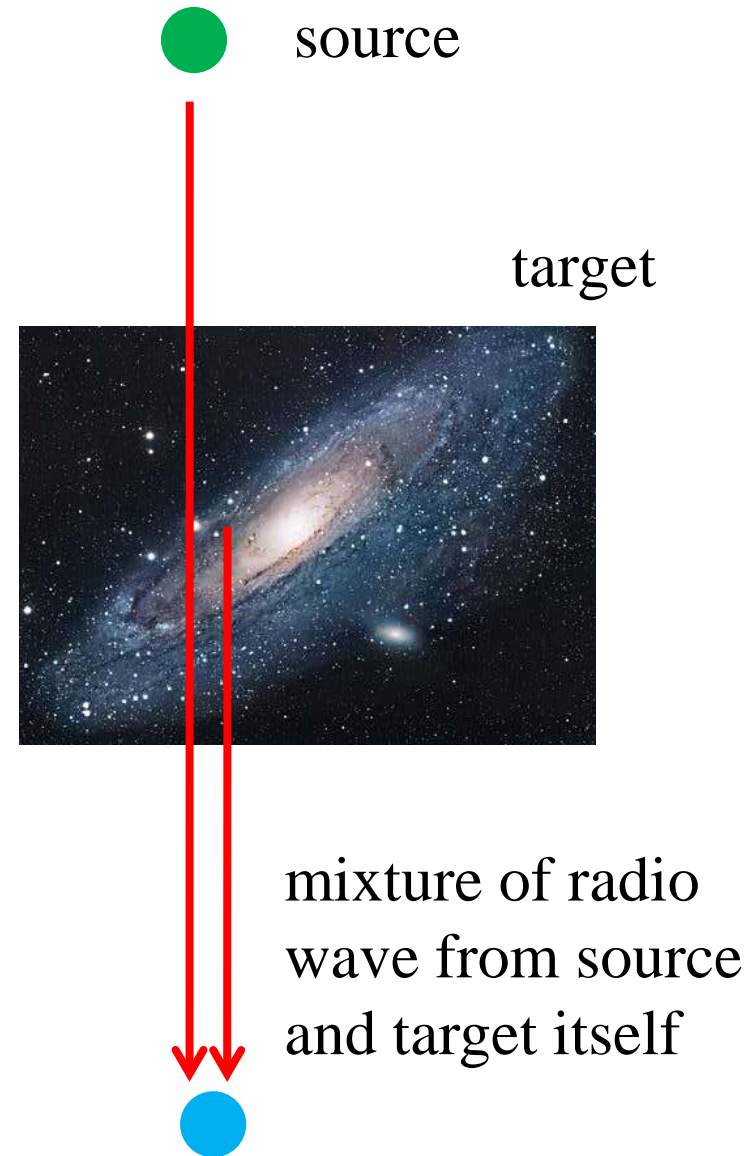
# Importance of Wideband

The situation is more complicated in general.

- emission of target itself
- emission of our galaxy



Brentjens & de Bruyn, A&A (2005)



Wideband observation is crucial to probe magnetic fields.



# SKA-Japan Consortium

Engineering Working Group

Science Working Group

“AGN”, “Astrometry”, “Pulsar”

“Galaxy Evolution”, “Spectral Line Survey”

**“Cosmic Magnetic Fields”**

11 researchers from 9 institutes

Keitaro Takahashi (Nagoya University)

Takuya Akahori (Chungnam National University)

Hidekazu Hanayama (NAOJ), Kiyotomo Ichiki (Nagoya University)

Makoto Inoue (ASIAA), Susumu Inoue (Kyoto University)

Takahiro Kudoh (NAOJ), Mami Machida (Kyusyu University)

Hiroyuki Nakanishi (Kagoshima University)

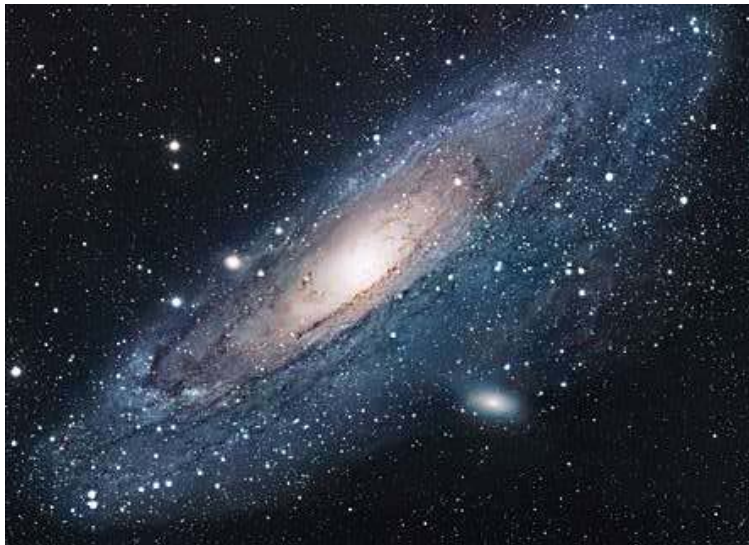
Yoshiaki Sofue (Meisei University), Hajime Susa (Konan University)

Method: theory, numerical simulation

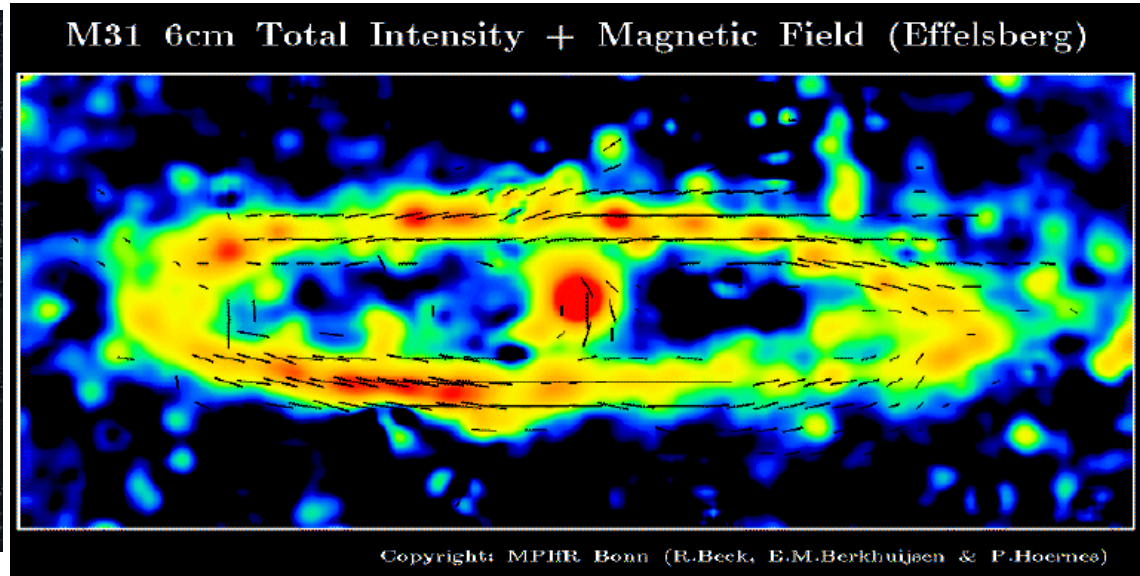
Target: galaxy, cluster of galaxies, cosmology

# Galaxy

M31 (Andromeda galaxy)



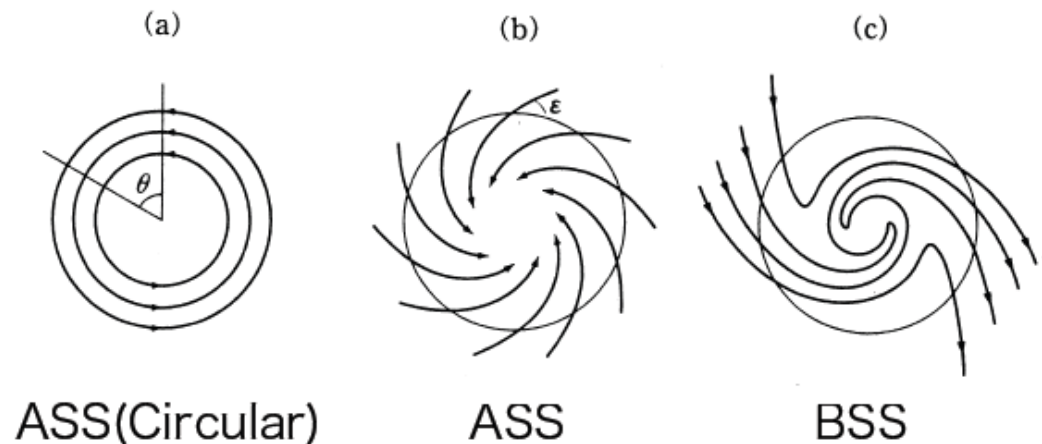
ring & vertical fields (Berkhuijsen et al. 2003)



global structure

- ring
- axisymmetric
- bisymmetric
- vertical

How were these formed?



# Galaxy

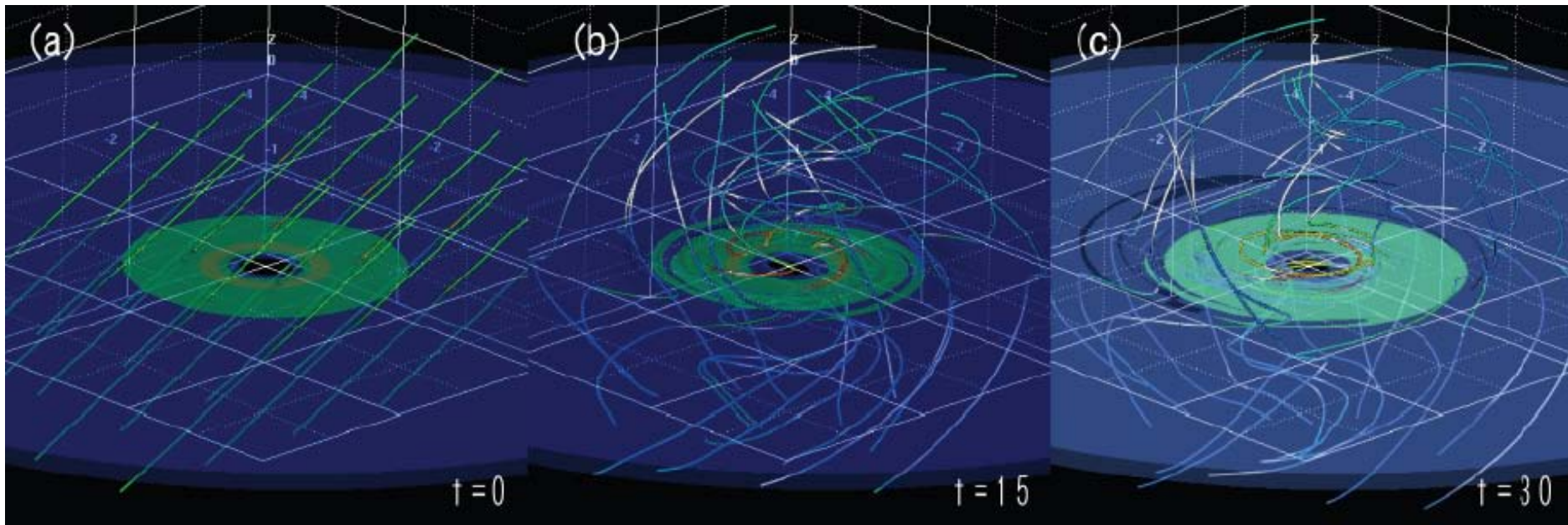
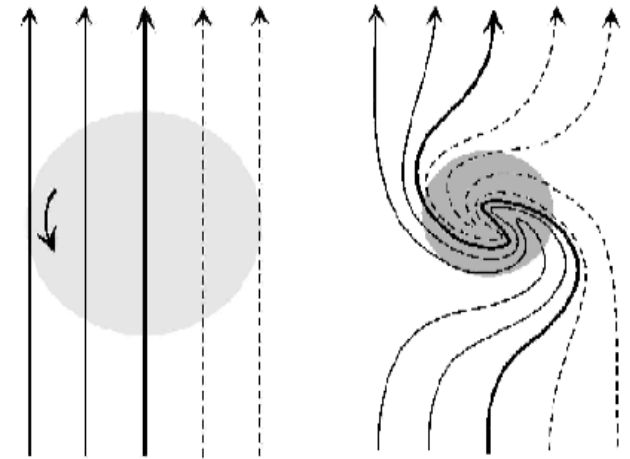
primordial origin (Sofue, Kudoh & Machida, 2010)

example: bisymmetric field

-uniform field at galaxy formation

-winding up with rotating disk

confirmation by numerical simulations





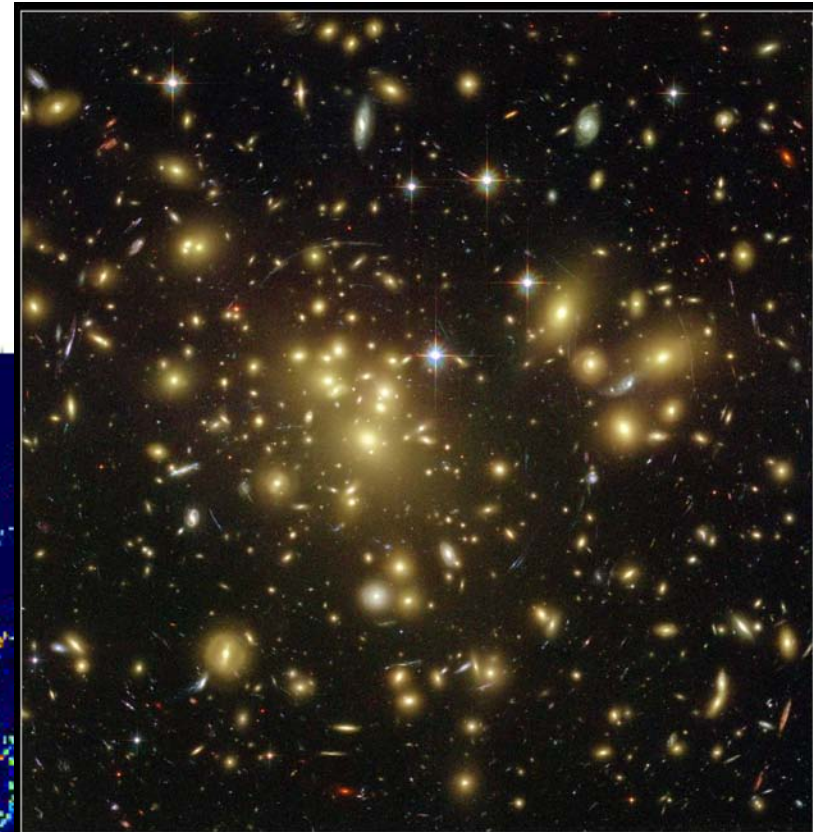
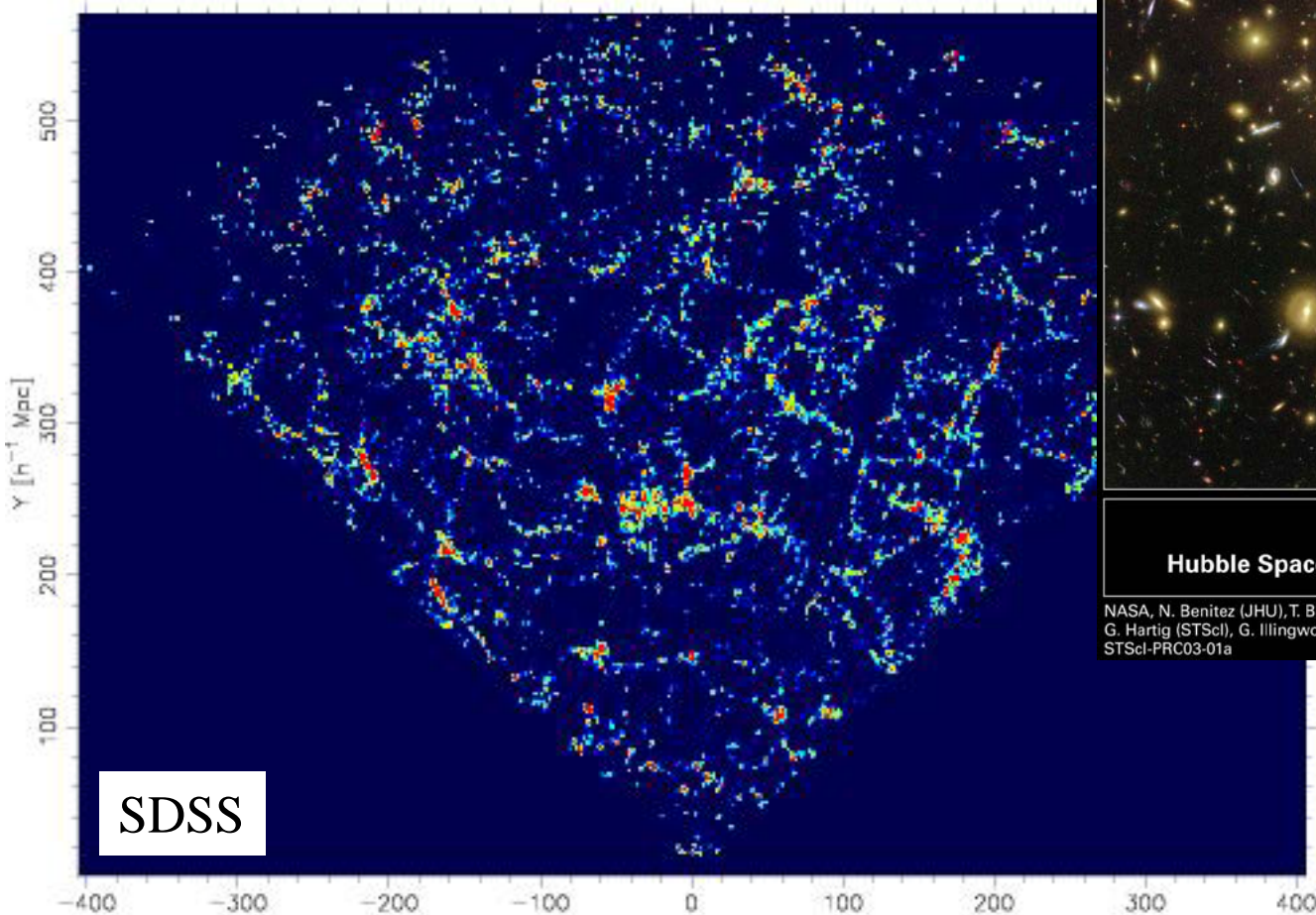
# Galaxy Cluster and Large Scale Structure

cluster of galaxies:  $\sim 10^{-6} G$

collection of 10-1000 galaxies

large scale structure: ???

filament, void



**Galaxy Cluster Abell 1689**  
Hubble Space Telescope • Advanced Camera for Surveys

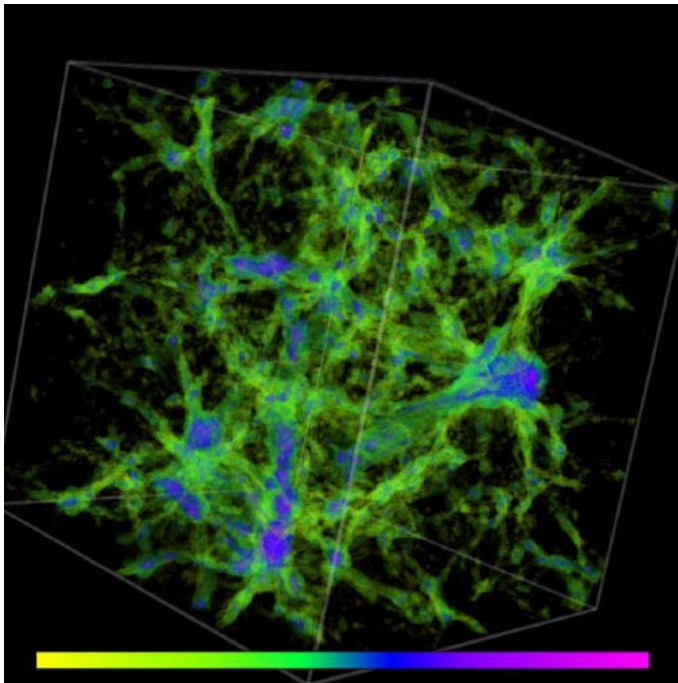
NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA STScI-PRC03-01a

# Galaxy Cluster and Large Scale Structure

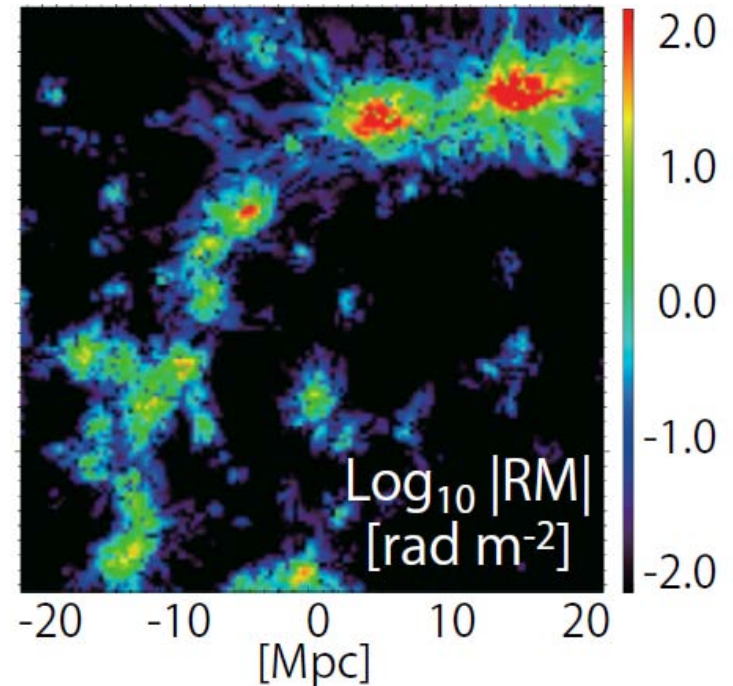
MHD simulation of large scale structure  
(Ryu et al., 2008, Akahori & Ryu, 2010)

Primordial magnetic fields evolve through structure formation.

magnetic fields associated  
with large scale structure



rotation measure  
so small for the present telescope  
but observable by SKA



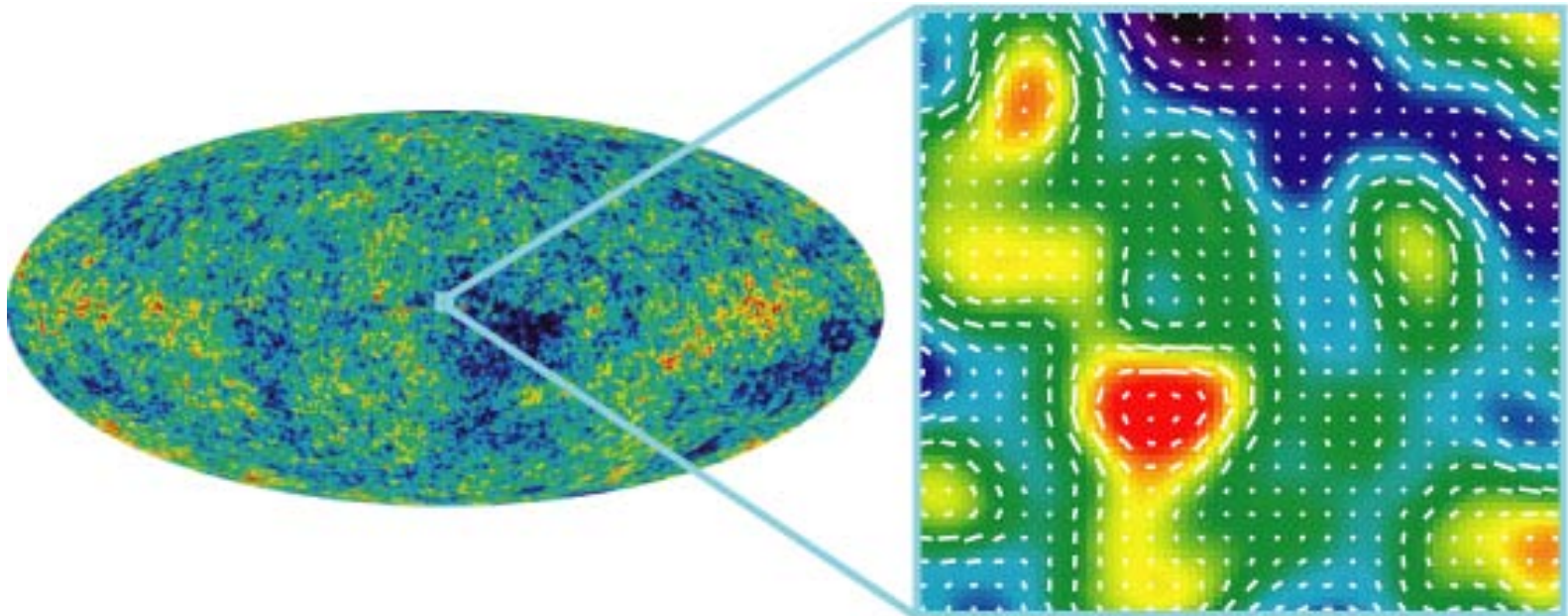


# Cosmological

generation of cosmological magnetic fields in the early universe  
(KT et al., 2005, 2006, 2007, 2008)

tiny density fluctuations in the early universe

=> anisotropy of cosmic microwave background radiation  
cosmological magnetic fields





# Summary

Origin of cosmic magnetic fields

- mystery in modern astrophysics
  - stars, galaxies, clusters of galaxies, universe itself
  - wideband is crucial for measurement through Faraday rotation
  - SKA-Japan consortium Science Working Group
- “Cosmic Magnetic Fields”
- theory, numerical simulation
  - galaxy, cluster of galaxies, cosmology

END