An investigation report of the Pulsar Research with MWA

Xuzhi Hu（胡旭志）

SHAO, ShanghaiTech

Mengyao Xue（薛梦瑶）

International Centre for Radio Astronomy Research (ICRAR),

Curtin University

OVERVIEW

1、Introduction to MWA

2、Voltage Capture System(VCS)

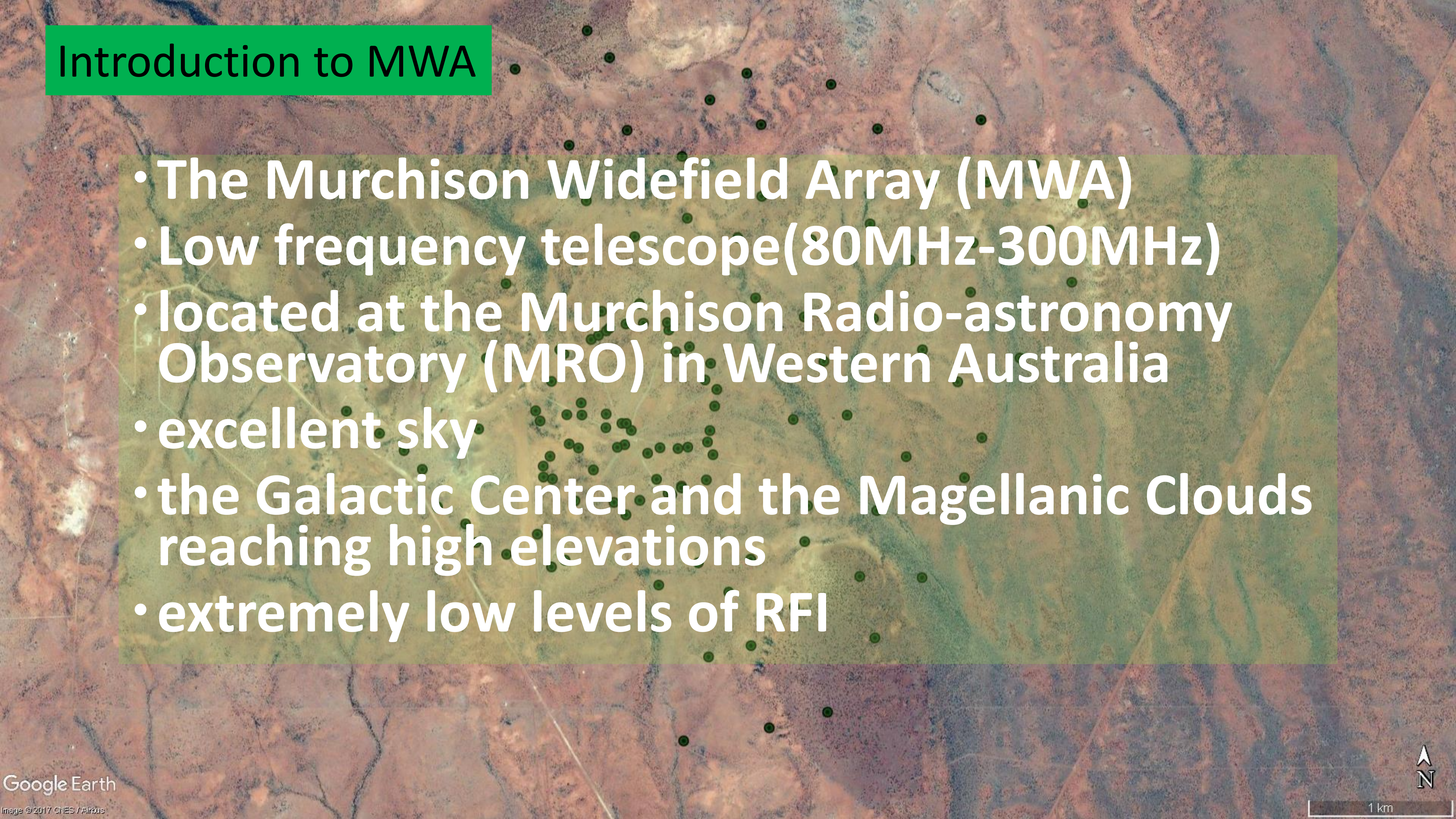
3、Variance Image

4、Science work and our plan

5、Summary

Introduction to MWA

- The Murchison Widefield Array (MWA)
- Low frequency telescope(80MHz-300MHz)
- located at the Murchison Radio-astronomy Observatory (MRO) in Western Australia
- excellent sky
- the Galactic Center and the Magellanic Clouds reaching high elevations
- extremely low levels of RFI



The Murchison Widefield Array (MWA)

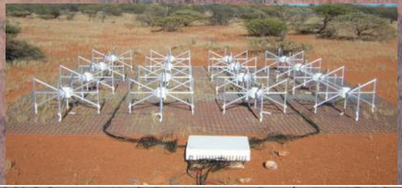
PHASE II

- 16 antennas → 1 tile (128)
- 8 tiles → 1 receivers (16)
- 256 Coarse Channels(1.28MHz)
- 24 per obs (total bandwidth 30.72MHz)
- 128 Fine Channels(10kHz)
- Each observation has its obsid of GPS time in seconds , a Project ID and observation name
- 8128 baselines
- 8256 including cross and autocorrelation

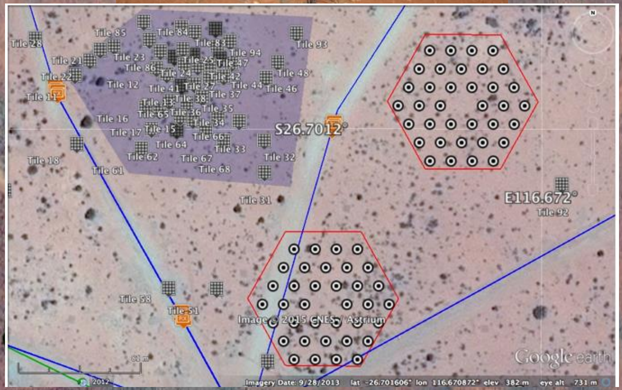
antenna

80-300MHz

Channels



TILE



receiver

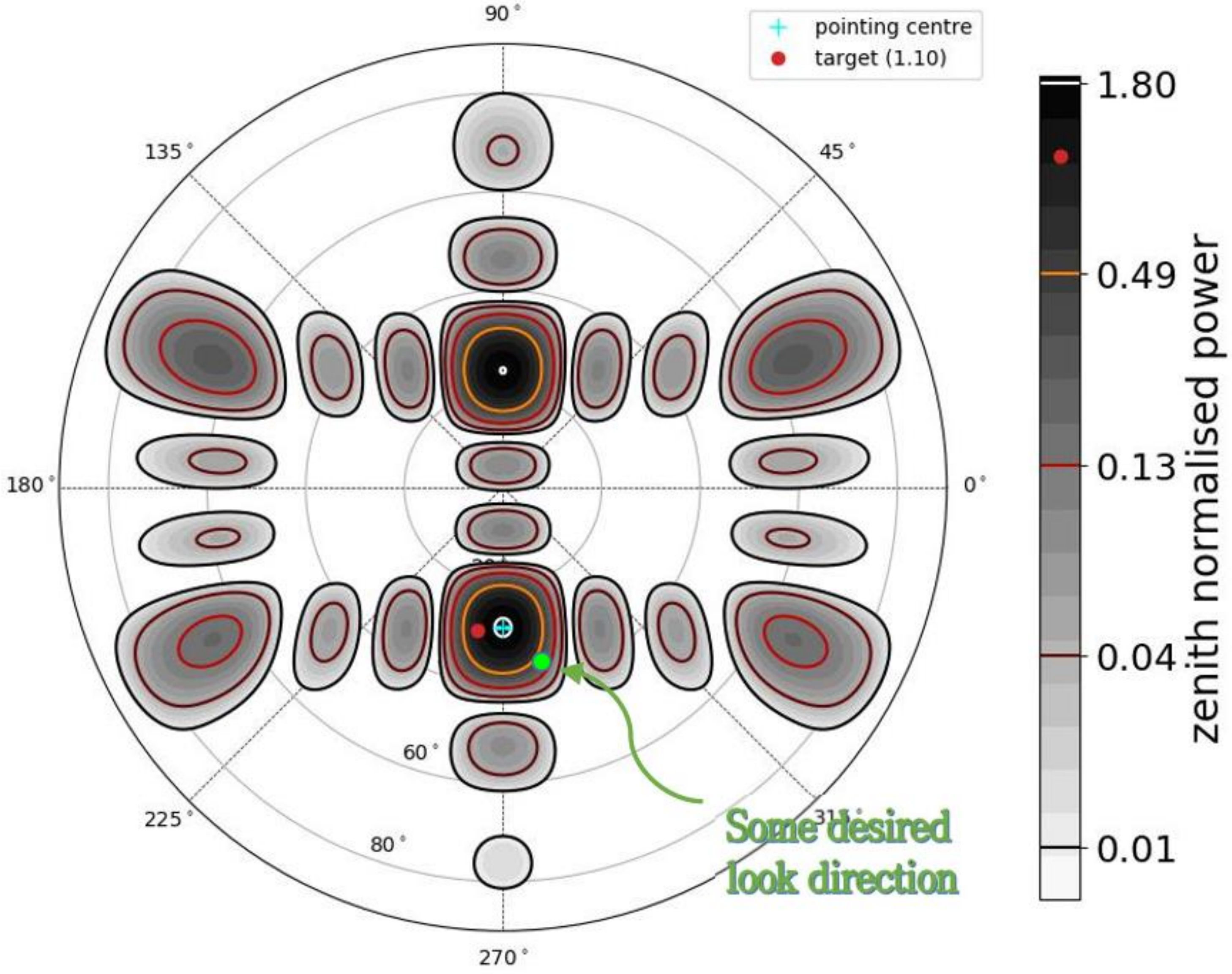
baseline

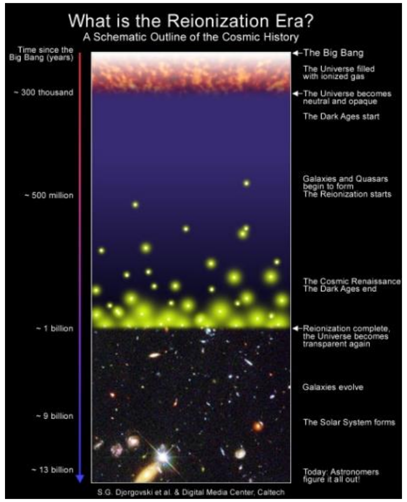
Google Earth

1 km

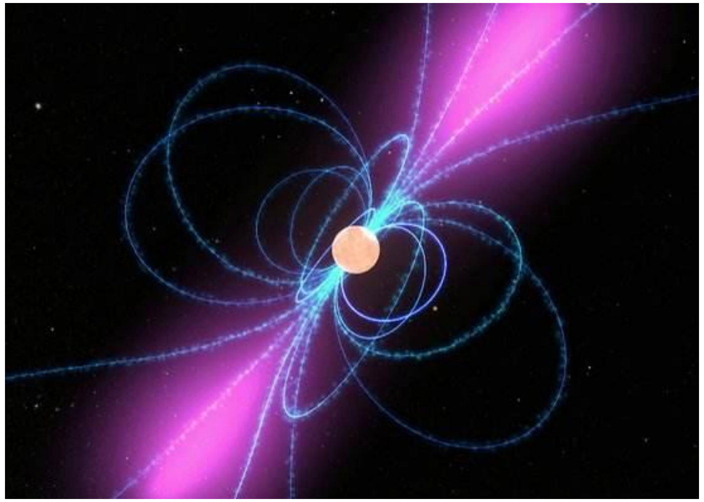
N

Sensitive to the look direction

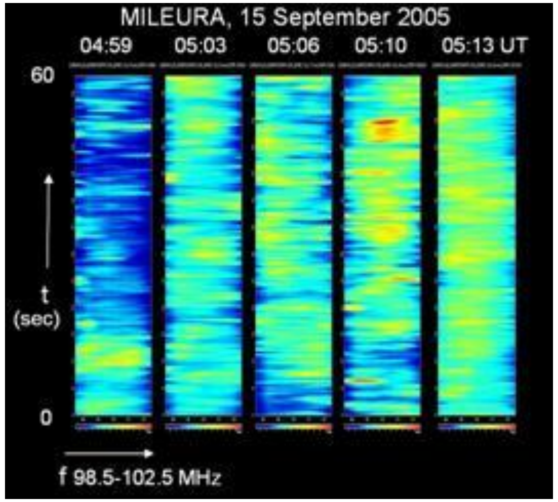




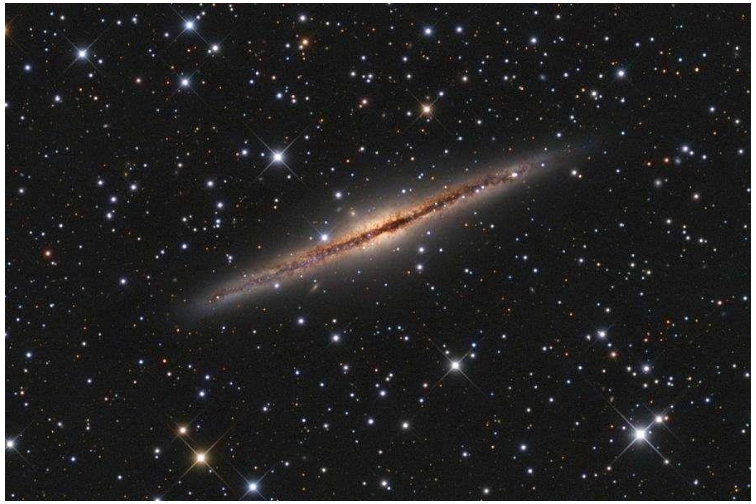
Epoch of reionization (EoR)



transients



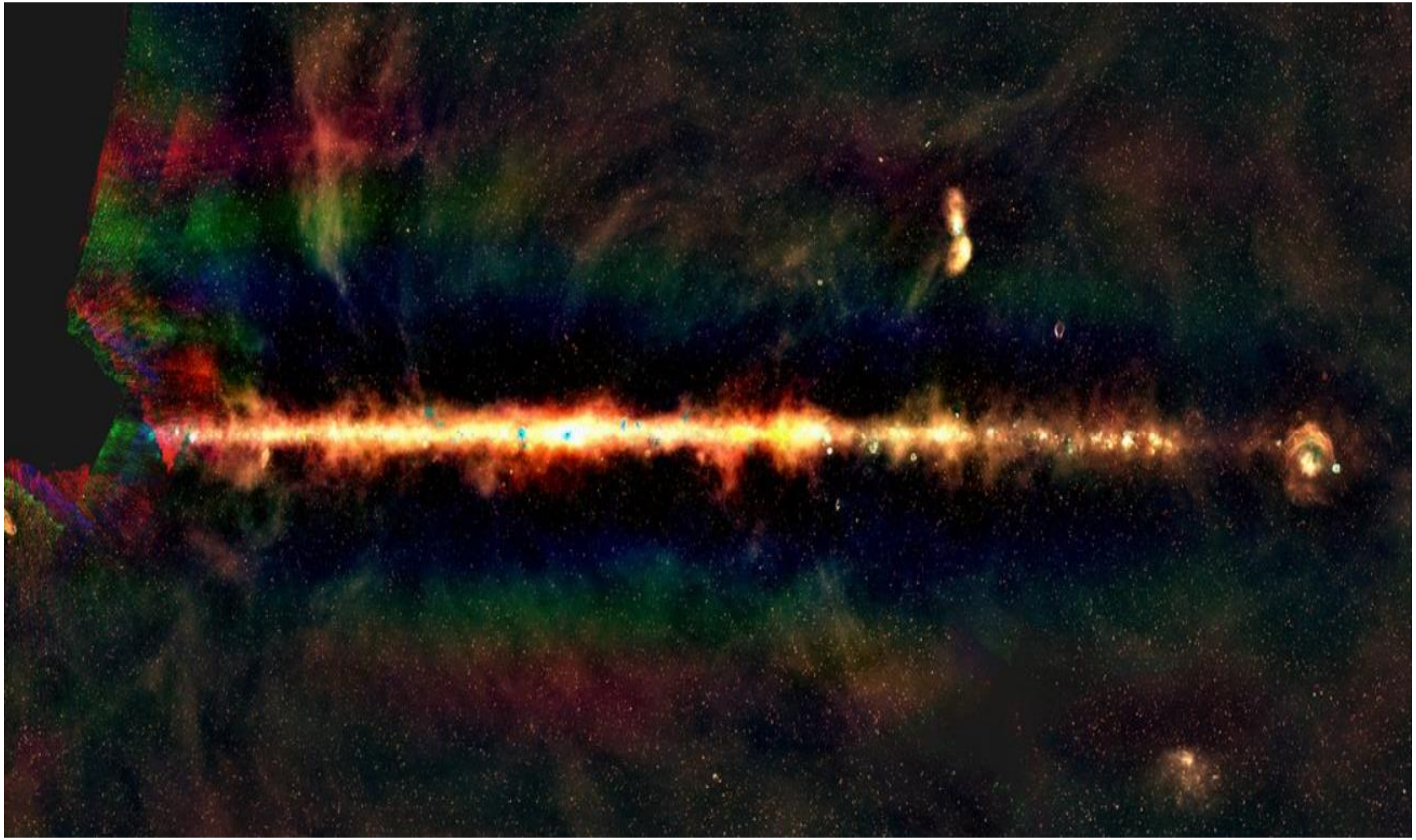
solar heliosphere and ionosphere (SHI)



Galactic and extragalactic (GEG)

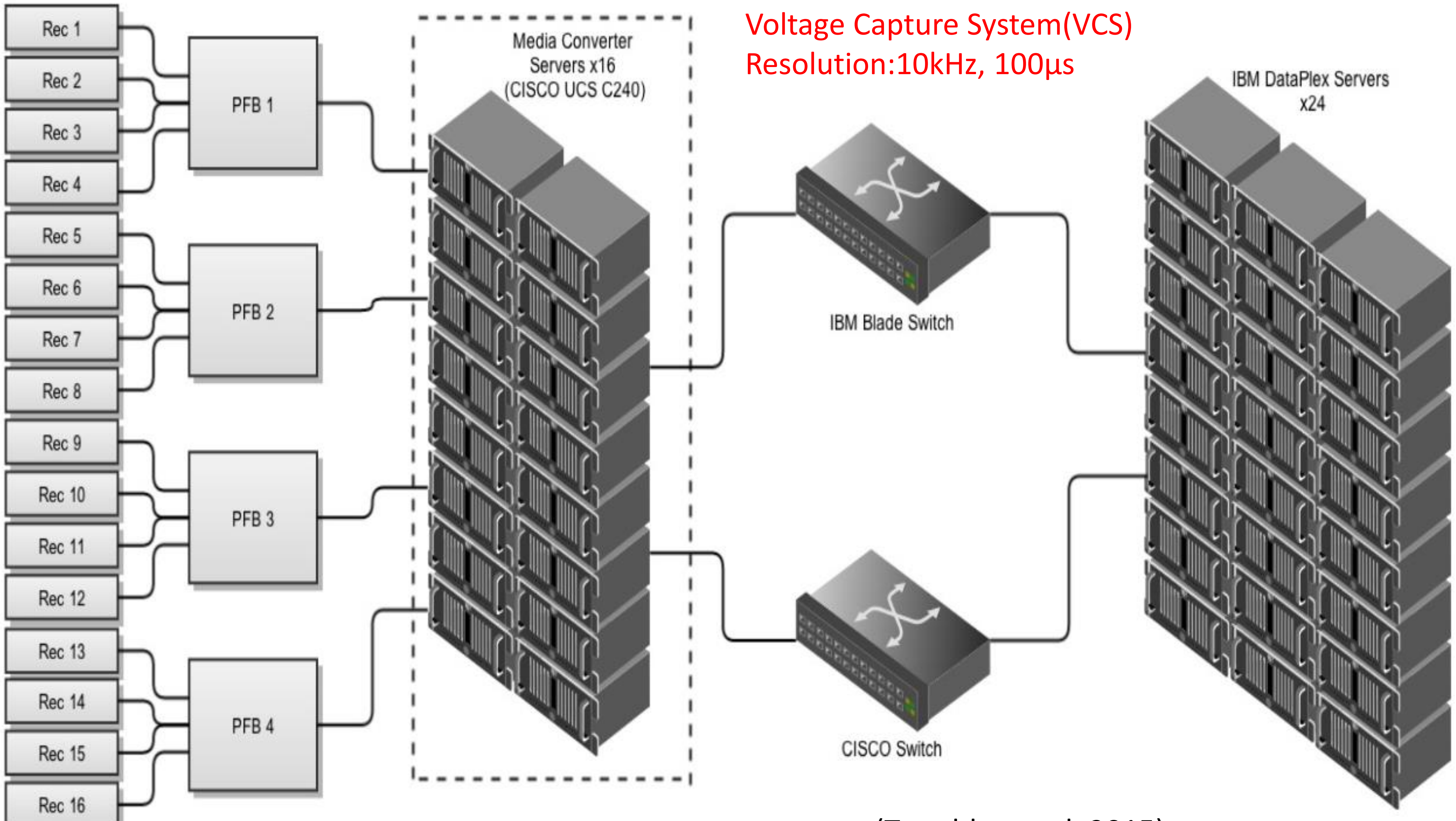
SCIENCE TEAM

GLEAM: the GaLactic and Extragalactic All-sky MWA survey



GLEAM team; Hurley-Walker+ (2017); Wayth+ (2016)
http://gleamoscope.icrar.org/gleamoscope/trunk/src/?w=2.2&l=355.5&b=-1&z=3

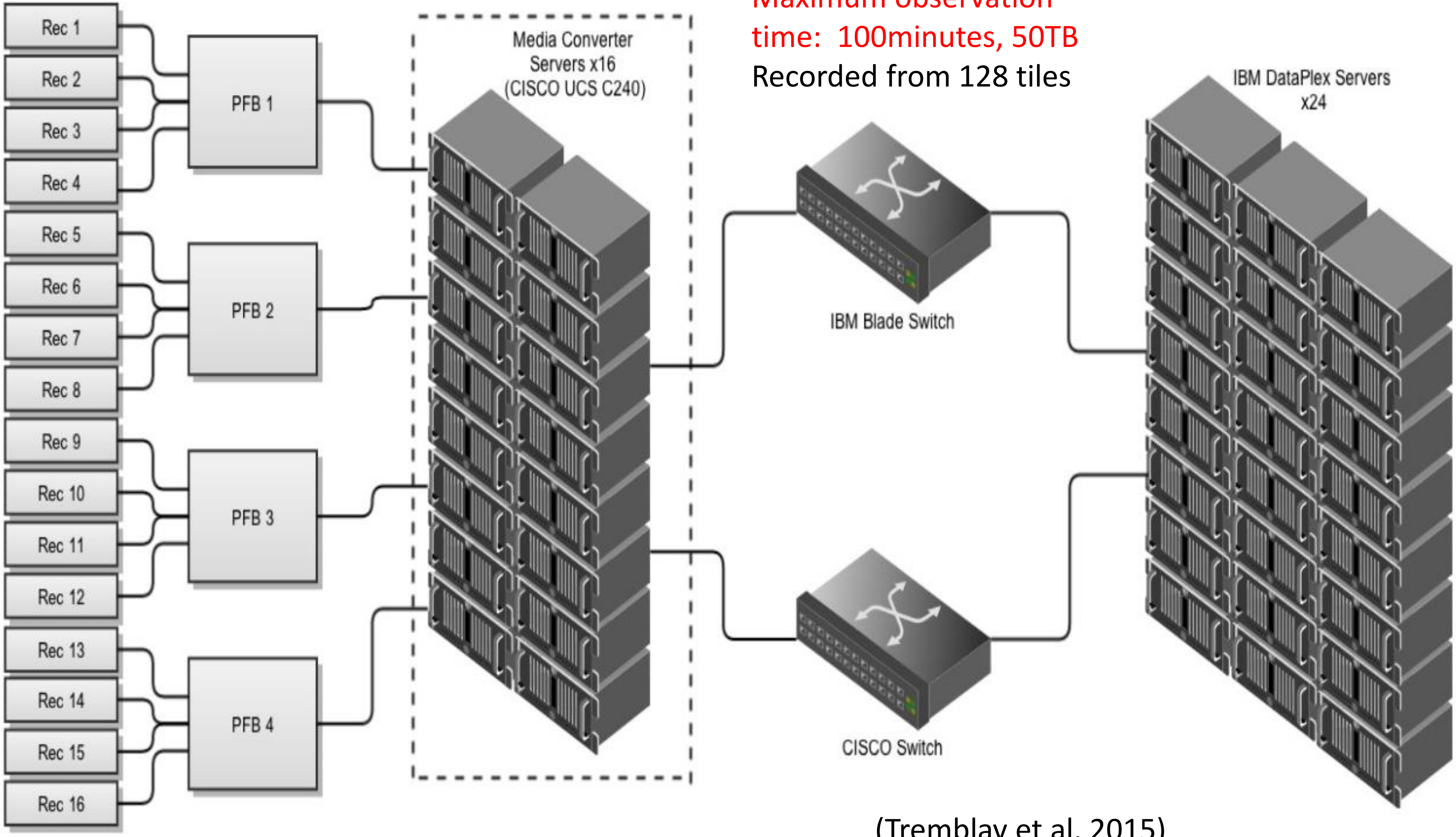
VCS



Voltage Capture System(VCS)
Resolution:10kHz, 100μs

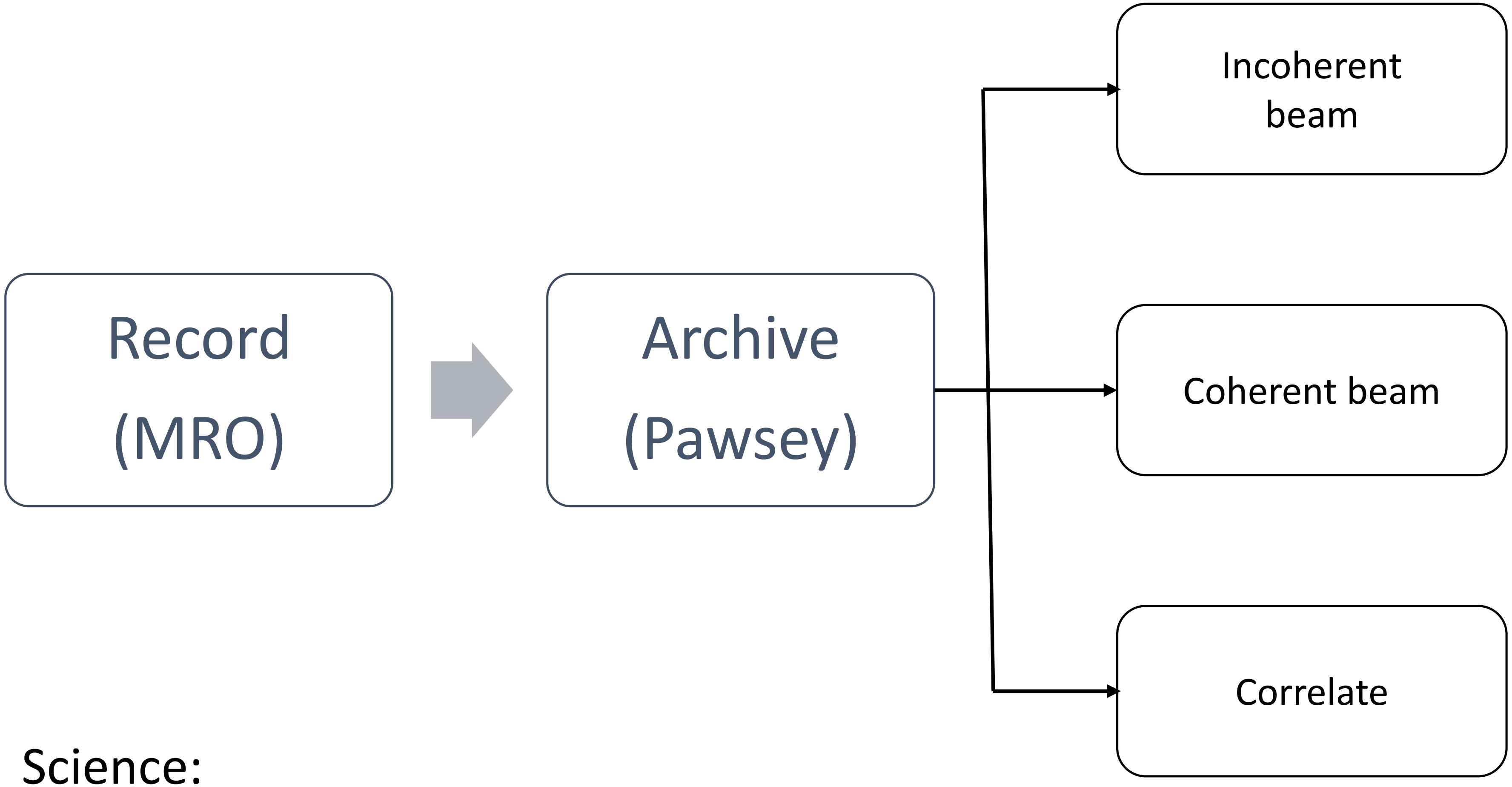
(Tremblay et al. 2015)

Maximum observation time: 100minutes, 50TB
Recorded from 128 tiles



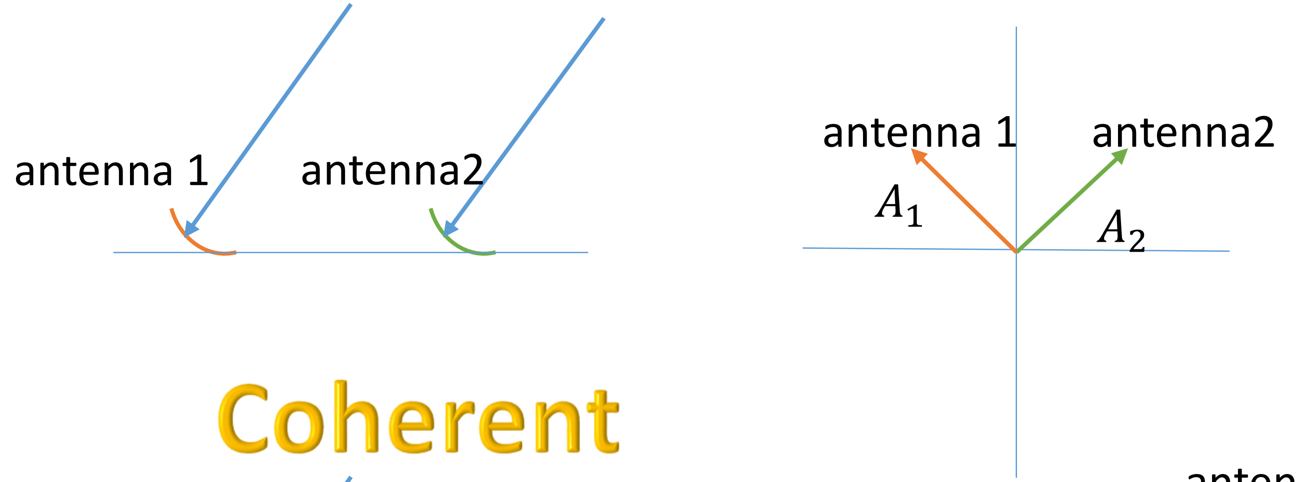
(Tremblay et al. 2015)

VCS DATA PROCESSING



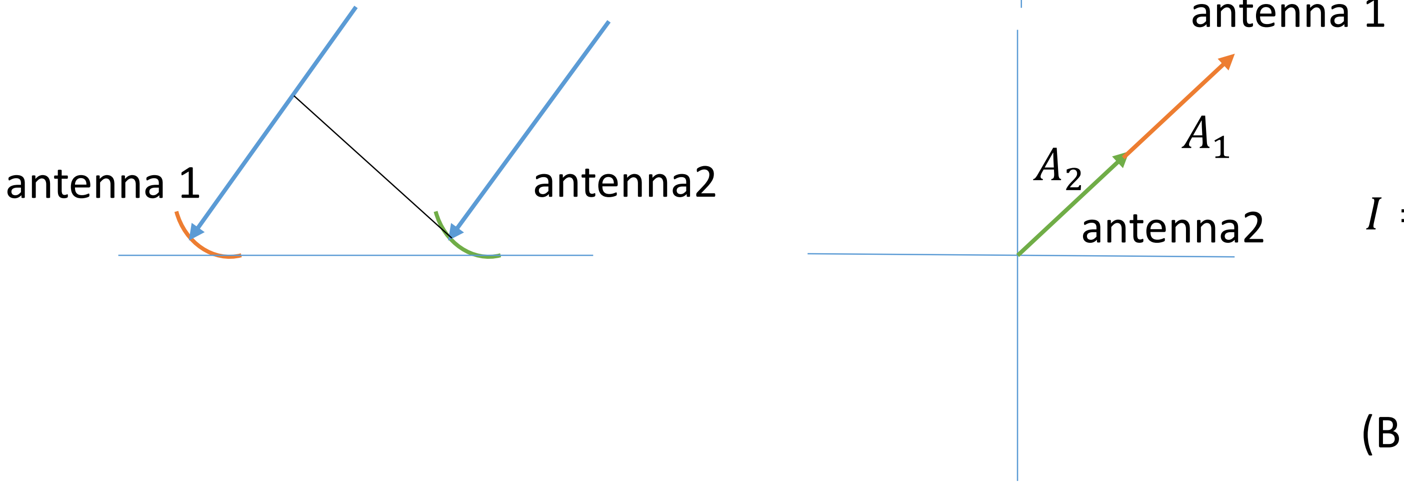
Science:
Pulsar, Fast Transients, FRBs. etc.

Incoherent



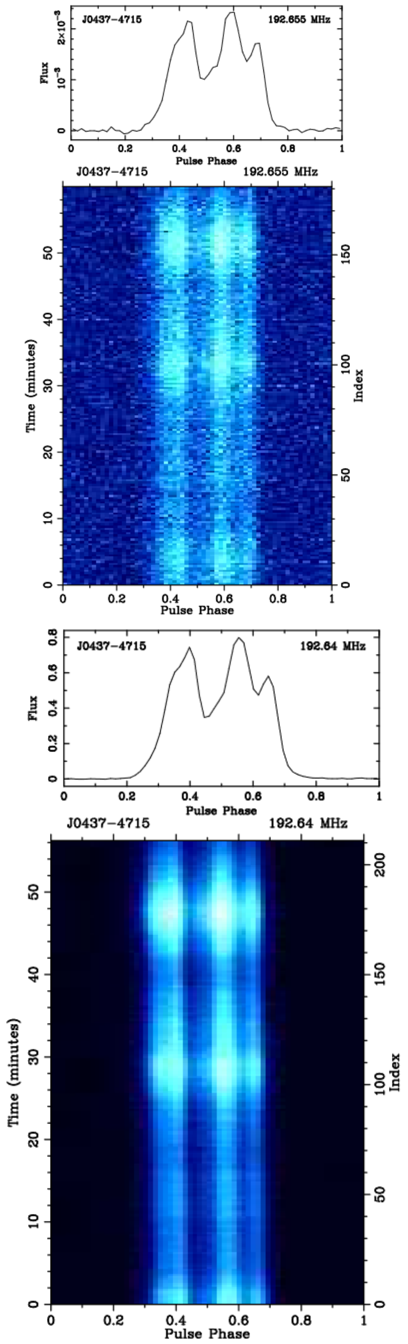
$$I = A_1^2 + A_2^2$$

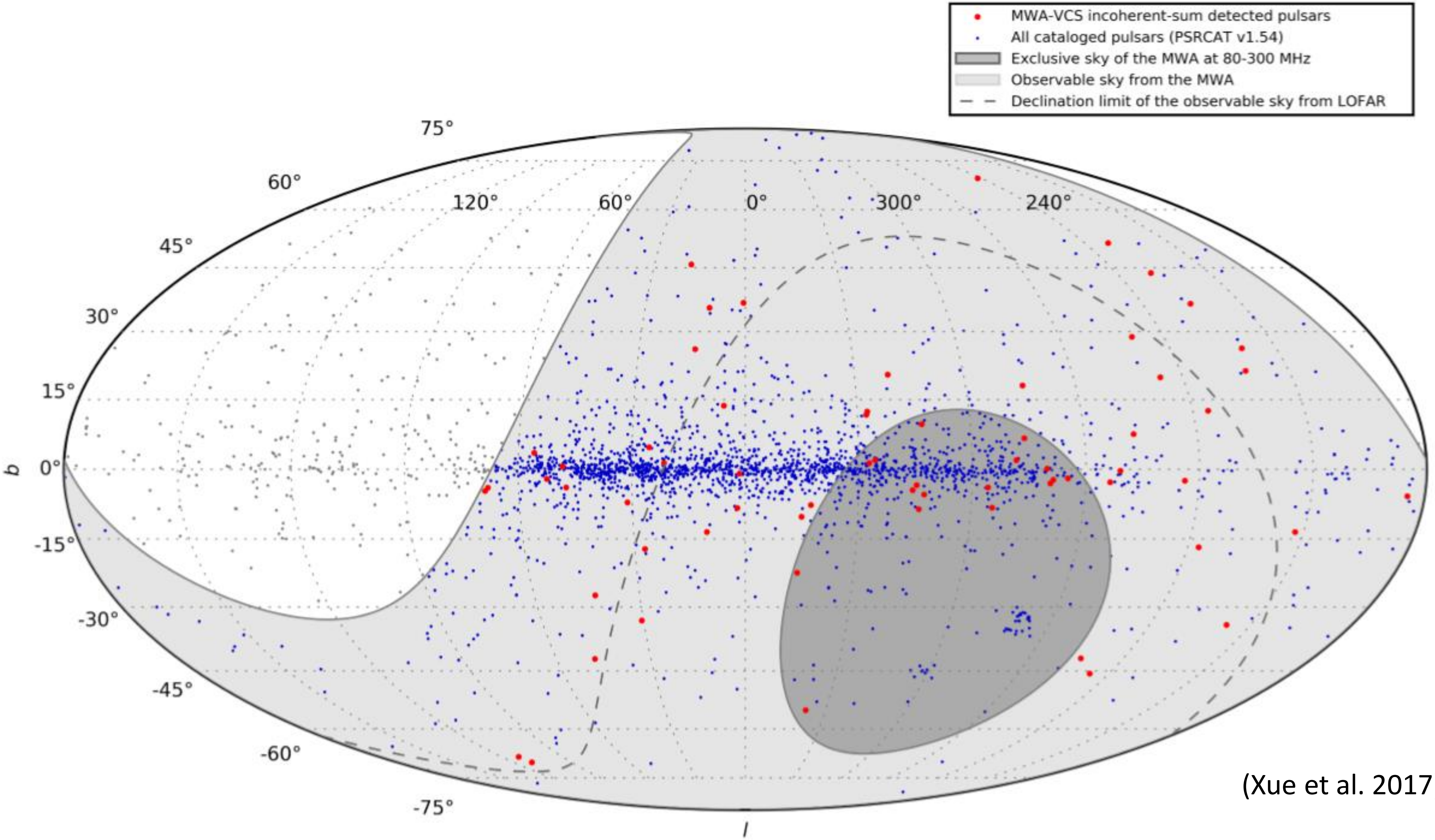
Coherent



$$I = (A_1 + A_2)^2$$

(Bhat et al. 2016)





(Xue et al. 2017)

IMAGE

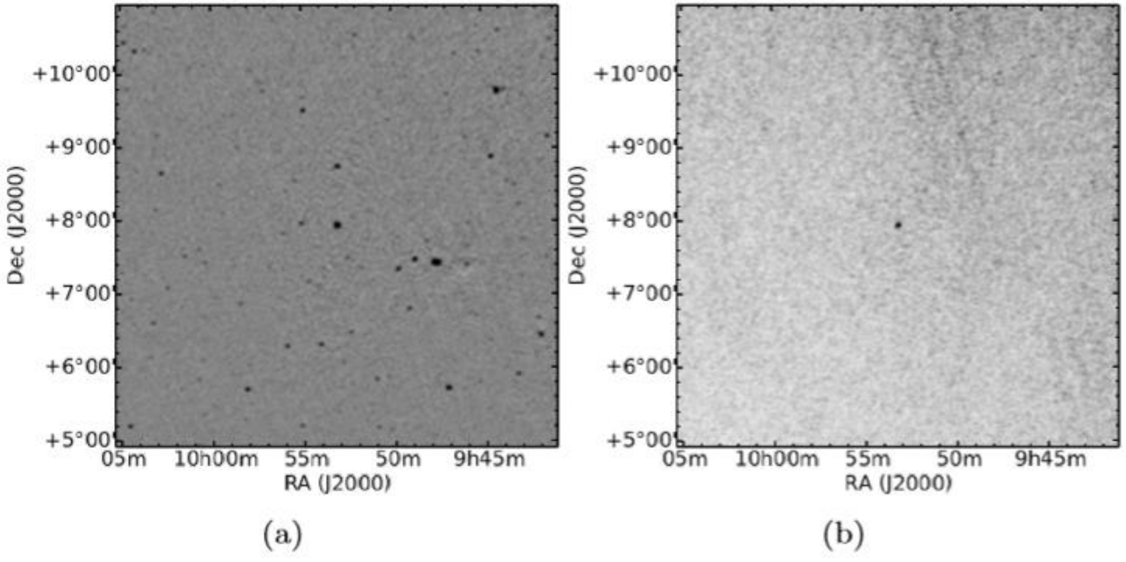
Pulsar: radio source

Detecting with Stokes I image

Challenge :distinguishing

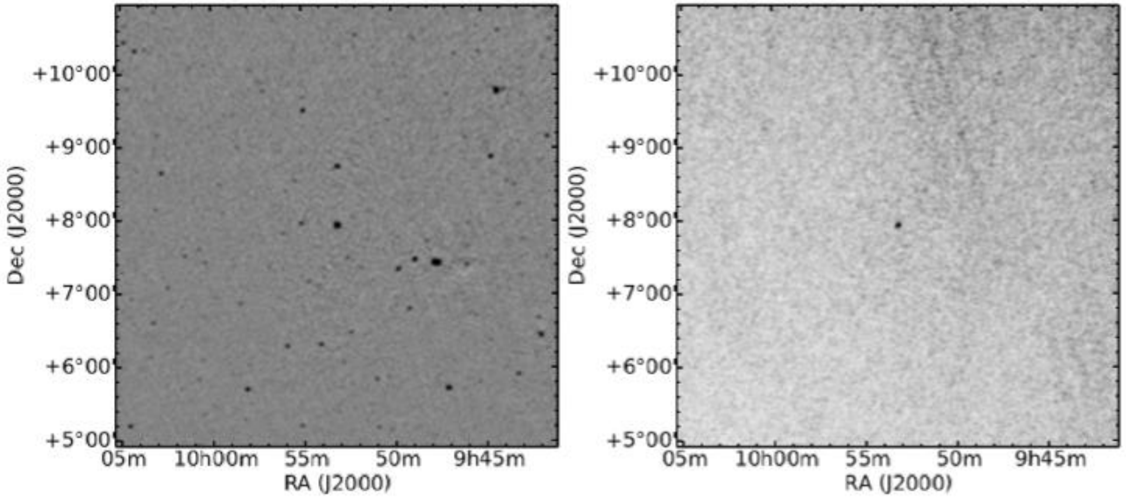
Problem: steep spectra and high fractions

of linear and circular polarization –not the only



(S. Dai et al. 2016)

IMAGE



(a) (b)

Pulsar: radio source

Detecting with Stokes I image

Challenge :distinguishing

Problem: steep spectra and high fractions

of linear and circular polarization –not the only

The only known compact sources showing diffractive interstellar scintillations(DISS).

(S. Dai et al. 2016)

Diffractive Interstellar Scintillations(DISS)

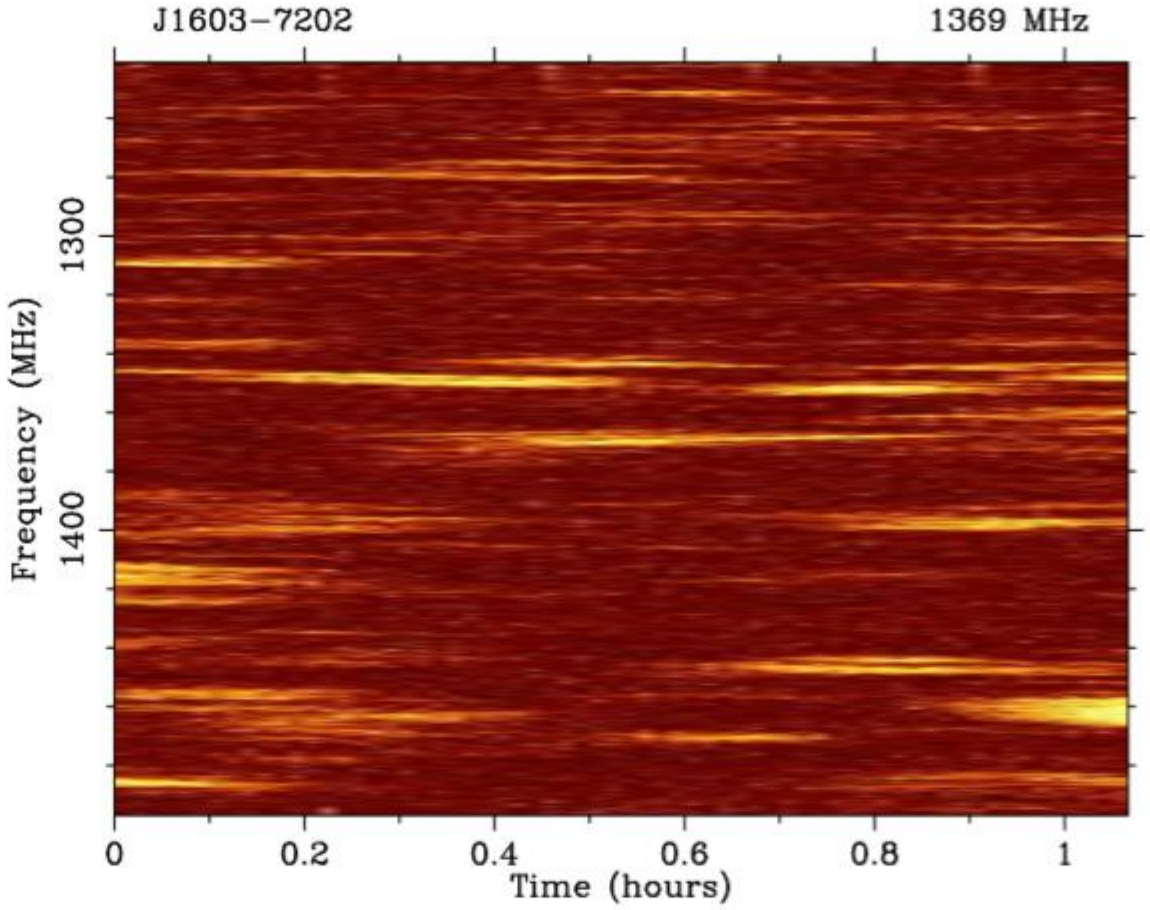
$$\tau_{\mathrm{DISS}} \propto \nu^{6/5} D^{-3/5} V_{\mathrm{eff}}^{-1}$$

$$\delta\nu_{\mathrm{DISS}} \propto \nu^{22/5} D^{-11/5}$$

Low frequency survey: MWA

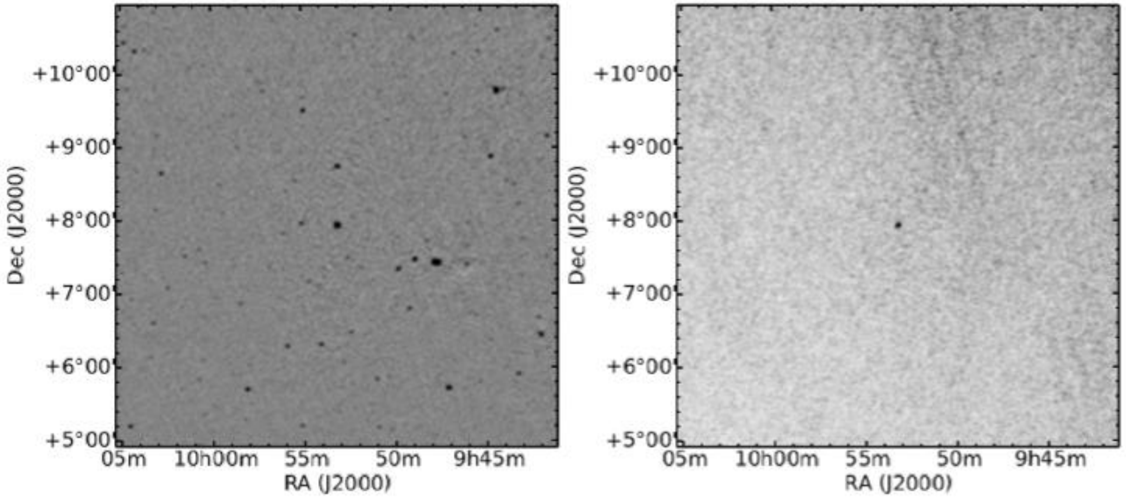
Small scintillation time-scale and bandwidth

Requiring high time and frequency resolution



(S. Dai et al. 2016)

IMAGE



(a) (b)

Pulsar: radio source

Detecting with Stokes I image

Challenge :distinguishing

Problem: steep spectra and high fractions

of linear and circular polarization –not the only

The only known compact sources showing diffractive interstellar scintillations(DISS).

(S. Dai et al. 2016)

DETECTION WITH VARIANCE IMAGE

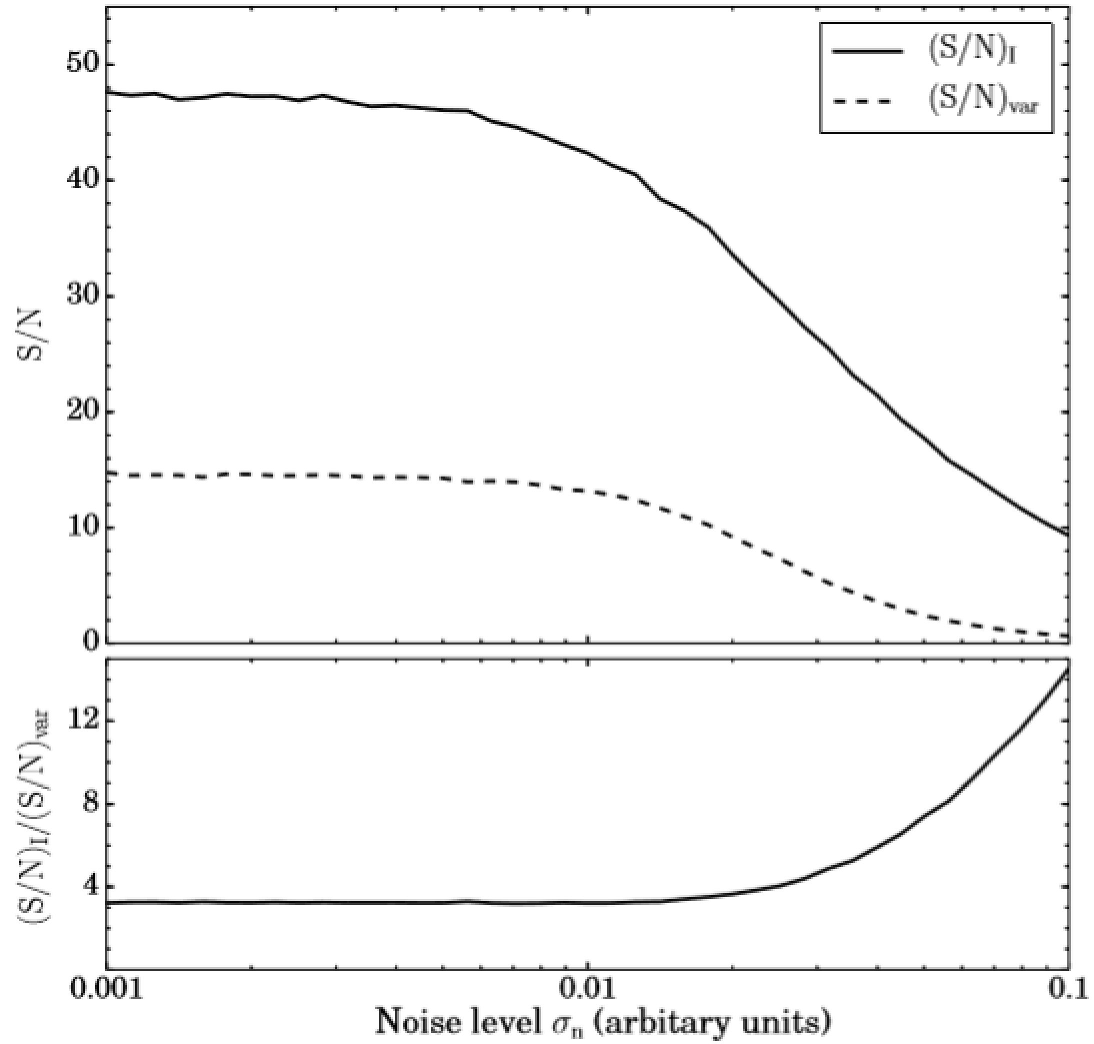
Diffractive Interstellar Scintillations(DISS)

Parameters of the simulations:
T=100, B=100, $\delta t/2 = \tau_{DISS} = 1$,
$\delta_{\nu}/2 = \nu_{DISS} = 1$ and $S_{psr} = 1$

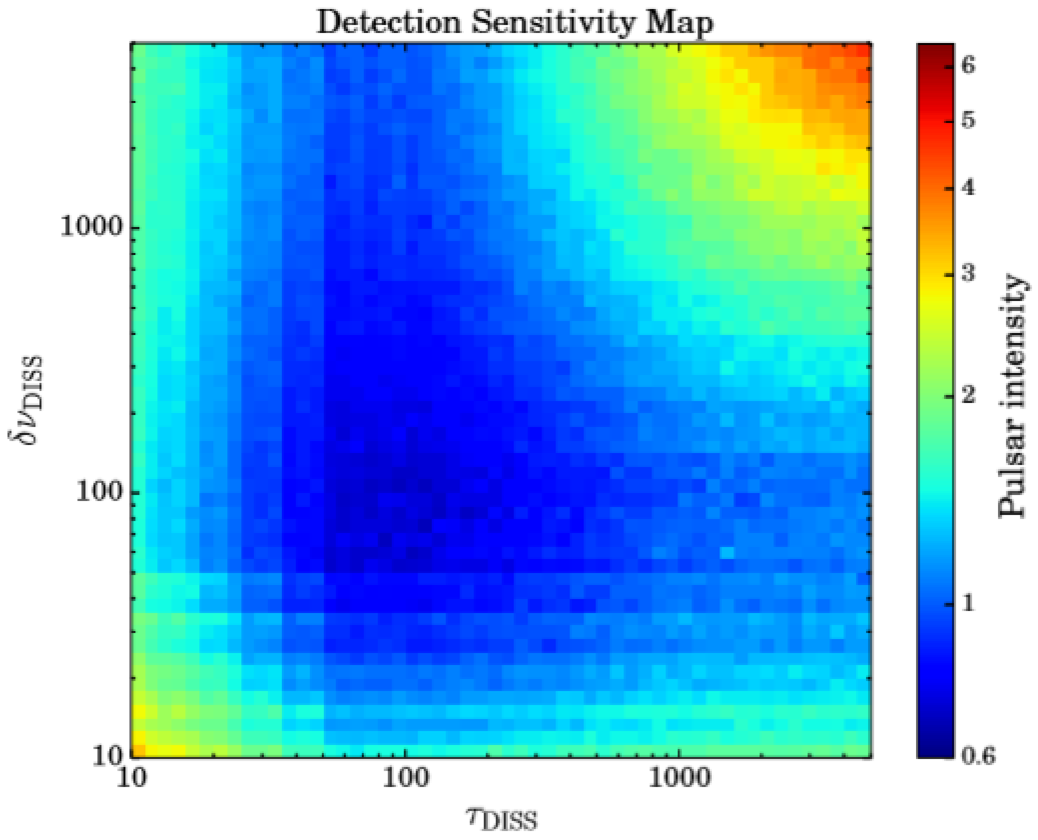
$$(\mathrm{S/N})_{\mathrm{I}} = S_{\mathrm{psr}}/\mathrm{Std}(S_{\mathrm{psr}})$$

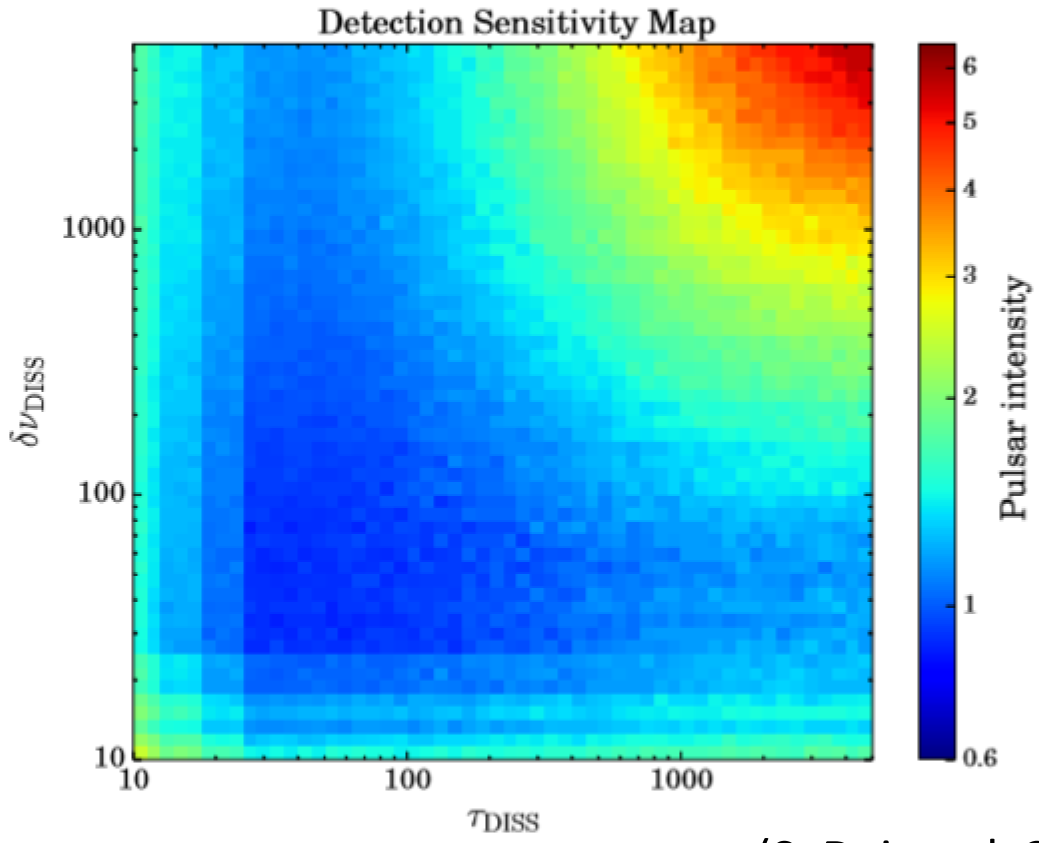
$$(\mathrm{S/N})_{\mathrm{var}} = V_{\mathrm{psr}}/\mathrm{Std}(V_{\mathrm{psr}})$$

(S. Dai et al. 2016)



Diffractive Interstellar Scintillations(DISS)





(S. Dai et al. 2016)

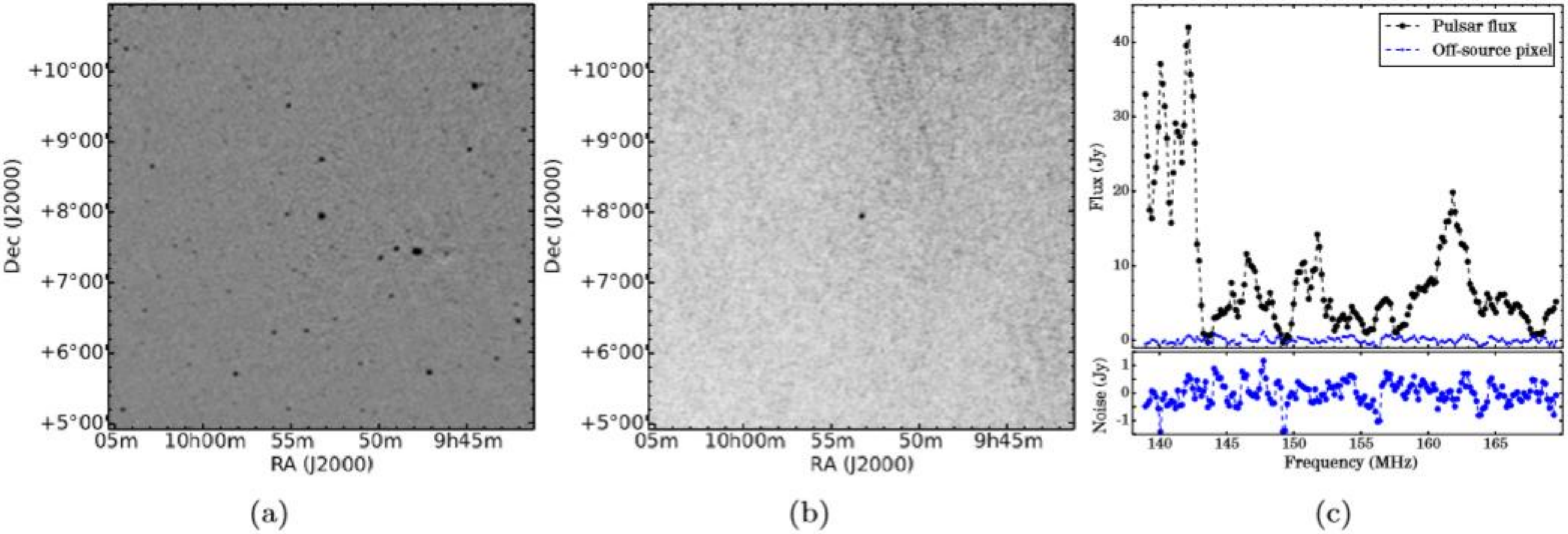
T=1000, B=1000, $N_t = 10, N_f = 10, \sigma_n = 0.1$
The sensitivity of Stokes I image ~0.25

$N_t = 20, N_f = 20$

$N_t \uparrow, N_f \uparrow$ ➡ More sensitive to small $\delta\nu_{\rm DISS}$, $\tau_{\rm DISS}$
Less sensitive to large $\delta\nu_{\rm DISS}$, $\tau_{\rm DISS}$

Demonstration of the technique

PSR J0953+0755 at 154MHz



(S. Dai et al. 2016)

T=112s, B=30.72MHz, $\tau_{DISS} = 28.8mins$, $\delta\nu_{DISS} = 4.1\text{MHz}$, $\delta_{\nu} = 1\text{MHz}$

Science work and our plan

Giant pulses

- Simultaneous observation of Crab pulsar with MWA (193MHz) and Parkes (1382MHz)
- Increasing capability of detecting more pulsars an hour with full-bandwidth VCS

and all MWA tiles combined coherently

- Correlation between spectral indices and the relative sensitivities of the two telescopes

(S.I. Oronsaye et al. 2015)

- Simultaneous observation of Crab pulsar with MWA (120.96, 165.76, 184.96 and 210.56MHz) and Parkes (732 and 3100MHz)

Flatten spectral at low frequencies

- Measurement of characteristic pulse broadening times
- Comment on the plausibility of a giant pulse origin of some FRBs.

(B. W. Meyers et al. 2018)

Science work and our plan

Drifting pulse

- Observation of PSR J0034-0721 with MWA at 185MHz
- Driftbands of the object exhibit more complex behavior than previous works

(McSweeney et al. 2017)

Other works

- Detection of gravitational waves
  Bhat et al.2014; Bhat et al.2016
- Sample analyses
  Spectral properties (Bell et al. 2016),
  Spectral energy distributions (Tara Murphy et al. 2017),
  Incoherent pulse profile (Xue et al. 2017)

Summary

- 1.The MWA telescope which consists of 256 tiles, is an excellent instrument to conduct radio astronomy science.
- 2.High time and frequency resolution of VCS give access to good experiment of Pulsar.
- 3.Variance image provide an innovative way to detect pulsars.
- 4.Several pulsar related science works have been done.
- 5.We are interested in Giant pulse and Drifting pulse.

谢谢聆听！

THANK YOU VERY MUCH!