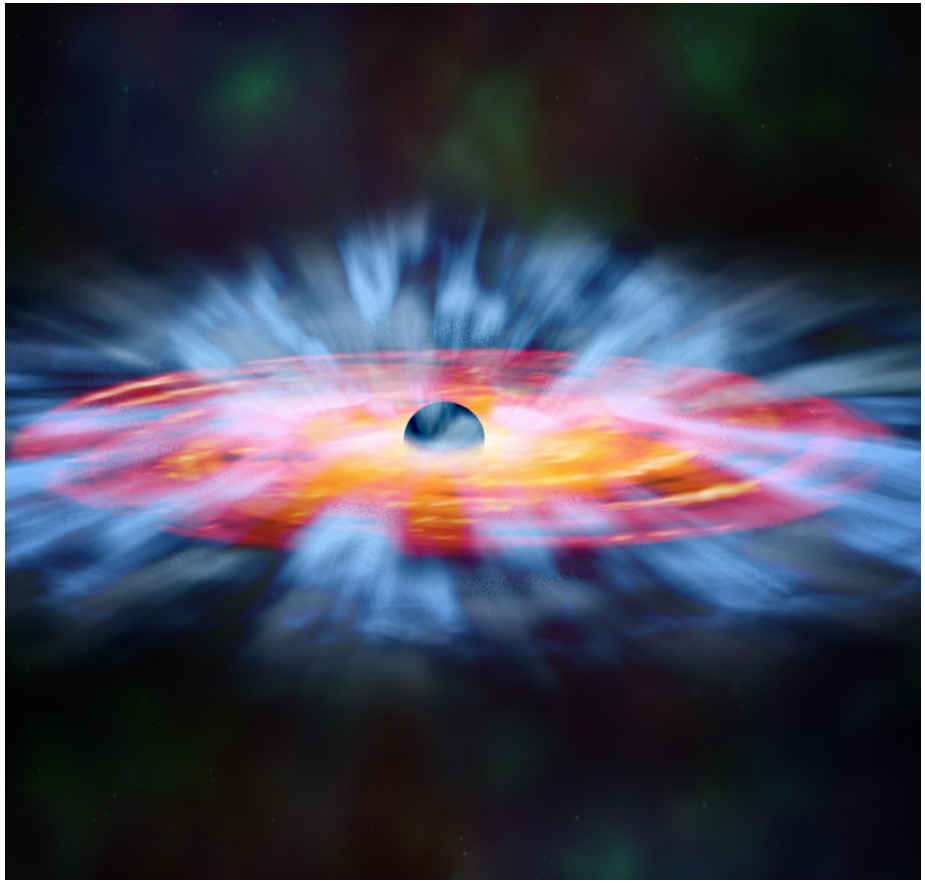
High-Ionization gas in AGNs: line profiles and physical conditions



(Illustration: NASA/CXC/M.Weiss)

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AGN Winds in Charleston October - 2011

LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

Outline

- NLR and Coronal lines – overview
- Measurement of T_e and n_e
- Emission line profiles
- An AO NIR approach (NGC1068)
- Conclusions

Overview

- Observations with the HST/STIS have suggested that radial outflow is the dominant component of motion in the NLR – i.e NGC1068, NGC4151, Mrk573 (Kraemer & Crenshaw 2000; Bennert et a. 2006; Fischer et al. 2010)

- Recent studies based on IFU spectroscopy (AO in the NIR) have started to confirm this picture in the NLR of Seyfert galaxies (Barbosa et al. 2009; Storchi-Bergmann et al. 2010; Riffel et al. 2010; Mazzalay 2010; Müller-Sanchez et al. (2011).

- Müller-Sanchez et al. (2011) modeled the spatially resolved kinematics of NIR IFU of a sample of Sy galaxies as a combination of an outflow bicone and a rotating disk coincident with the molecular gas using as tracers of the outflow, high-excitation lines.

- High-excitation emission (aka coronal lines, CLs) is seen in both components, suggesting it is leaking out of a clumpy torus. The outflow rate 2-3 order of magnitude > the accretion rate → mass loaded by the ISM.

Coronal Lines

- Due to their high IP (>100 eV), free of potential contributions from star formation → provide direct look into the inner NLR and probe dynamical forces associated with the AGN.

- Tend to be broader than low-ionisation forbidden lines (Phillips & Osterbrock 1975; Erkens et al. 1997). Their centroid position is blueshifted with respect to the systemic velocity of the galaxy (Penston et al. 1984, Rodríguez-Ardila et al. 2006).

- Above facts suggest a location for the CLR closer to the AGN than the classical NLR but outside the BLR and probably associated with outflows (Müller-Sanchez et al. 2006).

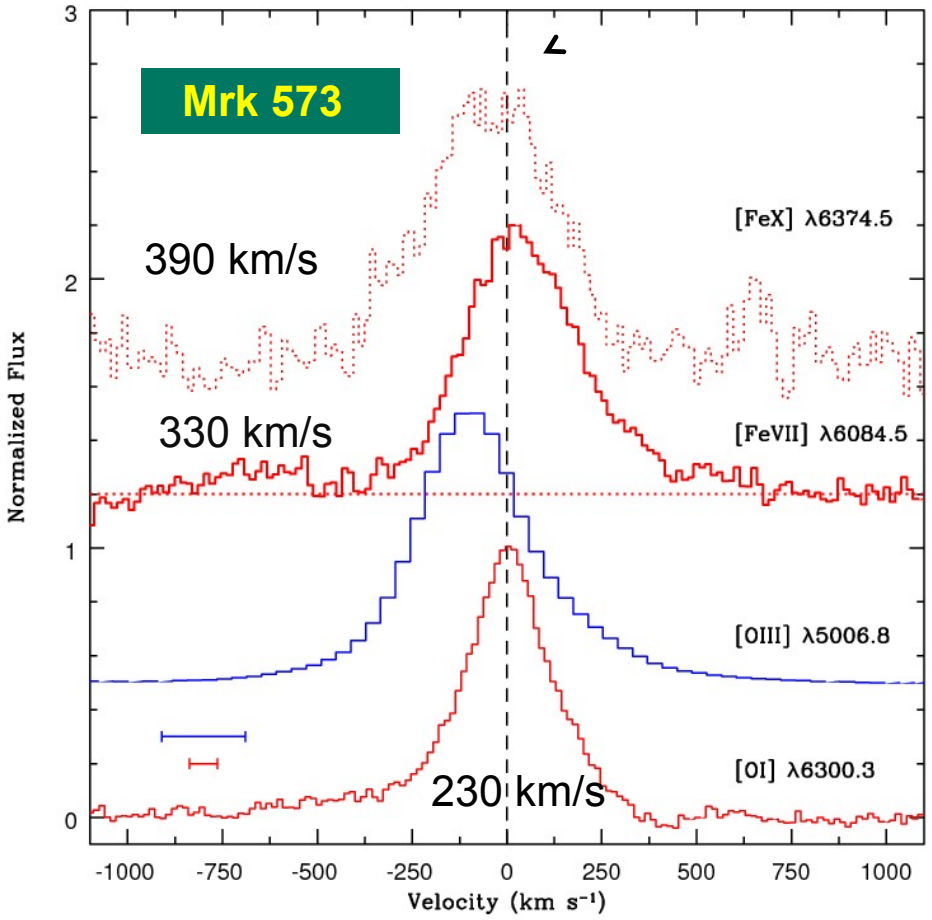
- Useful to study the much debated question of feedback from AGN via outflows of ionized gas, now recognized as a potentially crucial input to the *MBH* -σ* relation (e.g. Gebhardt et al. 2000).

Main goals of this work

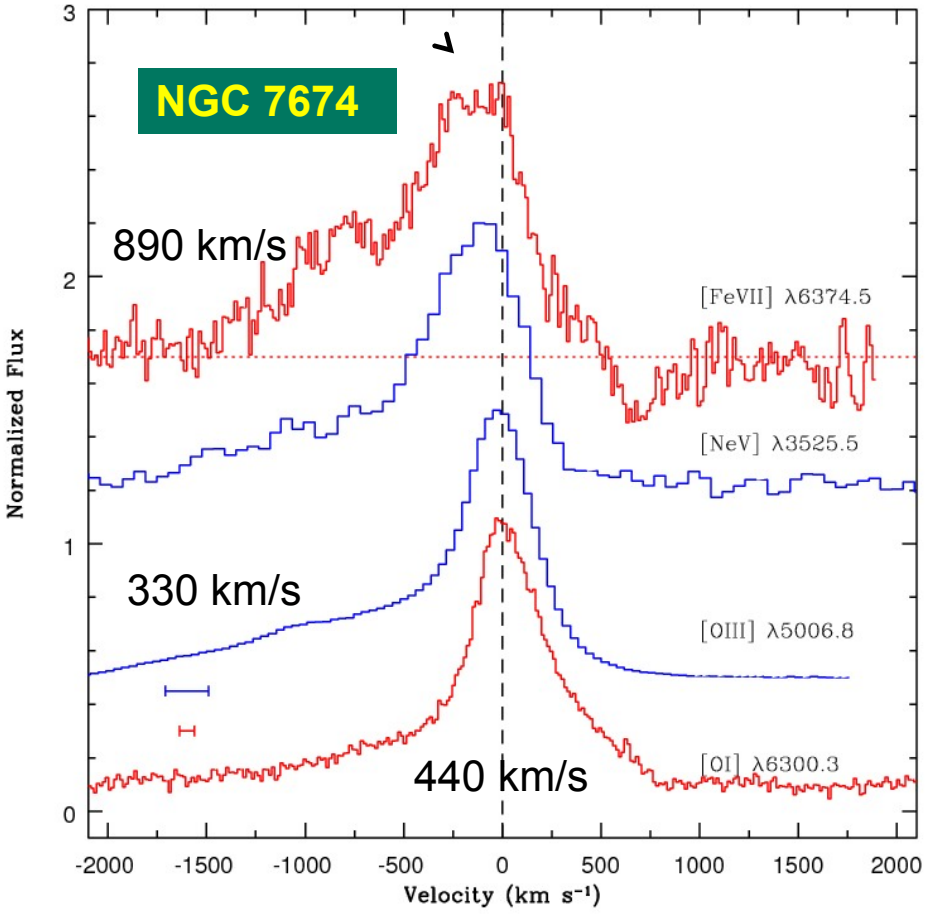
- Study the profiles of the [FeVII], [FeX] and [NeV] to detect signatures of outflows in the high-ionization gas.
- Determine *T*e and n_e of the coronal gas from the line ratios [FeVII] 3759/6087Å and [FeVII] 5159/6087Å.
- Map the CLR kinematics and its relationship with the radio jet by means of AO NIR observations (Gemini/NIFS, see Thaisa's talk).
- Data source:
  - 16 galaxies
  - SOAR 4m (0.32 – 0.7 μm); 11 objects
  - SDSS: (0.37 - 0.7 μm); 5 objects

Examples of CL profiles detected in the galaxy sample

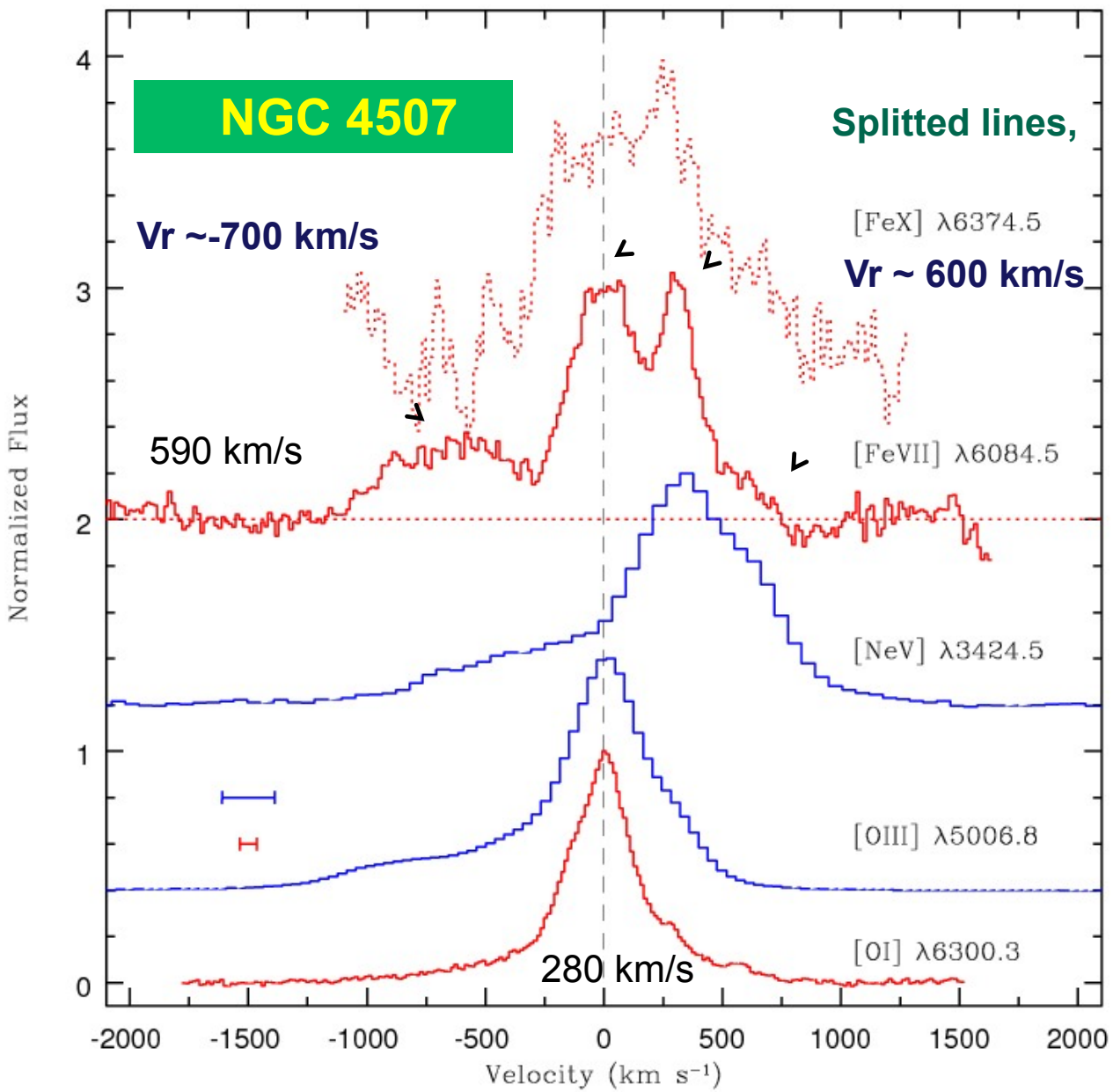
Splitted HIL. Not seen in LIL Outflowing gas



Outflow modeled by Fischer et al. 2010



Accelerated outflow (Shastri et al. 2006)



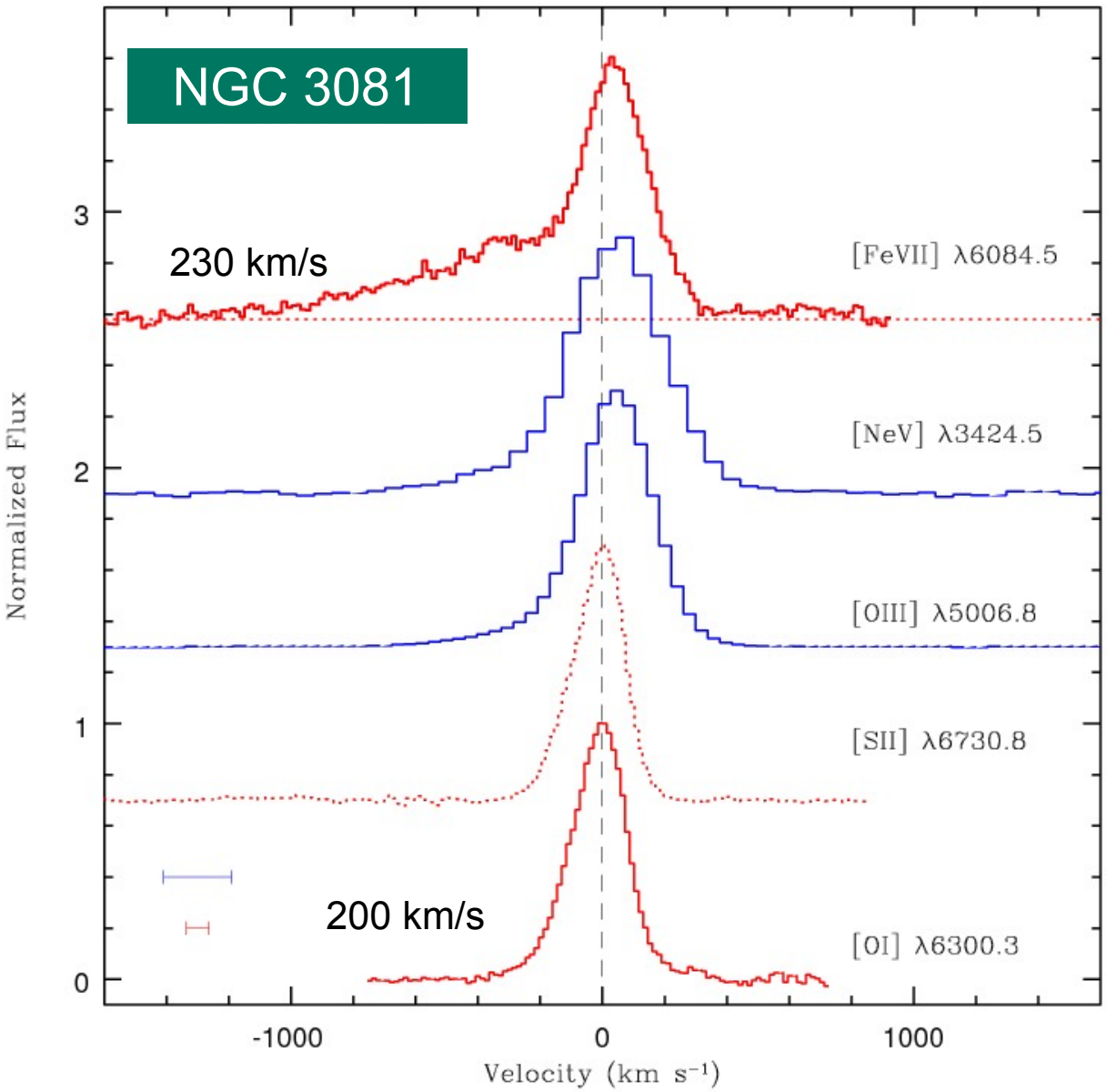
Gas is moving in radial directions within a nuclear colimated wind, whose
axis should be rather close to the plane of the sky.

[O I] is slower, mostly circular rotating gas.

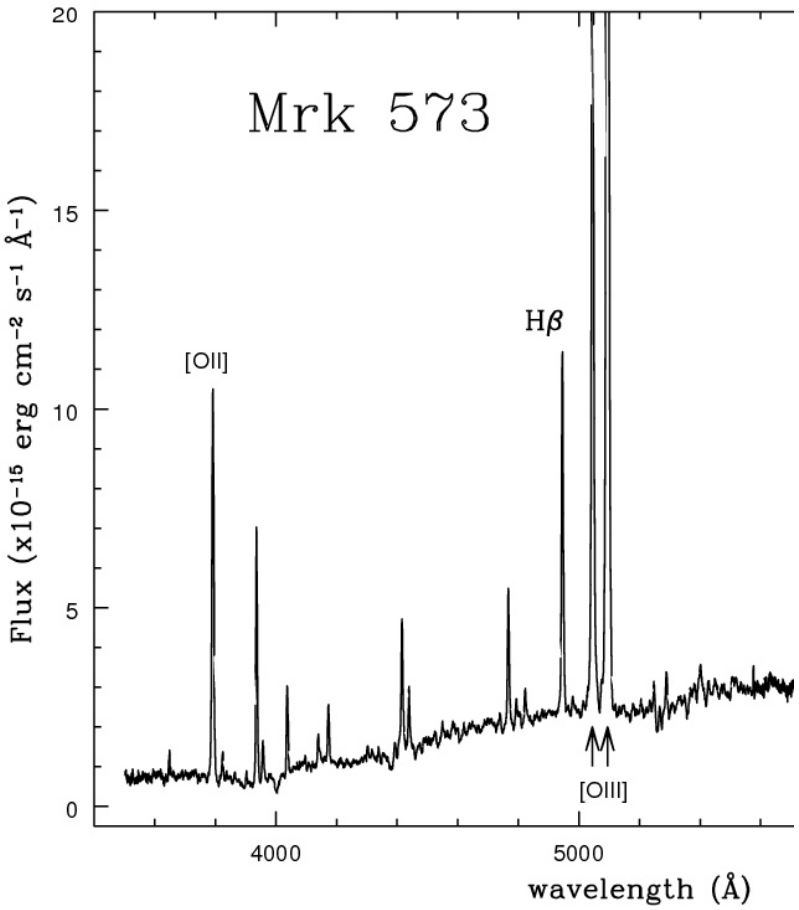
Ultra-fast outflow in X-rays (Tombesi et al. 2010).

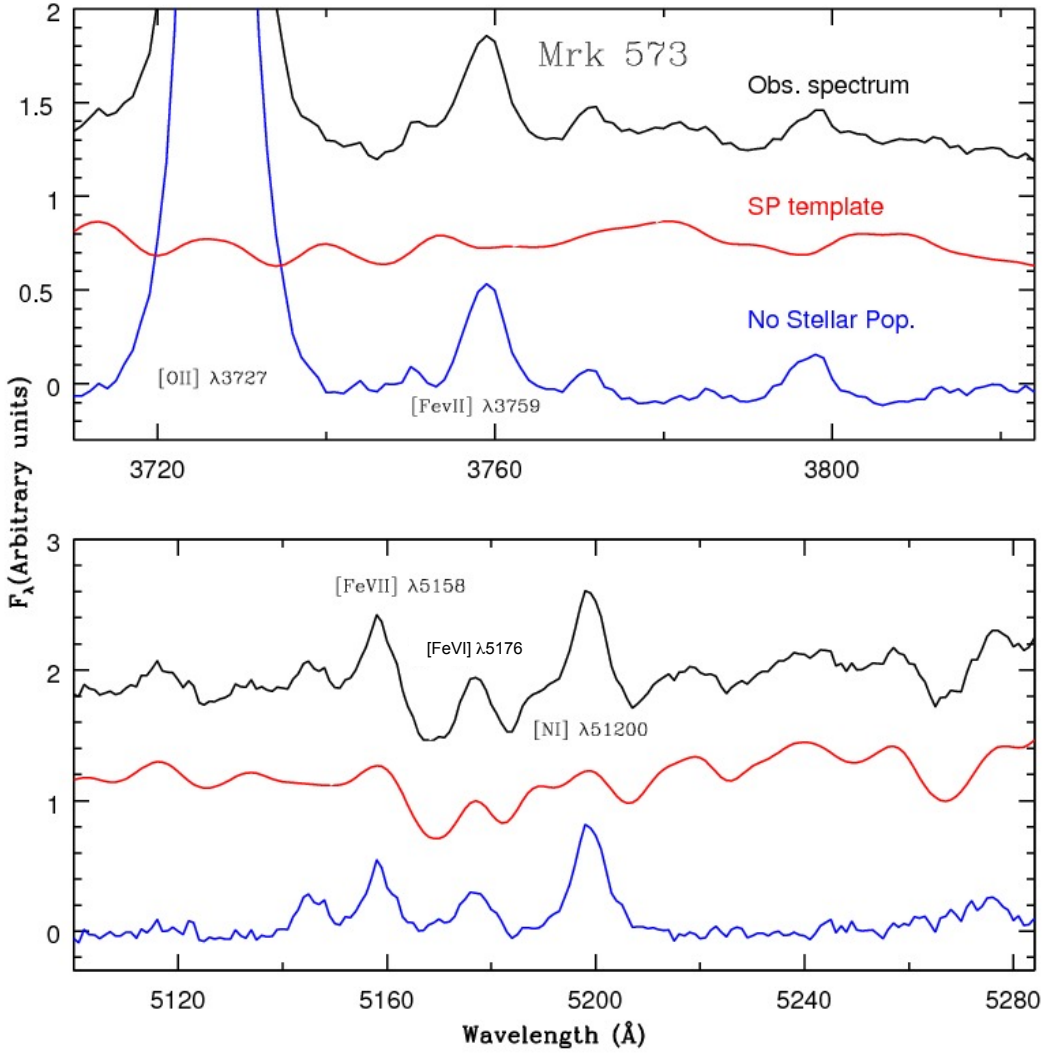
[FeVII] displays
A strong blue wing, extending up to 1000 km/s.

Evidence of outflow gas not easily detected in other lines (i.e [OIII])

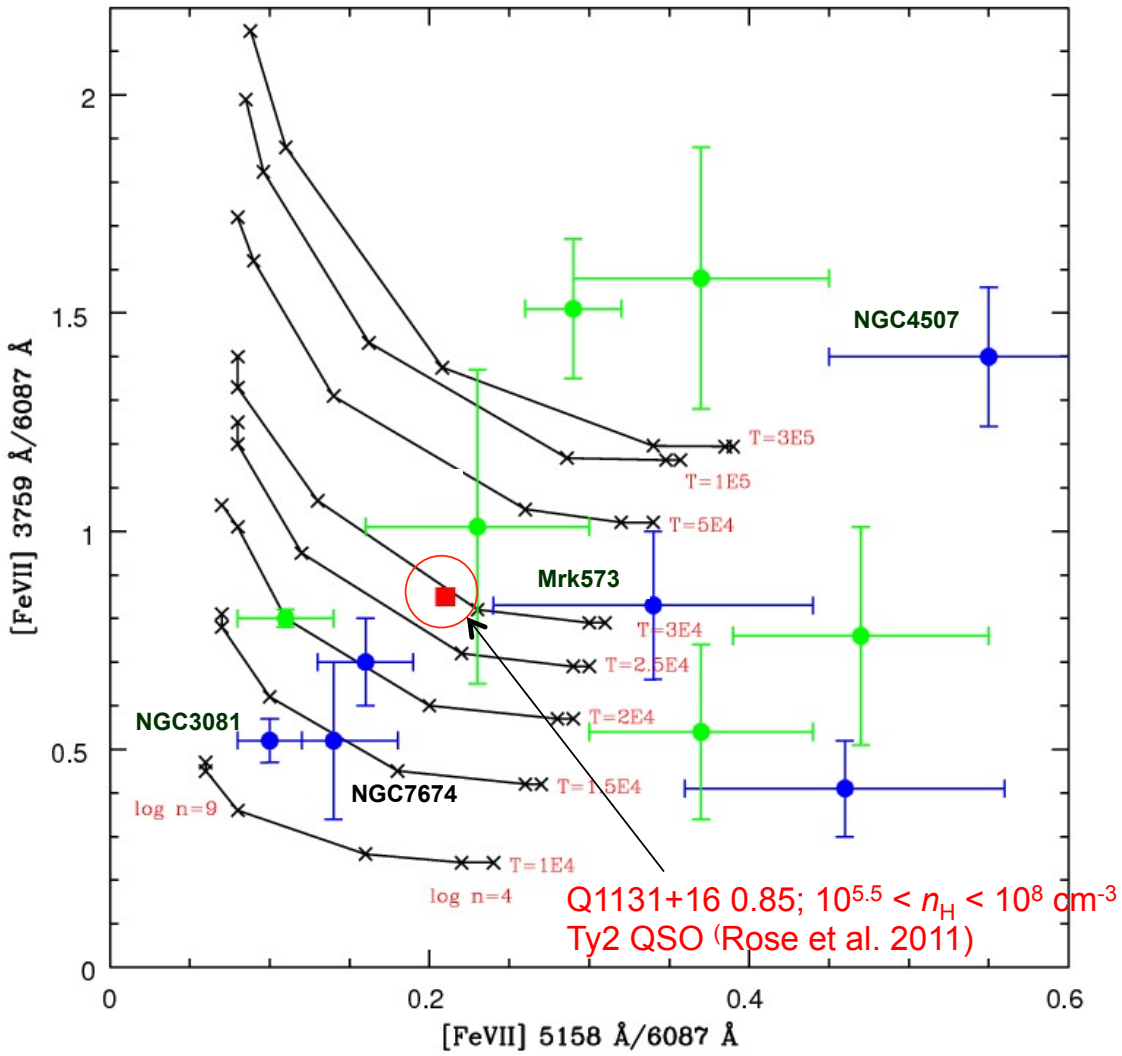


Temperature and density of the CLR: Examples of the lines we want to measure





Temperature and Density of the CLR gas



- Blue points are data from Goodman/SOAR. green points correspond to measurements done with a SDDS sample (Portilla & Rodríguez-Ardila, 2011).

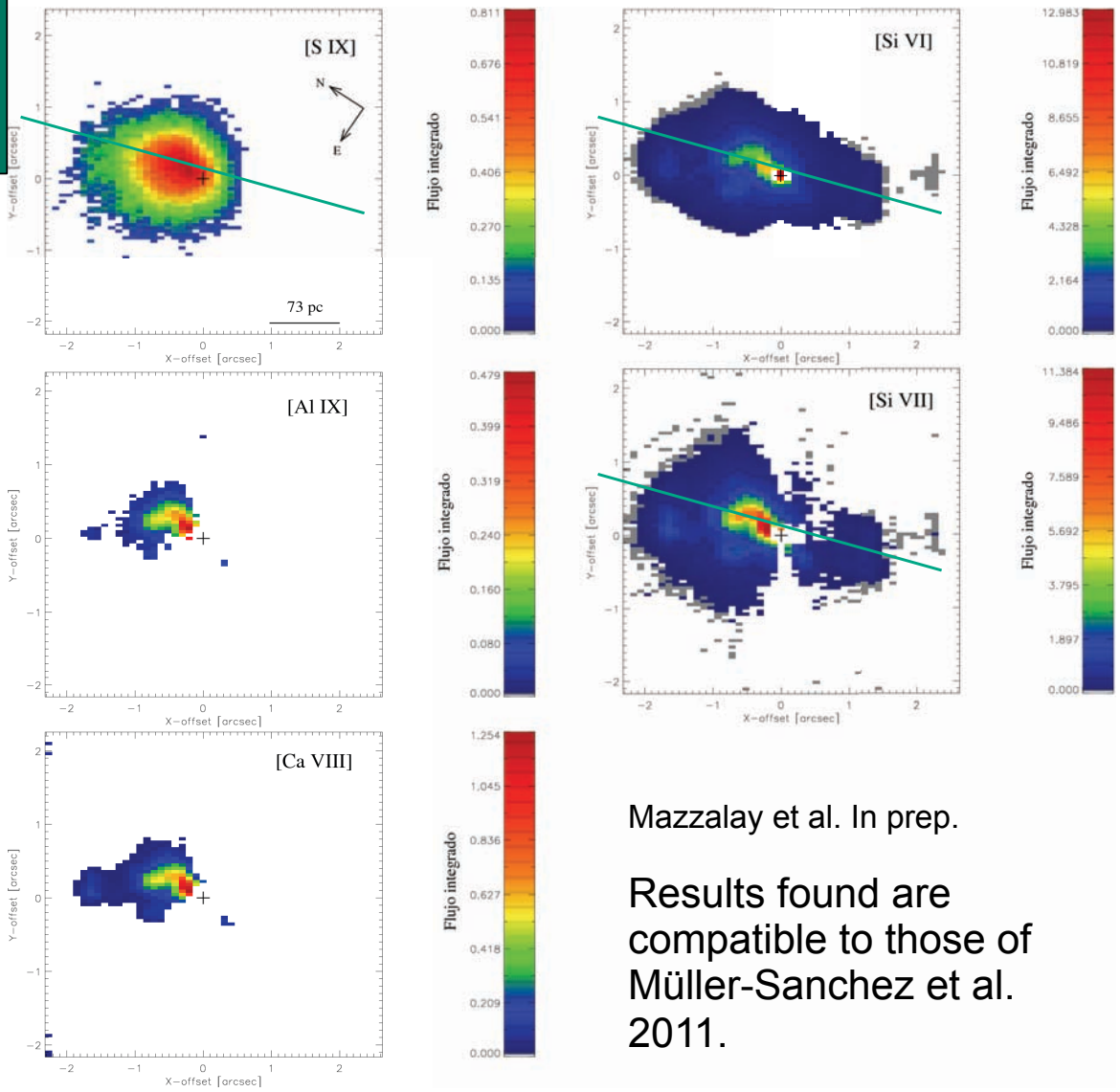
- Curves are theoretical values from Berrington et al.(2000) for Te = 10^4 to 3x10^5 K (bottom to top).

- Crosses correspond to values of n_e ranging from 10^5 (extreme right) to 10^9 (extreme left) in cm^{-3} at intervals of log n_e = 1.

- Large range in *T*e and n_e. All sources have *T*e ≥ 1.5x10^4 K; Most have $10^6 < n_e < 10^7$ cm^{-3} . Compatible with photoionization by the central source.

A NIR approach of NGC 1068 Gemini / NIFS Morphology & Extension of the CLR gas

- Elongated in the NE-SW direction
- Irregular morphology
- Brighter regions to N-NE from the nucleus. An arc that extends for ~0.8".
- Towards SW, weaker emission (extinction).
- Extension:
  - NE: 2.3" ~170 pc
  - SW: [SiVI] & [SiVII] have a secondary peak at ~2.2"
  - SW: [SIX] < 1"

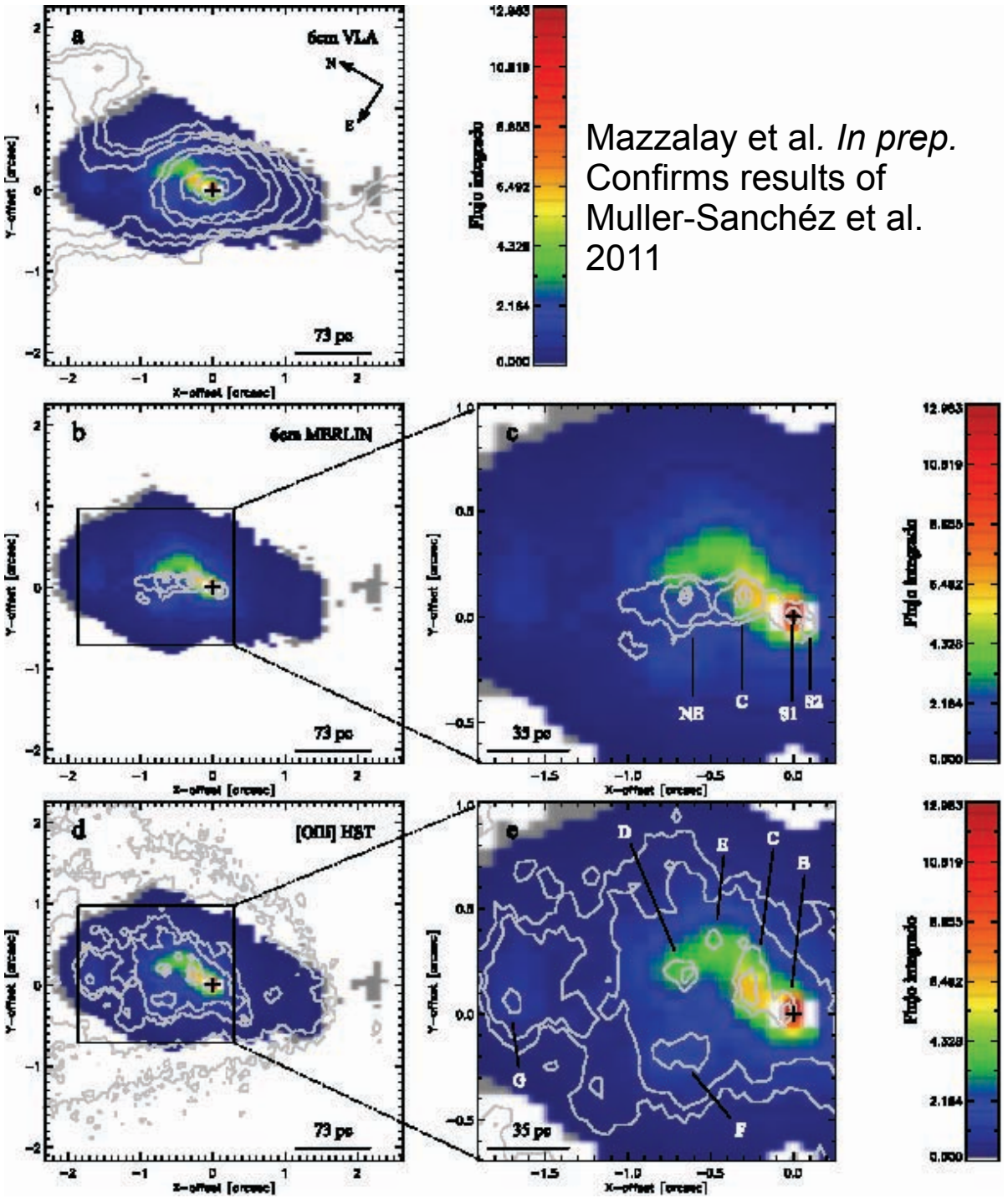


Mazzalay et al. In prep.

Results found are compatible to those of Müller-Sanchez et al. 2011.

[SiVI], [OIII] and radio emission

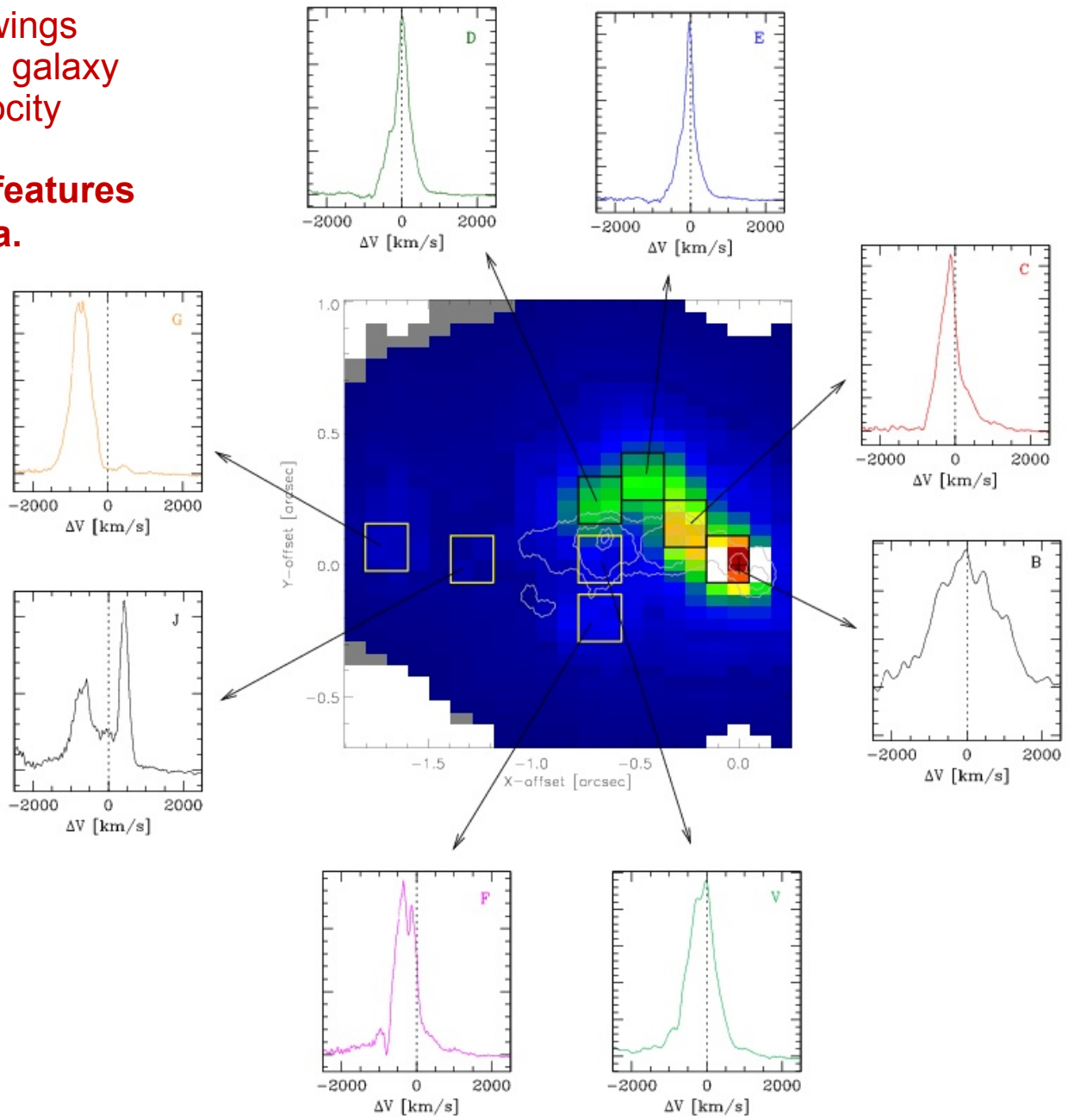
- [SiVI] very similar to [OII]
- Extinction to the SW
- Upper limit to the density of [SiVI]:
  - $N_{c,[OIII]} = 7x10^5 cm^{-3}$
  - $N_{c,CLs} > 10^8\ cm^{-3}$
- [SiVI] elongated in the direction of the radio-jet
- At smaller scales (Merlin): the jet cleans up a channel, increasing the gas density (an its emission in the border).
- The jet plays a fundamental role in the morphology of the CLR gas in NGC1068



Mazzalay et al. *In prep.* Confirms results of Muller-Sanchéz et al. 2011

- Line splitting
- Blue and red wings
- Shifts from the galaxy recessional velocity

Resemble the features seen in LS data.



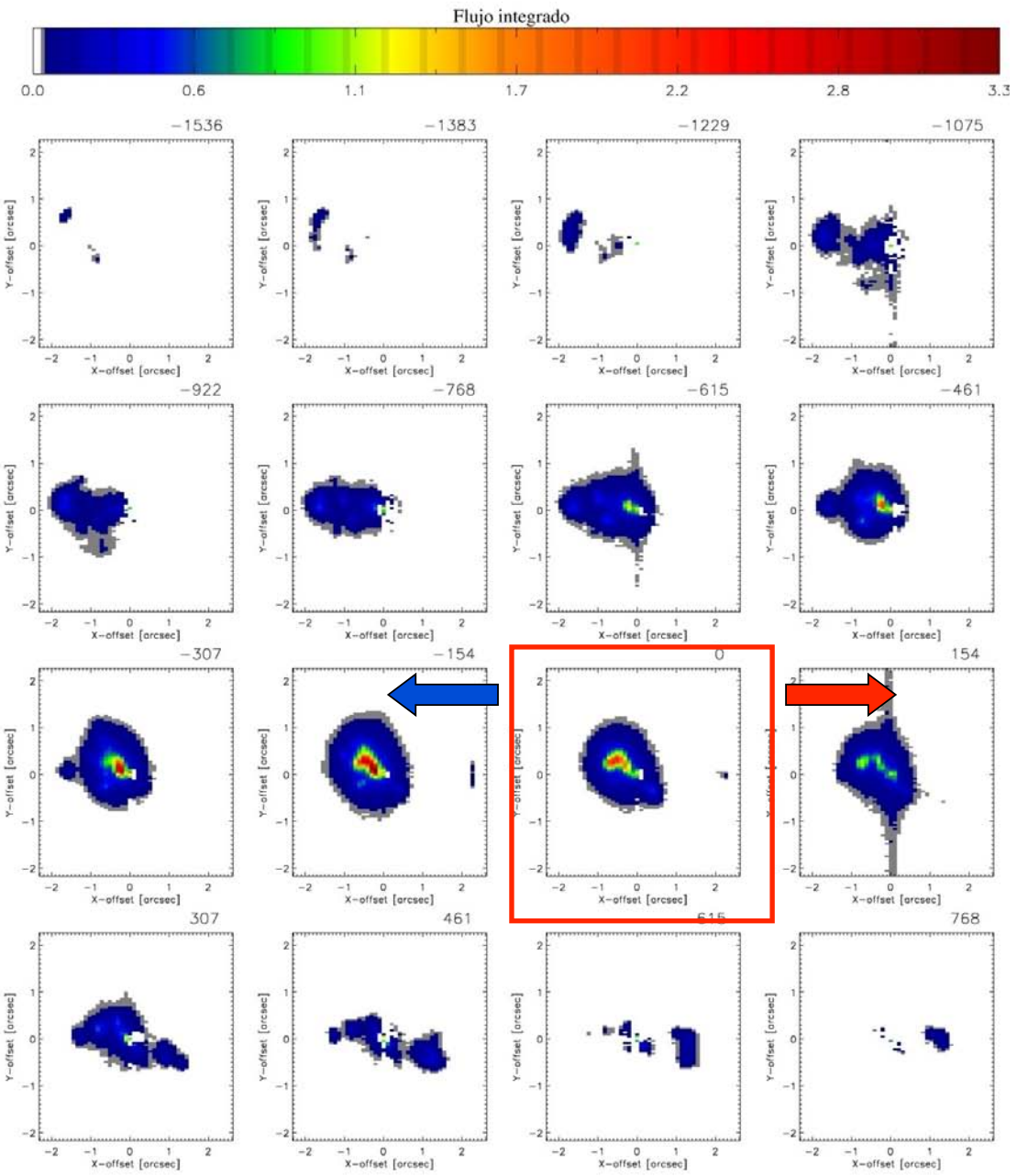
Kinematics

- [SiVII] kinematics coincident with that of [SiVI]

⇒ They shoud be formed in the same outflow

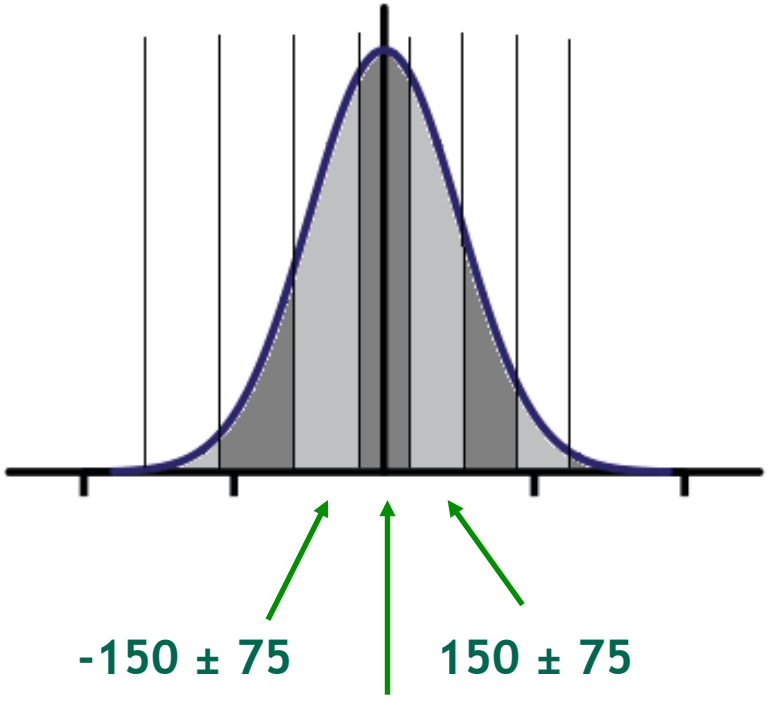
- Channel maps of [SIX] and Pab also points out to a similar kinematics.

[Si VII] 2.48 μm

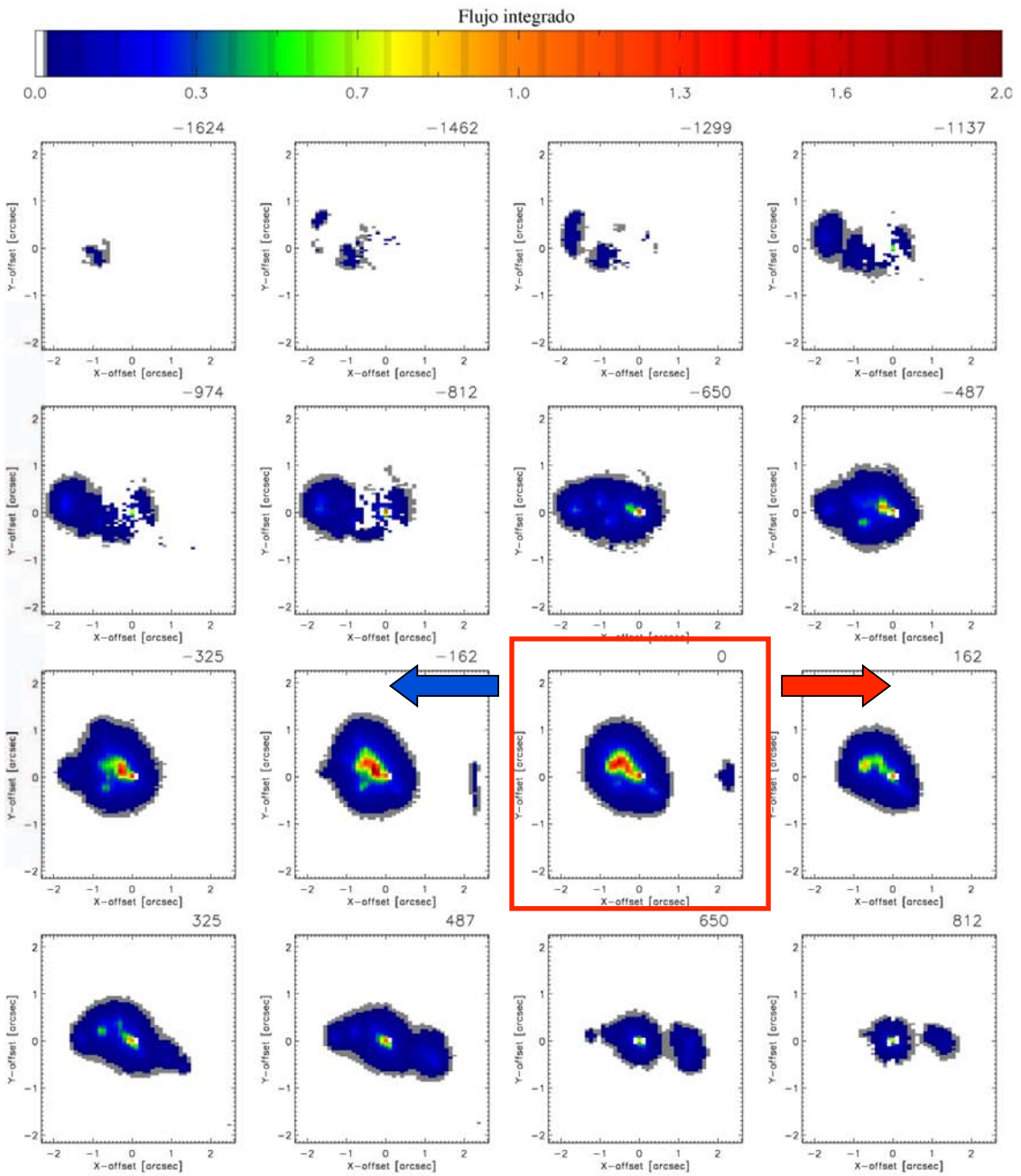


Kinematics

Emission line tomography



[Si VI] 1.96 μm



Final Remarks

- Most CLs are emitted in gas with temperatures typical of photoionization by a central source. In NGC 4507, the high *T*e (~5x10^4 K) suggests an outflow-dominated source.
- In NGC 4507, Mrk 573, and NGC7674, splitted [FeVII] and/or [FeX] lines are clearly detected. This supports the results obtained from other authors where nuclear outflows were detected.
- The coronal gas lines usually displays highly extended blue wings (strongly red-assymmetric line profiles), not observed in lower-ionization lines. This suggests the presence of strong winds/outflows at the inner portion of the narrow line region (r<300 pc). Thus, LS spectroscopy of CLs, combined with temperature measurements of the CLR seems to be an effective way of detecting outflowing sources.
- NIR IFU observations of NGC1068 confirms the presence of radial gas motions in the central region of this source, aligned to the radio jet,