UNCOVERING THE ENERGETIC OF THE INTERSTELLAR AND THE INTERGALACTIC MEDIUM WITH THE SKA

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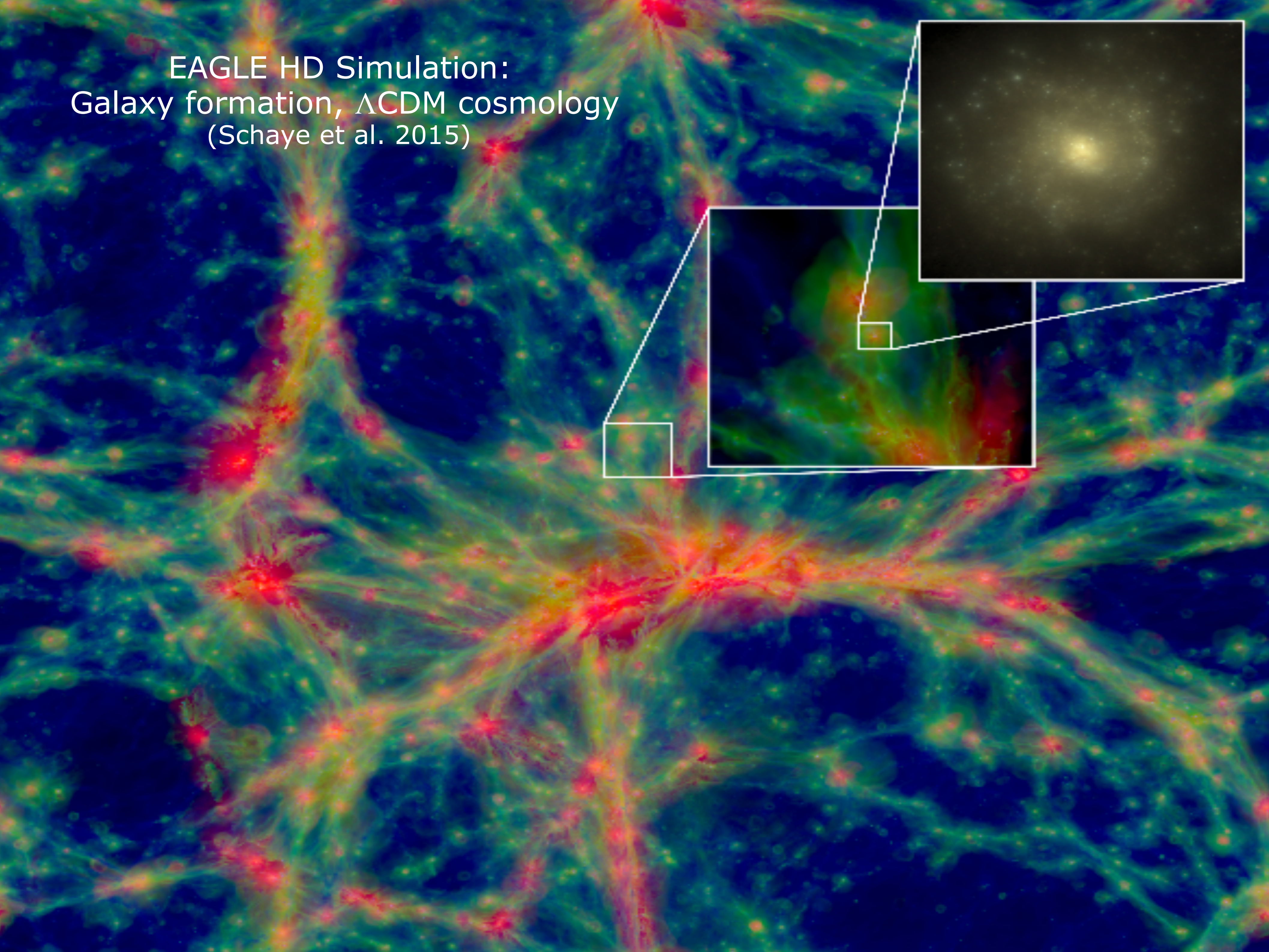
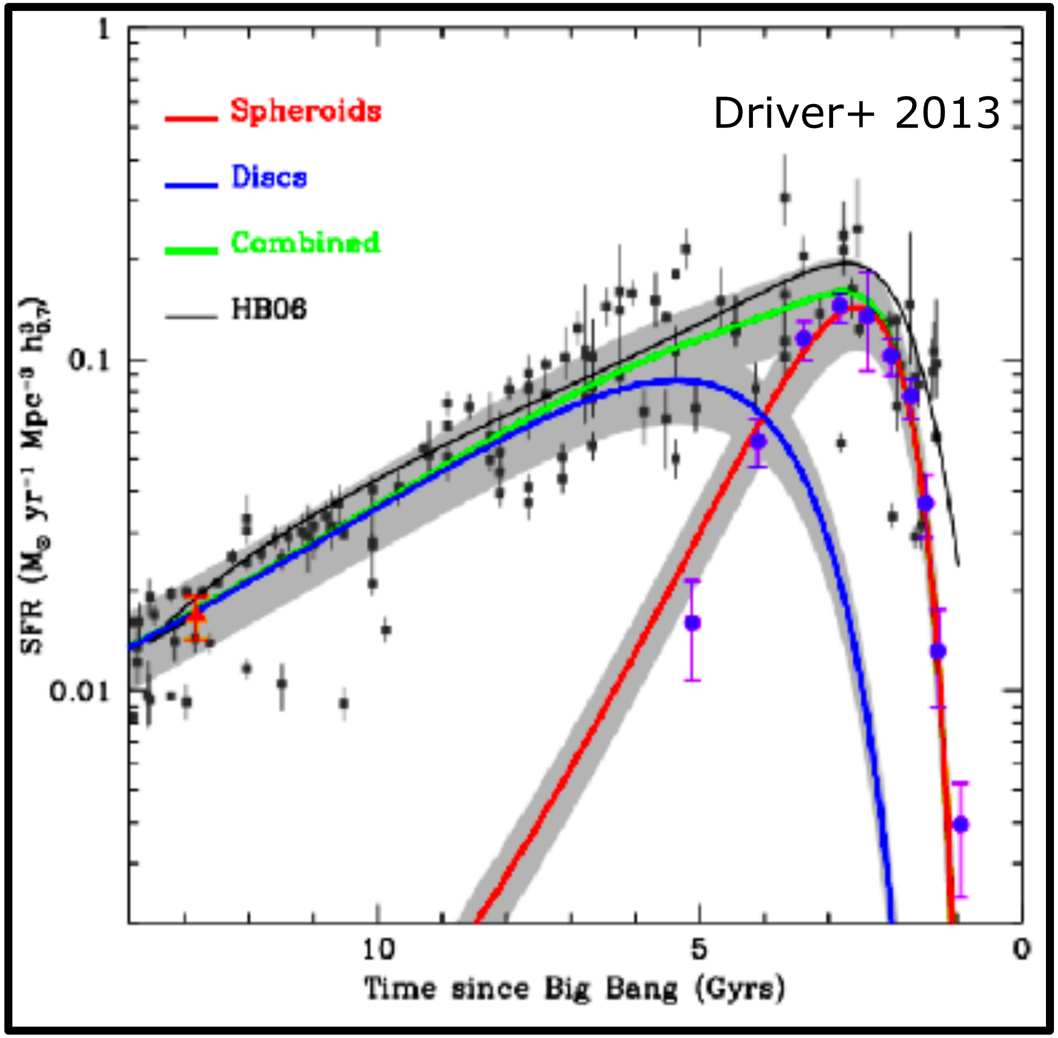
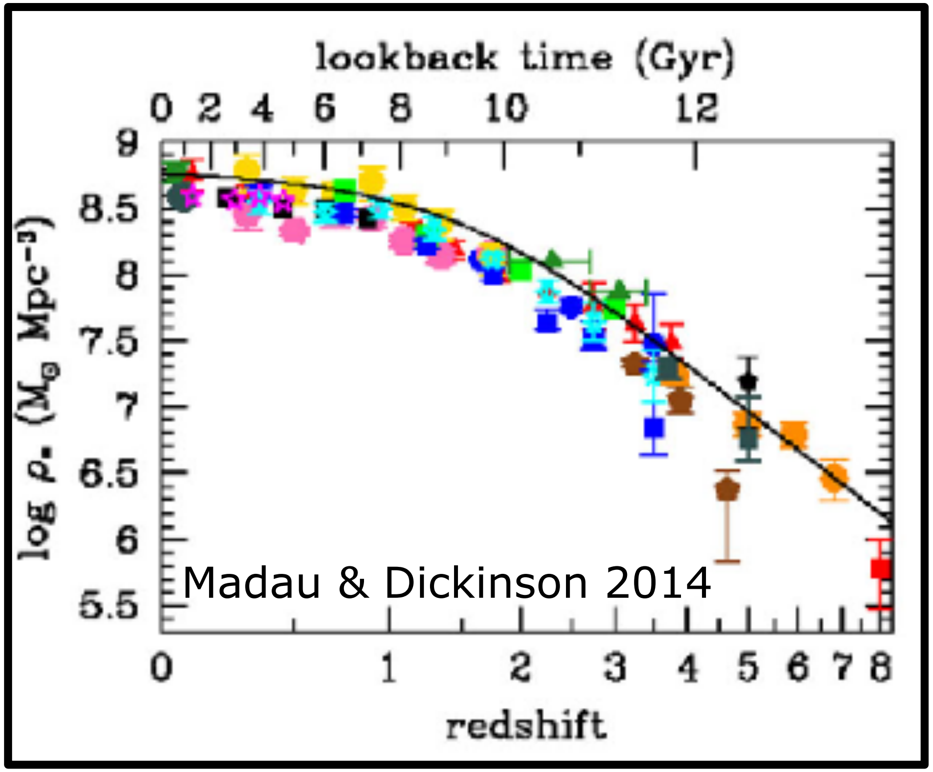

EAGLE HD Simulation:
Galaxy formation, ΛCDM cosmology
(Schaye et al. 2015)

Observations: Galaxies Quenched Over Cosmic Time

Massive star formation drops
with cosmic time

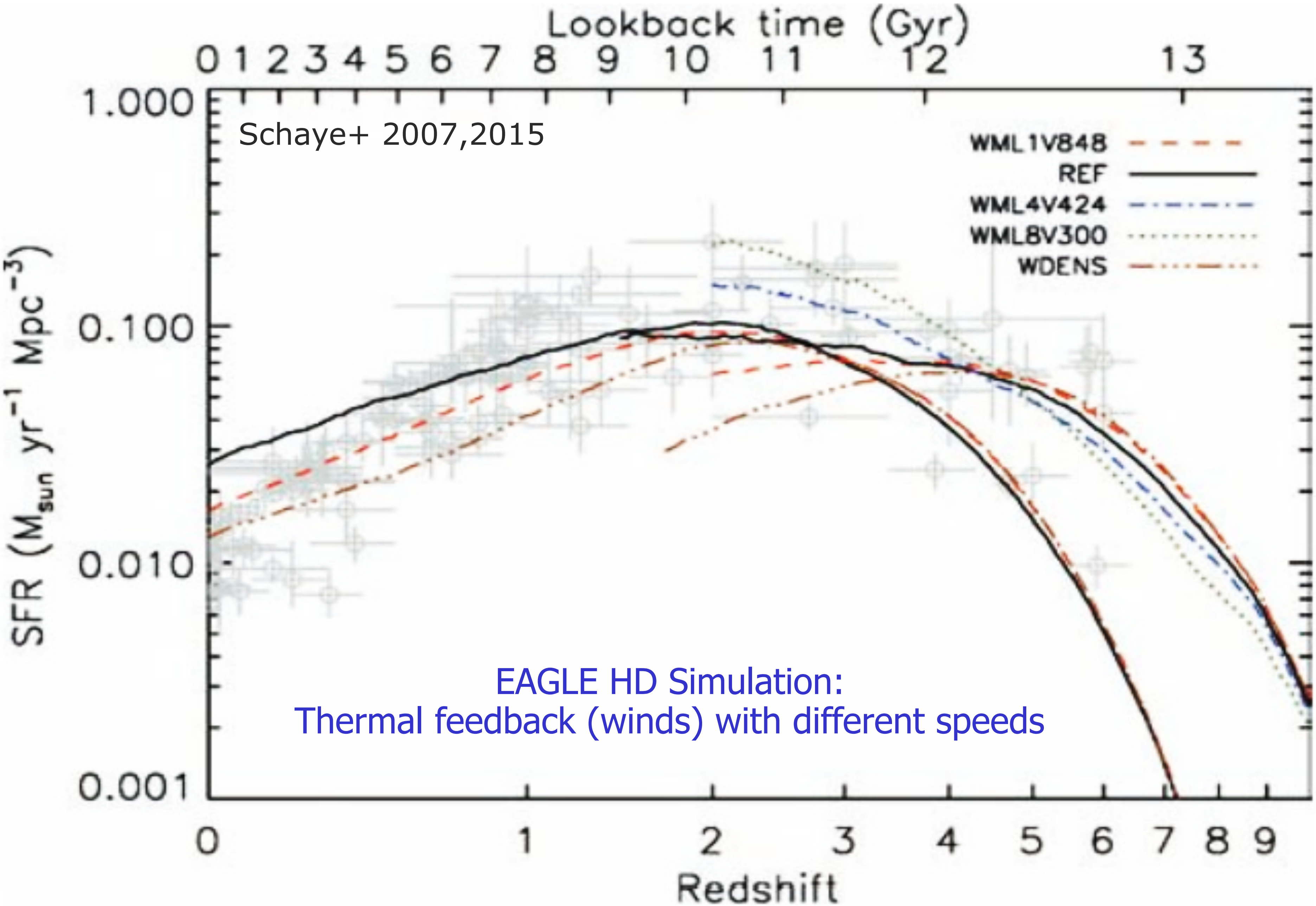


Stellar mass increases



Galaxies shut down their massive
star formation
with time

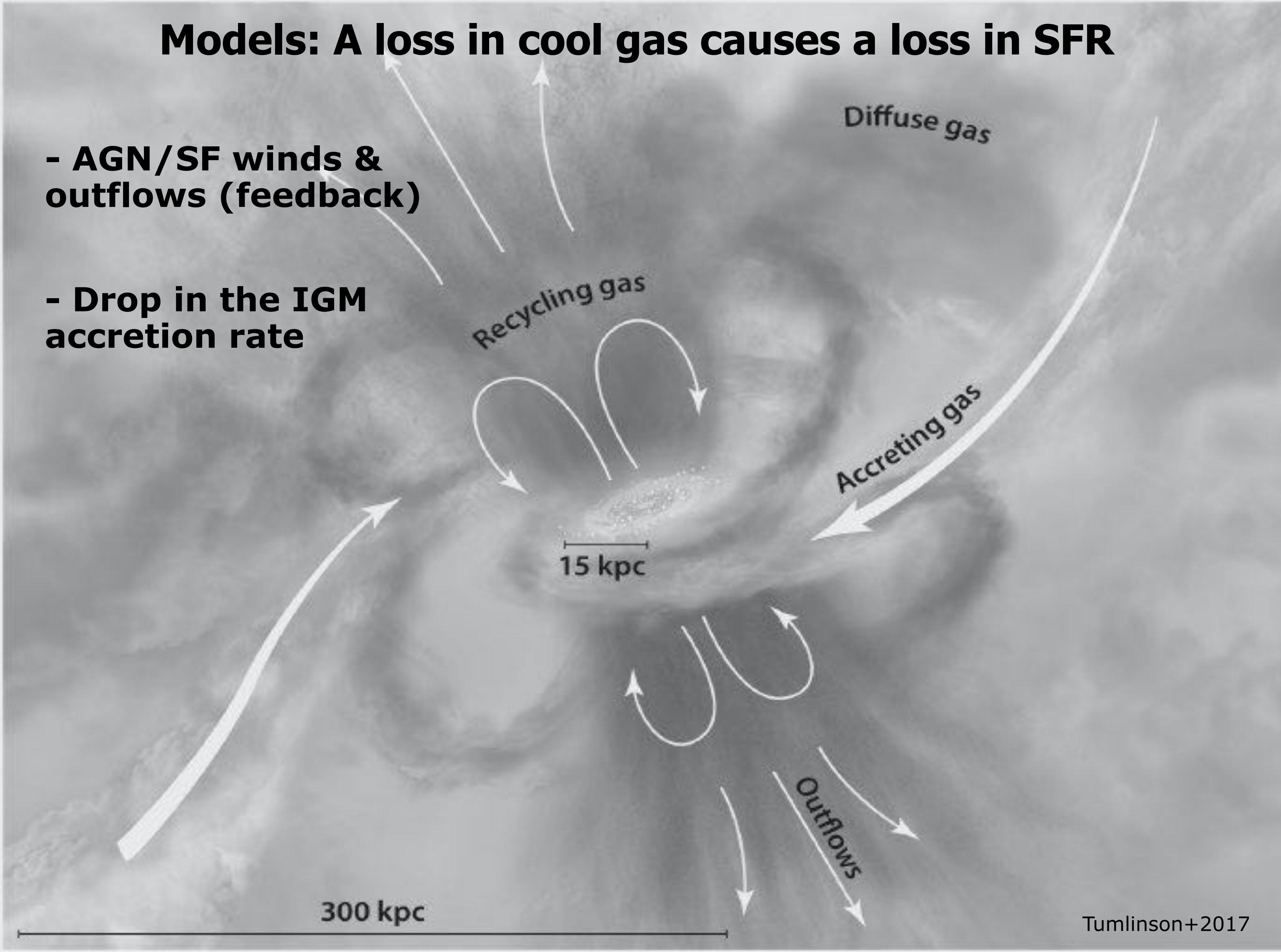
Cosmological simulations: Supernova, AGN feedback can explain SFR



Models: A loss in cool gas causes a loss in SFR

- AGN/SF winds & outflows (feedback)

- Drop in the IGM accretion rate

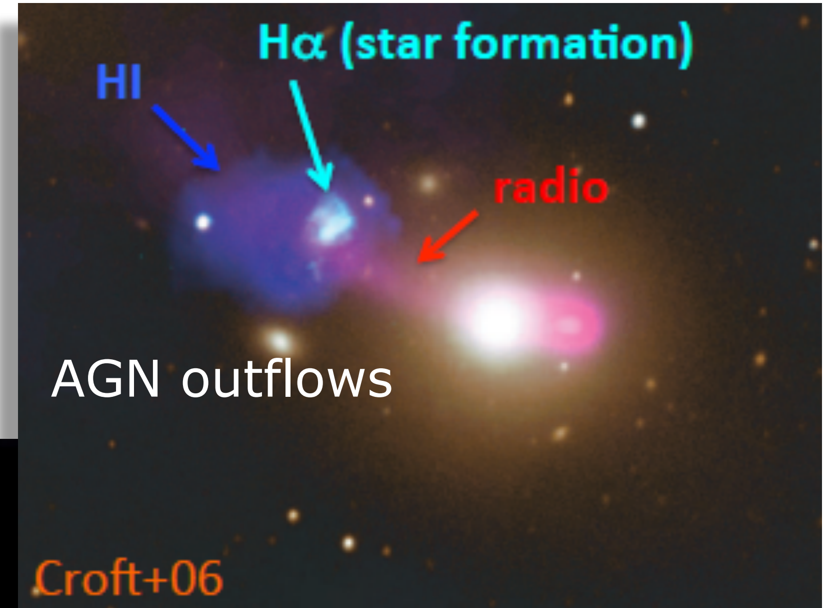


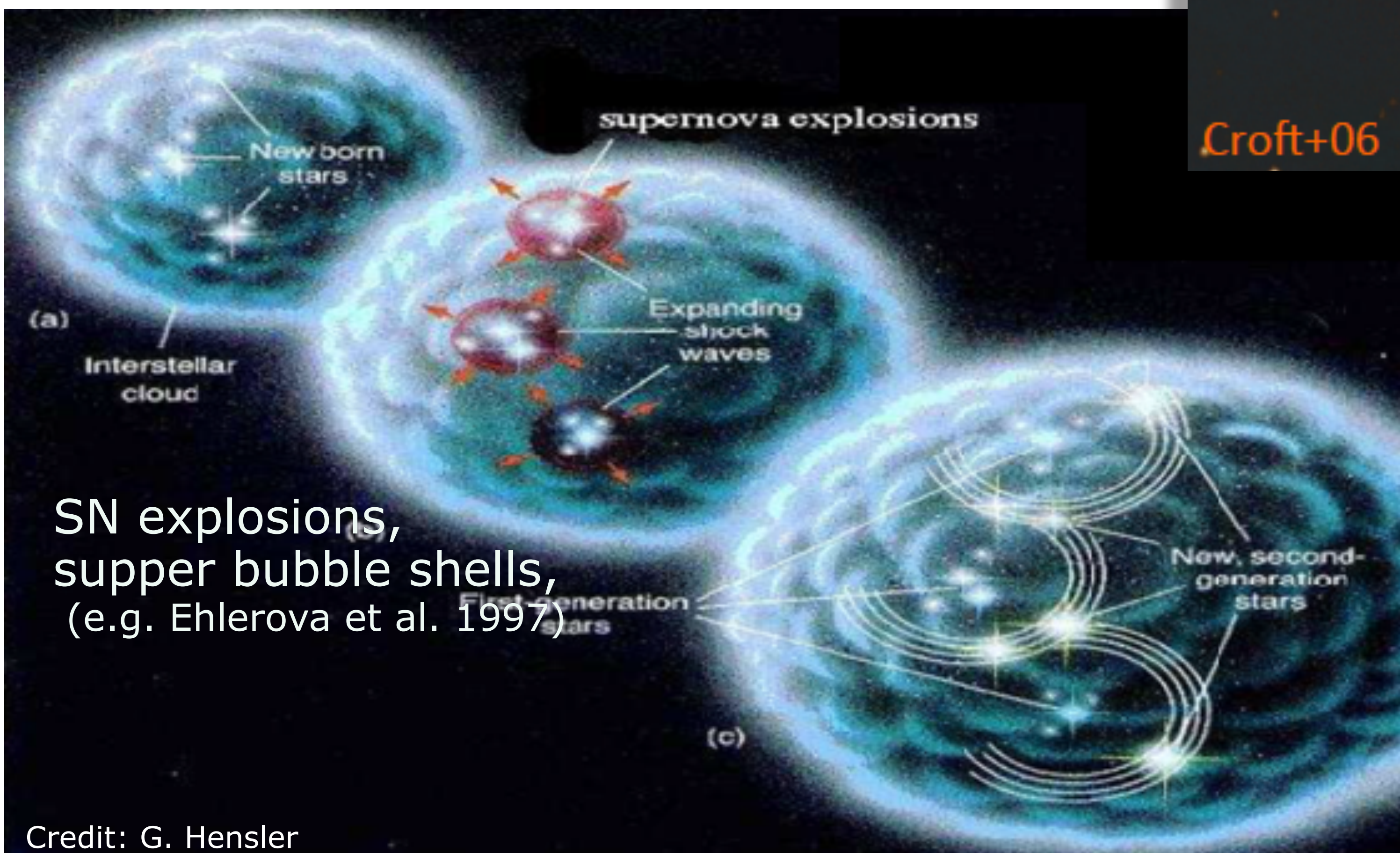
Tumlinson+2017

Observations: Feedback can be positive!

- Feedback can actually trigger formation of new stars!

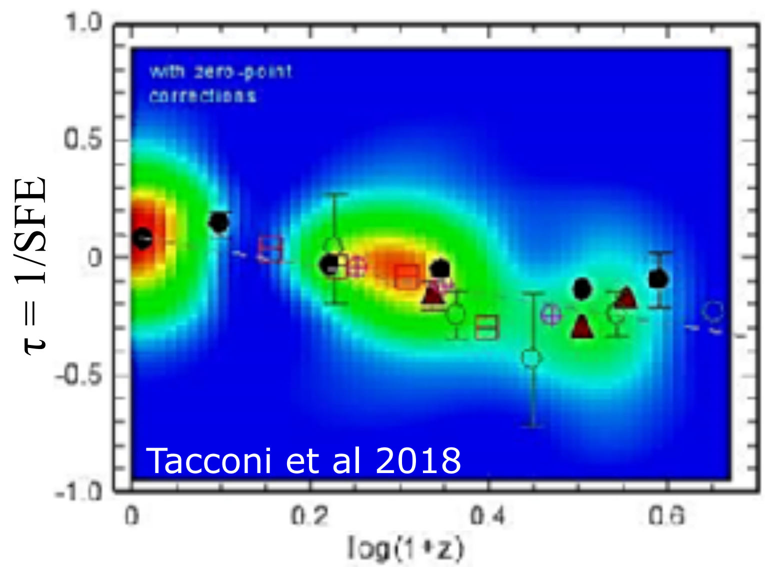
-AGN jets/outflows can damage their host galaxies, but unclear wether they can totally quench SF (e.g. Maiolino+2017, Silk 2005)





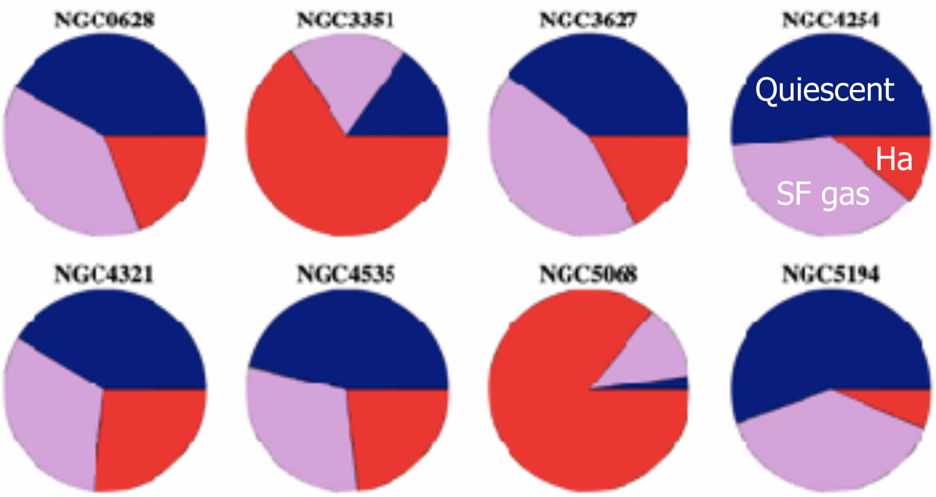
Observations: Cool gas always available

H2 drops slower than SFR,
it is SF efficiency=SFR/H2=1/τ
that falls over time
(e.g. Tacconi+2018, Combes+2018)



What can prevent cool gas to form massive stars?

fraction of star-forming gas in galaxies



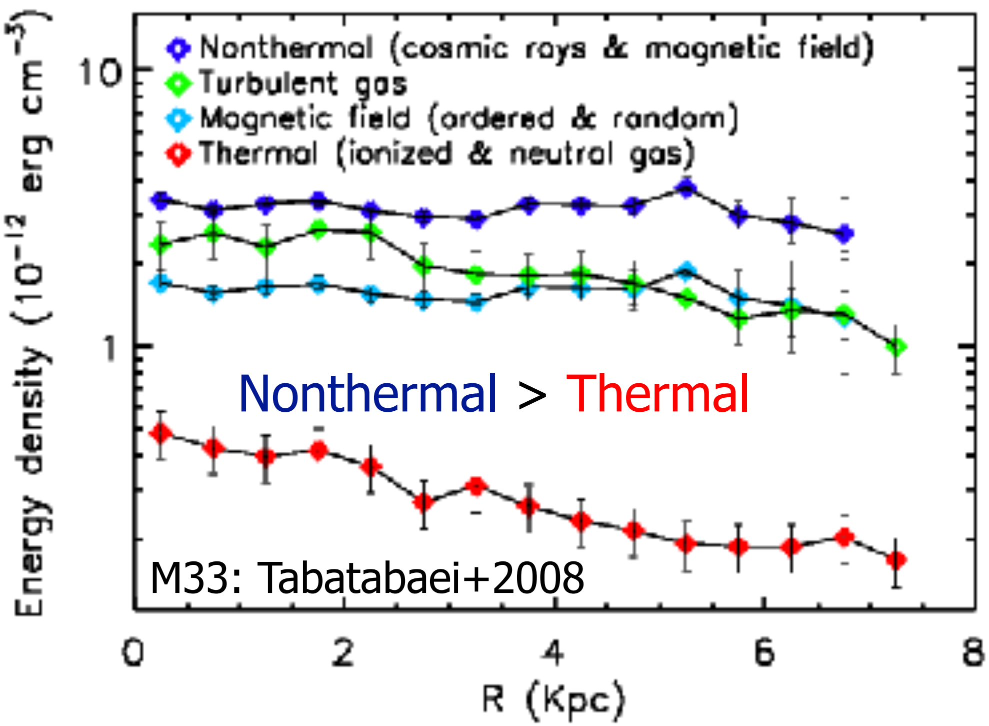
Quiescent gas fraction more dominant at higher resolutions (Schinnerer+2019)

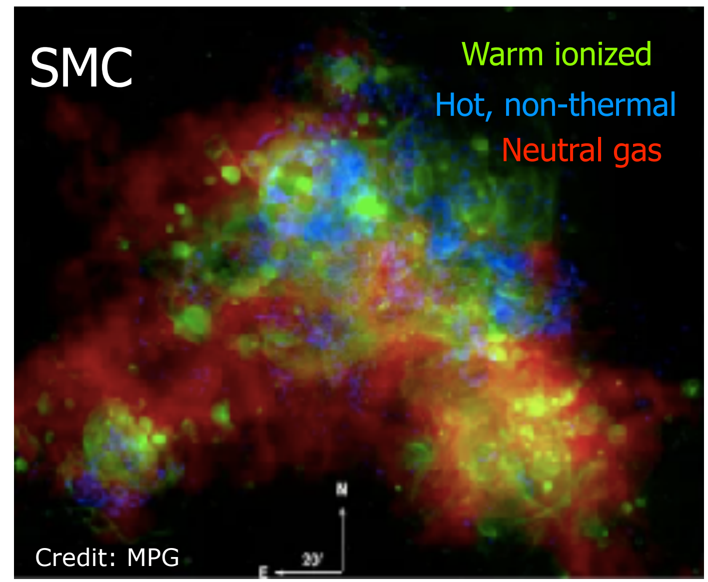
Schinnerer et al 2019

Physics of the ISM/IGM: Energy & Pressure Balance

Multi-phase ISM: thermal (ionized & neutral), turbulent, relativistic

Multi-component ISM: gas, dust, magnetic fields, high-energy particles





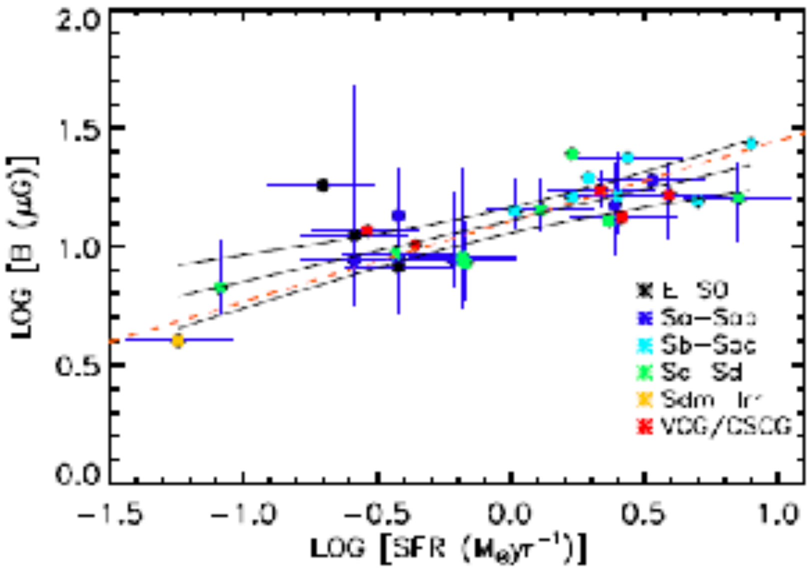
Same as in
The LMC & SMC: Hassani+ 2021
NGC6946: Beck 2007

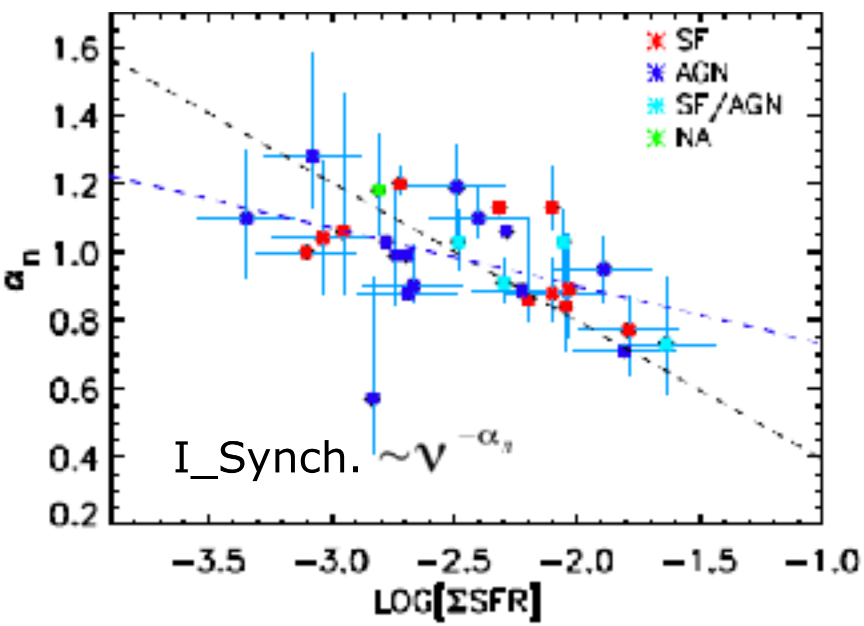
Nonthermal processes dynamically important?

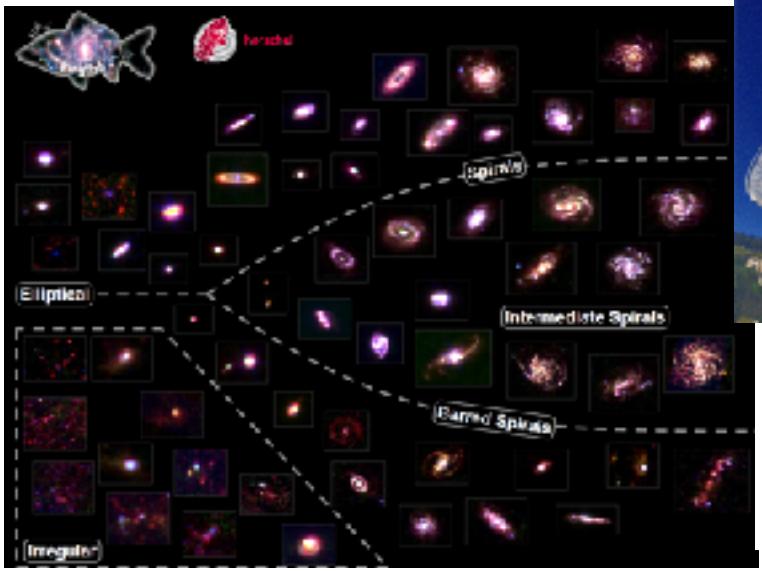
Nearby Galaxies: Cosmic-Ray-Driven Winds

Tabatabaei+2017:

Higher SFR, Stronger magnetic field,
Flatter synchrotron (CRe) spectrum flatter



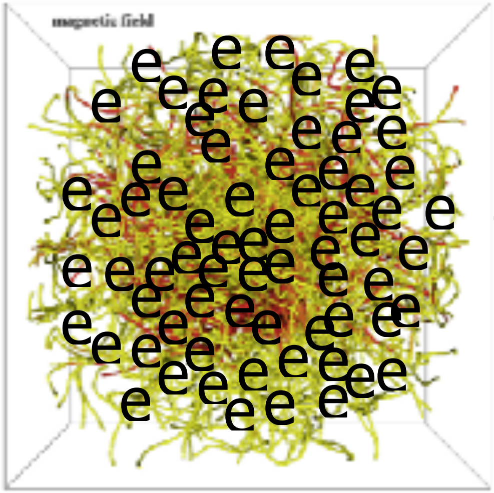




Effelsberg 100-m

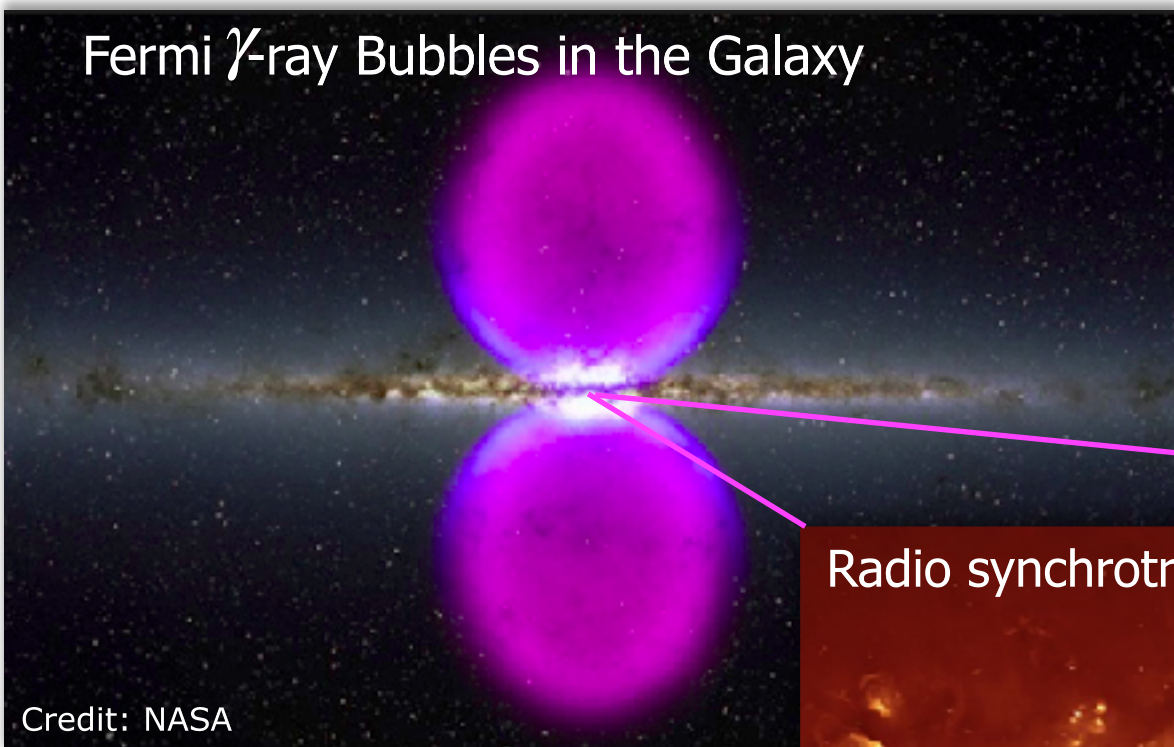
High-energy CRes scatter off from turbulent magnetic field pitch angles:

1- Preserving flatter CRe spectrum
2- Causing winds/outflows in starbursts

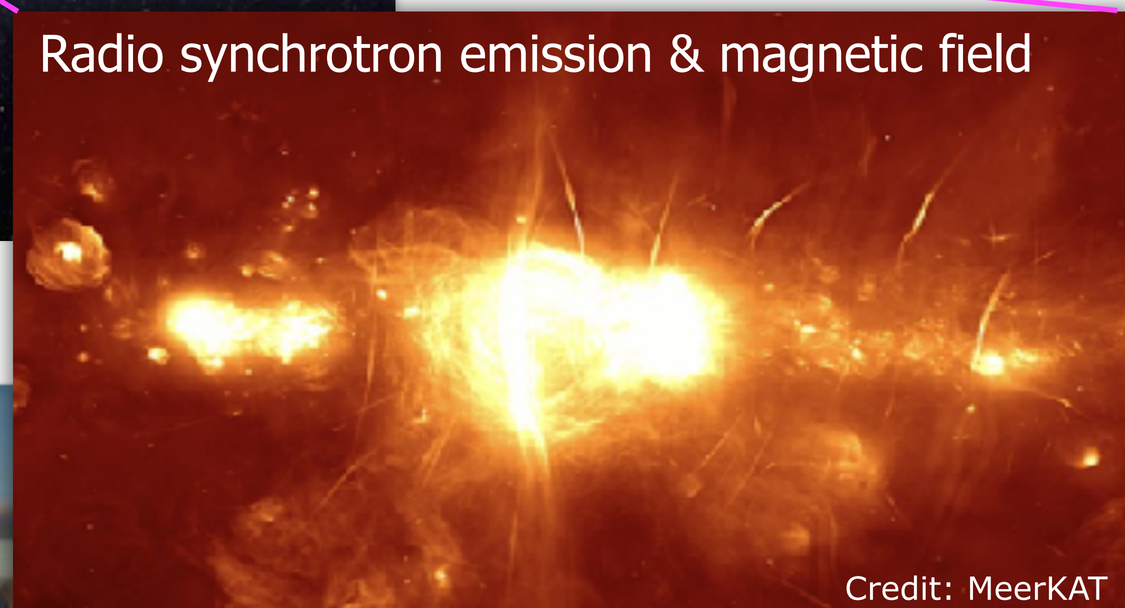


→**CR-driven winds**

Physics of the ISM/IGM: Energy & Pressure Balance



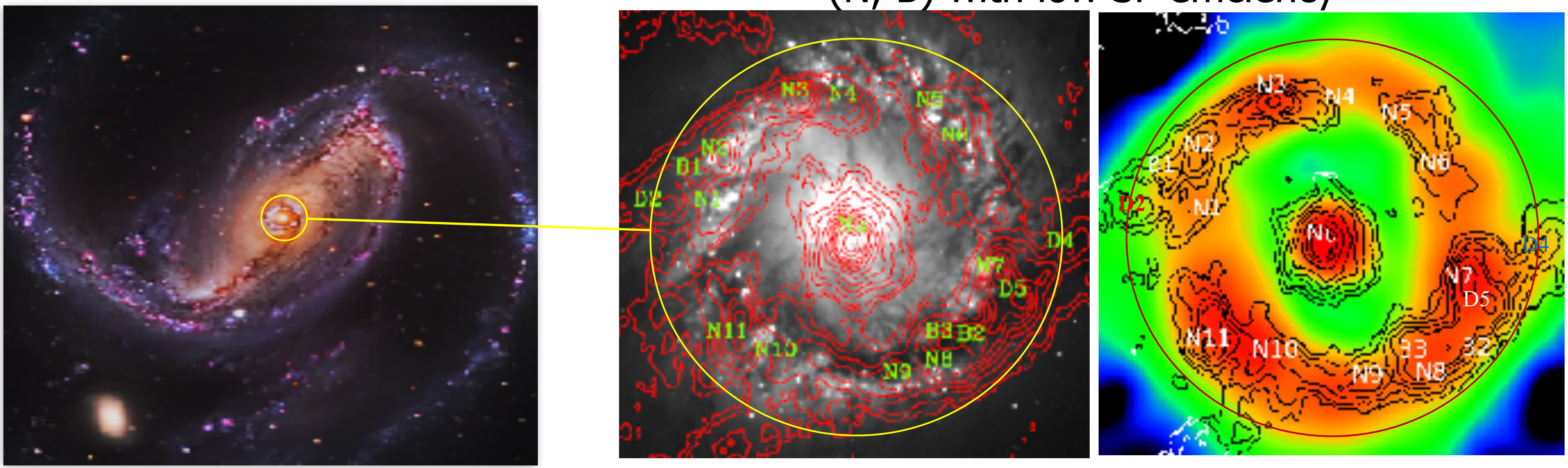
Nonthermal processes even more important at centers of galaxies with SMBH



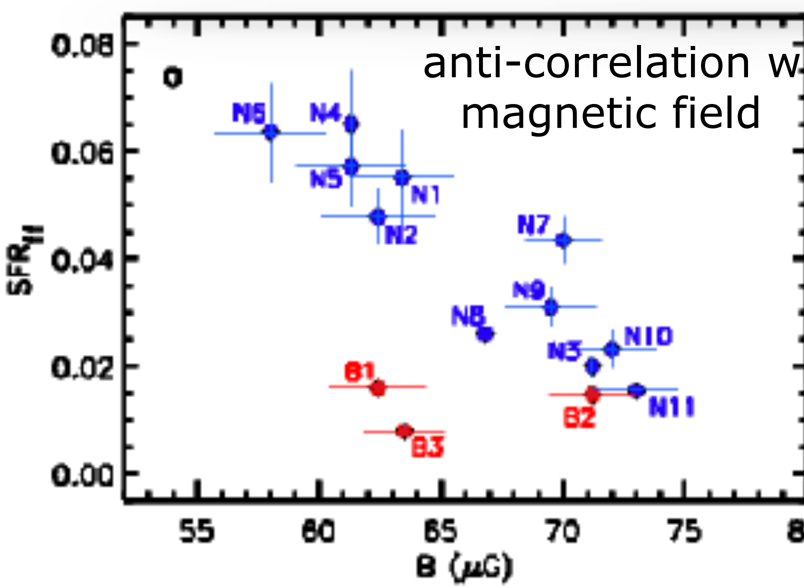
Magnetic field & CRs Controlling Clouds

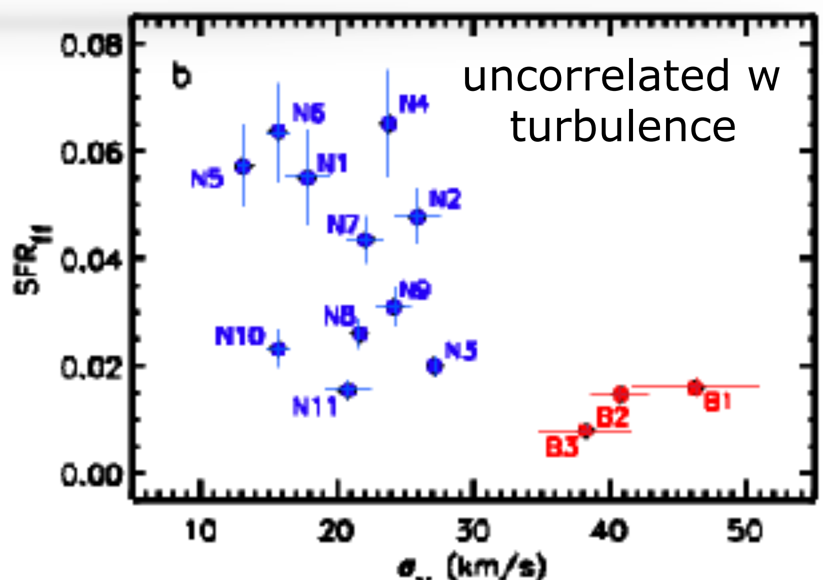
NGC1097: a green valley galaxy

Star-forming nuclear ring hosting molecular clouds (N, B) with low SF efficiency



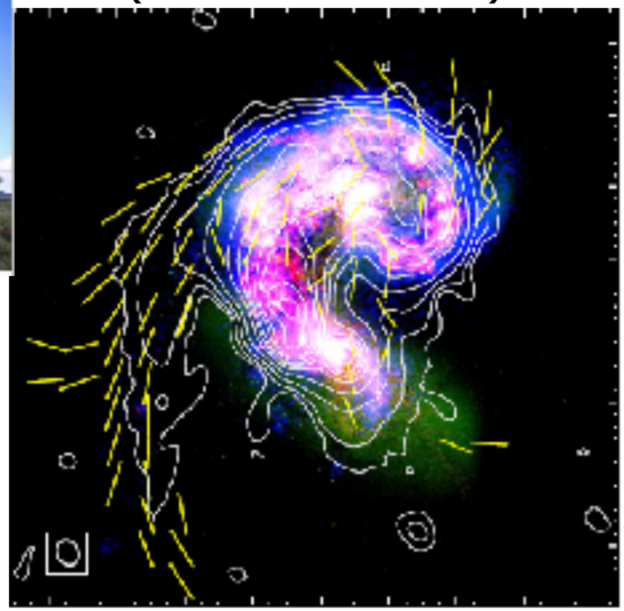
Star formation decelerated due to magnetic fields/cosmic rays
(Tabatabaei et al. 2018, Nature A)





Controlling IGM structures/gas accretion?

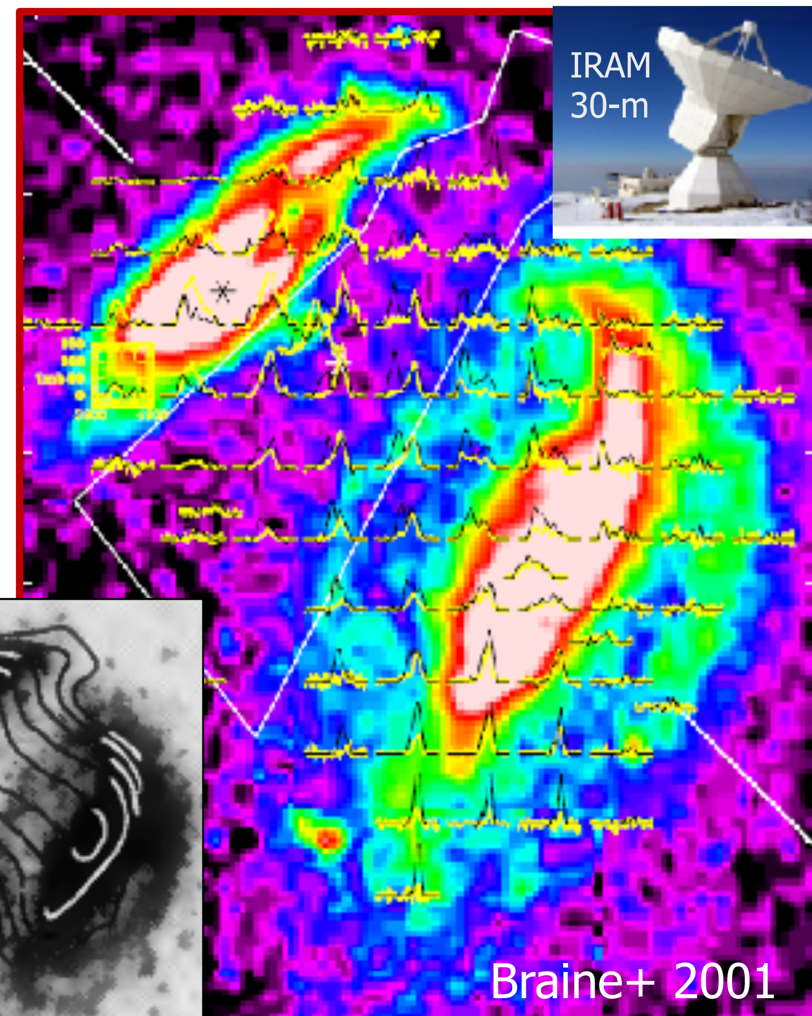
A 20 kpc polarized RC tidal tail
(Basu et al. 2017)



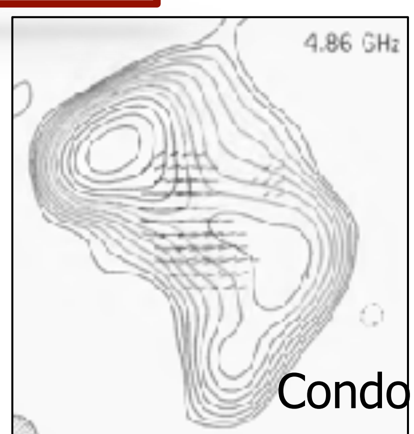
Importance of deeper radio observations for galaxy evolution studies

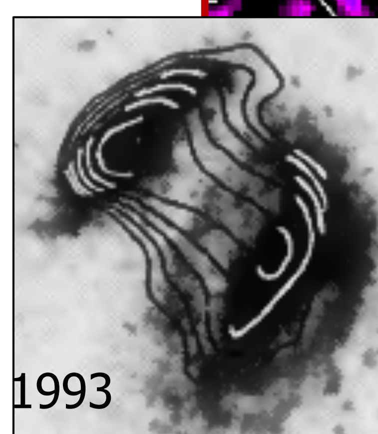
Tidal tails in merging systems:
excess RC, low FIR (Murphy+ 2012)

Taffy galaxies:
tight radio-molecular gas correlation not associated with SF



Gas & Polarized bridge
@ UGC 12914/5





Condon 1993

The SKA will be 50 times more sensitive and 10,000 faster than the best radio telescopes we have today. It will have the capacity to produce images with resolution quality 50 times higher than the Hubble Space Telescope.

The SKA's greater sensitivity will expand the range of the observable universe and has the potential to answer profound questions in astrophysics, cosmology and fundamental physics.

Square Kilometre Array

3 sites; 2 telescopes + HQ

1 Observatory

Design Phase: > €170M; 600 scientists+engineers

Phase 1

Construction: 2018 – 2024

Construction cost cap: €674.1M (inflation-adjusted)

Operations cost: under development (see below)

MeerKat integrated

Observatory Development Programme (€20M/year planned)

SKA Regional centres out of scope of centrally-funded SKAO.

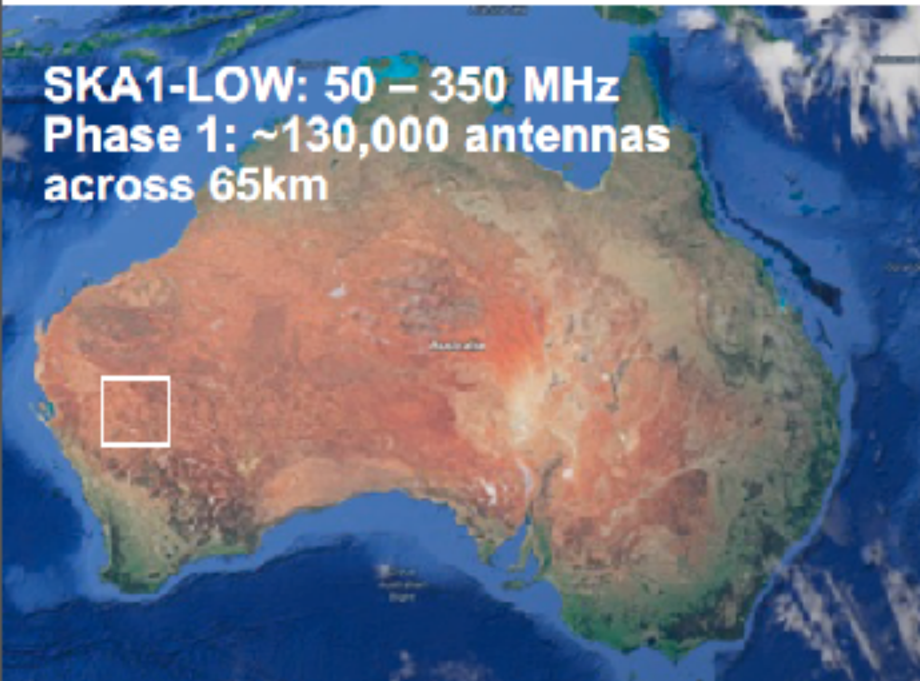
Phase 2: start mid-2020s

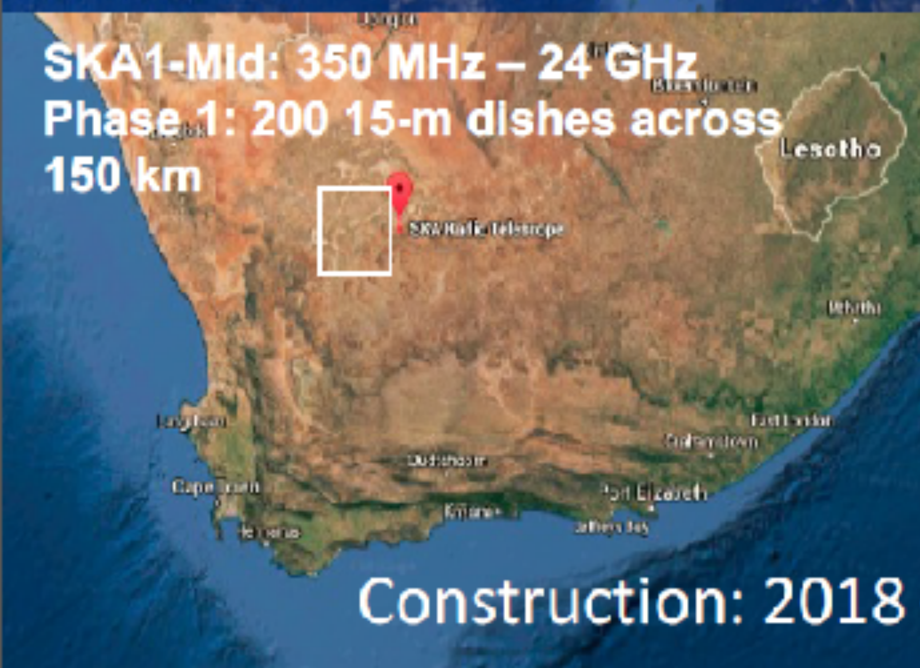
~2000 dishes across 3500km of Southern Africa

Major expansion of SKA1-Low across Western Australia

Credit:Philip Diamond-Director General

SKA: HQ in UK; telescopes in AUS & RSA





Construction: 2018 – 2024; Cost cap: €675M

Philip Diamond-Director General

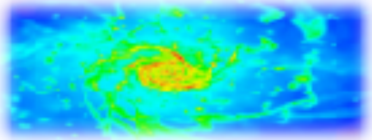
SKA Big Questions

- **The Cradle of Life & Astrobiology**
  - *How do planets form? Are we alone?*

- **Strong-field Tests of Gravity with Pulsars and Black Holes**
  - *Was Einstein right with General Relativity?*

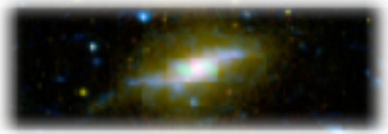
- **The Origin and Evolution of Cosmic Magnetism**
  - *What is the role of magnetism in galaxy evolution and the structure of the cosmic web?*

- **Galaxy Evolution probed by Neutral Hydrogen**
  - *How do normal galaxies form and grow?*

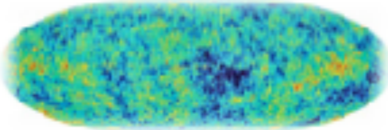


- **The Transient Radio Sky**
  - *What are Fast Radio Bursts? What haven't we discovered?*

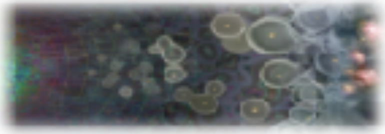
- **Galaxy Evolution probed in the Radio Continuum**
  - *What is the star-formation history of normal galaxies?*



- **Cosmology & Dark Energy**
  - *What is dark matter? What is the large-scale structure of the Universe?*



- **Cosmic Dawn and the Epoch of Reionization**
  - *How and when did the first stars and galaxies form?*



Credit: Philip Diamond-Director General

SKA Science Working Groups

- Current SWGs represent a wide range of scientific areas:
  - Extragalactic Spectral Line (non-HI)
  - Our Galaxy
  - Solar, Heliospheric & Ionospheric Physics
  - Epoch of Reionization
  - Cosmology
  - Extragalactic Continuum (galaxies/AGN, galaxy clusters)
  - Cradle of Life
  - HI galaxy science
  - Magnetism
  - Pulsars
  - Transients

+ new SWG: Gravitational Waves

- Technique focused Working Group:
  - VLBI
- Topical Focus Group:
  - High Energy Cosmic Particles

Membership open to any active researcher with willingness to contribute at appropriate level

Anyone can nominate themselves by contacting the current SWG Chairperson (per web site) or SKA Project Scientist/Science Director

Credit: Philip Diamond-Director General

12+1 countries,
100 organisations
… more joining

Credit: Philip Diamond-Director General

IPM Contributions & Activities:

- Membership at Science Working Groups (Continuum & Magnetism)
- Proposing and chairing a Focus Group (ISM/IGM)
- Proposing and producing a Science Use Case for SKA-1 Surveys
- Participation at the Data Challenges
- Taking part at the SKA Pathfinder Surveys Projects such as MeerKAT

Science data challenge 1 (SDC1)

- Science-ready (SRC) imaging product
- Radio continuum, SKA Mid
- Not too challenging data sizes
- 1 pointing, 3 freqs, 3 depths
- Source finding
- Source identification, classification & characterization

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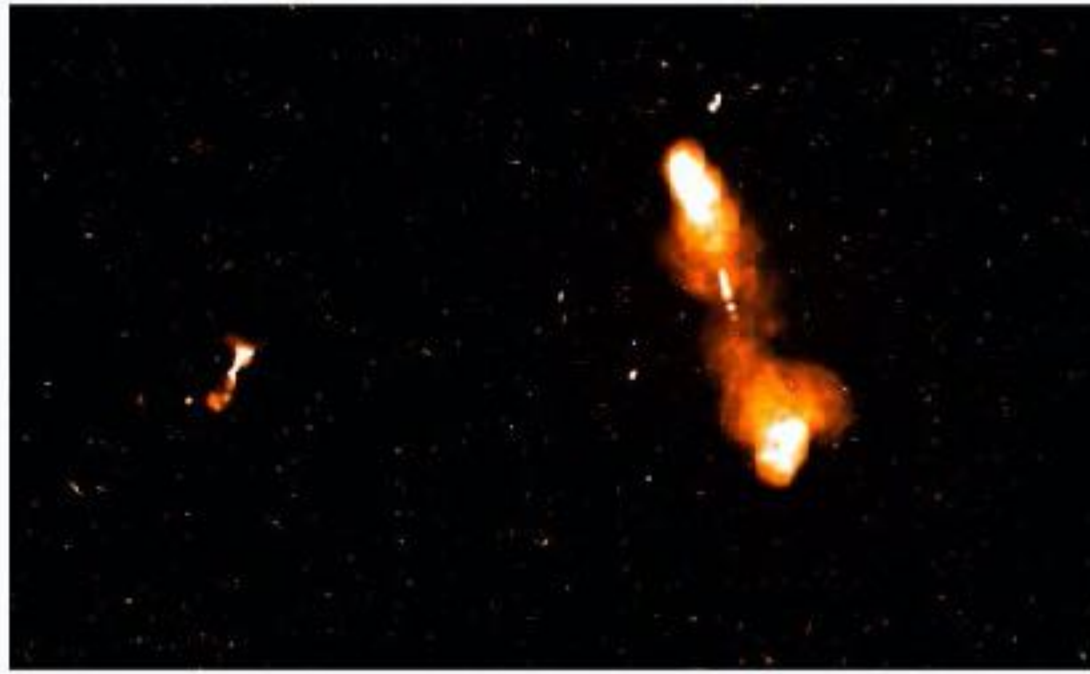
SKA Launches First Science Data Challenge For Astronomy Community



A snapshot from the SKA Science Data Challenge image, showing a large Active Galactic Nucleus (AGN) as it observed by SKA-mid at 1.4 GHz. (Credit: SKA Organisation)

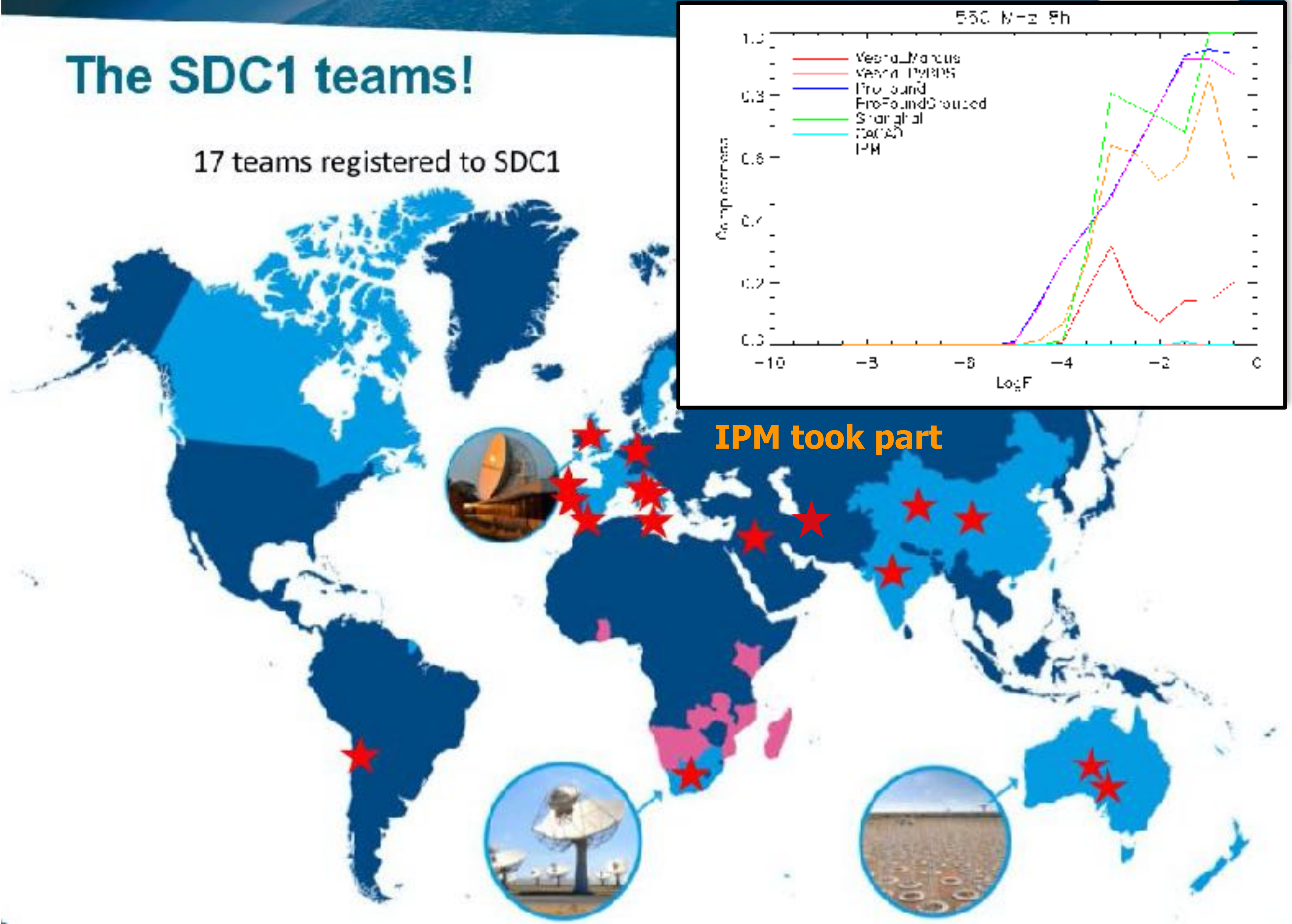
SKA Global Headquarters, 26 November 2018 – The Square Kilometre Array Organisation (SKAO) is today releasing its first ever Science Data Challenge, giving astronomers a taste of the highly detailed images the SKA will produce.

Developed by the SKAO's Project Science team, the challenge requires the analysis of a series of high resolution images created through data simulations. Researchers are invited to download the images and use their own software to find, identify and classify the sources.

The key aim of the series of Data Challenges is to prepare the science community for the kind of data products they will receive from SKA observations, and to gather valuable feedback which will inform the development of data reduction procedures.

The SDC1 teams!

17 teams registered to SDC1



IPM took part

Monthly Notices of the Royal Astronomical Society

MNRAS 00, 1 (2020)
Advance Access publication 2020 October 5

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Square Kilometre Array Science Data Challenge 1: analysis and results

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ABSTRACT

As the largest radio telescope in the world, the Square Kilometre Array (SKA) will lead the next generation of radio astronomy. The feats of engineering required to construct the telescope array will be matched only by the techniques developed to exploit the rich scientific value of the data. To drive forward the development of efficient and accurate analysis methods, we are designing a series of data challenges that will provide the scientific community with high-quality data sets for testing and evaluating new techniques. In this paper, we present a description and results from the first such Science Data Challenge 1 (SDC1). Based on SKA MID continuum simulated observations and covering three frequencies (560, 1400, and 9200 MHz) at three depths (8, 100, and 1000 h), SDC1 asked participants to apply source detection, characterization, and classification methods to simulated data. The challenge opened in 2018 November, with nine teams submitting results by the deadline of 2019 April. In this work, we analyse the results for eight of those teams, showcasing the variety of approaches that can be successfully used to find,

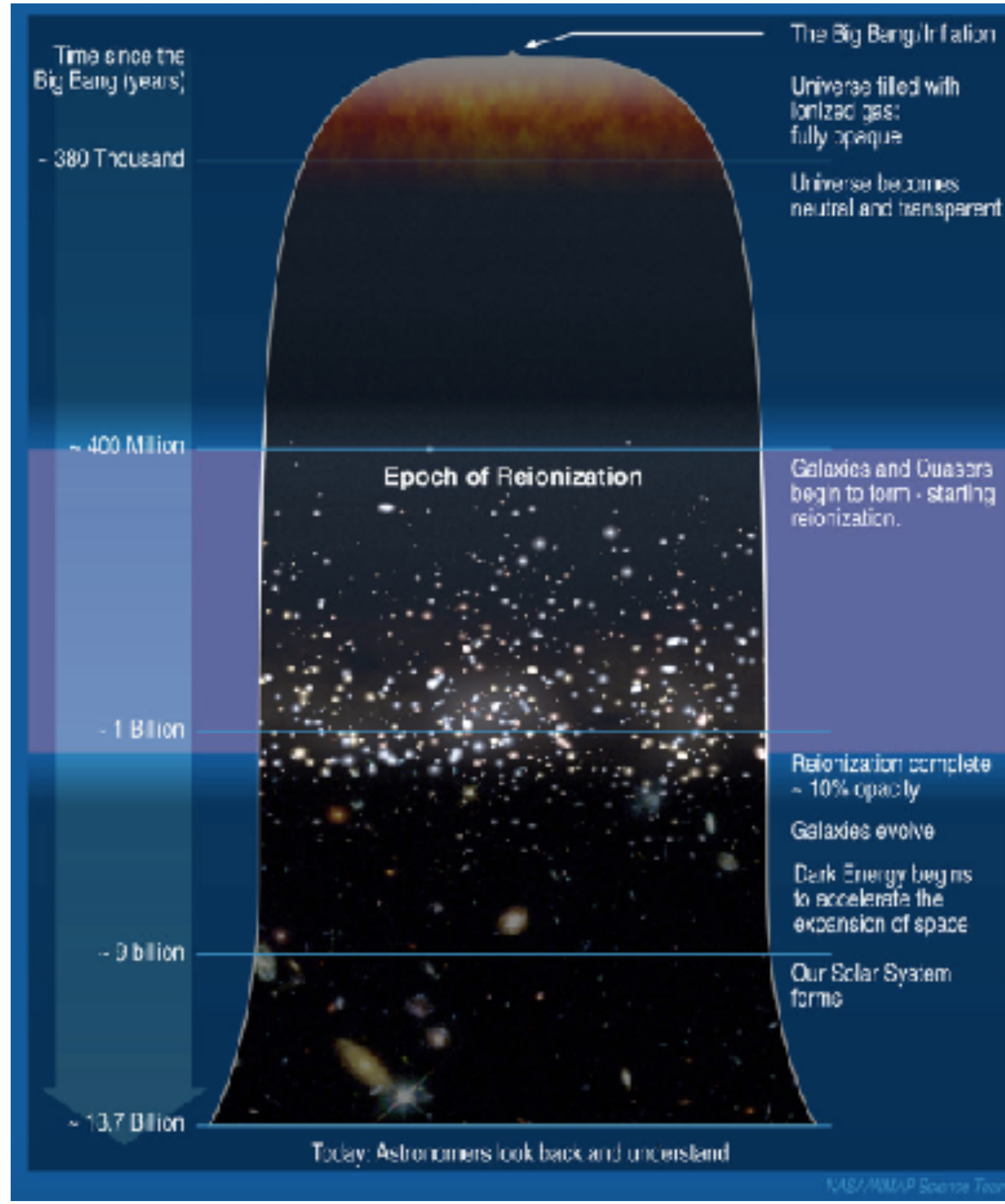
ISM & IGM Focus Group: Structure Formation and Energy Balance

F. Tabatabaei (chair), M. Ghasemi, H. Khosroshahi, M. Sargent, A. Bonaldi, M. Brüggen, E. Muphy, E. Schinnerer, T. Muxlow, R. Beswick, L. Feretti, V. Vacca, V. Heesen, S. Roy, M. Padovani,..

Main Goals

- Role of thermal/non-thermal processes in formation and evolution of galaxies?
- Physical parameters governing structure formation on various scales?
- How does ISM/IGM energy balance change over cosmic time?

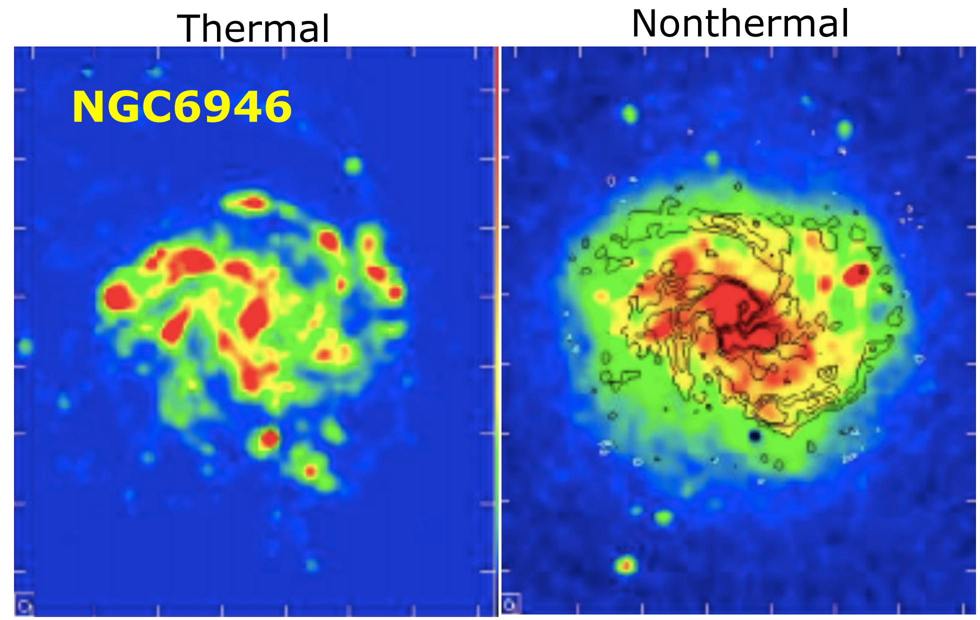
Evolution of the RC thermal/non-thermal fraction with redshift?

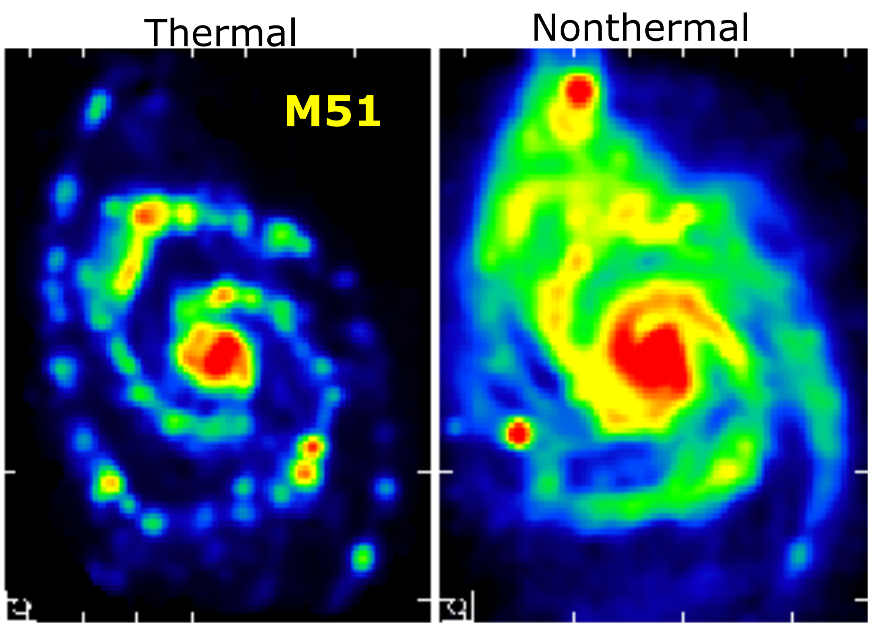


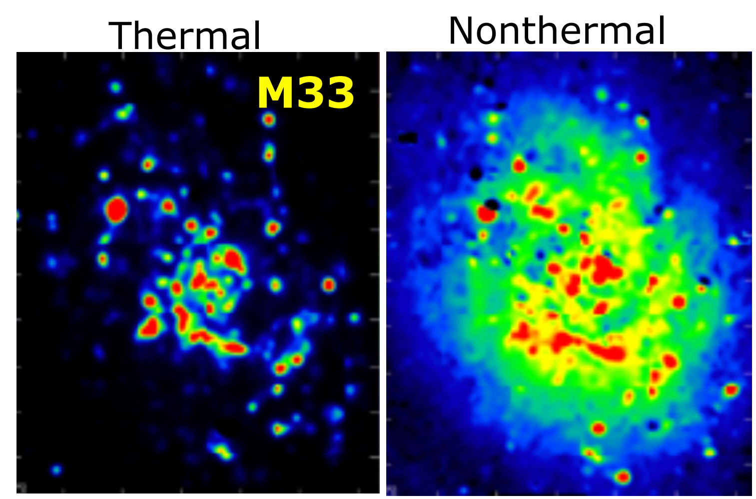
Thermal & Non-thermal Radio Continuum (RC) in Nearby Galaxies

VLA observations @1.4GHz

Separation method: Tabatabaei et al. 2007,2013



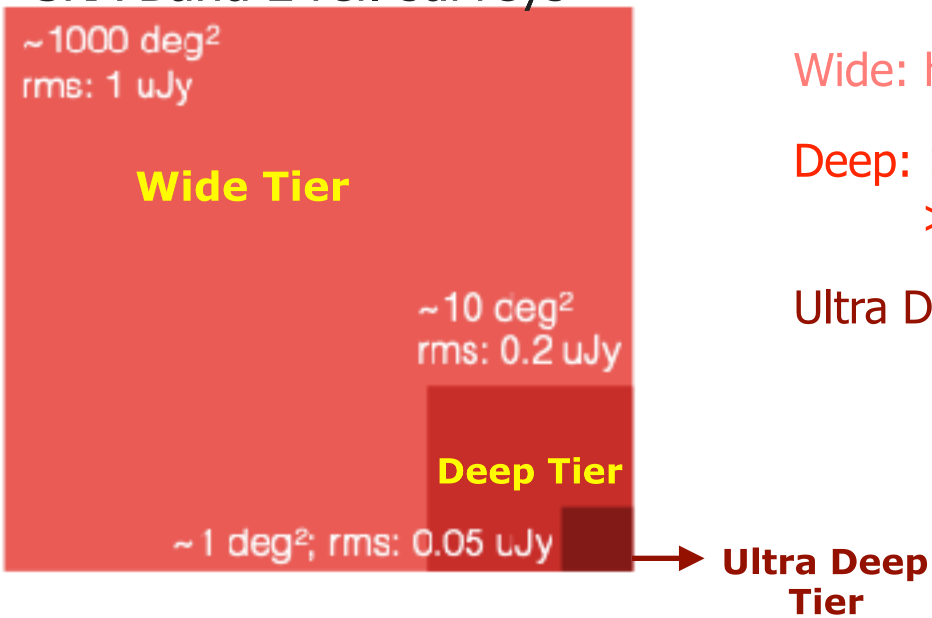




Both thermal and non-thermal RC emission correlate with SFR
(Condon 2002, Murpphy+ 2011, Tabatabaei+ 2017)

Detection with Proposed SKA Surveys?

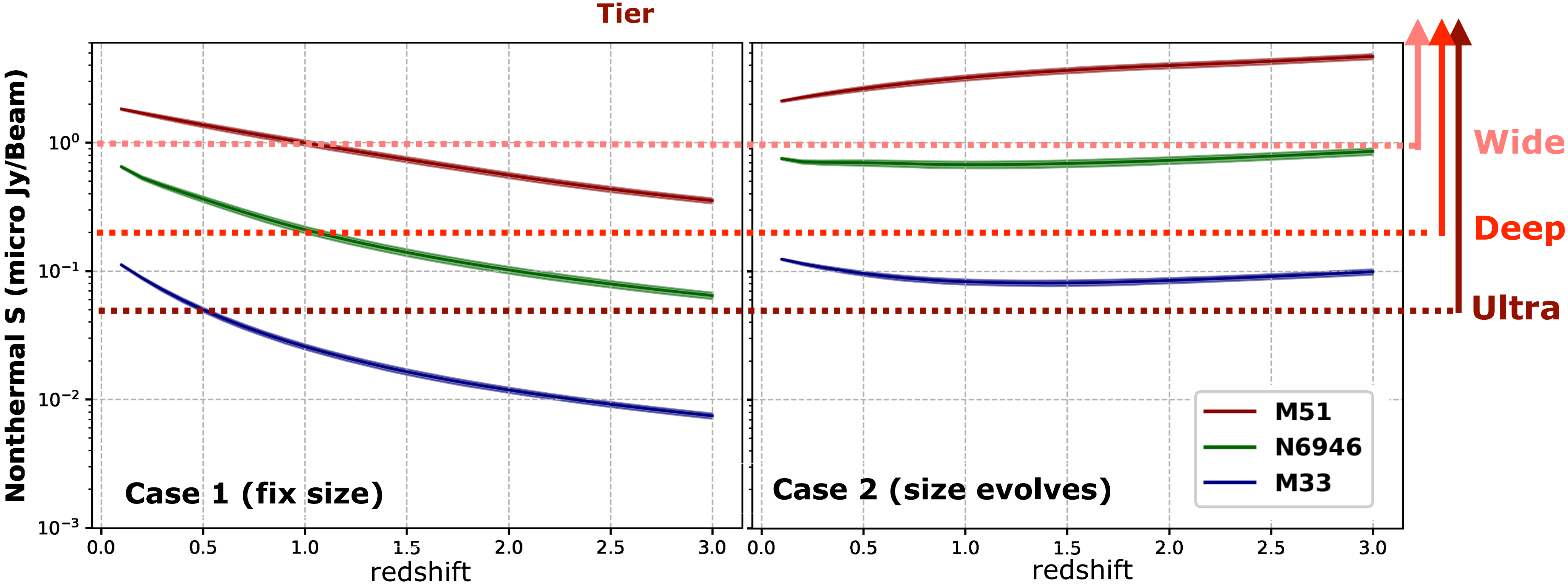
SKA Band 2 ref. surveys



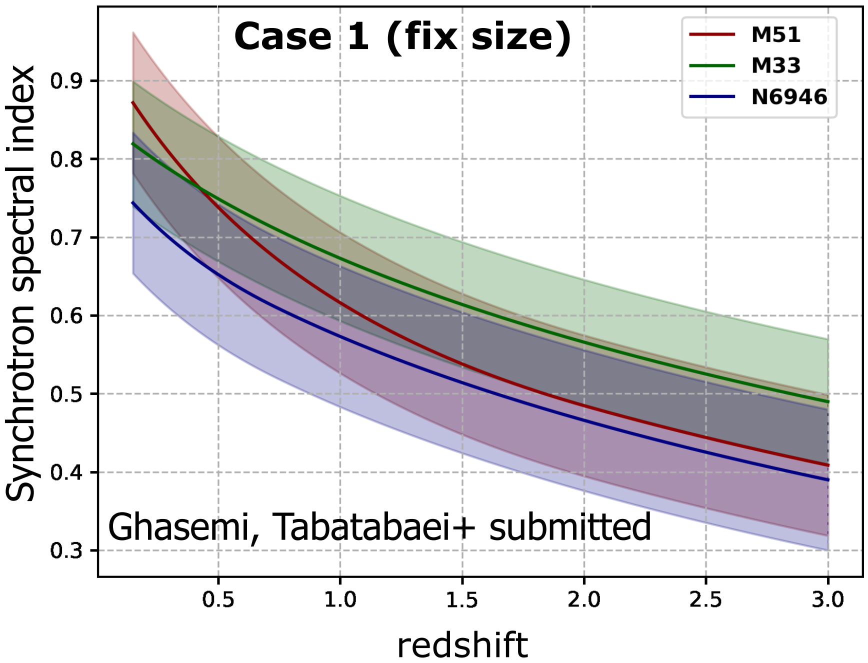
Wide: hardly detects M51-like galaxies (case 2)

Deep: $>5\sigma$ detection of M51-like up to z~1 (case 1)
$>4\sigma$ detection of N6946, M51-like at all z (case 2)

Ultra Deep : $>4\sigma$ detection of N6946-like up to z~1 (case 1)
$>10\sigma$ detection of N6946, M51-like (case 2)
$>2\sigma$ detection of M33-like at z<0.5 (case 2)

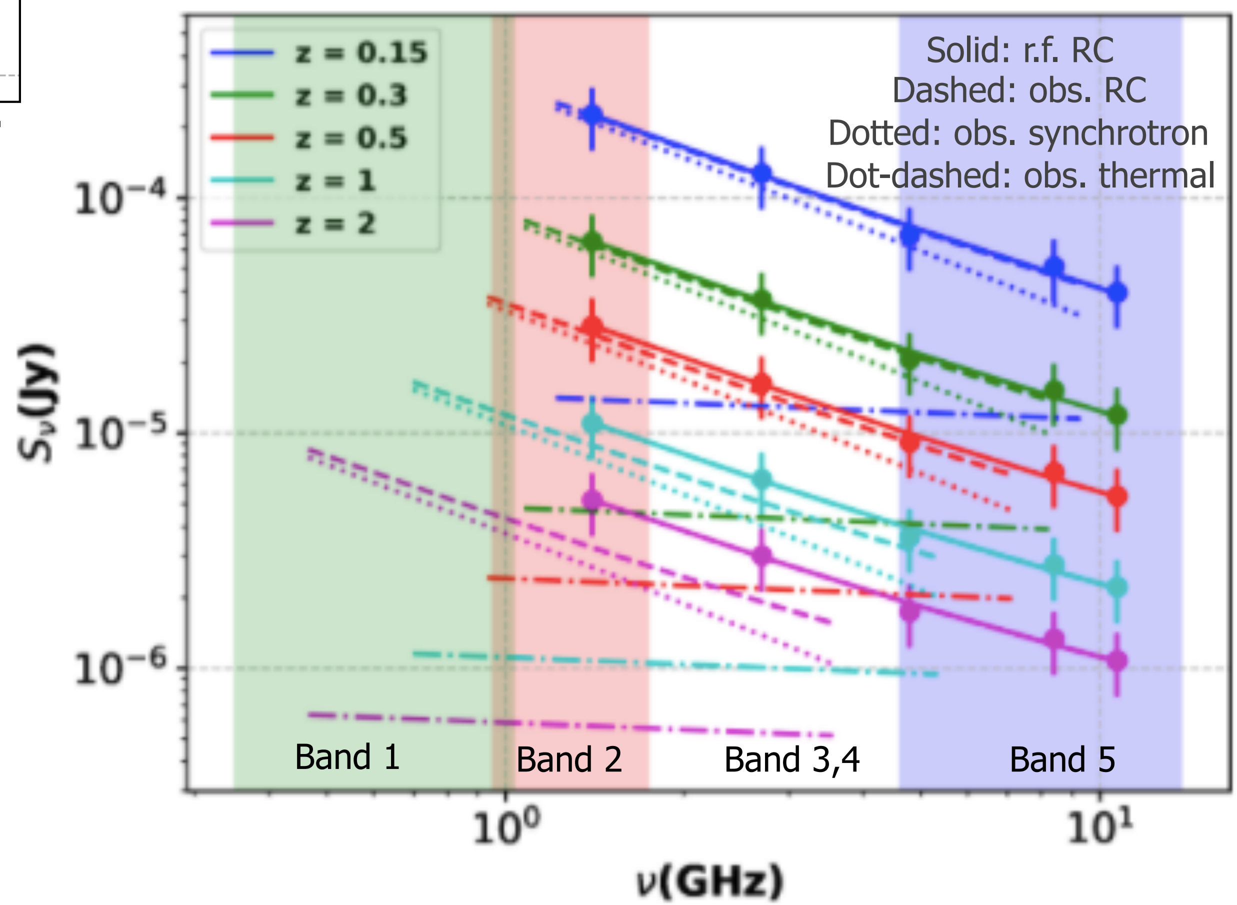


Evolution of Mid-RC SED and Synchrotron Spectrum



Synchrotron spectral index
flattens with redshift:
CRes more energetic at higher z

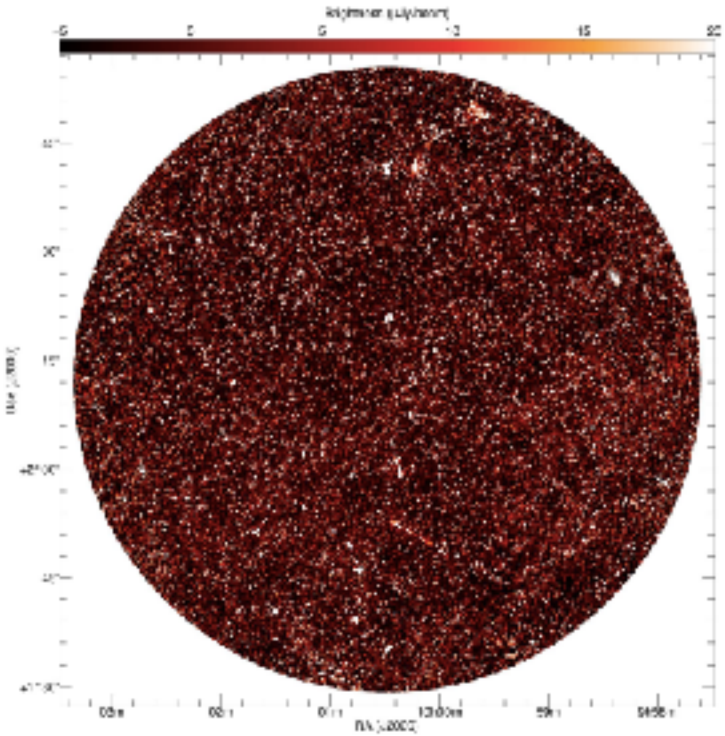
Mid-Radio SED of a M51-like galaxy

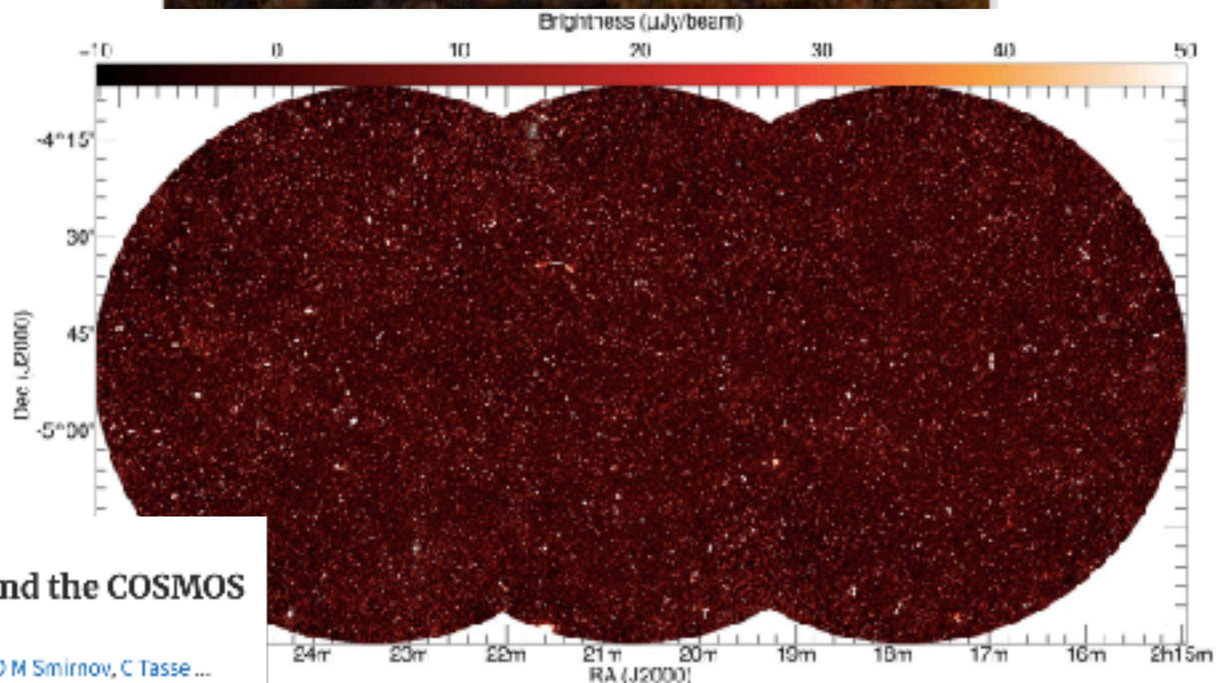


Message to SKA SWG:
Band 1 also needed to study
the era of maximum
star formation
(z=2)

A new reference survey
(+use case) added to
SKAI-MID

SKA Pathfinder Surveys: MeerKAT MIGHTEE





...ing MIGHTEE Early Science mosaic covering 3.5 deg^2 of the XMM-LSS field, with an angular resolution of 8''.2.

ACCEPTED MANUSCRIPT

MIGHTEE: Total intensity radio continuum imaging and the COSMOS / XMM-LSS Early Science fields

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Abstract

MIGHTEE is a galaxy evolution survey using simultaneous radio continuum, spectro-polarimetry, and spectral line observations from the South African MeerKAT telescope. When complete, the survey will image ~20 deg^2 over the COSMOS, E-CDFS, ELAIS-S1, and XMM-LSS extragalactic deep fields with a central frequency of 1284 MHz. These were selected based on the extensive multiwavelength datasets from numerous existing and forthcoming observational campaigns. Here we describe and validate the data

Postdoc position available @MIGHTEE project!

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Summary

- Radio observations open new window to the hidden Universe and the way it ’s building blocks evolve. SKA will resolve the ISM and IGM at the young ages of galaxies.

- Dissecting the thermal and nonthermal processes is vital to dissect the nature of feedback, study the energy balance and structure/star formation in the ISM.

- Simulations show that SKA’s UDT can unveil non-thermal processes on kpc scales in N6946-, M51-like galaxies at least up to z=2 with >3sigma depending on the radio size evolution. Deeper observations needed to detect resolved full ISM in M33-like galaxies at z>0.5.

- Synchrotron spectral index, thermal fraction change with redshift, indicating importance of multi-band surveys to fix radio SEDs, dissect thermal/non-thermal processes & study their role in the evolution of SF and their host galaxies.