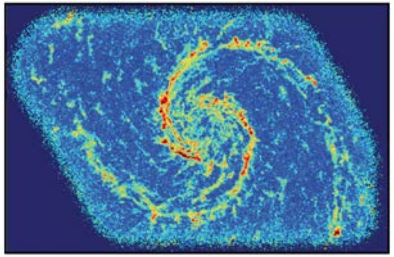
Science and Requirements – ngVLA Working Group 2

Continuum in M82: Marvil & Owen



CO in M51: Schinnerer+ '13

Next Generation Very Large Array Memo No. 7

Science Working Group 2

"Galaxy Ecosystems" : The Matter Cycle in and Around Galaxies

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"Galaxy Ecosystems"

Adam Leroy (OSU), Eric Murphy (NRAO) on behalf of **ngVLA Working Group 2**

Summary

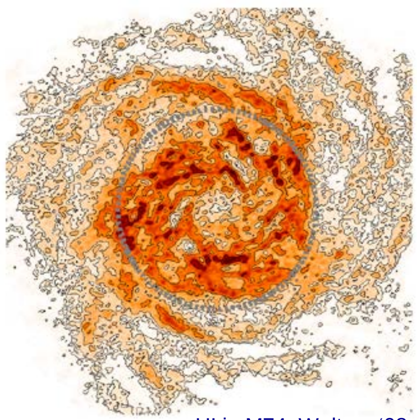
1. The frequency range between 20 and 115 GHz contains a stunning array of continuum and line diagnostics that access the physical and chemical state of the gas in and around galaxies.

2. Many of these diagnostics have been too faint to exploit in a systematic way, even with ALMA and the VLA.

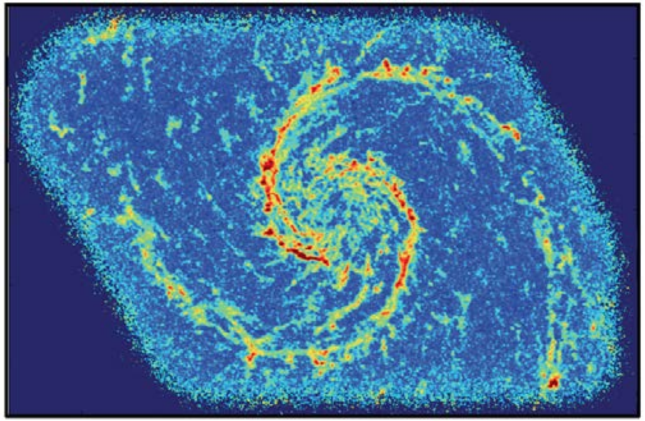
3. If optimized for surface brightness sensitivity (at, say, ~1'' resolution), the ngVLA can be an unparalleled machine to use these capabilities to learn about the physics of 'galaxy ecosystems.'

4. However, the nominal design being discussed does not noticeably exceed the capabilities of ALMA.

1-115 GHz Contains Main Diagnostics to Trace the Matter Cycle



HI in M74: Walter+ '08



CO in M51: Schinnerer+ '13

Continuum in M82: Marvil & Owen

- 1-115 GHz line emission offers a main way to observe distribution, motions, physical state, and chemical state of atomic (HI), molecular (H_2), and ionized (HII) gas.

- 1-115 GHz continuum contains information on recent star formation (ionized gas), cosmic ray electrons, magnetic field structure, and hot gas pressure (SZ effect).

- (See VLBI discussion in next session) Astrometry and kinematics with extremely high precision to trace structure of the Milky Way and the Local Group.

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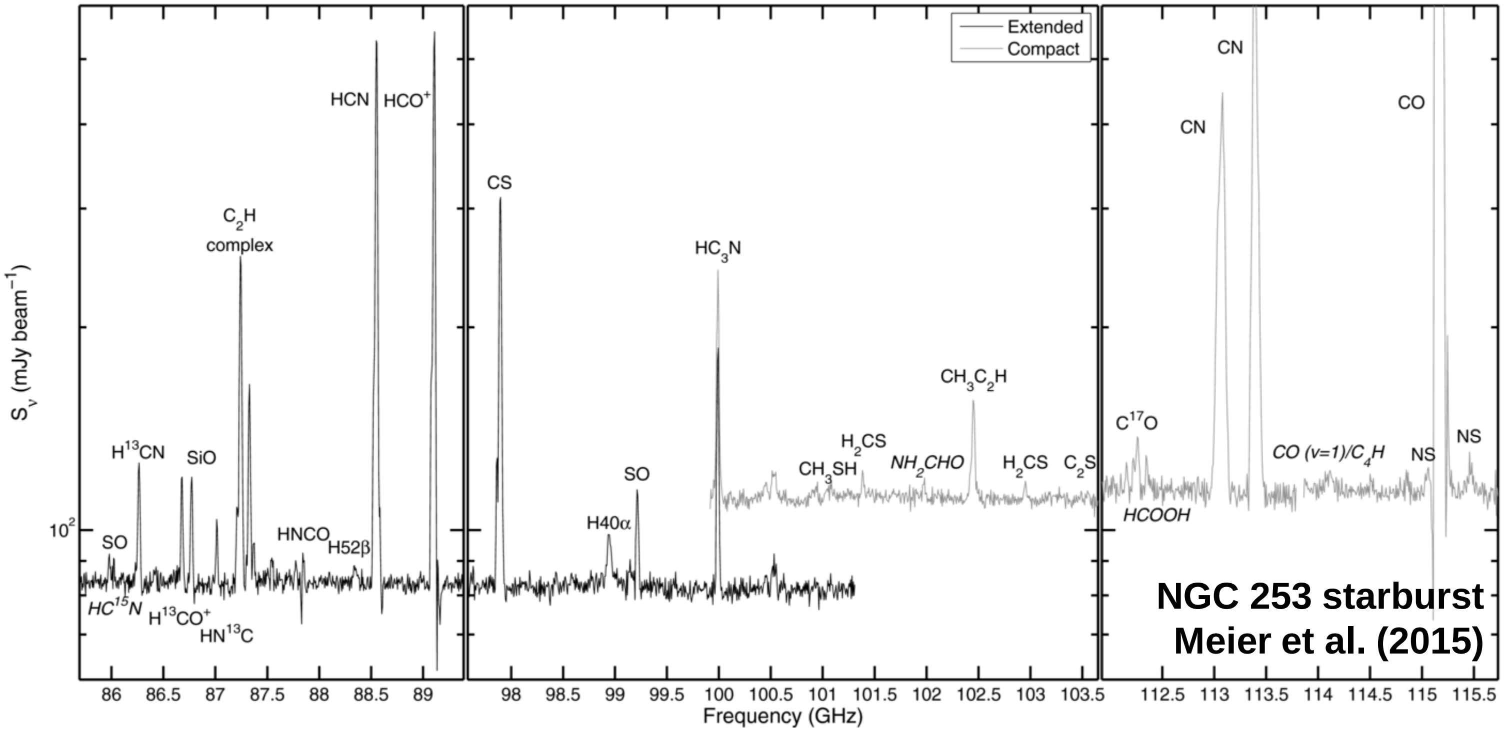
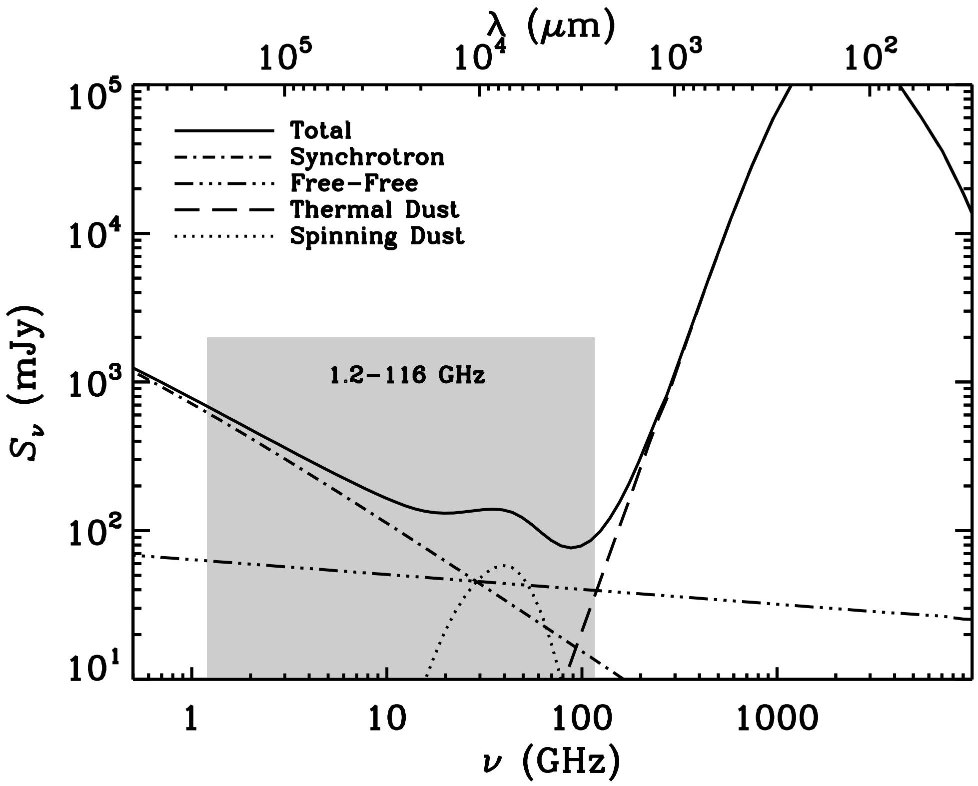


The 3-4 mm atmospheric window includes a wealth of molecular lines that together diagnose the physical and chemical state of molecular gas (density, excitation, XDR/PDR, chemistry, more).

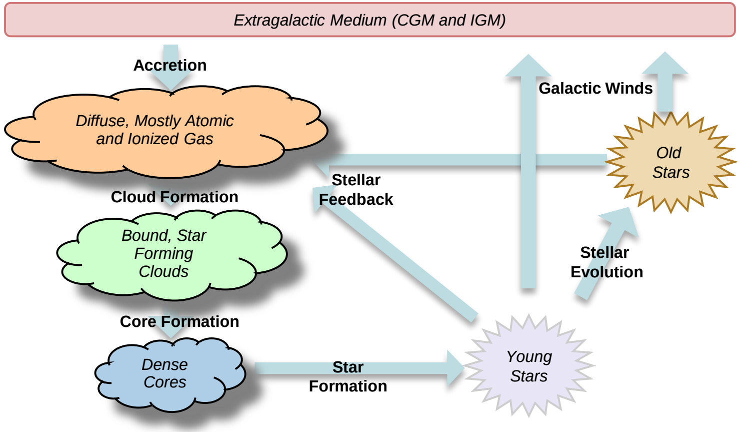
1-115 GHz Contains Main Diagnostics to Trace the Matter Cycle



Continuum in M82: Marvil & Owen

All major continuum processes visible: synchrotron, dust (RJ and spinning), thermal free-free. Polarization traces B-field structure. With enough sensitivity, see S-Z effect from normal galaxies.

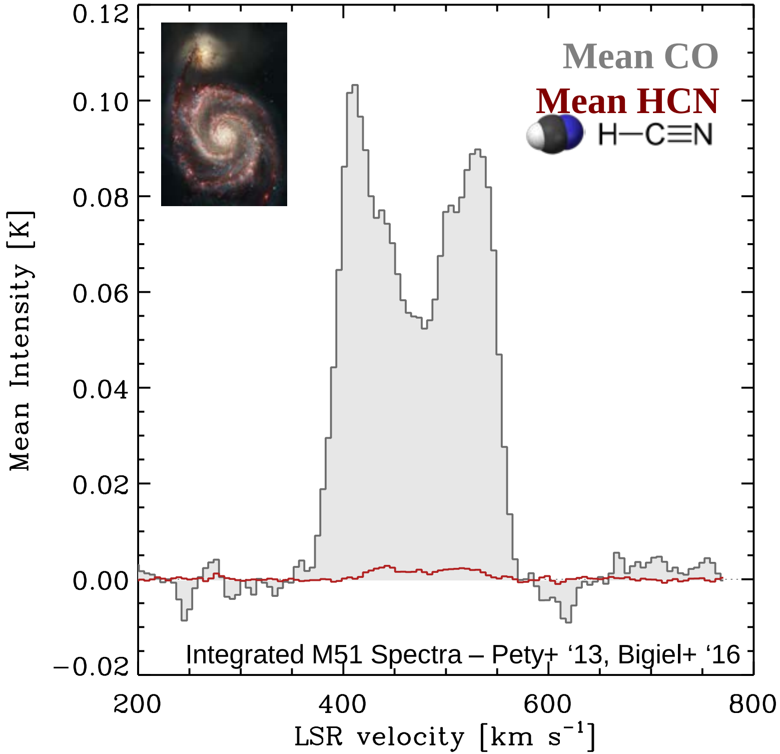
The Matter Cycle in and Around Galaxies

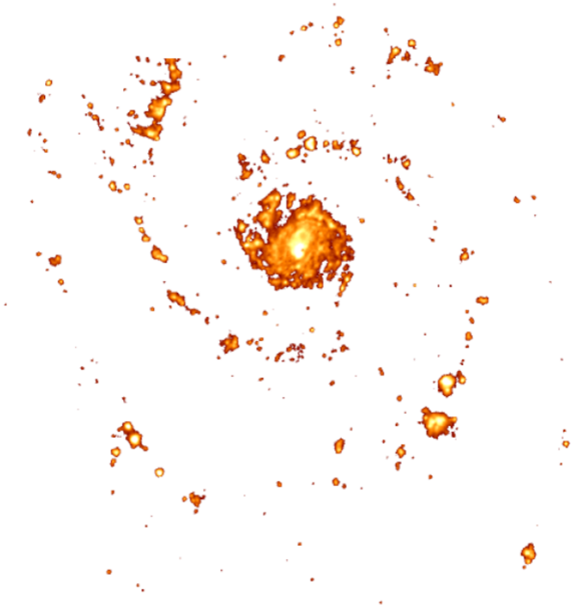


- How does gas move in and out of galaxies?
- How does the chemistry and physical state of the ISM depend on galaxy and environment?
- How do black holes and stars change the state and chemistry of the surrounding gas?
- How are high mass stars and clusters of stars formed, in detail?
- How does the state and chemistry of gas affect its ability to form stars?
- What is the structure of hot gas halos and magnetic fields in galaxies?

The Key Diagnostics are Faint

Both lines and continuum diagnostics are faint compared to capabilities of current telescopes in this regime: see HCN and free-free continuum in M51. Surface brightness sensitivity is key to advance.





33GHz Model
JVLA (~64 hr)

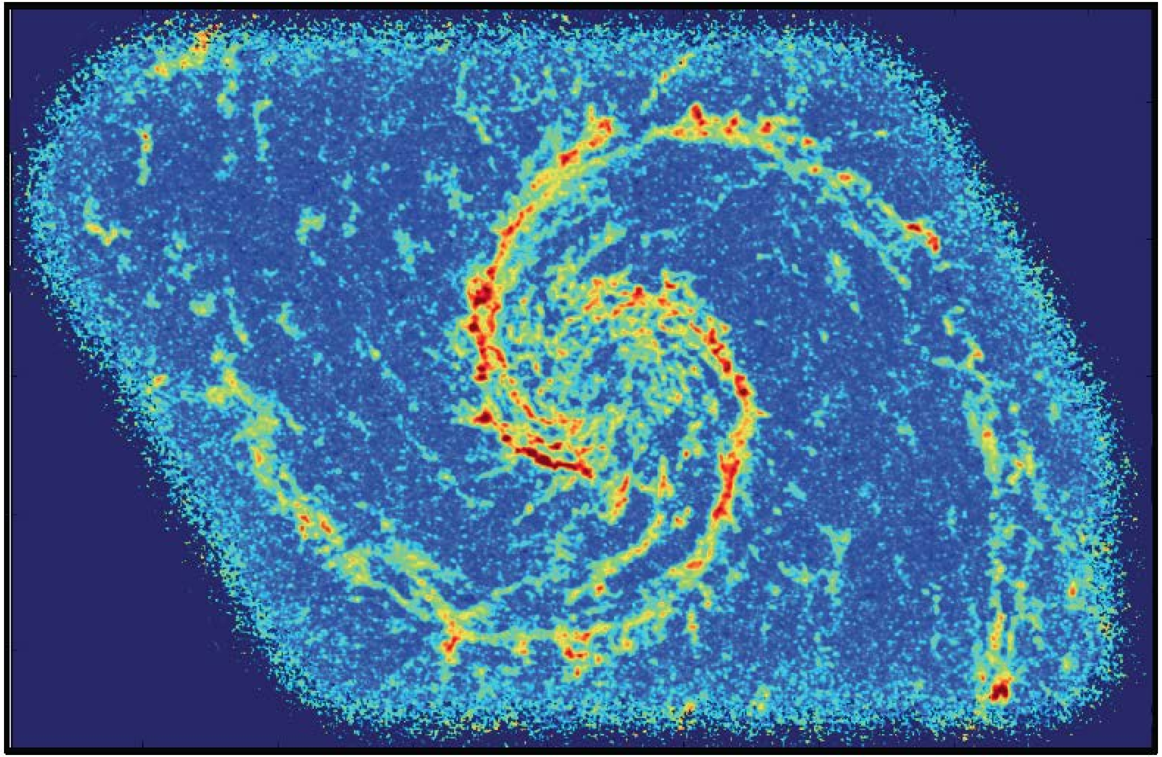
What We Should Ask For (And Is Not in the Specs Now)

A leap in surface brightness sensitivity (at ~0.1 to 1”) would bring powerful, but previously too faint, physical diagnostics in the range ν = 1-115 GHz in to regular use at high resolution, so that they could be applied to survey purposes and become regular tools for “P.I. science.”

The best way to achieve this is a **massive gain in collecting area** at the relevant baselines compared to previous facilities. For the “thermal” science in the galaxy ecosystems area, the relevant baselines are roughly those of the current VLA, especially a few km.

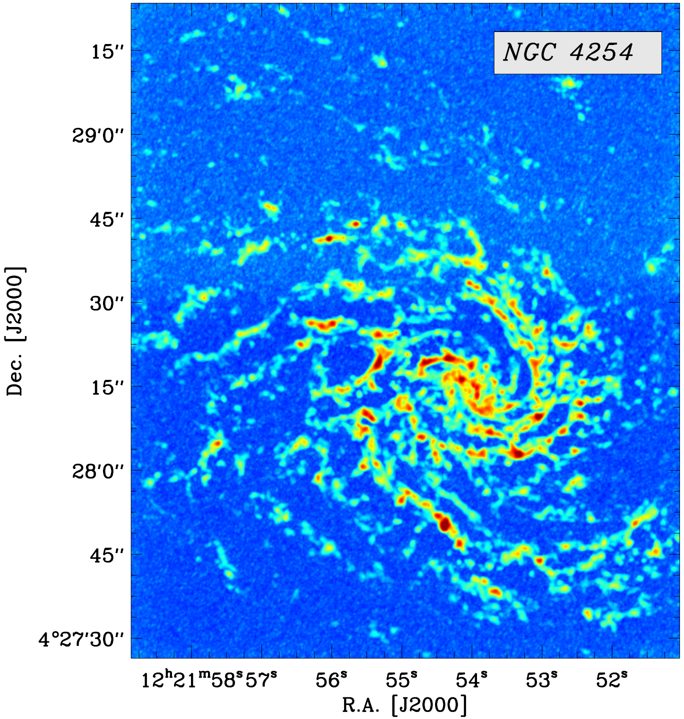
What We Should Ask For - Illustrated

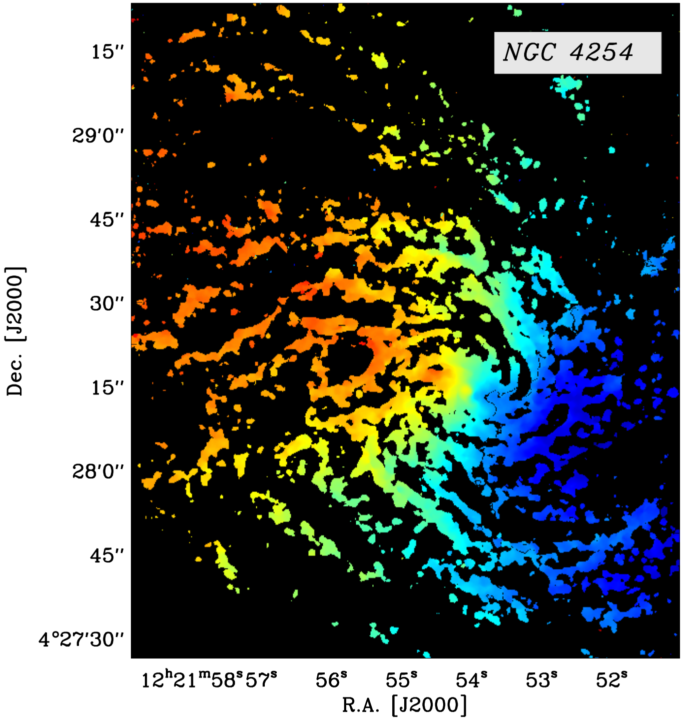
With PdBI (pre-ALMA) this 1'' CO 1-0 map of M51 (PAWS, Schinnerer+ '13) took ~200 hours.



What We Should Ask For - Illustrated

With ALMA this 1’’ CO 2-1 map of M99 takes 1.5 hours. Which means that this capability can be used for surveys but also that a line 10 times fainter can be surveyed as a key project. The leap in surface brightness sensitivity changes the science that can be done with the array.





Notional Sensitivity of Current ngVLA Does Not Exceed ALMA

ngVLA notional parameters from website (30, 80, 100 GHz)

Brightness Temp (T_B) rms continuum, 1 hr, [K]	14	7	6	15	23	g
Line rms 1 hr, 1" taper, 10 km/s [μJy/beam]	340	140	240	860	-	h
T_B rms line, 1 hr, 1" taper, 10 km/s, [K]	100	1.8	0.32	0.17	-	i

ALMA cycle 4 capabilities – line at 90 GHz

Common Parameters

Dec	00:00:00.000	
Polarization	Dual	
Observing Frequency	90.00000	GHz
Bandwidth per Polarization	10.00000	km/s
Water Vapour Column Density	◉ Automatic Choice ○ Manual Choice	
	5.186mm (7th Octile)	
tau/Tsky	tau0=0.046, Tsky=13.639	
Tsys	78.993 K	

Individual Parameters

	12m Array	
Number of Antennas	40	
Resolution	1.0	arcsec
Sensitivity (rms)	611.23274	uJy
(equivalent to)	0.09227	K
Integration Time	1.0	h

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