Measuring AGN & Starburst Wind Properties with ALMA and the ngVLA

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The Sunyaev-Zeldovich (SZ) effect is one of the few ways to constrain the energetically-dominant hot component of winds from AGN and starbursts. Studies of stacked data from Planck and ground-based mm/submm single dish telescopes have found significant detections of SZ from quasars (e.g. Chatterjee et al. 2010; Ruan et al. 2015), but contamination from other phenomena are hard to rule out given the large beams of single dishes. Direct detection of these winds is just feasible with observations with current facilities (VLA and ALMA), but with ngVLA we will be able to go beyond detections, and start to map the SZ effect around these objects.

Estimated magnitudes and scales

Rowe & Silk (2011) give estimates of the sizes and peak Compton y-parameters based on an simple analytic model for winds.

$$y_{\rm peak} = 1.13 \times 10^{-5} (L_{\rm W}/10^{12}{\rm L}_{\odot})^{3/5} (t/10^{7}{\rm yr})^{1/5} (1+z)^{6/5},$$

With a size of

$$R = 28.86\eta^{1/5} \left(\frac{M_{\odot}}{10^{3}{\rm M}_{\odot}{\rm yr}^{-1}}\right)^{1/5} \left(\frac{v_{\rm W}}{10^{3}{\rm kms}^{-1}}\right)^{2/5} \left(\frac{t}{10^{7}{\rm yr}}\right)^{3/5} (1+z)^{-3/5}{\rm kpc}$$

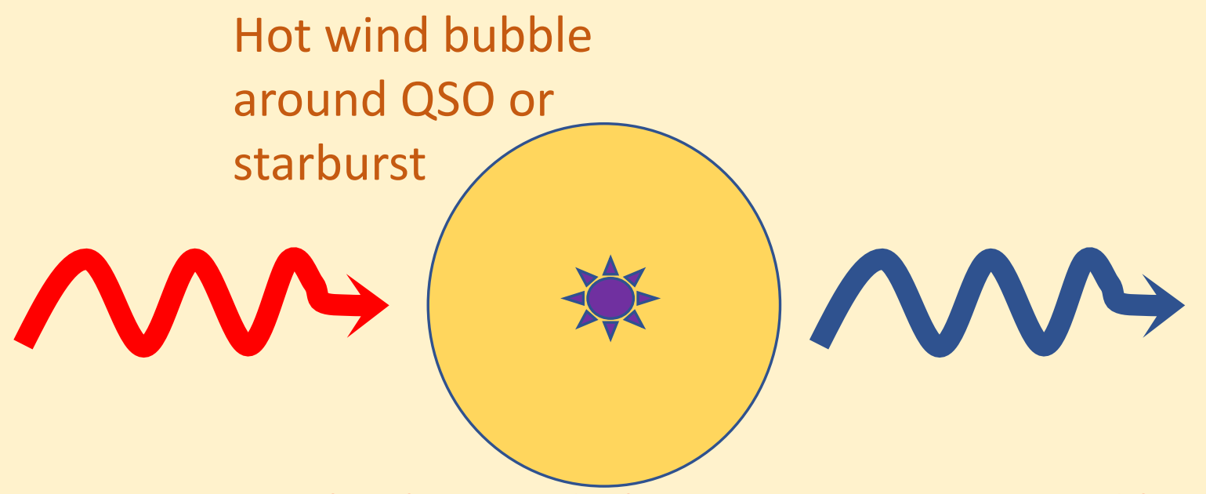
These analytic models do not account for multiple events during the history of the quasar. Chatterjee et al. (2008) use hydrodynamic simulations to show that these will build up the signal over time, especially on large (~100kpc) scales.

Constraints from ALMA observations of HE0515-4414

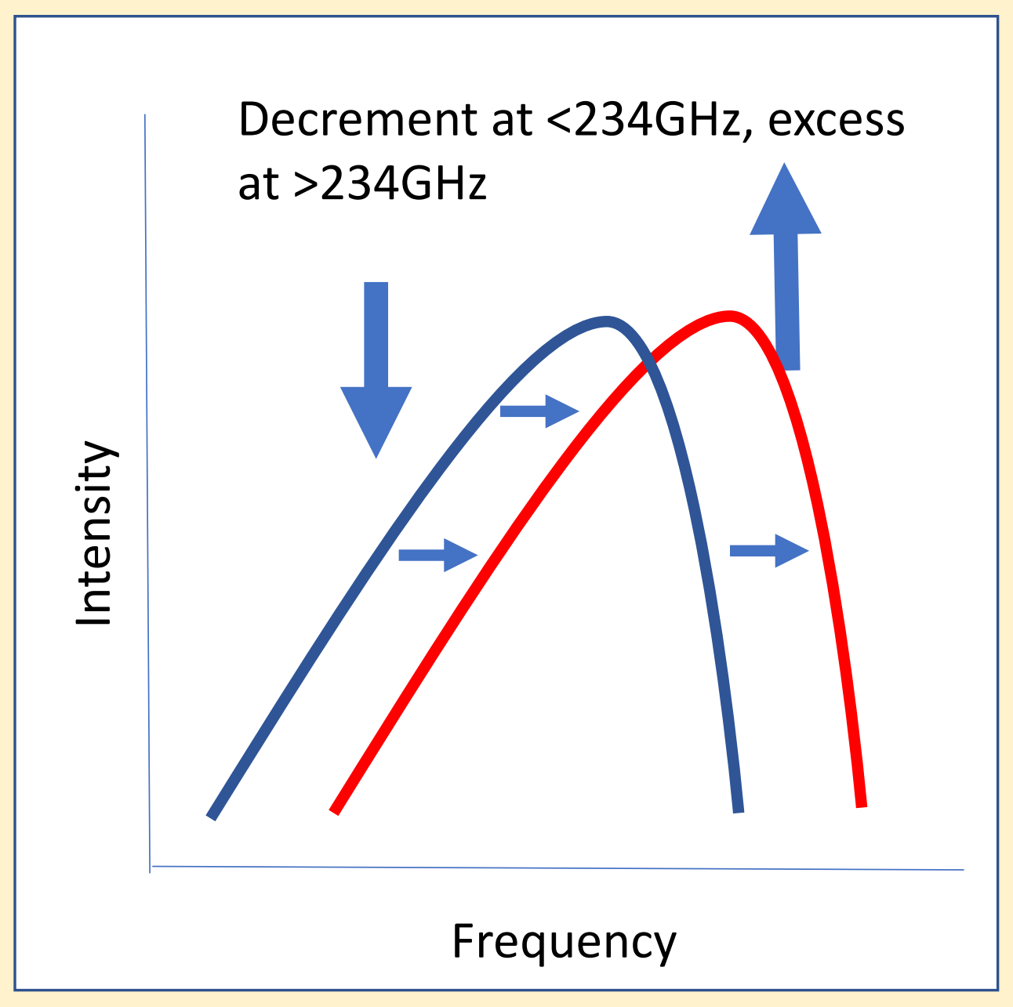
In ALMA program 2016.1.00309.S we obtained 12.4hr of on-source integration at 140GHz on the luminous quasar HE0515-4414. The quasar is detected as a 70μJy point source which was removed from the visibilities before the field was reimaged with a beam tapered to 6.5”. Our *preliminary* result is a tentative detection (3.5σ) of an SZ decrement to the SW of the quasar. Follow-up imaging with Spitzer (PID 13221) and Gemini (GS-2017B-FT-12) show no evidence of any dense cluster of galaxies around the quasar that could contaminate the SZ signal.

The SZ signal is consistent with a wind of a fewx10^{-3} of the bolometric luminosity of the quasar, on the low end of predictions.

The SZ effect from winds

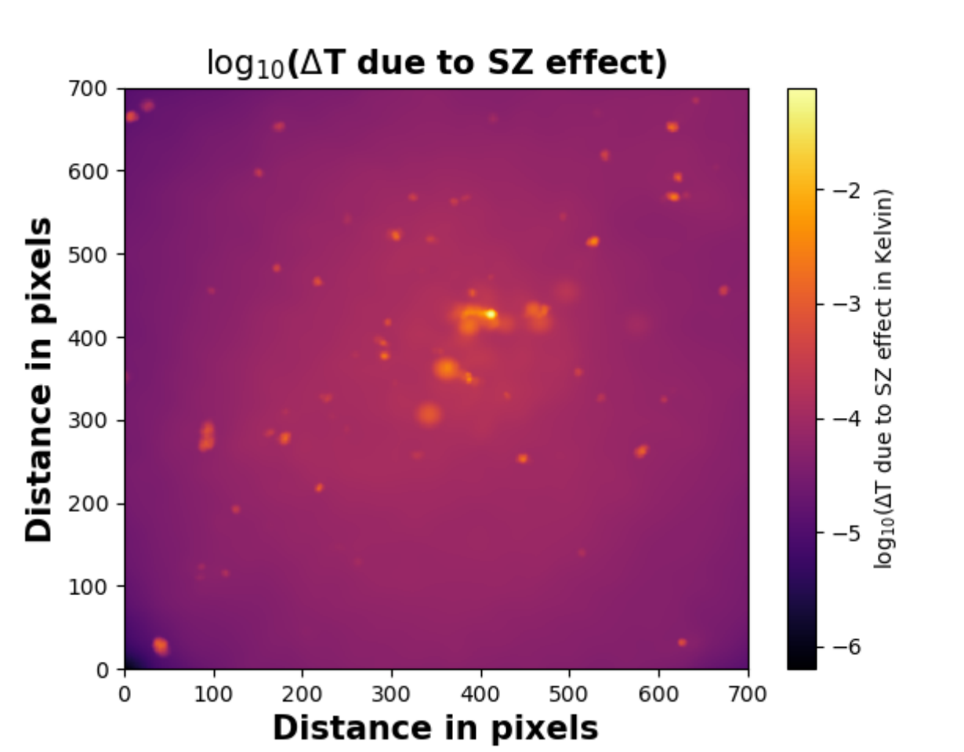


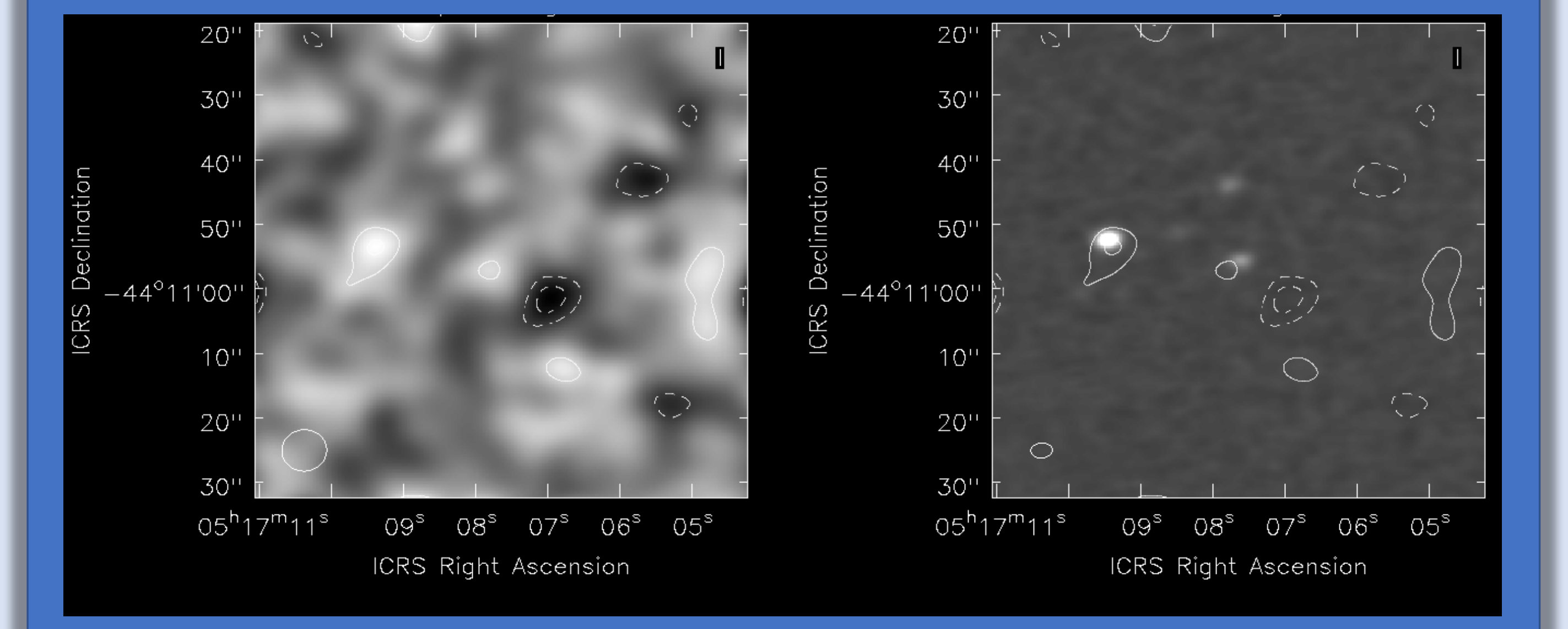
Microwave background photons are upscattered by interaction with hot electrons

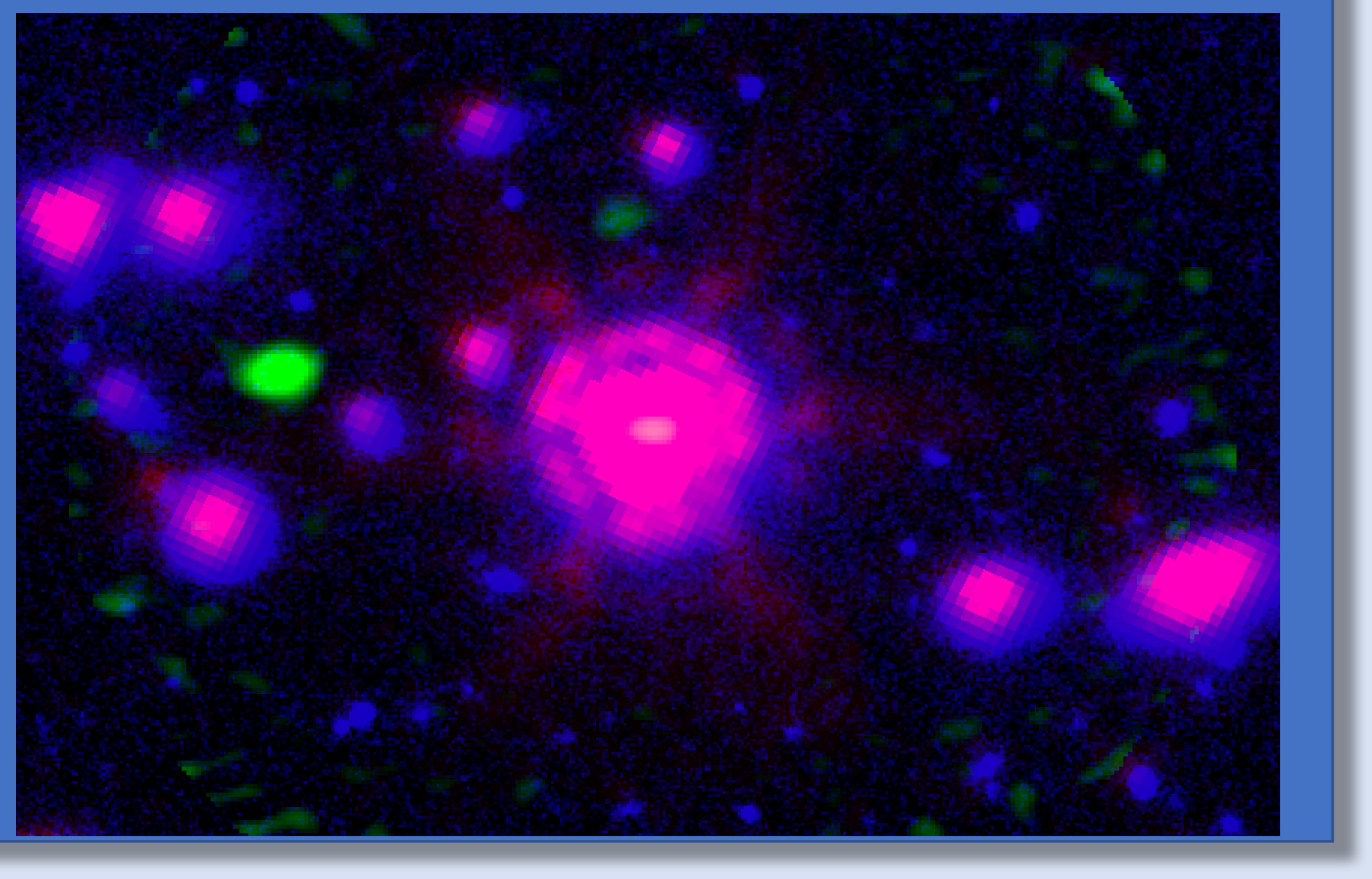


Simulations

Right: simulated SZ signal using the hydrodynamic simulations of Khandai et al. (2015). The central object is a quasar with a luminosity of 3×10^{11} L$_{\odot}$. Each pixel is 0.14kpc in size.







Top left – tapered ALMA image with 6.5” beam and contours at 2,3 -2 and -3σ, *top-right*, naturally-weighted image (3” beam) before point source subtraction of the quasar and field sources. *Right*: image of the field with the Spitzer 4.5μm image in red, ALMA image in green and GMOS Z-band image in blue.

Observability with ALMA and the ngVLA

ALMA can just detect a strong wind from very luminous quasars. It can also observe near the peak of the decrement at 130GHz. For a very luminous quasar with a strong wind (L_W ~ 0.01 L_{bol}~10^{13} L$_{\odot}$) the peak y~2×10^{-4} and the corresponding SZ decrement ~400μK, this is detectable with a matched (~6”) beam in ~10 hours of observation with ALMA (see below/left).

With ngVLA we will need to taper the beam to include only the inner core. The RMS sensitivity in 1hr with a 1-arcsec beam is estimated to be ~300μK at 100GHz (Selina & Murphy 2017), compared to a signal ~600μK. Even greater brightness temperature sensitivity could be gained by further tapering to the scale size of the emission. Thus a detection could be made in ~1hr.

Besides the greater sensitivity, the ngVLA has an important advantage in that the longer baselines can be used to image any radio continuum emission from the quasar or starburst that could contaminate the SZ signal. The longer baseline observations can be used to make a source model that can be subtracted from the data before making the tapered low resolution observation that is optimized for the SZ detection, without needing a second epoch observation in a larger configuration (which might be affected by variability)

References:

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