A magnified view of the ISM and star formation in a strongly lensed AGN hosting SMG at z = 2.6

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Collaborators

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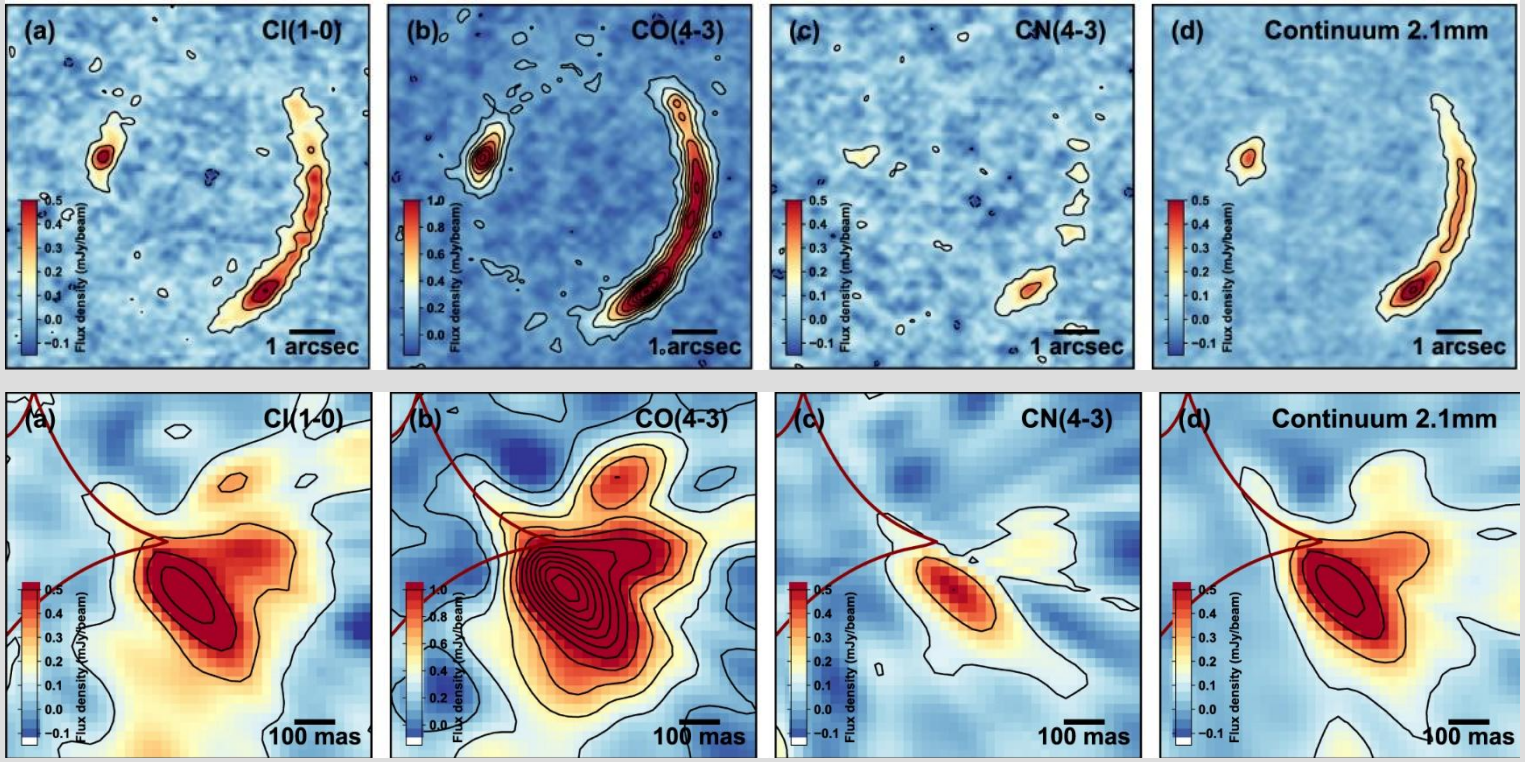
Outline

- Why this Galaxy?
- Previous Work: Integrated Properties and ALMA Band 4
- Current Work: [NII] doublet and Luminosity Map
- Future Work: Top heavy IMF?

Why this Galaxy?

It's Lensed!!!



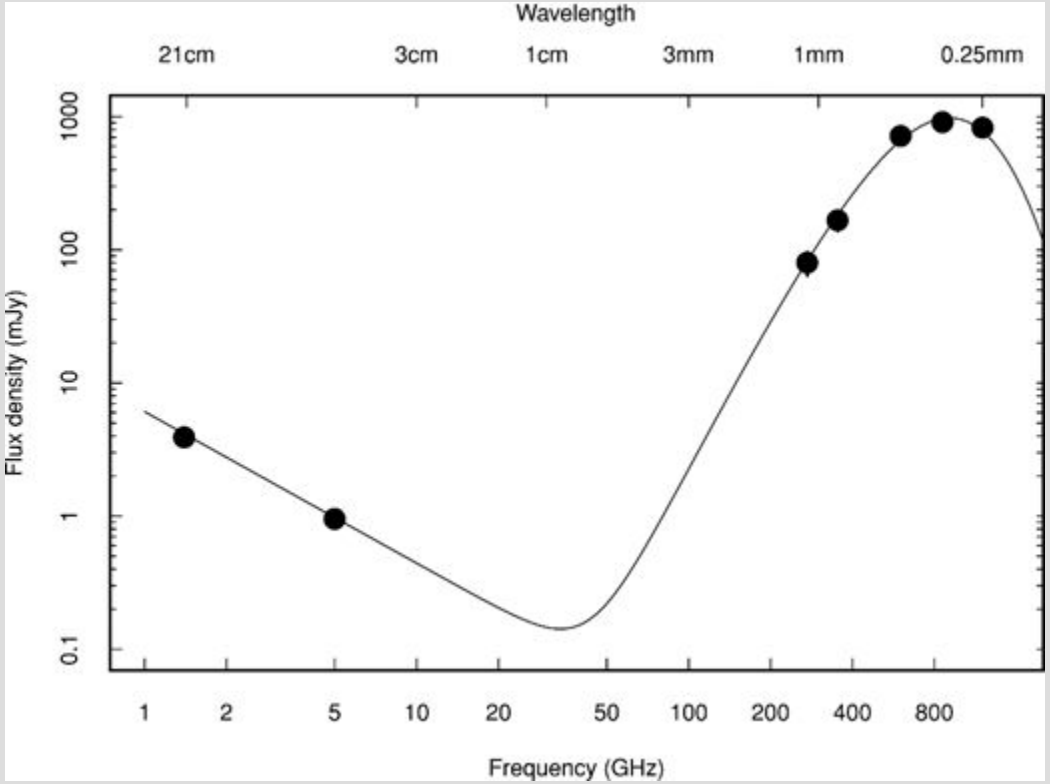
Credit: Geach et al. 2018

Why this Galaxy?

- It is an extreme galaxy with inferred SFR $> 1000\ M_{\odot} yr^{-1}$
- Hosts a radio loud AGN
- Magnification $\mu \approx 10$
- Perfect opportunity to study extreme Star formation in a AGN hosting galaxy $\sim 3Gyr$ after the Big Bang


iJK$_s$-band (CS82+VICS82)
5 asec

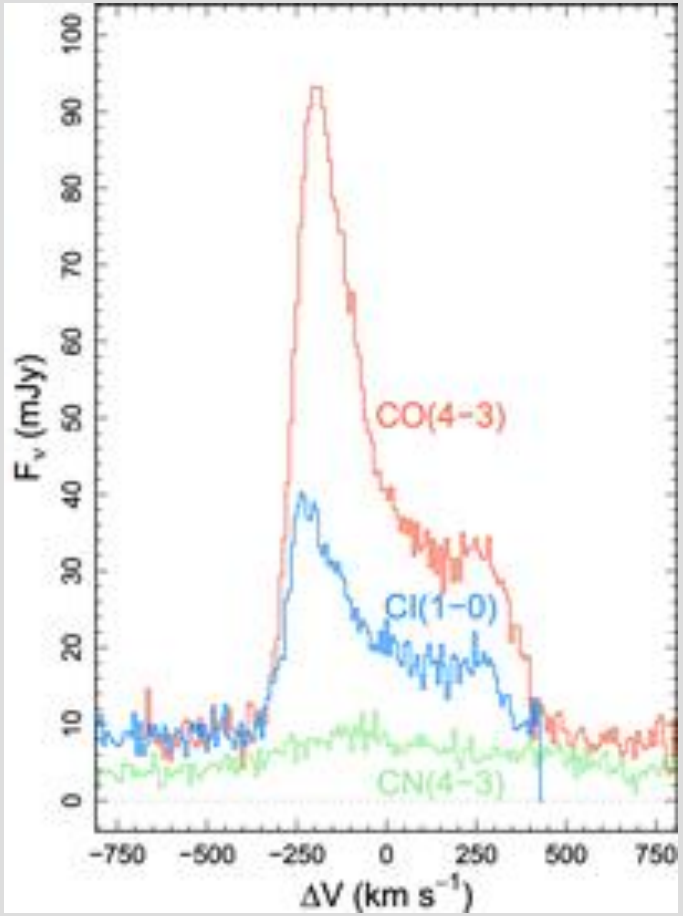
Previous Work: Integrated source properties



Credit: Geach et al. 2015

- It is incredibly bright SED peaking at ~1Jy
- Even in the source plane it has a luminosity of $L_{IR} \sim 10^{13}\ L_{\odot}$
- $q_{1.4GHz/L_{IR}} = 1.8 \pm 0.1$ not consistent with pure starburst where $\langle q \rangle \approx 2.5$ (Ivison et al. 2010)

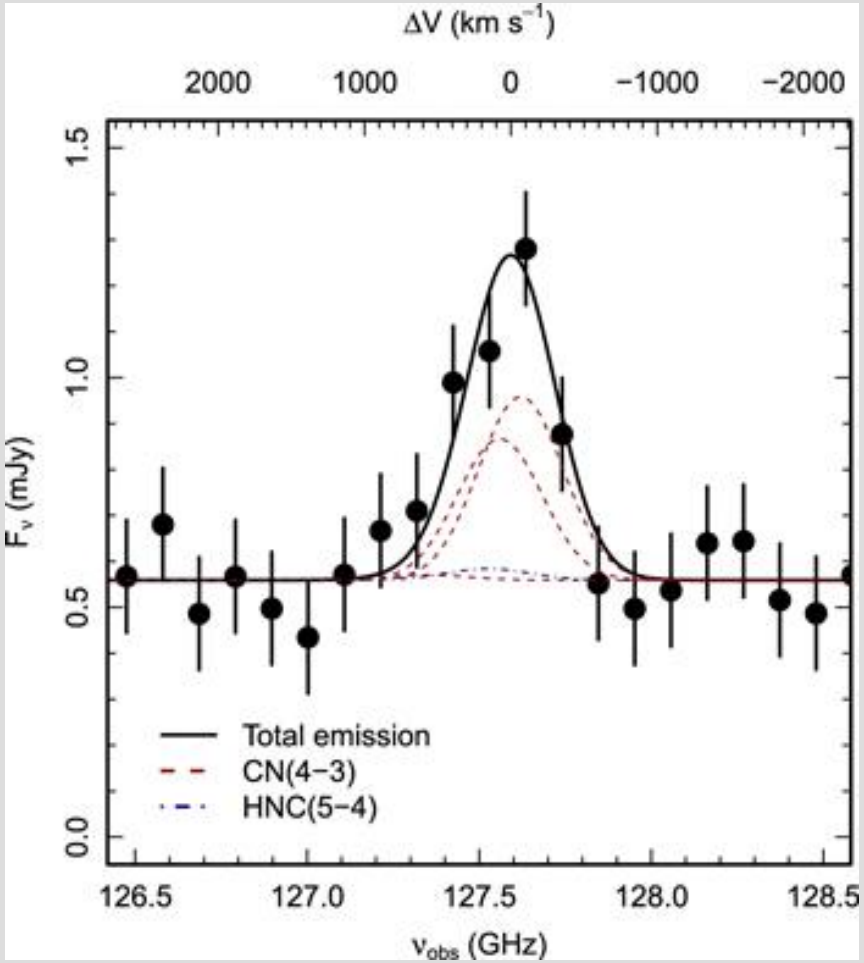
Previous Work: ALMA Band 4



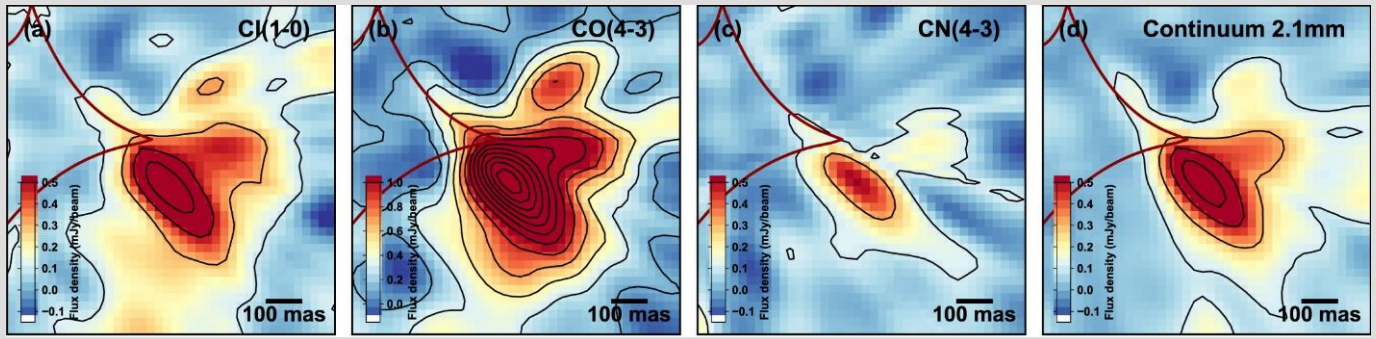
Credit: Geach et al. 2018

- The CO and CI have double horned profile
- H_2 gas mass derived from CI line luminosity: $M_{H_2} = 7.5 \times 10^{10} M_\odot$
- SFR from CO(4-3) and CI ≈ $2800\ M_\odot yr^{-1}$
- Gas depletion time scale $\sim 10s\ Myr$

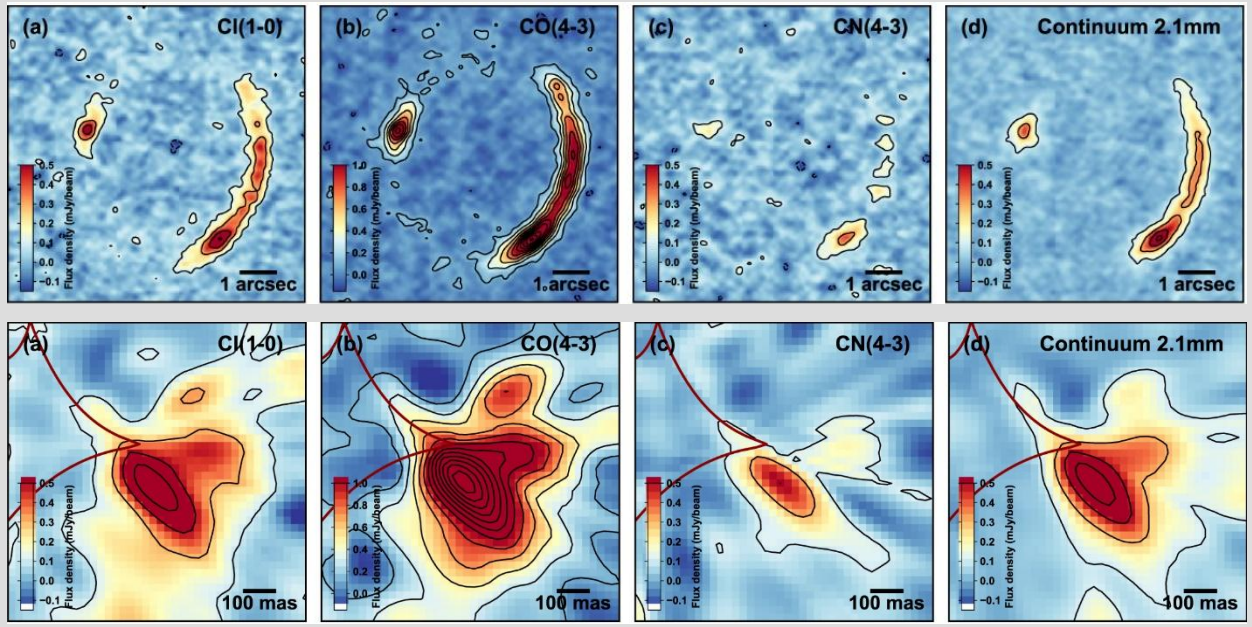
Previous Work: Possible Molecular Outflow?



- Broad emission feature FWHM 2x CO and CI (FWHM≈ 680kms^{-1})
- CN line emission more compact in source plane with ~80% flux unresolved (scales < 400pc)



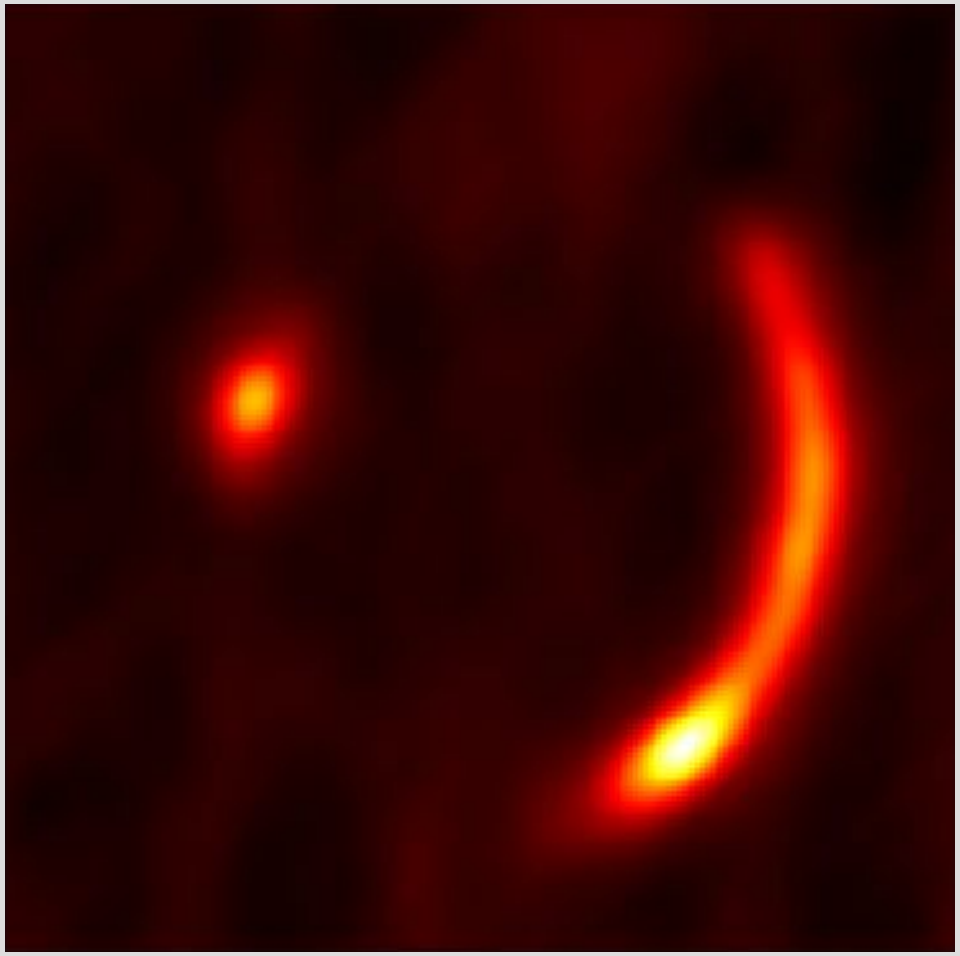
Previous Work: Possible Dense Molecular Outflow?



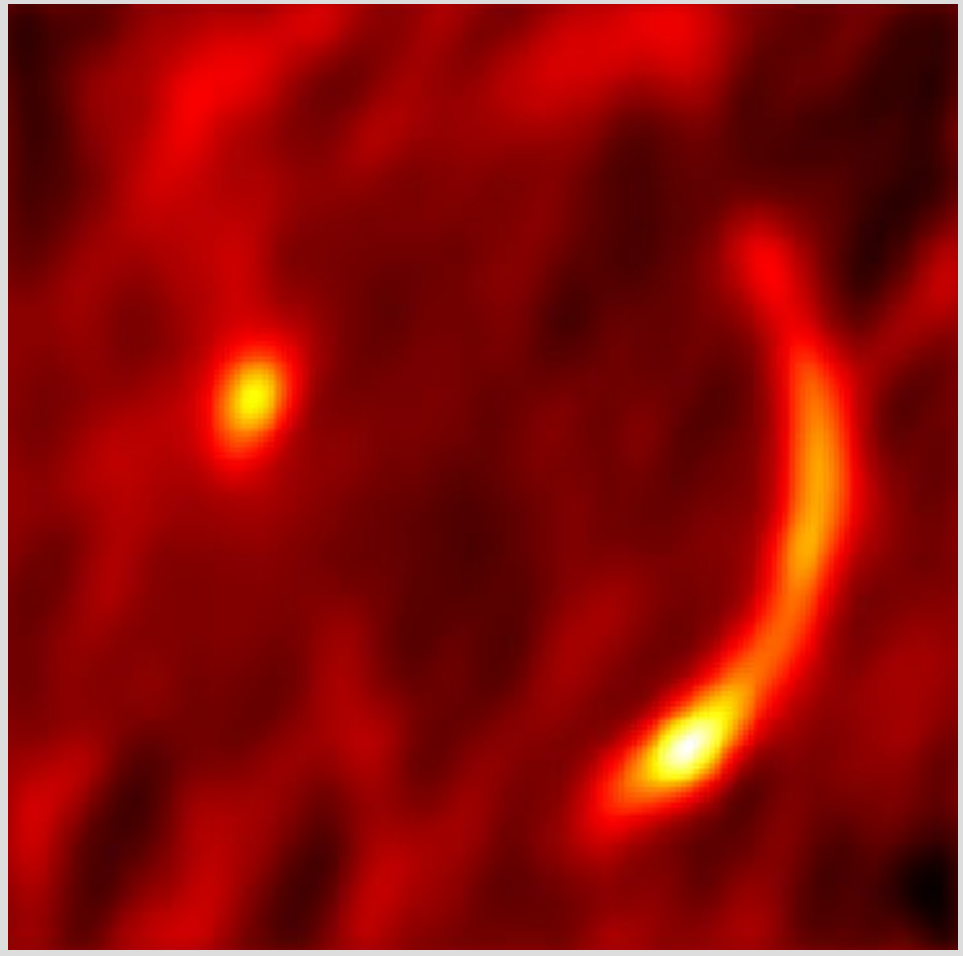
- CN does not appear to be tracing bulk of gas reservoir
- Possibly an outflow showing an interaction between AGN and molecular ring
- Gas exhaustion not quenching will result in 9io9 transitioning into a passive elliptical

Current Work: ALMA Bands 8 and 9

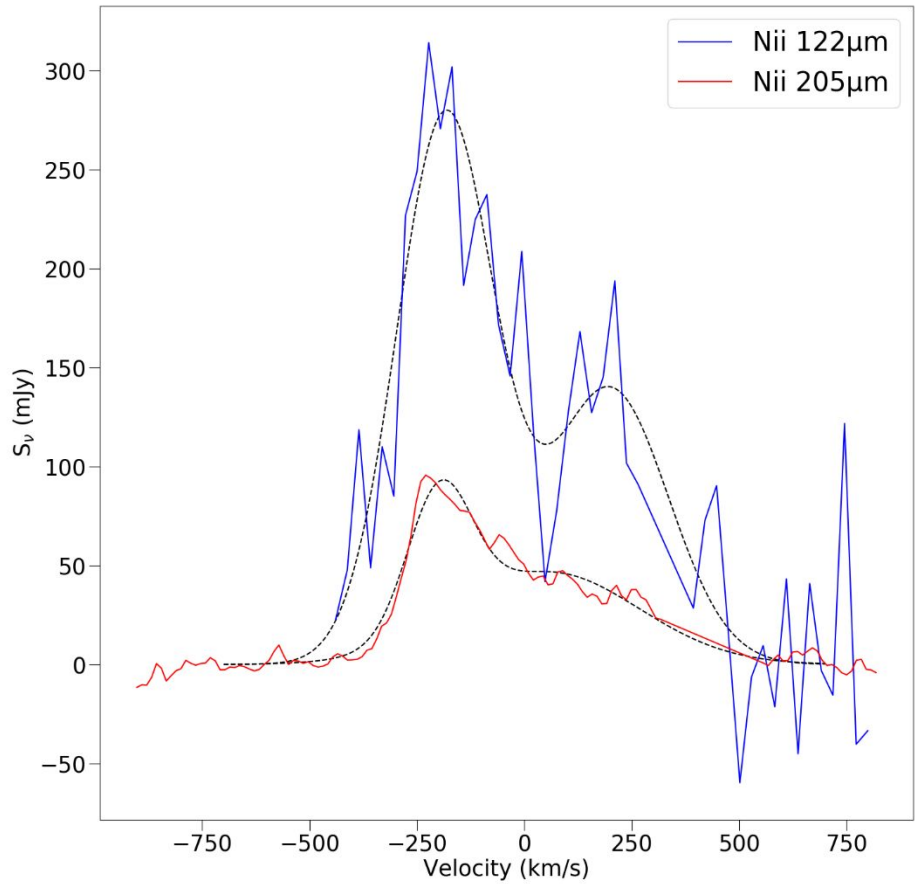
Band 8 ≈ 400GHz ≈ 0.75mm



Band 9 ≈ 680GHz ≈ 0.4mm

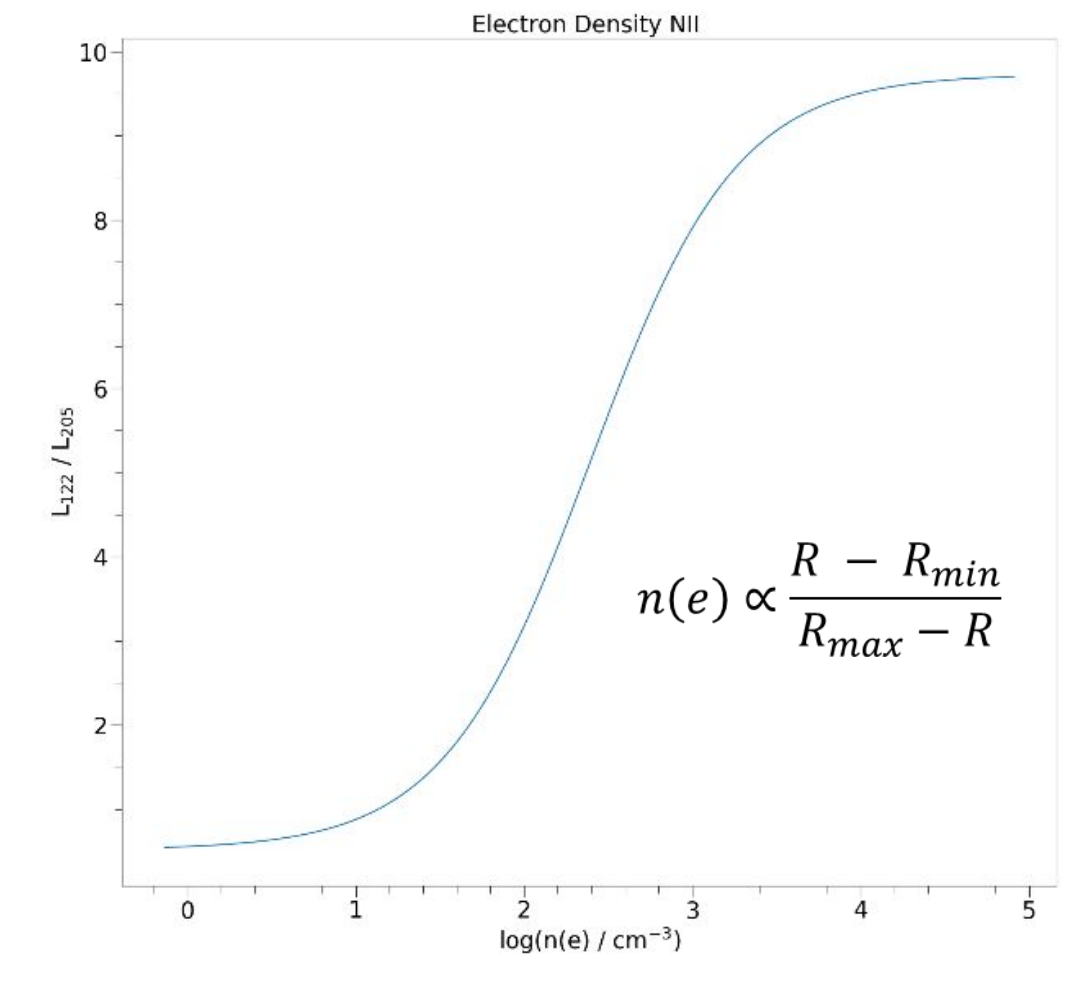


Current Work: [NII] Emission Lines and Electron density



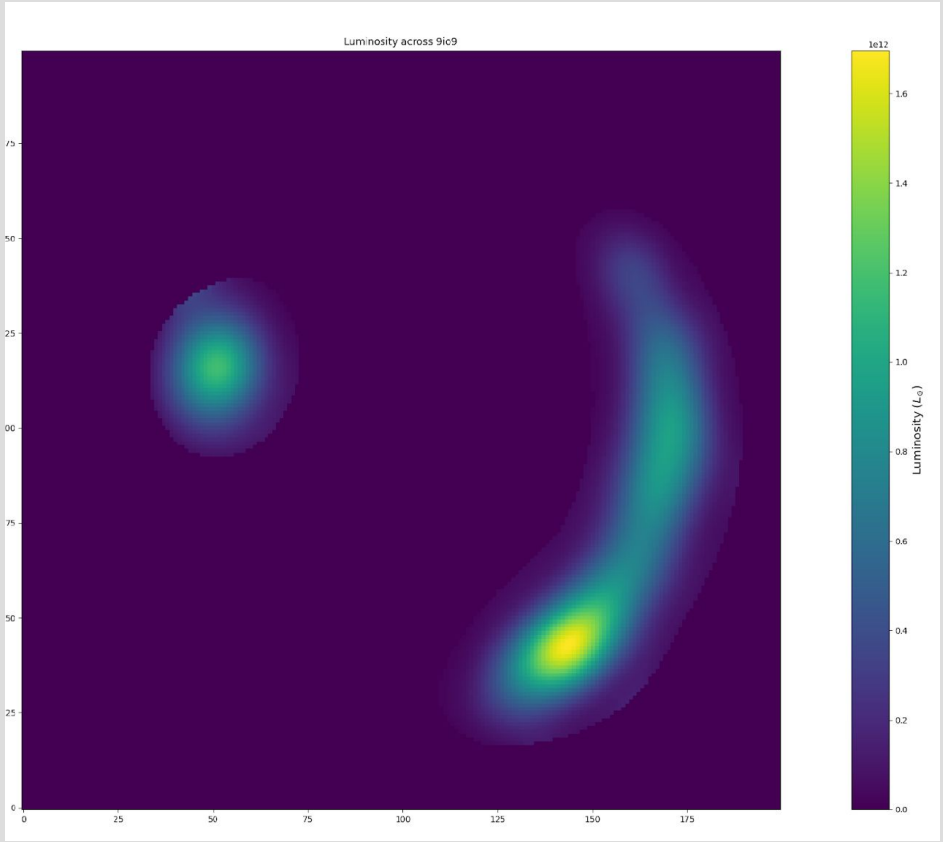
- Similar line profiles to CO and CI lines
- Ionisation potential 14.4eV so exclusively found within the ionised ISM
- $\mu L_{122} = 4.6 \times 10^{10} L_\odot$
- $\mu L_{205} = 7.8 \times 10^{9} L_\odot$

Current Work: [NII] Line ratio and electron density



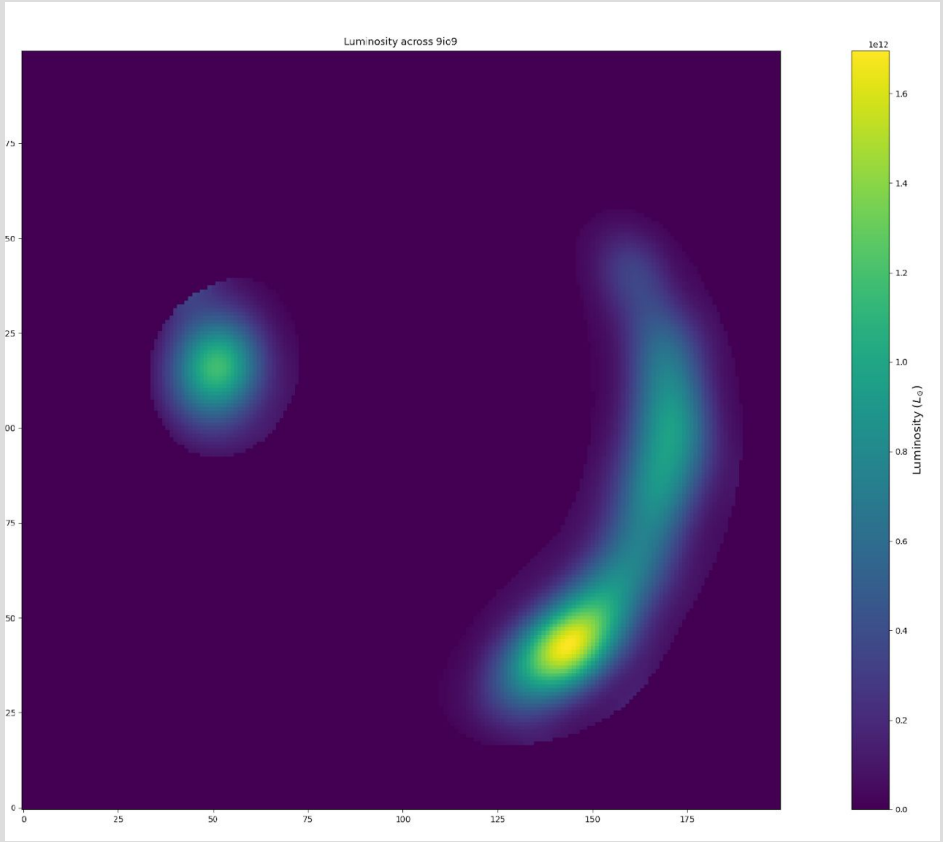
- Electron density can tell us about the density and pressure of ionized ISM
- [NII] doublet is a good tracer for n(e) between $\sim 10 - 1000\ cm^{-3}$
- We obtain a value for 9io9 of n(e) $\approx 340 cm^{-3}$
- Shimakawa et al. 2015 found n(e) $= 291 cm^{-3}$ for median SFR $\approx 100 M_{\odot} yr^{-1}$ using [OII] doublet

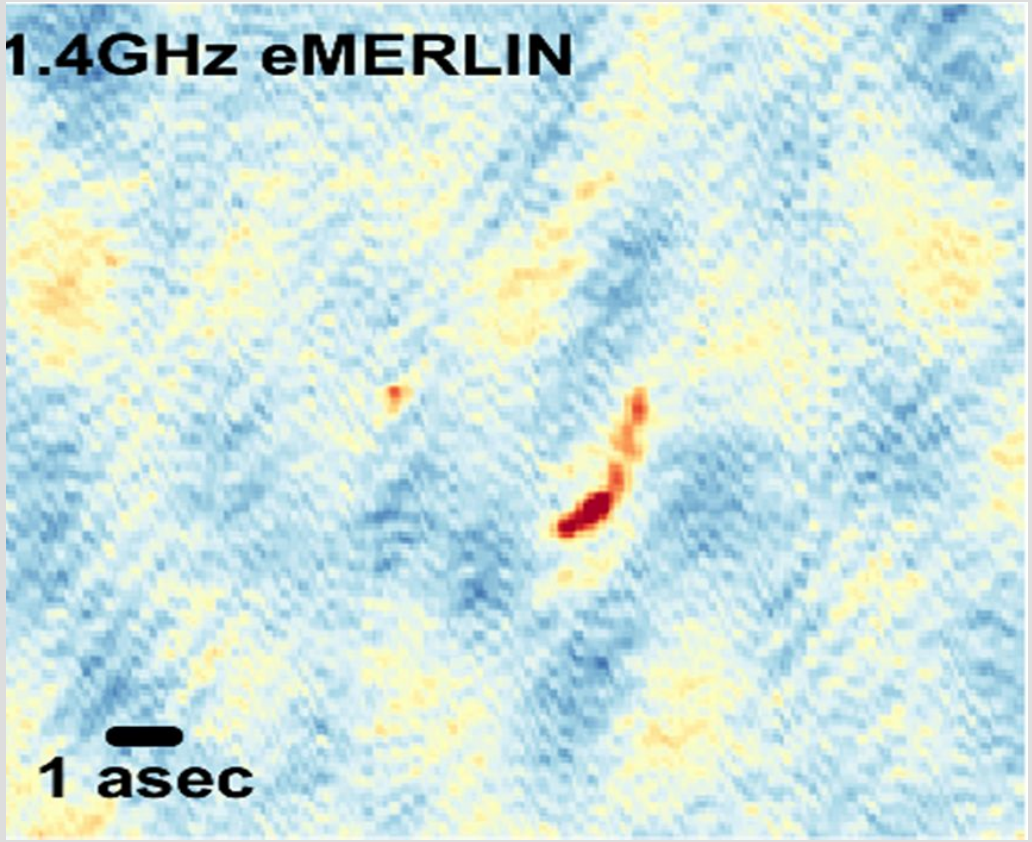
Current Work: Luminosity Map and SFR



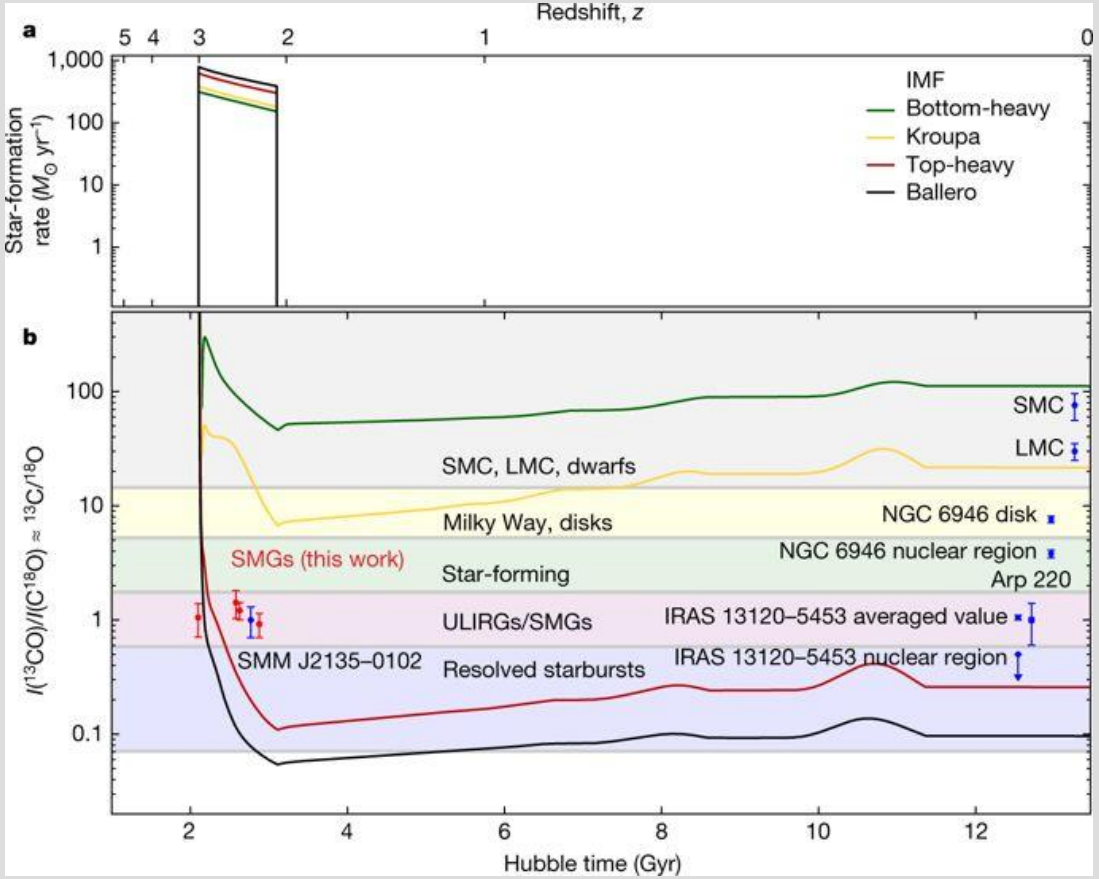
- Two ‘bulbs’ correspond to the AGN in the source plane.
- Integrated $\mu L_{IR} \approx 1.4 \times 10^{14} L_\odot$
- Source integrated SFR $\approx 2000\ M_\odot yr^{-1}$ (assuming $\mu \approx 10$ and no AGN contamination)
- Even allowing for 50% AGN component gives SFR $\approx 1000 M_\odot yr^{-1}$

Current Work: Luminosity Map and SFR





Future Work: Top heavy IMF?



Credit: Zhang et al. 2018

- IMF not well constrained in the high-z universe
- Looking at the CO(5-4) transition along with its isotopologues ($C^{18}O$ and ^{13}CO)
- ^{13}CO/ $C^{18}O$ ratio can be used to indirectly probe the IMF (Zhang et al. 2018)
- Galaxy resolved, should be able to probe the ratio across the source.

Conclusions

- Inferred SFR $> 1000 M_{\odot} yr^{-1}$ even accounting for AGN

- SFR leads to gas consumption time scales on order of 10s Myr (assuming standard IMF), AGN powerless to stop it

- The possibility of a top heavy IMF could explain the observations and would bring down SFR by a factor of 6/7

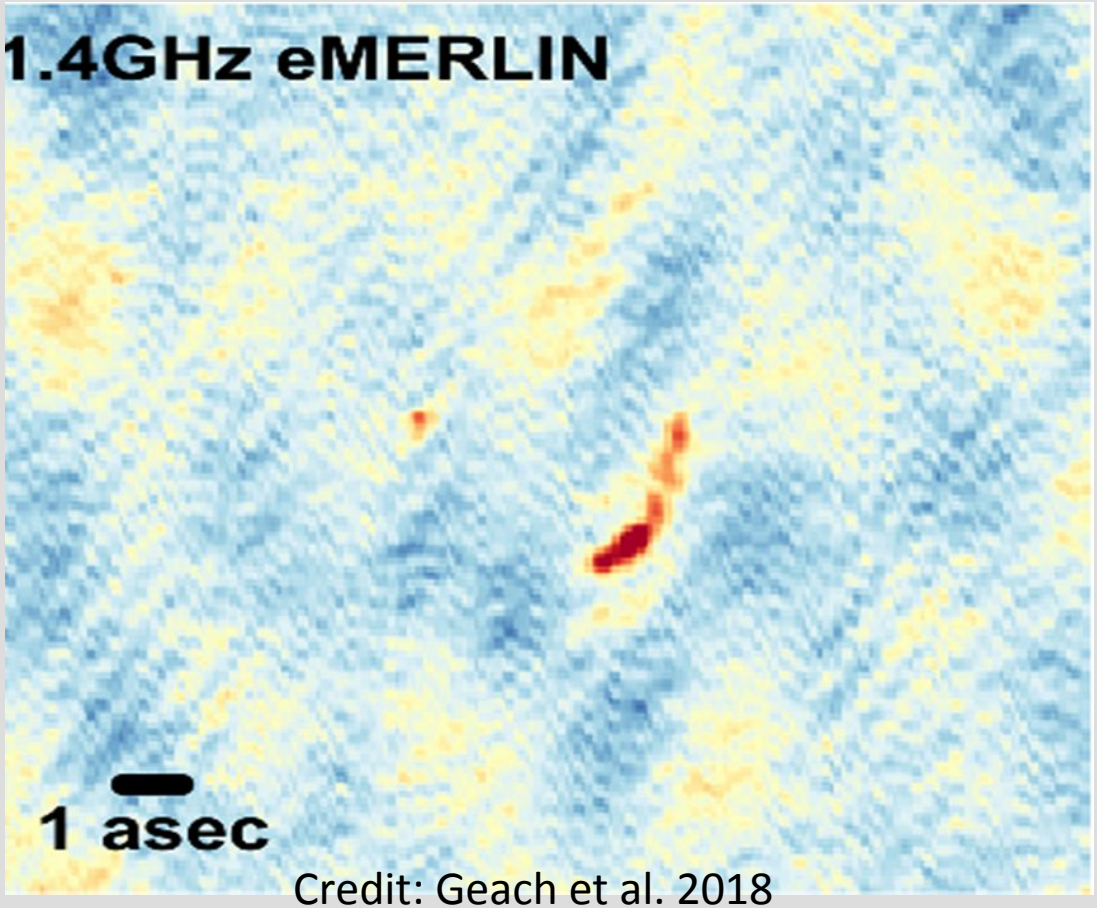
- n(e) $\approx 340 cm^{-3}$ far higher than values in the local universe n(e) $\approx 20 cm^{-3}$ probably due to intense nature of the starburst.

Extra slides

- $L_{IR} \approx 1.3 \times 10^{13} L_{\odot}$, corresponding to SFR $\approx 1900 M_{\odot} yr^{-1}$

- Allowing for 40% AGN correction still $> 1000 M_{\odot} yr^{-1}$

Current Work: AGN contribution to SFR



Credit: Geach et al. 2018

- By comparing q ratio across the source, should be able to determine AGNs sphere of influence

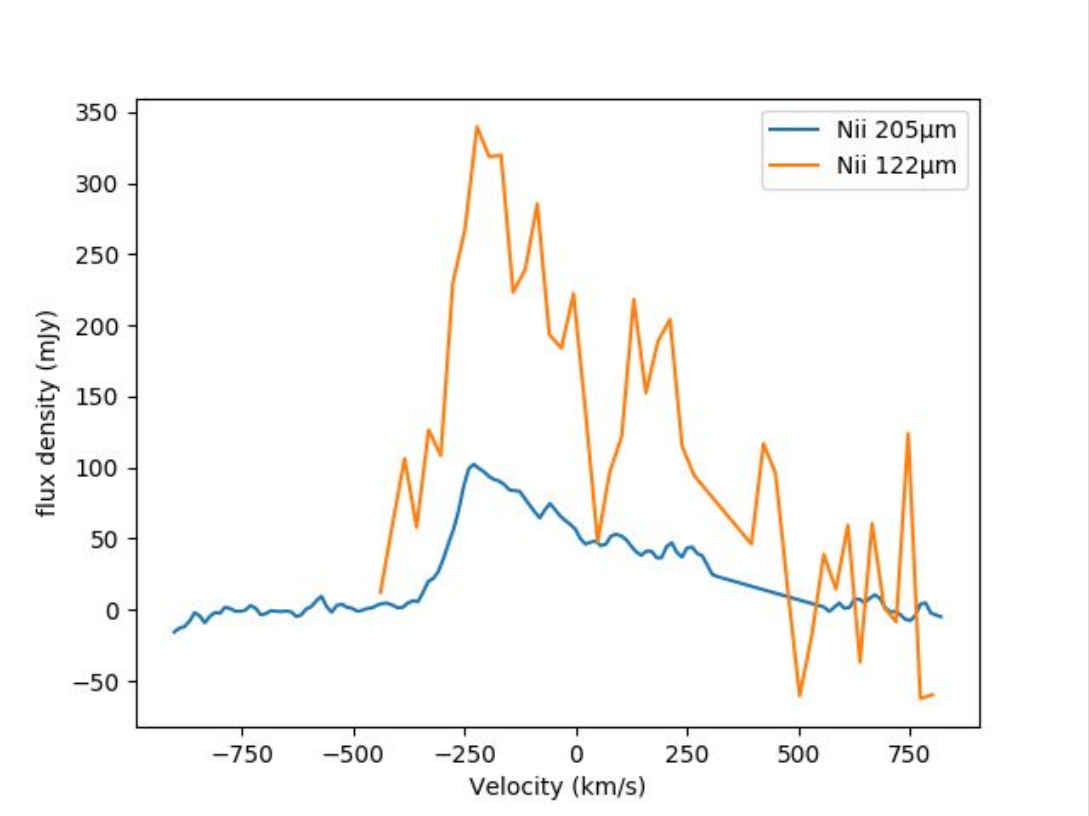
Temperature map and Luminosity

- Temperature increase around The AGN
- Likely result of AGN heating dust

Future Work:

- Looking at the CO(5-4) transition along with its isotopologues ($C^{18}O$ and ^{13}CO)
- $C^{18}O$/ ^{13}CO ratio can be used to indirectly probe the IMF (Zhang et al. 2018)
- Galaxy resolved, should be able to probe the ratio across the source.
- Isotopologues can also be used to probe optical depth of ^{12}CO

Current Work: NII Emission Lines and Electron density



- Similar line profiles to CO and C_I lines
- Fit both lines with a two component Gaussian
- $\mu L_{122} = 4.6 \times 10^{10} L_{\odot}$
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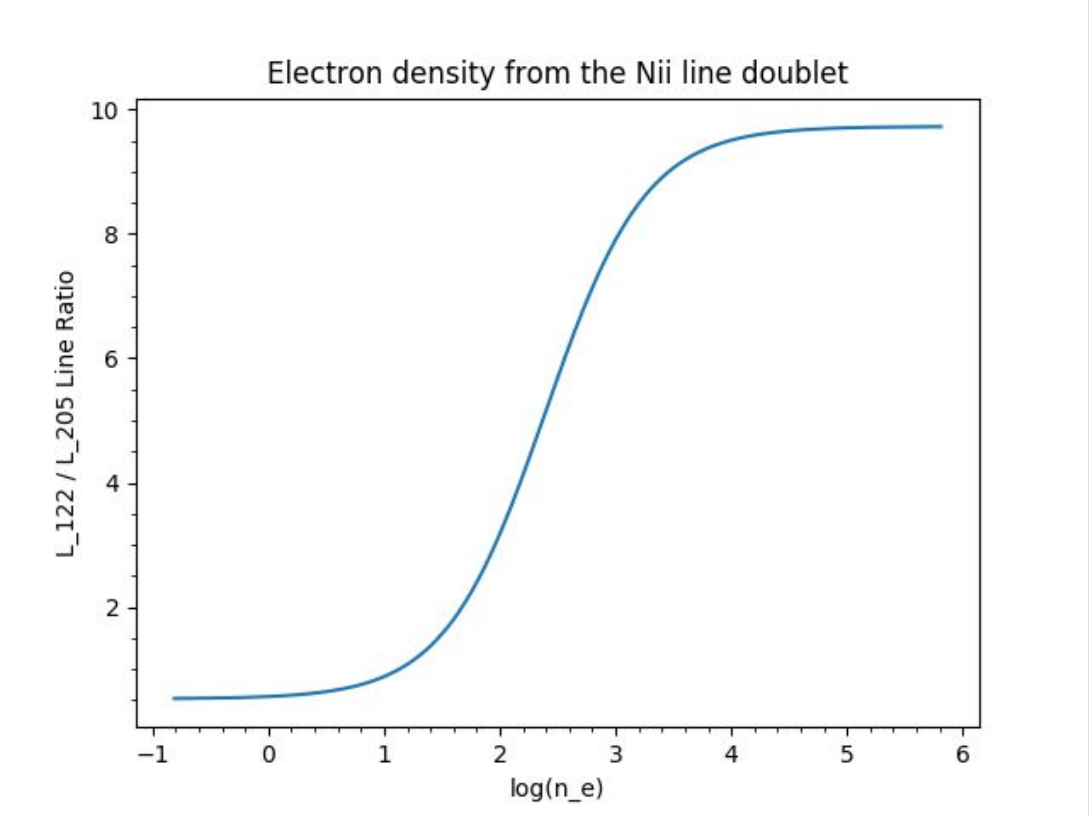
Current Work: NII Line ratio and electron density



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