Blazars under the lens of X-ray polarimetry: perspectives for the IXPE mission

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IXPE IN A NUTSHELL

(SEE ALSO MULERI'S AND SOFFITTA'S TALK TOMORROW)

- Bilateral collaboration between *NASA* and *ASI*.
- Selected by NASA in 2017, *launch* expected in *2021*.
- Baseline *duration* of *2 years*.
- It will be equipped with 3 *Gas Pixel Detectors*, sensitive to the polarisation of incoming X-ray photons in the 2—8 keV band.
- First mission since OSO-8 (1975) to be sensitive to (linear) X-ray polarisation.
- Thanks to the GPDs, IXPE will increase the sensitivity of the X-ray polarimeter on-board of OSO-8 by 2 orders of magnitude, allowing *observations* of a variety of astrophysical sources, including *blazars*.

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Marshall Space Flight Center

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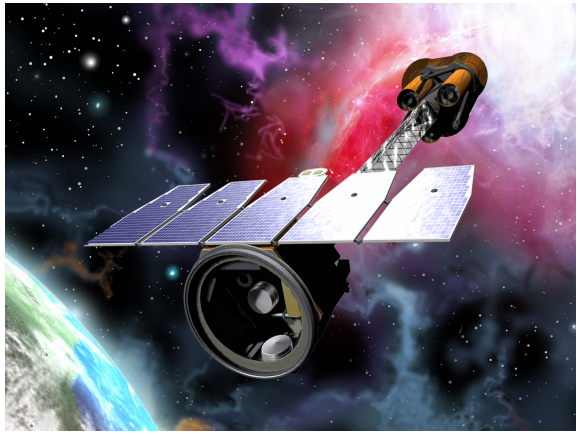
THE IXPE MISSION



new observables

P: polarization degree(%)

θ: polarization angle(°)

…in the 2—8 keV band

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Minimum Detectable Polarisation

$$MDP = \frac{4.29}{M}\sqrt{\frac{R_S + R_B}{R_S^2 t}}$$

- M: instrumental modulation factor
- R_S: source count-rate
- R_B: background count-rate
- t: exposure time

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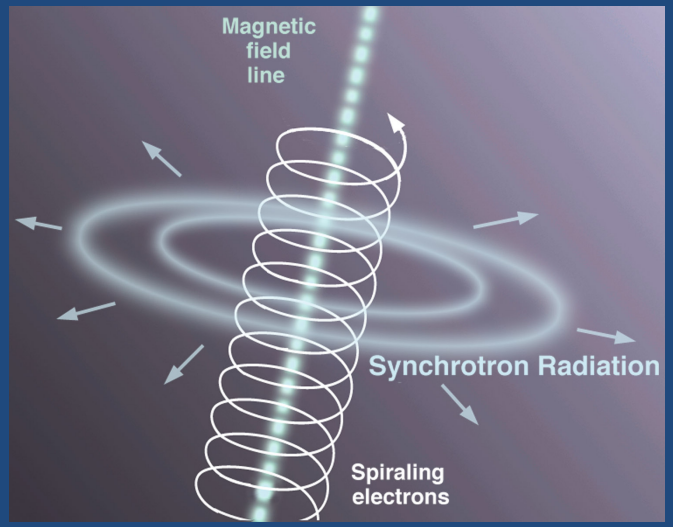
POLARISATION OF SYNCHROTRON RADIATION



$$\Pi = \frac{p+1}{4}\frac{\Gamma\left(\frac{p}{4}+\frac{7}{12}\right)}{\Gamma\left(\frac{p}{4}+\frac{19}{12}\right)} = \frac{p+1}{4\left(\frac{p}{4}+\frac{7}{12}\right)} = \frac{p+1}{p+\frac{7}{3}}$$

In a uniform B, the P depends on the index p of the energy distribution of the emitting particles

i.e. for p=2.5, P=70%

Ribicky & Lightman 1979

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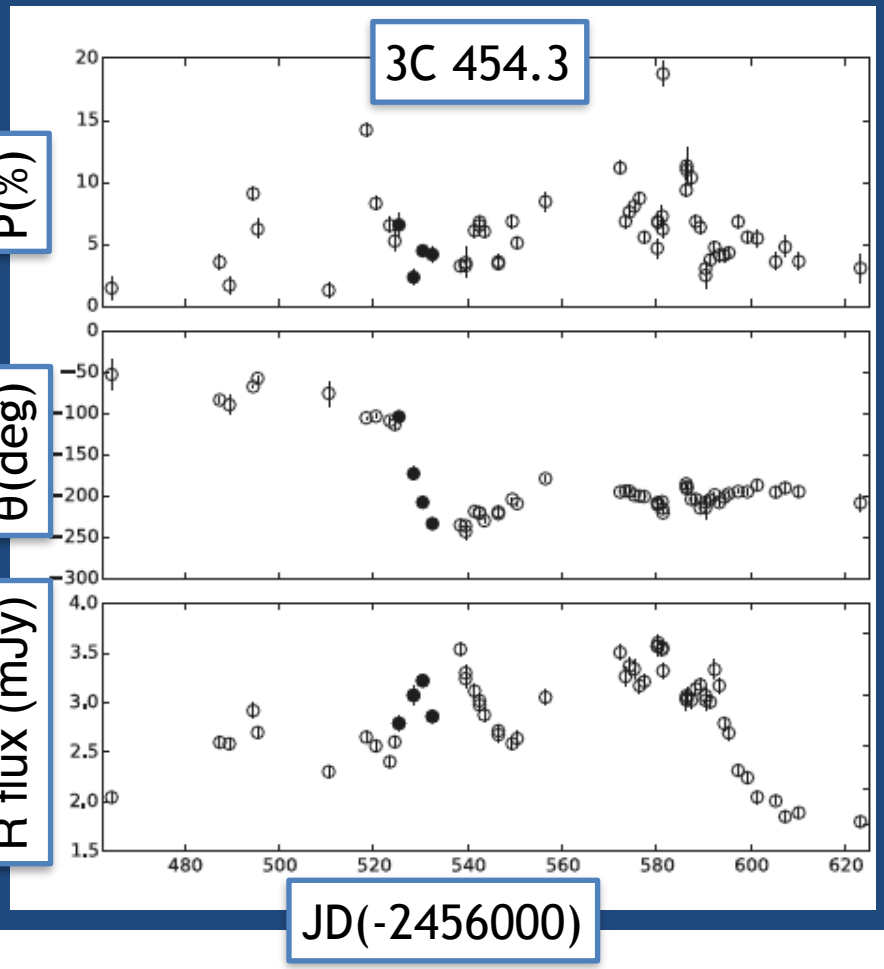
POLARISATION STUDIES IN THE OPTICAL



- P<70%
- θ rotates

e.g., Blinov+15,16,+18

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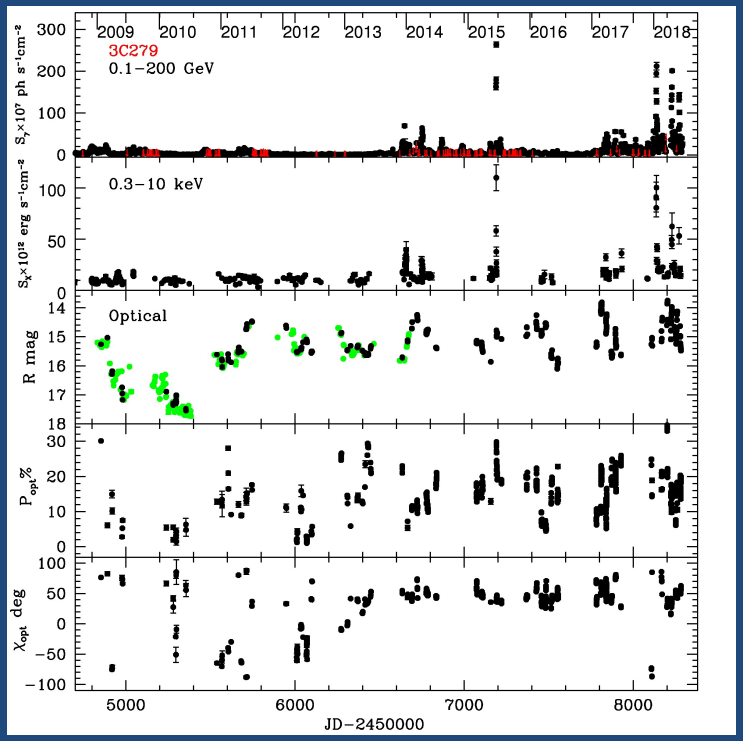
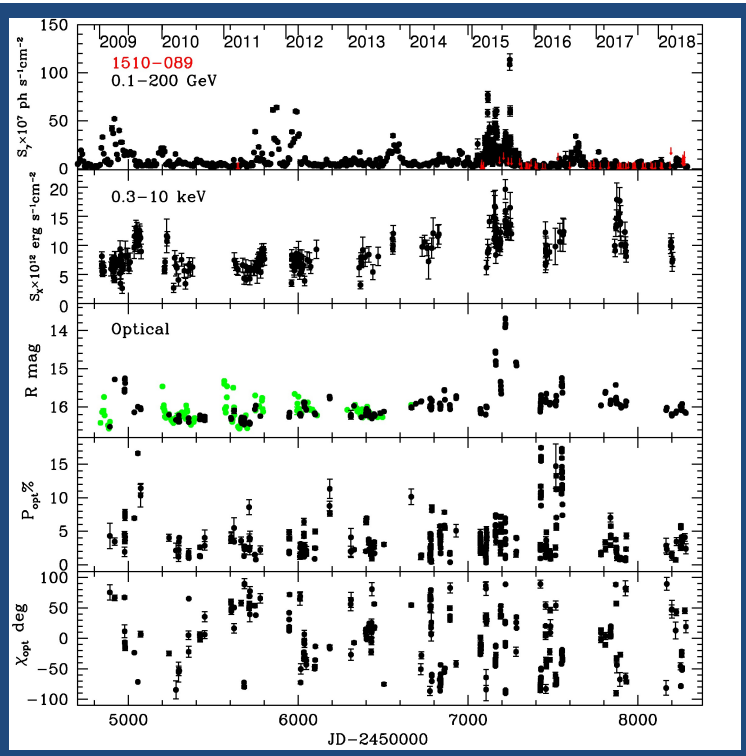
A VARIETY OF TEMPORAL BEHAVIOUR



3C 279: moderate polarisation (even > 10%) sometimes peaking during flares.



1510-089: low polarisation (2%) that may rise after flare

Jorstad & Marscher +16

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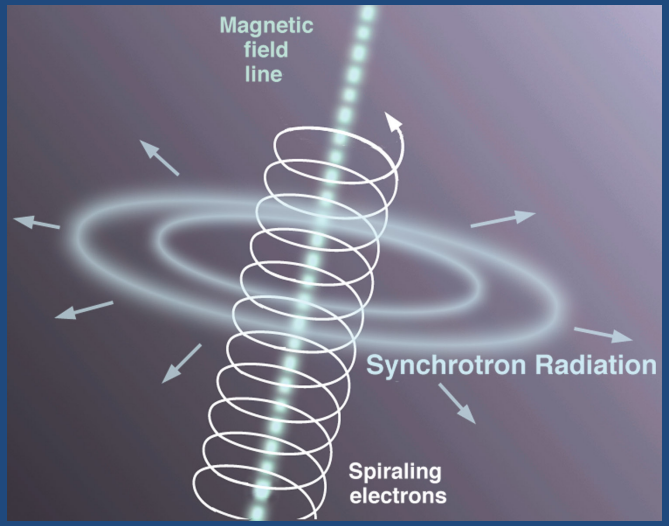
THE SIMPLE SYNCHROTRON CASE FOR HSP



$$\theta_x \sim \theta_{opt} \quad P_X \sim P_{opt}$$

….if X-ray and optical emission regions are one and the same.

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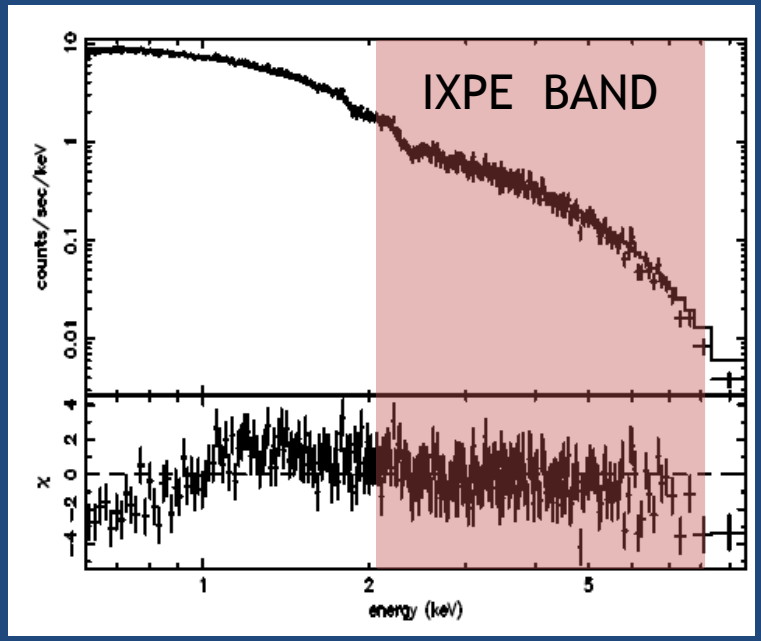
SIMULATING THE AVERAGE STATE OF MRK 421



Tramacere+07

- single Γ=2.5 adequate above 2 keV
- Flux (2-10 keV)=3 $\times 10^{-10}$ erg s-1 cm^2= 10 mcrab
- $P_x=P_{opt}=5\%$
- Variable exposure time

GOAL: at least 3σ determination of P

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SIMULATING THE AVERAGE STATE OF MRK 421

EXPOSURE:	*MDP:*	*RESULTS:* *(1σ errors are quoted)*
10 ks	7% ☹	$P < 6\,\%$
20 ks	5% ☹	$P = 4 \pm 2\,\%\ \ \theta = 50^\circ \pm 10^\circ$
50 ks	3% 🙂	$P = 5 \pm 1\,\%\ \ \theta = 47^\circ \pm 5^\circ$
550 ks	<1%	$P = 4.6 \pm 0.4\,\%\ \ \theta = 44^\circ \pm 2^\circ$

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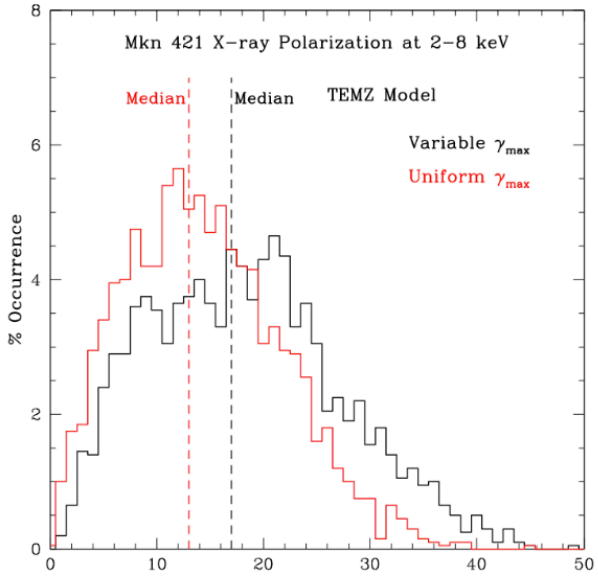
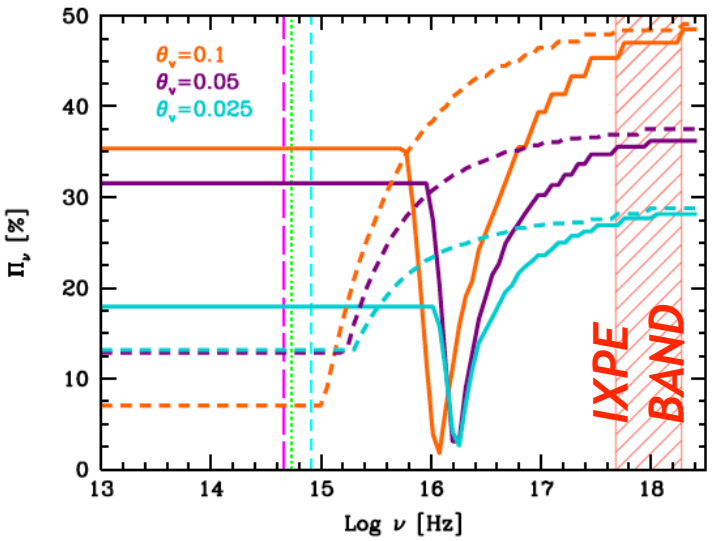
BEYOND THE SIMPLE SCENARIO:





In the framework of turbulent jet model (Marscher+13), predicted X-ray polarisation is up to 20%, depending on how the maximum electron energy relates to the direction of B relative the shock front.

X-ray polarisation up to 50% is predicted for shocks occurring in a weakly magnetized flow (Tavecchio+18).

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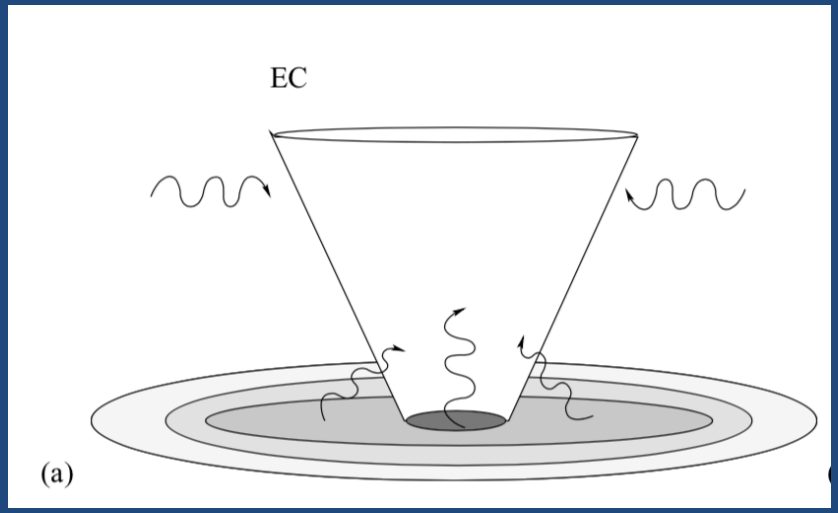
PROCESSES IN FSRQ: EXTERNAL COMPTON



P increases with the viewing towards the jet (Mc Namara+09)

…practically unpolarised in blazars

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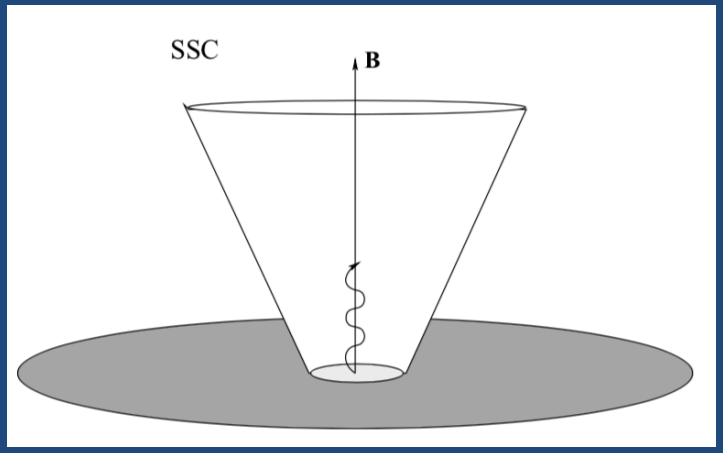
PROCESSES IN FSRQ: SYNCHROTHRON SELF COMPTON



$$P_X \sim 1/2\, P_{opt} \quad \theta_X \sim \theta_{opt}$$

SSC scattering preserves the polarisation angle and a large fraction of the polarisation degree of the incoming radiation (Mc Namara+09, Celotti&Matt 1994)

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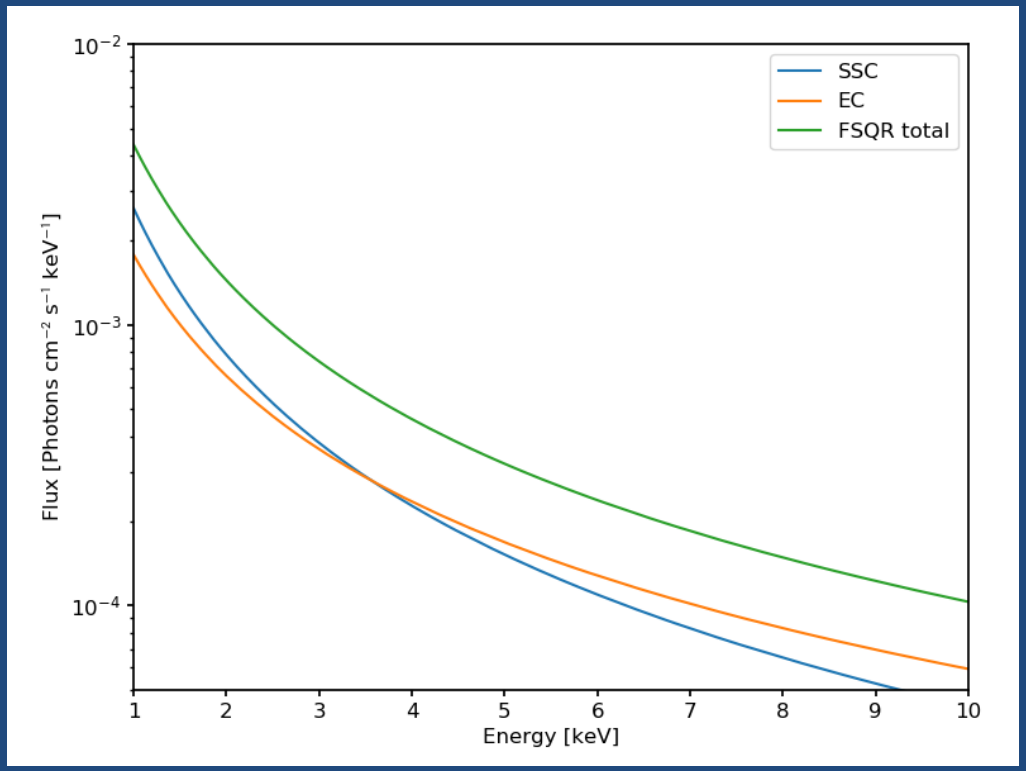
SIMULATING THE SSC+EC SCENARIO



- $\Gamma(SSC)=1.8$
- $\Gamma(EC)=1.5$

- $P_{SSC}=10\%$
- $P_{EC}=0$
- Variable flux

GOAL: at least 3σ determination of P in 500 ks

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SIMULATING THE SSC+EC SCENARIO:

EXPOSURE:	*FLUX:* *erg/s/cm²*	*RESULTS:* *(1σ errors are quoted)*
500 ks	2×10^{-11} ☹	$P = 5 \pm 2\%$ $\theta = 50^\circ \pm 10^\circ$
500 ks	3×10^{-11} 🙂	$P = 6 \pm 1\%$ $\theta = 44^\circ \pm 8^\circ$
500 ks	2.5×10^{-11} 🙂	$P = 5 \pm 1\%$ $\theta = 50^\circ \pm 6^\circ$

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BEYOND THE SIMPLE SCENARIO:

- There are reasons to expect *higher X-ray polarisation* if, for instance:
- If *hadronic processes* are present in the jet, then the X-ray polarisation is predicted to be high because of the contribution of synchrotron emission from protons (e.g. Zhang&Bottcher+13, Paliya+18).
- Scattering of BLR photons from a shell of cold electrons has been proposed as a possible source of transient (1 day) soft (Celotti+07), highly-polarised (Begelman&Sikora+87) X-ray radiation in blazars. This *"Bulk Comptonization"* model was used to explain the unusual "soft excess" seen in few FSRQs (e.g, De Rosa+2008, Kammoun+2017).

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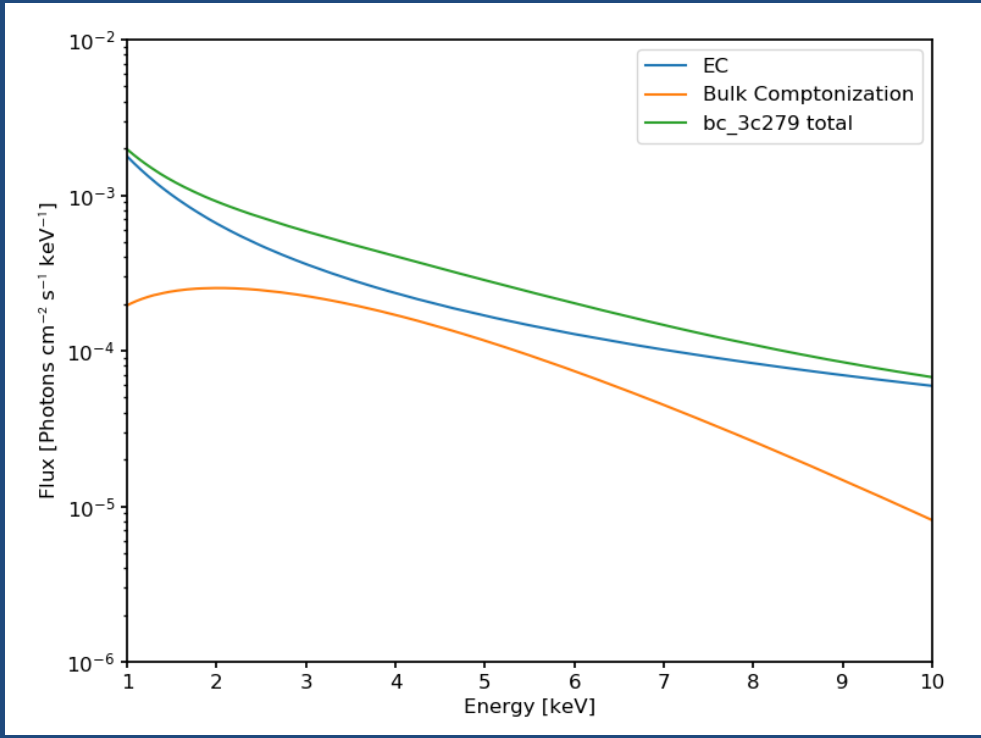
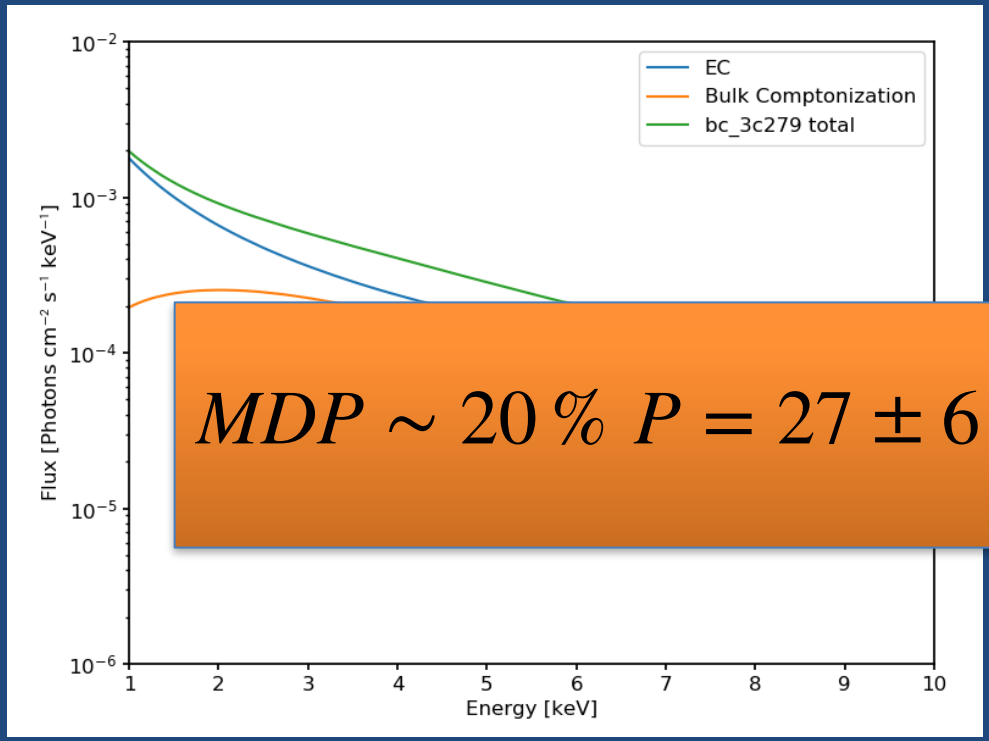
SIMULATING BULK COMPTONIZATION IN E.G.3C 279



- T_{BC}=1.9 keV (Celotti+07)
- Norm BC=1.7E-4 (Kammoun+17)
- Γ(EC)=1.5
- P_{BC}=50%
- P_{EC}=0

GOAL: at least 3σ determination of P in 50 ks.

Simulating Bulk Comptonization in e.g. 3C 279



- T_{BC}=1.9 keV (Celotti+07)
- Norm BC=1.7E-4 (Kammoun+17)

$$MDP \sim 20\% \; P = 27 \pm 6\% \; \theta = 41^\circ \pm 5^\circ$$

GOAL: at least 3σ determination of P in 50 ks.

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.....STAY TUNED FOR 2021

THANKS FOR YOUR ATTENTION!