Mapping the Universe with the Square Kilometre Array

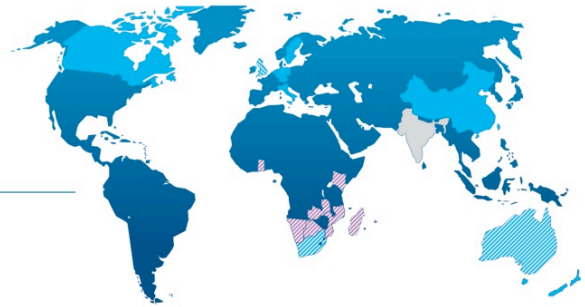
[probing AGN activity down to the radio-quiet regime]

Isabella Prandoni

INAF - IRA

www.skatelescope.org

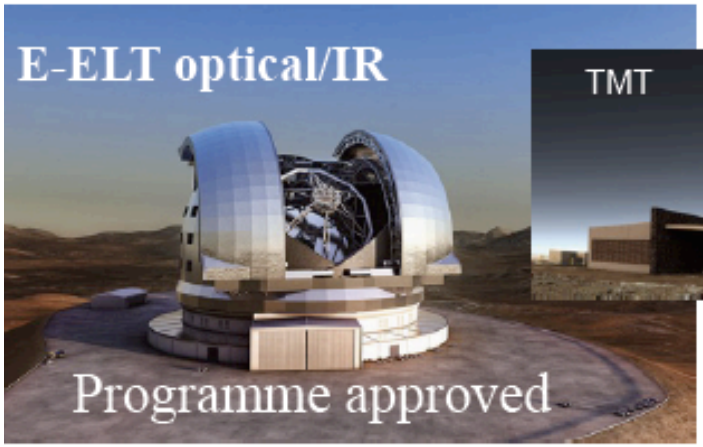
Exploring the Universe with the world's largest radio telescope

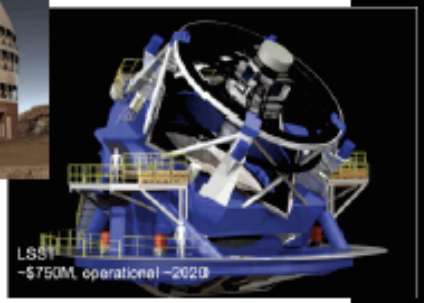


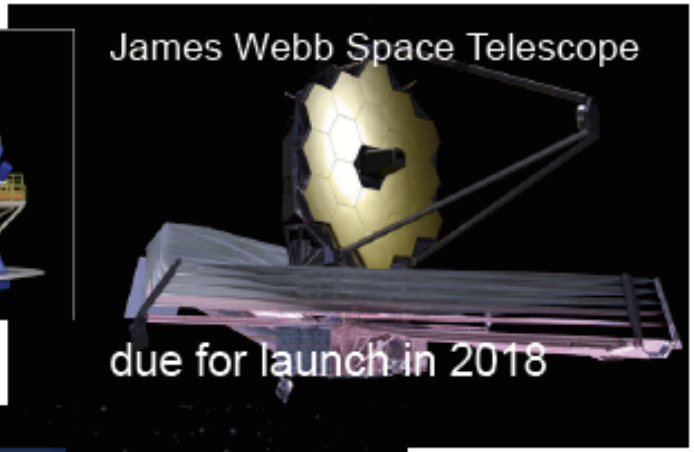
Full members Associate members SKA Observatory hosts (members)

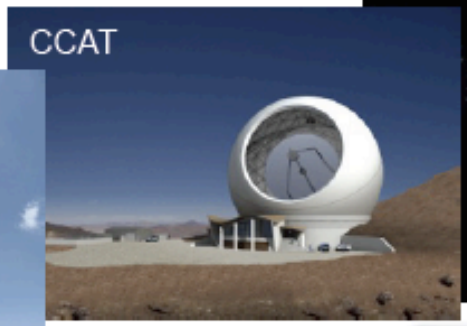
SKA Observatory hosts (non-members) SKA Headquarters host

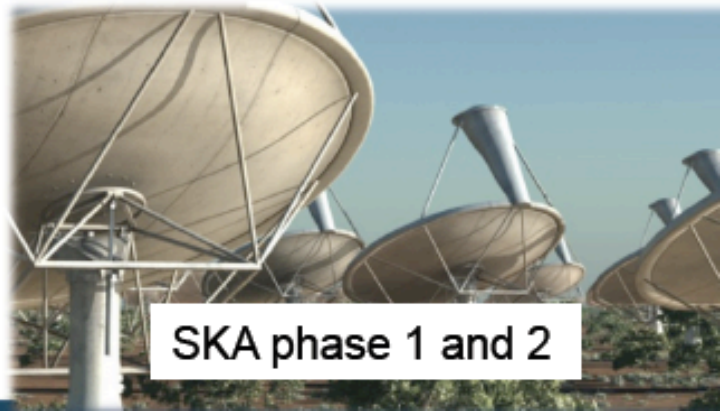
Great Observatories for >2020











The SKA in a nutshell

SKA: Major radio facility of the 21° Century [1 Billion €]

Main parameters:

- **1 km^2 collecting area → 100x sensitivity**
- **Large FoVs → 100x survey speed**
- **3000+ km max baseline → mas angular resolution**
- **large frequency range [50 MHz – 10+ GHz]**

Broad multi-wavelenth/multi-messenger science

The SKA in Phases

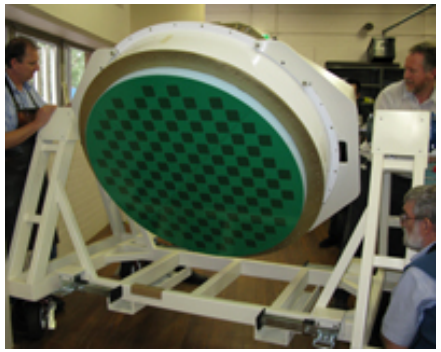
SKA will be implemented in phases:

- Precursors: MWA (2014) Meerkat (RSA, 2017), ASKAP (Aus, 2016)
- SKA_1 subset (~10% area) of SKA_2

SKA1-low (sparse AA): Freq. Range: 70 - 350 MHz

SKA1-mid (dish+SPF): Freq. Range: 0.45 – 10 GHz (3 Bands)

SKA1-survey (dish+PAF) : Freq. Range: 0.7 – 1.7 GHz
PAF for Survey Speed

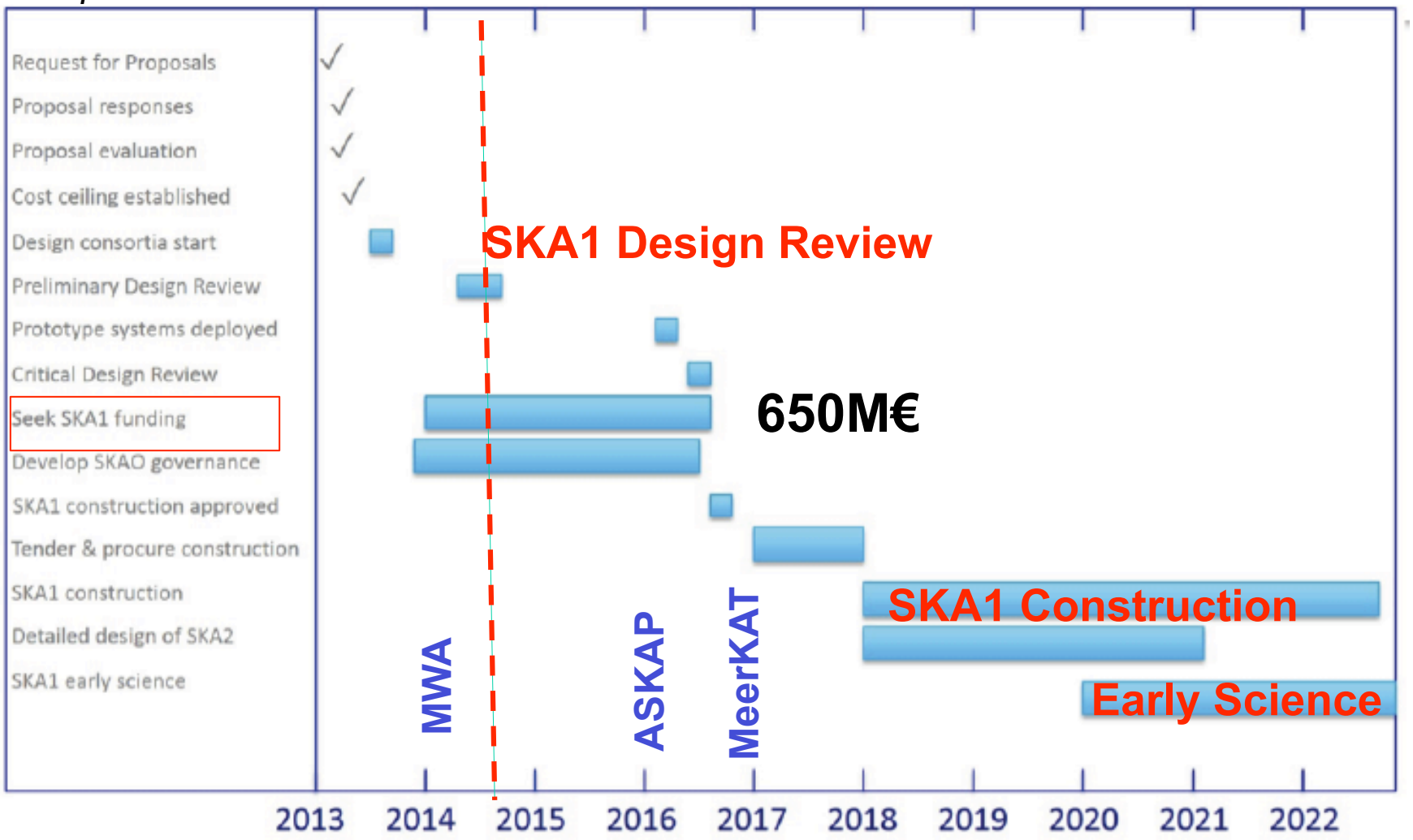


- SKA_2 : full SKA capability between 70 MHz and 10 GHz

Phased construction allows maximum use of advances in technology and incremental fine-tuning of science drivers/technical requirements

SKA_1 Timeline

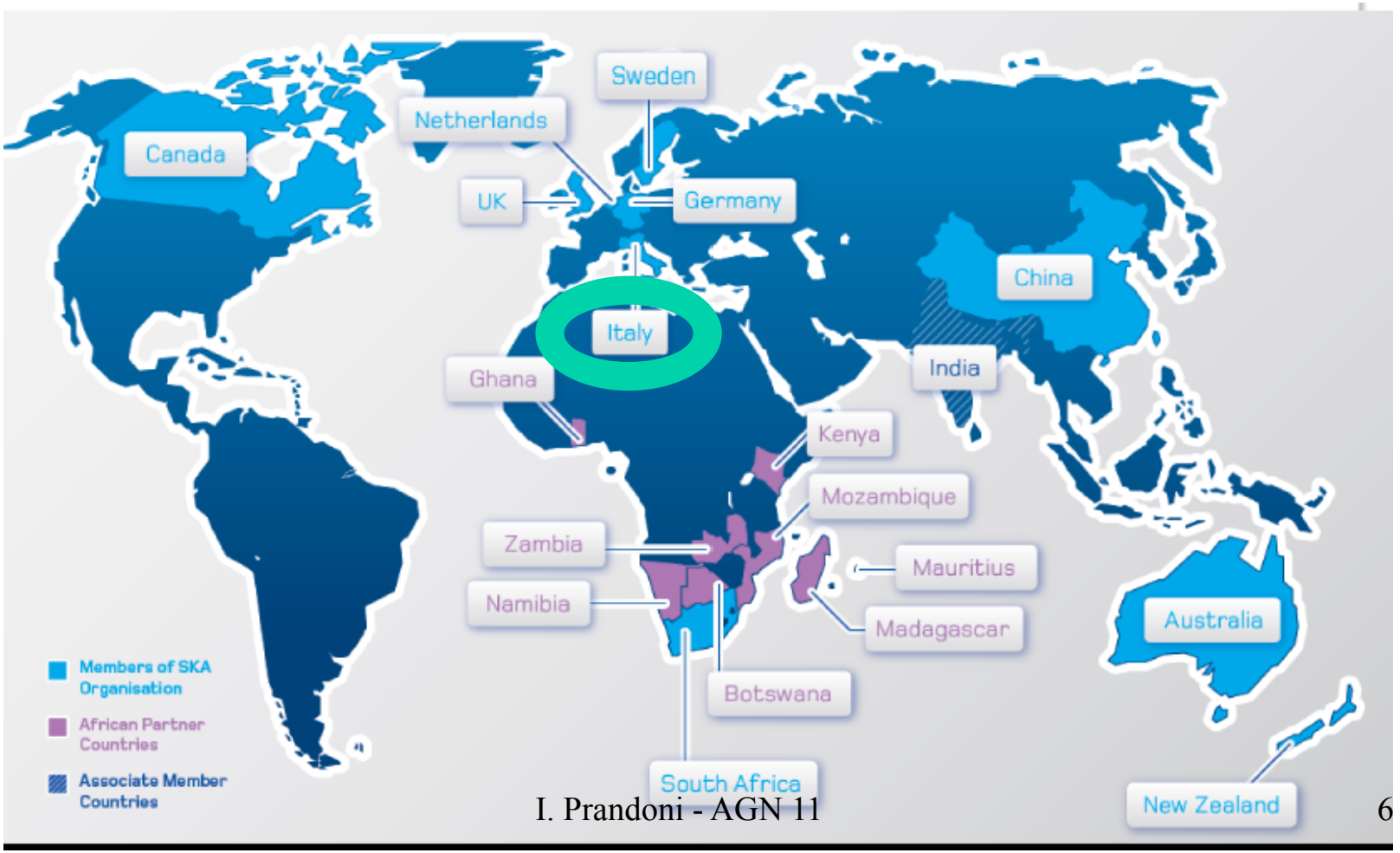
Adapted from P. Diamond



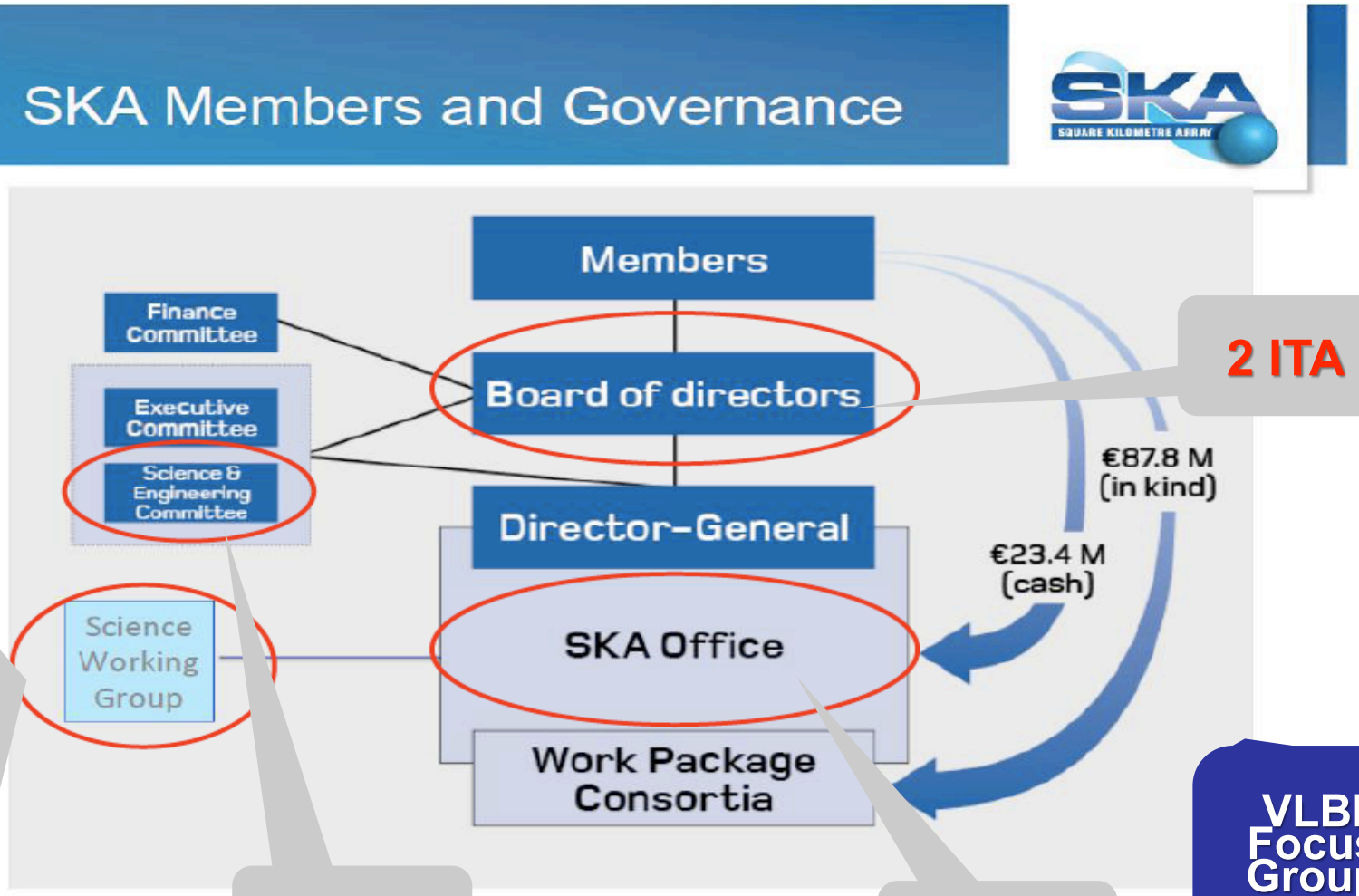
The SKA Organization

Founded in 2011

Scope: seek Funding and coordinate Design Phase



SKA Governance - Role of Italy

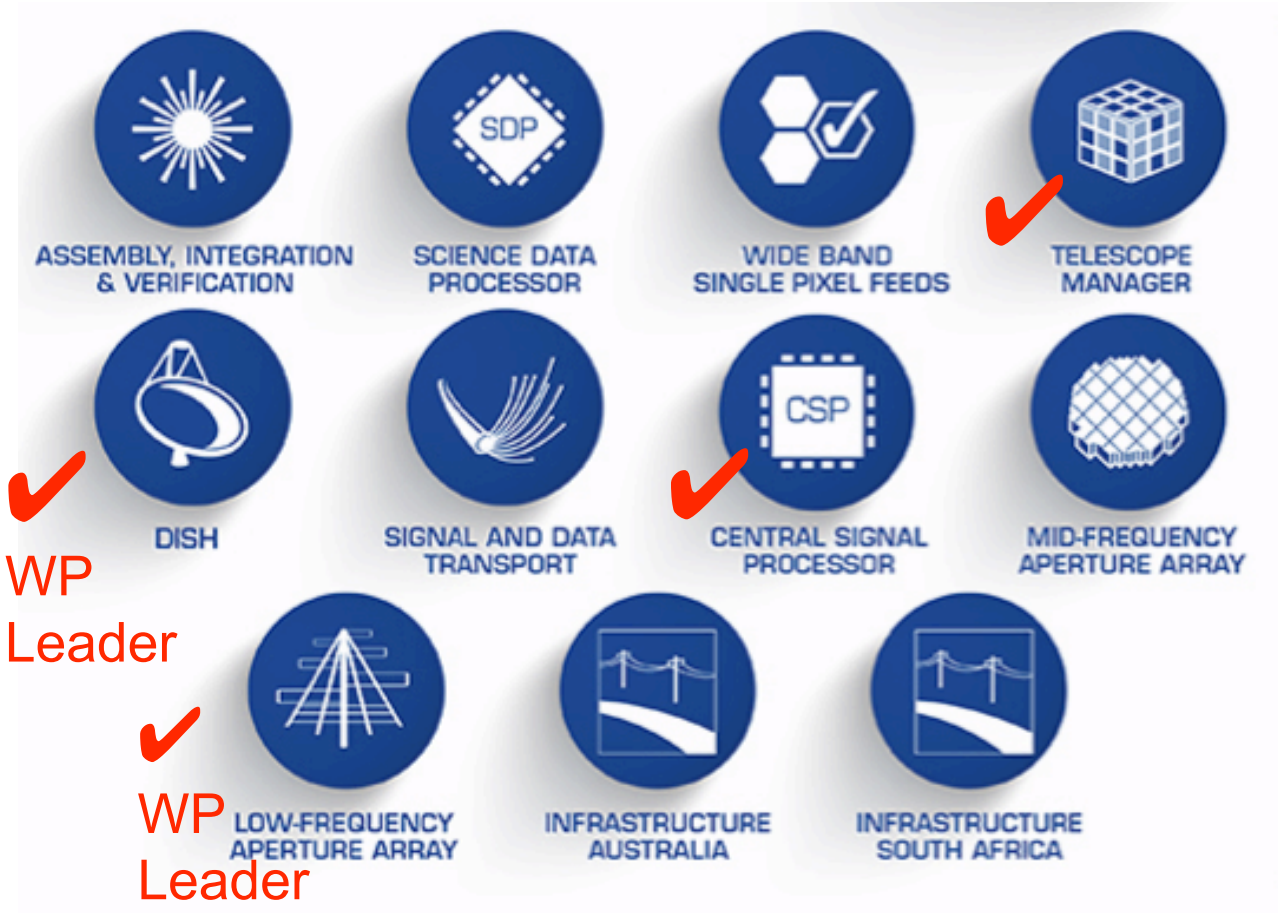


- EoR
- HI
- Continuum
- Cosmology
- Magnetism
- Pulsars
- Transients
- Cradle of Life

20 ITA

SKA_1 Design Consortia – Role of Italy

Started in 2013



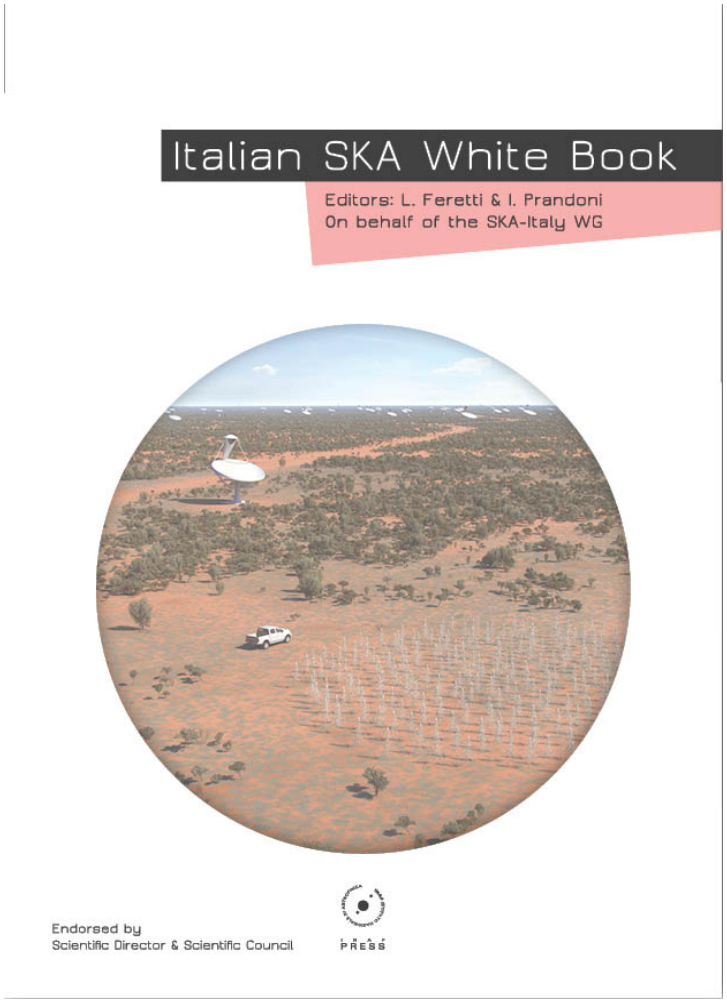
Italian SKA White Book

Eds. L. Feretti, I. Prandoni et al., INAF Press, ISBN: 978-88-98985-00-5, 2014

Available at:

http://www.ira.inaf.it/SKA-Italy/SKA-Italy-WB.html

- **Editorial Board:** 16 members from 13 INAF institutes
- **Contributions**: ~80 astronomers from all INAF Institutes + 10 Universities



New SKA Science Book

- Science Drivers defined in 2004
- Naxos, June 9-13, 2014
- Scope: new Science Book

  Add Continuum Science Case

- **152 chapters** submitted
- **1/3** involving Italy (**17% PI**)
- **114 selected** speakers
- **17 speakers from Italy (15%) [**12 Institutes represented]

- Chapters will inform re-baselining
- March 2015: Final decision on SKA1 Design

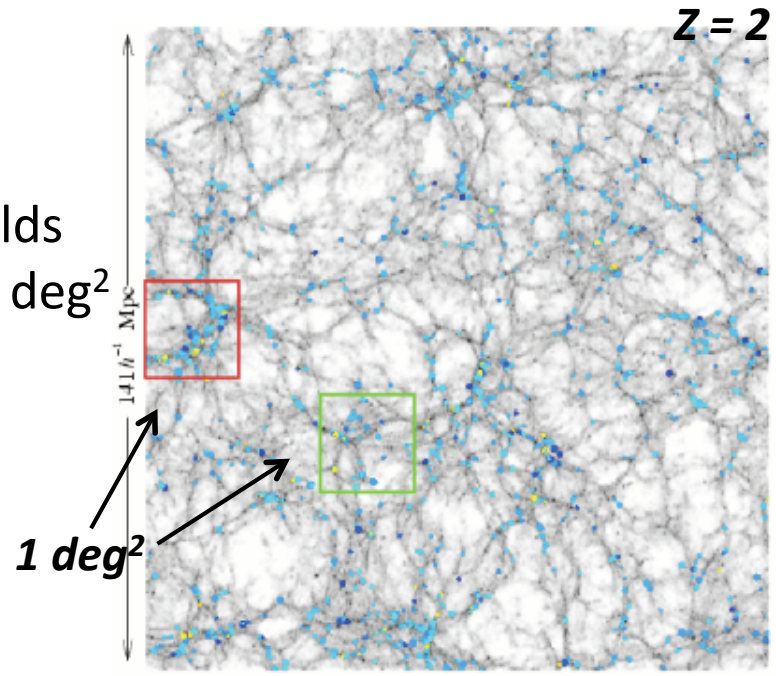
The new SKA Radio-Continuum Science Case

•Evolution of galaxies and clusters
(in combination with HI + multi-λ information)

- **Star formation & BH accretion** history
- Role **of AGN feedback** over cosmic time
- Interplay between SF and AGN activity
- Origin of **FIR-Radio correlation**
- diffuse **non-thermal emission in clusters**

Deep fields
~10-100 deg^2

- steady-shocks emission from the **cosmic web**
- **first galaxies**, BHs & protoclusters
- Detailed study of **ISM physics in nearby galaxies**



GALFORM, Benson et al. 2000

•Cosmology (in combination with HI/redshift surveys)
(Constrain dark energy and non-Gaussianity)

- Baryonic Acoustic Oscillations
- Integrated Sachs-Wolfe Effect
- Magnification Bias
- **Weak lensing**
- **HI Intensity Mapping**

Shallower wide-area surveys
>1/4 sky

- Commensality between line/continuum/polarization surveys
- Synergy with surveys in other wave-bands

(Many) AGN science cases to be addressed

1. AGN Evolution & BH Accretion History down to radio-quiet regime

   AGN component seen in current deepest radio fields → physics & evolution of AGN possibly down to the radio-quiet regime (not affected by obscuration!) (sensitivity/area)

2. Role of AGN feedback in galaxy evolution (different accretion modes)

   → role of AGN feedback (radio/QSO modes) (radio/multi-band studies of host galaxies)

   → co-existence of SF & AGN activity *within* galaxies (deep, multi-λ, high resolution)

3. Influence of galaxy environment on AGN activity and feedback

   probe different environments at all redshifts (nested survey strategy)

4. Growth and duty cycle of radio sources, and role of IGM in accretion

   What determines the FRI/II dichotomy? Is it possible to directly determine DC from detection of old very steep-spectrum outbursts? Hot/cold accretion (low v/multi-band)

5. Highest redshift (z>6) AGN searches and studies

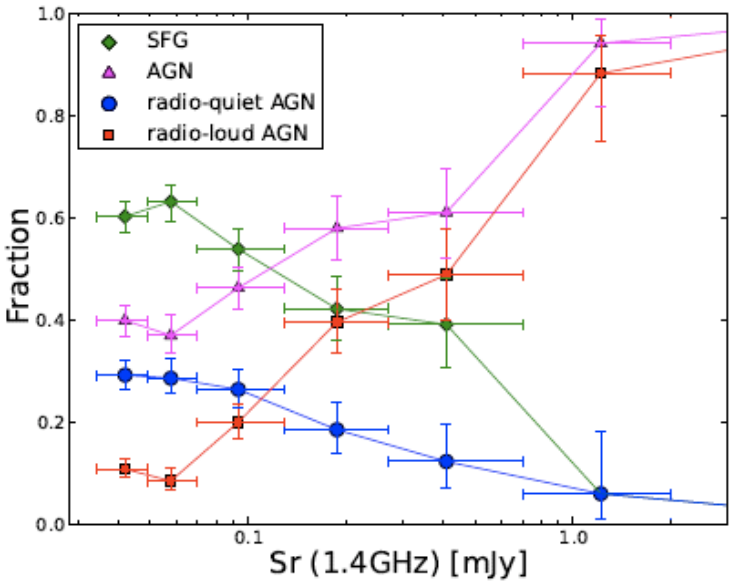
   see USS (Low frequency+multi-λ), rare population (large area needed)

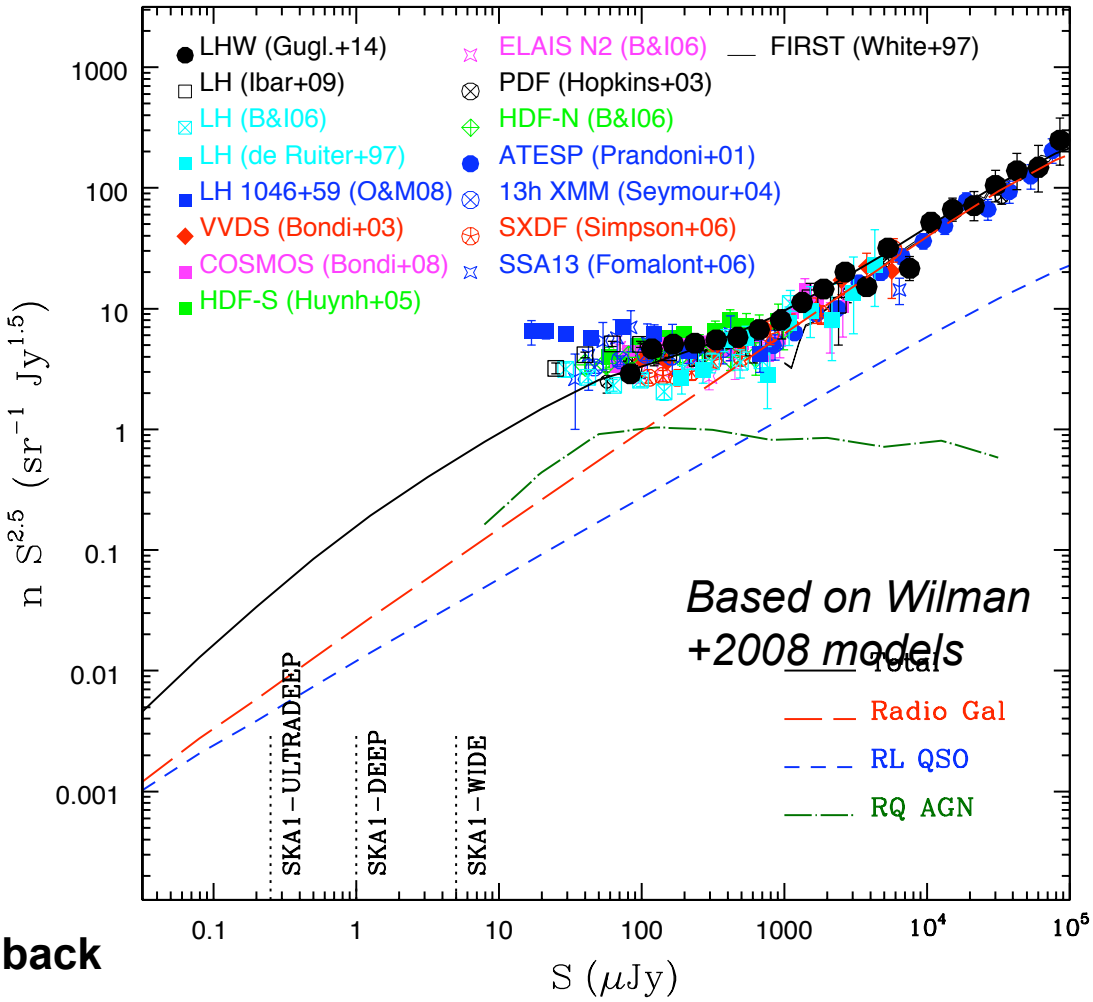
6. etc….

Based on science cases being developed for the new SKA Science Book

AGN: Why SKA deep radio surveys?

Adapted from Bonzini+ 2013



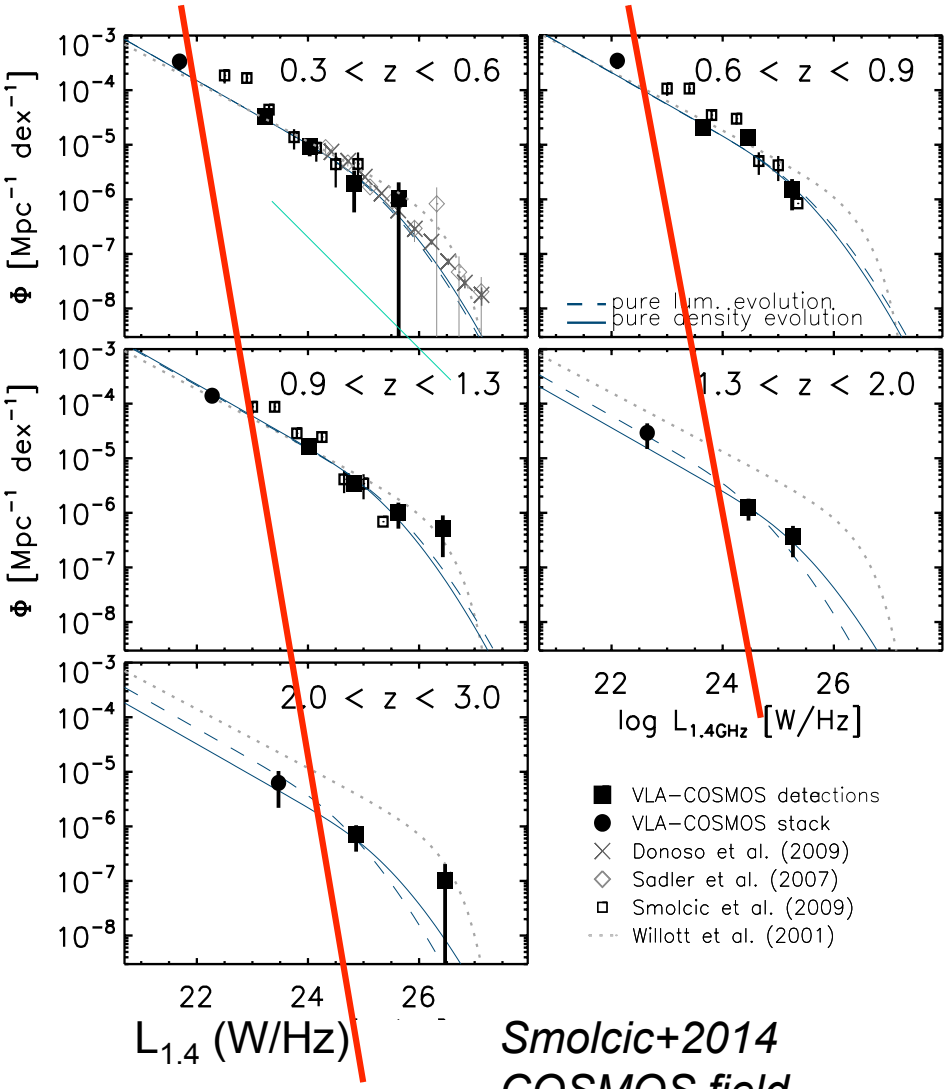


- **Complete census of RL and RQ AGNs**
- **No obscuration effects**
- **Sub-arcsec resolution**

➔complete view of AGN accretion/feedback modes:

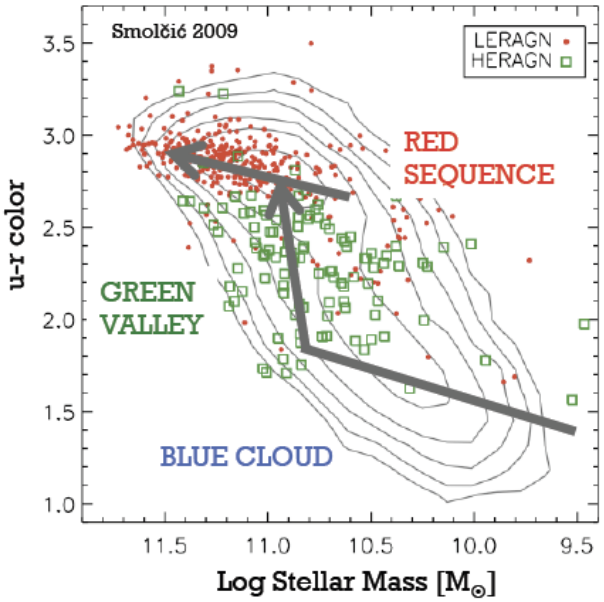
RL AGN – Radio Mode (jet-driven mechanical feedback)
RQ-AGN - QSO Mode → radiation-driven feedback (winds)

Radio AGN Evolution/Feedback



Smolcic+2014
COSMOS field

z>1 evolution of radio AGN poorly constrained at $L<10^{24\text{-}25}$ W/Hz (dominated by LERG)

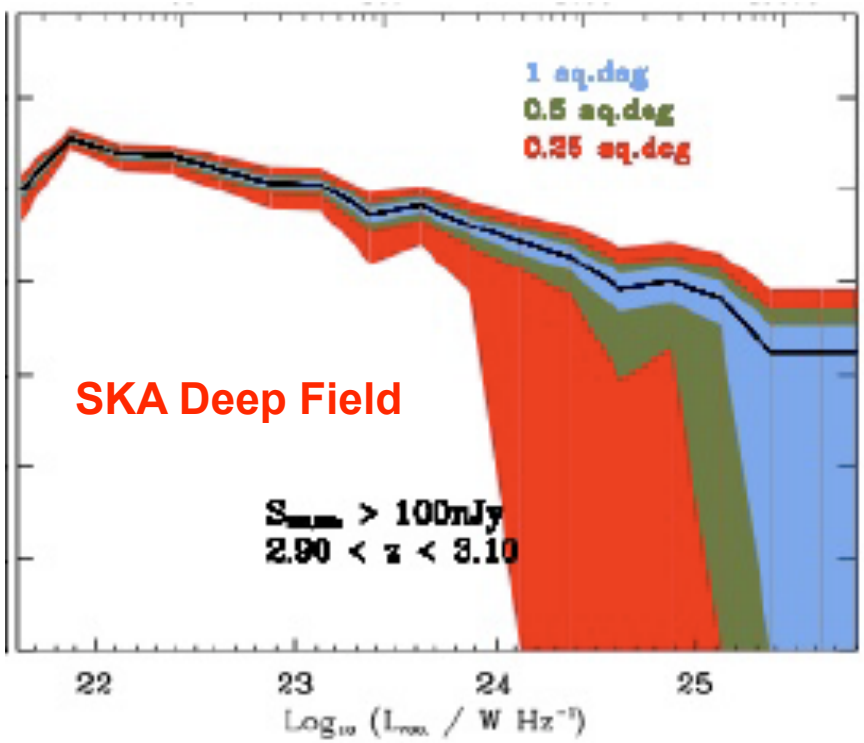


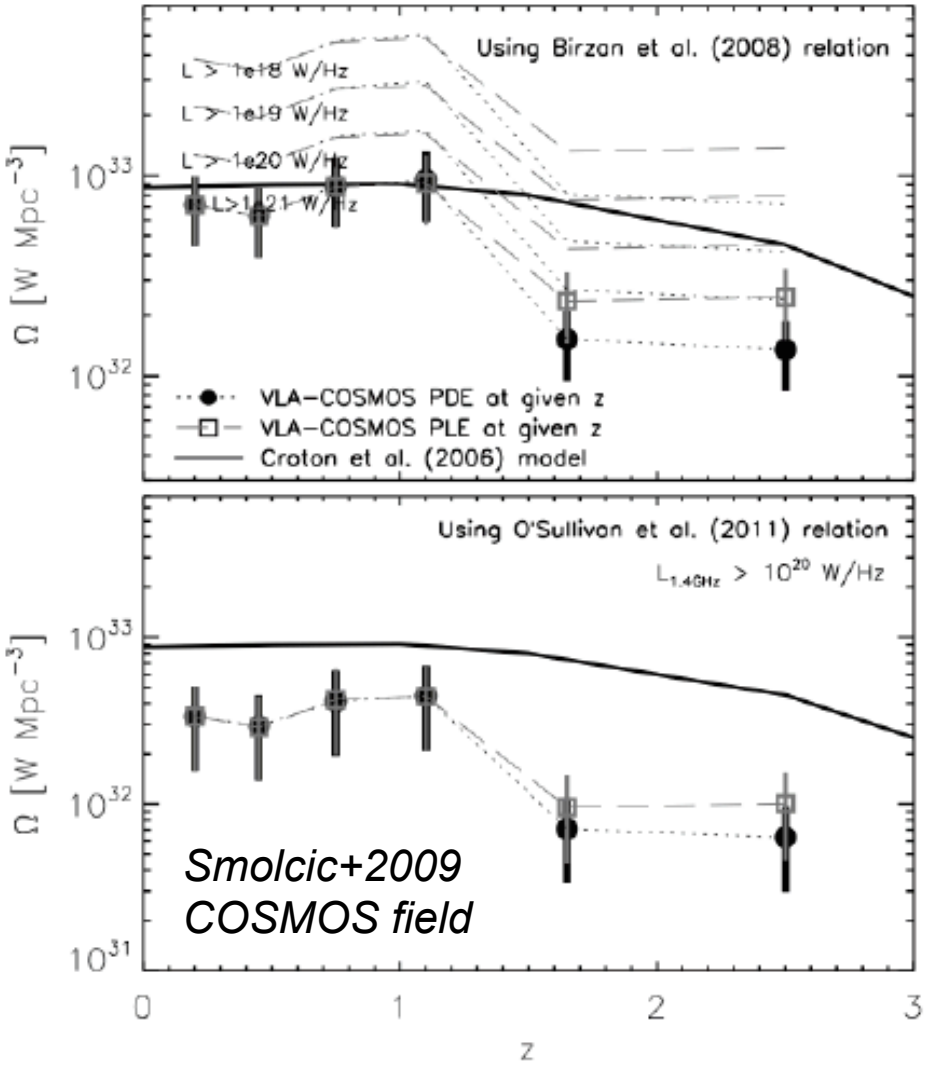
LERG → Role of radio feedback in 'galaxy evolution

Radio mode Feedback

- $L_{1.4}$ – kinetic power scaling relations
- kinetic power density → comoving volume averaged heating rate

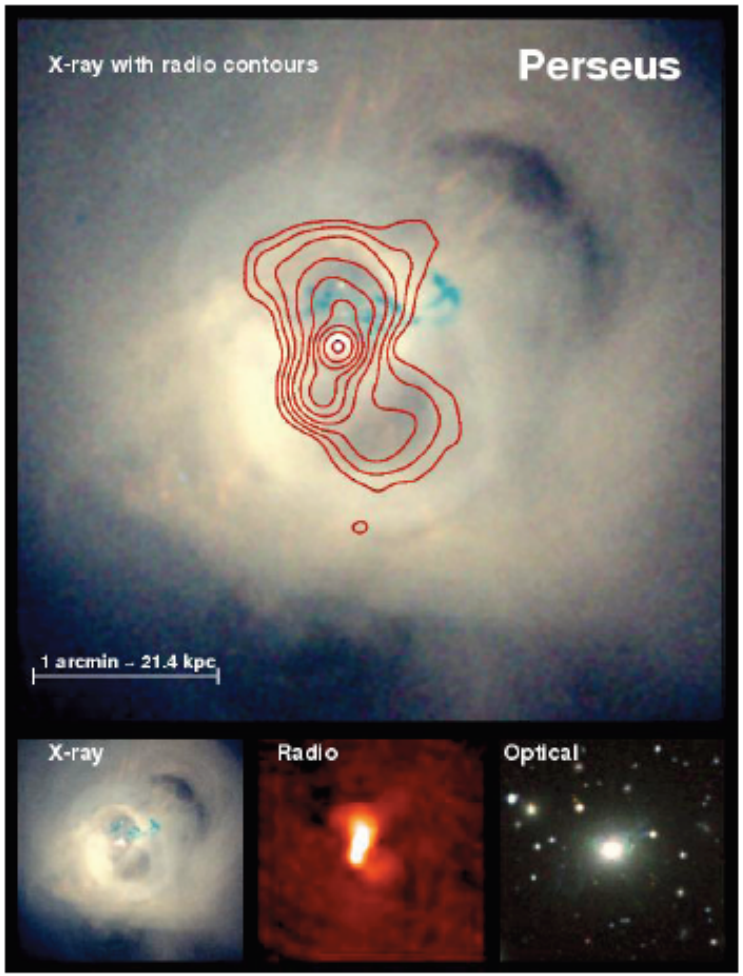
Strongly dependent on
- scaling relation
- low end of AGN LF

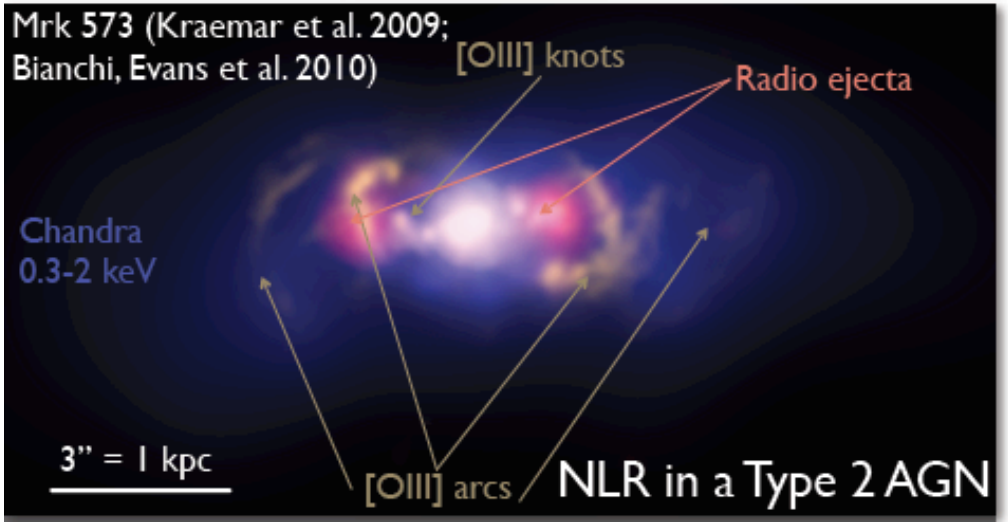




Radio-mode Feedback on galaxy-scale

From galaxy cluster to individual galaxy scales





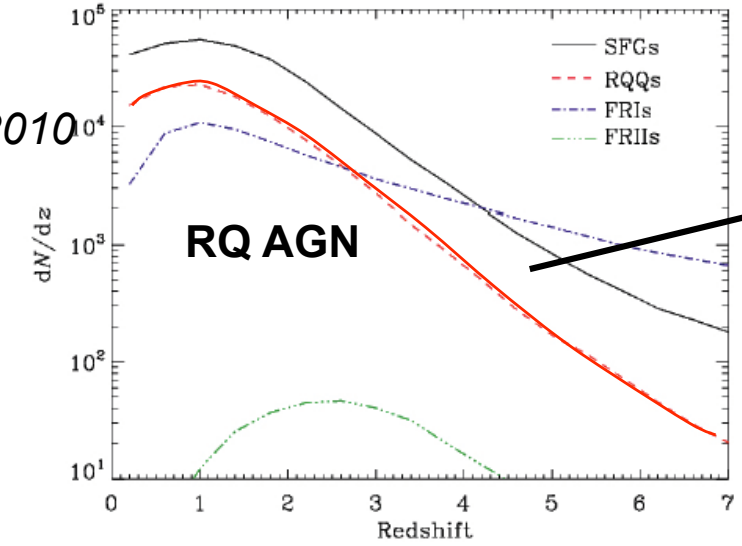
Requirement: sub-uJy sensitivity at sub-arcsec spatial resolution

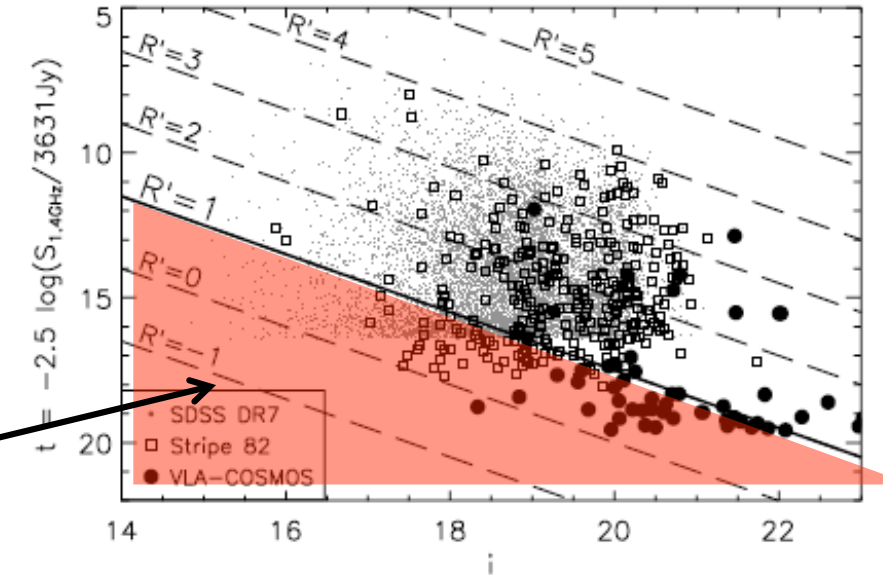
SKA_1 → 0.5 arcsec resolution at 1.4 GHz
~0.05 arcsec at ~10 GHz
SKA_2 → mas resolution at 1.4 GHz

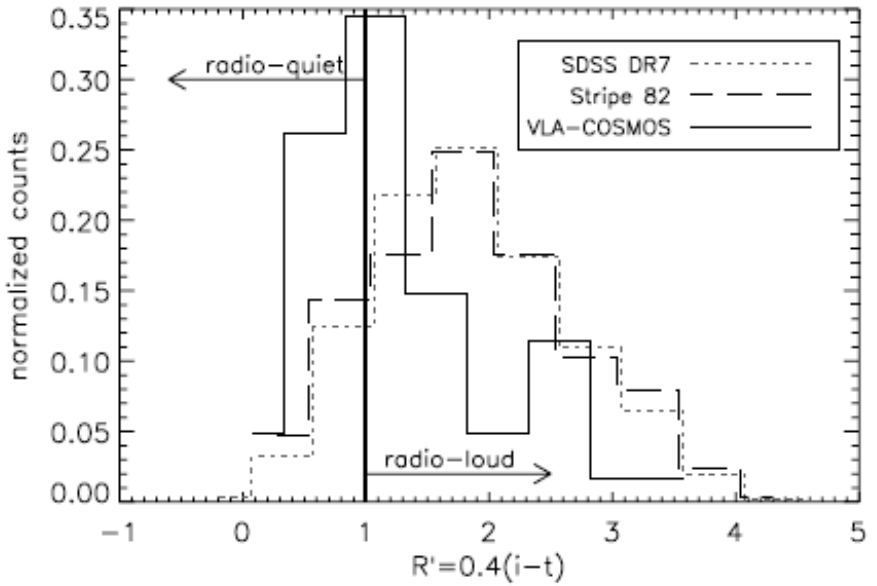
RL/RQ Bimodality & RQ-AGN physics

- 90% of optically-selected QSO are RQ
- Start to be detected in deepest radio fields

n(z) SKA
Wilman+2010





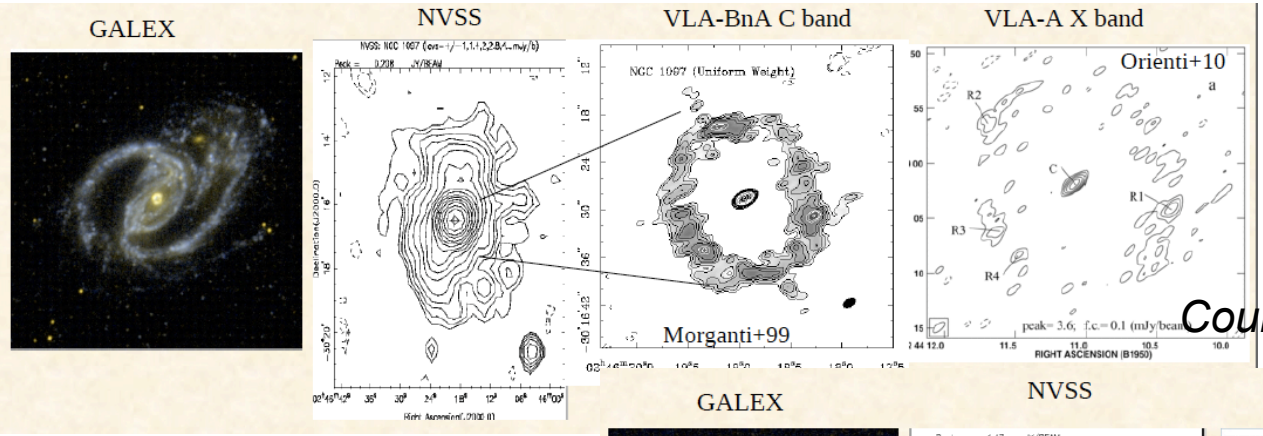


Physically distinct objects?
[M_{BH}, spin, accretion, host galaxy properties]
Jet vs disk dominated? ADAF?

Separating AGN/SF activity in RQ AGN

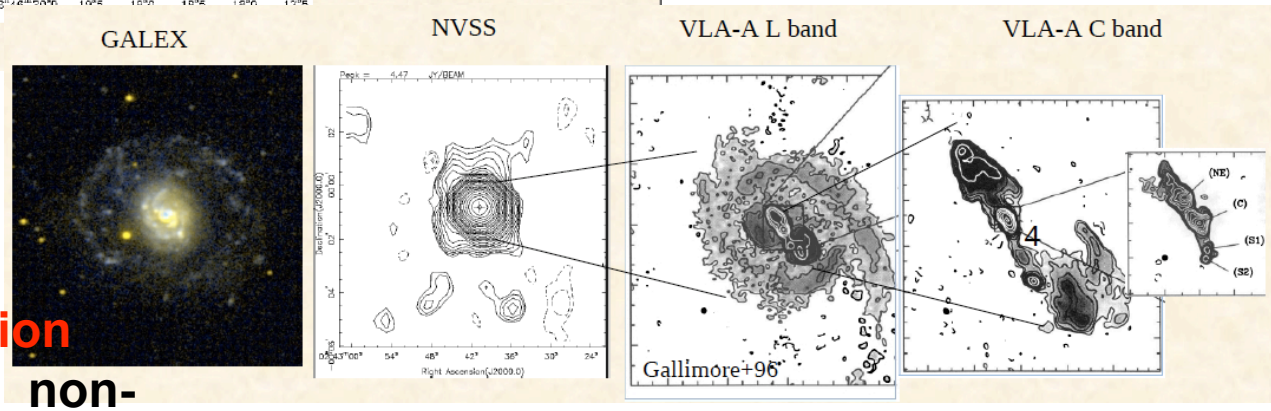
RQ-AGN often associated to disk galaxies → Need to separate AGN from SF radio emission → unbiased and complete AGN demography

Requirements: sub-arcsec resolution + uJy/sub-uJy sensitvity



Now possible for small samples in local Universe

Courtesy Orienti



SKA → larger samples & higher redshift

Multi-frequency/Polarization disentangle thermal vs non-thermal emission

Conclusions

- Radio surveys dust-extinction/gas-obscuration-free tool to study thermal and non-thermal emission from galaxies
- next-generation radio surveys increasingly sensitive to same populations as IR, optical and X-ray surveys [will become important component of multi-band studies and useful to a very broad community]
- Radio potentially new promising band to study *all types* of AGN: both the RL and the most common RQ component (dust/gas unbiased samples, sub-arcsec angular resolutions)
- SKA science will benefit from ancilliary, multi-λ information and viceversa. Coordination between surveys planned at various λ. Strong synergies to be exploited with other facilities
- SKA-related science can be done already now (get involved!)