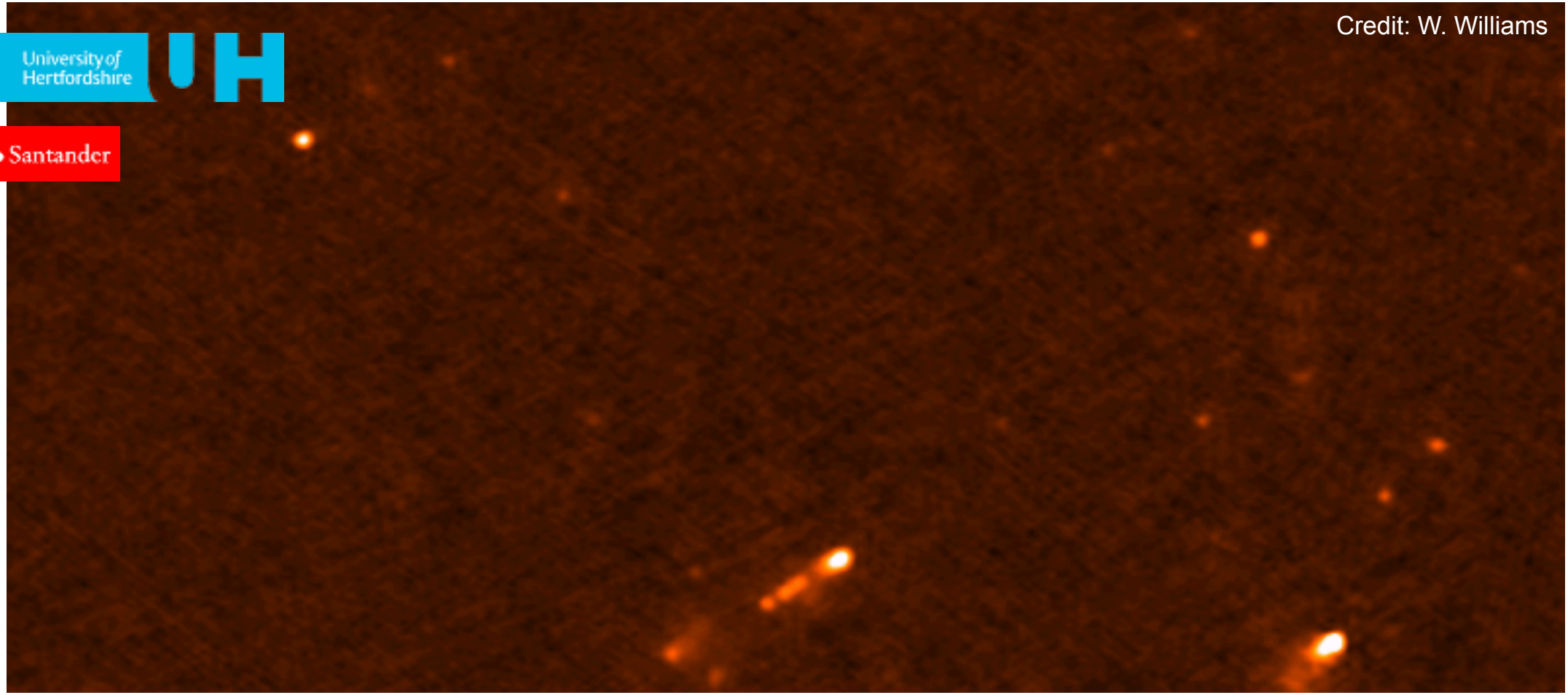

The WEAVE-LOFAR survey

Daniel J.B. Smith & The WEAVE-LOFAR Team

Research Fellow, University of Hertfordshire
WEAVE-LOFAR Science Team Leader

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The WEAVE-LOFAR Survey
Outline

- The WEAVE instrument
- LOFAR Surveys KSP
- Highlights from the WEAVE-LOFAR Survey science case
- The WEAVE-LOFAR Survey
- Summary

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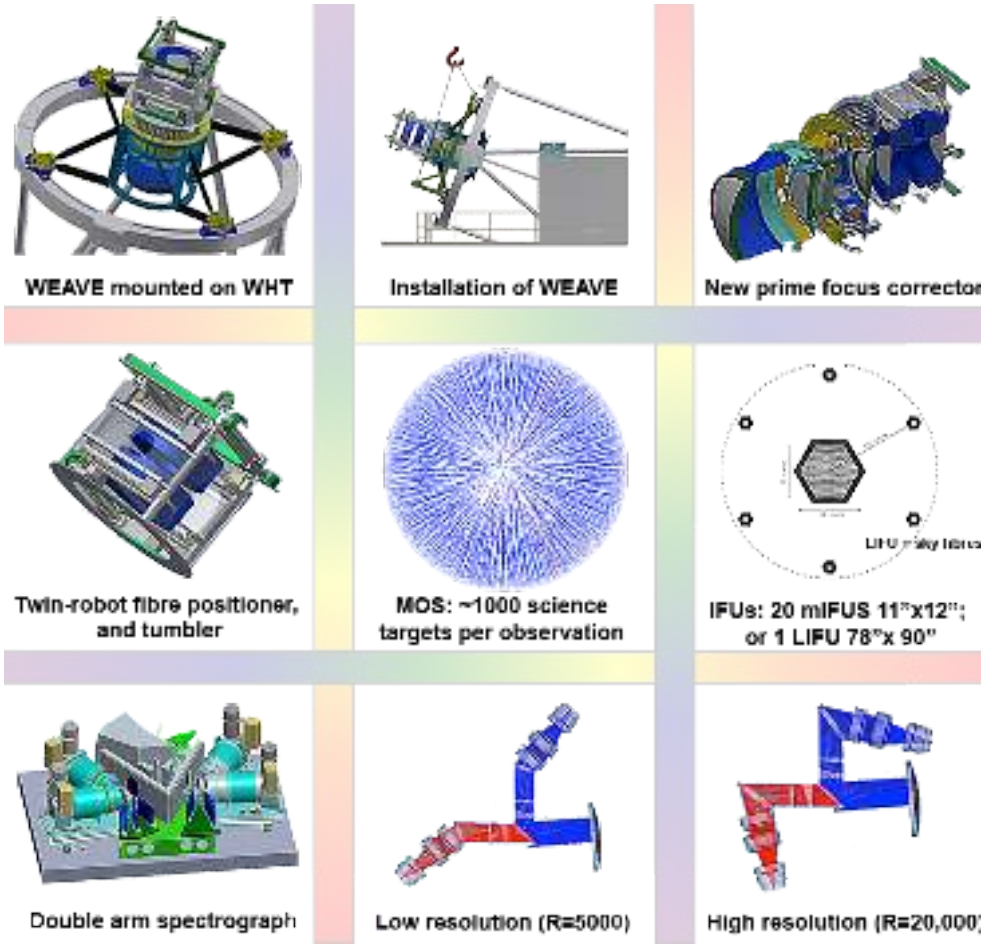
What is WEAVE?
The WHT Enhanced Area Velocity Explorer

- A multi-object spectrograph, with:
  - 1,000 x 1.3” fibres
  - 2 deg diameter field of view
  - R=5,000 with coverage from 370nm to 1μm
  - R=20,000 with reduced coverage
  - mIFU and LIFU modes
  - See Dalton et al. (2012) for details

- First light in 2017, then five years of survey operations. *One of the primary surveys that it will do is follow-up of LOFAR targets*

- www.ing.iac.es/weave/



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LOFAR: the Low Frequency Array
Surveys Key Science Project

Tier-1, the "Wide", will cover whole northern hemisphere, multi-frequency, 0.1 mJy RMS at 120 MHz; SFR sensitivity > Herschel

Tier-2, the "Deep", will cover 100s of deg^2 to faint flux limits (25 μJy RMS @ 120 MHz)

Tier-3, the "Ultra-Deep", will cover 10s of deg^2 to sensitivities > the deepest existing imaging (6 μJy @ 150 MHz)

Details: Röttgering et al. 2011

Steve Rawlings Array, Chilbolton

Superterp, NL

University of Hertfordshire UH

WEAVE-LOFAR Science Case:
What is the nature of the faint radio source population?

- The star-formation history of the Universe
- Accretion and AGN-driven feedback
- Probing the Epoch of Reionization
- Cosmology
- Protoclusters & Clusters Halos/Relics

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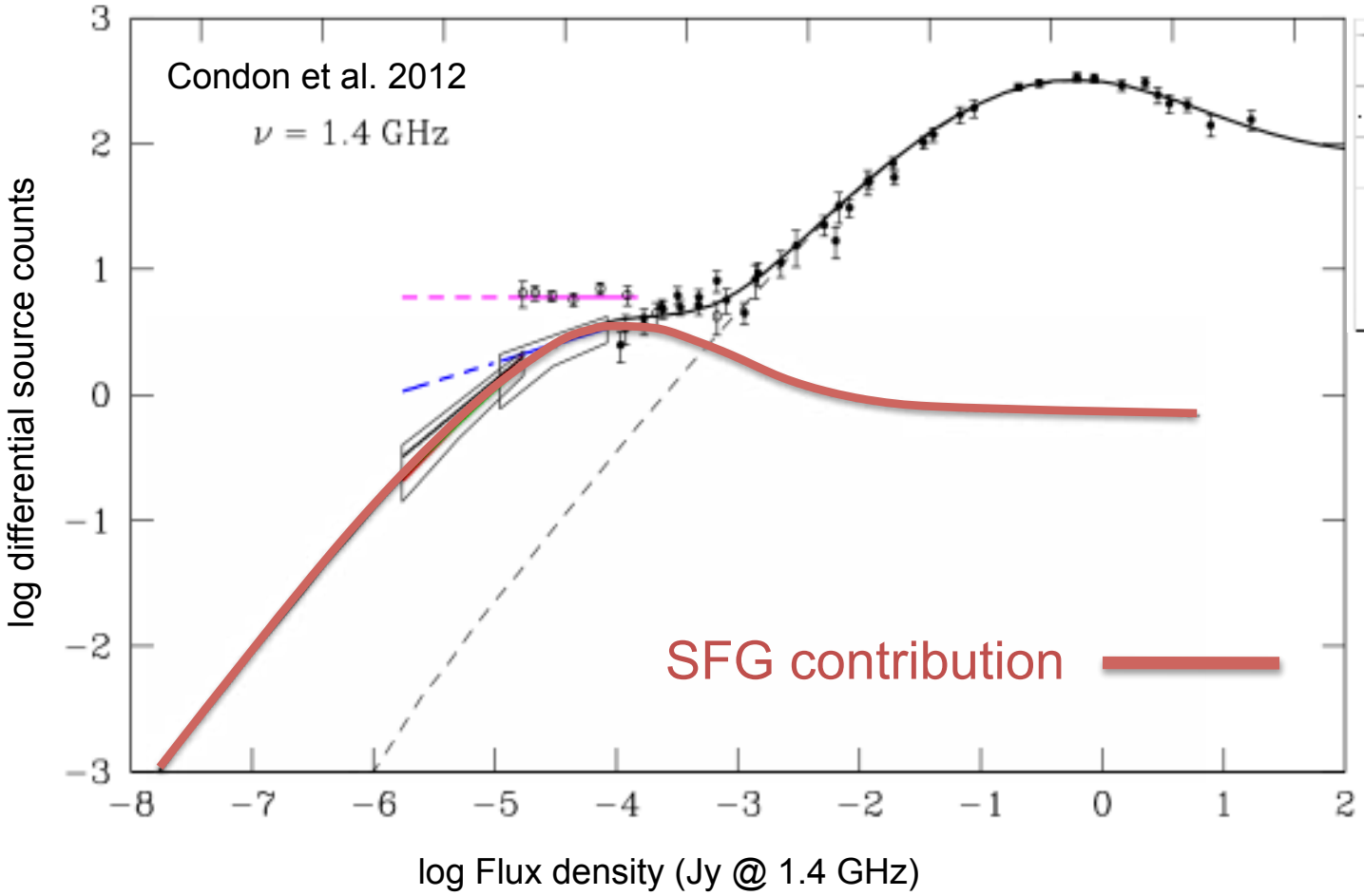
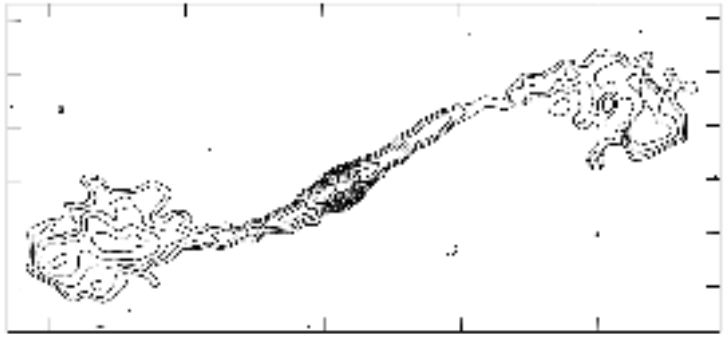
The future of star formation is at radio frequencies

Star forming galaxies dominate the faint sources in new radio data





At bright flux densities, radio sources predominantly active galactic nuclei (AGN)

However, fainter sources are more diverse

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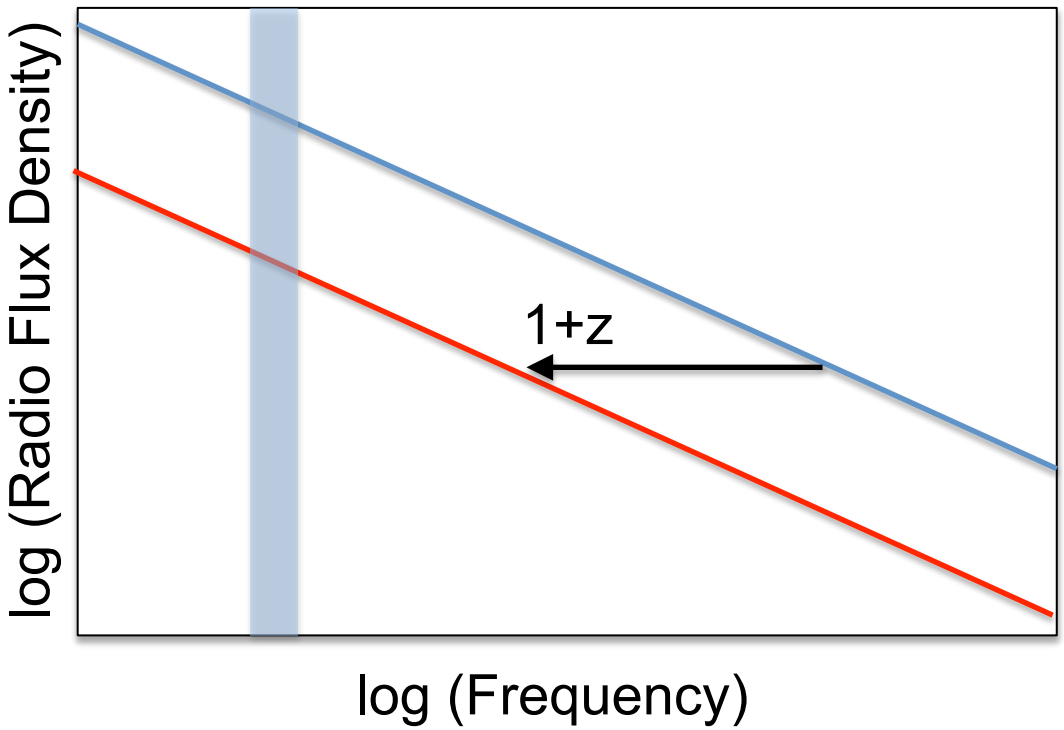
"There's nothing as useless as a radio source"
Jim Condon, 2013



Radio source spectra are well-described by power laws:

$$S_\nu \propto \nu^{-\alpha}$$

No redshift information!

Spectroscopy is essential to get redshifts

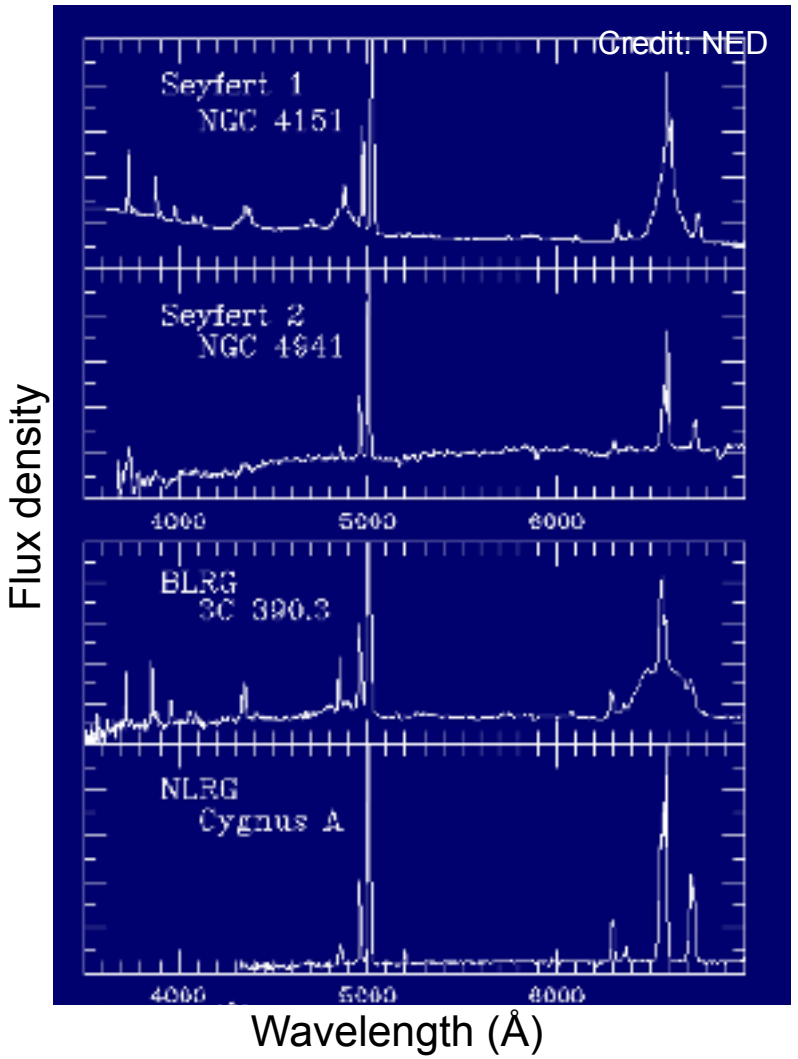
Spectra also critical to split SF and RQ-AGN, distinguish accretion modes

Getting the redshift information that we need
Why can't we use photometric redshifts?

- Faint radio sources are among the most difficult sources for photo-z:
  - AGN (radio loud & quiet)
  - high-EW emission lines

- Bright emission lines make radio sources ideal for spectroscopy
  - You don't have to detect the continuum
  - Can classify sources
  - **Spectroscopy is very efficient**

Also lots more science possible with spectroscopy…



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The star-formation and accretion history of the Universe
What can WEAVE-LOFAR tell us (very abridged)?

Which galaxies formed all of the stellar mass in the Universe?

What is the relationship between star formation and the different accretion modes?

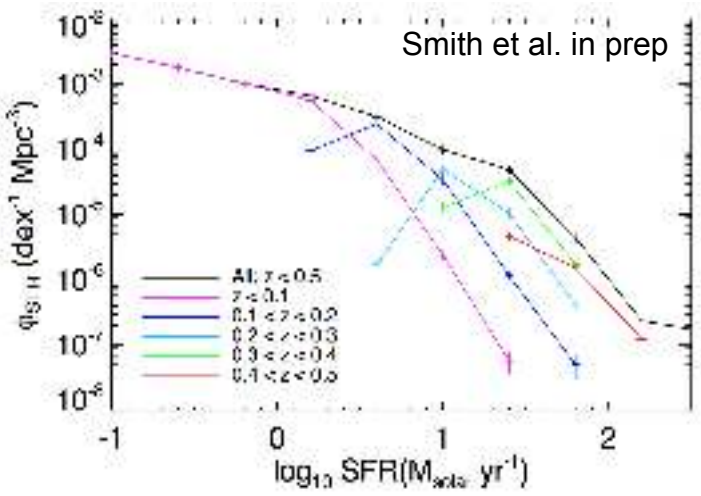
Obscuration free, how star formation & AGN activity varies as a function of Stellar Mass, Environment, Redshift

What is the physical mechanism of the correlation with far-IR?

What is the origin of the radio-loudness dichotomy?

Search for starburst/AGN-driven outflows; individual and statistical

How was the Universe re-ionized?



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The star-formation and accretion history of the Universe
Why low-frequency selection?

Radio surveys offer the best way to trace SF and AGN:

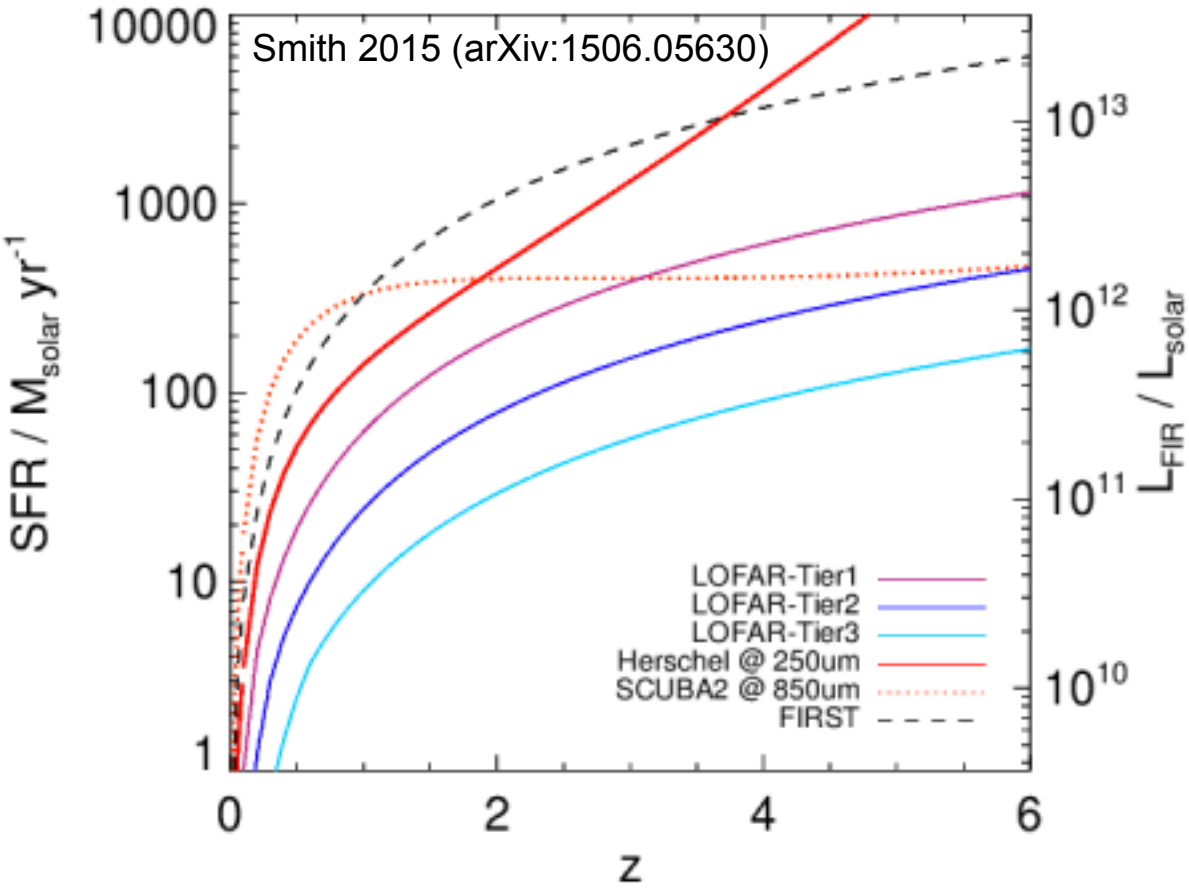
- Supreme sensitivity

- Dust independent (i.e. even Compton thick AGN)

- Deep confusion limits

- Detect SMG-like galaxies at z > 5!

- Low frequencies are (always?) better



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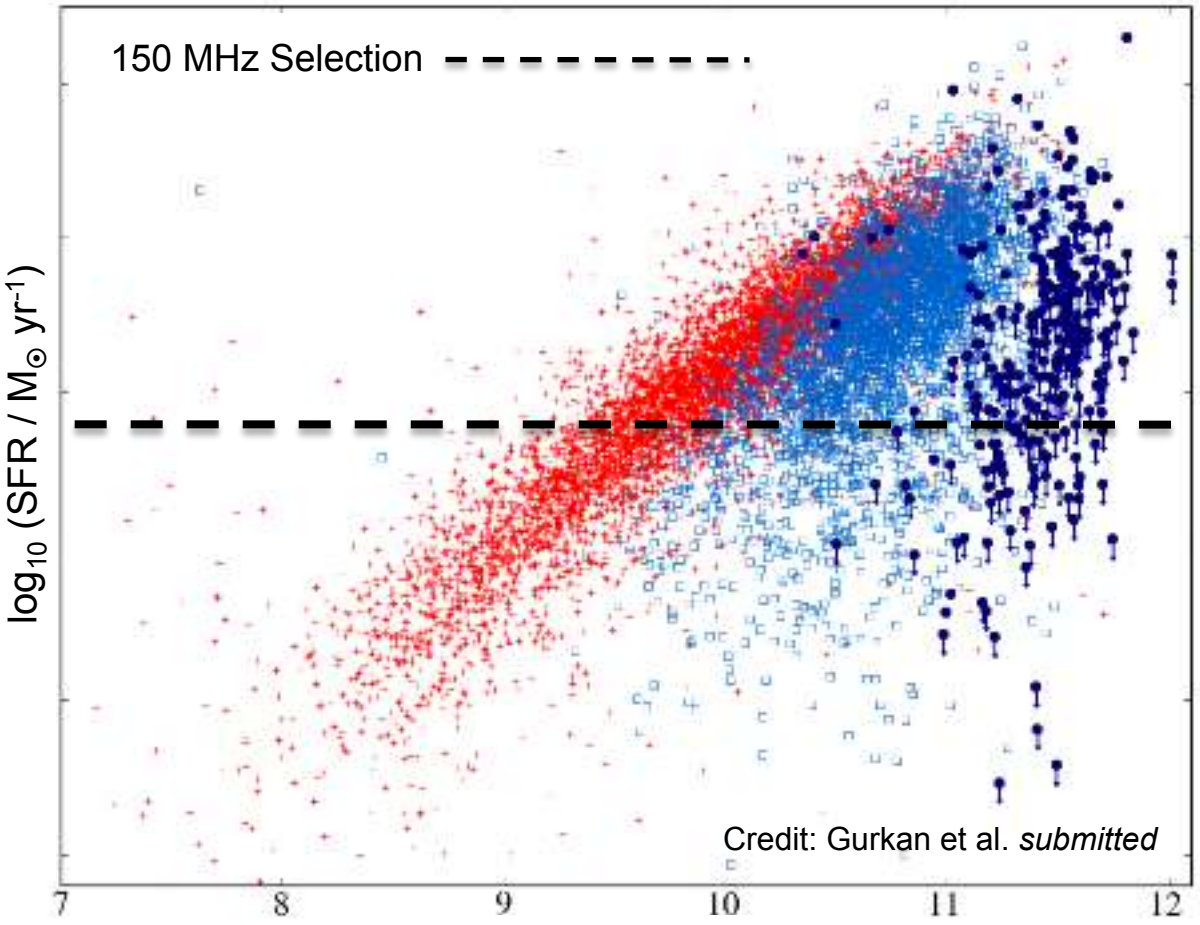
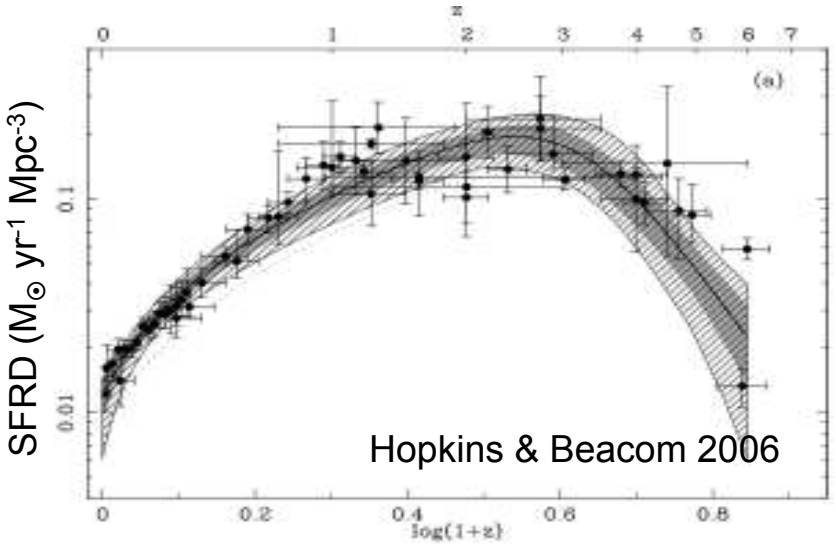
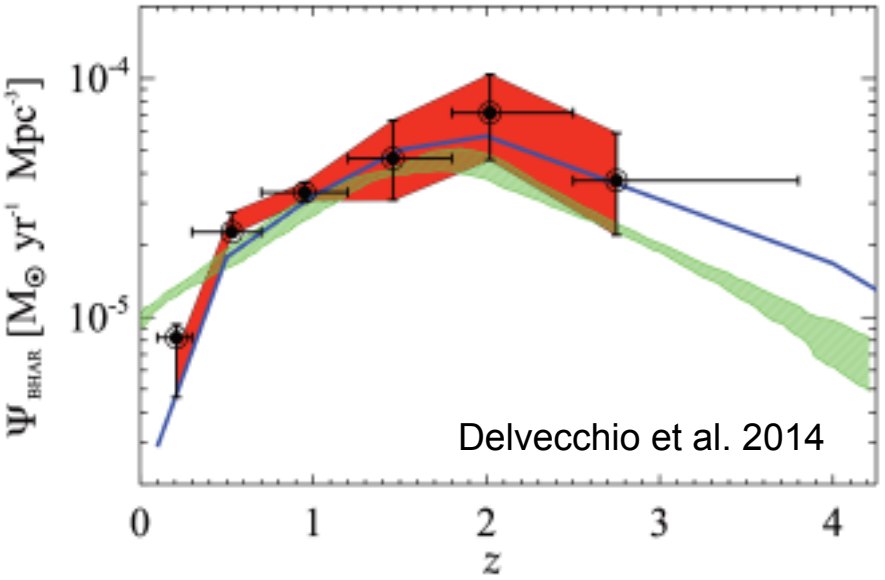
150 MHz selection vs the “Main Sequence”
What sort of galaxies does it give us?







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WEAVE-LOFAR
How to realize the science case

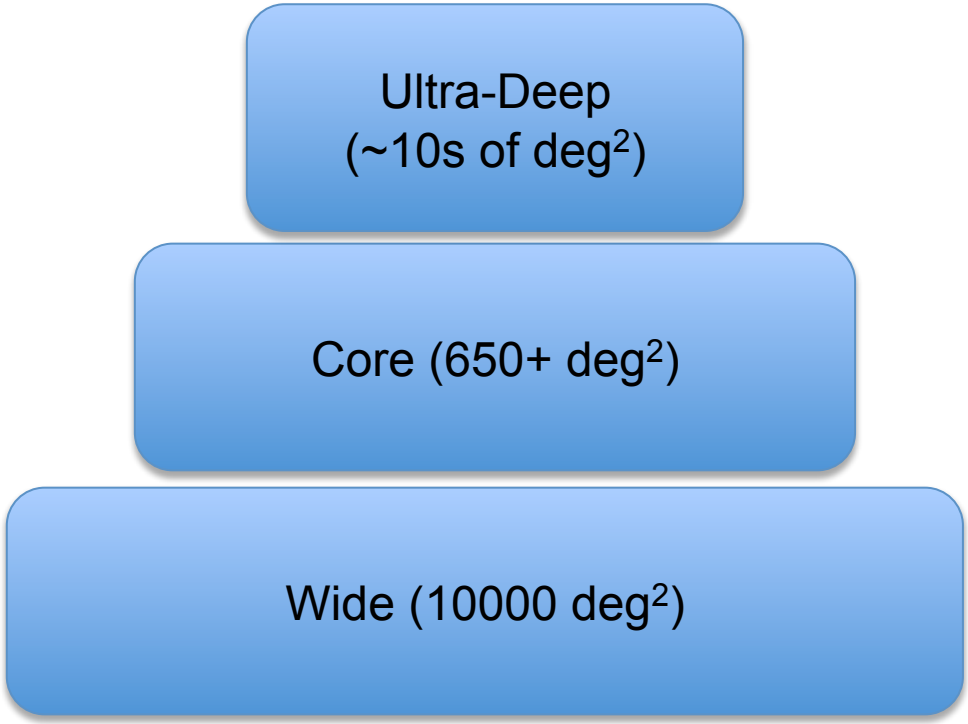
WEAVE-LOFAR represents a unique capability in the Northern hemisphere

Spectroscopic follow-up of:
- 100,000s of LOFAR-selected sources
- in three tiers

We will get *a complete picture of SF and AGN co-evolution since z < 1.3 and z > 2*
- *(and a lot more!)*

Fields include: ELAIS-N1, Lockman Hole, Bootes, XMM-LSS, COSMOS, HATLAS-NGP, HETDEX-N, etc

First light: end of 2017 then 5 years of surveys



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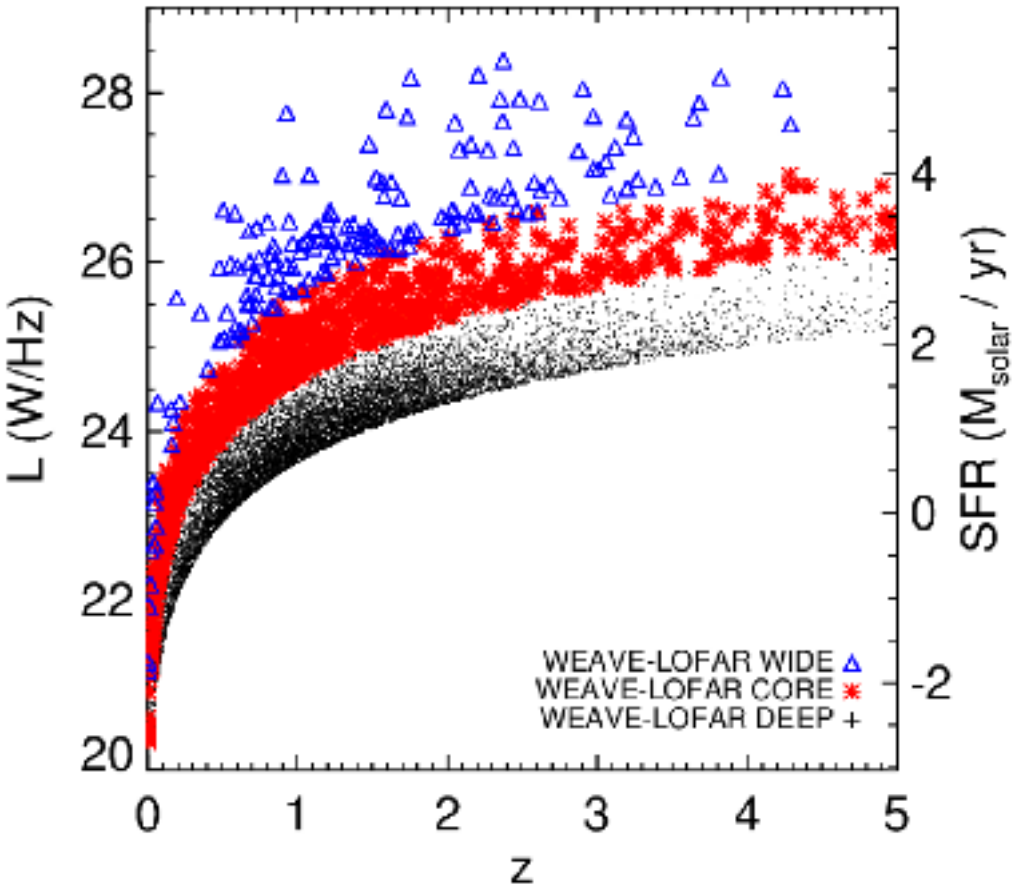

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Thanks for listening

Drop me an email if you're interested in contributing!
daniel.j.b.smith@gmail.com

The WEAVE-LOFAR Team
Current team members

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David Bacon (Portsmouth), Chris Conselice (Nottingham), Kristen Coppin (Herts), Tim Davis (Herts), Chiara Ferrari (Nice), Barbara Lo Faro (Marseille), Gulay Gurkan (Herts), Nancy Hine (Herts), Eleni Kalfountzou (Herts/ESA), Matt Lehnert (Paris), Natasha Maddox (Groningen), Sean McGee (Birmingham), George Miley (Leiden), Rafaella Morganti (Astron), Bob Nichol (Portsmouth), Seb Oliver (Sussex), Shaun Read (Herts), Emma Rigby (Leiden), Aayush Saxena (UCL), Paul van der Werf (Leiden), Sarah White (Oxford), Michael Wise (Astron) & ***the LOFAR Surveys team***

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LOFAR surveys: Opening up a new window on the Universe

Members Core team Röttgering[1,2,3,9](Leiden), Barthel[1,19,6](Groningen), Best[1,2,3,15] (Edinburgh), Brüggen[2] (Bremen), Brunetti[2] (Bologna), Chyży[2,20] (Kraków), Conway[3,22] (Göteborg), Jarvis[1,3,9] (Hertfordshire), Lehnert[3,6] (Meudon), Miley[1,2,15] (Leiden), Morganti[3,6] (Dwingeloo), Wise[3,6,5] (ASTRON)

Regular members: Haverkorn[5] (ASTRON), Jackson[7] (Manchester), White[3,8] (Open University), Abdalla[9] (UCL London), Anderson (MPIfR Bonn), Arnaud[3] (Meudon), Bacon[7,9] (Portsmouth), Beck[5] (Bonn), Beswick[3,22] (Manchester), Brentjens[5] (ASTRON), Britzen[5] (Bonn), Conselice (Nottingham), Croston[2] (Southampton), Dettmar[5] (Bochum), Eales[5] (Cardiff), Edge[2] (Durham), Engels[5] (Hamburg), Enßlin[2] (Garching), Falcke[4,5] (Nijmegen), Feretti[2] (Bologna), Ferrari[7] (Nice), Franx[5] (Leiden), Garrett[5,7] (ASTRON), Génova-Santos[7] (IAC), Hardcastle (Hertfordshire), Hendry[11] (Glasgow), Hoeft[5] (Tautenburg), Horellou[2,14] (Onsala), Israel[11] (Leiden), Ivison[5] (Edinburgh), Jamrozy[5,4] (Krakow), Kassim[5] (Washington), Kauffmann[4] (Garching), Klein[5] (Bonn), Kuijken[5] (Leiden), Kunert-Bajraszewska[4,5] (Torun), Lobanov[5] (Bonn), Marecki (Torun), Marti Vidal[16] (Onsala), Martinez Sansigre (Portsmouth), McKean[5,7] (ASTRON), Merloni[4,5] (Garching), Middelberg[5] (Bochum), Murgia[5,18] (IAC), Nichol[9] (Portsmouth), Oliver[13] (Sussex), Oosterloo[5,7] (ASTRON), Otmianowska-Mazur (Krakow), Page[14] (London), Paragi (JIVE), Pentericci[17] (Rome), Percival[9] (Portsmouth), Peters[5] (Washington), Polatidis[5,7] (ASTRON), Prandoni[7,5] (IAC), Raychaudhury[3] (Birmingham), Reich[5] (Bonn), Schwarz[5] (Bielefeld), Simpson[3,14] (Liverpool), Steinmetz[5] (Potsdam), Strom[5,22] (ASTRON), Tadhunter[3] (Sheffield), Valentijn[5,6] (Groningen), van der Werf[5,6] (Leiden), van Driel[7] (Meudon), van Weeren[15,6] (ASTRON / Leiden), Varenius[3] (Gothenburg), Vink[5,6] (Amsterdam), White[1] (Garching), Wisotzki[14] (Potsdam), Wucknitz[5] (Bonn), Zarb-Adami[3] (Oxford), Zensus[5] (Bonn)

Postdocs: Asgekar[1,5] (ASTRON), Bertacca[3] (UWC), Birzan[2,15] (Leiden), Bonafede[2] (Bremen), Bonfield[9] (Hertfordshire), Cassano[2] (IAC), Deller (ASTRON), Dwelly[3] (Southampton), Faltenbacher[3] (UWC), Heald[5] (ASTRON), Heesen[2,5] (Hertfordshire), Heywood[9] (Oxford), Johnston[3] (UWC), Kapinska (Portsmouth), Kloeckner[11] (Oxford), Konig (Koln), Macario[2] (Nice), Mahony (ASTRON), Mauch[3,4] (Oxford), McKay (Chilbolton), McKee[3] (Leiden), Oonk[1,5] (ASTRON), Orru[1,4,5] (Nijmegen), Patel[9] (Portsmouth), Pizzo[5] (ASTRON), Raccanelli[9] (Portsmouth), Rafferty[1,5,6] (Leiden), Sabater Montes[4] (Edinburgh), Seymour[5] (Sydney), Smith[7,9] (Herts), Smith[3] (UWC), Stewart (Bonn), Tasse[4] (Meudon), Tudose (ASTRON), Vaccari[3,9] (UWC), van Bemmel (ASTRON), Zwart[3,9] (UWC)

PhDs: Balega[3,5] (Gothenburg), De Gasperin[5,7] (Garching), Deane[3] (Oxford), Drozga[5,6] (Krakow), Fielding[4] (Edinburgh), Guglielmino[4,5] (Bologna), Harwood[2] (Hertfordshire), Heidenreich[3] (Southampton), Israel[5] (Leiden), Junkelwitz[5] (Garching), Jurusik[4] (Krakow), Ker[3,4] (Edinburgh), Kuligowska[4,5] (Krakow), Lazell[3] (Birmingham), Lindsay[3] (Hertfordshire), Madhanpall[3] (UWC), McAlpine[3] (UWC), Morabito (Leiden), Nail[3] (Open University), Ogrean[5] (Bremen), Rubart[5] (Bielefeld), Shulevski[5] (Groningen), Stroe[5] (Leiden), Temoutian[3] (Hertfordshire), Trasatti[2] (Bonn), van Velzen[1] (Nijmegen), Williams[1,6] (Leiden).

WEAVE-LOFAR Fields
Where will this be done?

The best large-scale northern fields are:

HETDEX northern field 420 deg^2

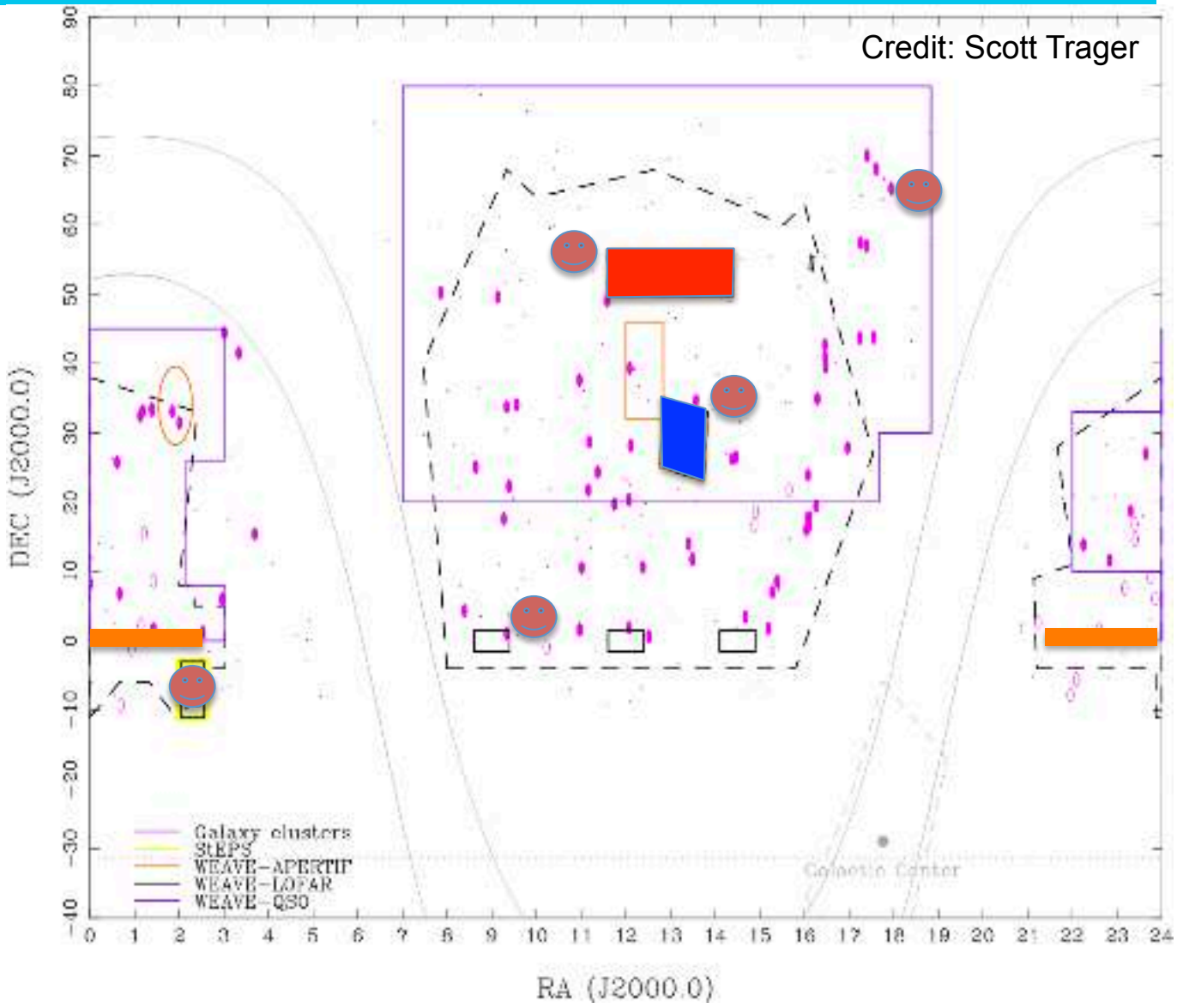
HATLAS NGP: 140+ deg^2,

HATLAS Equatorial: 180+ deg^2

Stripe 82: 300+ deg^2

Deep fields: XMM-LSS, COSMOS, Bootes, Lockman, ELAIS-N1 etc.

Wide Tier: Galactic Halo



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Some science goals of WEAVE-LOFAR
Radio sources with redshifts are very informative!

- Precisely trace the assembly history of galaxies as a function of mass, environmental density and galaxy type
- Probe the relationship between accretion and star-formation over cosmic history, with large samples of radio quiet AGN & SFGs
- Discriminate between efficient (cold a.k.a. QSO-mode/ high-excitation) and inefficient (hot or radio mode, low-excitation) radio galaxies
- Find the rarest sources (e.g. radio sources in the Epoch of Re-ionization) for 21cm absorption
- What causes the RL-RQ dichotomy and how does it evolve
- Statistical reverberation mapping and accretion disk structure
- Stack large numbers of spectra to study average properties of very faint galaxies (i.e. individual sources only have emission lines detected; stack to get the continuum)
- Learn to derive good photometric redshifts, including separating the AGN from the SFGs
- Measure galaxy velocity dispersions and metallicities, virial black hole masses in QSOs
- Complete samples of high redshift proto-clusters for galaxy evolution and cosmology
- Accurate redshifts for SN host cosmology
- Precise *separable* redshift distributions for cosmology over wide fields (informed by the deep fields)

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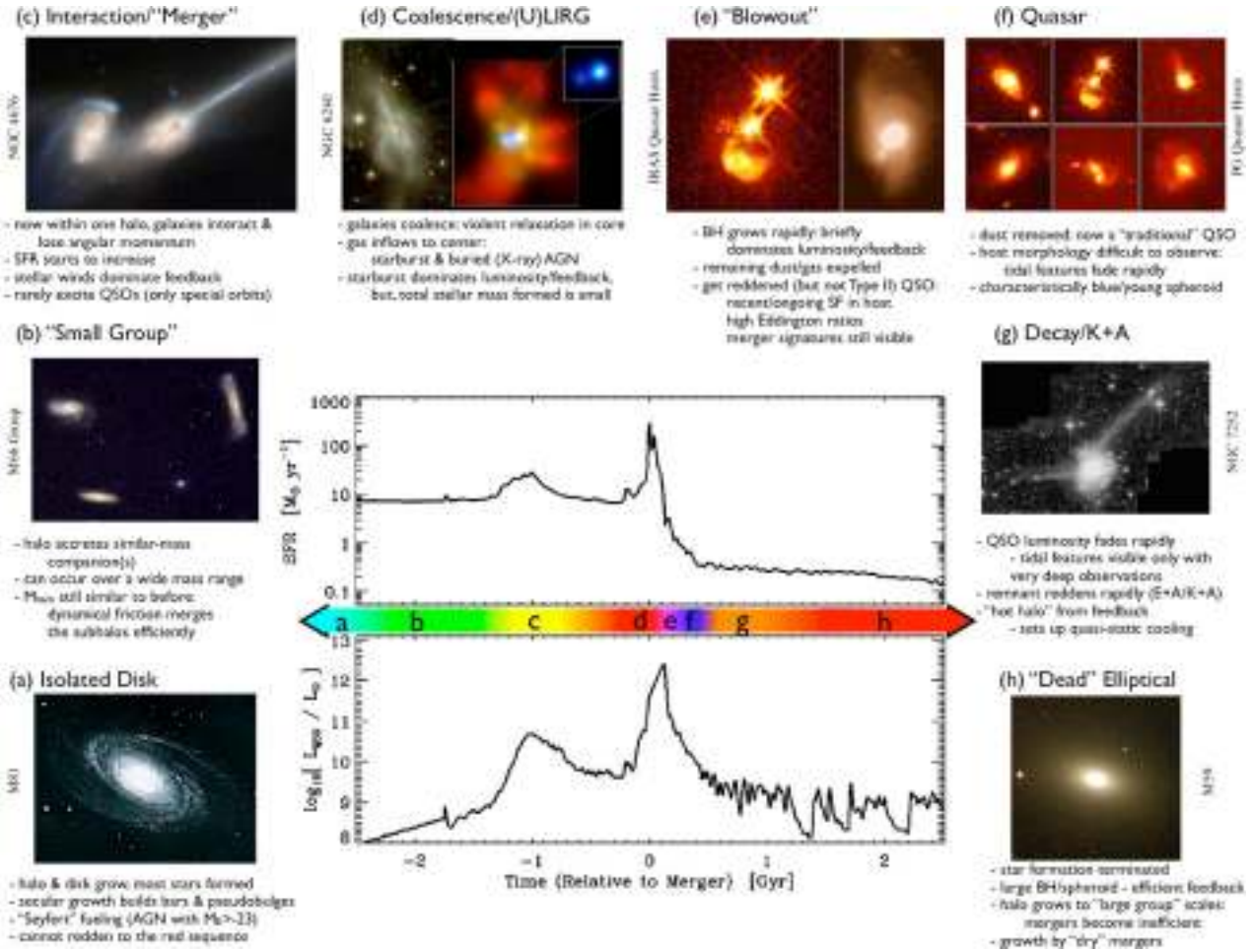
Accretion and AGN-driven feedback
Why should we care about this?



Credit: Hopkins et al. 2008

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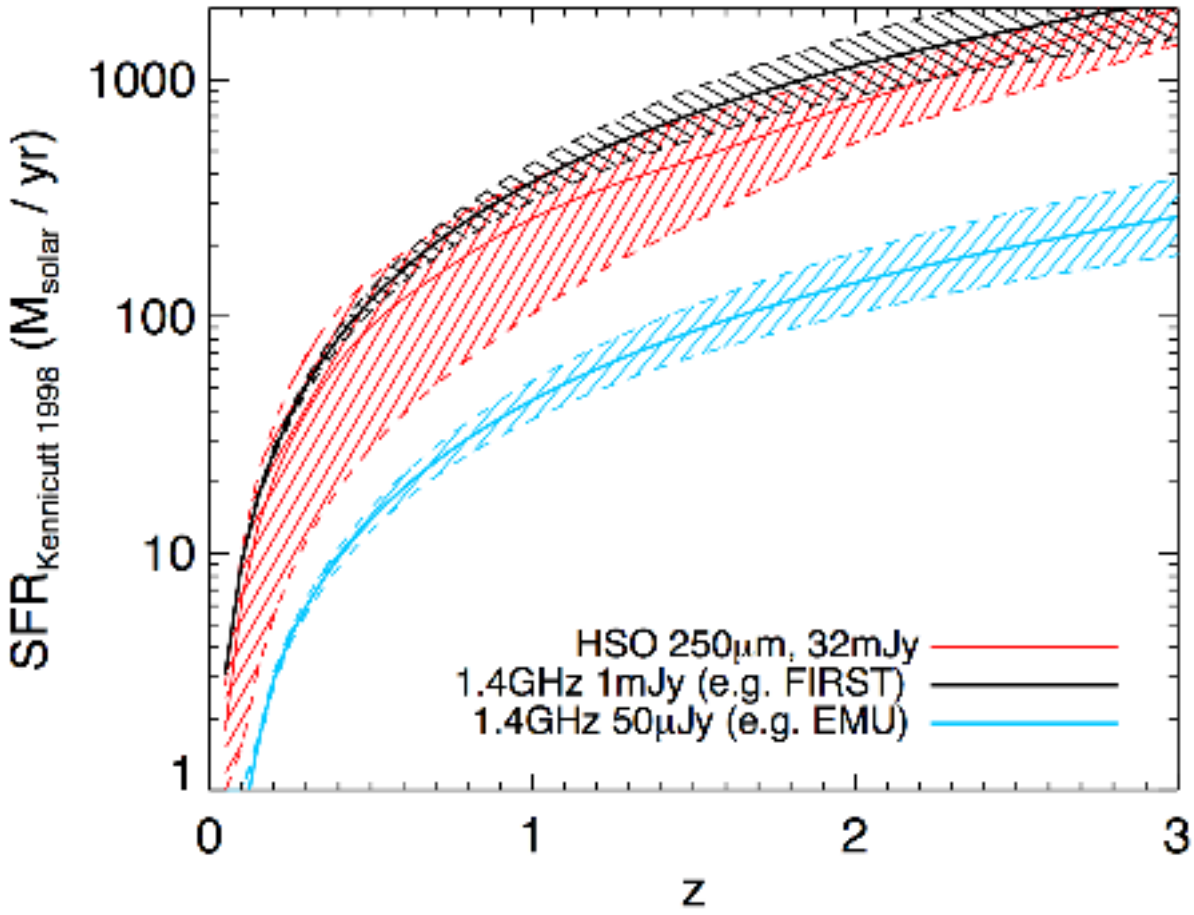
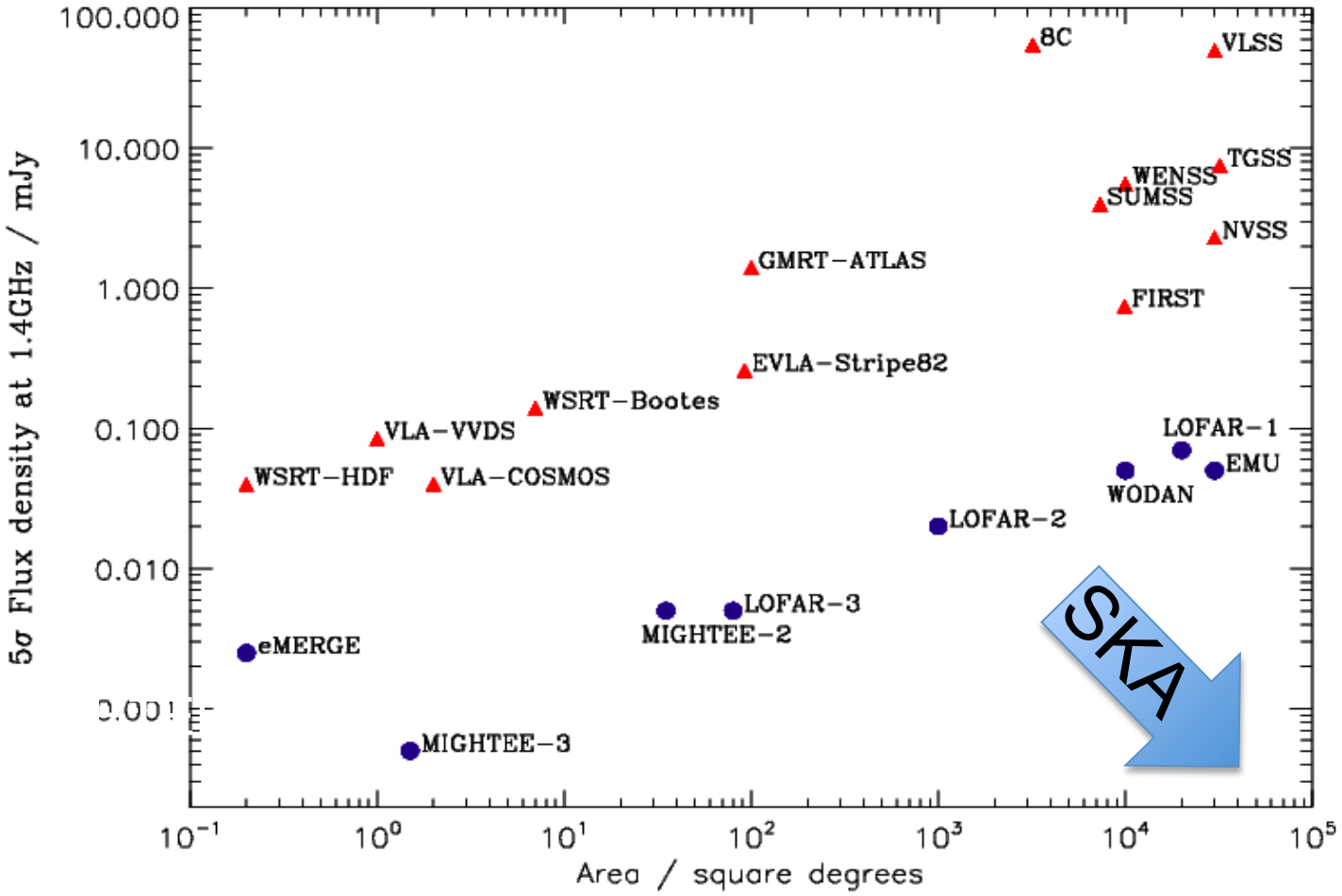
SFR sensitivity
Dependence on FIR SED and spectral index



The new radio continuum surveys
LOFAR surveys



LOFAR Tier 1: “Large Area”
Whole northern sky, 10x as deep as FIRST; similar to ASKAP-EMU in the South

LOFAR Tier 2: “Deep”
~500 deg^2, 10 M_{solar}/yr @ z=1

LOFAR Tier 3: “Ultra Deep”
100 deg^2, deeper than deepest existing data
ULIRGs at z=8!

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LOFAR