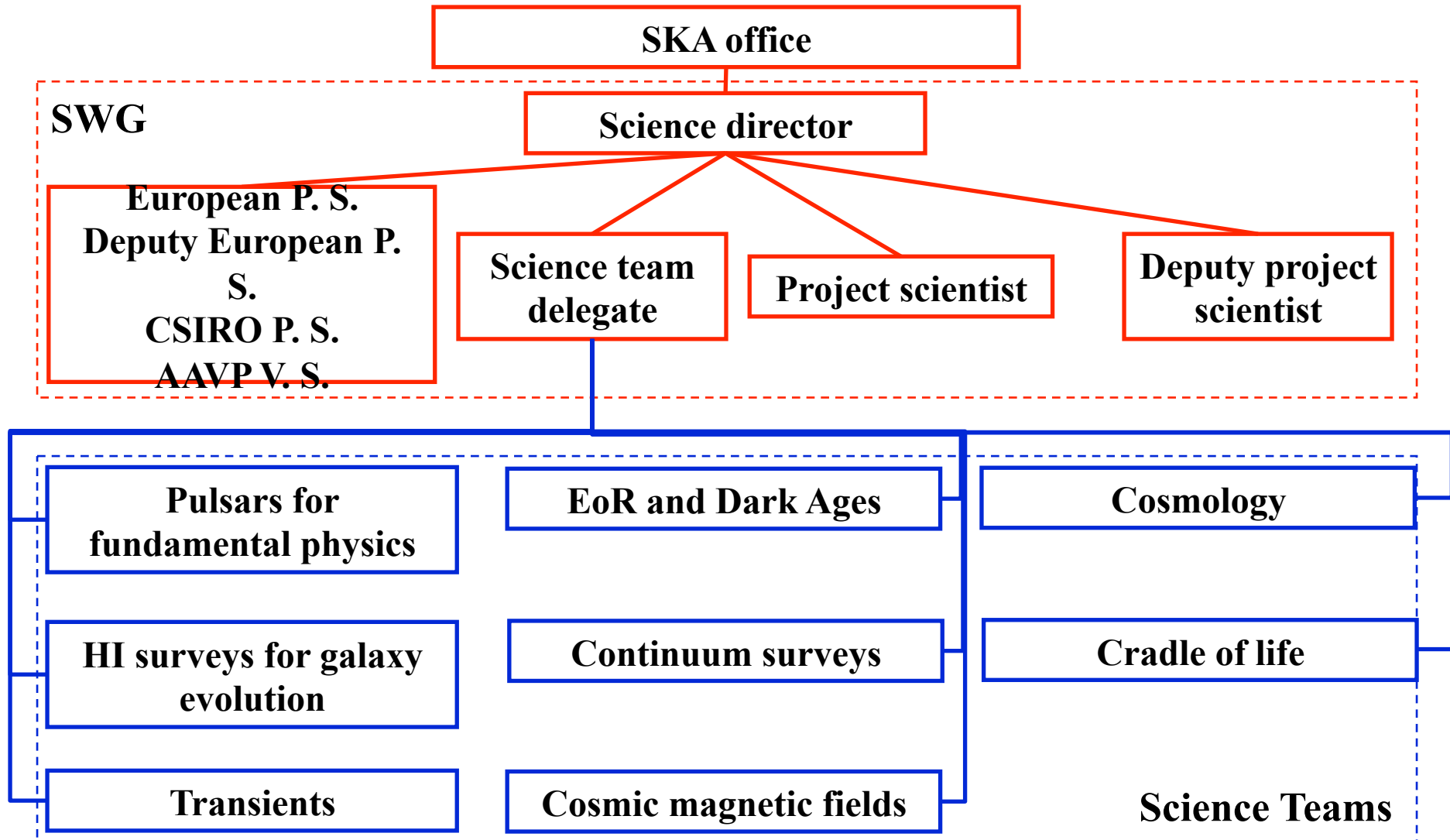# 国際SWGの報告(まとめ)

竹内 努
名古屋大学理学研究科素粒子宇宙物理学専攻

宇電懇シンポジウム, 名古屋, 2013年12月19日

1 SKA国際Science Working Group

1.1 国際SWGの構成

Evolution

- **SWG** consists of key personnel from projects world-wide and delegates from Science Teams
- **Science Teams** consist of broad representation from community

➢ **Rationale**: Allow for even broader international participation, while maintaining an effective structure

➢ **Expectations**:
  - Each science team holds ~ 1 telecon per 2 or 3 months
    - Review status of projects at Precursors and pathfinders, suggest issues for SWG to consider, developments from other telescopes, etc.
  - Attended by Science Director, Project Scientist, and/or Deputy Project Scientist
  - Science team delegates members to attend SWG meetings (virtual or face-to-face)
  - Science team members continue to advocate for SKA

➢ **Goals**:
  - More focused input to SKA Office, including suggestions from science teams for design changes to improve science return
  - Continue science development and coordination world wide

Exploring the Universe with the world's largest radio telescope

Terms of Reference

Key roles for each Science Team

- Provide guidance to the SPO/SWG on the science drivers from each respective area

- Provide assistance in developing technical requirements derived from science goals and requirements

- Serve as liaisons to broader community of SKA progress

1.2 国際SWGへの参加者

昨年12月に改組し、以下の8グループとなった。

1. Epoch of Reionization 　　　　　　　井上、市來
2. HI surveys and galaxy evolution 　　竹内、平下
3. Transients
4. Pulsars for fundamental physics 　　今井
5. Continuum surveys
6. Cradle for life
7. Cosmology 　　　　　　　　　　　　高橋
8. Magnetic fields and polarization 　　赤堀、高橋

それぞれのグループが、2-3ヶ月に1回ペースで電話会議。
重要な連絡はメールベース。

1.3 最近の重要な話題

Document for top level science requirements

抜粋:

SKA1 will provide researchers with a general-purpose astrophysics facility to permit state-of-the-art observations of astronomical sources over a wide range of angular resolutions between radio frequencies of 50 MHz and at least 3 GHz (within the context of an upgrade path to at least 20 GHz). The facility will be optimised for both large area surveys as well as deep pointed observations and will provide point-source sensitivity at least five times greater than currently existing facilities in this frequency range and a survey speed at least 25 times as great.

⇒　各SWGが、それぞれのテーマでこの要求について持ち帰って検討

Current Baseline Design provides:

- A/T ~ 1000 m^2/K >100MHz, down to ~150 m^2/K @ 50MHz:

  i.e. A_{coll}=1km^2 Consensus. Tomography needs it, although power-spectra maybe not, but SKA1 should take the next steps beyond current pathfinders in 10 years!

- ν_{low} = 50 MHz lower frequency limit

  Consensus. Many new interesting physics seems to take place starting at z~25; risk is higher but reward of detection is very high as well.

- D_{stat} ~ 35 meter station size in the core

  Seems sweet-spot for FoV and computational effort. Multi-beaming can not make up loss in FoV if D>>35m. (non-EoR) Stations outside core could be larger.

- Baselines up to ~90 km:

  Needed for calibration and compact-FG using different baselines than those for EoR science. Understand the sky/ionosphere. Information content is small on short baselines. i.e. short-baseline problems are more visible on long-baselines.

2 各SWGからの報告

1.1 HI surveys and galaxy evolution

Level 1 science requirementsについての議論

Tom Oosterlooより
1: The Level 1 Science Requirements (the document I sent you a few days ago). The aim of the requirements document is not to "define" the surveys one would like to do with SKA1, but to give context to the technical requirements. Nevertheless, I would feel much better if there is an explicit mention of the ambition to work on HI in emission out to large redshifts (i.e. beyond 800 MHz) and to include a sensitivity requirement of a single high-z pointing after 1000 hr. It is difficult to translate the requirements stated as they are now, into requirements for single feed deep pointings. So if you agree, I will suggest to Robert to include such a thing.

Level 1 science requirementsについての議論

5: Bands for SKA1-Mid. We should make up our minds what we want to do here. The conclusion of the Jodrell meeting was a different definition of the bands so have cover high-z emission better. In the mean time, Justin Jonas has made another proposal (band 1 = 350-650 MHz, band 2 600-1100 MHz and band 3 1-3 GHz). Band 1 and 2 would then be octave receivers and would have good performance, band 3 would be 20-30% worse. In our proposal band 1 would be the bad receiver. I have brought Justin's proposal up before (because I like it) and some of you commented that Justin's proposal would make it impossible do use deep integrations of nearby galaxies for high-z studies. My question is: high feasible is it to use nearby galaxy observations for this?

Key HI Science

- **HI and galaxy evolution**

  Resolved studies of HI emission in and around galaxies out to z ~ 1,
  i.e. from Now to ~8 Gyr ago. Current work is out to z=0.2.
  Pathfinders will cover this redshift range, but will not resolve
  galaxies.
  Unresolved statistical studies (emission & absorption) beyond 8 Gyr

  Will provide, for large part of the life span of the Universe,
  information about the cold-gas in galaxies and their environment for
  multi-wavelength, multi-archive studies of galaxies evolution.

- Star formation declined factor 10 over this period

  WHY???
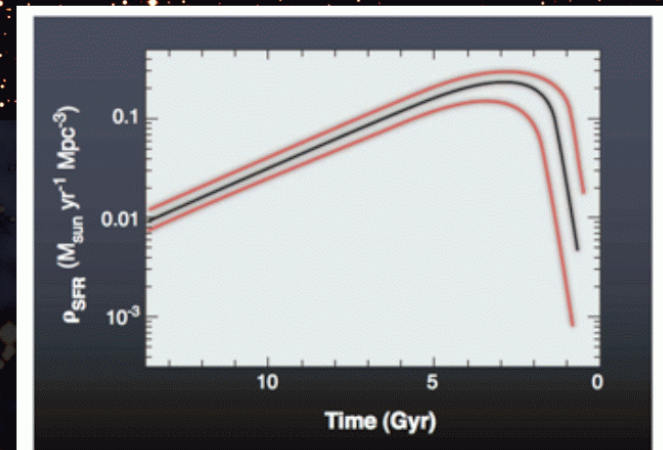
Fig. 2. A simple representation of our current knowledge of the rise and fall of globally averaged star-formation activity over the 13.7 billion years of cosmic history.

Key HI science

- **ISM** in nearby galaxies

  at high-spatial resolution (< 500 pc) to study the physics of the ISM and star formation below scales where statistical relations (KS-law) break down and simulations cannot (yet) go.

  Approach optical resolution.

  The synergy with ALMA for this kind of work is very exciting

HI in M31 with 100 pc resoution (WSRT) Braun 2013
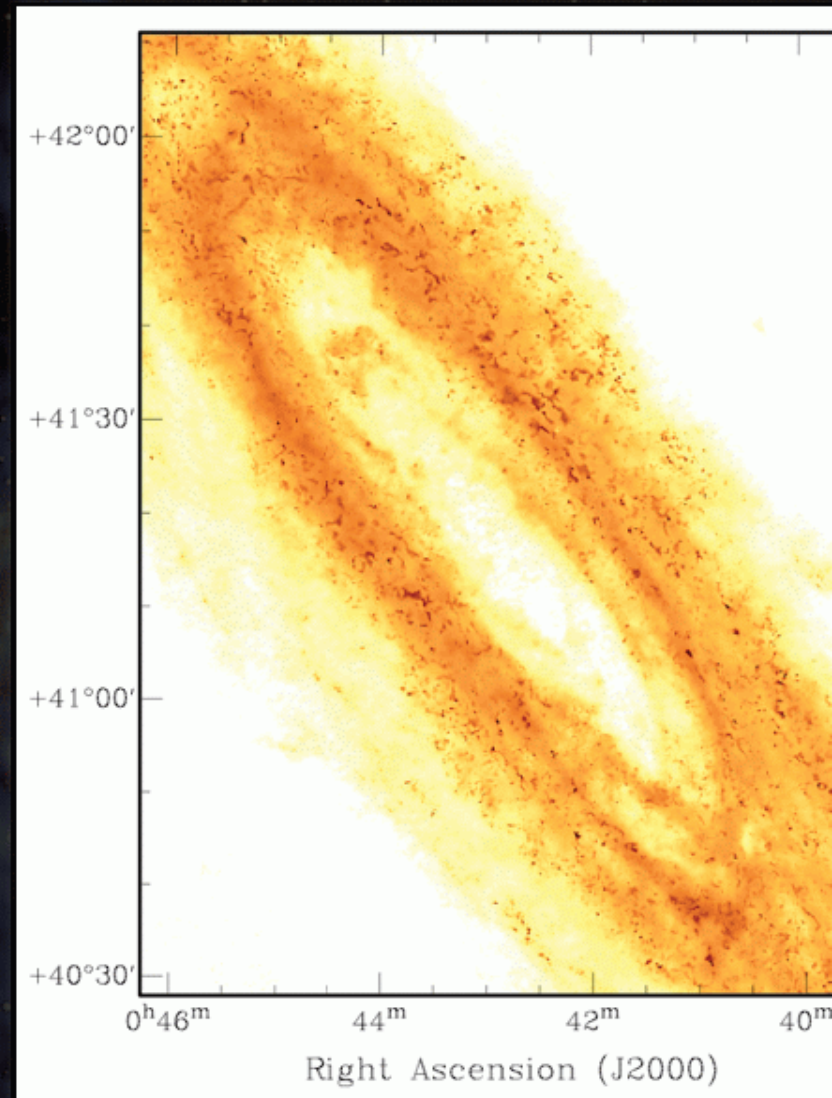
Other Key HI Science

- HI absorption studies to study the role of AGN feedback in galaxy evolution over large redshift ranges.

- HI studies of the Galaxy and of the Magellanic Coulds down to sub-pc scales

- Low-resolution (~1 arcmin) observations of low-column density HI around nearby galaxies to study the gaseous interface (cold accretion) between galaxies and the IGM. Search for the smallest galaxies.

  SKA1-Mid offers the first possibility to probe the column densities of the IGM.

- Baryonic-acoustic oscillations through Intensity Mapping up to high redshift

2.2 EoR and Dark Ages

SKA1-AA-low: CD/EoR Science, Requirements and Request for (no/some) Change

Leon Koopmans *(Kapteyn Astronomical Institute)*
Chair of the CD/EoR SKA Science Team

F. Abdalla, J. Aguirre, K. Ahn, A. Parsons, I. van Bemmel, G. Bernardi, F. Briggs, A.G. de Bruyn, T.-C. Chang, L. Greenhill, G. Mellema, M. Morales, U.-L. Pen, J. Pritchard, M. Santos, B. Semelin, T. Tsutomu, R.L. Webster

- Cosmic-Dawn/EoR Science Requirements
- Implications on the design of SKA(-1)
- Rf(no)C of the current baselines design

SKA1: Transformational or not?

For SKA1 to be *transformational* and not a statistical HI detection instrument like its pathfinders MWA, PAPER, LOFAR, GMRT, it should be able to:

(1) Study the Cosmic Dawn (to z~25) via tomography on large scale and via power-spectra on smaller scales.

(2) Enable tomography on all scales (few arcmin-degrees) during the full Epoch of Reionization (z~6-15).

Top-level Science Requirements

- Redshift/Freq. Range:
  - z~25-6 - trace the Cosmic Dawn prior to EoR and the EoR till full reionization (z~5-6) [motiv.: CMB-pol, G-P].

- Angular scales for power-spectrum & tomography:
  - arcminute - degrees - Allow PS measurement on degree scales over the full freq. range and tomography on degree scale at z=25 and on all scales >5' at z=10.

- Brightness temperature:
  - dT_b ~ 1 mK rms between bubbles; ~10 mK on/off bubbles [set by state-of-the art simulations plus CMB/G-P limits]

In excellent agreement with

Request for (no) Change

Overall (see RfC document + science assessment workshop outcome) the CD/EoR ST is content with the current BLD, but requests some minor modifications/changes and also makes several other recommendations.

- No RfC in frequency range, resolution or optimal frequency
  Required to cover the CD/EoR eras.

- No RfC in A_{eff} as function of radius, apart from maybe minor rearragments
  Required to reach 1-mK Tb levels from 5' to 1° (from z=6 to z=25)

- No RfC on long baselines of 90 km
  Required for sky, instrument and ionospheric calibration.

- Recommends to put central D=400m core on a regular grid (redundancy/FFT).
  Enables rapid calibration, saves time/comput. costs, possibly enables FFT-type telescope

- Recommends signal fibers to central bunker for flexible beam forming and correlation
  Enables flexible beam-forming as function of experiment/freq./etc.

What is detrimental to CD/EoR studies and should certainly _not be done_ for SKA1.

- Reduce A_{eff} (or A/T) in the core significantly below the current baseline design: SKA(1) would reduce to a power-spectrum instrument and tomography during the EoR will be difficult if not impossible. CD studies will become hard.

- Reduce the frequency coverage or shift to higher frequencies:
  The Cosmic Dawn starts at z~25-30, i.e. ~50MHz; not going to those freq. will close that window for SKA(1). No other instrument can do this in the future.

- Reduce long baselines to <90 km: Experience with LOFAR has shown that longer baselines (~100km) are extremely powerful for creating a sky model, for calibration, for ionospheric corrections and for diagnosing the overall system performance and data-quality.

- Do beam-forming "on-site" and build "the beam" in to the hardware system/layout of the receiver elements: Severely limits the flexibility in the system to adjust to novel/future science cases.

2.3 Cosmic magnetism

国際SKA宇宙磁場科学検討班：メンバー(20 + 2 SKAO staffs*)

Takuya Akahori

Annalisa Bonafede

Tobia Carozzi

Katia Ferriere

Ivan Agudo

Rainer Beck
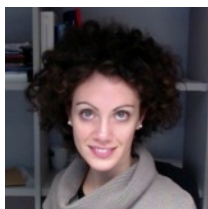
*Tyler Bourke

Luigina Feretti

Bryan Gaensler

*James Green

Marijke Haverkorn

George Heald

Federica Govoni
(co-chair)

Lisa Harvey-Smith

Melanie Johnston-Hollitt
(co-chair)

Larry Rudnick

Anna Scaife

Keitaro Takahashi

Ann Mao

Dominic Schnitzeler

Jeroen Stil

Russ Taylor

国際SKA宇宙磁場科学検討班：
活動拠点

CIBERSKA
http://www.cyberska.org/pg/groups/31244/ska1-
cosmic-magnetism-science/

PBworks
http://skamagnetism.pbworks.com/w/
page/65580311/FrontPage

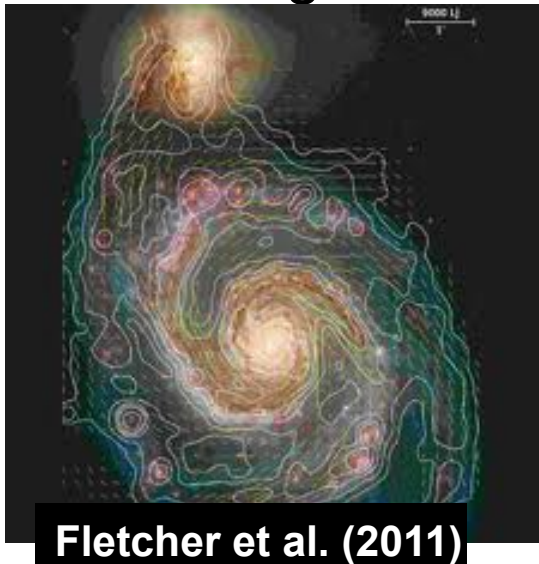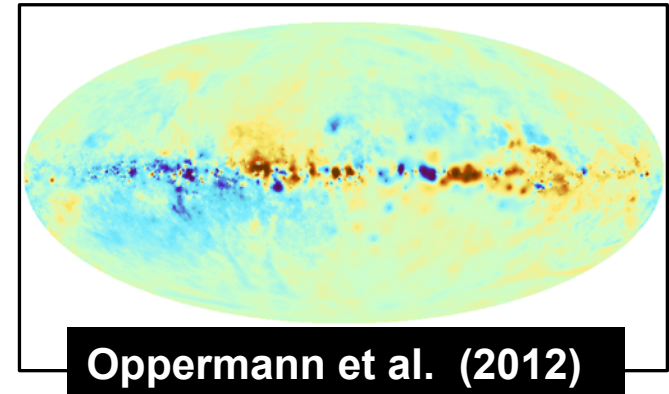＋定期的な電話会議＋メールベースでの議論
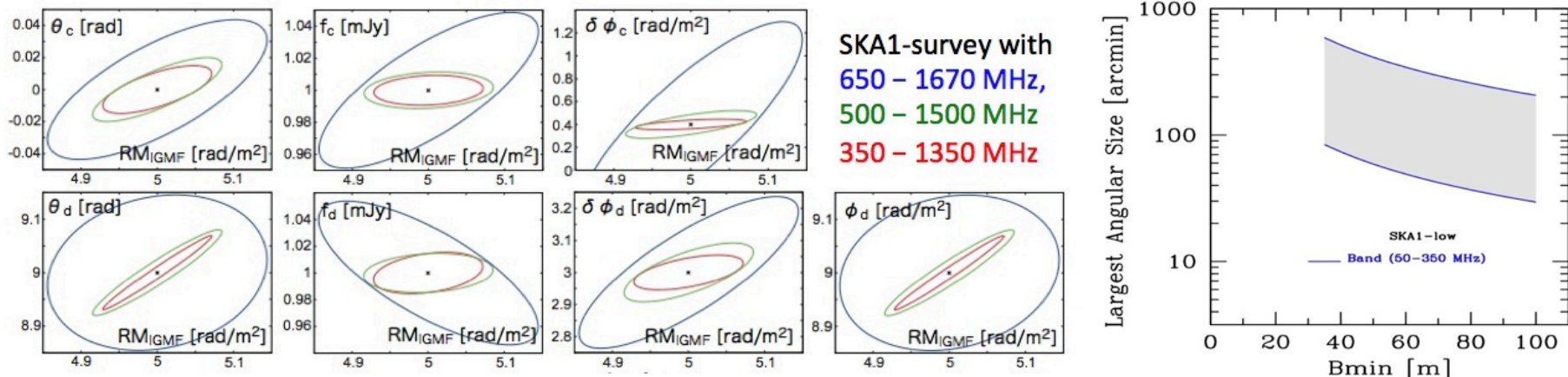＋研究会の開催(2015年IAU総会中を計画中)

国際SKA宇宙磁場科学検討班：
Baseline Designへのインプット(1/2)

- Cosmic Magnetism Science Drivers

  1) The Galactic magnetic field

  2) Magnetism and galaxy Evolution

  3) Mangetic fields in galaxy clusters

  4) Detection and Charaterization of magnetic fields in the cosmic web

Oppermann et al. (2012)

Fletcher et al. (2011)

Vacca et al. (2010)

Akahori & Ryu (2010)
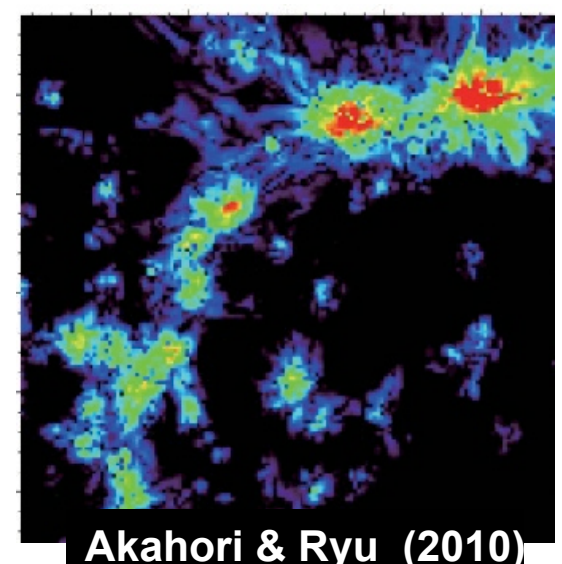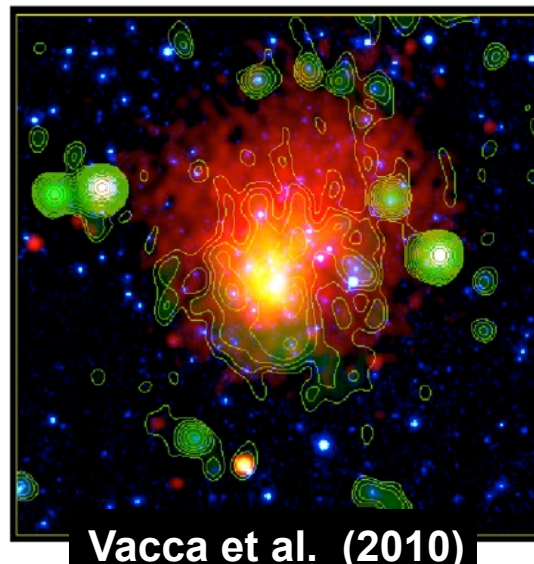
国際SKA宇宙磁場科学検討班：
Baseline Designへのインプット(1/2)

- Frequency: As wide frequency range as possible, not to have gaps in range between the instruments. For SKA1-survey, if no PAF Band1, going to slightly lower frequencies would be better for RM synthesis.

- Angular Resolution: High angular resolution reduces beam depolarization

- Largest Angular Scale: As minimum as possible (SKA1-low stations not larger than 35 m).

- Polarization Purity: Proper info. on polarization performances are missed in the document

- Survey Speed: Apparent similarity in capabilities between SKA1-mid and SKA1-survey. Higher survey speed for the one dedicated to wide field observations

2.4 Pulsars for fundamental physics

Pulsar Science Working Group (PSWG)

- 参加者： 今井 裕
  - SKA-JP Astrometry sub-WG世話人
  - SKAでVLBI/astrometryを想定しているのが PSWG
                                                    (with Adam Deller)
- SKA Assessment Workshop of PSWG (2013 July 17-18)
  - Design Reference Mission の見直し
  - それぞれの天域における最適掃天周波数
    銀河系中心>10 GHz (SKA-mid), 銀極方向 ~100 MHz (low)
  - パルサー探査の戦略
    - Low-band: 広い視野、乏しい角分解能
    - mid-band: 幾つbeamが必要？
    - 1000個の程度のミリ秒パルサーが検出できるはず (SKA1)
  - データサイズ: dispersion measureの測定／除去

VLBI in SKA

- Baseline Design ではVLBIに関しては殆ど言及なし
  - →新規追加要望項目に
- Pulsar astrometry は重力波検出(PTA)においても重要
  - 理想的な点源→高感度ほど高精度(σ~20μas)
  - 年周視差： 短期間ではastrometryで、
                                      長期(>10年)ではpulsar timing
  の方が精度が高い
  - 位置・固有運動： astrometryでないと計測できない
- In-beam (low) or multi-beam (mid) astrometry
  - L-band(1.6 GHz)で数10μasの年周視差計測精度(Deller+12)
- SKA1 + existing telescopes
  - LBA (南半球), EVN (欧州), EAVN(東アジア)
  - 多数基線による大気遅延残差（水蒸気,電離層）の影響の緩和
  - 相関局との光ファイバー結合(>40 Gbps)