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Polarized emission in the mm band of PKS0521-365: ALMA observations.

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Abstract:
The role of magnetic field in the AGN jet physics is still not fully determined. At pc scale, it is known that it is important in the acceleration and collimation processes while at arcsecond scale it could reveal fundamental pieces of the jet dynamics and energetics and its surrounding environment. At intermediate scales, the scenario is more debated. To contribute in this framework, we need to resolve polarized emission even in the low surface brightness extended structures (e.g. lobes). This absolutely requires high sensitivity observations. With the advent of ALMA, now it is possible also in the millimeter, a band which was unexplored by previous facilities. Here I present the impressive images in polarization obtained using ALMA archival multi band data of an ALMA calibrator PKS 0521-365 which represents a prototype of BL Lac object with extended resolved structures (jet and hotspot) at all frequencies from optical to X-rays.

The peculiar case of PKS 0521-365

This is a nearby (z = 0.0554) radio-loud object and bright FERMI source, exhibiting a variety of nuclear and extranuclear phenomena (Falomo et al. 2009). It is one of the most remarkable object in the sourthern sky: It is one of the three known BL Lac objects showing a kiloparsec-scale jet well resolved at all bands (Liuzzo et al. 2011). As showed in Fig.1, a one-side radio jet extends in N-W side up to 7 arcsec , with the presence of many knots that are also detected from optical to X–rays (Falomo et al. 2009). An hotspot is also detected in all bands at 8 arcsec from the nucleus in the southeast direction. At low frequency, the arcsecond-scale radio structure is dominated by an extended lobe.
The overall energy distribution of PKS 0521-365 is consistent with a jet oriented at about 30 degrees with respect to the line of sight. This is also in agreement with the absence of superluminal motion in the parsec–scale jet (Falomo et al. 2009).
In the millimeter bands, extended structures (hotspot and jet) of this object are detected up to 320 GHz, with similar structures from optical to X–rays (Liuzzo et al. 2015, Leon et al 2016). An estimate of molecular gas content is also given together with an analysis od the SED of each source component (Liuzzo et al. 2015).

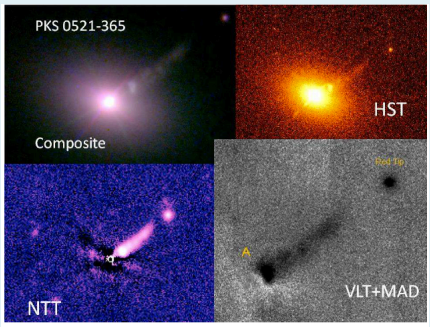

Fig. 1 Multiband images of PKS 0521-365

ALMA observations and results

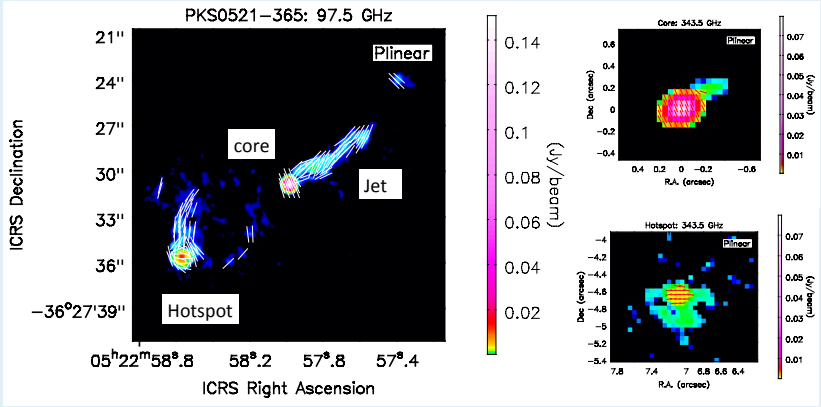

Fig. 2 Linear polarization emission (colours) and position angles (vectors) in ALMA Band 3 and 7 of PKS 0521-365

We analysed polarization data in
- Band 3 from our propretary data (PI: V. Galluzzi);
- Band 5 from science verification observations;
- Band 7 from public archival data.

We found that the source is well resolved upt to 350 GHz with detection of core, inner jet and hotspot.

Polarized emission is revealed:
- in the core and hotspot up to B 7.
- also in the extended jet and lobe in B 3 with position angle parallel to the jet direction and to the shock front in the lobe.

Next steps and perspectives:

In the following I discuss what it is now possible to do thanks the presented high quality ALMA data in polarization, like those presented here:

- ***Magnetic field study in radio loud AGN***: Nearly 10-20 % of AGN are radio loud and the form of their spectra as a function of frequency implies that the radio emission is non-thermal (synchrotron) in origin, due to relativistic plasma moving in strong and ordered magnetic fields. Since the polarised signal in these objects is typically a few percentage of the total intensity, collecting information on magnetic field of RL AGN requires telescope with high sensitivity (<<1mJy/beam) as ALMA. The results obtained for PKS 0521-365 show that in only 10 mins on source polarized emission is revealed even in the lobes with angular resolution < 0.5 arcsec, demonstrating that now with ALMA impressive results could be reached also for faint source components (<0.1 mJy) and for large sample of sources.

- ***Faraday Rotation Synthesis analysis***: The study of the rotation measure, defined as the change of polarization angle as a function of wavelength squared, is particularly important as this quantitiy is directly related to the plasma density and the strength of the magnetic field along the line of sigth. ALMA can perform observations in spectro-polarimetric mode. This offers a unique possibility to apply the Faraday Rotation (FR) Synthesis technique (Brentjens & de Bruyn 2005), allowing a 3D representation of the magnetic field at angular scale even of subarc. To do this, it is however crucial to correct the observed polarized emission for any external/internal medium contribution. In the mm band, the observed FR could be dominated by either thermal, magnetised plasma external to the source or by the relativistic plasma responsible for the synchrotron emission from the jet. Procedures similar to those applied by O'Sullivan et al. 2012 will be used to discriminate the various scenarios.

- ***Particle acceleration mechanism:*** The study of the magnetic field in bright compact regions at the terminations of powerful jets, i.e. hotspots, is also crucial. Those regions are believed to be shocks at which the jet material interacts with plasma already present in the lobes and the external one. With these ALMA polarization observations, I will be also able to determine the unknown particle acceleration mechanism in the hotspot: Fermi-II acceleration or multiple shocks (e.g. Prieto et al. 2002)?

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