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
- A Community-led Program to define a new radio sky survey using the upgraded Karl G. Jansky Very Large Array (VLA)
- Open *international* participation, public data and products
- SOC to set up AAS workshop and process now started
- 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!**

  This talk is based on results from AAS Workshop 5 Jan 2014
- Website : https://science.nrao.edu/science/surveys/vlass

  Email : vlass@nrao.edu

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:

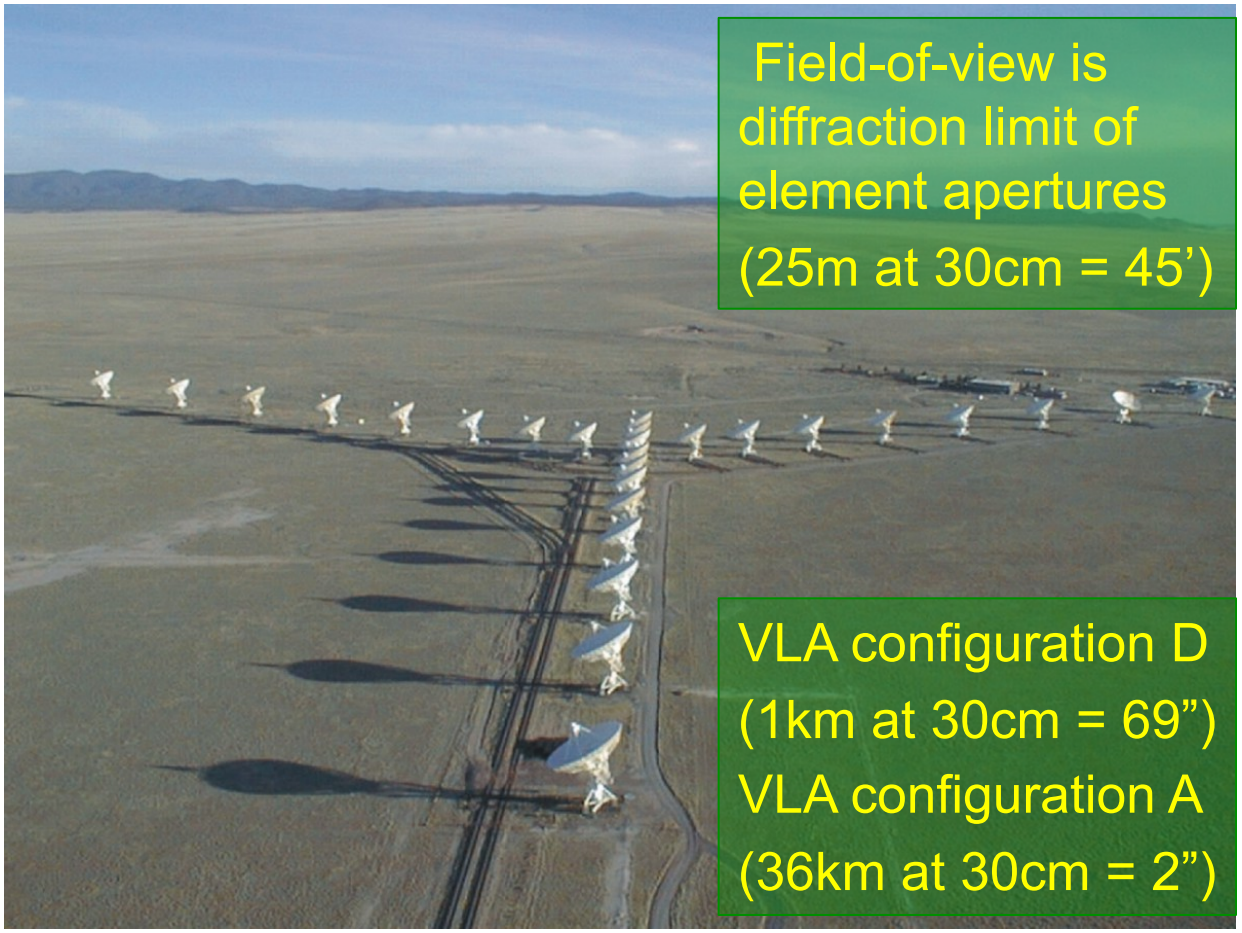
Digitized at antenna (3&8-bit)

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

Science Definition – Results of Workshop

- Not pre-determined: SSG will define the survey
  - Expect 3000-10000 hours (NVSS+FIRST ~6000h)
- Battle lines from discussion and the 21 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

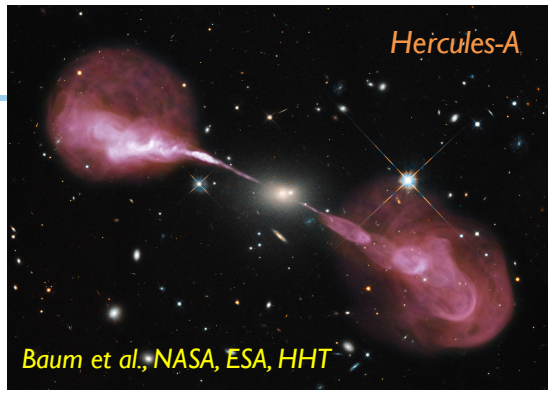
- Medium/Deep Fields for Galaxy Evolution & Cosmology
  - AGN and Clusters of Galaxies, Feedback
  - Star-forming Galaxies
  - Weak Lensing
- Large Area Survey for Transients & Faraday Tomography
  - Full Polarimetry for B-field Studies
  - EM Counterparts to GW events (LIGO/VIRGO)
  - Radio Bursts on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

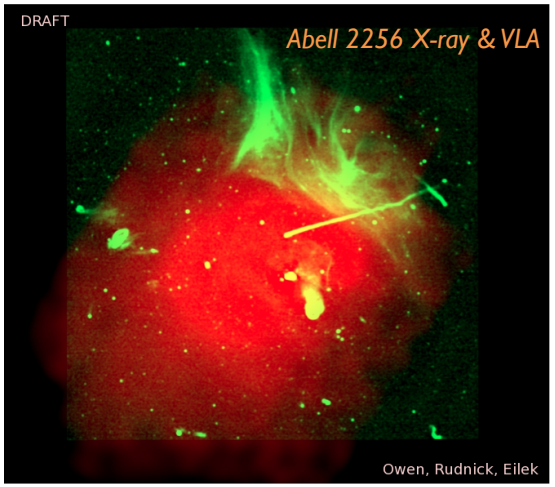
Cosmology & AGN: Brown et al., Mao et al., Spoalor et al.,

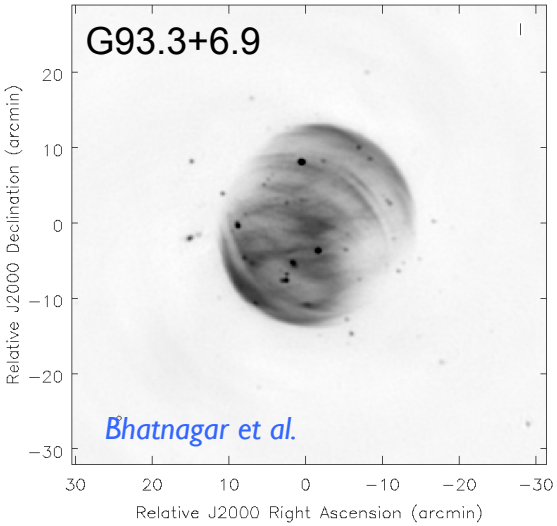
Clusters & Polarization: Clarke et al., Edge et al., Mao et al.
Cosmic Deep Fields: Hales et al,, Jarvis et al., Richards et al., Wang et al.

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.

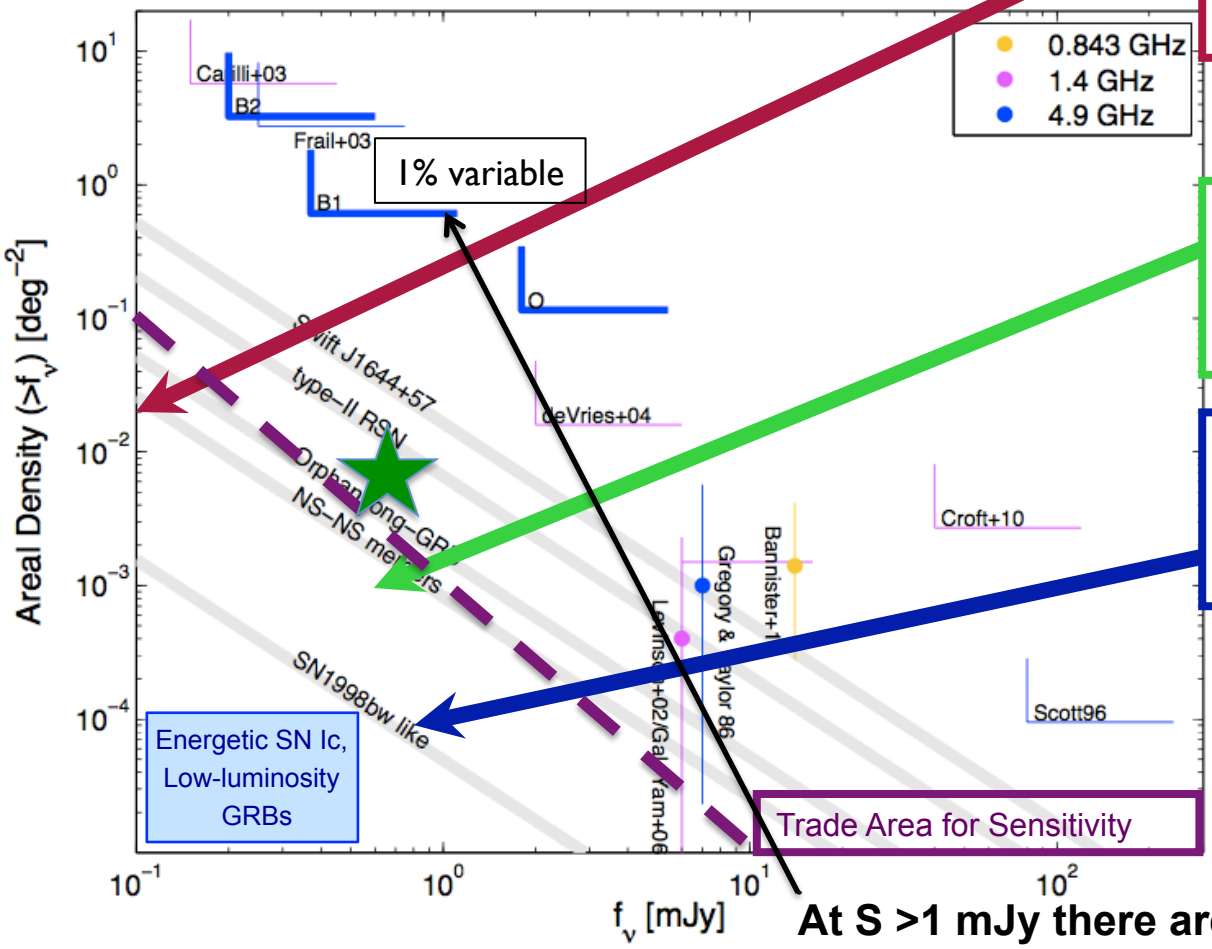






The Dynamic Radio Sky with VLASS

- 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}

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 (5+ years)
  - Characterize the "null" (static+variable) sky
  - Find optimal band to minimize variable "background"
    - Lay groundwork for LIGO & LSST era

Prepare for the Future – Science Proving Ground for SKA

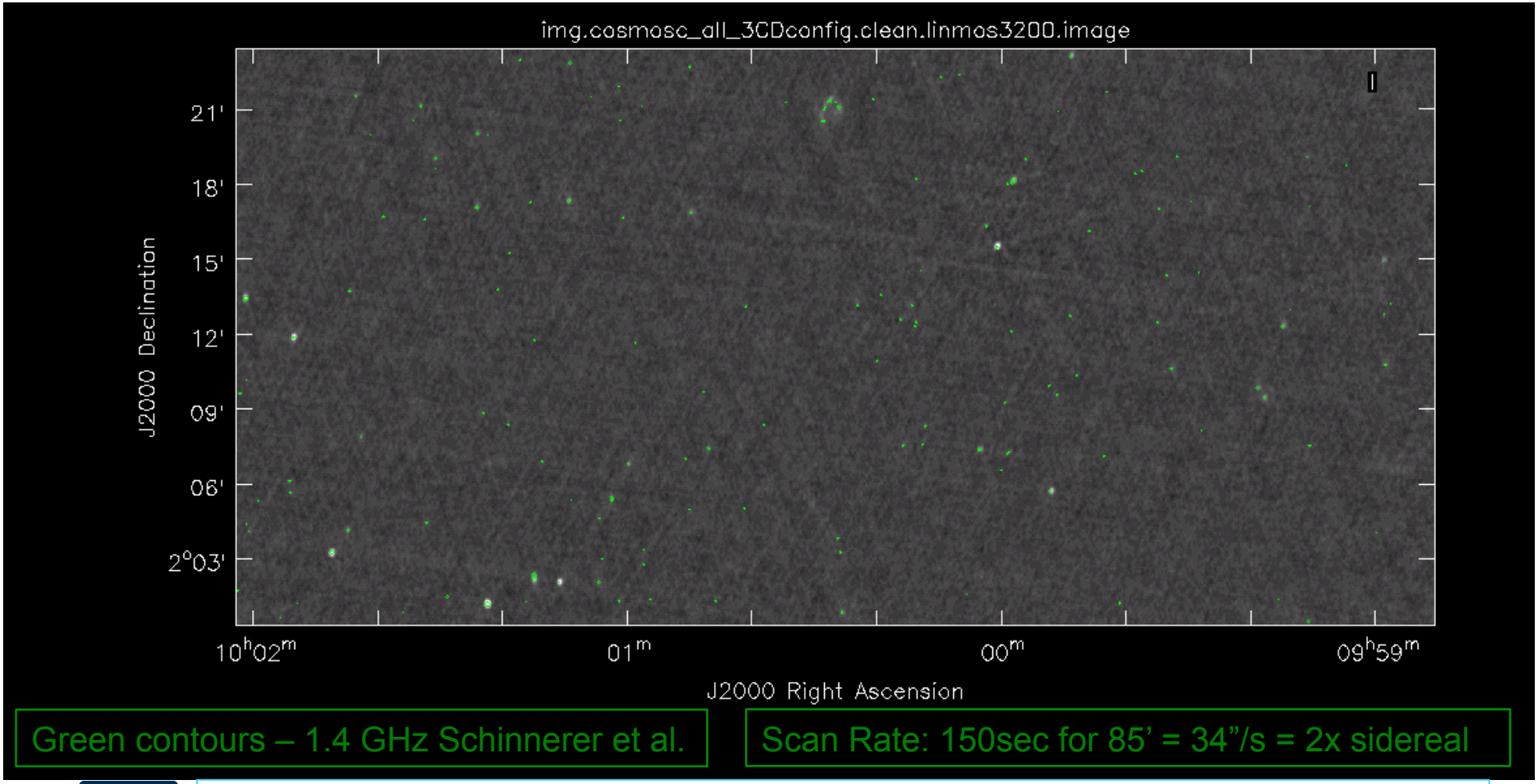
Key Jansky VLA Enabling Technologies

- 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 OTF Mosaicking (in CASA)

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)



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** ★
  - Range of available data products for science-ready utility
  - Coordinate observations of key fields
  - **Enable co-observing by publishing survey schedules** ★
  - Flexible scheduling in response to events and opportunities
  - Prompt analysis and publication of transient event alerts
  - Quality control and assurance
- Data Products
  - 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)

Survey Principles – all we need is "luck"

- 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

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
- 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?

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