Millimeter Interferometry: Radio Quiet Quasars and Galaxy Evolution

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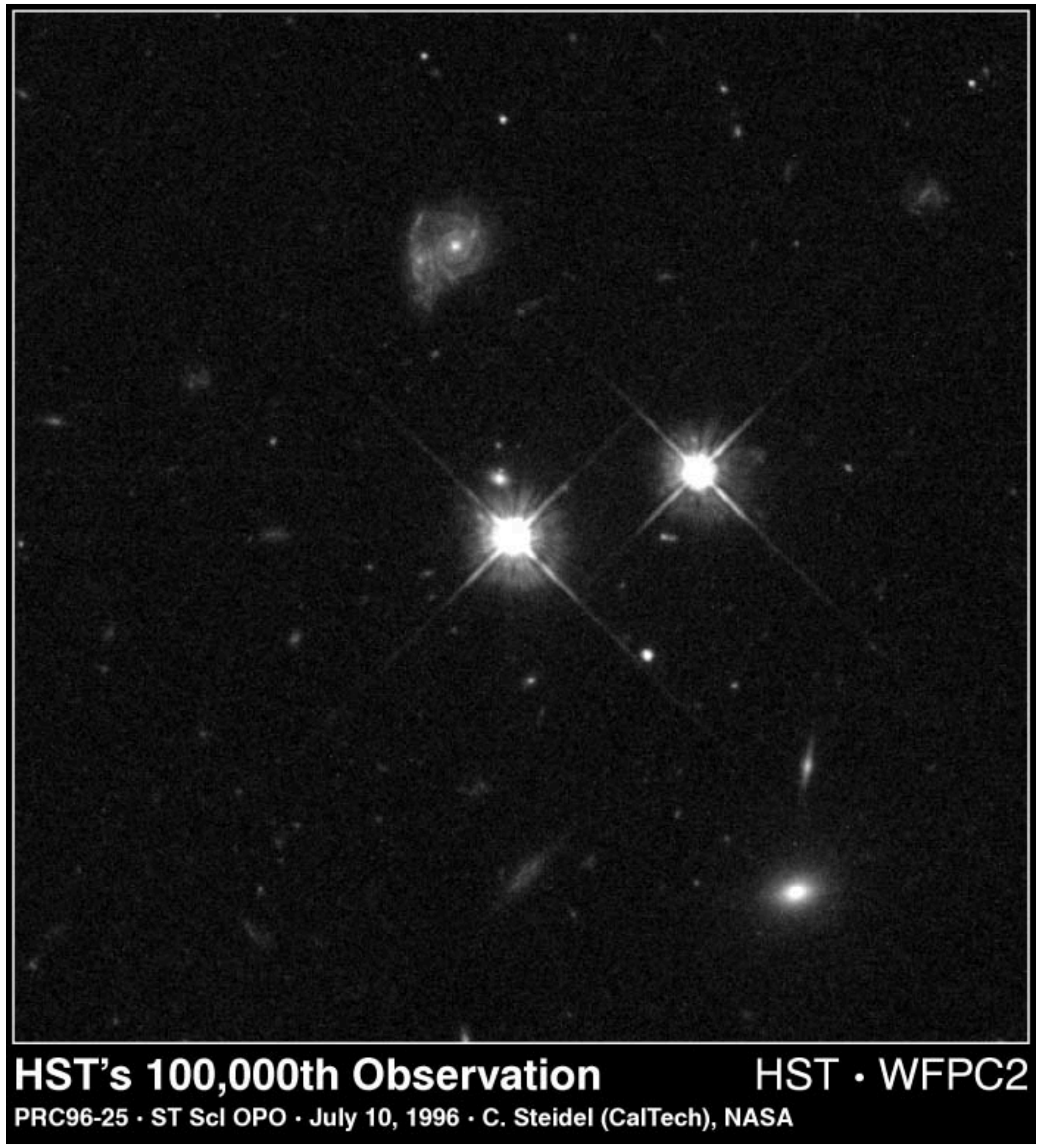
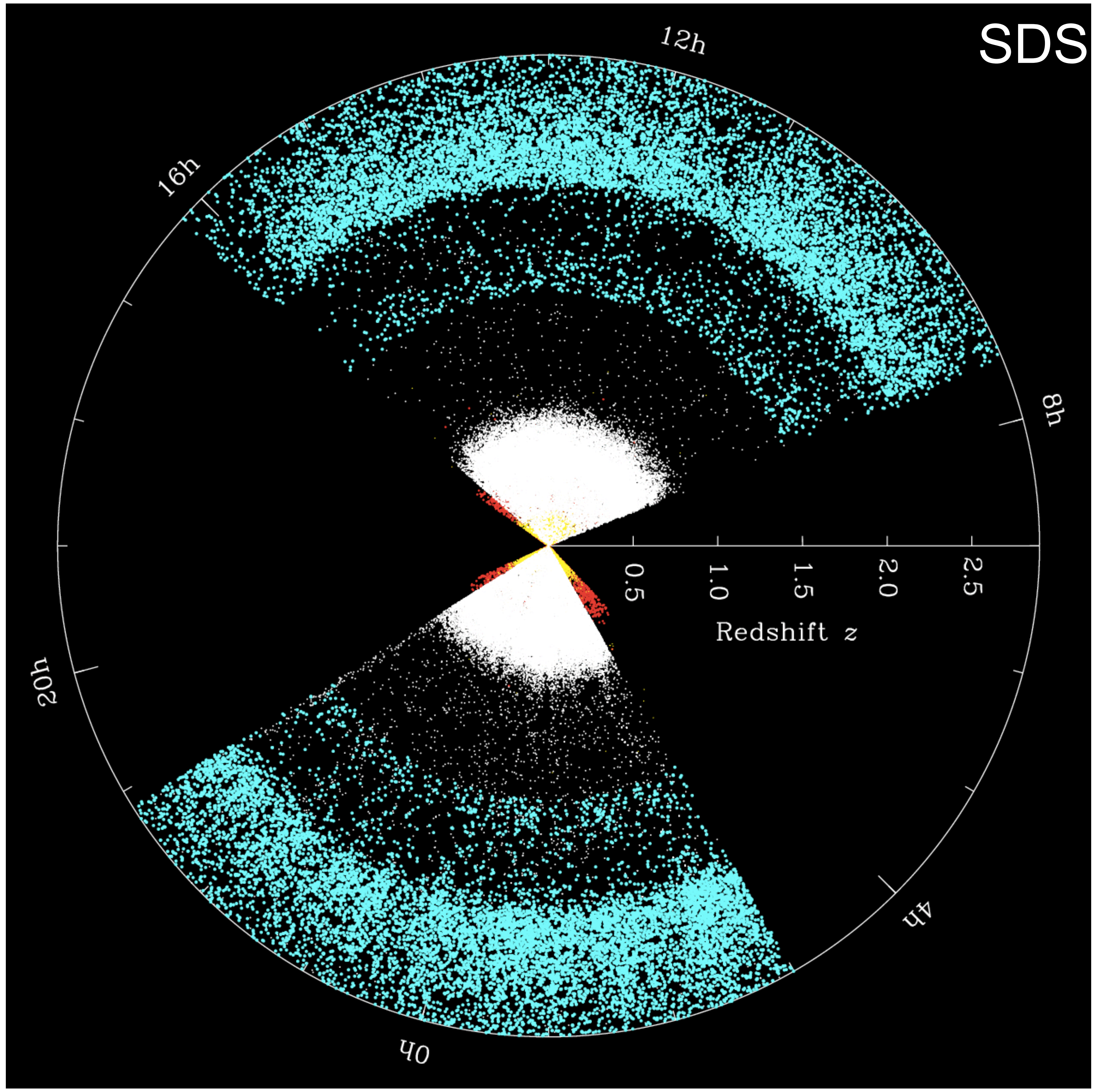
Center for Astrophysics | Harvard & Smithsonian

mm Universe Conference
Tuesday, June 27, 2023

Radio "Quiet" Quasars (RQQs)

aka radio "weak"/lacking jets, 90% of all quasars





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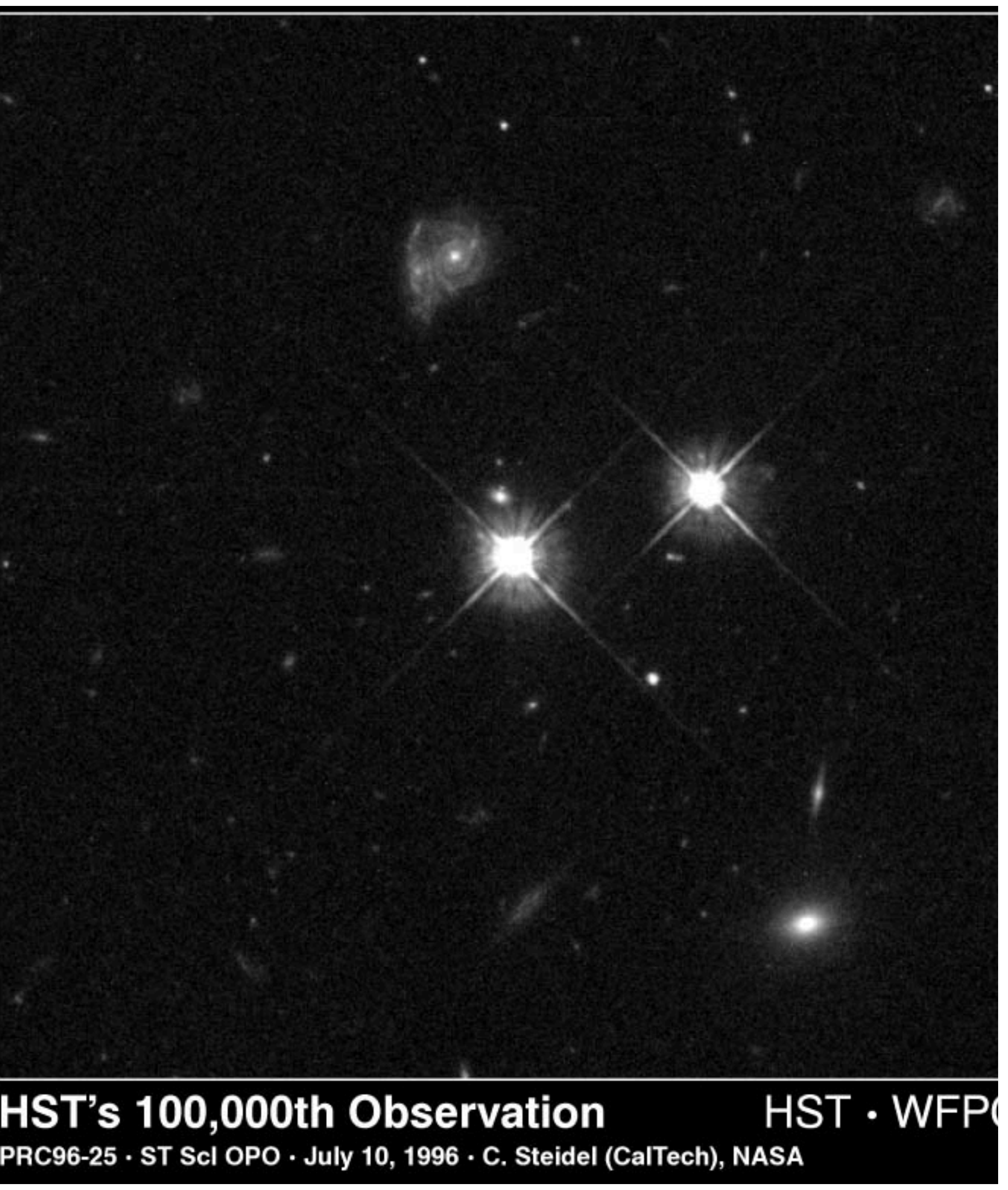
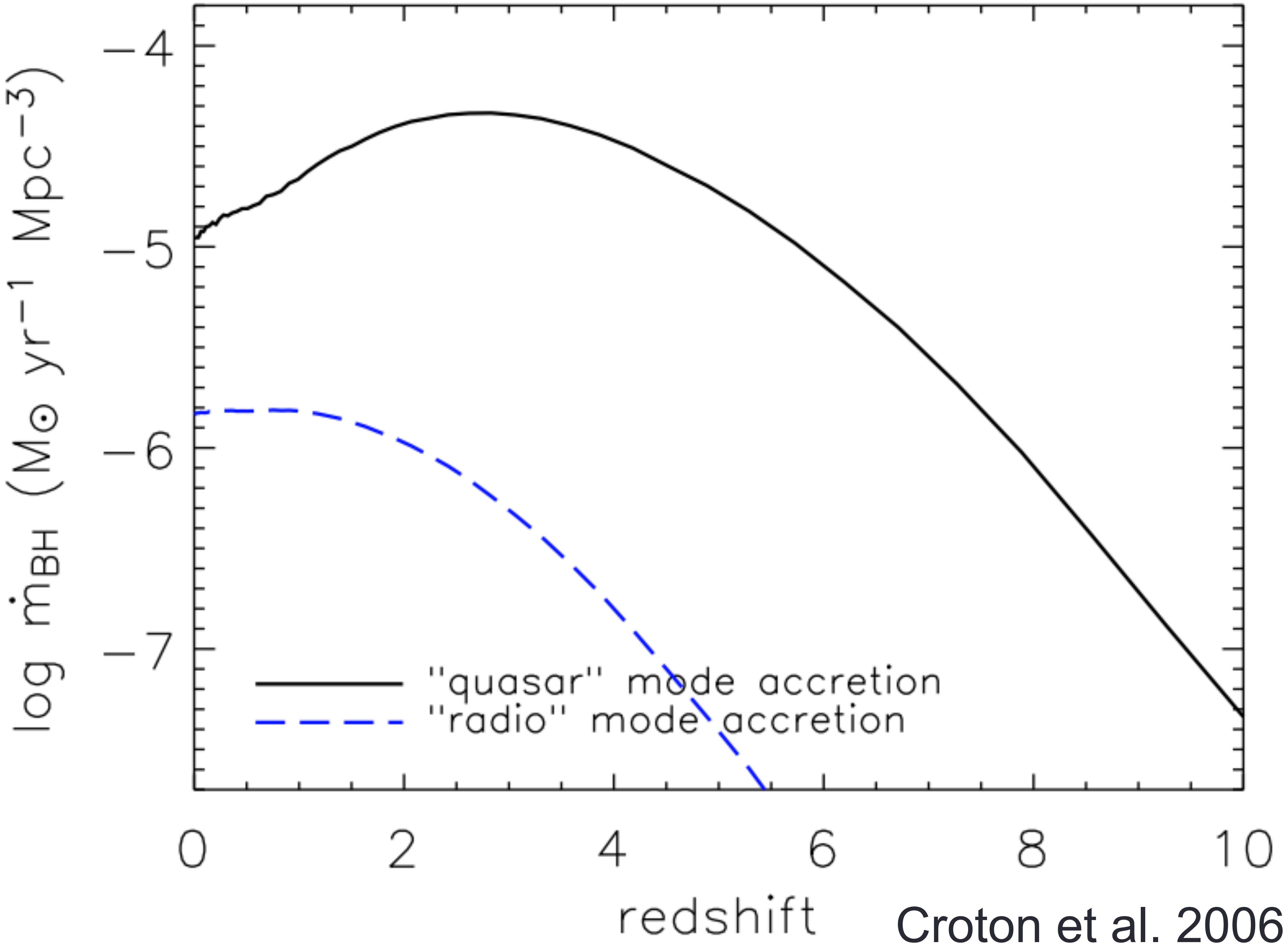
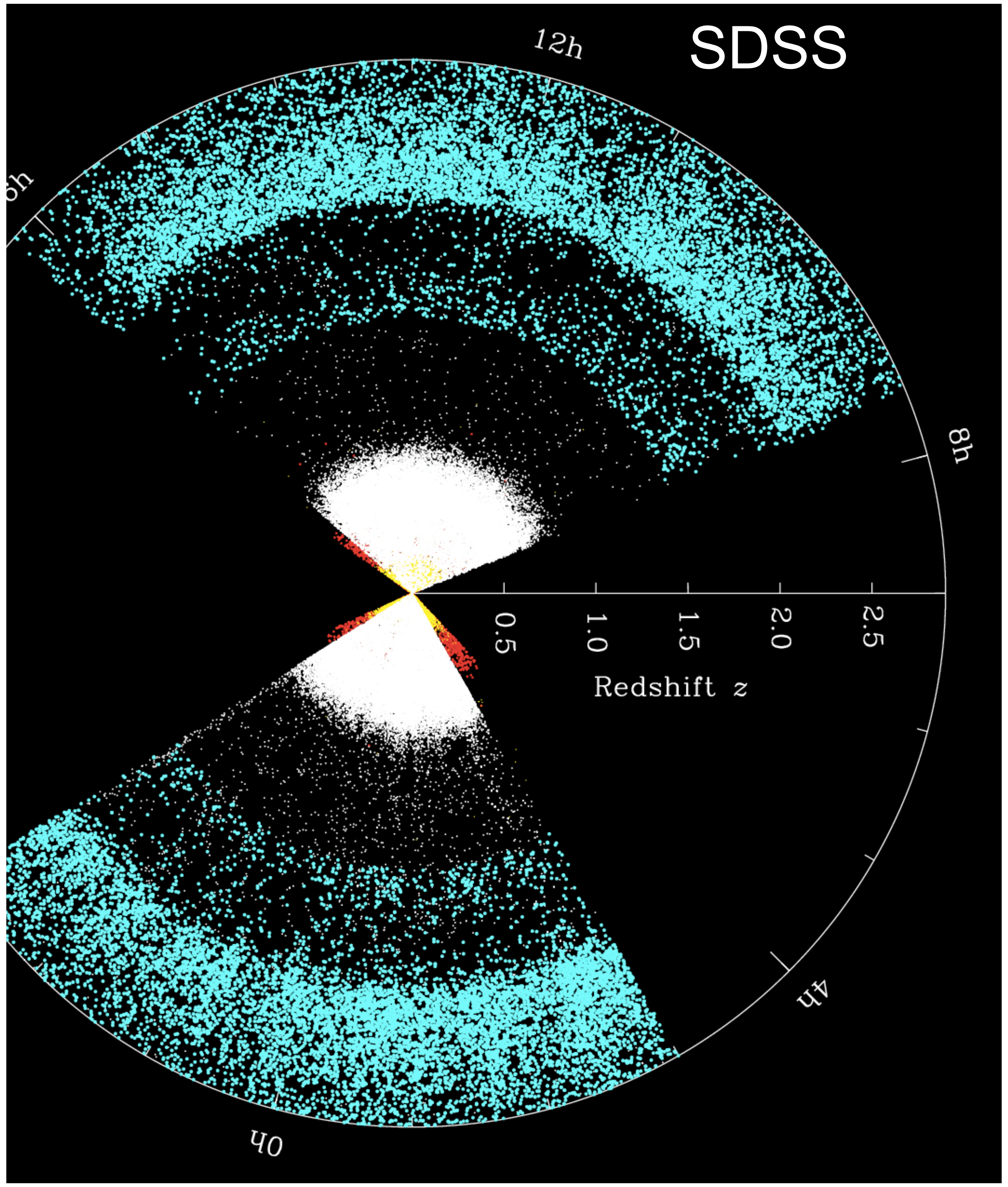




Croton et al. 2006



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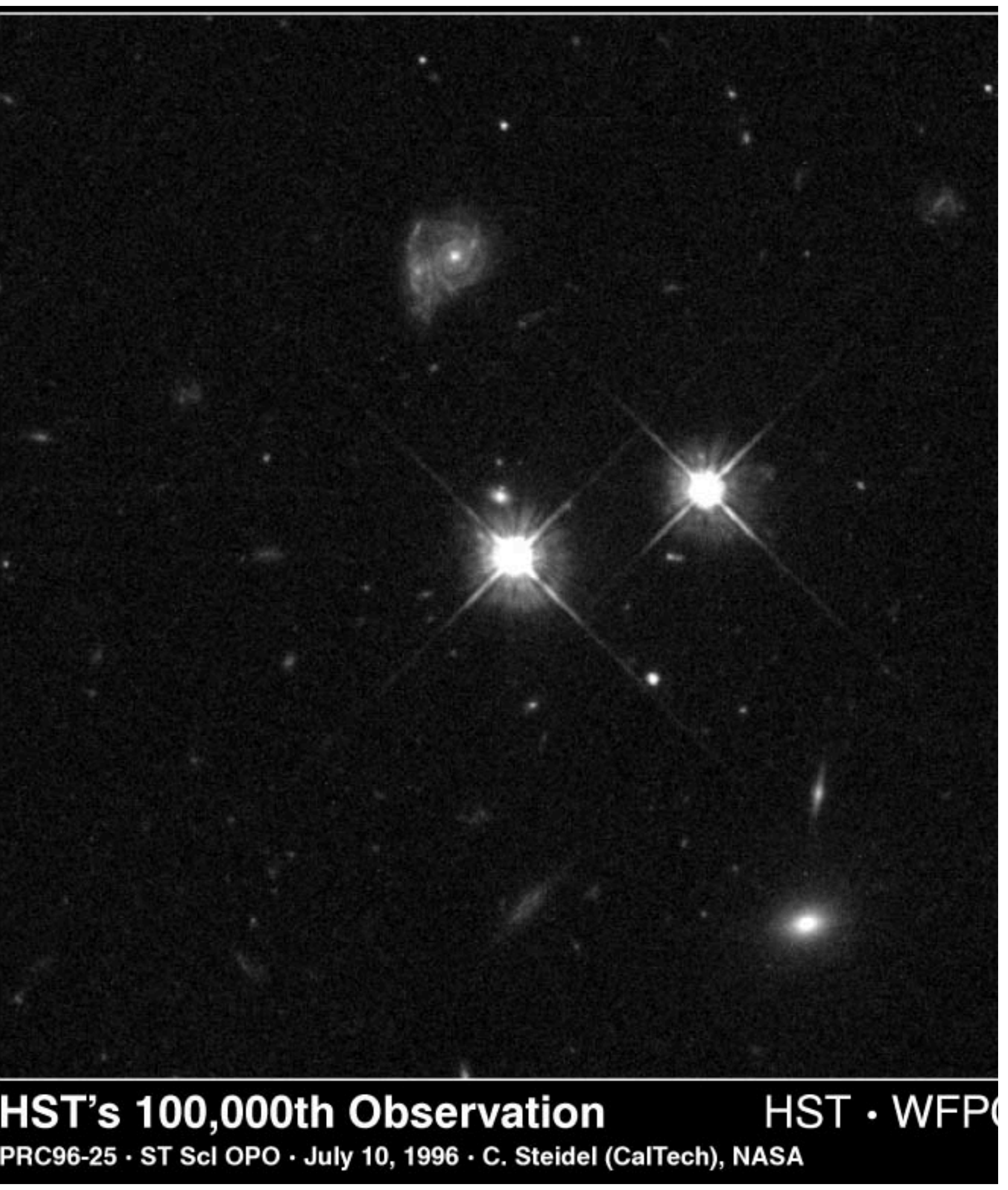

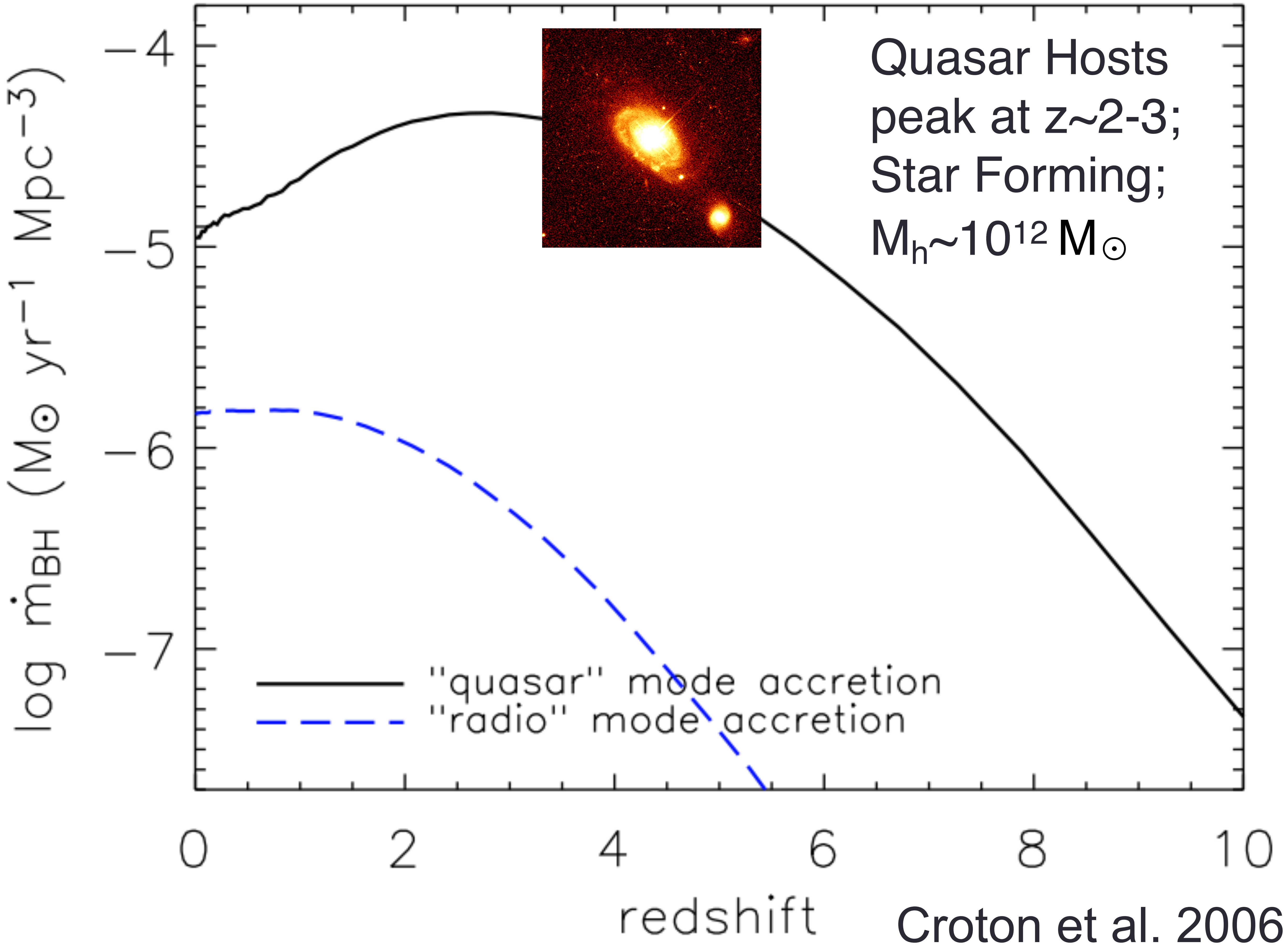

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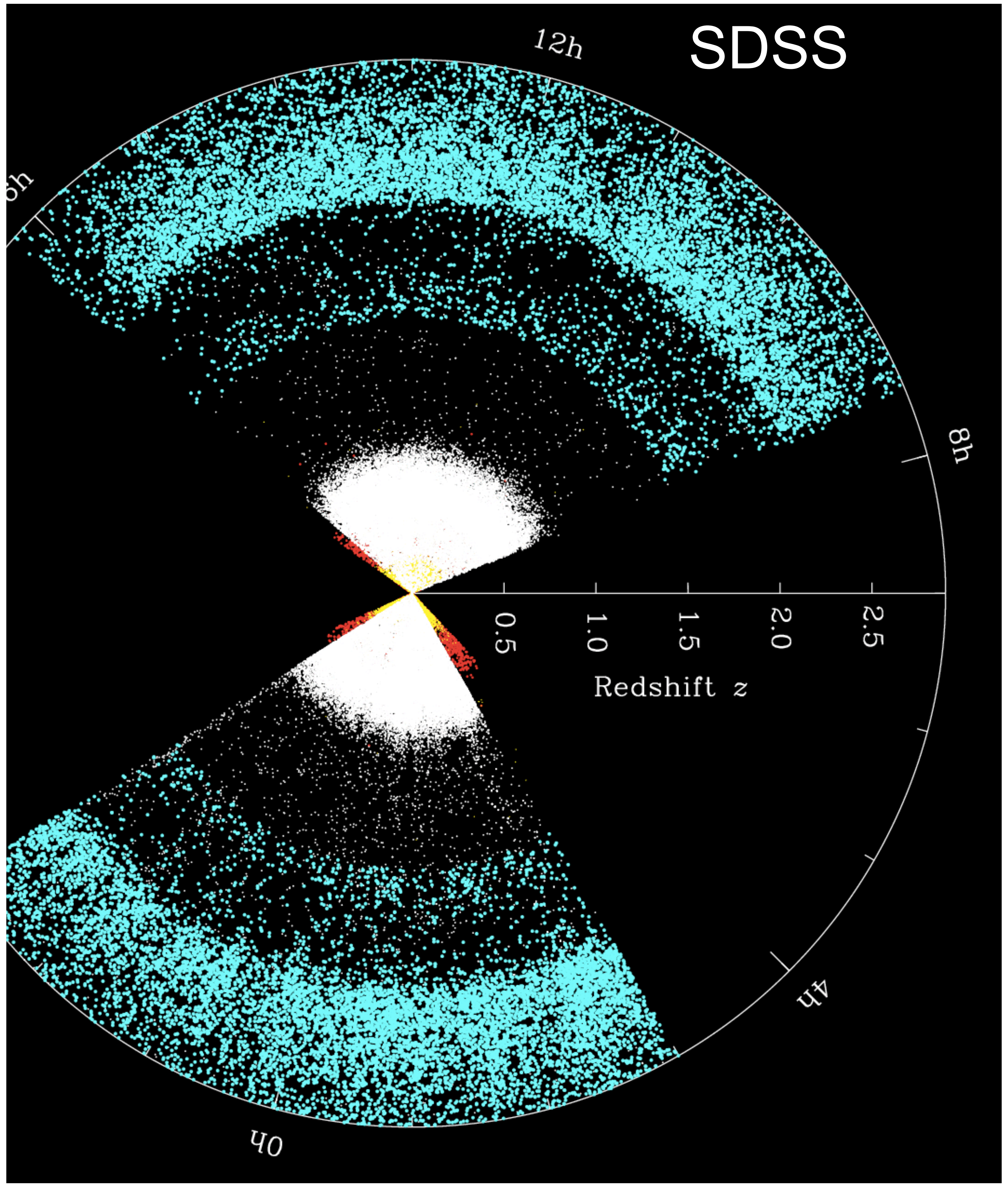

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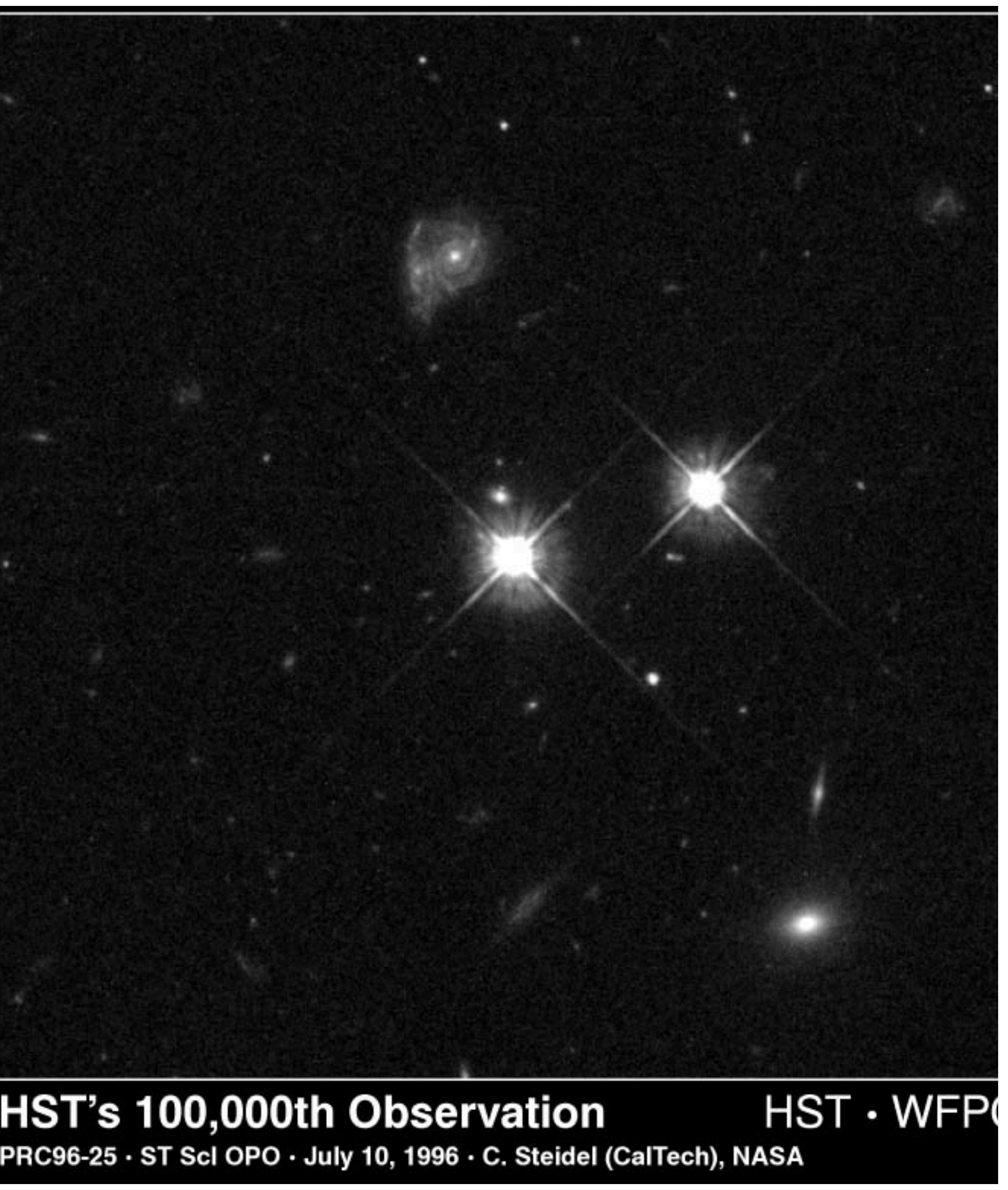

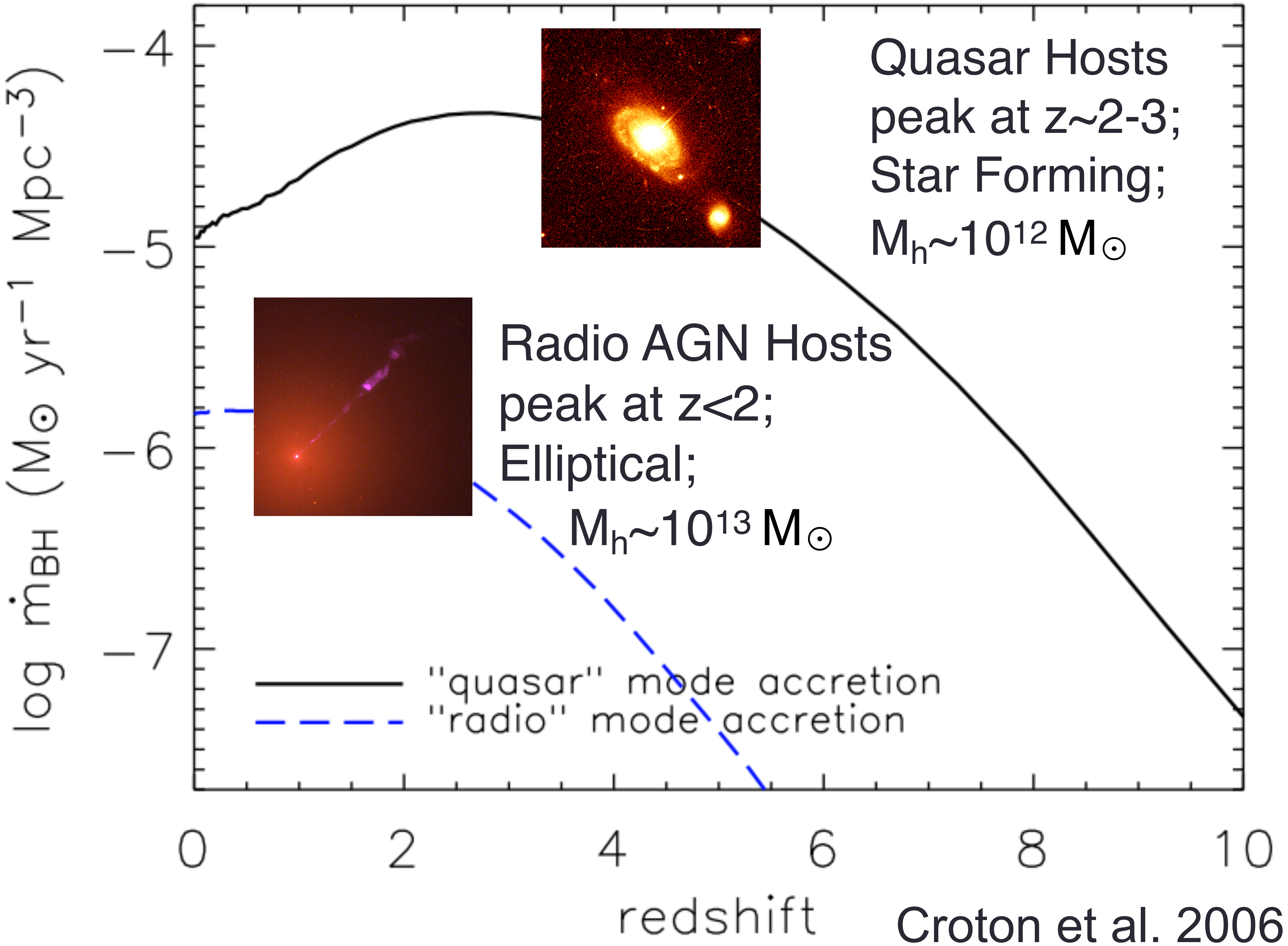

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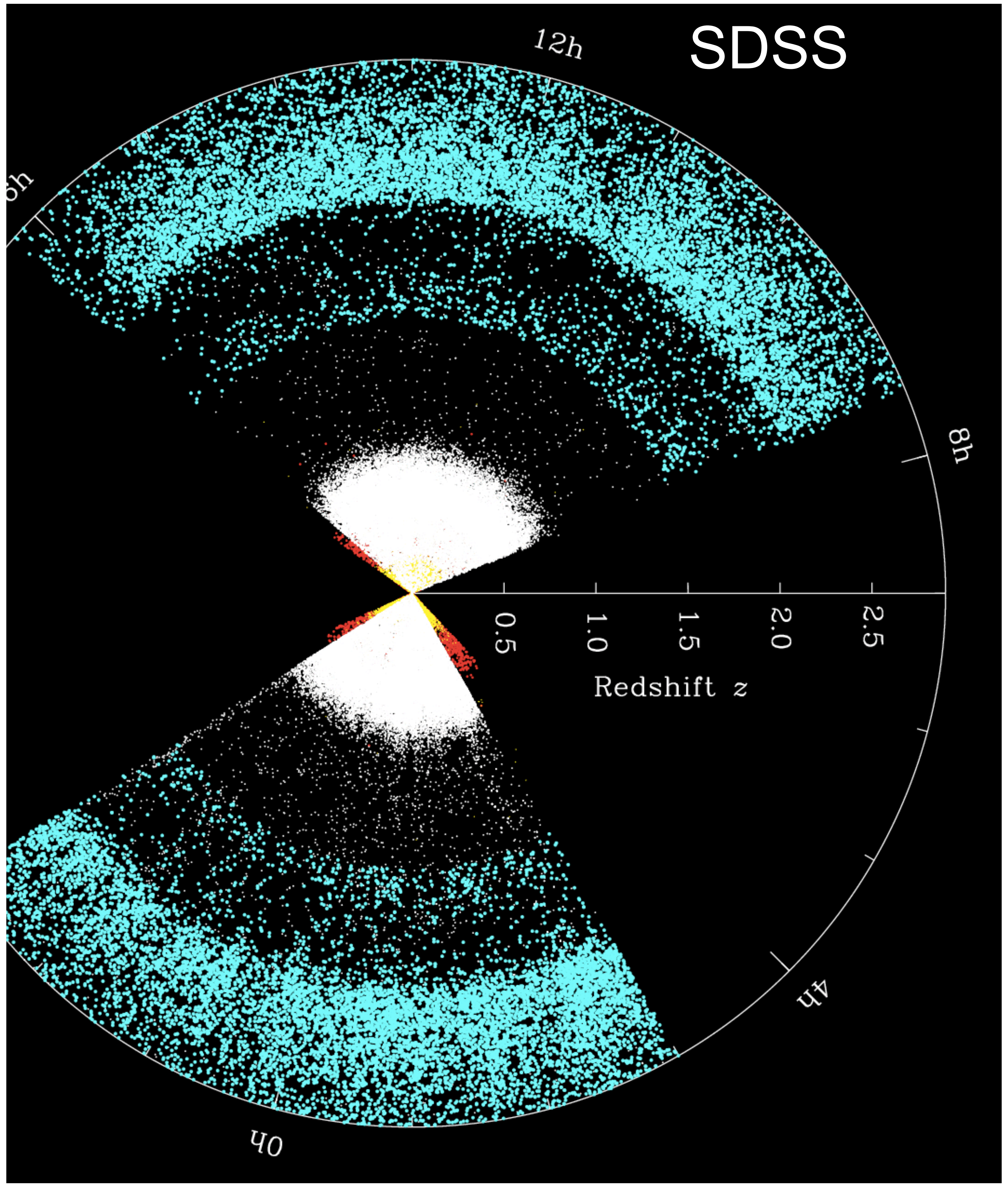
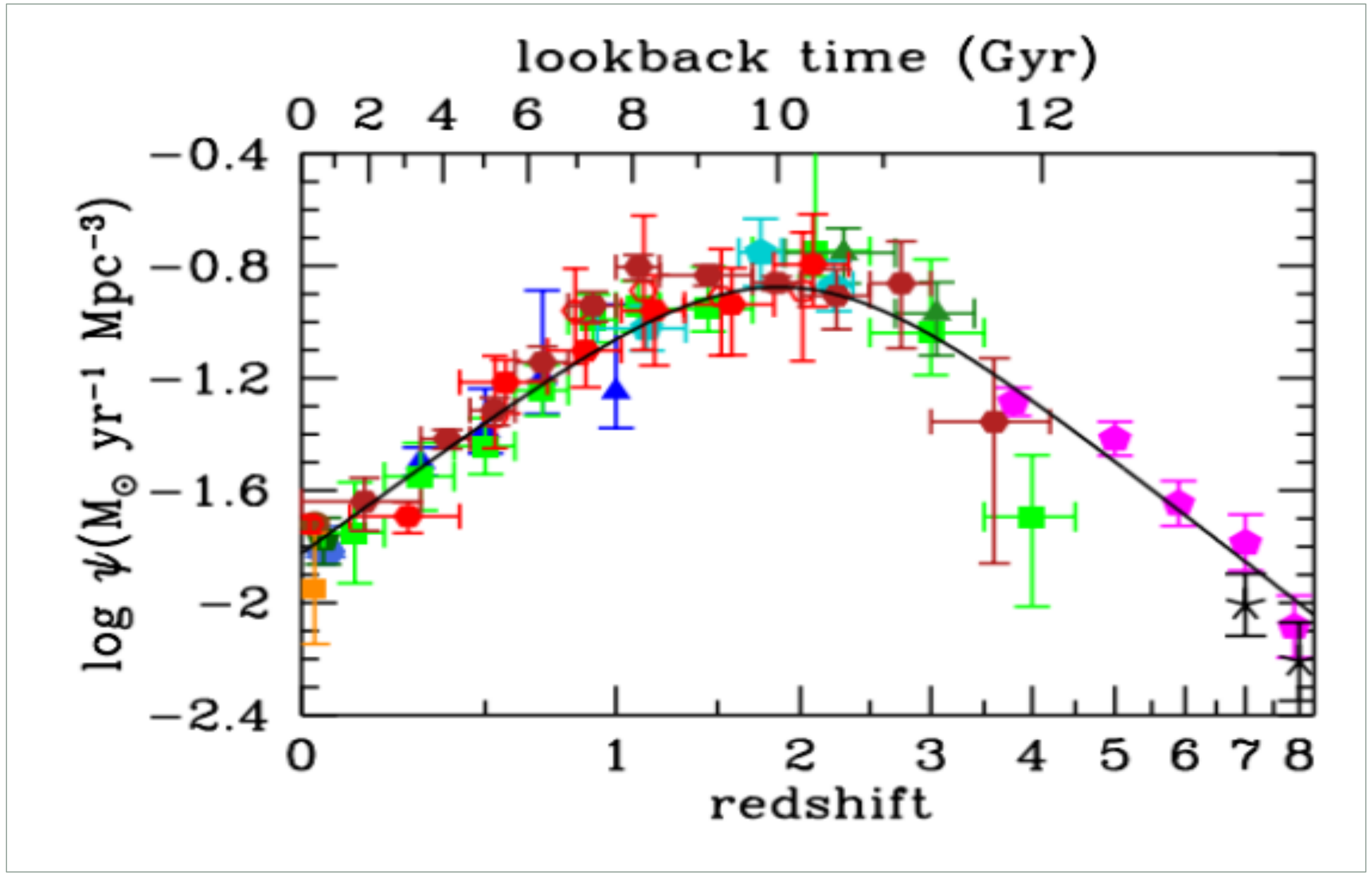
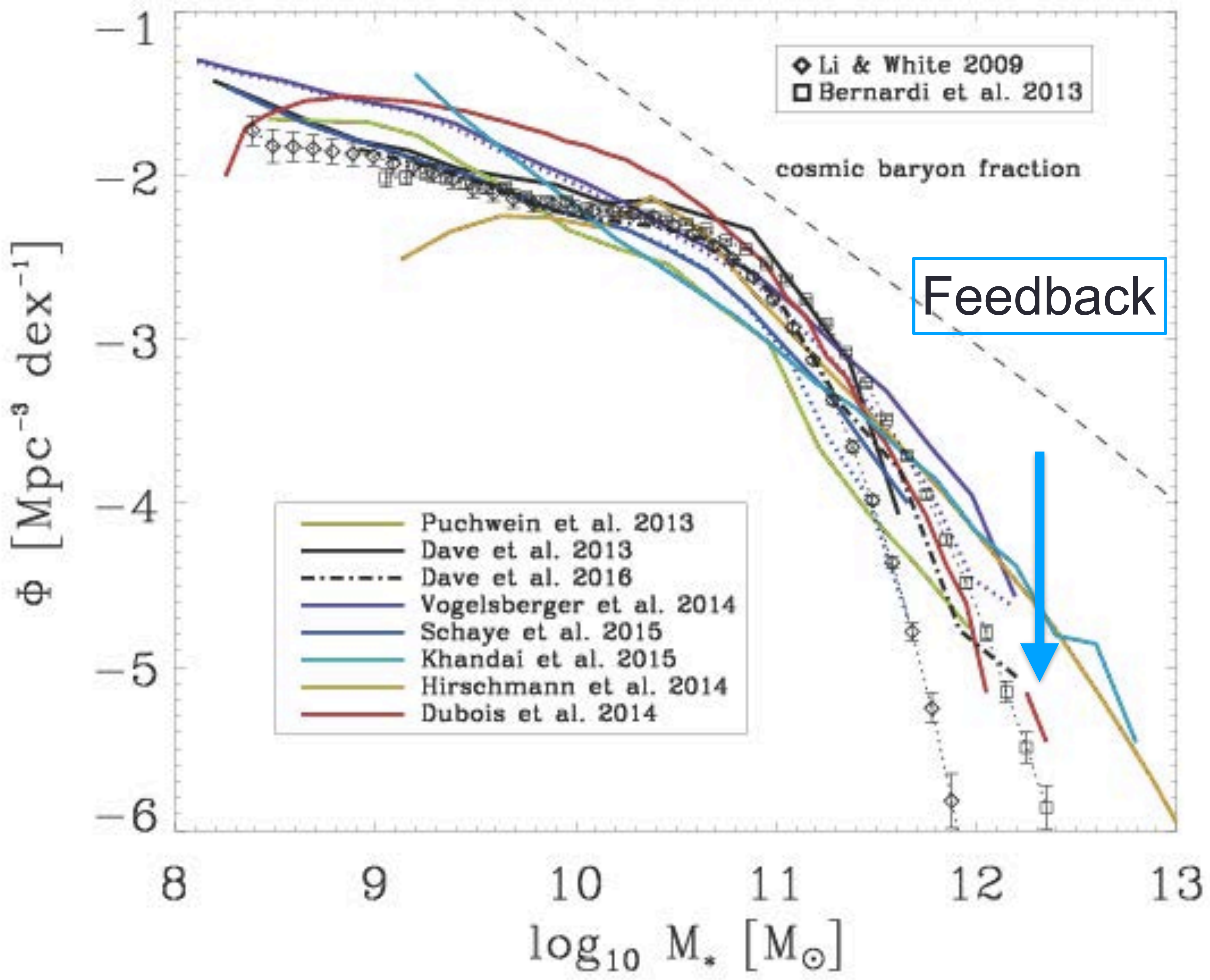


Feedback to quench star formation

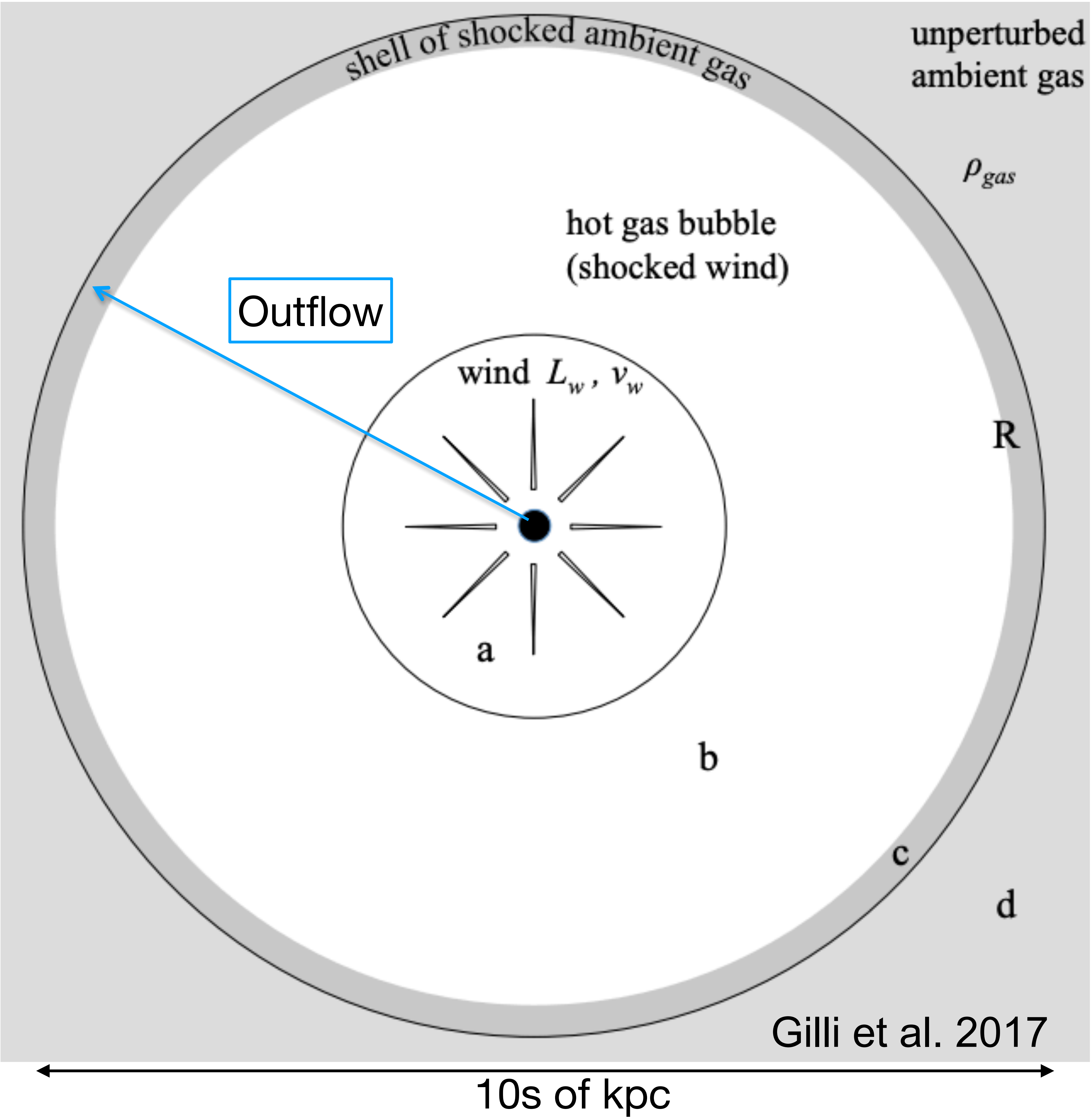




Naab & Ostriker 2017

Quasar outflows are multi-phase

Hot (T > 10^8 K), low density volume filling plasma + higher density "clumps"



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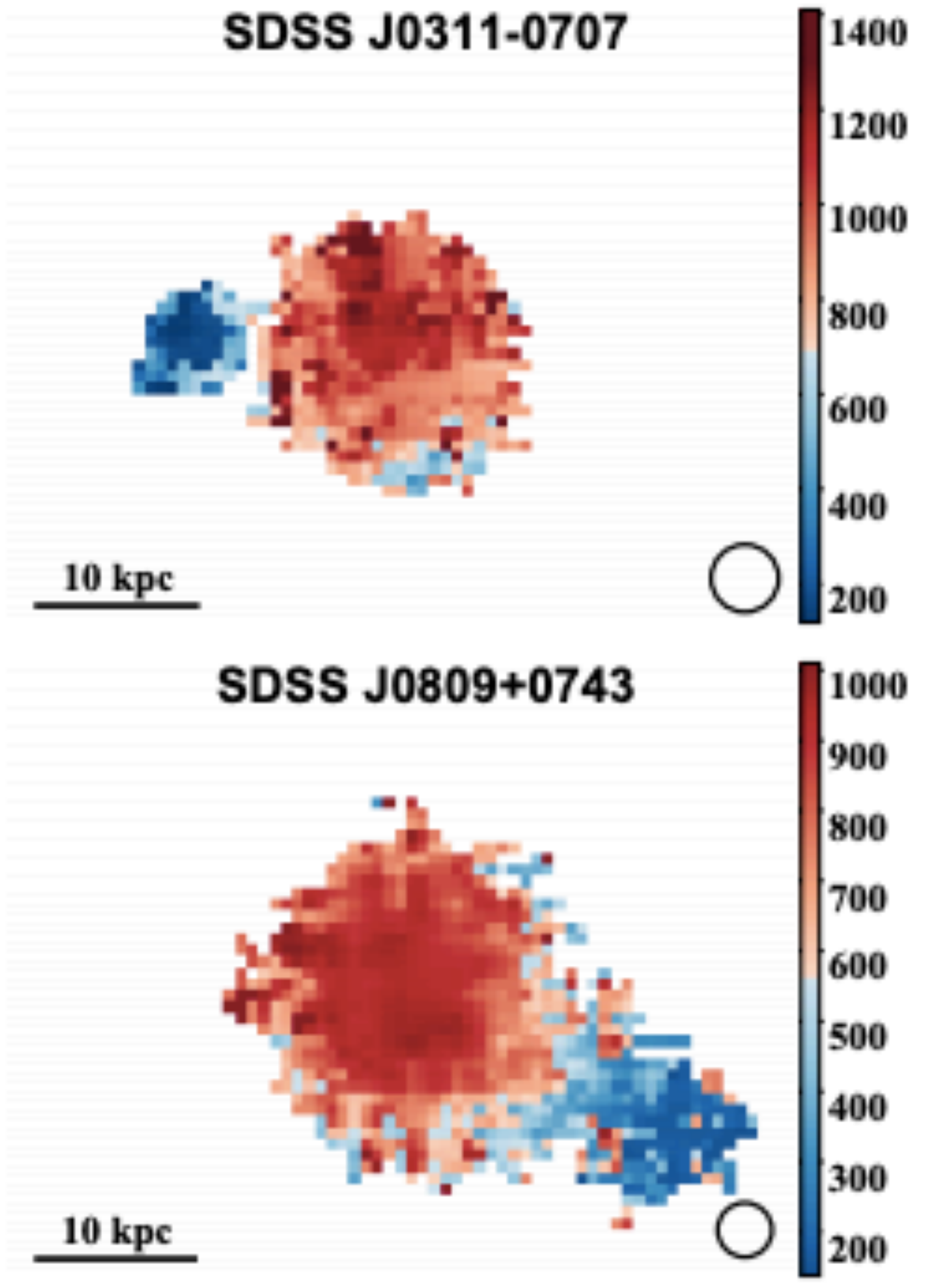
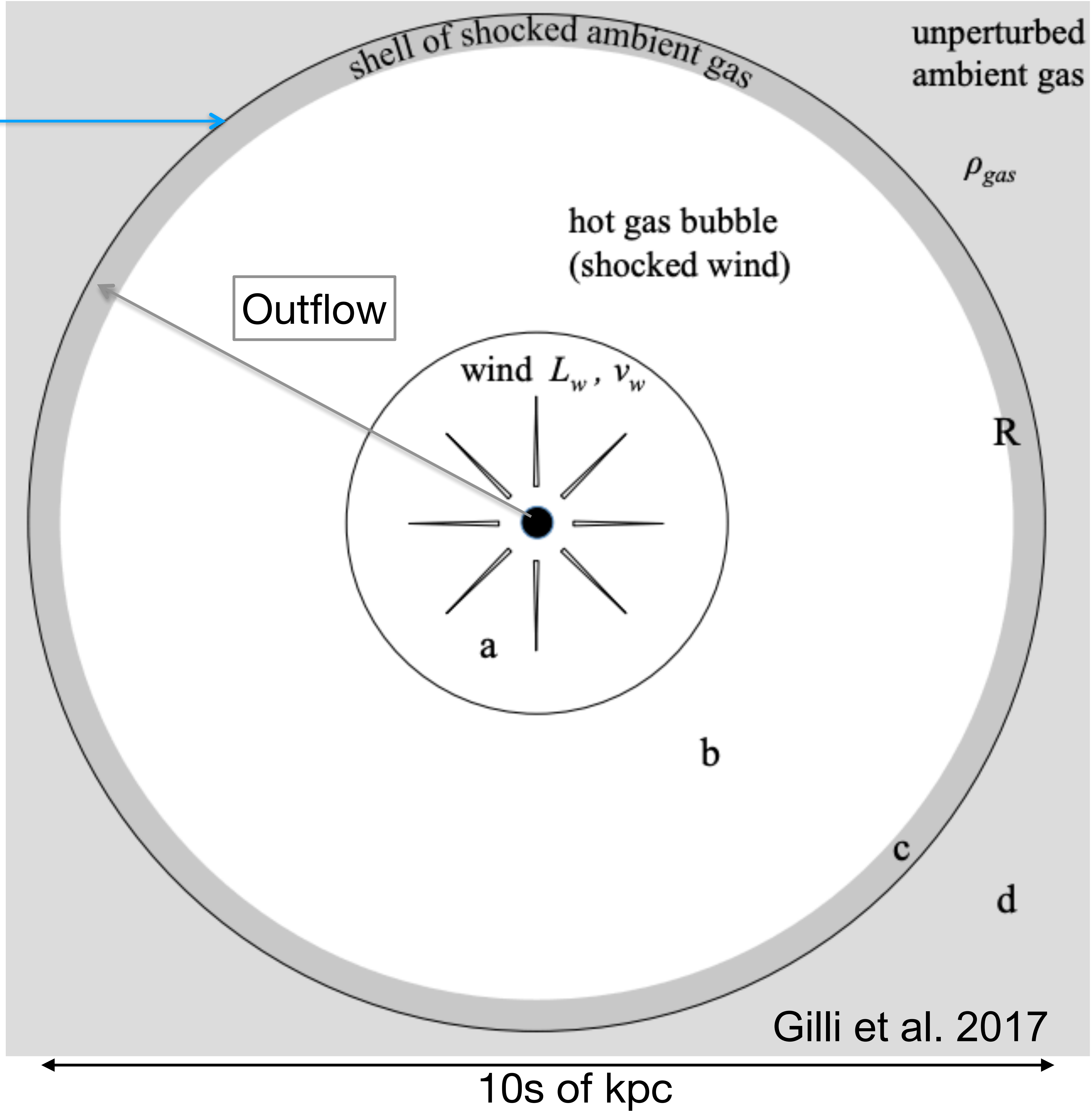


Liu, Zakamska & Greene 2014

High velocity outflows of ionized + molecular gas Observable with emission line diagnostics

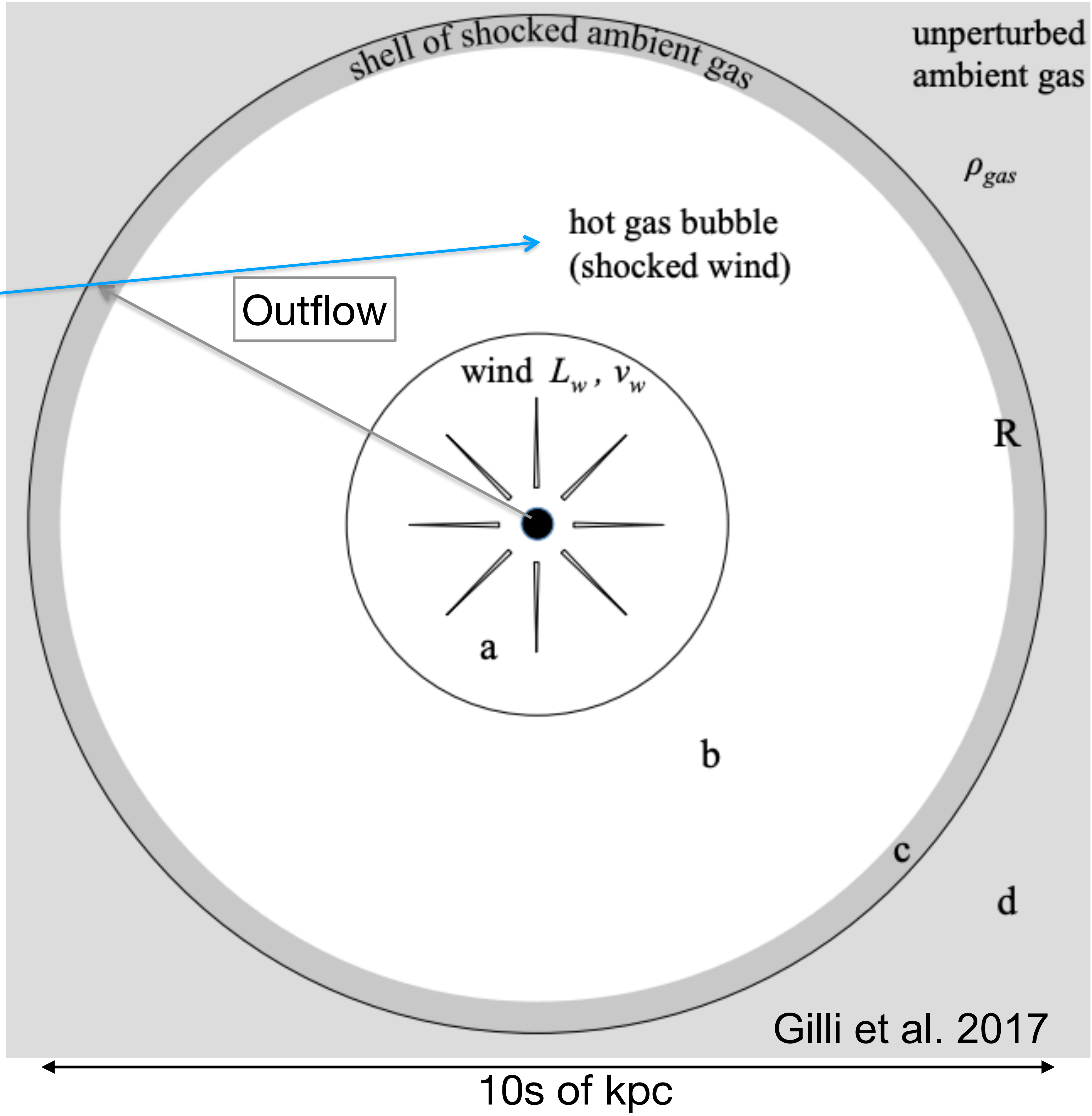


Quasar outflows are multi-phase

Hot (T > 10^8 K), low density volume filling plasma + higher density “clumps”

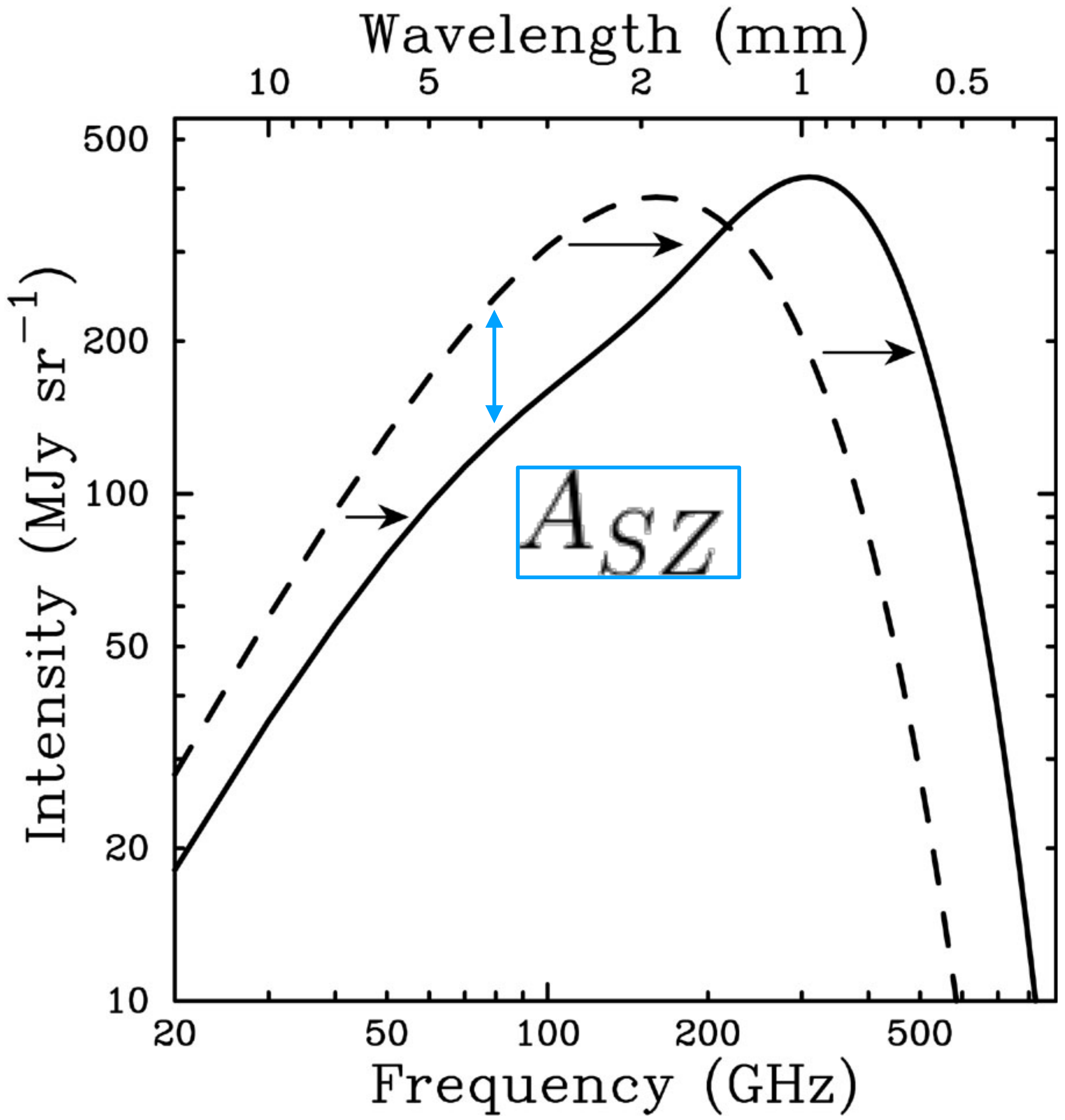
How to measure the more elusive, post-shocked component that is often too diffuse for emission-in diagnostics?

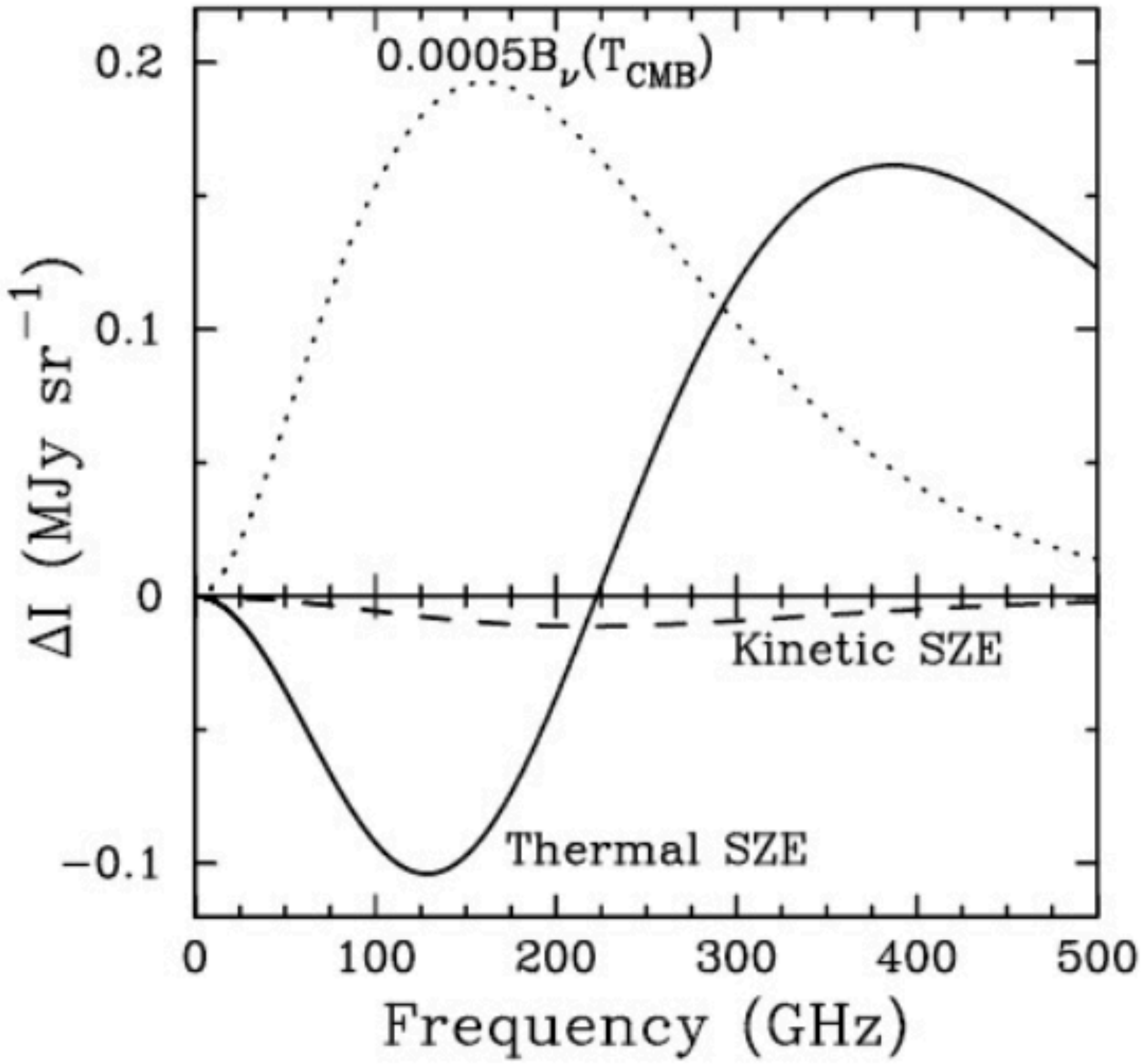
Which phase carries the most energy/mass/momentum? And with what efficiency?



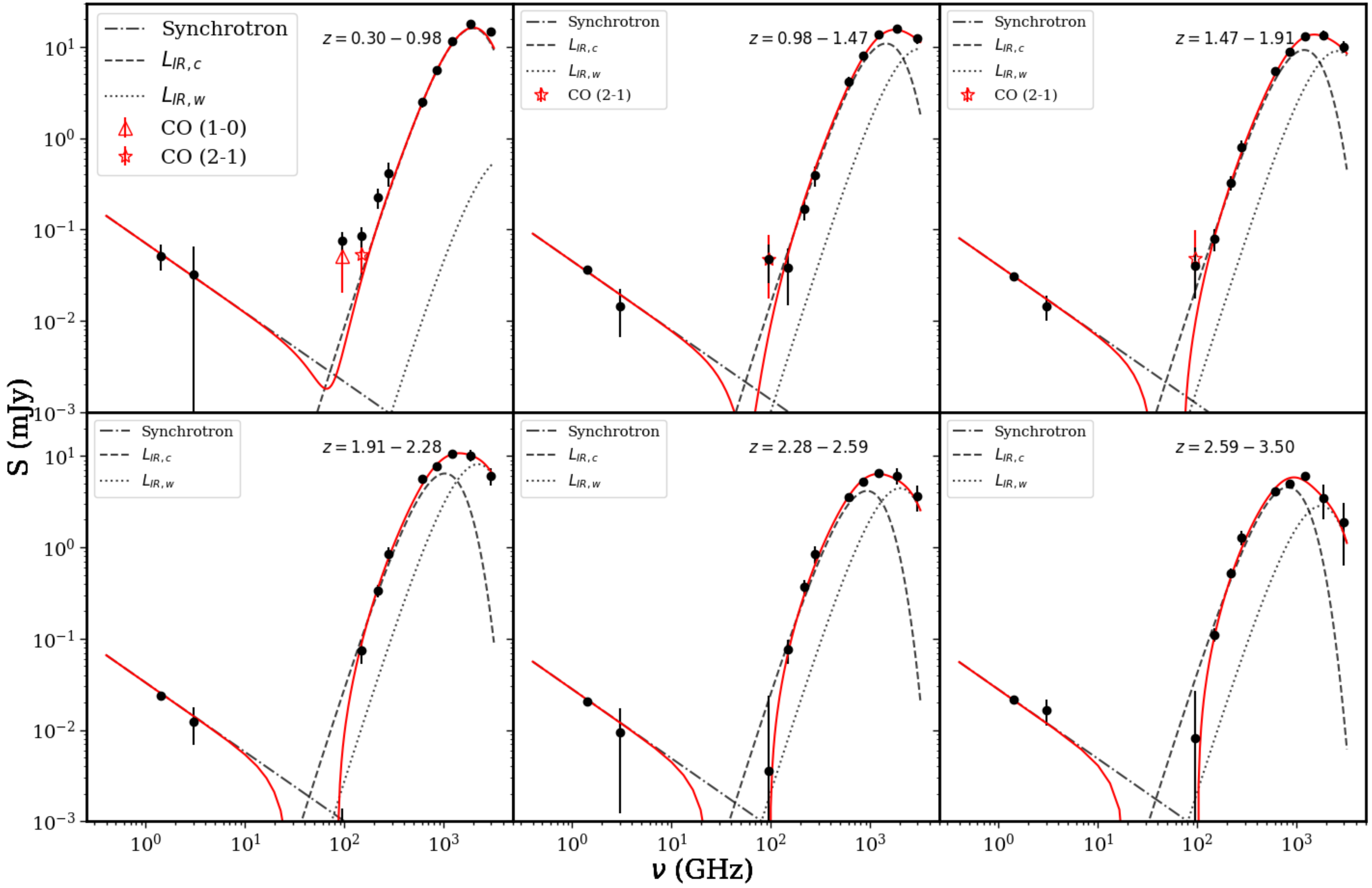
Thermal SZE

$$\boxed{A_{SZ} \propto E_{th}}$$



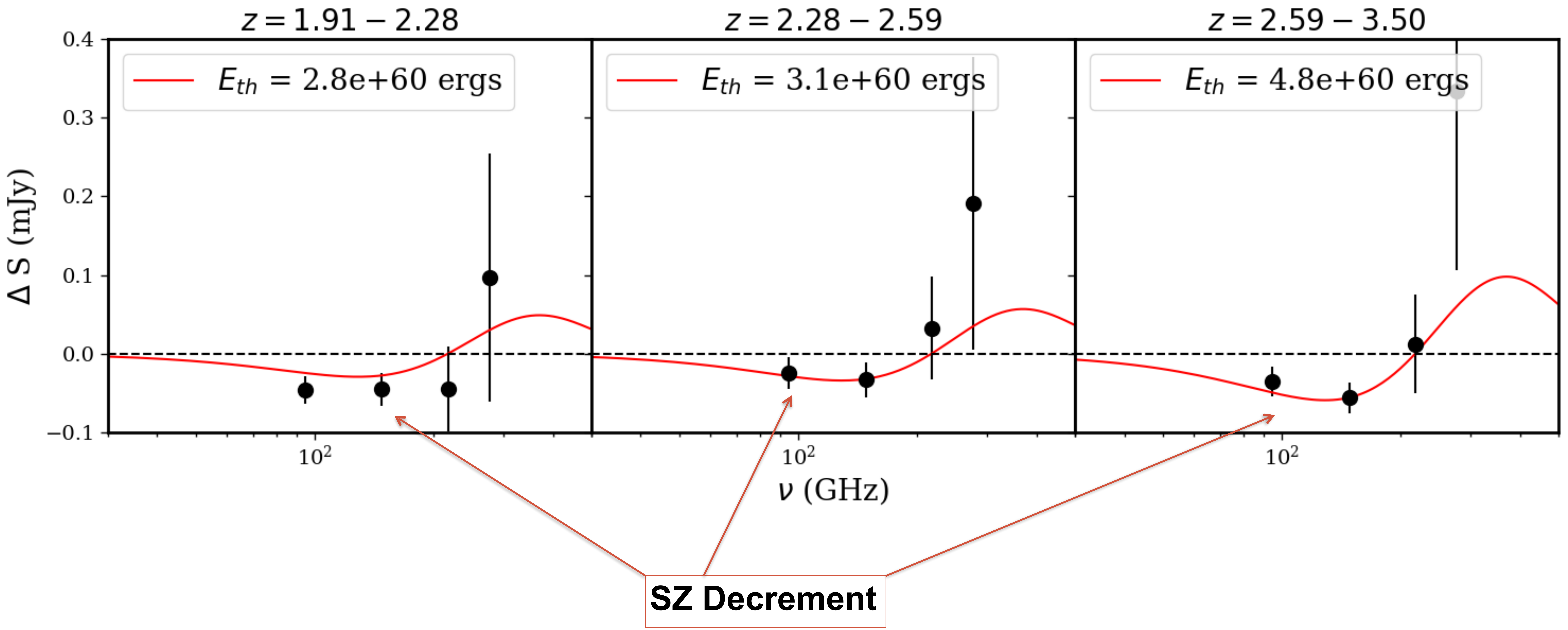


Stacked RQQ SEDs (>17,000 in each z bin)



Hall et al., 2019

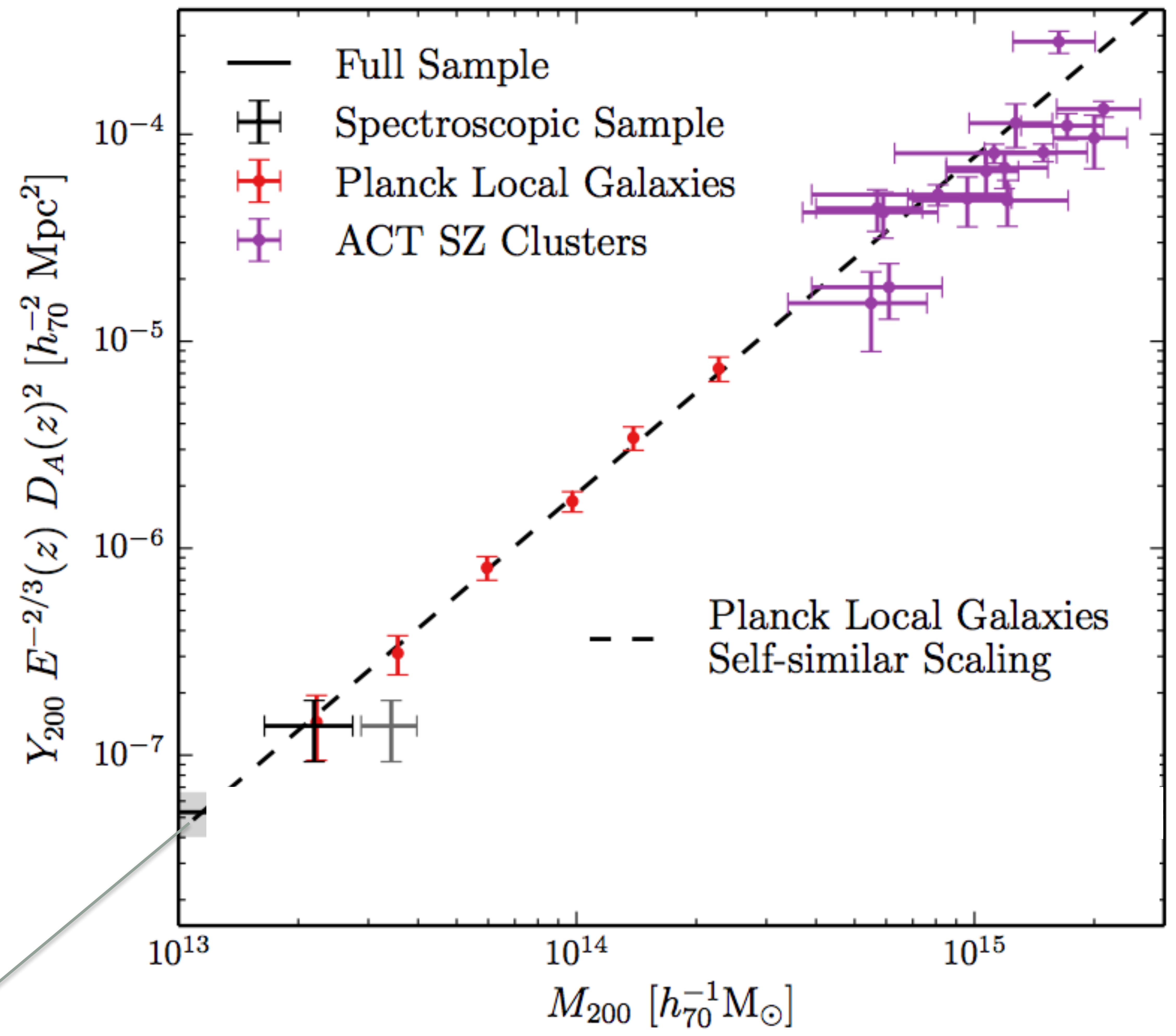
tSZ from RQQ Host Halos



Hall et al., 2019

Do we measure more tSZ signal due to quasar feedback than expected in the halo?

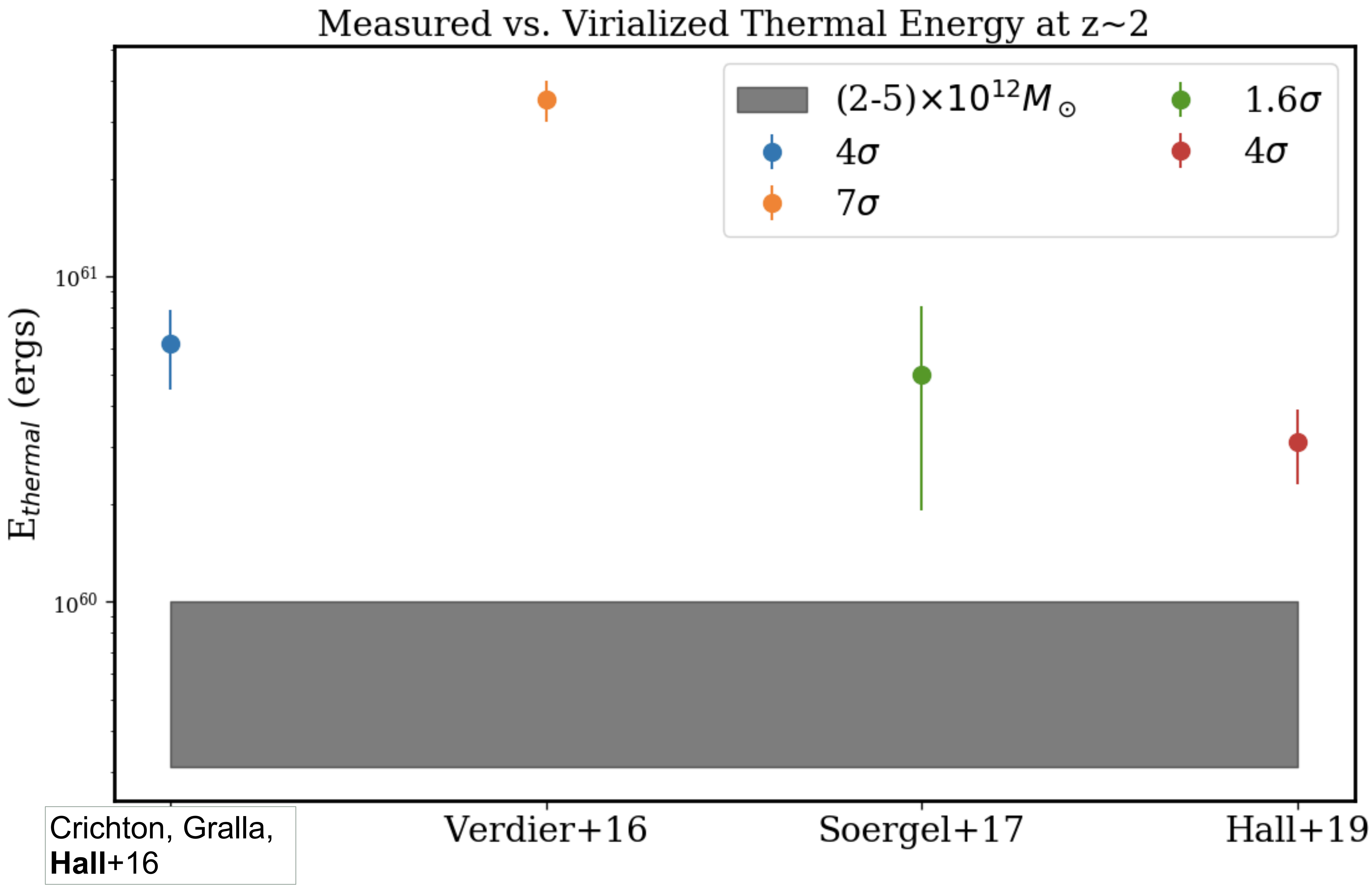
Expected tSZ as a function of halo mass



Extrapolate to $M = 10^{12} M_\odot$

Gralla et al. 2014

Predicted Halo vs Measured Thermal Energy



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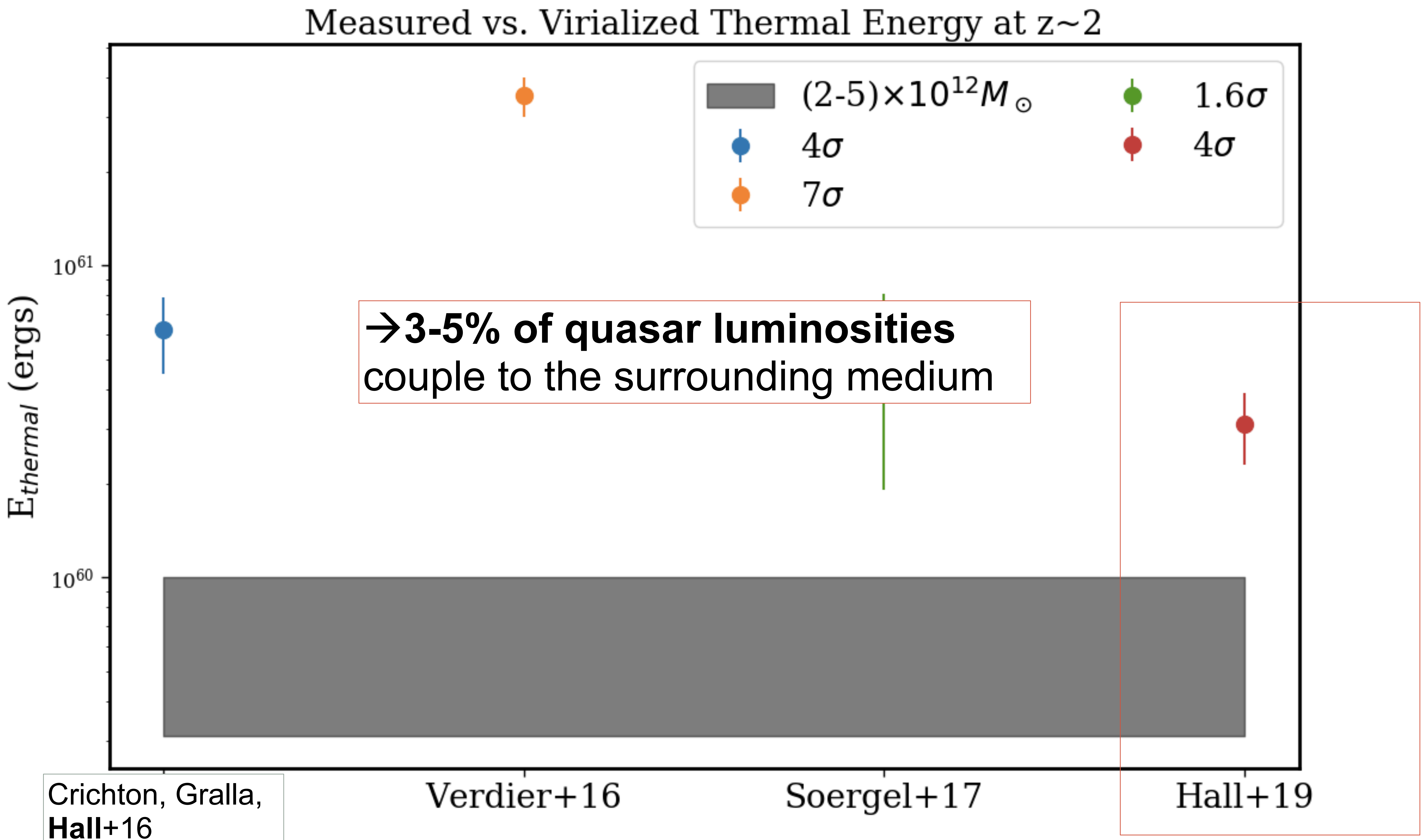


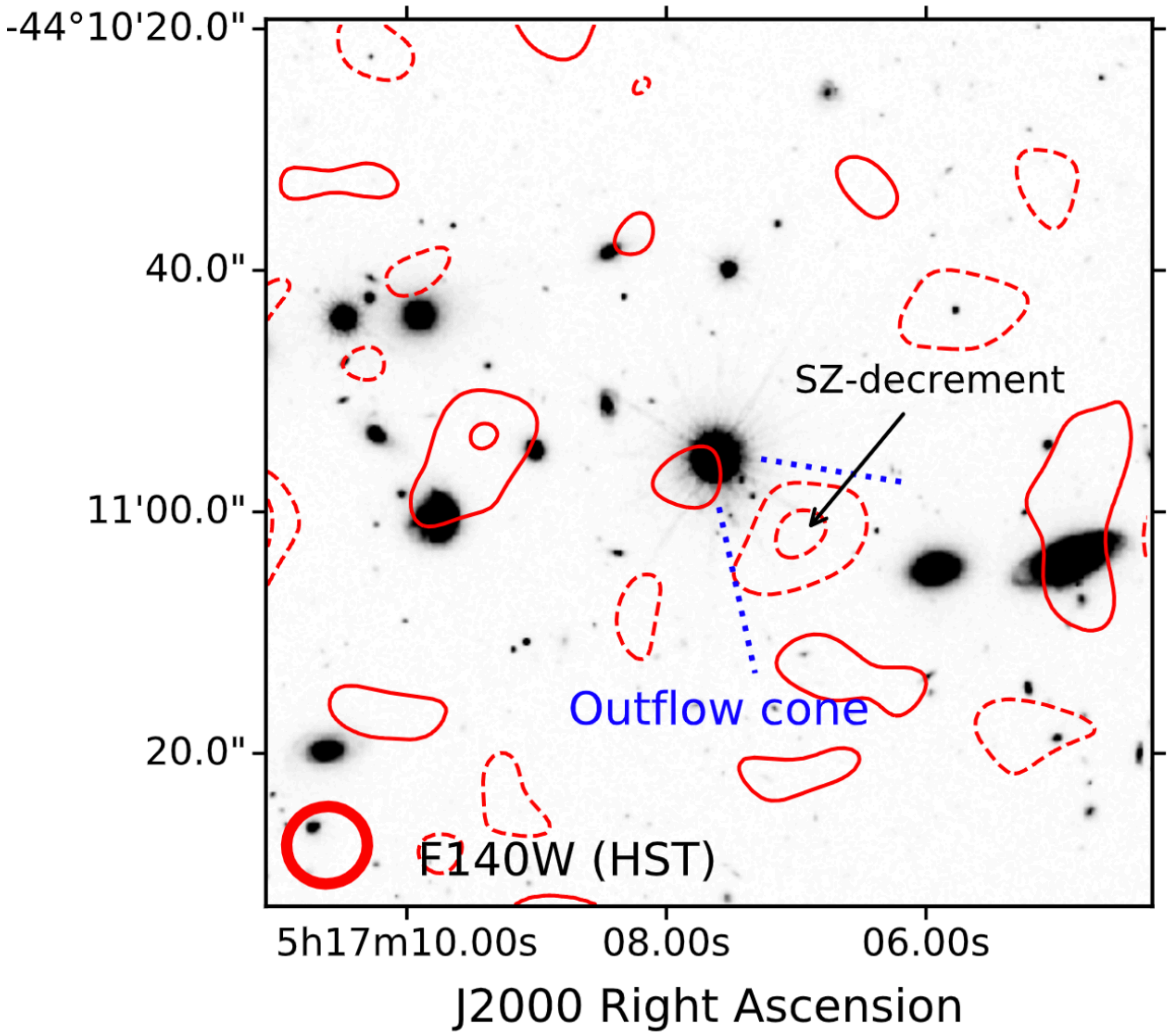
→3-5% of quasar luminosities couple to the surrounding medium

Crichton, Gralla, **Hall**+16

RQQ HE0515-4414:

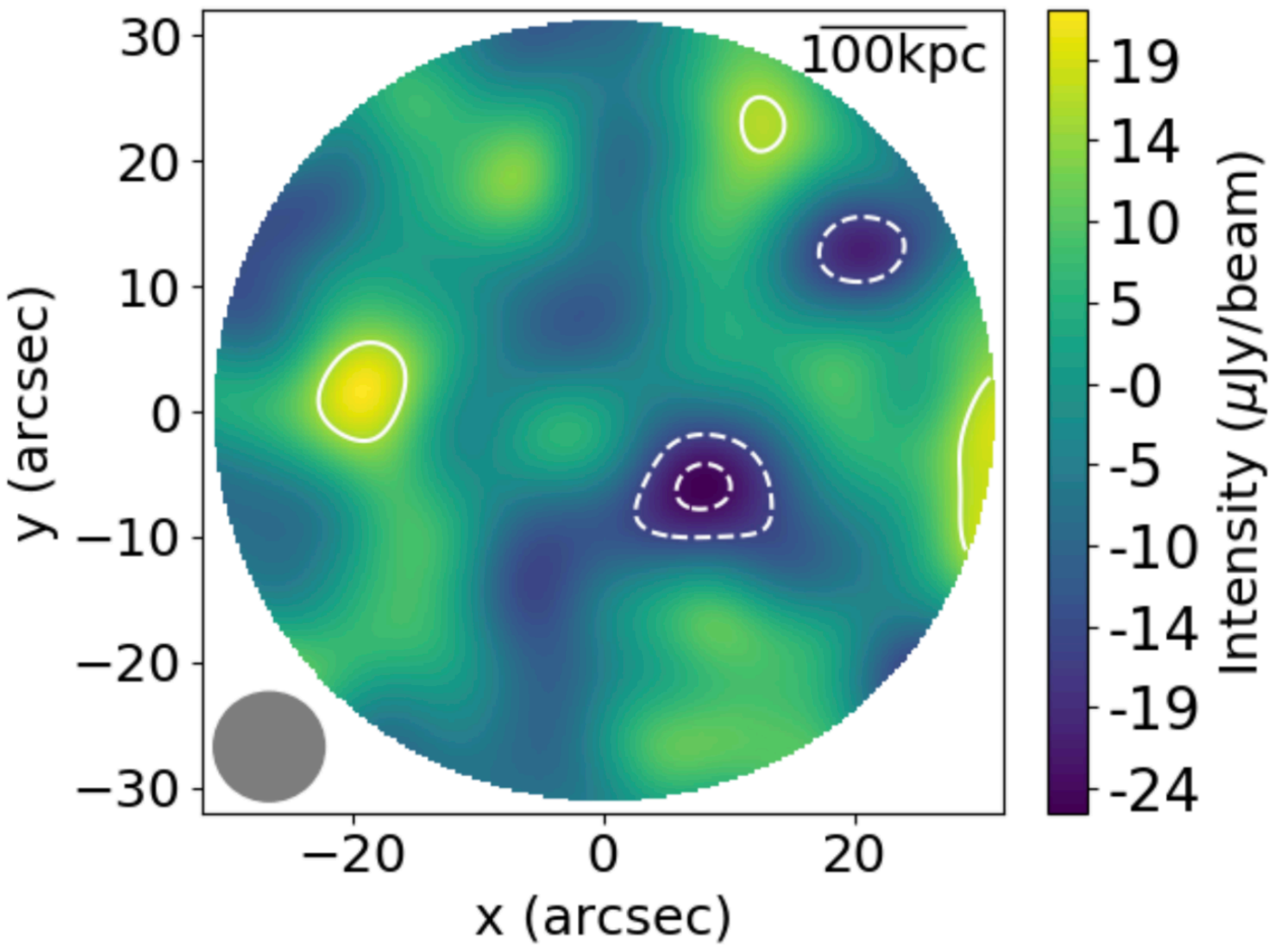
~3-3.2σ measurement —> ~0.01% quasar luminosity

140 GHz Image residuals ~6 arcsec uv taper



Lacy et al., 2019

140 GHz Image residuals 10 arcsec uv taper

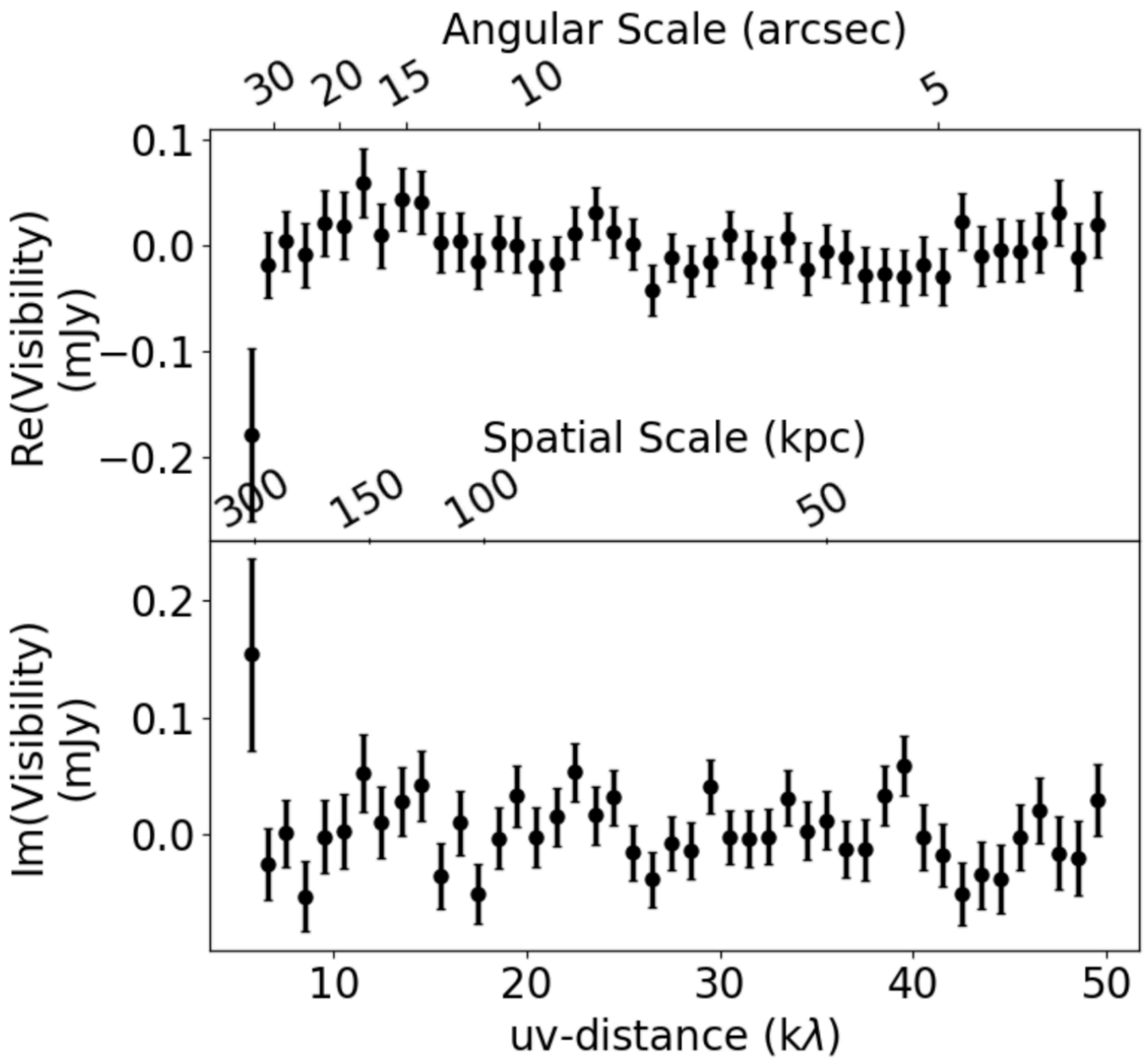


Brownson et et al., 2019

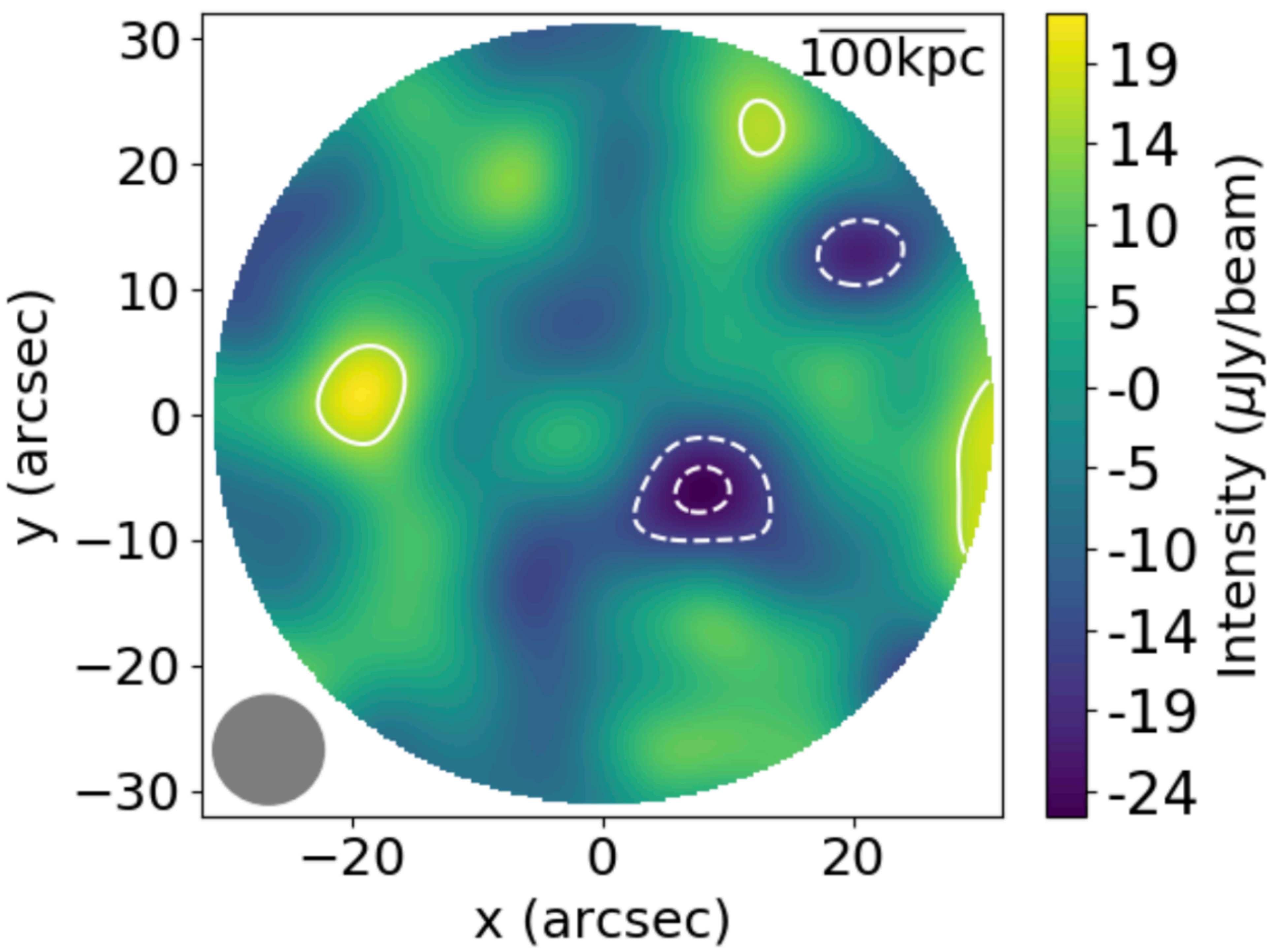
RQQ HE0515-4414

~3-3.3σ measurement; A_{SZ} ~ 0.2-0.5 mJy

Residuals



140 GHz Image Residuals - uvtaper = 10”



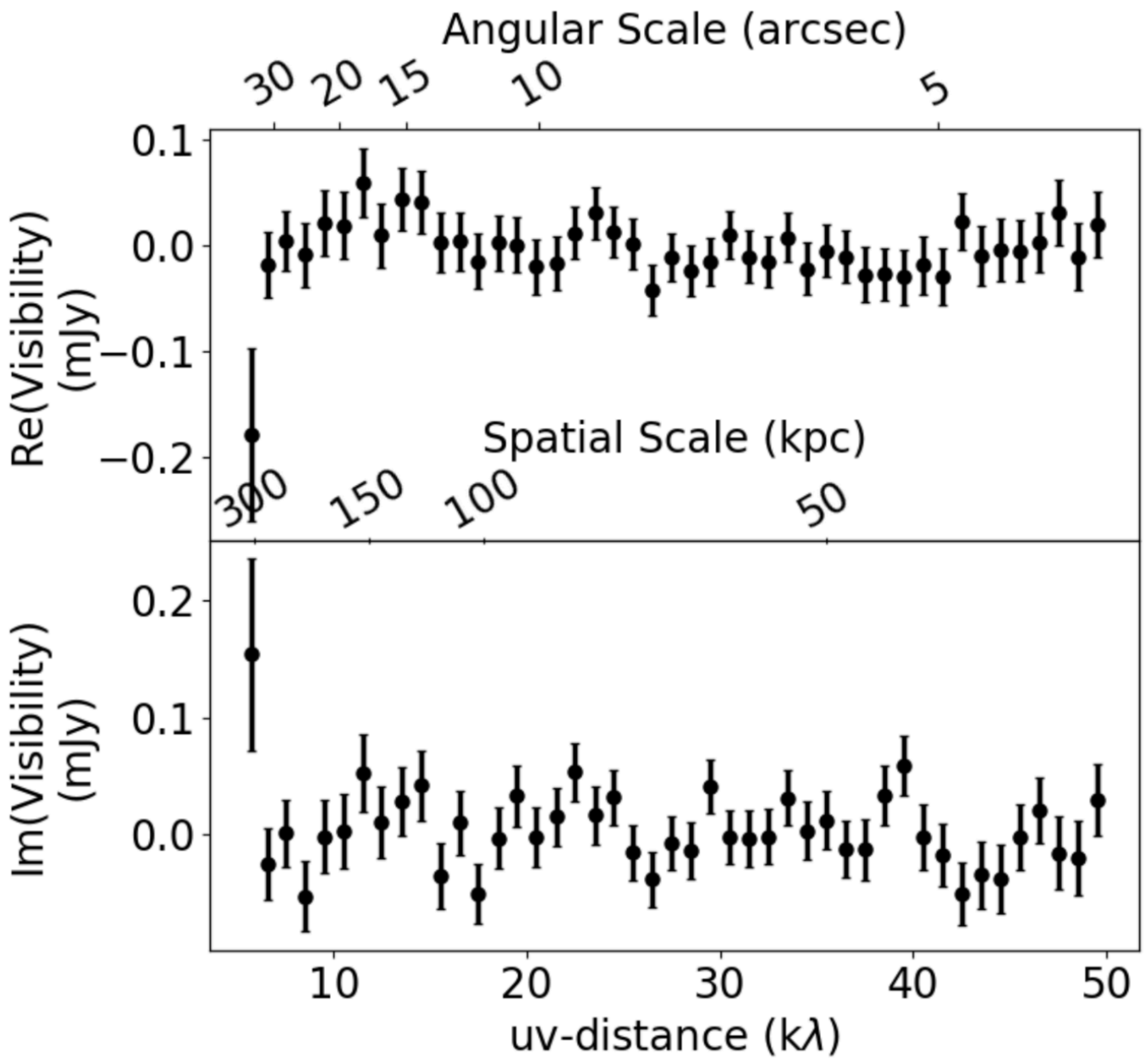
Brownson et et al., 2019

RQQ HE0515-4414

~3-3.3σ measurement —> ~0.1% quasar luminosity

~factor 10 below expectations

Residuals



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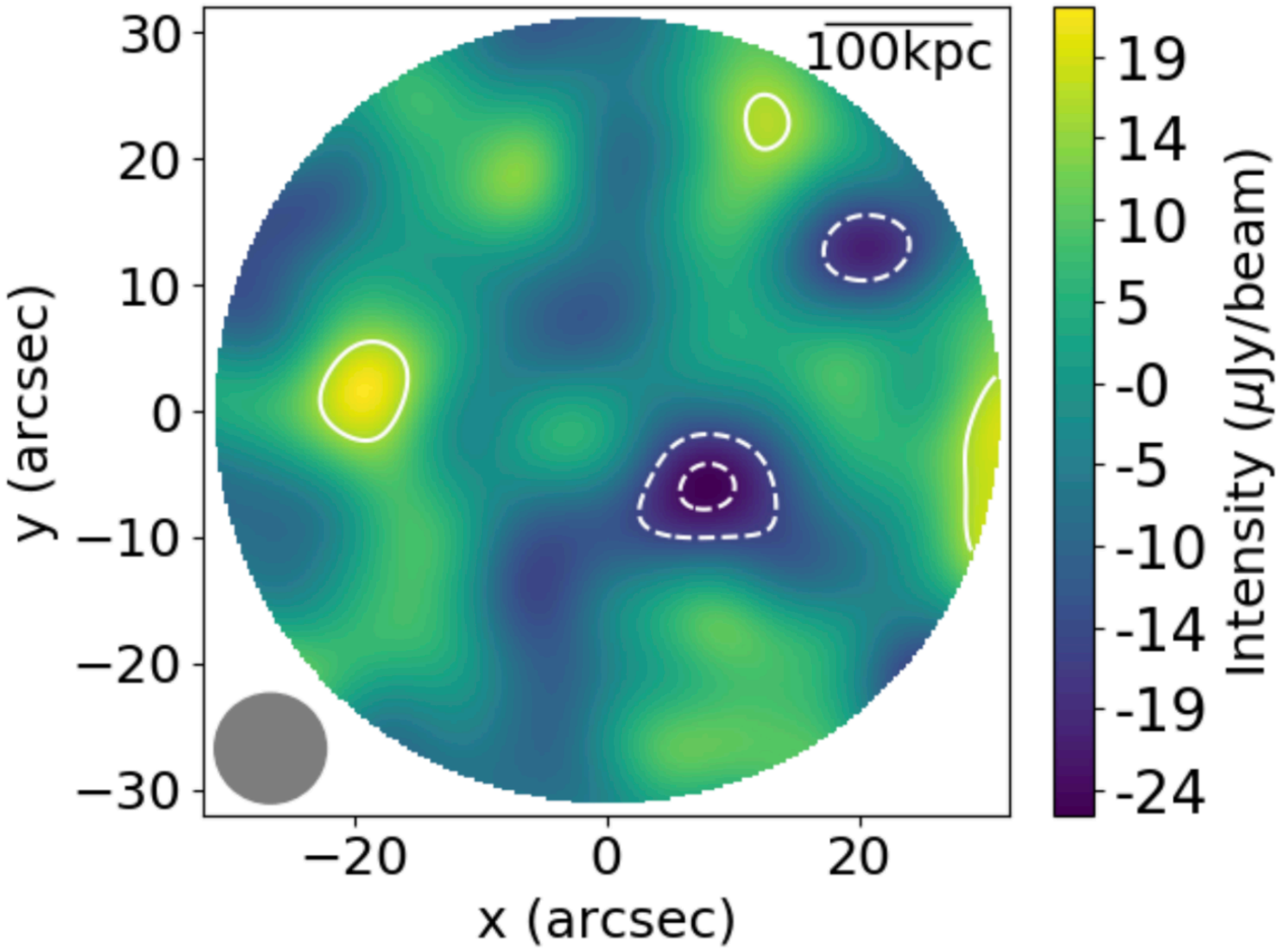
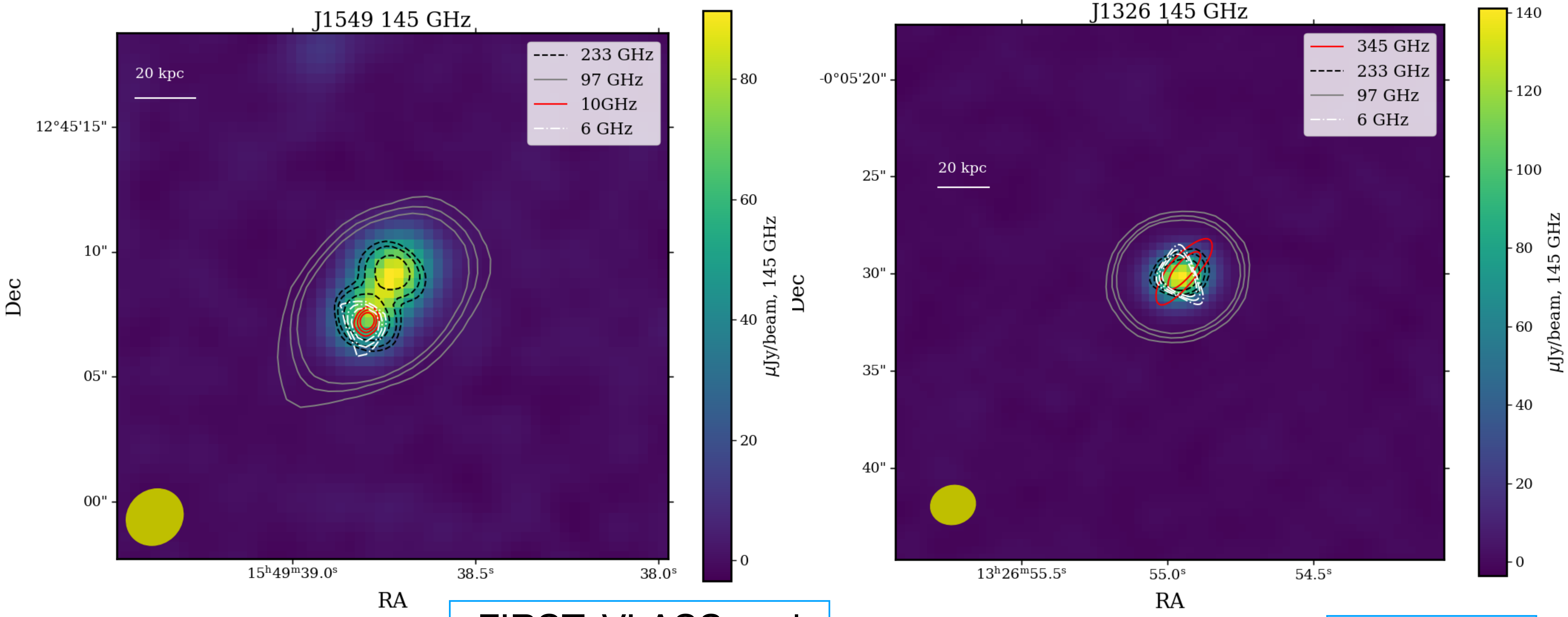


Brownson et et al., 2019

VLA, ALMA, SMA study of 2 Hyperluminous Quasars

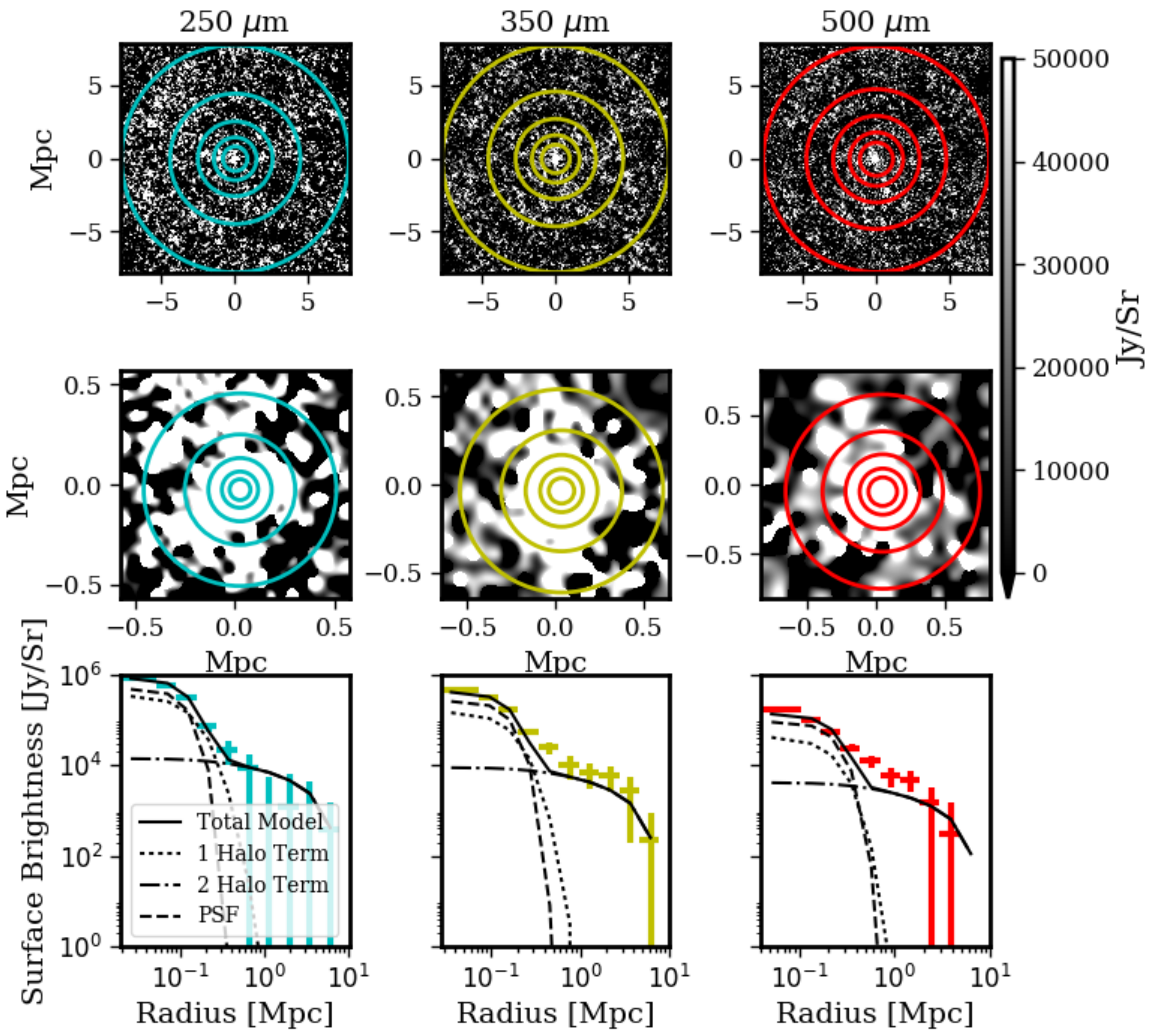


Hall et al., in prep

+FIRST, VLASS and VLA & ALMA archival

+VLASS

Quasars Trace Overdensities



Hall et al., 2018

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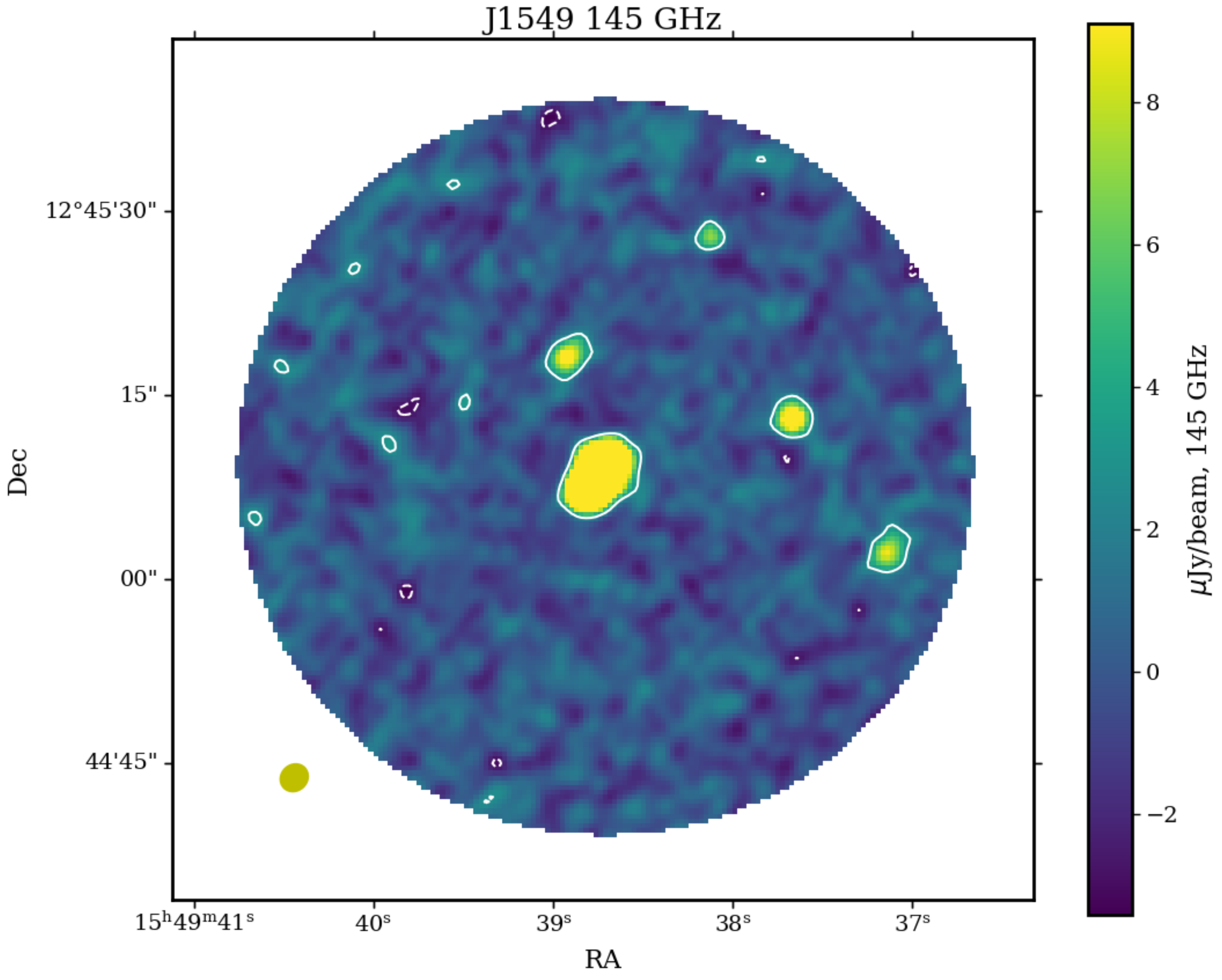
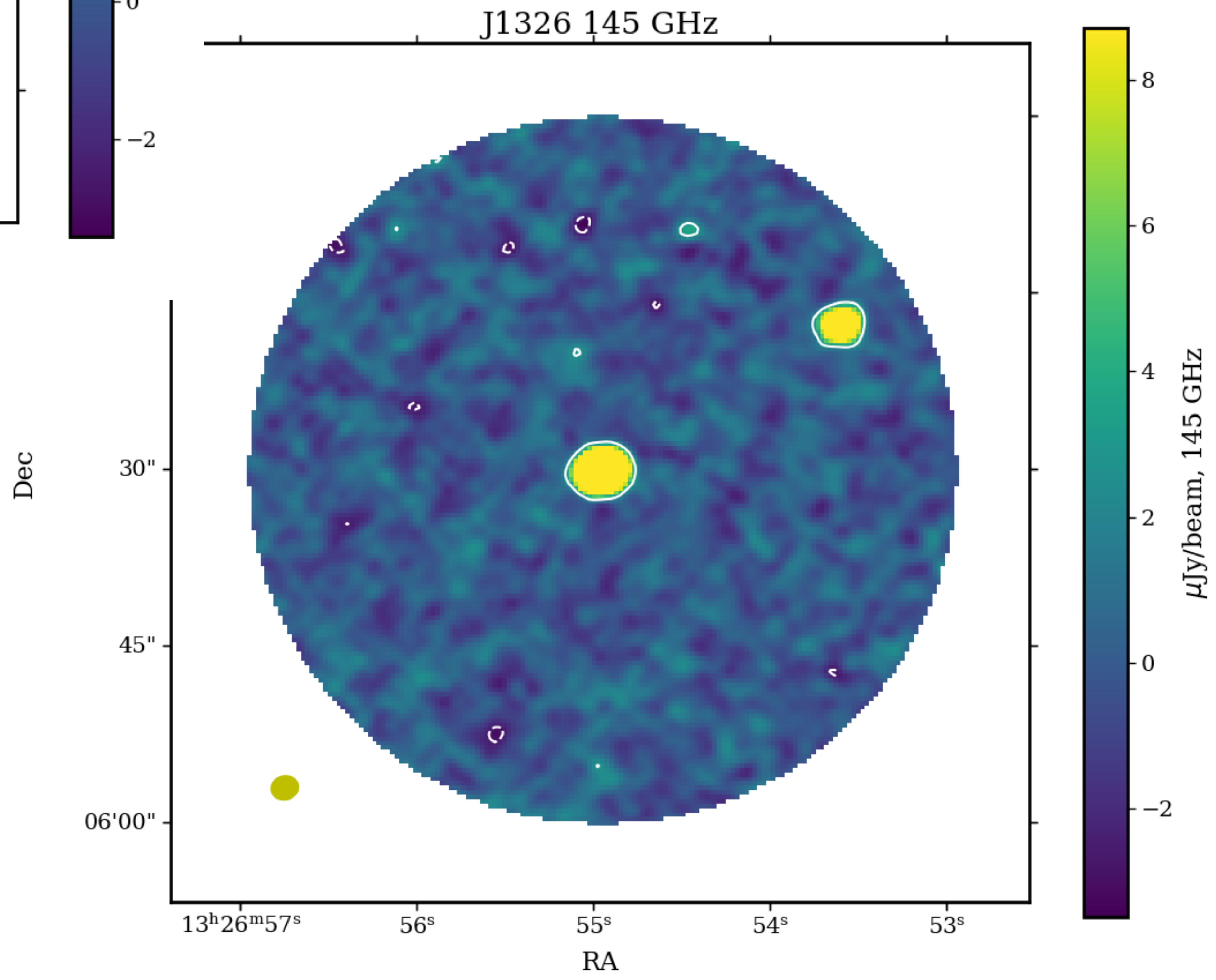
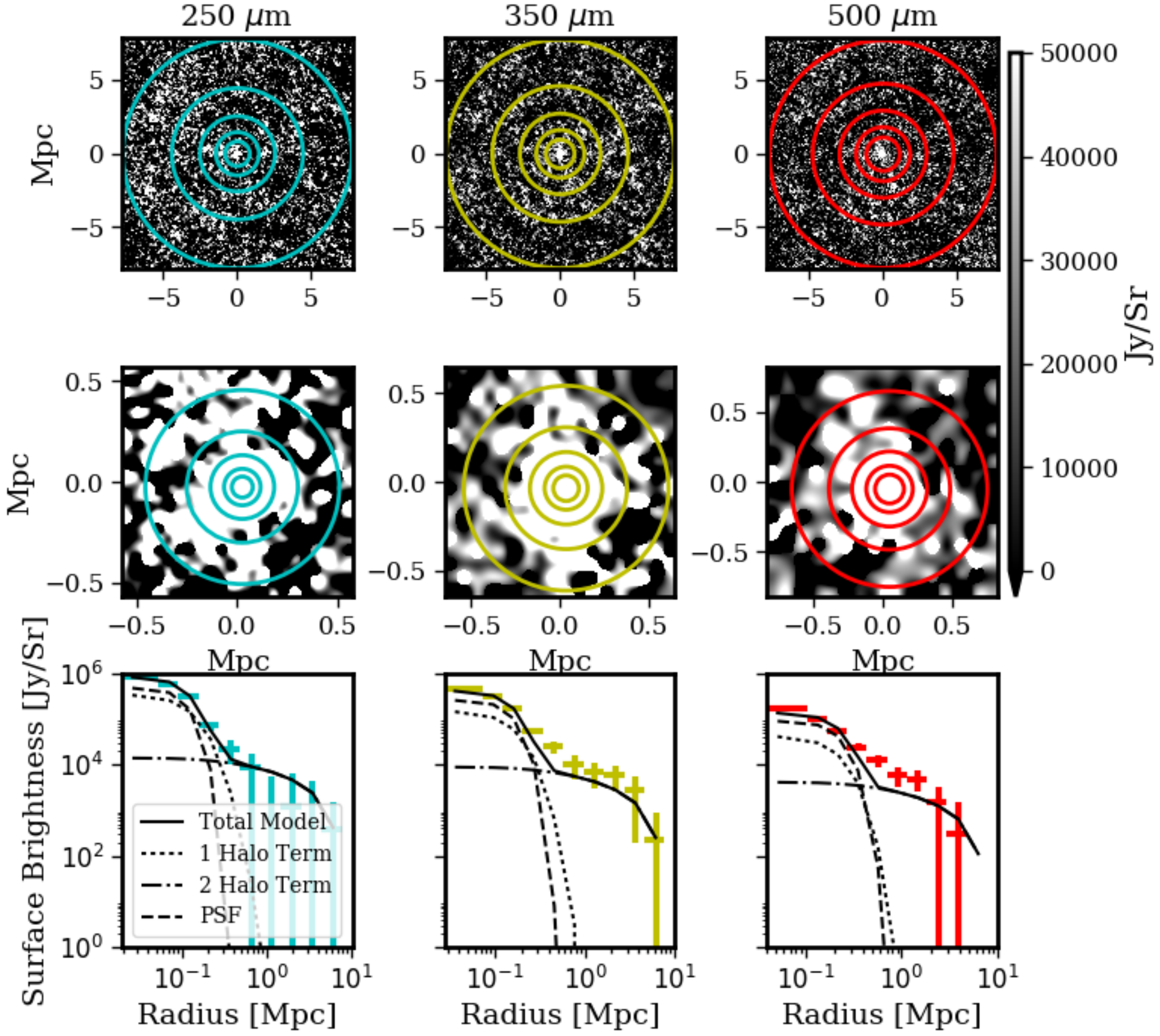


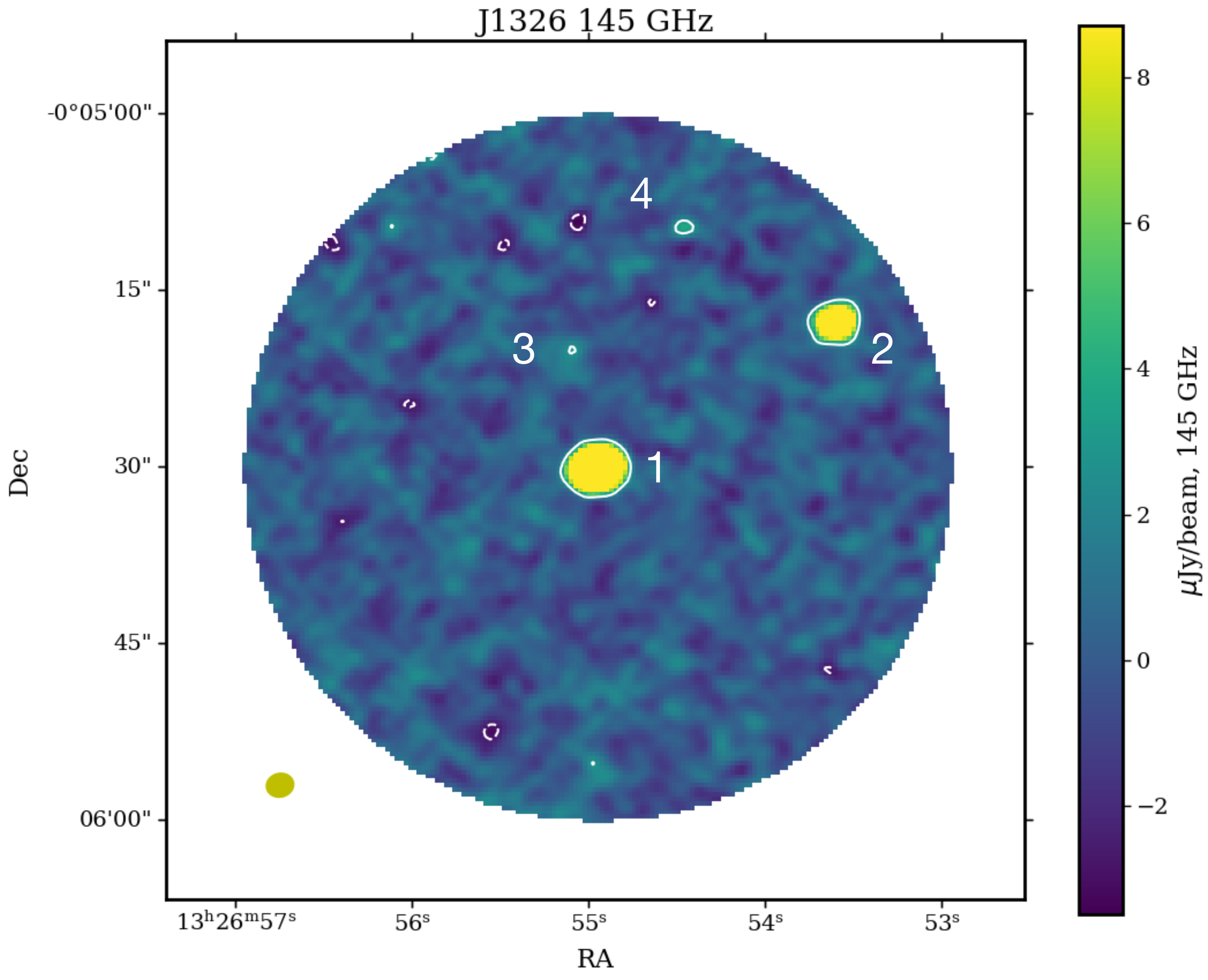


Hall et al., in prep



Hall et al., 2018

Visibility Modeling



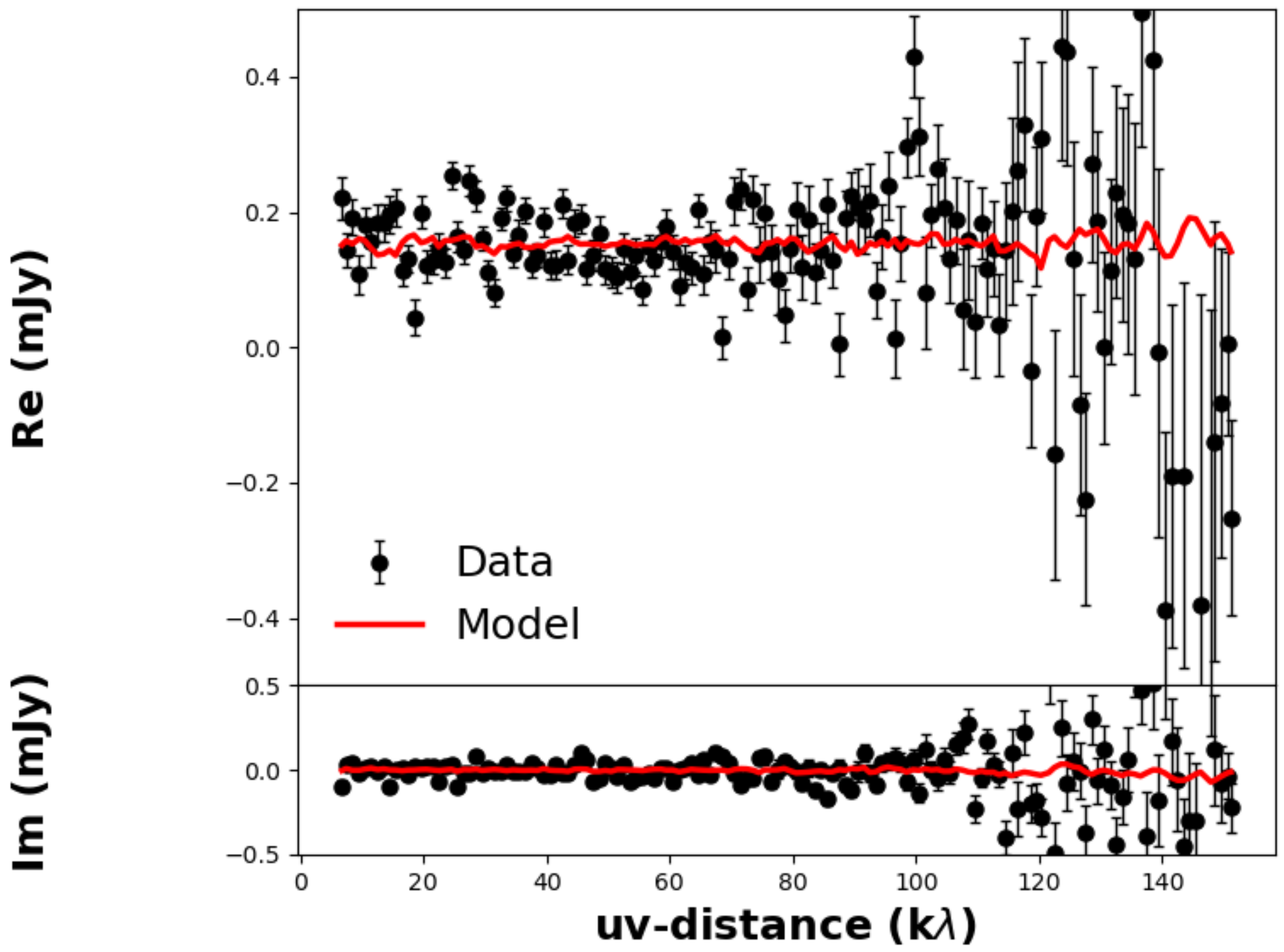


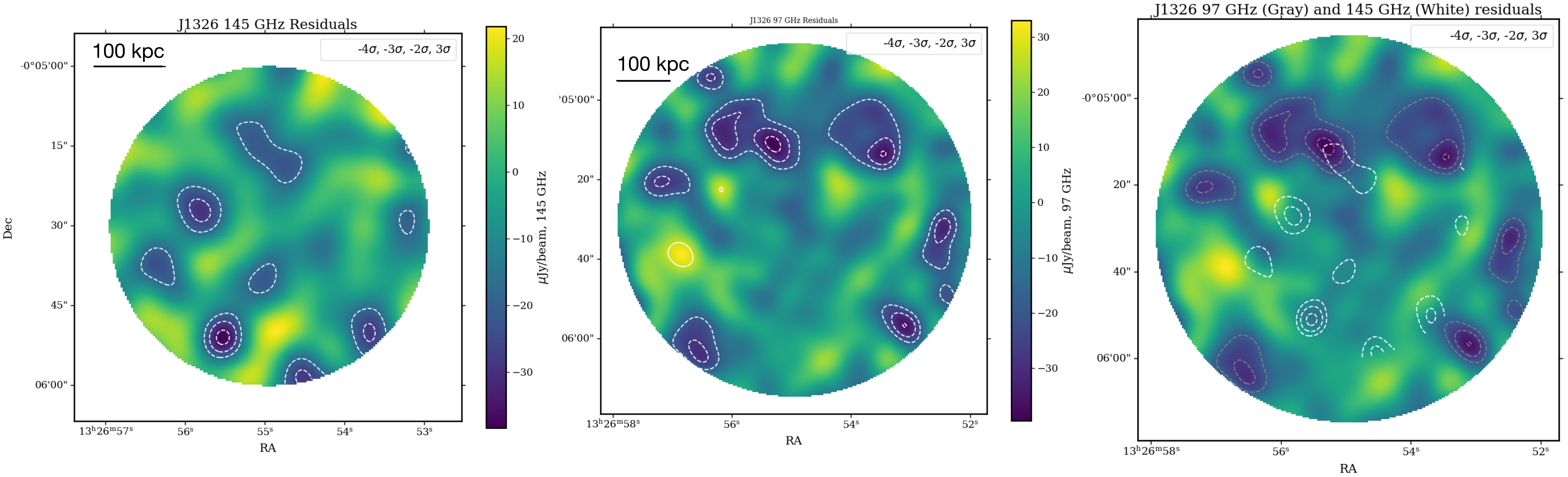
Image Residuals

In Progress

Image Residuals - 3 arcsec taper

In Progress

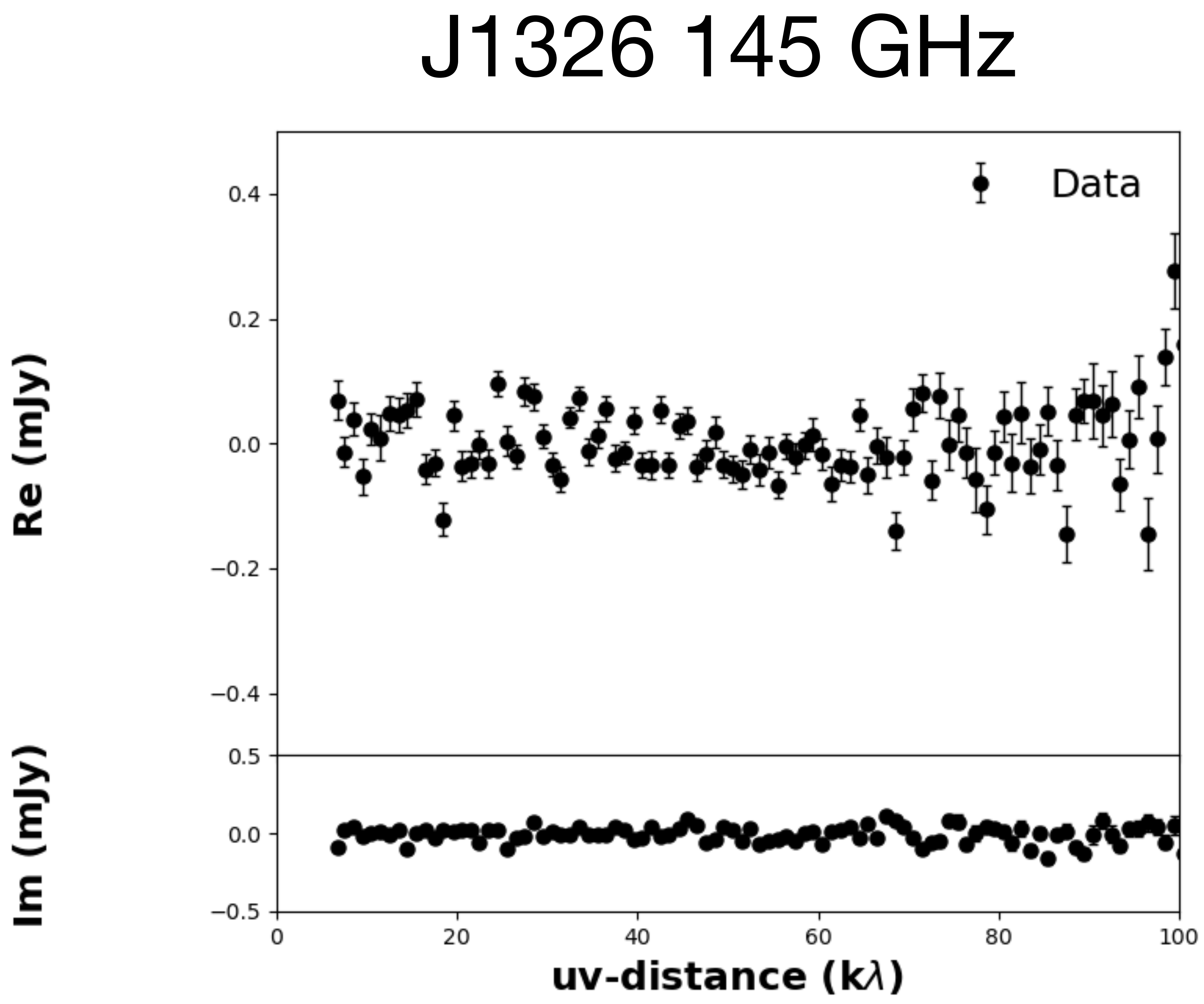
Image Residuals - 8 arcsec taper

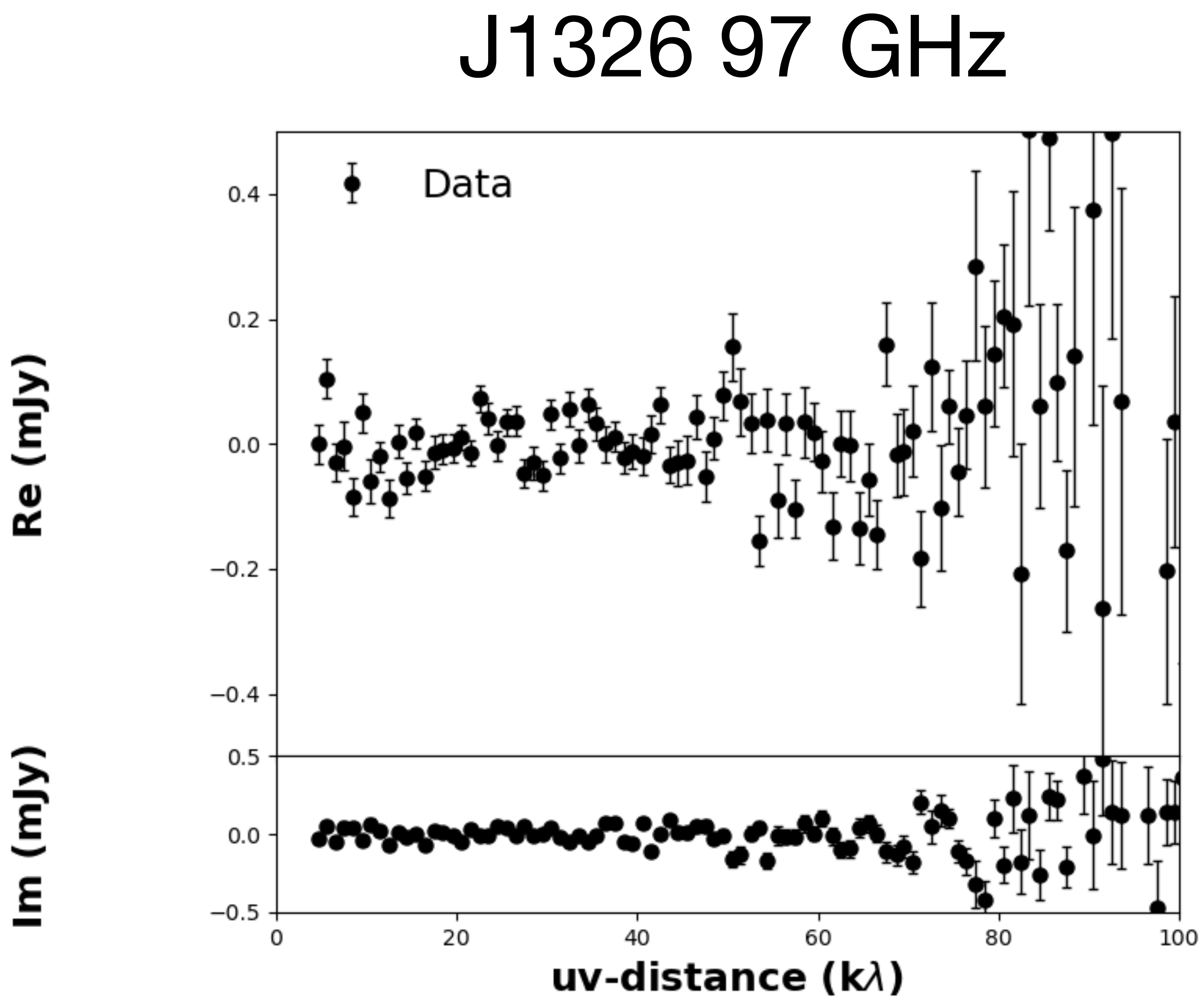


~50μJy —> ~0.2% quasar luminosity over 100 Myr

In Progress

Visibility Residuals





In Progress

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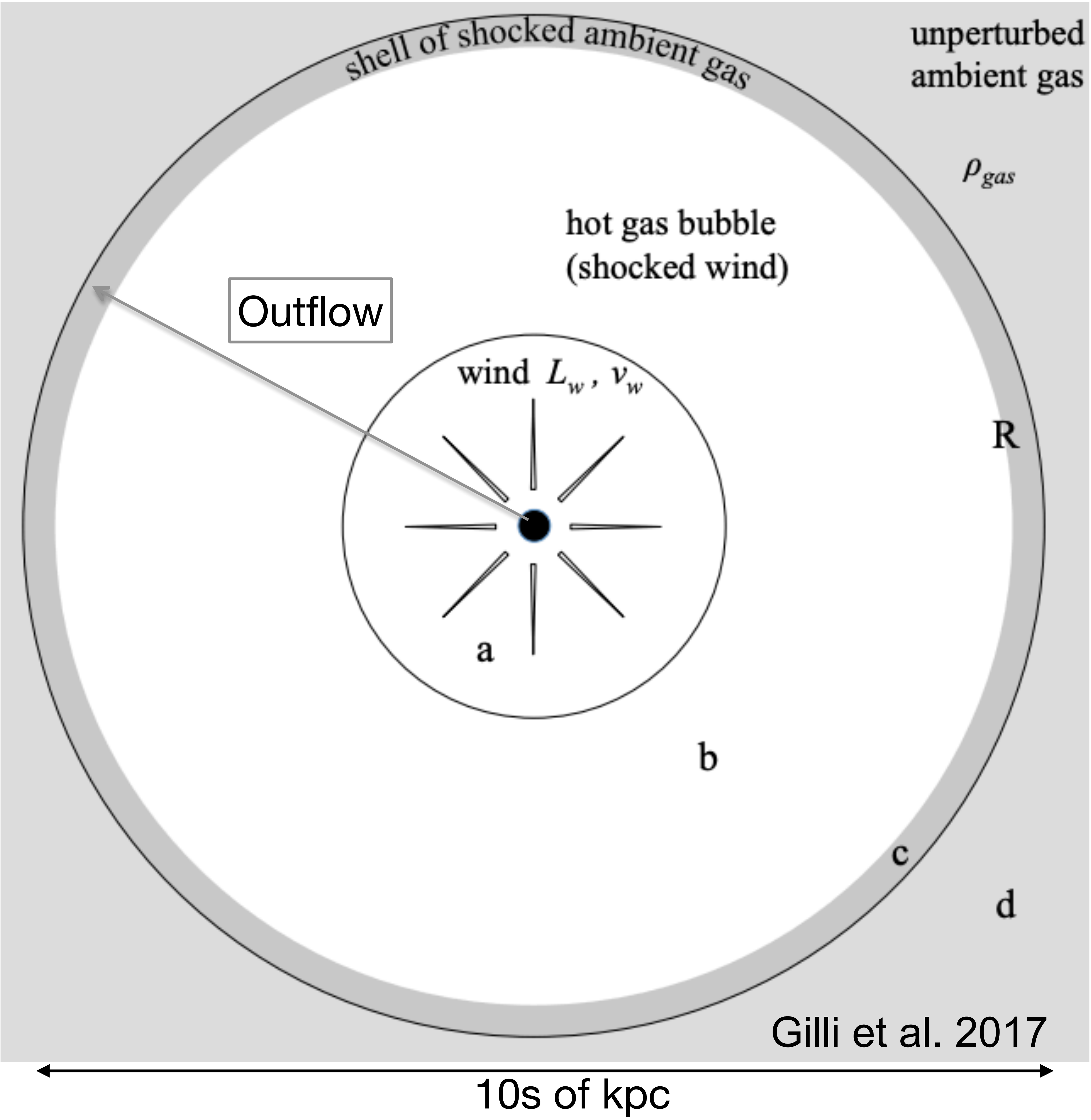


Summary

Tentative 4σ tSZ measurement —> 0.2% $L_{bol,quasar}$

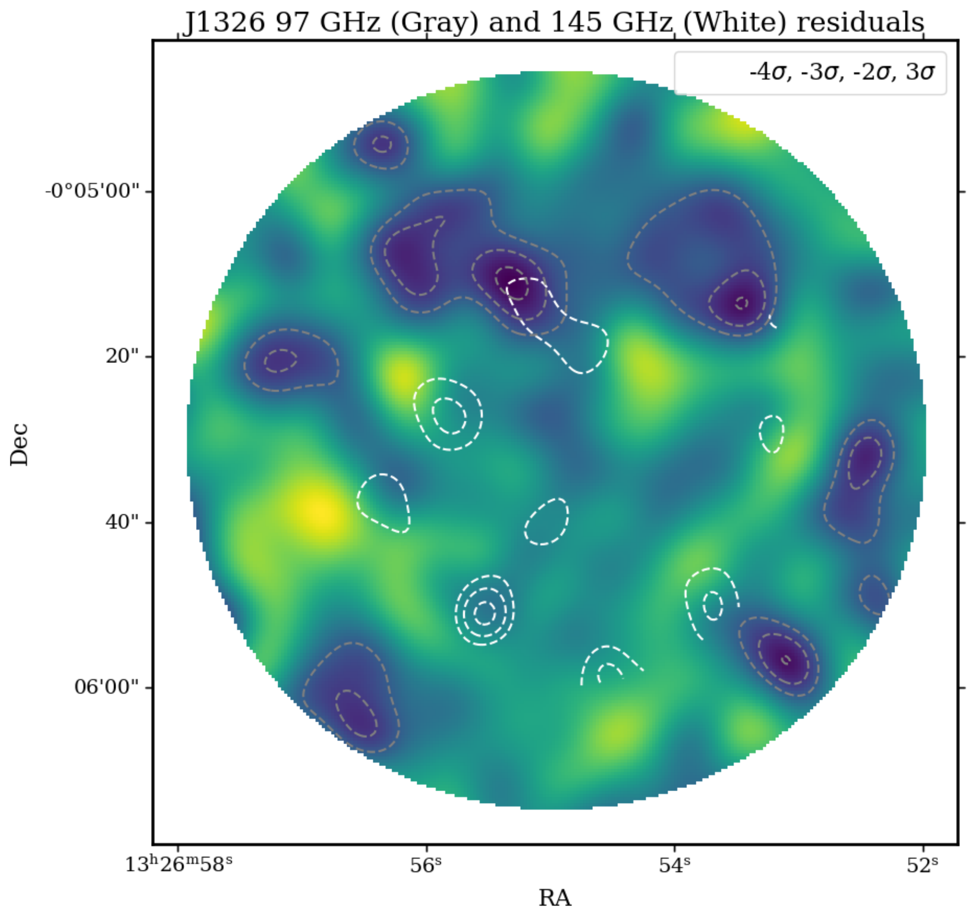
Multifrequency interferometry is the pathway forward, but the data are *complex*

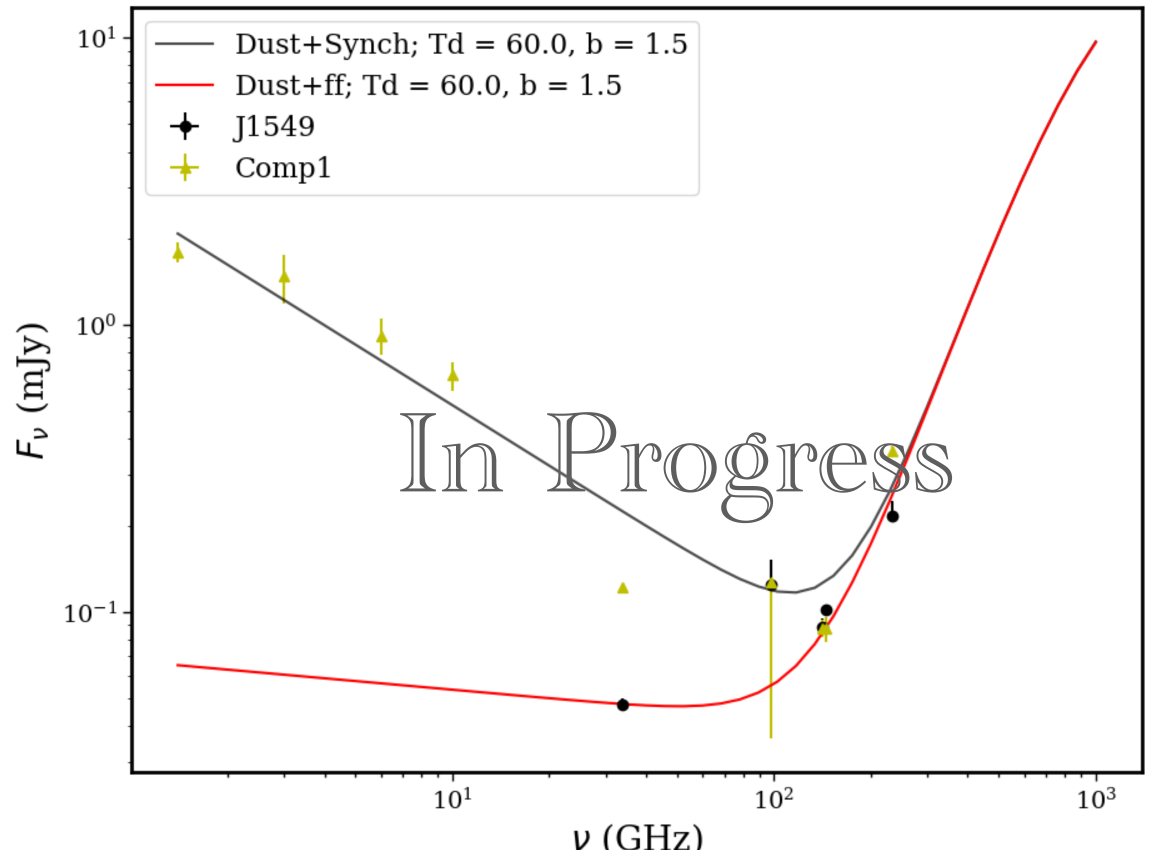
To Do:

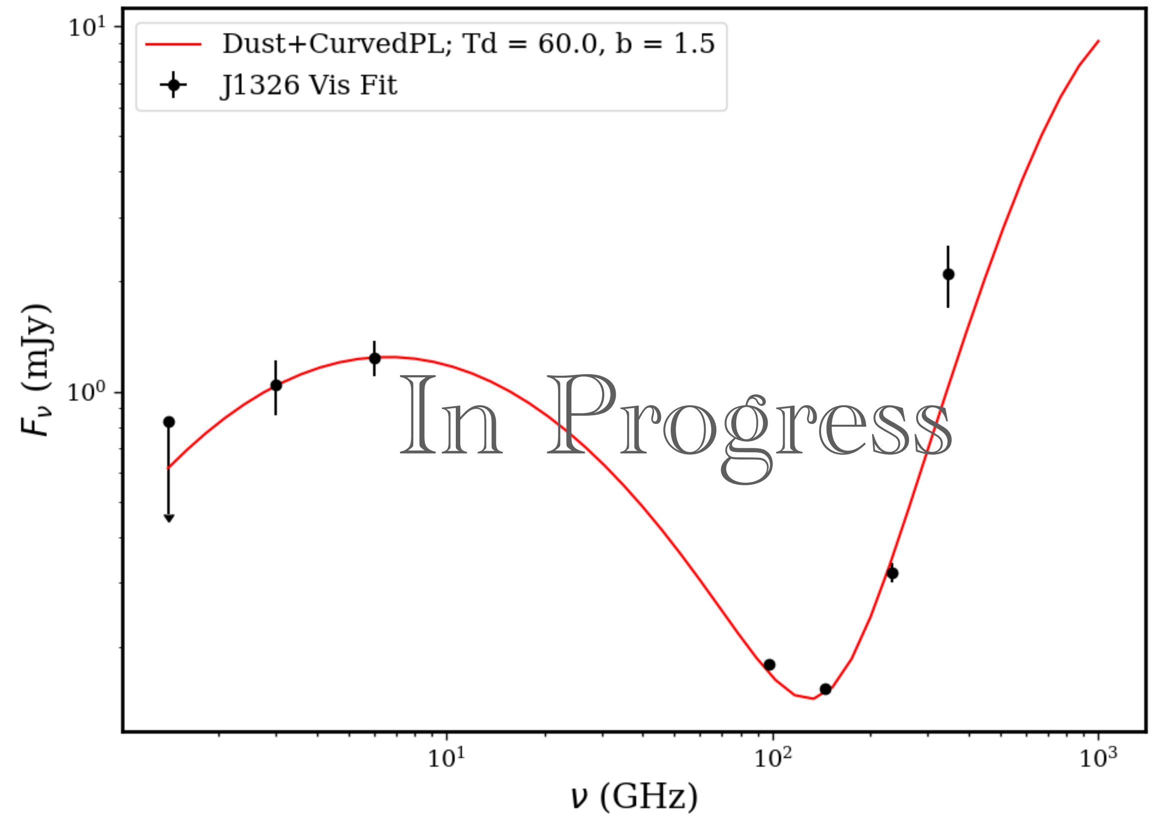
- tSZ map combining 97 and 145 GHz
  - And 30 GHz VLA for J1549
- Radio through Sub-mm SED modeling
- CO SLED in J1549+1245

Stay Tuned!

Kirsten Hall, kirsten.hall@cfa.harvard.edu







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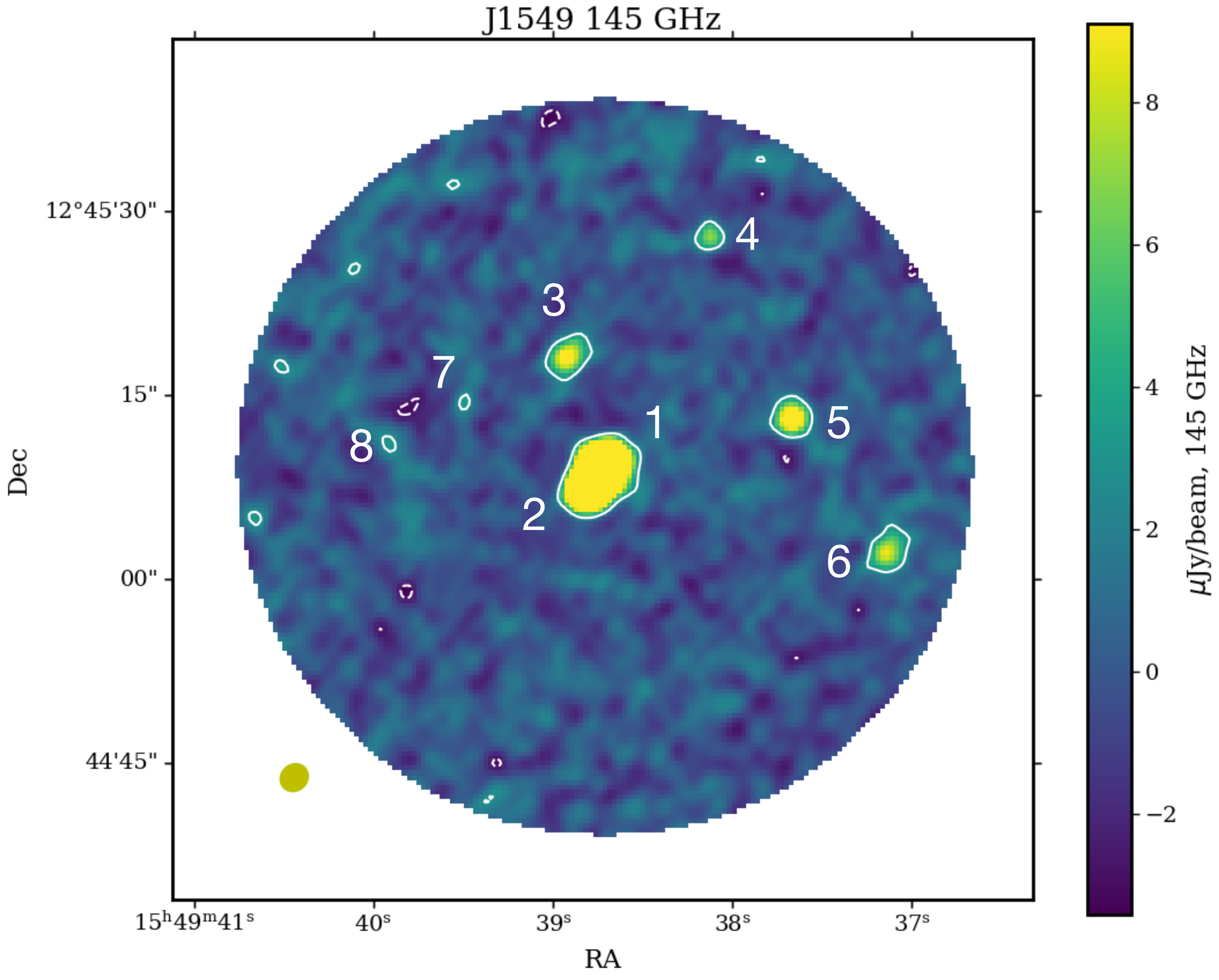

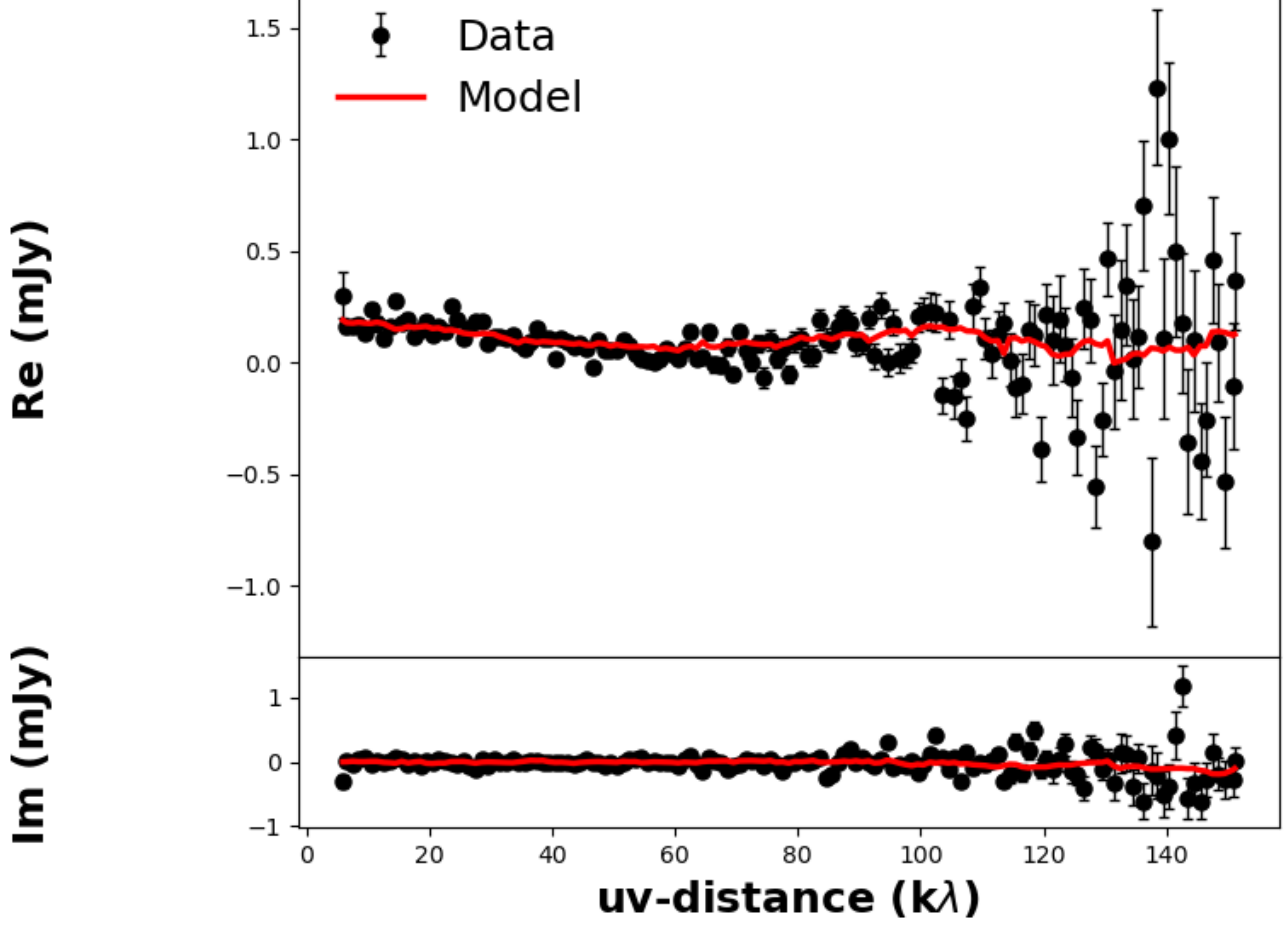

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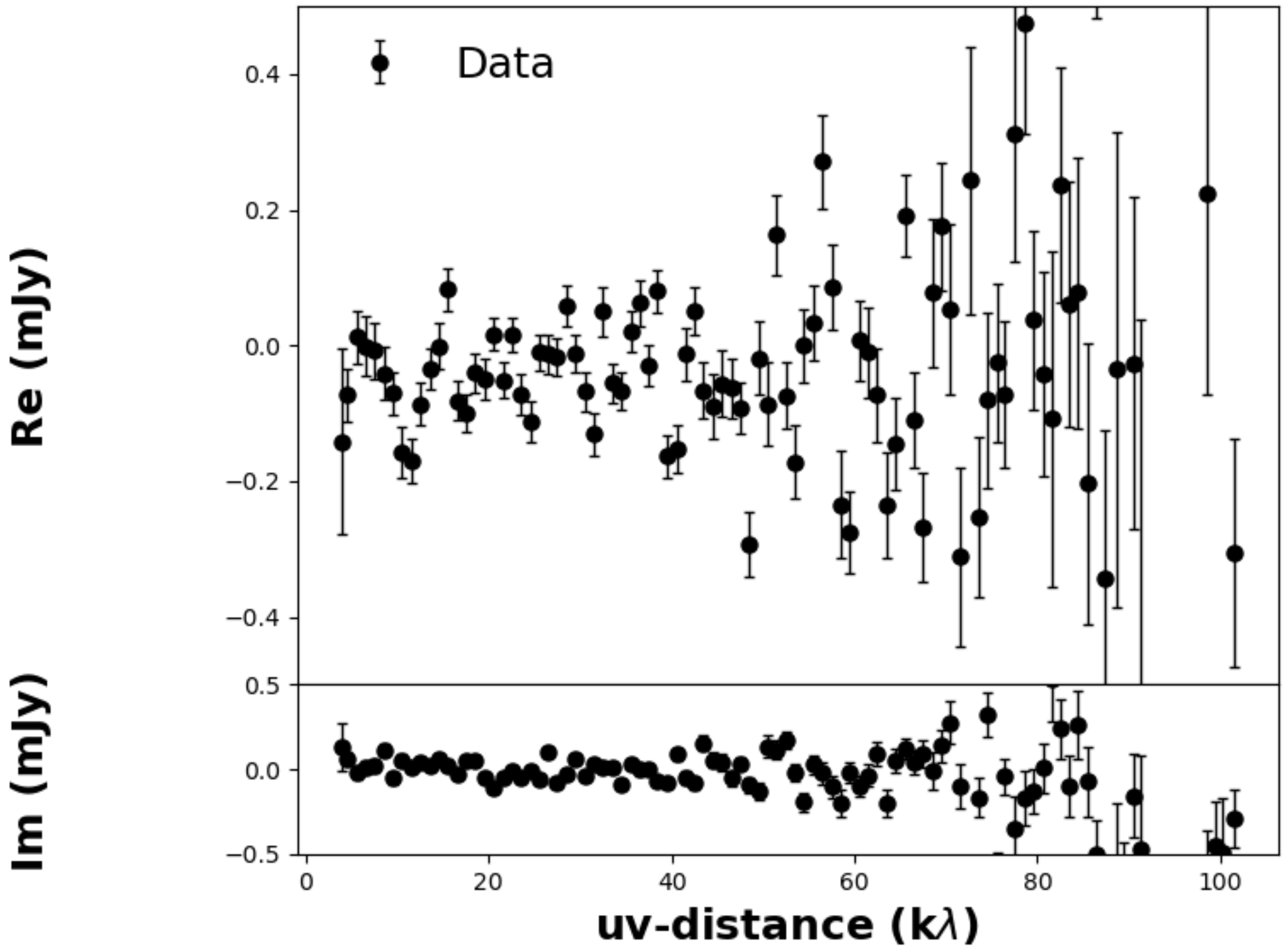

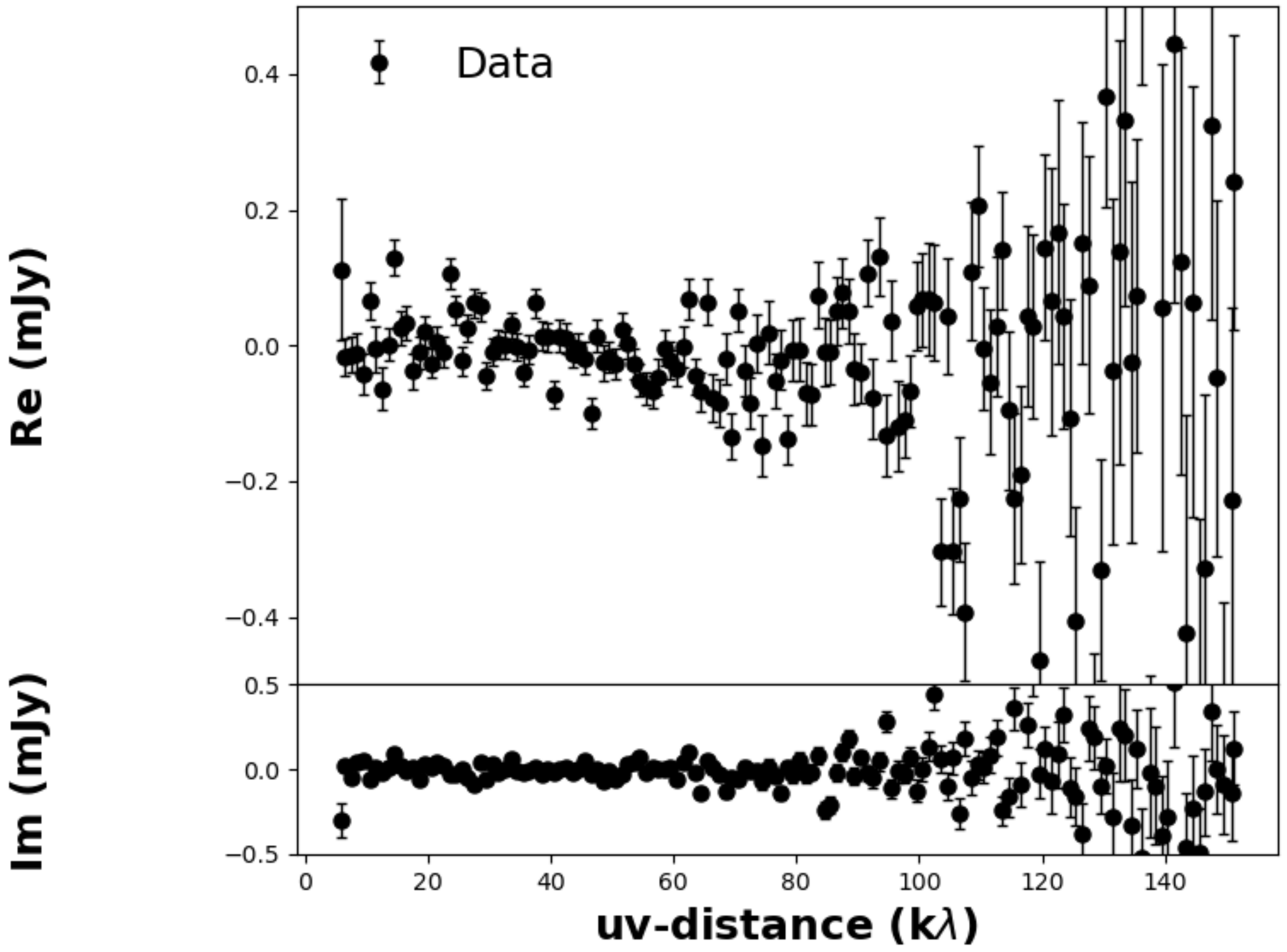

Preliminary