



# The Next Generation VLA - AGN synergies with TMT

Mark Lacy (with Caitlin Casey and Jackie Hodge for the NGVLA galaxy evolution group)

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*TMT Science forum June 2015, SMBH ISDT discussions*

# What is the NGVLA?

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- ❖ Massive expansion of current VLA in New Mexico
- ❖ 5-10 times the collecting area of the VLA
- ❖ Longest baseline 5-10 times longer (resolution up to 3-6mas at 100GHz)
- ❖ Wide bandwidth receivers (octave and higher; e.g. 5-15GHz)
- ❖ Sensitivity to ~100GHz (current VLA stops at ~50GHz)

# What are the science goals?

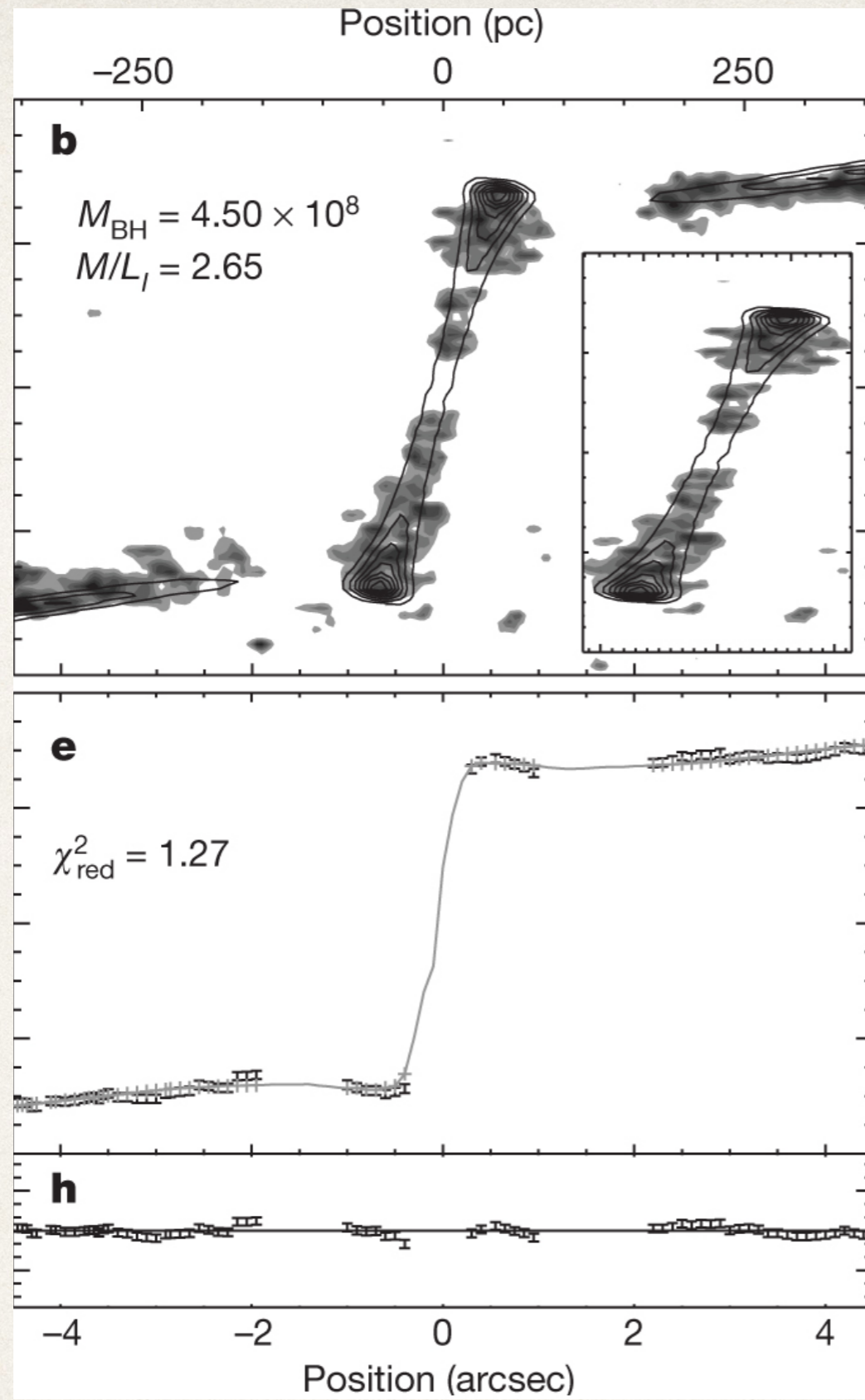
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- ❖ “Cradle of life” - protoplanetary disks, star and planet formation
- ❖ “Galaxy ecosystems” - nearby galaxies
- ❖ “Galaxy evolution” - molecular gas in high- $z$  galaxies, AGN, feedback, SZ effect.
- ❖ “Cosmology” - pulsars, real-time cosmology via proper motions, time domain.

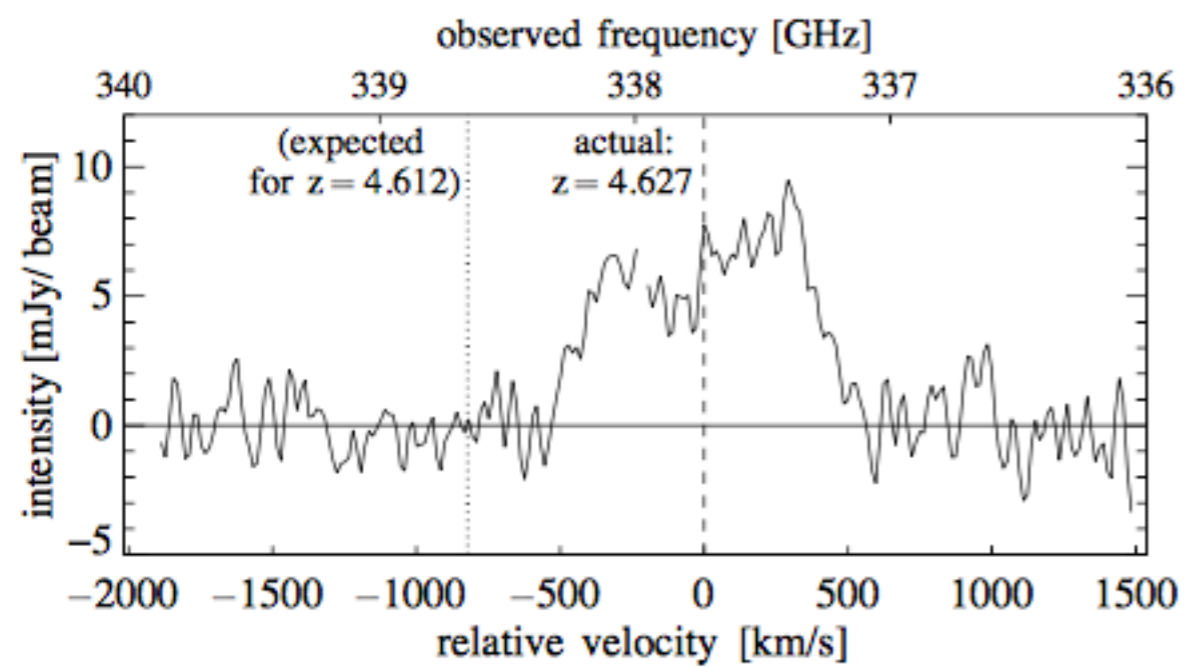
# Specific AGN-related science - lines

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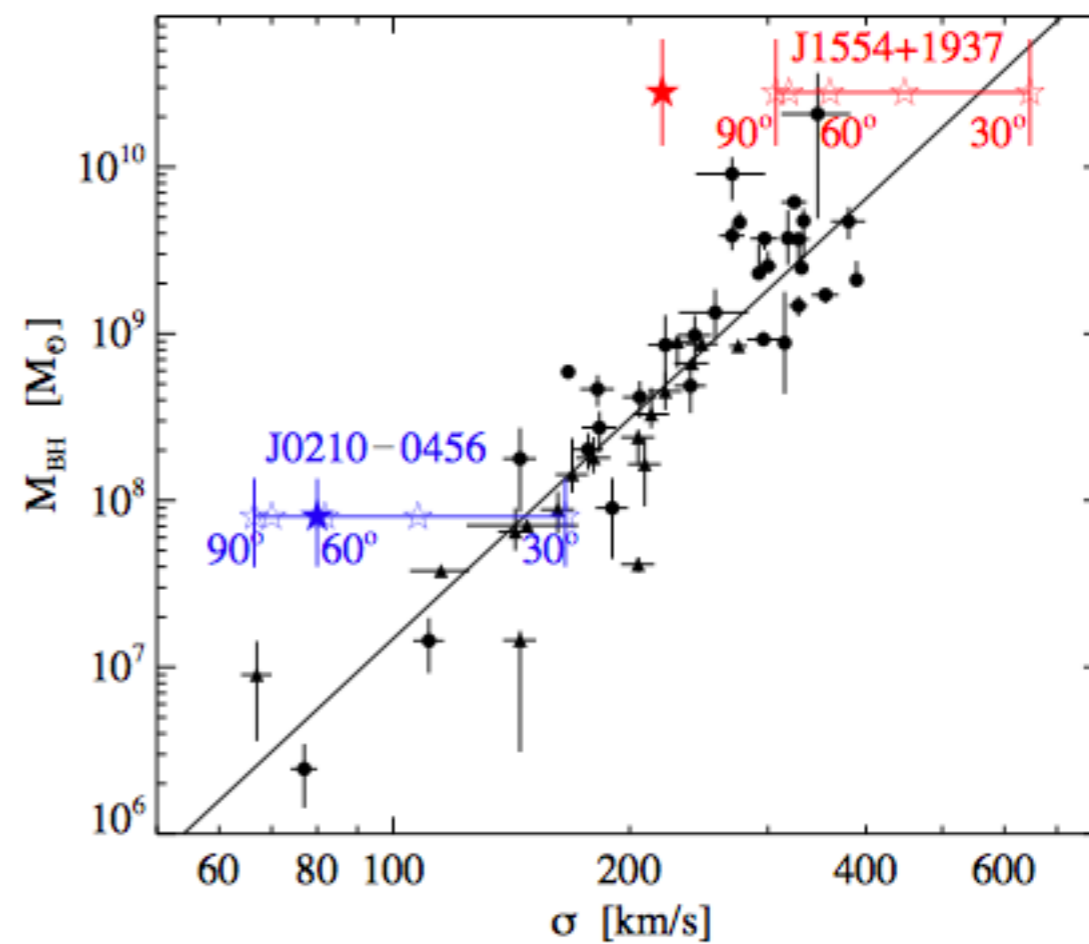
- ❖ Resolving the black hole radius of influence out to  $z \sim 0.1$ .
  - ❖ NGVLA will have resolution up to  $\sim 5$  mas, compared to the radius of influence of a black hole at  $z \sim 0.1$  of 30 mas. Complementary to TMT in situations where nuclei are heavily obscured by dust.
- ❖ Detailed dynamics of outflows of molecular gas
  - ❖ Feedback
  - ❖ Merger vs secular hosts
  - ❖ M-sigma
  - ❖ Complementary to TMT's ability with ionized gas outflow.

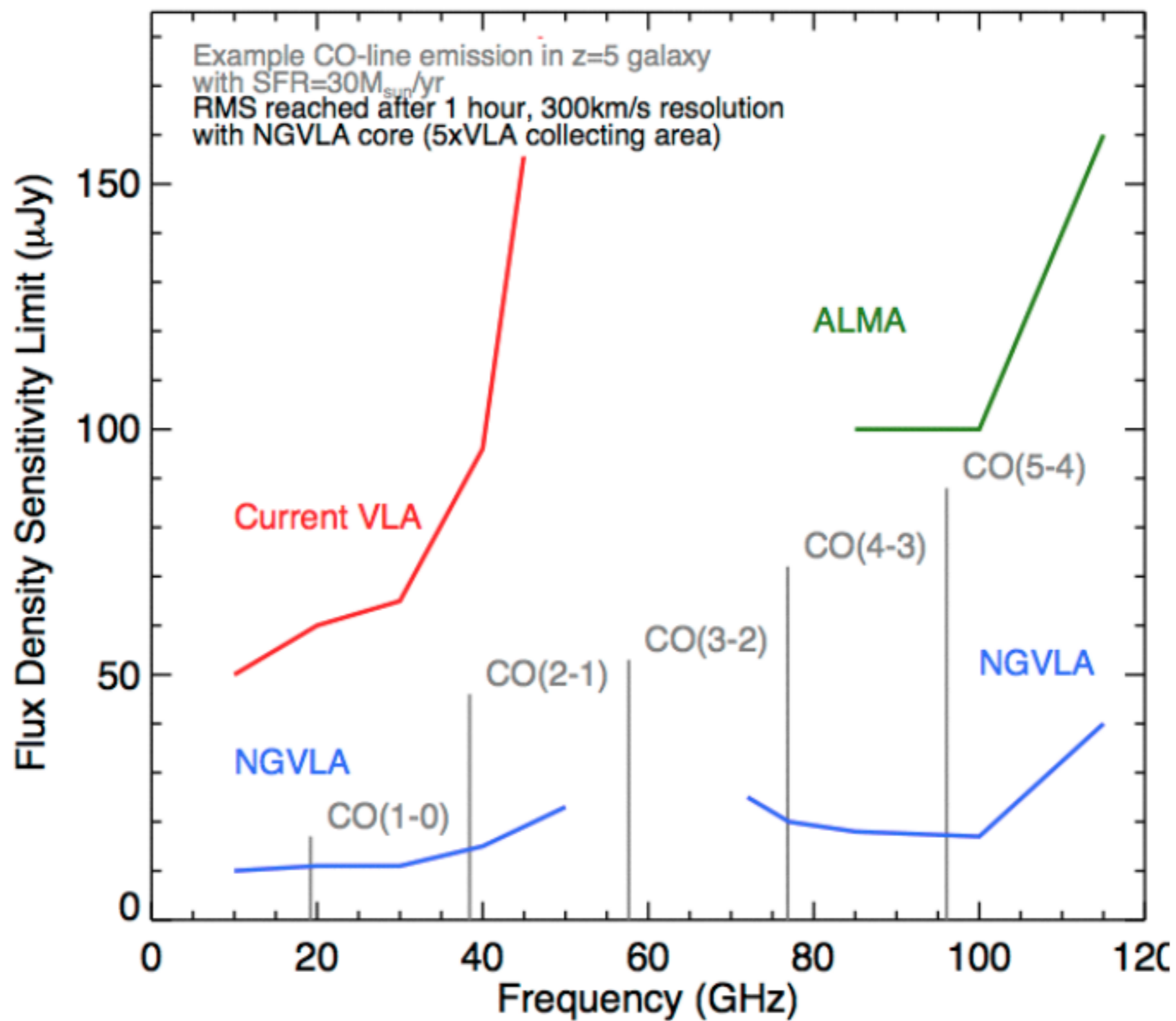


Davis et al. 2013, Nat, 494, 328 (CARMA),  
NGC4526 (16.4 Mpc)

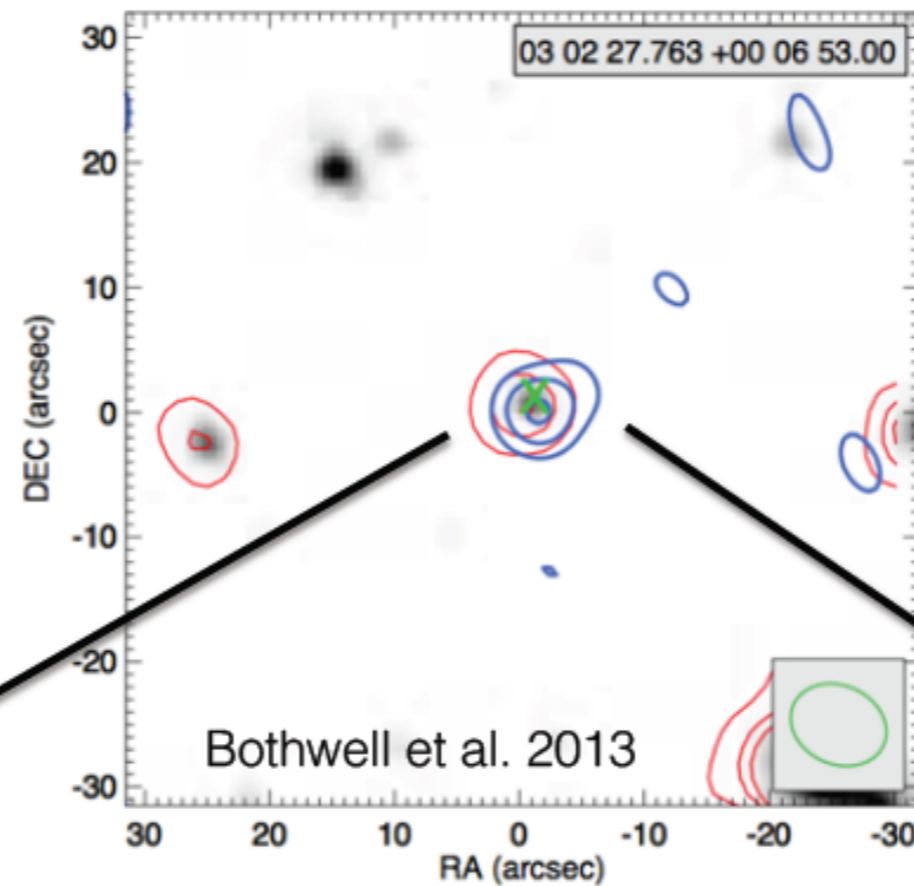


Kimball et al. 2015





# Dynamics



Merger?

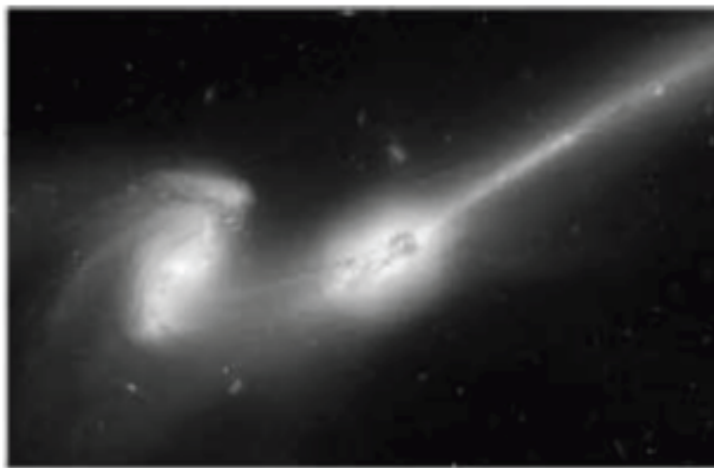


Image credit: NOAO/AURA/NSF

Disk?

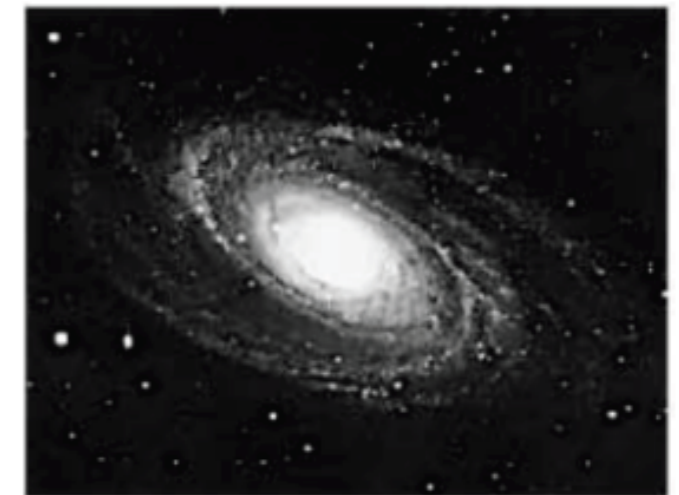


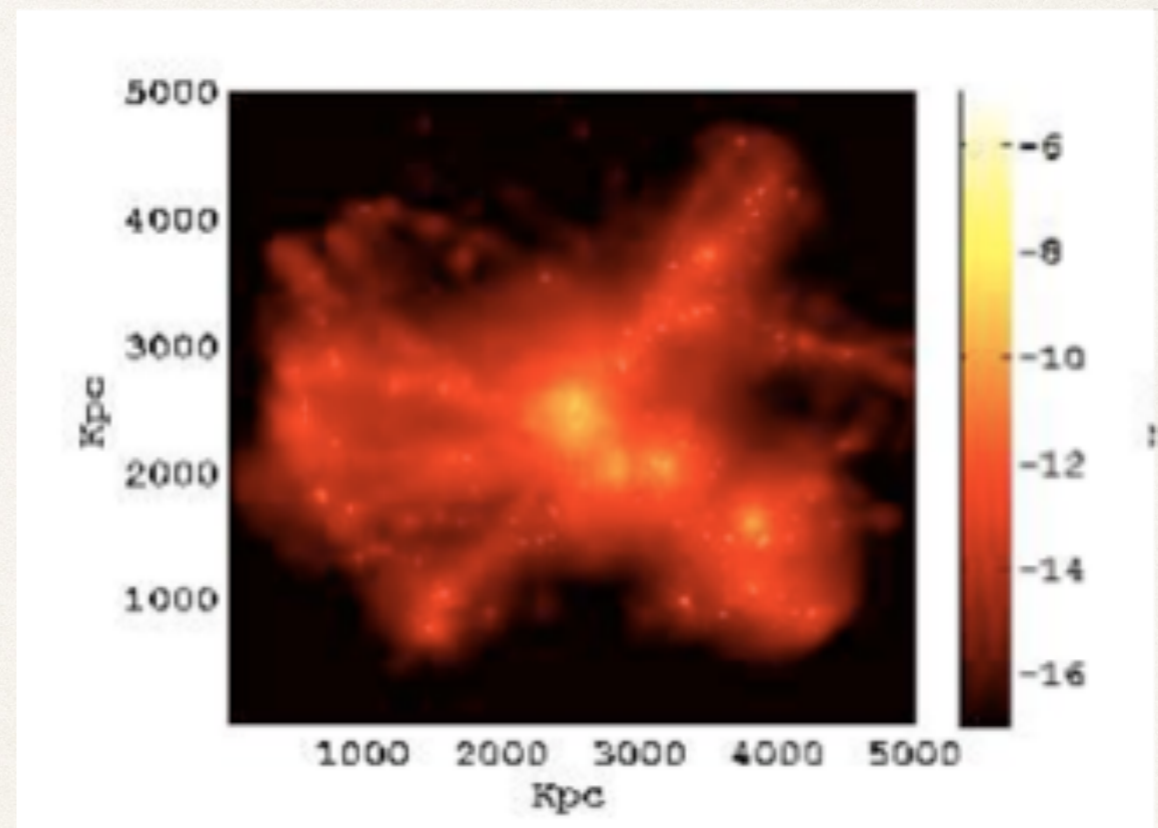
Image credit: NASA/STScI/ACS  
ScienceTeam

A Next Generation VLA  
is needed to reveal the  
morphology and  
dynamics of high- $z$   
galaxies

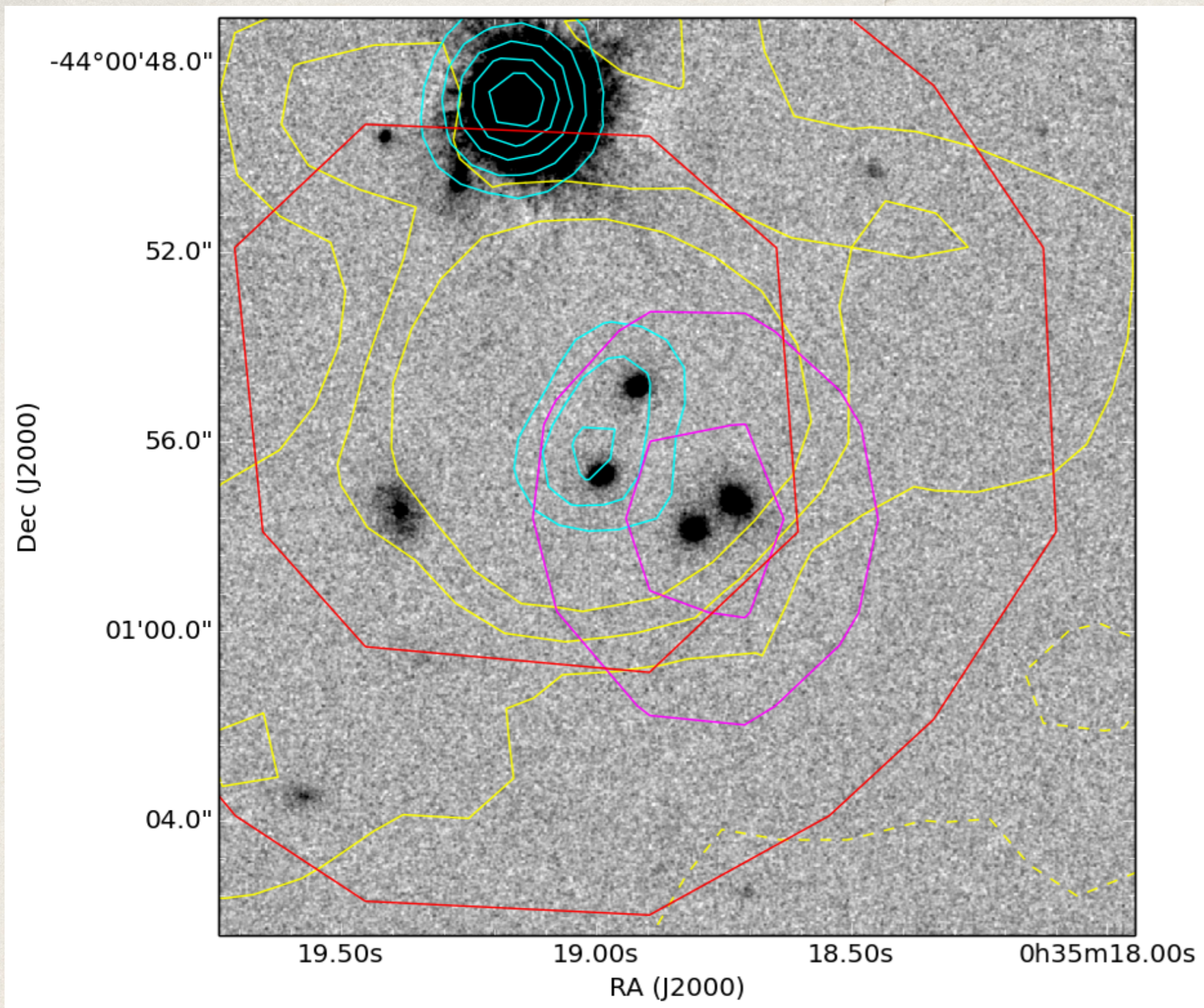
# Continuum

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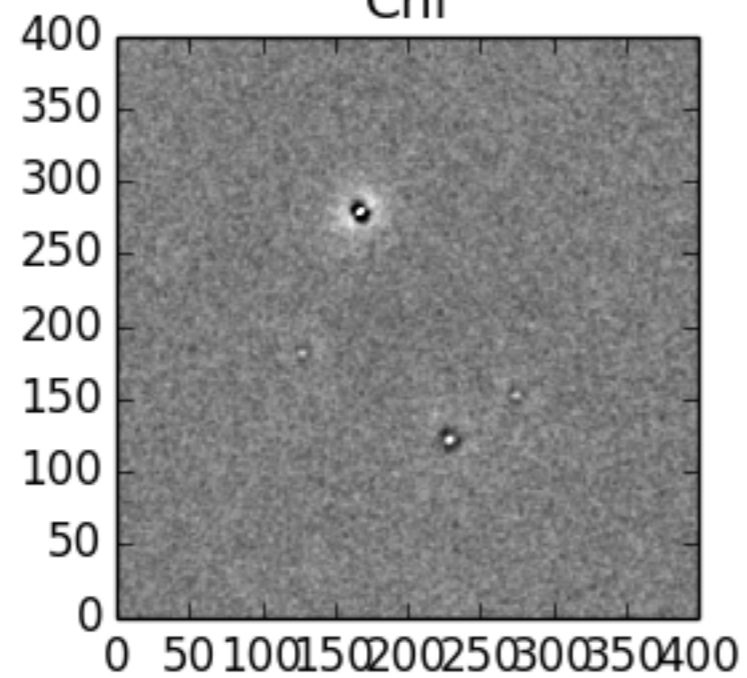
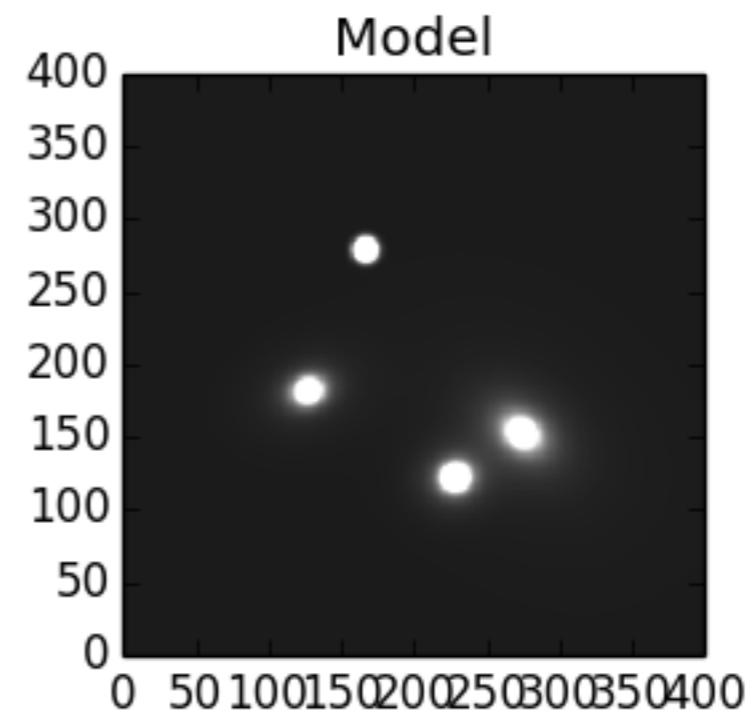
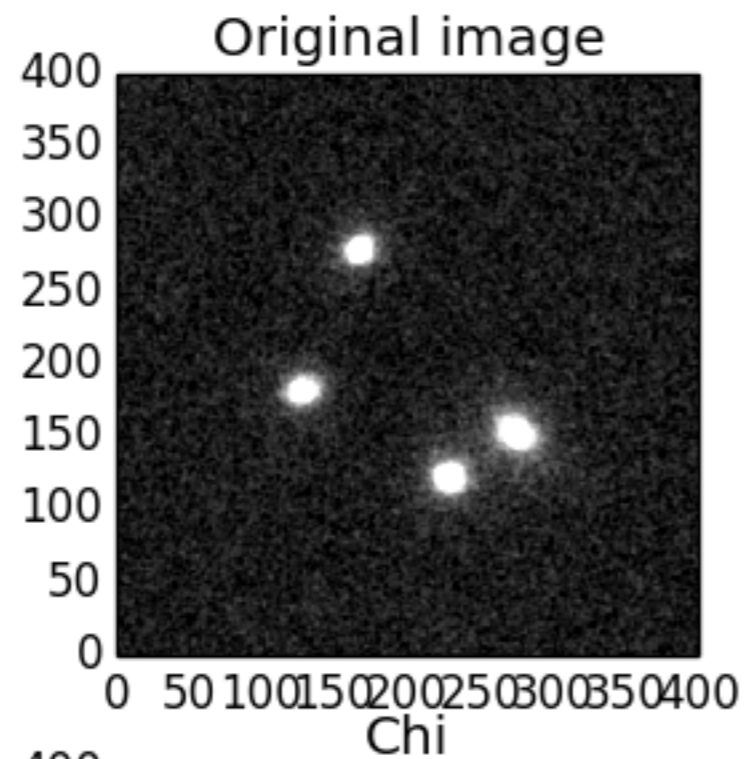
- ❖ Synchrotron and free-free emission from quasar hosts
- ❖ AGN multiplicity
- ❖ SZ effect from outflows - one of the few ways of seeing the hot wind.



Chatterjee et al. 2008



Herschel - red  
Spitzer 24μm - yellow  
Spitzer 8μm - cyan  
Radio (ATCA) - magenta



Modeled using Tractor  
(Lang & Hogg 2014)

# Complementarity to TMT

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- ❖ NGVLA in the GHz radio regime will be the perfect complement to TMT in the optical / near-IR
- ❖ Resolution will be similar, allowing comparisons of molecular and atomic gas distributions and dynamics.
- ❖ Both are in the Northern Hemisphere, allowing optimal low airmass / low elevation observations in both the near-IR (good for laser AO) and the synthesized beam in the radio.

# Why can't ALMA or SKA do this?

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- ❖ ALMA has about half the collecting area of the current VLA, and is difficult to expand beyond its current site. It will always dominate at 1mm and shorter wavelengths, but will be inferior to the NGVLA for studies of lower excitation lines like CO 1-0 and 2-1, typical of the “normal” ISM in high redshift objects.
- ❖ SKA will be optimized for studies of HI (1.4GHz and lower), and its dishes will not work above 20GHz.

# How to get involved

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- ❖ There will be a series of workshops co-funded by AUI and the Kavli Foundation to discuss the next steps. The first of these is scheduled for 15-17th December 2015 in Chicago.
- ❖ Feel free to contact the chairs of the working groups to contribute to the science case:
  - ❖ Galaxy Assembly: Caitlin Casey, Jackie Hodge, Mark Lacy
  - ❖ Galaxy Ecosystems: Adam Leroy, Eric Murphy
  - ❖ Cradle of Life: Andrea Isella, Arielle Moullet, Chat Hull
  - ❖ Time domain / Cosmology / Physics: Geoff Bower, Paul Demorest