UNIVERSITÀ DEGLI STUDI FIRENZE

Fast outflows quenching star formation in quasar host galaxies

Alessandro Marconi

Department of Physics and Astronomy
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INAF-Arcetri Astrophysical Observatory, Florence

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

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Open questions

- Outflows of ionised and molecular gas are ubiquitous in AGN
- What are the origin and physical properties of outflows?
  - Accelerating mechanism ?
  - Clumpy vs continuous?
  - Physical conditions of gas in outflows (very hot vs ionized vs molecular)?
  - How can molecular gas be accelerated to >1000 km/s without being destroyed?
  - Momentum vs energy driven winds?

- Are Outflows galaxy “killers”?
  - Do we really need AGN feedback?
  - Are there viable alternative and/or complementary physical processes?
  - Do observed massive outflows really affect star formation up to quenching?
  - Do they last long enough to expel all the gas from a galaxy?
  - Do outflowing material really escape not to be recycled any more?

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  - ☐ [illegible]
  - ☐ [illegible] without being destroyed?
  - ☐ [illegible] energy driven winds?

→ studies of AGN feedback in nearby "laboratories"
MAGNUM SURVEY (see talk by G.Venturi tomorrow)

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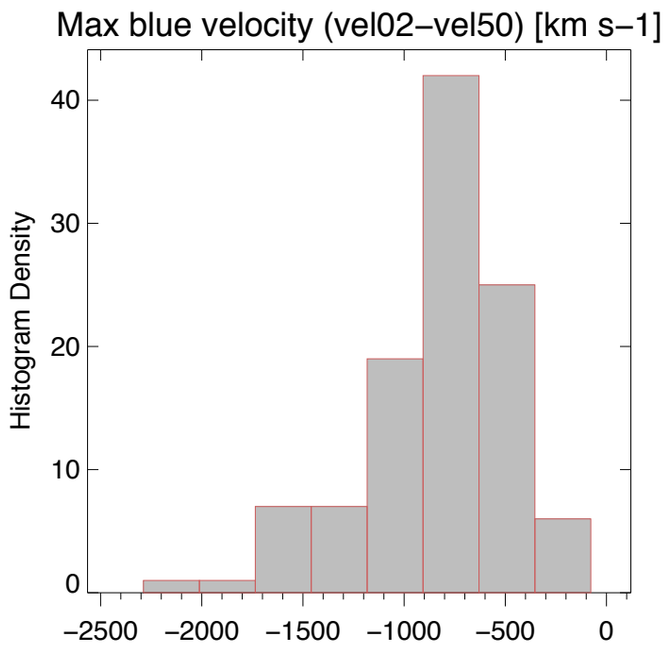
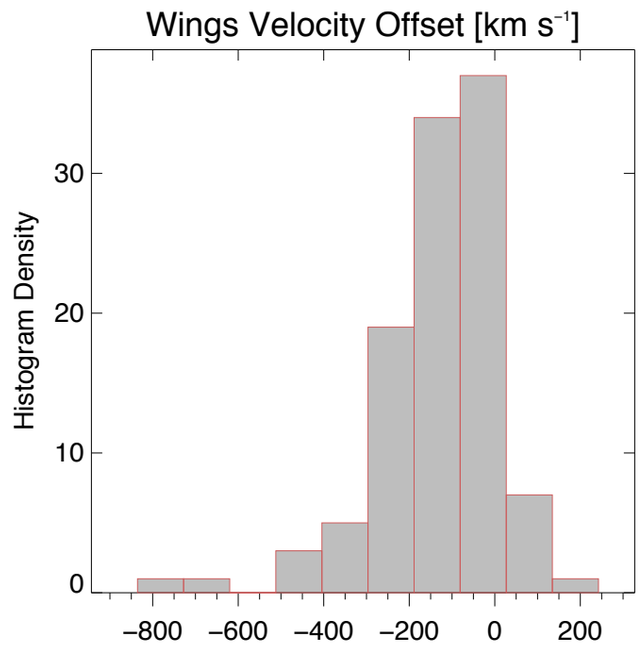
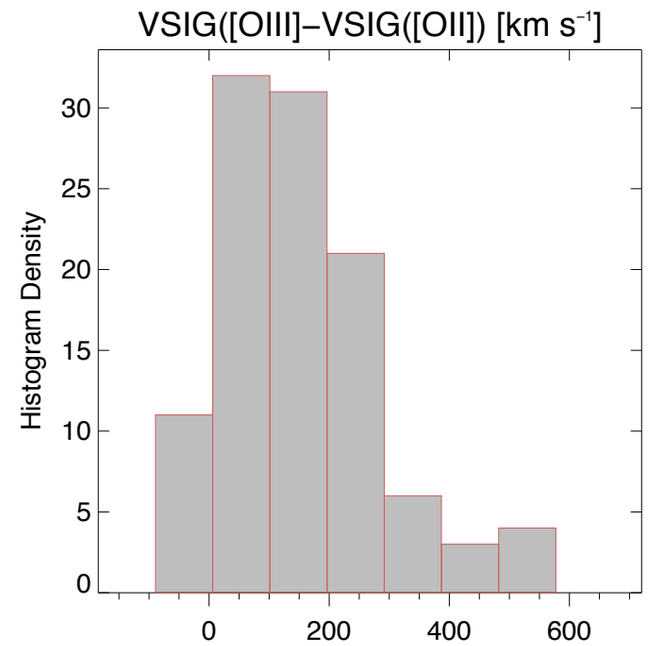
→search for AGN feedback in massive active galaxies (both unobscured and obscured) at peak of cosmic star formation history
THIS TALK, talk by G. Cresci,
WISHH SURVEY (G.Vietri, F. Fiore tomorrow)
SUPER SURVEY (C. Circosta tomorrow)

Ionized outflows and SF in local quasars

- Sample: ~100 luminous unobscured quasars from SDSS DR7 and DR 10 with z < 1 observed by Herschel: *SFRs & [OIII] Line widths*
- Mean SFR in four z bins: outflow-dominated and unperturbed galaxies.







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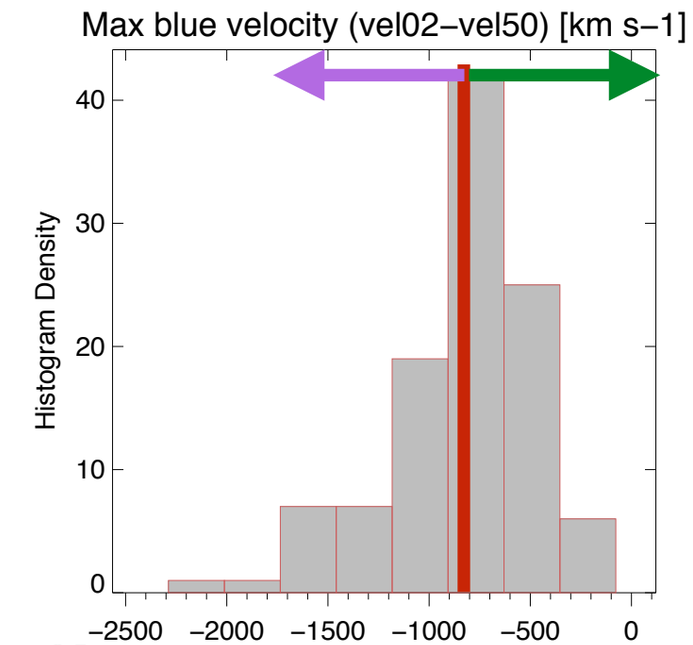

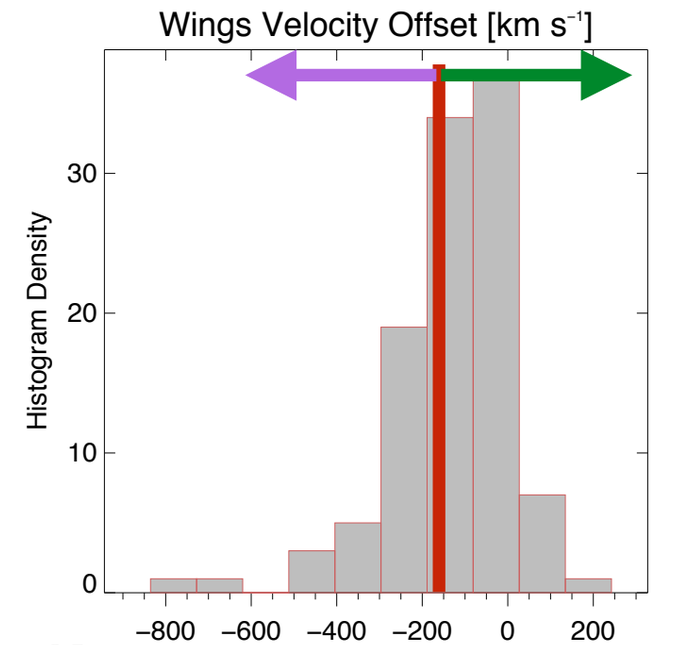

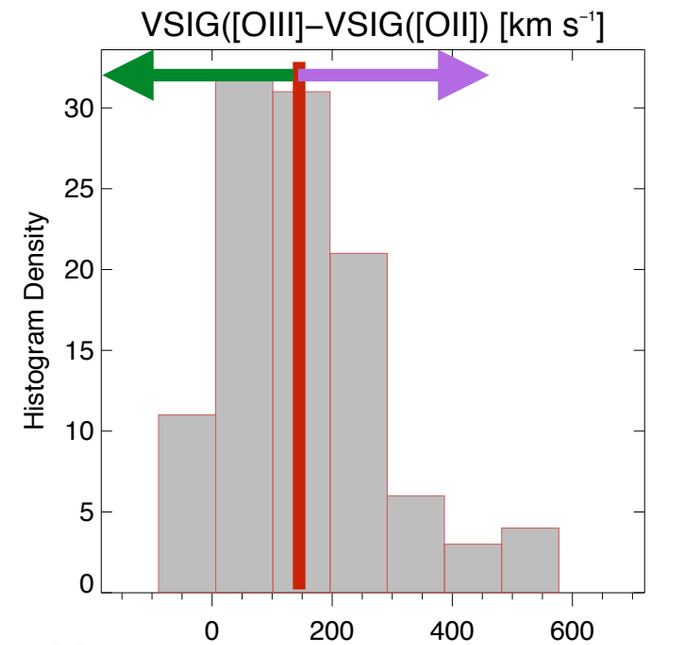

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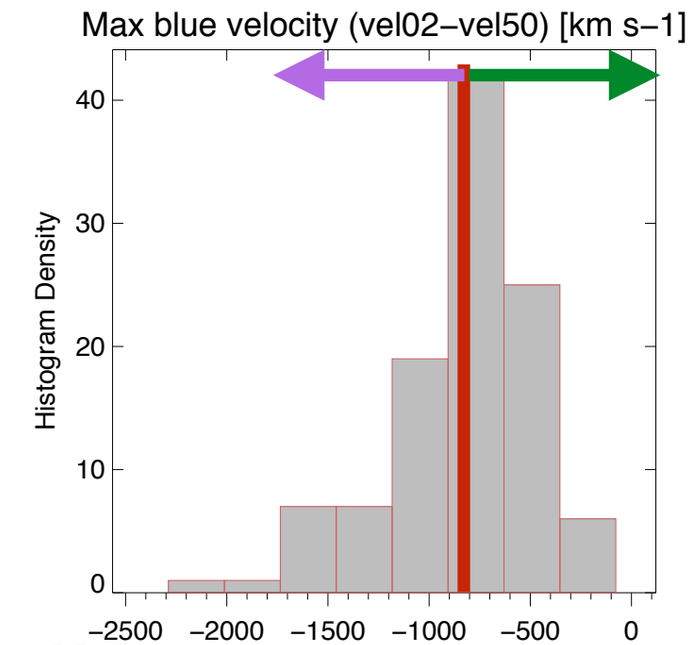
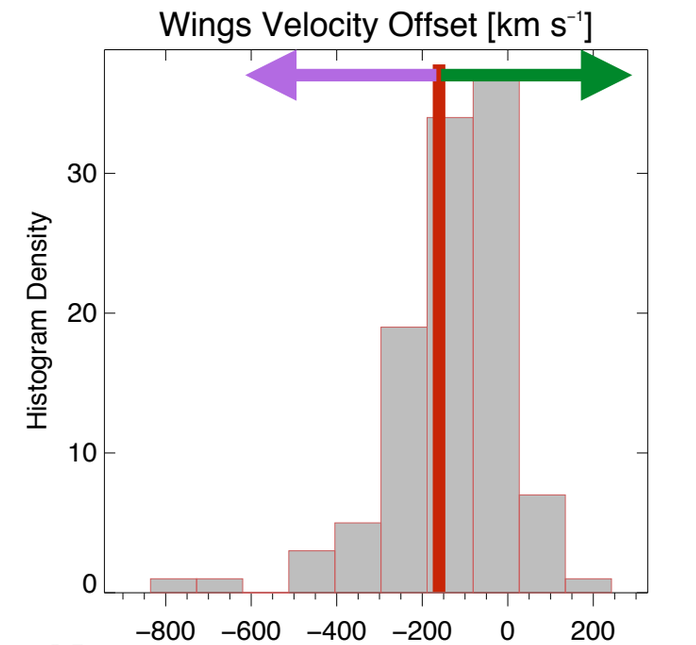
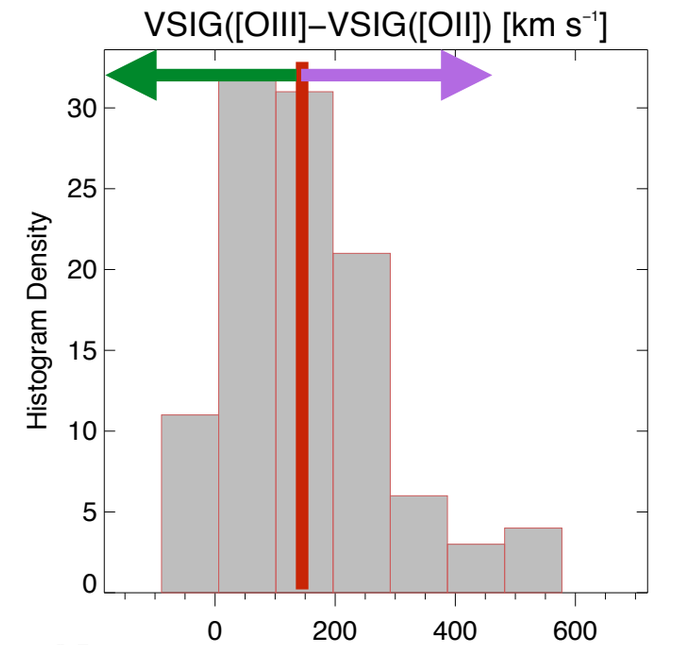
- Sample: ~100 luminous unobscured quasars from SDSS DR7 and DR 10 with z < 1 observed by Herschel: *SFRs & [OIII] Line widths*
- Mean SFR in four z bins: outflow-dominated and unperturbed galaxies.
- Results are clearly in contrast with the negative AGN model







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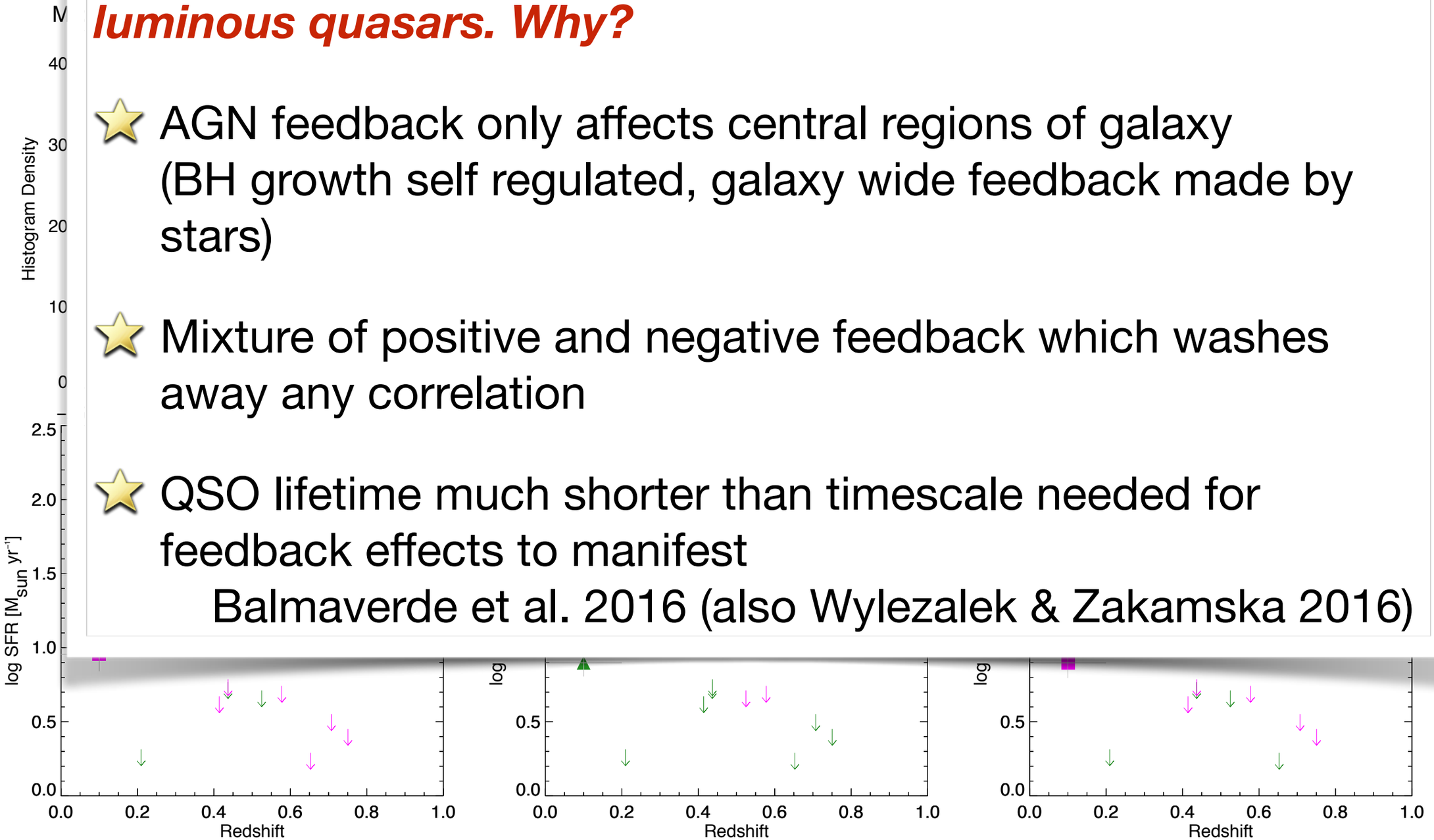
- Re

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

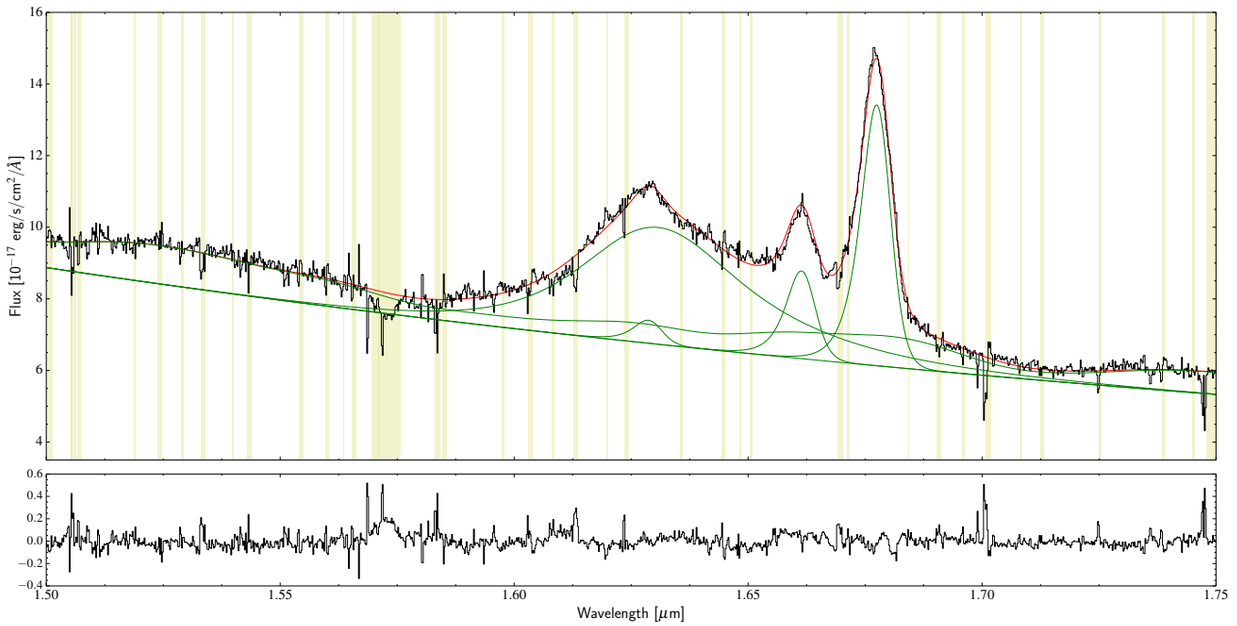
- AGN feedback only affects central regions of galaxy (BH growth self regulated, galaxy wide feedback made by stars)
- Mixture of positive and negative feedback which washes away any correlation
- QSO lifetime much shorter than timescale needed for feedback effects to manifest

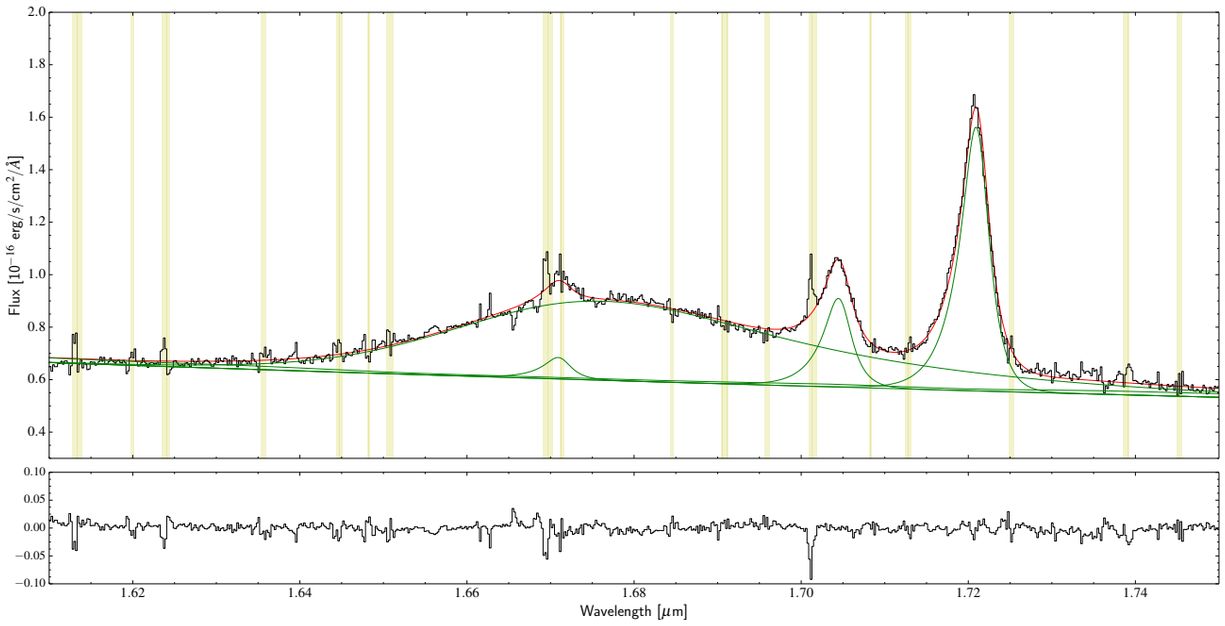
Balmaverde et al. 2016 (also Wylezalek & Zakamska 2016)

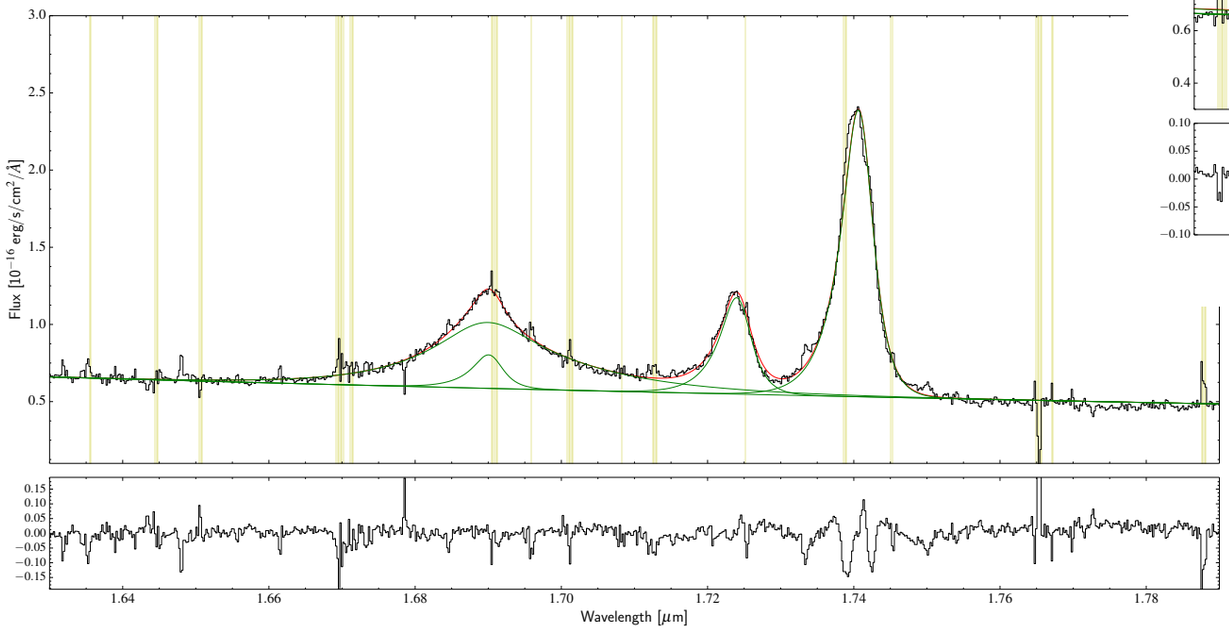


Ionized outflows in luminous quasars

- 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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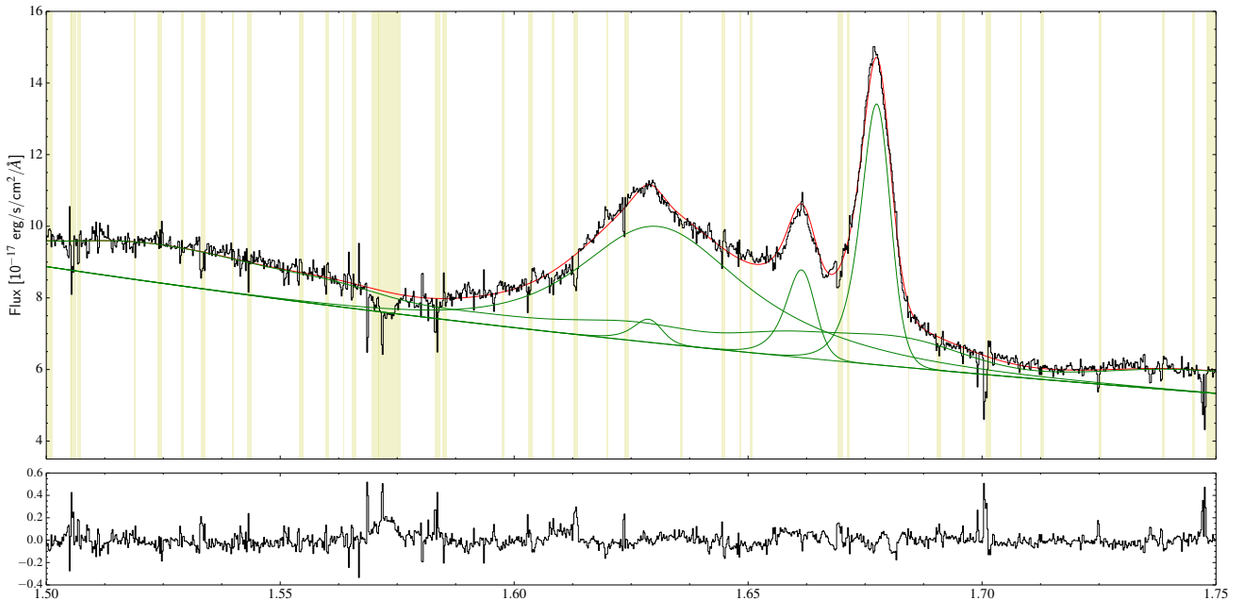

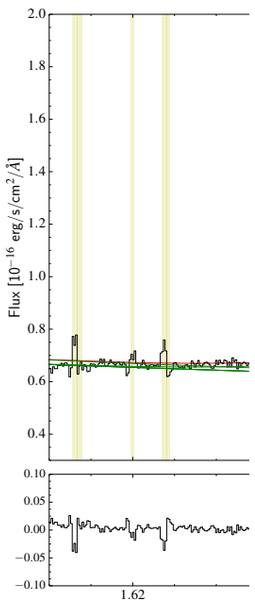

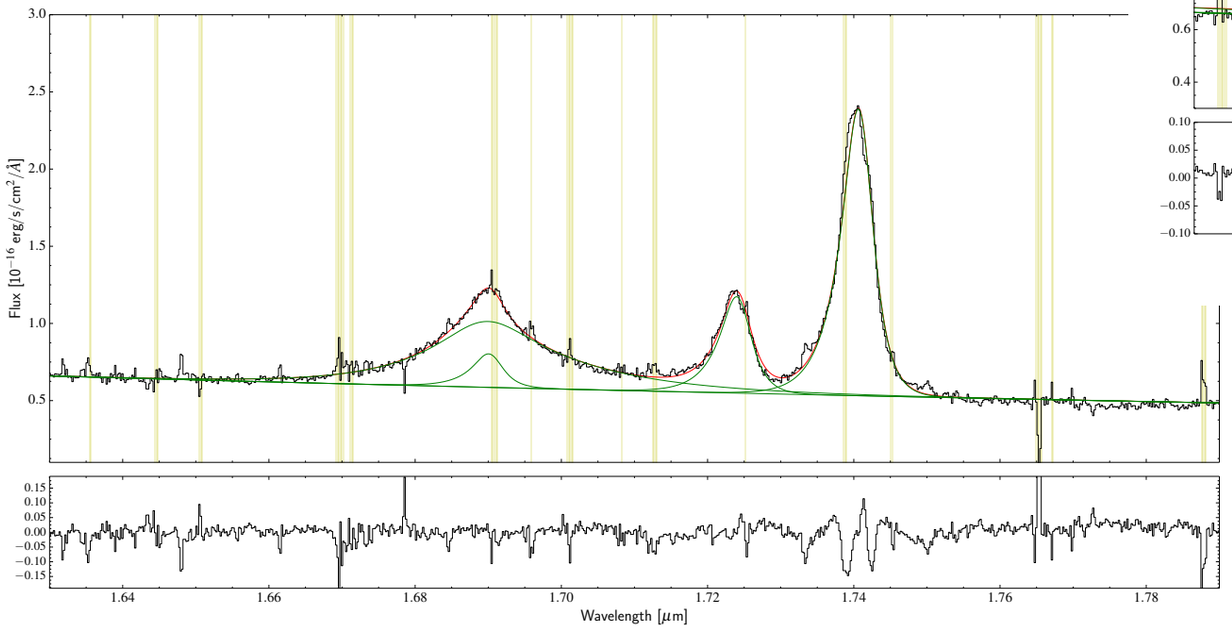

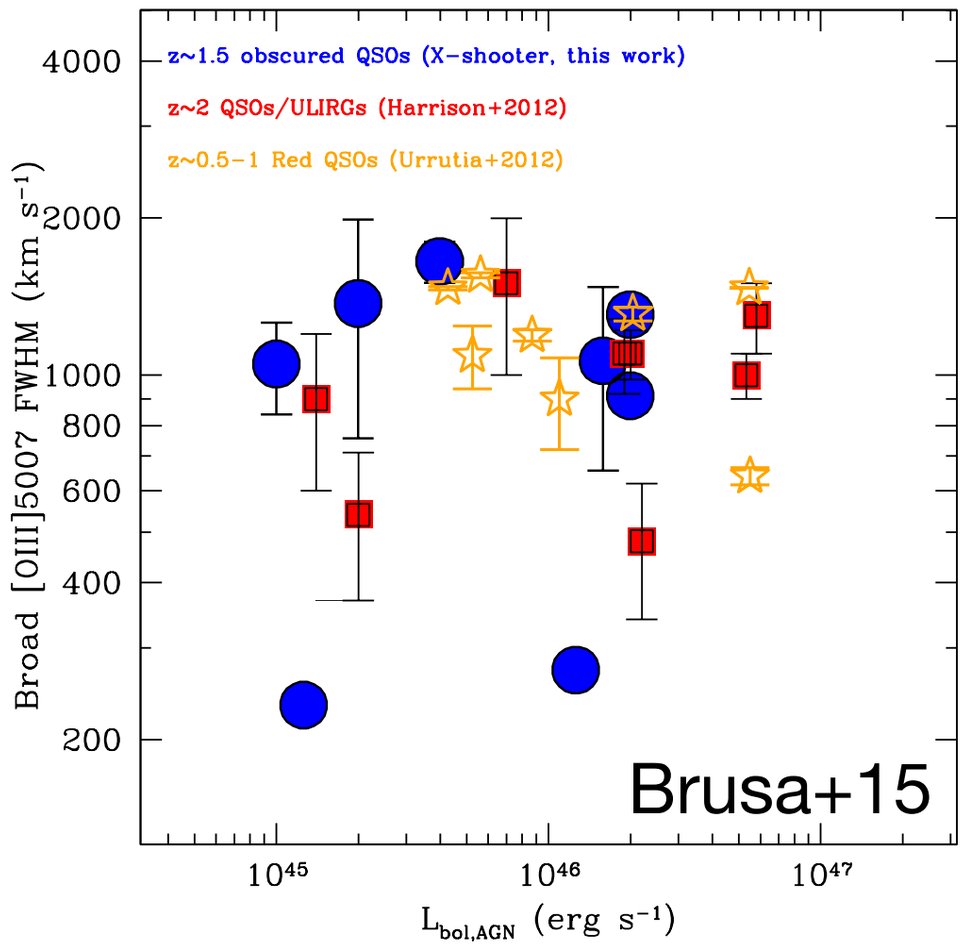

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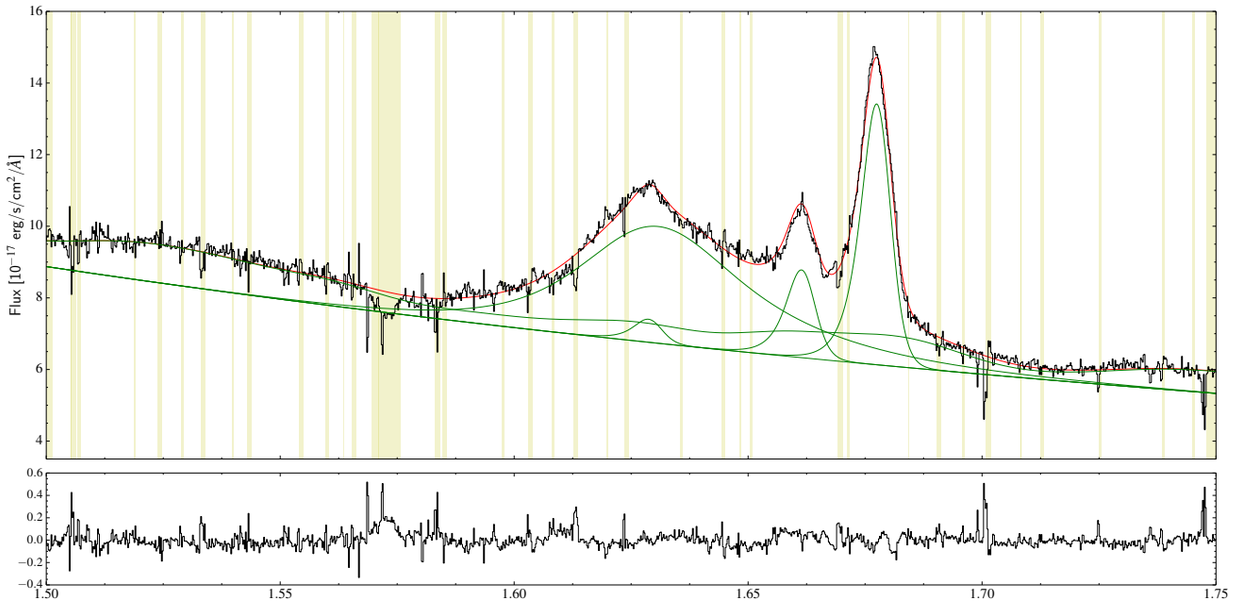
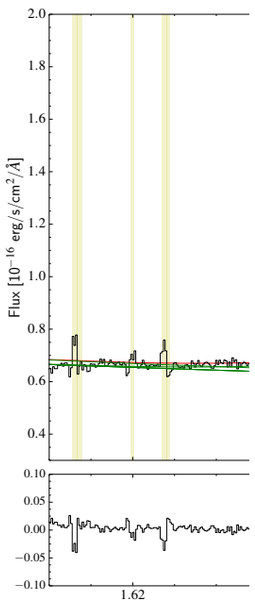
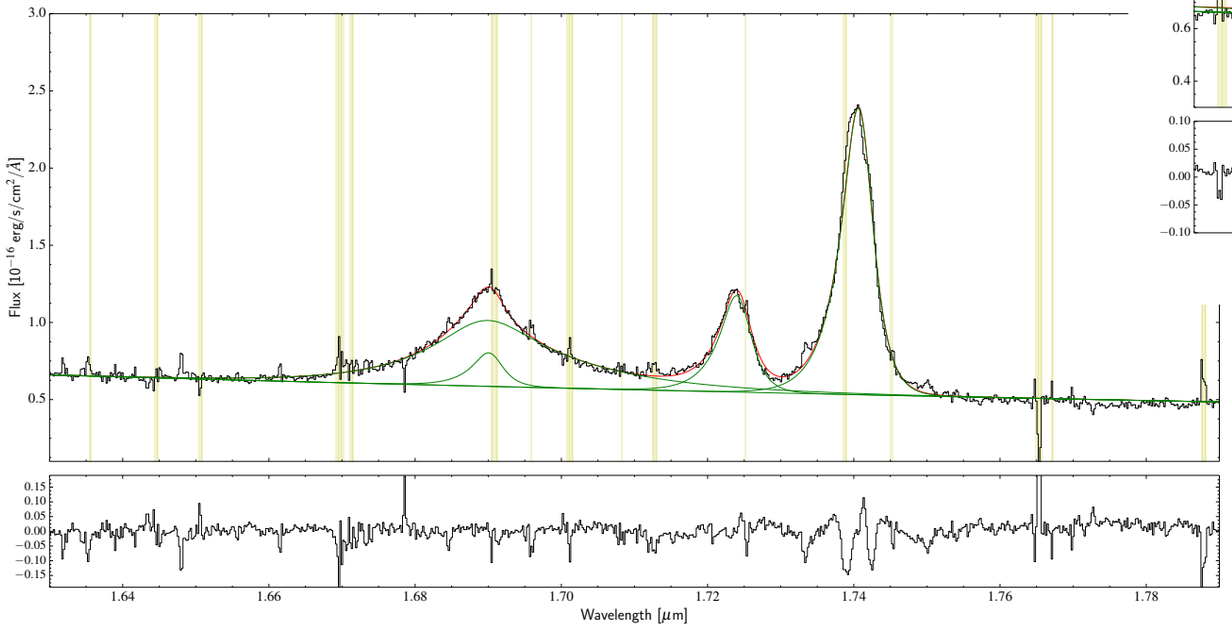
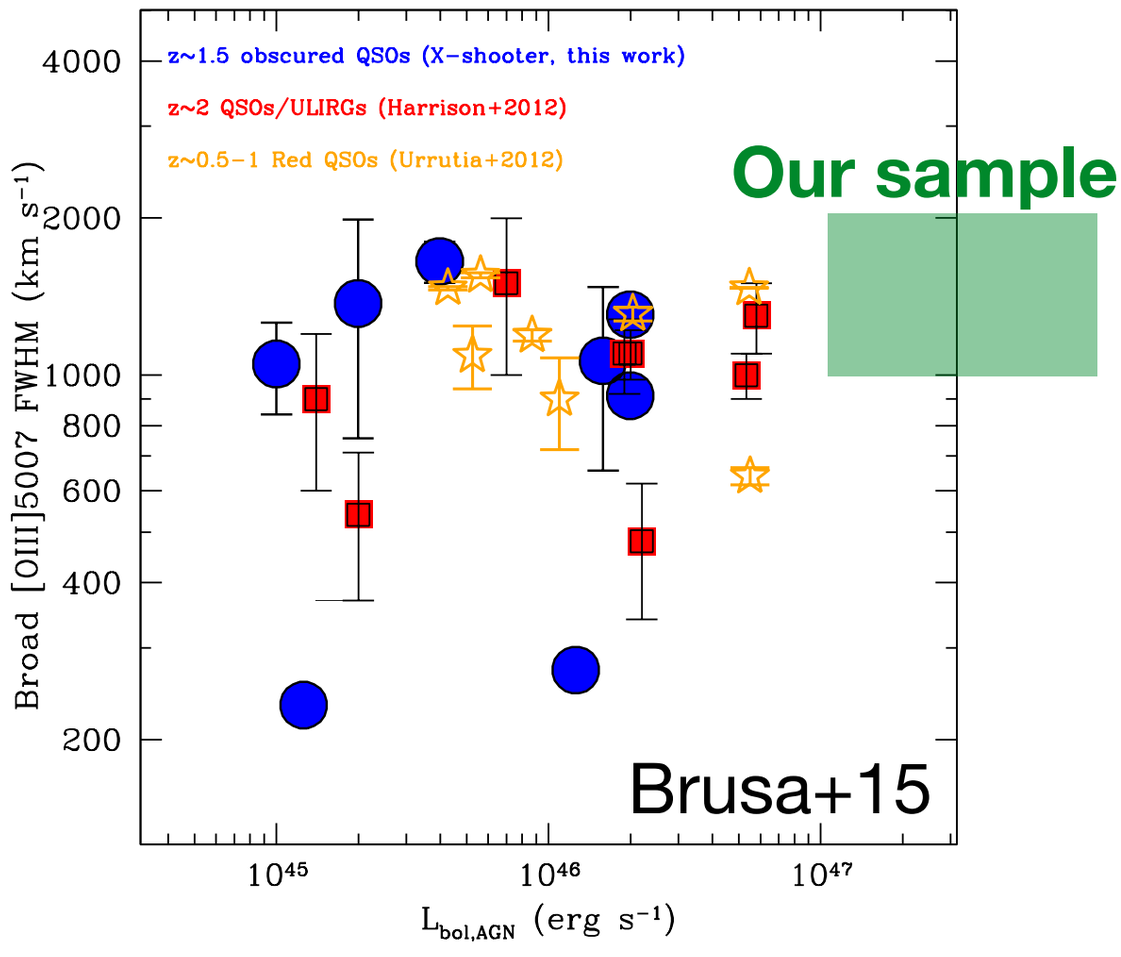
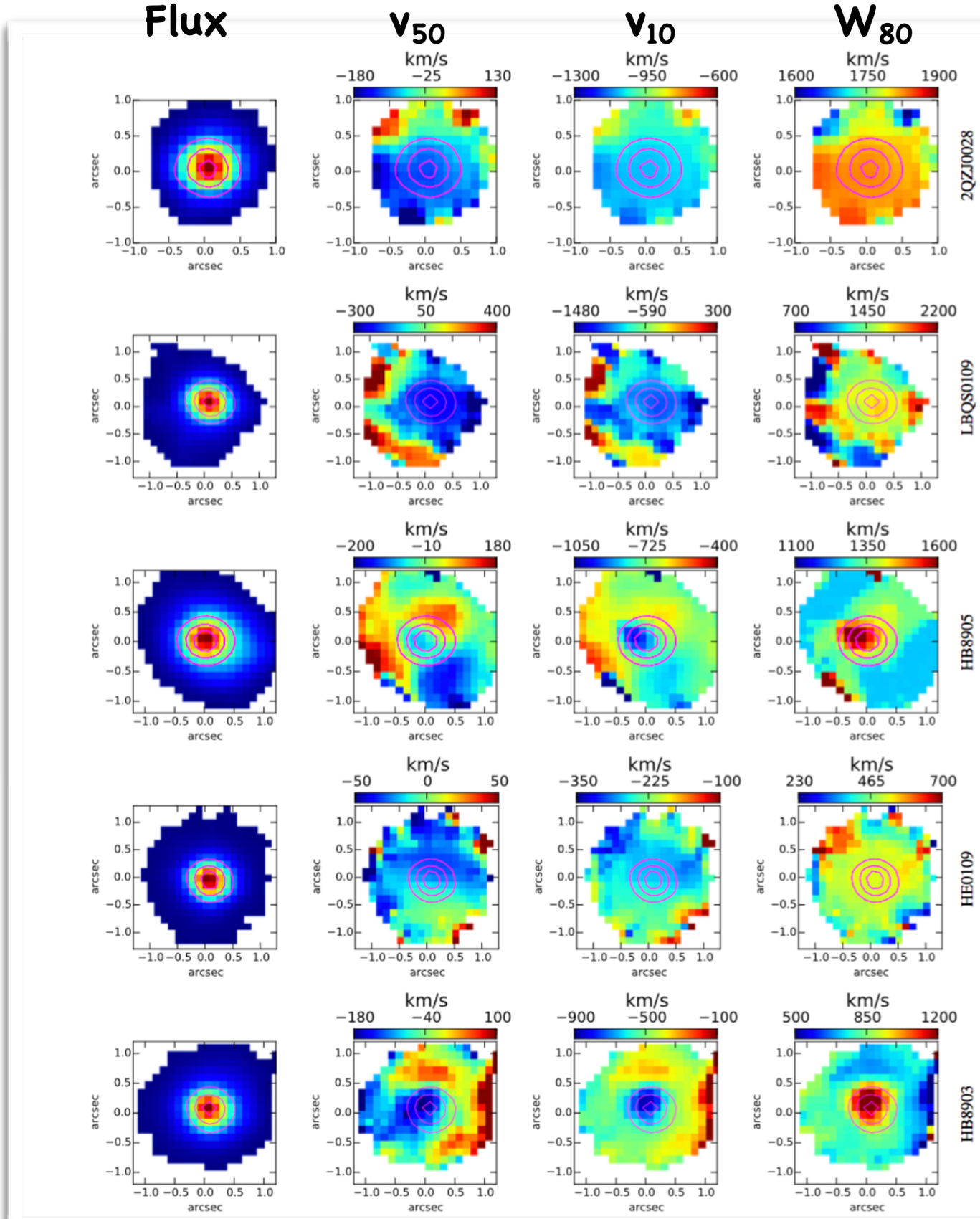


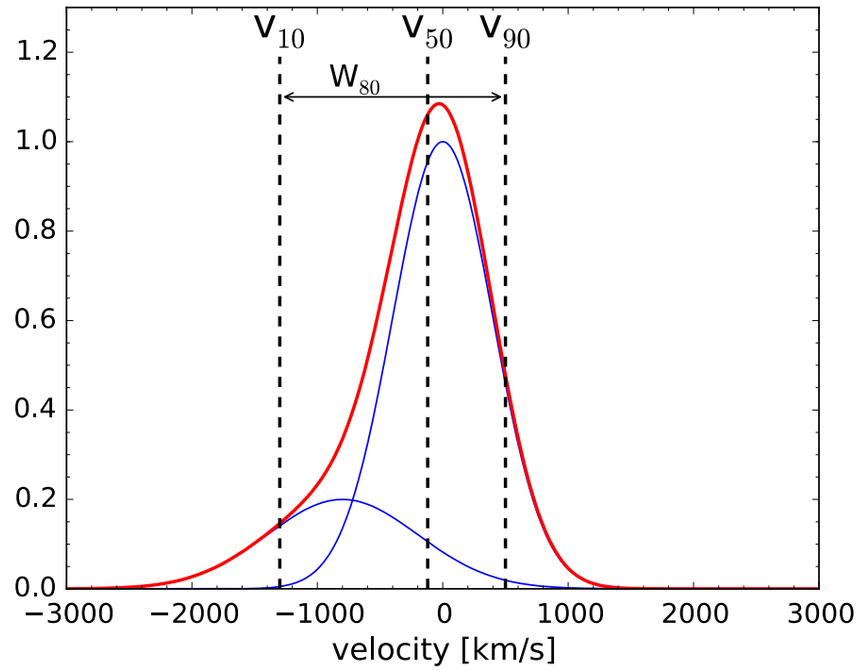






[OIII] Kinematic Analysis





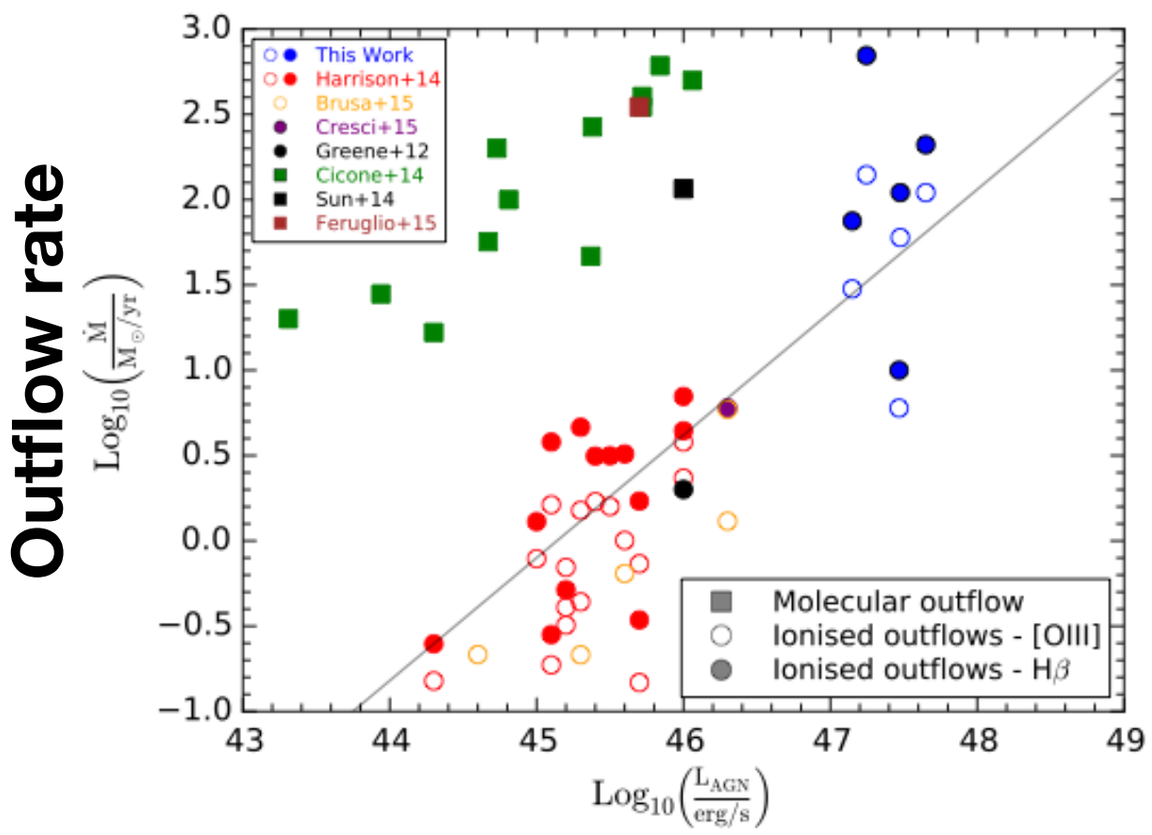
Spatially resolved [OIII] kinematical maps for 5 objects

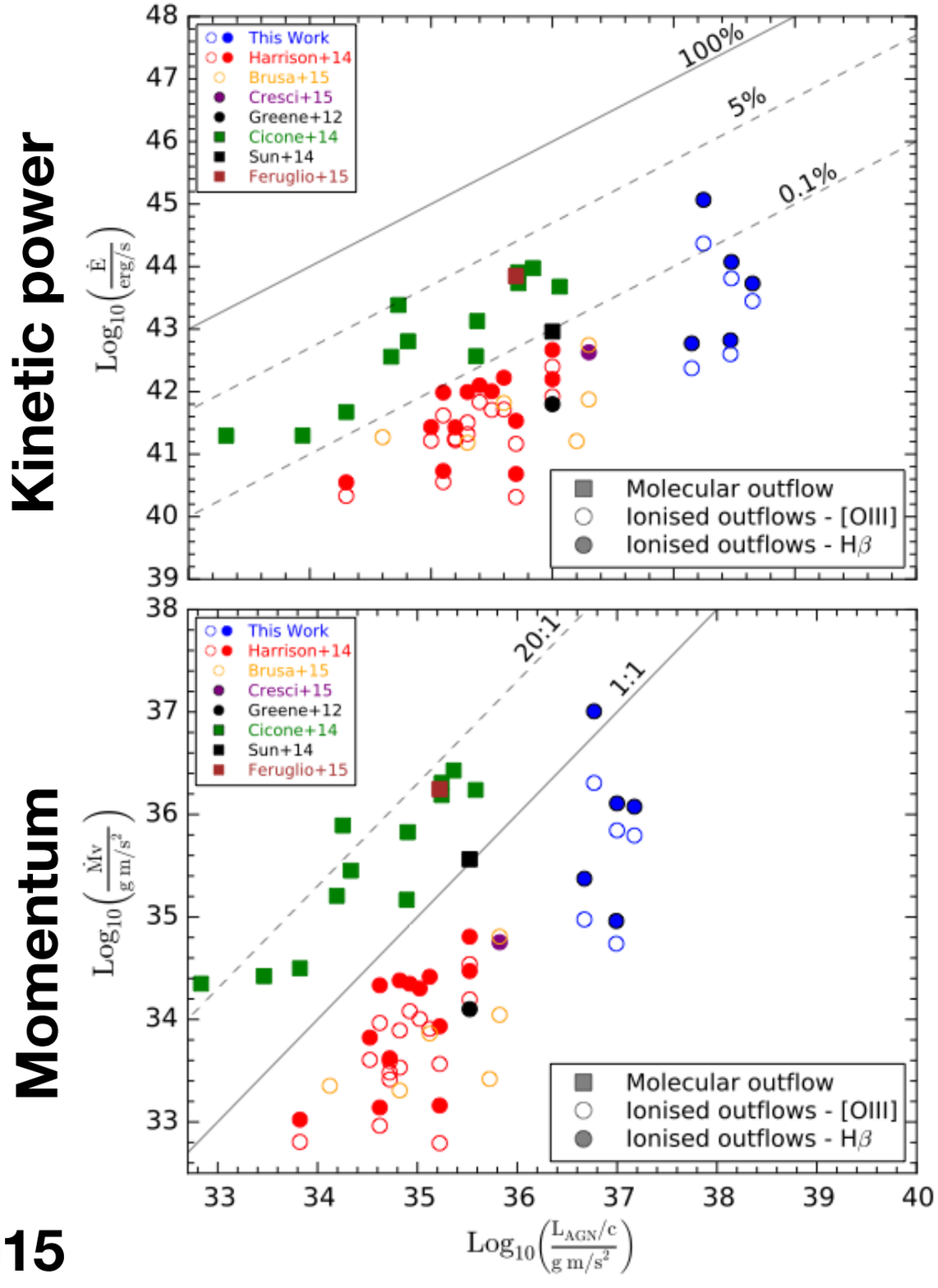
Velocity dispersion up to 900 km/s

Outflow velocities > 500 km/s

Ionized outflows in luminous quasars

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



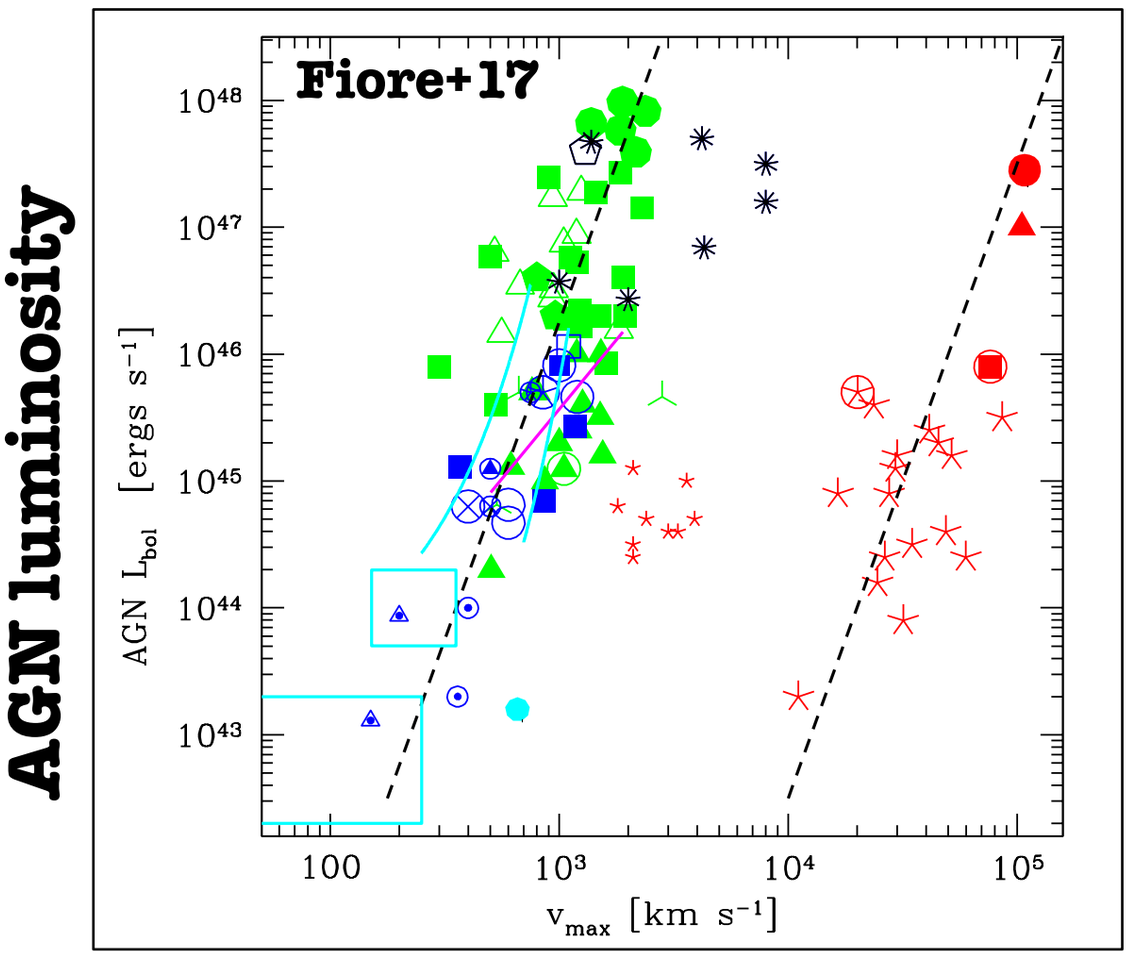


- Molecular outflows in local AGN (Cicone+2014)
- [OIII] outflows in Type 2 local AGN (Harrison+2014)
- [OIII] outflows in X-ray obscured AGN (Brusa+2014)
- [OIII] outflows in z~2.5 quasars (Carniani+, 2015)

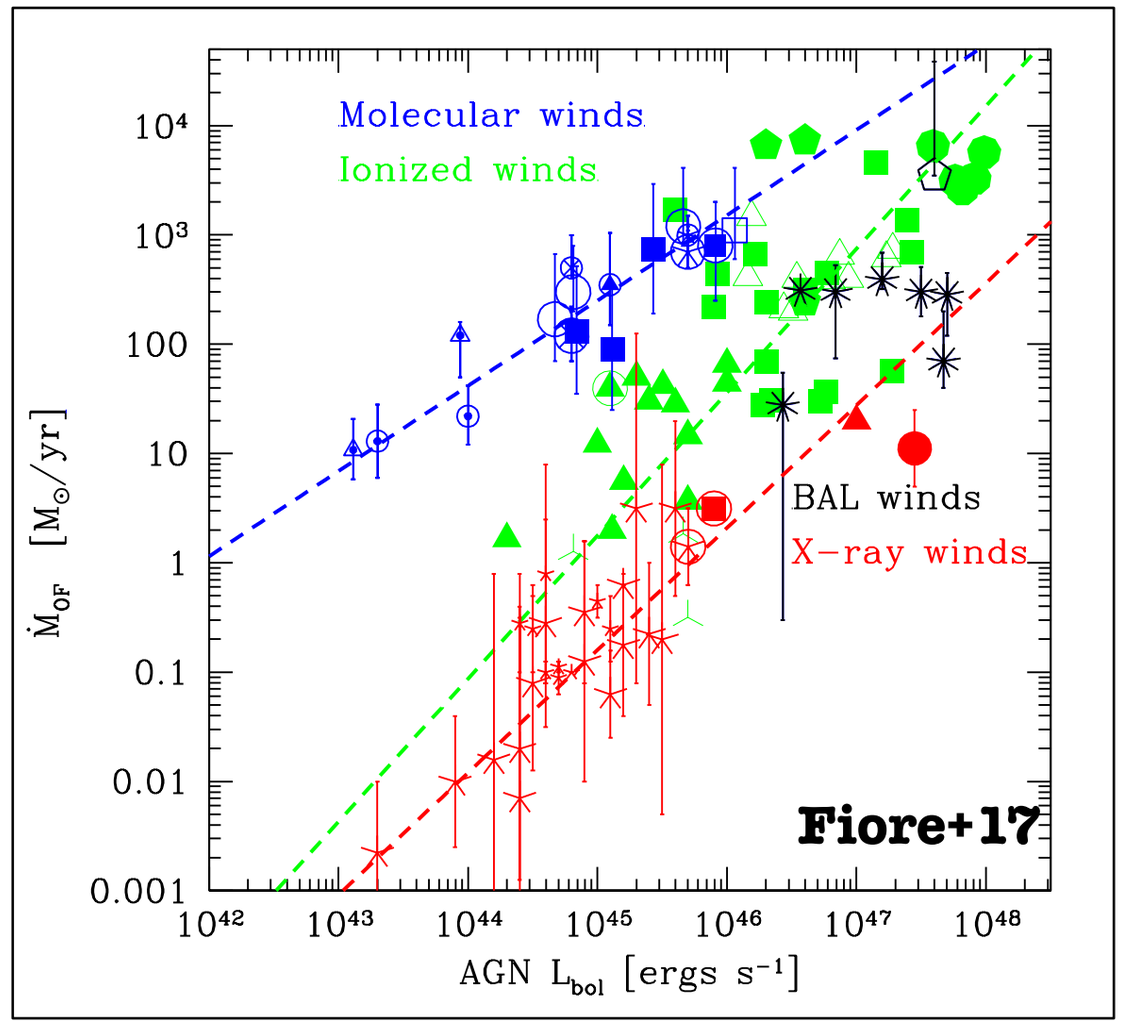
Carniani, AM+, 2015

Ionised Outflows Properties

$$\dot{M} \simeq \frac{M_{out} v_{out}}{R_{out}}$$



Outflow velocity



AGN luminosity

$$M = 8 \times 10^7 M_\odot \left(\frac{C}{10^{[O/H]}}\right) \left(\frac{L_{[OIII]}}{10^{44} erg/s}\right) \left(\frac{< n_e >}{500 cm^{-3}}\right)^{-1} \quad T_e = 10^4 K$$

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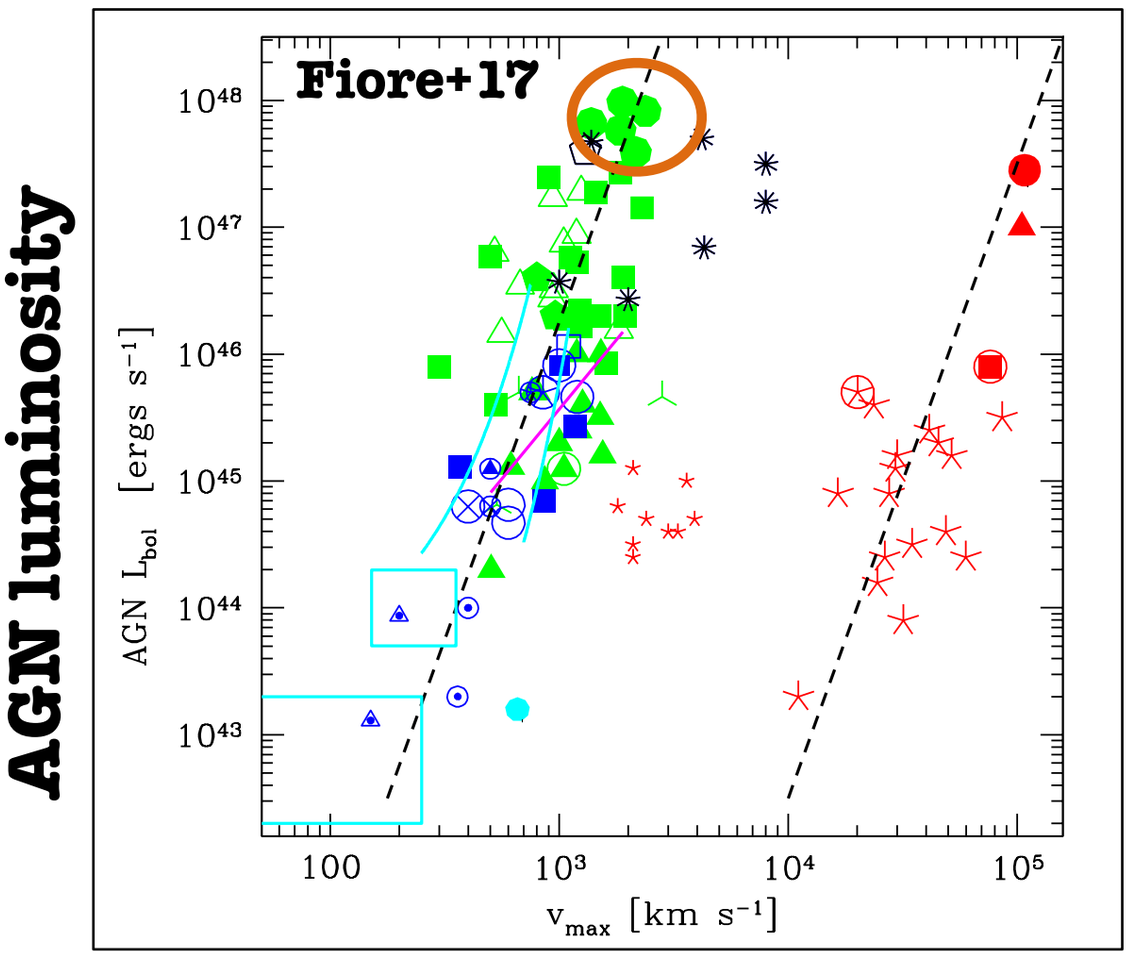

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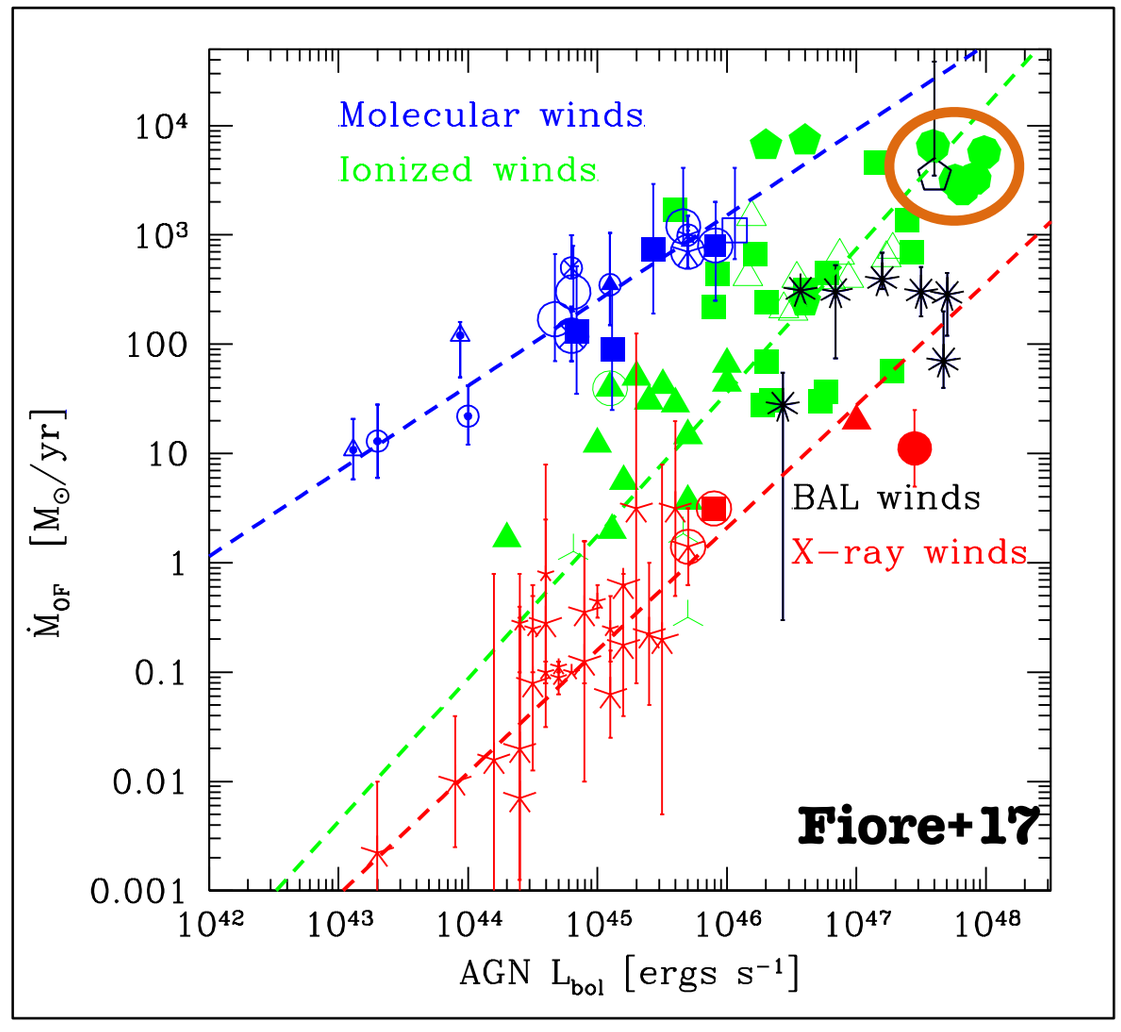

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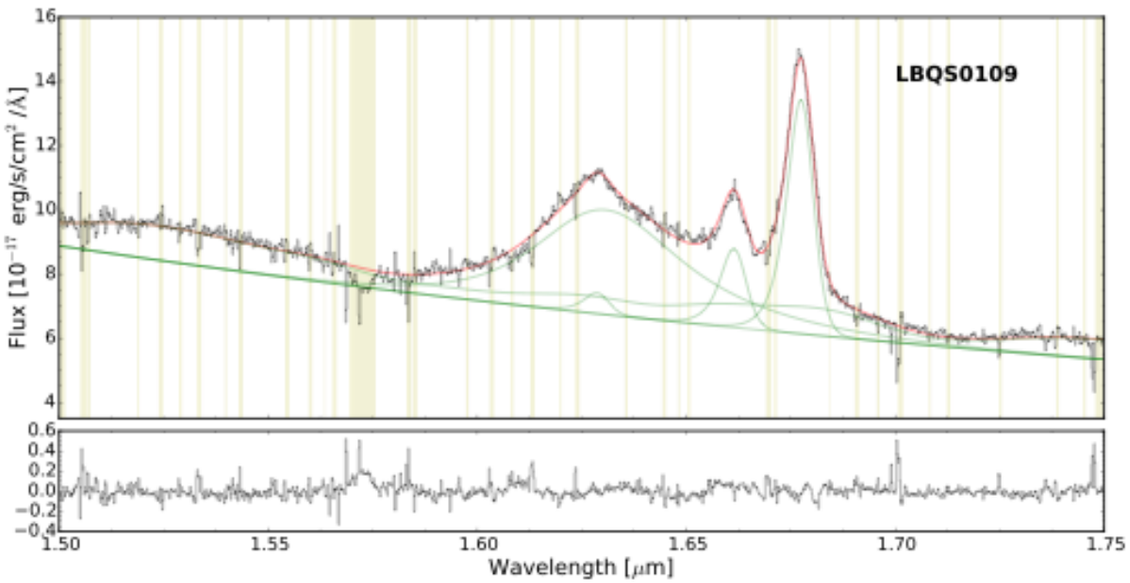
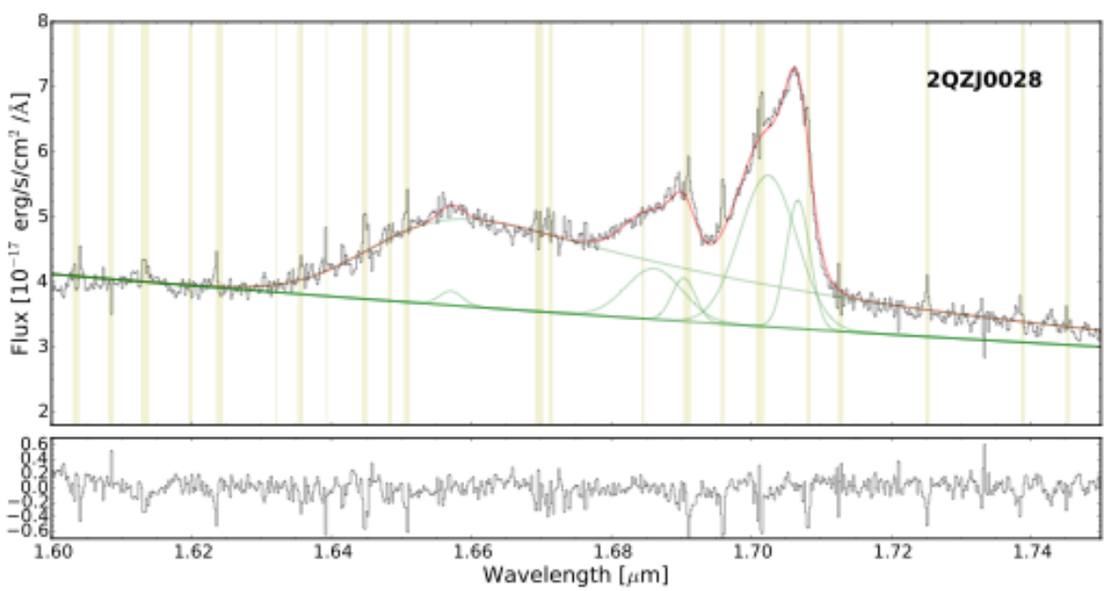
Ionized outflows in luminous quasars

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

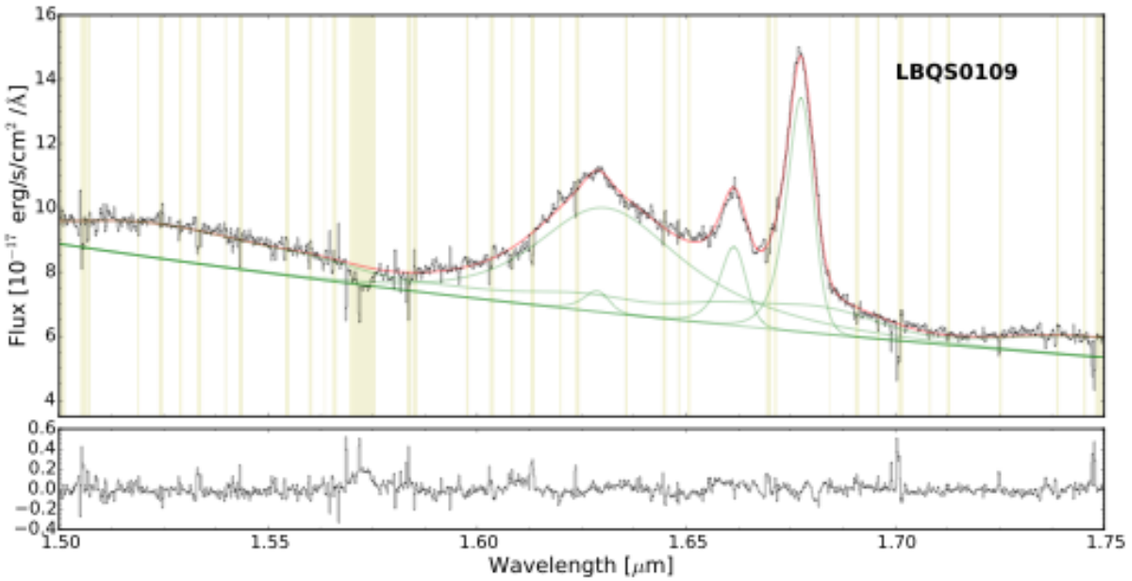


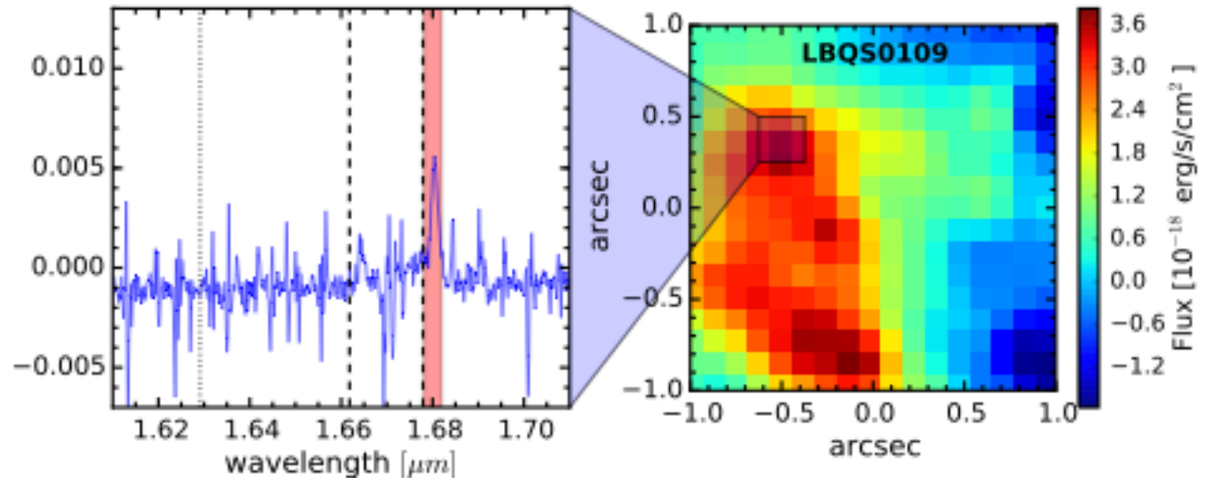


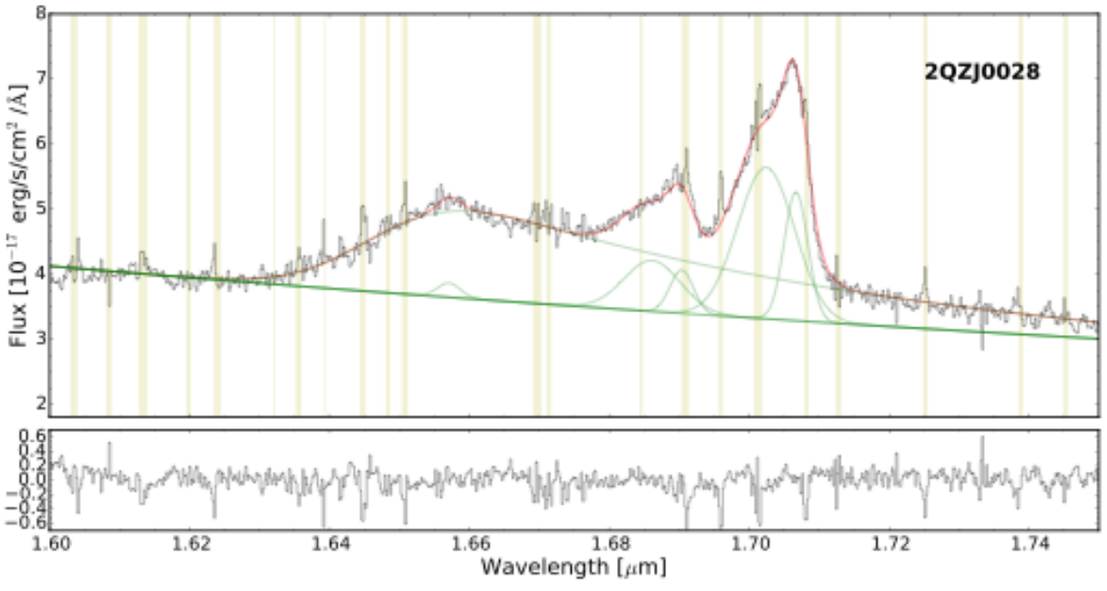
Ionized outflows in luminous quasars

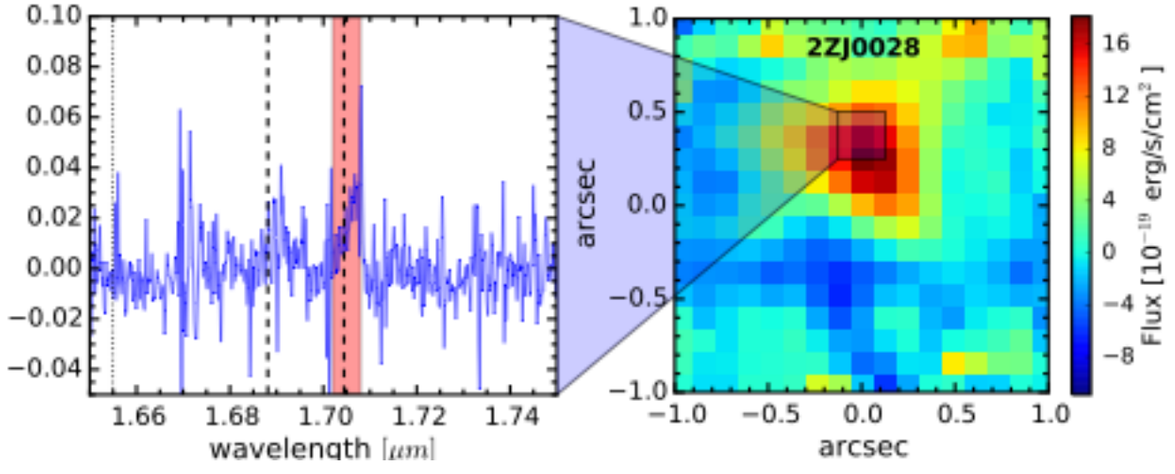
Subtract “broad” (~1000-1500 km/s) [OIII] ➙ outflow

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





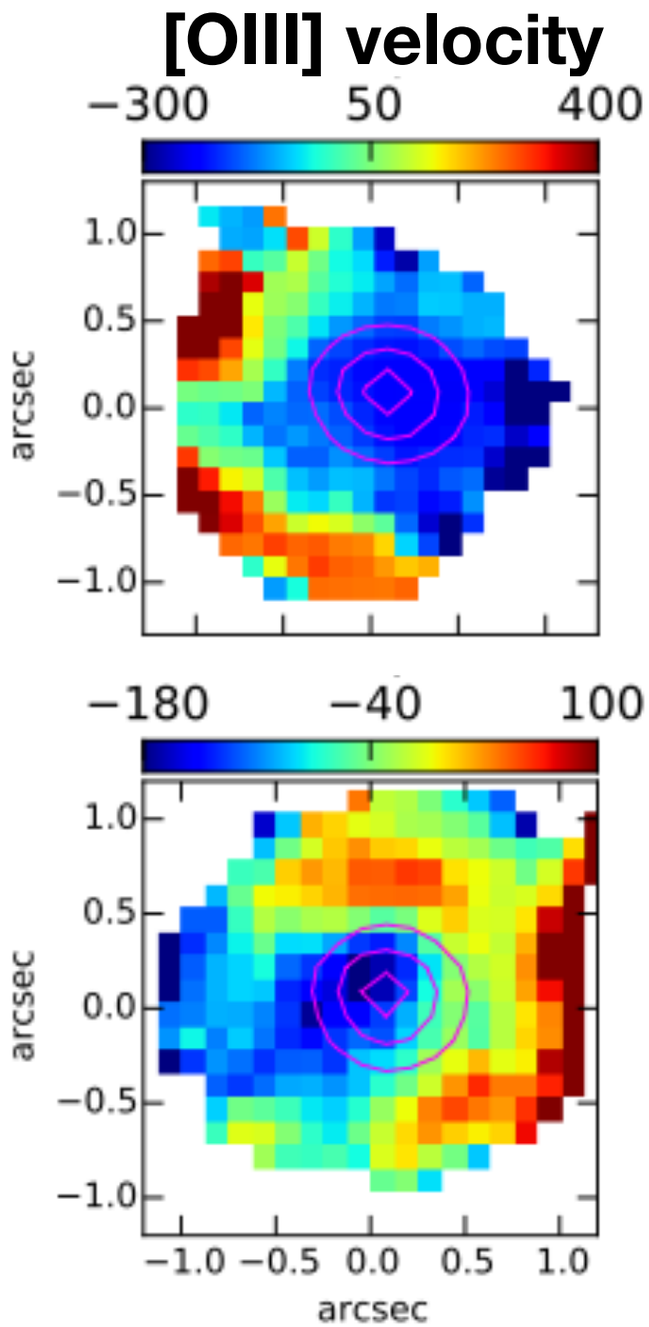




Ionized outflows in luminous quasars

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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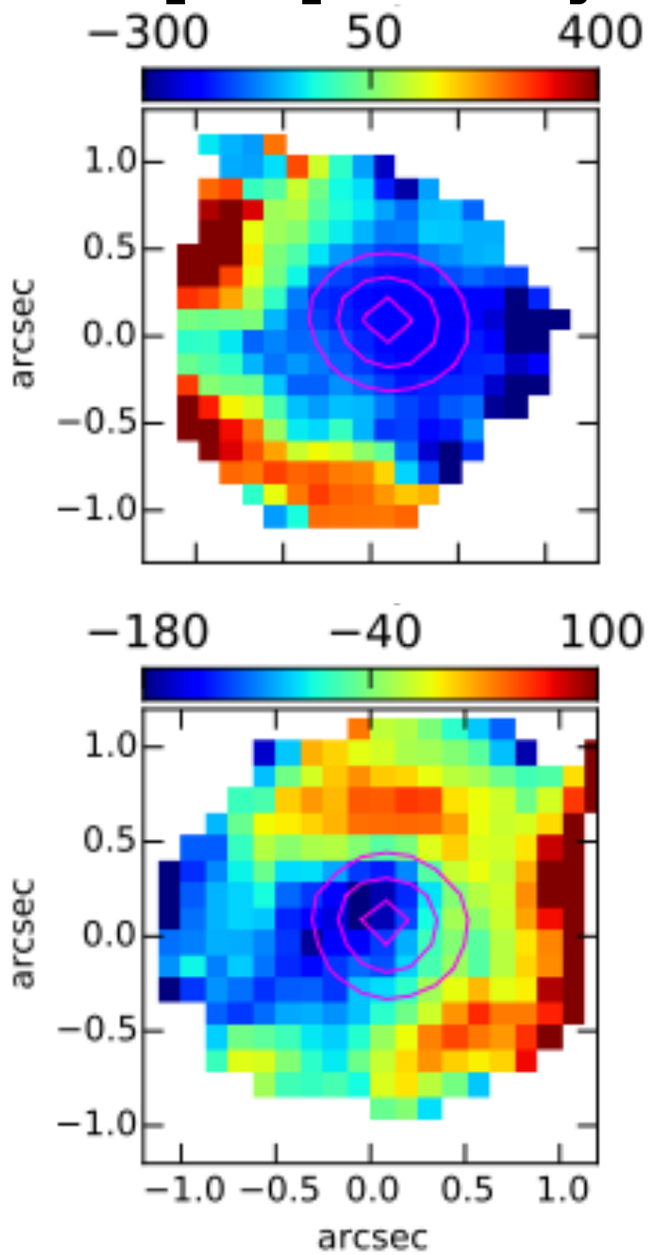
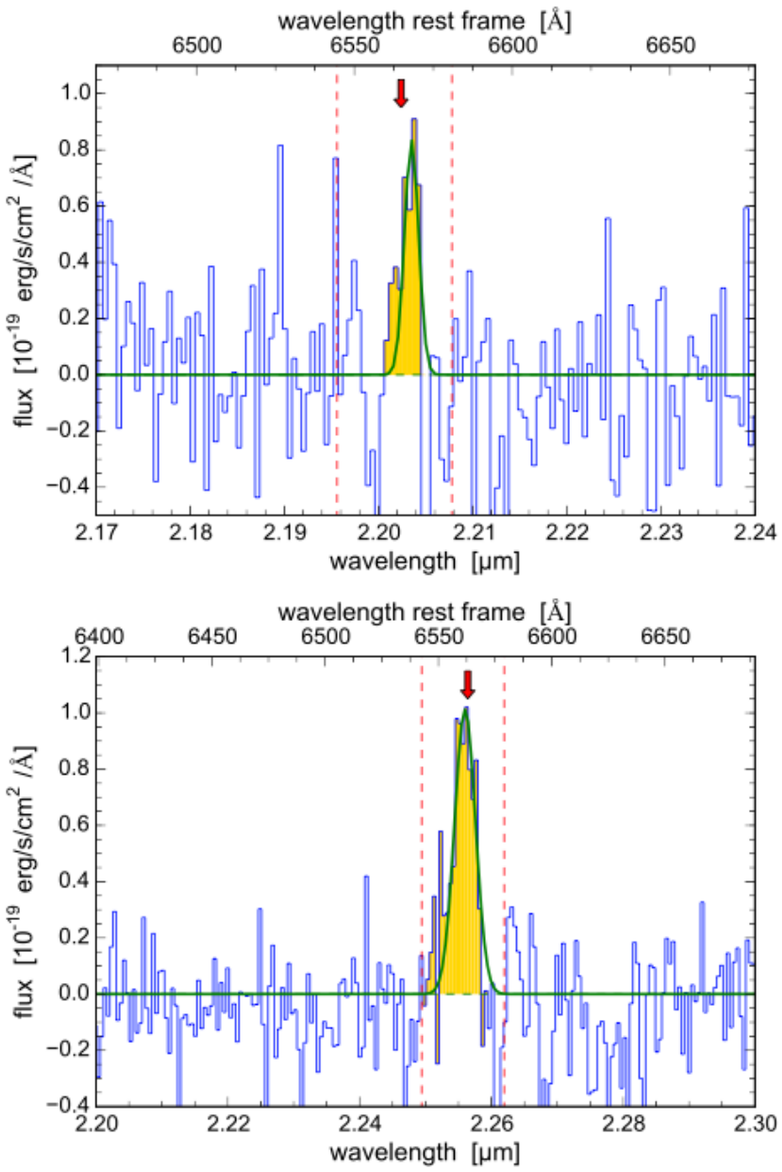
[OIII] velocity



K band: broad Hα subtracted



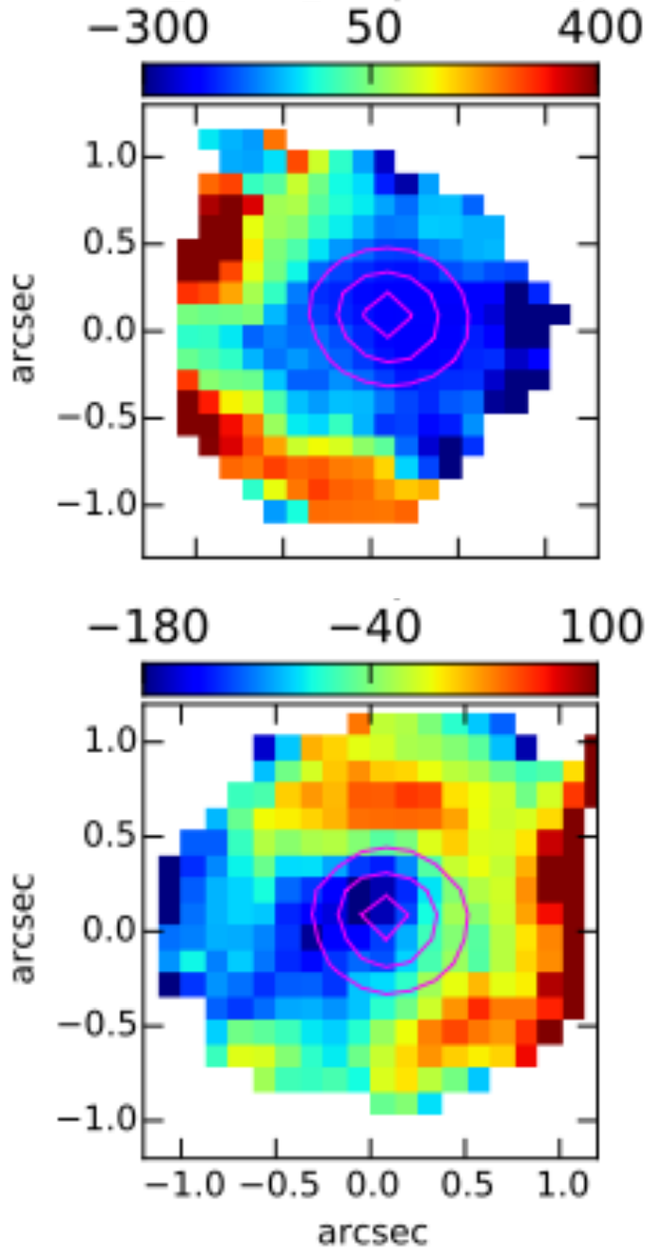
Ionized outflows in luminous quasars

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!

[OIII] velocity



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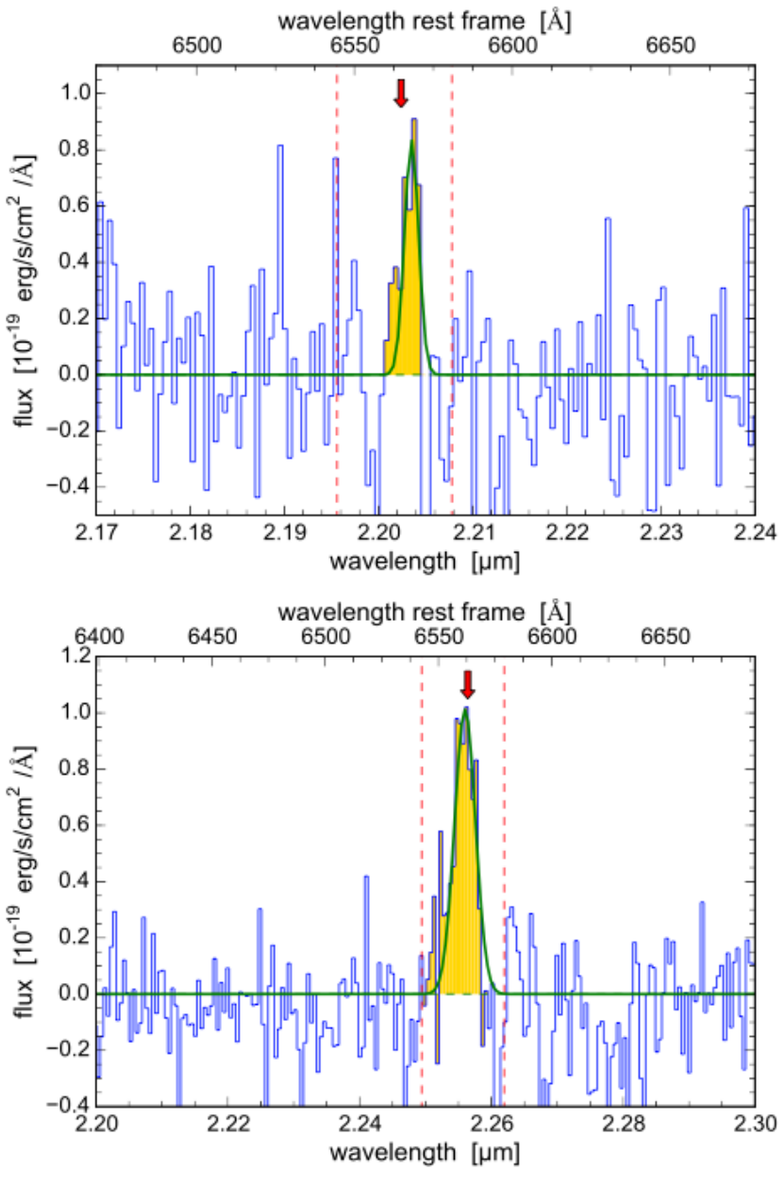
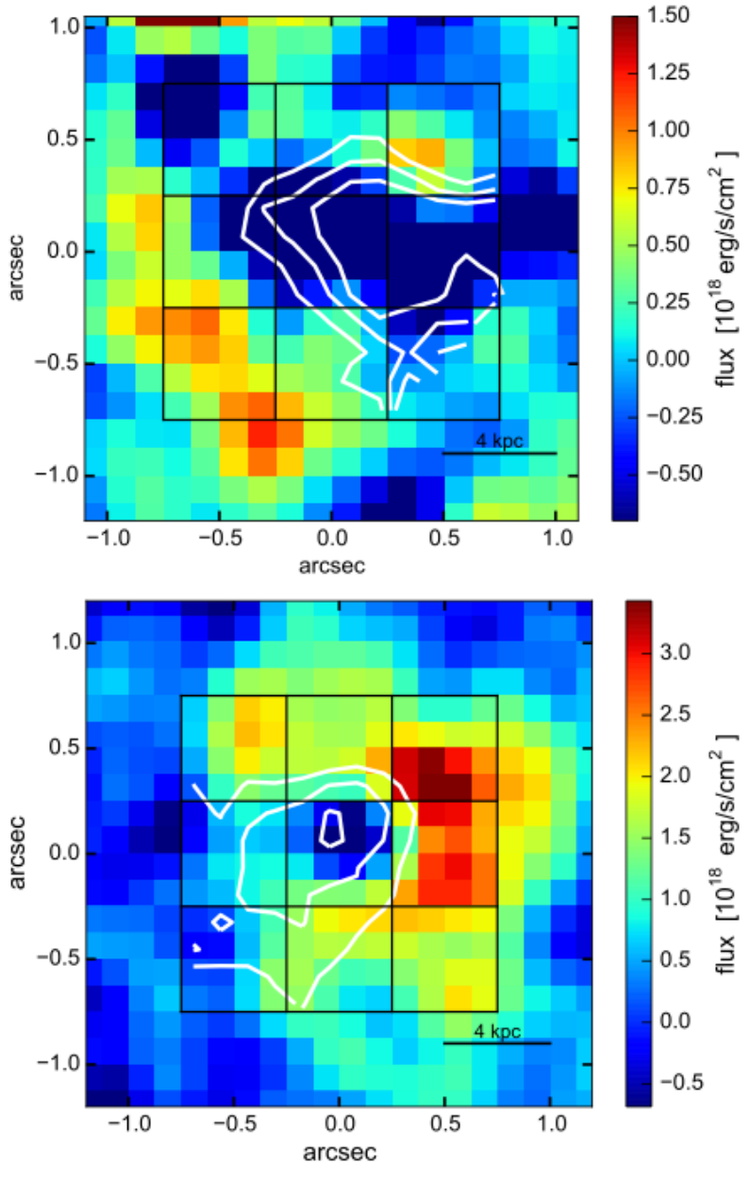


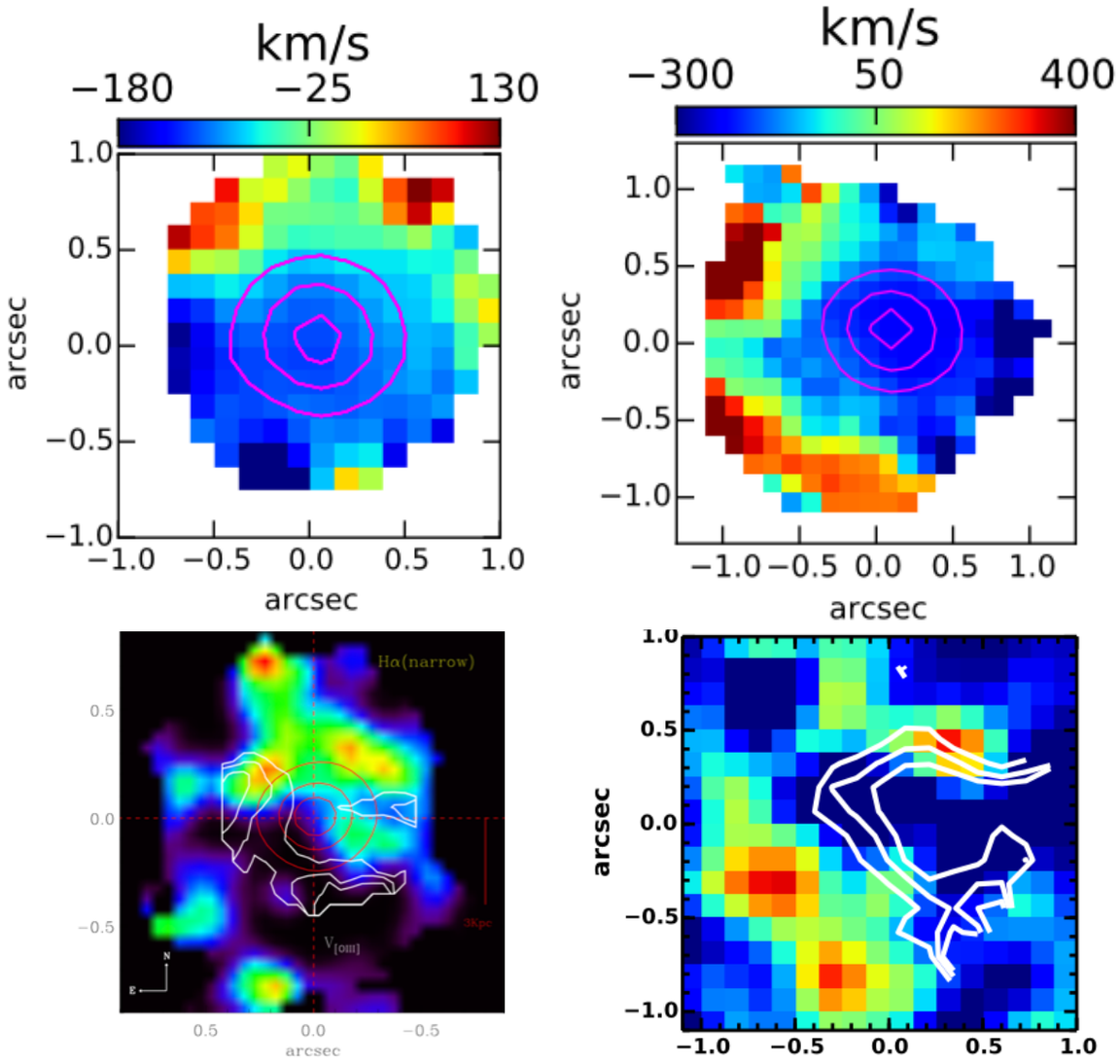
Narrow Hα flux



Negative Feedback

The effects of AGN-driven outflows on SF are clearly visible.

Vel. map of broad [OIII] comp. (outflow)



Flux map of narrow Ha comp. (SF)

Cano-Diaz+12, Carniani+15,+16

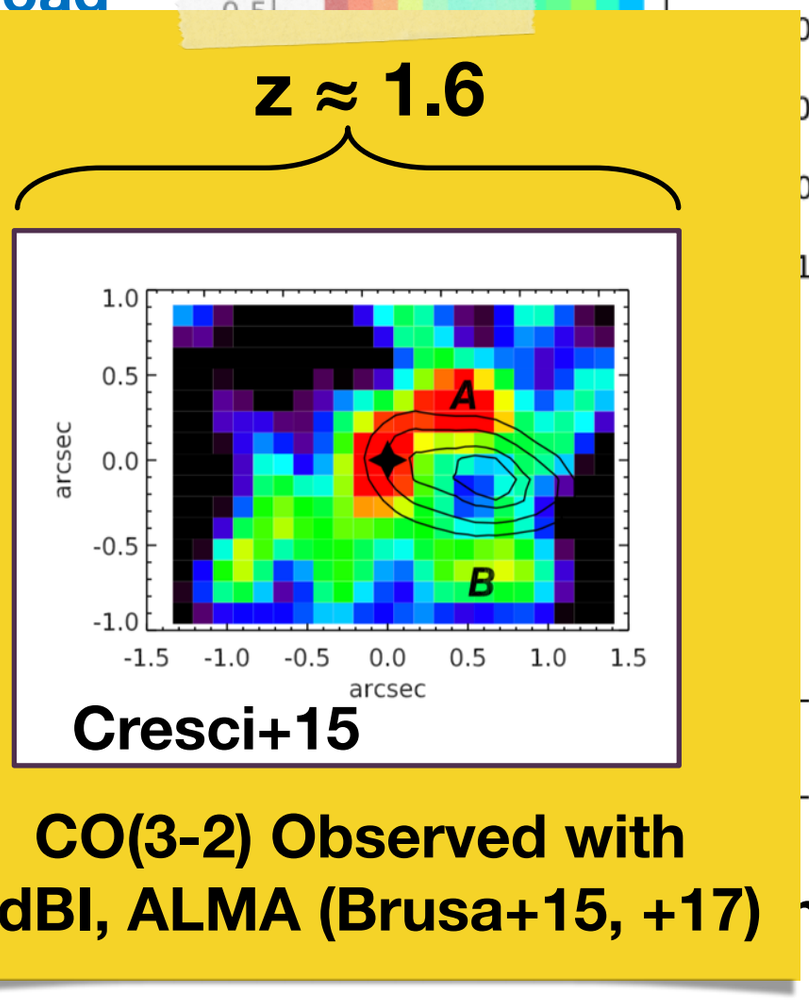
Negative Feedback

The effects of AGN-driven outflows on SF are clearly visible.

Vel. map of broad

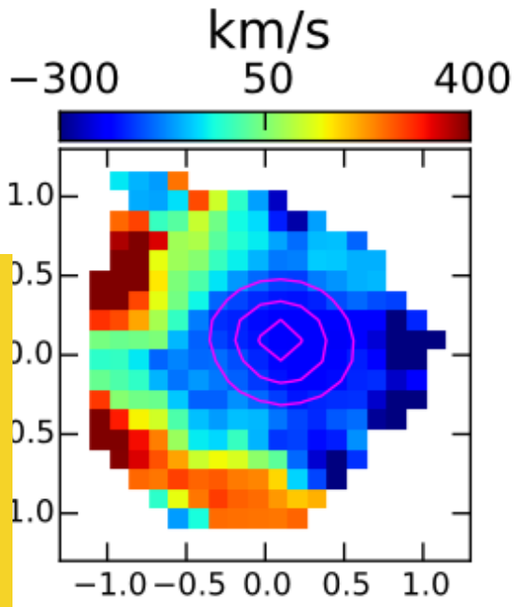
Flu of Ha

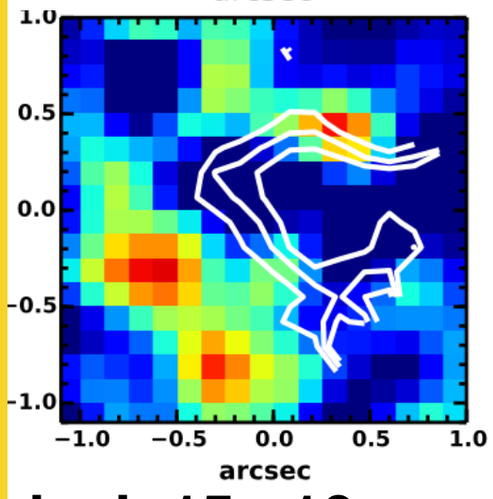
z ≈ 1.6



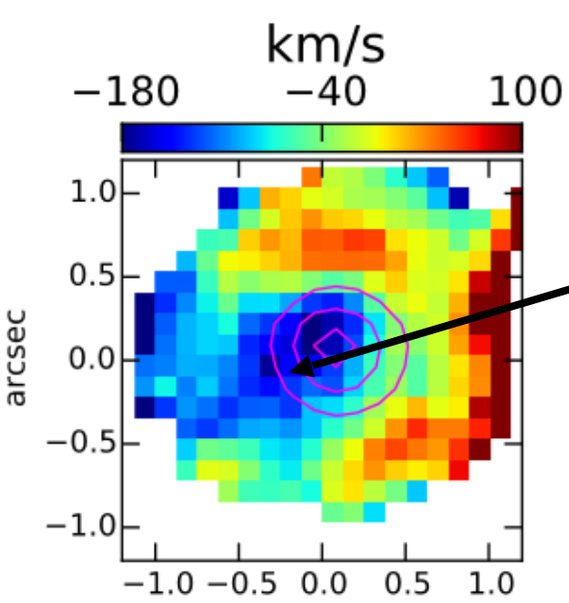
Cresci+15

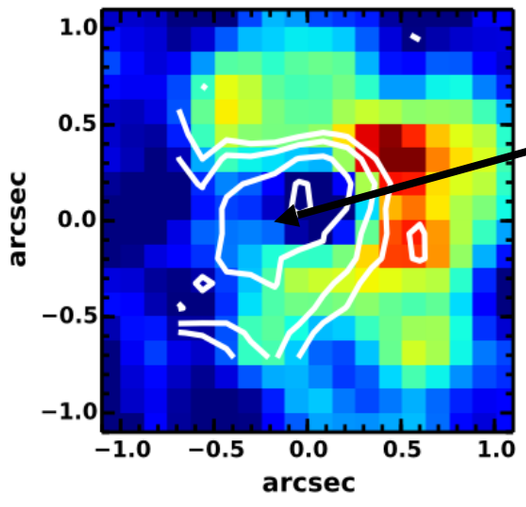
CO(3-2) Observed with PdBI, ALMA (Brusa+15, +17)





niani+15,+16





ionised outflow

SF is suppressed by the outflow

Negative F…back

The e… …ble.

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

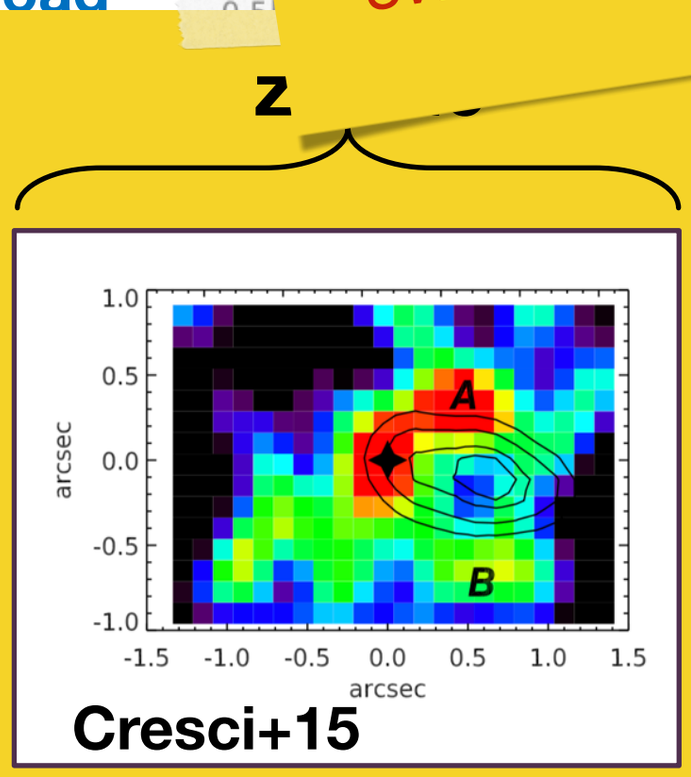
Detailed analysis of high luminosity quasars provides evidence for fast outflows quenching star formation, AGN feedback revealed! (?)

Vel. map of broad

c… (o…

Flu… of … Ha

z



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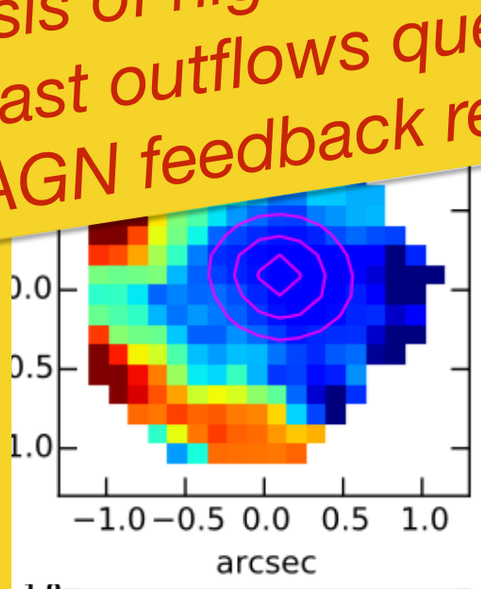

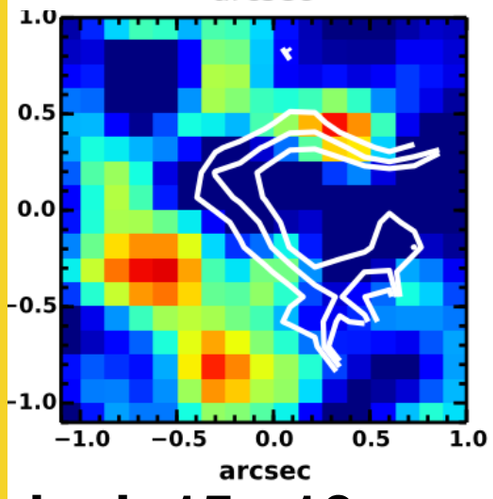

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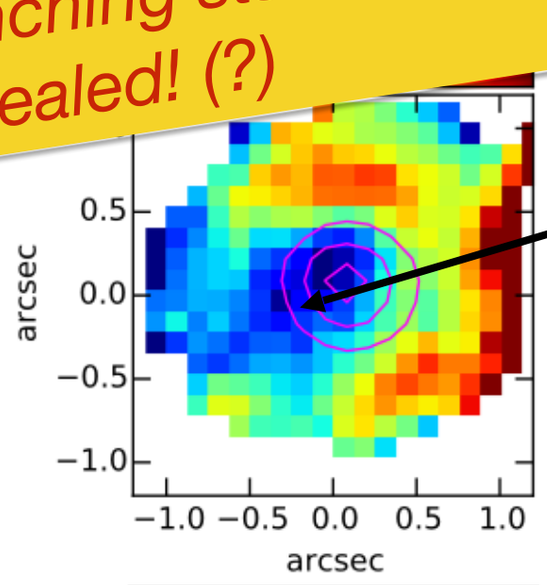

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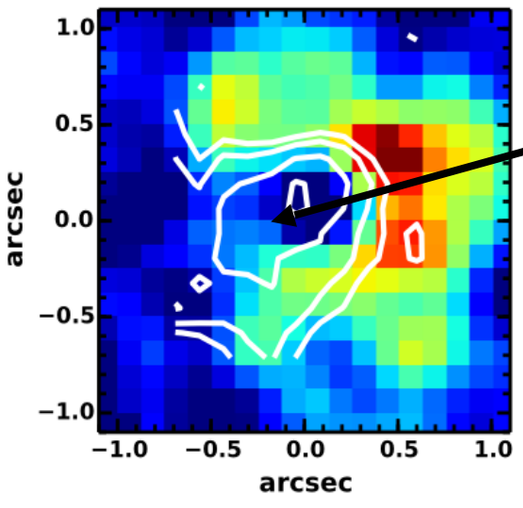

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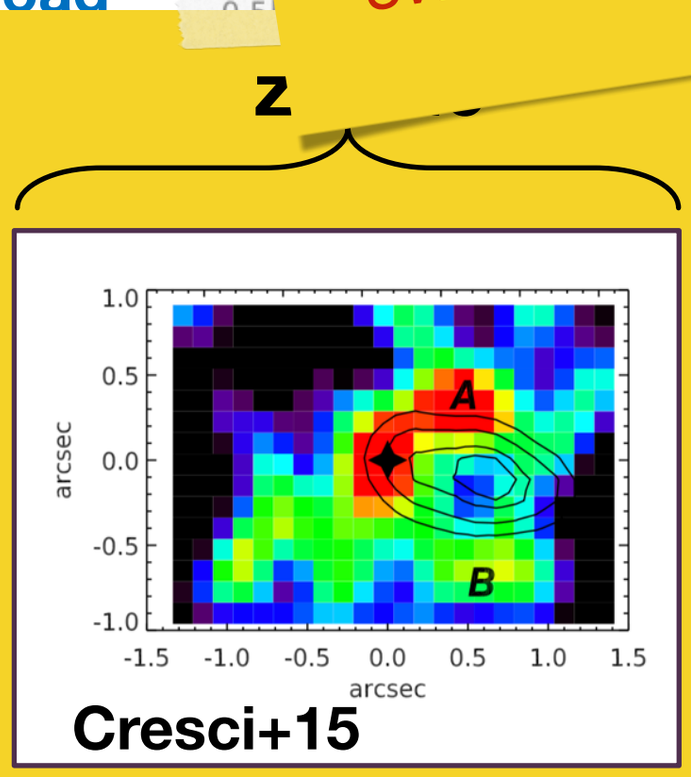

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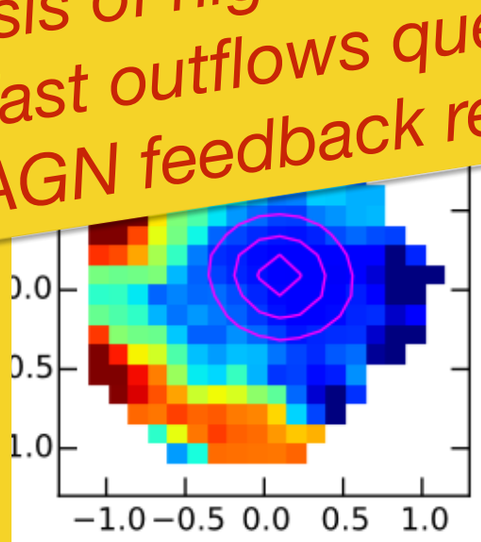

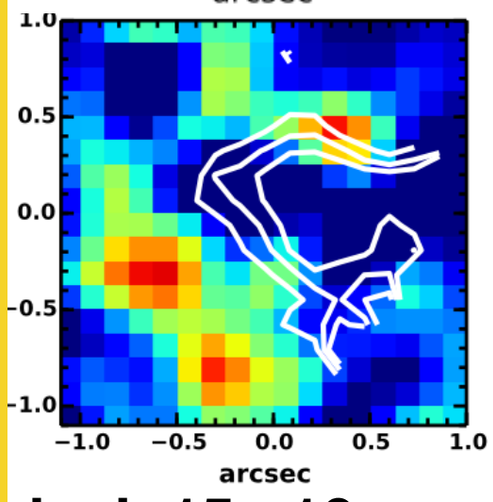

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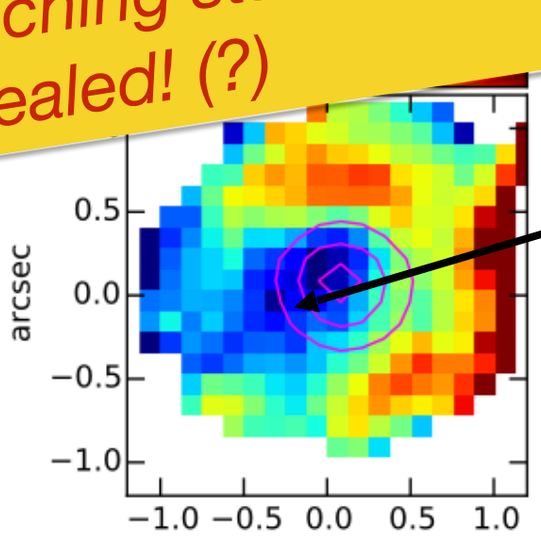

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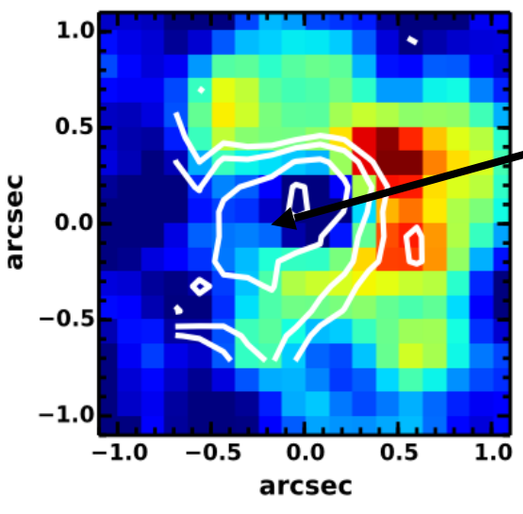

SF is suppressed by the outflow

Molecular gas? → **ALMA Cycle 2&3**
Follow-up: Band 3 0.5” beam (~ SINFONI PSF)
GOAL: CO(3-2) emission

ALMA observations

t_{exp} ~1 h per target

CO(3-2) emission has been detected only in one out of the three QSOs

	LBQS0109	2QZJ0028	HB8903
S_{3mm} [μJy]	165 ± 12	170 ± 12	5738 ± 18
M_{dust} [10^9 $M_\odot$][a]	0.5-0.8	0.6-0.9	20-30
$\lambda_{CO(3-2)}$ [mm]	2.9094±0.0004	-	-
$z_{CO(3-2)}$ [mm]	2.3558±0.0005	-	-
$FWHM_{CO(3-2)}$ [km/s]	400±60	-	-
$S_{CO(3-2)}\Delta v$ [Jy km/s][b]	0.34 ± 0.03	< 0.09	< 0.08
$L'_{CO(3-2)}$ [10^{10} K km/s pc^2]	1.04 ± 0.33	< 0.3	< 0.3
$L_{CO(3-2)}$ [10^7 $L_\odot$]	1.4 ± 0.2	< 0.4	< 0.3
$M_{gas}(r_{31}=1, \alpha_{CO}=0.8)$ [10^{10} $M_\odot$]	0.8 ± 0.5	< 0.2	< 0.2
$M_{gas}(r_{31}=1, \alpha_{CO}=4)$ [10^{10} $M_\odot$]	4.0 ± 2.4	< 1.2	< 1.0

Carniani+17

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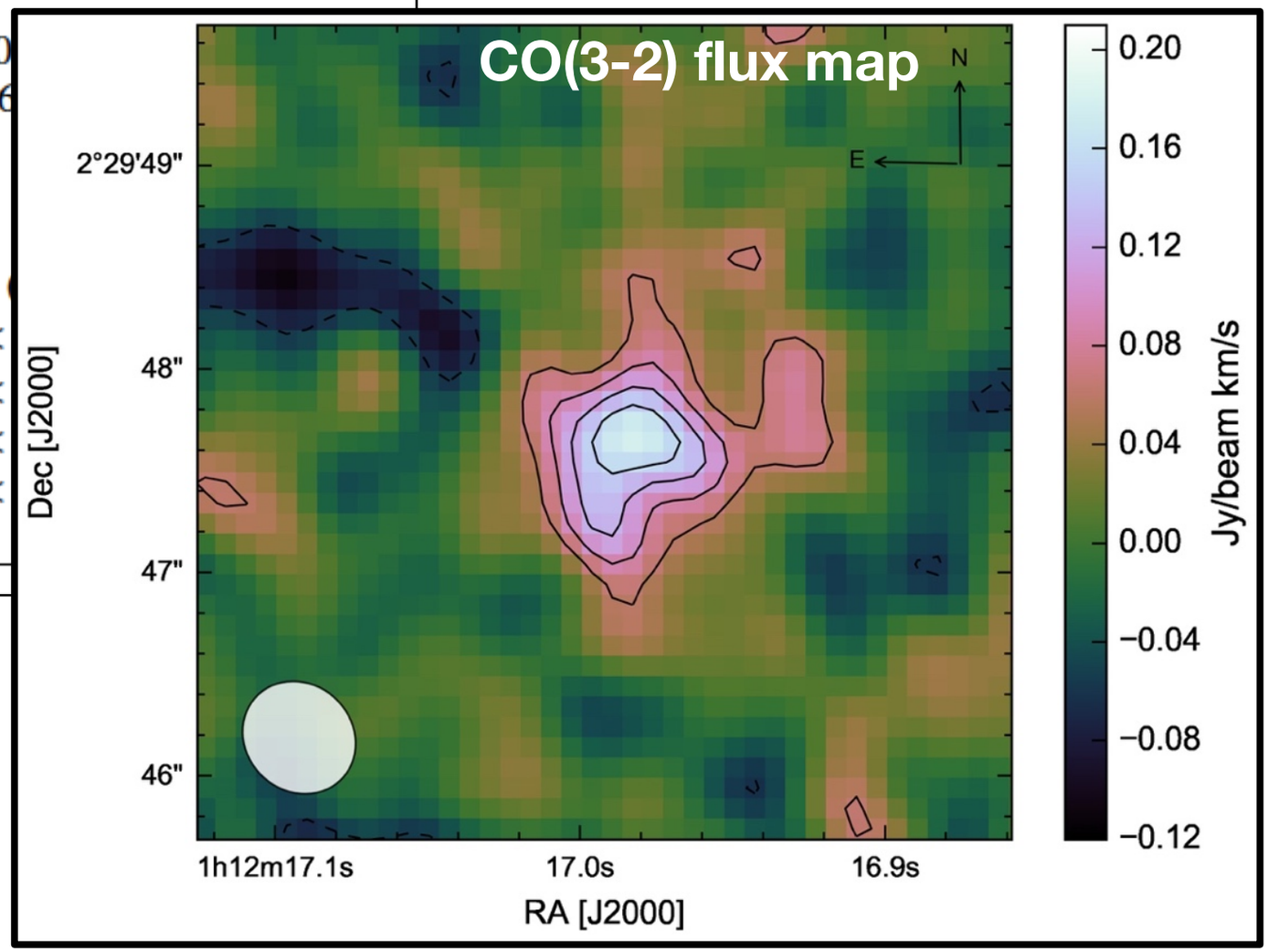

Carniani+17

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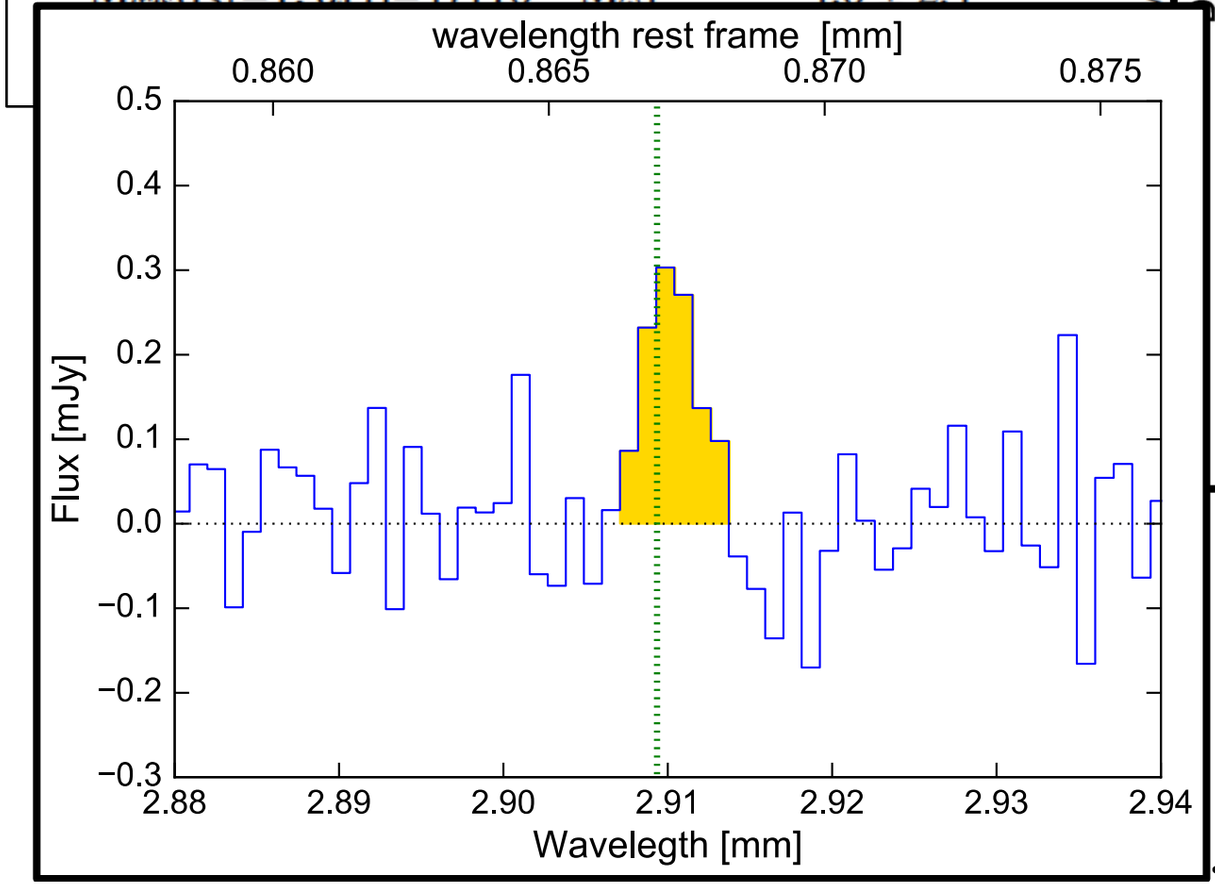

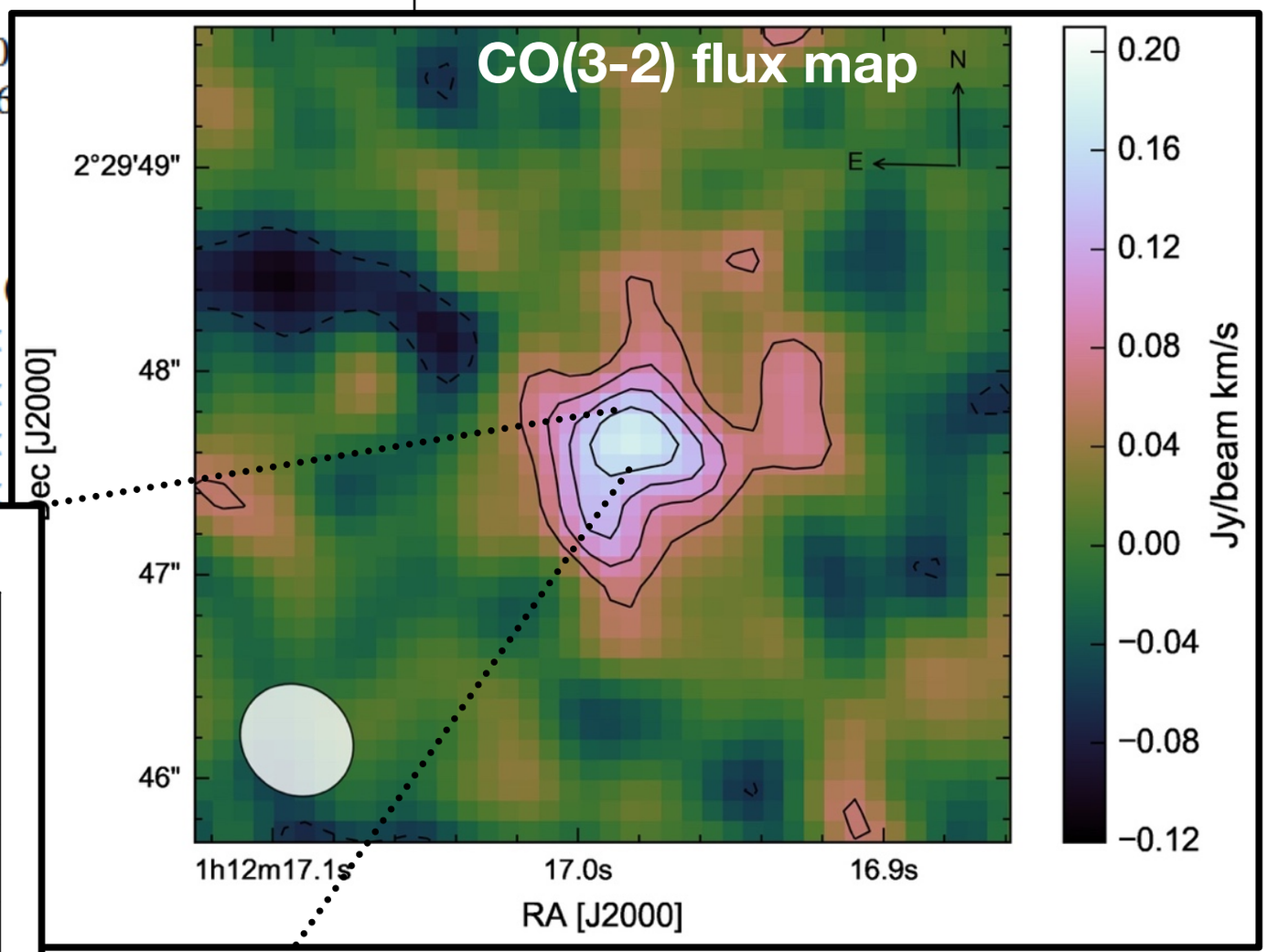

Carniani+17

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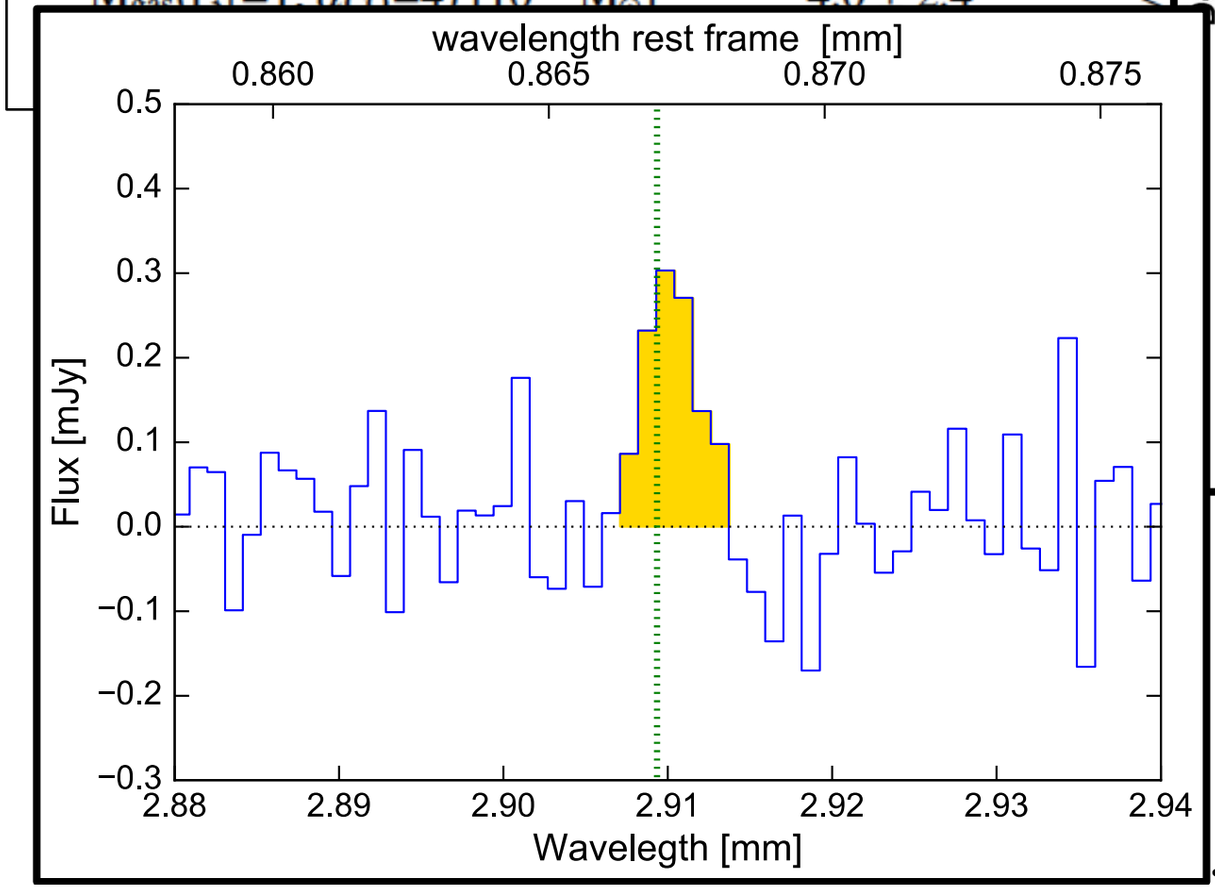
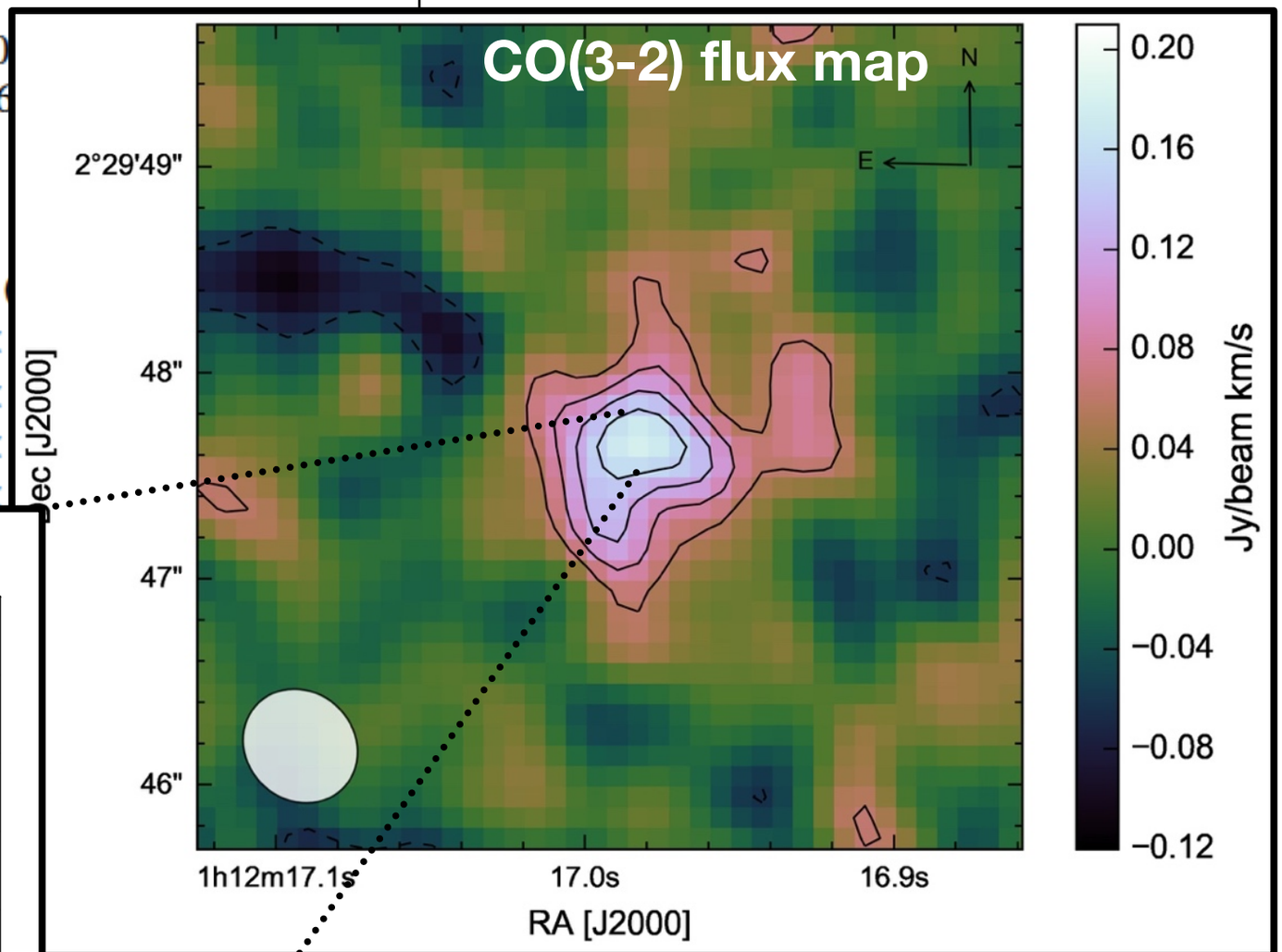




Same velocity as

[OIII]/Hβ narrow component!

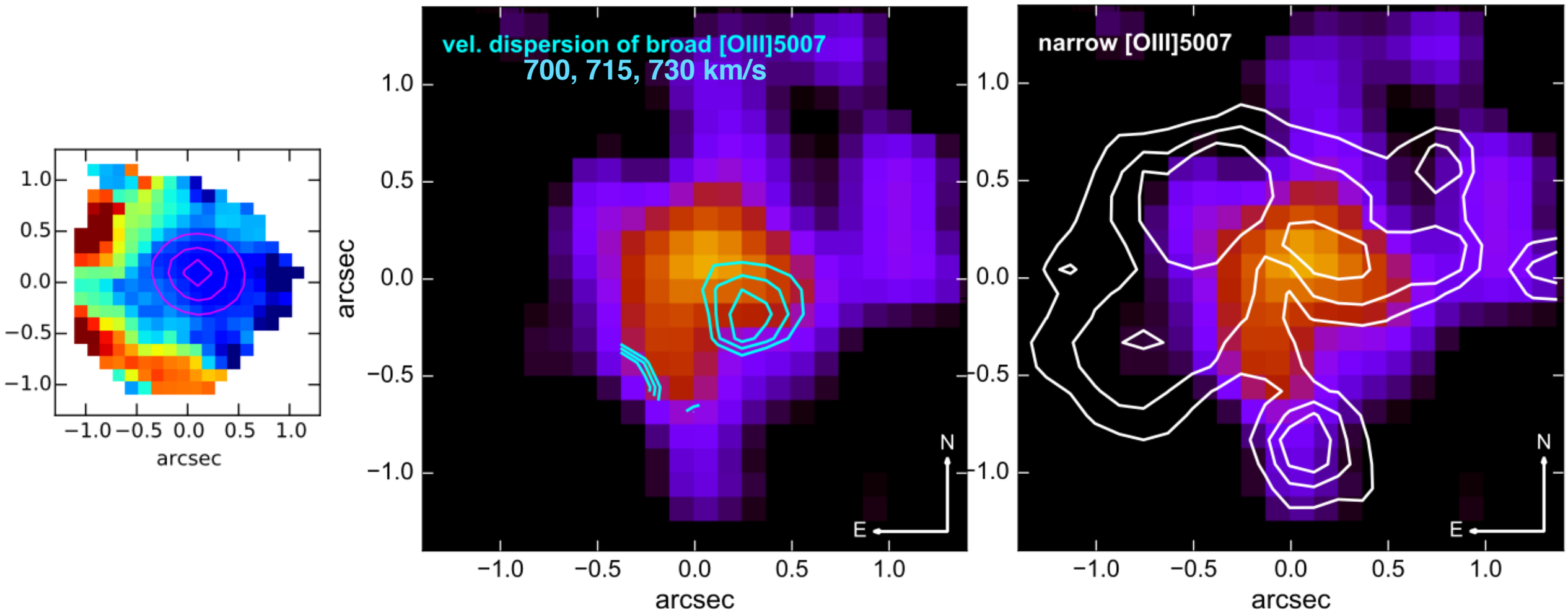
FWHM = 400 km/s

M_{mol} = 0.5- 4.0 10^{10} $M_\odot$

Carniani+17

ALMA observations: LBQS0109

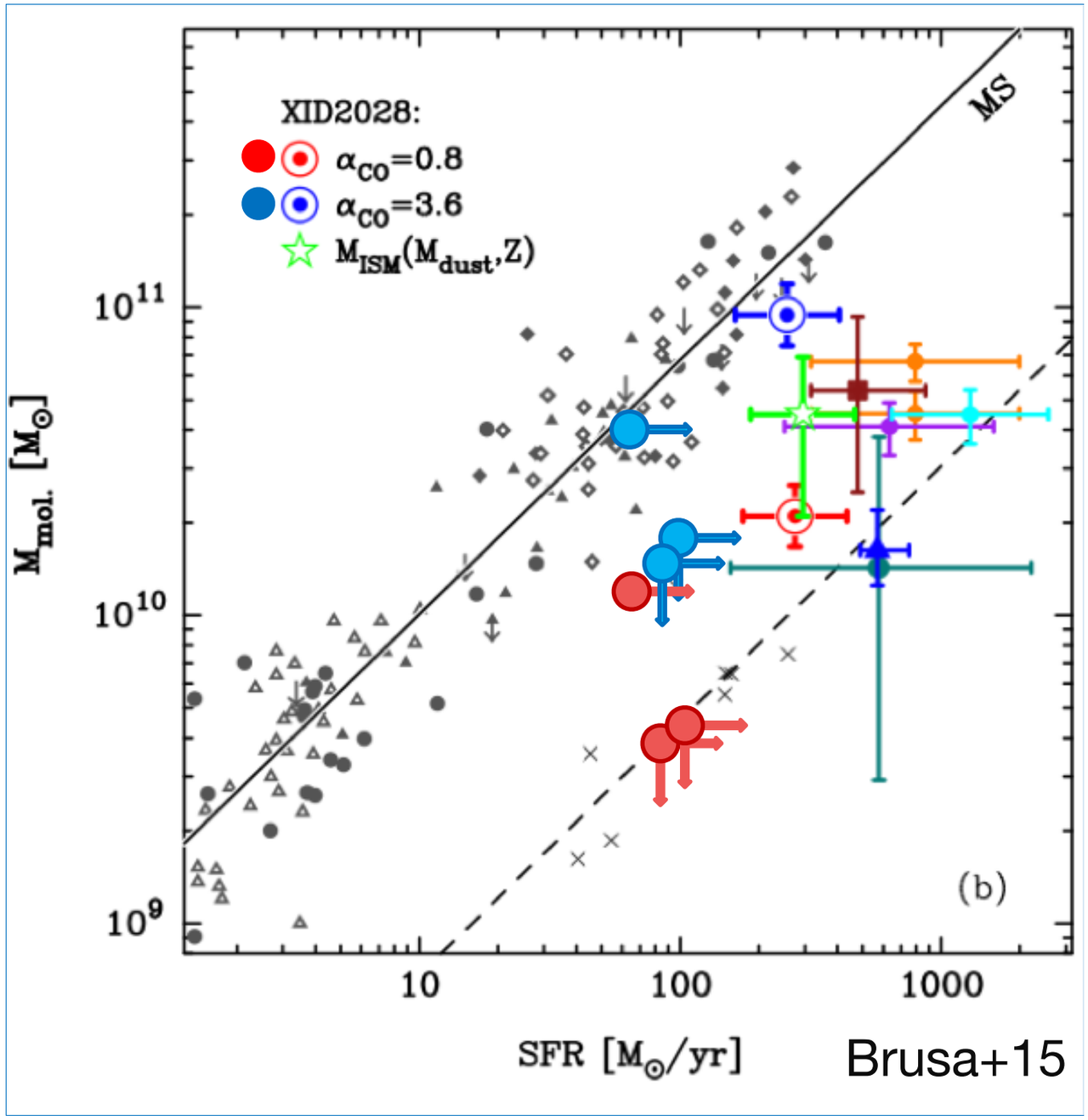
CO(3-2) flux map ≈ narrow [OIII] and Ha flux maps



CO emission faint/absent in the outflow region

Carniani+17

Lack Of Molecular Gas



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z~2 SMG→QSO (Ya10)

XID2028 QSO z≈1.6 Brusa+15

2 QSOs z≈2.4 Carniani+16b

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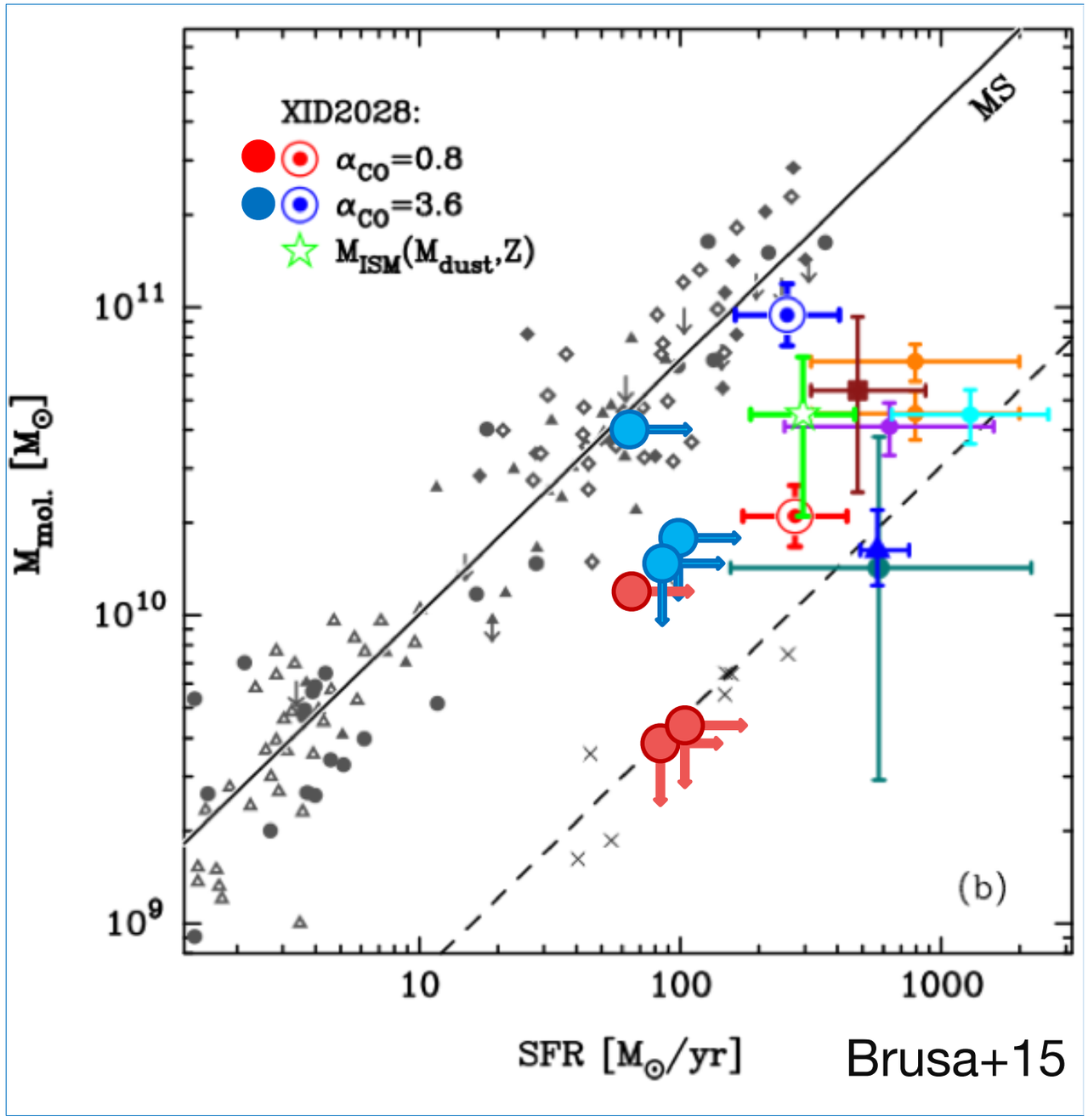

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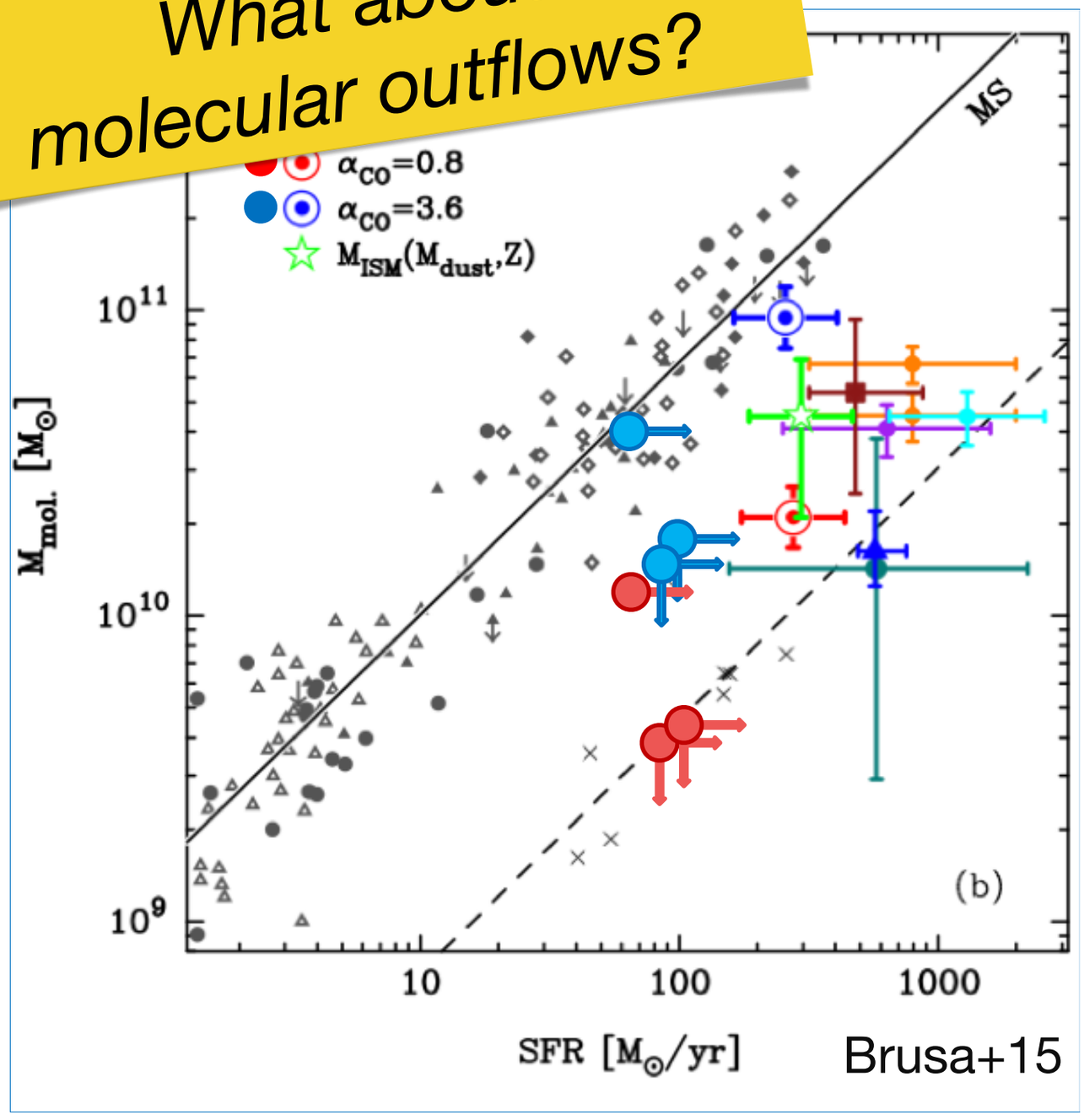
less gas than expected

Negative feedback!?!?

Lack Of Molecular Gas

What about molecular outflows?



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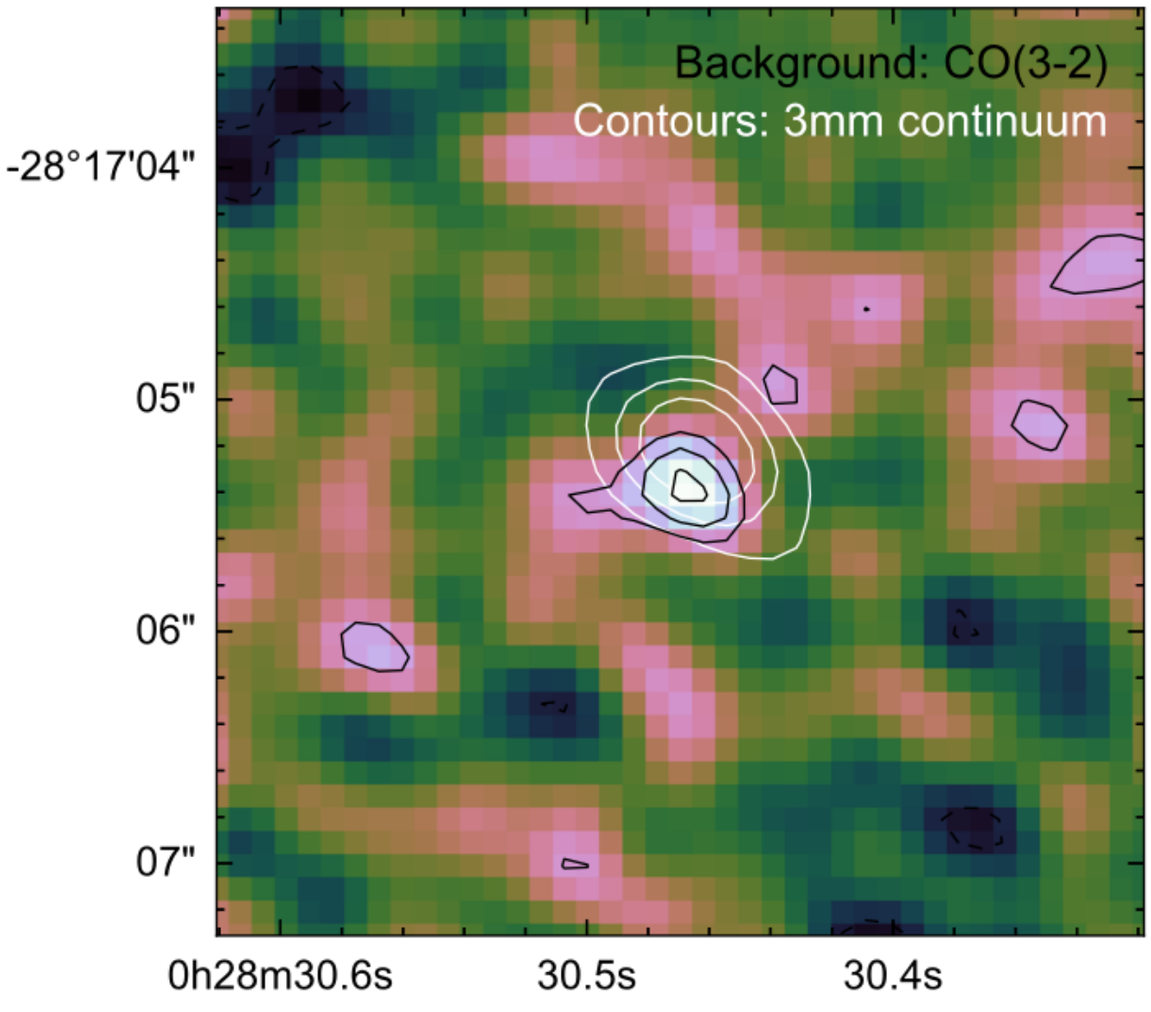
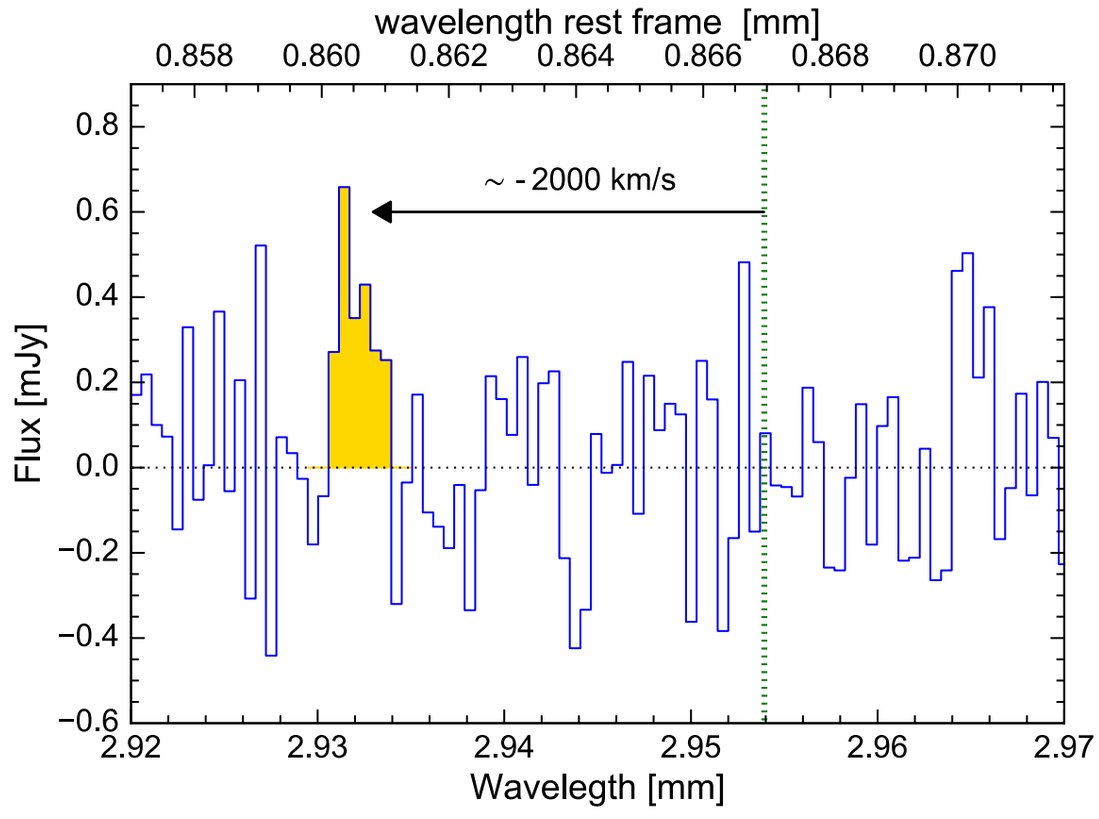
The peak of the CO(3-2) emission is spatially offset by ~0.2″ (1.3 kpc) toward the South relative to the QSO centre





Carniani+17

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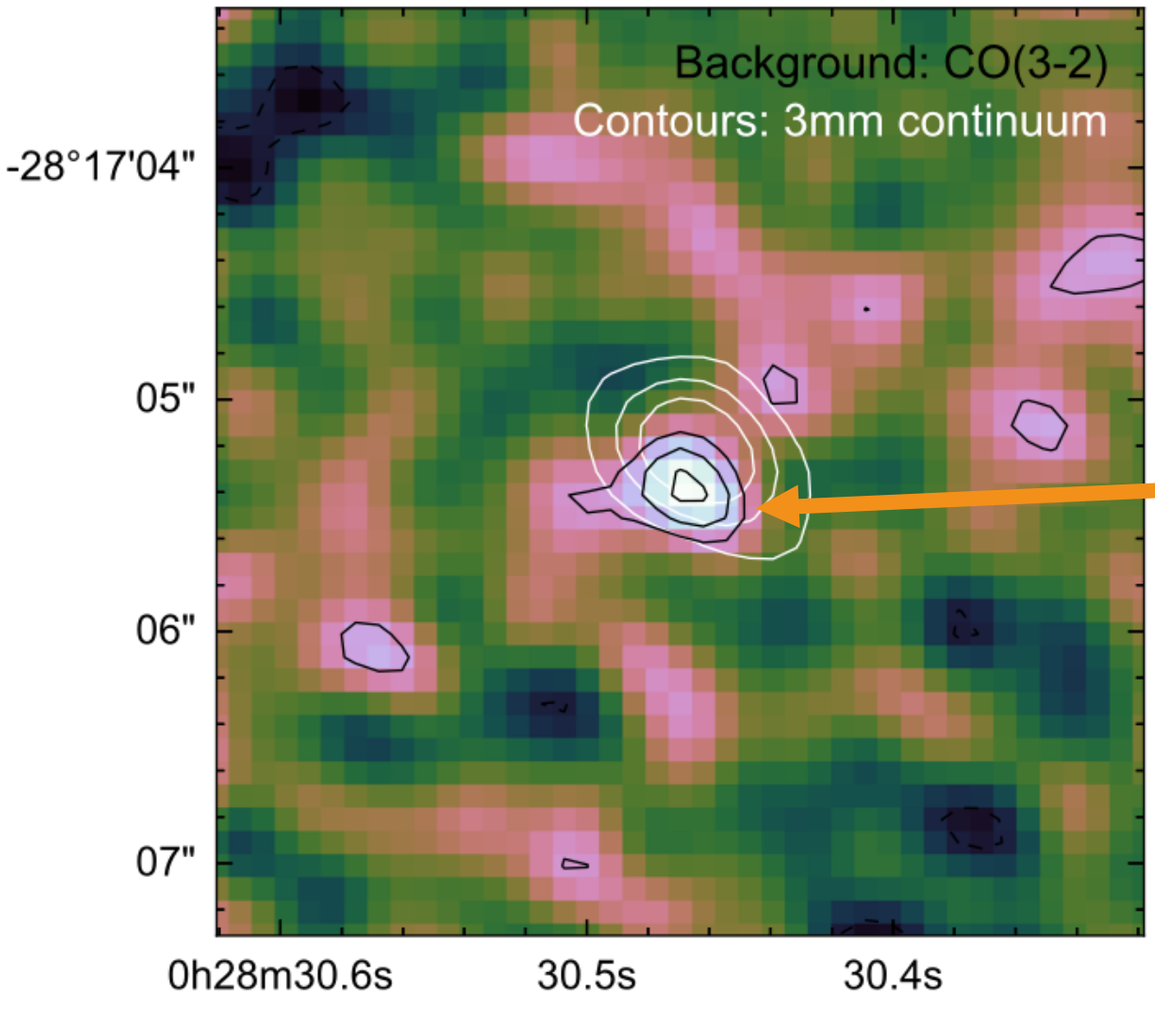

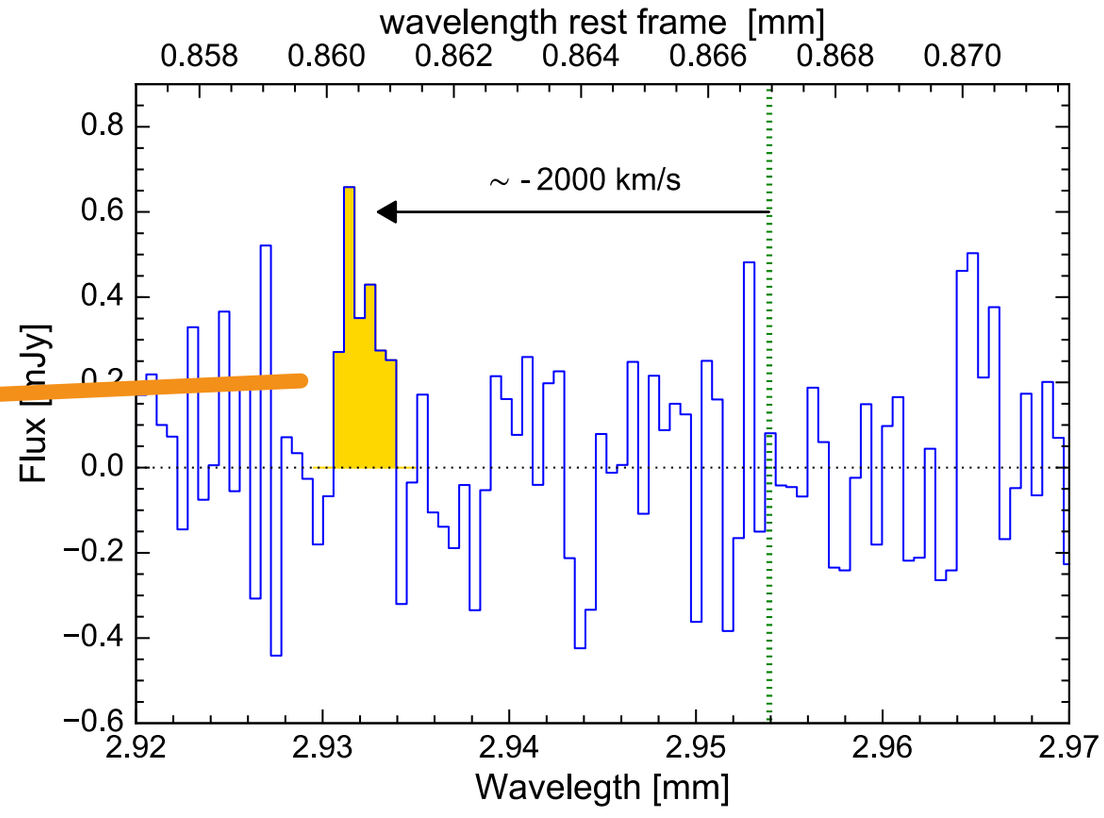

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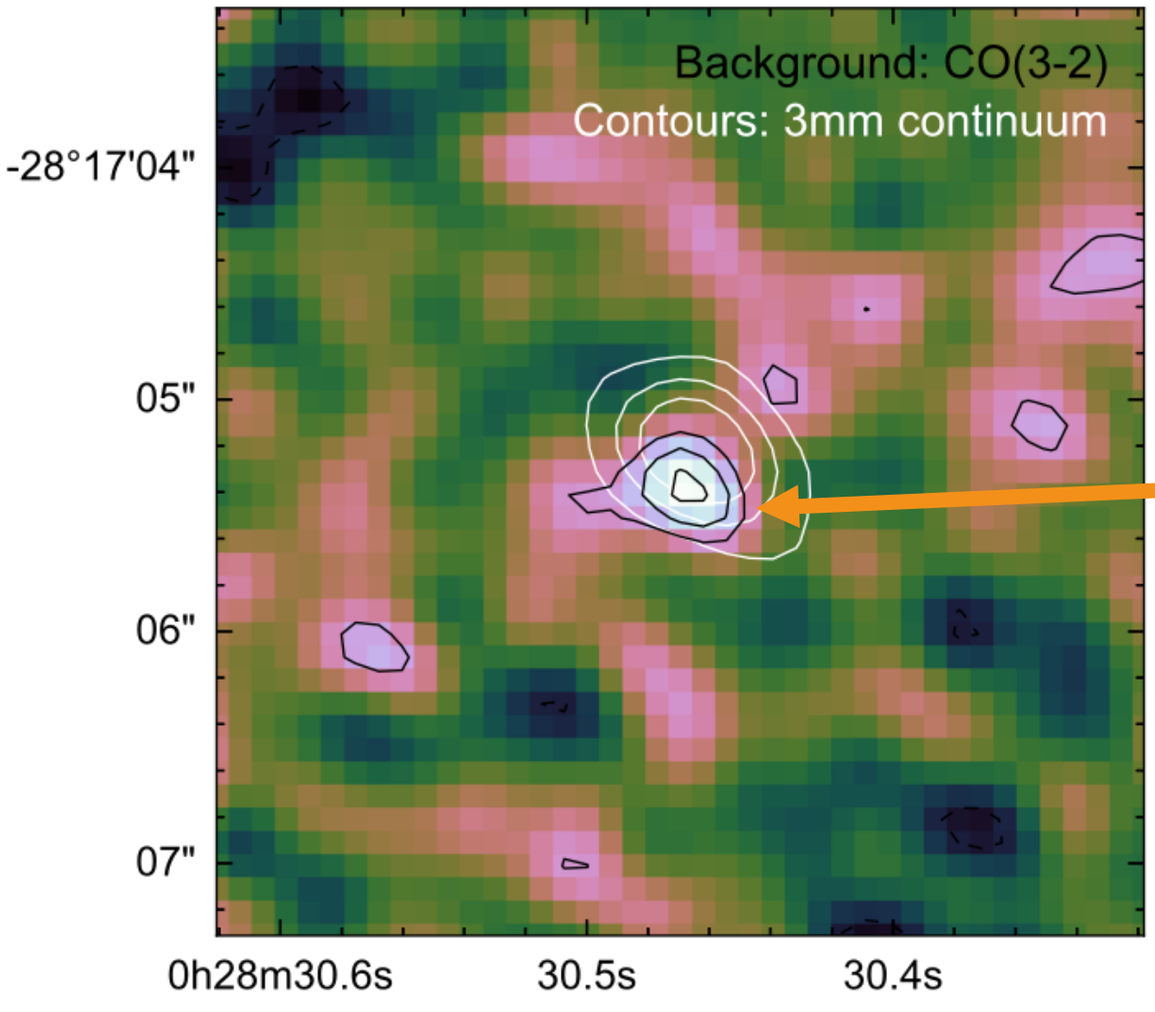
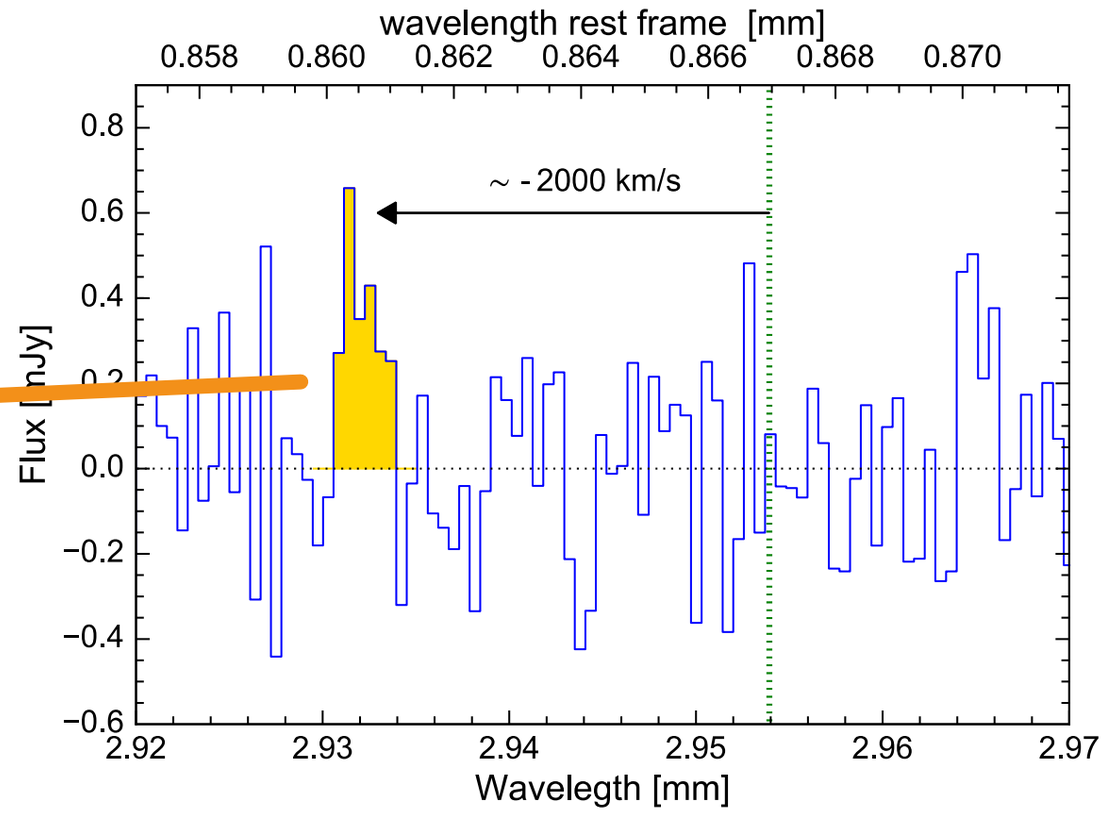
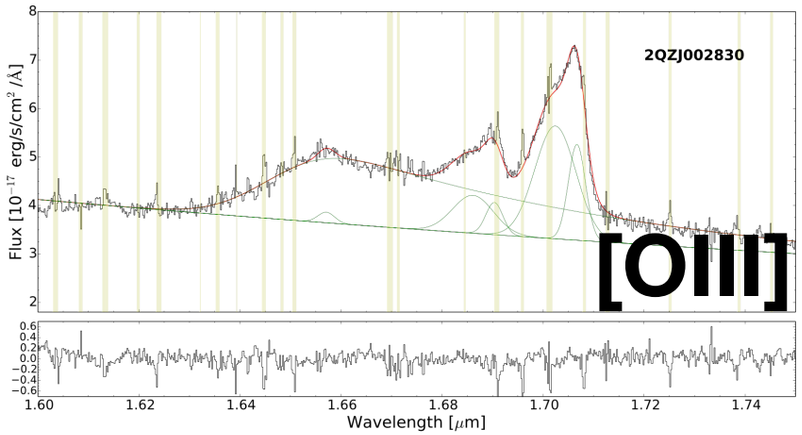


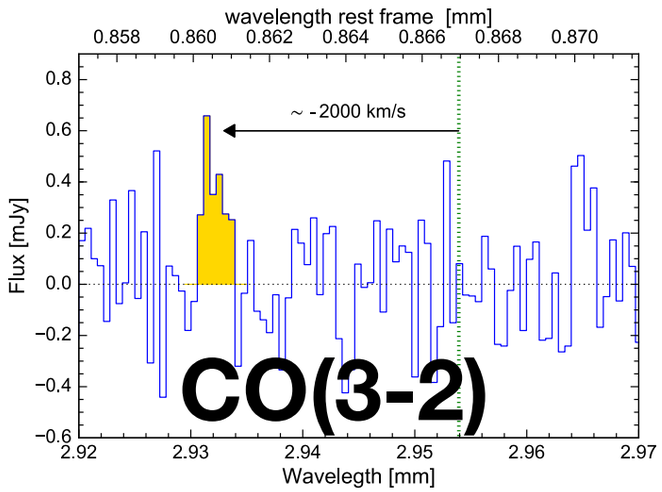


Carniani+17

molecular gas in the outflow region may be more highly excited than the rest of molecular gas in the host galaxy.

2QZJ0028: Molecular Outflow?





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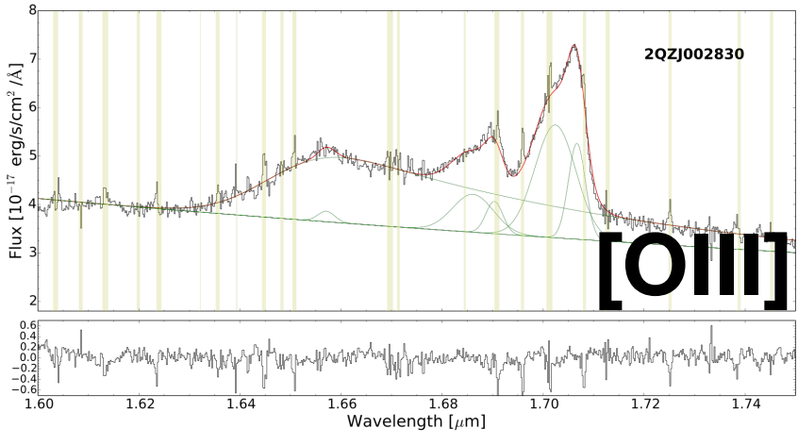

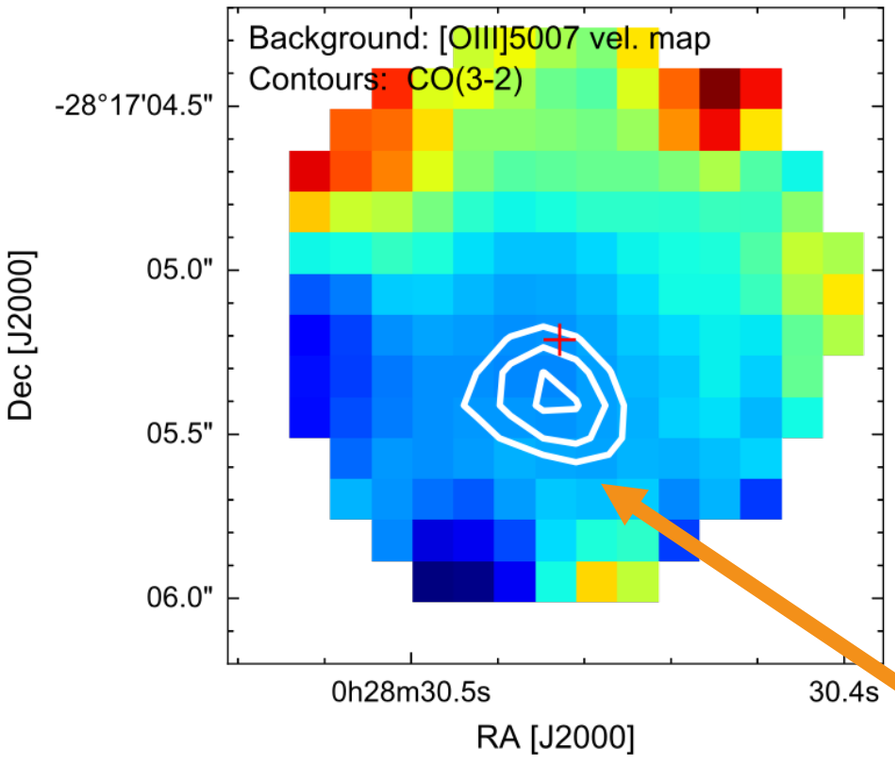

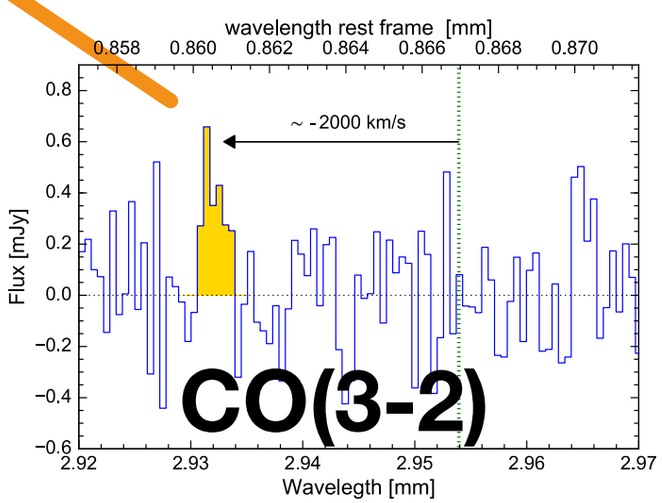

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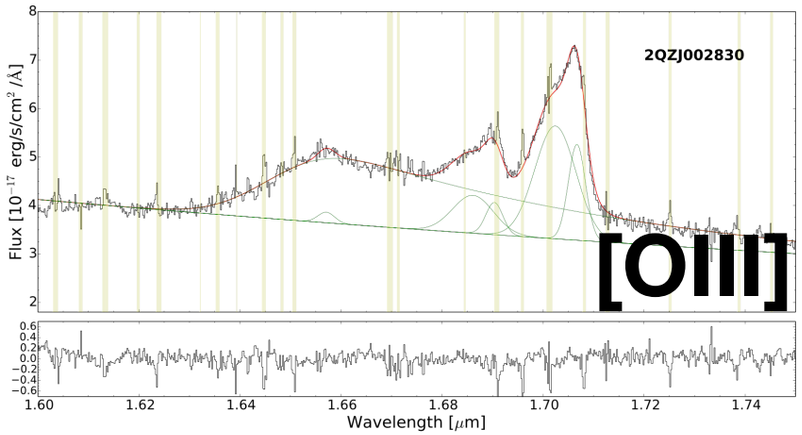

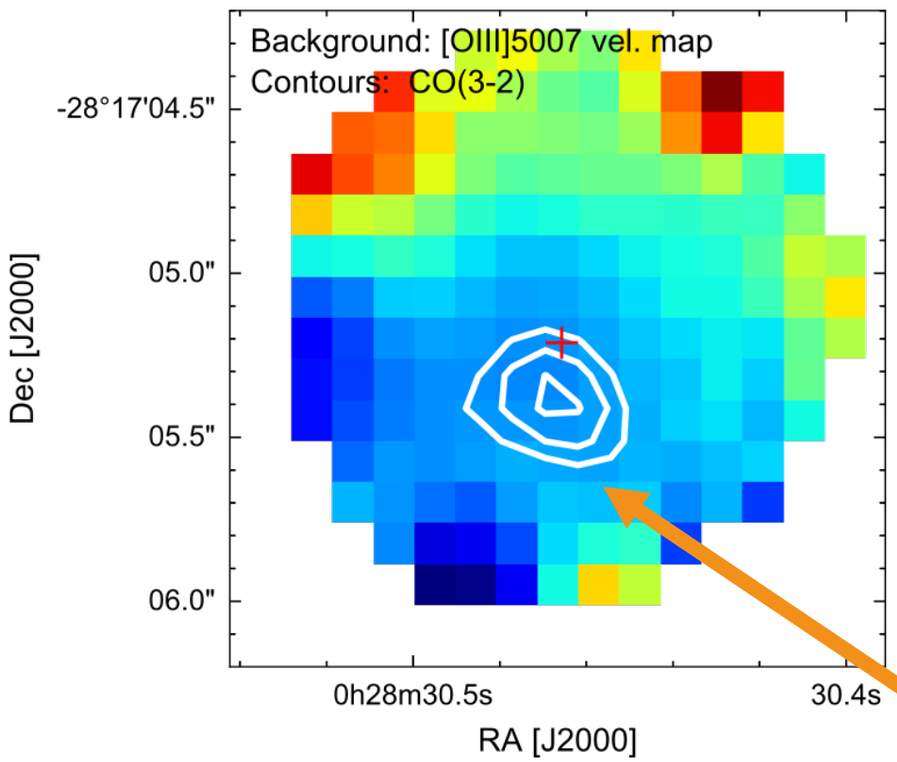

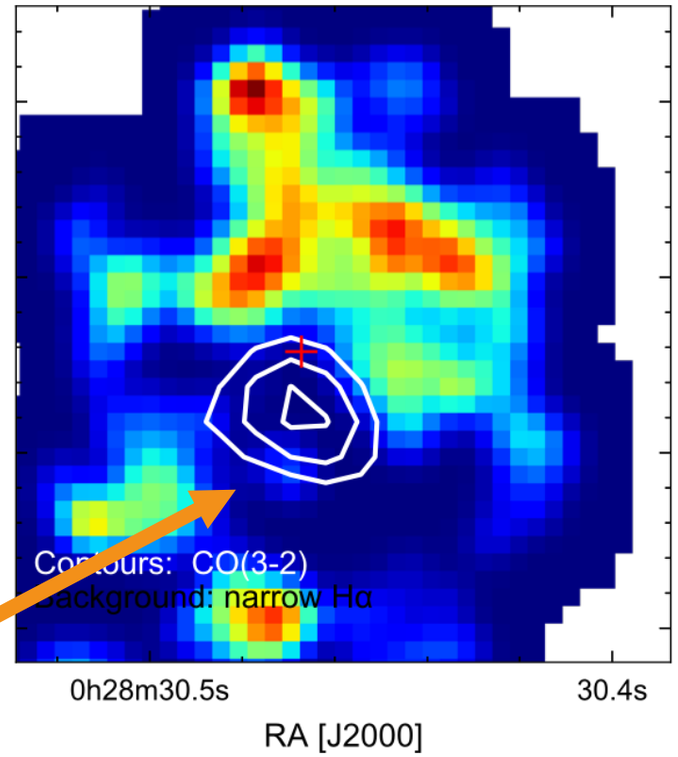

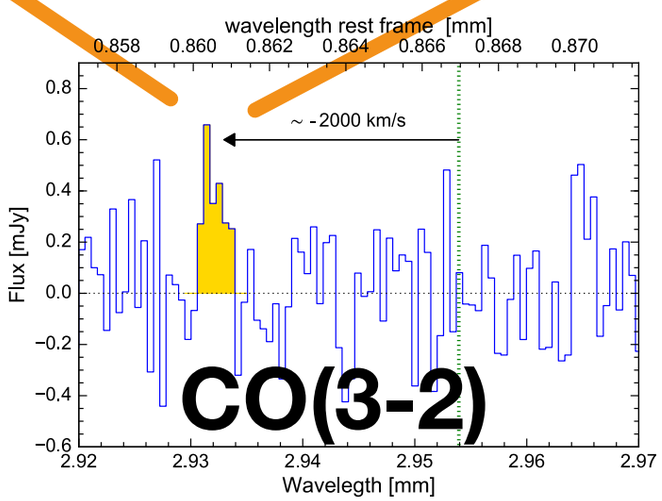

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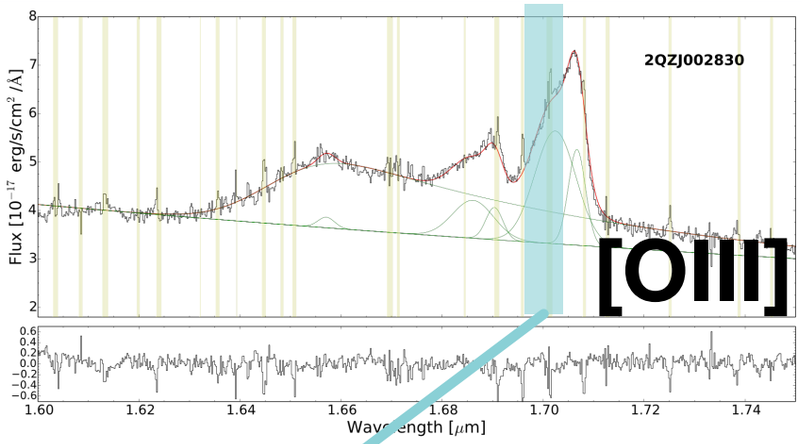

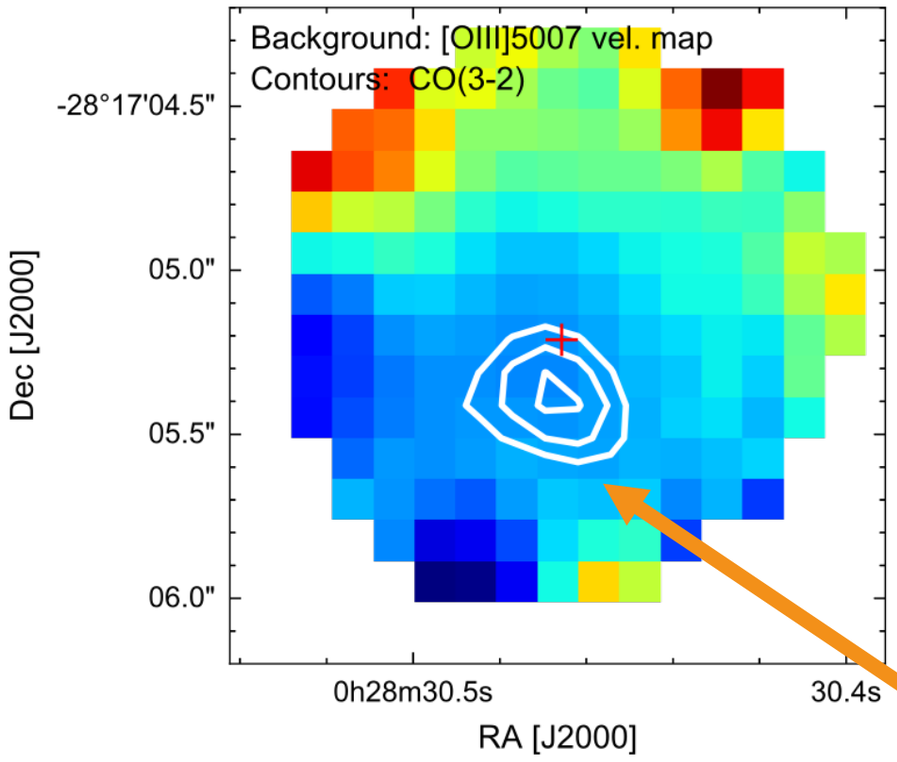

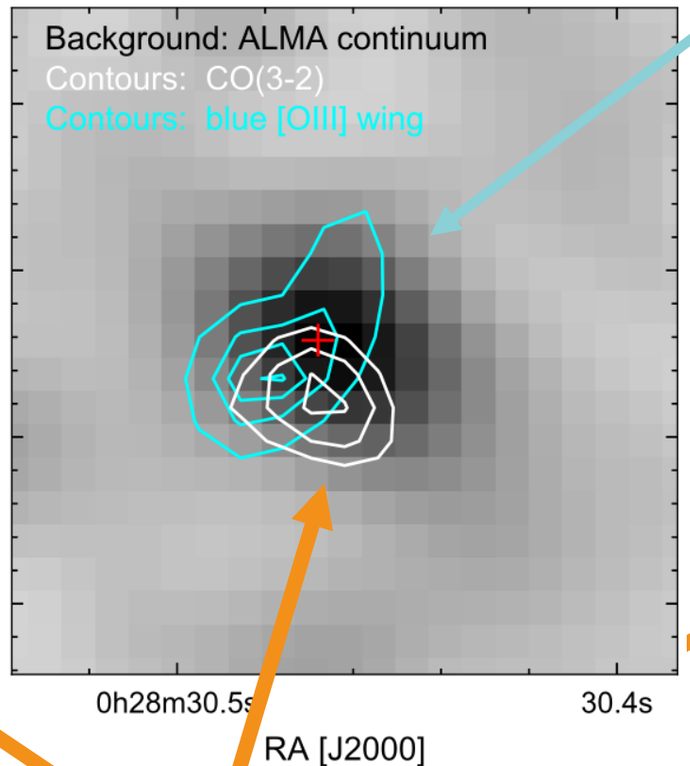

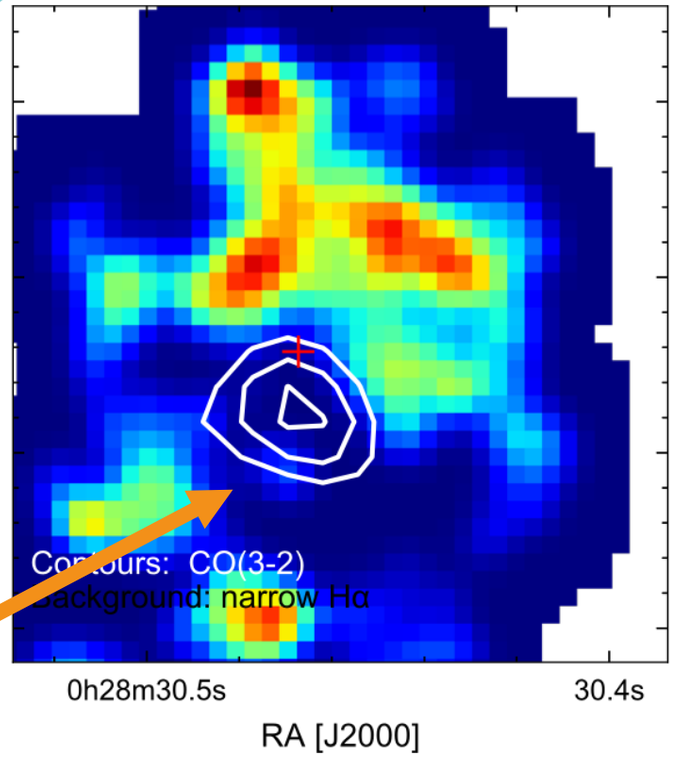

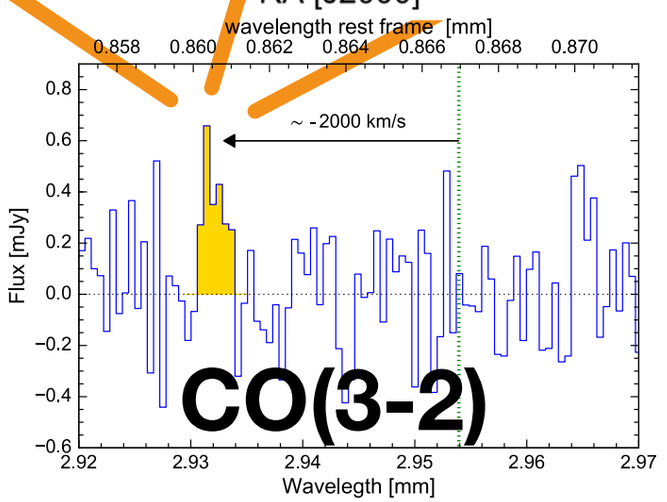

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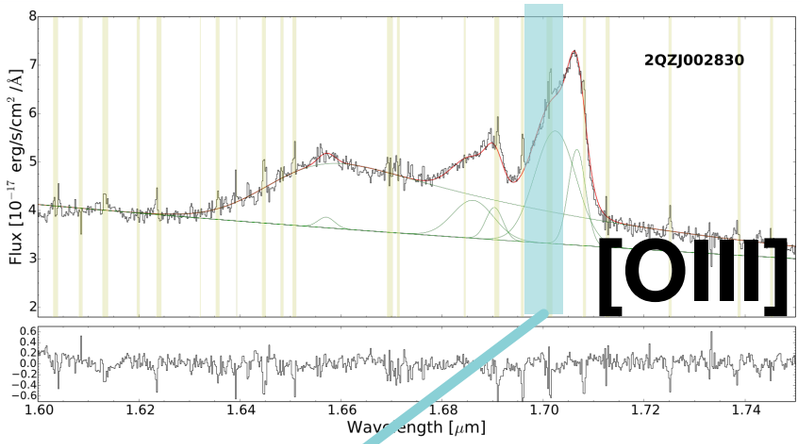
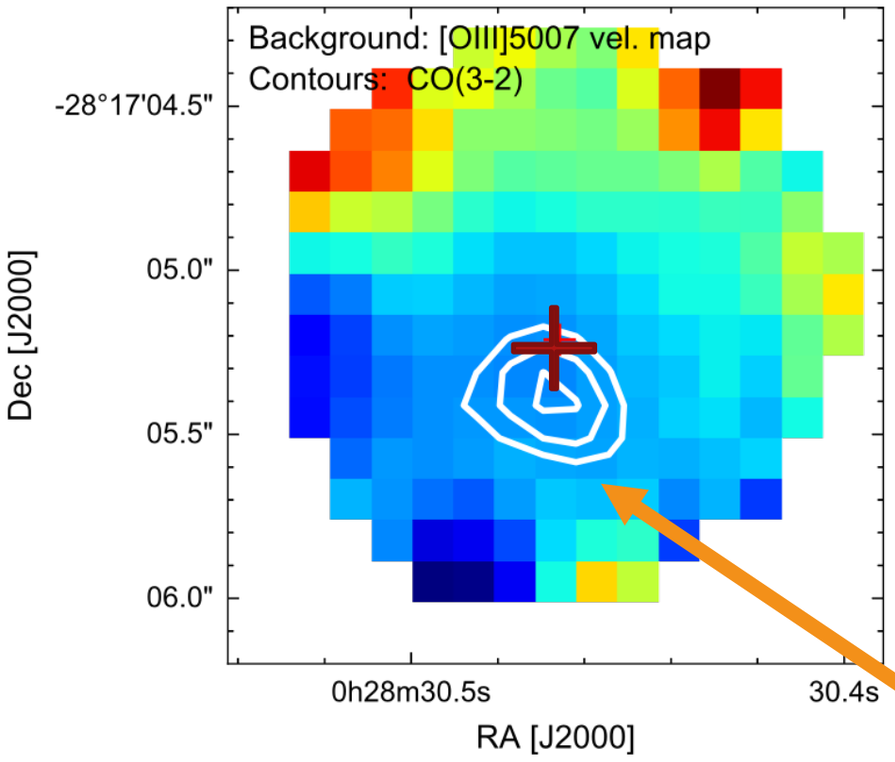
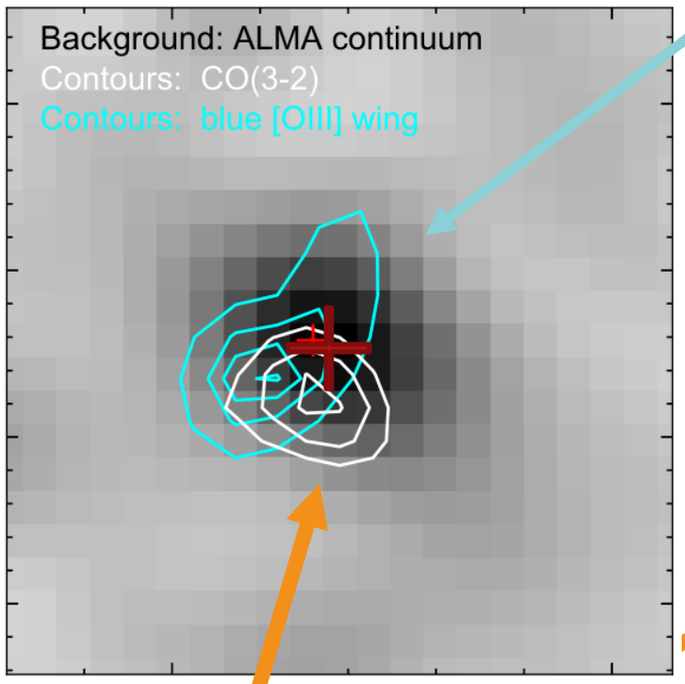
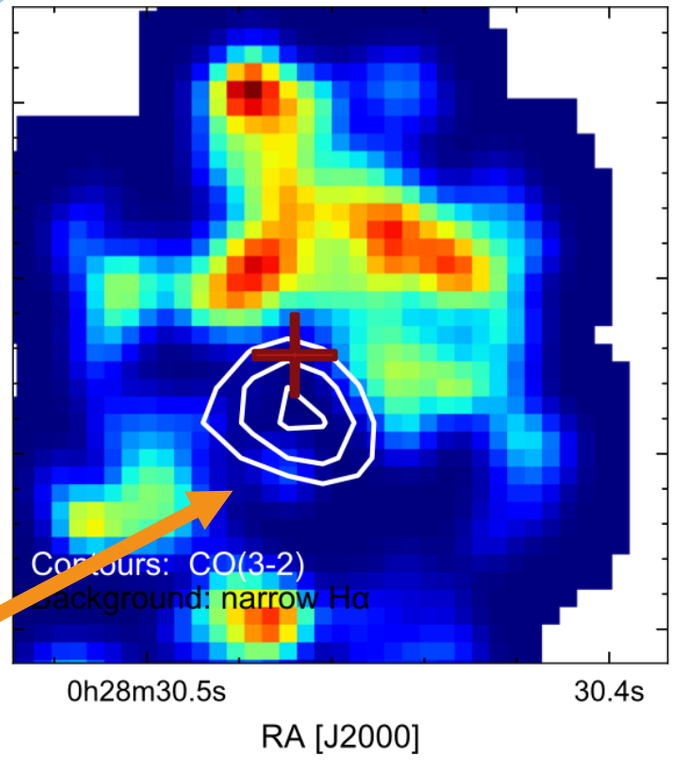
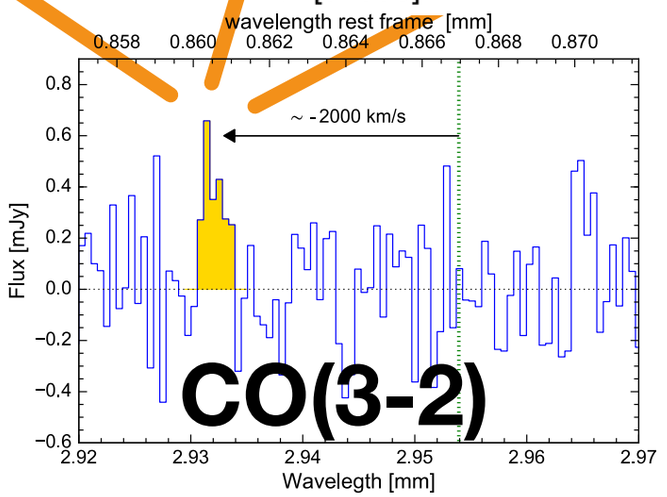
2QZJ0028: Molecular Outflow?











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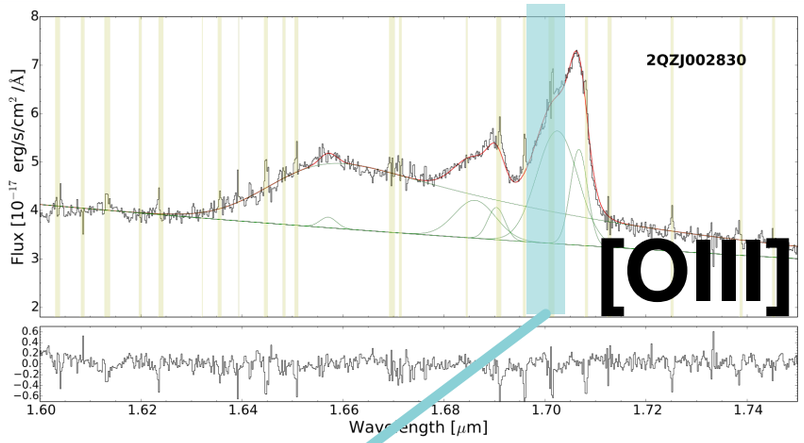
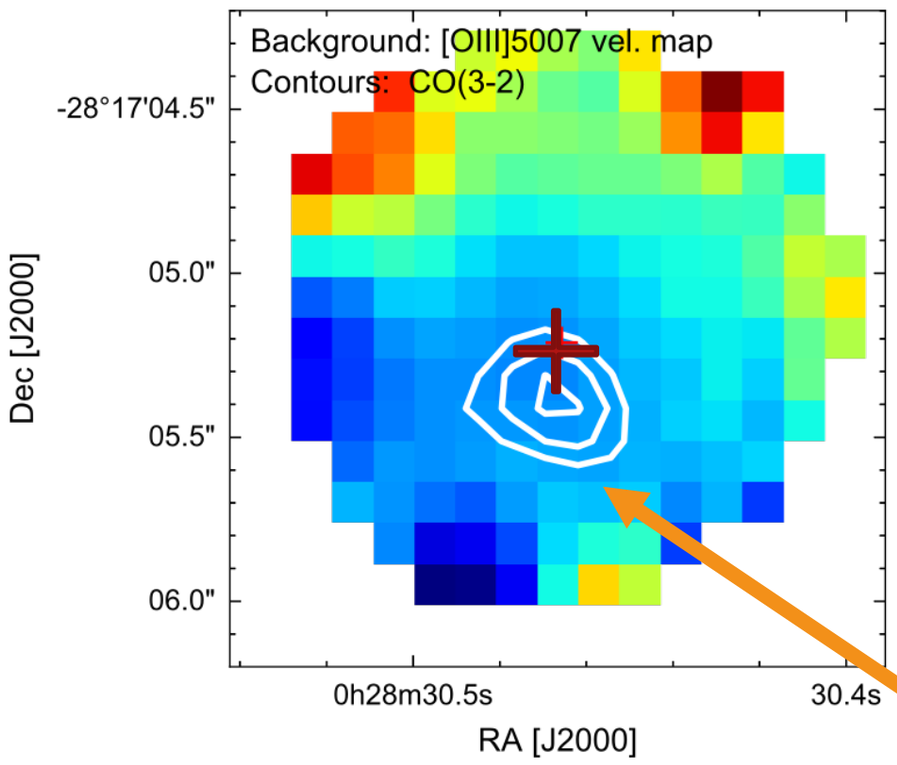
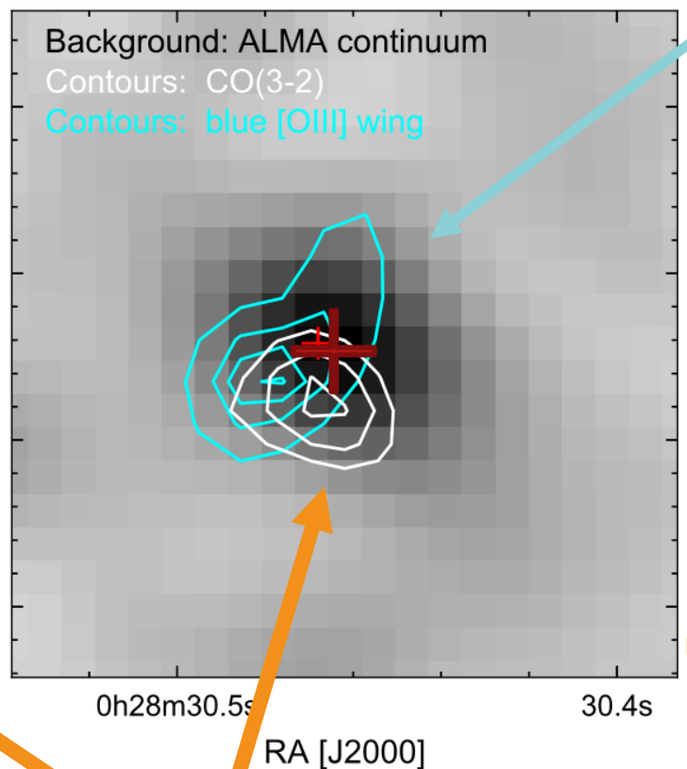
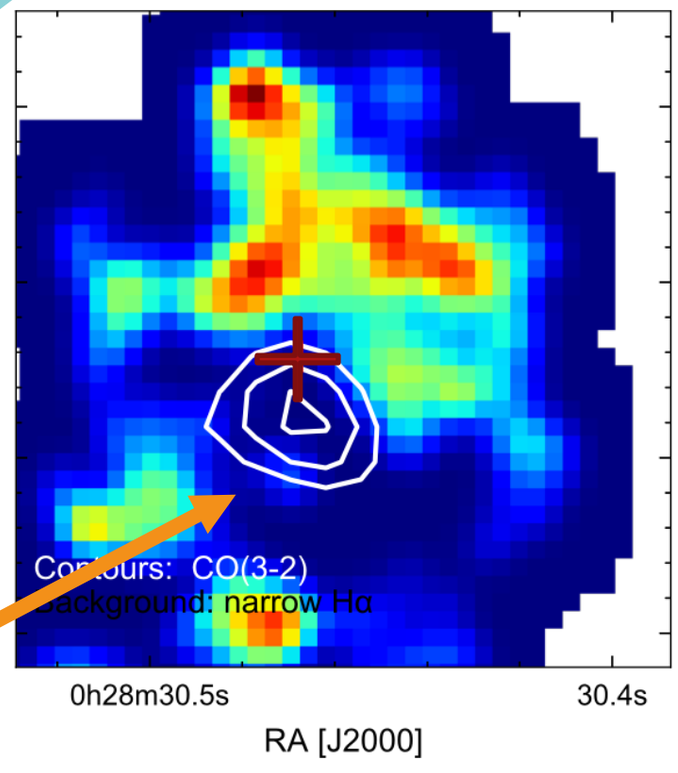
2QZJ0028: Molecular Outflow?

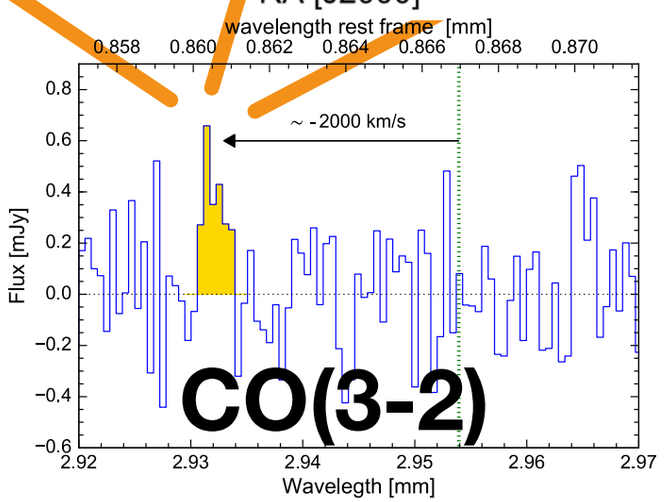
CO(3-2) emission blueshifted by 2000 km/s and spatially coincident with the ionised outflow emission: molecular outflow??











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Conclusions

- Local quasars at z < 1: *the presence of ionized outflows does not appear to significantly affect star formation (problem of time scales?)*
- Obscured AGN at 1.5 and quasars at z~2.5 with detailed Integral Field Spectroscopy: *ionized gas outflows (partially) sweep away gas in quasar host galaxies and prevent star formation*
- ALMA observations detect (1) CO emission of the host galaxy, anti-correlated with fast outflows (LBQS0109), (2) fast molecular outflow but no host galaxy emission (2QZJ0028)
- *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. Is feedback important?*
- Brusa+ 2015, **2017**
  Cresci+ 2015
  Balmaverde+, 2015
  Carniani+, 2015, 2016, **2017**