Polarised Emission from Astrophysical Jets

June 12-16, 2017, Ierapetra, Greece

Conference Summary

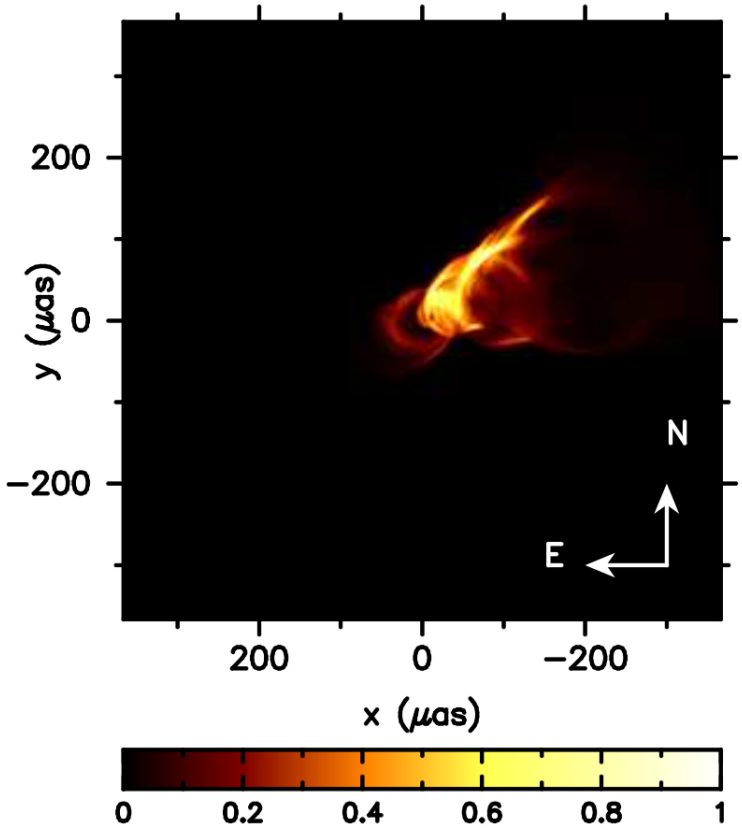
Lukasz Stawarz
Jagiellonian University, Krakow, Poland

Theory & Simulations

BHs and **Disks**

Mościbrodzka: "Polarized emission from 3-D GRMHD simulations of black hole jets"

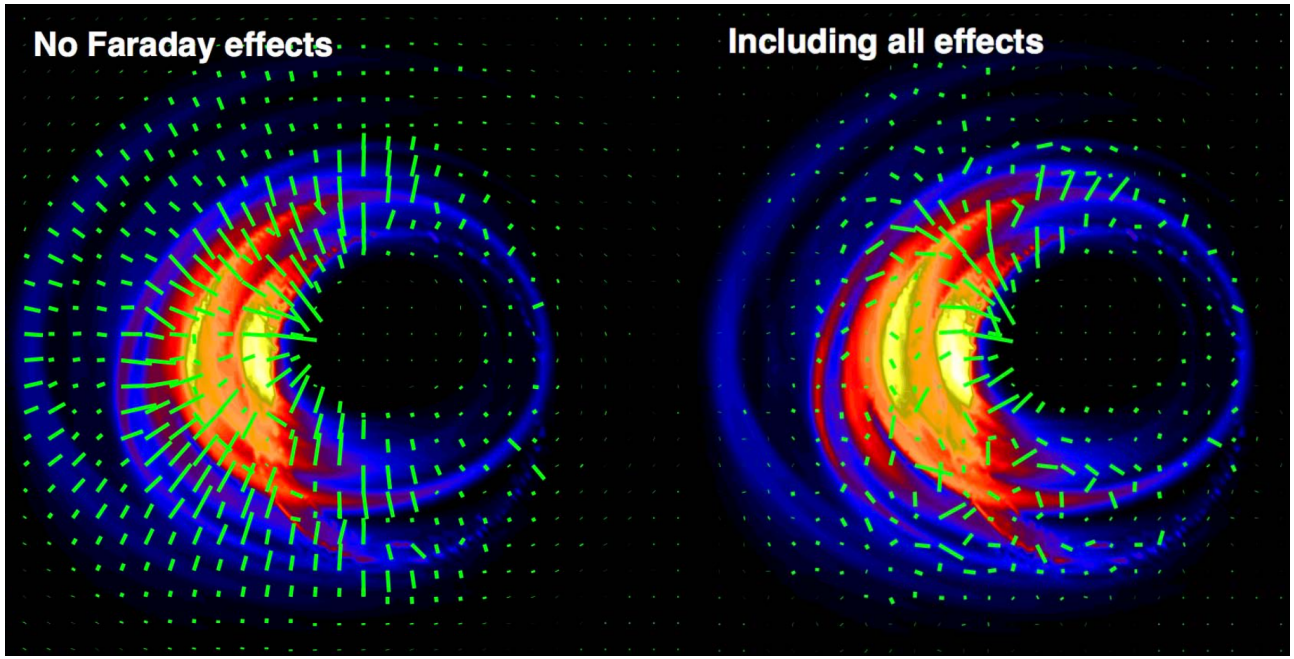
- idea 3D GRMHD
- MF put-in by hand and amplified by turbulent MRI
- relativistic polarised radiative transport by ray-tracing



Accretion flow may be optically thin, but "Faraday thick" (not much absorption, but lots of Faraday conversion and rotation!); a very complex polarisation structure expected within 100Rg.

- appropriate rather only for low-luminosity AGN (radiatively inefficient accretion flows)
- disk plasma physics not included ("ideal MHD"!)
- no jet (non-thermal) physics

BHs and Disks: Sgr A*



Jimenez-Rosales: "Impact of Faraday effects on event horizon scale GRMHD images of Sgr A*"

Janssen: "High-resolution polarimetric study of Sgr A* with the GMVA"
LP<1% on 0.2mas scale

Shazamanian: "Polarized near-infrared emission from the Galactic center"
jet/outflow?

BHs and Disks: Sgr A*

Johnson: "Imaging Magnetic Fields at the Event Horizon of a Black Hole"

somewhere in between tangled and uniform MF

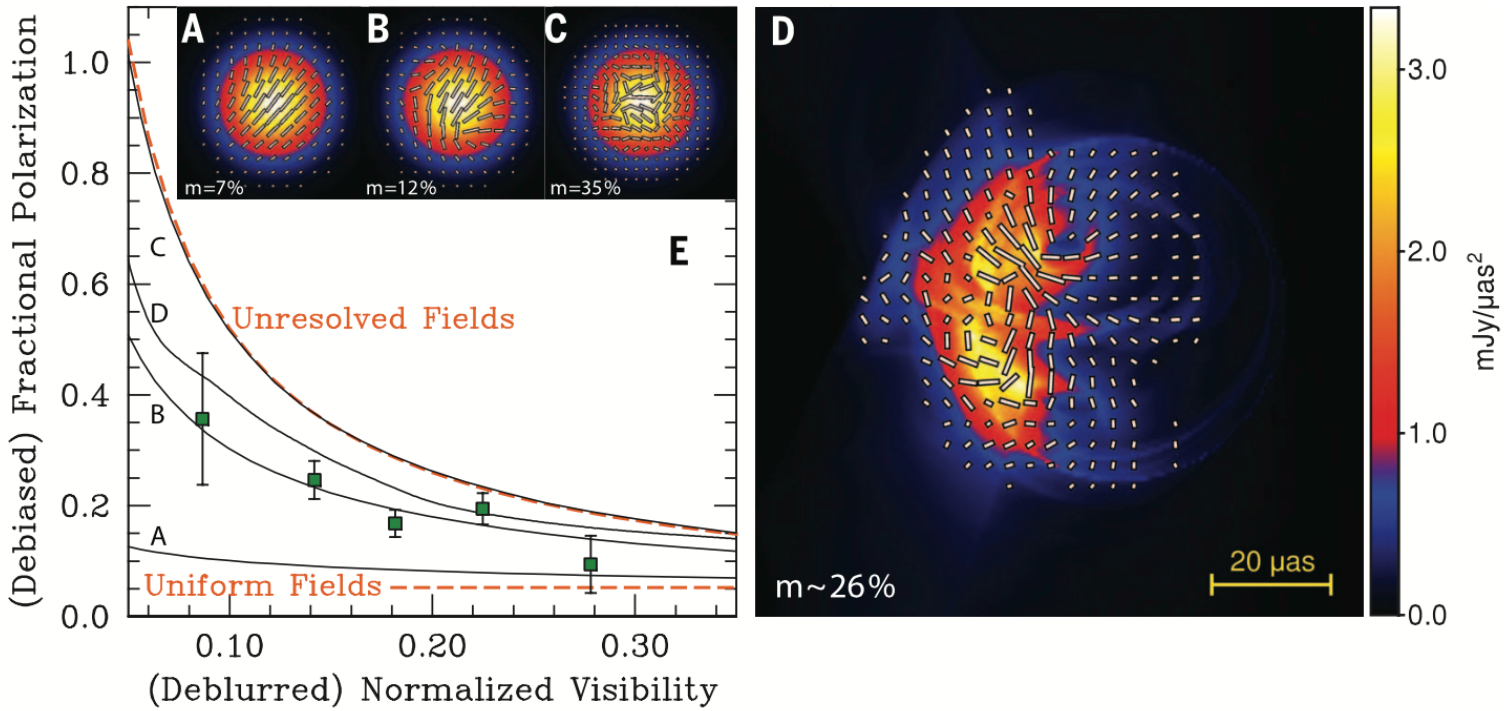
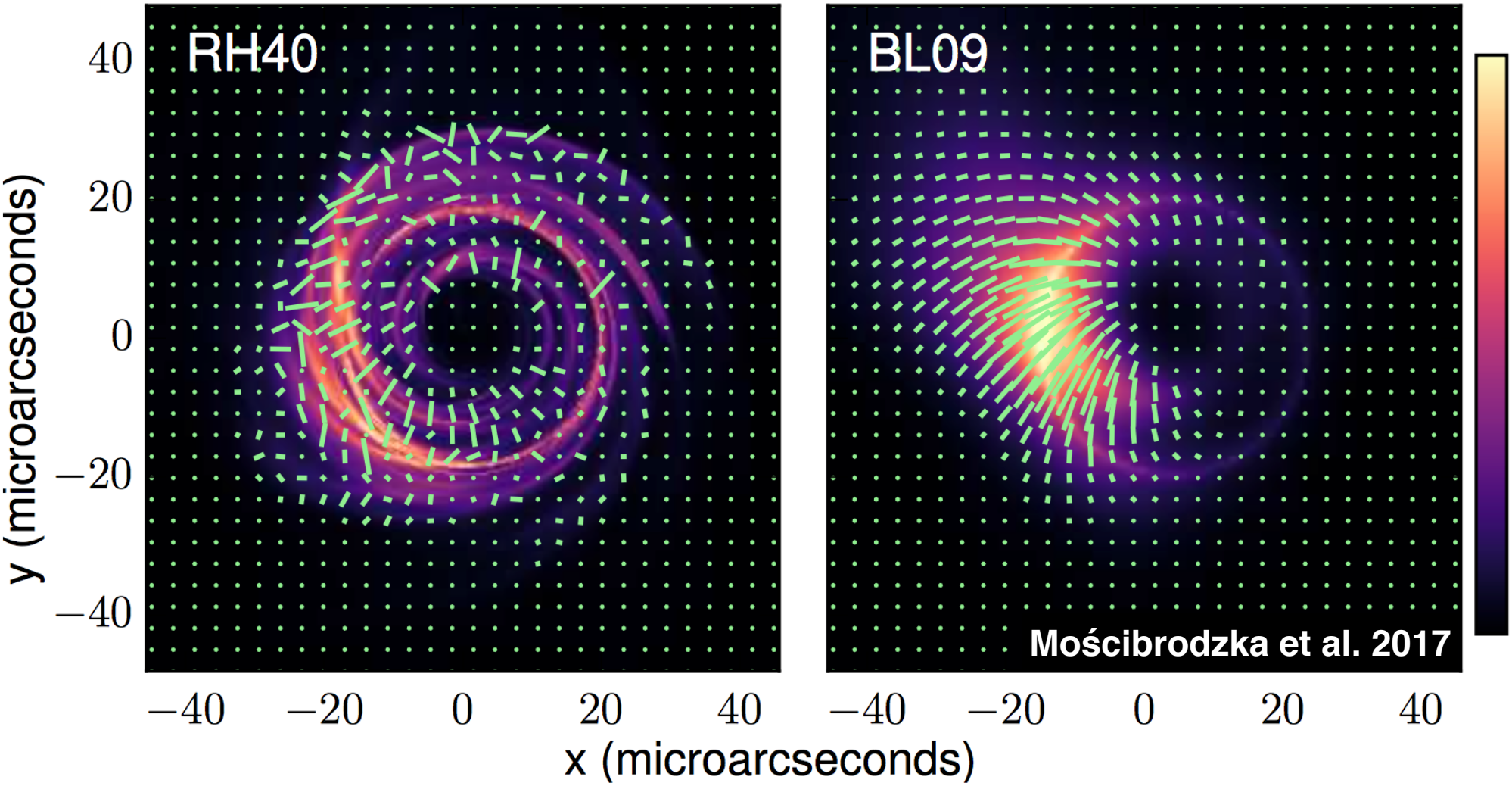


Fig. 3. Strength and order of the polarization field from 1.3-mm VLBI. (**A**, **B**, and **C**) Example realizations from three models with Gaussian distributions of intensity. Color indicates total flux on a linear scale; ticks indicate polarization amplitude and direction. Each model has a constant polarization fraction but stochastically varying polarization direction with prescribed coherence lengths (0.64, 0.29, and 0.11 times the Gaussian full width at half maximum). The polarization fractions are determined by matching the ensemble-average zero-baseline polarization to the averaged CARMA measurements. (**D**) A sample image from a general relativistic magnetohydrodynamic simulation with polarimetric radiative transfer (*9*). The image-averaged polarization fraction, weighted by brightness, is 26%. (**E**) Points with errors (±1σ) show the average of VLBI measurements from Fig. 2 after grouping in bins of width 0.05. Dashed orange lines indicate two limiting cases: a uniform polarization field and a highly disordered (unresolved) polarization field. Each is set equal to 5.2% when the normalized visibility is unity so that the zero-baseline polarization matches the average of all CARMA-only measurements. Our data differ from model (A) at a significance exceeding 4σ, differ from model (C) by 3.4σ, and are compatible with model (B) (*20*). The GRMHD simulation (E) also exhibits a balance between order and variation in the polarization field that is compatible with our observations.

BHs, Disks, and **Jets**

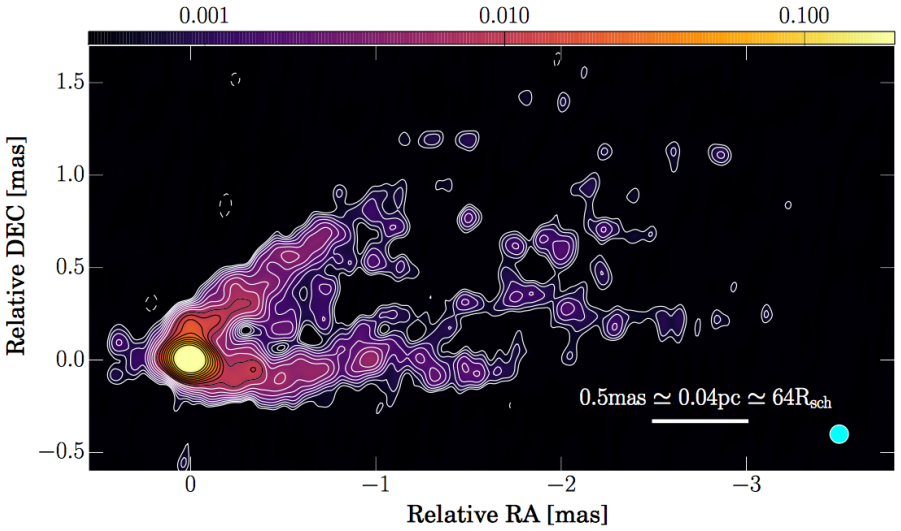


Intensity (colors) and polarization maps (ticks) for model RH40 (left) and a semi-analytic force-free jet model (right, Broderick & Loeb 2009, BL09). The strong Faraday rotation through the accretion disk leads to a scrambled polarization pattern in the RH40 case, while the force-free jet shows coherent polarization which traces its helical magnetic field structure.

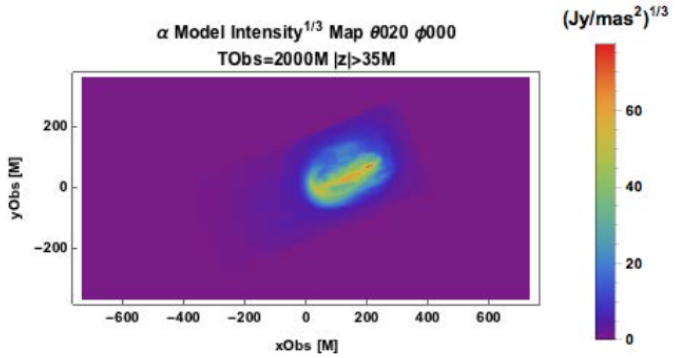
BHs, Disks, and Jets

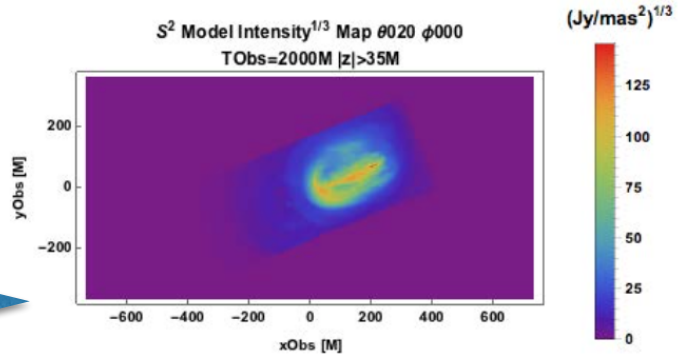
Anantua: “Towards multi-wavelength observations of relativistic jets from general relativistic magnetohydrodynamic simulations”

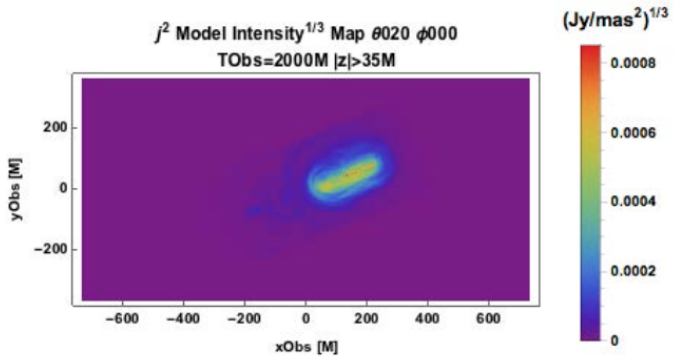
Post-processing GRMHD simulations (MF structure, velocity profile), with ***some prescription*** for electron acceleration **(pressure, shear, currents)**
-> synchrotron maps (including polarisation) of the innermost jet regions (M87)



?







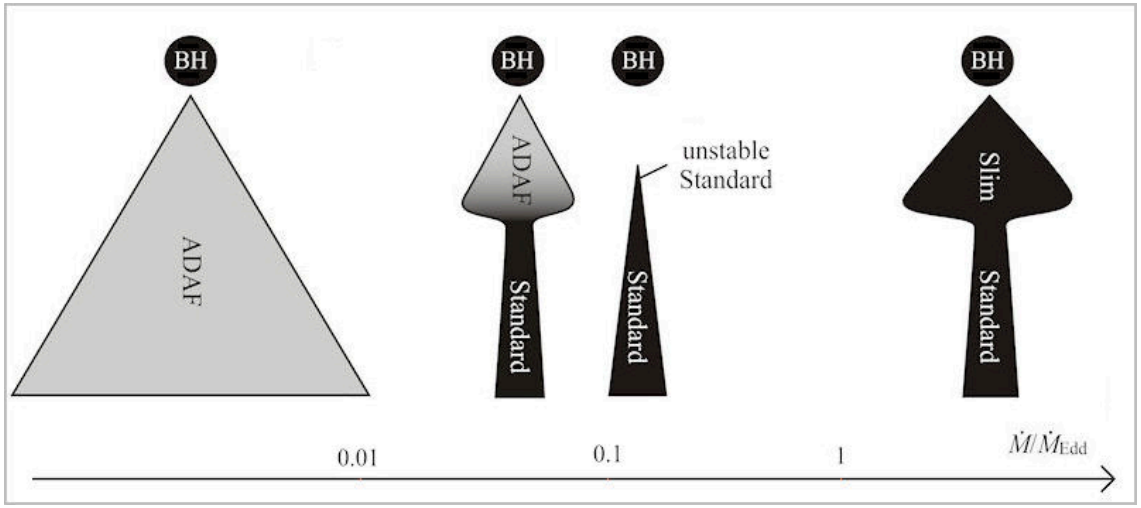
Lu: “The polarimetric structure of M87 with 3mm-VLBI”

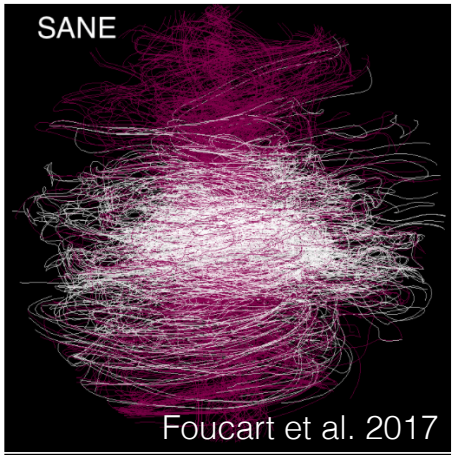
BHs, Disks, and Jets

Asada: "ALMA and SMA polarimetric observation towards M87"
Nagai: "Accretion Flow Property of 3C 84: A View Through Faraday Rotation"
Hovatta: "Probing the magnetic fields in 3C273 through Faraday rotation observations"

- Bondi accretion rates: but Bondi radii hardly resolved (X-rays)
- radiative output: low radiative efficiency, but how low exactly? (plasma physics!)
- 300% jet production efficiency: BZ model, but needs very strong MF (MAD?)
- ***Faraday depolarization: implies lower accretion rates (however, only when using rather simplified scaling relations)***

how well do we understand accretion disks?
RIAFs vs SS, MAD vs SANE, …

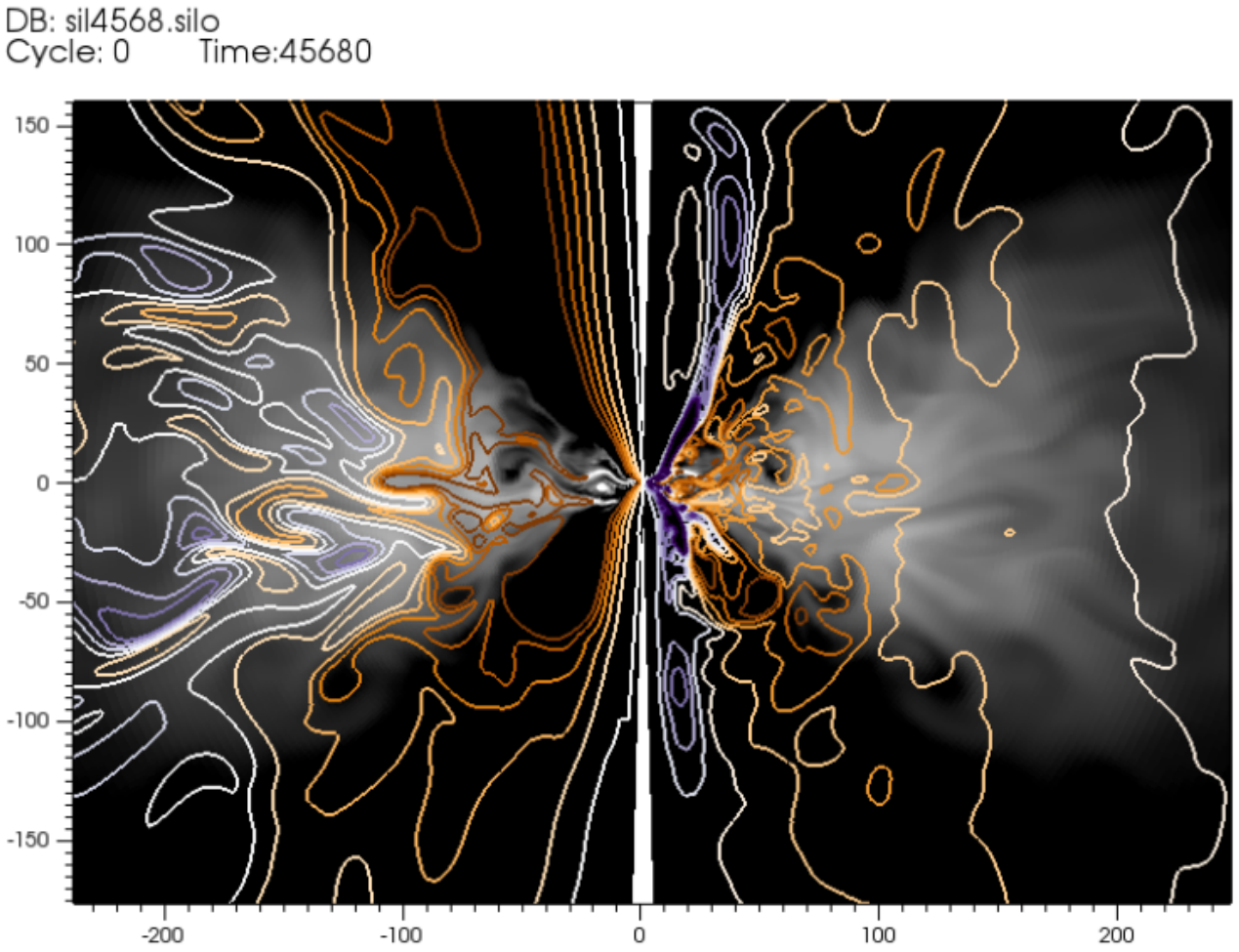




BHs, Disks, and Jets

Contopoulos:

"Electric currents along astrophysical jets"

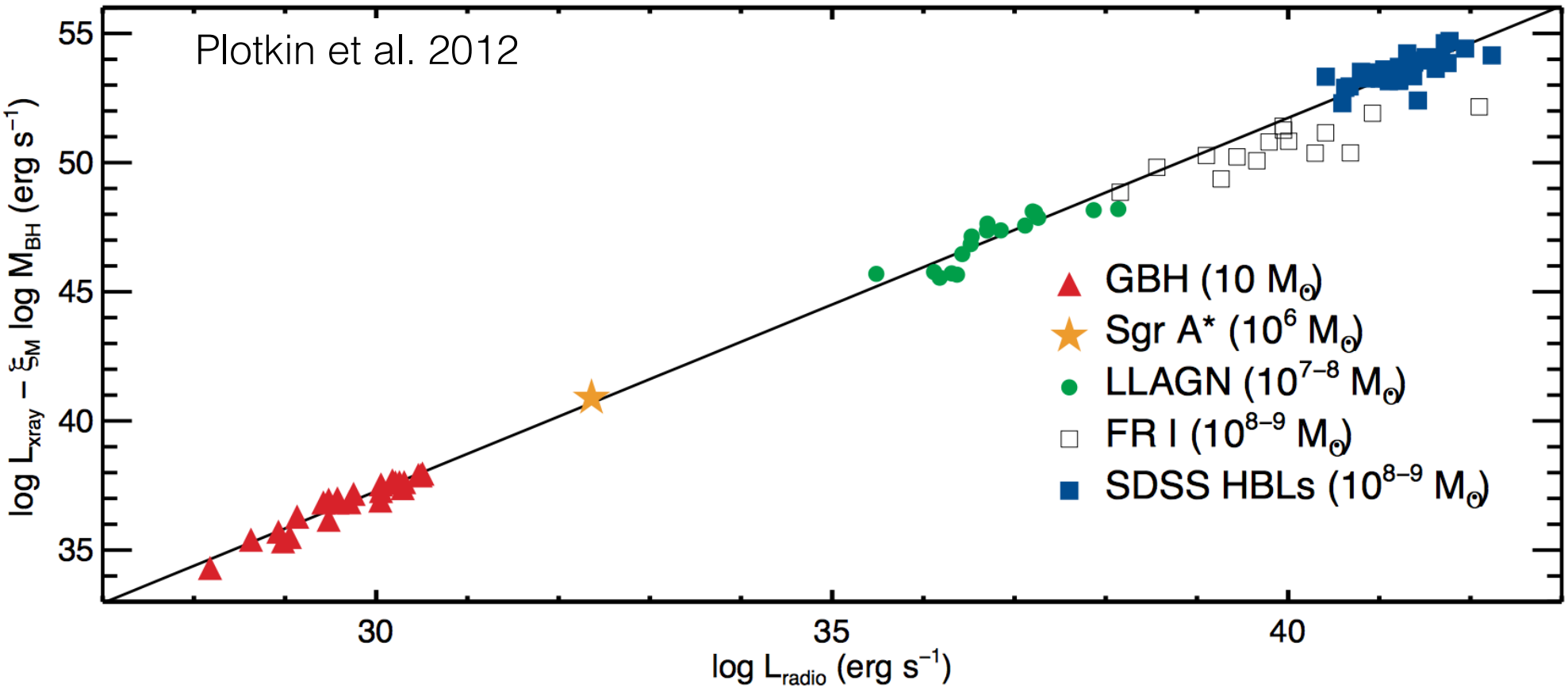


"…initial SANE model is driven [by the Cosmic Battery] towards a MAD state. (…) The CB battery term gives rise to poloidal magnetic loops in the disk. As accretion proceeds, the inner part of these loops is advected onto the black hole horizon and contributes to the buildup of a large scale magnetic field of a particular polarity."

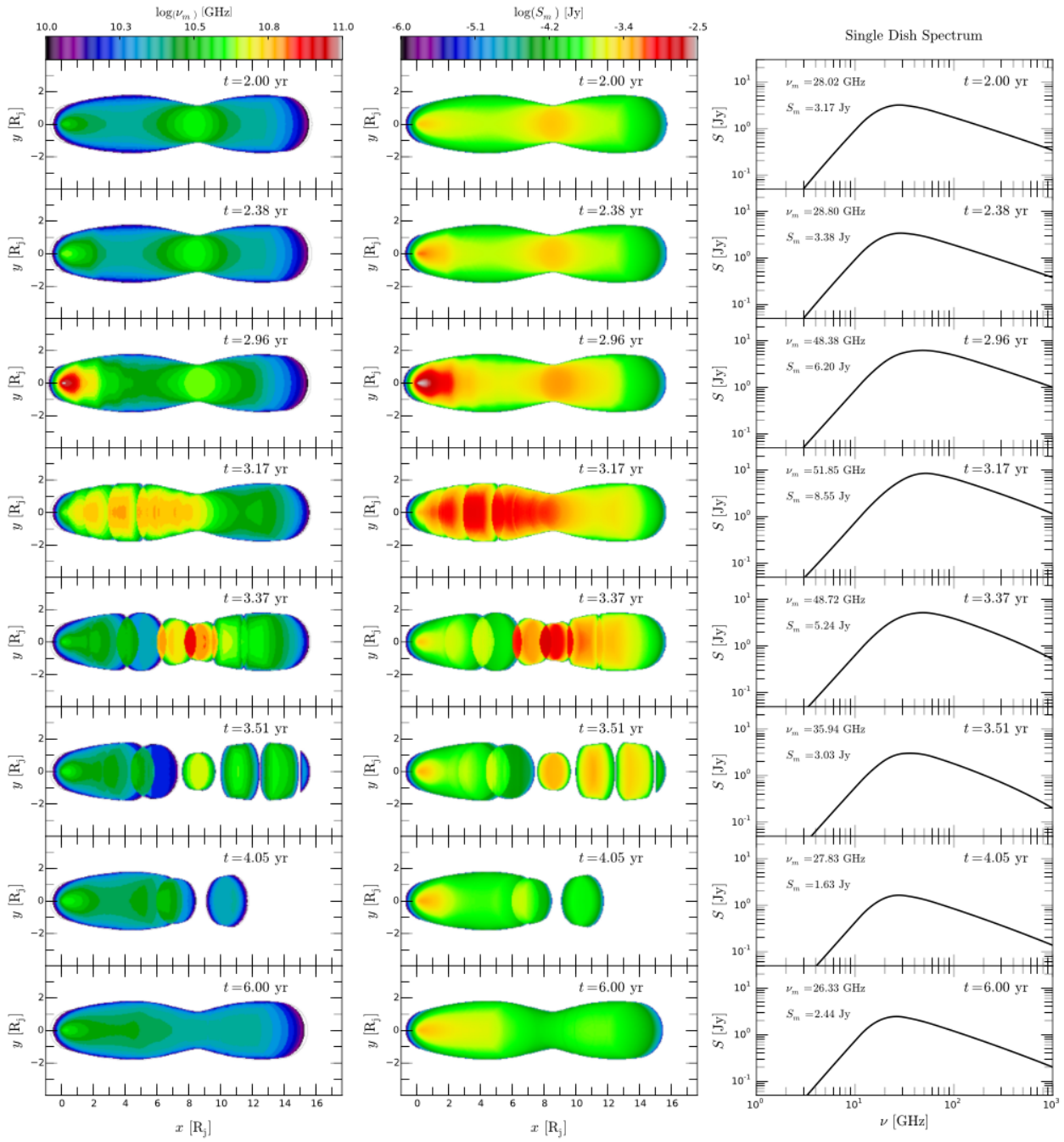
BHs, Disks, Jets, and **Coronae**

Markoff: "Unravelling the complexities of the disk/corona/jet relationship"

so, what is this corona?



Jets: Standing Shocks



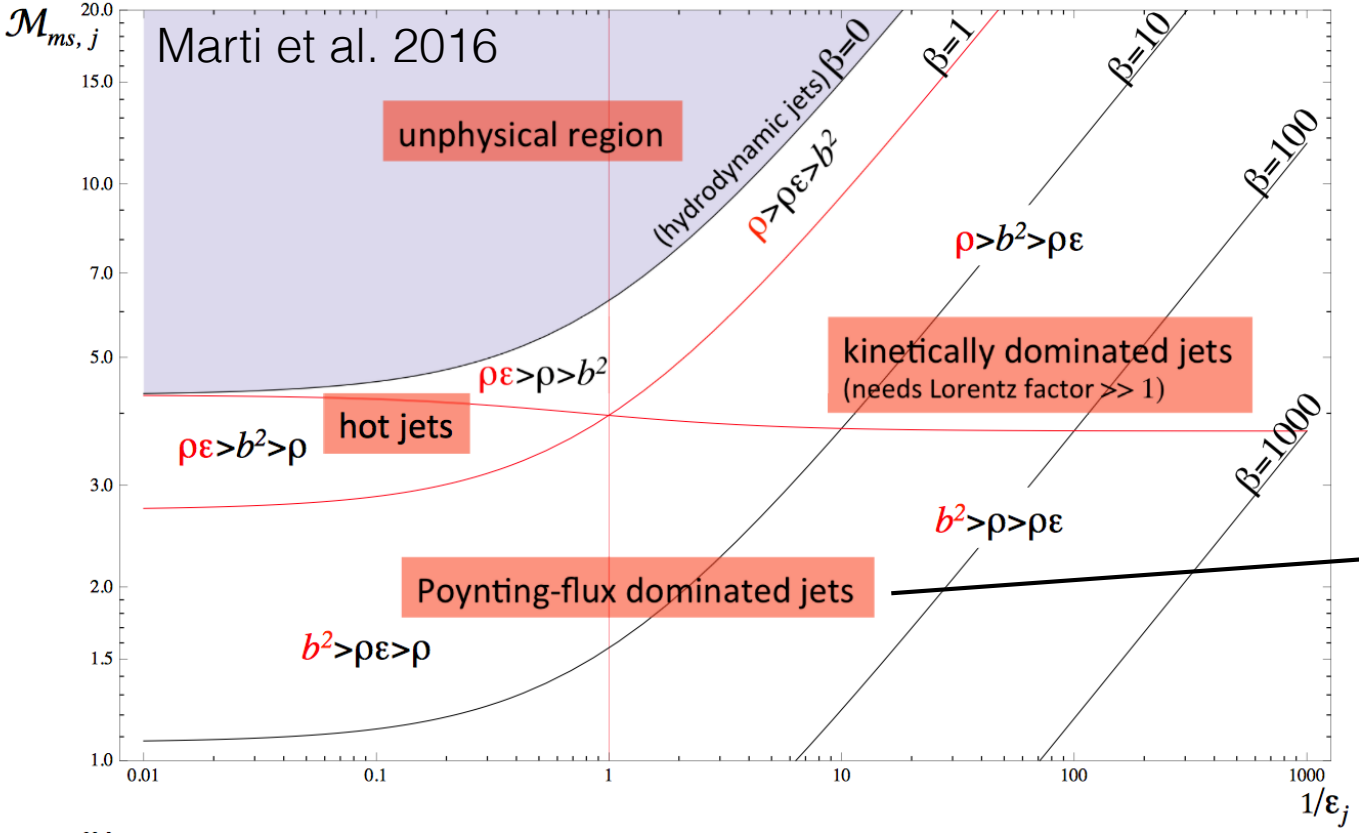
Fromm: “Radiative signature of large scale magnetized jets”

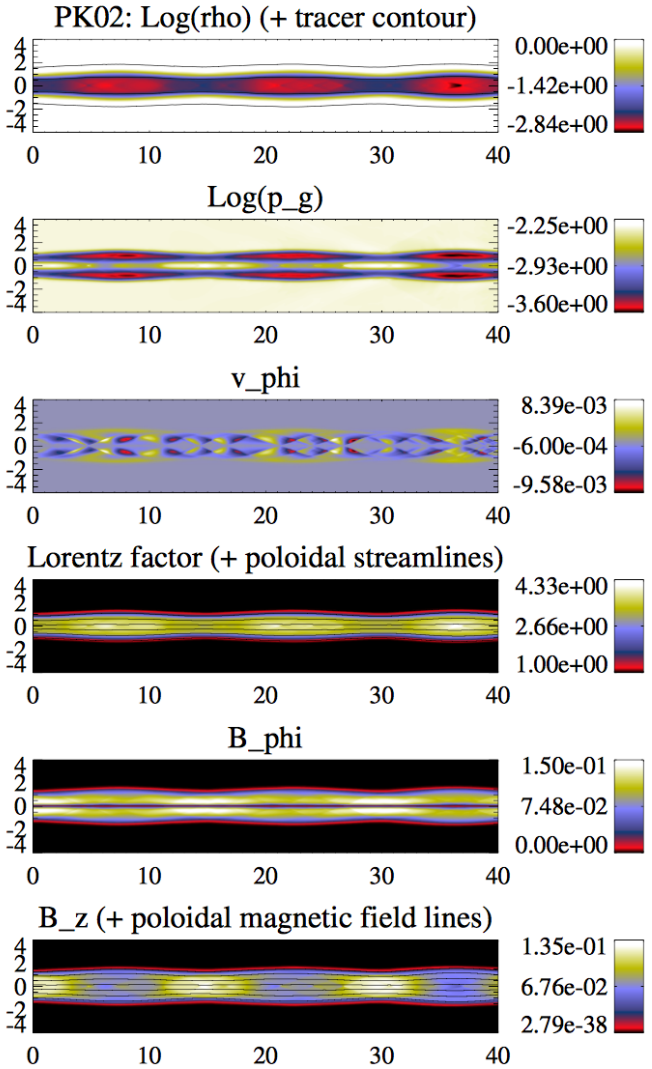
post-processing (G)RMHD simulations

Jets: Standing Shocks

Fuentes: "Total and linearly polarized synchrotron emission from overpressured magnetized relativistic jets"

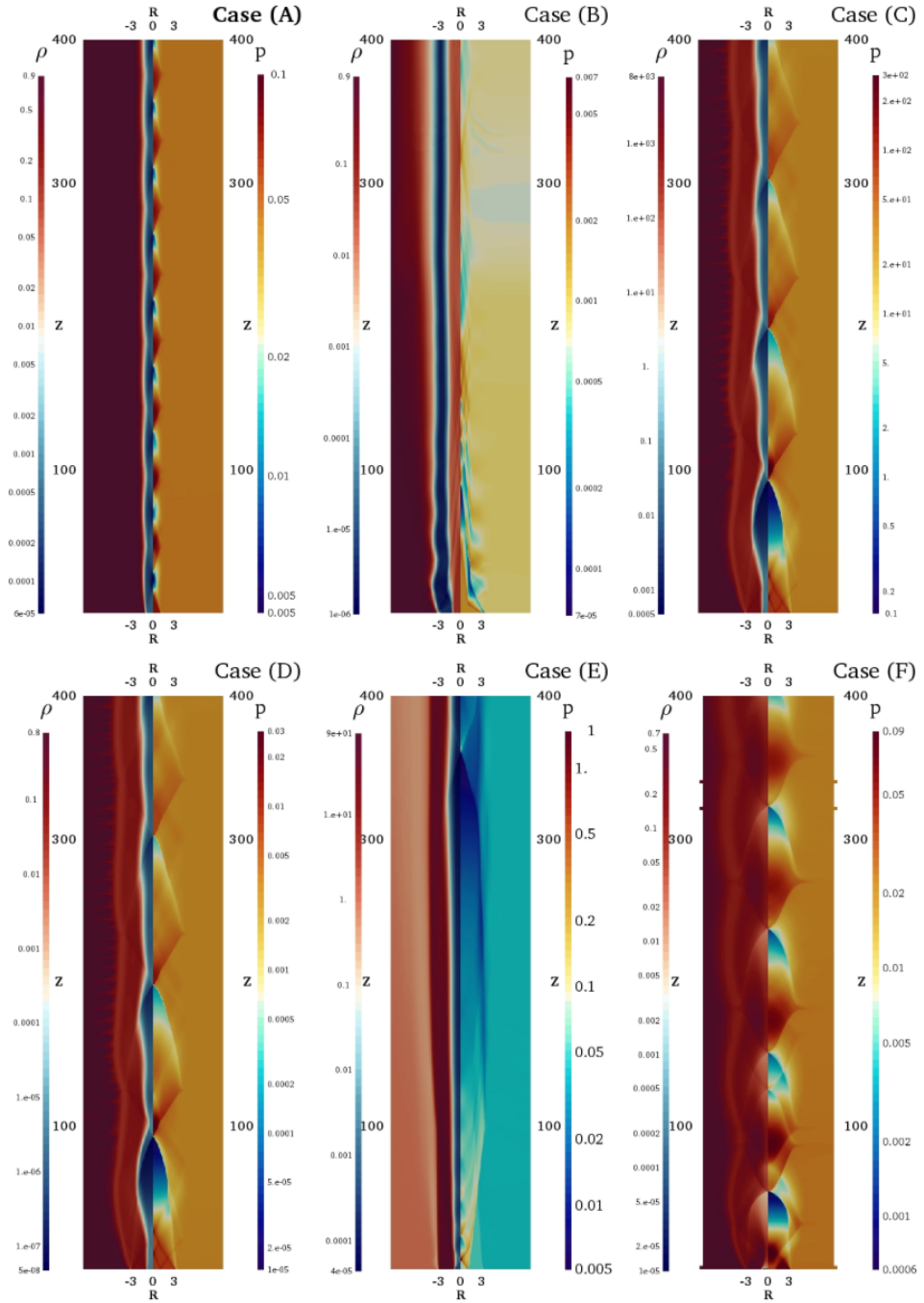
MF or particles? reconfinement shocks present even in P-dominated jets!





also, **Kaye:** "Hydrodynamical Jet Simulations with Passive Magnetic Fields"

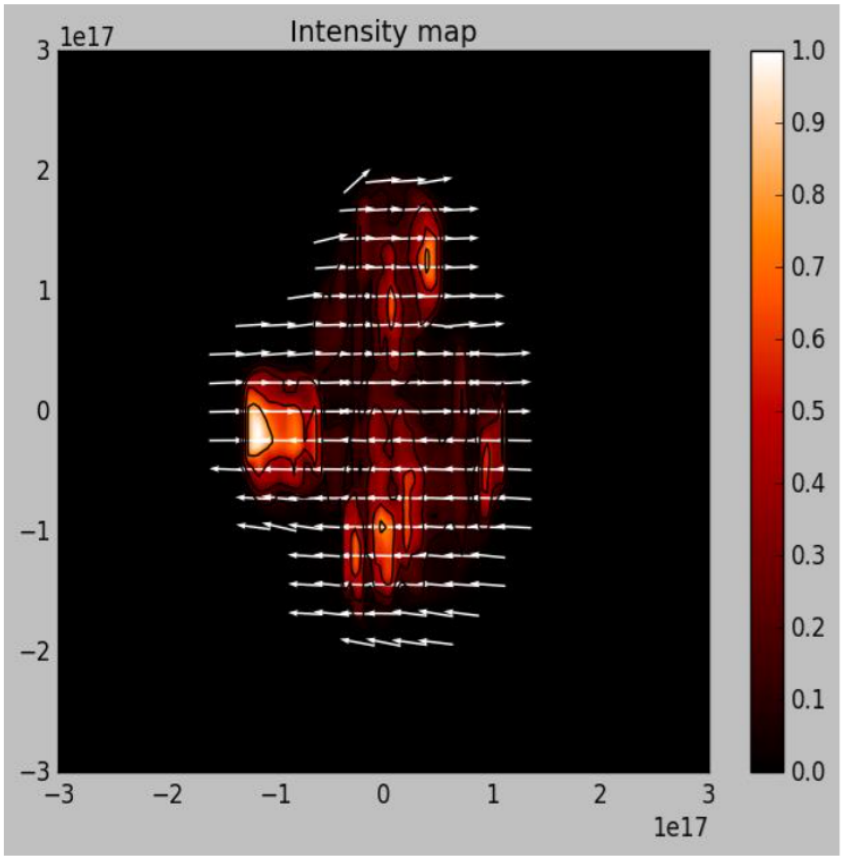
Jets: Spines+Sheaths



Meliani: “Internal shocks in relativistic transverse stratified jets”

Millas: “Synthetic radiation maps from relativistic MHD jet simulations”

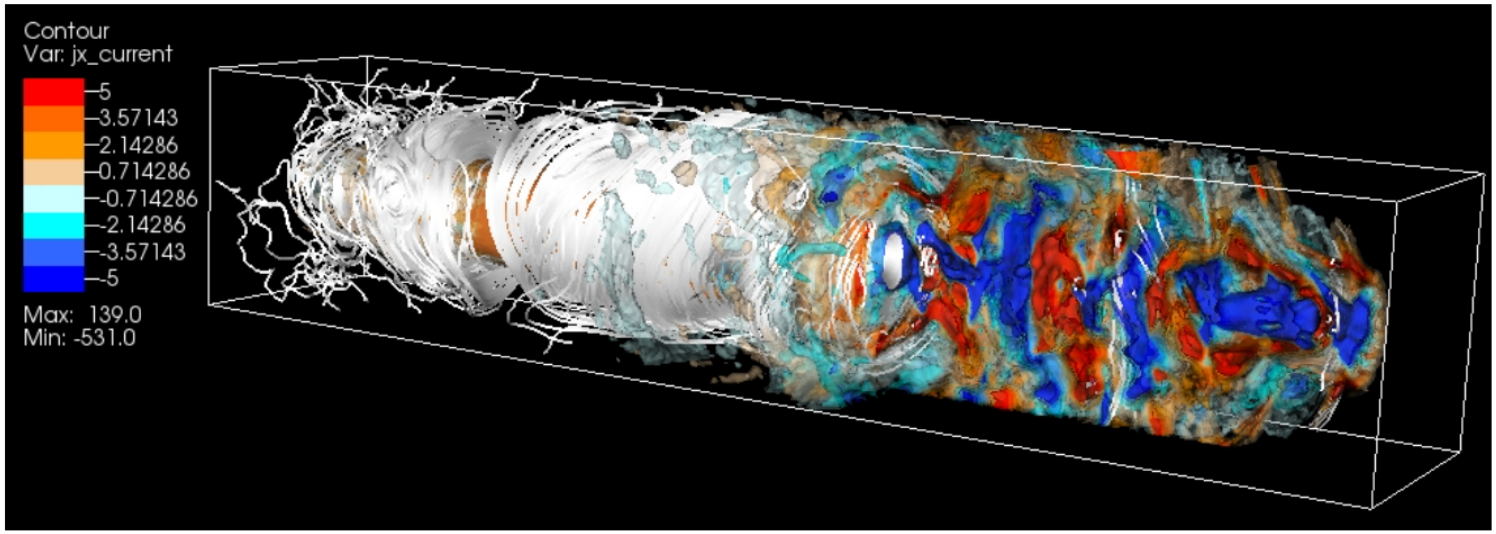
$\sigma = 10^{-3}$



Jets: Particles

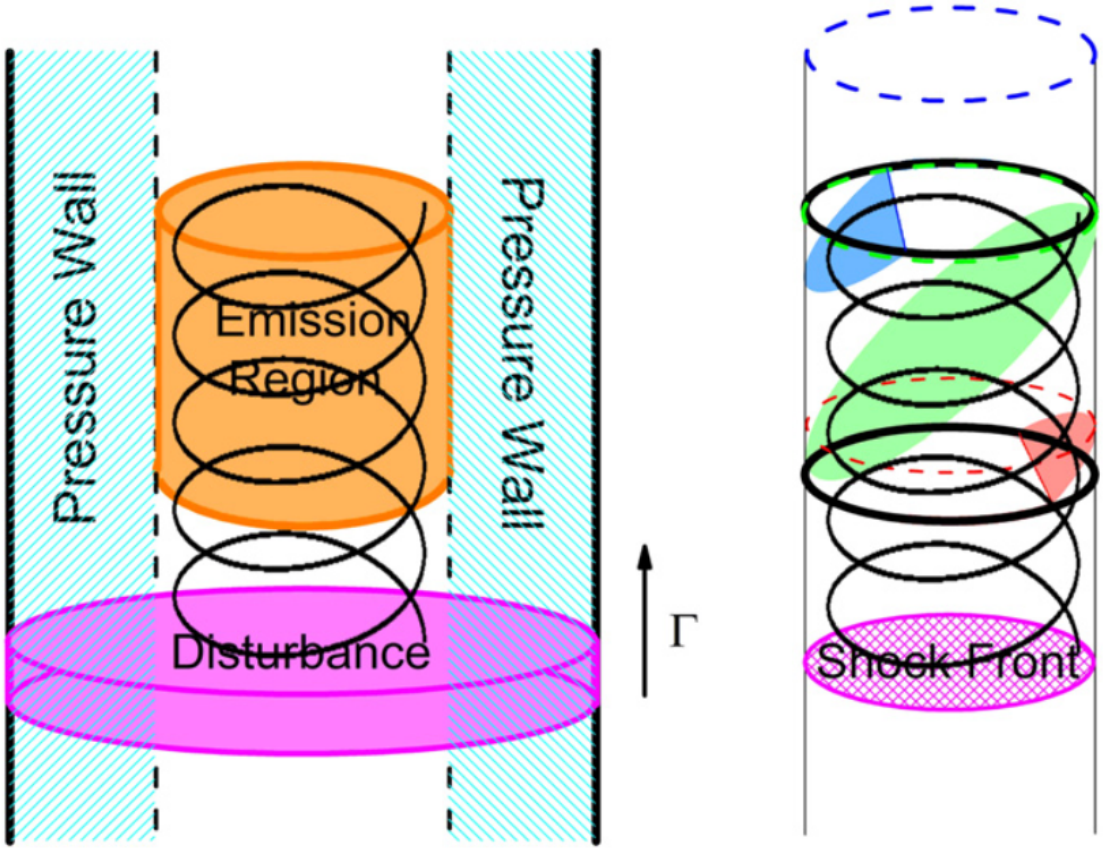
A crucial problem in this context
(not discussed enough during the meeting):
electron acceleration/electron energy spectra

Nishikawa: “Recollimation, Reconnection and Associated Flares in Global Relativistic Jets Containing Helical Magnetic Fields with PIC Simulations”



also **Kylafis:** “The energy distribution of electrons in radio jets”

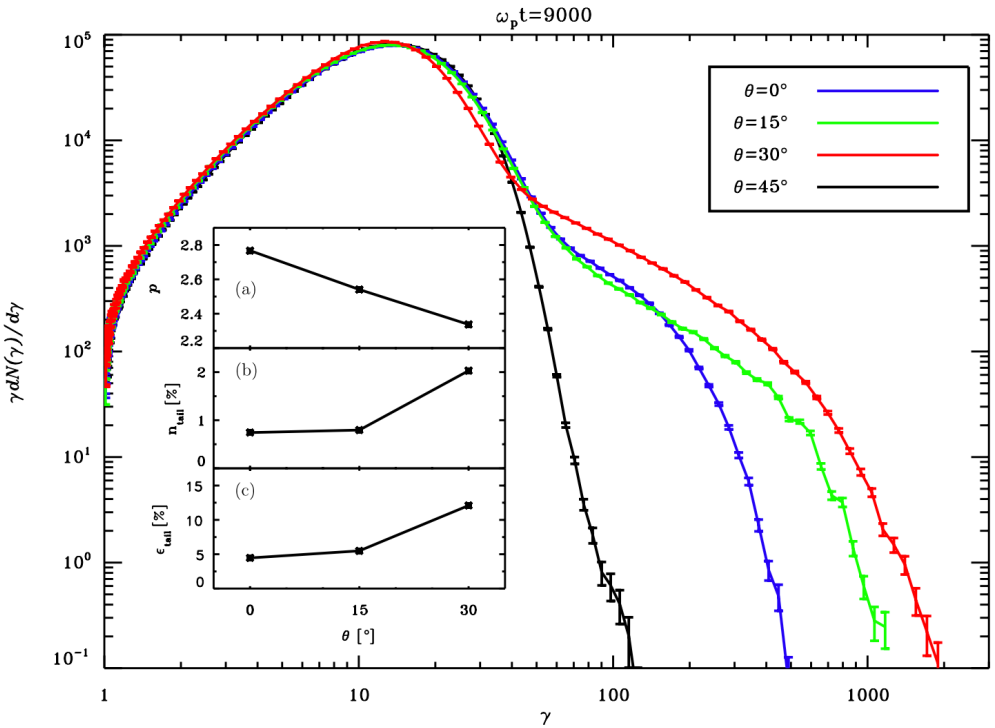
Jets: Particles



Zhang: "Multi-wavelength polarization signatures probe the blazar jet physics"

- combination of the Monte-Carlo/Fokker–Planck, 3D multi-zone synchrotron polarization ray-tracing, and RMHD
- diffusion approximation for particle acceleration
- **polarization sensitive to the plasma content (hadronic vs leptonic), MF structure (obviousy), but also the dominant acceleration process (shcoks vs turbulence vs reconnection)**

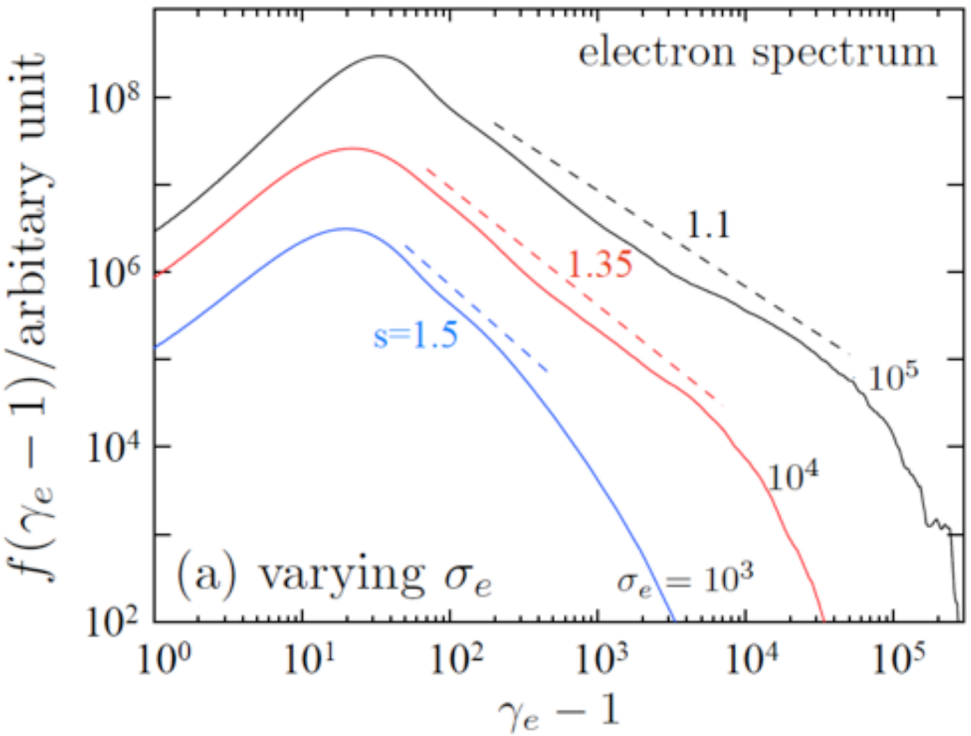
Jets: Particles



Sironi & Spitkovsky

relativistic shocks: steep electron spectra (especially for quasi-perpendicular shocks)

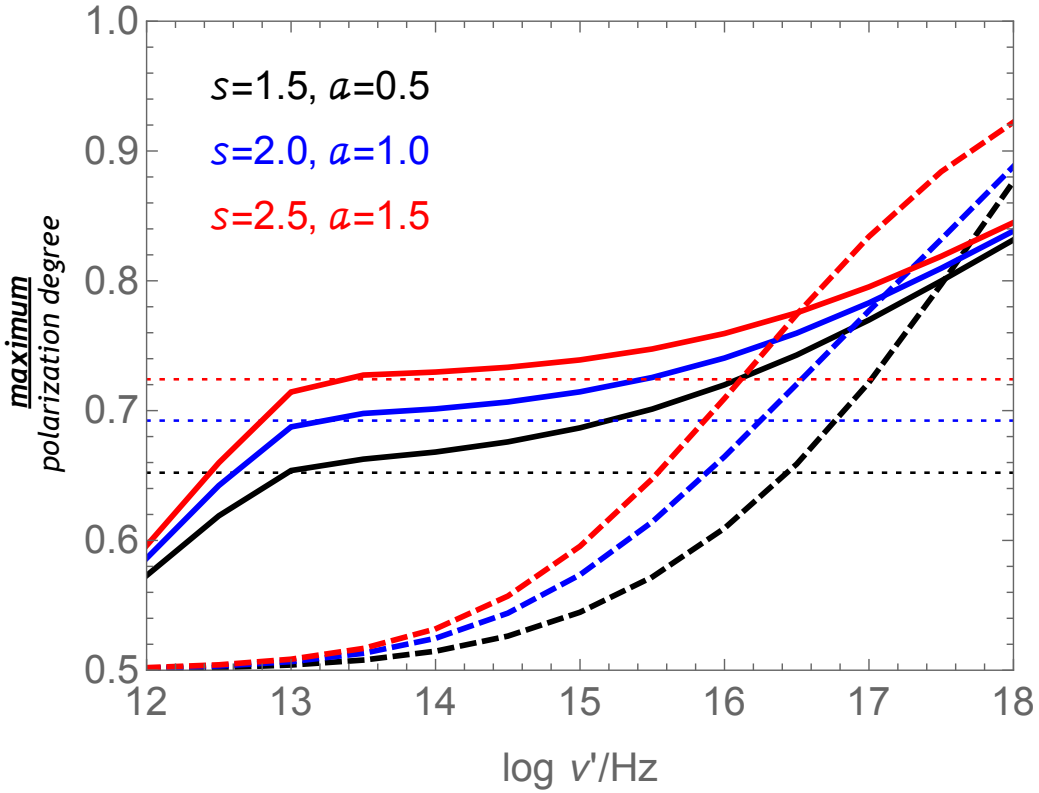
Guo et al.

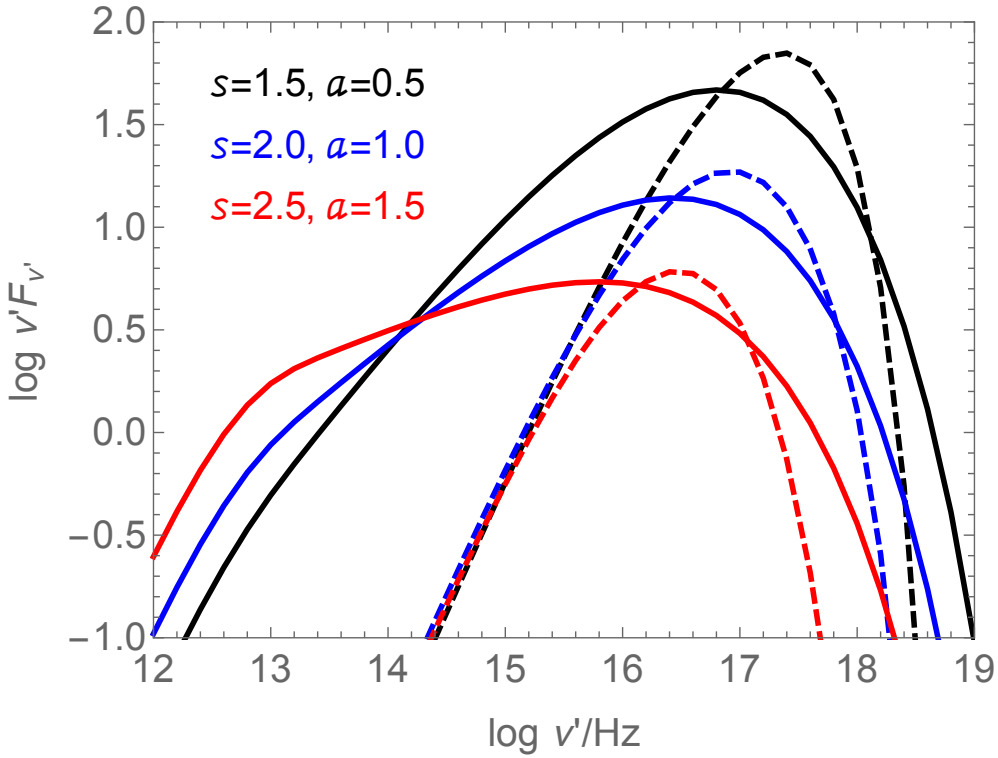


relativistic reconnection: flat electron spectra (for high magnetization)

Jets: Particles

$$\frac{dN'_e}{d\gamma} = \begin{cases} N'_0\,\gamma^{-s}\,\exp\left[-\left(\frac{\gamma}{\gamma_{\max}}\right)\right] & \text{for } 1 \leqslant \gamma_{\min} \leqslant \gamma \quad \text{(PL)} \\ N'_0\,\gamma^{2}\,\exp\left[-\frac{1}{a}\left(\frac{\gamma}{\gamma_{\rm eq}}\right)^{a}\right] & \text{for } 1 \leqslant \gamma \quad \text{(UM)} \end{cases}$$





crucial also for interpreting the CP results!

Data & Interpretation

Spencer: “An Old Fogey's History of Jets”
100yr since the discovery of astrophysical jets
>50yr of a radio observations

Micro-arcsecond Imaging

Micro-arcsecond Imaging

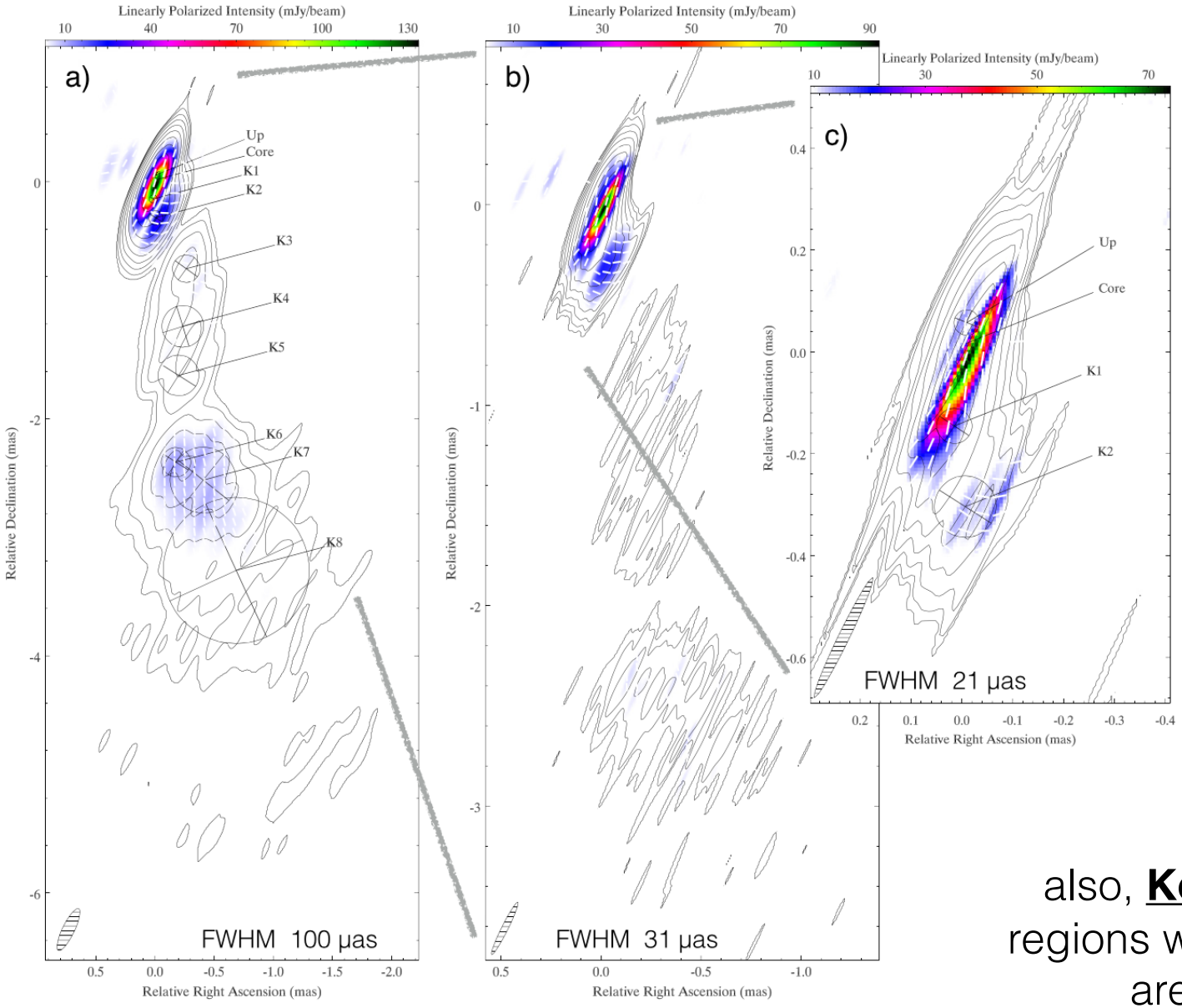
Johnson: “Imaging Magnetic Fields at the Event Horizon of a Black Hole”

- 2017: first science observations with EHT+ALMA
- 2017-18: IMAGING (M87, Sgr A*); in the case of SgrA* not static images, since too short dynamical timescales at the event horizon (minutes!) -> dynamical imaging
- other targets: OJ287, 3C273, 3C279

Gómez: “Probing the innermost regions of AGN jets and their magnetic fields with RadioAstron”

- the first space VLBI mission, with polarimetric capabilities
- BL Lac, 3C273, 3C279, 0716, OJ287, 3C345, 0642
- future: combined with ALMA and EHT and GMVA

Micro-arcsecond Imaging

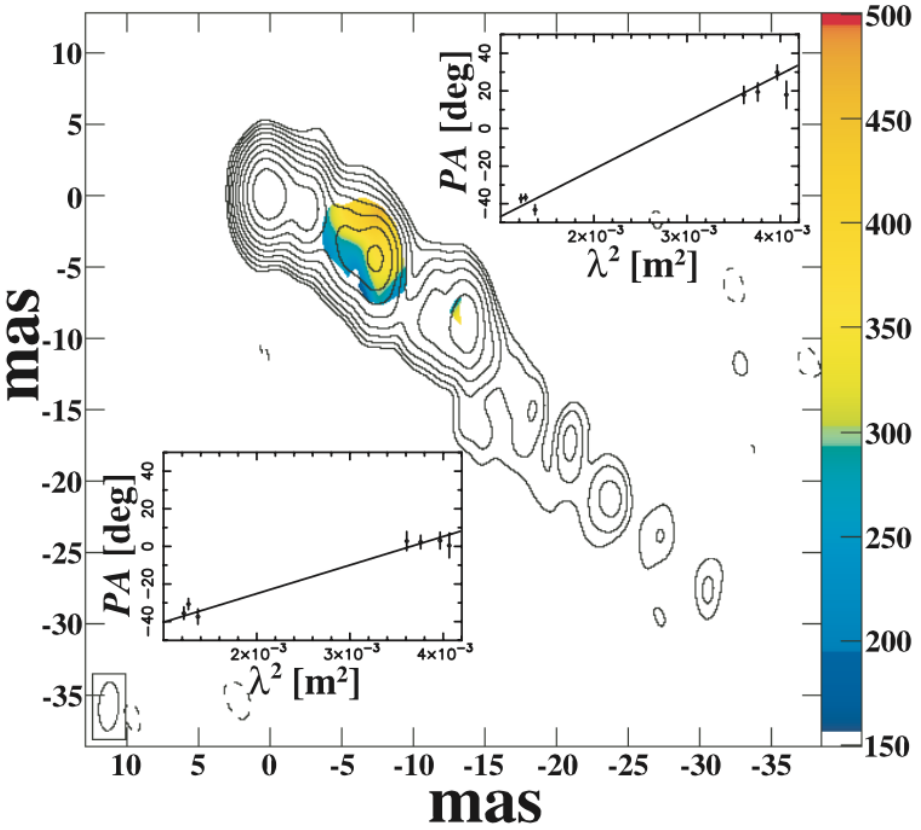


Gomez et al. 2016:
BL Lacerta

also, **<u>Kovalev:</u>** "Ultra-compact regions with very high polarization are found in quasars"

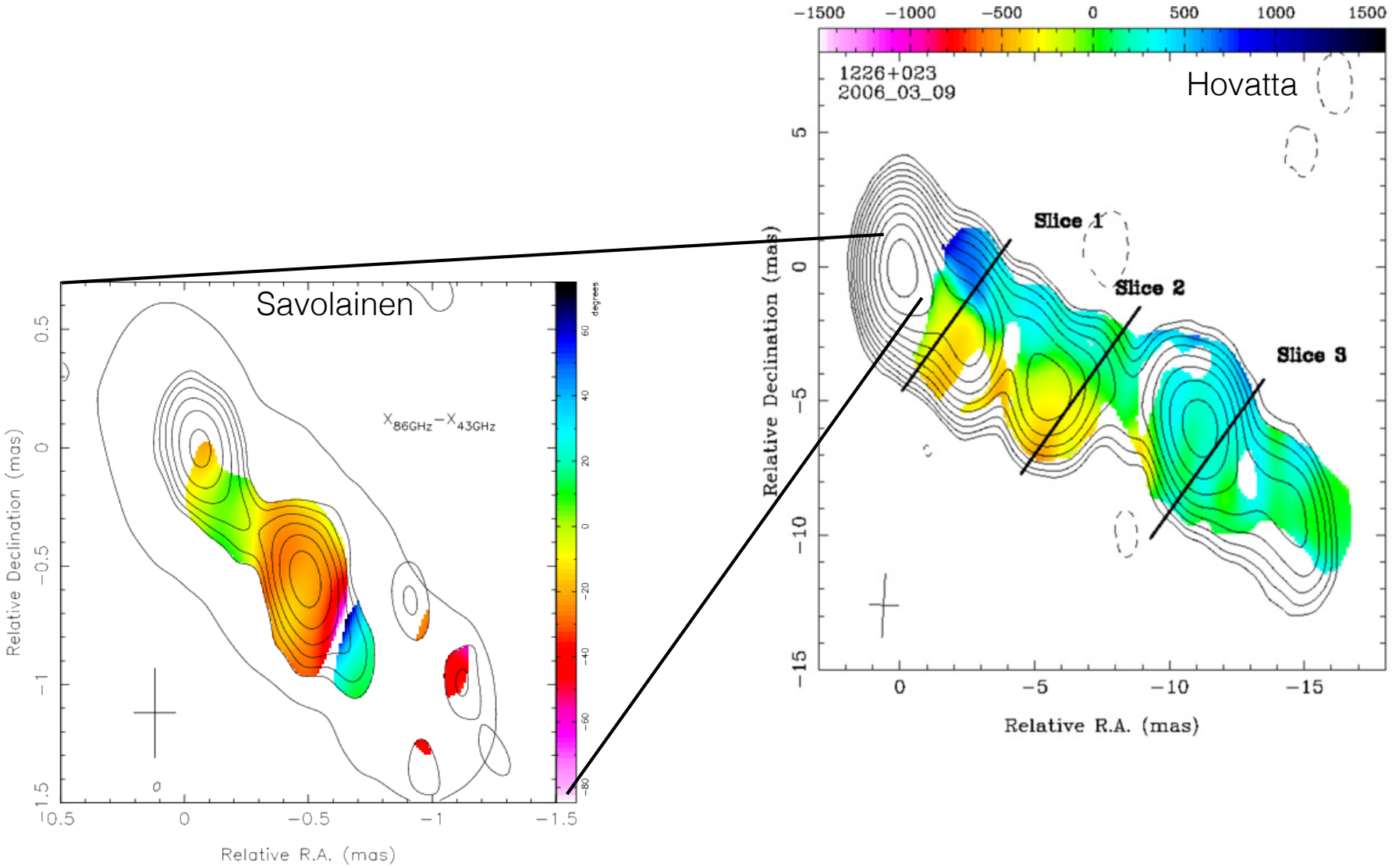
RM Studies

RM Gradients



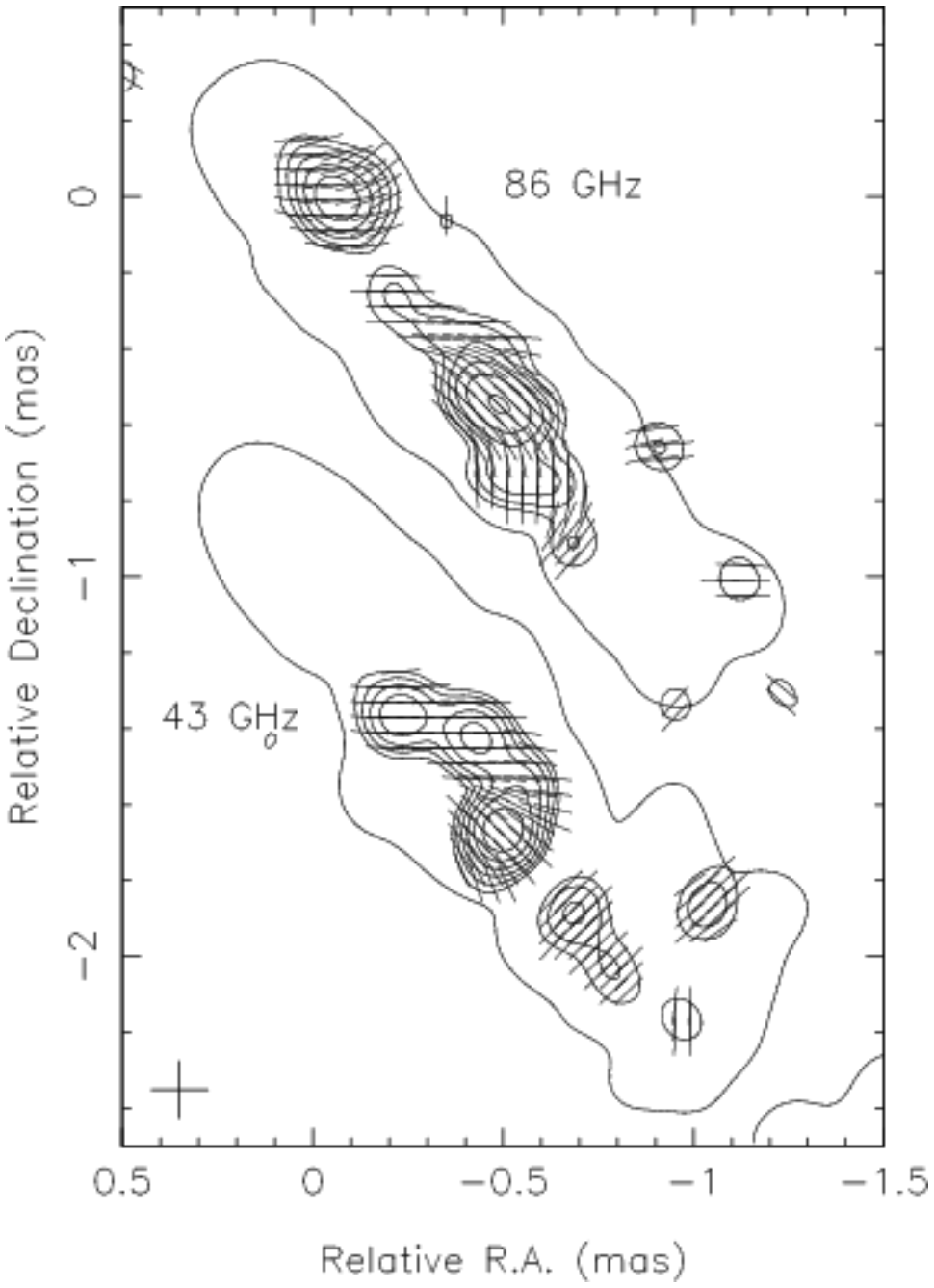
Asada et al. 2002

RM Gradients



Hovatta: "Probing the magnetic fields in 3C273 through Faraday rotation observations"
Savolainen: "Multifrequency polarization structure of the (sub-)parsec scale jet of 3C273 at mm-wavelengths"

RM Gradients



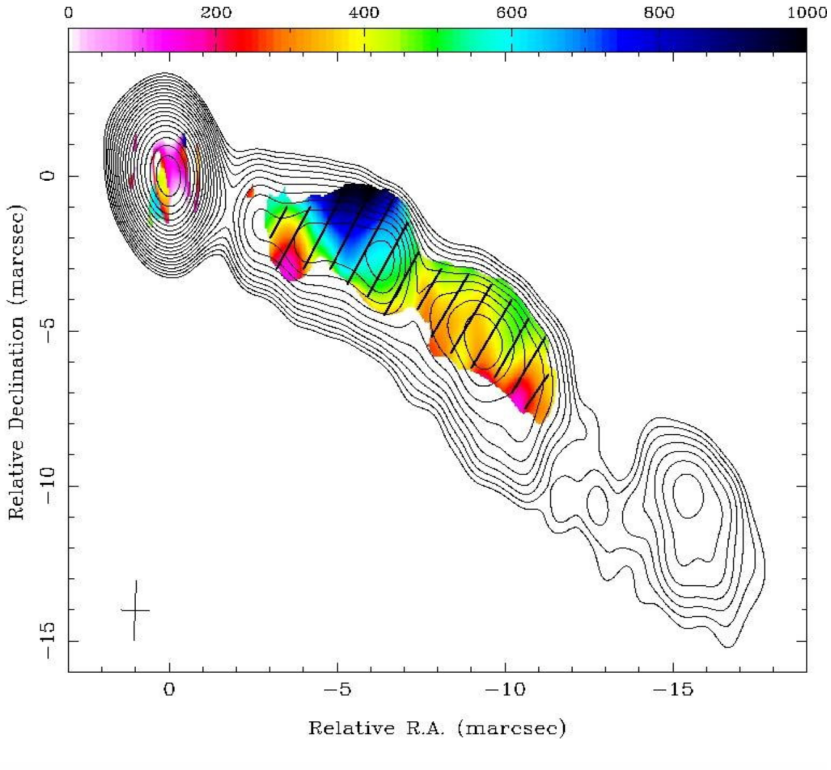
<u>Savolainen:</u> "Multifrequency polarization structure of the (sub-)parsec scale jet of 3C273 at mm- wavelengths"

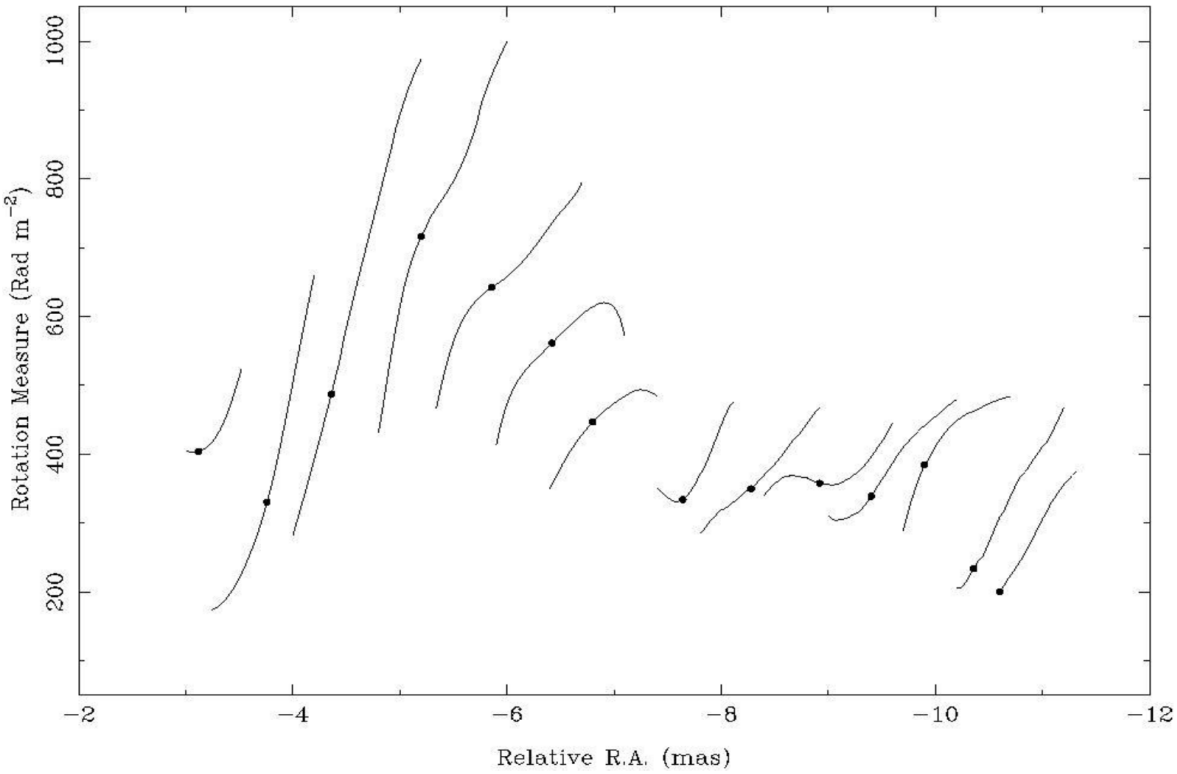
transverse polarization structure within 1mas ~ 2.4pc ~ 4000Rg

this is the closest to the quasar core we can get at this moment!

RM Gradients

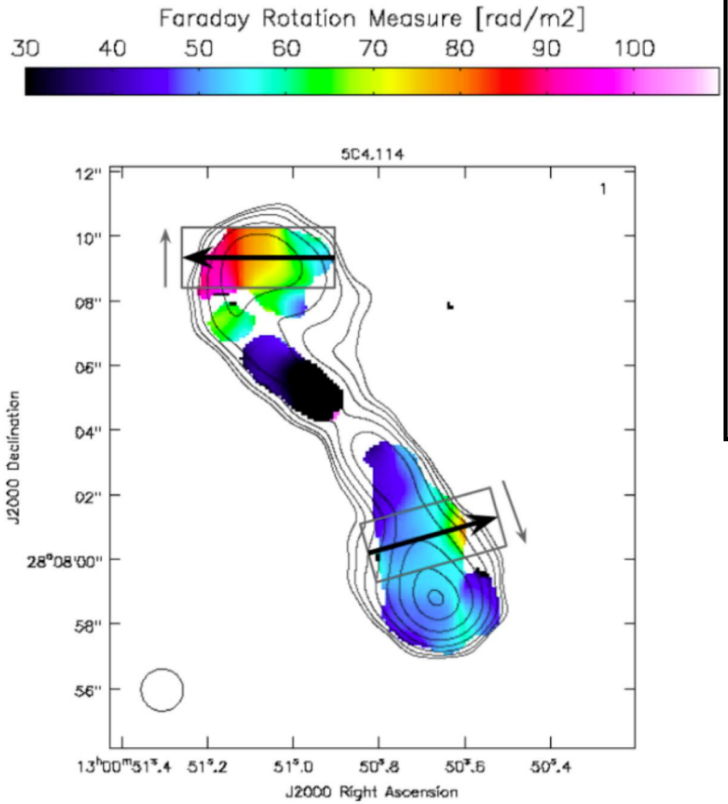
Wardle: “Understanding jet launching through polarisation observations”

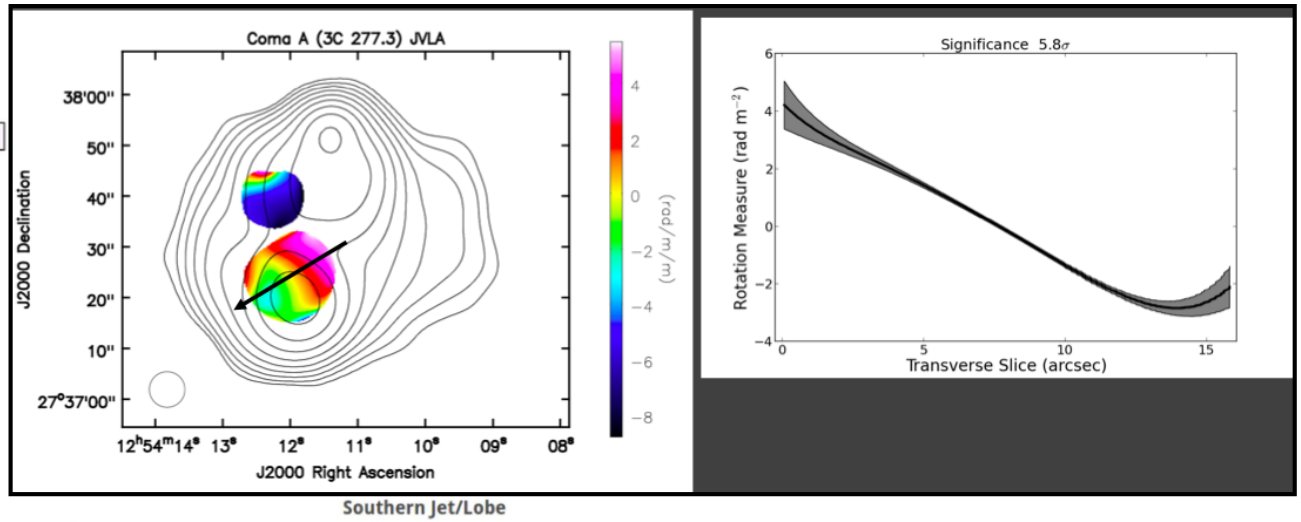




also, **Molina:** “Magnetic field studies in BL Lacertae throught Faraday rotation and a novel astrometric tecnique”

RM Gradients

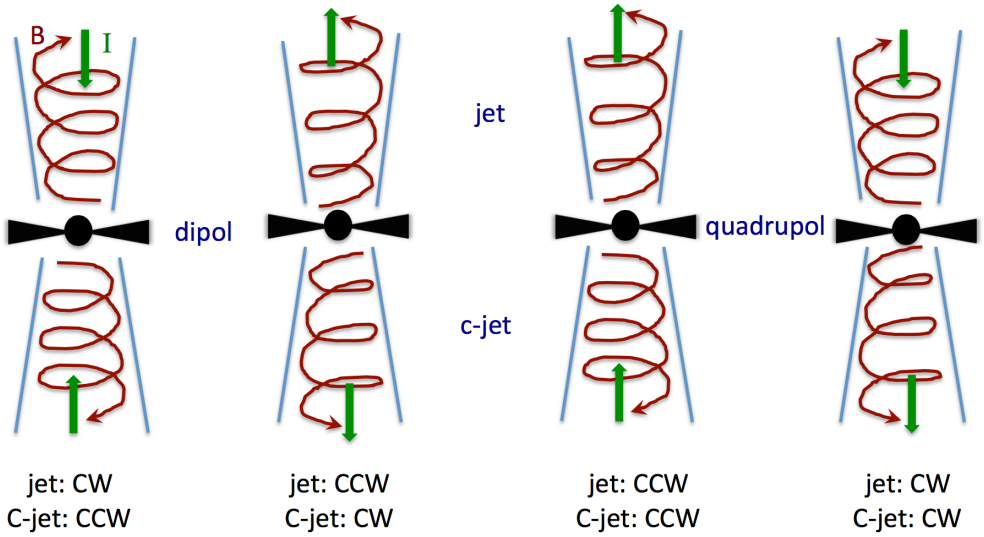


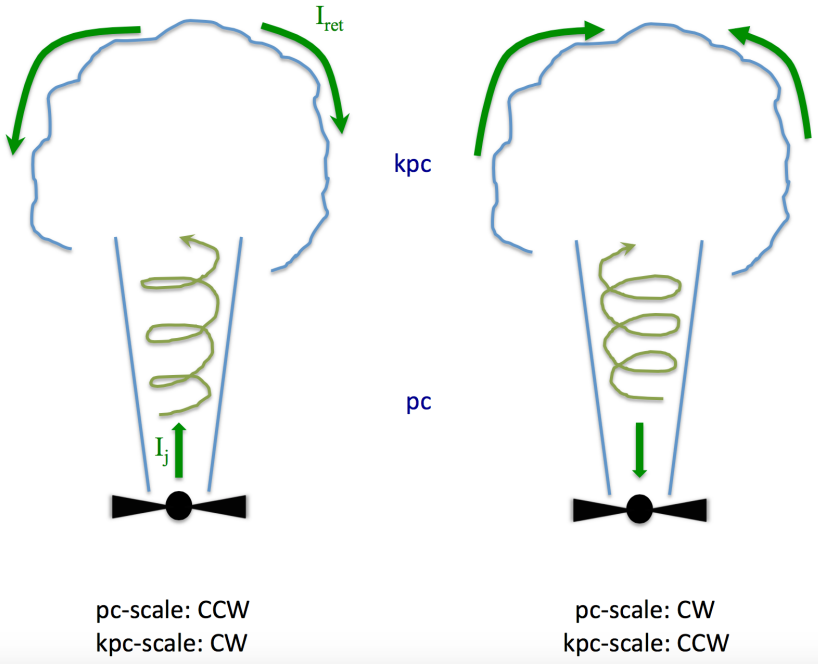


Knuettel: "Evidence for toroidal B-field components in AGN jets on kiloparsec scales"

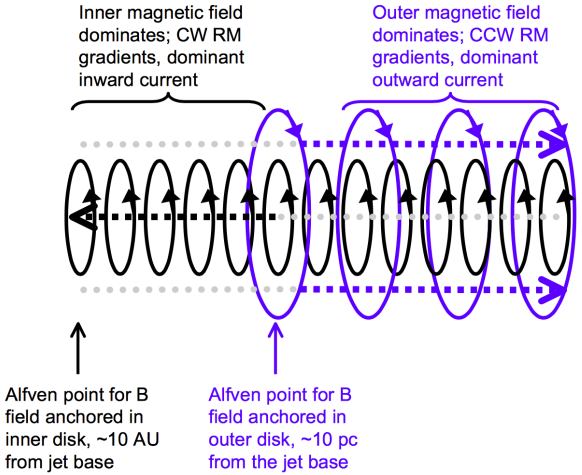
Johnston-Hollitt: "Evidence for Helical or Toroidal Magnetic Fields in a Jet on kpc-scales"

RM Gradients





OR: COSMIC BATTERY?

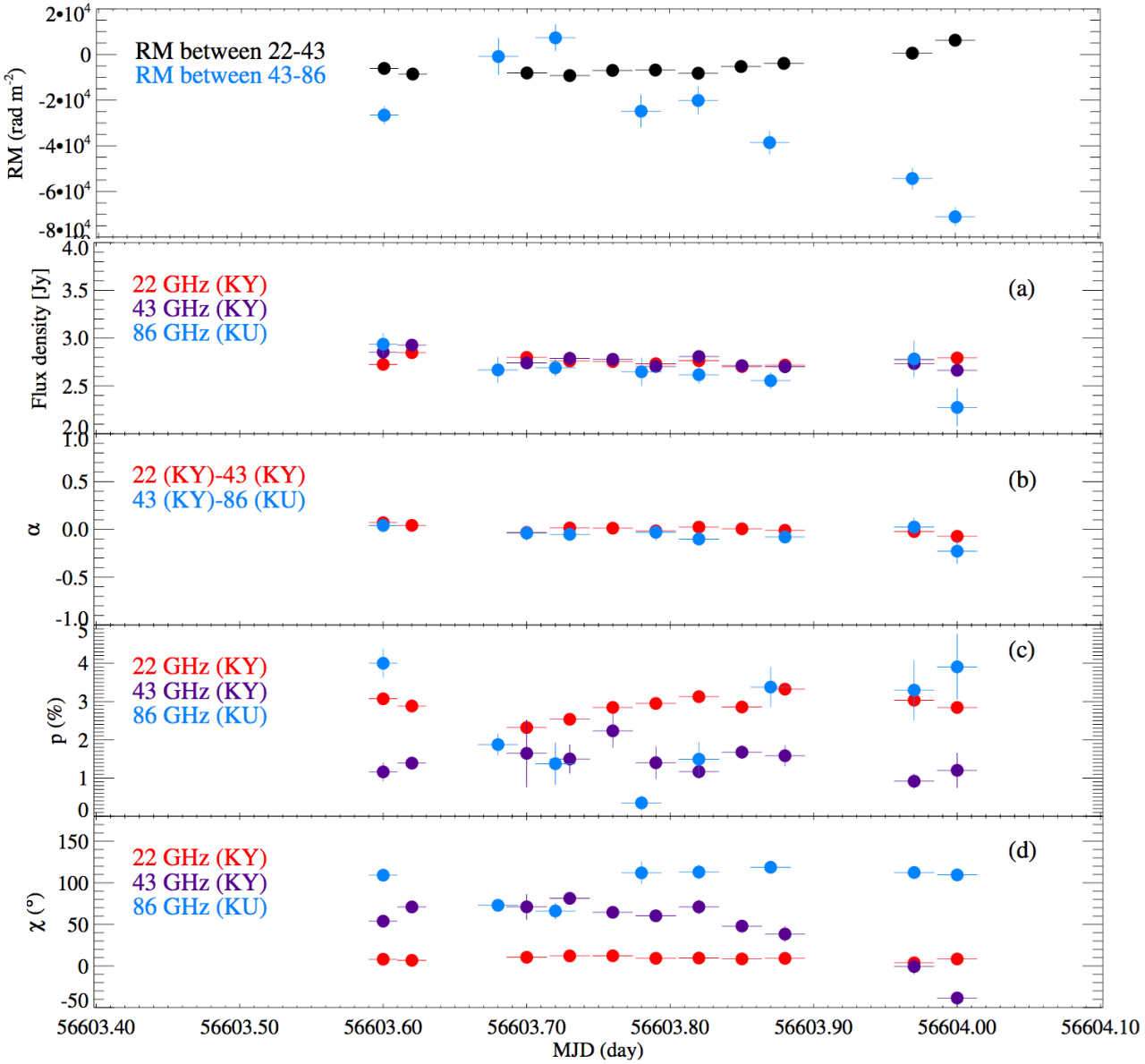


it would be so very cool to have RM gradients on both pc and kph scales, in both the jet and counter-jet, in a single source!

RM Variability

Lee: “Detection of short-term flux density variability and intraday variability in polarized emission at millimeter-wavelength from S5 0716+714”

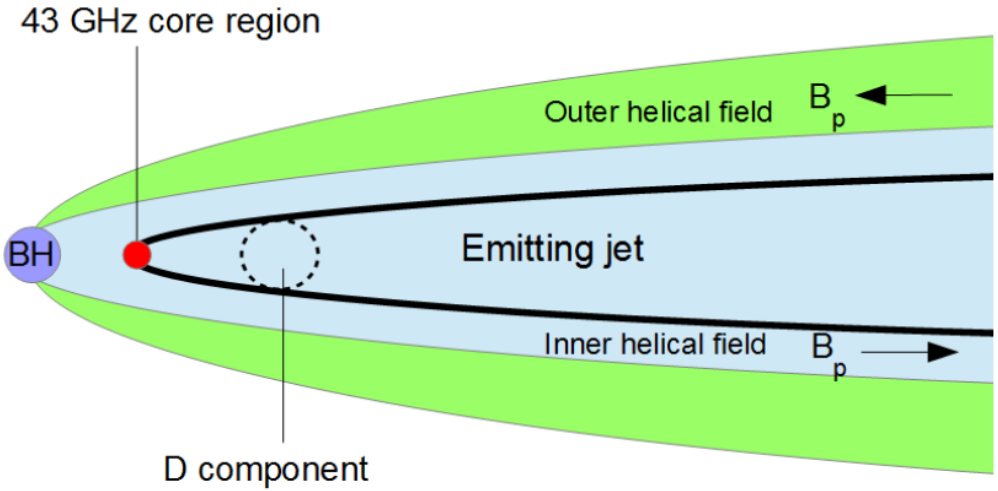
really fast!

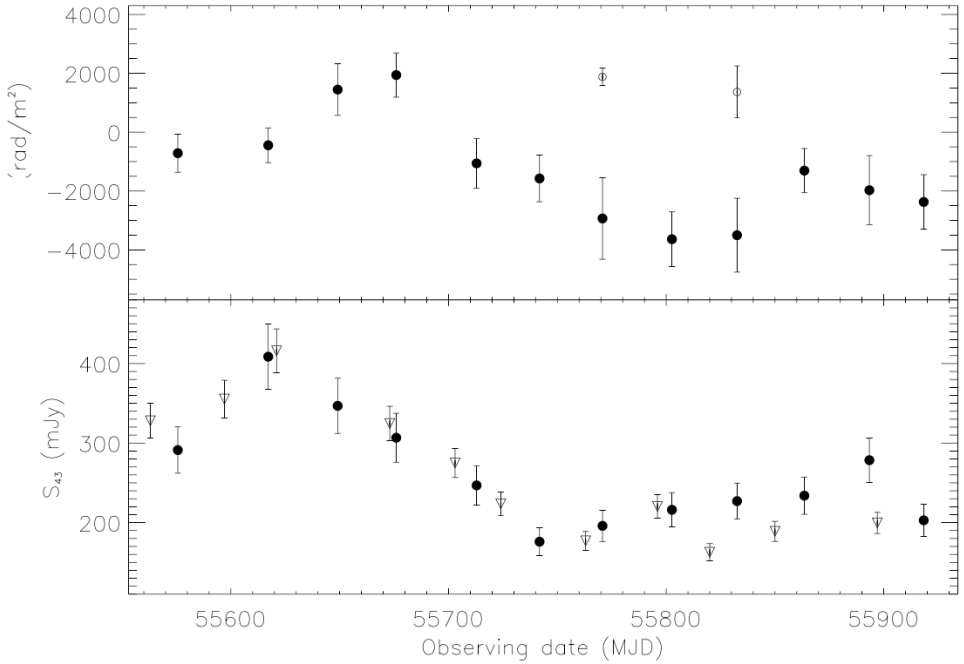


RM Variability

Lico: “On the time variable rotation measure in the core region of Markarian 421”

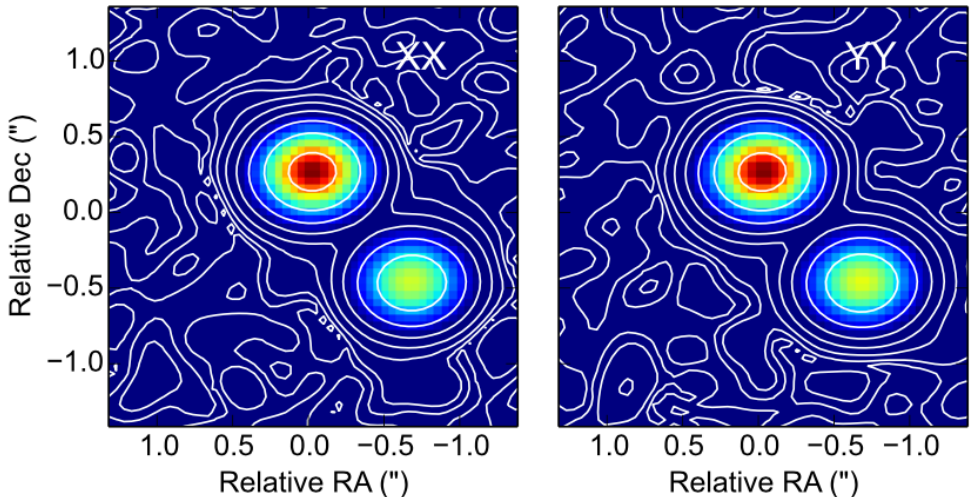
So what is this Faraday screen?

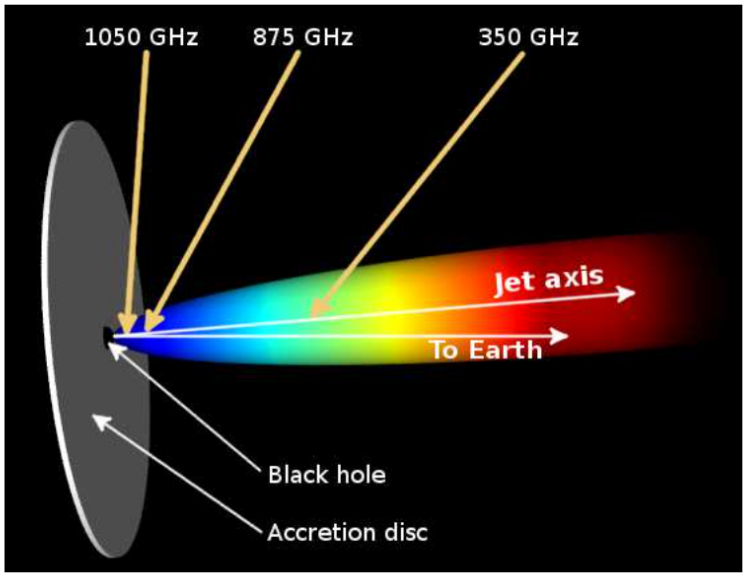


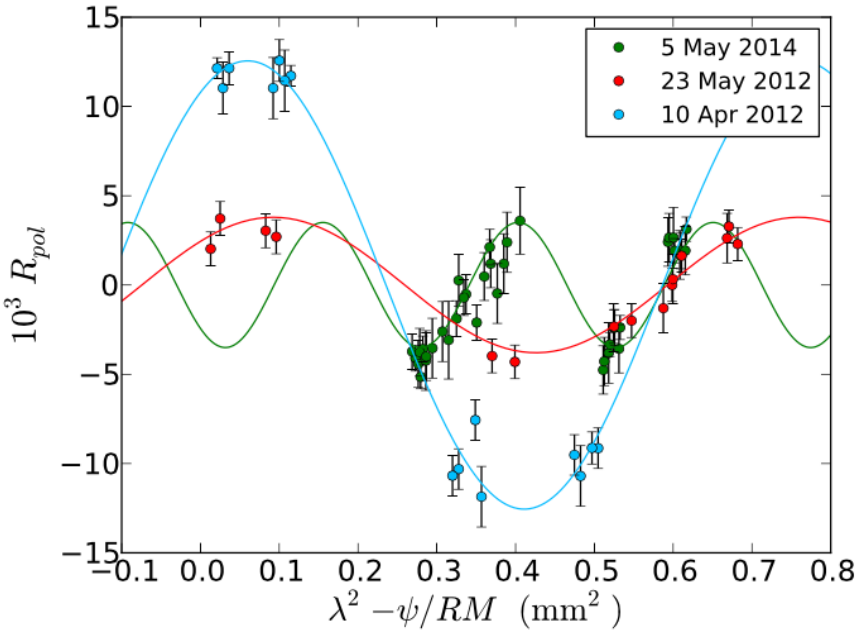


RM: Toward the Core

Martí-Vidal: "AGN polarization at the highest radio-frequencies and resolutions"





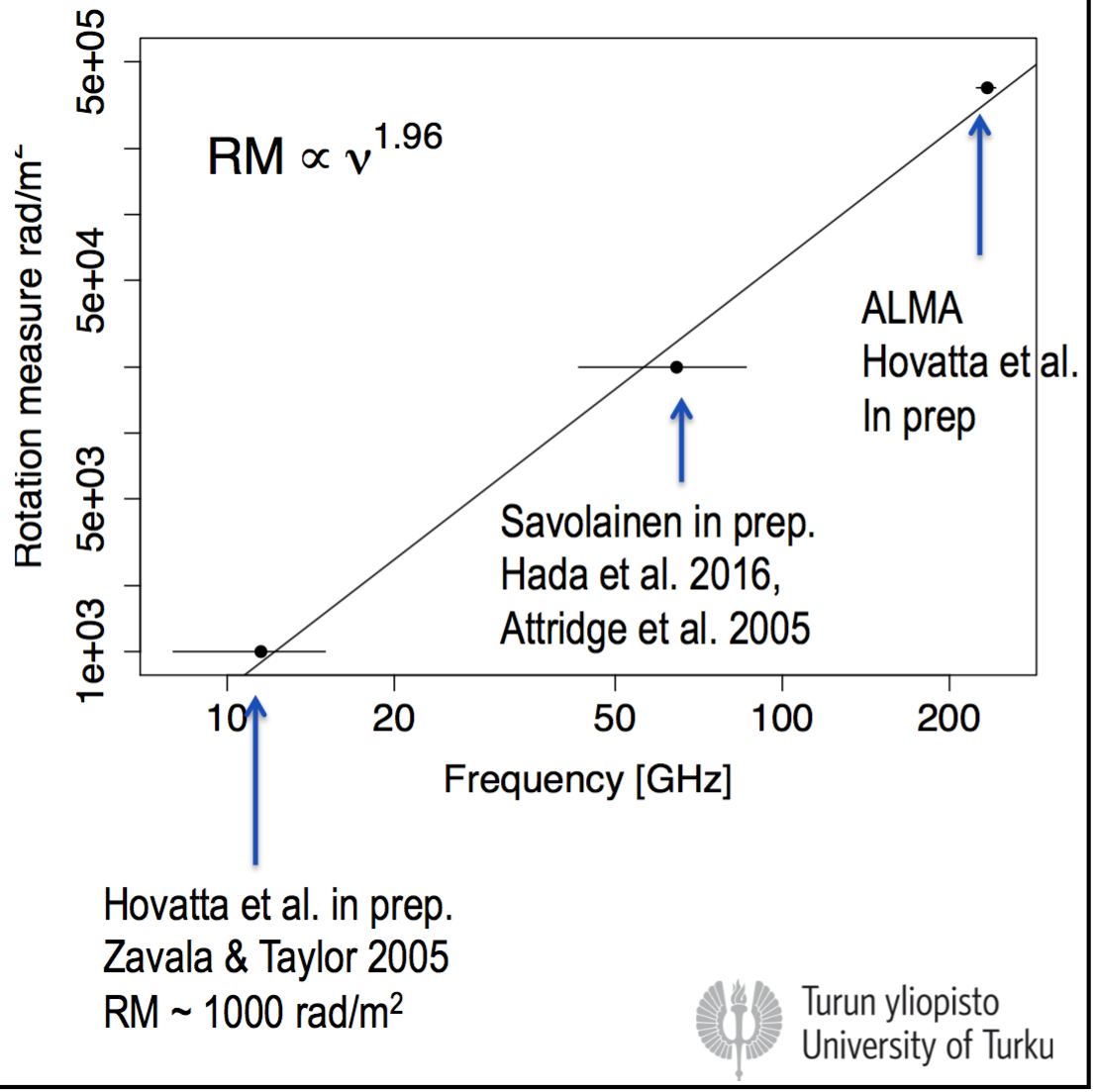


gravitationally-lensed PKS 1830−211
RM ≈ 1e8 rad/m2
->
"magnetic fields in the sub-parsec regions (…) are at least a few tens of Gauss, and possibly much higher"

RM: Toward the Core

Hovatta: "Probing the magnetic fields in 3C273 through Faraday rotation observations"

- We detect a high RM of ~ 3.8 x 10^5 rad/m^2 in our 1mm ALMA observations of 3C273
- Together with earlier results, this indicates that RM as a function of wavelength behaves as expected for a helical magnetic field in a conical jet (see also Jorstad et al. 2007, O'Sullivan & Gabuzda 2009, Kravchenko et al. 2014)
- Outlook: EHT observations to resolve the Faraday rotation region



Turun yliopisto
University of Turku

RM Studies: Environment

Anderson: “Beyond rotation measures: Leveraging broadband polarimetry and all-sky radio surveys to probe spatially- unresolved magneto-ionic structure in AGN jets”

Kierdorf: “Probing the Magnetized Medium of AGNs using Wideband Polarimetry”

Ma: “Radio Polarisation Study of High Rotation Measure AGNs — How to Distinguish Intrinsic from External Sources of Rotation Measure?”

Pasetto: “Exploring the environment of high Rotation Measure Active Galactic Nuclei with wideband radio spectropolarimetry observations”

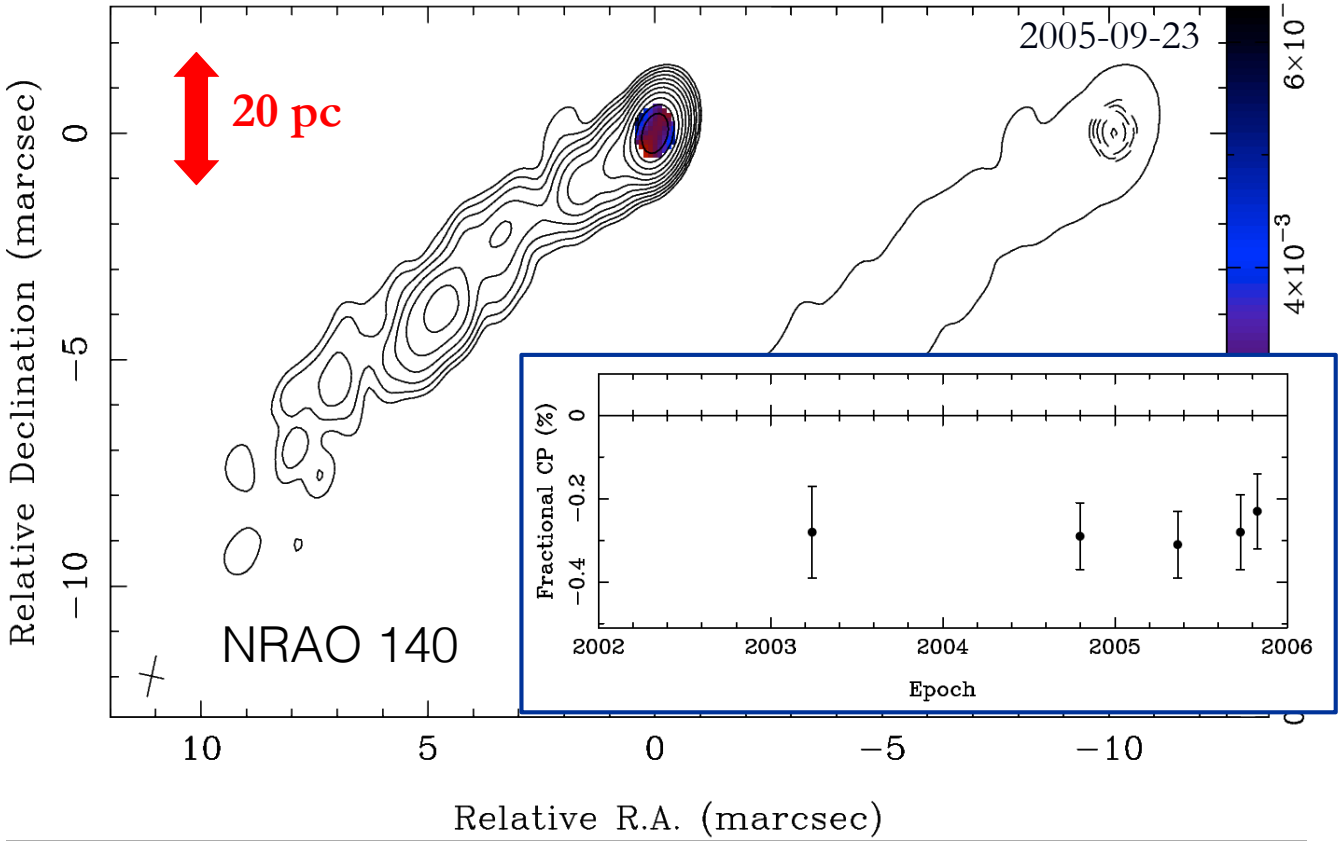
Circular Polarisation

Circular Polarisation

Homan: "Constraints on Particles and Fields from Full Stokes Observations of AGN"

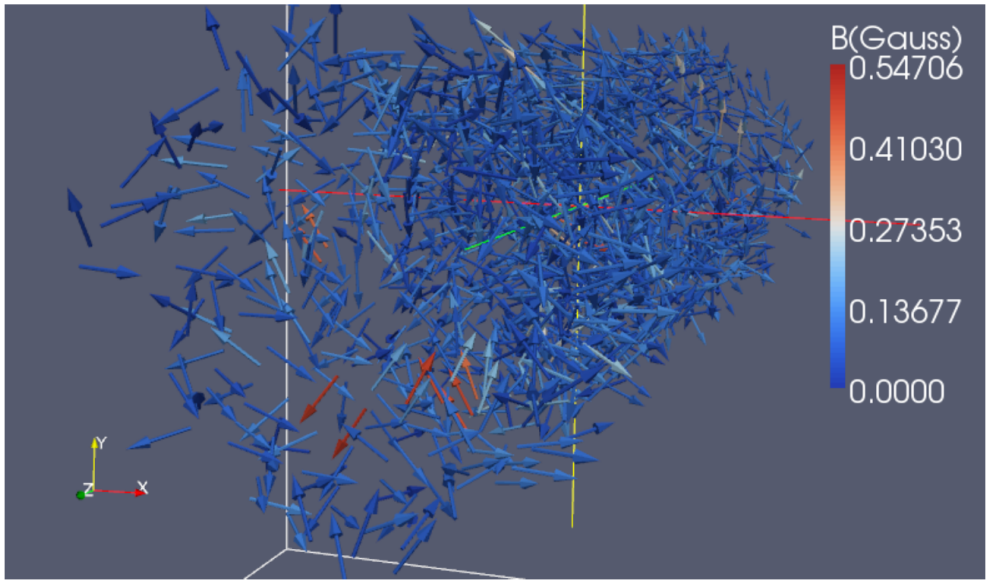
- **typical 0.3-0.7%, a few up to 1%; tens of significant detections**
- **persistent regarding the sign; in a few cases flips from >0 to <0**
- **consistent with Faraday Conversion in a e-p+ plasma; intrinsic CP not ruled out**

Gabuzda: "Determining the Jet Longitudinal Magnetic Field Directions and Black-Hole Rotation Directions in AGNs" **helical MF?**

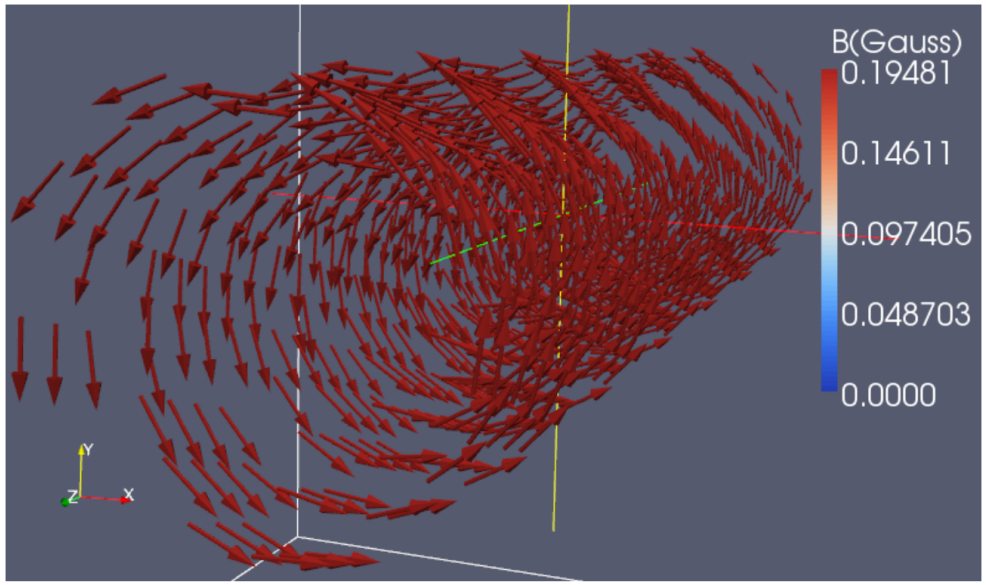


Circular Polarisation

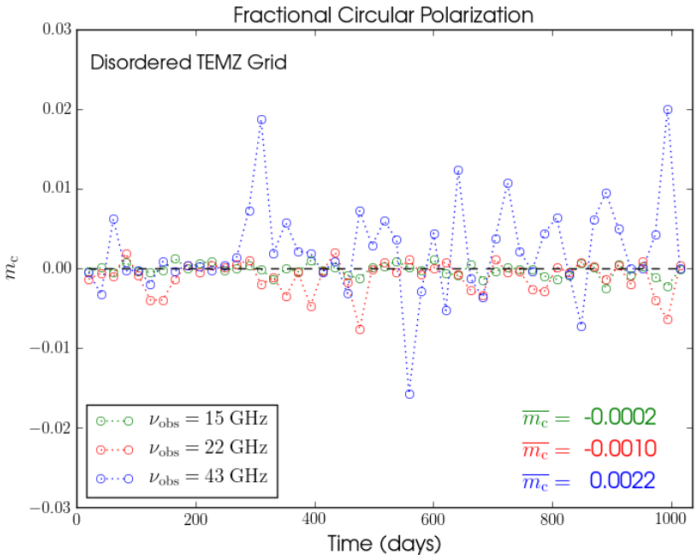
MacDonald: "Faraday Conversion in Turbulent Blazar Jets"

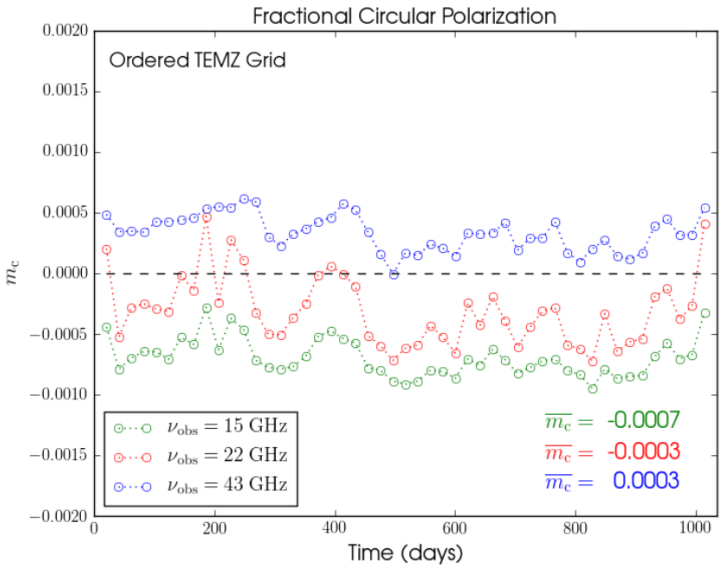


rendering of the three-dimensional distribution of an initially disordered magnetic field, after partial ordering by a conical standing shock, within a turbulent TEMZ grid.



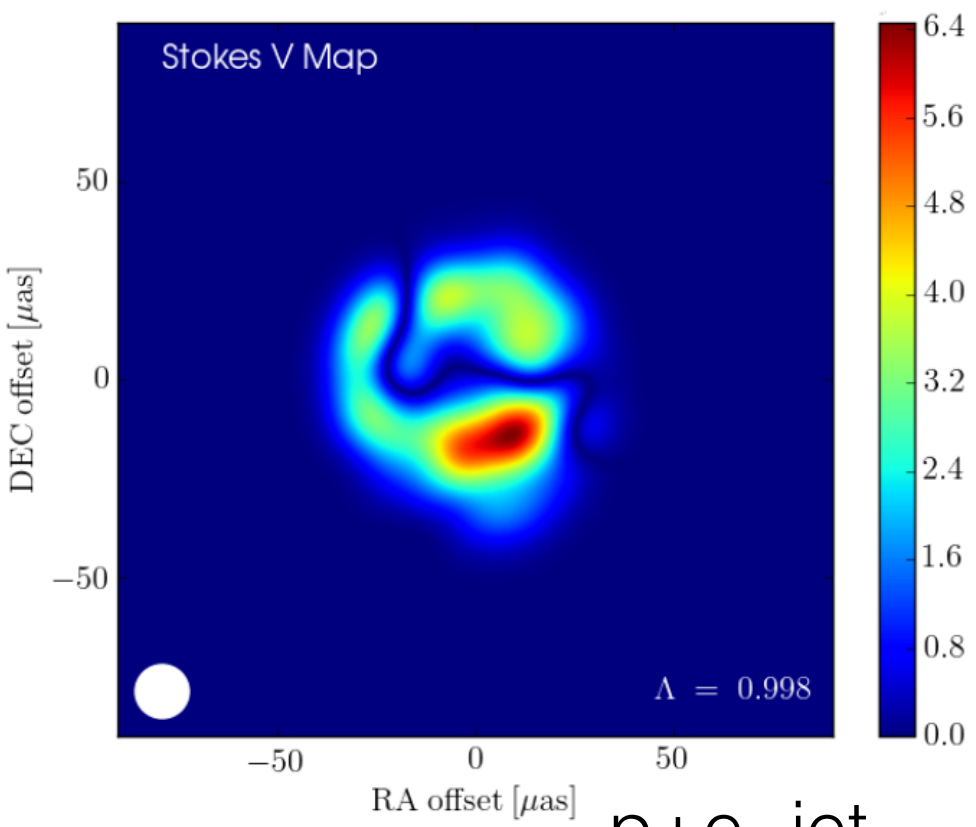
A rendering of the three-dimensional distribution of well-ordered magnetic field within the TEMZ grid.



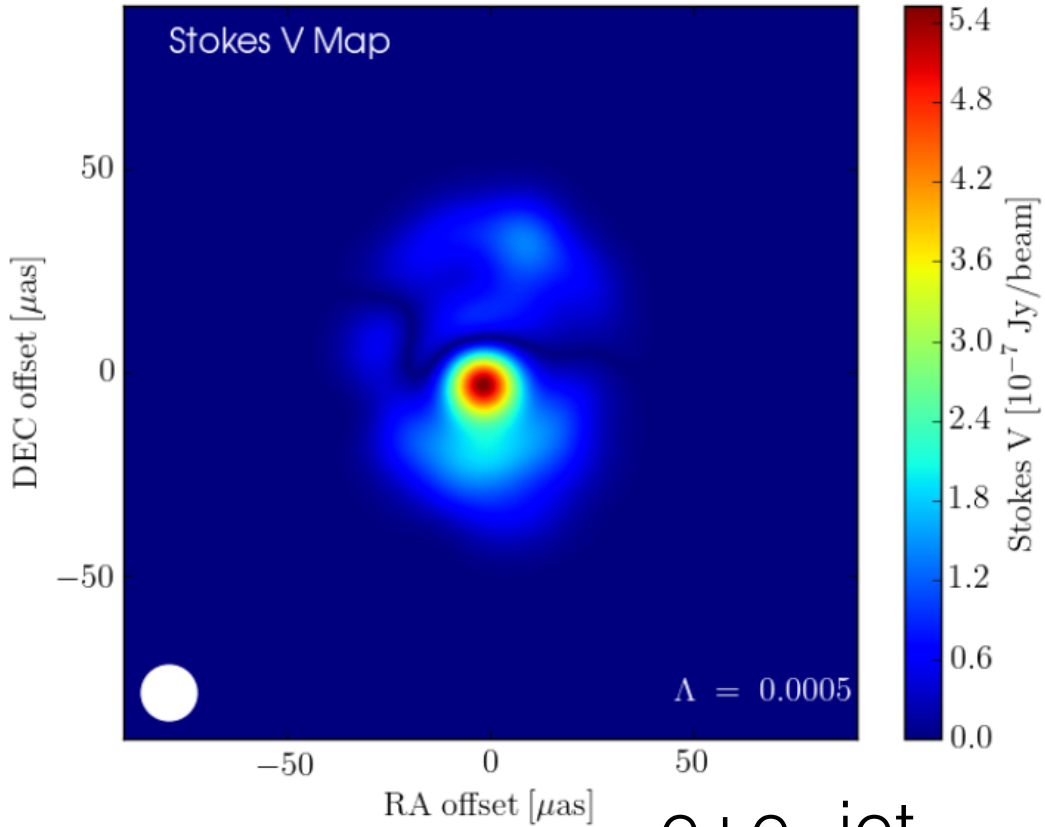


Circular Polarisation

MacDonald: “Faraday Conversion in Turbulent Blazar Jets”



p+e- jet

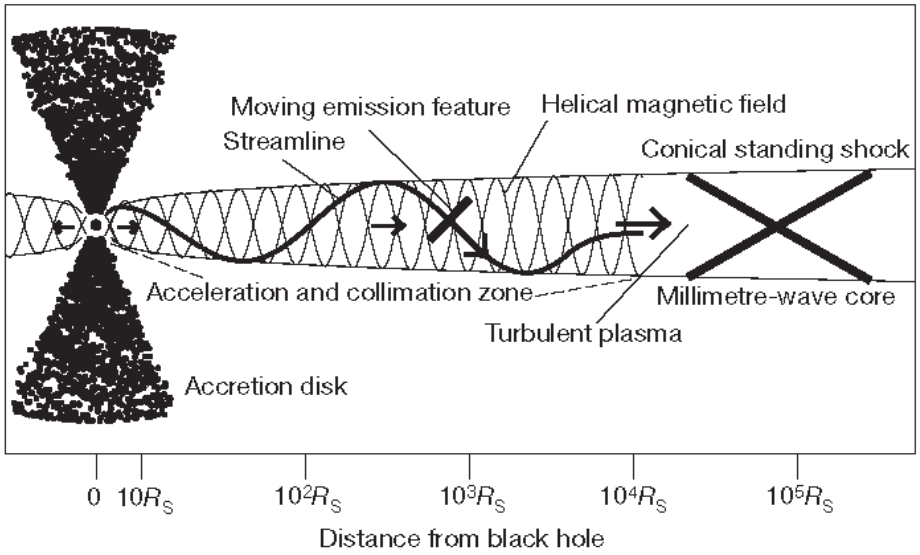


e+e- jet

EVPA Swings

EVPA Swings

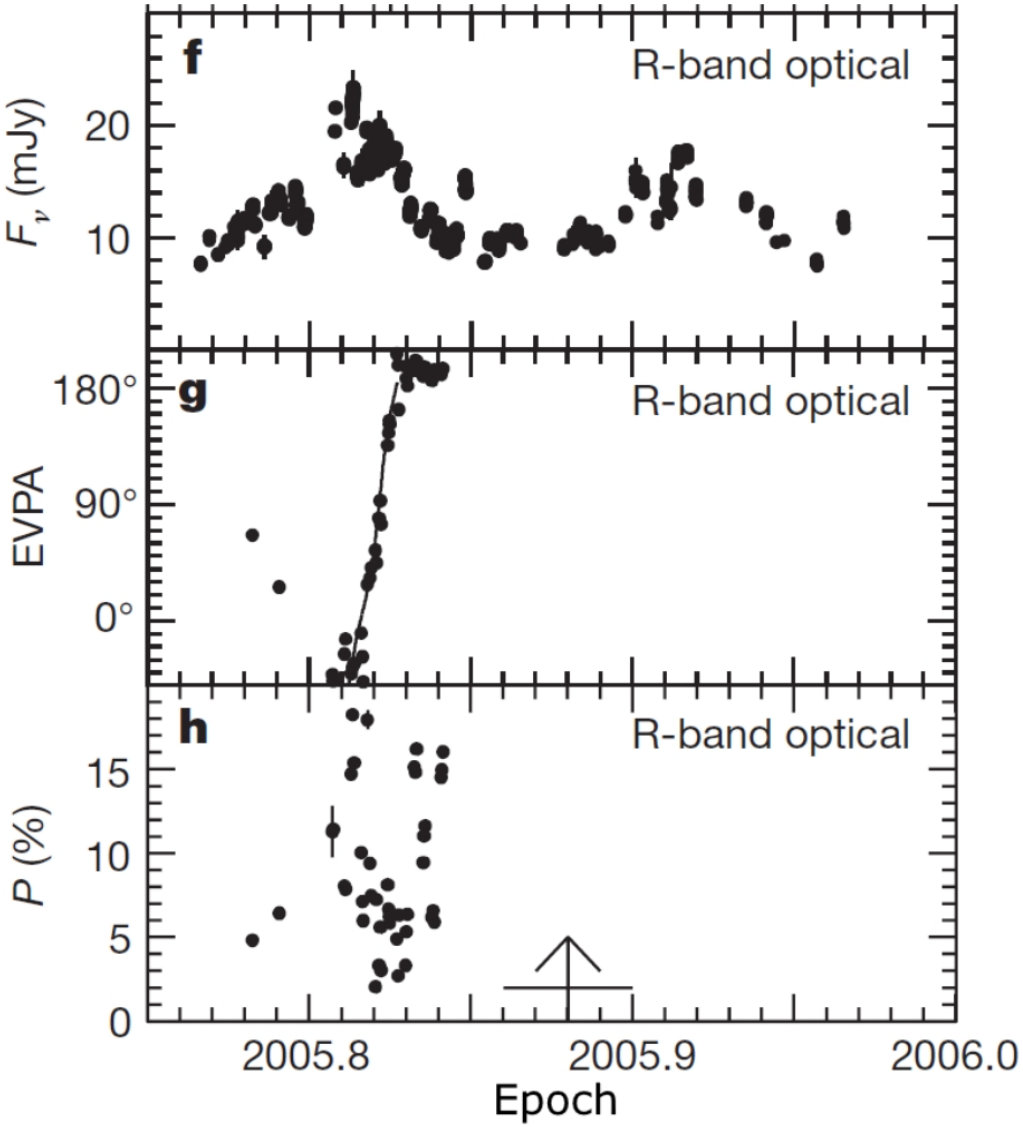
helical MF + blobs
Vlahakis, Marscher



Liodakis: "Coherent changes in the polarization angle and broadband SED: the case of 3C454.3"

Myserlis: "OJ287 polarization"

Marscher et al. 2008

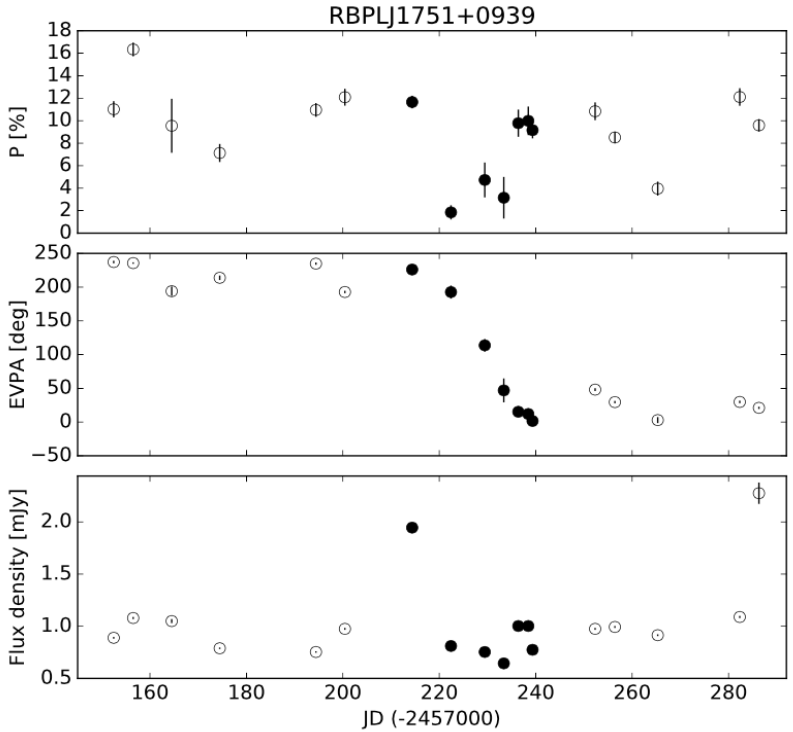


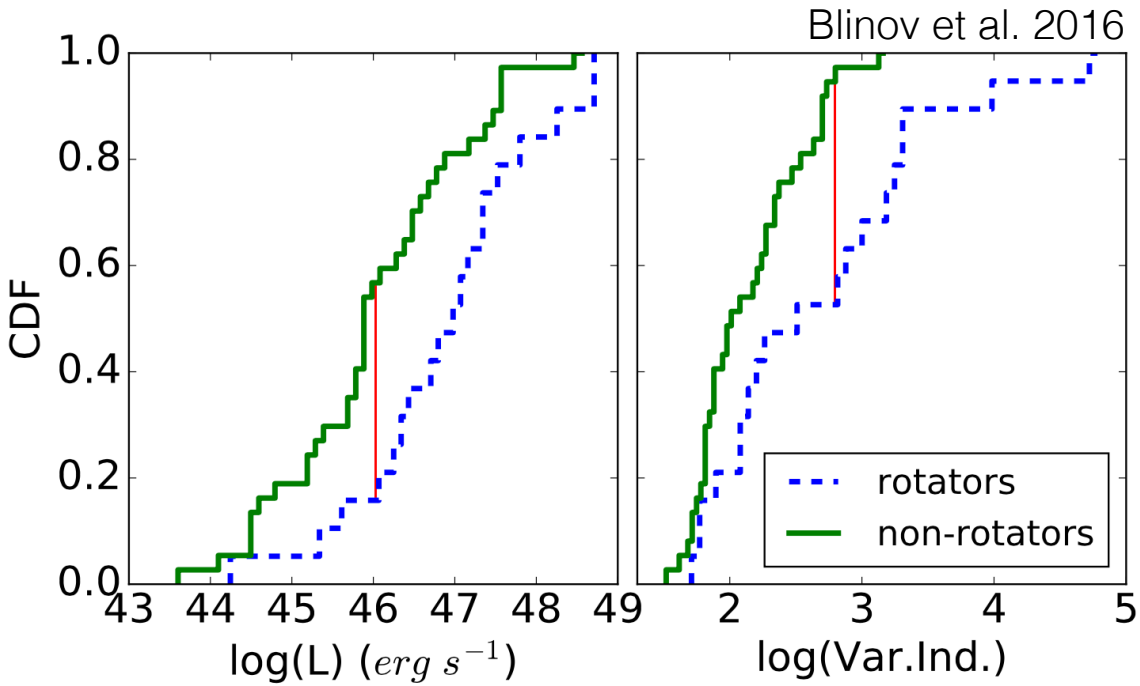
EVPA Swings

Pavlidou: "The RoboPol optopolarimetric blazar monitorng program"

prior to RoboPol: 16 rotations in 10 blazars
3yr of RoboPol: +40 rotations in 24 blazars

rotators are brighter and more variable in gamma-rays

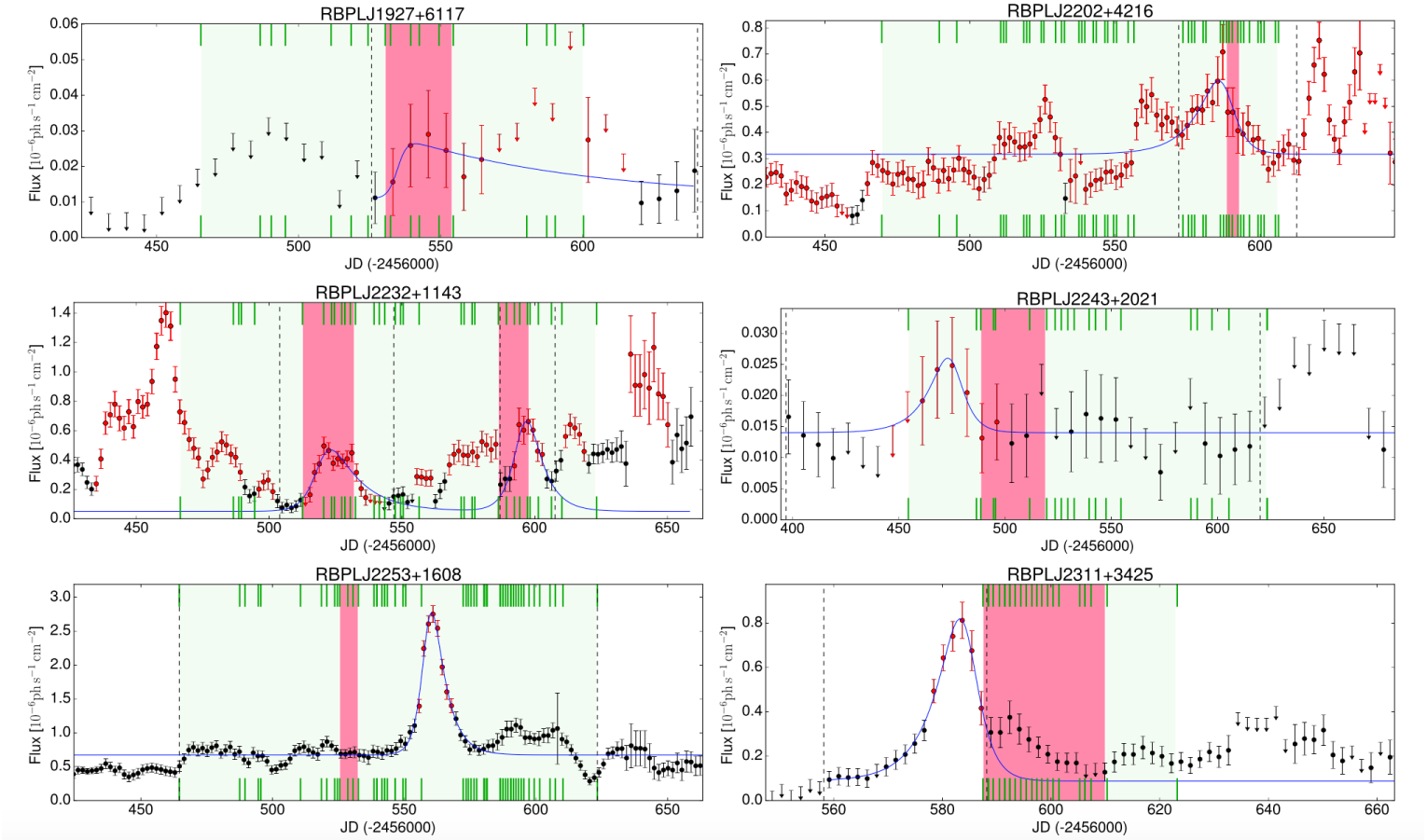




EVPA Swings

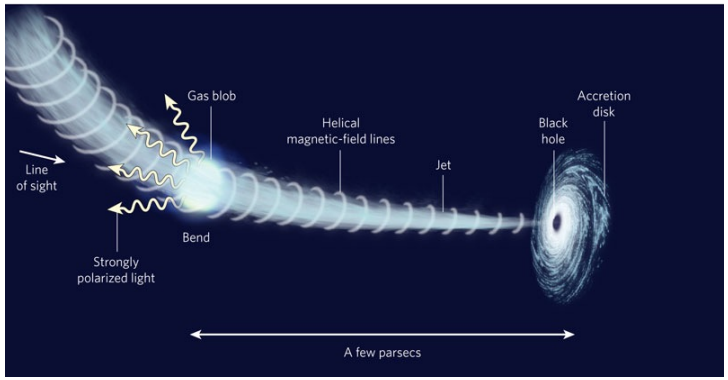
Blinov:

"Connection between optical polarization plane rotations and gamma-ray flares in blazars"

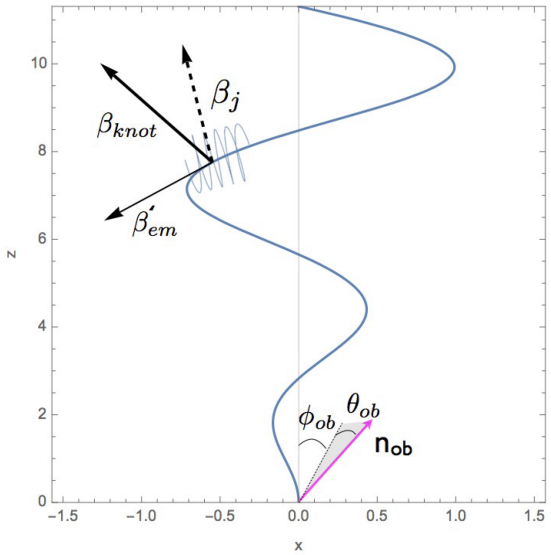


Gamma-ray light curves of objects with detected rotations of EVPA. The RoboPol observational season is marked by the green (light) area. The pink (dark) area shows duration of the rotation. Green ticks mark moments of our optical EVPA measurements. All curves are centred to the mean day of the RoboPol observing season. Detected flares are marked by red points, while the blue curve is the analytical function fit of the flares closest to observed rotations. Vertical dashed lines indicate intervals of the light curves used in the fitting procedure.

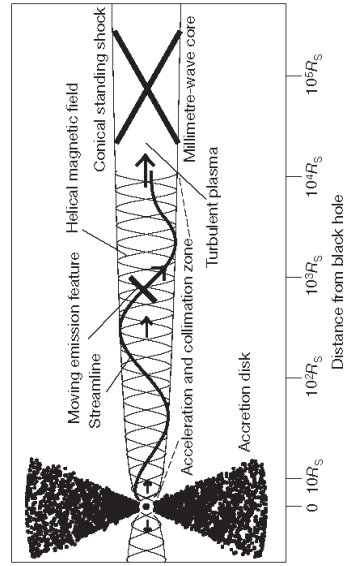
EVPA Swings



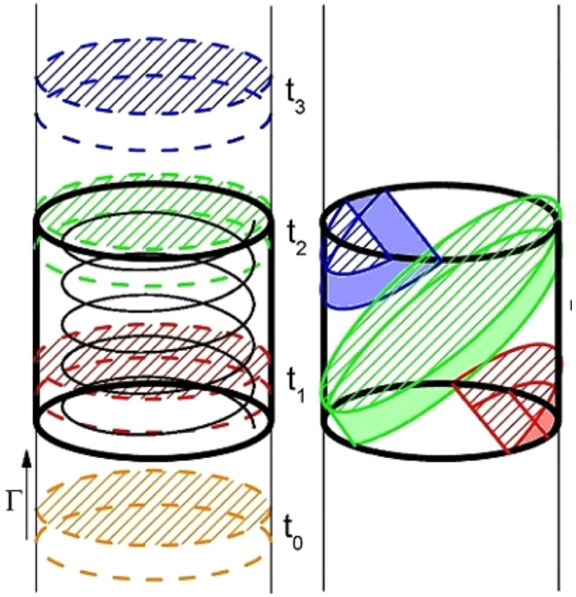
bending jets
Fermi-LAT



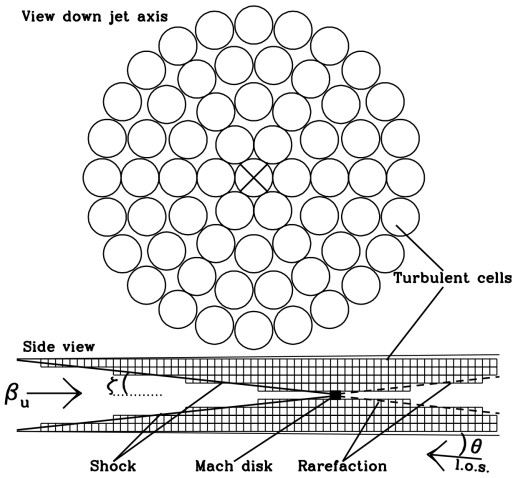
jet precession
Lyutikov & Kravchenko



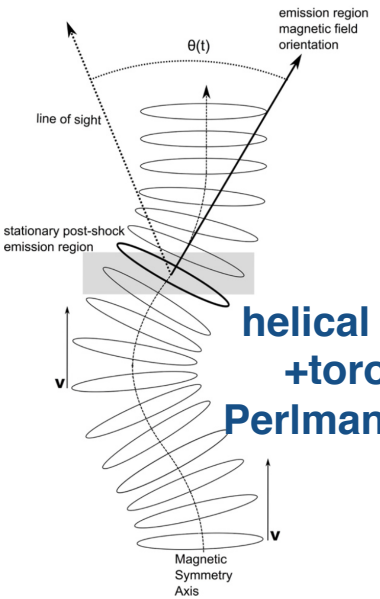
helical MF + blobs
Vlahakis



Helical MF+disturbance
Zhang et al.



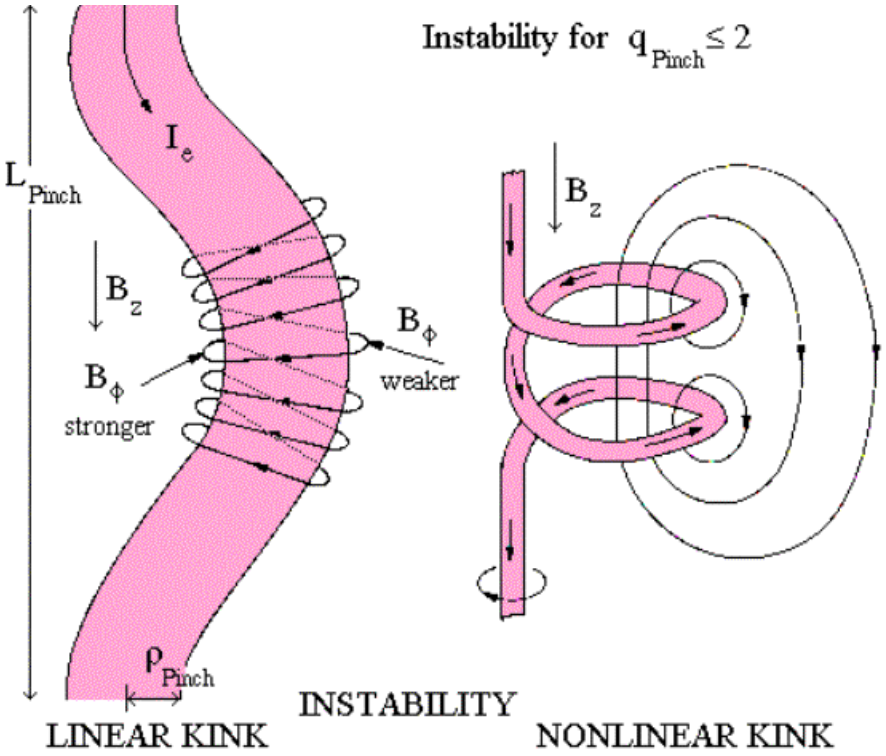
standing shock+turbulence
Marscher



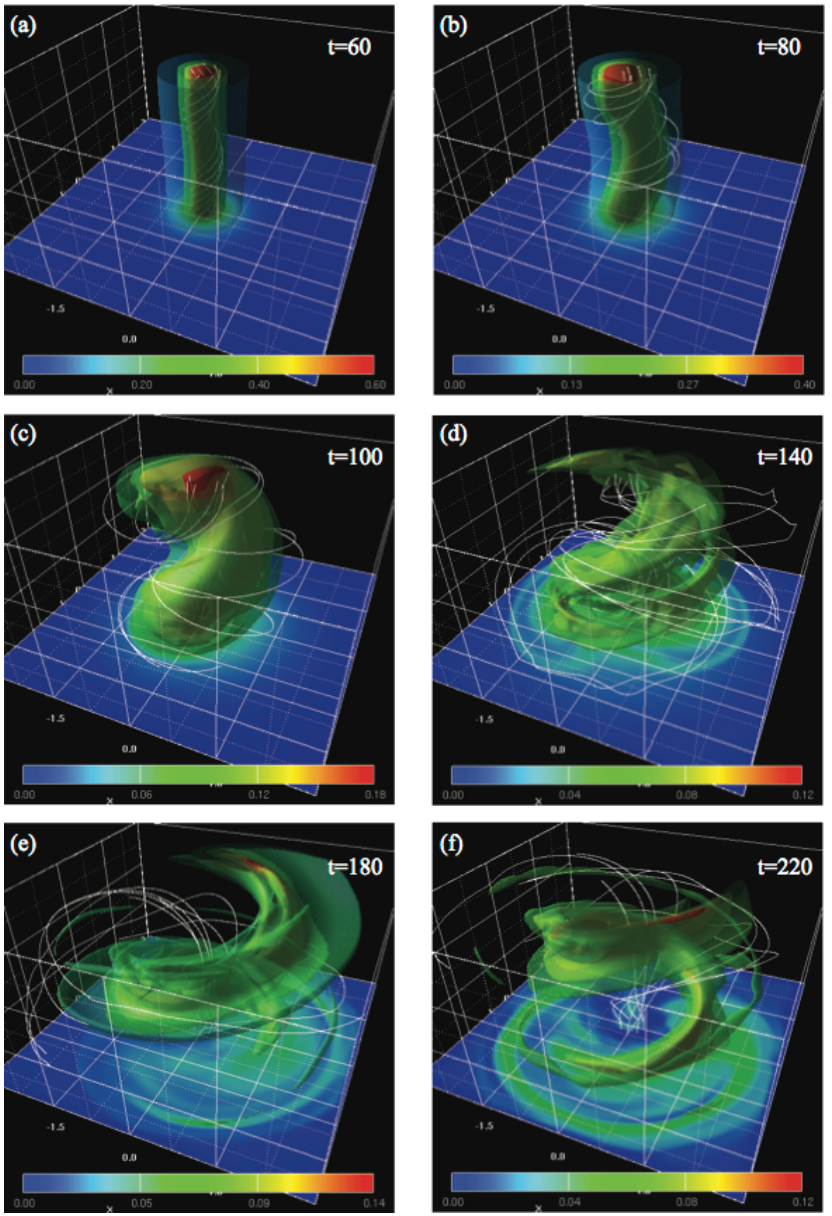
helical distortion
+toroidal MF
Perlman et al. 2011

EVPA Swings

Nalewajko: "A model of polarization angle swings in blazars based on kink instability of magnetized jets"



Mizuno et al.



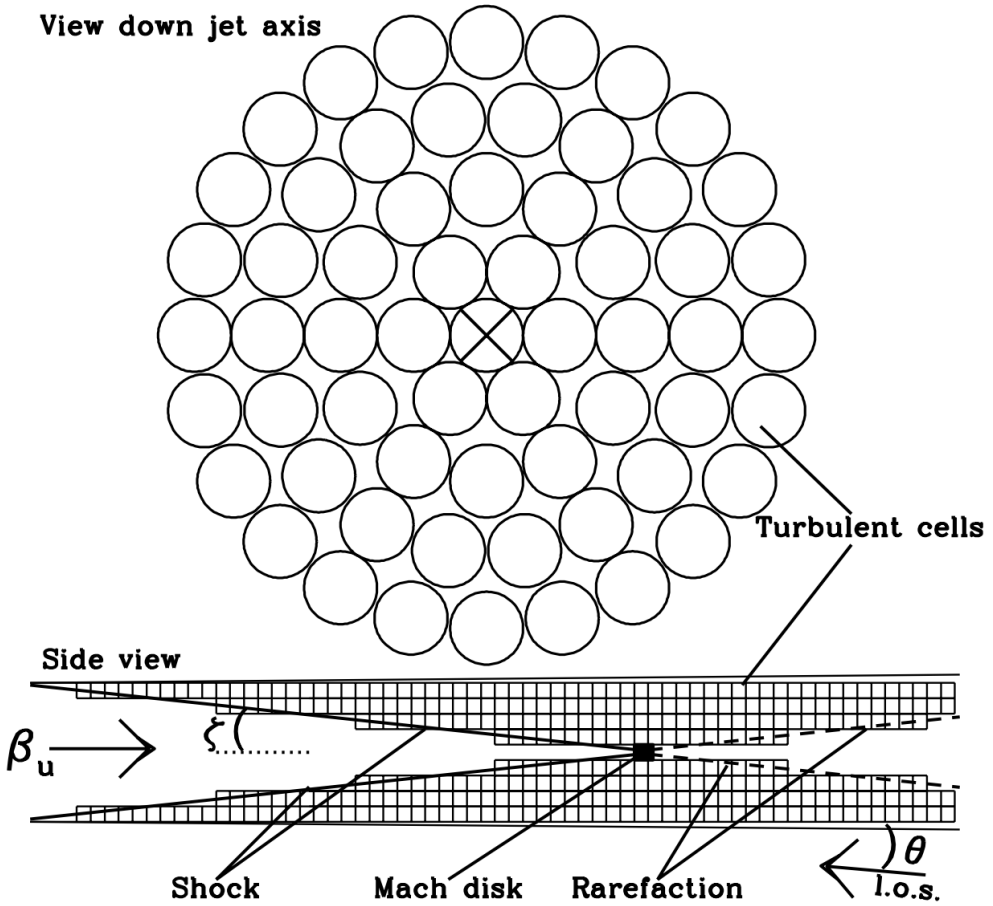
EVPA Swings

Marscher:

"Modeling the Time-Dependent Polarization of Blazars"

- shocks ordering field?
- turbulence!
- all together?

Turbulent Extreme Multi-Zone (TEMZ) Model, with or without standing shock; turbulence mildly/sub-relativistic (0.1c), Kolmogorov spectrum: when no shock, the model produces frequency-dependent polarisation signatures, but **NO** smooth EVPA swings



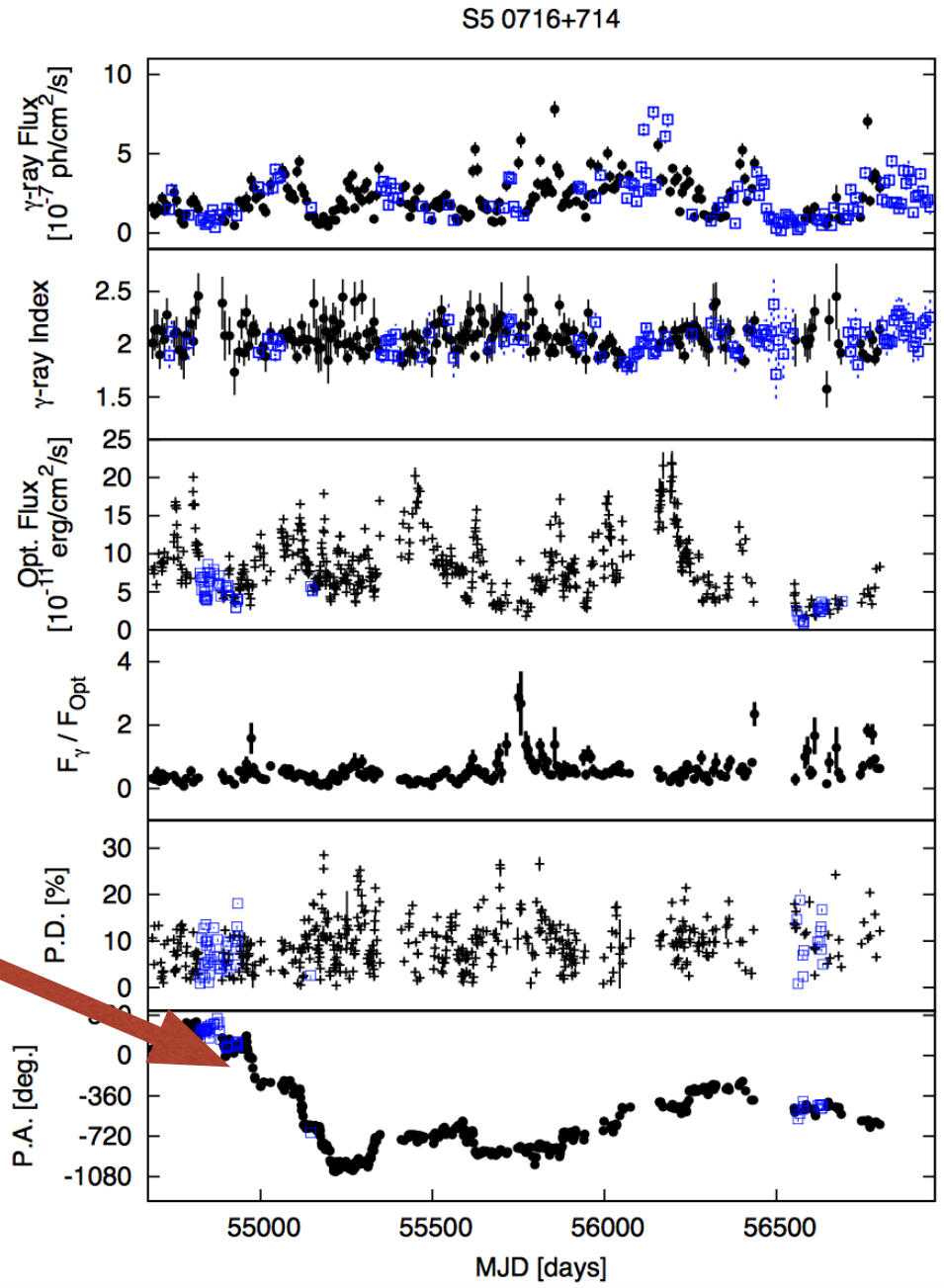
EVPA Swings

Itoh: “Polarimetric monitoring of jets with Kanata Telescope”

Kiehlmann: “Testing a stochastic variability model of optical EVPA rotations in blazars with RoboPol data”

- low polarization during EVPA swings expected
- how coherent/smooth are large EVPA swings?
- can we explain all but a few particularly large and smooth EVPA swing events?

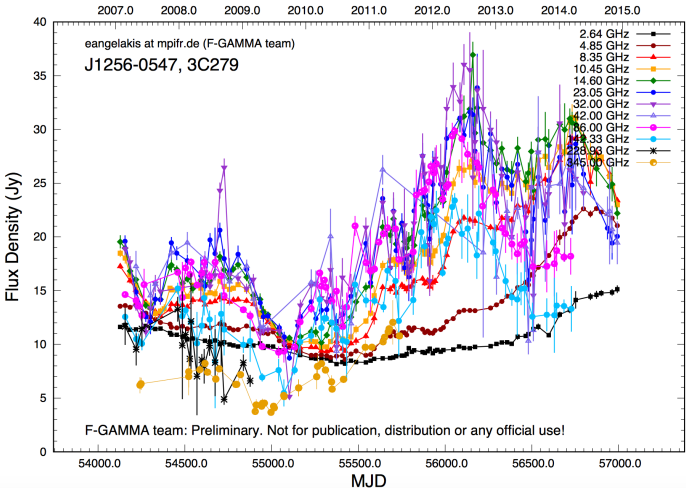
Cohen: “Double Rotations in EVPA in OJ287”

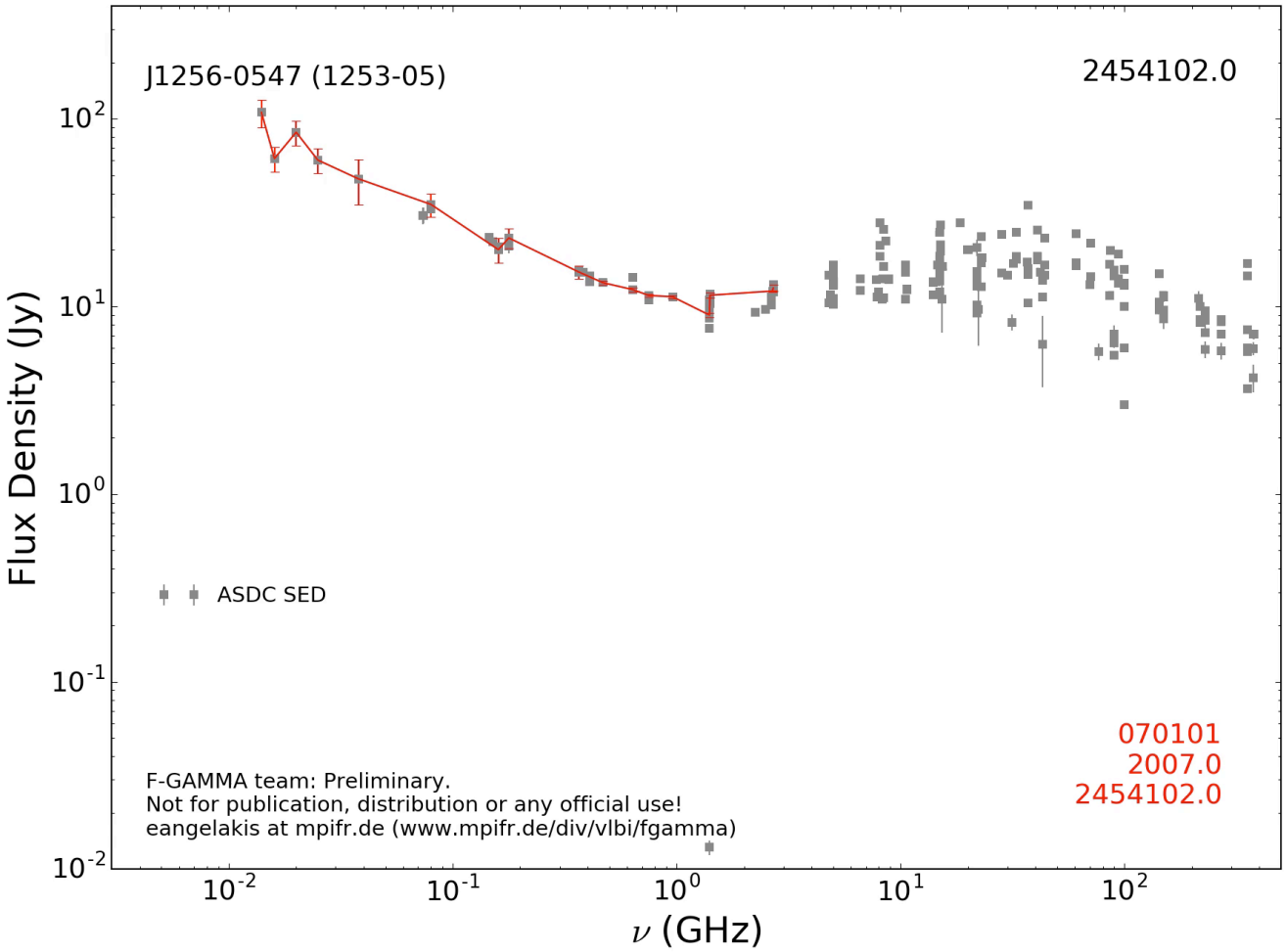


Blazar Monitoring

Blazar Monitoring

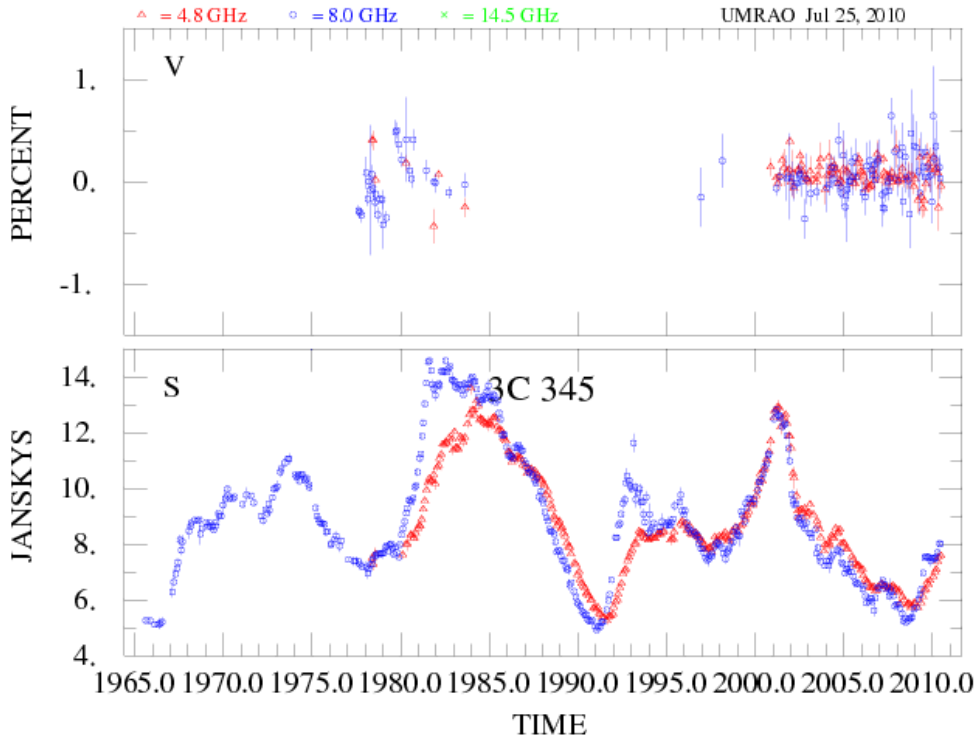
Angelakis: “Full-Stokes multi-band polarimetry” **F-GAMMA**



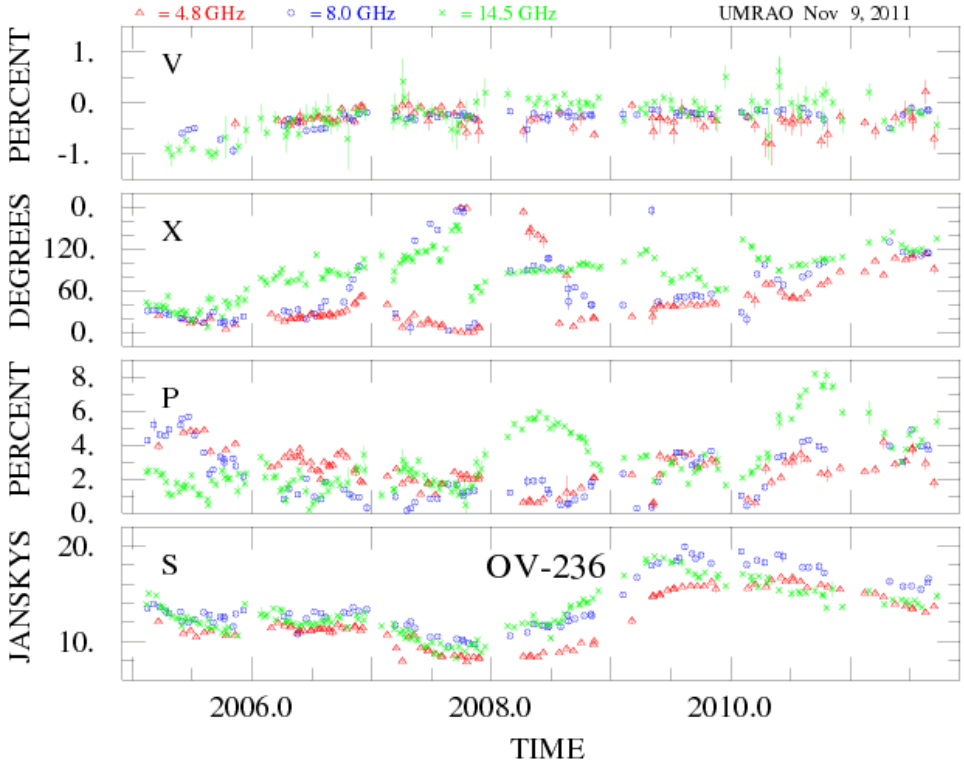


Blazar Monitoring

Aller: "Centimeter-Band All-Stokes Observations of Blazar Variability" **UMRAO**



Monthly-averaged total flux density and circular polarization for 3C 345. Note the change in polarity in circular polarization during the early 1980s (top panel)



Weekly averages of the UMRAO data for QSO OV-236. The top panel shows fractional circular polarization (Stokes V), the middle two panels show the linear polarization, and the bottom panel shows the total flux density.

Blazar Monitoring

Jorstad: "The VLBA-BU-BLAZAR program: Comparison of linear polarization in parsec scale jets with optical polarization of gamma-ray blazars" **BU-BLAZAR**

- **a strong similarity of optical and VLBI core evolution in Q-U plane; differences between FSRQs and BL Lacs**
- **in FSRQ, optical flux correlates with optical PD, while in BL Lacs the opposite is seen**
- **majority of optical and VLBI core EVPAs align within 20deg for BL Lacs; this is not that obvious in FSRQs anymore**

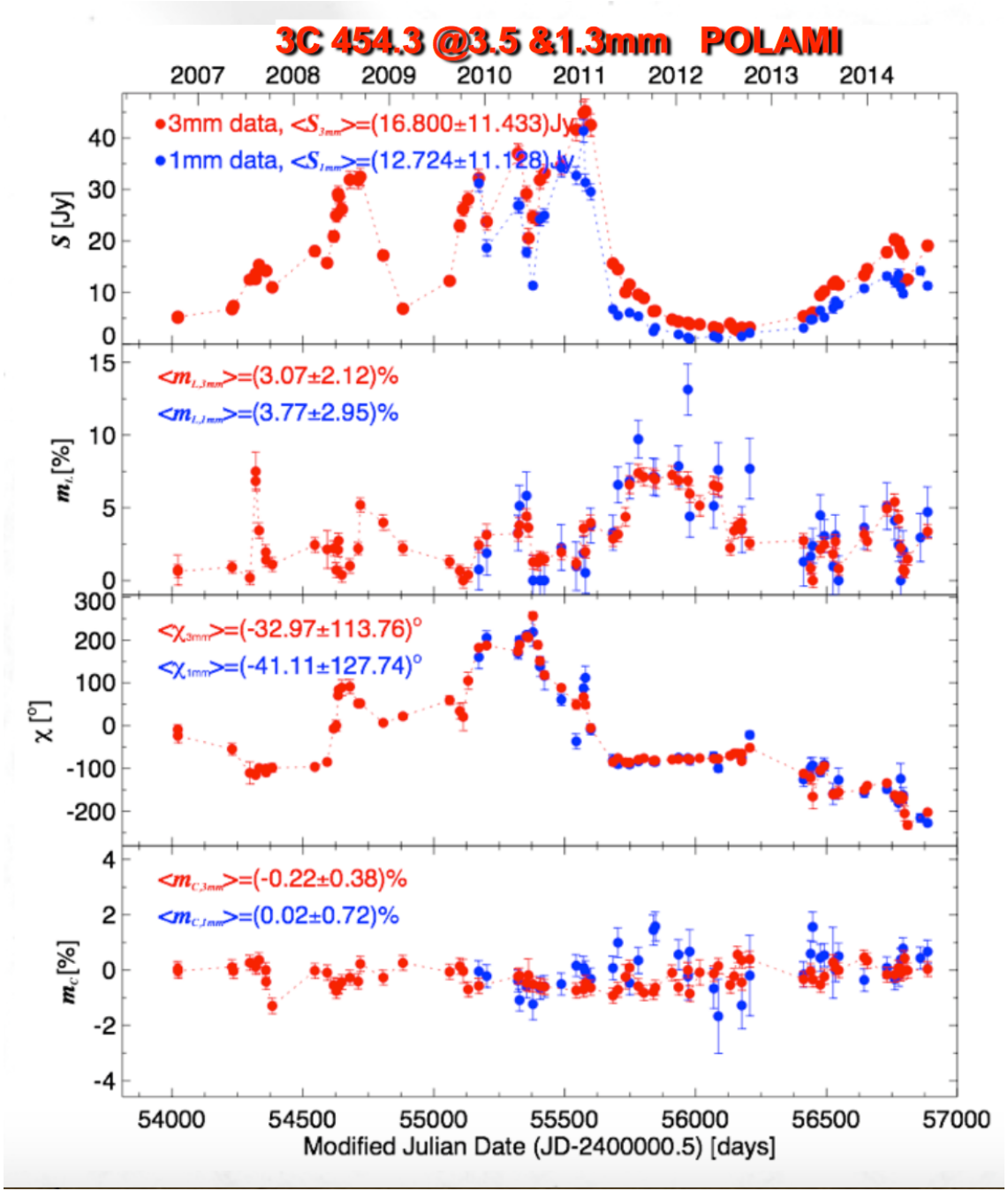
Pushkarev: "Linear Polarization Properties of Parsec-Scale AGN Jets" **MOJAVE**

- **LP increases along and across the jets**
- **BL Lacs more polarised than quasars**
- **P peaks offset from VLBI cores by ~0.2mas (1.5pc projected) in quasars, and ~4mas (2.4pc projected) in galaxies**

Blazar Monitoring

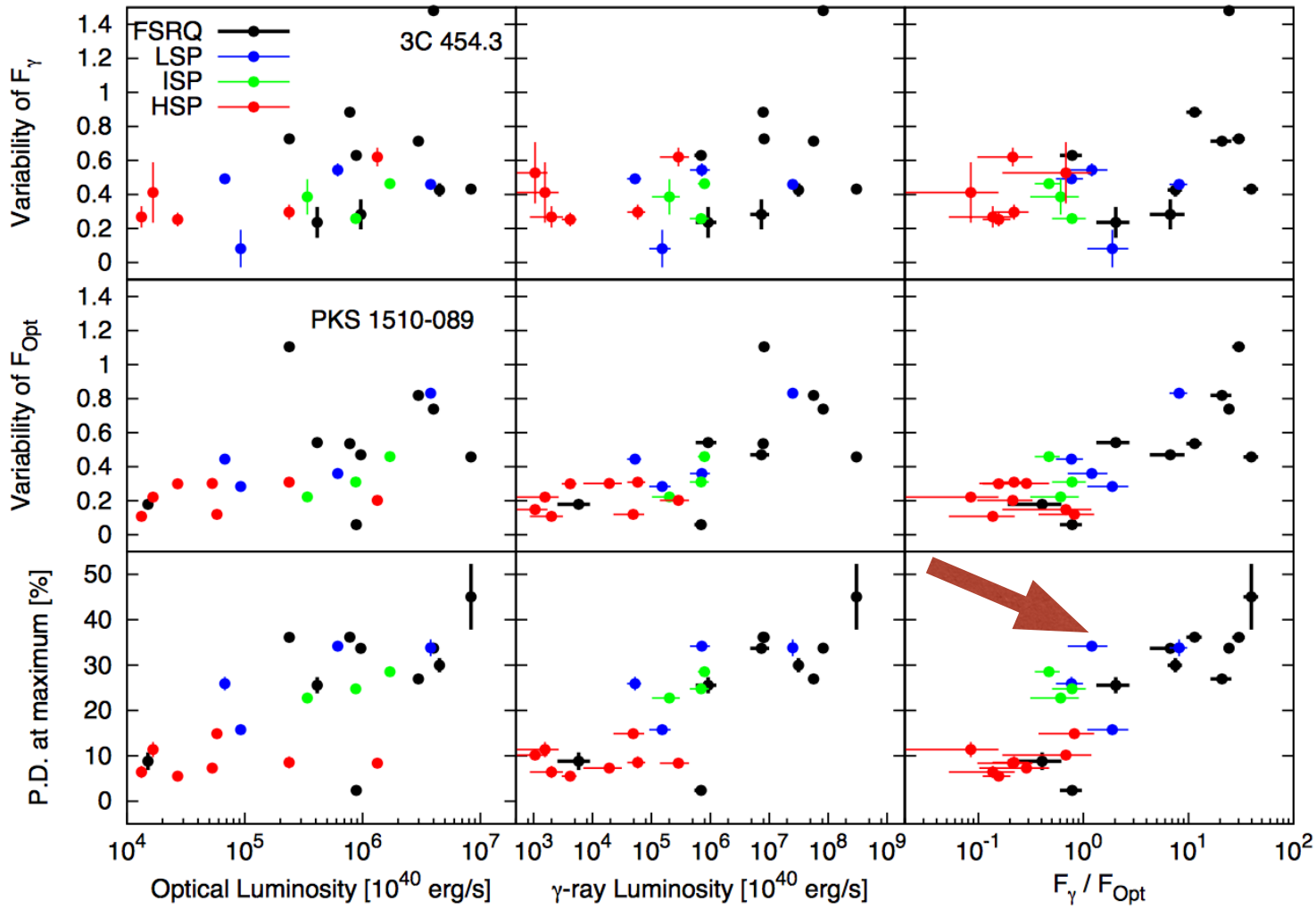
Agudo: “Linear and Circular Polarization Variability Properties of AGN Jets at Short Millimeter Wavelengths” **POLAMI**

also, **Readhead (Hovatta):** “SPRITE: the Stokes Polarimetric Radio Interferometer for Time-domain Experiments”

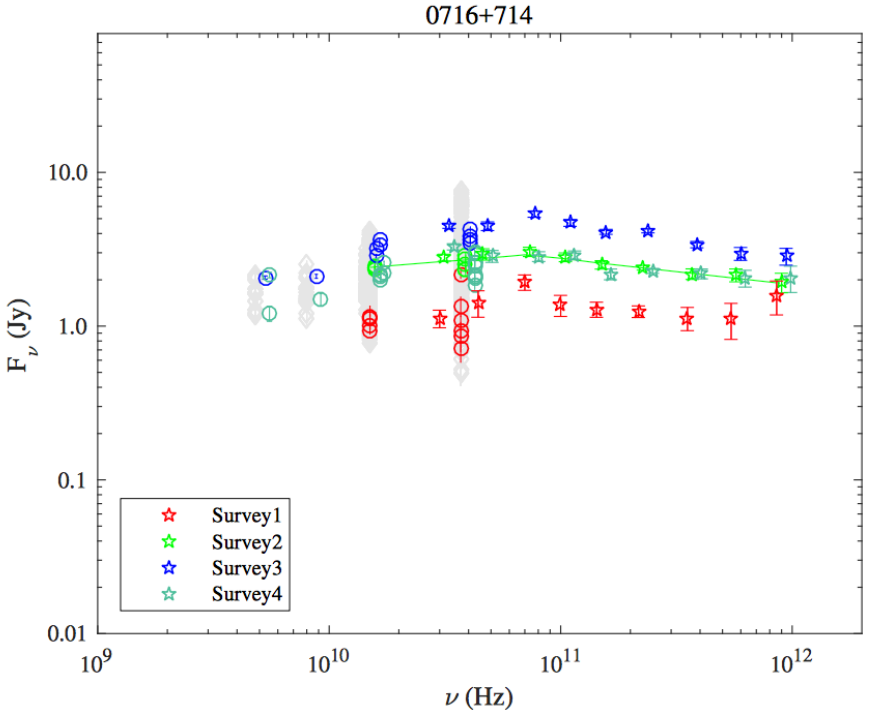


Blazar Monitoring

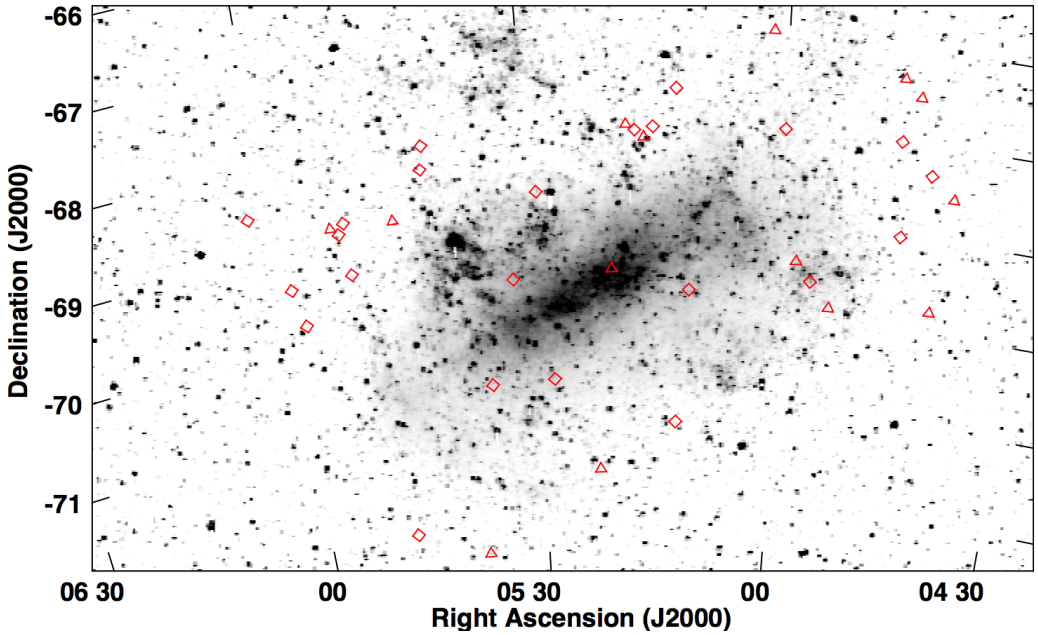
Itoh: “Polarimetric monitoring of jets with Kanata Telescope” **KANATA**



Blazar Monitoring



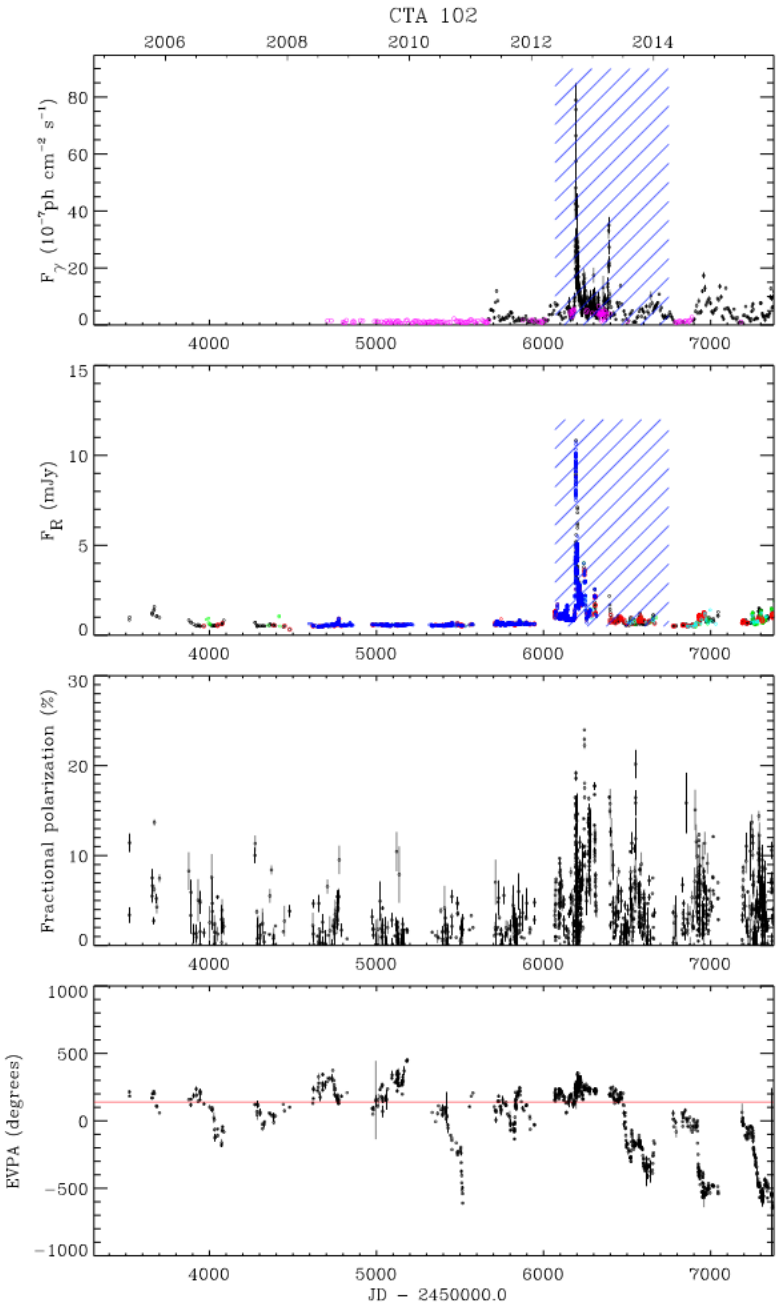
Partridge: "Can CMB Surveys Help the AGN Community?" **PLANCK**



Żywucka-Hejzner: "OGLE Blazars behind the Large and Small Magellanic Clouds" **OGLE**

Moody: "Automated Polarimetry with Smaller Aperture Telescopes: The ROVOR Observatory"

Individual Sources



Beaklini: "Optical Polarimetry And Radio Observaions of PKS 1510 Between 2009 And 2013"

Beuchert: "VLBA polarimetry monitoring of 3C 111 as a tool to probe AGN jet physics on parsec scales"

Biggs: "Polarization monitoring of the lens system JVAS B0218+357"

Casadio: "3mm GMVA observations of total and polarised emission from blazar and radiogalaxy core regions"

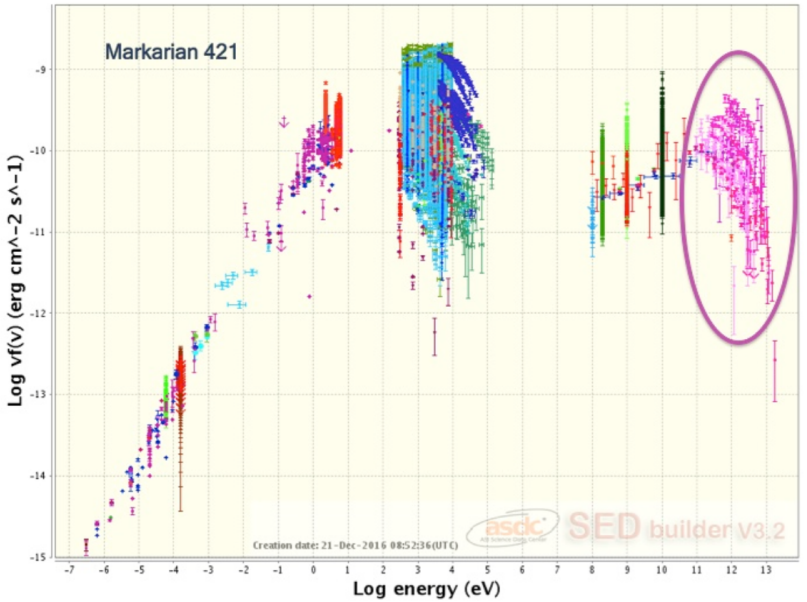
Kravchenko: "Multi-frequency polarimetric analysis of the quasar 0850+581"

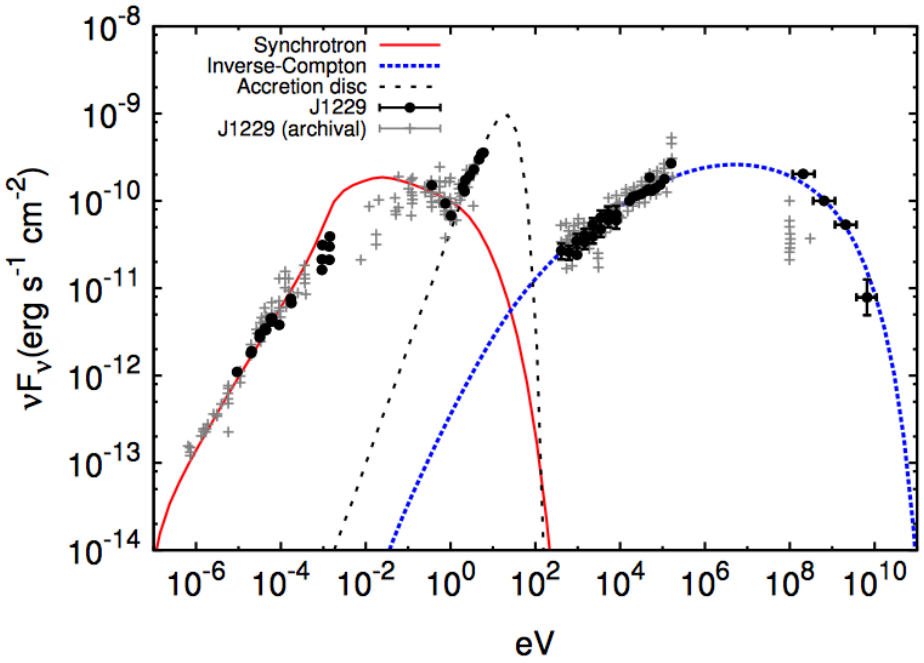
Larionov: "The blazar CTA 102 behaviour during two giant outbursts"

Zola: "Polarisation and spectral energy distribution in OJ 287 during the 2016 outbursts"

Blazar Modelling

Barres de Almeida: “Time-Evolving SED of MKN421: a long-term multi-band view and polarimetric signatures” **BSDC**





W. Potter: “Modelling blazar flaring using a time-dependent fluid jet emission model - an explanation for orphan flares and radio lags”

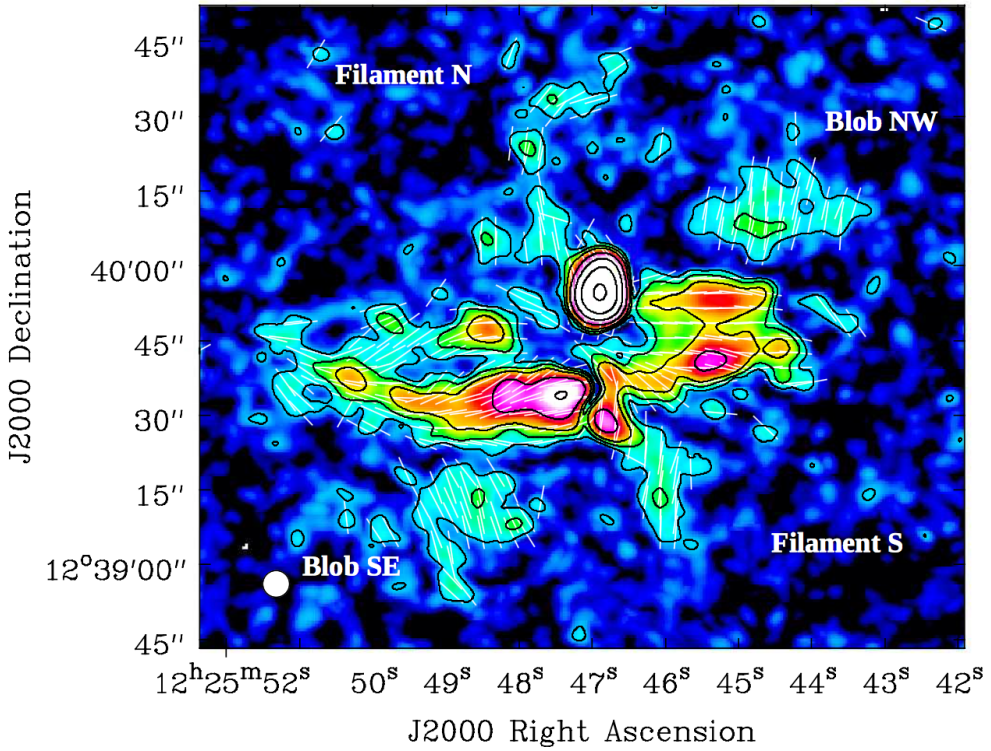
Boettcher: “SALT spectropolarimetry and self-consistent SED and spectropolarimetry modeling of blazars”

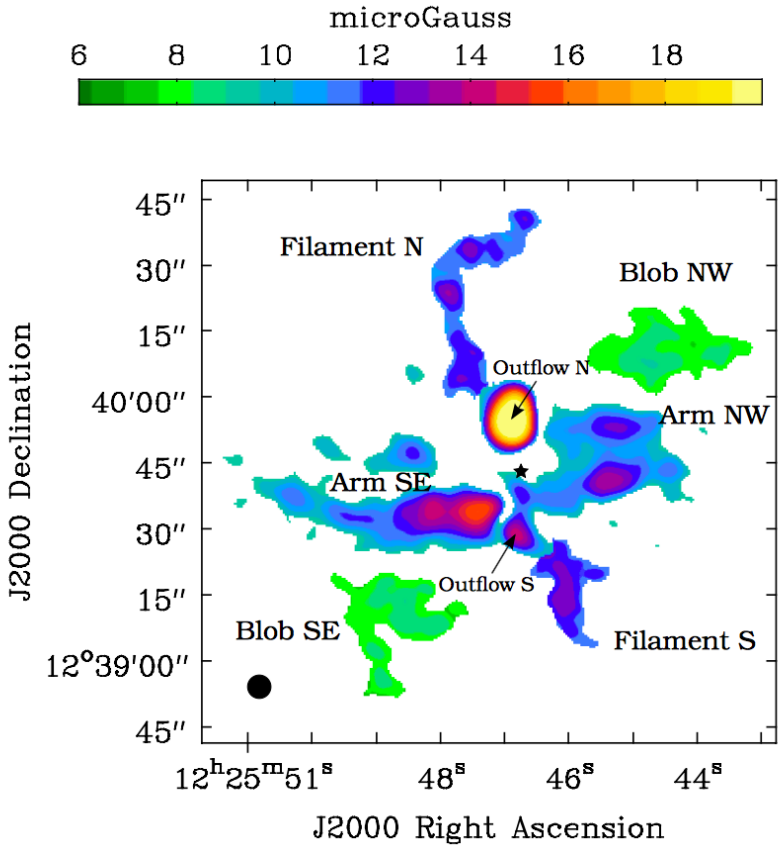
Large-Scale Jets

Precessing Jets

Adebahr: “Polarised structures in the restarted radio galaxy B2 0258+35 - Magnetic field compression or magnetic draping?”

Damas-Segovia: “Rotation measure asymmetry reveals a precession of the AGN outflow in a Seyfert galaxy”





Damas-Sergovia et al. 2016: edge-on Virgo galaxy NGC4388

Individual Sources

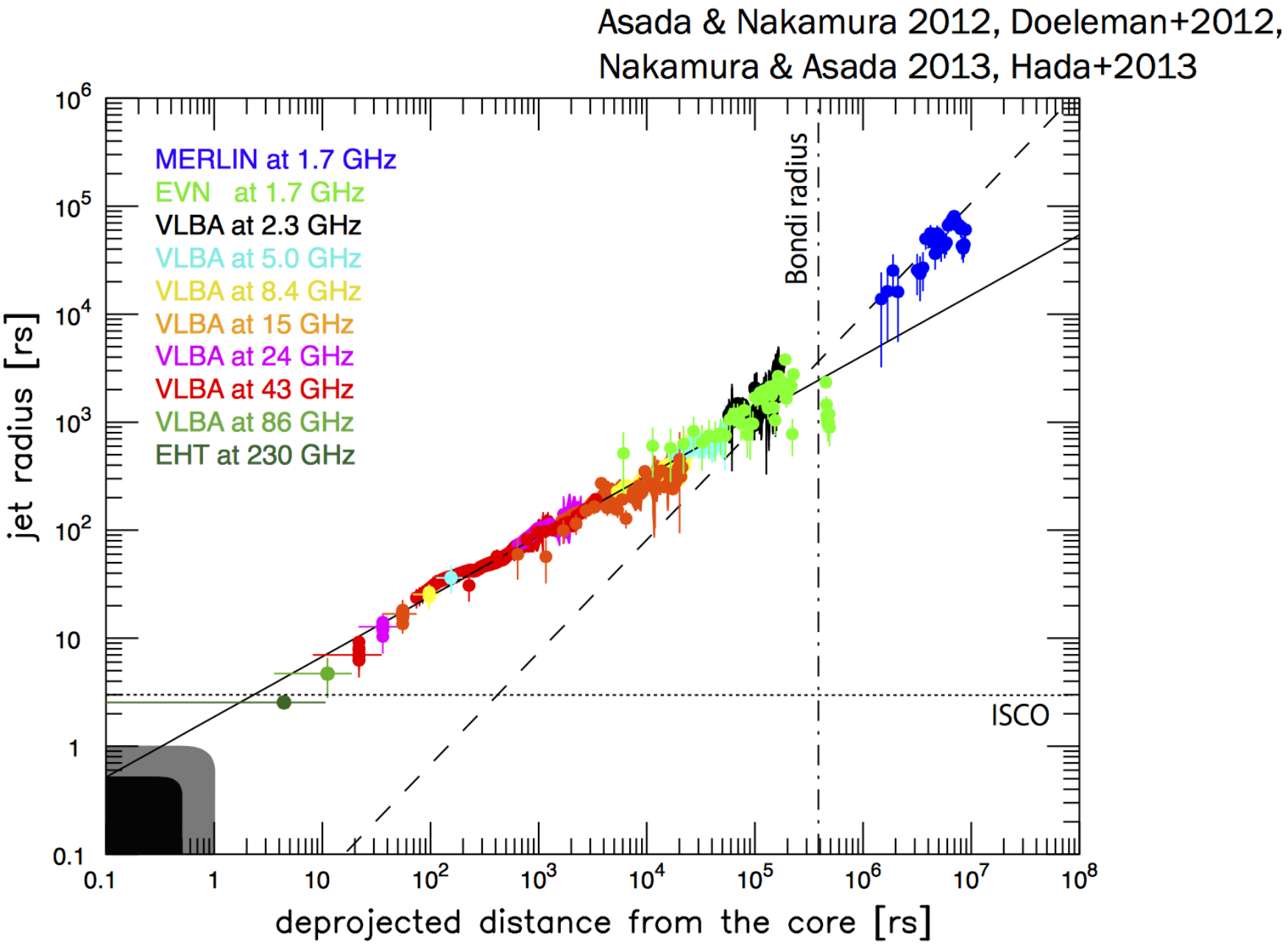
Cantwell: “Low frequency Polarization observations of NGC 6251”

Hesterly: “Resolving Quasar 3C334 with e-MERLIN and the Jansky VLA”

Johnston-Hollitt: “Evidence for Helical or Toroidal Magnetic Fields on in a Jet on kpc-scales"

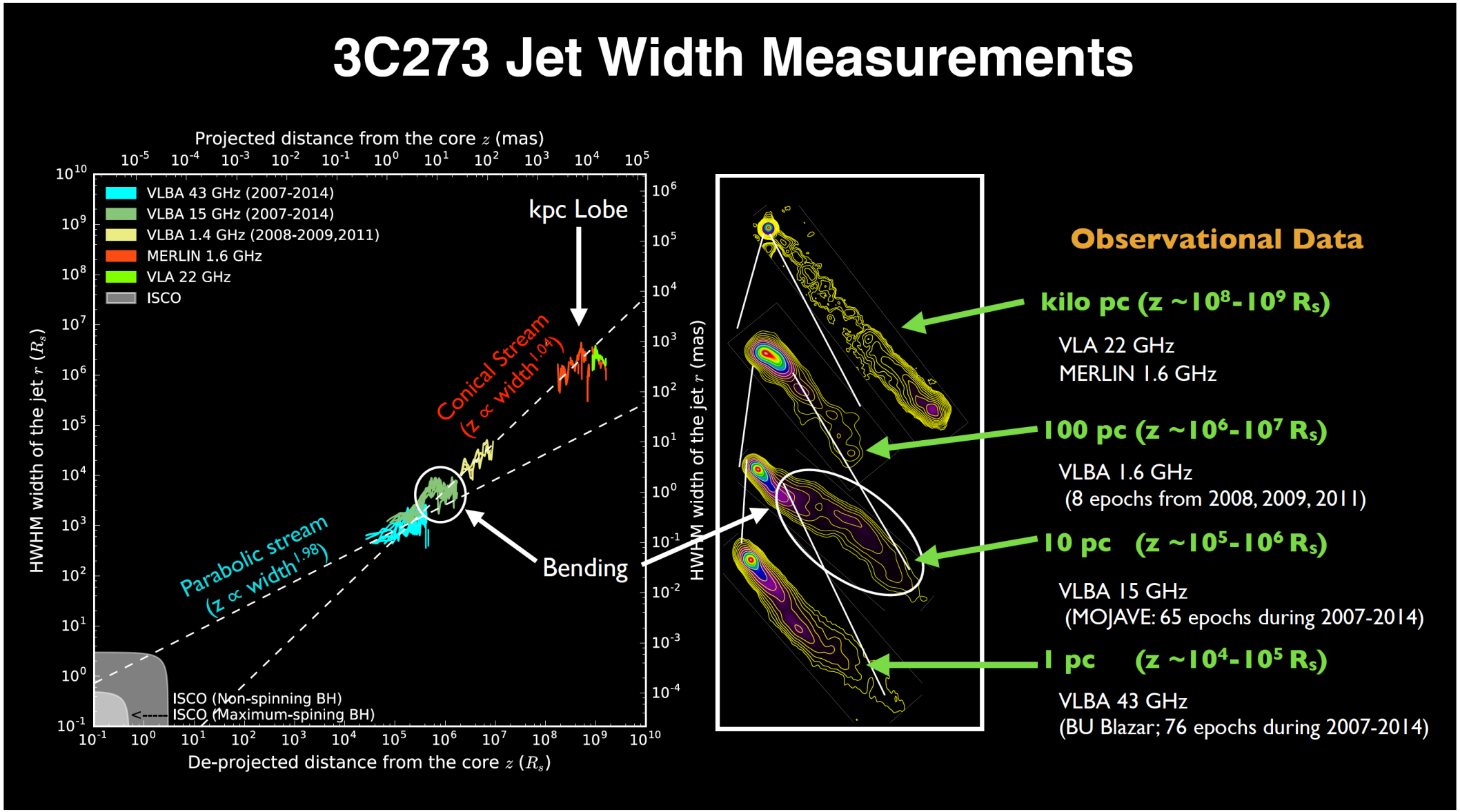
Knuettel: “Evidence for toroidal B-field components in AGN jets on kiloparsec scales”

Jet Collimation



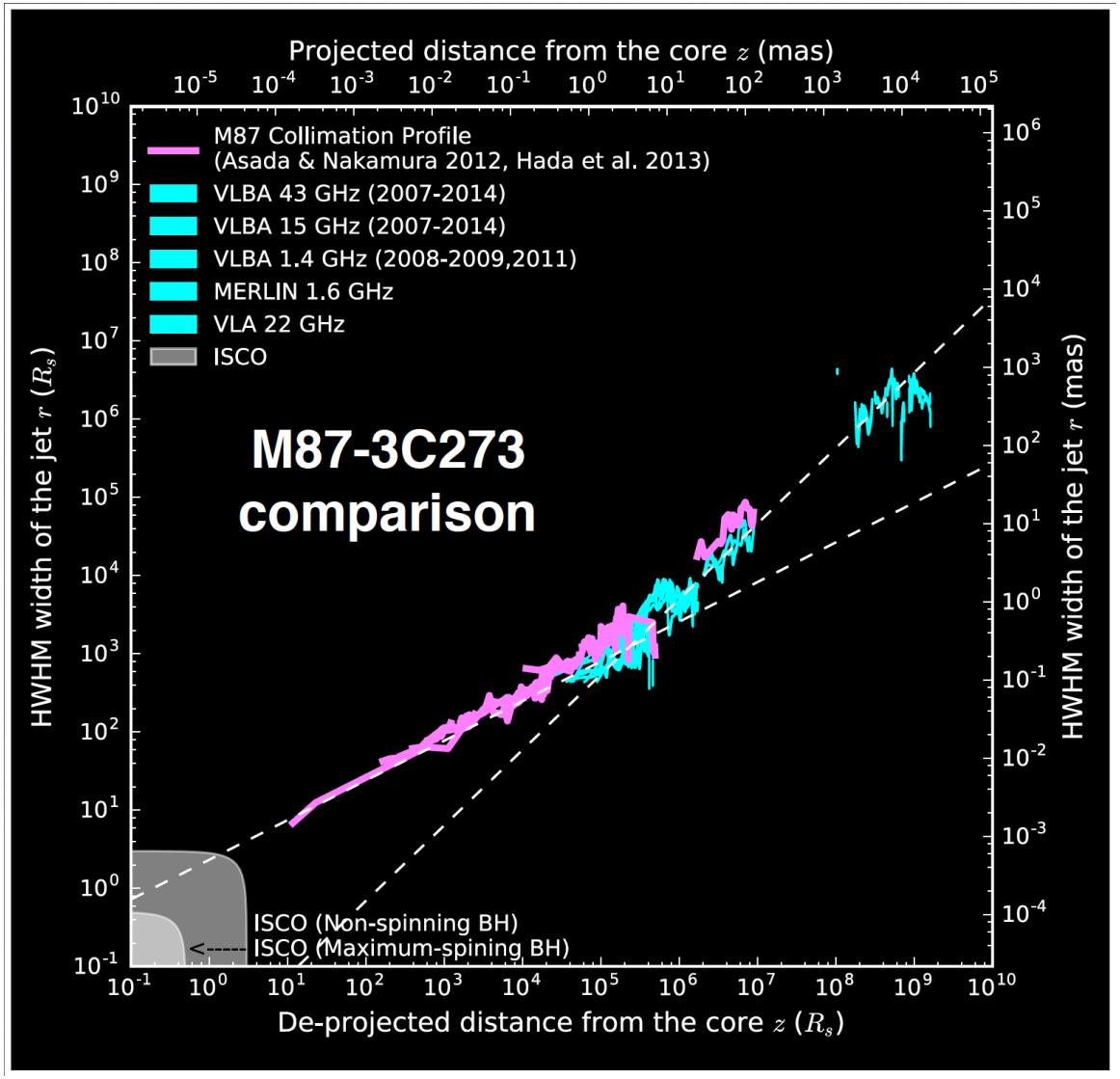
Jet Collimation

Lonsdale: "The Jet Collimation Profile of 3C273"



Jet Collimation

Lonsdale: "The Jet Collimation Profile of 3C273"



completely different systems regarding accretion rate, jet power, environment…

Not only AGN!

GRBs

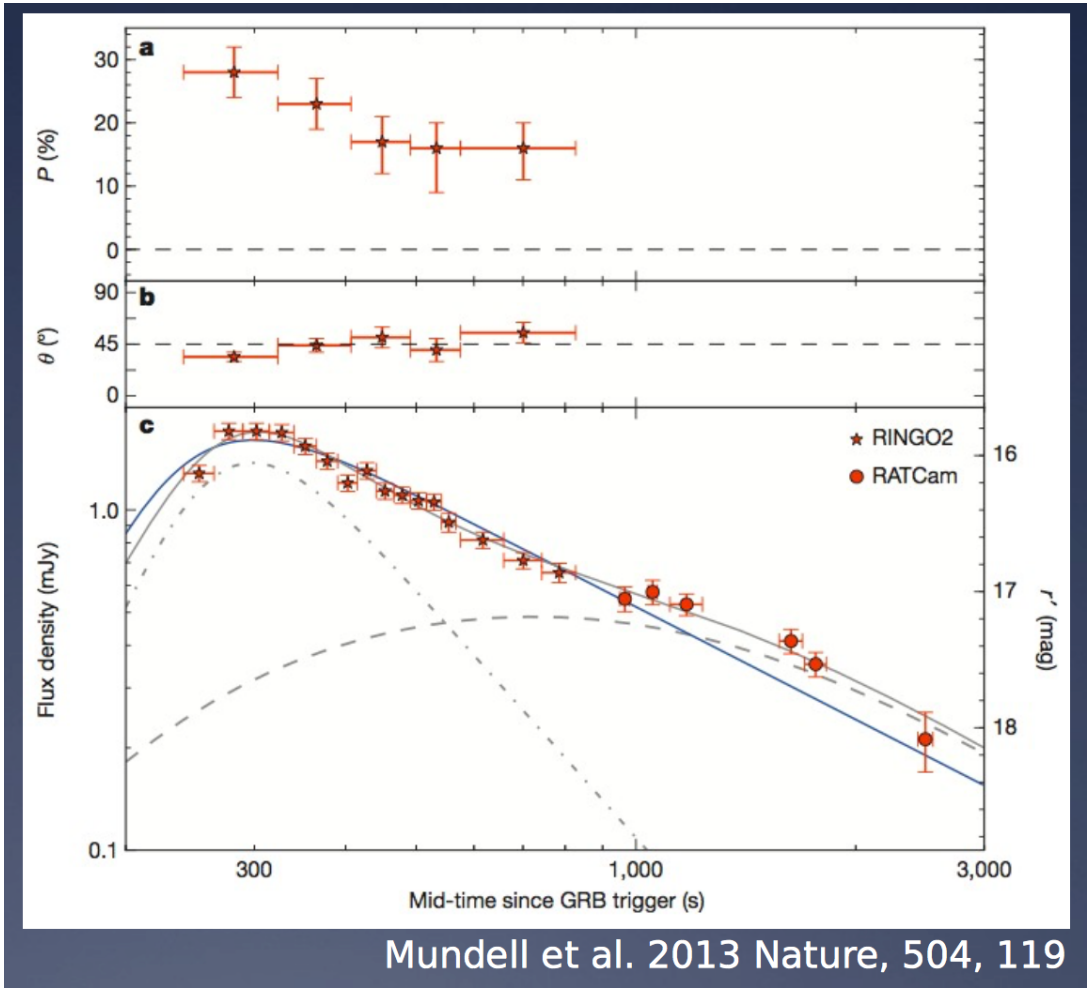
Mundell: "Probing magnetic fields in relativistic jets with real-time polarimetry"

Kobayashi: "Polarised Emission from Gamma-Ray Burst Jets"

INTEGRAL, RHESSI: large PD (up to 70%) in hard X-ray/soft gamma-rays reported for a few GRBs

RINGO real-time, multi-band polarimetry: "long-lived large-scale MF" BUT consistent with the FS-RS model, so matter-dominated jets (sigma <1), and not Poynting-dominated jets (no RS expected!)

optical CP?



XRBs

Markoff: “Unravelling the complexities of the disk/corona/jet relationship”

Miller-Jones: “Polarised radio emission from X-ray binary jets”

Russell: “Optical/infrared polarised emission in X-ray binaries”

Trushkin: “The jets of microquasars during giant radio flares and quiet state”
“The giant flares of the microquasar Cygnus X-3: X-rays states and jets”

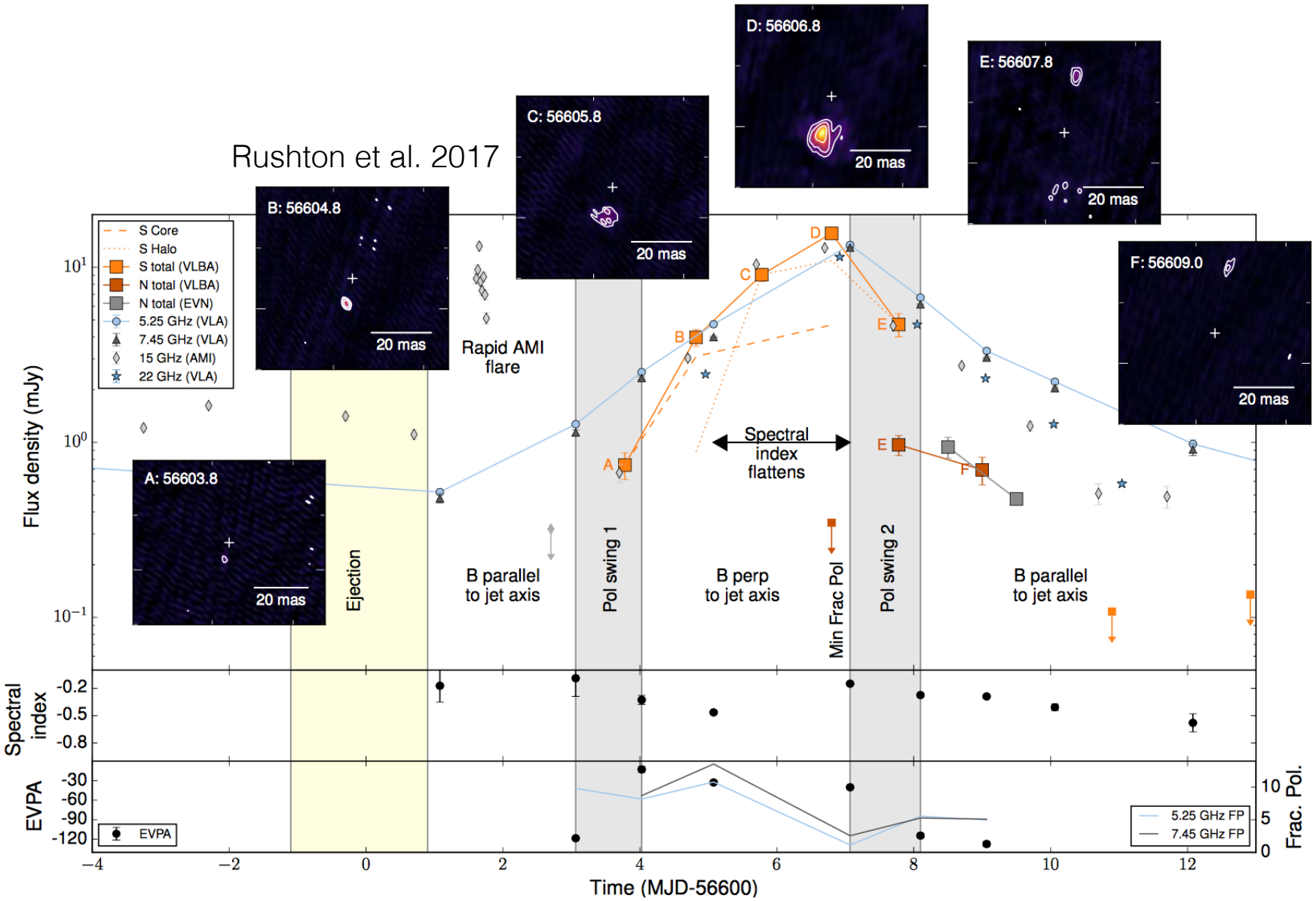
- radio LP ~ 1% in steady jets, 1-25% in transient ejecta; shock?
- optical polarization; X-ray polarization (Cyg X-1): corona or jets?
- a few cases of CP (Faraday conversion?)

Baglio: “Neutron star low mass X-ray binaries jets: a polarimetric view”

synchrotron vs. Thomson scattering

XRBs

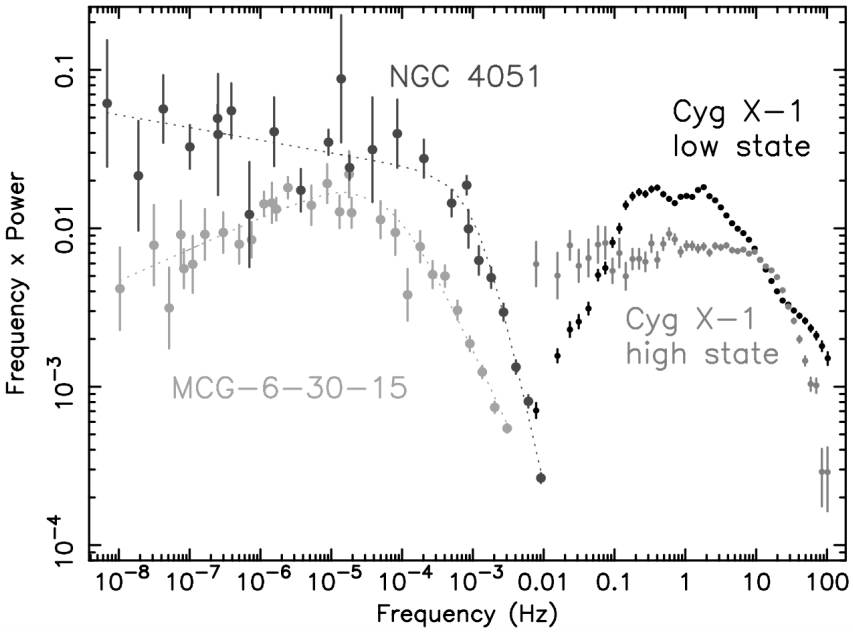
Rushton et al. 2017



The polarization angle swings correspond to the appearance and disappearance of the southern component, and the flattening spectral index corresponds to the re-energisation of the core of the southern component.

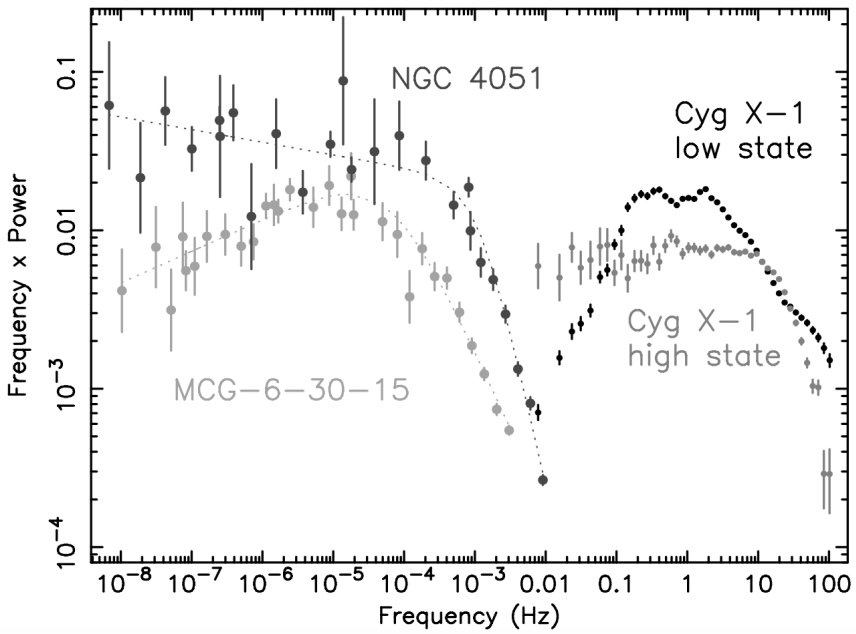
XRBs vs Seyferts

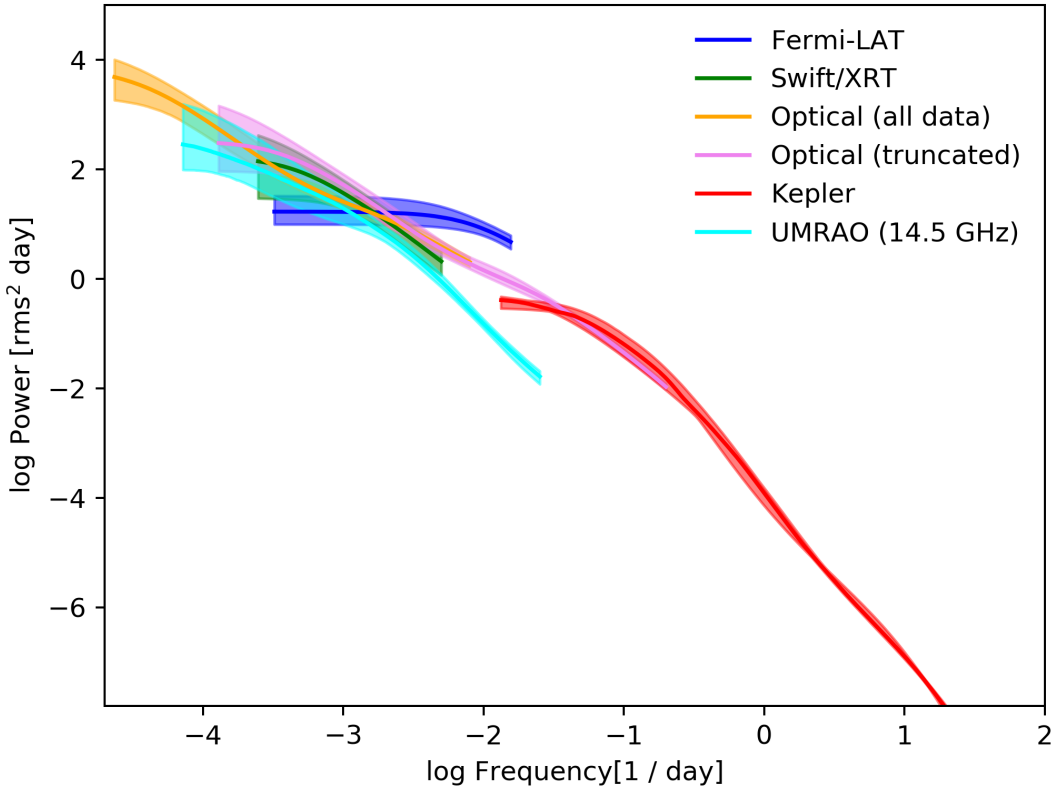
McHardy et al.



XRBs vs Seyferts vs Blazars

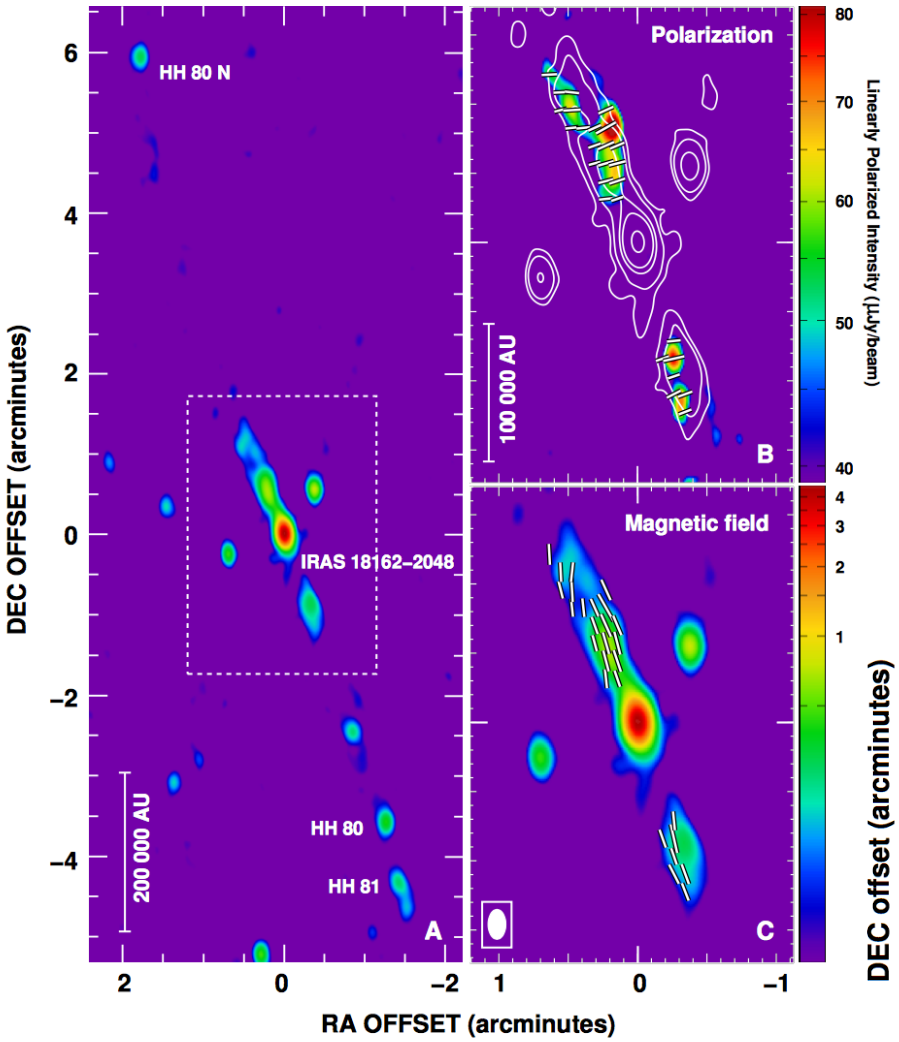
McHardy et al.





Goyal: "Multiwavelength variability study of the BL Lac objects PKS 0735+178 and OJ 287 on timescales ranging from decades to minutes"

Protostellar Jets

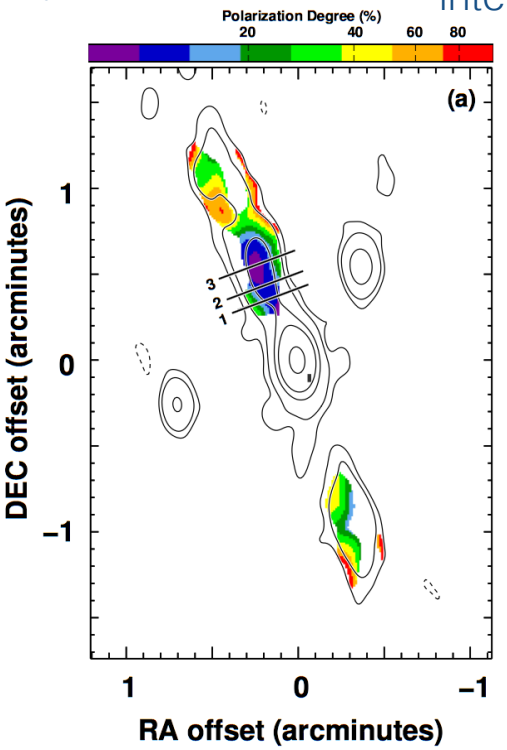


Carrasco-Gonzalez et al. 2010

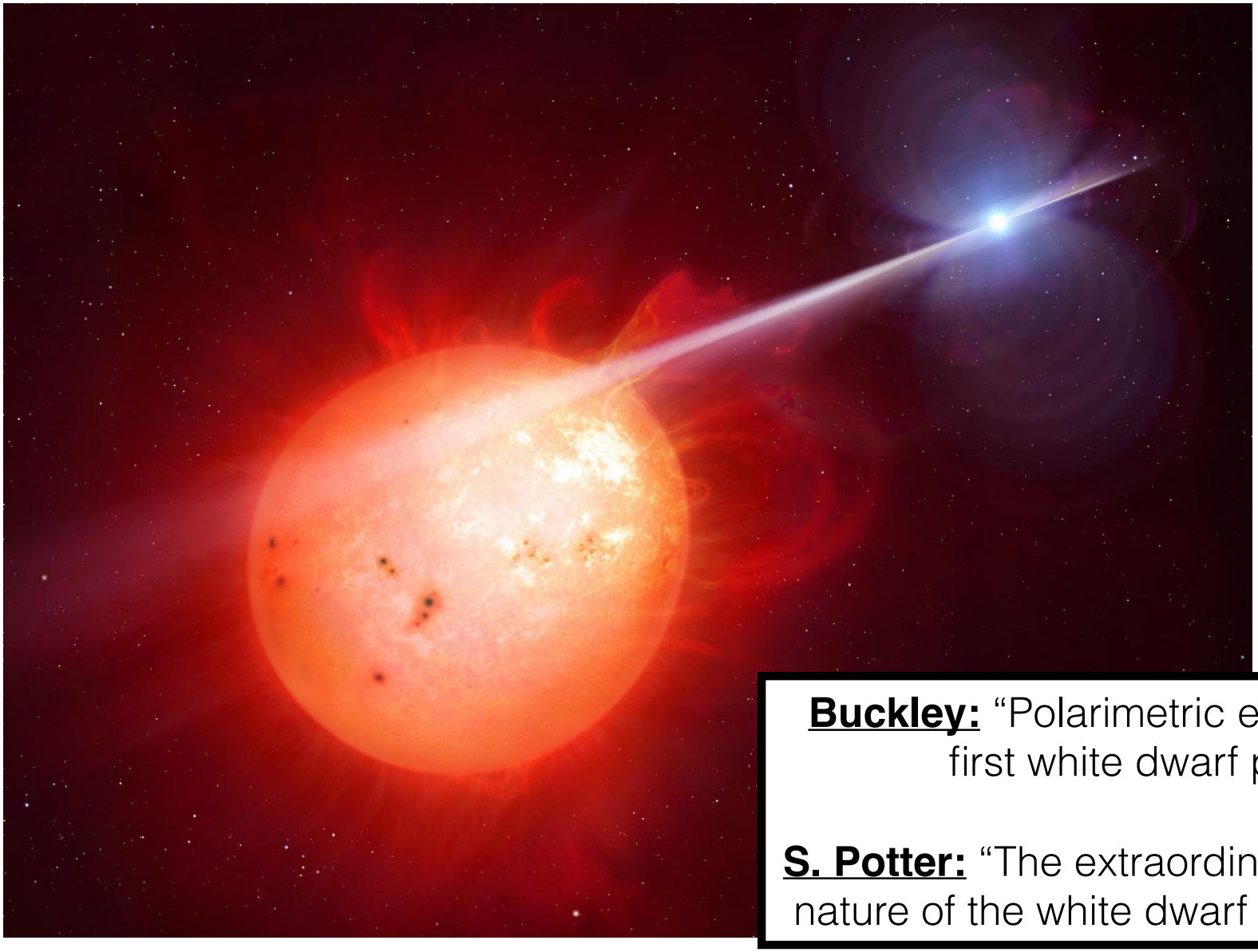
Carrasco-Gonzalez: "These guys can accelerate particles: synchrotron emission from protostellar jets"

Johnston: "A search for polarised emission in jets from high-mass protostars"

- non-relativistic (up to 1000km/s)
- linearly polarised emission -> synchrotron!
- internal shocks?



White Dwarf Pulsar

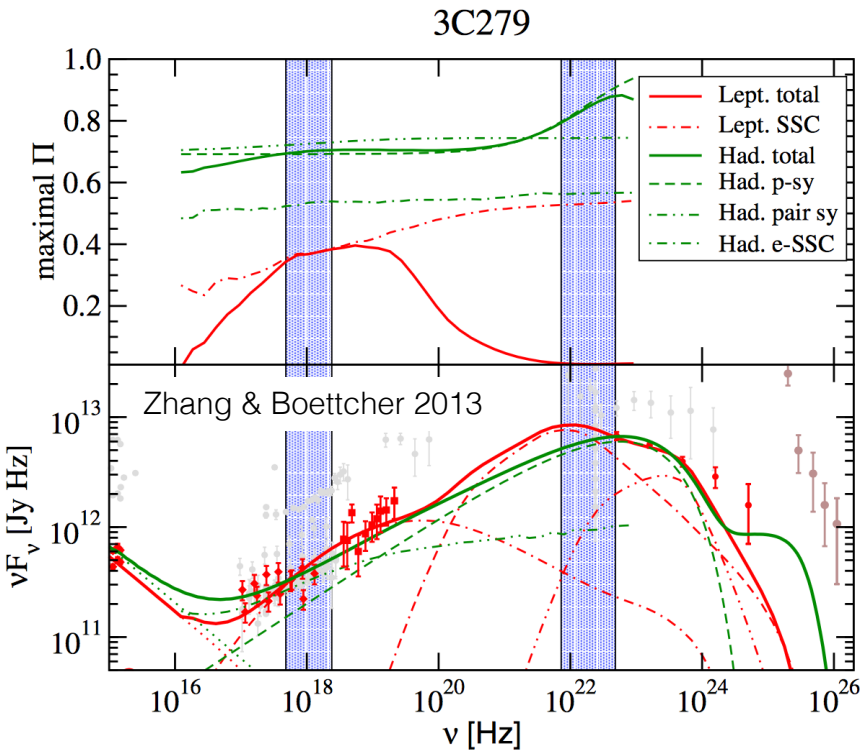


Buckley: “Polarimetric evidence of the first white dwarf pulsar”

S. Potter: “The extraordinary polarimetric nature of the white dwarf pulsar ARSCo”

High Energies

X-rays/gamma-rays



Marshall: "The Imaging X-ray Polarization Explorer (IXPE)"

Briggs: "LEAP – A LargE Area burst Polarimeter for the ISS"

Bernard: "Gamma-ray astronomy with magnetic-field-free active targets: Optimal measurement of charged particle momentum from multiple scattering with a Bayesian analysis of filtering innovations"
"High angular-resolution high sensitivity gamma-ray astronomy and linear polarimetry with low density (gas) detectors in the MeV-GeV energy range"
"A Bethe-Heitler 5D polarized photon-to-e+e-pair conversion event generator"

X-rays/gamma-rays

Polarization signatures in X-rays/gamma-rays may arise from vastly different processes, including bremsstrahlung emission from anisotropic electron distribution, synchrotron emission in ordered magnetic fields, anisotropic Compton scattering, inverse-Comptonization of a polarized photon field, or finally, photon propagation through a highly magnetized plasma

–>

stellar flares, pulsars, pulsar nebulae, magnetars, accreting white dwarfs, SNRs, black hole accretion disks and coronae, jetted AGN, microquasars, GRBs

Polarimetry in the hard X-ray/soft gamma ray regime

previously: OSO-8 (2.6 & 5.2 keV) - Crab
currently: INTEGRAL SPI & IBIS (20 keV - 1 MeV) - Crab, GRB041219, Cyg X-1
baloon experiments: PoGoLite (2-100 keV), X-Calibur (20-80 keV), POLAR (50-500 keV), GRAPE (50-500 keV)
future: POET (2-500 keV), GEMS (2-10 keV), POLARIX (2-10 keV), XIPE/IXPE (2-10 keV), SPHiNX (50-500 keV), PolariS (2-80 keV), e-ASTROGAM (0.2-2 MeV), *Hitomi SGD (80-600 keV)*

Summary of a Summary

Theory & Simulations

Ideal (G)RMHD, polarised radiative transport by ray-tracing
disk physics: MF, electron heating (shear-box MHD?)
jet physics: electron acceleration (MC FP/PIC?)

disks: RIAFs vs SS disks, MAD vs SANE, …
coronae: X-ray spectroscopy & polarization
winds, outflows, & jets

Data & Interpretation

Toward the Core
microarcsec imaging with EHT, RadioAstron
RM studies with ALMA

RM gradients
pc vs kpc scales; CW vs CCW; jets vs counter-jets
variable on timescales of years, days, and hours!
large-scale helical MF? Cosmic Battery? something else?
AGN environment

Radio Circular Polarization
CP<1%; relatively stable, although sometimes changing the sign
Faraday Conversion
a unique probe of the jet MF and particle content/energetics

EVPA Swings
RoboPol, KANATA
how large and “smooth”? connection with gamma-rays
helical MF vs kinks vs jet precession vs jet bends vs standing shocks vs turbulent cells…

Blazar Monitoring
F-GAMMA, UMRAO, MOJAVE, BU-BLAZAR, POLAMI, KANATA, PLANCK, etc., etc.
excellent, rich dataset for the entire the community
plenty of new polarimetric results; data archives allowing for a systematic timming analysis and SED modelling

Large-scale jets
jet collimation an precession

Not only AGN
GRBs: Matter-dominated after all?
XRBs: timming; disk-jet connection
protostellar jets: particle acceleration

Future: X-ray/gamma-ray polarimetry

Thank you All for such a fantastic meeting!

And, most of all, special thanks to Emmanouil!