UNIVERSITÀ DEGLI STUDI FIRENZE

Fast outflows quenching star formation in quasar host galaxies

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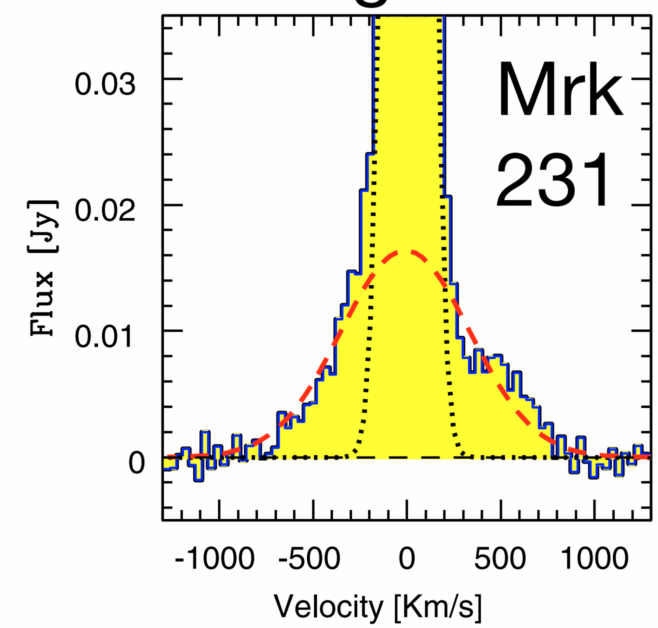
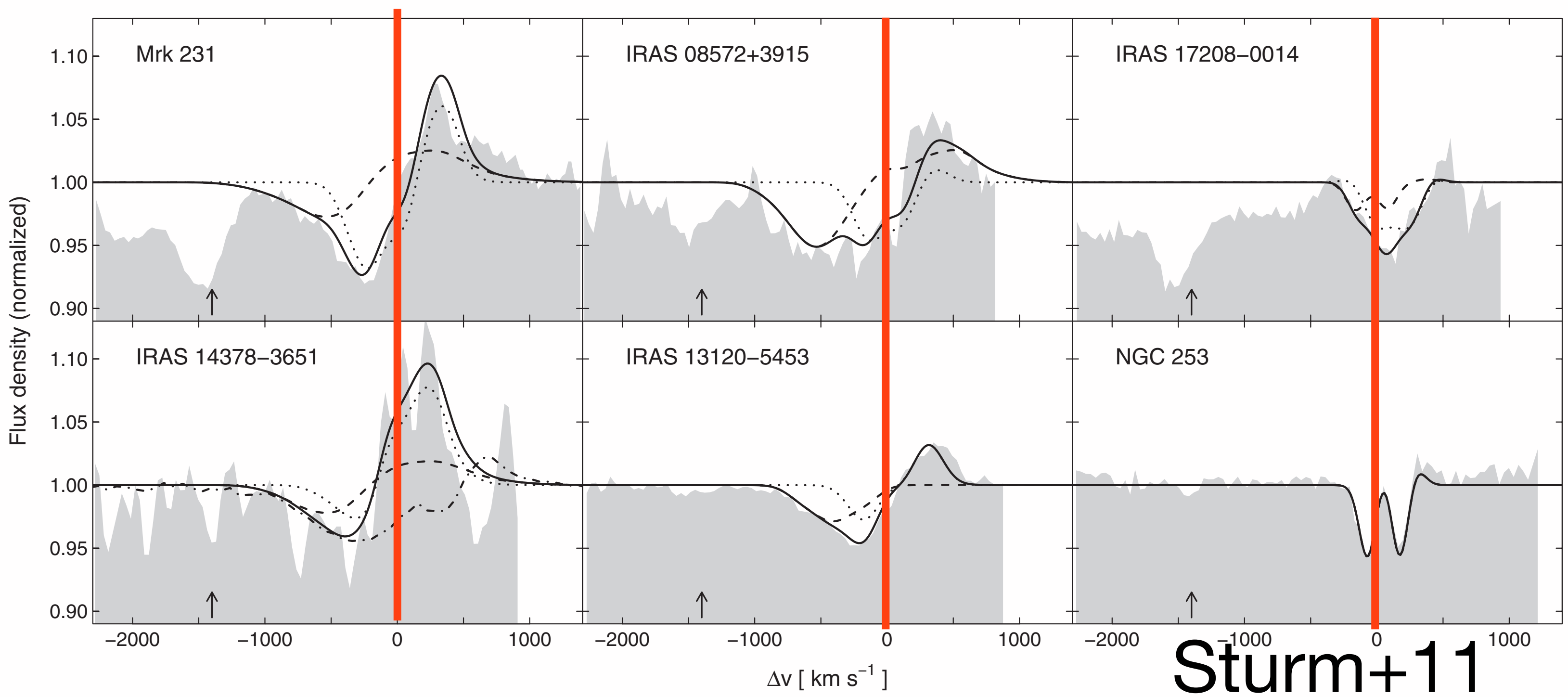
B. Balmaverde, S. Carniani, C. Cicone, *R. Maiolino, G. Cresci, F. Mannucci, T. Nagao, H. Netzer, G. Risaliti, M. Salvati, O. Shemmer, M. Brusa, F. Fiore, F. La Franca, A. Comastri, M. Cano-Diaz, David J. Axon (1951-2012)*

Evidences for AGN feedback?

- Scarce direct evidence (suppression of Star Formation) but almost ubiquitous fast winds in ionised and, especially, molecular gas
- Large outflow rates for SFRs and gas masses (up to ~100-1000 $M_\odot$/yr, several ×SFR) ➙ short depletion time scale (~10^7 - 10^8 yr)

Feruglio+11

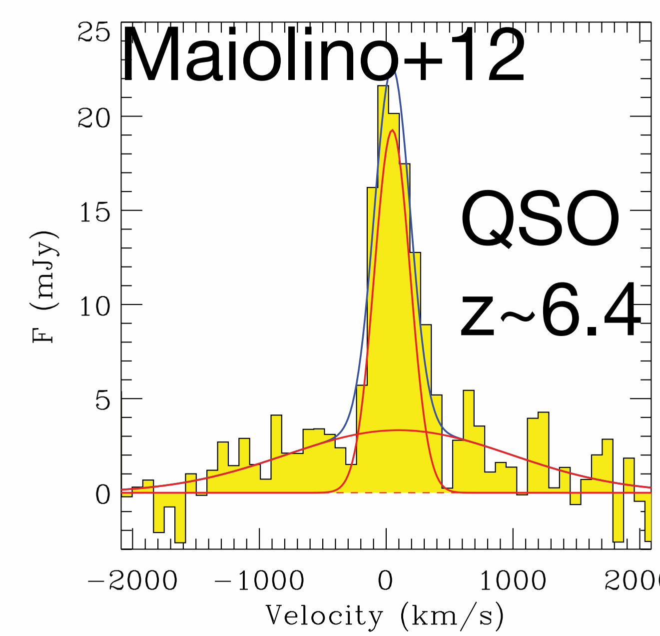




Sturm+11

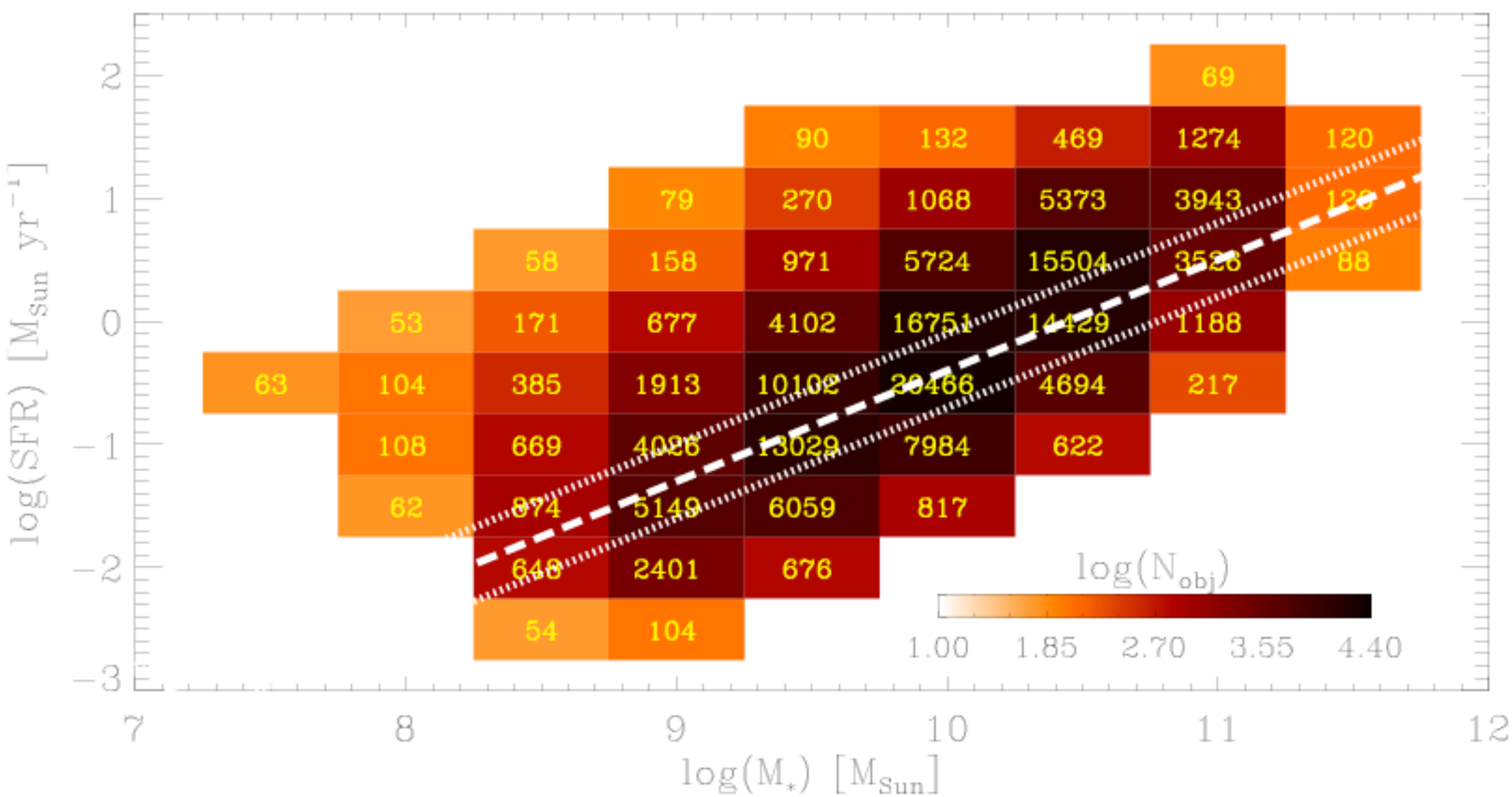
- see also Nesvadba+08,+11, Alexander+09, Harrison+12, Cicone+13,14, Greene+11,+14, Liu+14, Mullaney+13, Harrison+14, Brusa+14 …
- *If outflows are the source of AGN feedback there should be a connection between outflows and quenching of star formation*

Maiolino+12



Outflows in star forming galaxies

- Spectral stacking of SDSS galaxies in bins of M_{star},SFR (no AGN!)
- Accurately measure ionised gas and star kinematics
- Outflow velocity (gas velocity — star velocity) as a function of position across the Main Sequence of Star Formation …



Cicone, Maiolino, Marconi, submitted

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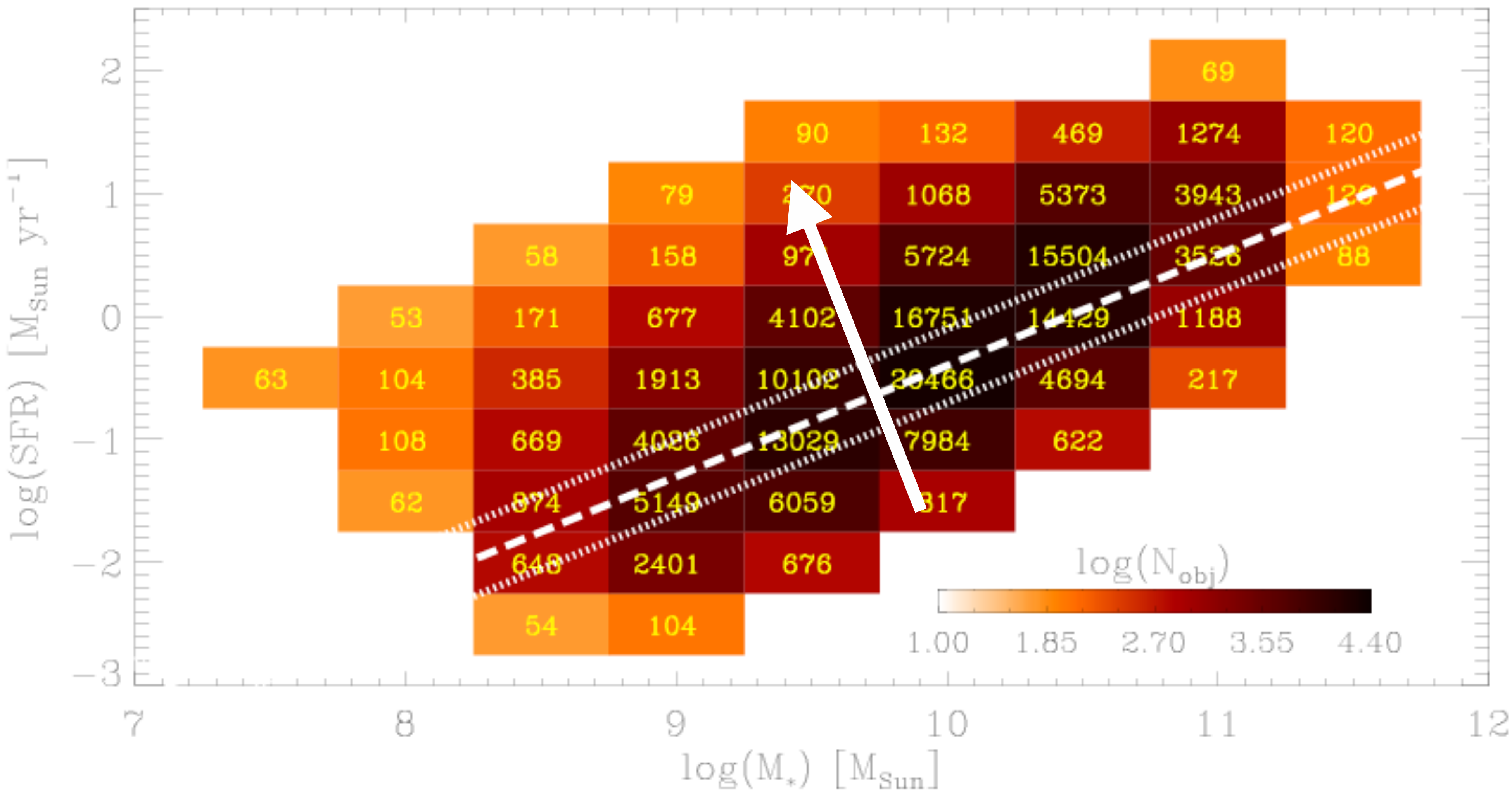

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Outflows in star forming galaxies

- Gas outflows are only present in galaxies above the MS, velocity increases with offset from MS
- Outflows may be responsible for shaping the upper envelope of the MS by providing a self-regulating mechanism for the SFR

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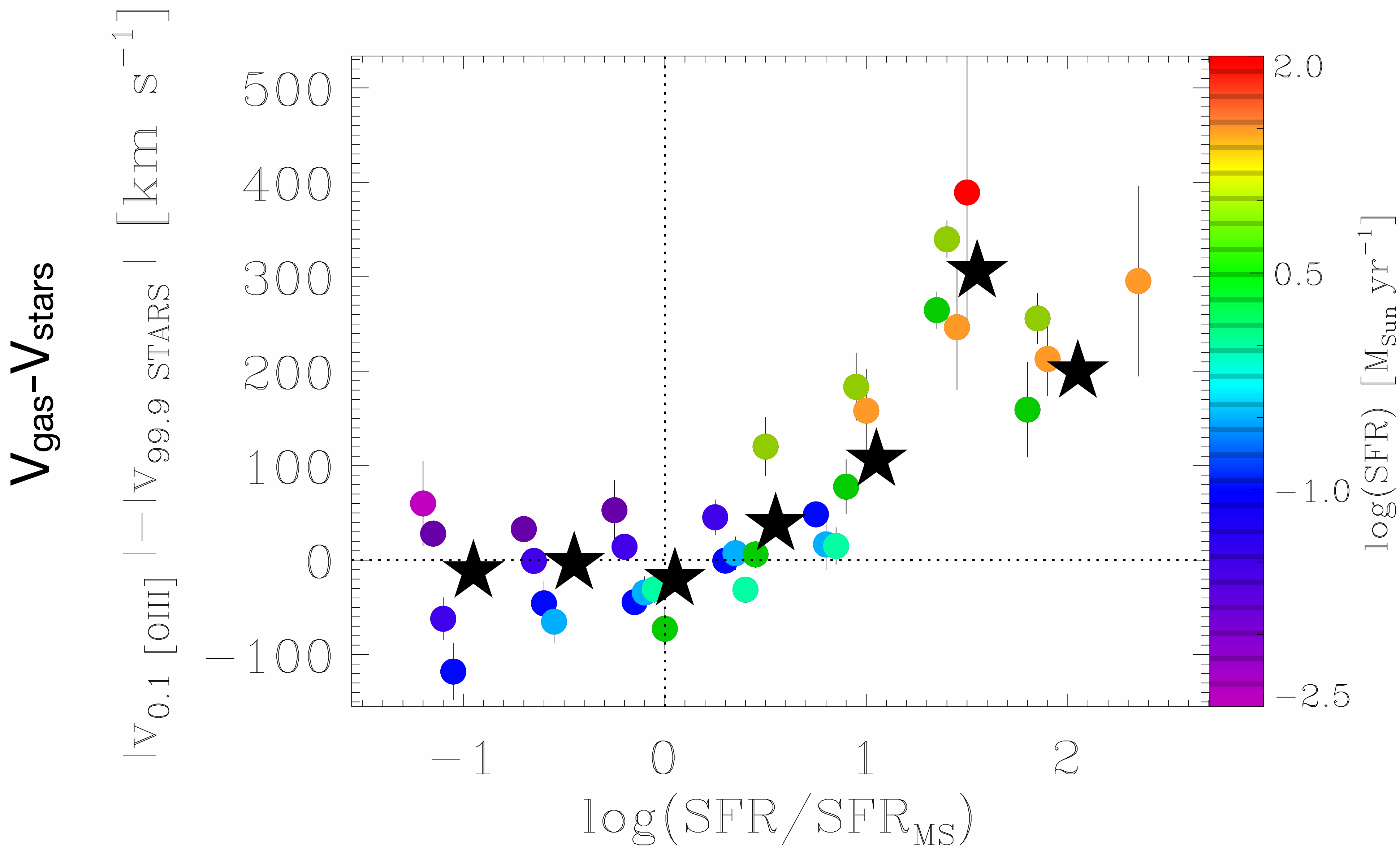

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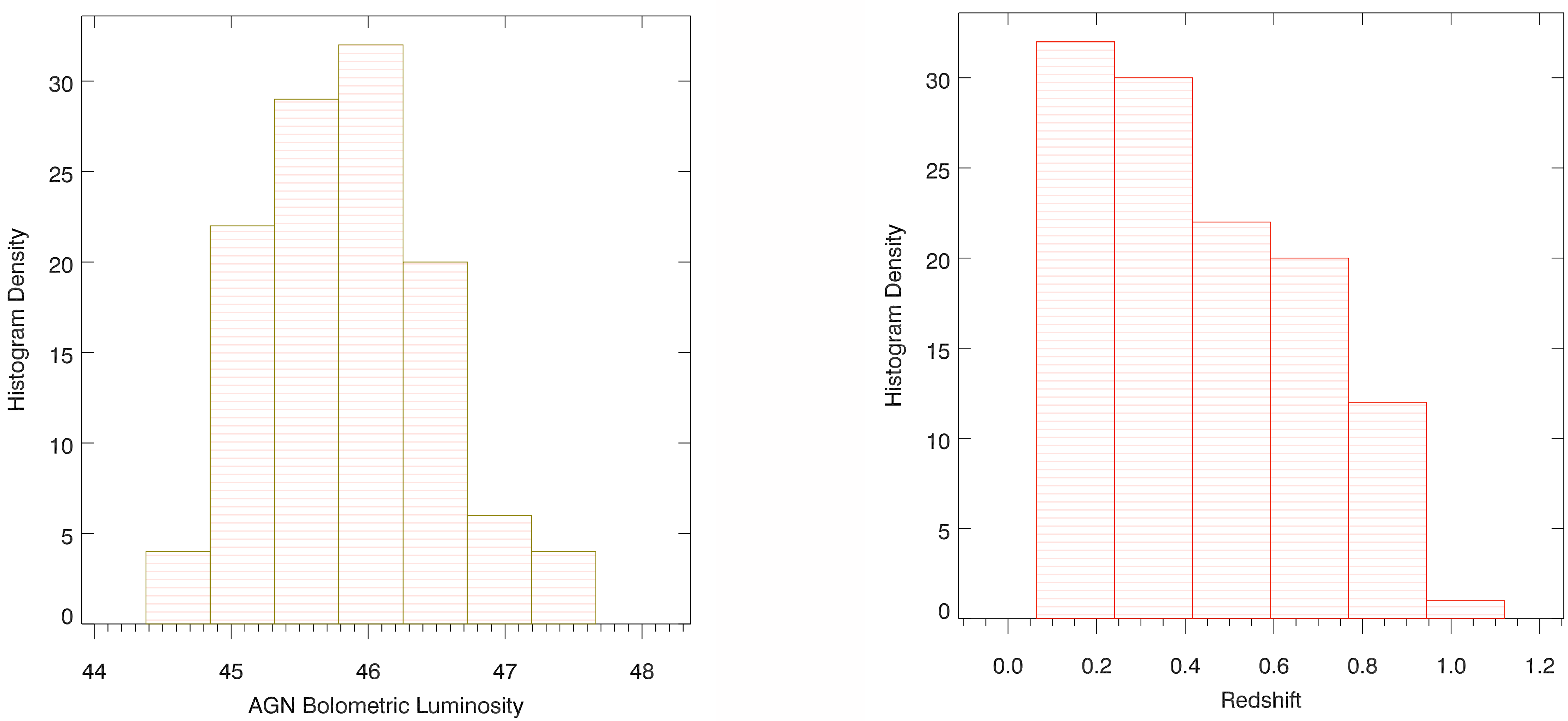
Ionized outflows and SF in local quasars

- Quasars host galaxies are precursors of local massive galaxies; feedback is needed here!
- Quasar phase is the one where “quasar mode” feedback should be operating
- Sample: ~100 luminous unobscured quasars from SDSS DR7 and DR 10 with z < 1 observed by Herschel



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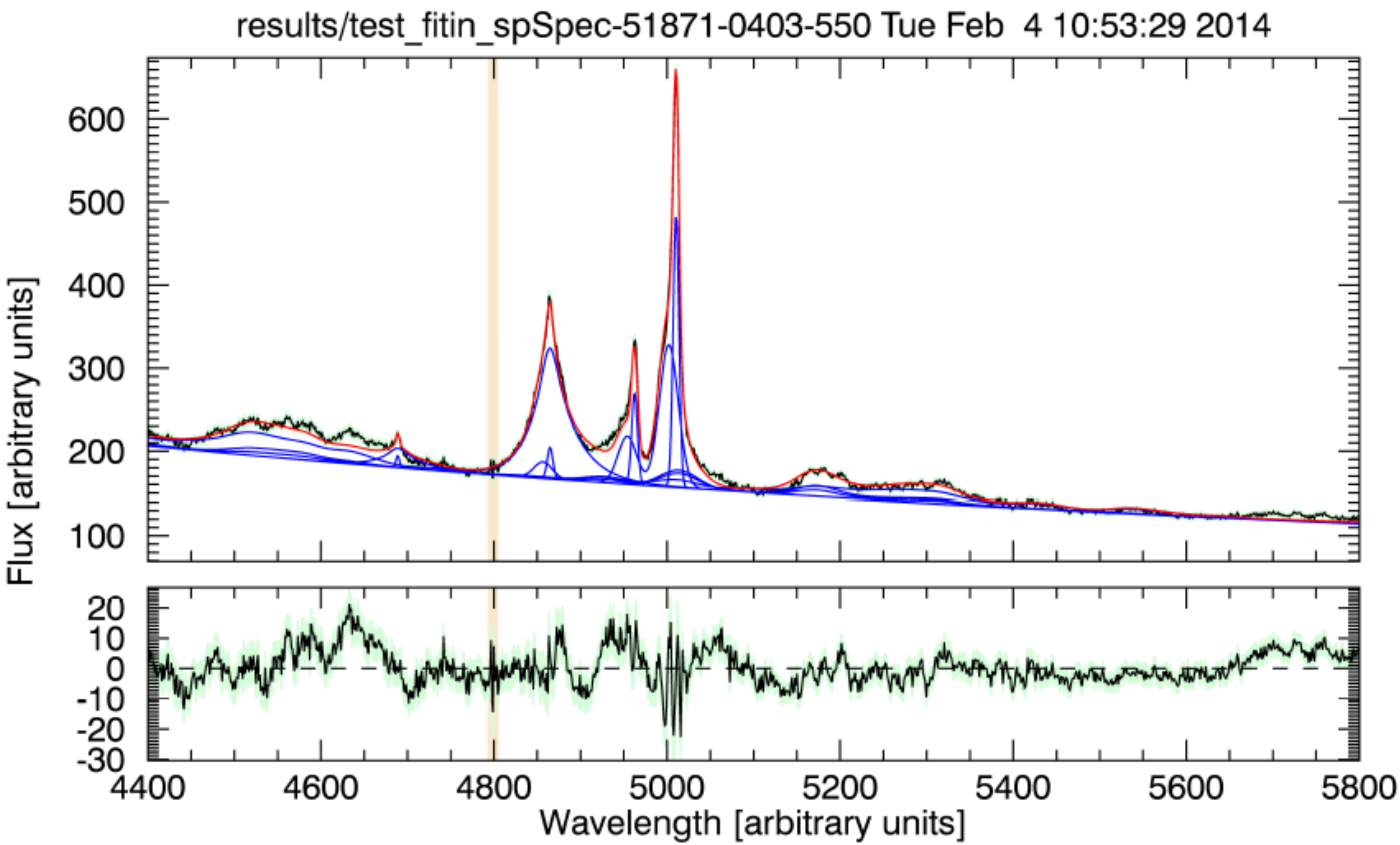

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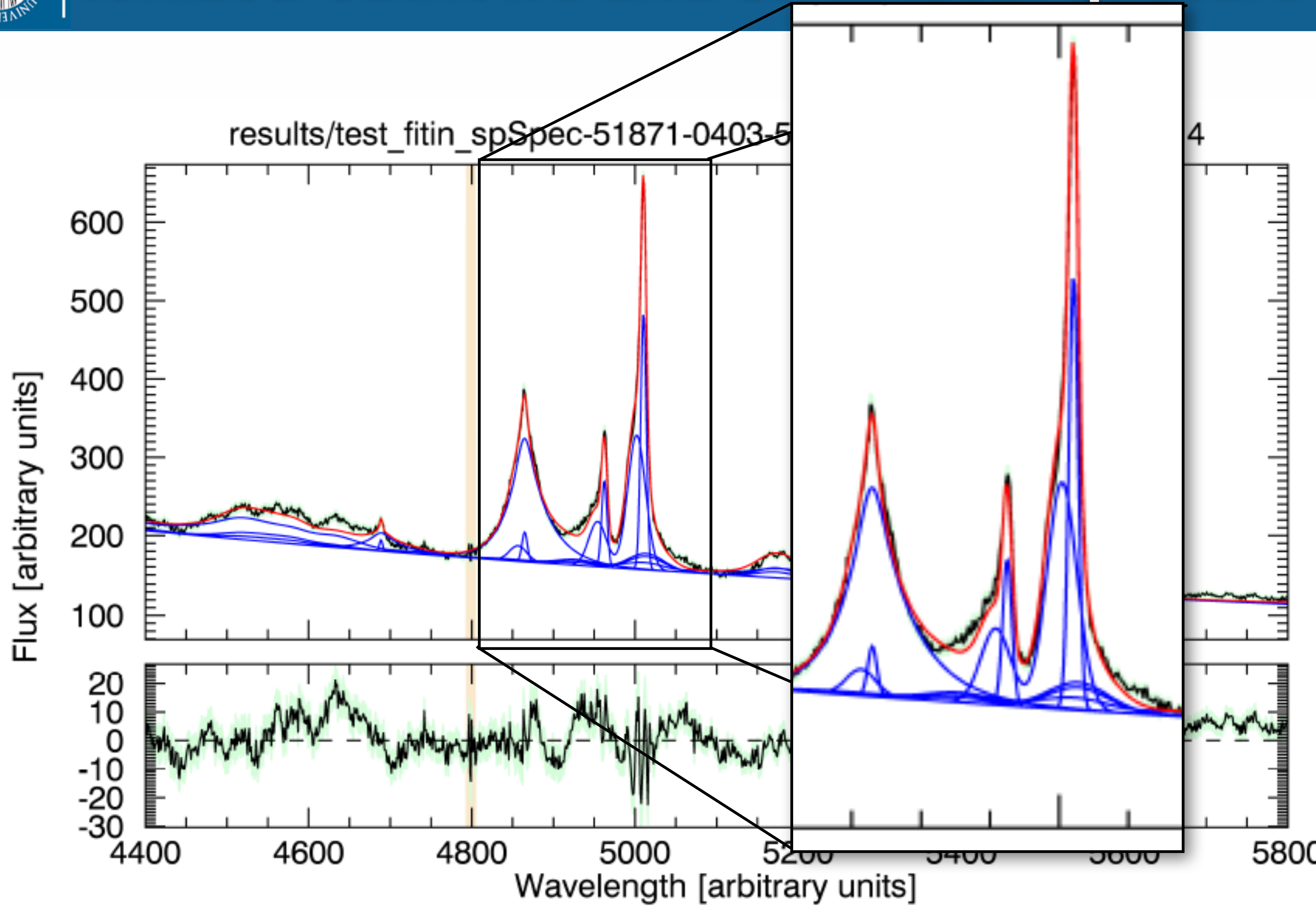
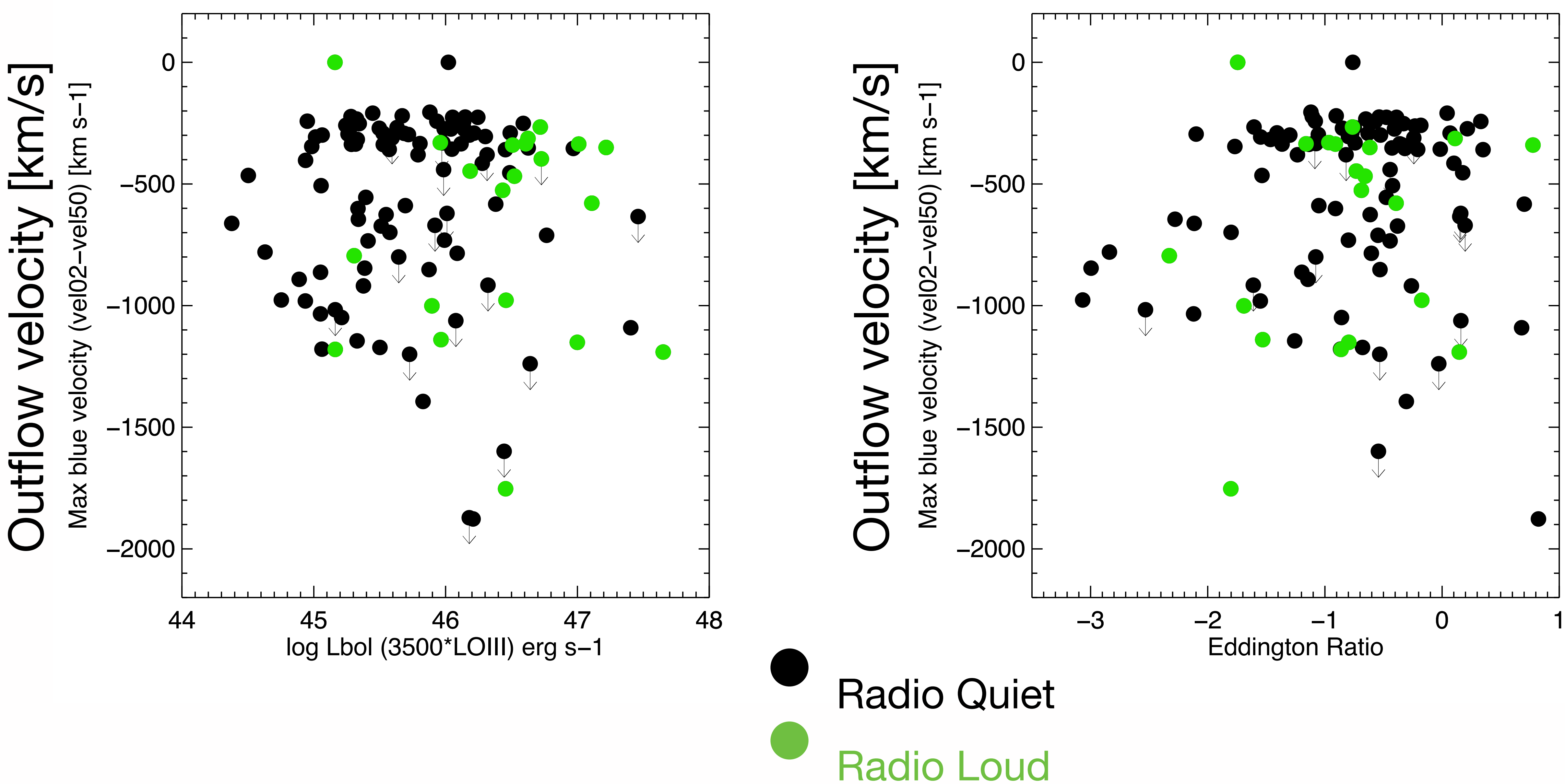


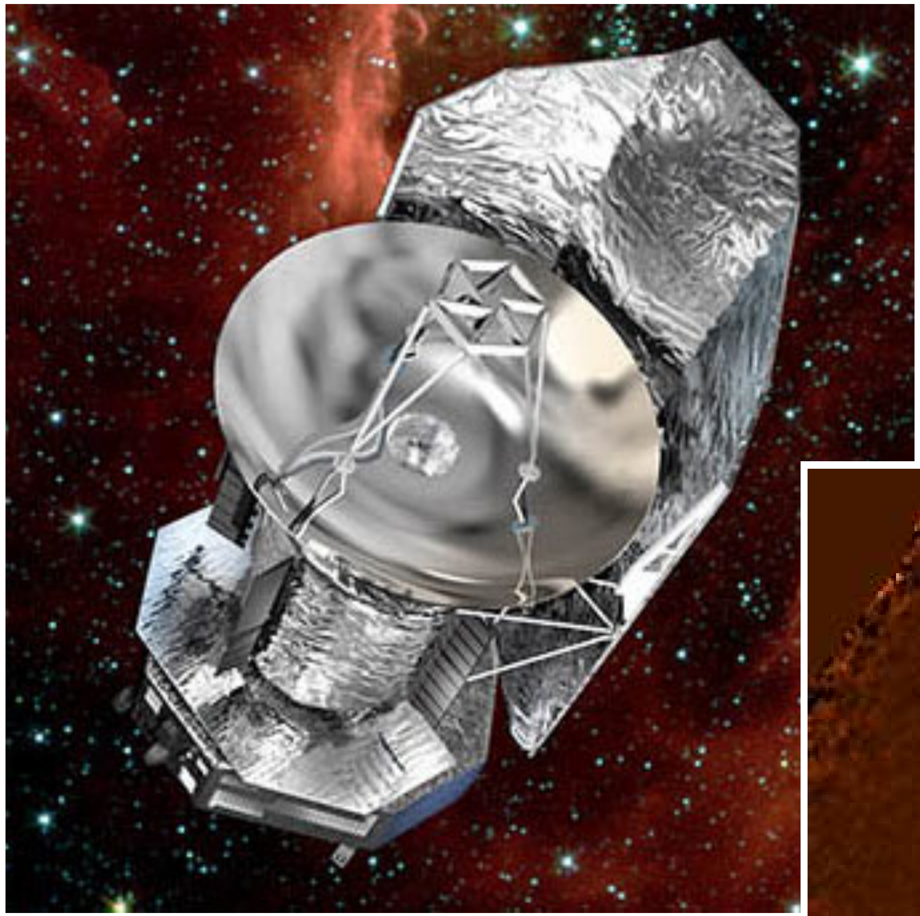
Ionized outflows and SF in local quasars

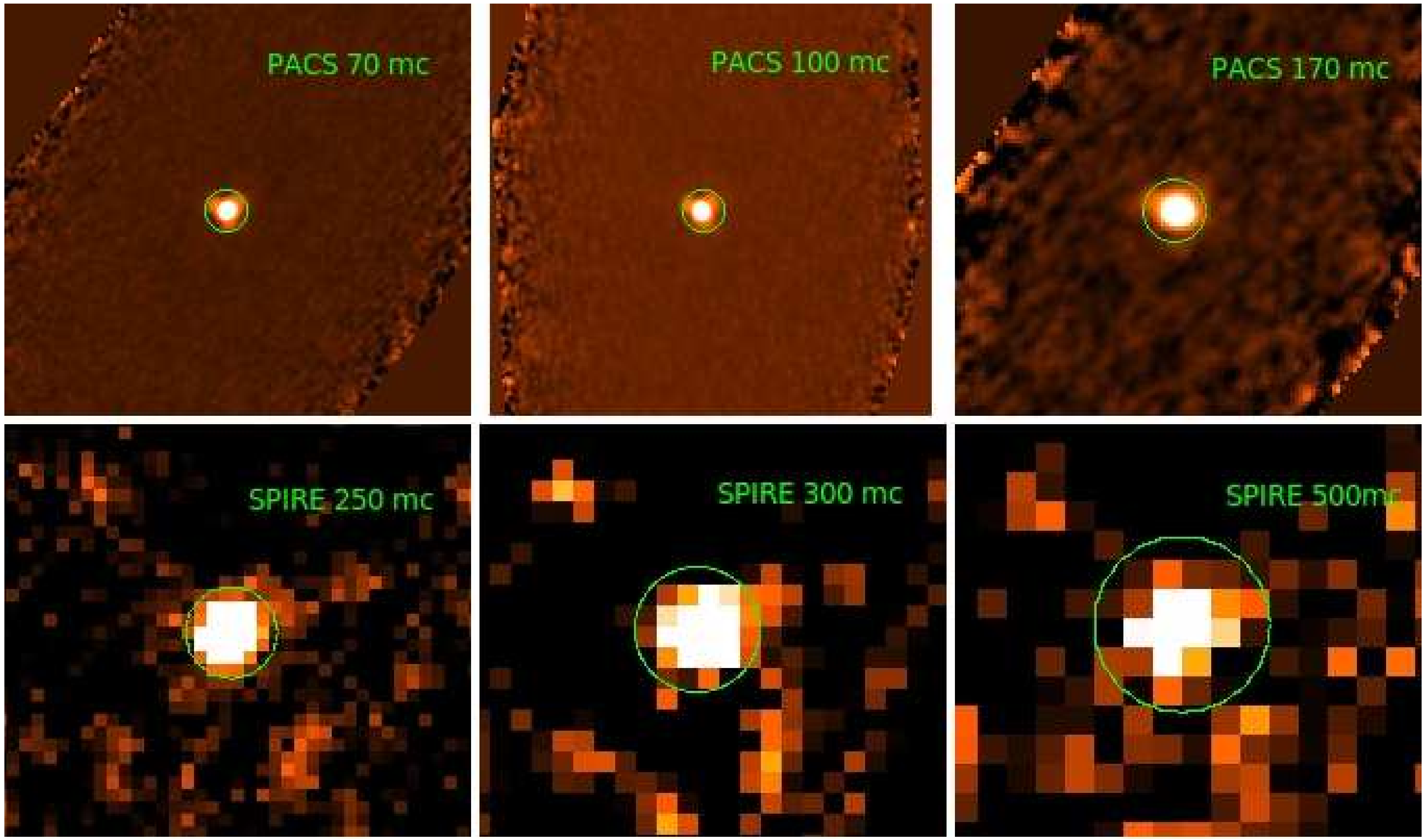
- Fast ionised outflows …
- … but no apparent relation between outflow velocity and bolometric luminosity and Eddington ratio as might be expected for radiatively driven winds from the AGN



Ionized outflows and SF in local quasars

- Herschel observations at ~100 μm to measure the emission of "cold" dust heated by young stars

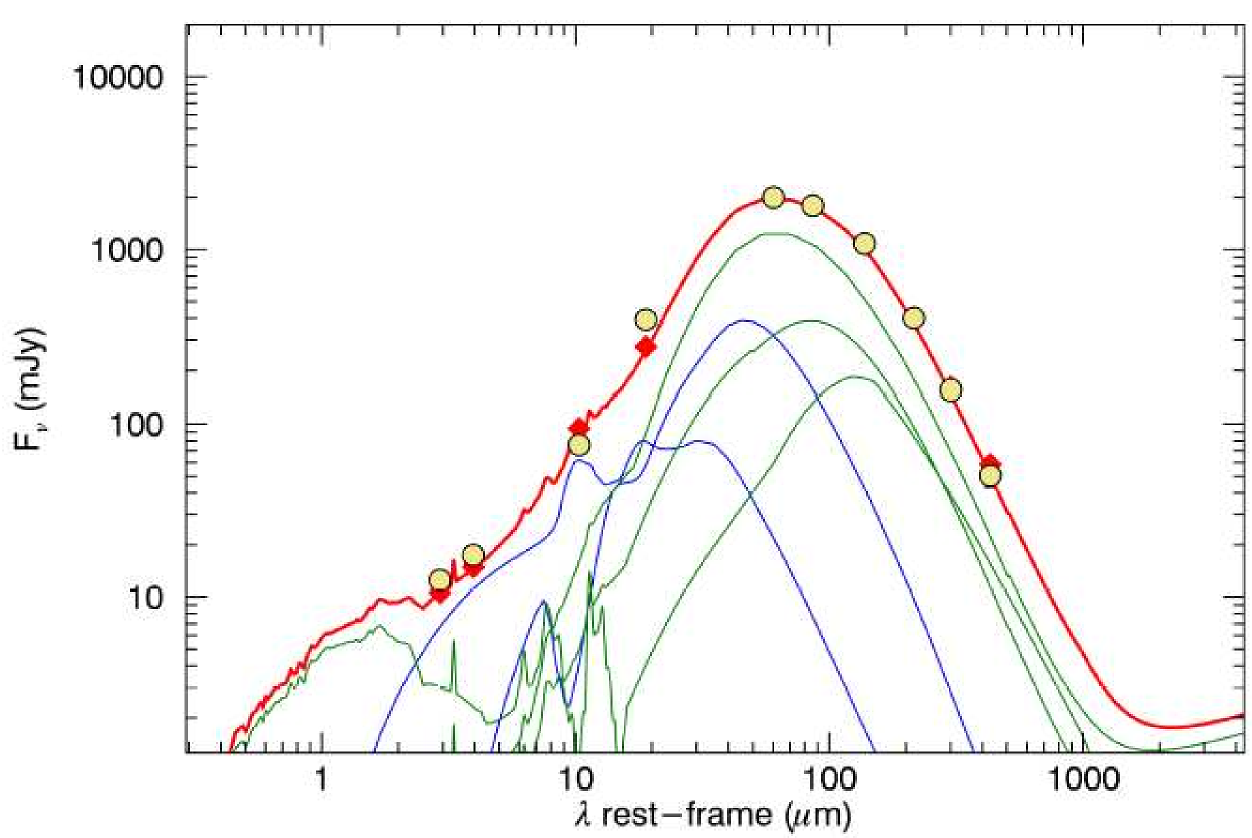


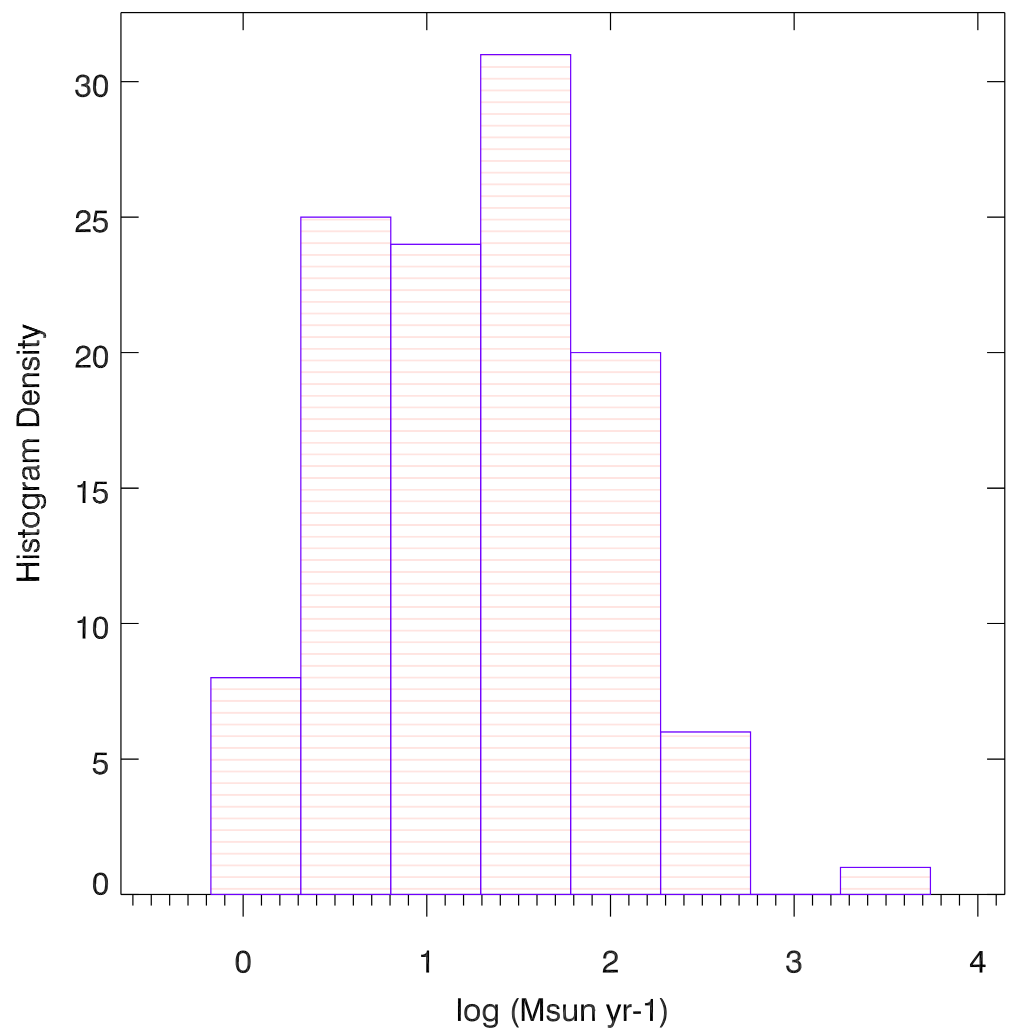


Ionized outflows and SF in local quasars

- SED combining Herschel + WISE measurements
- SED fitting to estimate AGN IR luminosity and SF (Clumpy torus models by Nenkova & Elitzur, Starburst templates by Chary & Elbaz)
- From Kennicutt+98

$$SFR = 4.5 \left(\frac{L_{FIR}}{10^{44}\,\mathrm{erg\,s^{-1}}} \right) \mathrm{M_\odot\,yr^{-1}}$$





Ionized outflows and SF in local quasars

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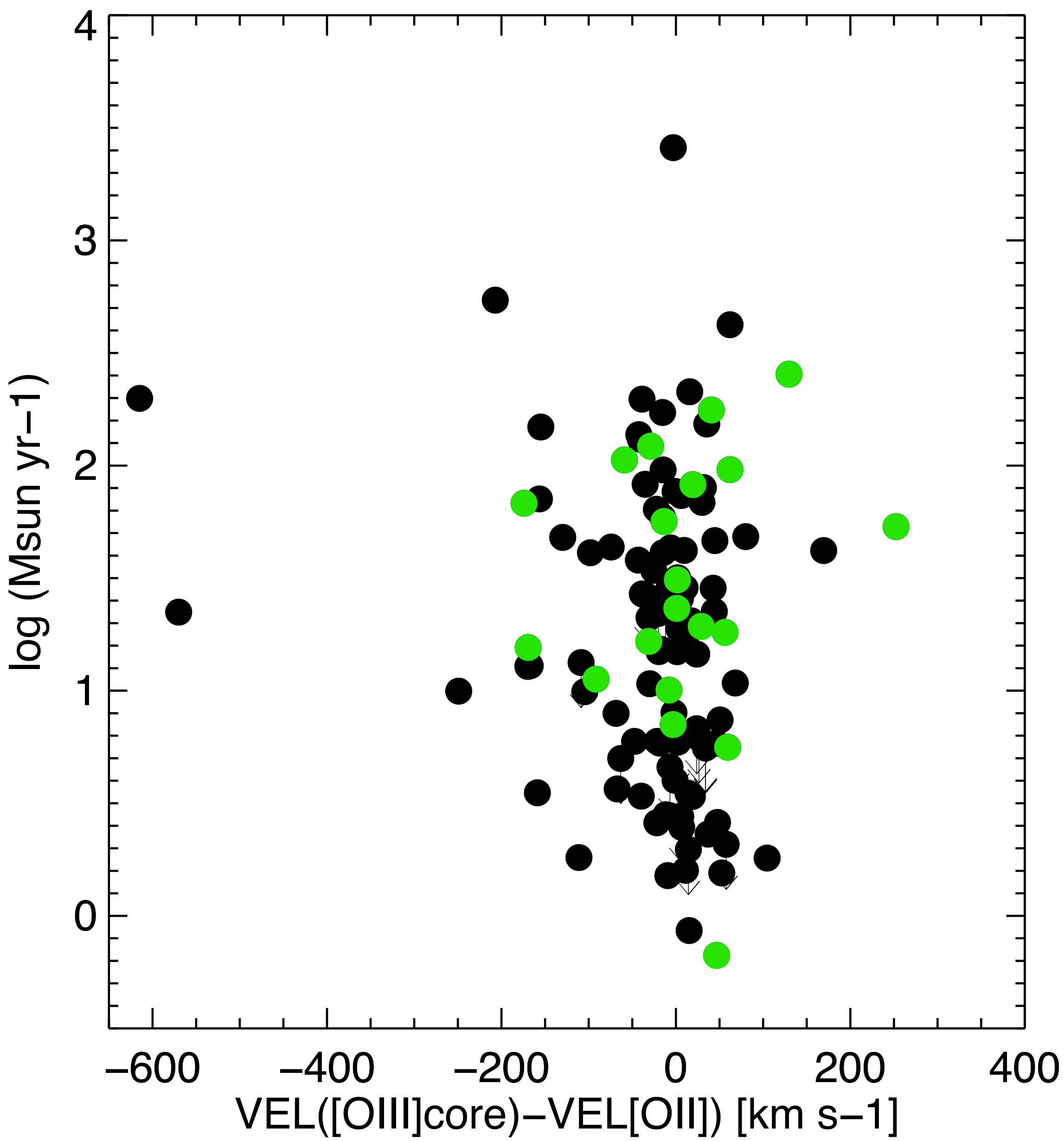

large scale outflow velocity

Balmaverde,AM+, in prep.

small scale outflow velocity

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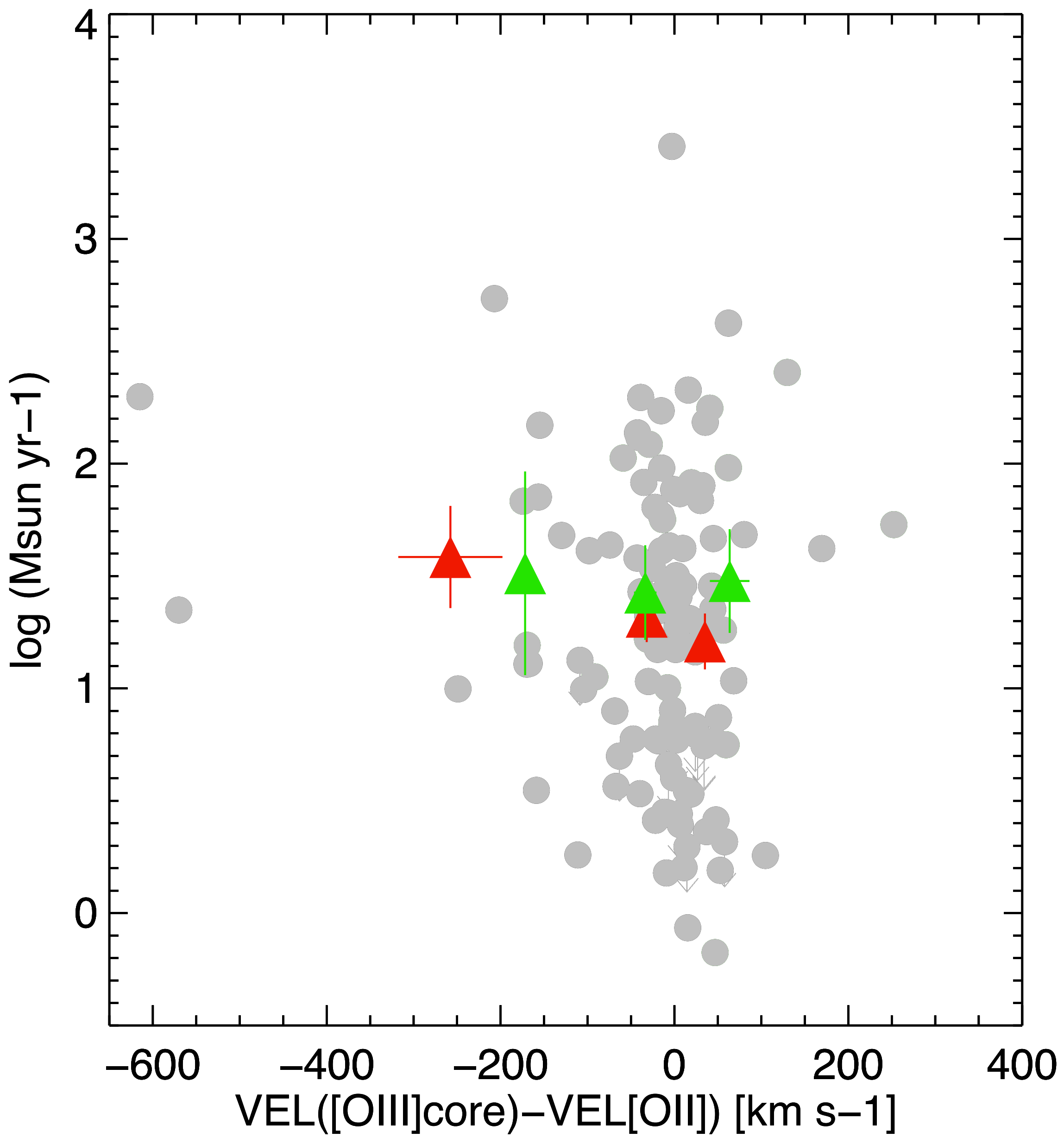

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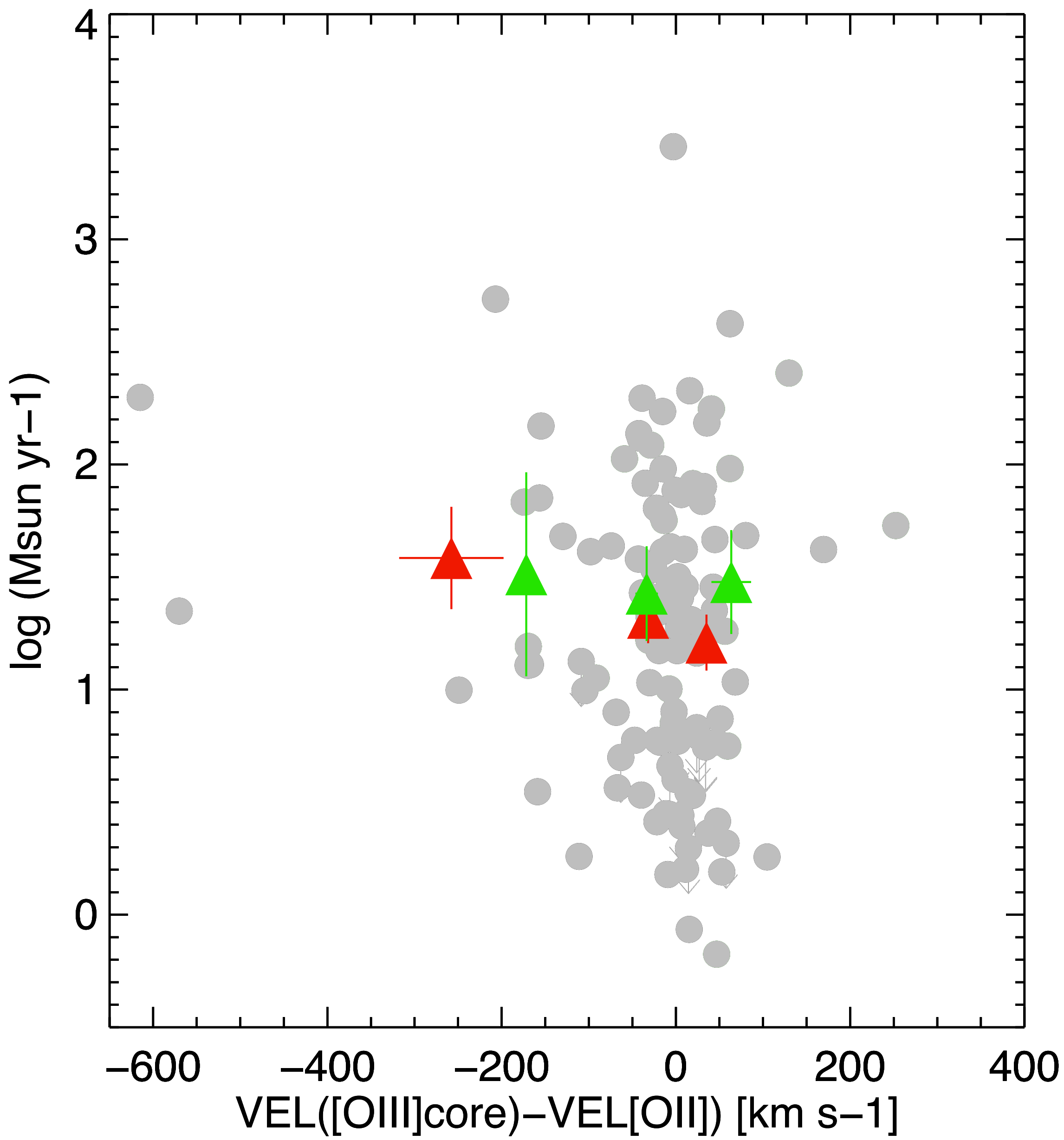

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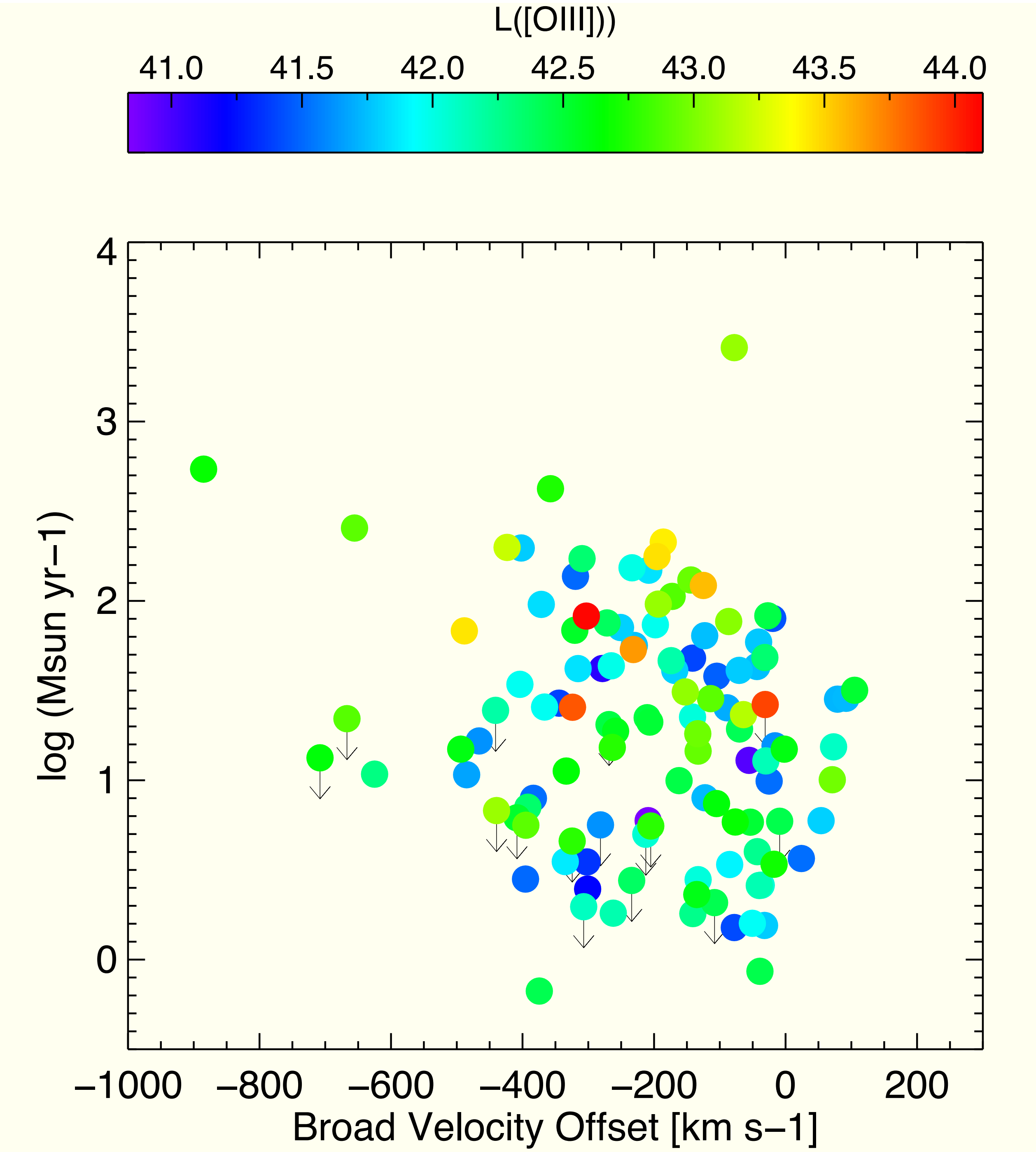

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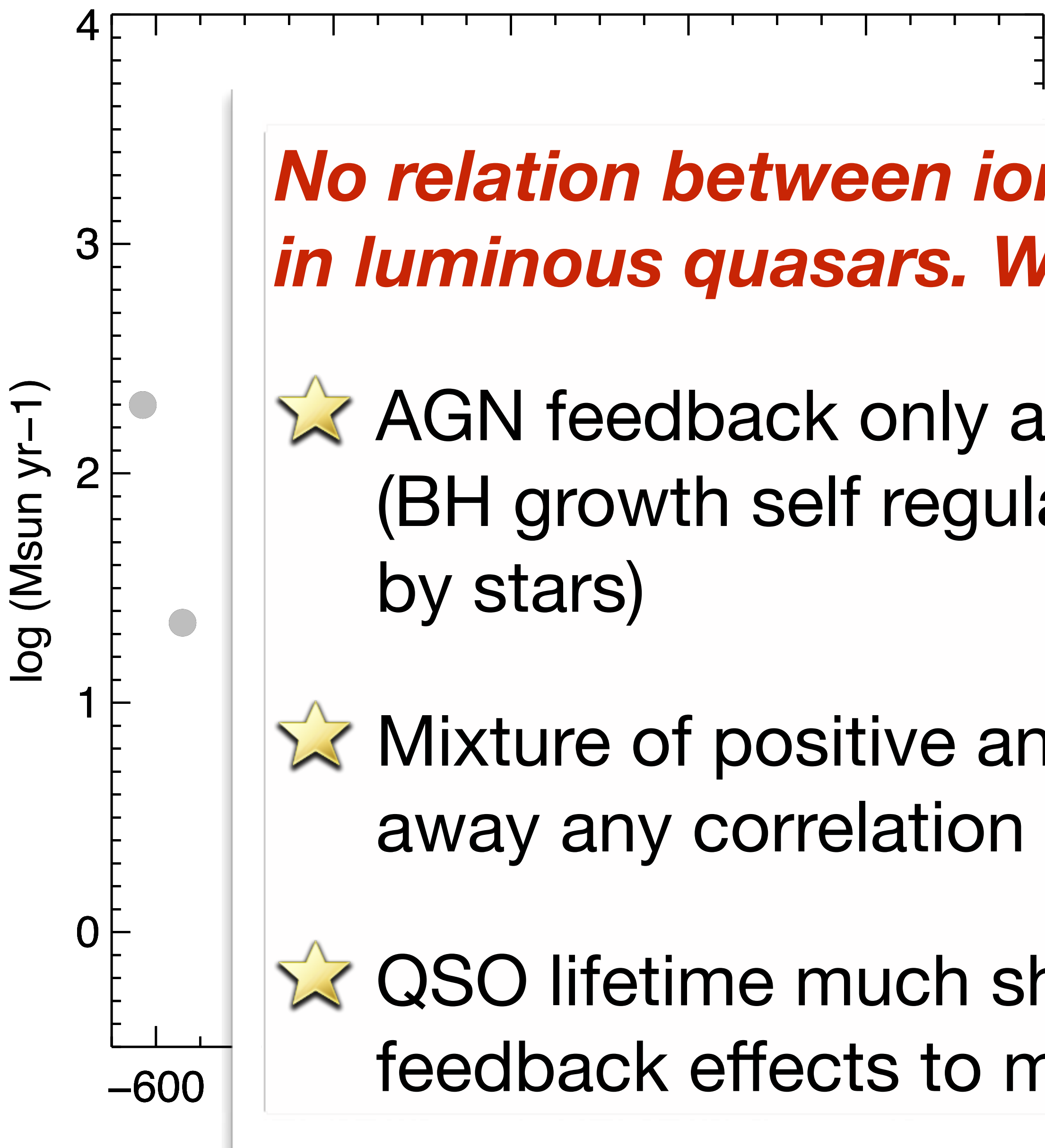

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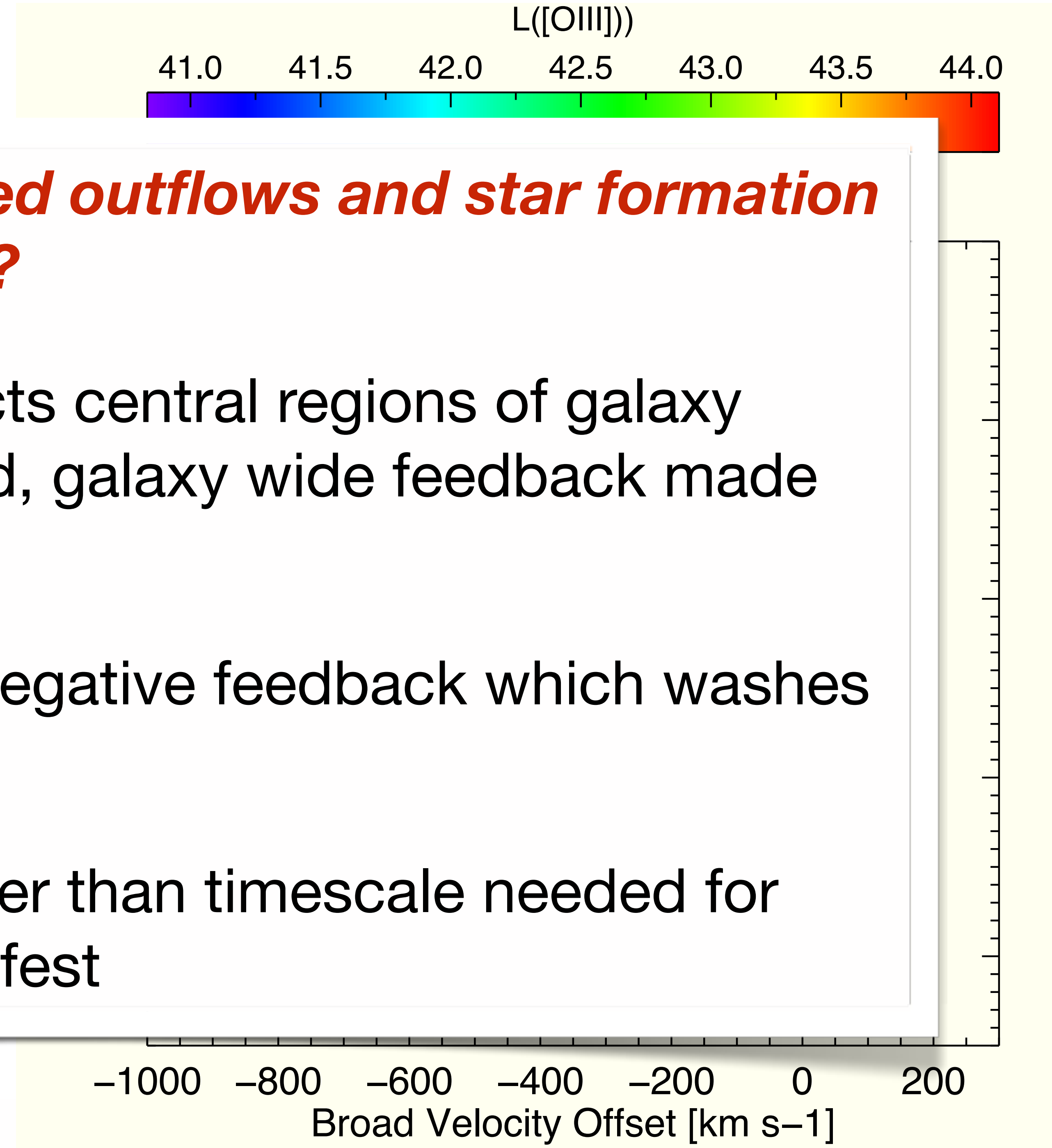


small scale outflow velocity

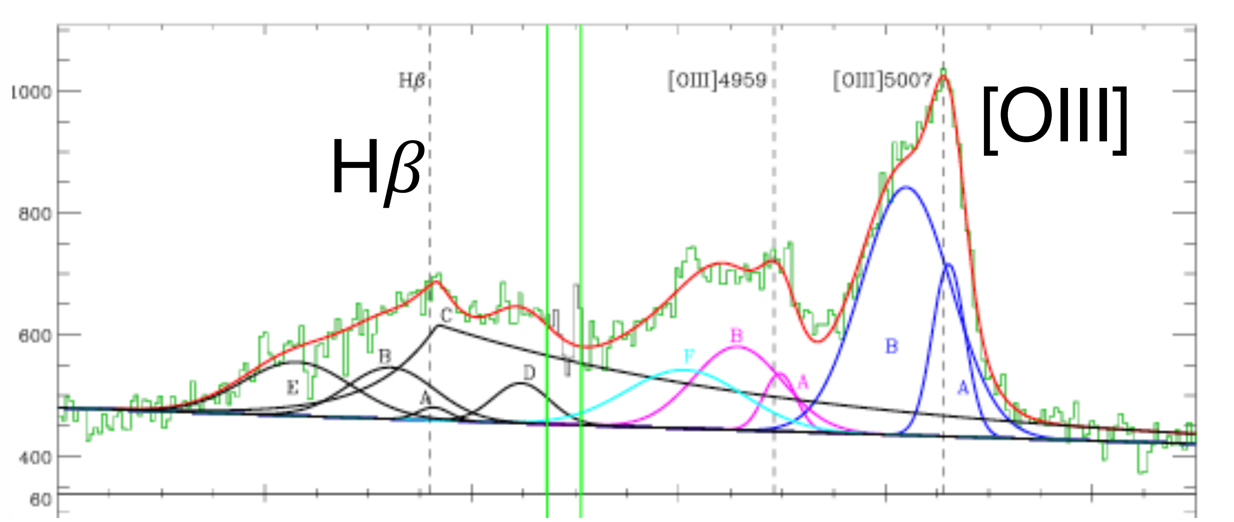
No relation between ionised outflows and star formation in luminous quasars. Why?

- AGN feedback only affects central regions of galaxy (BH growth self regulated, galaxy wide feedback made by stars)
- Mixture of positive and negative feedback which washes away any correlation
- QSO lifetime much shorter than timescale needed for feedback effects to manifest

Balmaverde,AM+, in prep.

Ionized outflows in luminous quasars

- The prequel: luminous "normal" quasar at z~2.4 VLT/SINFONI H band



Very "broad" [OIII] FWHM ~1500 km/s

Cano-Diaz+12

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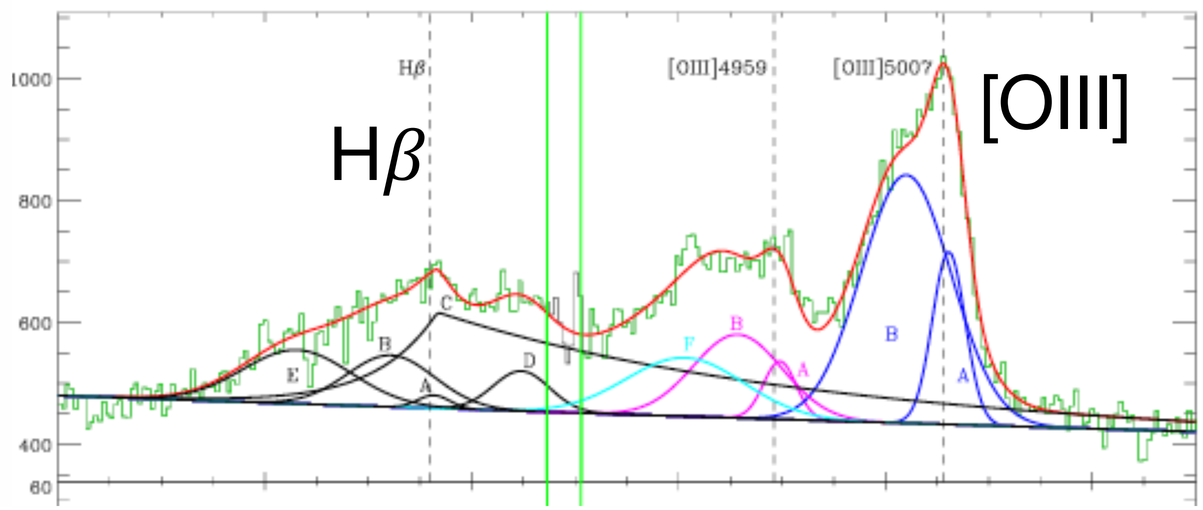

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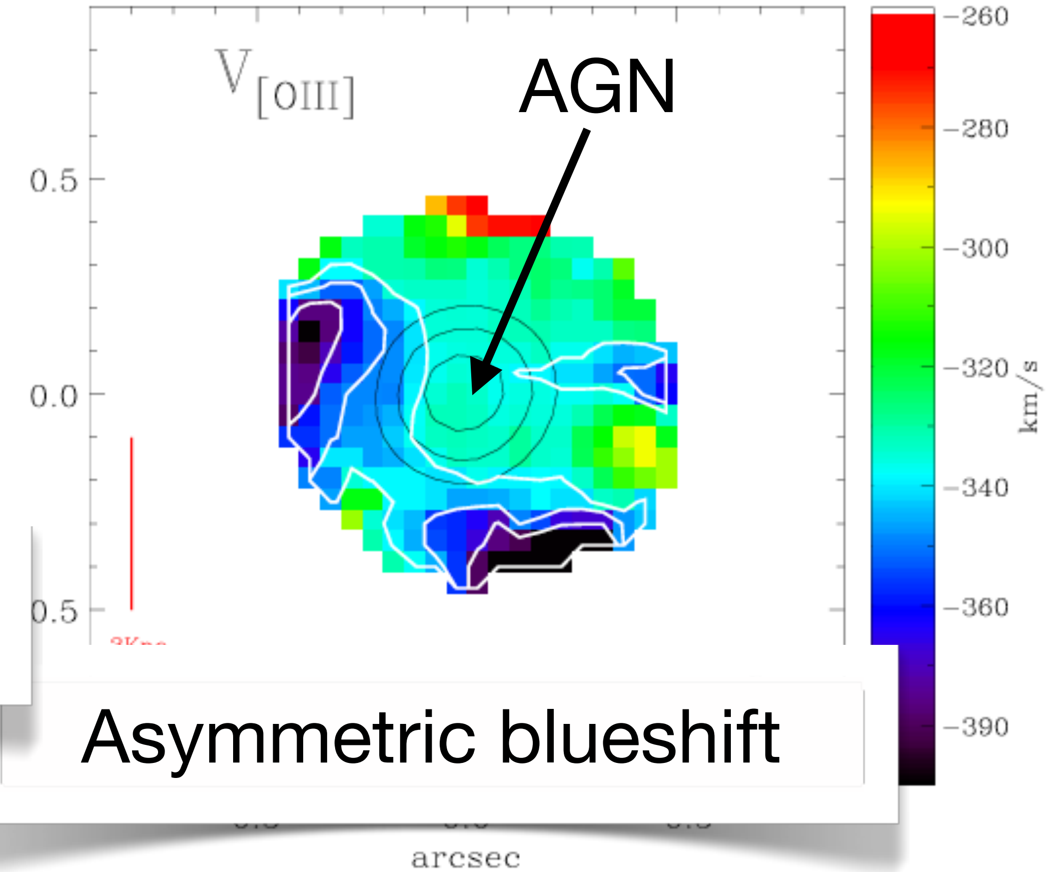

Asymmetric blueshift

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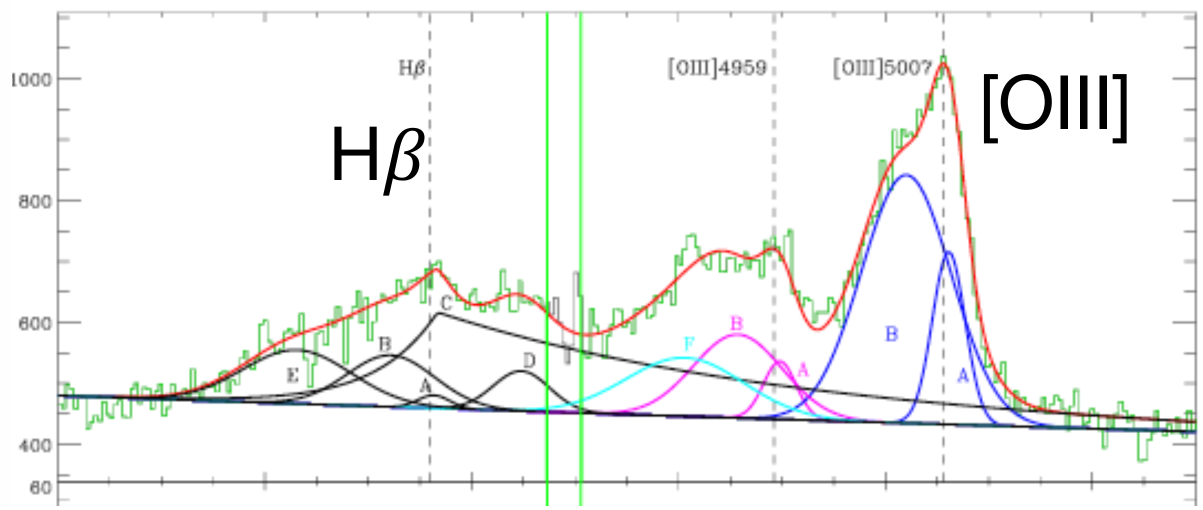

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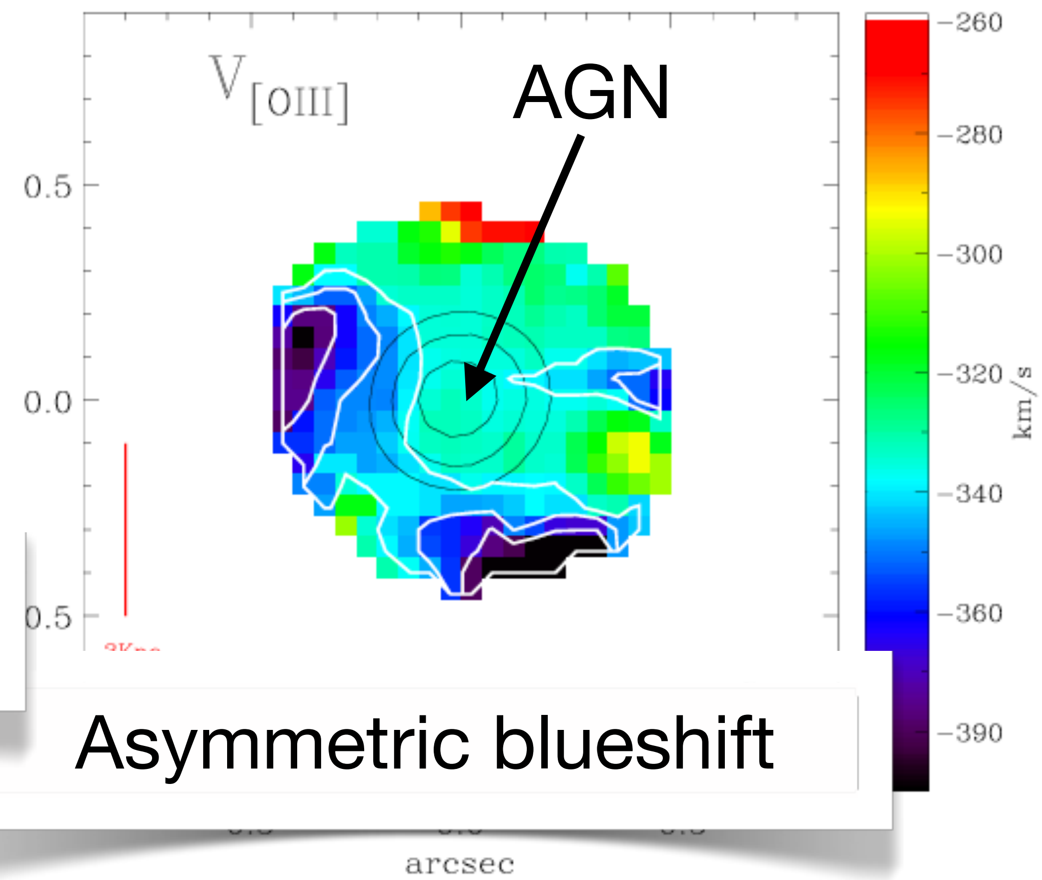

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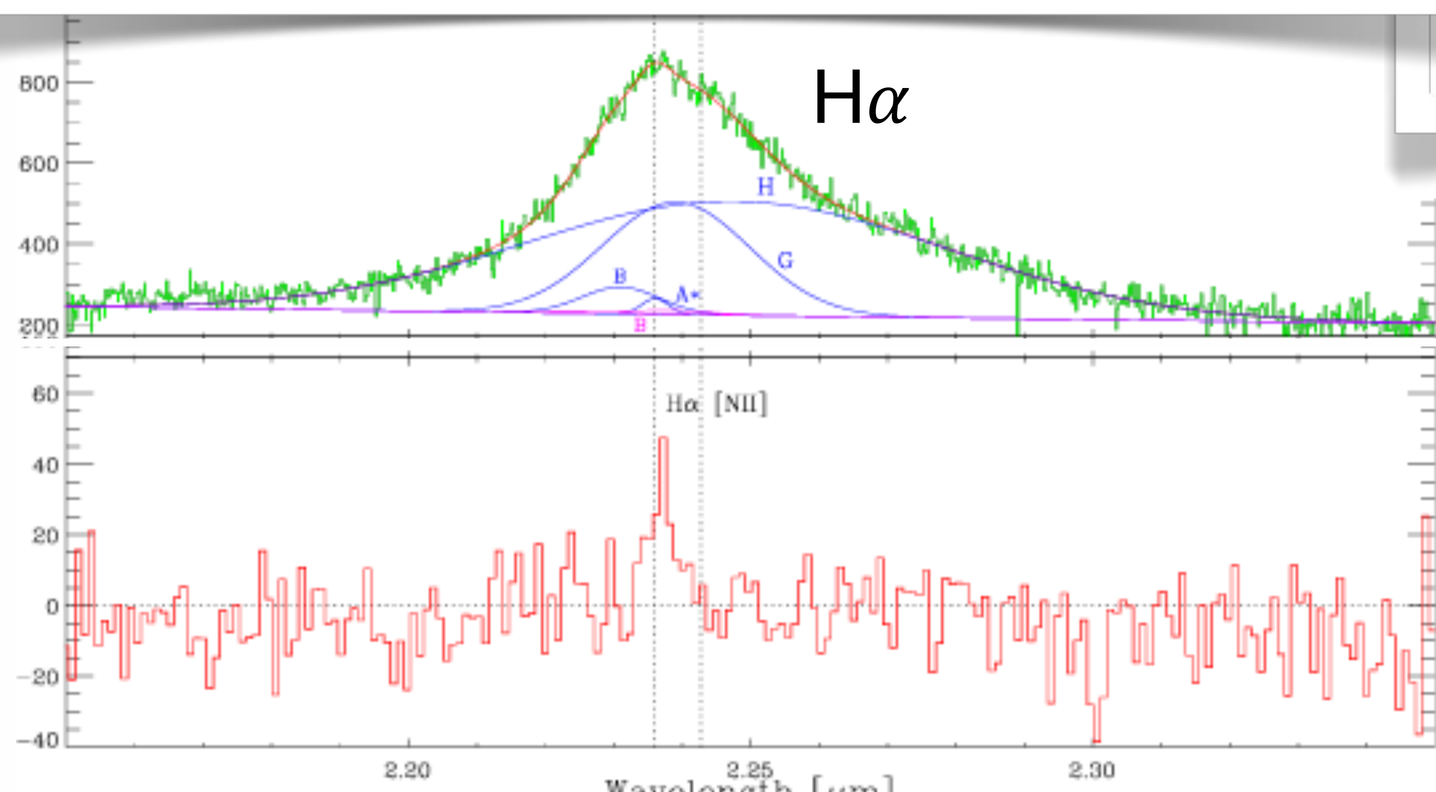

Narrow Hα from SF

Cano-Diaz+12

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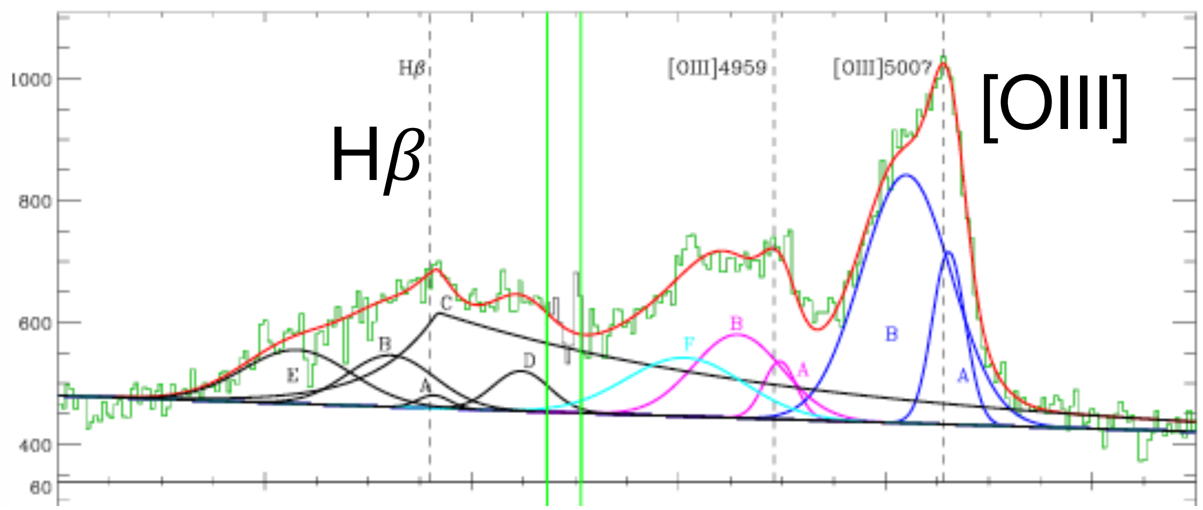

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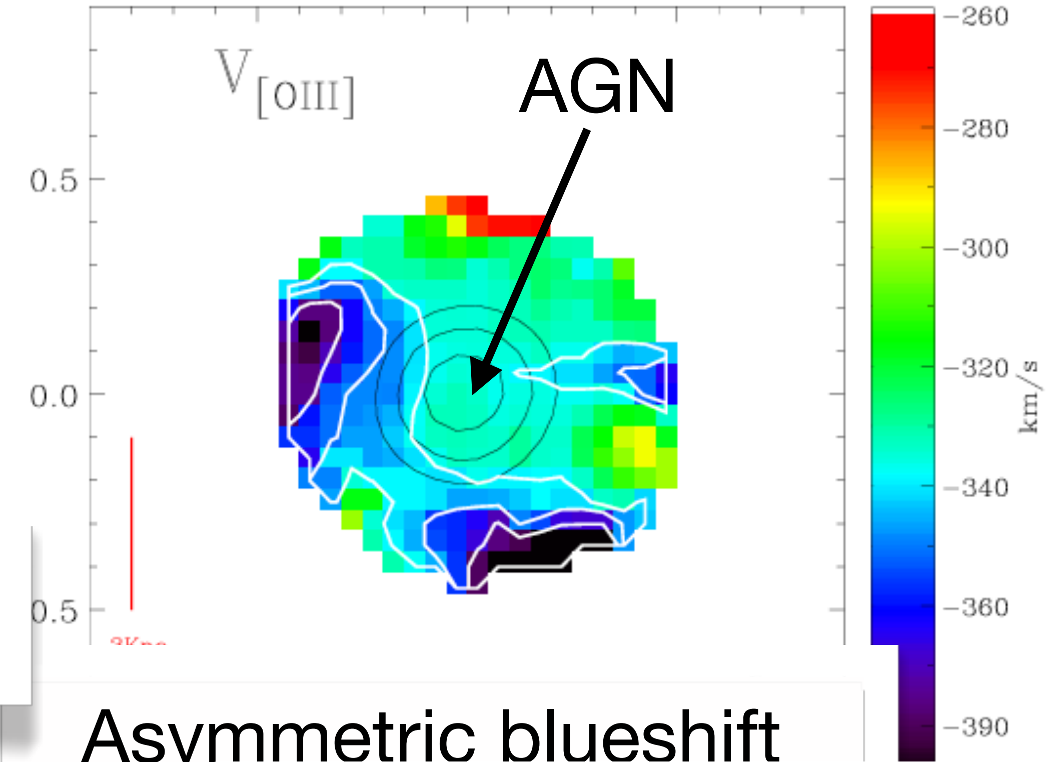

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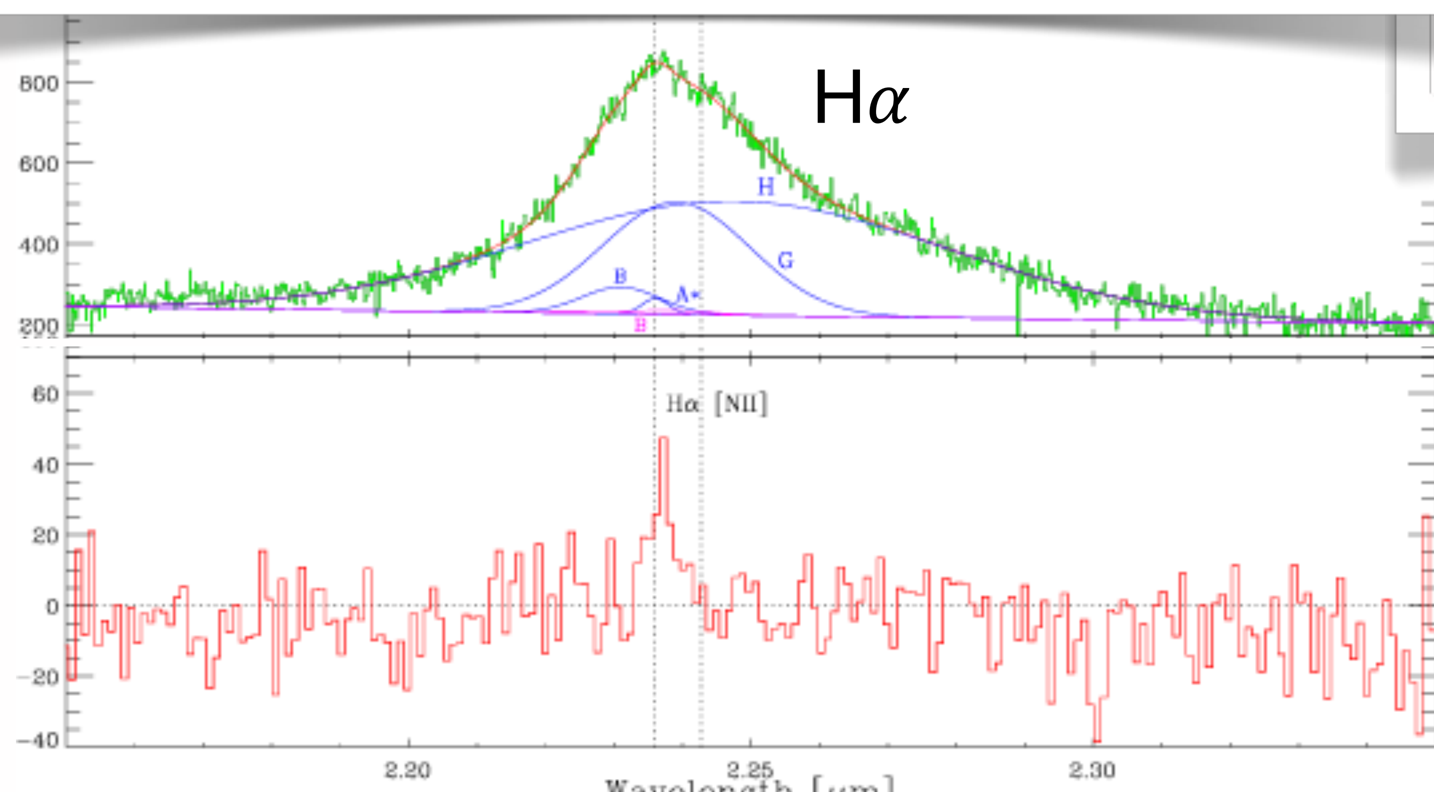
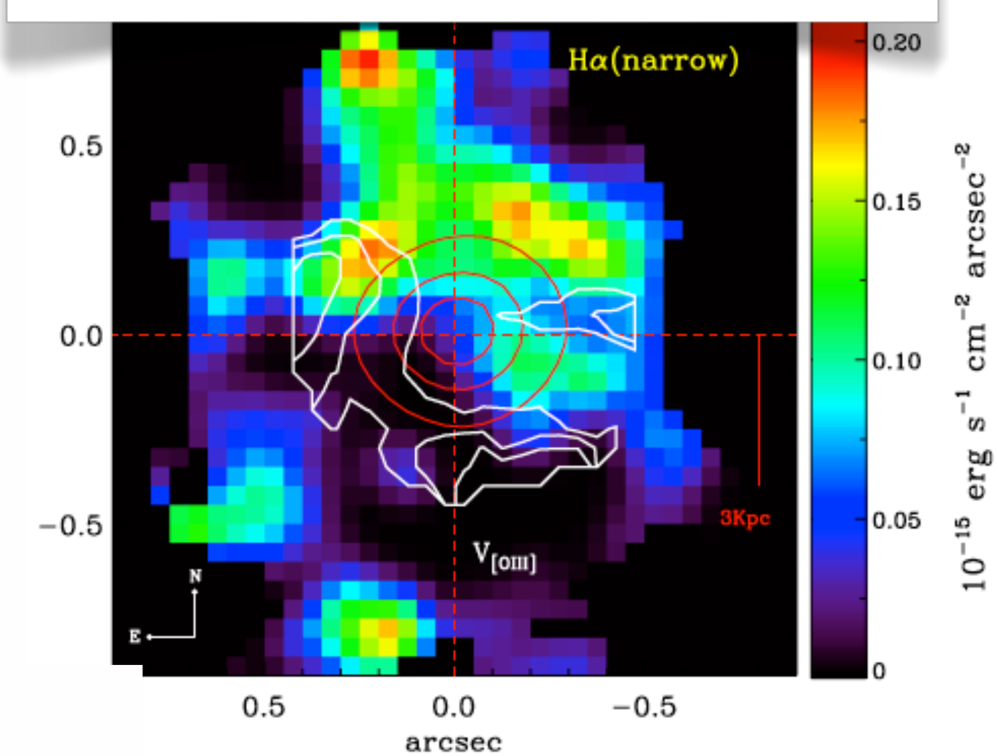


No SF with fast outflow!



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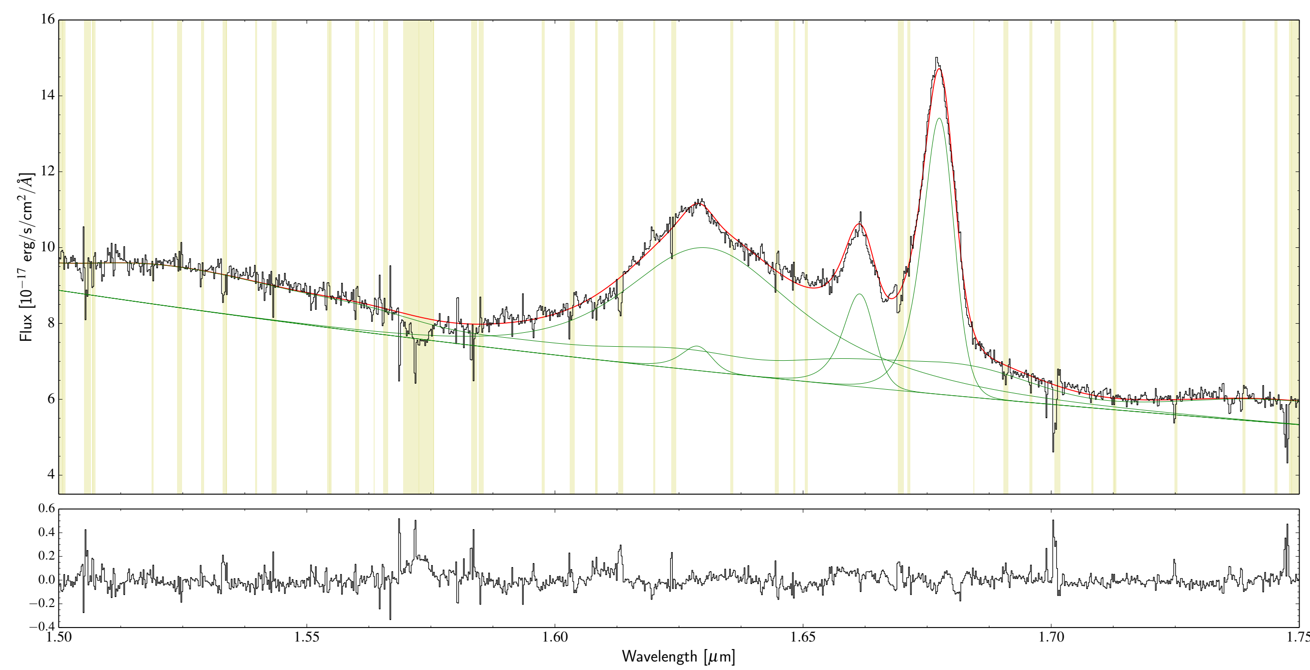
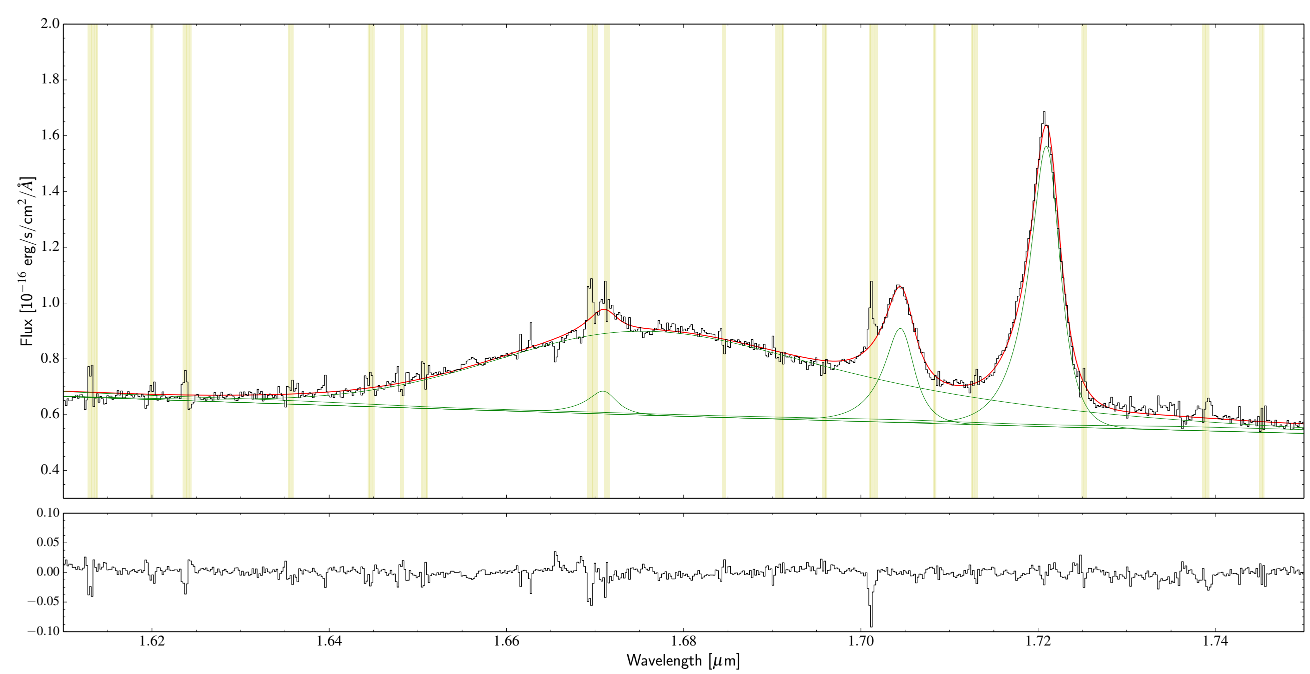
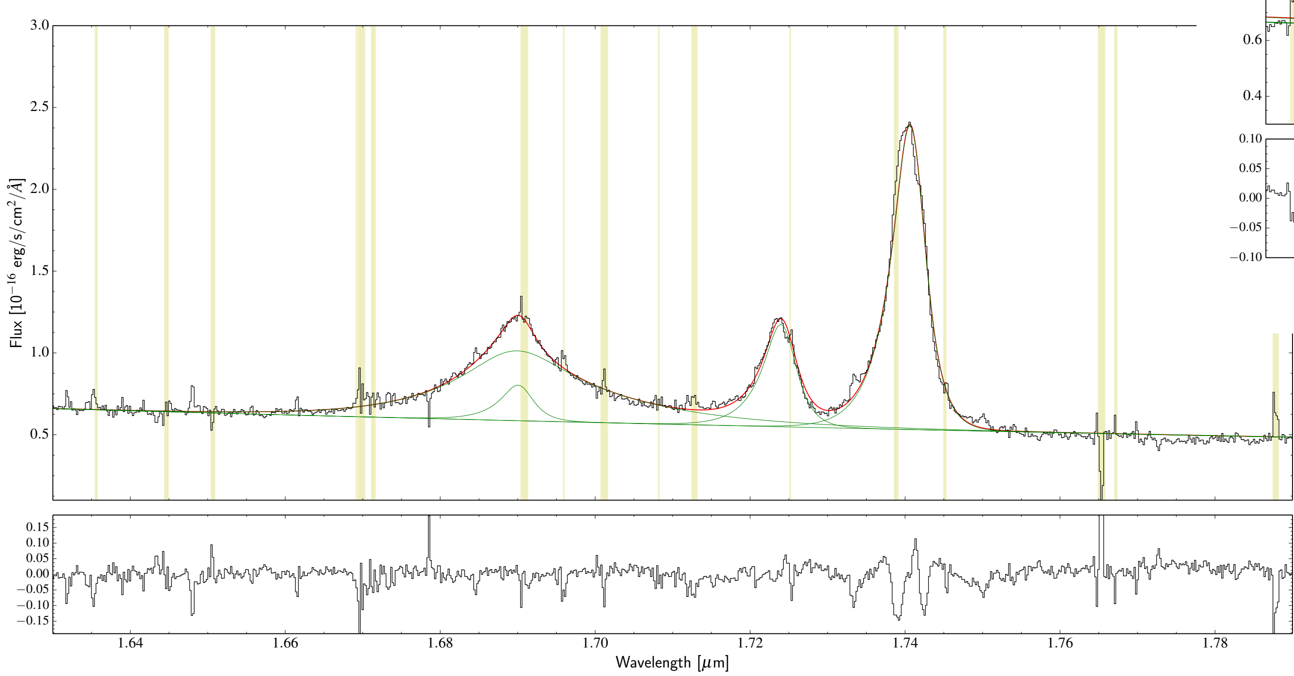
- The sequel: sample of 6 luminous “normal” quasars at z~2.3-2.5
- L_{bol}~ 10^{47} - 10^{48} erg sec^{-1}
- SINFONI@VLT spectroscopy in H band
- seeing limited resolution (~0.5” → ~4 kpc @ z=2.4)
- broad [OIII], FWHM ~ 1000-2000 km/s







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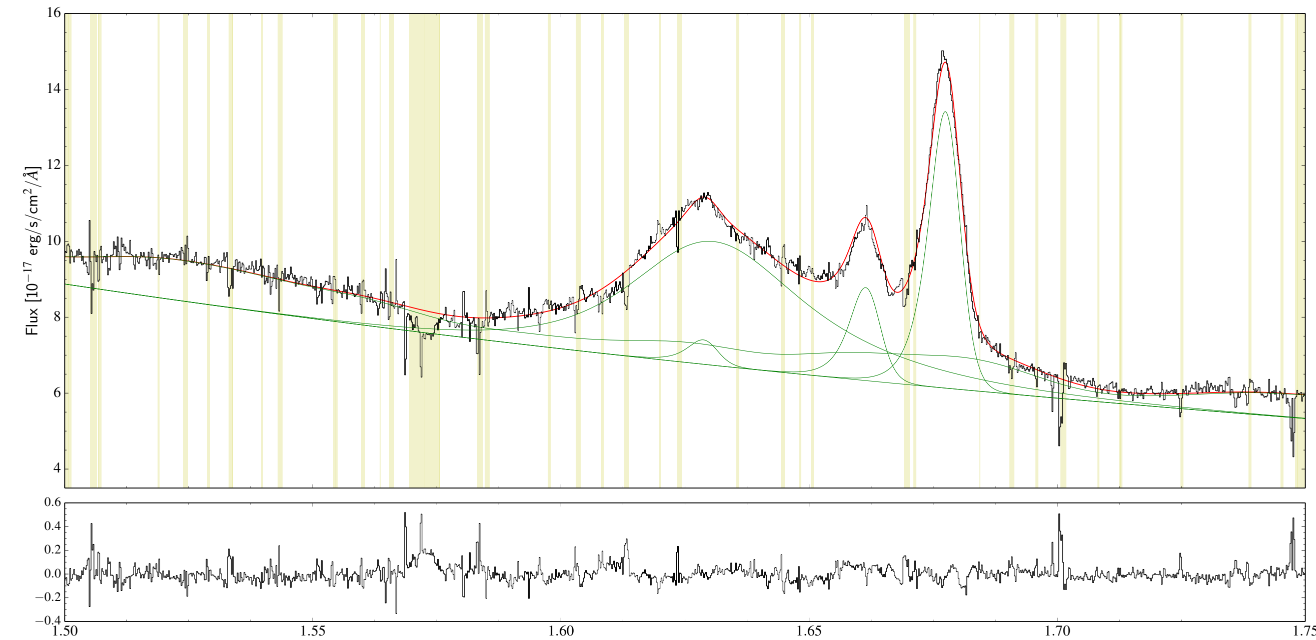

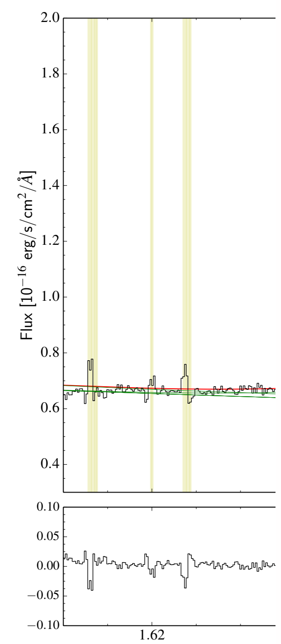

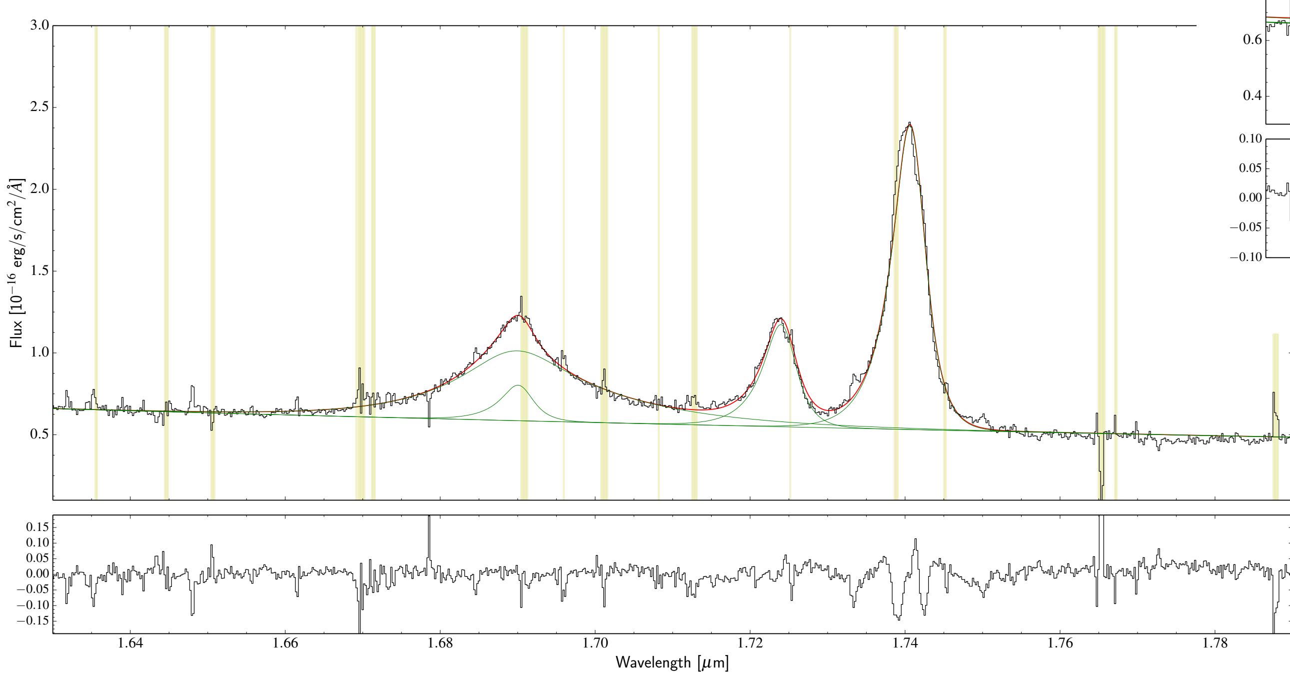

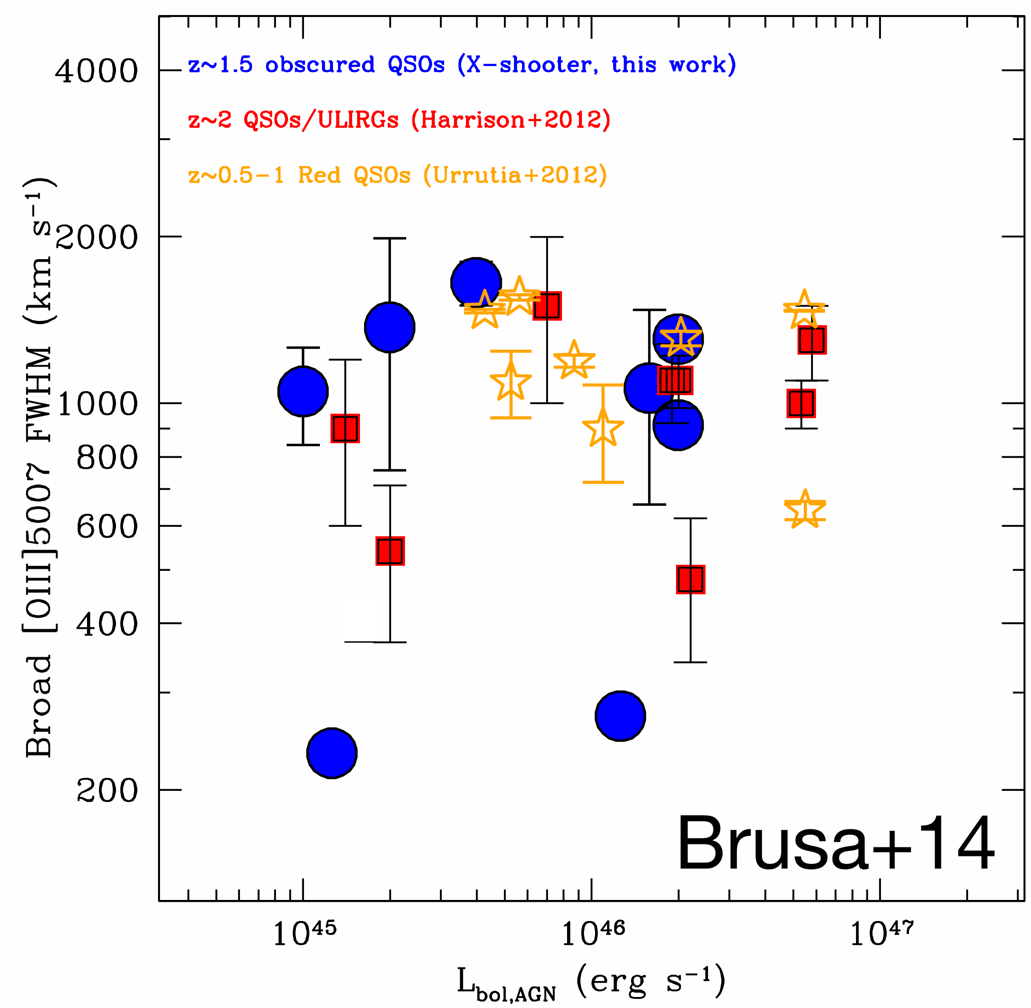

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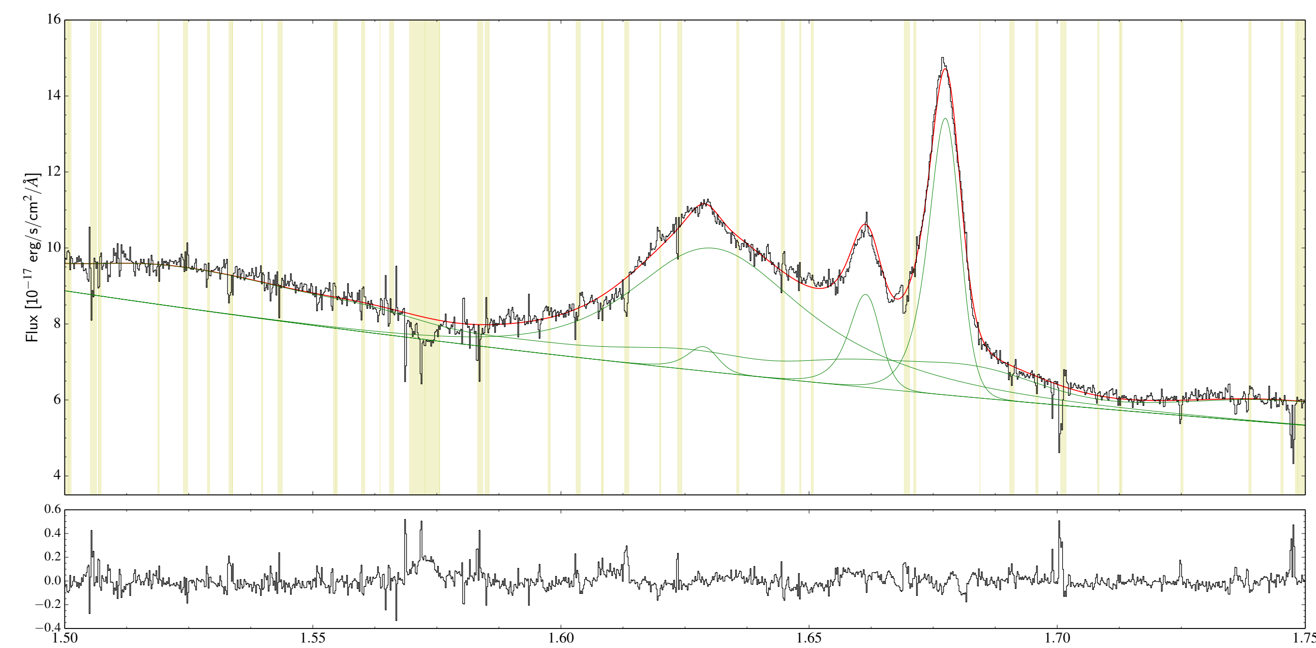
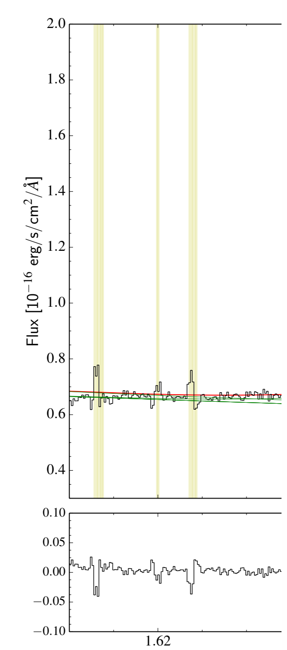
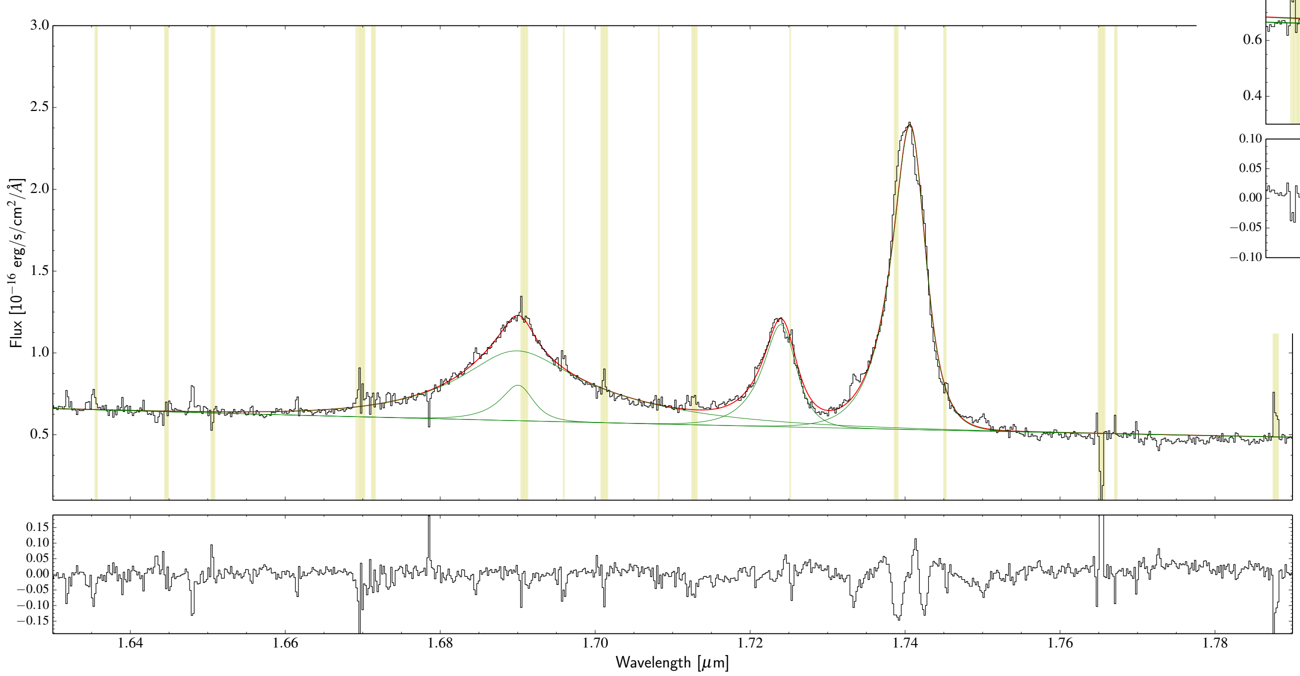
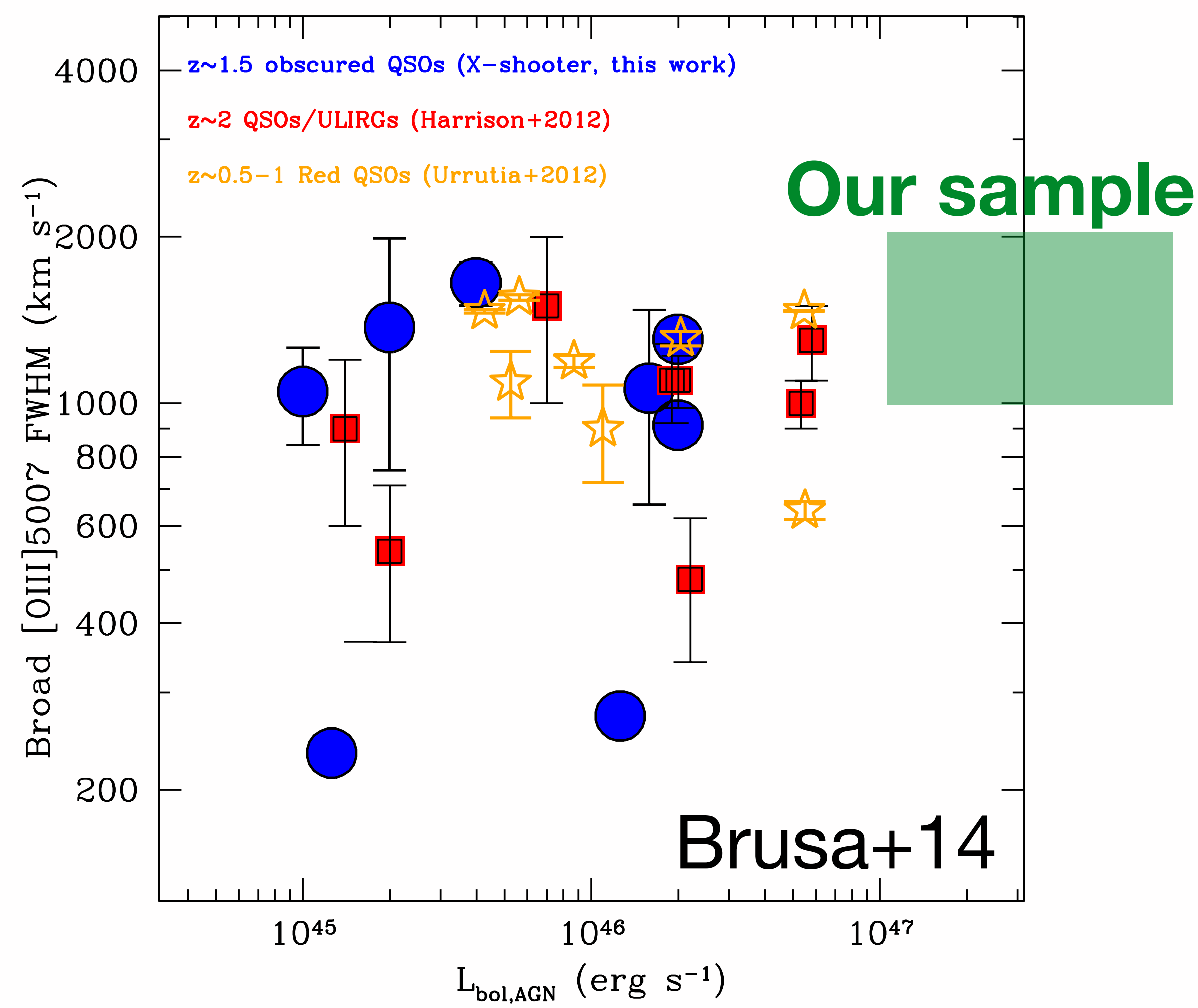


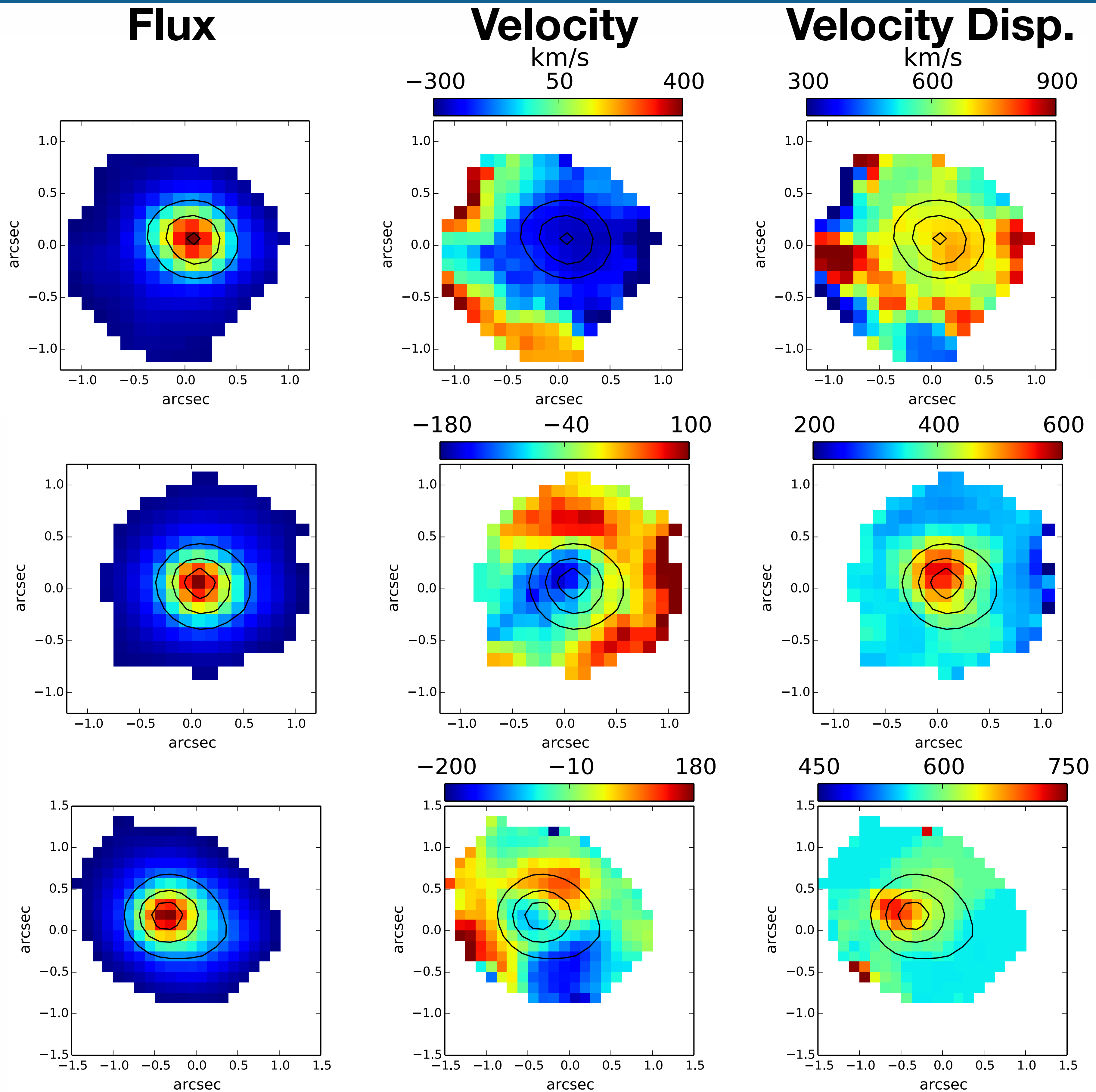






Ionized outflows in luminous quasars

- Get PSF from broad Hβ flux map
- *Spatially resolved [OIII] kinematical maps in 5/6 objects*
- *Outflow velocities of ~300-600 km/s*
- *Velocity dispersions up to ~800 km/s*



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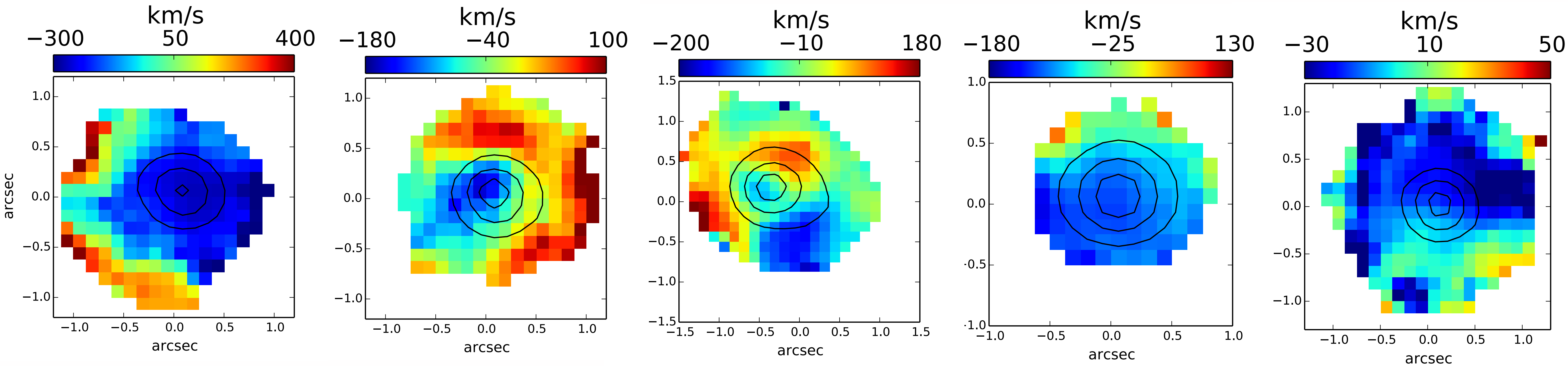

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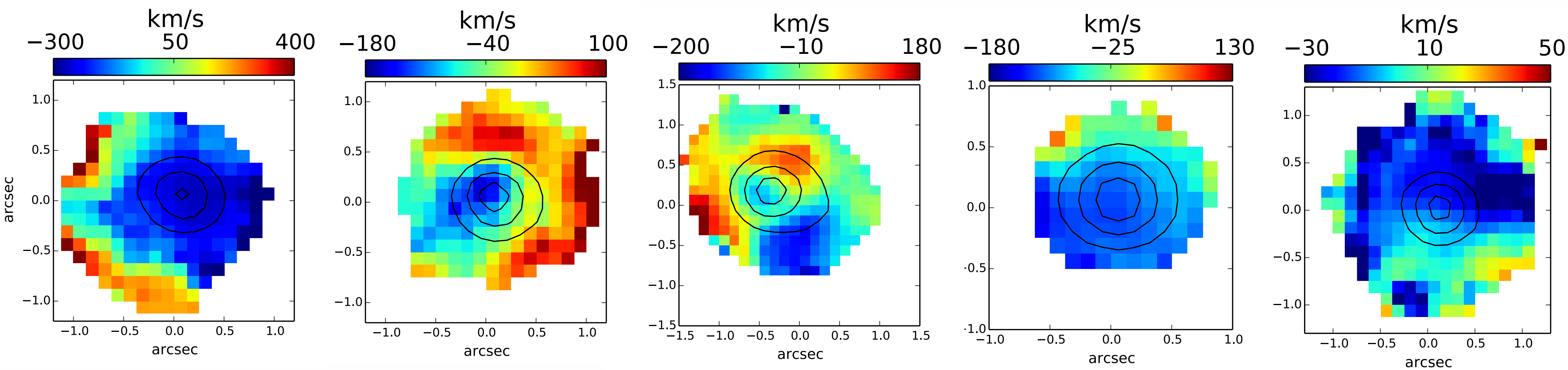
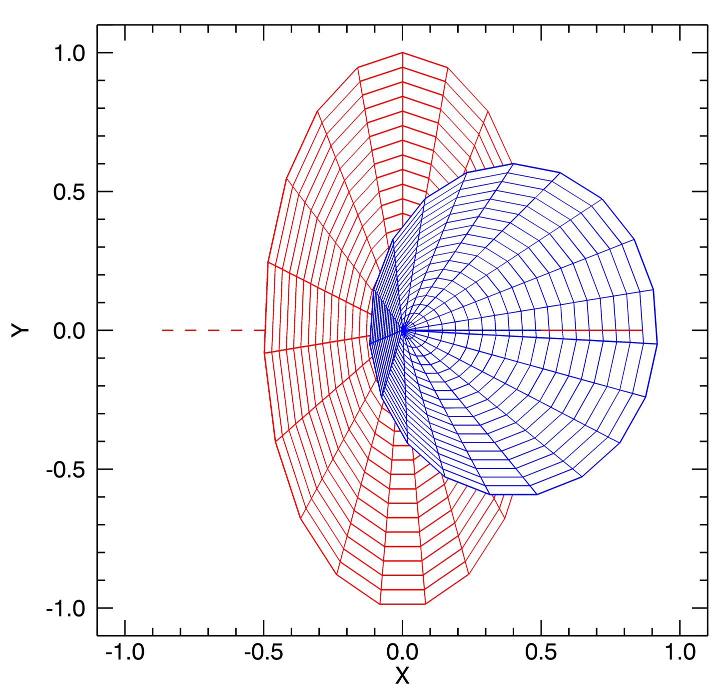


Simple kinematical model:
disk + conical outflow



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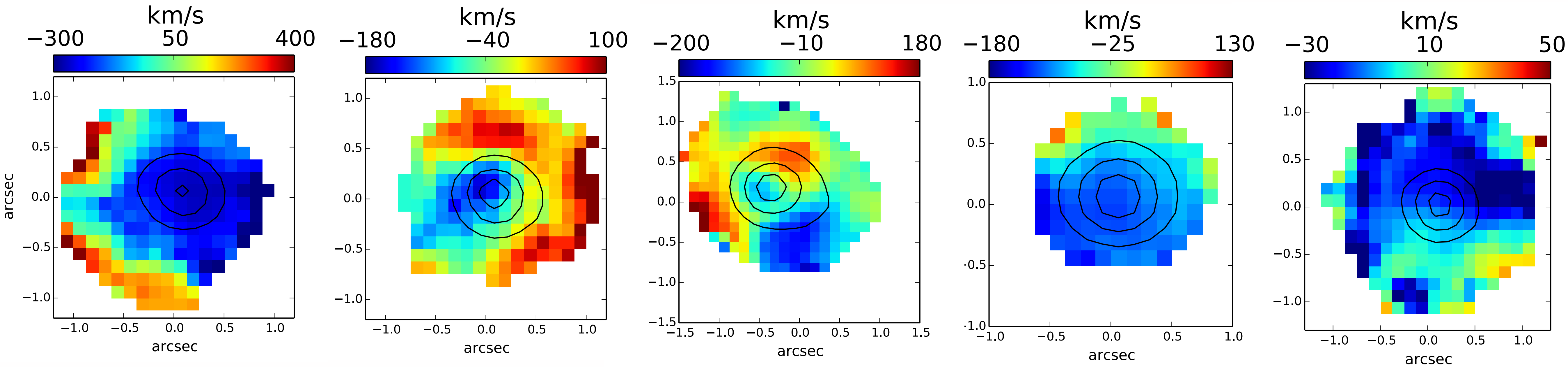

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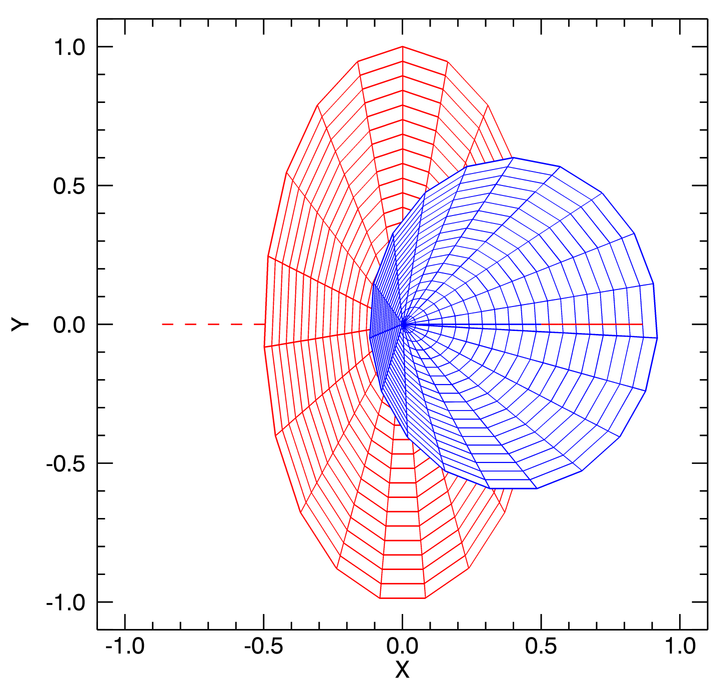
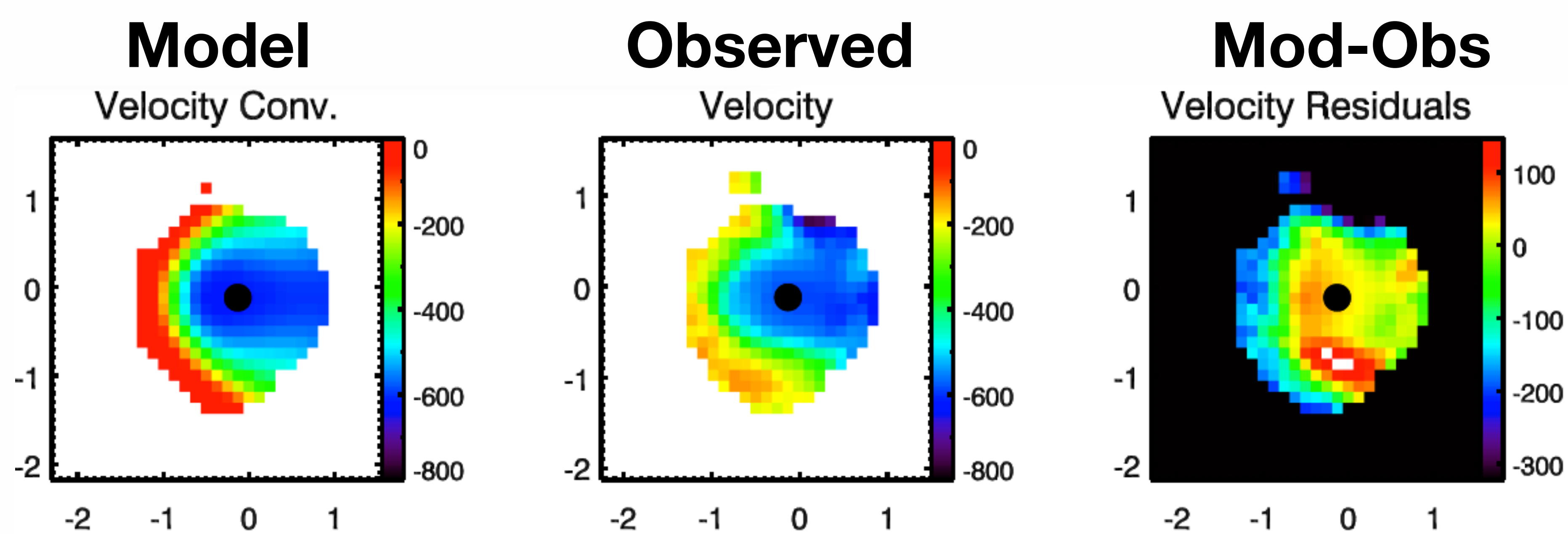


Observed velocity maps provide evidence for conical outflows



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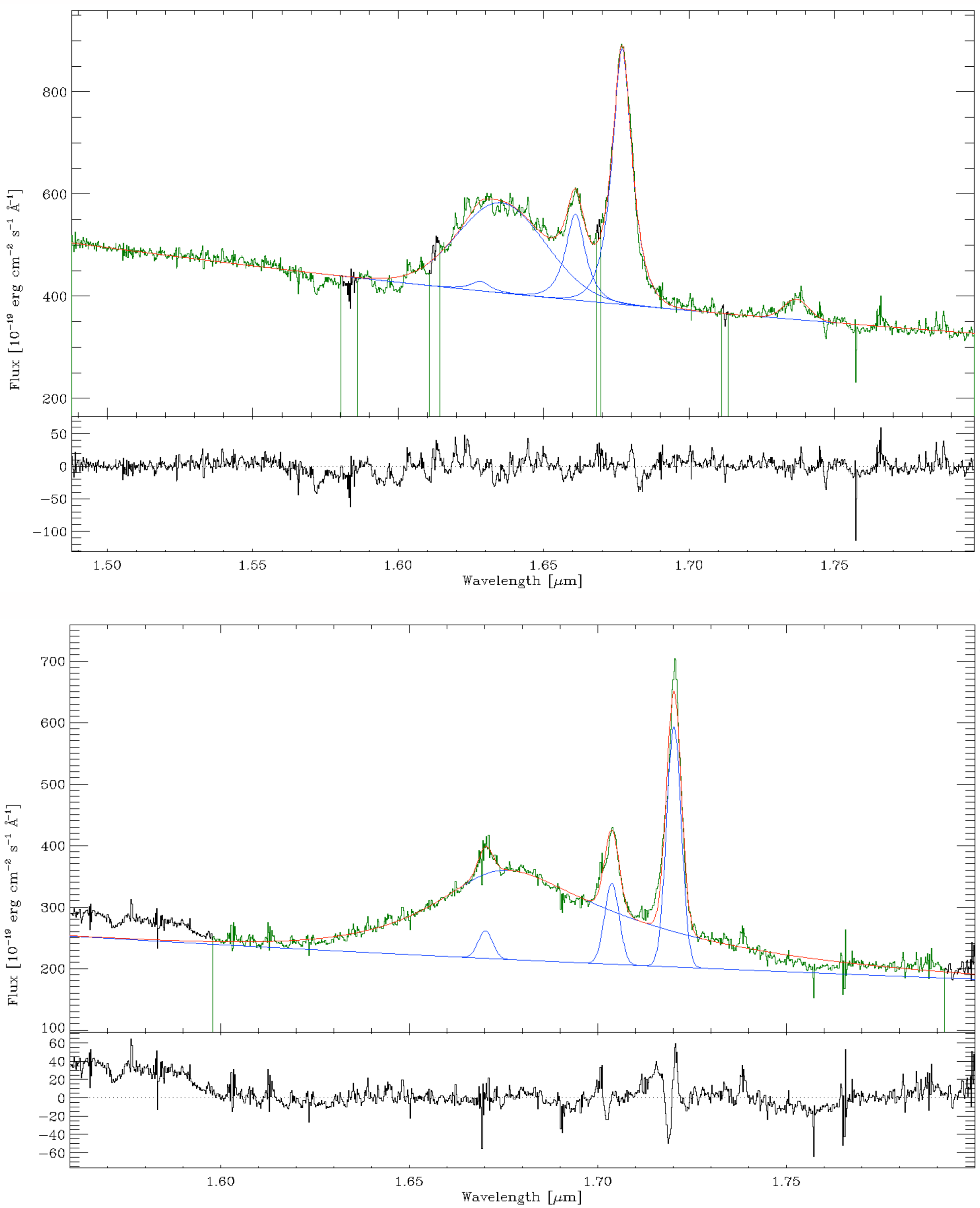
Subtract “broad” (~1000-1500 km/s) [OIII] ➙ outflow



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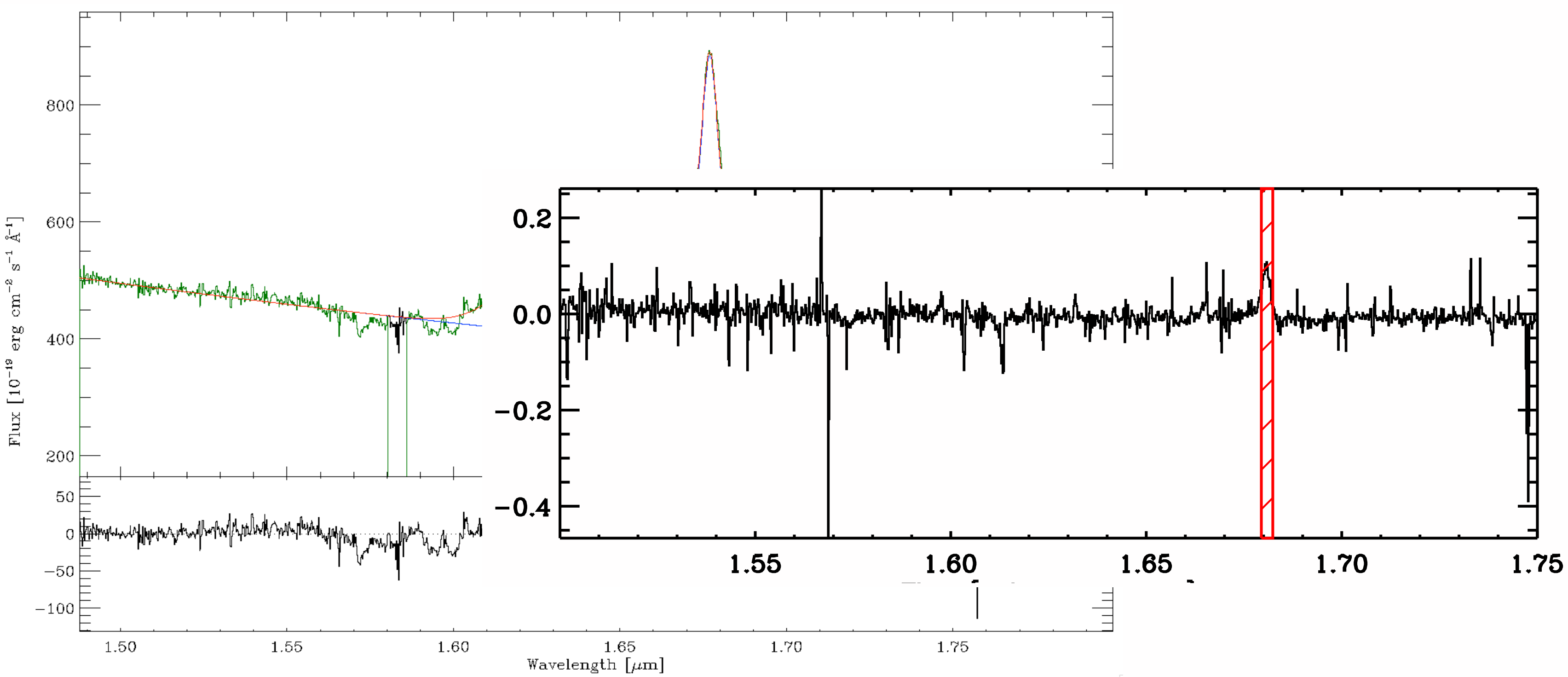

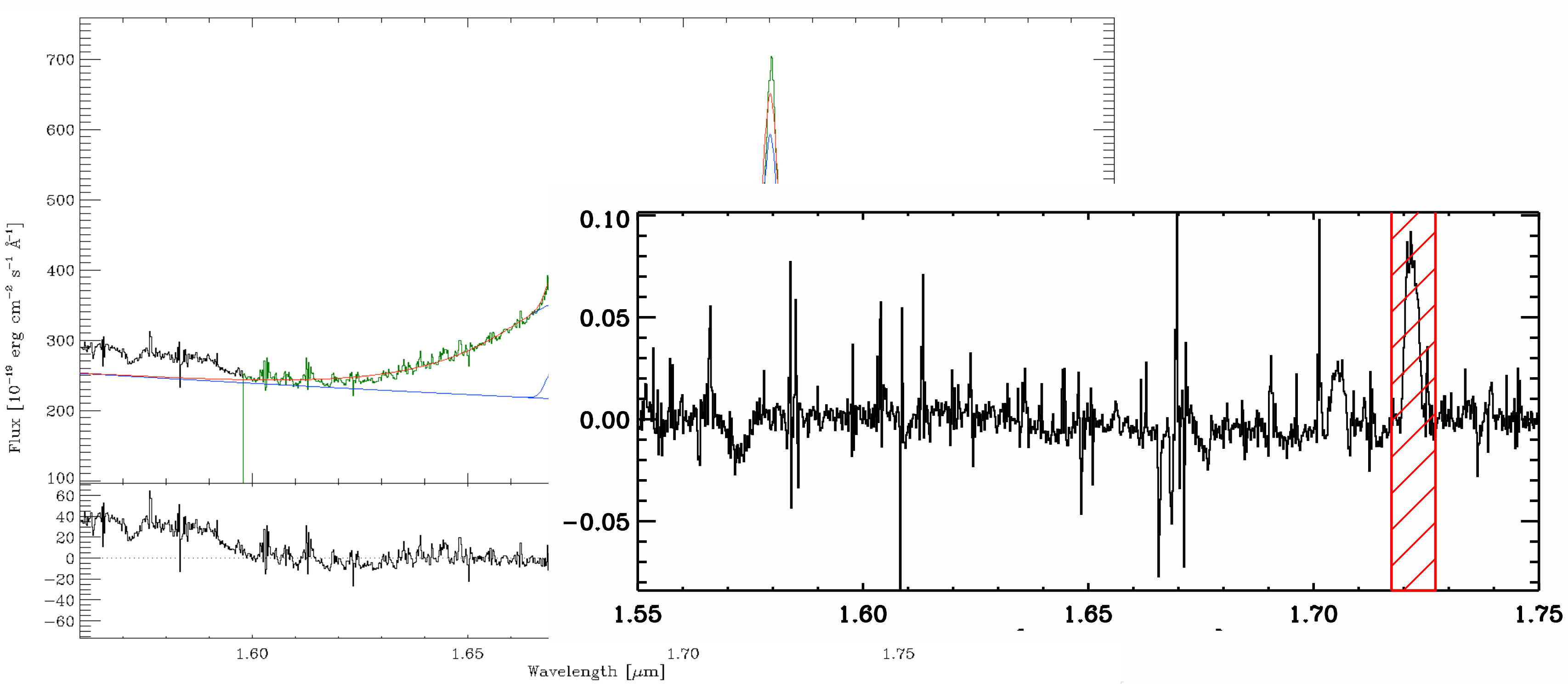

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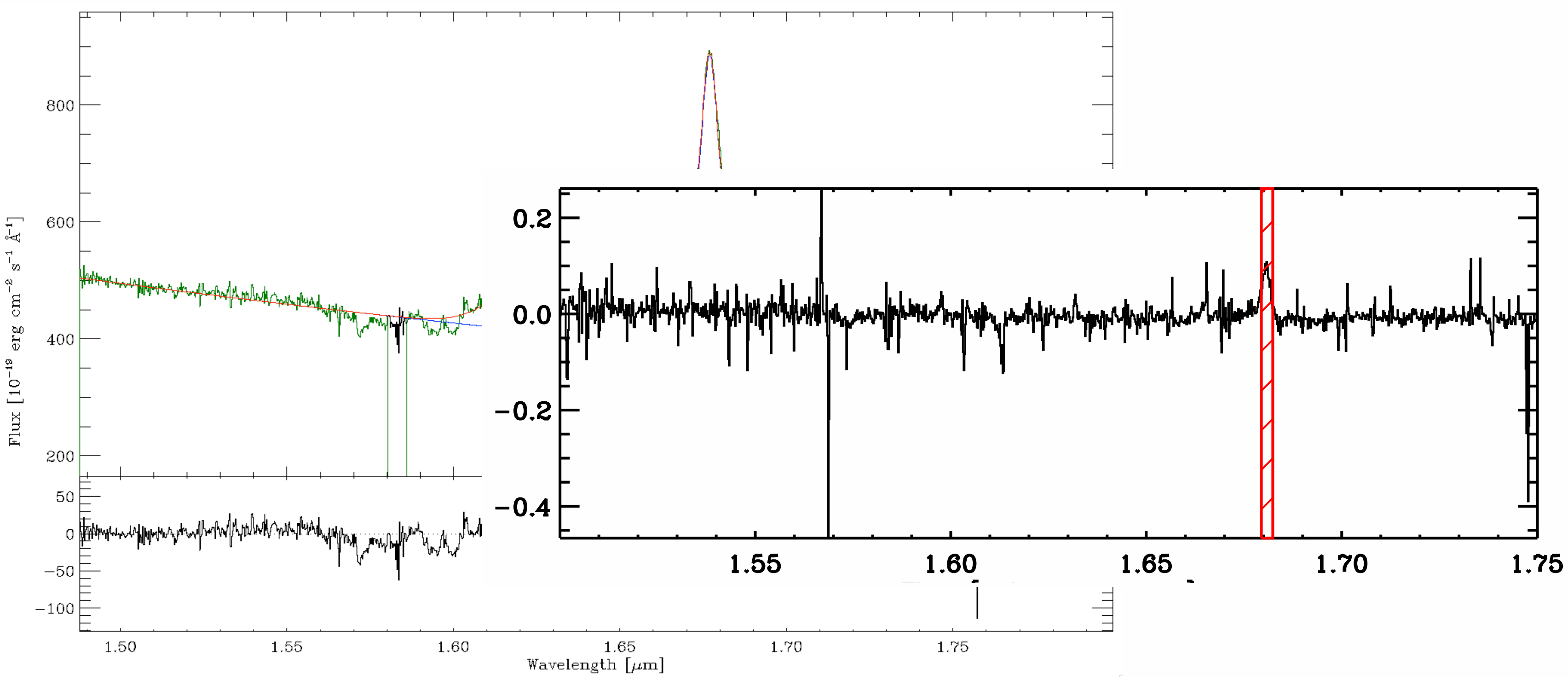
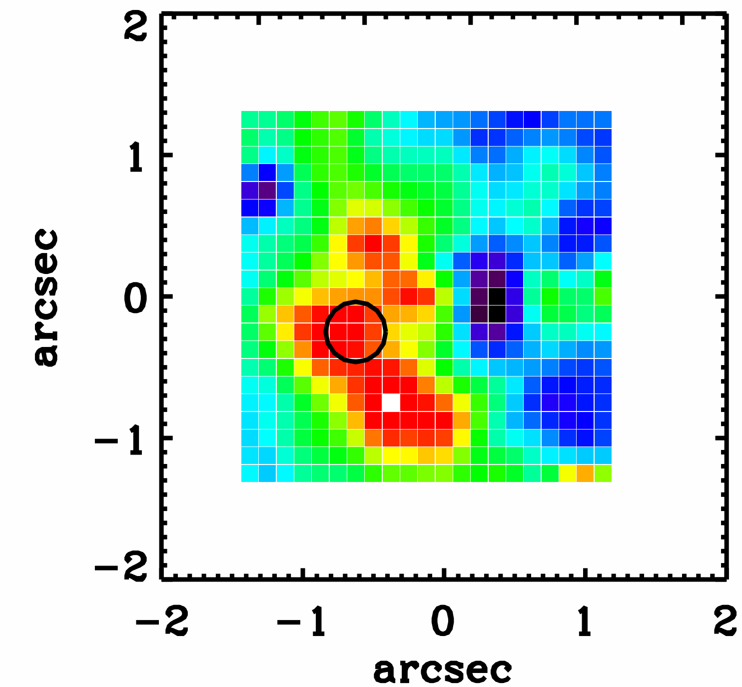
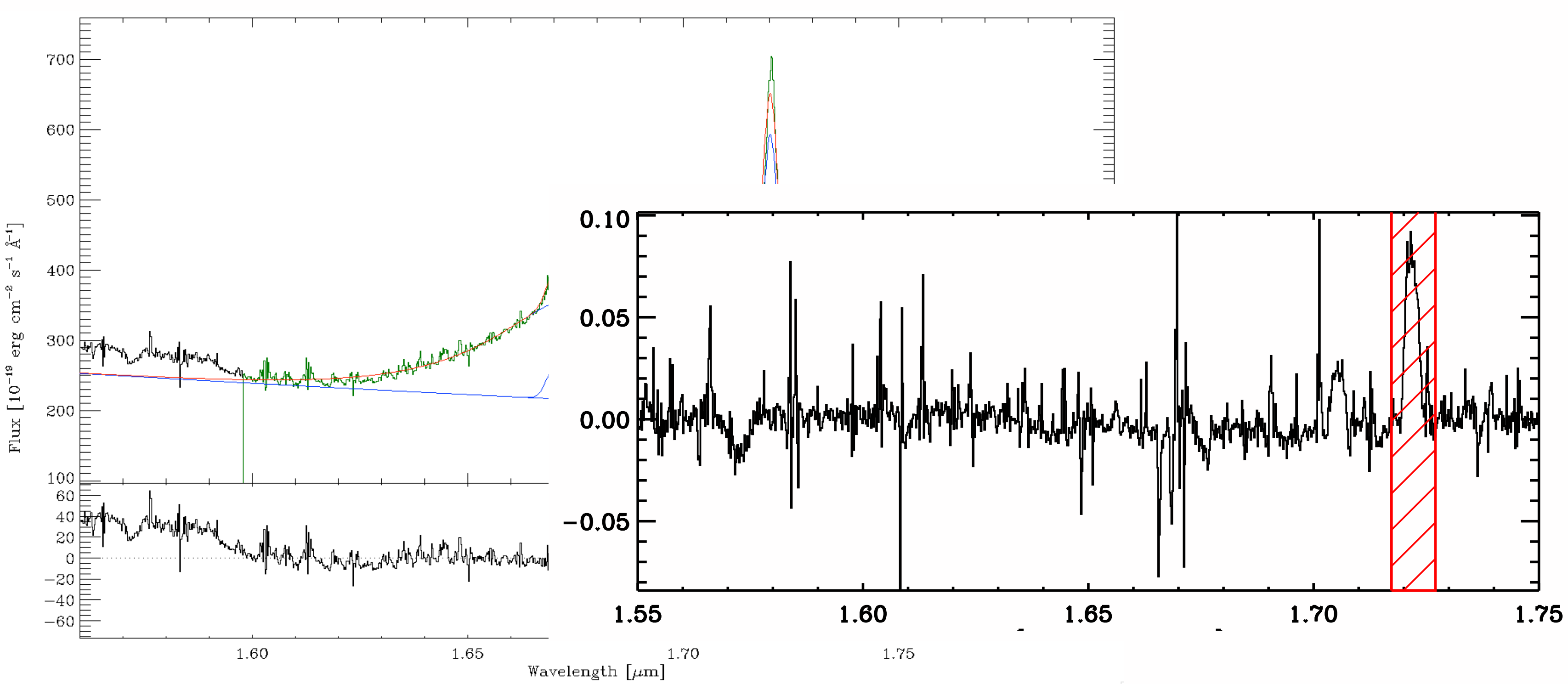
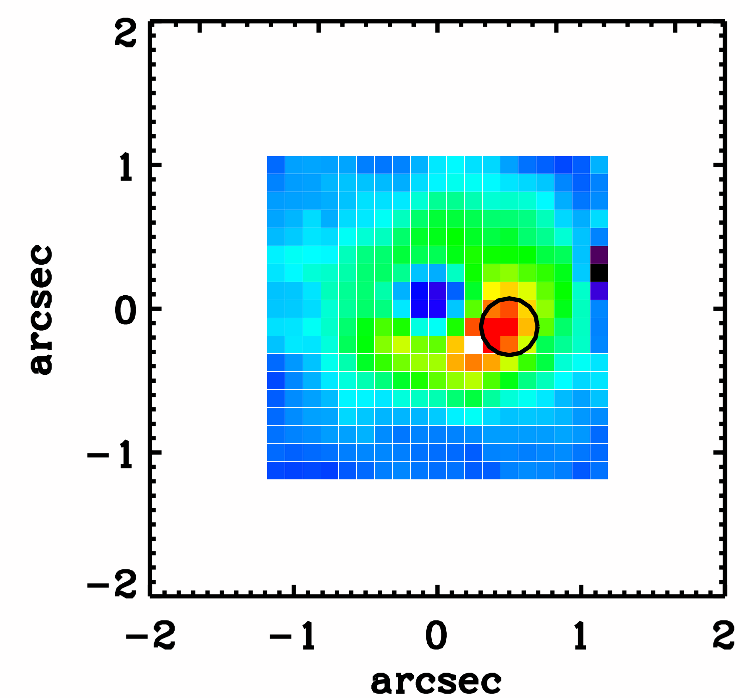
Residual faint “narrow” (~100-200 km/s) [OIII] ➙ host galaxy, star formation?









Ionized outflows in luminous quasars

Origin of “narrow” [OIII] emission? AGN or Star Formation excited?

K band observations targeting *Hα … subtract broad Hα and outflow component … narrow Hα residual*

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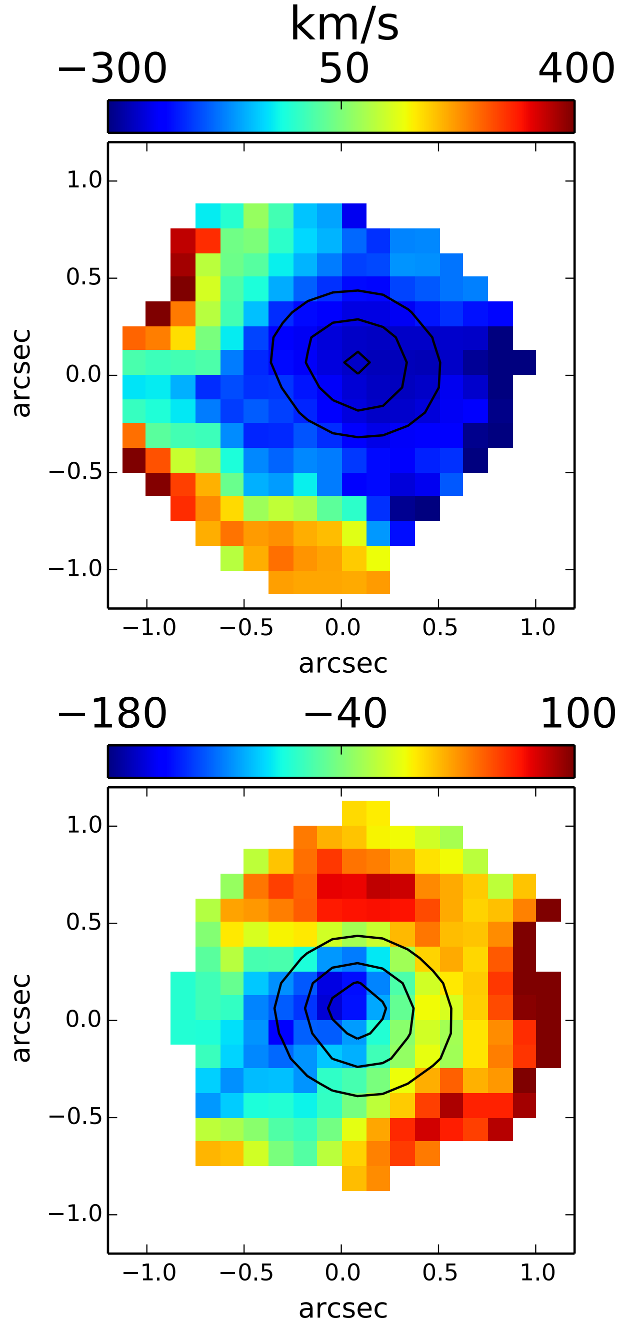
[OIII] velocity



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K band observations targeting *Hα … subtract broad Hα and outflow component … narrow Hα residual*

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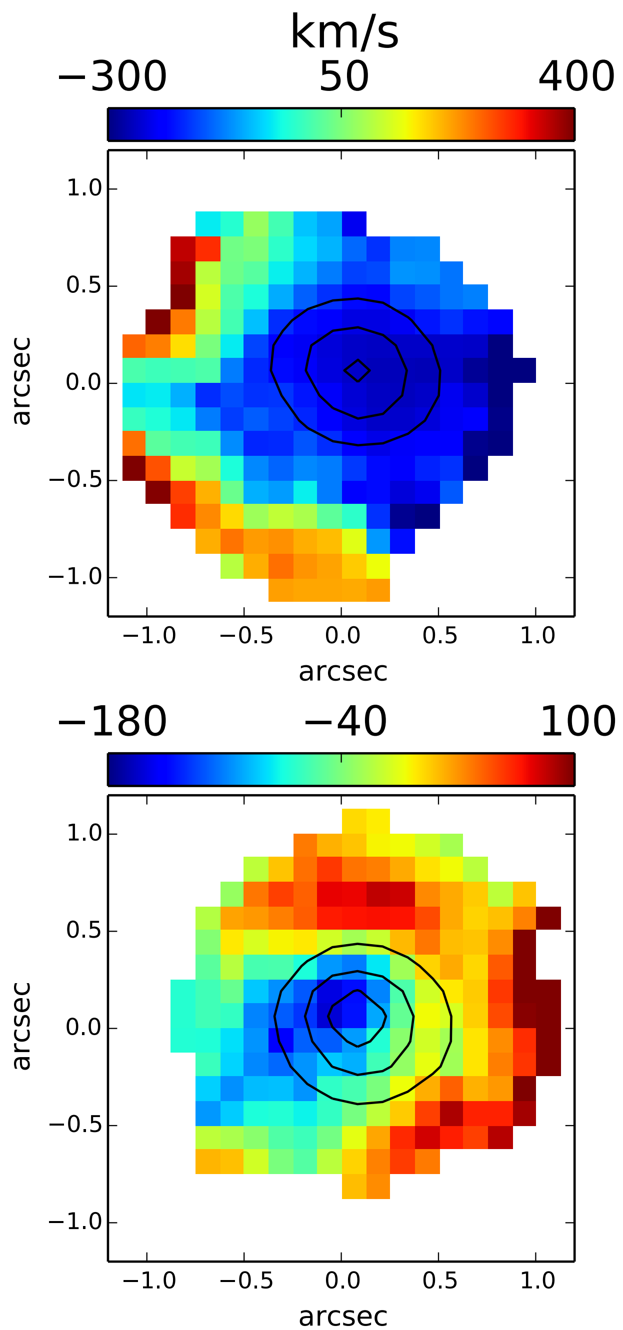
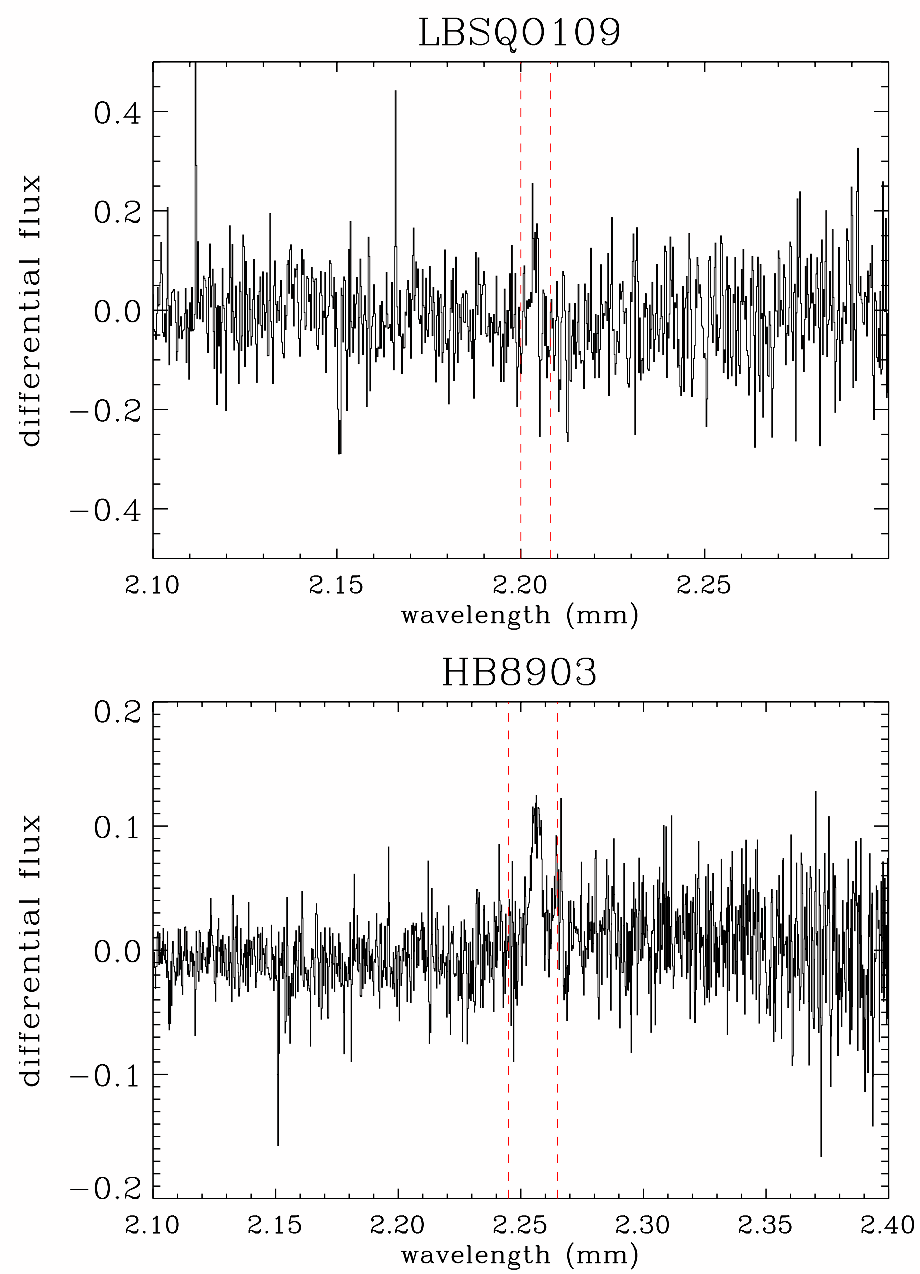


K band: broad Hα subtracted



Ionized outflows in luminous quasars

Origin of “narrow” [OIII] emission? AGN or Star Formation excited?

K band observations targeting Hα *… subtract broad Hα and outflow component … narrow Hα residual*

no [NII], upper limit on [NII]/Hα excludes AGN excitation → star formation!

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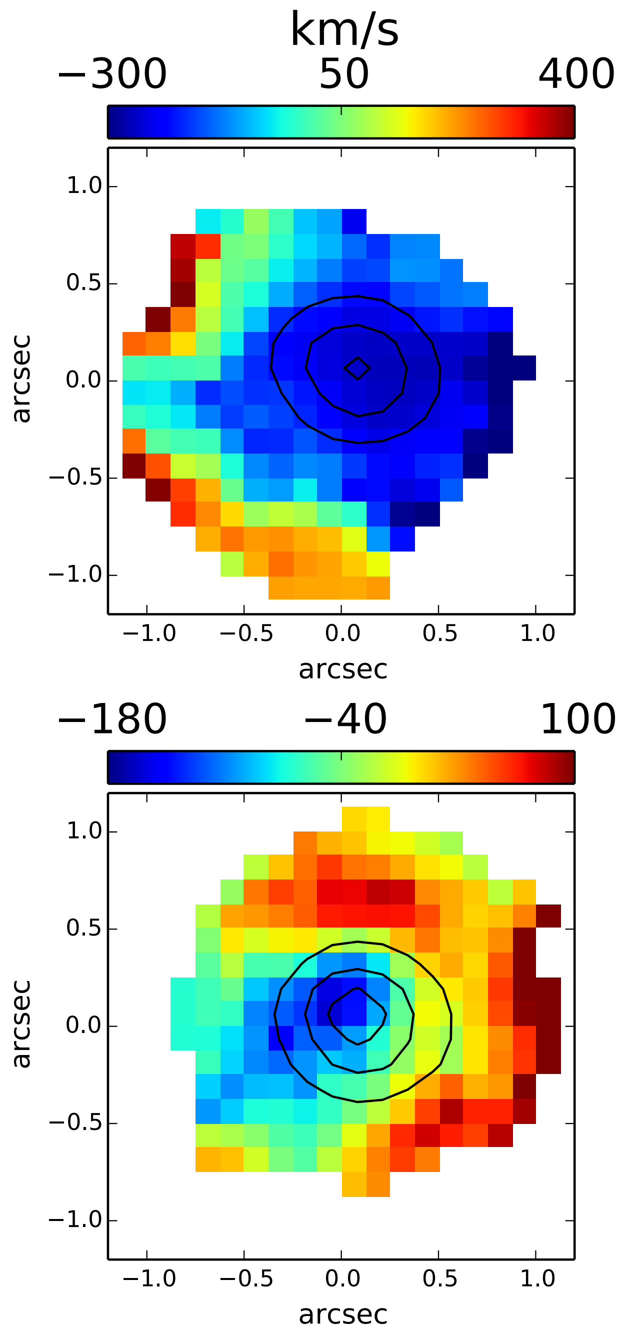

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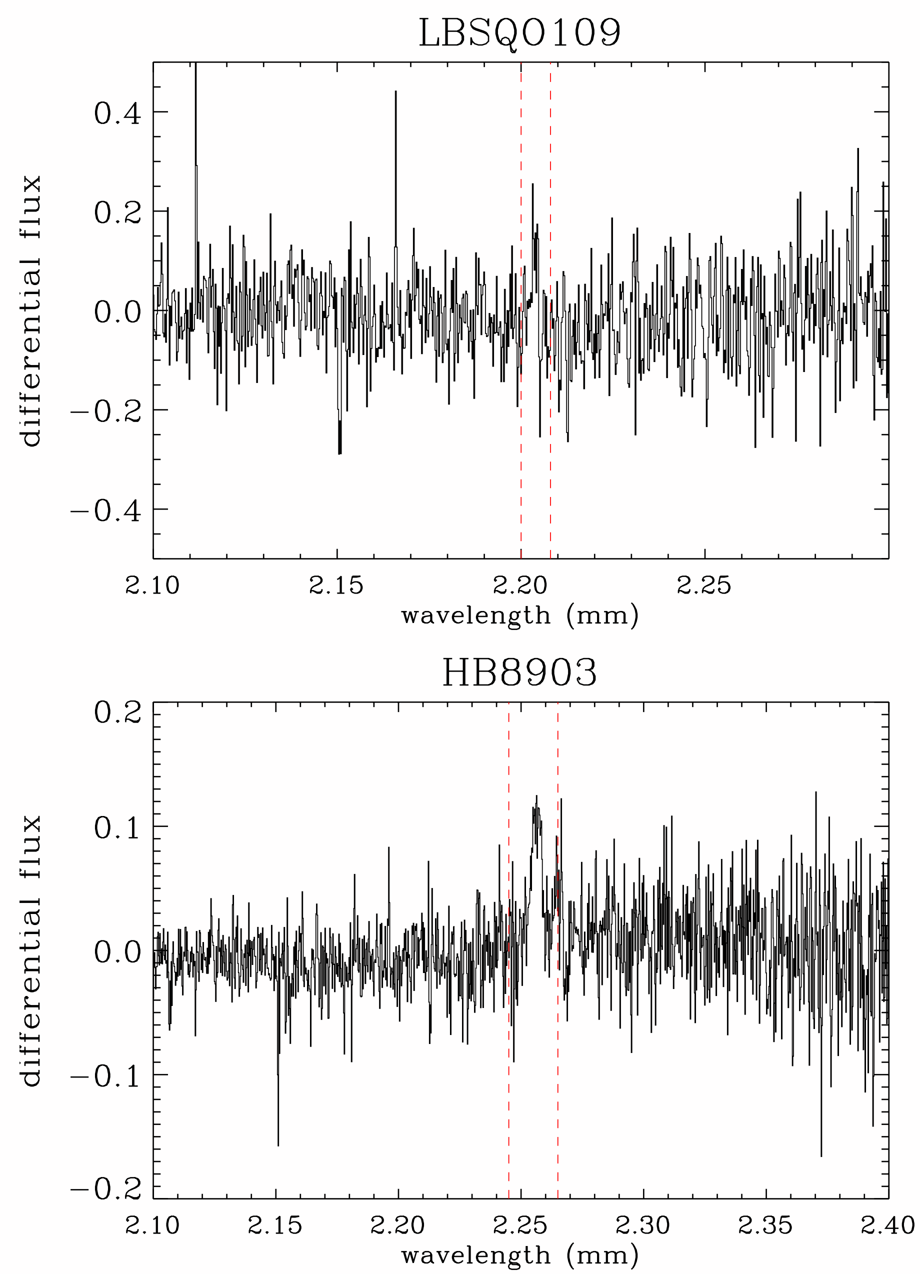

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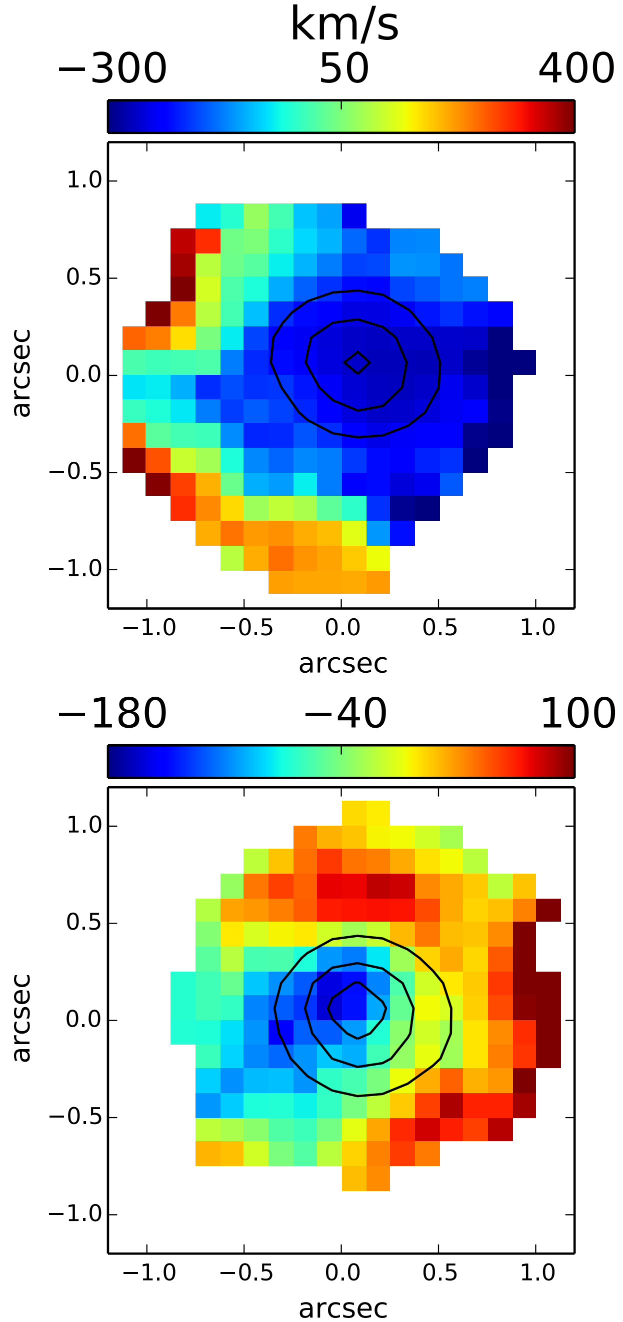

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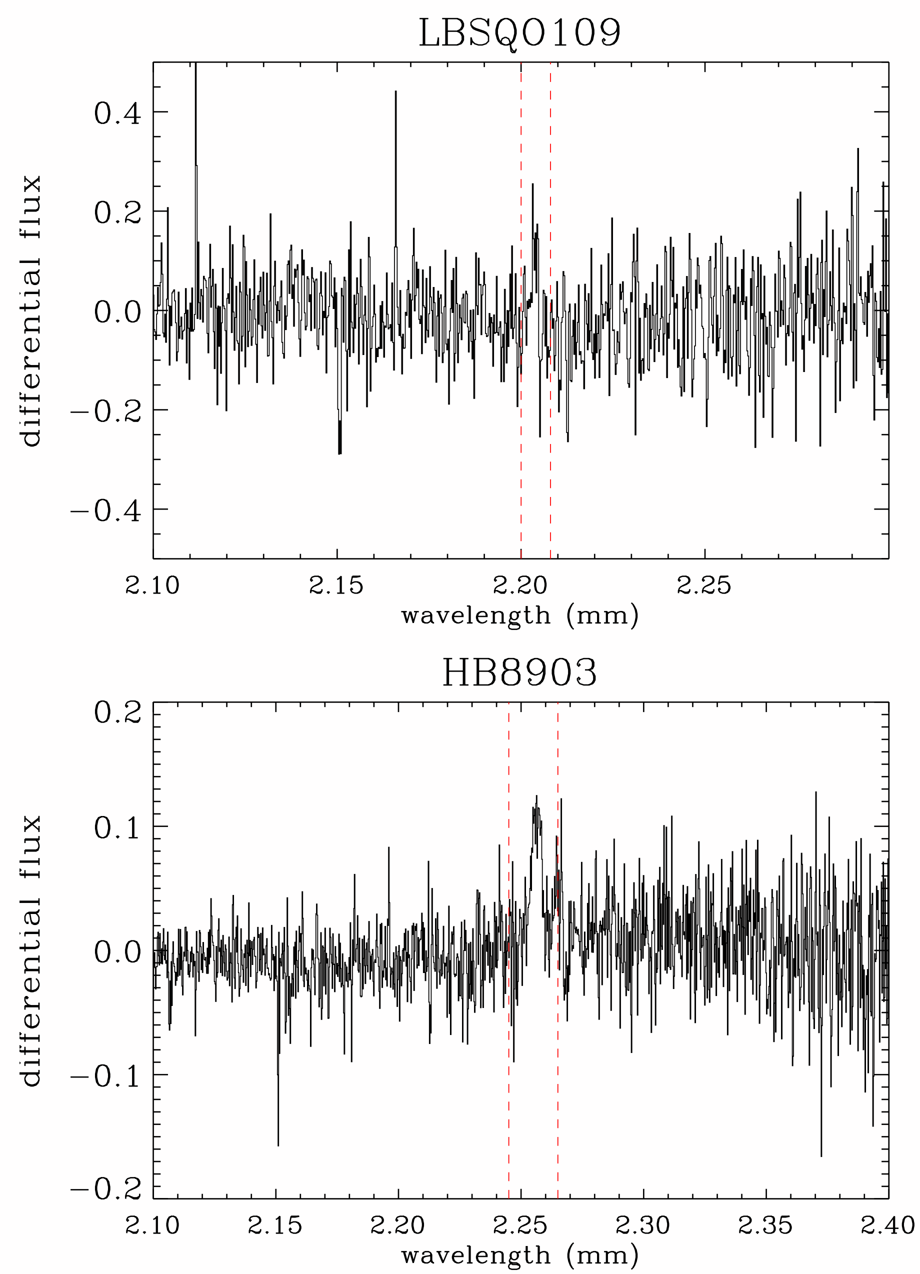
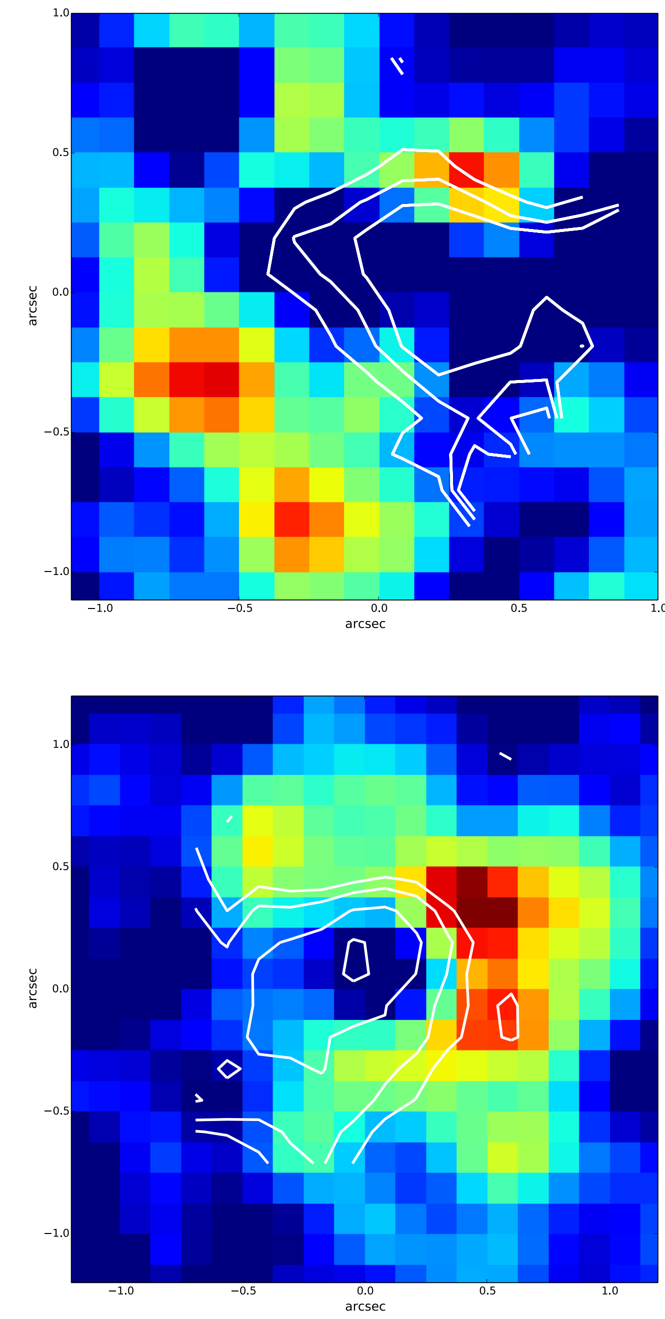


Narrow Hα flux



Ionized outflows in luminous quasars

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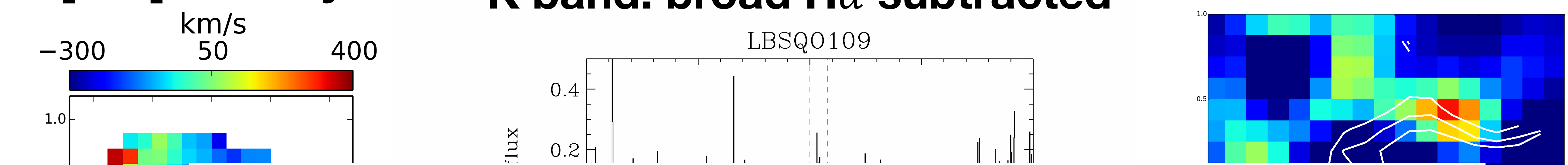
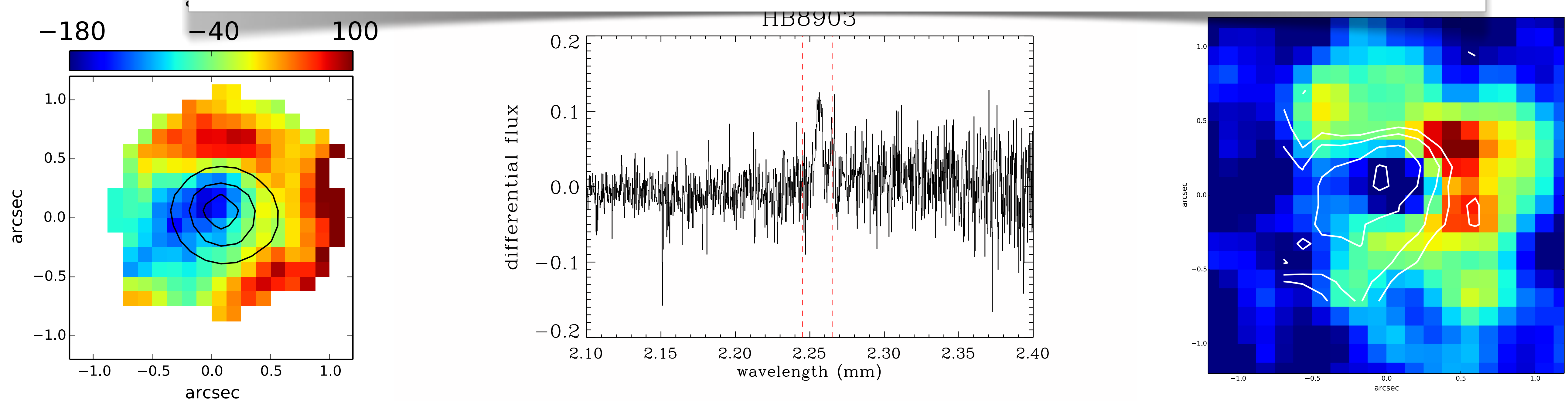
[OIII] velocity | **K band: broad Hα subtracted** | **Narrow Hα flux**



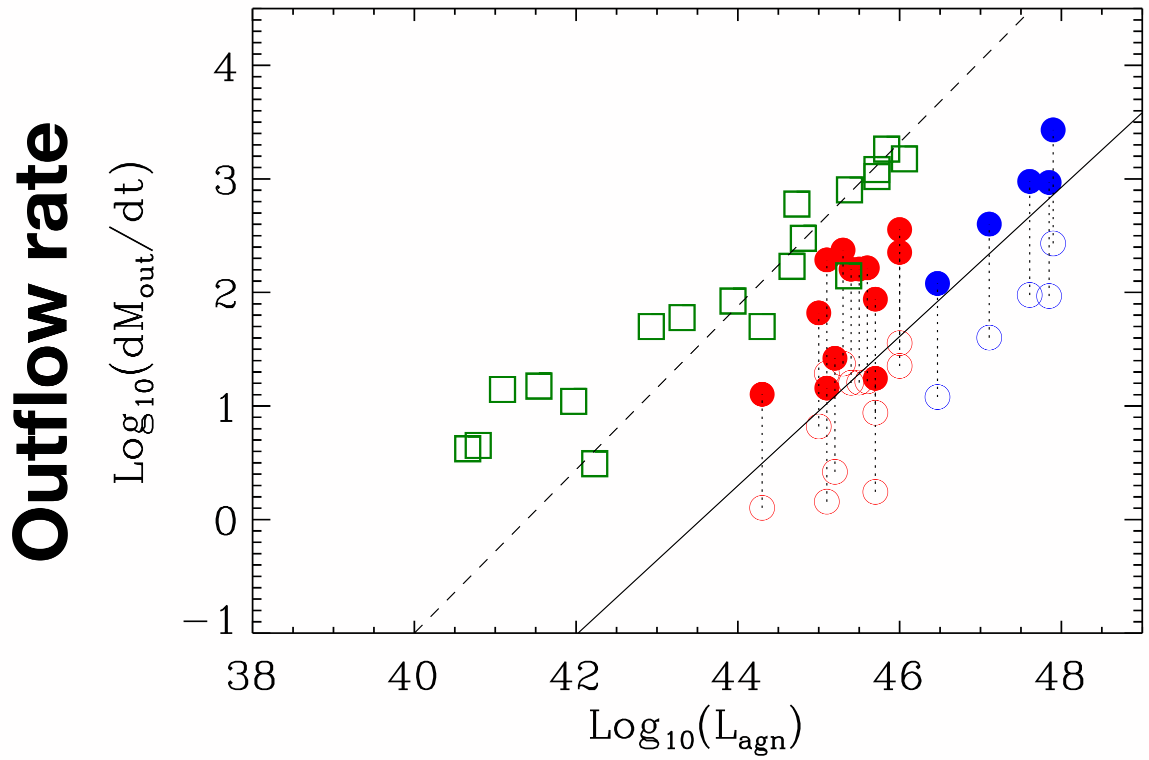
Narrow Ha/[OIII] emission traces star formation
and is anti-correlated with the presence of fast outflows!

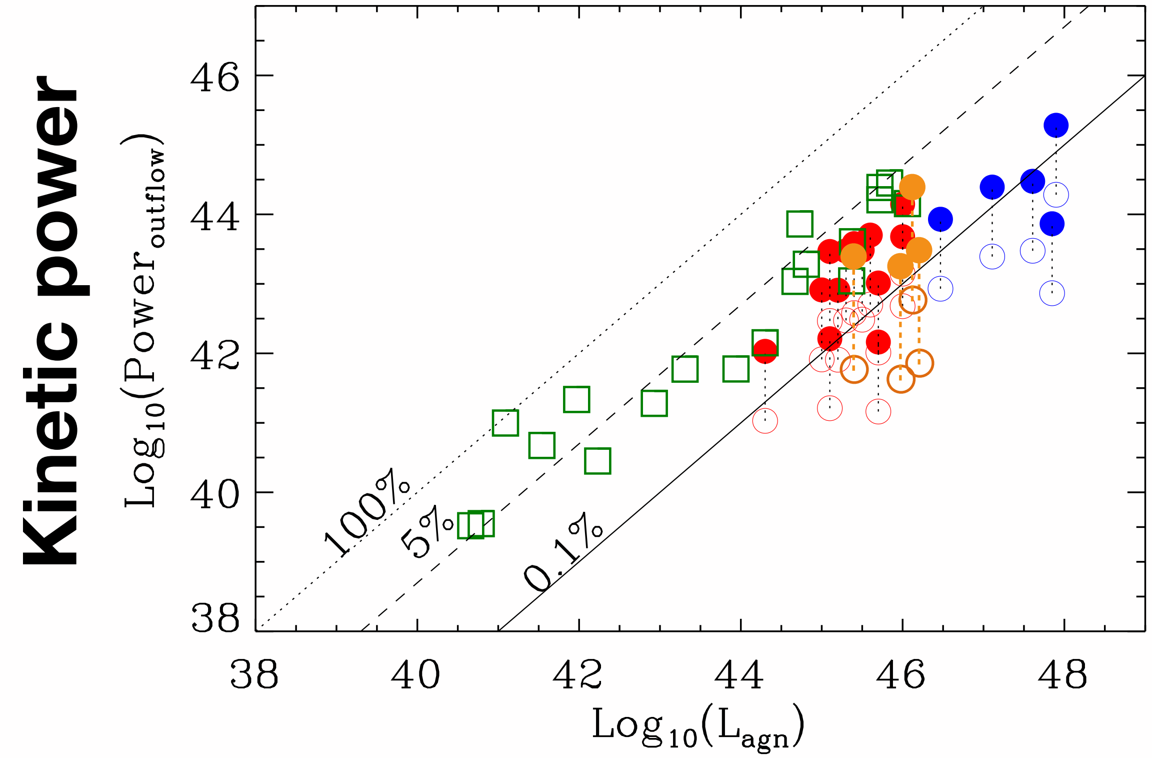
Fast outflows “quench” star formation, feedback revealed! (?)



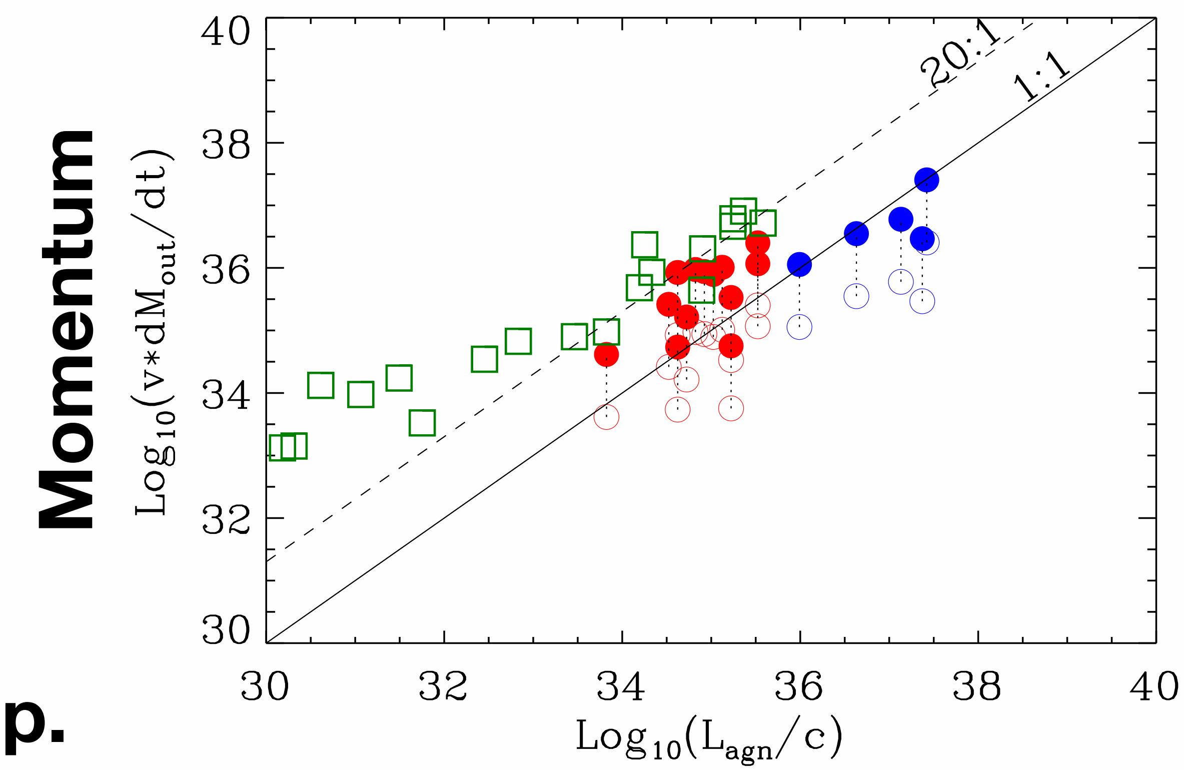
Ionized outflows in luminous quasars

Physical properties of ionised outflows: uncertainty on outflow mass, only ionised gas is traced !





- Molecular outflows in local AGN (Cicone+2014)
- [OIII] outflows in Type 2 local AGN (Harrison+2014)
- [OIII] outflows in X-ray obscured AGN (Brusa+2014)
- [OIII] outflows in z~2.5 quasars (Carniani+, in prep.)



Carniani, AM+, in prep.

Ionized outflows in luminous quasars

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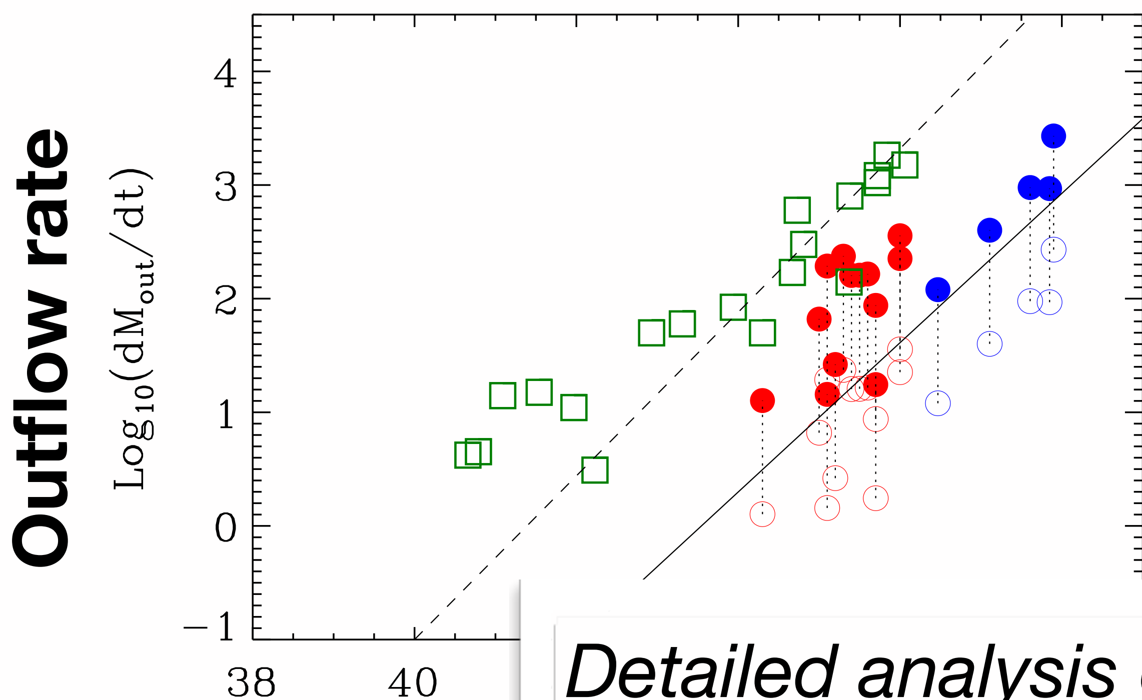

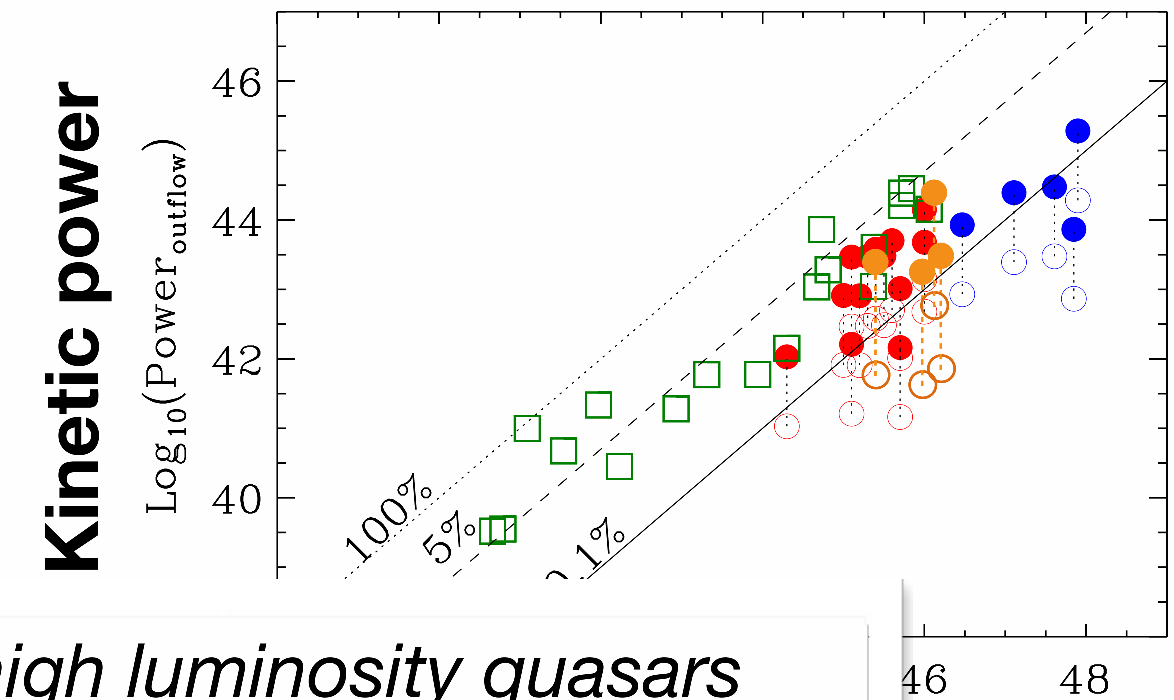

Detailed analysis of high luminosity quasars provides evidence for fast outflows quenching star formation, AGN feedback revealed! (?)

- Molecular outflo… AGN (Cicone+2…
- [OIII] outflows in Type 2 local AGN (Harrison+2014)
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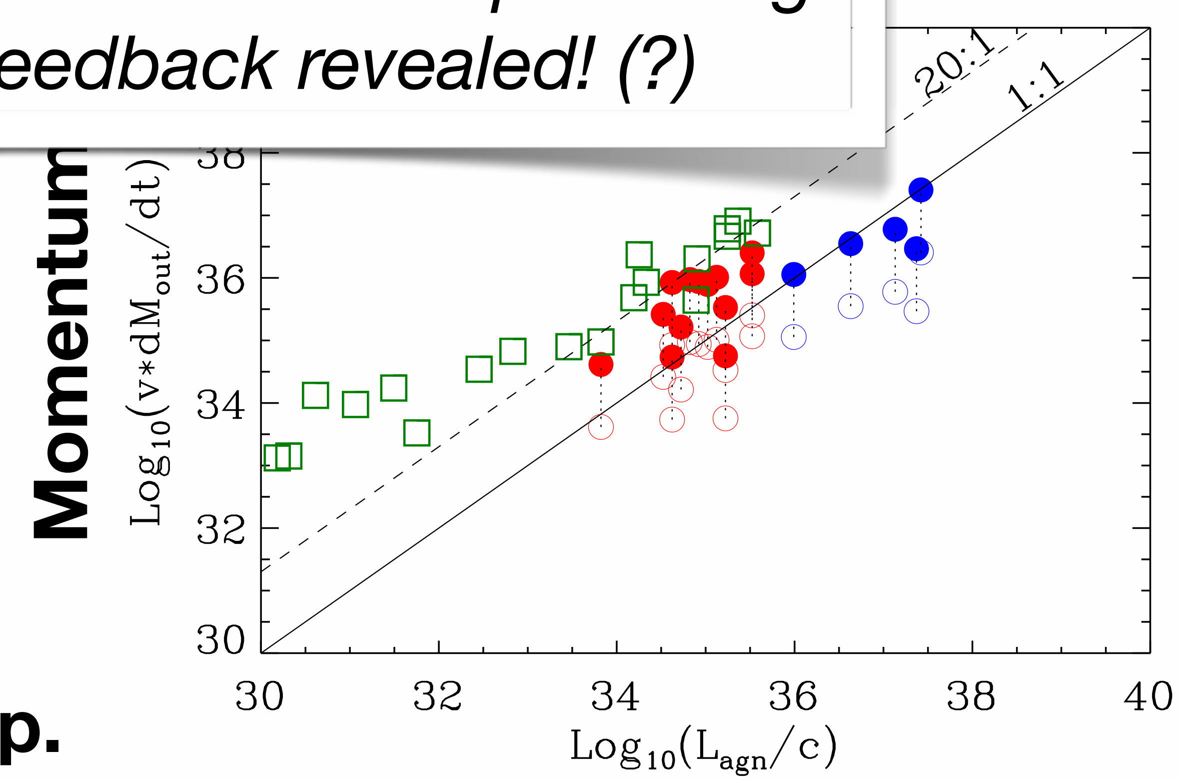

Carniani, AM+, in prep.

Conclusions

- From larger sample of local quasars at z < 1
  The presence of ionized outflows does not appear to significantly affect star formation (problem of time scales?)

- From the small sample of quasars at z~2.5:
  Ionized gas outflows (partially) sweep away gas in quasar host galaxies and prevent star formation

- One possibility which reconciles both results is that feedback from a single episode of quasar activity does not significantly affect SF on the whole galaxy; the "feedback" observed in the z~2.5 quasars does not significantly depress SF over the whole galaxy

- ALMA observations planned

- Stay tuned for more !
  Balmaverde+, in prep
  Carniani+, in prep