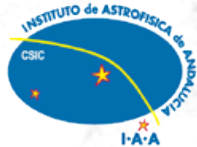


# POLAMI: Polarization Monitoring of AGN at Millimeter Wavelengths

**Iván Agudo, IAA-CSIC**

Instituto de Astrofísica de Andalucía-CSIC

Granada (Spain)



**CSIC**

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

# **POLAMI: Polarization Monitoring of AGN at Millimeter Wavelengths**

## **Acknowledgements to entire POLAMI Team:**

**Clemens Thum  
Alessia Ritacco  
Gabriel Paubert  
David Morris  
Albrecht Sievers  
Carsten Kramer**

**Sol Molina  
Antonio Fuentes  
José L. Gómez**

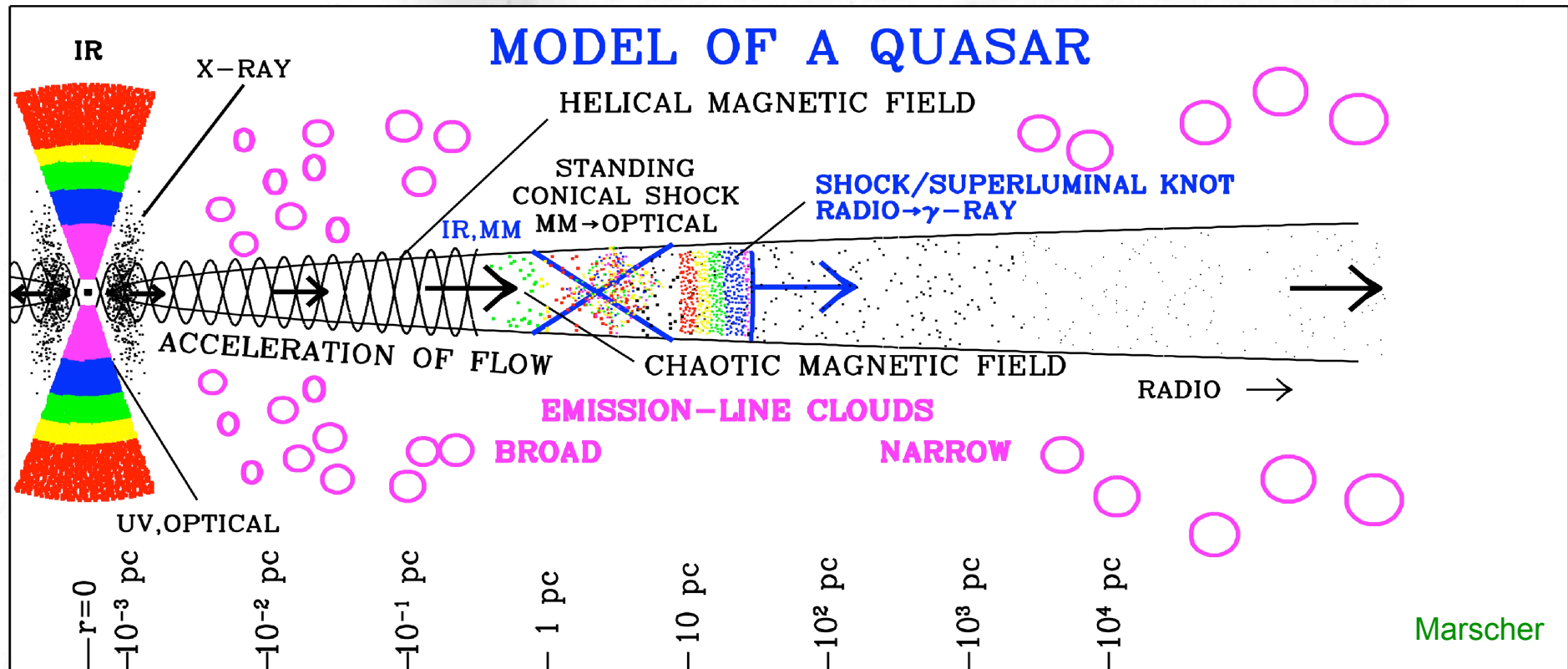
**Venkatessh  
Ramakrishnan**

**Alan Marscher  
Svetlana Jorstad**

**Carolina Casadio  
Helmut Wiesemeyer  
Ioannis Myserlis  
Jae-Young Kim  
Thalia Traianou  
Thomas Krichbaum  
Emmanouil Angelakis  
Eduardo Ros  
Anton Zensus**



# Introduction





## POLAMI: Polarimetric Monitoring of AGN at Millimeter Wavelengths

- Long term monitoring of the 4 Stokes parameters @ IRAM 30m Telescope (XPOL, Thum et al. 2008, Wiesemeyer et al. 2010)

IRAM 30m Millimeter Telescope  
Sierra Nevada, 2850m  
(Granada, Spain)

- In principle no huge Faraday rotation of linear polarization emission from the jet at mm wavelengths

- No huge Faraday depolarization

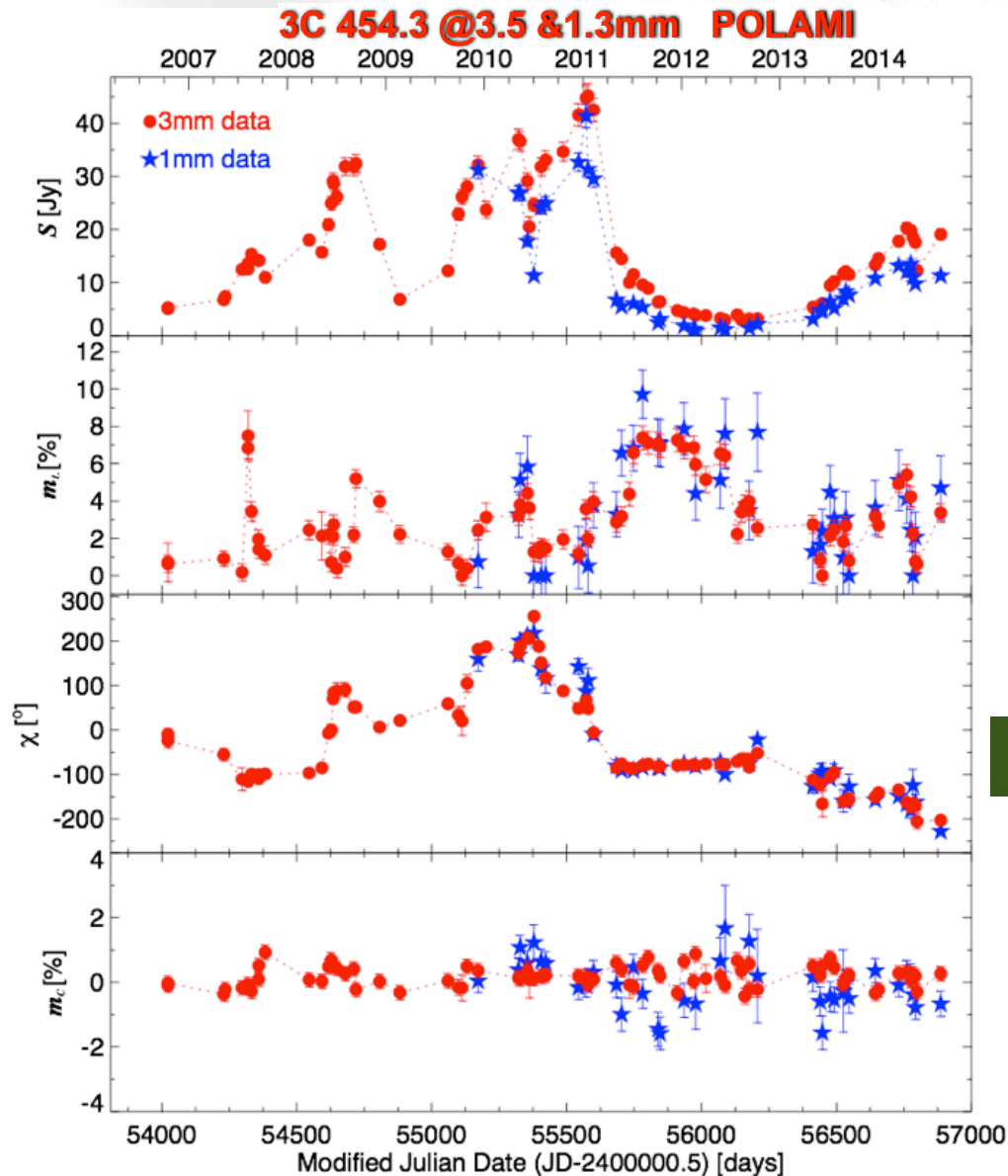
- Essentially no opacity effects

- mm emission is compact and represents well the inner regions of jets



# POLAMI: Polarimetric Monitoring of AGN at Millimeter Wavelengths

- 3C 66A
- AO 0235+16
- 3C 84
- CTA 26
- 3C 111
- PKS 0420-01
- 3C120
- PKS 0528+134
- S5 0716+71
- PKS 0735+17
- OJ 248
- OJ 49
- 4C 71.07
- OJ 287
- S4 0954+65
- PKS 1055+01
- MRK 421
- PKS B1127-145
- 4C 29.45
- ON 231
- PG 1222+216
- 3C 273
- M 87
- 3C 279
- B2 1308+30
- PKS 1406-076
- PKS 1510-08
- DA 406
- PKS 1622-29
- 4C 38.41
- 3C 345
- NRAO 530
- OT +081
- BL Lacertae
- 3C 446
- CTA 102
- 3C 454.3



• ~40  $\gamma$ -ray bright sources, most of them on list of Boston University VLBA monitoring program.

•  $I$ ,  $m_L$ ,  $\chi$ ,  $m_c$  @ 3.5 & 1.3mm simultaneous observations ( $1\sigma$  sensitivity 5%, 0.5%,  $5^\circ$ , 0.3%, and 5%, 1.7%,  $10^\circ$ , 0.5%, respectively)

• Time sampling ~2 weeks since ~mid 2006

***We still keep monitoring!***

~mid 2006 to ~mid 2014

Agudo et al. (arXiv:1709.08742)

Thum et al. (arXiv:1709.08743)

Agudo et al. (arXiv:1709.08744)

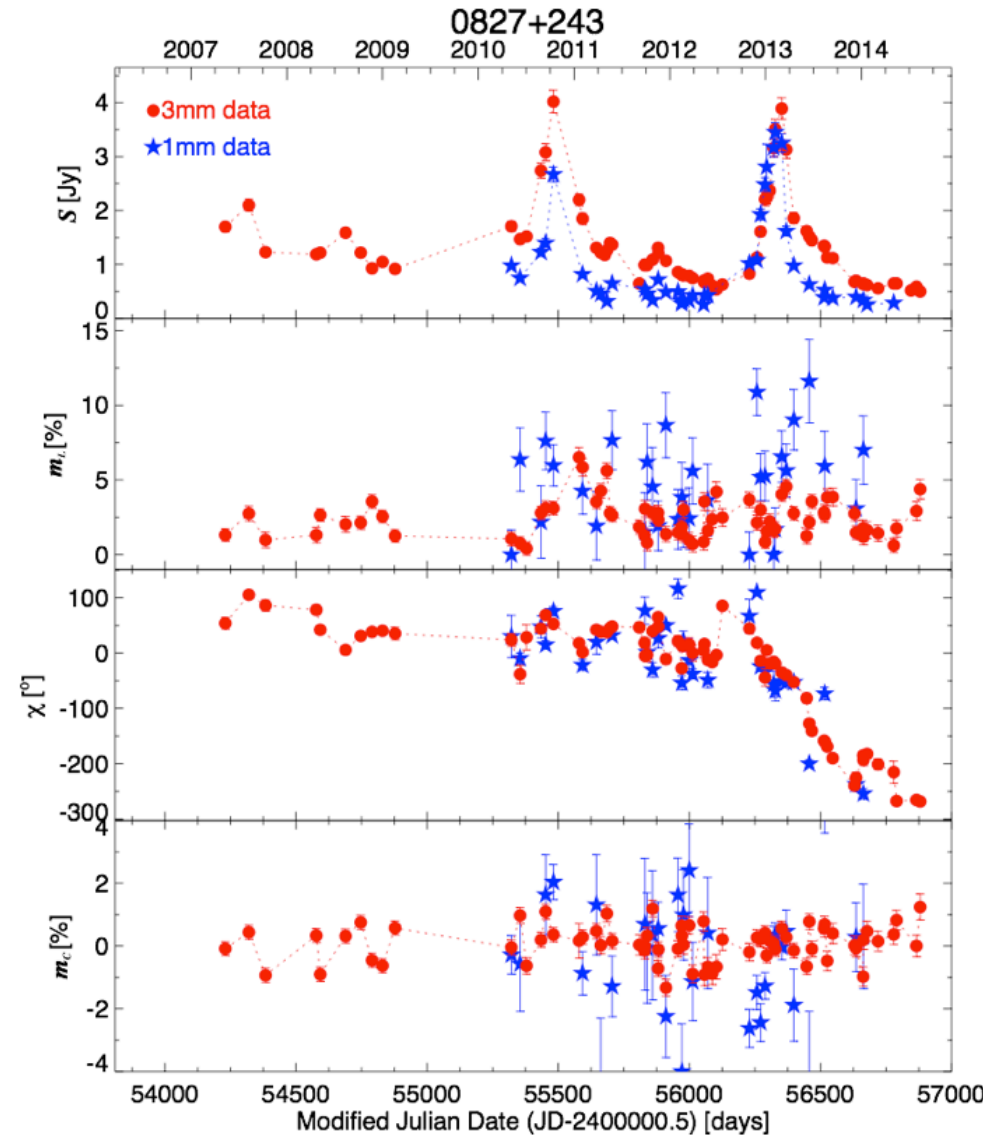
POLAMI Papers I, II, and III  
in press for MNRAS

## Increase of linear polarization degree with $\nu_{\text{obs}}$

- Significantly larger fractional linear polarization at 1mm than at 3mm by median factor  $\sim 2.6$  (over  $> 2000$  measurements)

- Since we rule out strong opacity effects:

**1) Average  $B$  is better ordered on the shorter  $\lambda$  regions as compared to the longer  $\lambda$  ones**



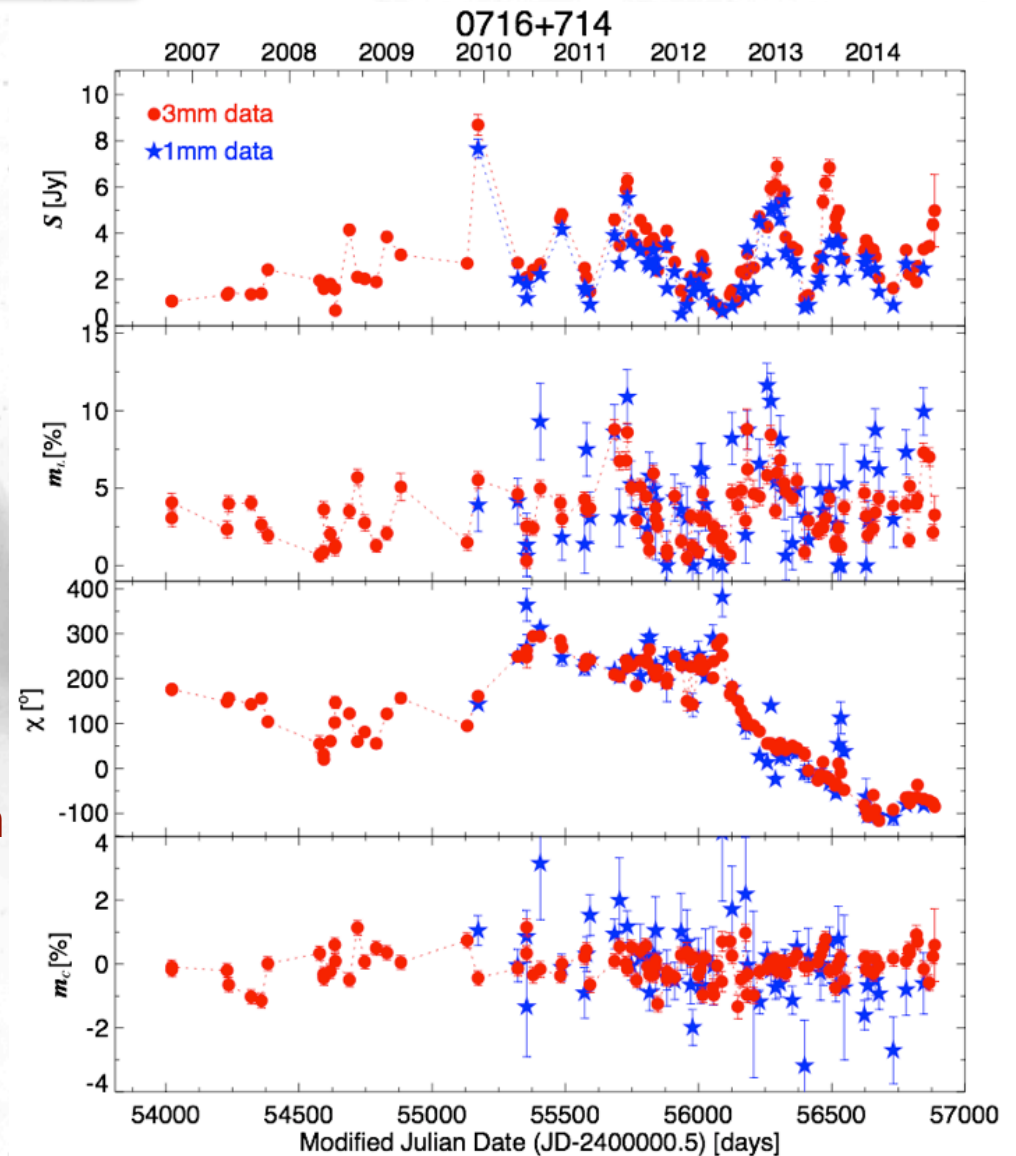
POLAMI Paper III



## Variability of linear polarization degree

- $m_L$  also highly variable (range from  $\sim 0\%$  to  $\sim 15\%$ )
- More rapid variability is observed in  $m_L$  than in total flux (total flux emission not affected by emission cancelation of orthogonal polarisation)
- Time scale of variability also significantly shorter at 1mm than at 3mm

**2) Consistent with shorter wavelength emission coming from smaller regions**

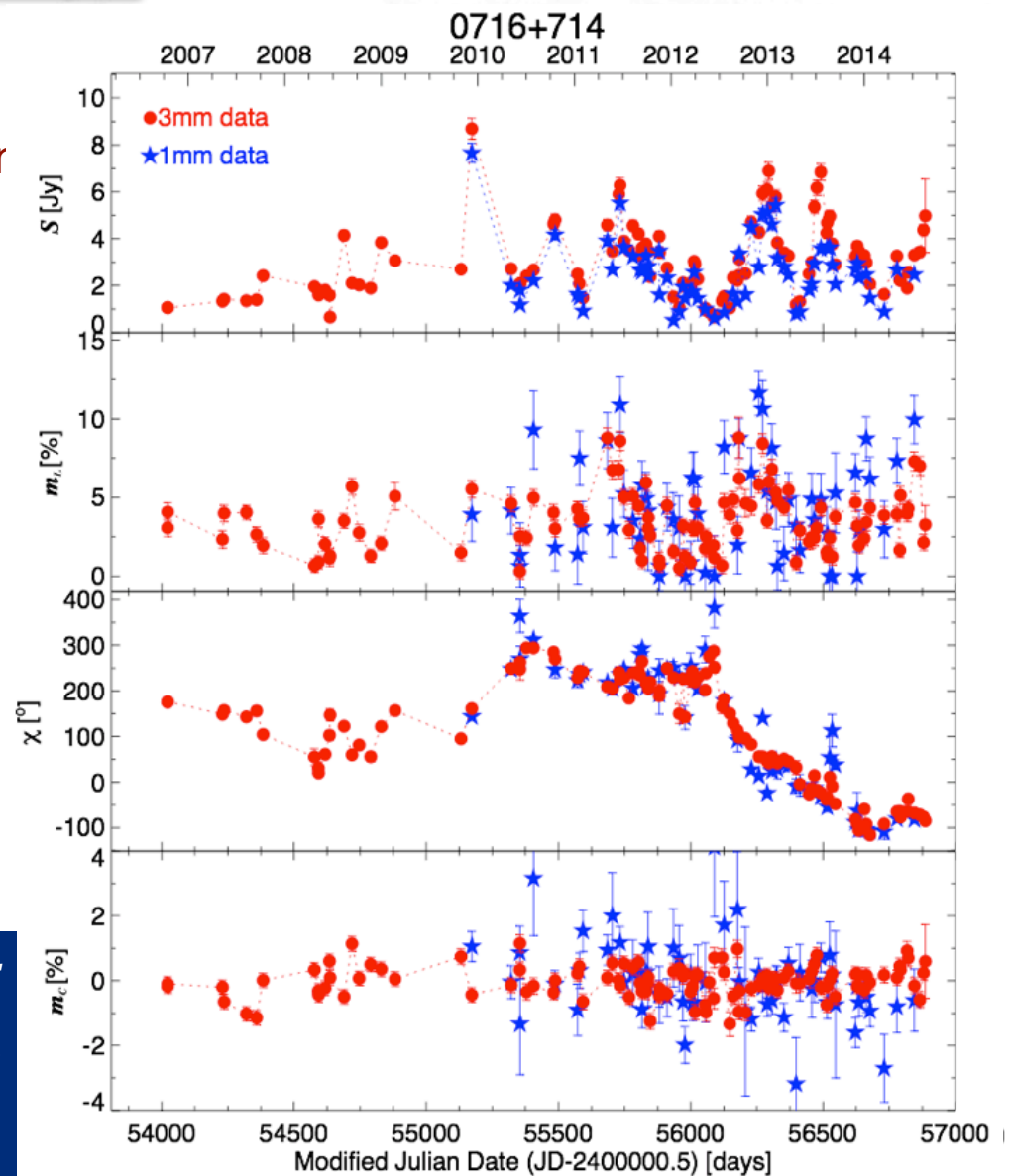


POLAMI Paper III

## Variability of linear polarization angle

- $\chi$  at 3 and 1mm also highly variable
- 21/36 sources at least a  $> 180^\circ$  rotation
- Time scales from a few weeks to a year (typical 3-5 weeks)
- $\chi$  in general not correlated with  $S$ ,  $m_L$ , (also not correlated among each other)
- Variability of the linear polarization cannot be explained by the time evolution of a single emission region

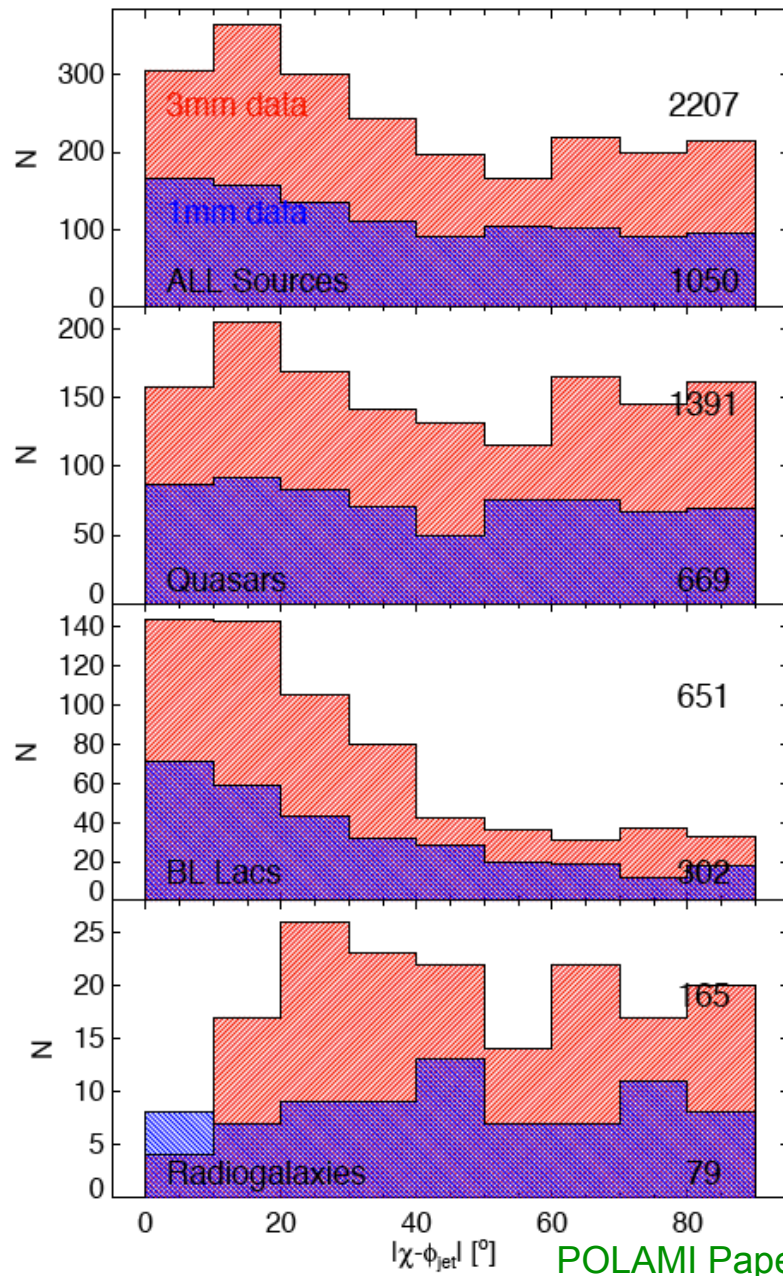
**3) Excludes 1-zone models. Number of emission zones should then be larger than one (probably larger than two in some cases)**



POLAMI Paper III



## Linear polarization angle vs. jet position angle



- In general, very weak trend to align  $\chi$  almost parallel to the jet axis (for  $\sim 19\%$  of sources)

- Similar results found in Agudo et al. (2010, 2014), and Lister & Homan (2005)

- For purely axisymmetric jets,  $\chi$  has to be observed either parallel or perpendicular to the jet axis owing to cancellation of orthogonal polarization components (e.g, Lyutikov et al. 2005; Cawthorne 2006)

- What we get for most of the sources is the other way round!

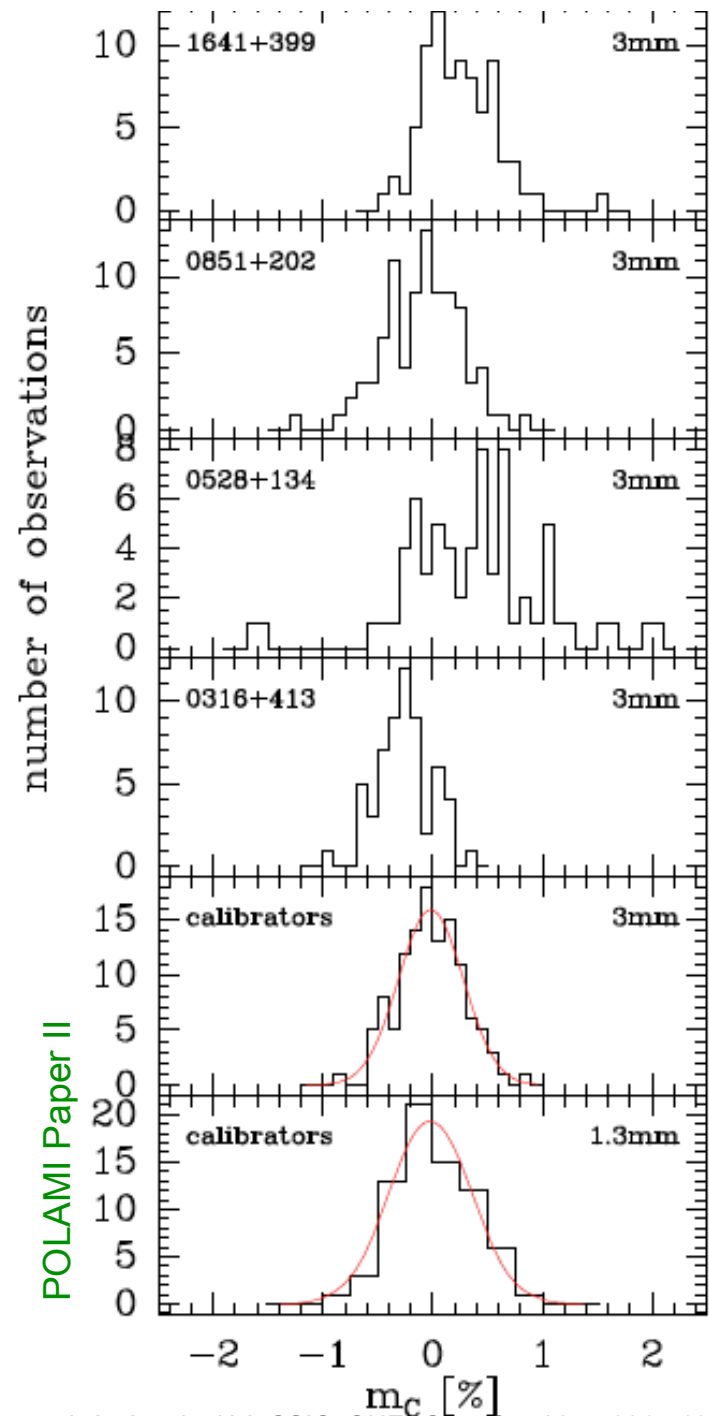
**4) Blazar jets are not axisymmetric, at least on which regards to their polarization emission**

POLAMI Paper III

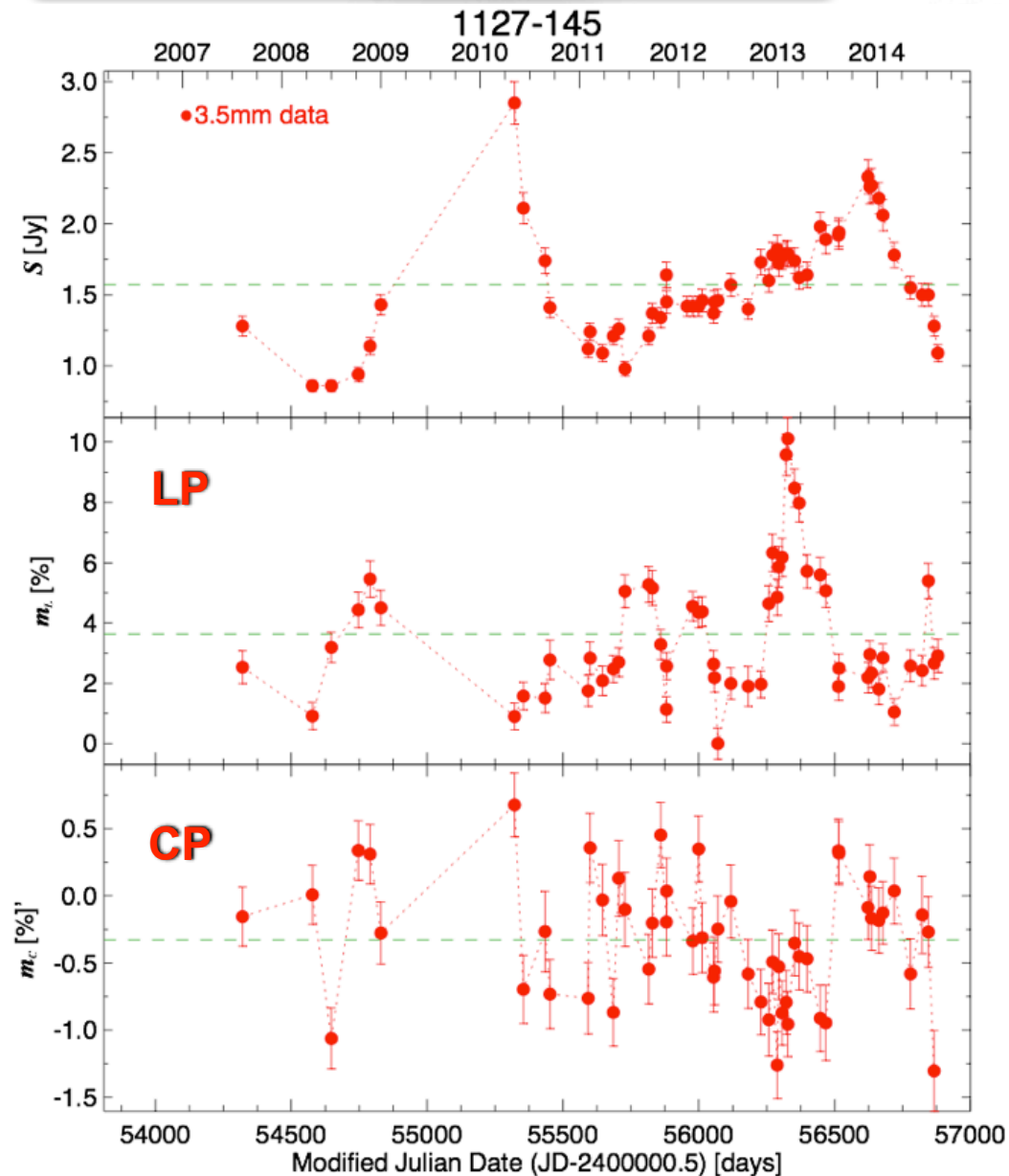
## Circular polarization

- Mars & Uranus (unpolarized), shows Gaussian profile with  $\sigma \sim 0.3\%$  ( $\sigma \sim 0.5\%$  at 1mm, all measurements together) and  $\langle m_C \rangle = 0.0\%$
- Blazars show different distributions (>99.7% conf):
  - Broader  $m_C$  distributions, even double-peaked
  - Sometimes significantly shifted from 0.0%
  - Several detections  $>5\sigma$  up to  $\sim 1\%$  (even  $\sim 2\%$ )

**5) Circular polarization routinely detected at mm- $\lambda$  and as large as those reported at cm- $\lambda$ !**



## Circular polarization variability



- CP time evolution show hints of:
- Time scales of months
- Perhaps even much shorter time scales (~weeks)
- Frequent sign changes

**6) Time variability and CP sign changes point to some level of small scale of inhomogeneities allowing for variability**

**Data is compatible with Faraday conversion, e.g. in the presence of helical B field, but also production of intrinsic synchrotron CP**

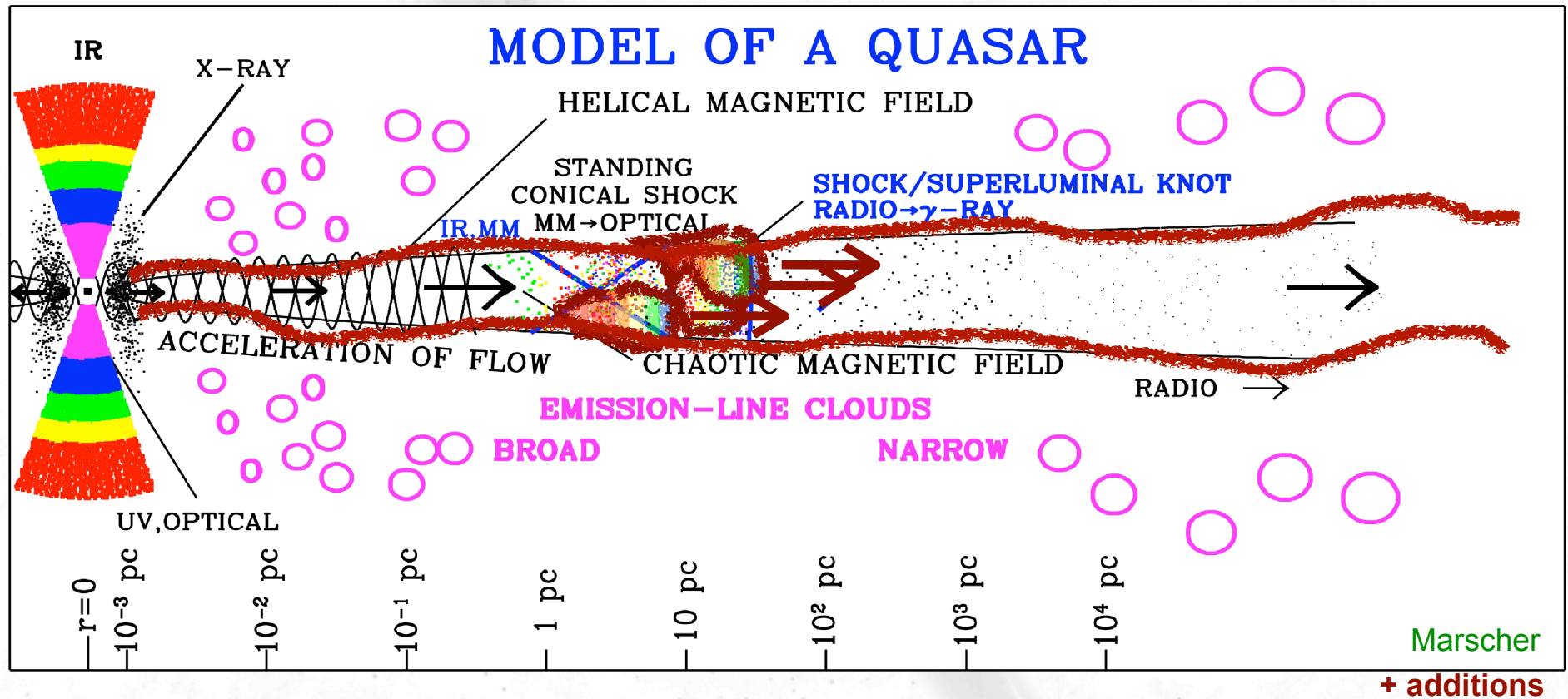
POLAMI Paper II



## Summary

- Shorter mm emission comes from smaller regions with progressively better B order
- One zone models excluded by general properties of mm polarization of blazars
- Blazar Jets not axisymmetric in general, regards to their polarization emission
- Hints of fast CP variability and frequent sign changes
- Circular polarization seems to be present in blazars at mm wavelengths in general at levels  $\leq 2\%$
- Faraday conversion of LP into CP from helical B field, inhomogeneous dynamic processes, and intrinsic CP production can explain our CP data

# Conclusions





## Description of the POLAMI program

POLAMI is a long-term program to monitor the polarimetric properties (Stokes I, Q, U, and V) of a sample of around 40 bright active galactic nuclei (AGN) at 3.5 and 1.3 millimeter wavelengths with the [IRAM 30m Telescope](#) near Granada, Spain. The program has been kept running since October 2006 and it currently time samples with a goal cadence of ~2 weeks. The [XPOL polarimetric observing setup](#) has been routinely used as described in [Thum et al. \(2008\)](#) since the start of the program.

Data obtained by the POLAMI collaboration are combined with other IRAM 30m projects approved by the IRAM program committee as well as other survey and target-of-opportunity projects, and the results are presented here. Therefore, the POLAMI database includes measurements of over 200 AGN. Most of these sources were observed in the single-epoch surveys published in [Agudo et al. \(2010; 2014\)](#).

Thu, 04/20/2017 - 14:14

## First series of POLAMI papers

A series of 3 papers have just been submitted together as a single pack for [MNRAS](#). In the first paper of this series (POLAMI Paper I) we present the results of the first 8 years of POLAMI observations, we provide detailed information about the observing program, the most intensively monitored source sample of ~40 sources, the data reduction and calibration, and we demonstrate the quality of our data by showing the results obtained for the main calibrators. The data obtained from the science targets, as well as an analysis of their circular polarisation properties and of their total flux and linear polarisation

**polami.iaa.es**