POLAMI: Polarization Monitoring of AGN at Millimeter Wavelengths

First Results and Impact on AGN Science

Iván Agudo, IAA-CSIC

Instituto de Astrofísica de Andalucía-CSIC

Granada (Spain)

INSTITUTO DE ASTROFÍSICA DE ANDALUCÍA

EXCELENCIA SEVERO OCHOA

CSIC

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

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Acknowledgements to entire POLAMI Team:

Juan Escudero
Thalia Traianou
Antonio Fuentes
José L. Gómez

IAA INSTITUTO DE ASTROFÍSICA DE ANDALUCÍA

CSIC Consejo Superior de Investigaciones Científicas

Carolina Casadio

FORTH

Clemens Thum
Ioannis Myserlis
Gabriel Paubert
David Morris
Albrecht Sievers
Carsten Kramer

iram Institut de Radioastronomie Millimétrique

Joana Kramer
Emmanouil Angelakis
Nick MacDonald
Helmut Wiesemeyer
Thomas Krichbaum
Eduardo Ros
Anton Zensus

Max-Planck-Institut für Radioastronomie

Alan Marscher
Svetlana Jorstad

BOSTON UNIVERSITY

Venkatessh Ramakrishnan

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Jae-Young Kim

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Valeri Larionov
Sergey Savchencko
Daria Morozova

Saint-Petersburg State-University

POLAMI: Polarimetric Monitoring of AGN at Millimeter Wavelengths

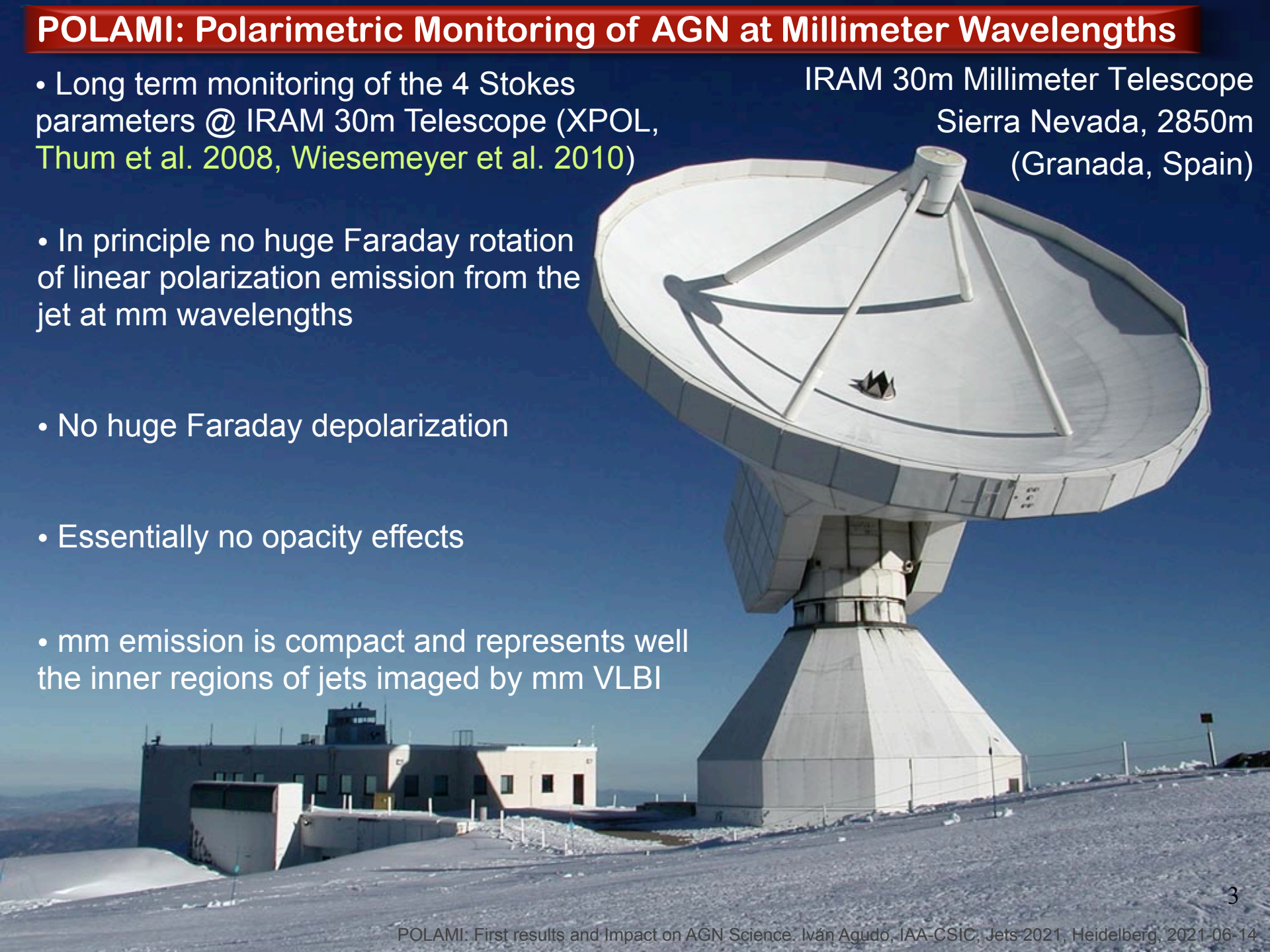
- Long term monitoring of the 4 Stokes parameters @ IRAM 30m Telescope (XPOL, Thum et al. 2008, Wiesemeyer et al. 2010)

- 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 imaged by mm VLBI



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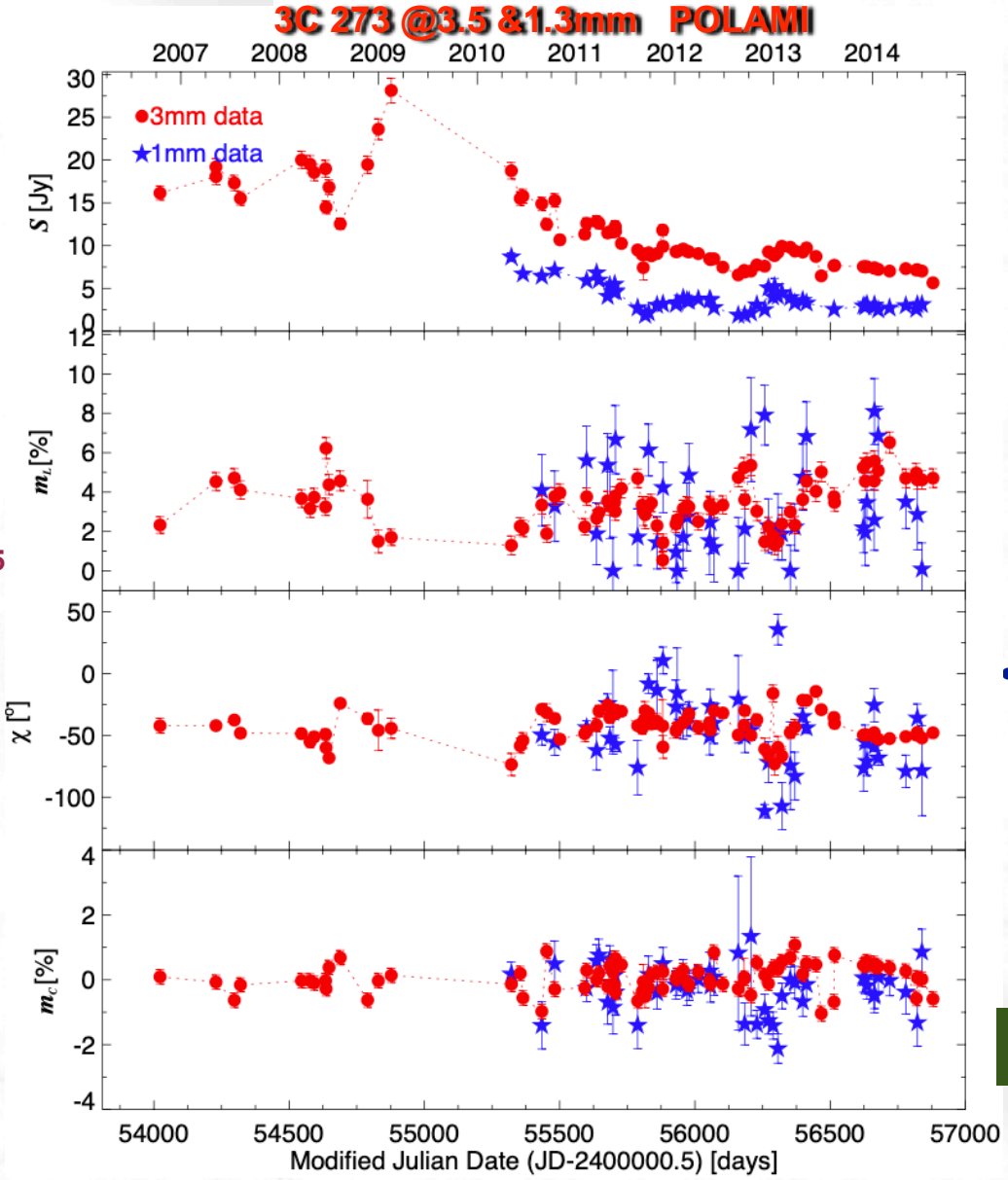
- 3C 66A
- AO 0235+16
- 3C 84
- CTA 26
- 3C 111
- PKS 0420−01
- 3C120
- PKS 0528+134
- S5 0716+71
- PKS 0735+17
- OJ 248
- OJ 49
- 4C 71.07
- OJ 287
- S4 0954+65
- PKS 1055+01
- MRK 421
- PKS B1127-145
- 4C 29.45
- ON 231
- PG 1222+216
- 3C 273
- M 87
- 3C 279
- B2 1308+30
- PKS 1406−076
- PKS 1510−08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



- ~40 γ-ray bright sources, most of them on list of Boston University VLBA monitoring program.
- I, m_L, χ, m_C @ 3.5 & 1.3mm simultaneous observations (1σ sensitivity 5%, 0.5%, 5°, 0.3%, and 5%, 1.7%, 10°,0.5%, respectively)
- Time sampling ~2 weeks
- ~mid 2006 to ~mid 2014

POLAMI Papers I, II, and III:

Agudo et al. (2018, MNRAS, 474, 1427)

Thum et al. (2018, MNRAS, 473, 2506)

Agudo et al. (2018, MNRAS, 473, 1850)

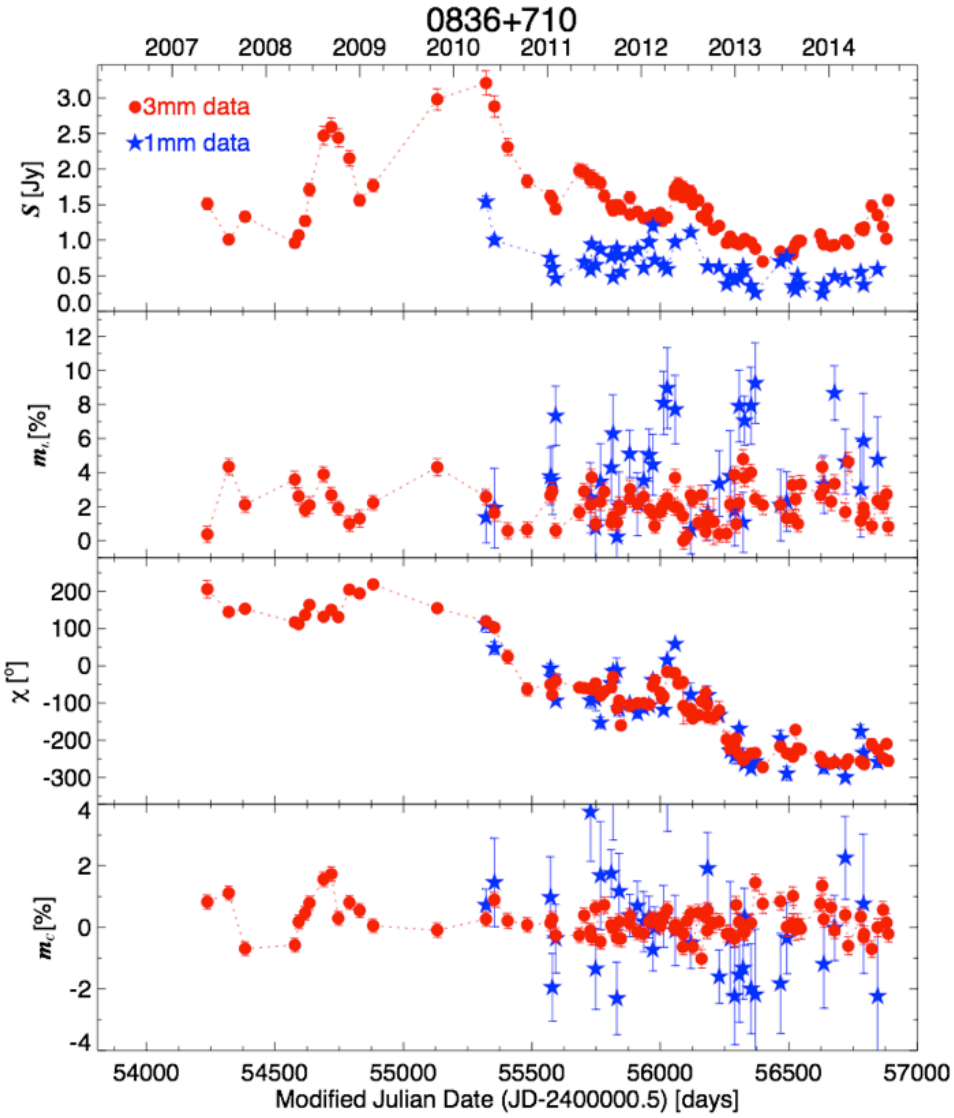
We still keep monitoring!

Increase of linear polarization degree with ν_{obs}

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

- Since we rule out strong opacity effects:

1) Average B is better ordered on the shorter λ regions as compared to the longer λ ones

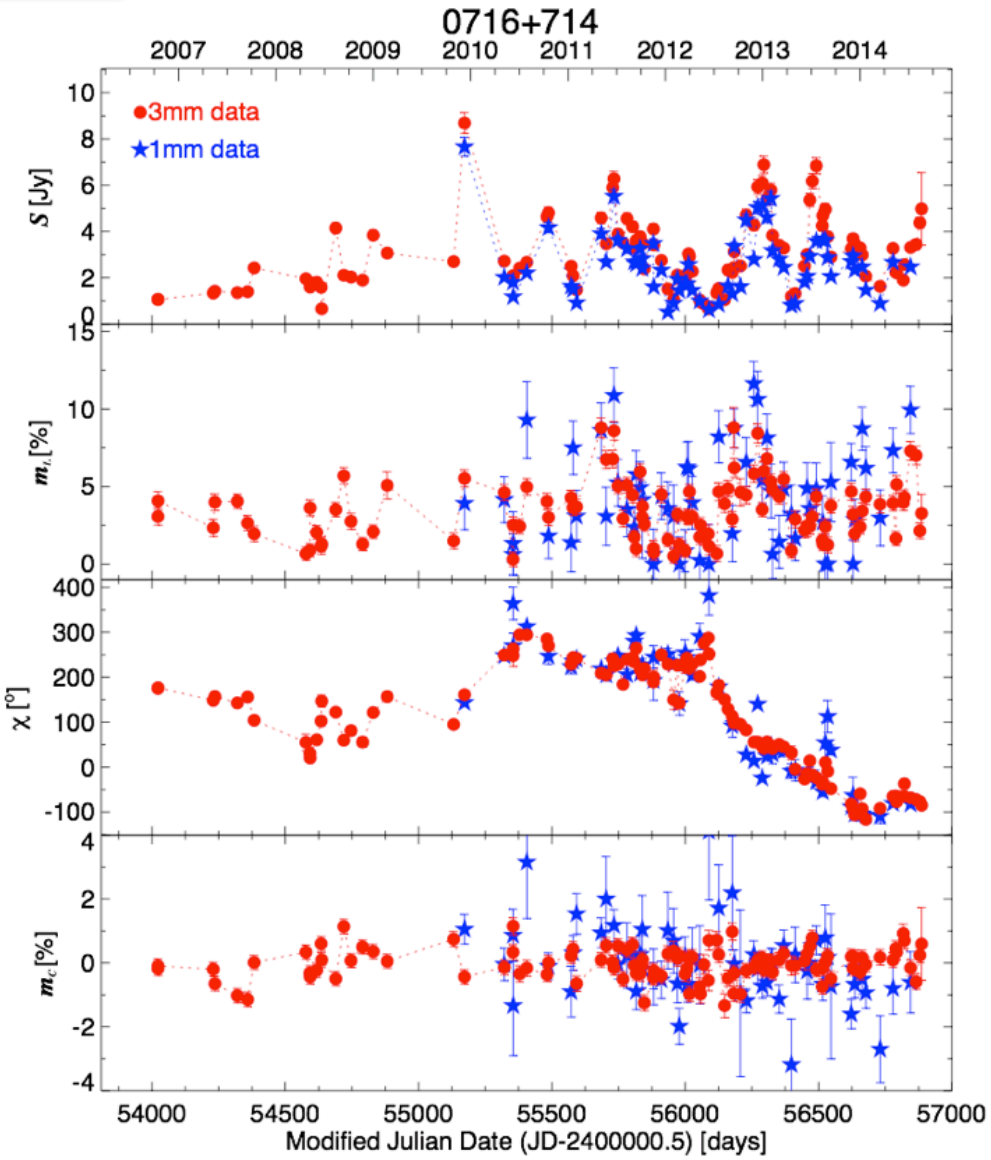


POLAMI Paper III

Variability of linear polarization degree

- m_L also highly variable
- Range from ~ 0% to ~ 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

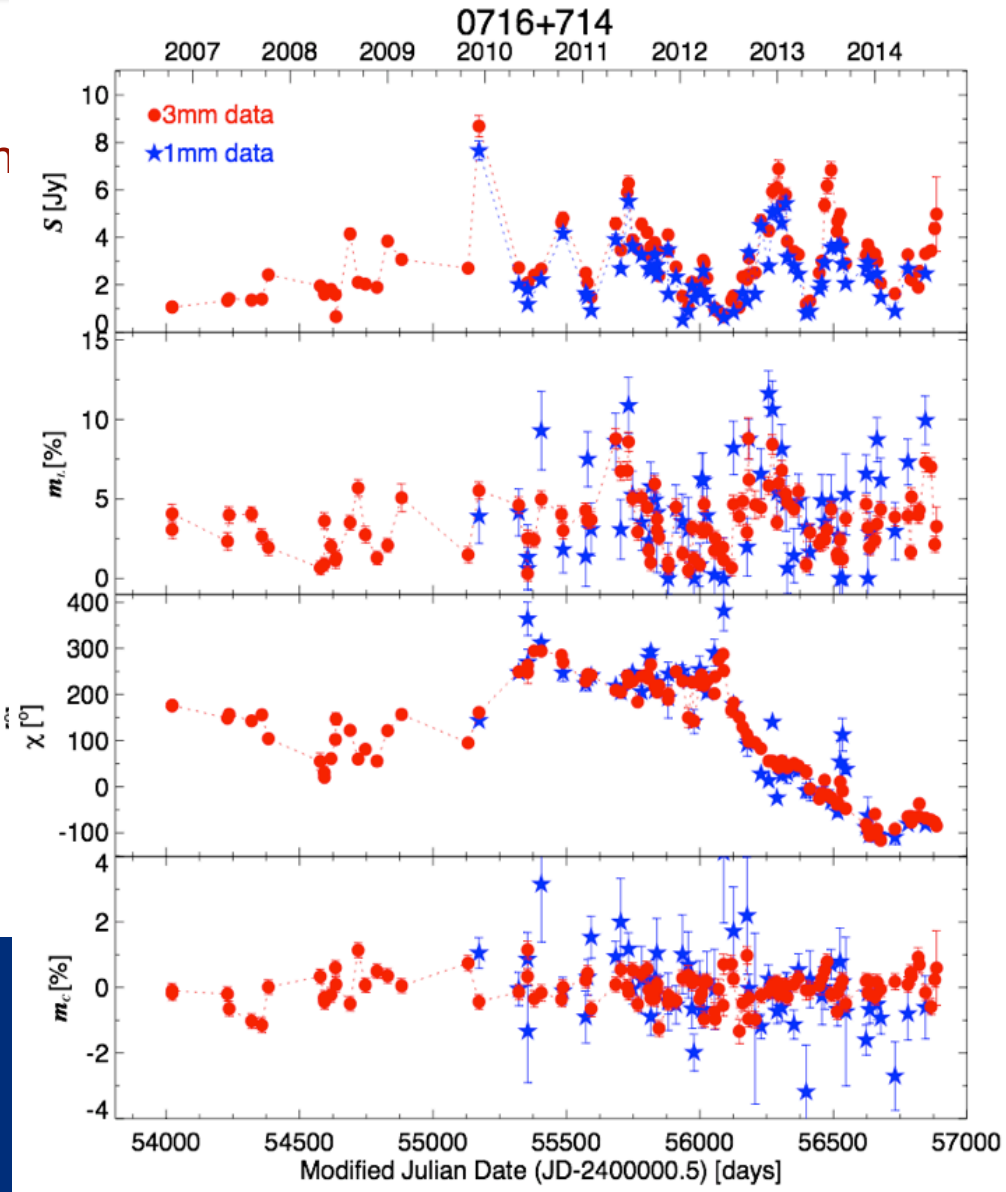


POLAMI Paper III

Variability of linear polarization angle

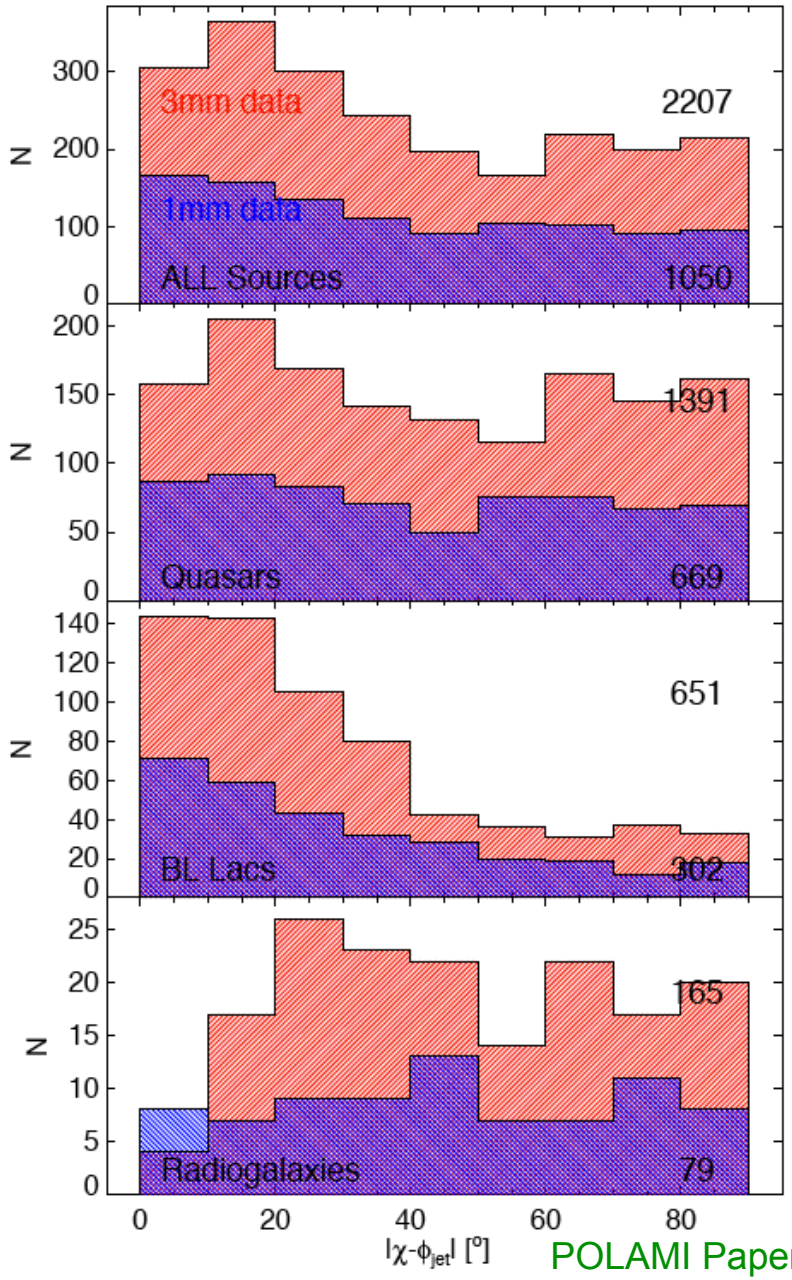
- χ at 3 and 1mm also highly variable
- 21/36 sources at least a > 180° rotation
- Time scales from a few weeks to a year (typical 3-5 weeks)
- χ in general not correlated with S, m_L, (also not correlated among each other)
- Variability of the linear polarization cannot be explained by the time evolution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

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



POLAMI Paper III

Linear polarization angle vs. jet position angle



- In general, very weak trend to align χ almost parallel to the jet axis (for ~19% of sources)
- Similar results found in Agudo et al. (2010, 2014), and Lister & Homan (2005)
- For purely axisymmetric jets, χ 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!**
- **Although BL Lacs seem to tend to align their χ with the jet position angle**

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

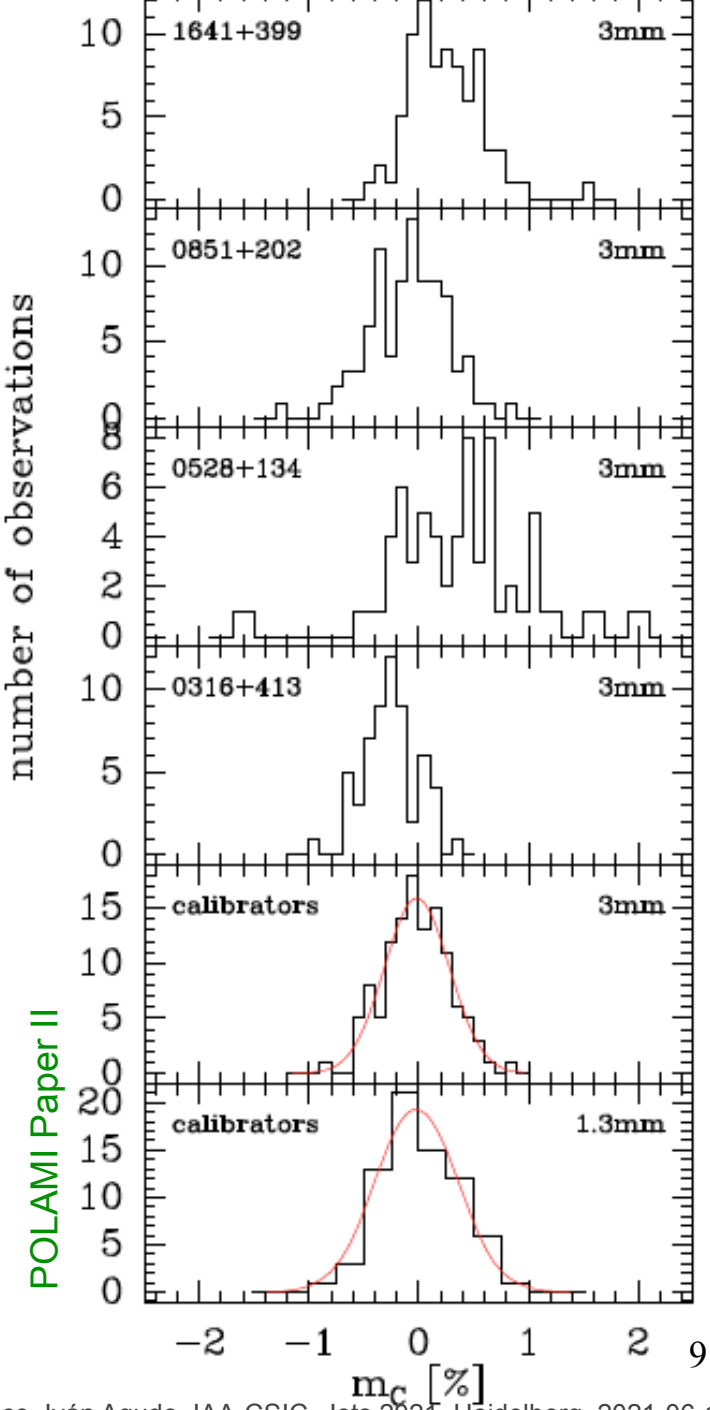
POLAMI Paper III

Circular polarization

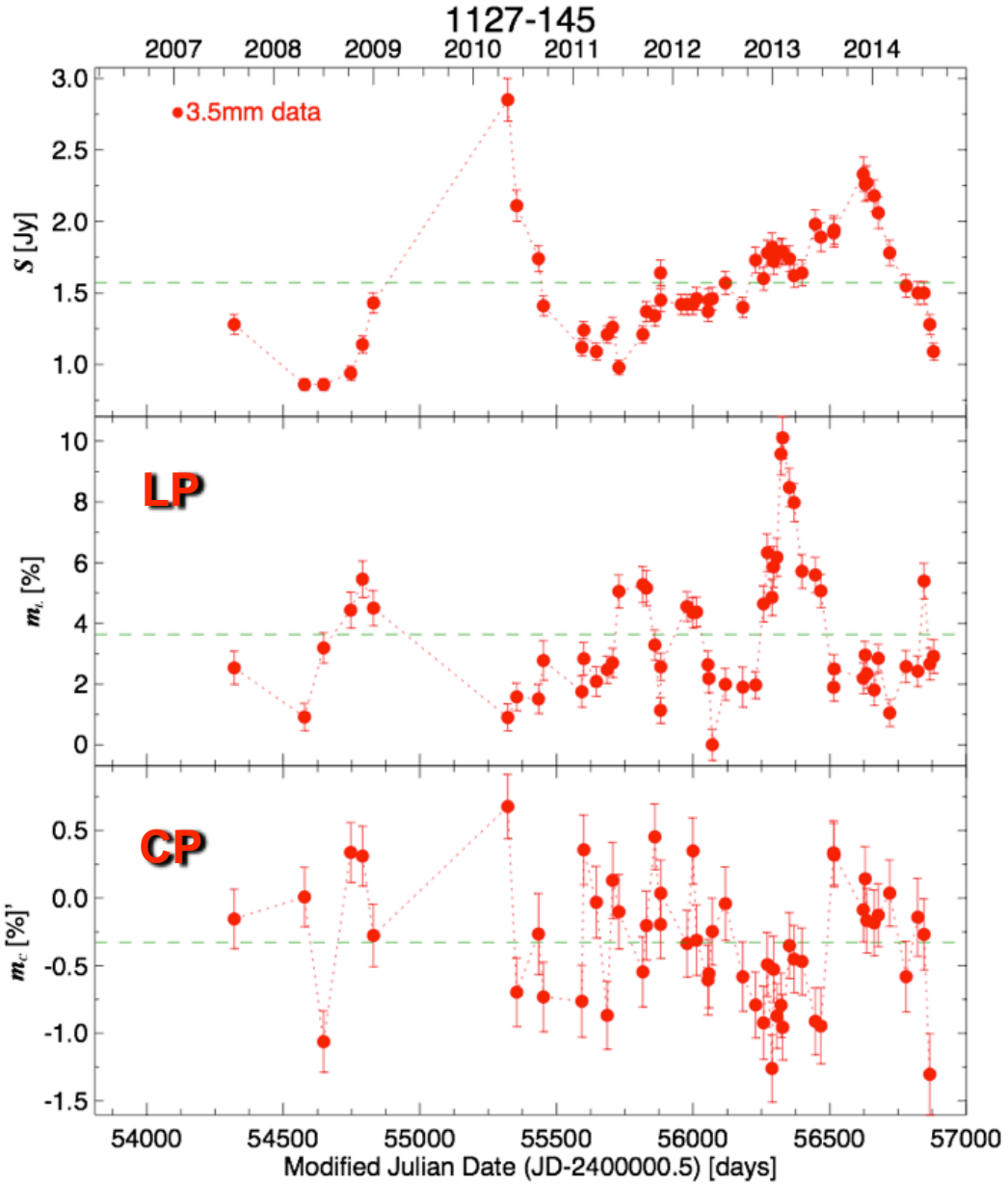
- Mars & Uranus (unpolarized), shows Gaussian profile with σ~0.3% (σ~0.5% at 1mm, all measurements together) and $<m_C>$=0.0%

- Blazars show different distributions (>99.7% conf):
  - Broader m_C distributions, even double-peaked
  - Sometimes significantly shifted from 0.0%
  - Several detections >5σ up to ~1% (even ~2%)
  - CP is detected in all but one source, often more than once
  - A number of sources have CP detected always of the same sign

5) Circular polarization routinely detected at mm-λλ and as large as those reported at cm-λλ!



Circular polarization variability



- **CP time evolution show hints of:**
- Faster than LP and total flux
- 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

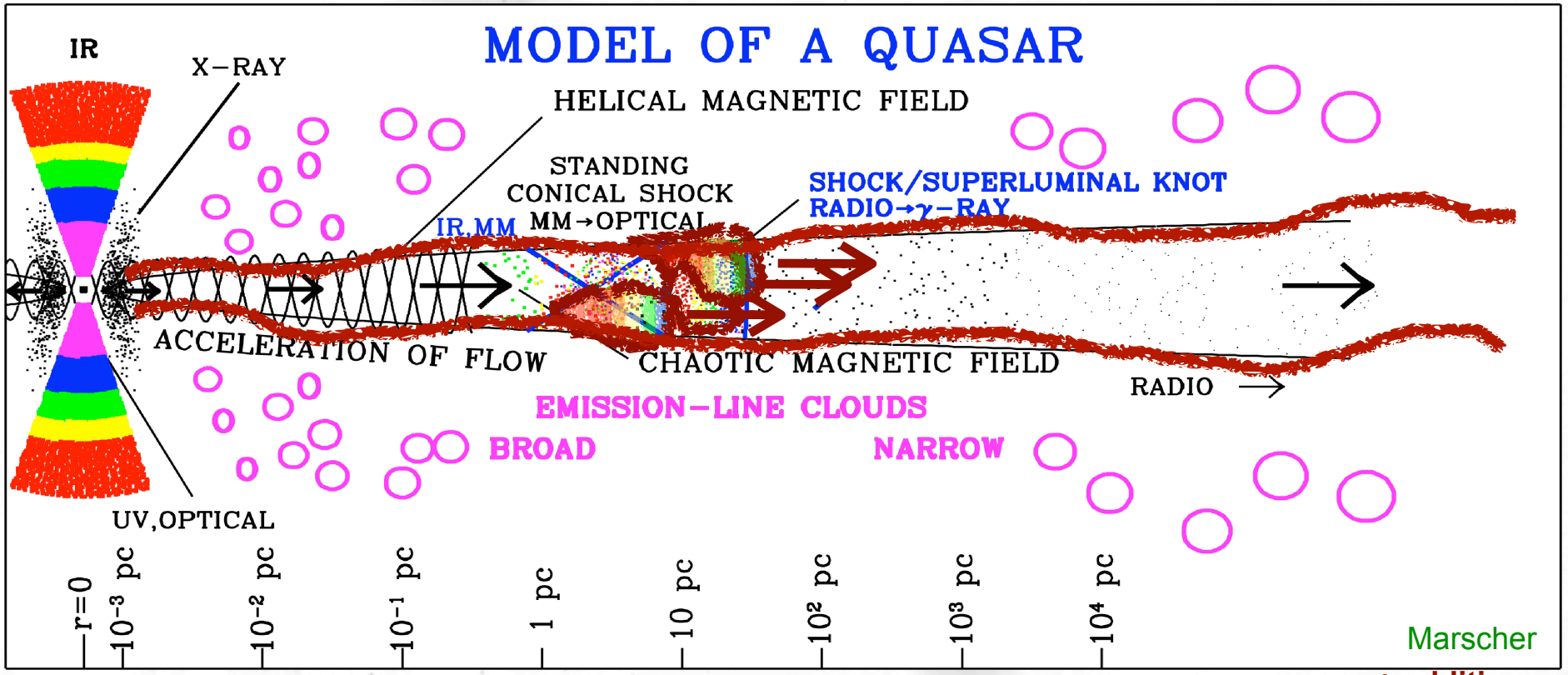
Data is compatible with Faraday conversion, e.g. in the presence of helical B field, but also production of intrinsic synchrotron CP

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 $\lesssim$2%
- Faraday conversion of LP into CP from helical B field, inhomogeneous dynamic processes, and intrinsic CP production can explain our CP data

Conclusions



Marscher

+ additions

Thanks a lot for your attention!