The Karl G. Jansky Very Large Array Sky Survey (VLASS)

Advancing the Frontier with a New Radio Synoptic Sky Survey

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VLASS Survey Design Group Lead

Atacama Large Millimeter/submillimeter Array

Karl G. Jansky Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array

The VLA Sky Survey (VLASS) Initiative

- Announced 11 July 2013 : Community-led Program to define a new radio sky survey using the upgraded Karl G. Jansky VLA
- Open *international* participation, public data and products
- SOC to set up AAS workshop and SSG structure underway
- We are soliciting White Papers on aspects and science goals for the survey (your input needed!) **21 Papers so far!**
- Survey Science Group (SSG) to be formed, starts in **Feb 2014**
  - **SSG Working Groups open to community – JOIN US!**
- Survey Design Group (SDG) NRAO + community
  - SDG will carry out testing and technical design
- Website : https://science.nrao.edu/science/surveys/vlass

Email : vlass@nrao.edu

VLASS Science Planning Workshop

- Held 5 Jan 2014 just before AAS 223 meeting National Harbor
- Agenda and Talks posted online

https://science.nrao.edu/science/surveys/vlass/vlass-science-planning-workshop

- Around 50 attendees
- Morning talks
- Afternoon discussion
- Video posted soon!

This talk based on presentations and discussion from Workshop

The Karl G. Jansky Very Large Array

- Interferometric array of 27 antennas of 25m diameter
  - Resolution of 1km to 36km aperture, area of 130m aperture

Location:

Plains of San Augustin, New Mexico

El. 2100m

VLA c.1980

Upgraded 2001-2012:

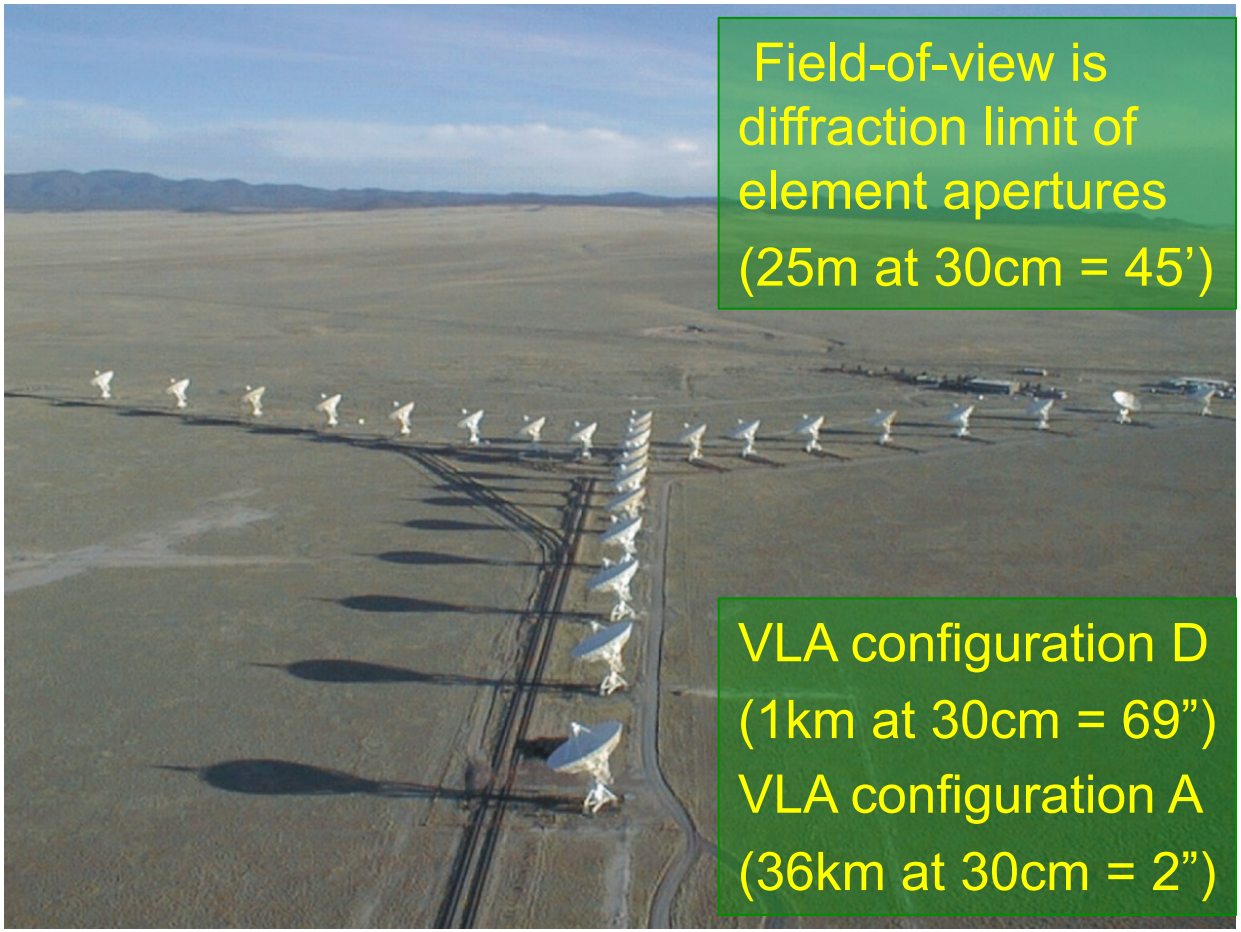
Digitized at antenna (3&8-bit)

Bandwidth 1-8GHz

Fiber linked

WIDAR correlator (DRAO-NRC)

$90M total cost



Frequency Range:

1-50 GHz in 8 bands; also 230-470 MHz and 58-84 MHz

Sensitivity (5GHz):

100 □° to 100μJy (1σ) in 50ksec (14h) continuum

1 mJy (1σ) 1 km/sec, 9ksec (2.5h) line

Why a VLASS Now? Capability is Here Now

- **The Cosmic View:**
  - Radio galaxy surveys need wide areas at substantial depth
  - Arc-second or better resolution for identification
  - Other multi-wavelength surveys, co-observing opportunities
    - ALMA science in obscured and distant Universe
- **The Dynamic View:**
  - Synoptic surveys need time baseline (3+ years)
  - OTF scanning allows rapid coverage of sky
  - Characterize the "null" (static+variable) sky
    - Lay groundwork for LIGO & LSST era

Prepare for the Future – Science Proving Ground for SKA

Why a VLASS Now? Astro2020 & Beyond

- Astro2020 starts in 2019, need strong US radio case mid 2018
  - Proposal review by June 10 2014 allows 15A (B-config Feb 2015) start. Complex surveys may need 1 year pilot.
  - Survey could take 2-3 years e.g. 2015-2017. Delays endanger having robust results and wide community use by 2018.
  - Spreading over 5 years reduces impact on normal observing
    - 6000h total science per year: VLASS 1000h/yr = 17%
- Mobilize US and international communities to be involved with and use the VLASS and its data products.
  - VLASS must involve a wide demographic from its inception.
- New radio facilities (e.g. ASKAP, APERTIF, MeerKAT) 2016+
  - Factor in realistic schedules and complementary capabilities

Survey Principles – the bigger picture

- Legacy
  - The VLASS must have science legacy value for decades to come
- Uniqueness
  - The VLASS must provide an important snapshot of the Universe unique in space and time
- Complementarity
  - The VLASS should maximize its utility in combination with other multi-wavelength surveys current and planned
- Quality
  - The VLASS should be carried out and processed in a manner that will provide to the broadest community the highest quality data and data products

Science Definition – Results of Workshop

- Not pre-determined: SSG will define the survey
  - Expect 3000-10000 hours (NVSS+FIRST ~6000h)
- Discussion points from Workshop and White Papers:
  - Wide (1000-30000 deg^2) vs. Deep
  - Low (1-4 GHz) vs. Mid/High (>4 GHz)
  - High resolution (<3") or Low Resolution (>3")
  - Monolithic vs. Tiered ("Wedding Cake")
  - Targeted (Deep or Medium-deep) Fields?
  - Multi-epoch with month/year cadence over decade?
  - Complementarity with O/IR (e.g. Pan-STARRS,LSST)

Key Science Cases – Highlights

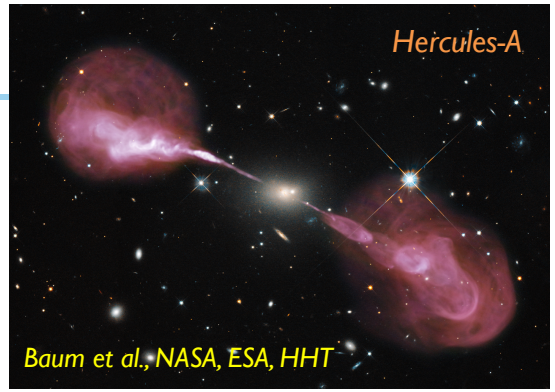
- Medium/Deep Fields for Galaxy Evolution & Cosmology
  - AGN and Clusters of Galaxies, Feedback
  - Star-forming Galaxies
  - Weak Lensing
- Large Area Survey for Transients & Faraday Tomography
  - Full Polarimetry for B-field Studies
  - EM Counterparts to GW events (LIGO/VIRGO)
  - Radio Bursts on timescales from 1ms to >1 year
- Galactic Plane and Center
  - Atomic and Molecular Lines from 0.2-50 GHz
  - Stars and Stellar Systems

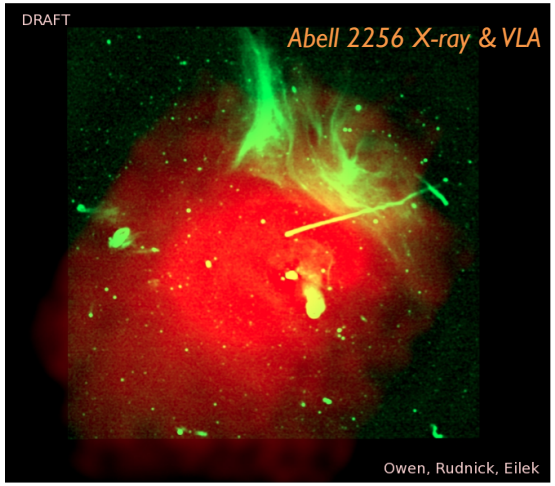
Cosmology & AGN: Brown et al., Mao et al., Spoalor et al.,

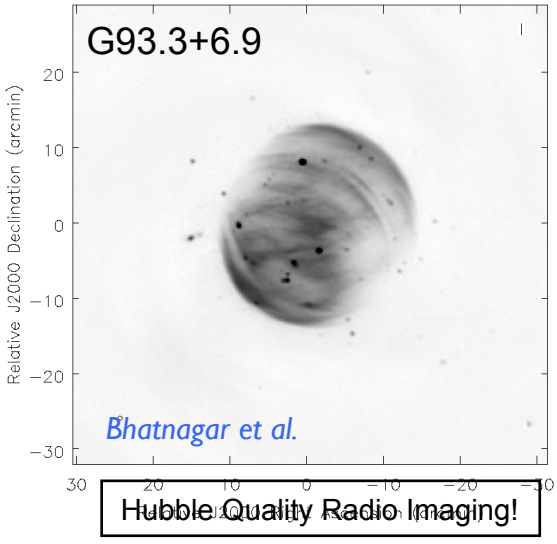
Clusters & Polarization: Clarke et al., Edge et al., Mao et al.
Cosmic Deep Fields: Hales et al,, Jarvis et al., Richards et al., Wang et al.

Transients: Chatterjee et al., Hallinan et al., Kamble et al., Law et al., Wilson et al.

Galactica: Bastian et al., Bhatnagar et al., Sjouwerman et al., Mills et al.



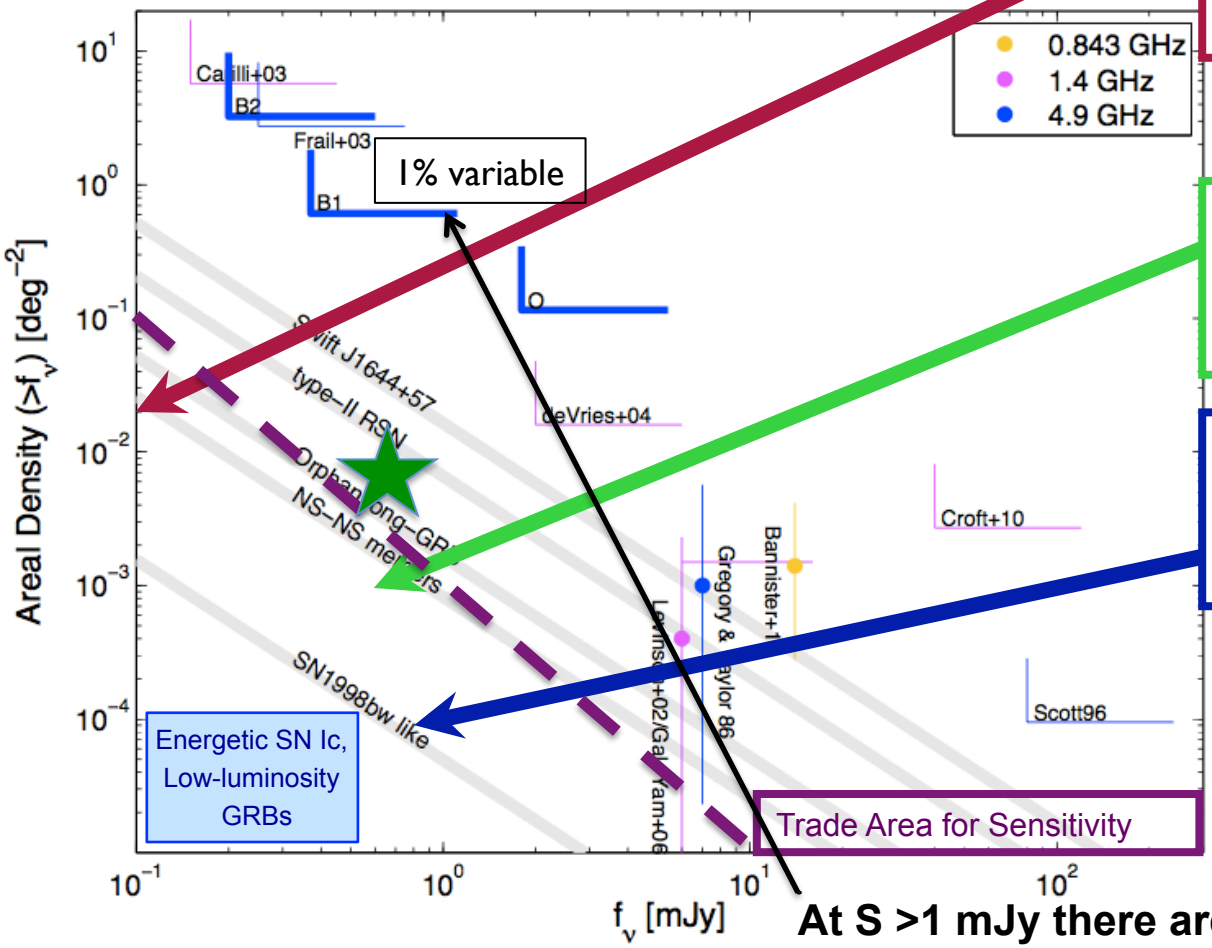




Hubble Quality Radio Imaging!

The Dynamic Radio Sky with VLASS

- Areal density vs. Flux density (Frail et al. 2011)
  - $N/t = S^{-1.5} / S^{-2} = S^{0.5}$ (shallow wins)



Deeper Narrower Survey
50sq.deg at 12.5μJy rms
2-4GHz in 194 hours

Times are per Epoch

Medium-Wide Survey
10^3sq.deg at 75μJy rms
2-4GHz in 107 hours

Wide-Shallow Survey
10^4sq.deg at 100μJy rms
2-4GHz in 605 hours

See White Papers: Chatterjee et al., Hallinan et al., Kamble et al., Law et al., Wilson et al.

At S >1 mJy there are 90 persistent sources deg^{-2}

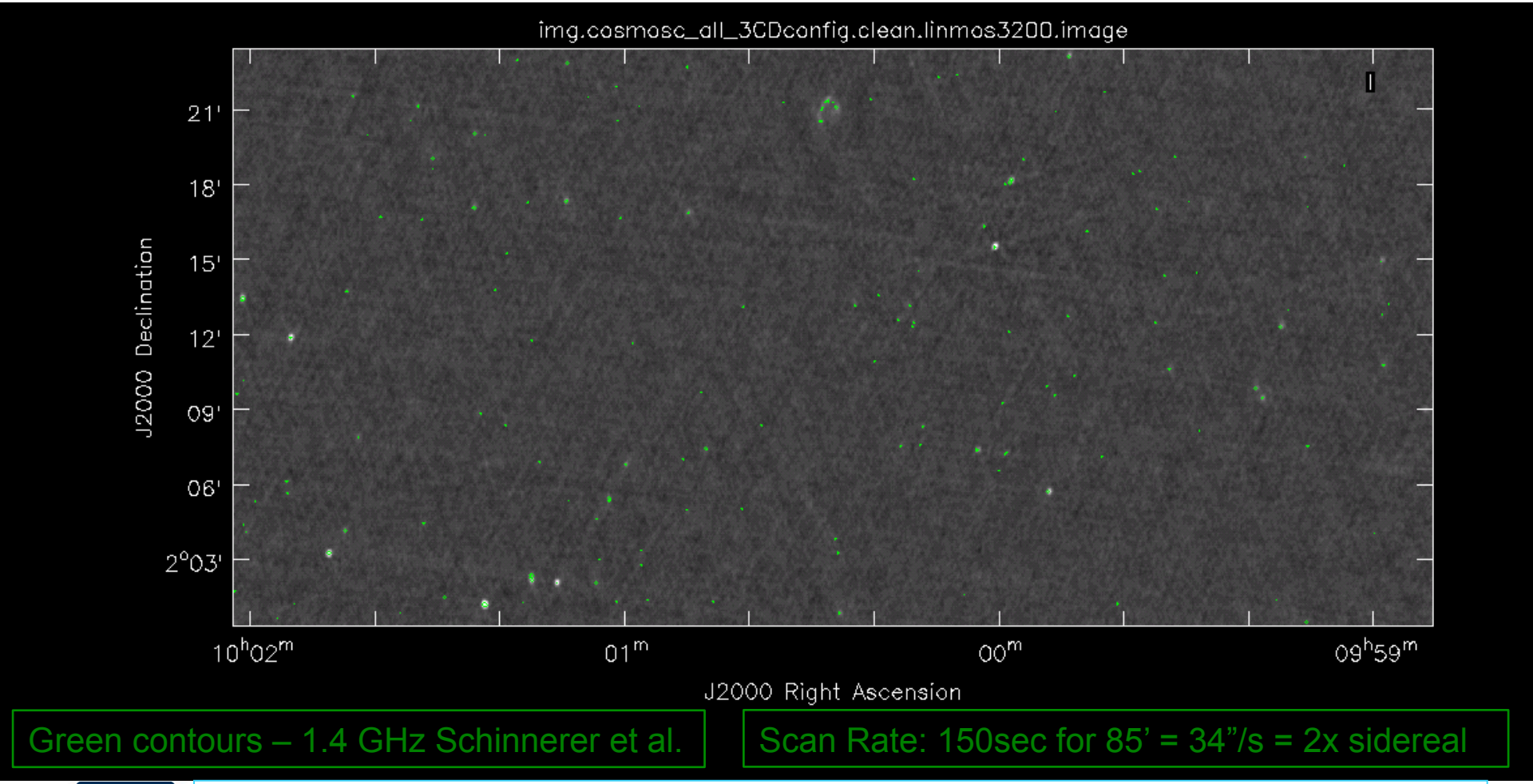
Key Jansky VLA Enabling Technologies

- Tremendous advances in performance since FIRST/NVSS (1993-2002)!
- Wide-bandwidth correlator – instantaneous 2GHz to 8GHz
- High Time Resolution – 5ms to 1s possible (data rate limited)
- "On-the-Fly" (OTF) mosaicking for efficient coverage of large areas
  - Scan telescopes continuously stepping phase centers
  - Demonstrated with scan rates up to ~6'/s
    - Areal Survey Speeds of 16 deg^2/hr at 100μJy (rms) proven
    - Speeds of 160 deg^2/hr at 300μJy (rms) or higher plausible
  - Currently available only as part of Resident Shared Risk (RSRO)
    - Currently under extensive development and testing…
  - Image Processing support for Wideband OTF Mosaicking (in CASA)
    - Needs new algorithm and code development!

See https://science.nrao.edu/facilities/vla/docs/manuals/obsguide/modes/mosaicking

OTF Now – COSMOS C-band C&D

- C & D-config C-band 3 epochs – OTF 3200^2 2" cells – 51μJy rms (ZOOM IN)



Green contours – 1.4 GHz Schinnerer et al.

Scan Rate: 150sec for 85' = 34"/s = 2x sidereal

13A-362 (Myers) C-band 1hr SB (4.2-5.2 + 6.5-7.5GHz) ~ 85μJy rms per epoch
2 square degrees / OTF scans in RA / 432 phase centers / Repeat bi-monthly.

Assembling the Survey – Example

- **Multi-Tier Survey** (integration/dwell times) **Total 5614 (7017) hours**
  - Tier 1 : 30000 deg^2 all-sky
    - S1 – 2-4GHz in 2 configs to 100μJy (1815h)
  - Tier 2 : 10000 deg^2
    - S2 – 2-4GHz in 2 epochs at 100μJy (1210h) [58 μJy S2+S1]
    - C2 – 4-8GHz in 2 config (B/D 8mos apart) at 100μJy (1400h)
  - Tier 3 : 1000 deg^2 split into Gal Plane, Gal Cap, targets (Virgo? M31?)
    - S3 – 2-4GHz in 6 epochs at 100μJy (363h) [33 μJy S3+S2+S1]
    - C3 – 4-8GHz in 3 epochs at 100μJy (416h) [50 μJy C3+C2]
    - X3 – 8-12GHz in 1 epoch at 100μJy (338h)
    - L3 – 1-2GHz in 2 configs (A/C or B/D) at 100μJy (72h)
  - Science Case: multiple, see VLASS White Papers!
  - This "Survey" is intended as an example only, not a proposal.

See White Papers: Hales et al., Jarvis et al., Myers, Richards et al., Wang et al.

Maximizing Science Opportunity

- Enabling principles / Cultivating a Multi-wavelength Community View
  - **Involve a broad *international* community in the SSG**
  - **Open process, no proprietary data**
  - **Design in opportunities for EPO and Citizen Science**
  - Strong and diverse student program (survey internships?)
  - Flexible schedule response, coordinate observations of key fields
  - **Enable co-observing by publishing survey schedules**
  - Prompt analysis and publication of transient event alerts
  - Quality control and assurance
  - Ease of community access (VO, portals)
- Range of available data products for science-ready utility
  - Calibrated uv data
  - **Basic images and catalogs, prompt with levels of quality assured**
  - **More advanced products as added value by community**

See White Paper: Spuck et al. (EPO, Citizen Science)

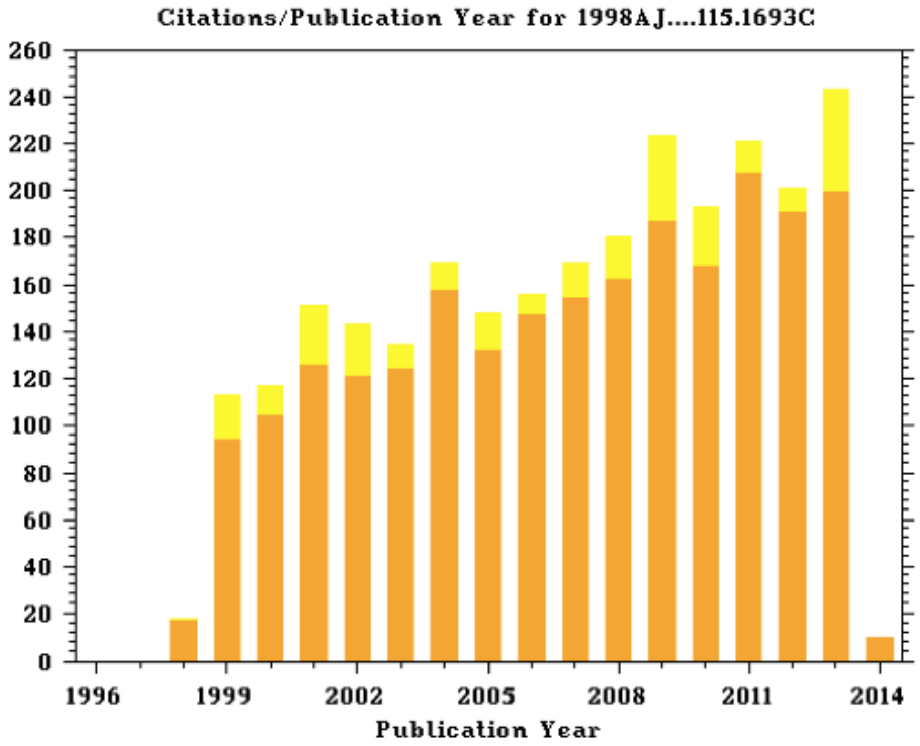
Timeline – Stay Tuned!

Notional dates only, this is a draft schedule!

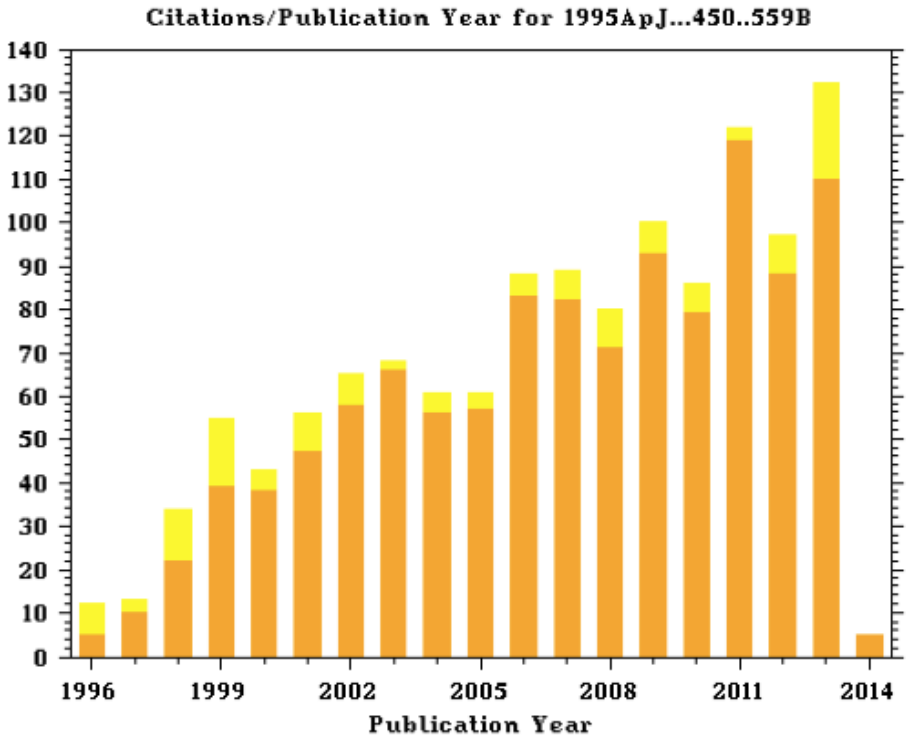
- 1 Feb 2014 – SSG starts science design plan
- Feb – Mar 2014 SSG Working Groups "meet" and plan
- 31 Mar 2014 – SSG delivers science design plan
- 1 Apr 2014 – SDG starts technical design plan
- ? Technical Design Workshop/CoDR in Socorro NM ?
- 1 Jun 2014 – Full Survey Proposal to NRAO director for review
- 1-5 Jun 2014 – Splinter Meeting at AAS 224 in Boston?
- Jan 2015 – Community Workshop at AAS 225?
- Early 2015 – first pilot or production observations in B-array?

Final Thoughts…

NVSS: 2580+ citations



FIRST: 1260+ citations



Survey relevance can be decade or longer

Final Thoughts

Why to do surveys

The FIRST image server (third.ucllnl.org) provides JPEG or FITS cutouts extracted from the FIRST survey at user-specified positions.

Currently the cutout server delivers on average more than 12,000 image cutouts every day.

Each image served is equivalent to a three-minute VLA observation; thus, our image server issues the equivalent of a 3-minute VLA observation every 7 seconds!

Every week the FIRST cutout server distributes snapshots with a total exposure time equal to the entire 4000 hours invested in the FIRST survey.

White – VLASS workshop Jan 2014

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