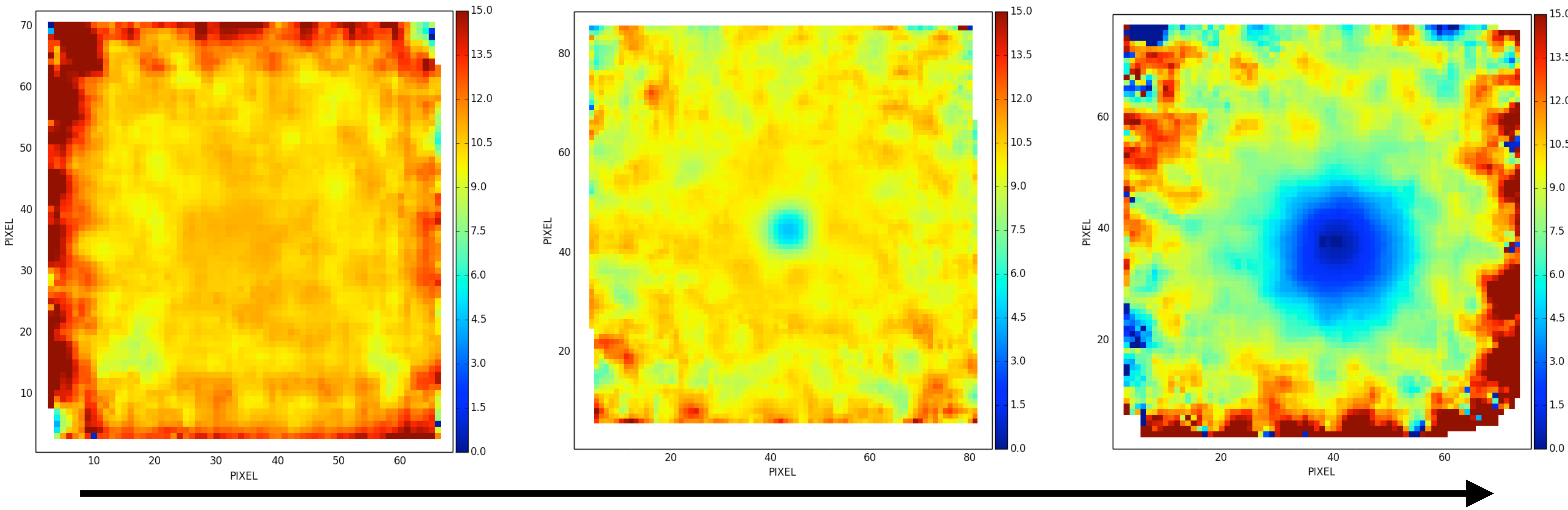
The search for a disappearing AGN torus

Leonard Burtscher, Richard I. Davies, Ming-yi Lin, Gilles Orban de Xivry, David Rosario, Allan Schnorr-Müller

CO 2.3 μm equivalent width maps



AGN luminosity

IAU Symposium 309, July 2014, Vienna

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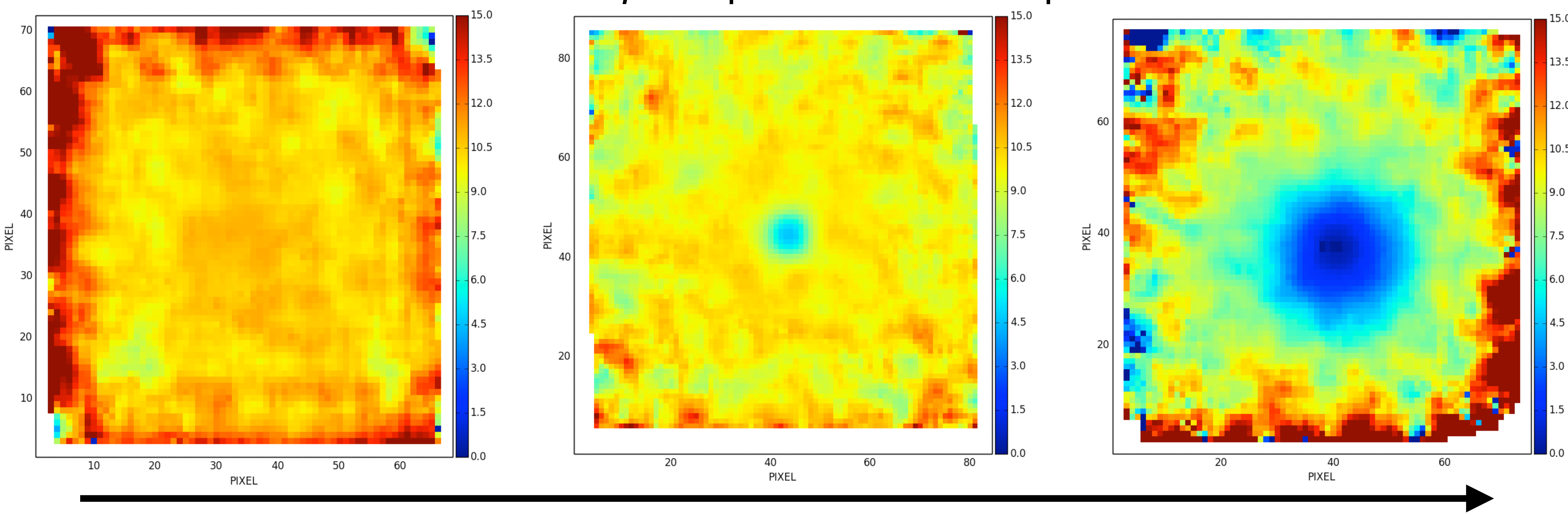


AGN luminosity

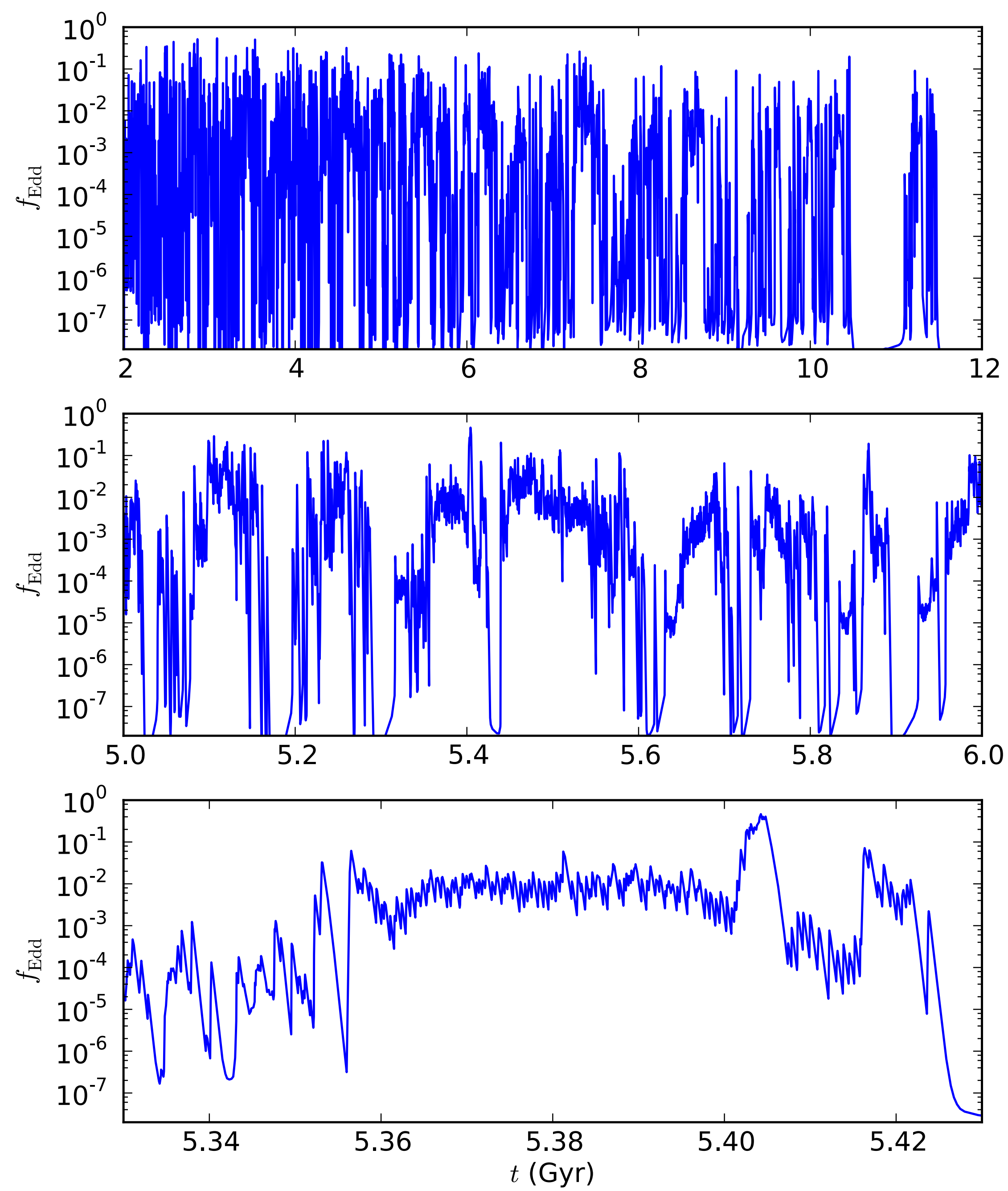
IAU Symposium 309, July 2014, Vienna

What causes AGN activity?

Novak+ 2011

What causes AGN activity?

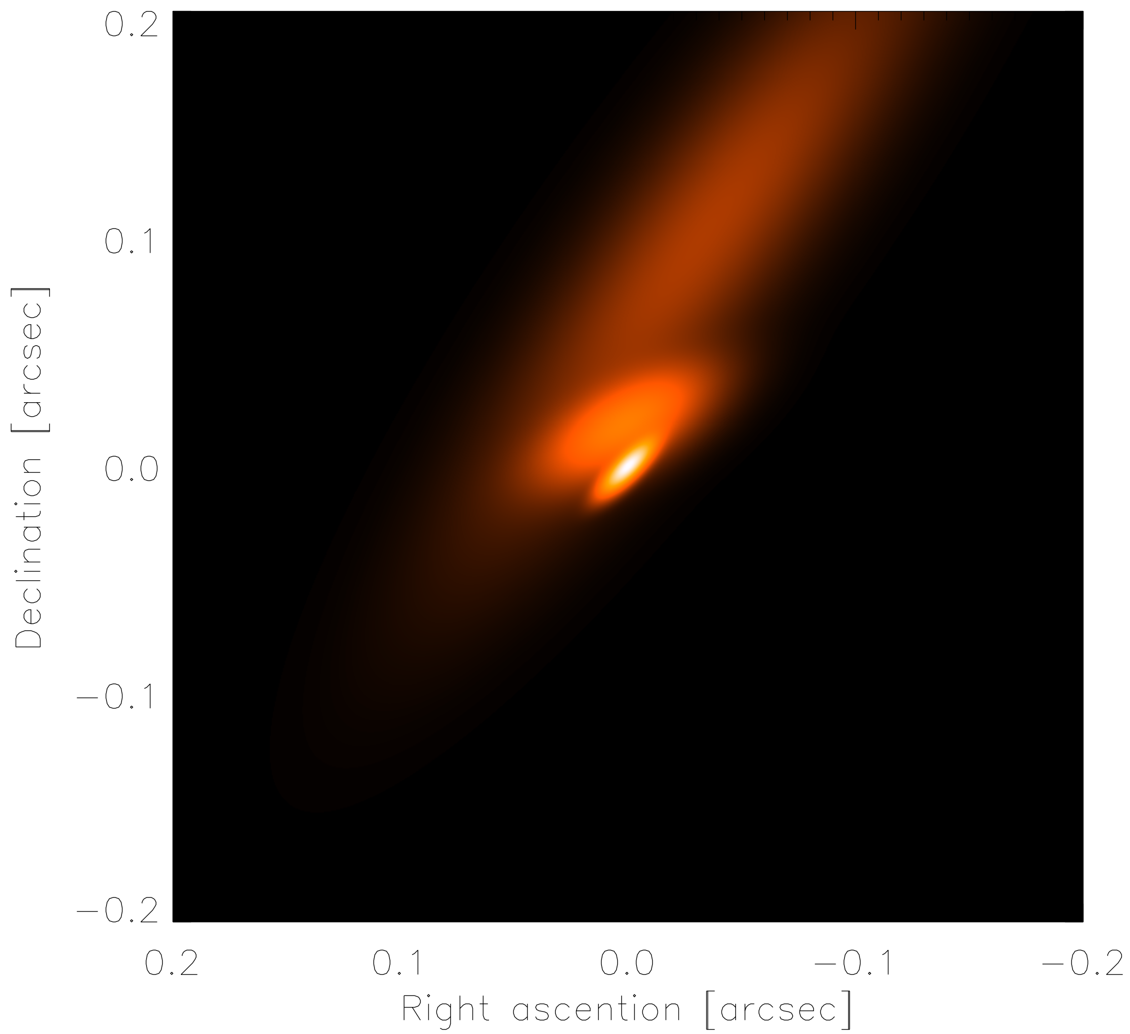
Variability on „short“ timescales



Novak+ 2011

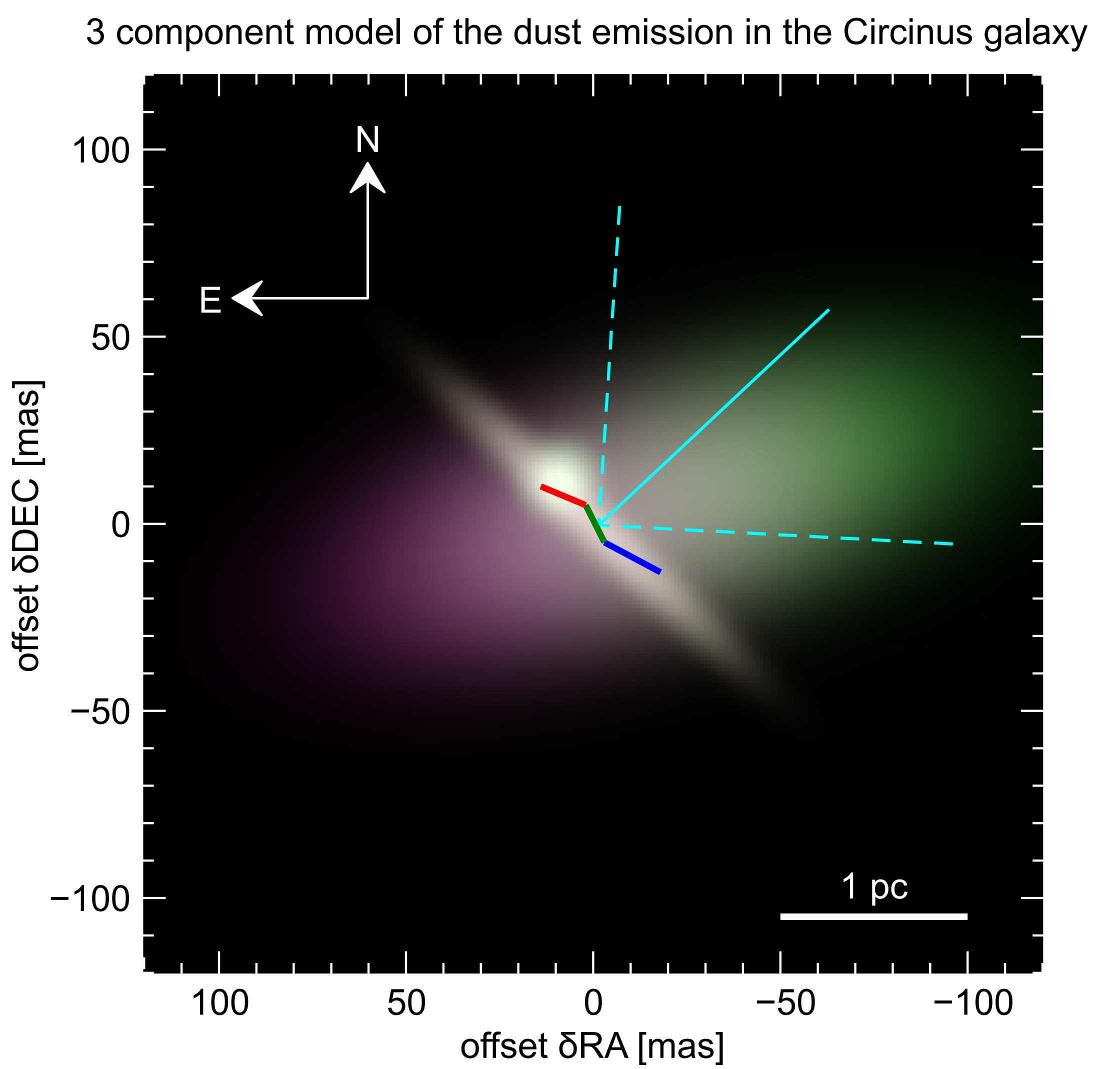
The AGN „torus“

as resolved on sub-pc scale with VLTI



NGC 1068

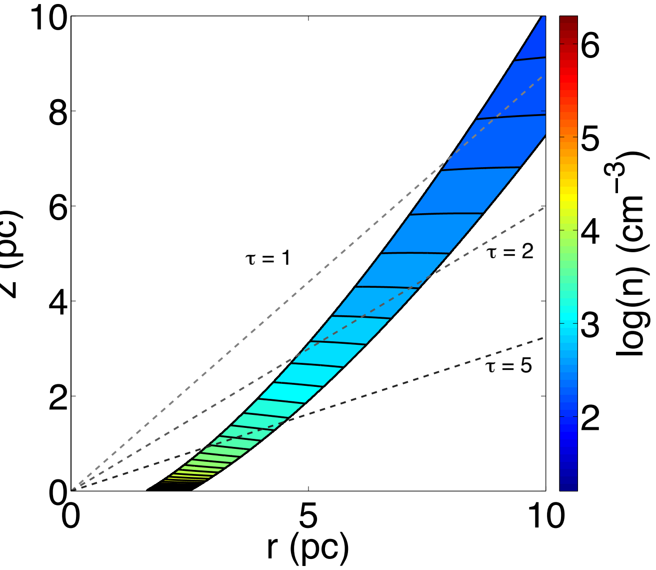
Lopez, Jaffe, Burtscher+ 2014

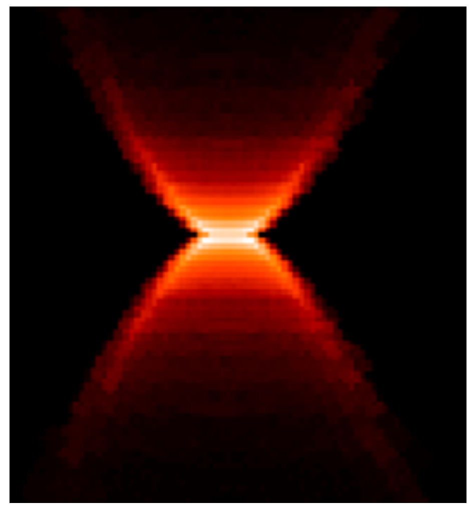


Circinus galaxy

Tristram, Burtscher+ 2013

AGN Torus disappearance





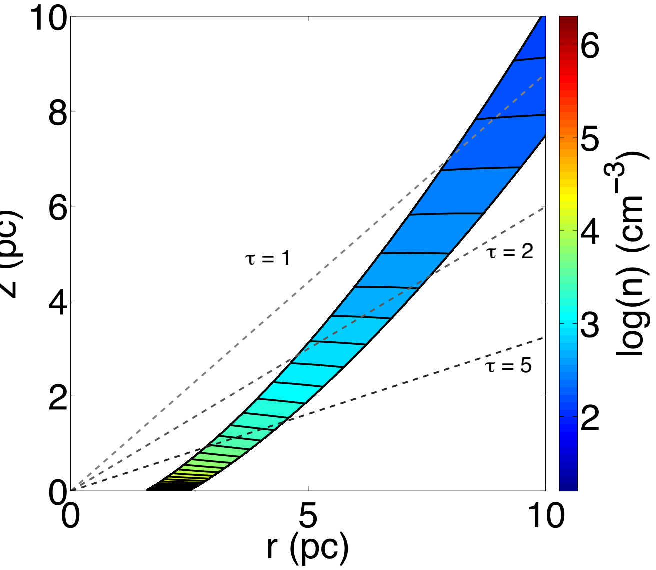
Radiation-driven outflow / disk wind
(e.g. Gallagher+ 2013)

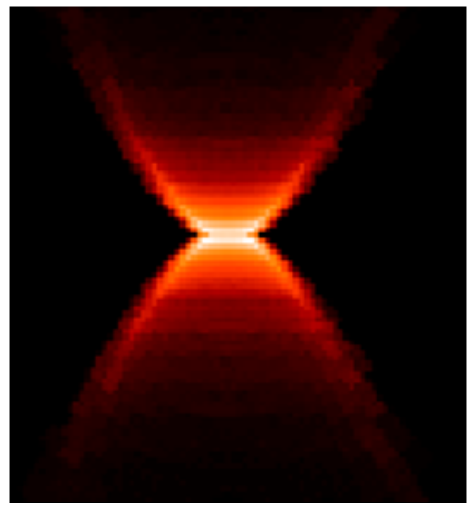
Disk wind scenario

- Mass outflow ~ $L^{1/2}$; L ~ $\dot{M}_{in}$
  → $\dot{M}_{out}/\dot{M}_{in}$ ~ $L^{-1/2}$

- since $\dot{M}_{out}$ must be < $\dot{M}_{in}$, torus disappears at L_{bol} ~ 10^{42} erg/s (Elitzur & Shlosman 2006)

AGN Torus disappearance





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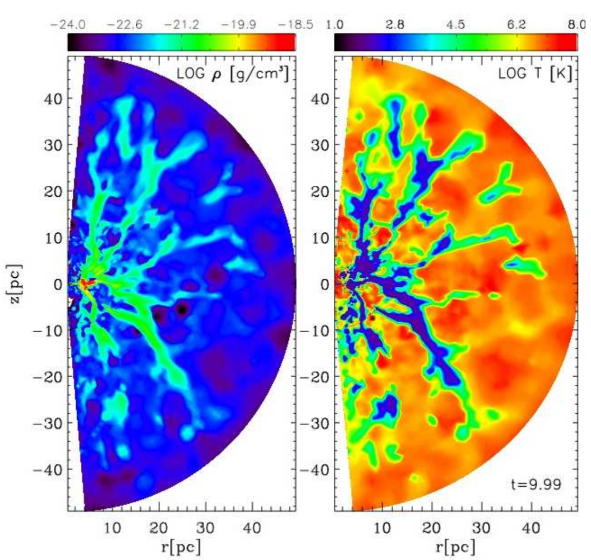
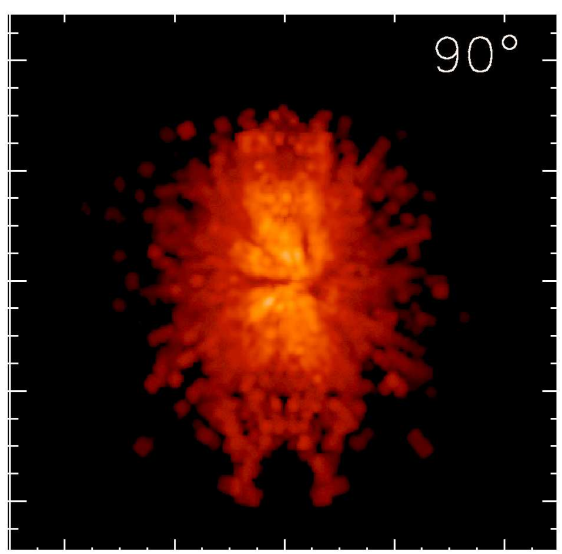




Starburst-driven inflow
(e.g. Schartmann+ 2008)

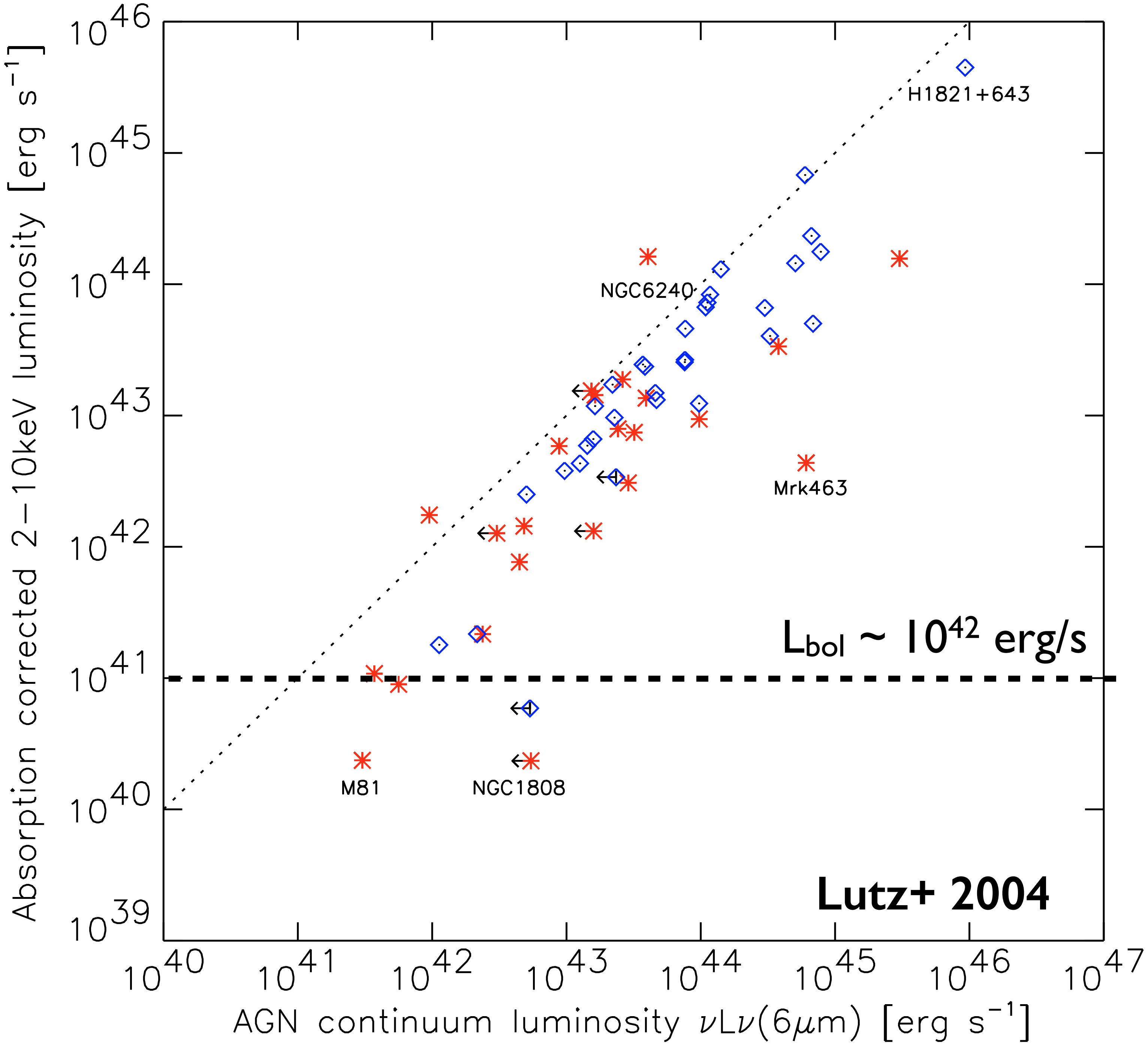
Disk wind scenario

- Mass outflow ~ $L^{1/2}$; $L \sim \dot{M}_{in}$
  → $\dot{M}_{out}/\dot{M}_{in} \sim L^{-1/2}$
- since $\dot{M}_{out}$ must be < $\dot{M}_{in}$, torus disappears at $L_{bol} \sim 10^{42}$ erg/s (Elitzur & Shlosman 2006)

Stationary accretion model

- volume filling factor $\Phi \sim \dot{M}_{torus}^{-1/2} \sim L^{-1/2}$
  → $\Phi \sim L^{-1/2}$ (Beckert & Duschl 2004)
- clumpy torus: $\Phi \ll 1$ → lower limit for existence of obscuring torus at $L_{bol} \sim 10^{42}$ erg/s (Hönig & Beckert 2007)

The mid-IR-X-ray relation



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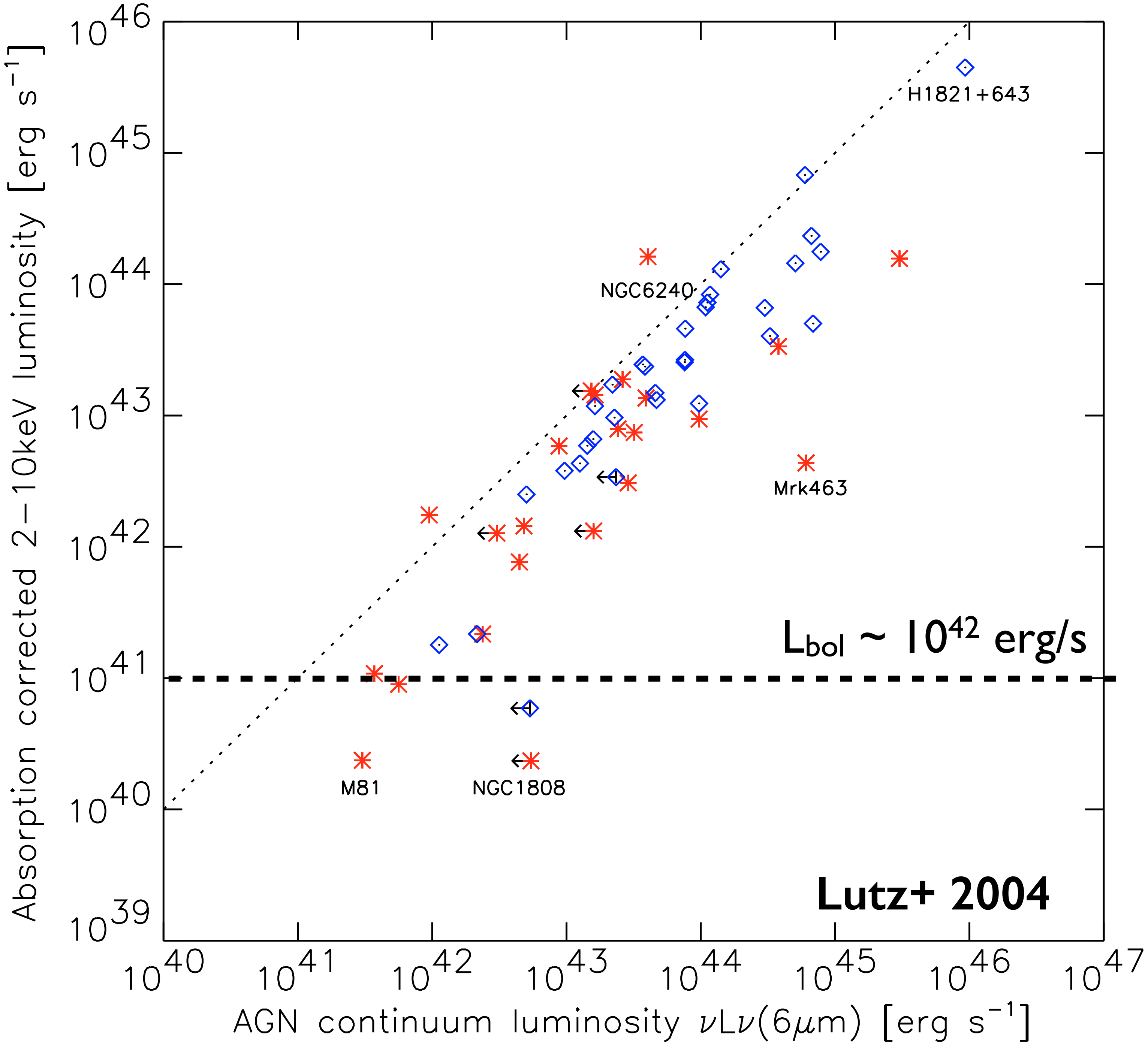
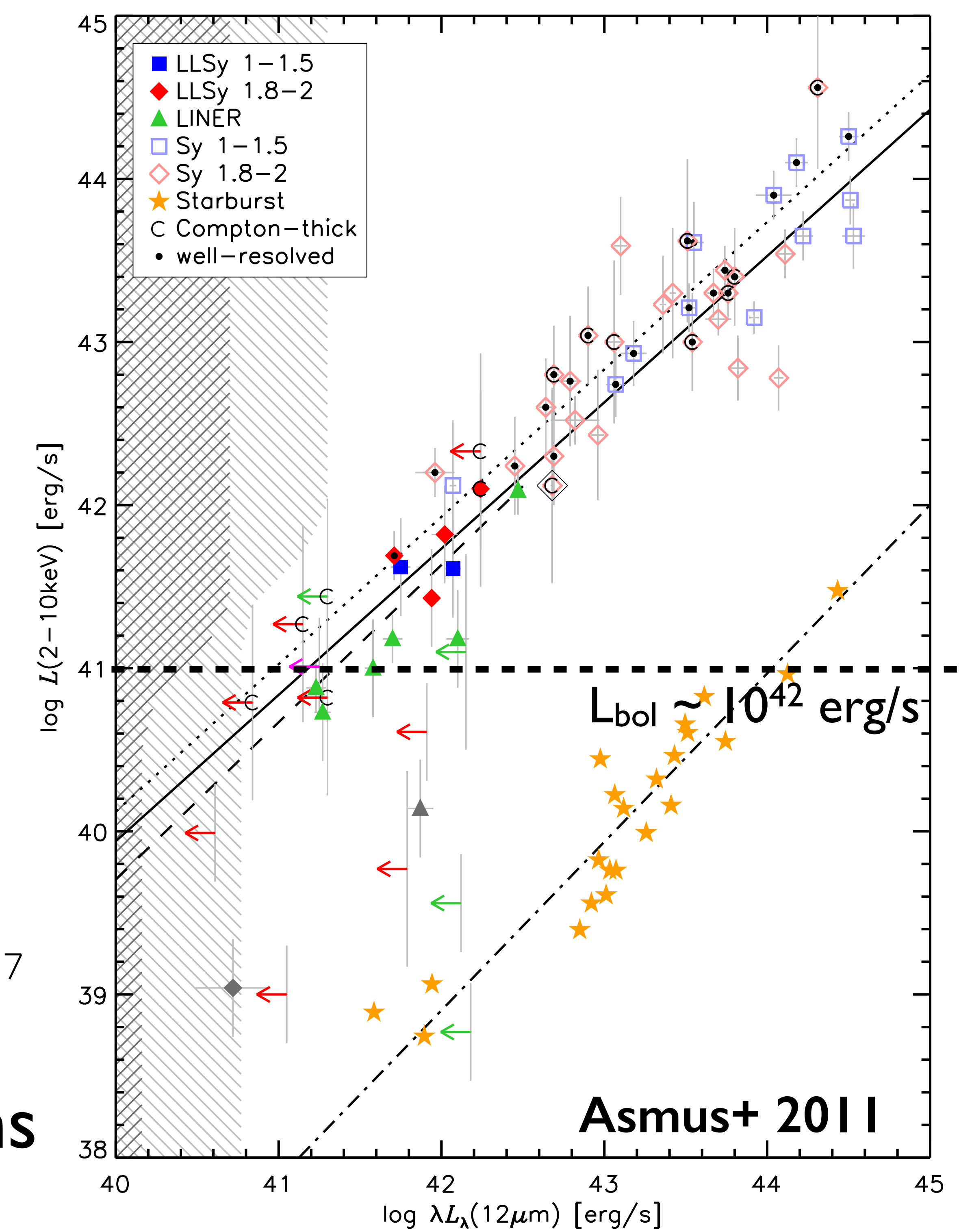
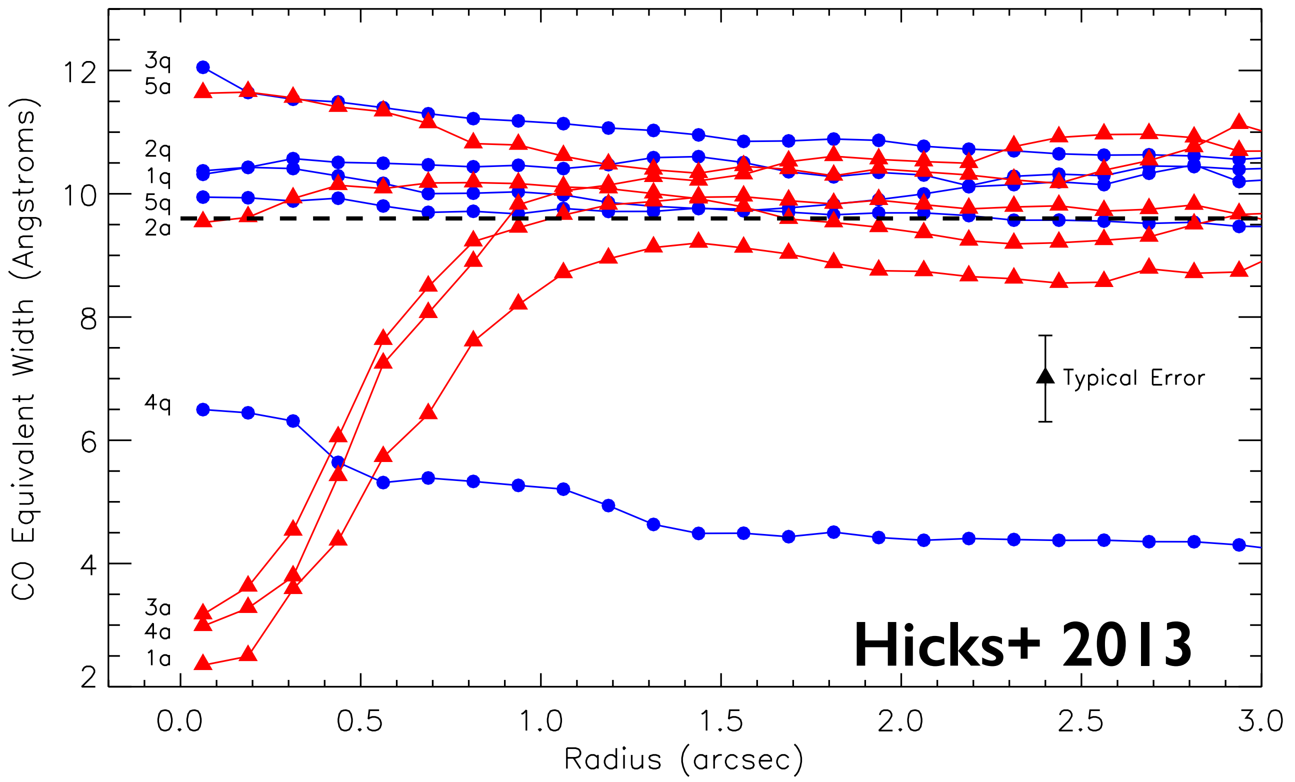




Even with sensitive mid-IR observations it is hard to push below this limit

Probing the non-stellar continuum with SINFONI



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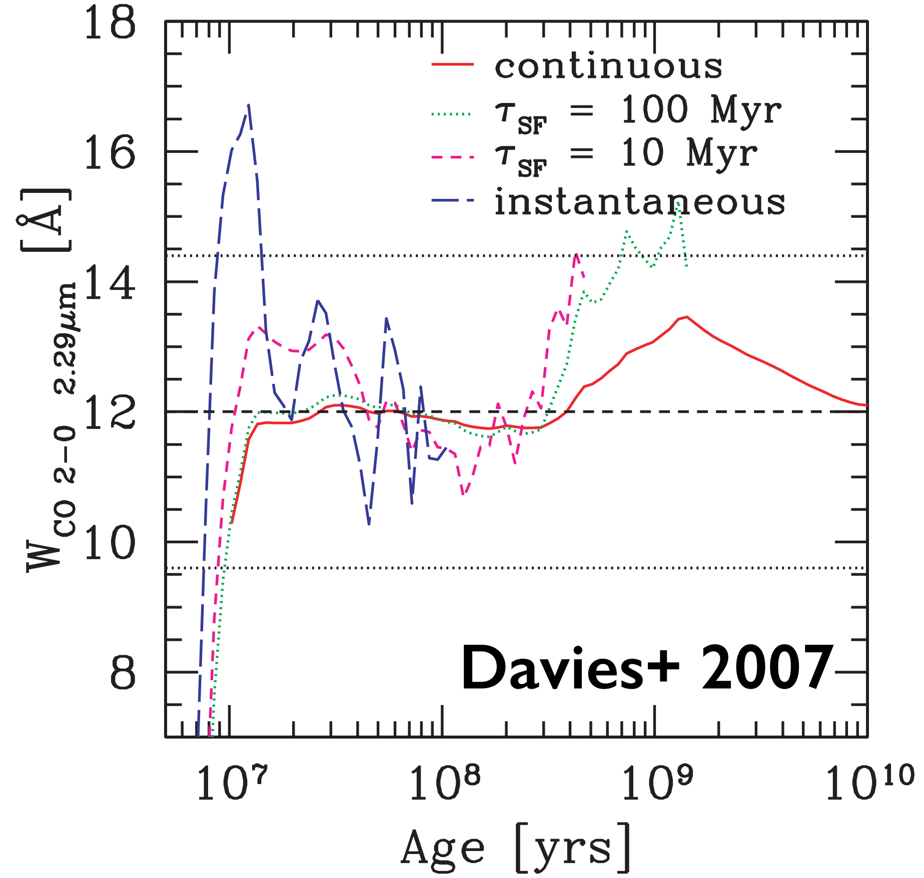

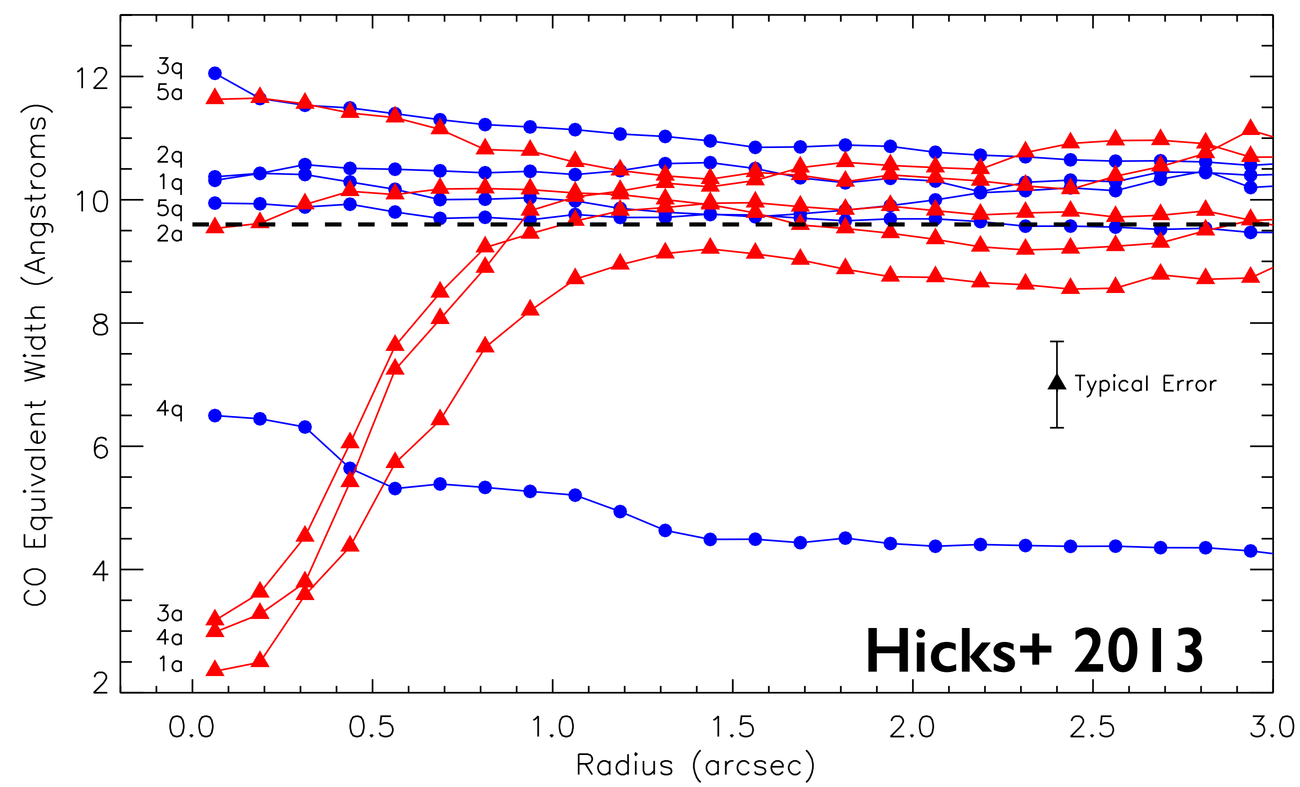

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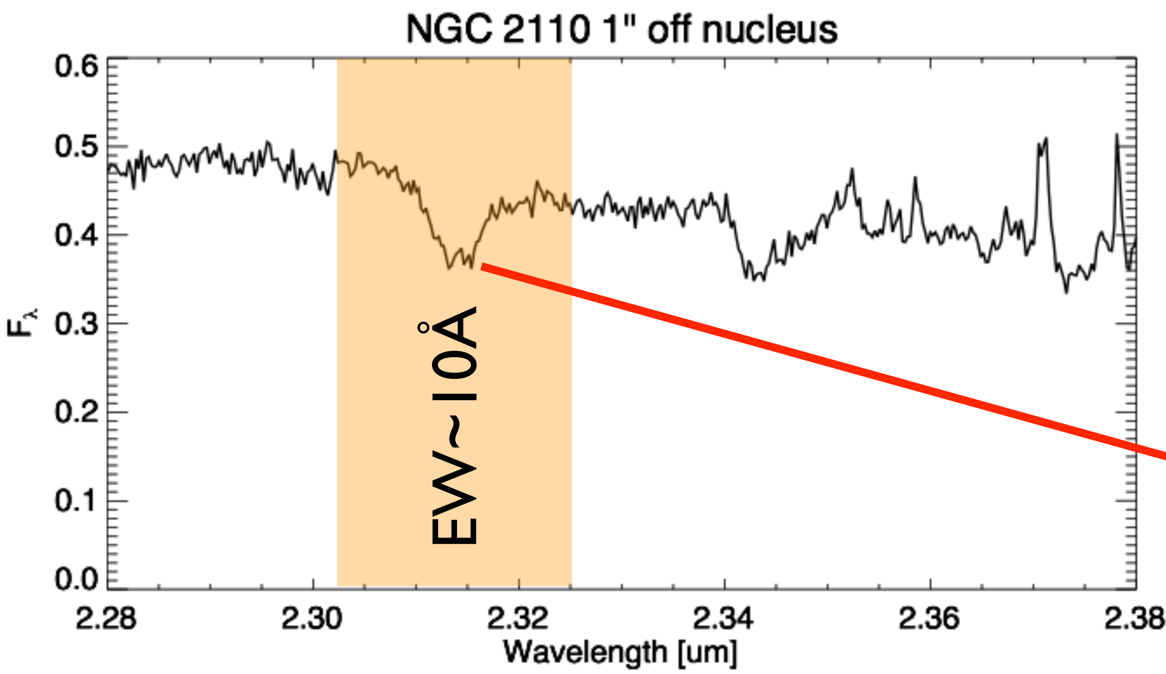

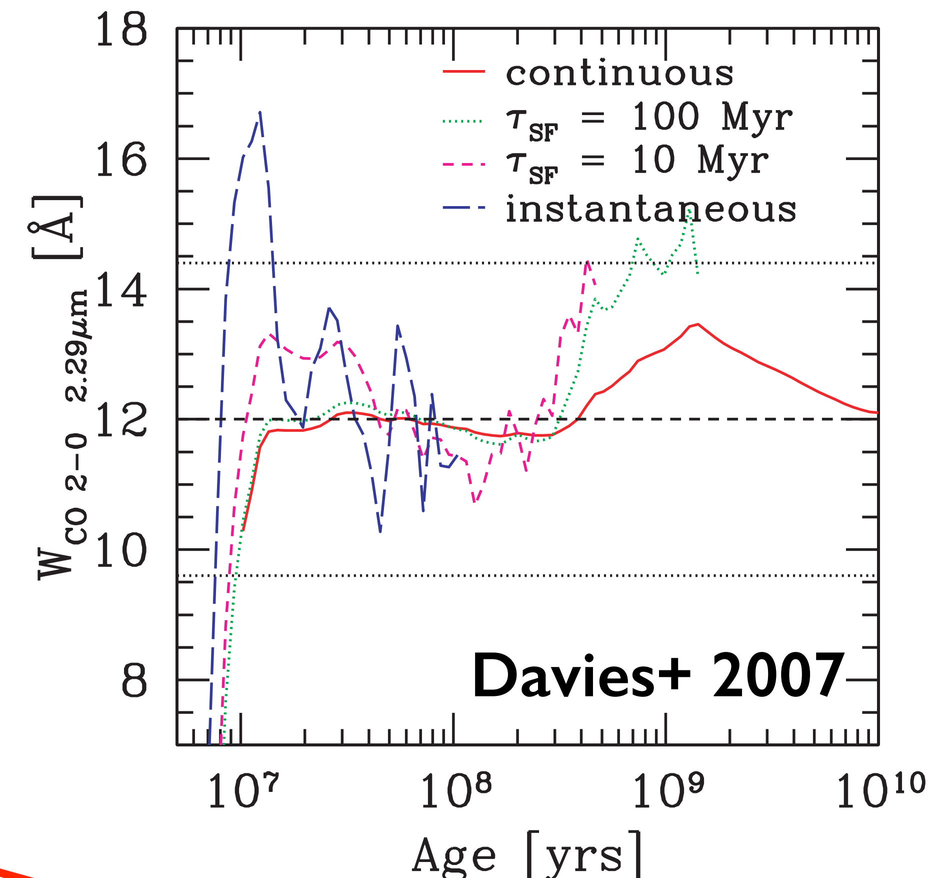

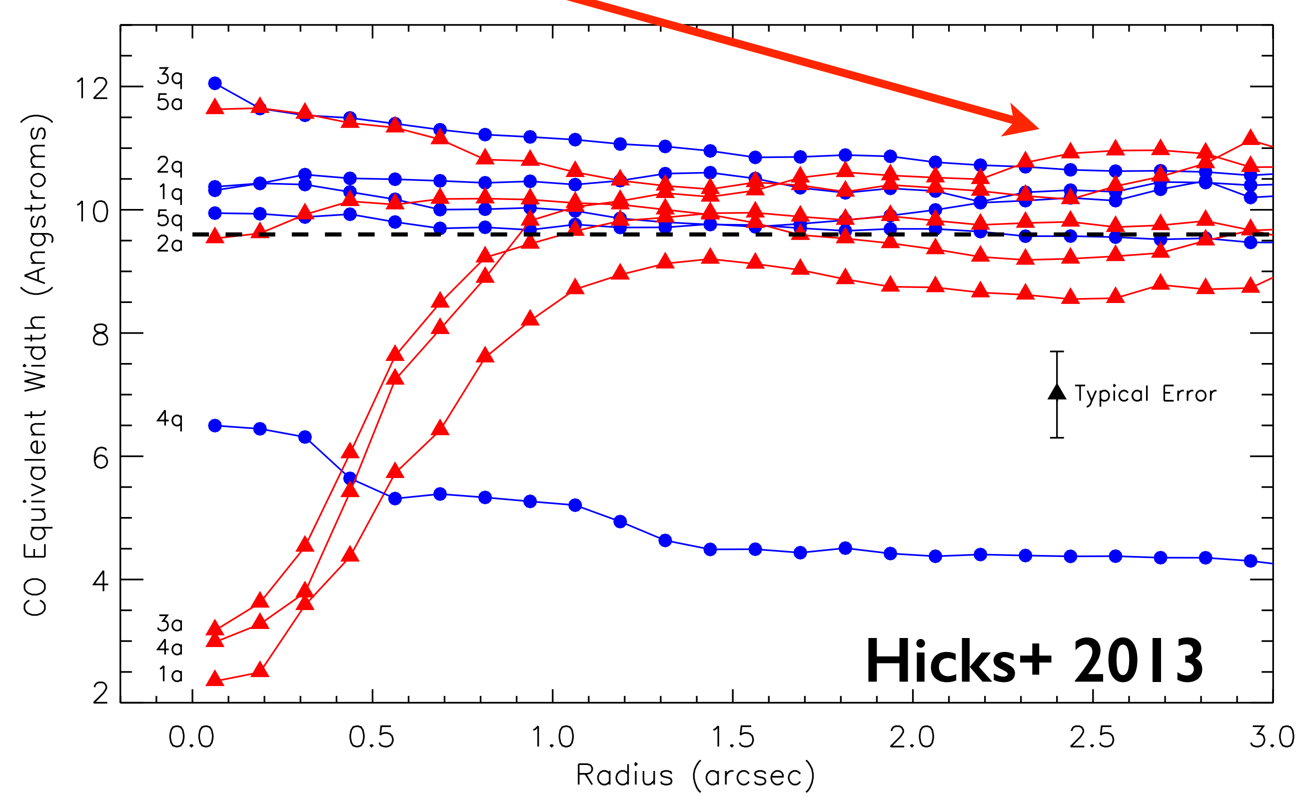

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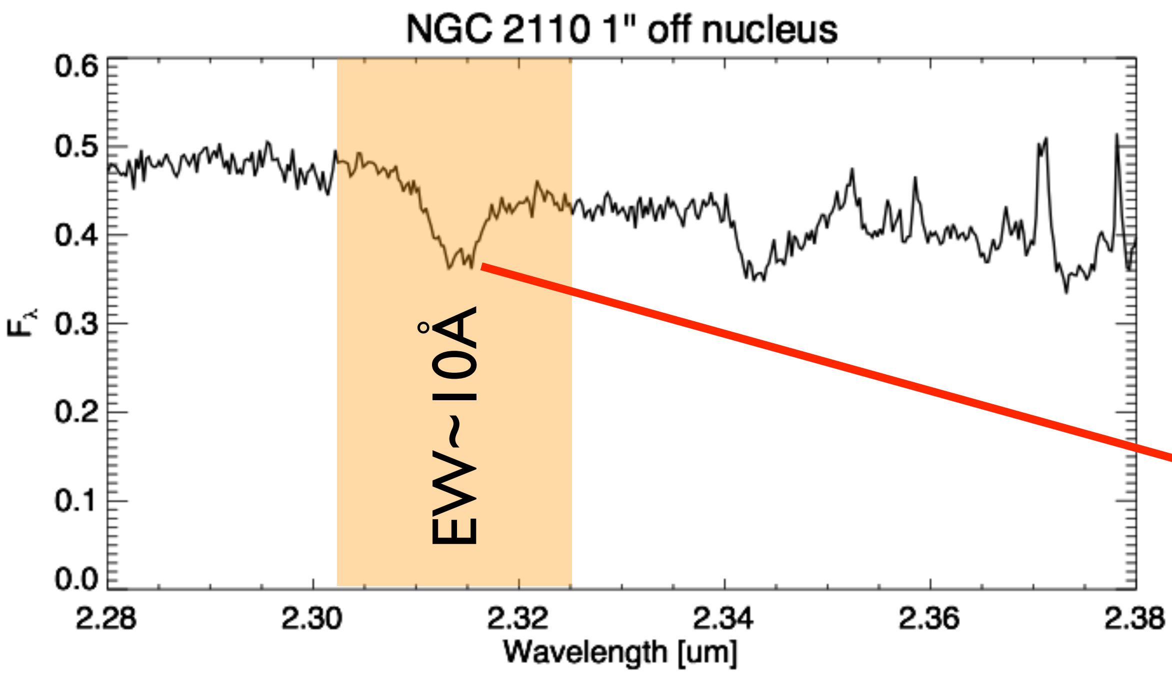

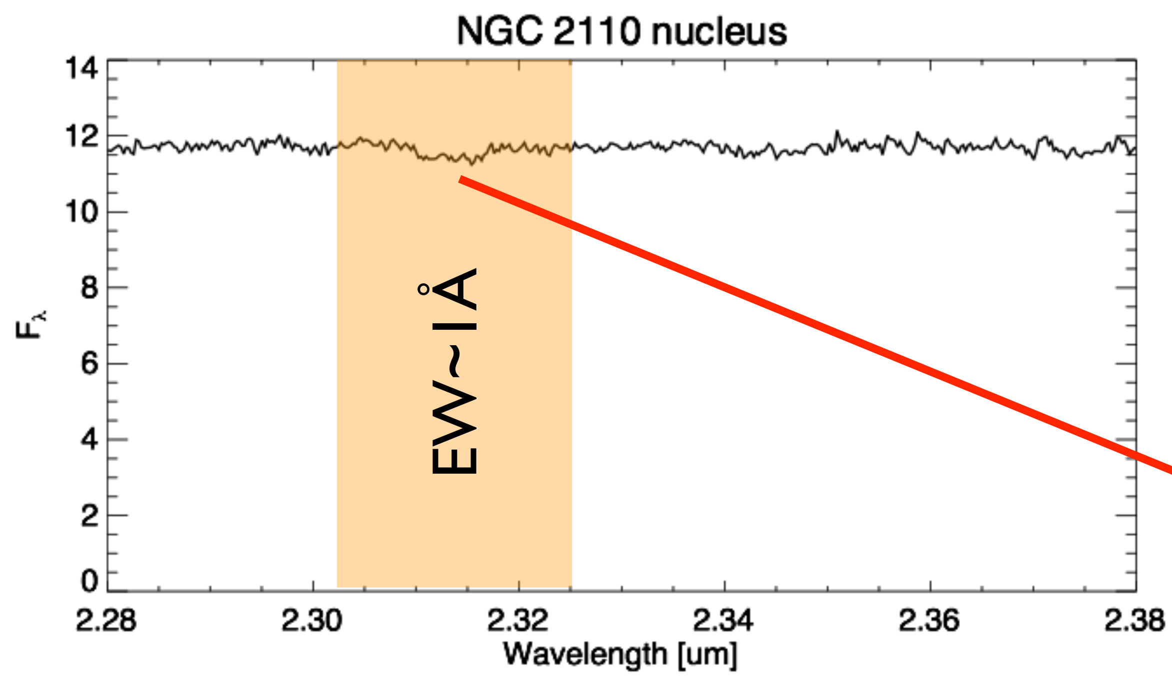

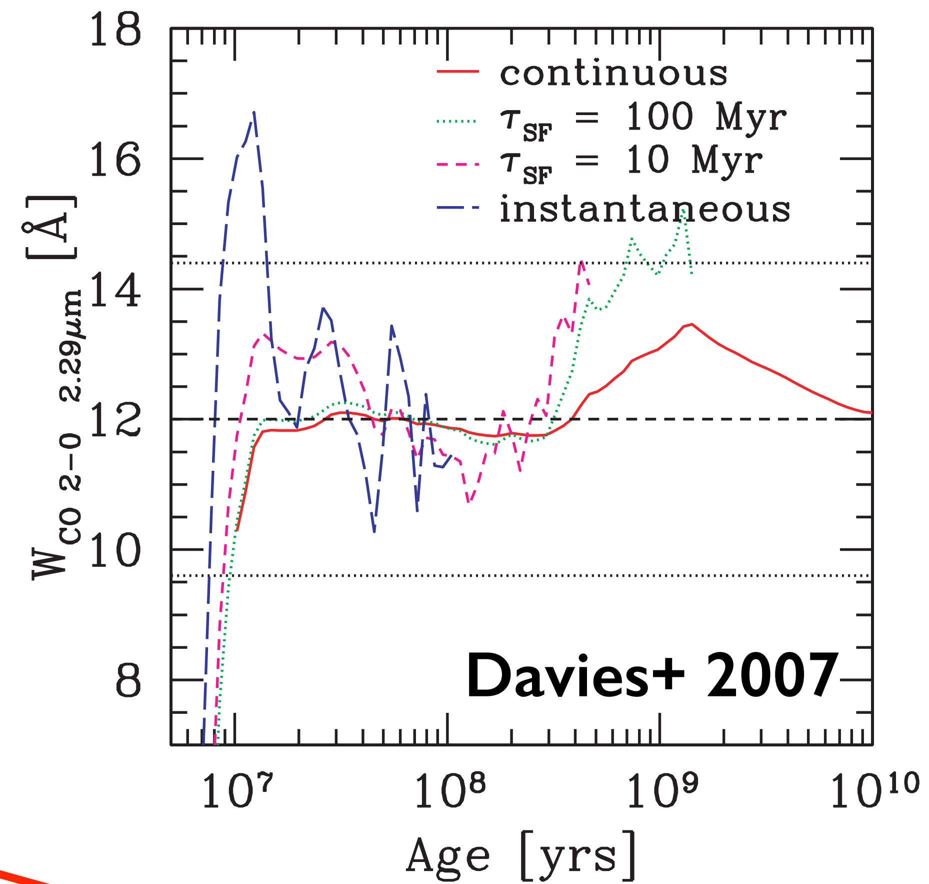

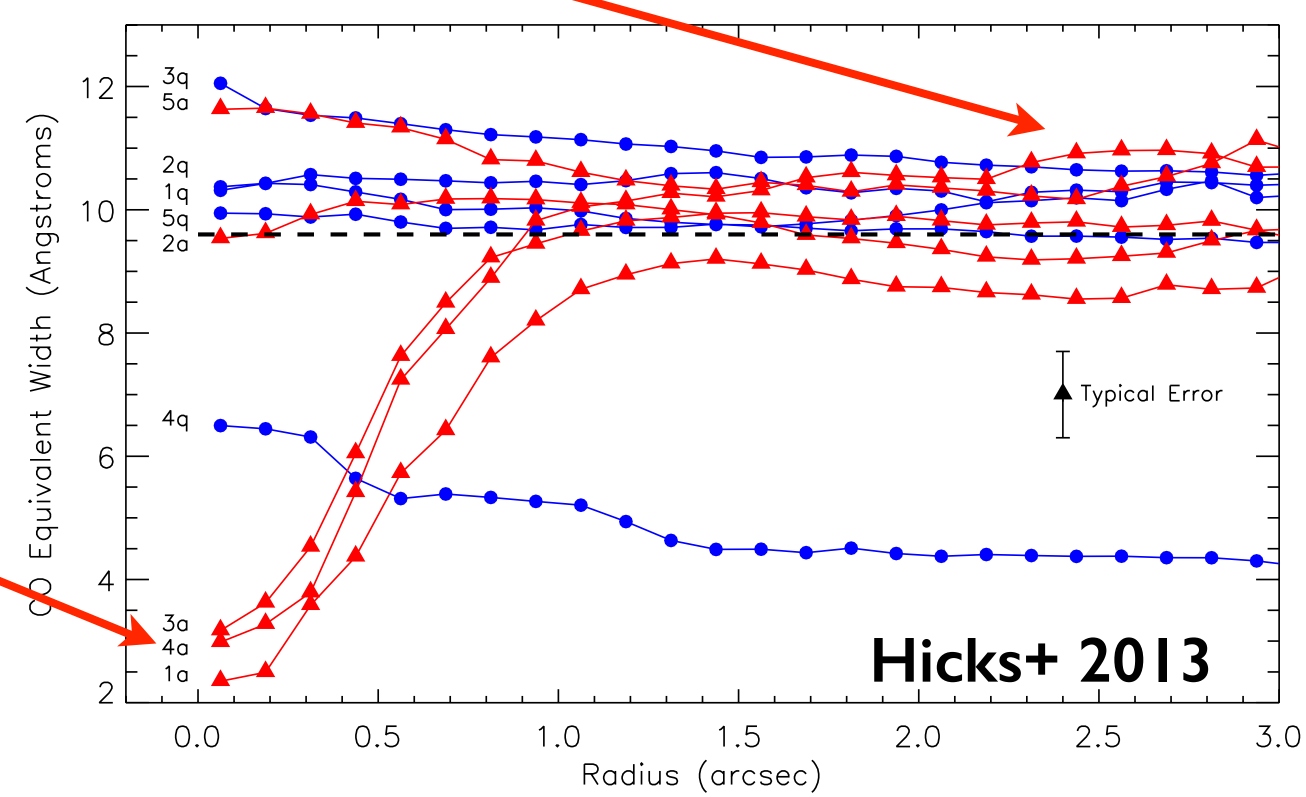

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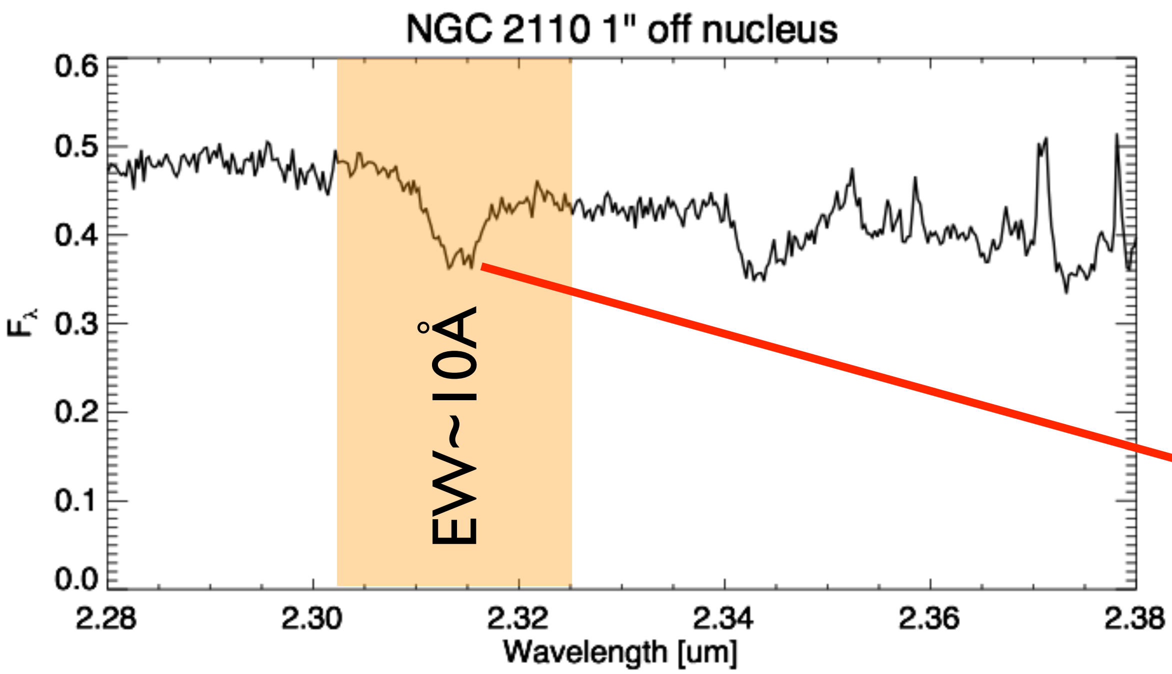

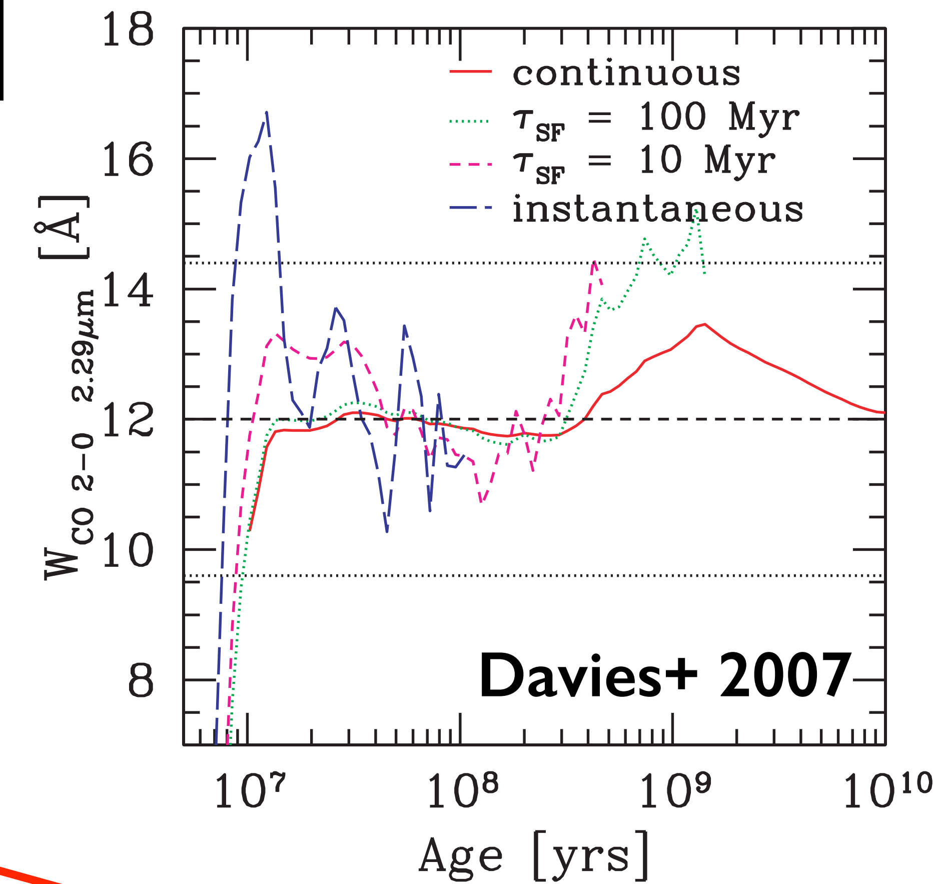

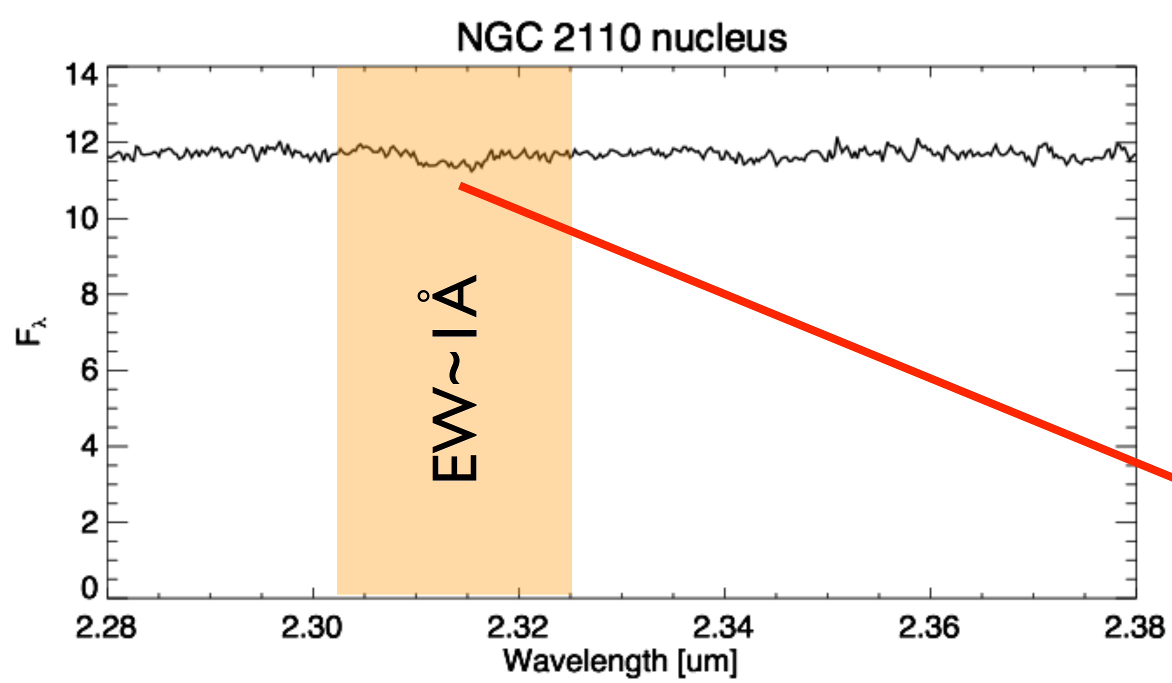

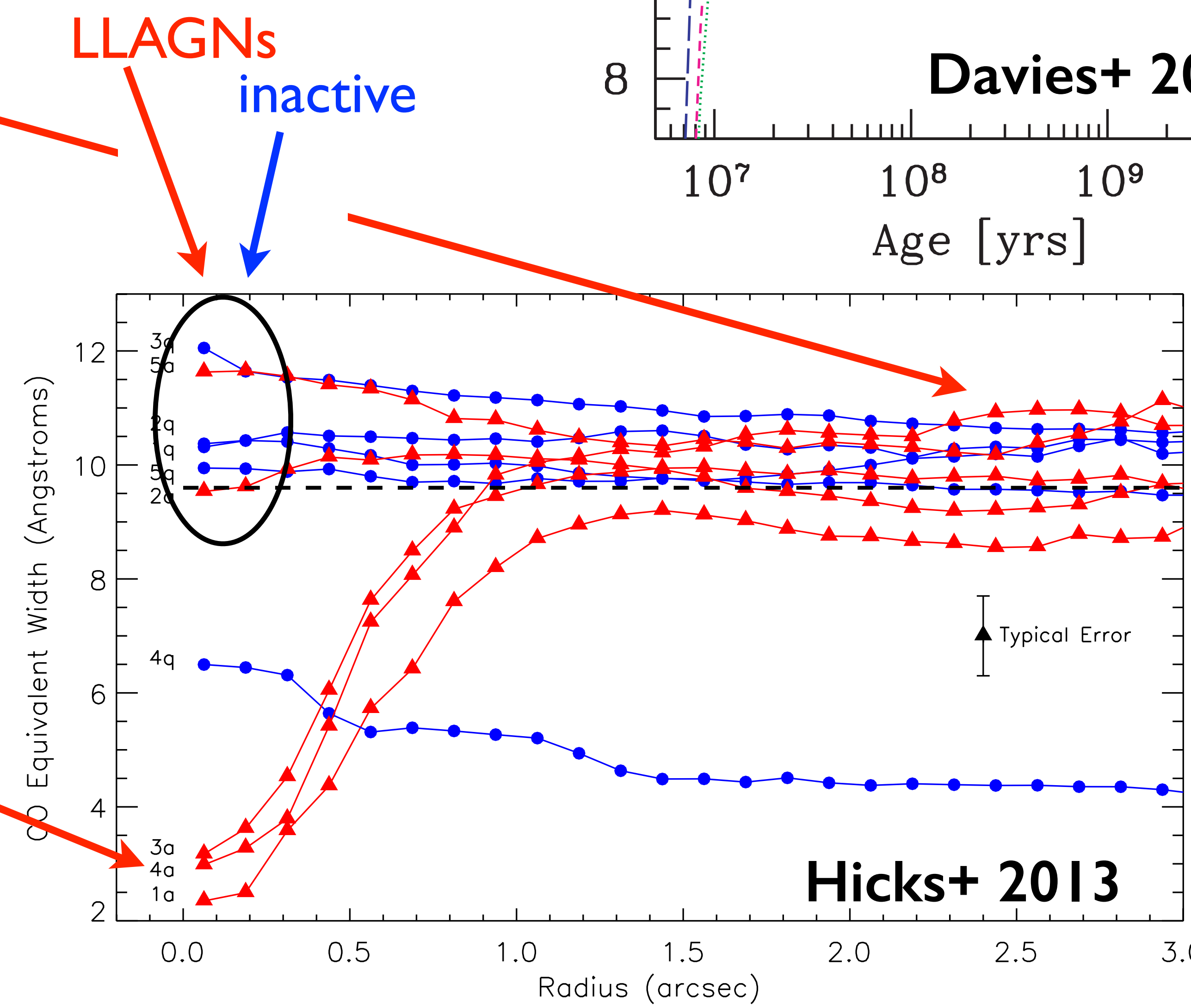

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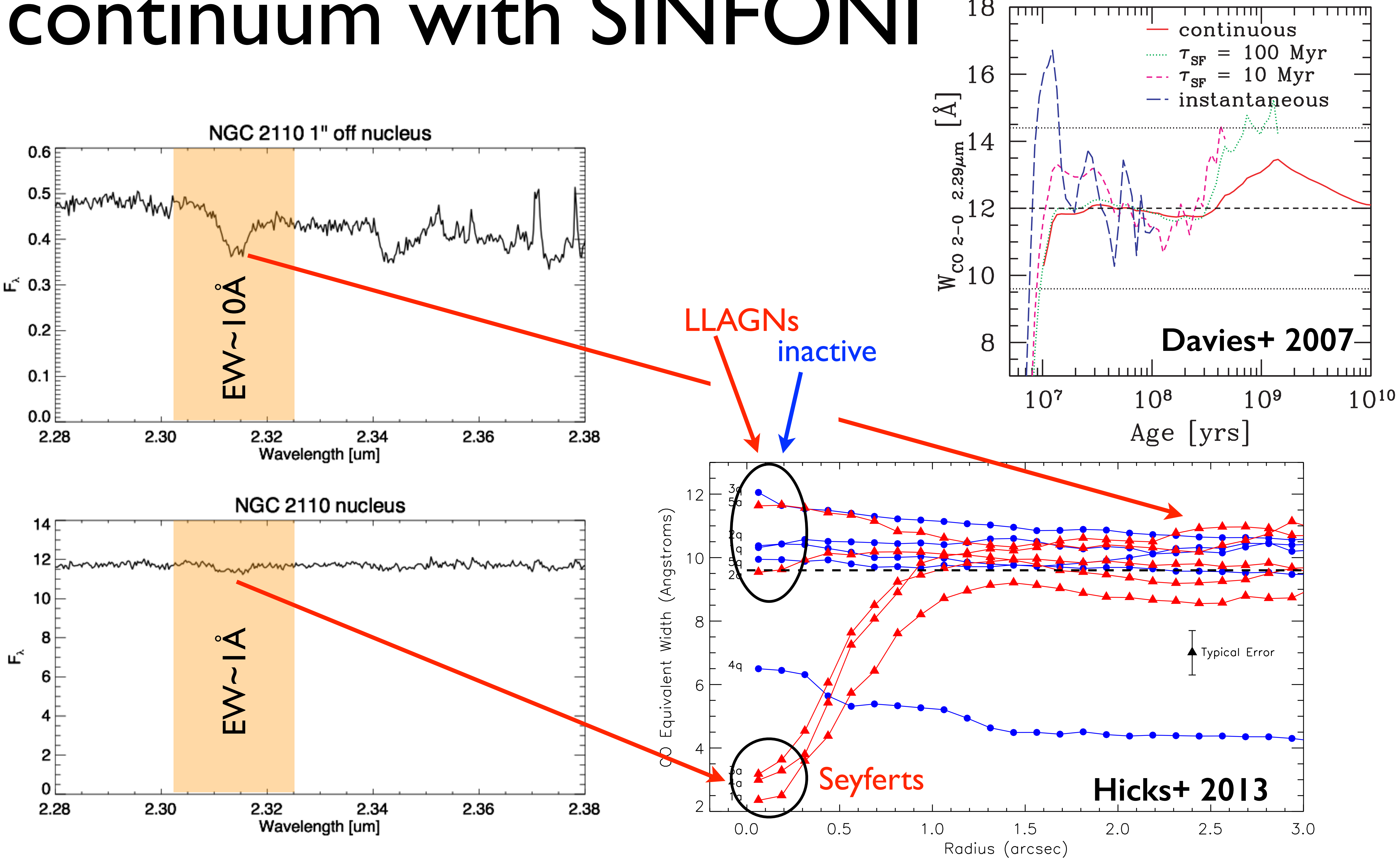
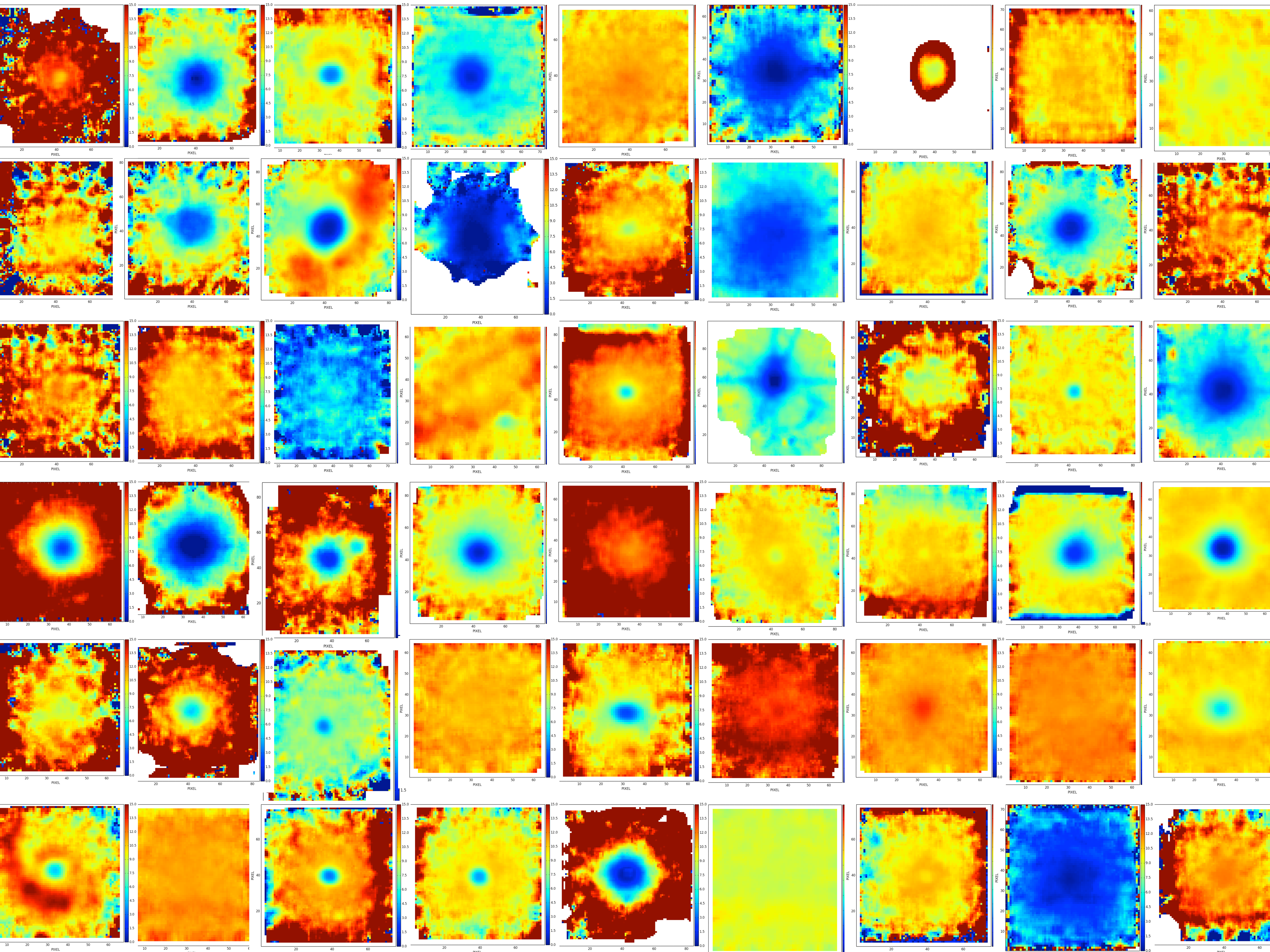
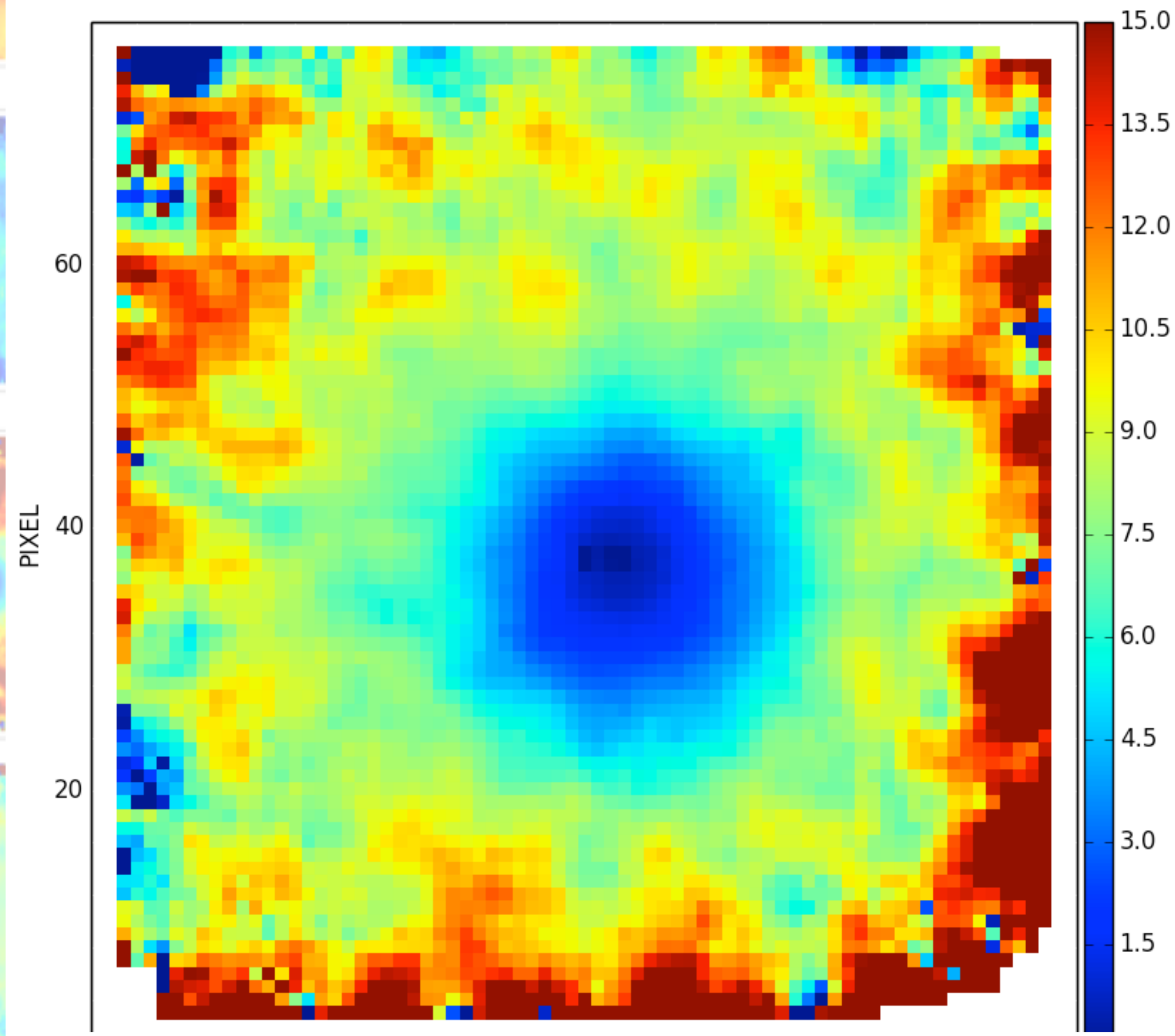




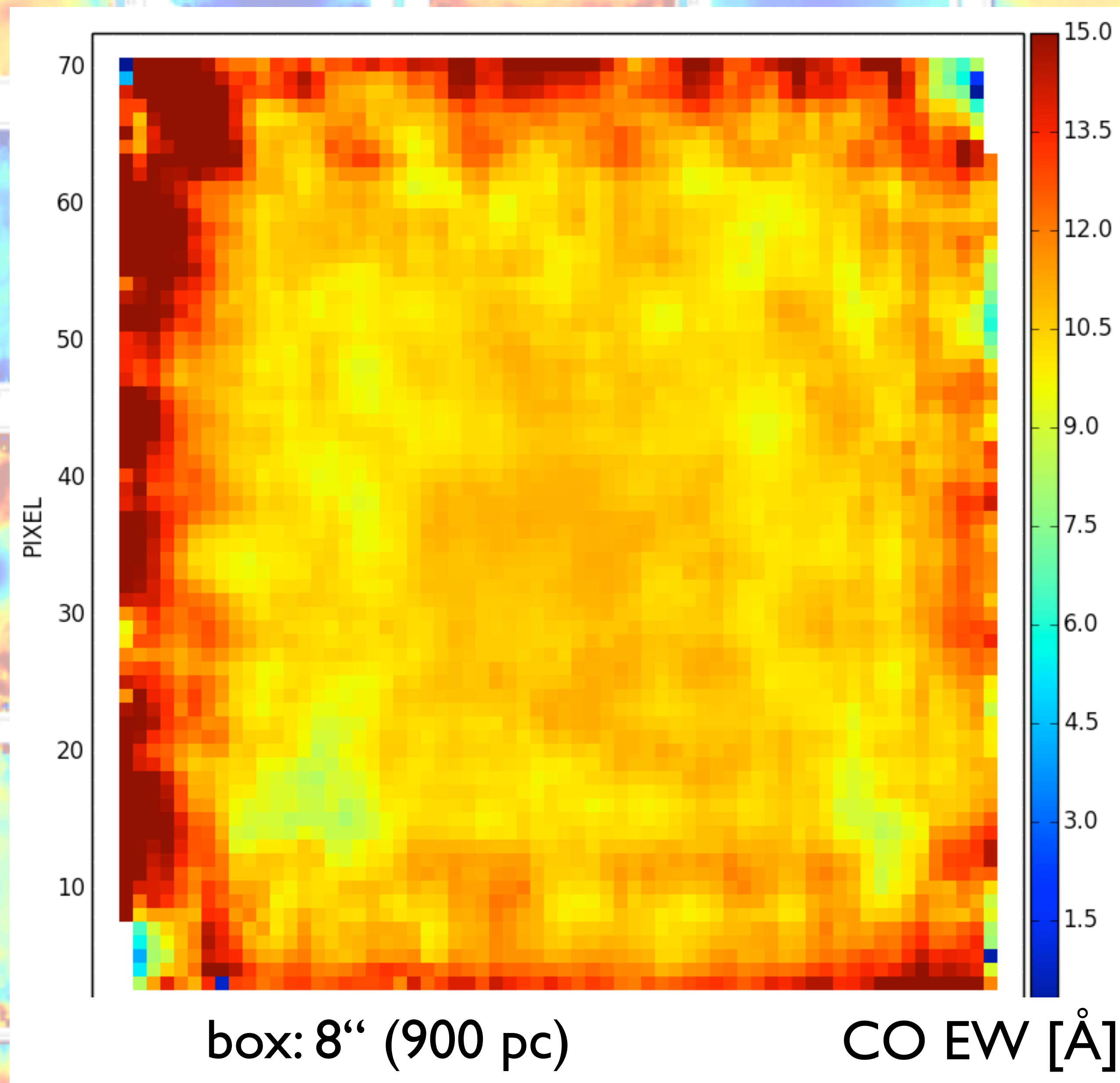
NGC 3281 (AGN)



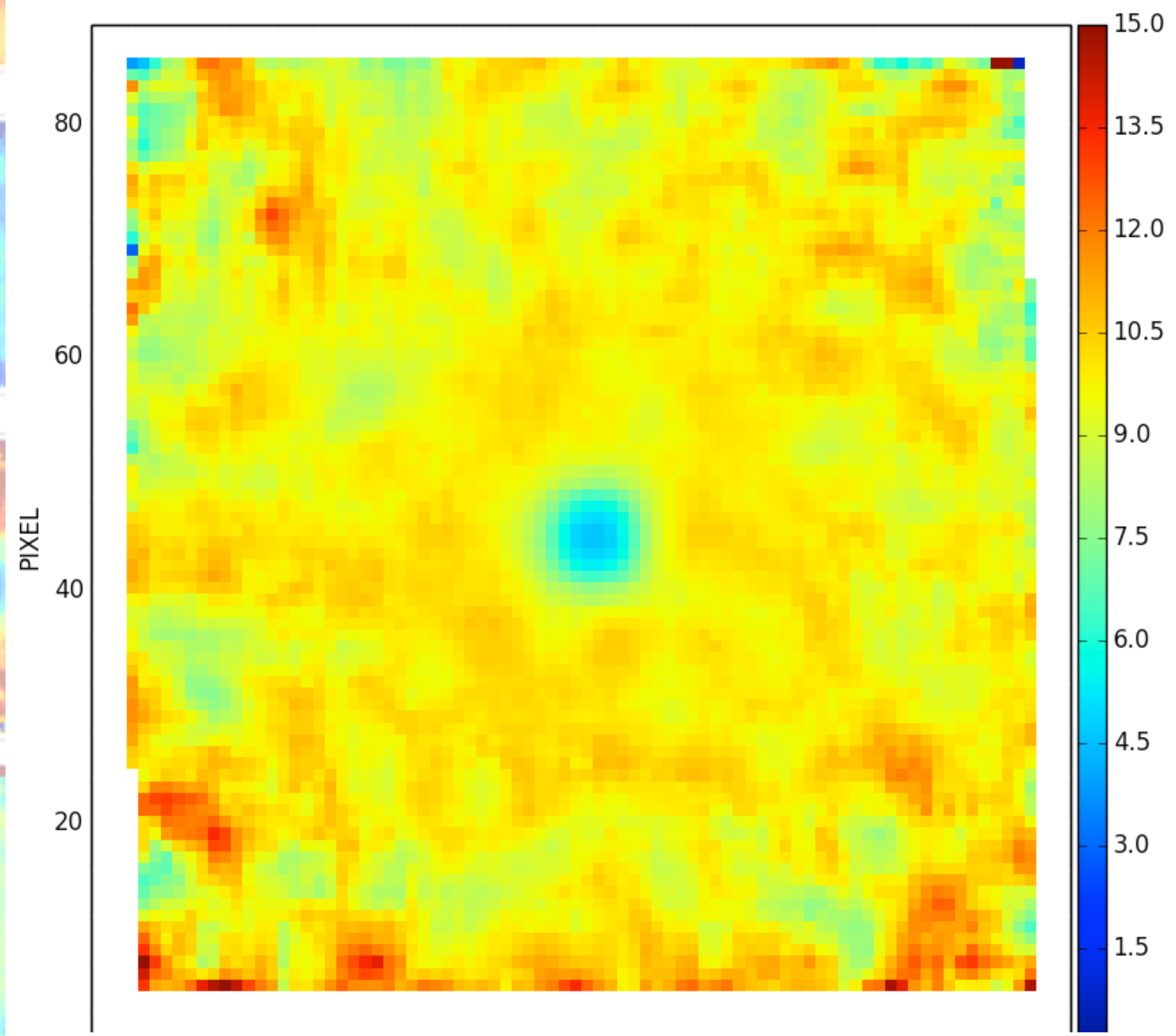
box: 3" (700 pc)

CO EW [Å]

NGC 4030 (inactive)



NGC 1097 (LINER)

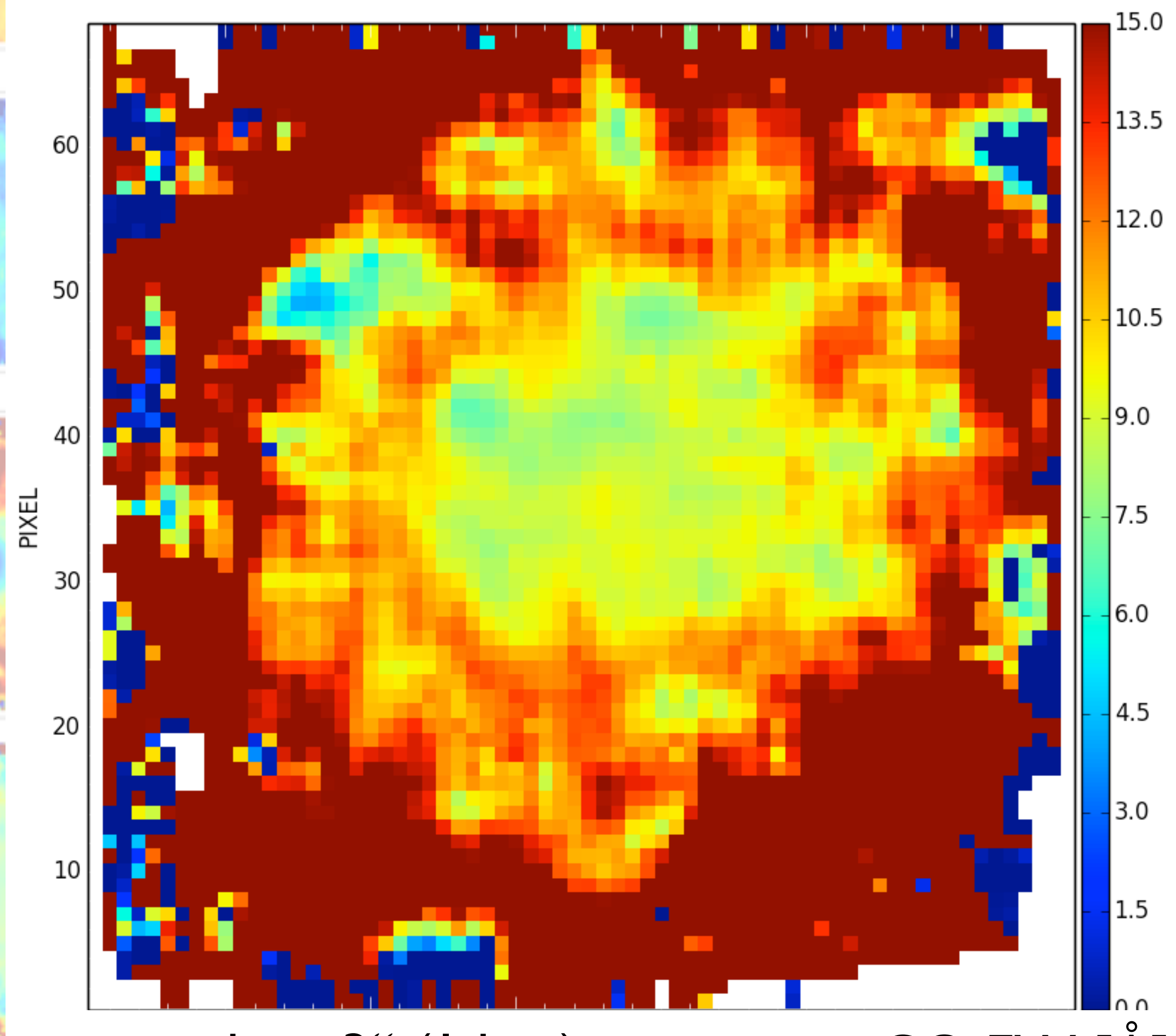


box: 3" (400 pc)

CO EW [Å]

NGC 2911 (LINER)

no dilution, but two stellar populations

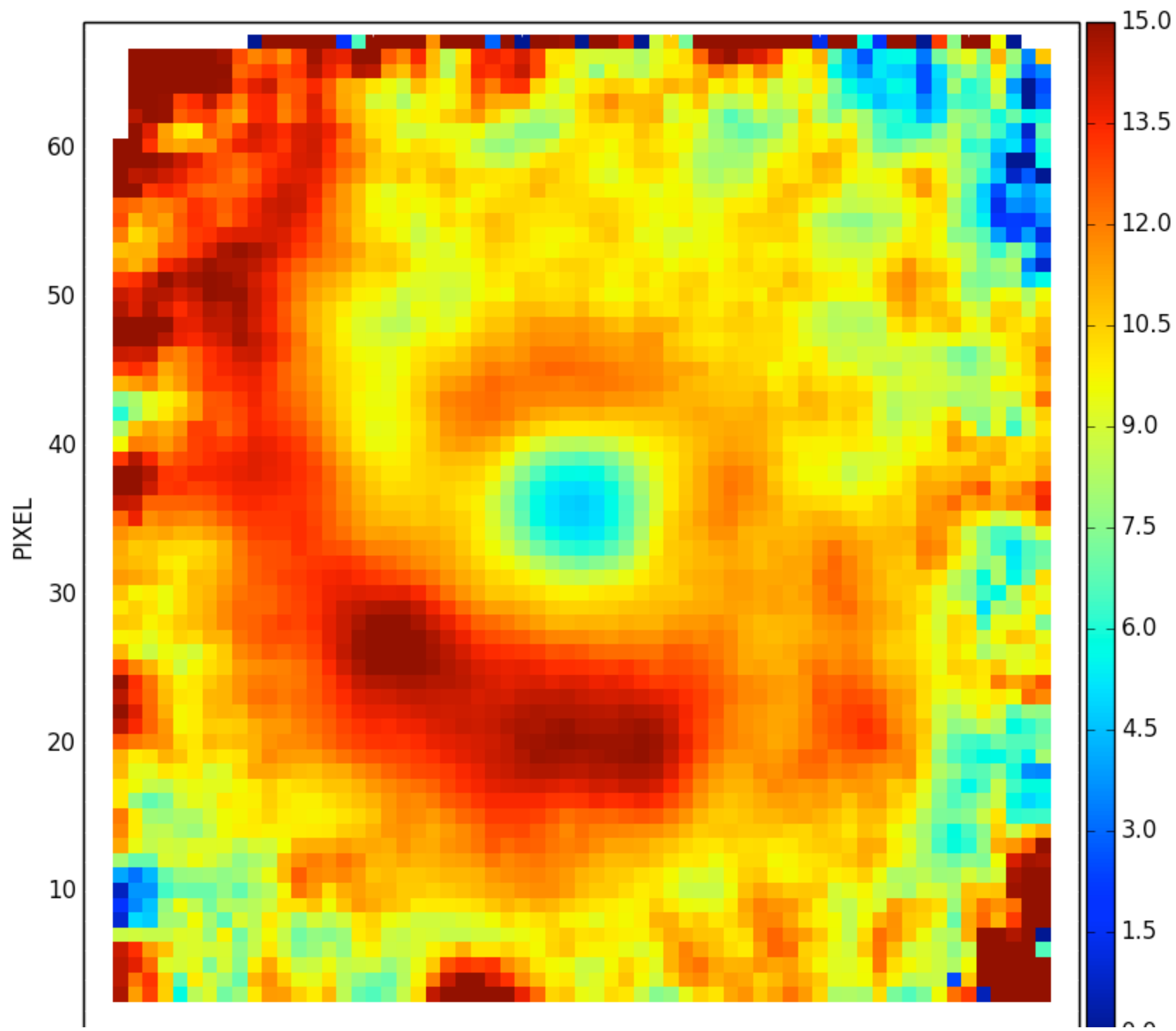


box: 3“ (1 kpc)

CO EW [Å]

NGC 5135 (Seyfert 2)

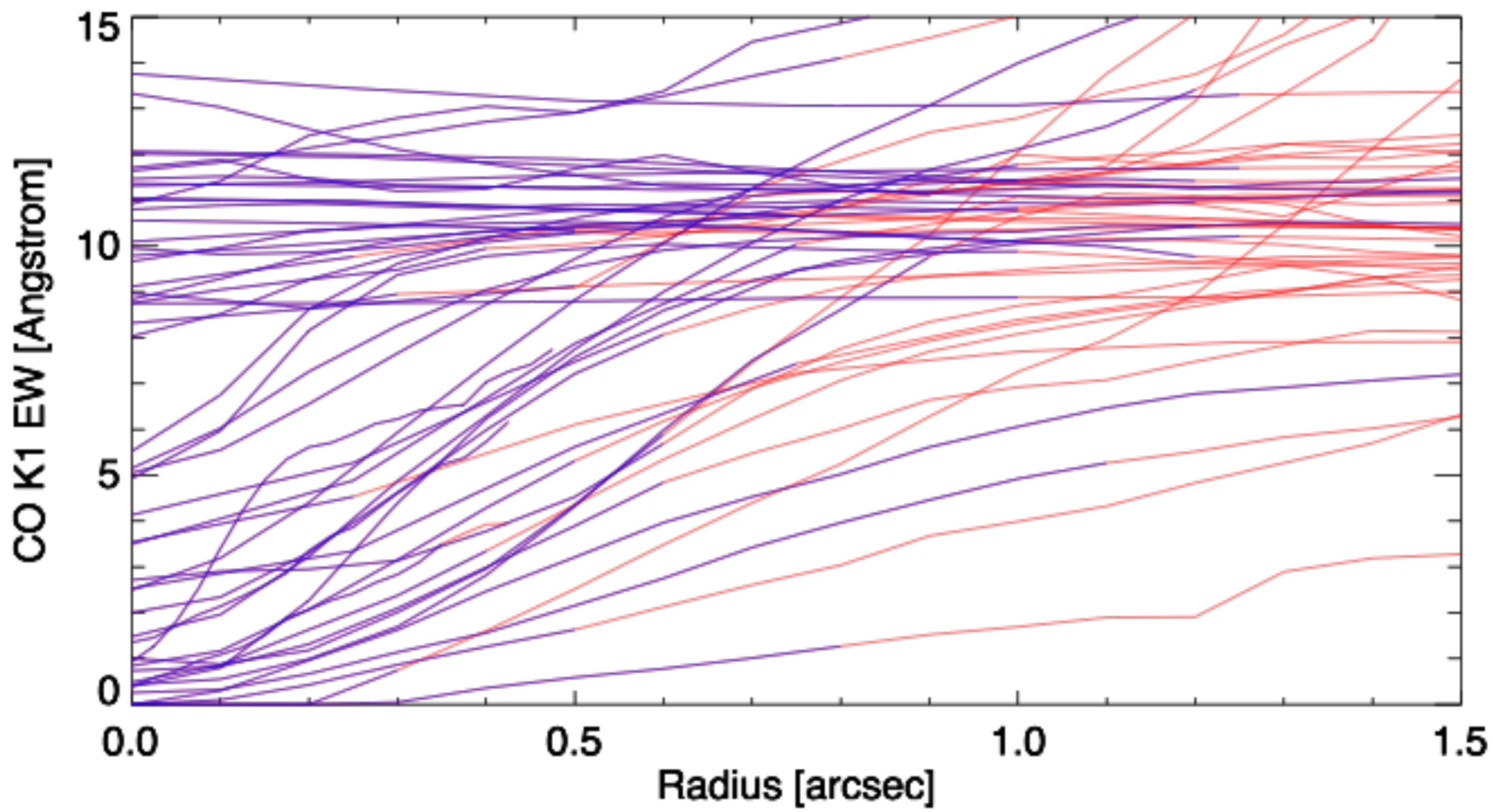
some dilution and two spiral arms



box: 8“ (2 kpc)

CO EW [Å]

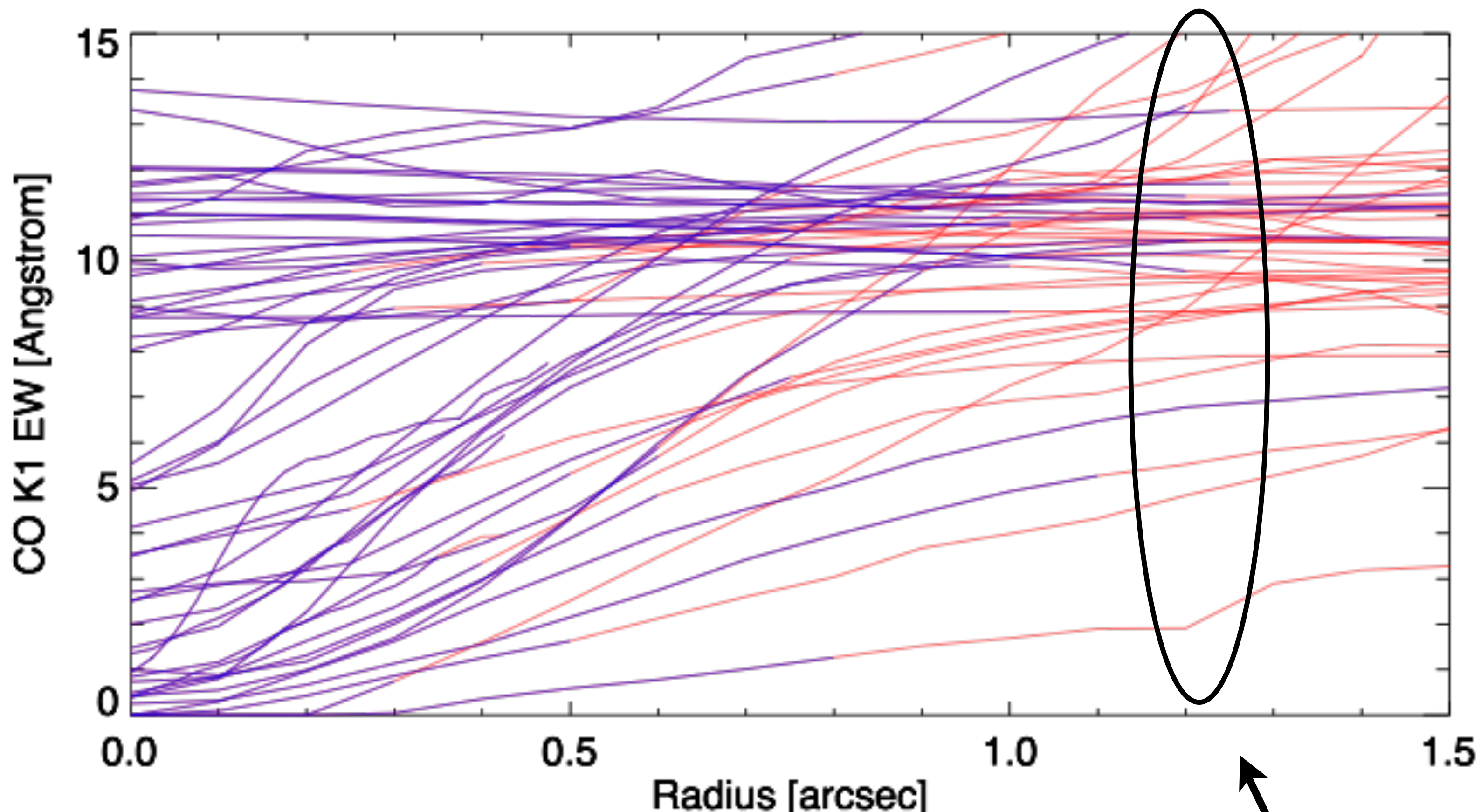
Equivalent Width (r)



r < 200 pc

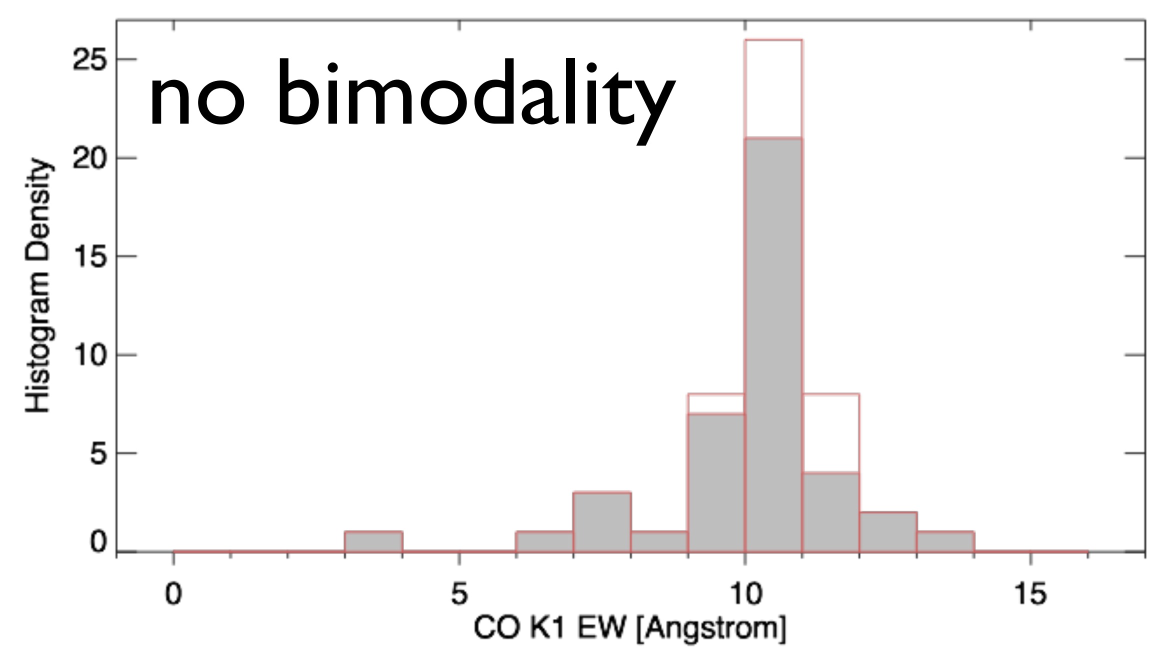
r > 200 pc

Equivalent Width (r)



r < 200 pc
r > 200 pc

intrinsic distribution



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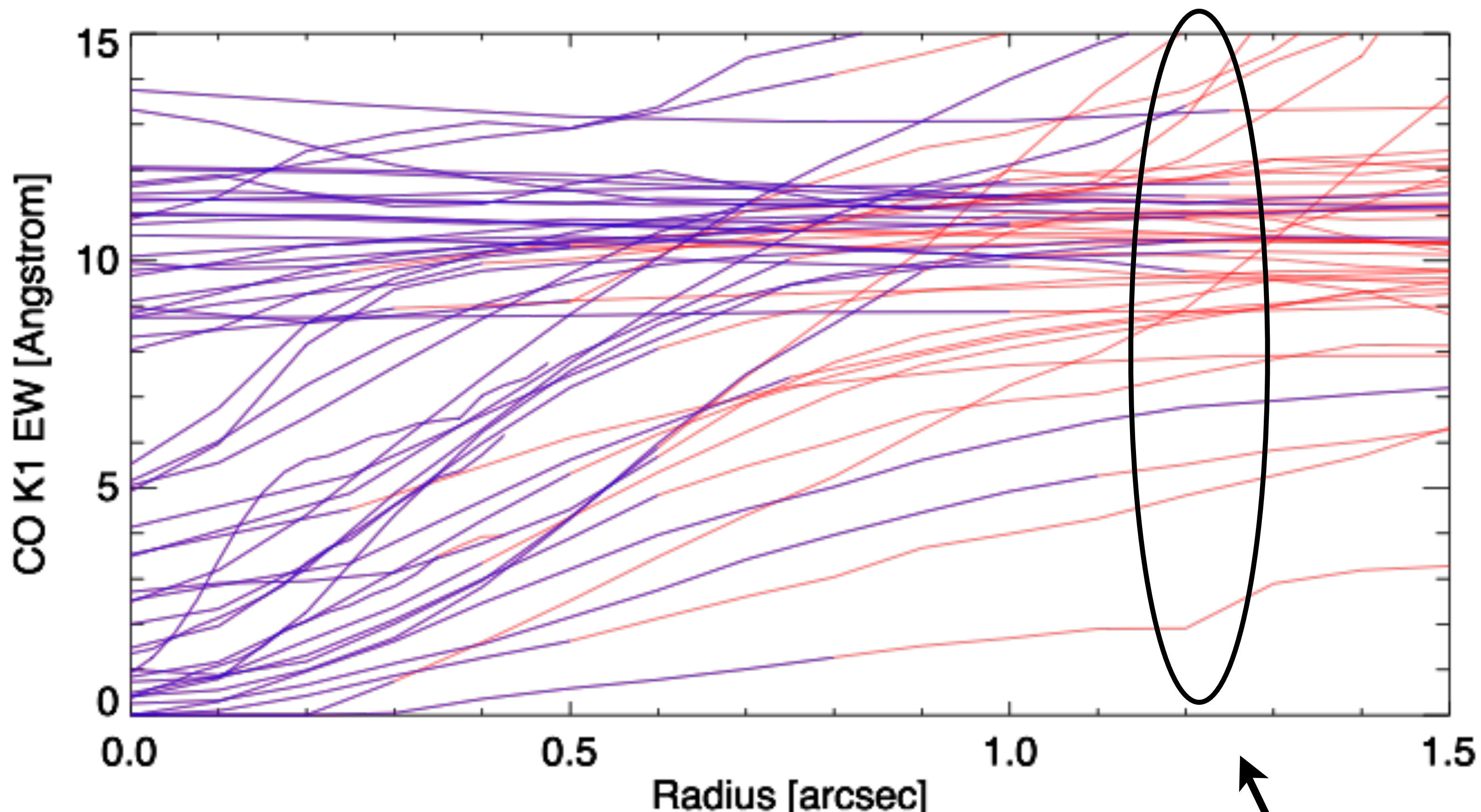
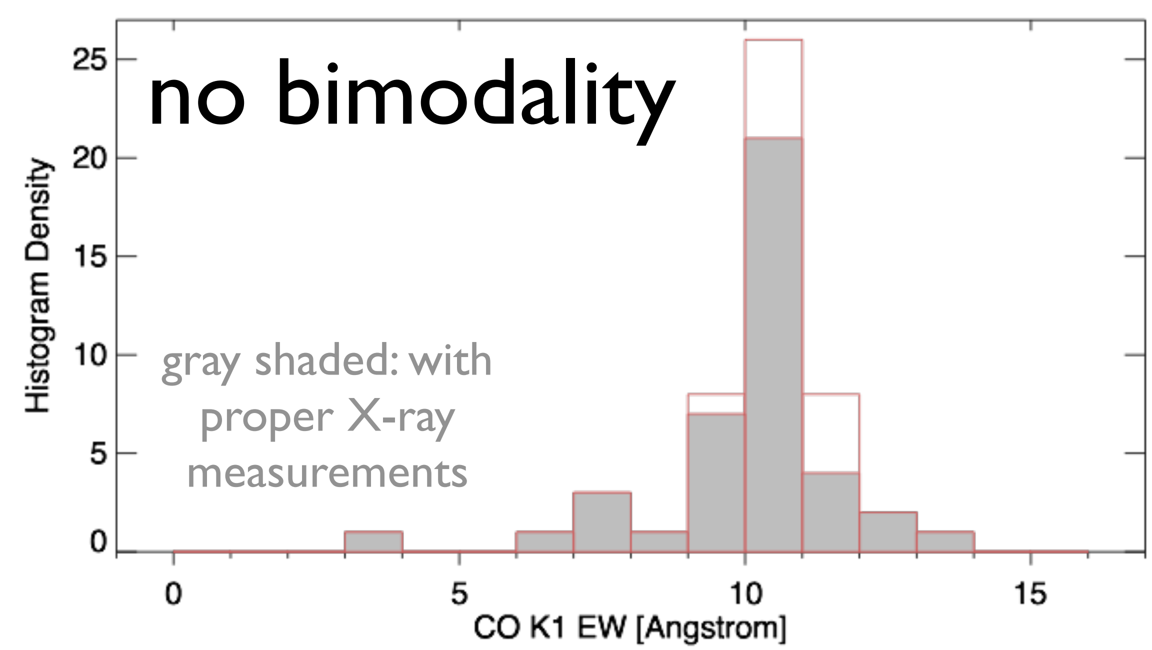
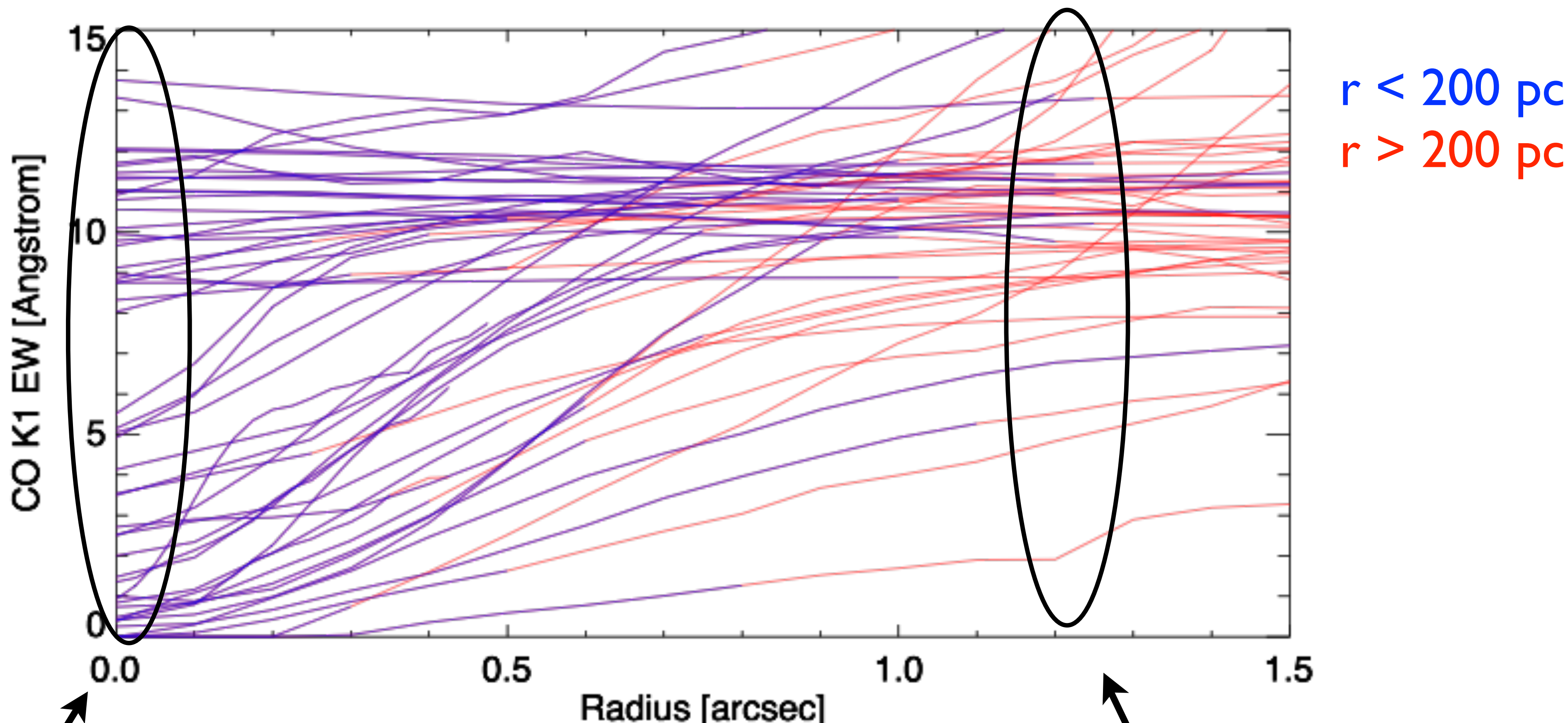


r < 200 pc
r > 200 pc

intrinsic distribution

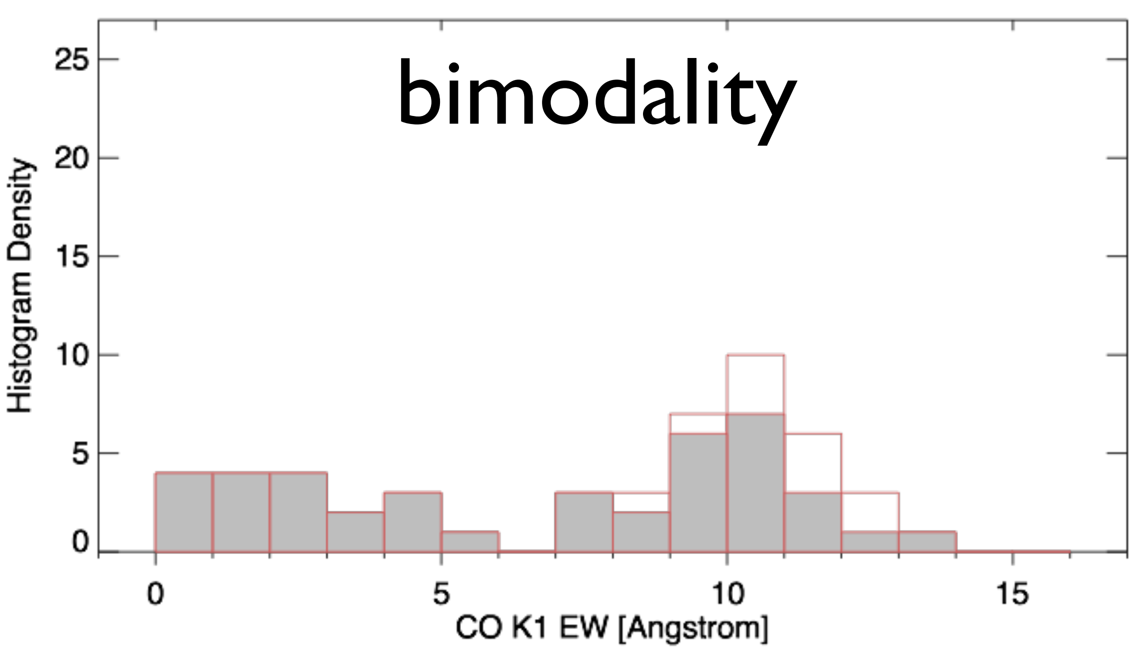


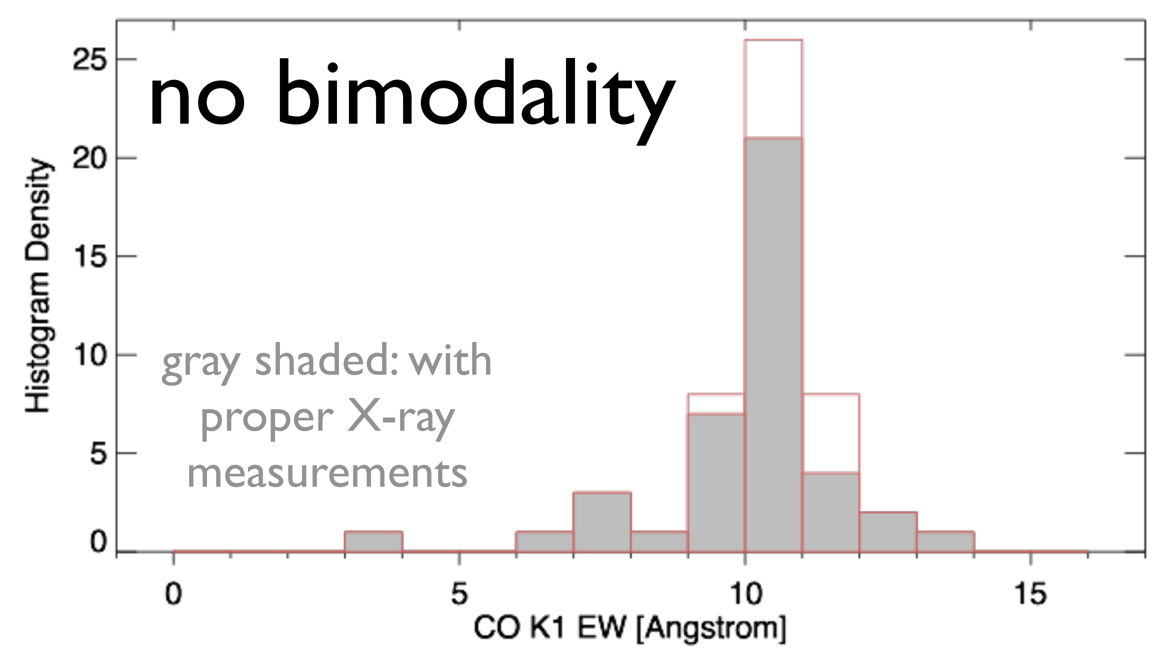
Equivalent Width (r)



nuclear distribution

intrinsic distribution

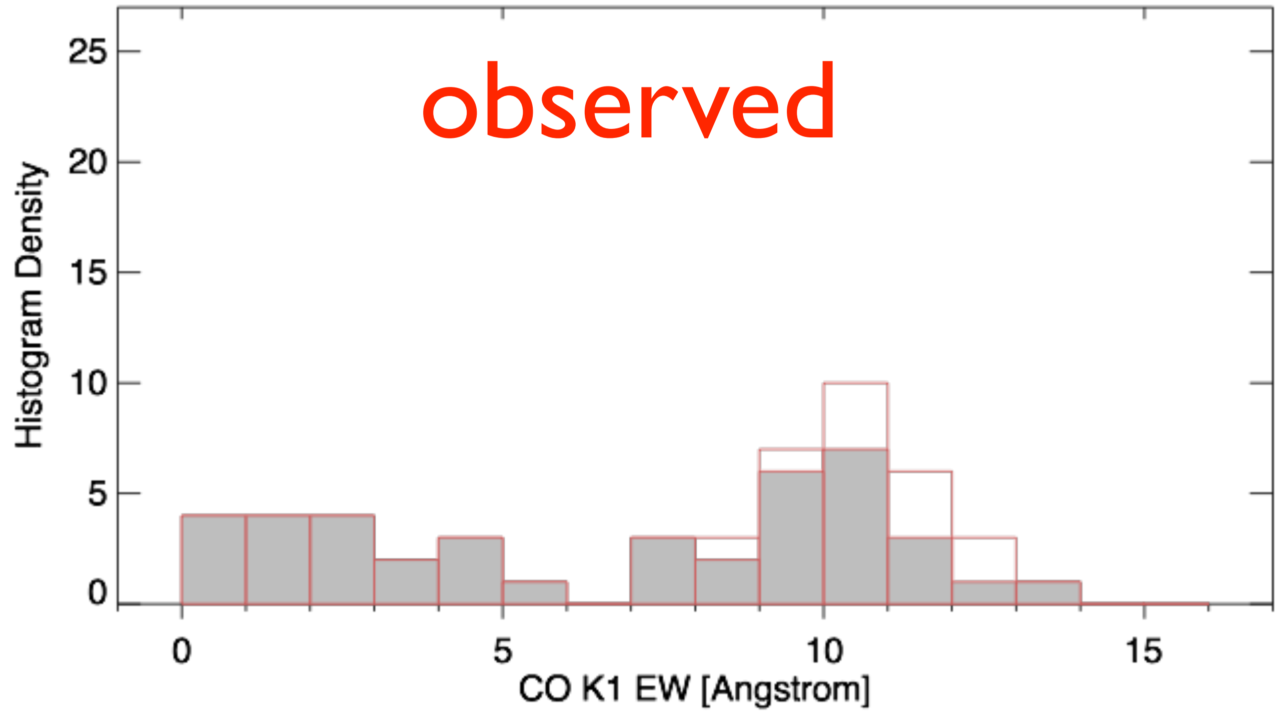




The EW distribution

$$EW_{\text{obs}} = \frac{EW_{\text{int}} \cdot L_{\text{stars}} + \overbrace{EW_{\text{dilute}}}^{=0} \cdot L_{\text{dilute}}}{L_{\text{stars}} + L_{\text{dilute}}} = \frac{EW_{\text{int}}}{1 + \frac{L_{\text{dilute}}}{L_{\text{stars}}}}$$

expected



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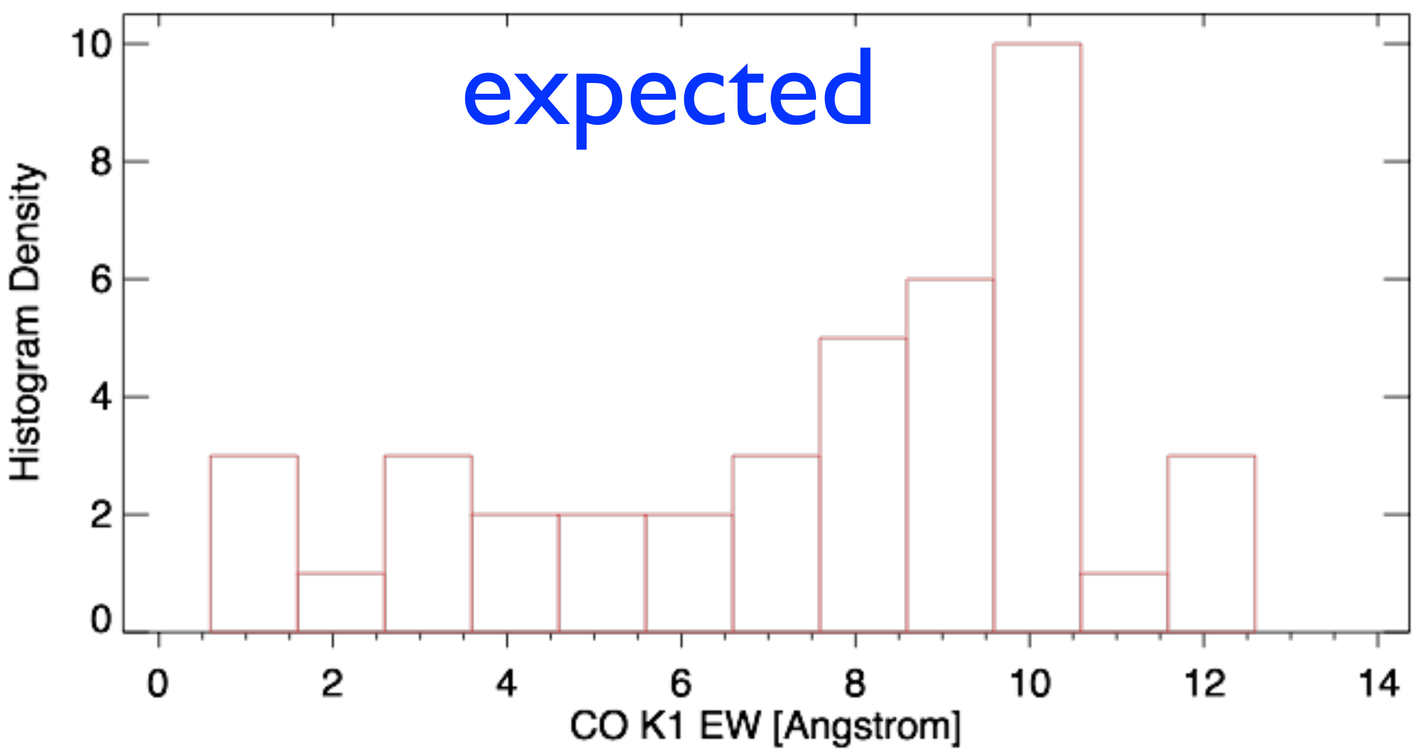

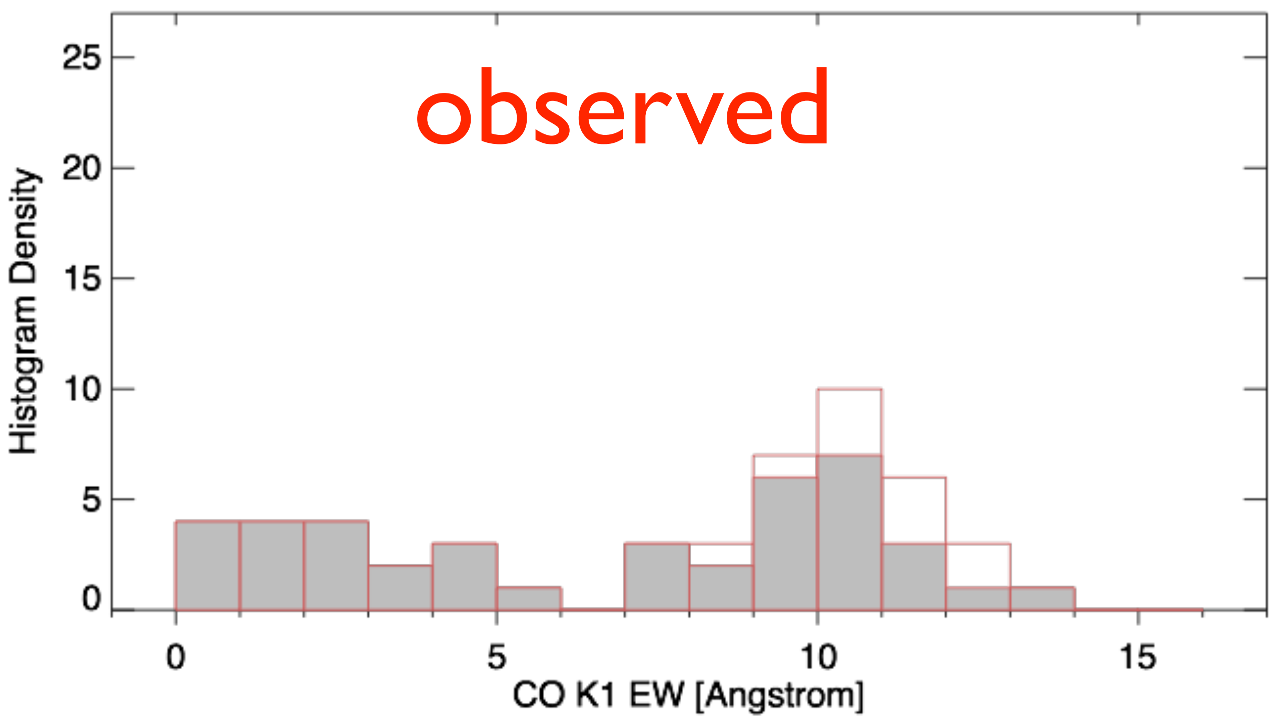

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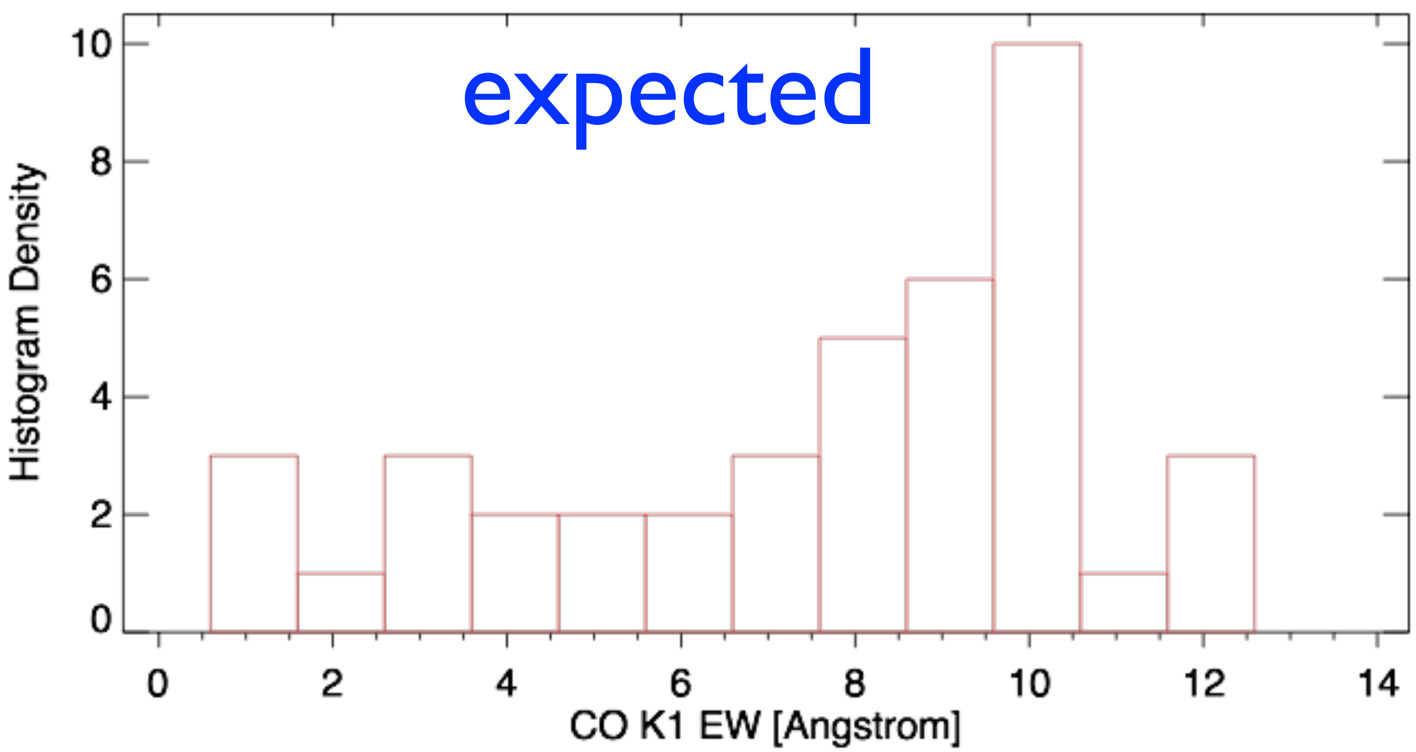

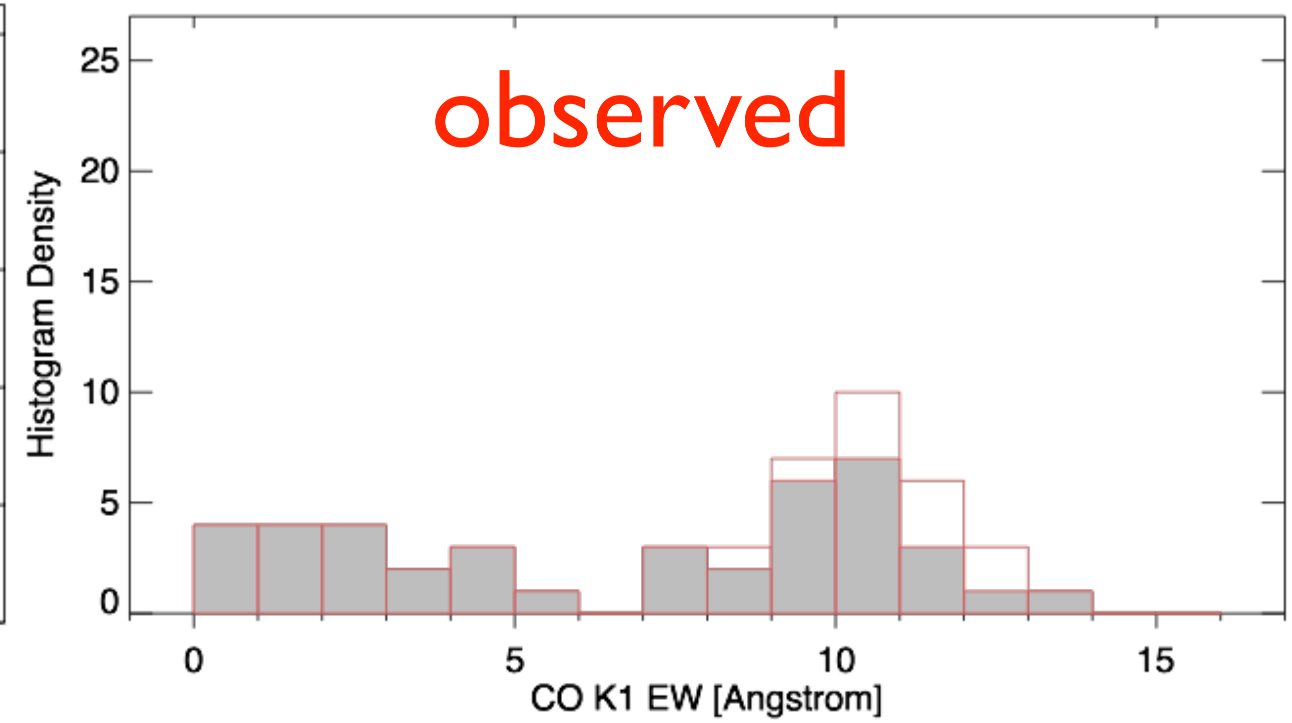

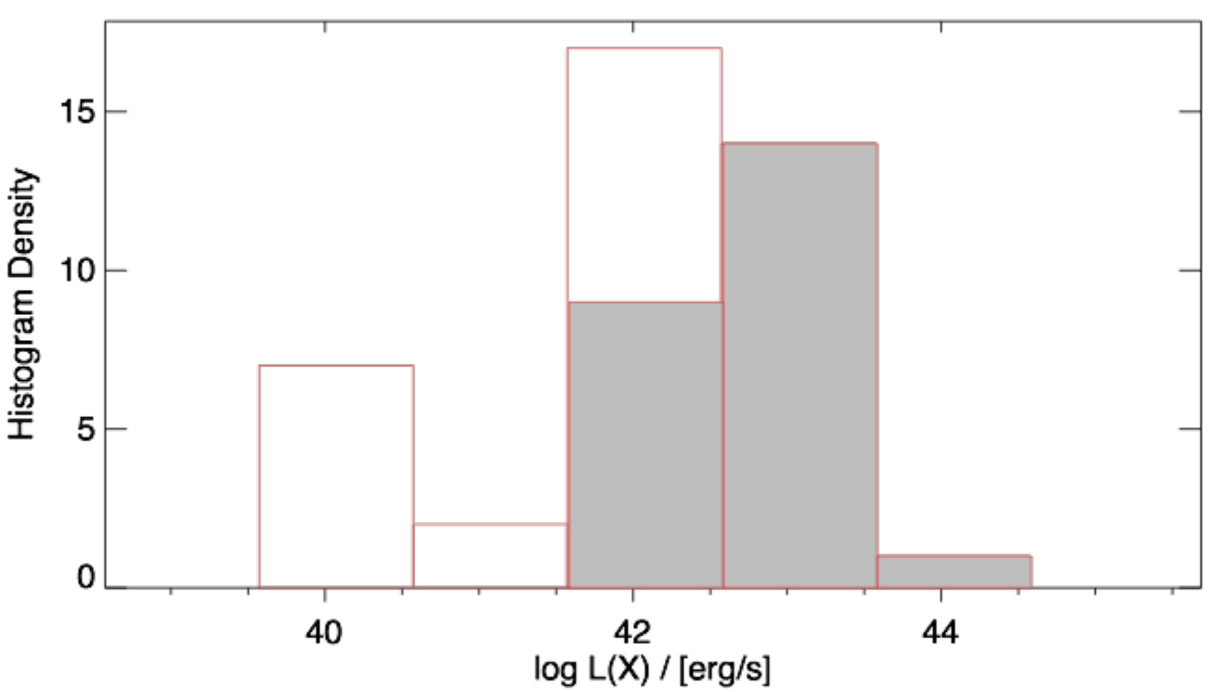

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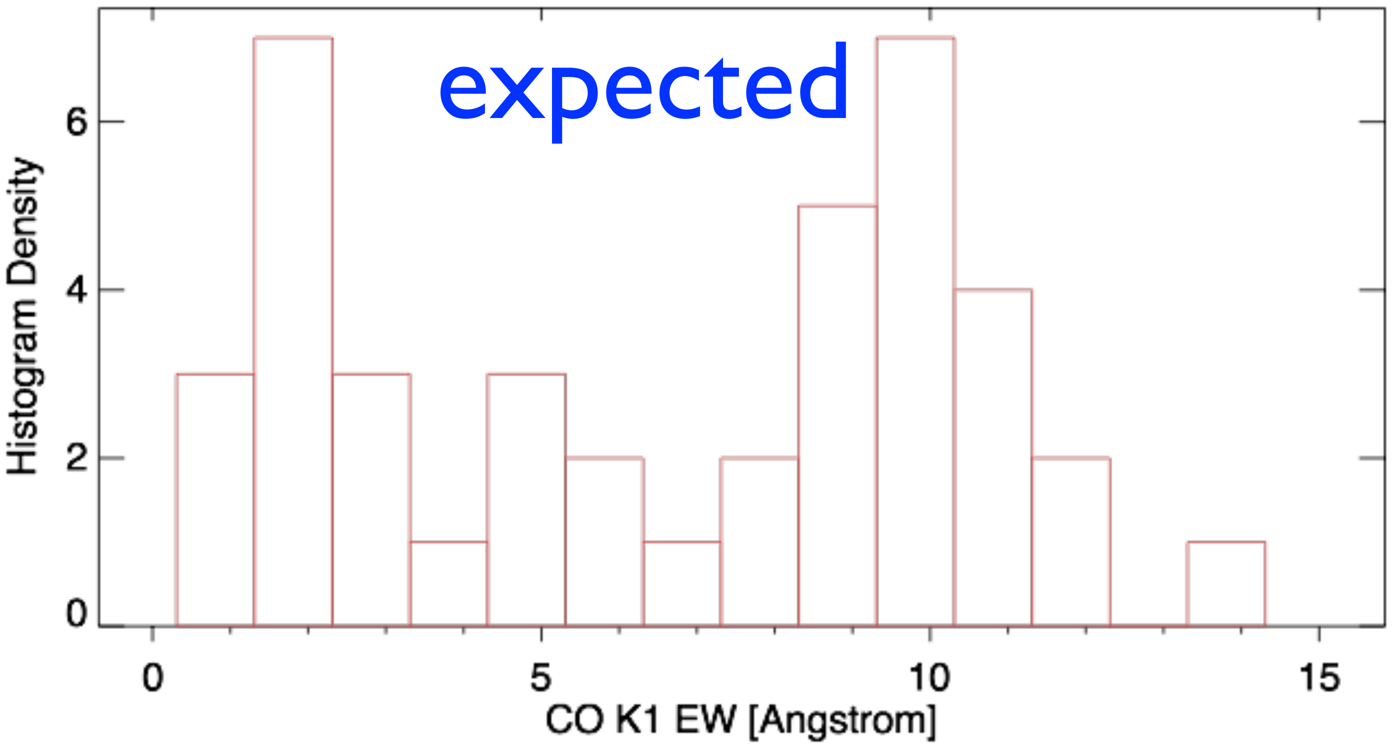

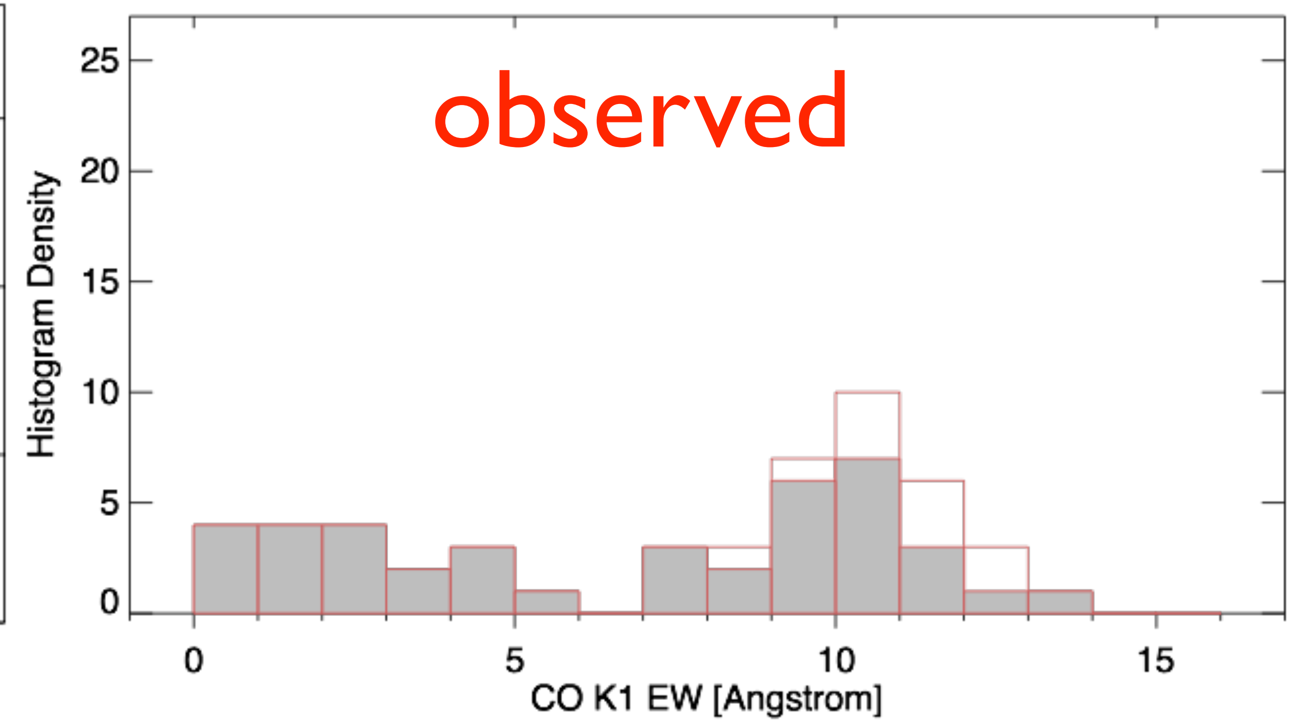

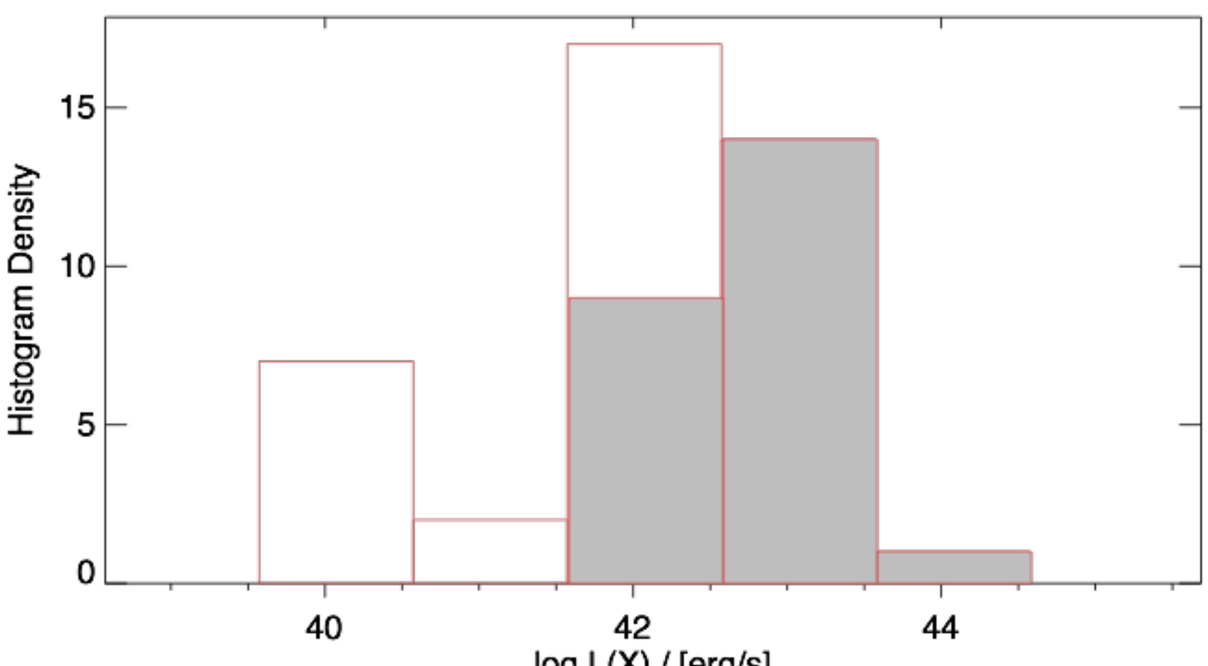

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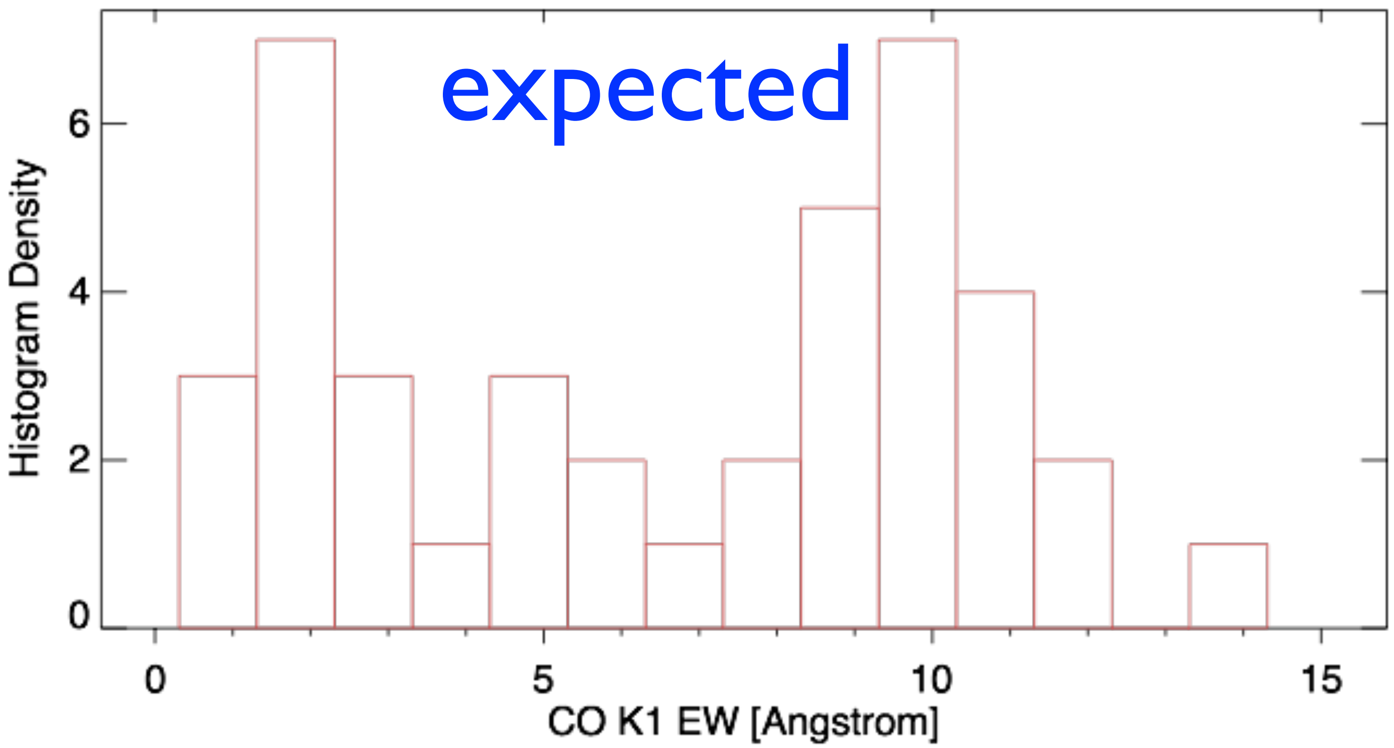
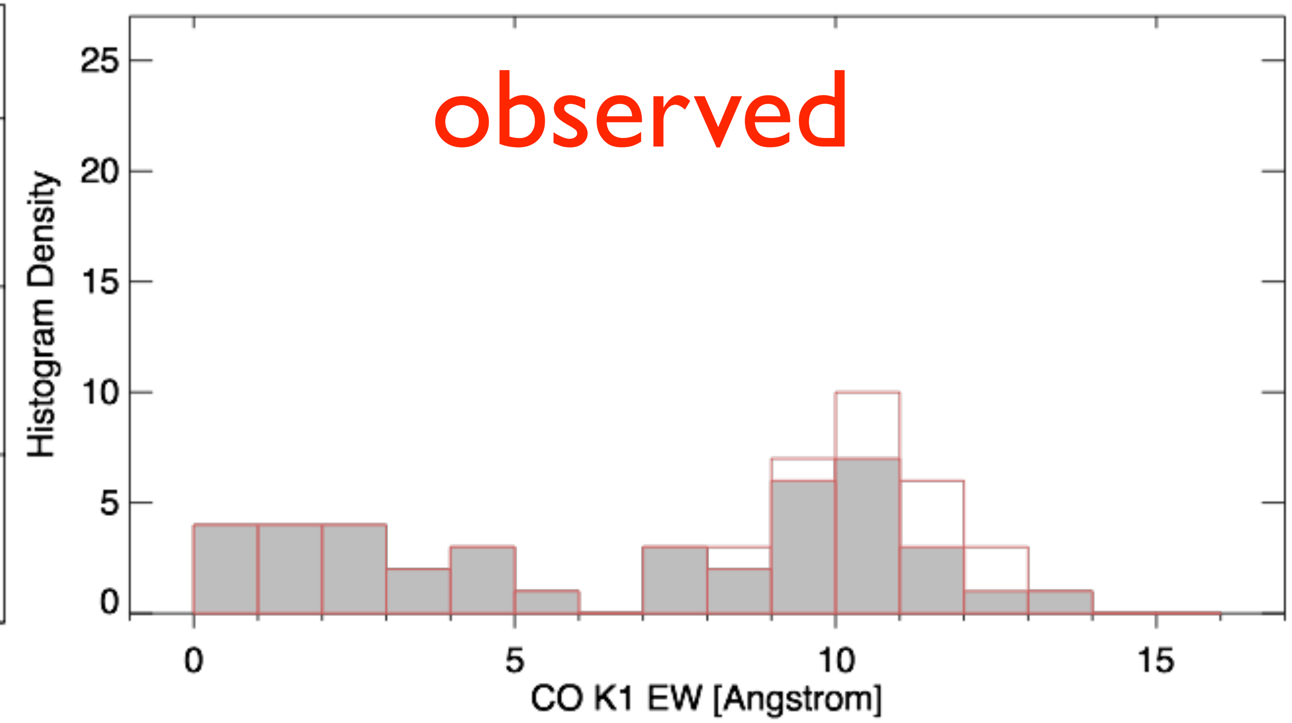
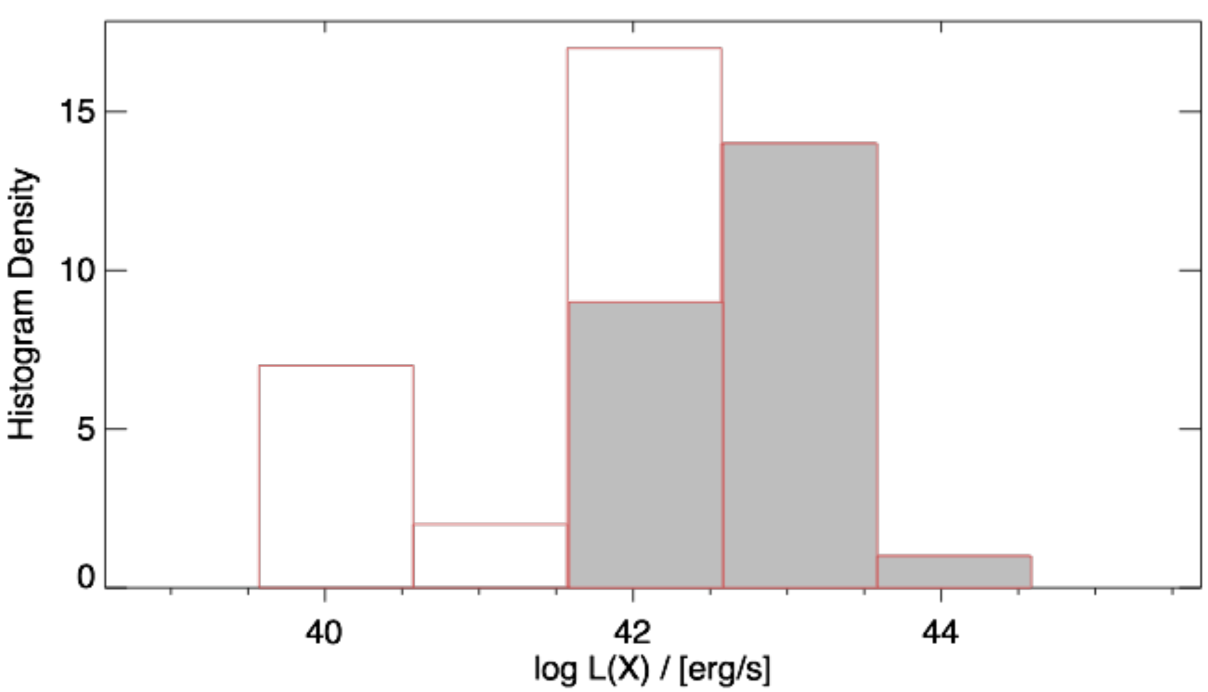
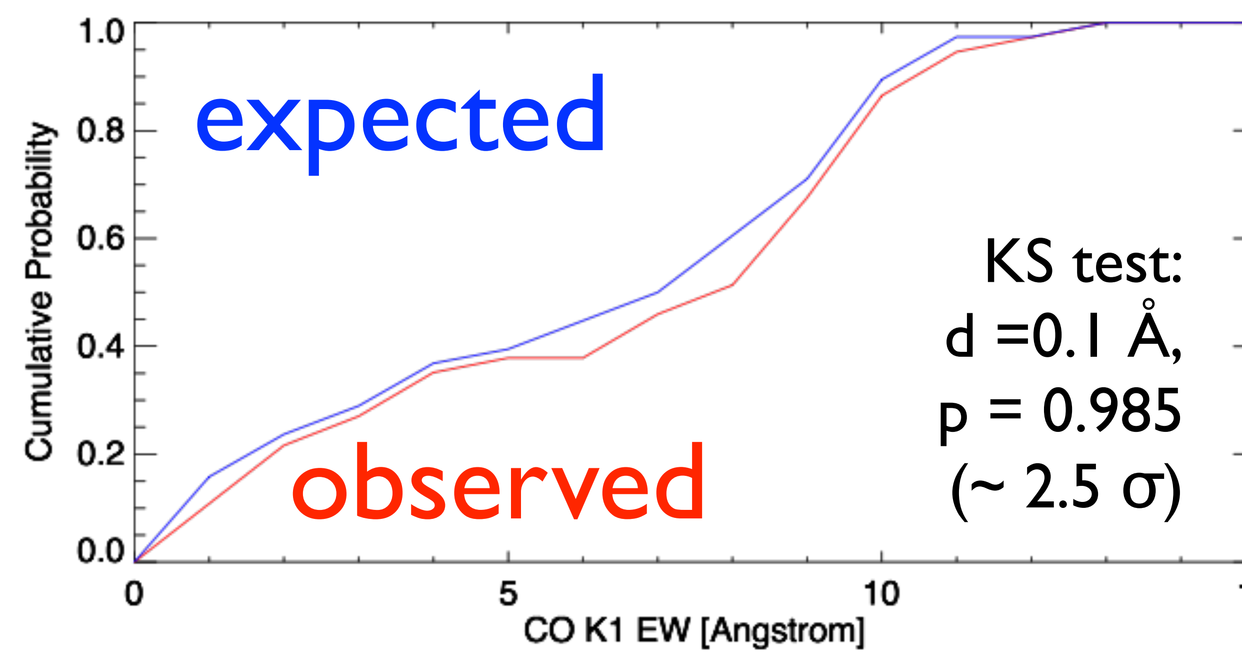
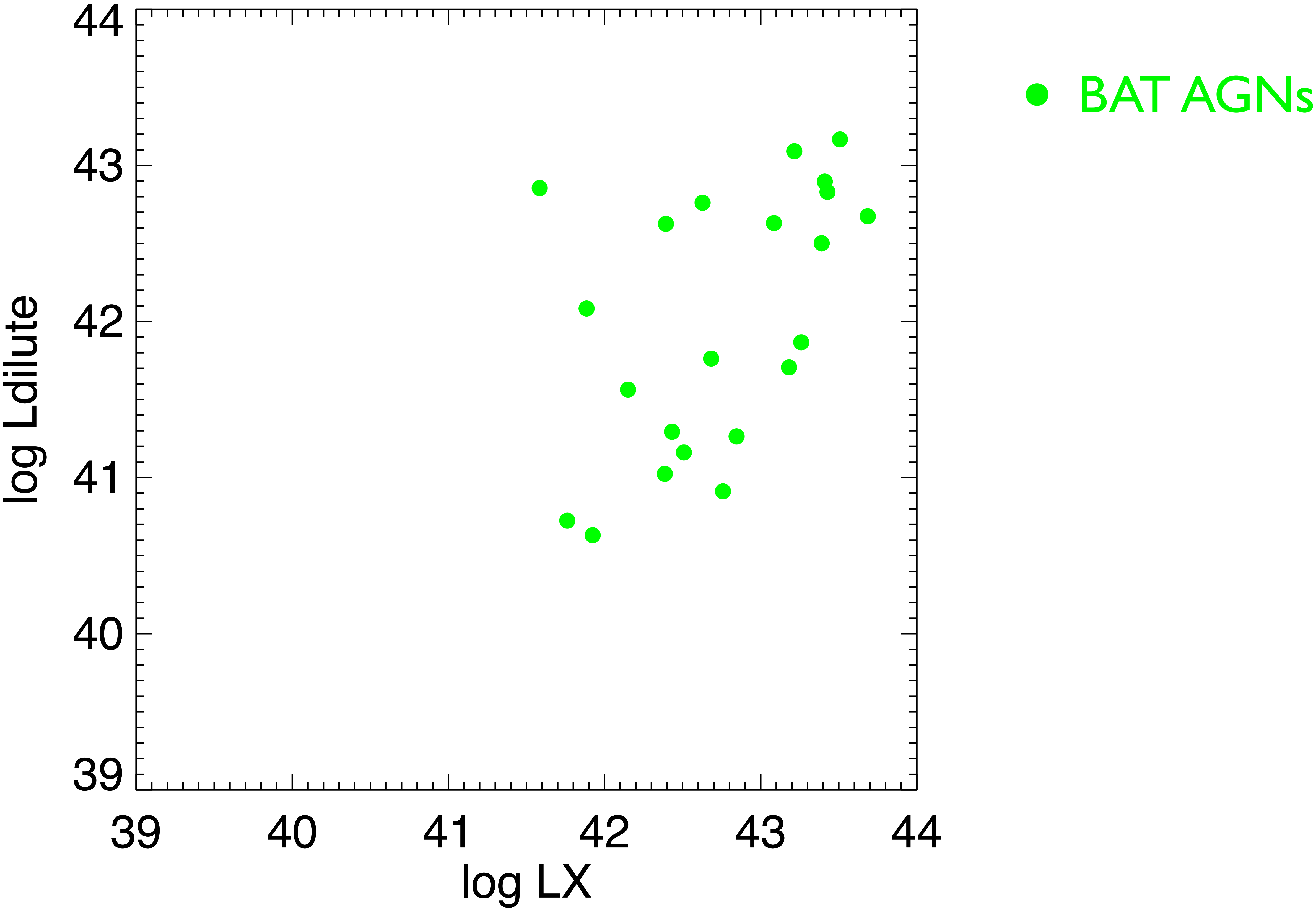








L_{dilute} vs. L_X



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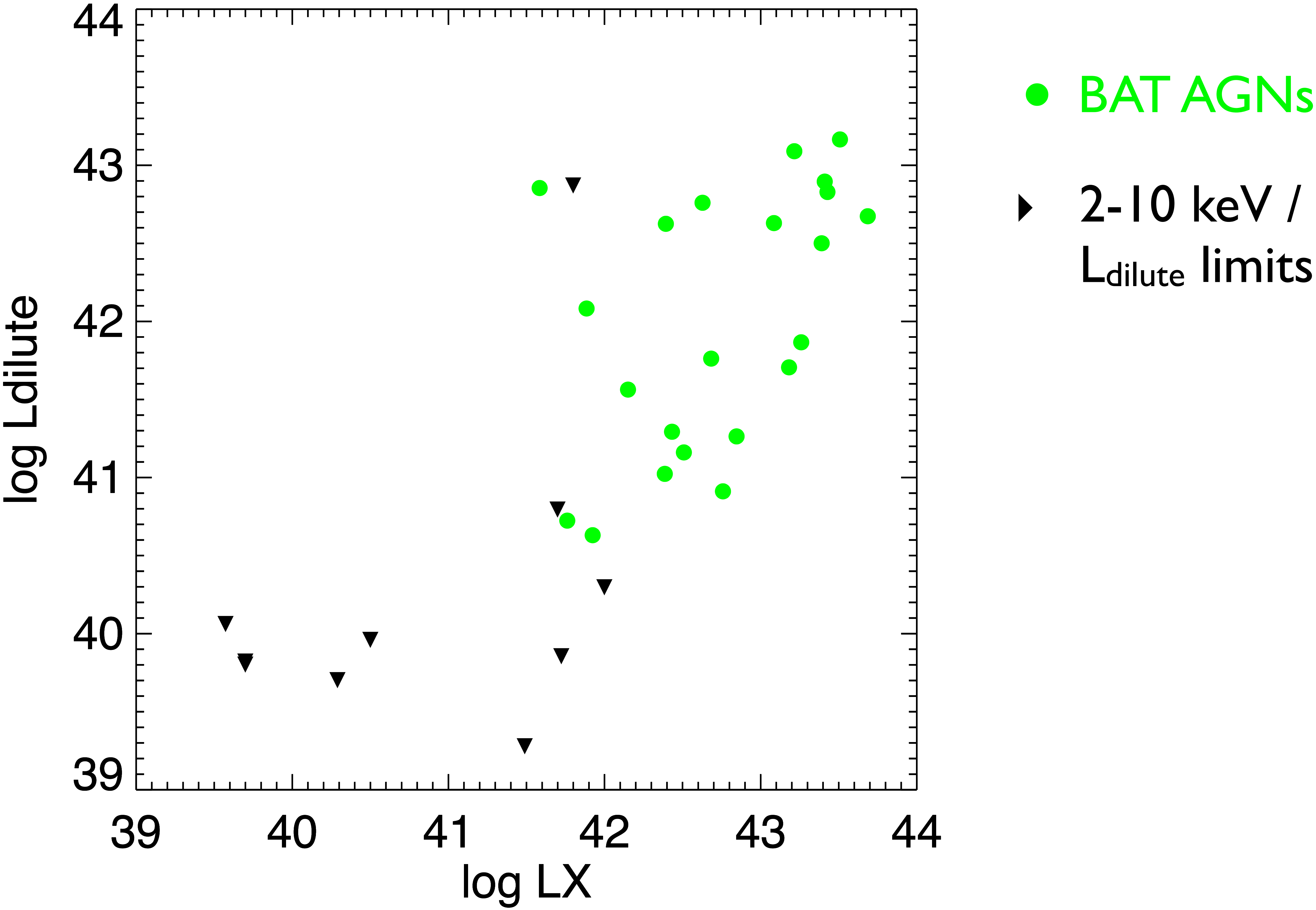

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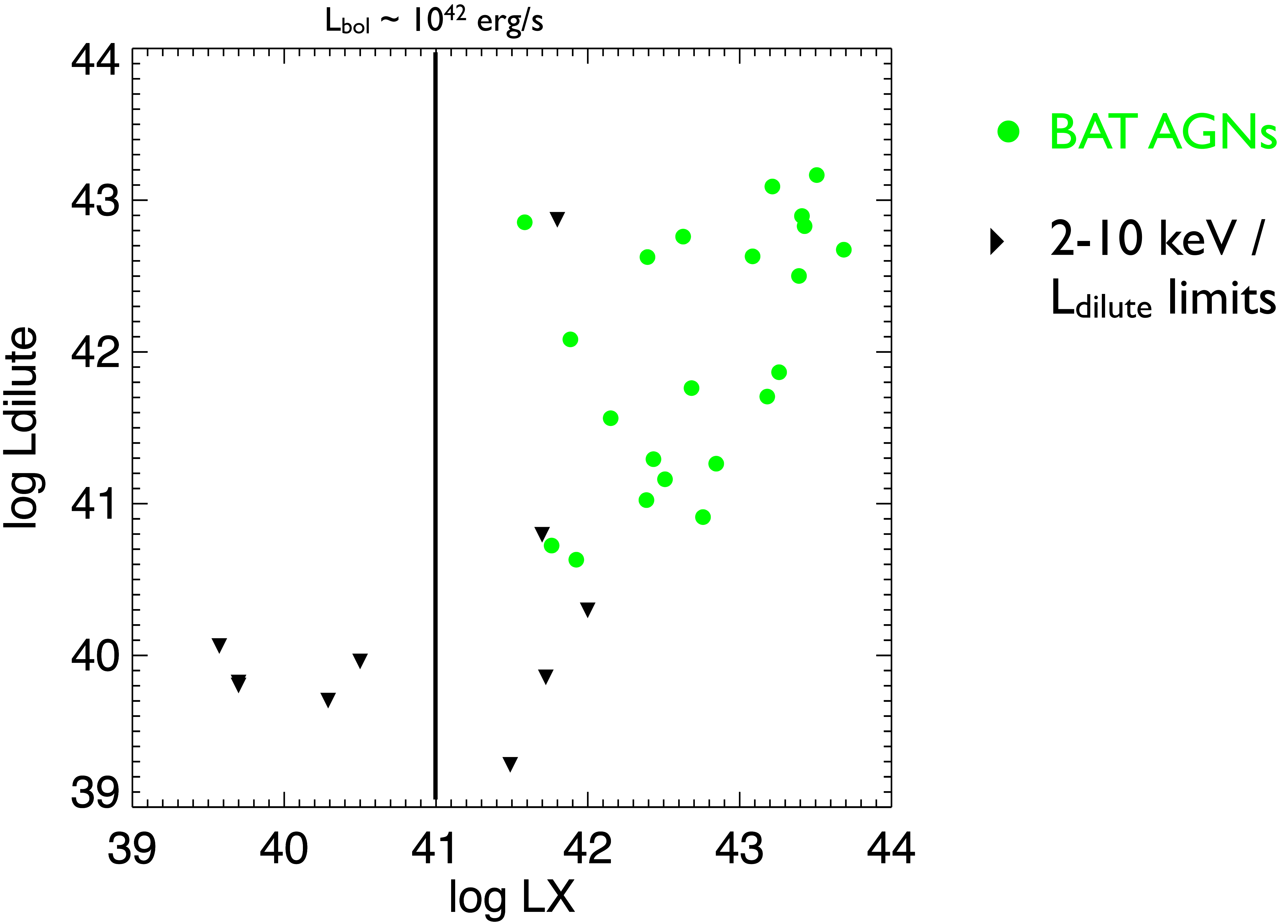

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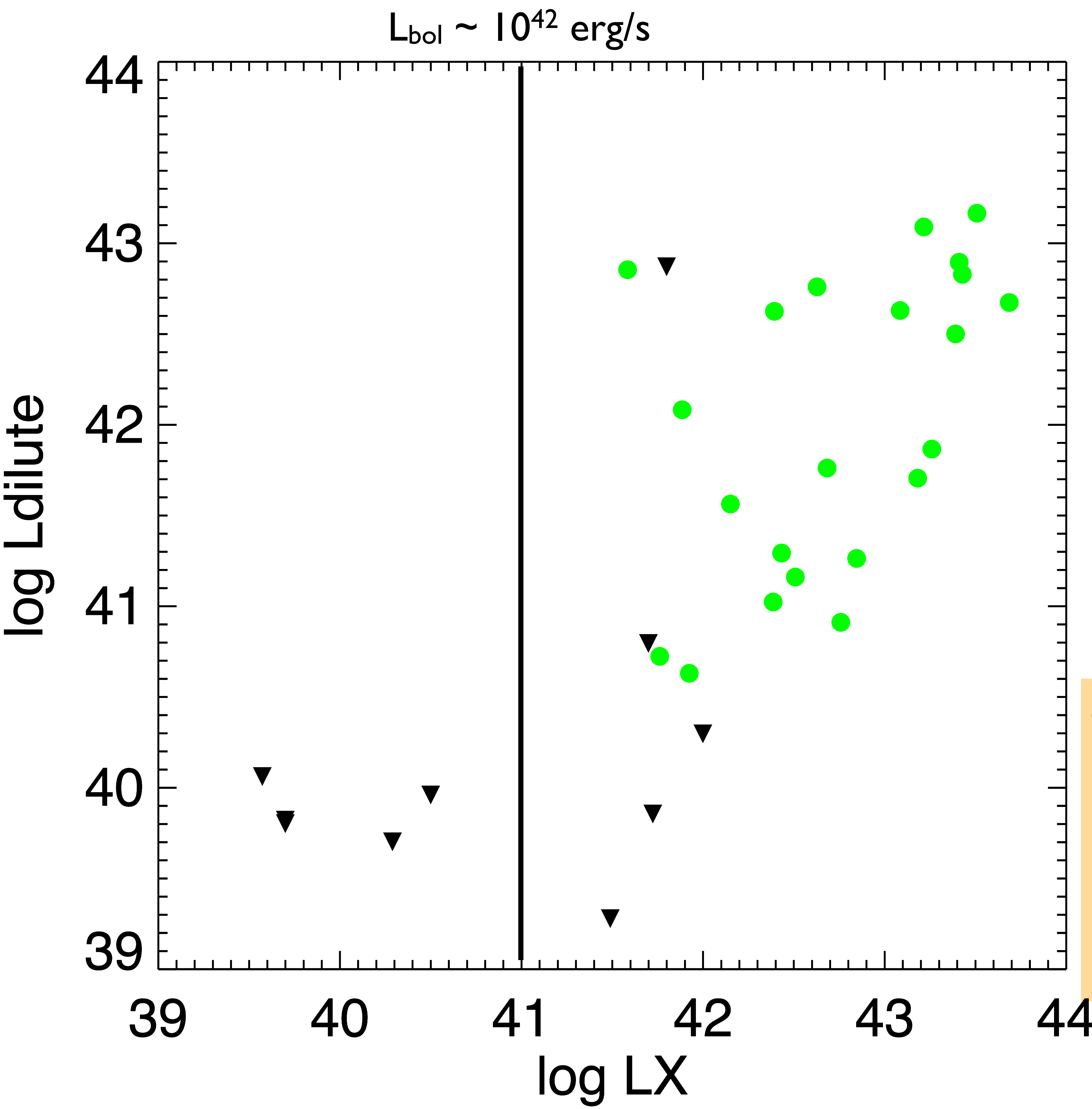
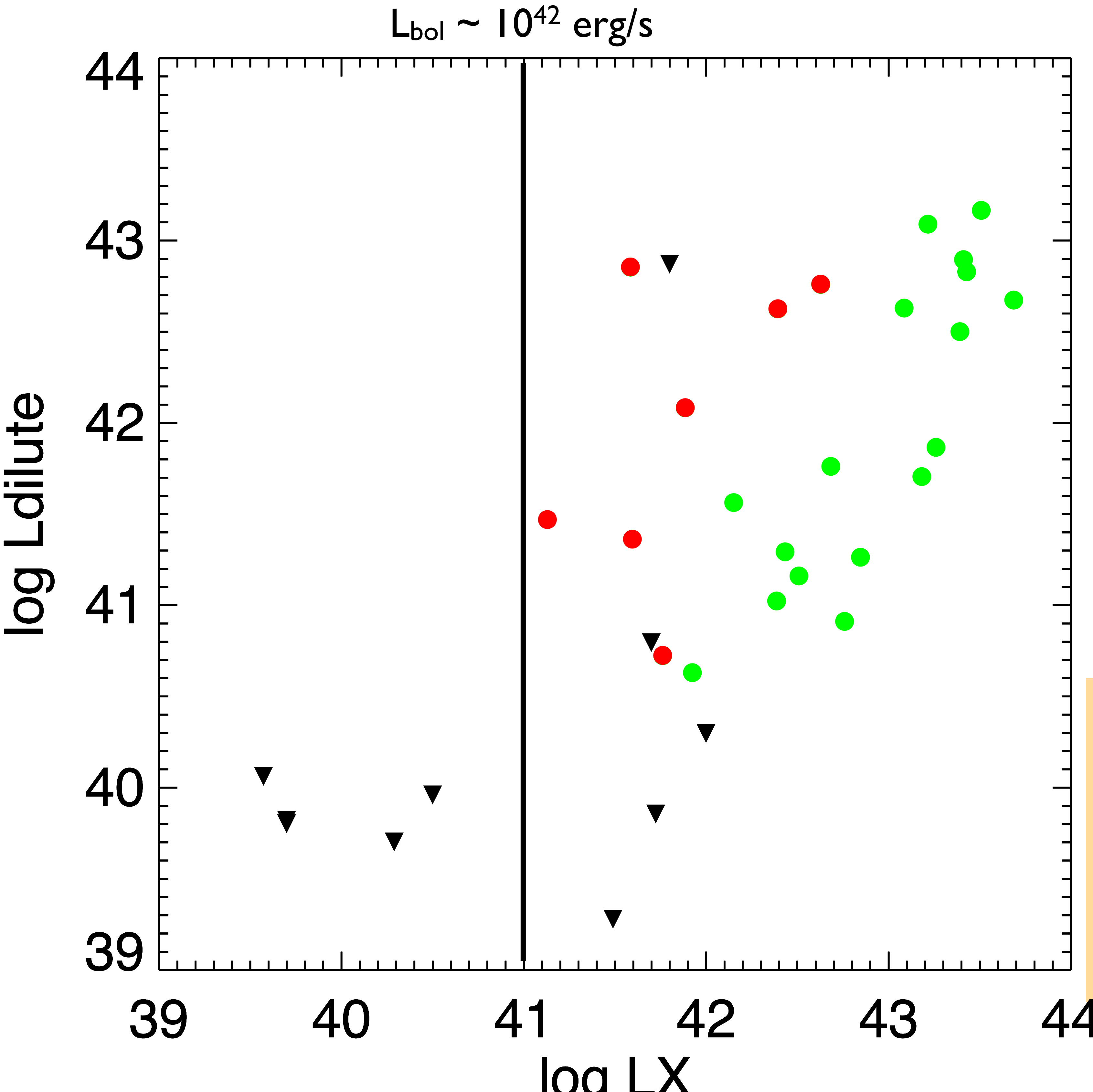


BAT AGNs

2-10 keV / L_{dilute} limits

Good correlation between non-stellar K-band light and X-ray light.
Torus does not disappear above $L_{bol} \sim 10^{42}$ erg/s.

L_{dilute} vs. L_X



- BAT AGNs
- 2-10 keV / L_{dilute} limits
- Compton-thick sources

Good correlation between non-stellar K-band light and X-ray light.
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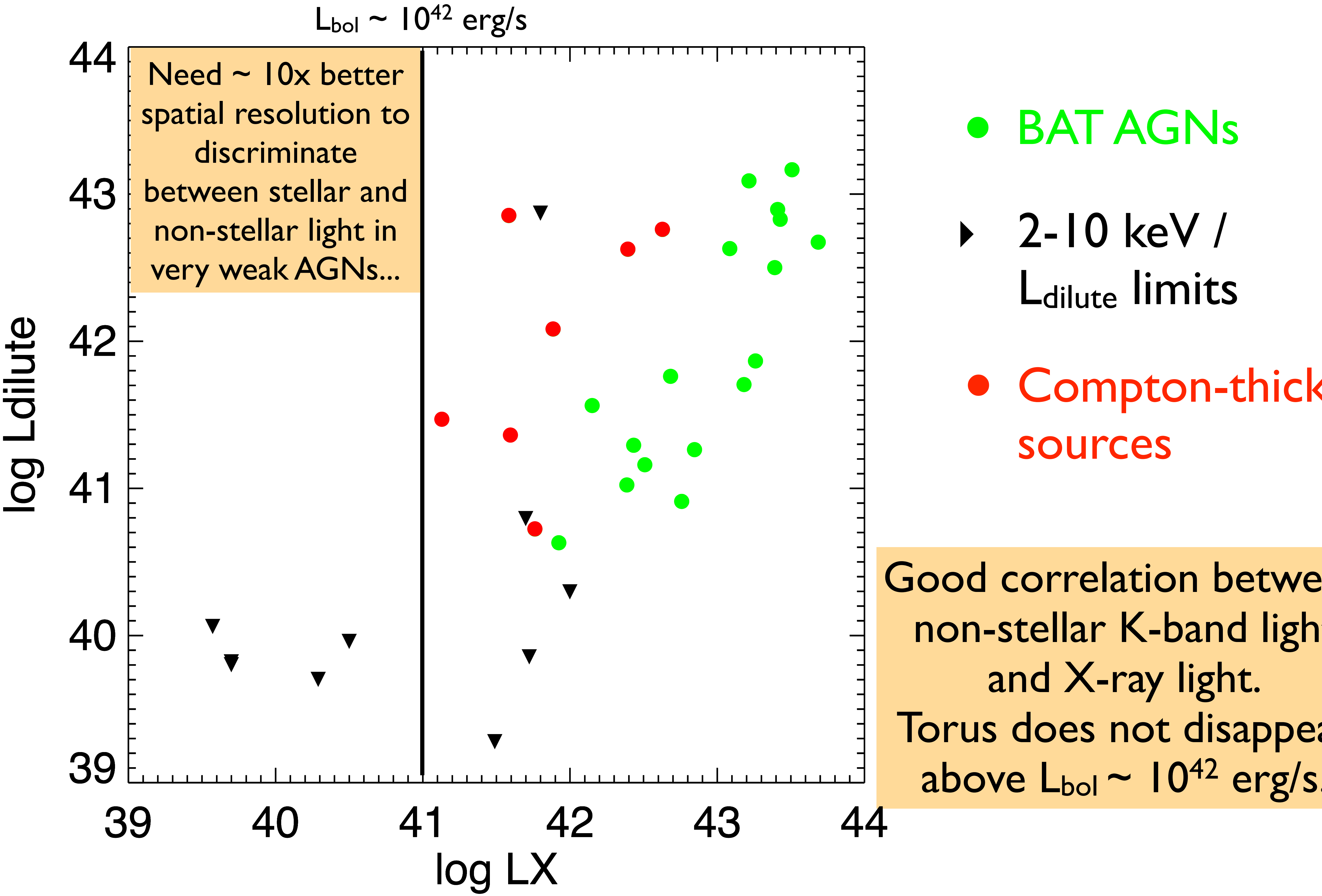
L_{dilute} vs. L_X



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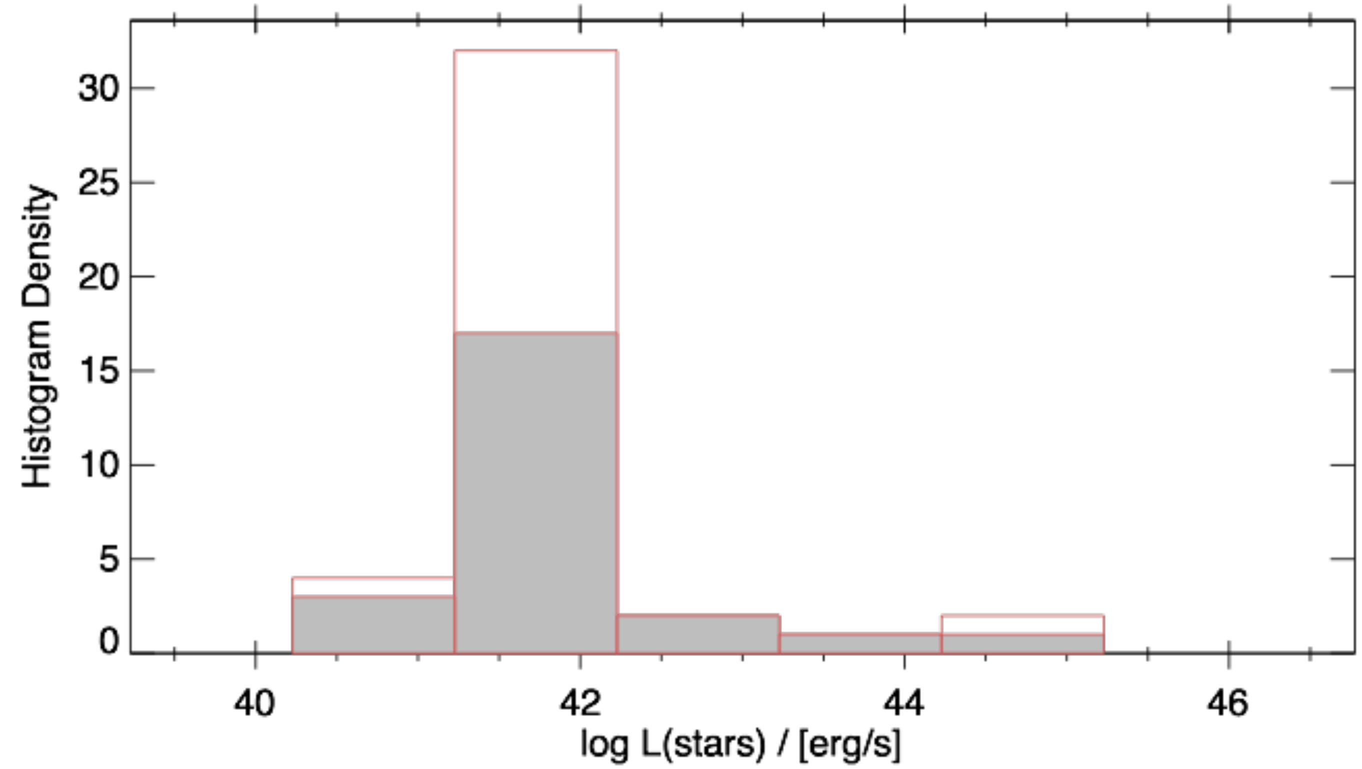
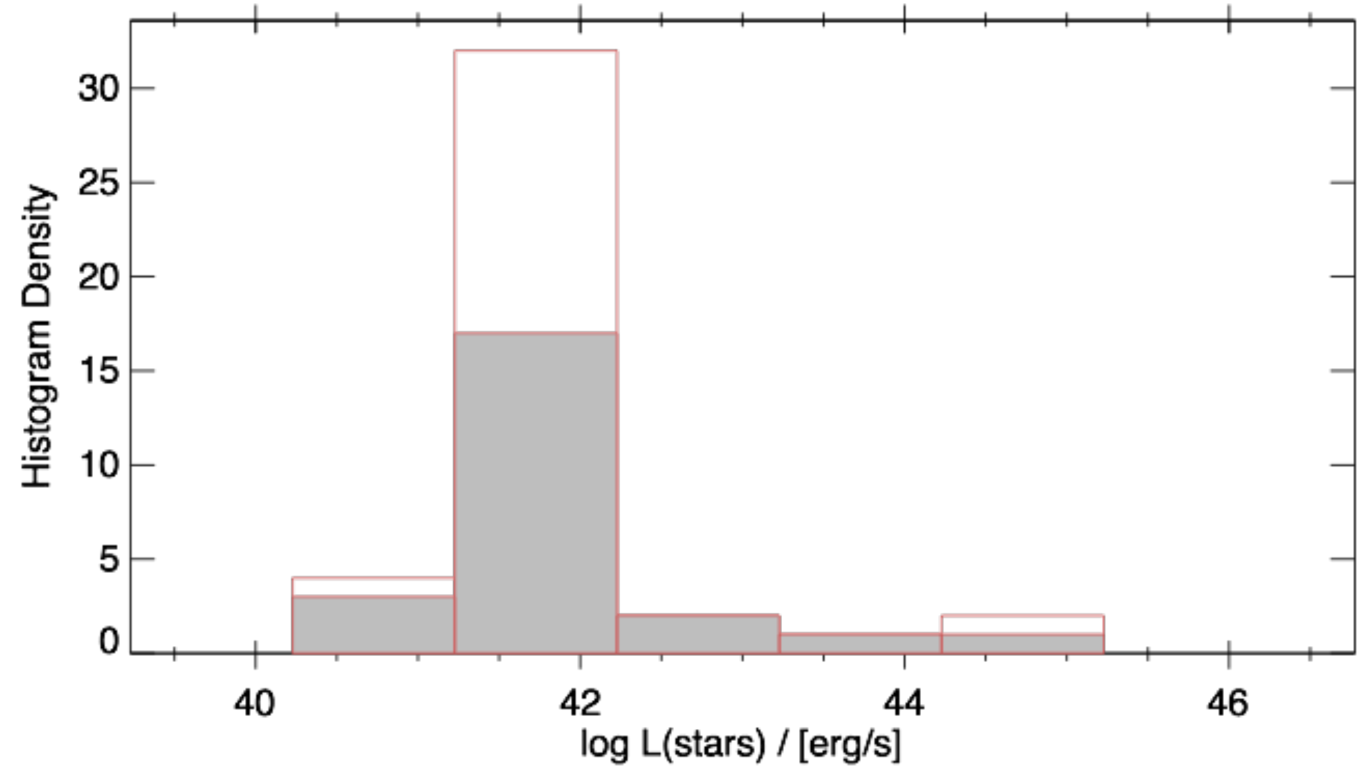
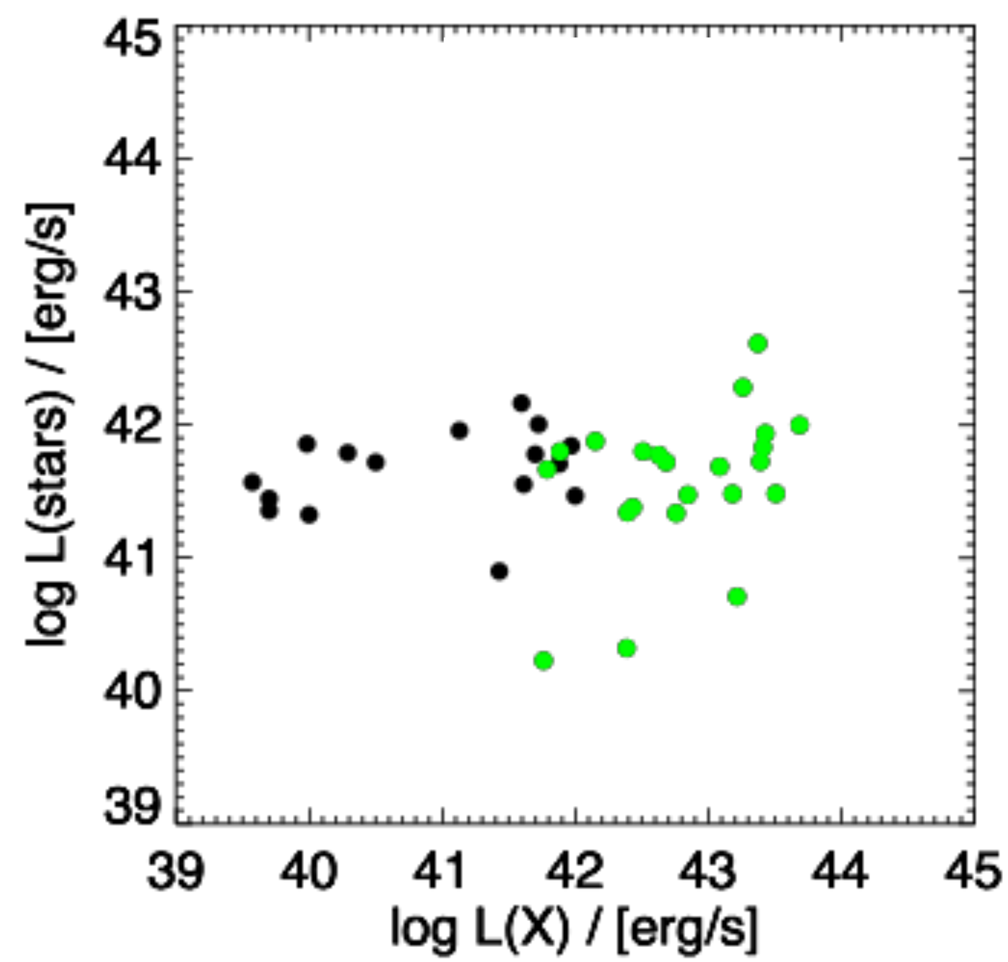
Torus does not disappear above $L_{bol} \sim 10^{42}$ erg/s.

Stellar luminosity



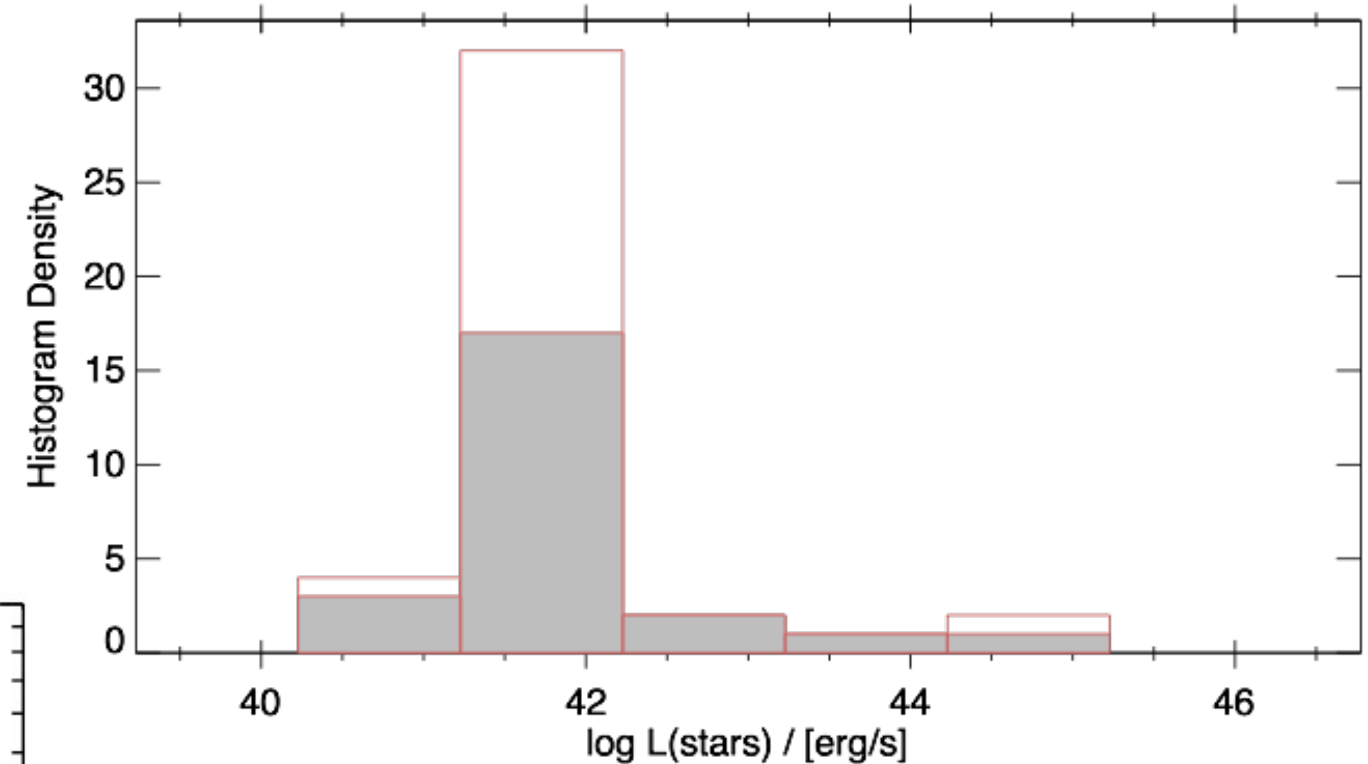
Stellar luminosity

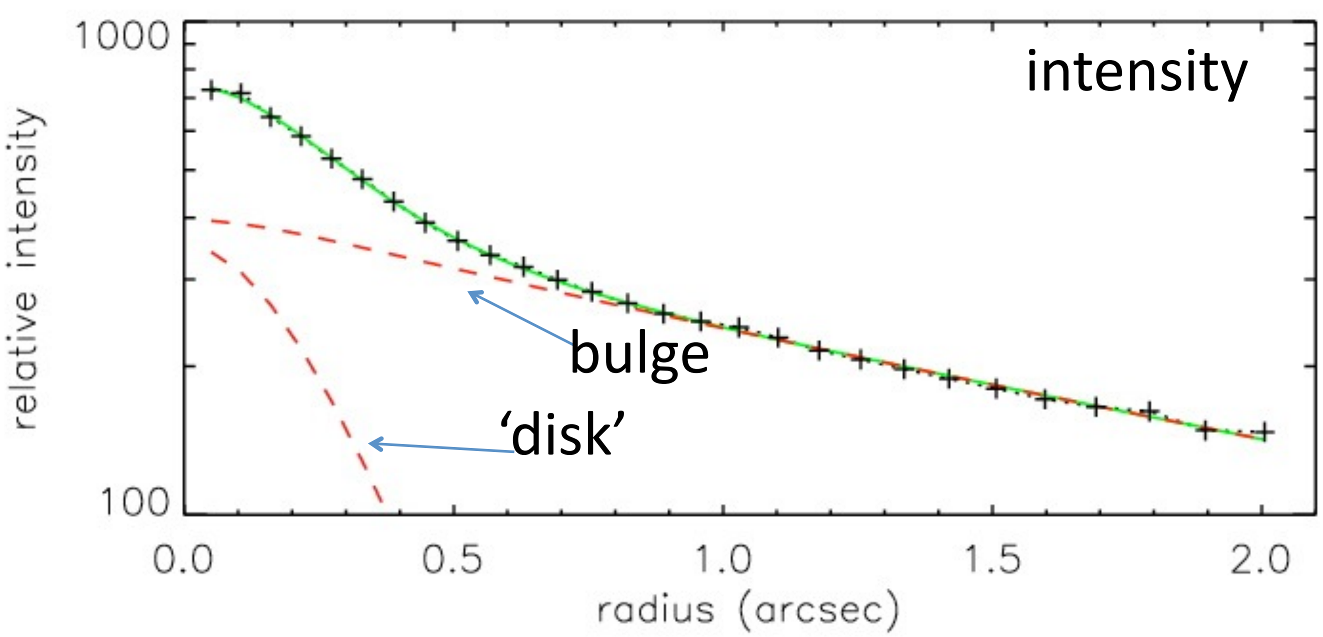


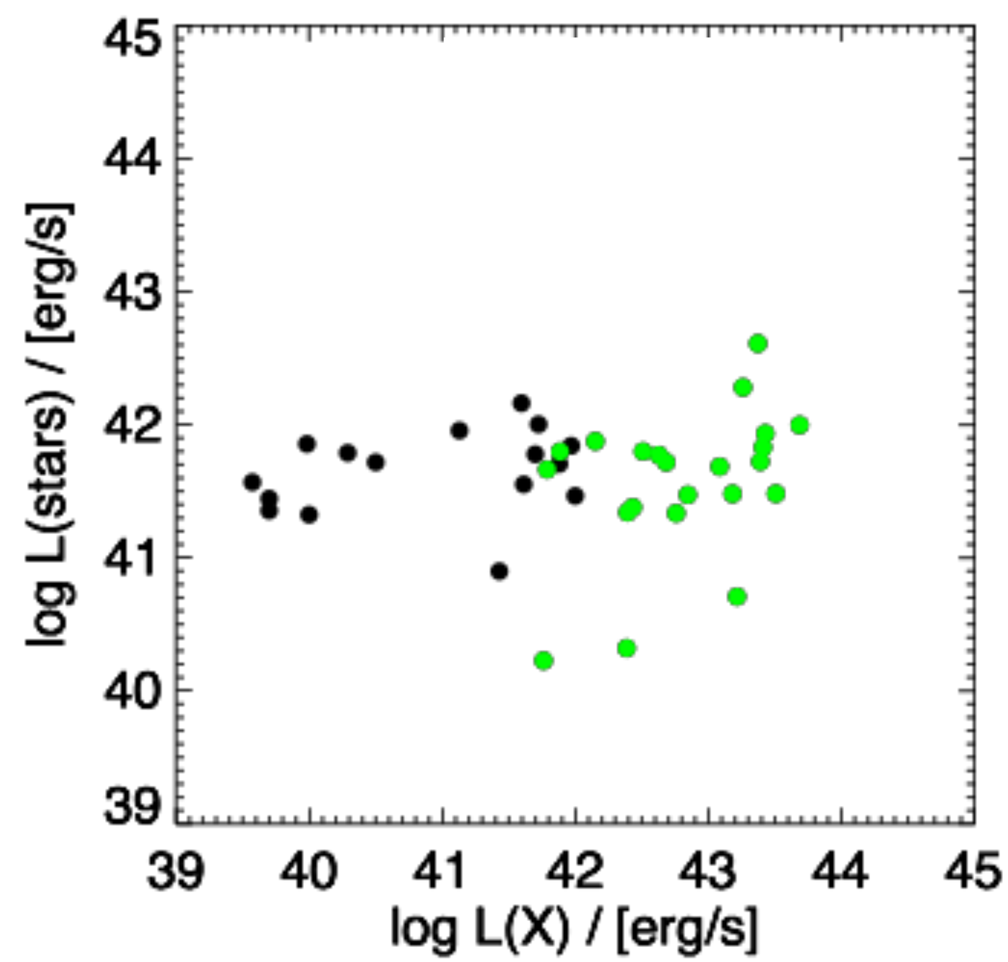


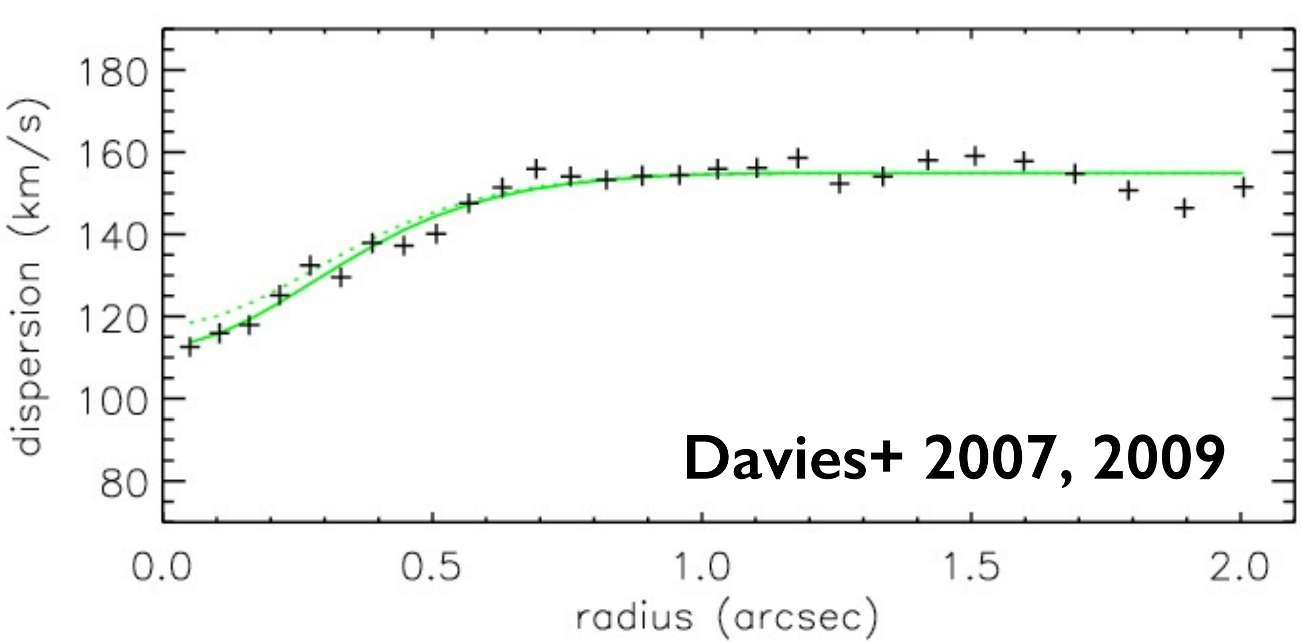
Stellar luminosity

NGC 1097

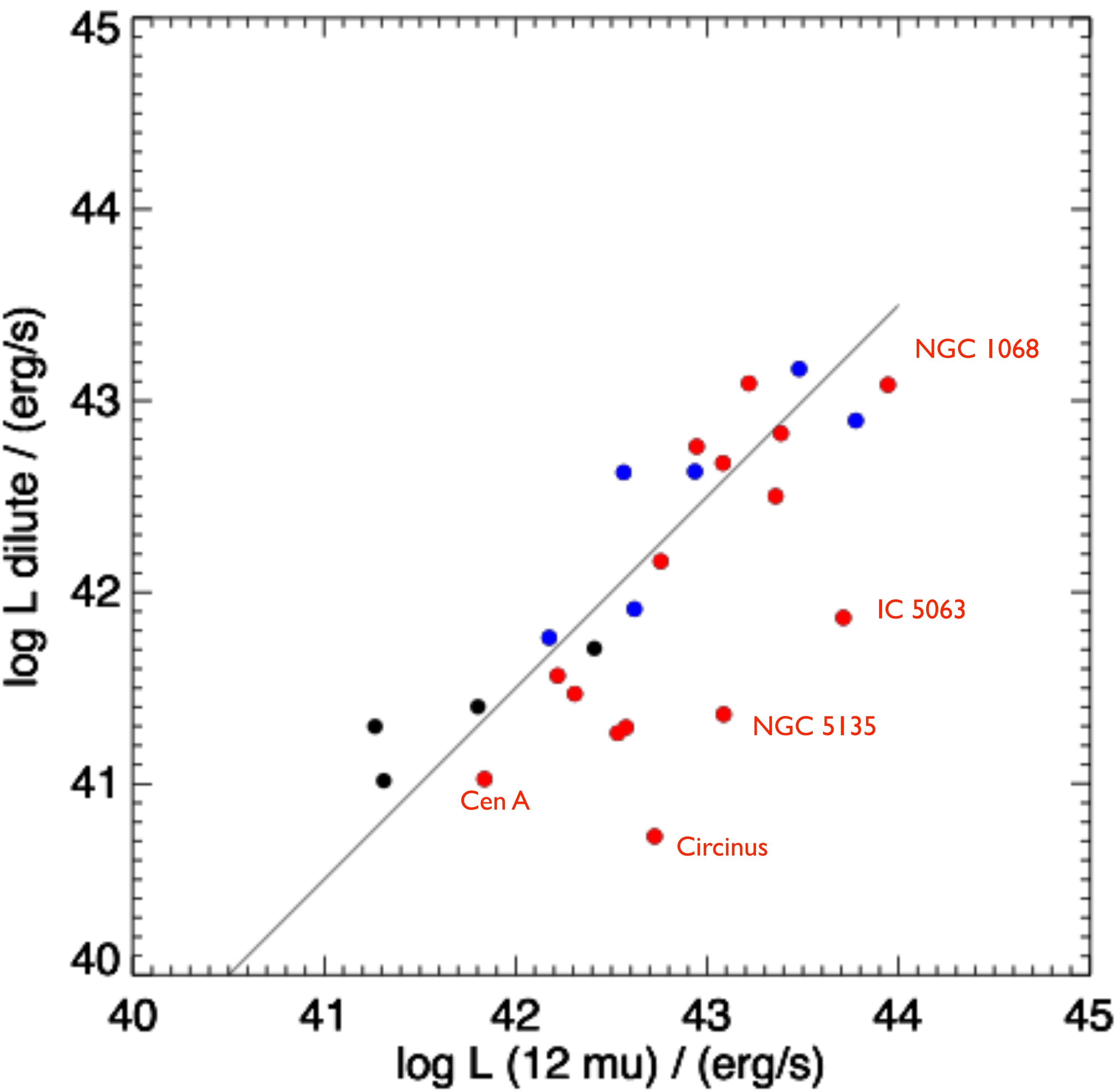








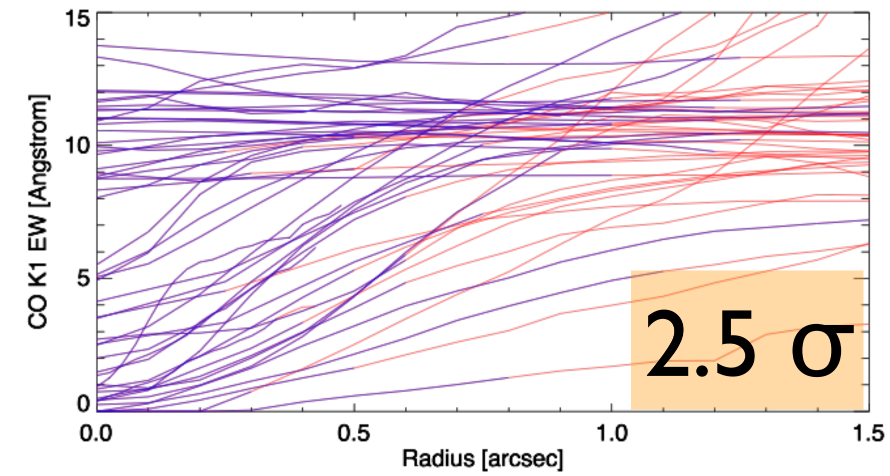
A near-IR – mid-IR correlation

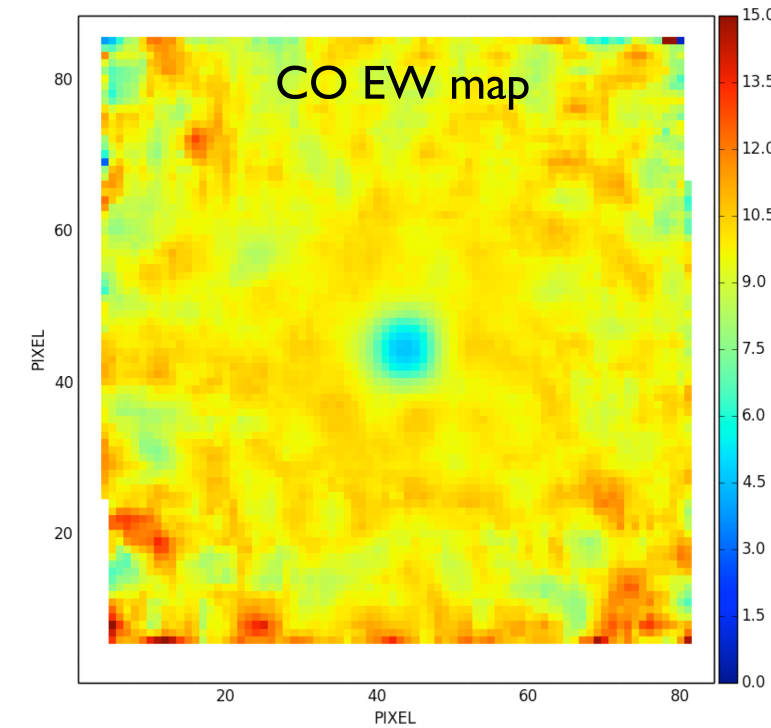


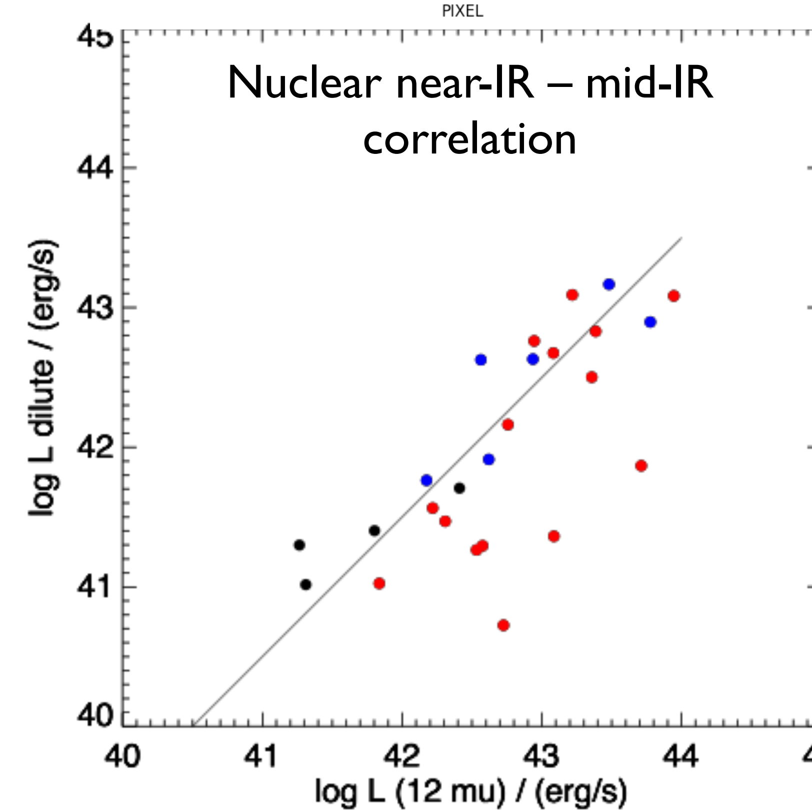
- Tight correlation between near-IR non-stellar light and mid-IR
- no type 1/2 dichotomy (see also Lutz+,Gandhi +,Horst+,Asmus+, ...)
- but: perhaps some interesting outliers

Conclusions + Outlook

- The bimodality in the dilution of starlight by the AGN is caused by a nearly constant stellar surface brightness and a wide range of AGN luminosities
- We establish a new correlation between non-stellar continuum in the K band and X-ray luminosity. Outliers have peculiar X-ray properties.
- We also find a good correlation between the nuclear non-stellar near-IR light and the nuclear mid-infrared light. Some of the few outliers are known to be devoid of hot dust.



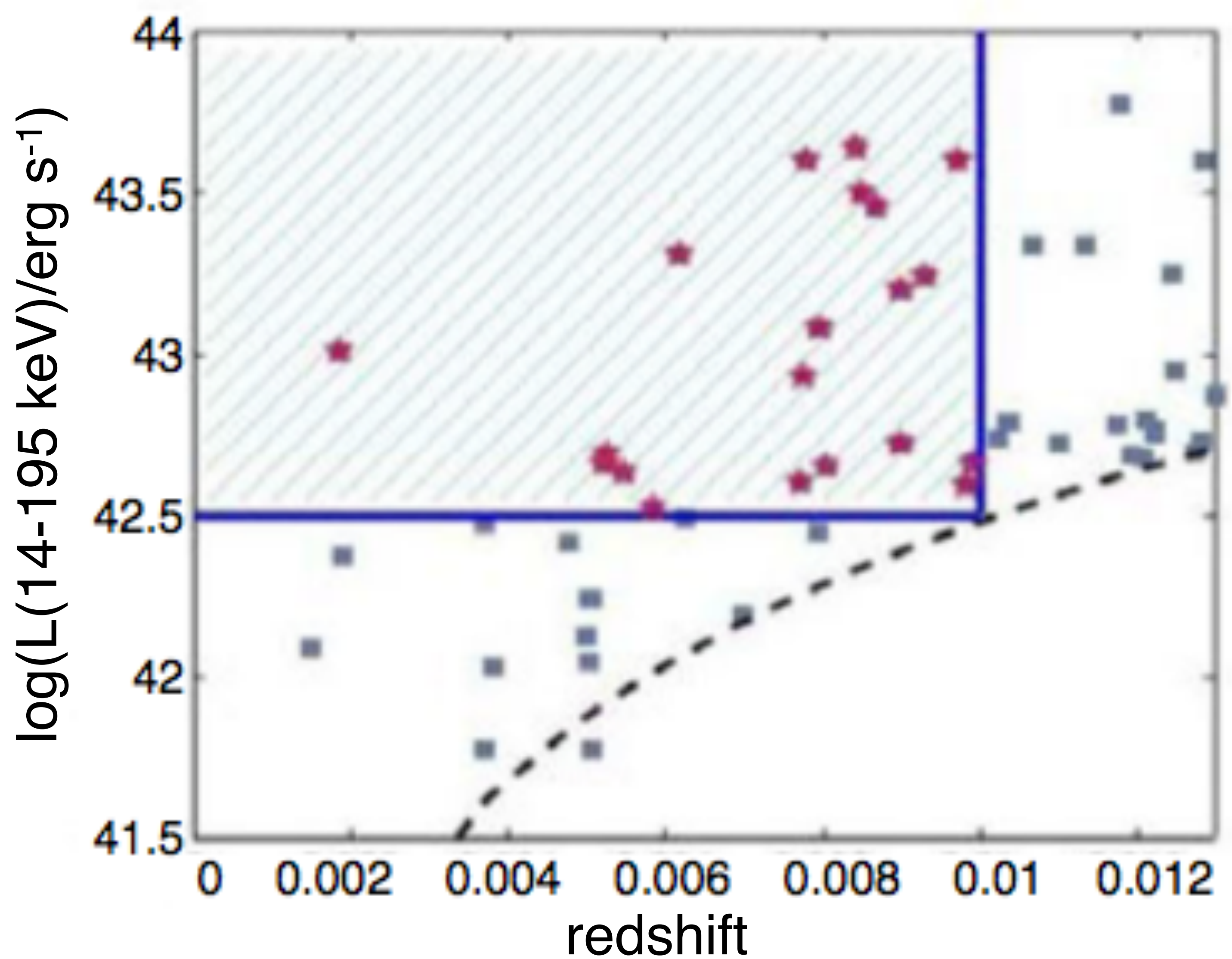




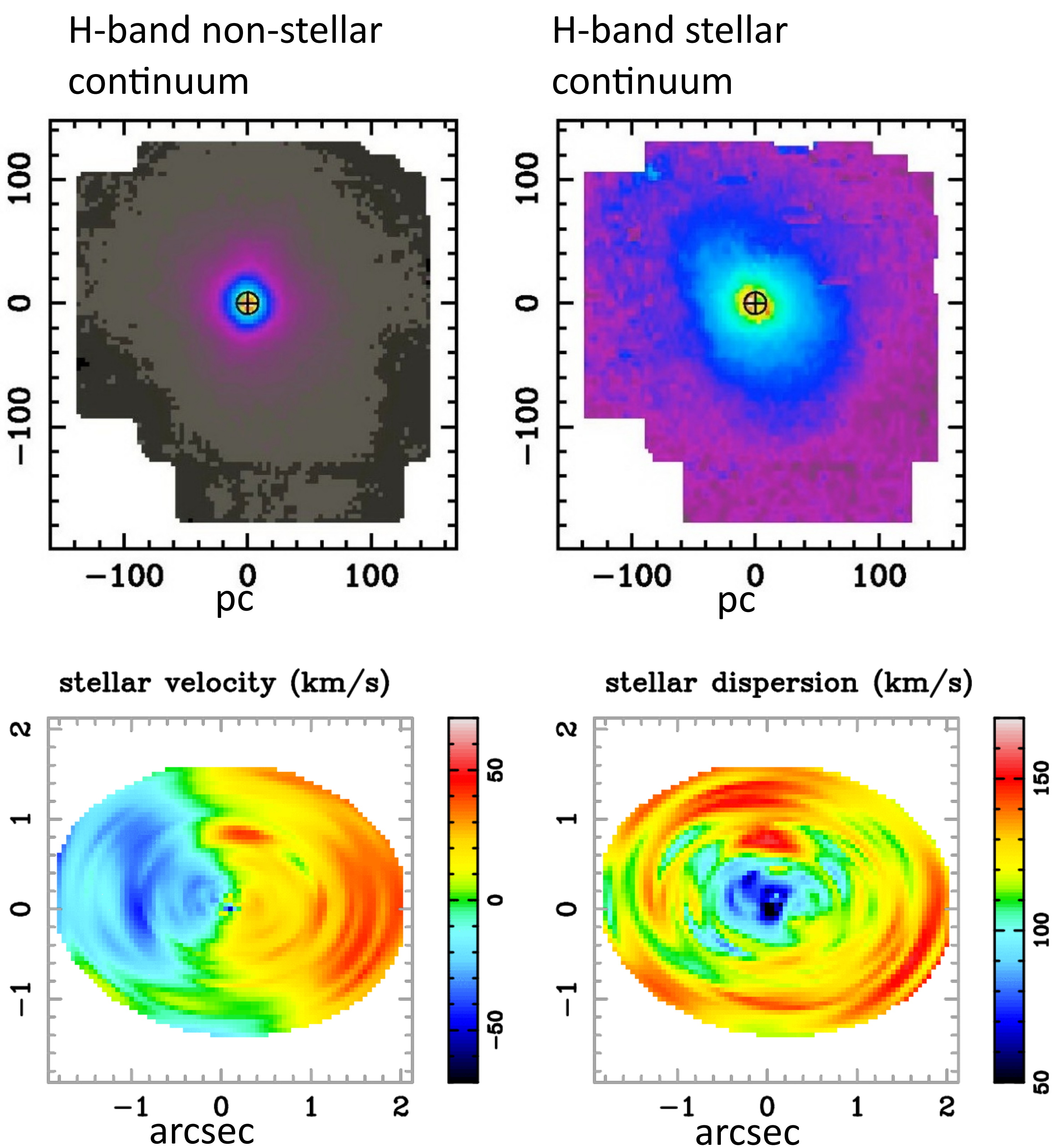
Backup slides

Powerful AGN sample

ongoing SINFONI + XSHOOTER observations



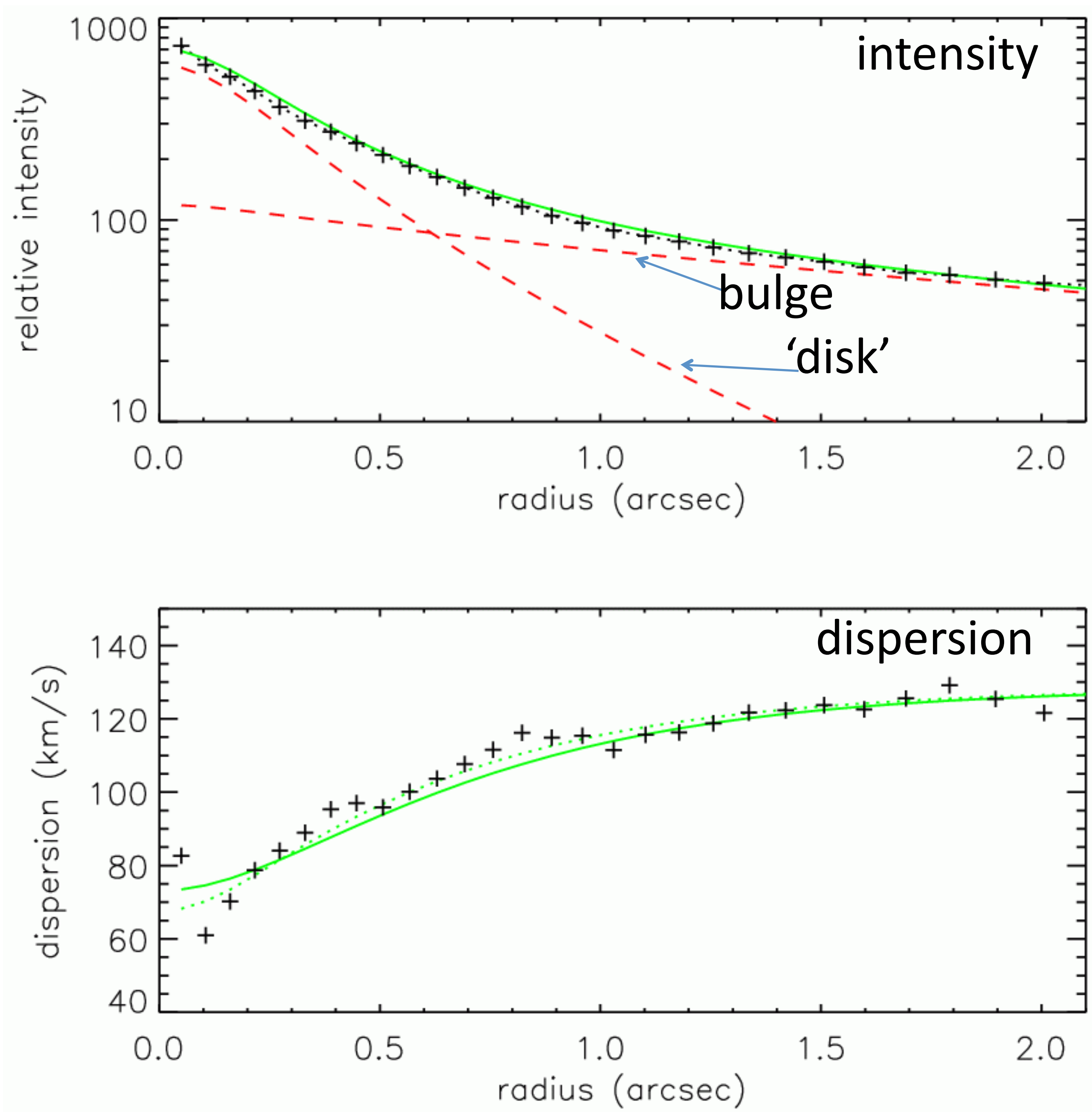
Nuclear Starburst in NGC1068



Davies+ 07

Star forming Region Size & Mass

fit intensity & dispersion simultaneously with bulge + ‘disk’



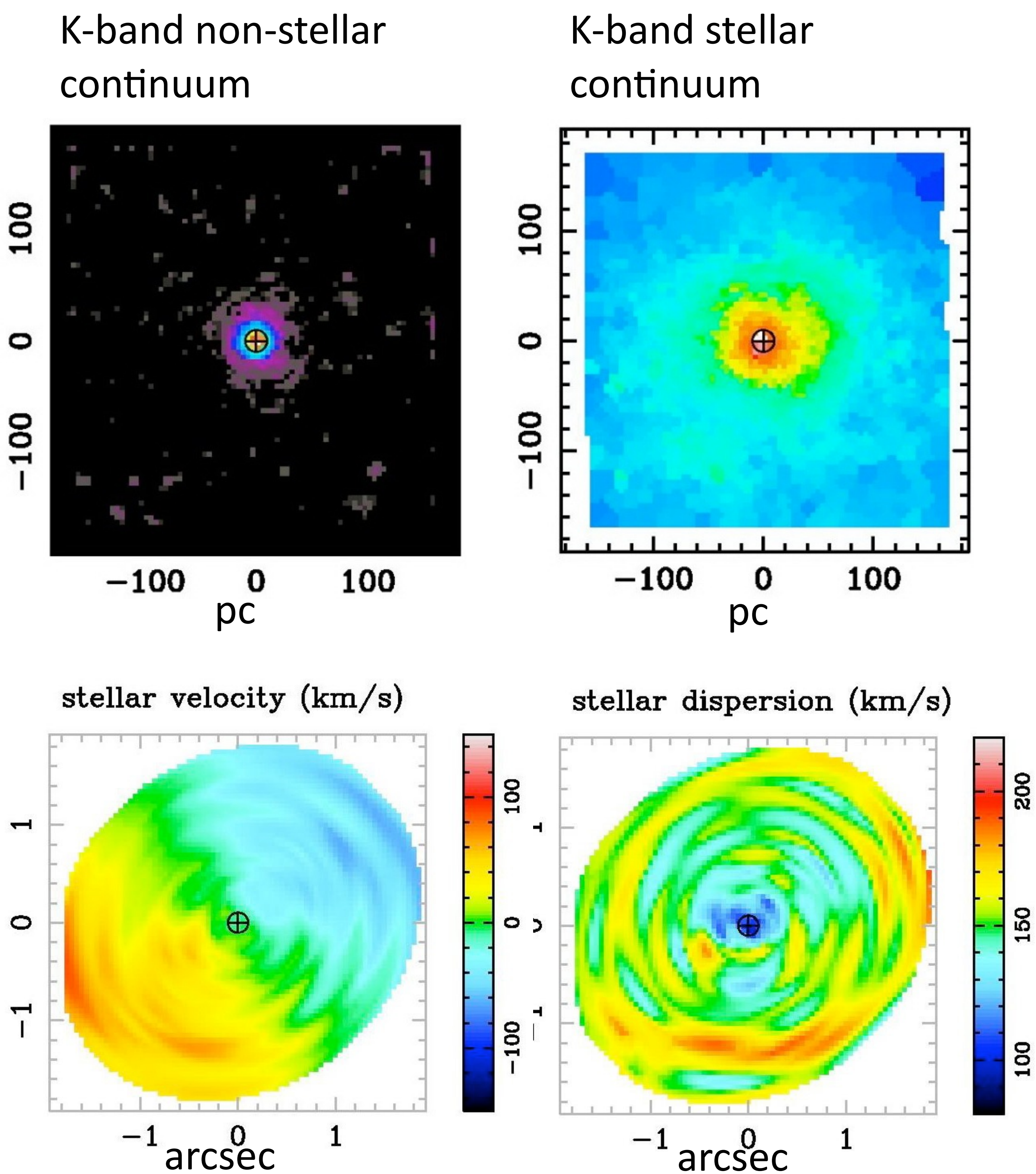
- for each component, fit: R_{eff}, n, I_0, σ
- bulge component

  R_{eff} & n similar to NICMOS profile
- nuclear ‘disk’ component

  R_{eff} = 0.51” = 36pc n = 1.6 σ = 35-55km/s

- $M_{dyn} = 5\text{-}9\times10^7 M_{sun}$
- $M_{BH} \sim 1\times10^7 M_{sun}$ (Greenhill+ 96)
- $\Sigma_{dyn} \sim 2\times10^4\ M_{sun}/pc^2$
- $M_{dyn}/L_K \sim 4$ agrees with starburst age 200-300Myr (Davies+ 07)
- $M_{BH}/M_{stars} \sim 0.15$

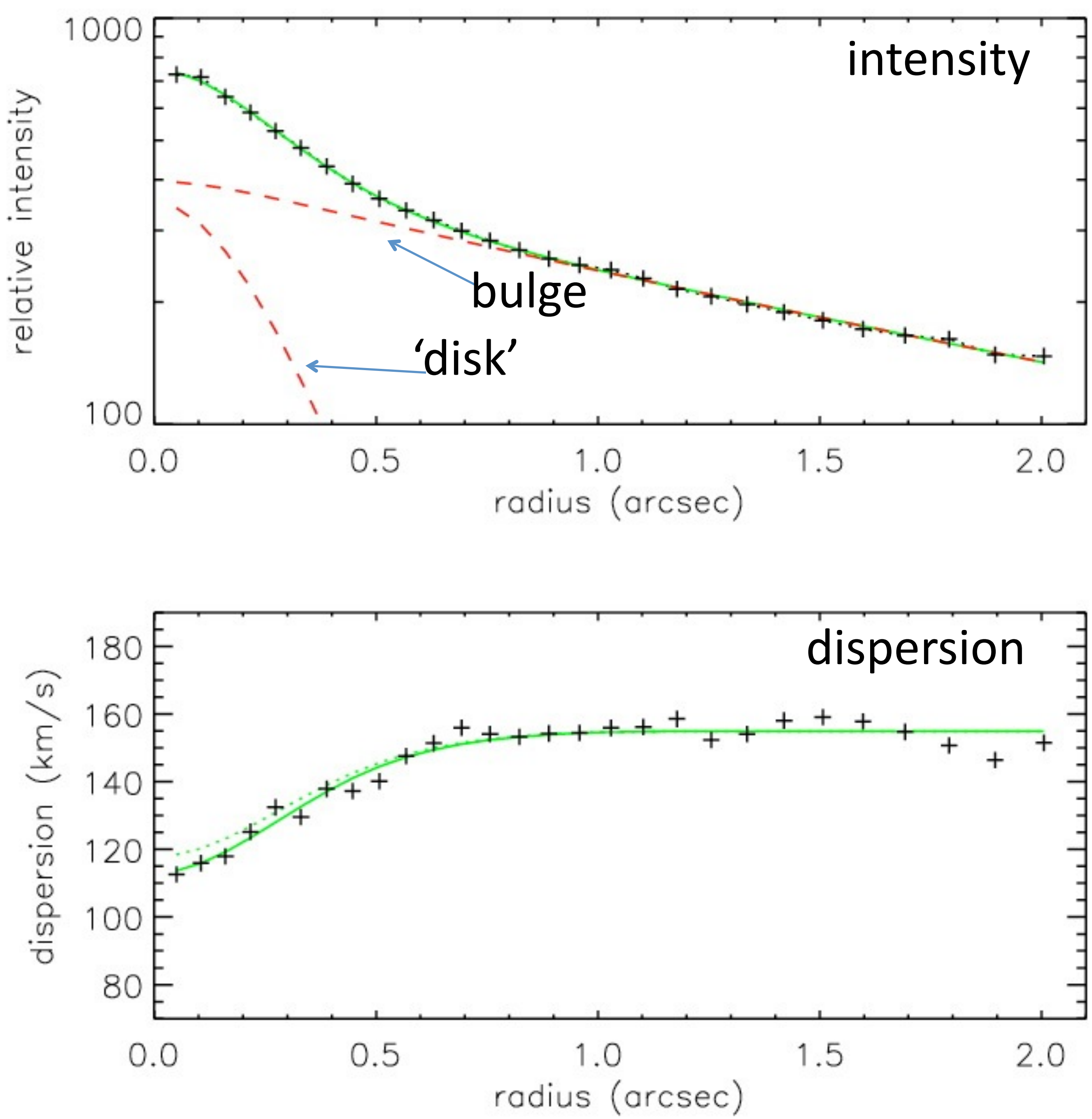
Nuclear Starburst in NGC1097



Davies+ 07, 09

Star forming Region Size & Mass

fit intensity & dispersion simultaneously with bulge + 'disk'



- for each component, fit: R_{eff}, n, I_0, σ
- bulge component

  R_{eff} & n similar to NACO profile (Prieto+05)
- nuclear 'disk' component

  R_{eff} = 0.28" = 24pc n = 0.8 σ <~ 30km/s

- $M_{dyn} = 1\text{-}5\times10^7 M_{sun}$
- M_{BH}

  $12\times10^7 M_{sun}$ (Lewis+ 06, σ=196km/s)

  $5\times10^7 M_{sun}$ (using σ=155km/s)
- low stellar mass, consistent with young age ($M_{dyn}/L_K < 1$)
- $M_{BH}/M_{stars} > 1$