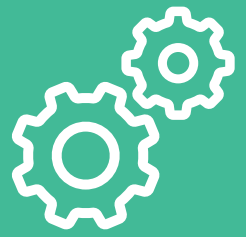
GRB 080928 afterglow polarization analysis and GRBs spectropolarimetry

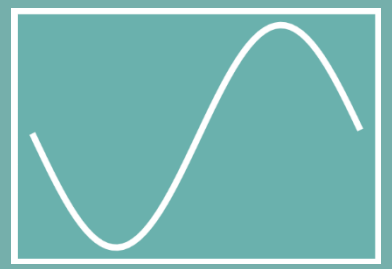
Transient Universe 2023 – Cargese (FR) – 2023/05/30-2023/06/09

Riccardo Brivio
Università degli Studi dell'Insubria – Como
INAF, Osservatorio Astronomico di Brera – Merate (LC)

GRB POLARIMETRY



DATA ANALYSIS



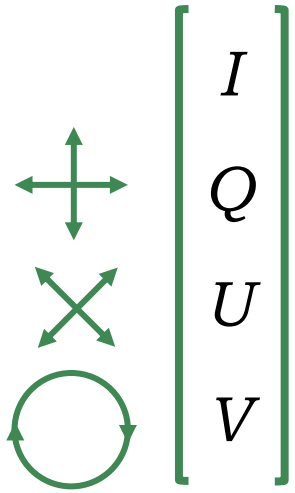
RESULTS

MODELING

CONCLUSIONS

GRBs POLARIMETRIC ANALYSIS

POLARISATION OF
ELECTROMAGENTIC RADIATION



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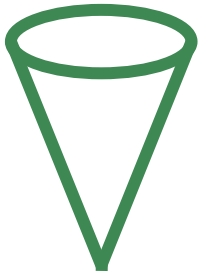
$$\theta = \frac{1}{2}\operatorname{atan}\left(\frac{U}{Q}\right)$$

GRBs POLARIMETRIC ANALYSIS



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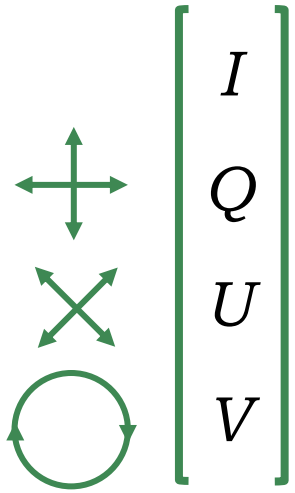

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GAMMA-RAY BURSTS

PARADIGM?

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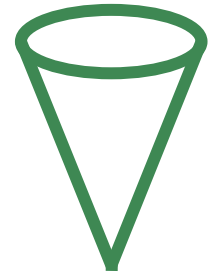

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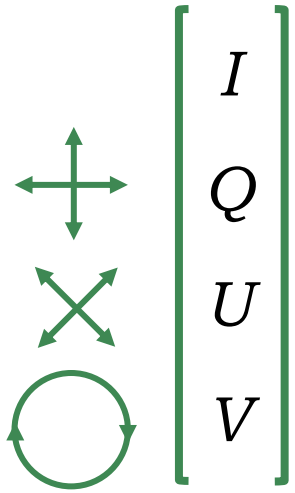

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Emitting region features,
jet geometry, magnetic fields, …

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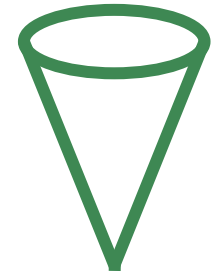

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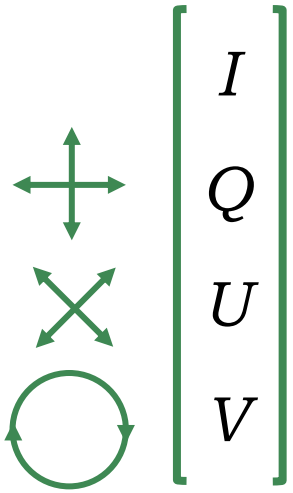

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POLARISATION ANALYSIS!

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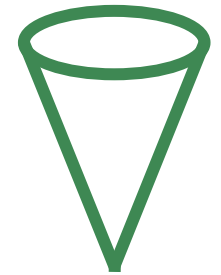

Asymmetries in the emitting region

POLARISATION OF ELECTROMAGENTIC RADIATION

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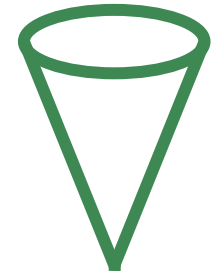

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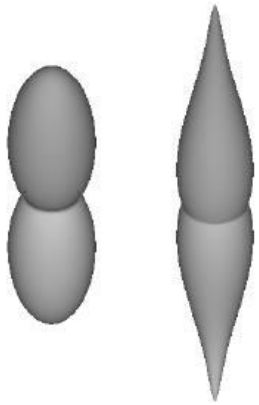
Asymmetries in the emitting region

INTRINSIC?

GAUSSIAN/ STRUCTURED JET



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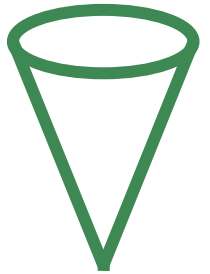

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Asymmetries in the emitting region

INTRINSIC?

ANGLE-DEPENDENT?

GAMMA-RAY BURSTS

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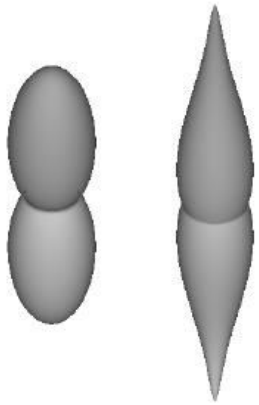
Emitting region features, jet geometry, magnetic fields, …

GAUSSIAN/ STRUCTURED JET

HOMOGENEOUS JET

POLARISATION ANALYSIS!



From Rossi E. et al (2004)

GRB 080928 – INSTRUMENTATION

INSTRUMENTATION: ESO-VLT FORS1

LOCATION: CASSEGRAIN focus of UT1 (ANTU)

OBSERVING MODES: Imaging - spectroscopy
Imaging/Spectro-polarimetry

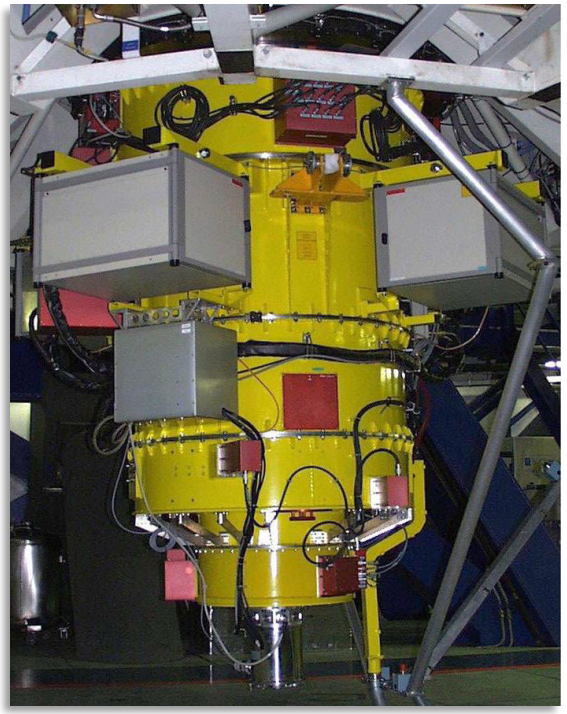
WAVELENGTH: OPTICAL, 330-1100 nm

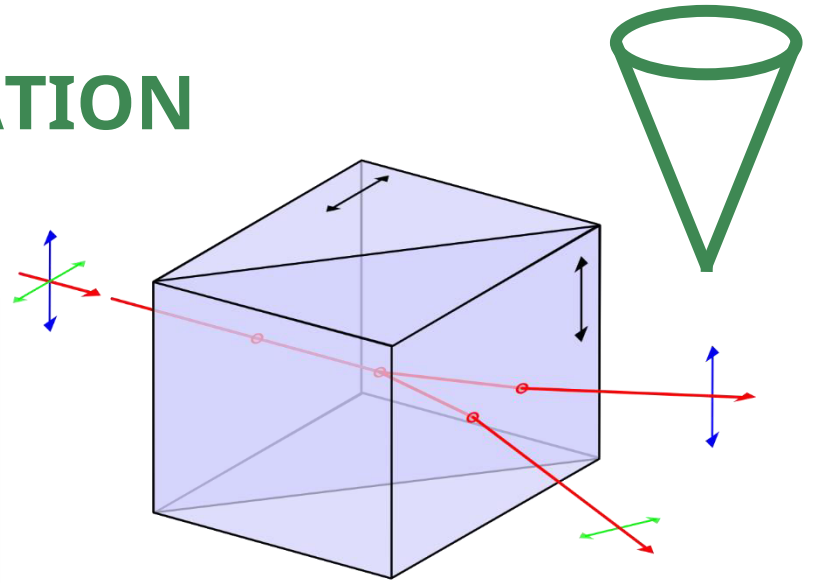
SPATIAL RESOLUTION: 0.25”/pixel (SR) / 0.125”/pixel (HR)

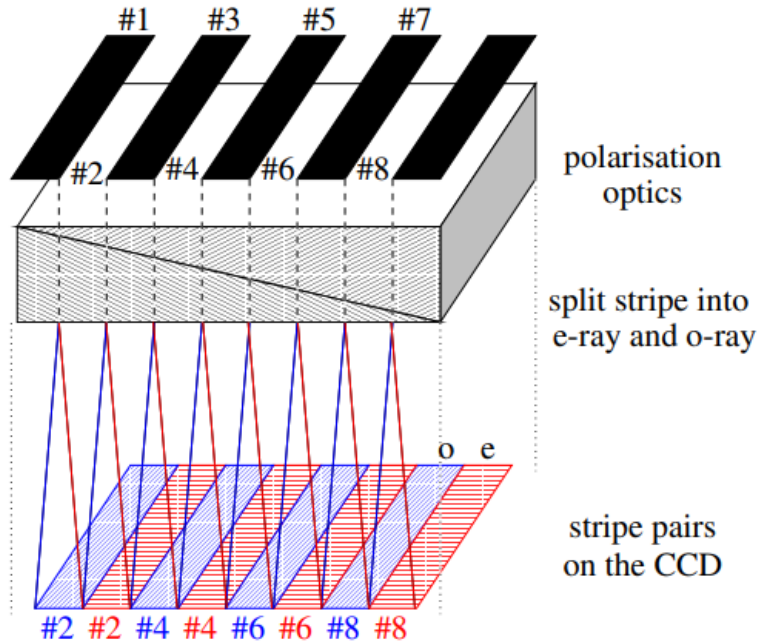
SPECTRAL RESOLUTION: 260 to 1600 (low to medium)

$$\frac{Q}{I} = \frac{1}{2}\left[\left(\frac{f_o - f_e}{f_o + f_e}\right)_{0^\circ} - \left(\frac{f_o - f_e}{f_o + f_e}\right)_{45^\circ}\right]$$

$$\frac{U}{I} = \frac{1}{2}\left[\left(\frac{f_o - f_e}{f_o + f_e}\right)_{22.5^\circ} - \left(\frac{f_o - f_e}{f_o + f_e}\right)_{67.5^\circ}\right]$$







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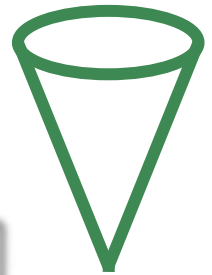

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OBSERVATIONS

MODE	$t - t_0$ [h]	FILTER/GRISM
IPOL	14.01 – 14.81 h	V_HIGH filter
PMOS	14.95 – 16.60 h	300V grism
IPOL	39.39 – 42.01 h	V_HIGH filter

GRB AGs SPECTRO-POLARIMETRIC OBSERVATIONS

GRB	Telescope	Instrument	$t - t_0$ [h]	P [%]	ϑ [°]	Ref
020813	Keck	LRISp	4.7 – 7.9	1.8 – 2.4	148 – 162	Barth et al. (2003)
021004	VLT	FORS1	18.83	0.8 – 1.7	100 – 147	Wang et al. (2004)
	VLT	FORS1	"	1.9	118	Lazzati et al. (2004)
030329			24 – 72	0.3 – 1.5		Greiner et al. (2004)
	VLT	FORS1	86.4	0.5 – 0.9	73 – 83	Covino et al. (2003)
191221B	SALT	RSS	3.26	1.5 ± 0.5	65 ± 10	Buckley et al. (2021)
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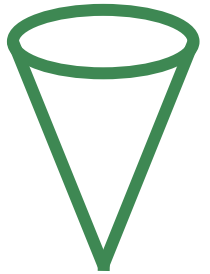

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No evidence of λ-dependence

Mild ISM polarisation

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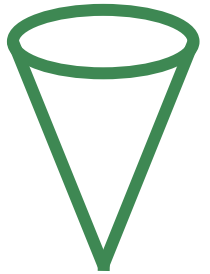

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080928	VLT	FORS1	14.95			Brivio et al. (2022)

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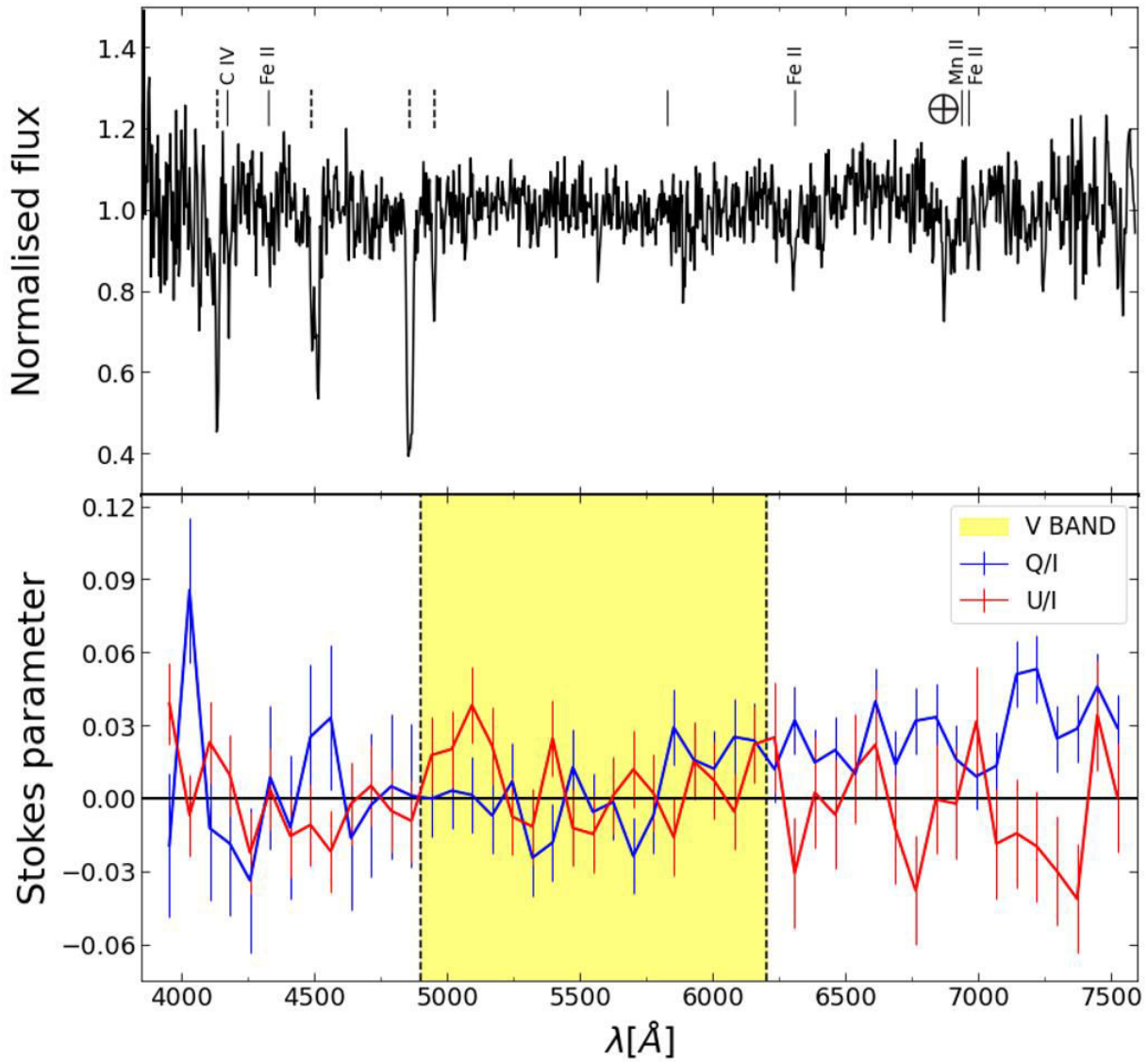
SPECTRO-POLARIMETRY RESULTS

1st night – $t - t_0 \sim 0.66$ d

$$P_{OA} < 1.57\ \%$$



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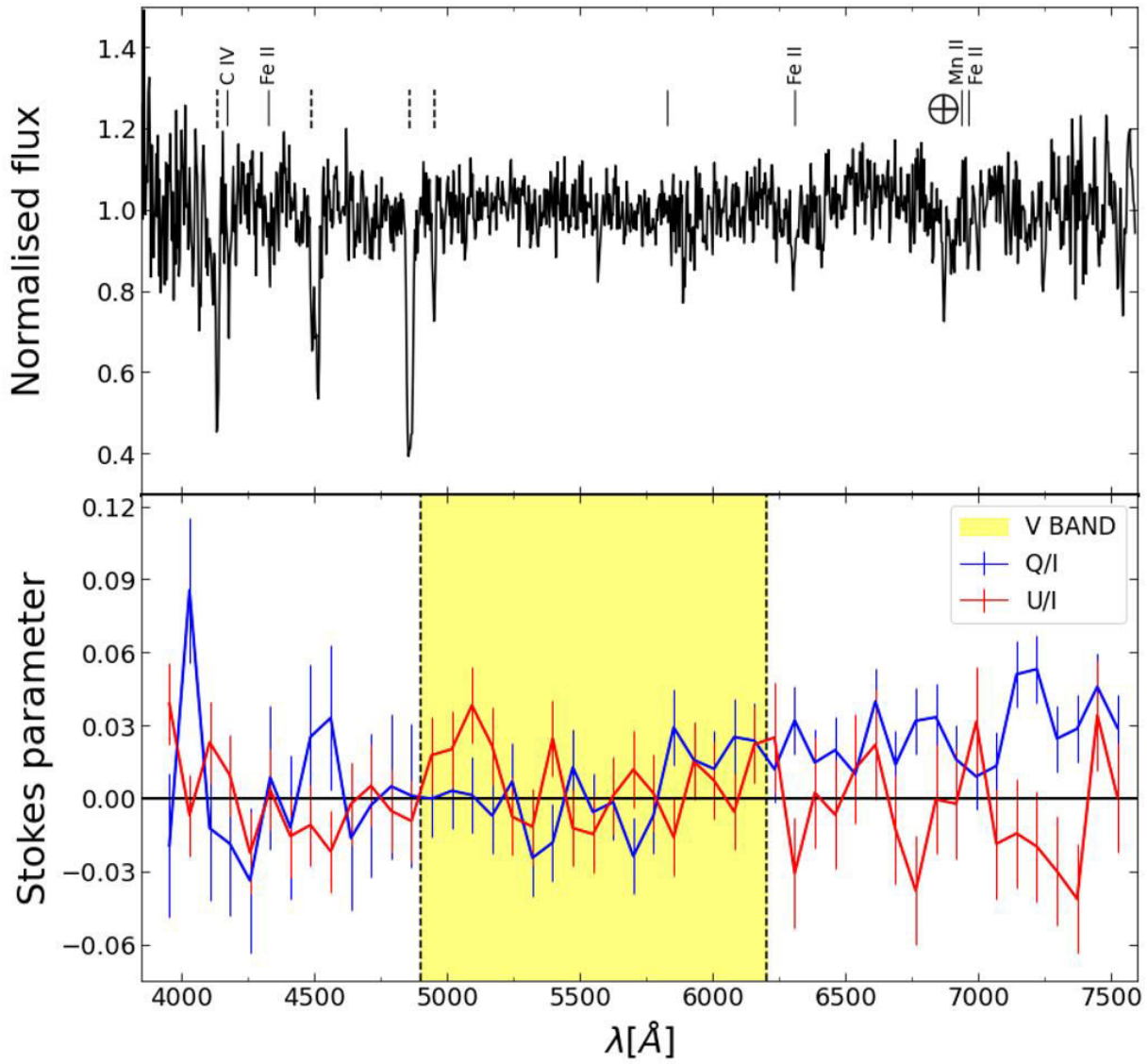


$$P_{max}(\%) \leq 9.0 \; x \; E(B-V)$$

✗ MW-LIKE

✗ $A_V^{host} = 0.37$

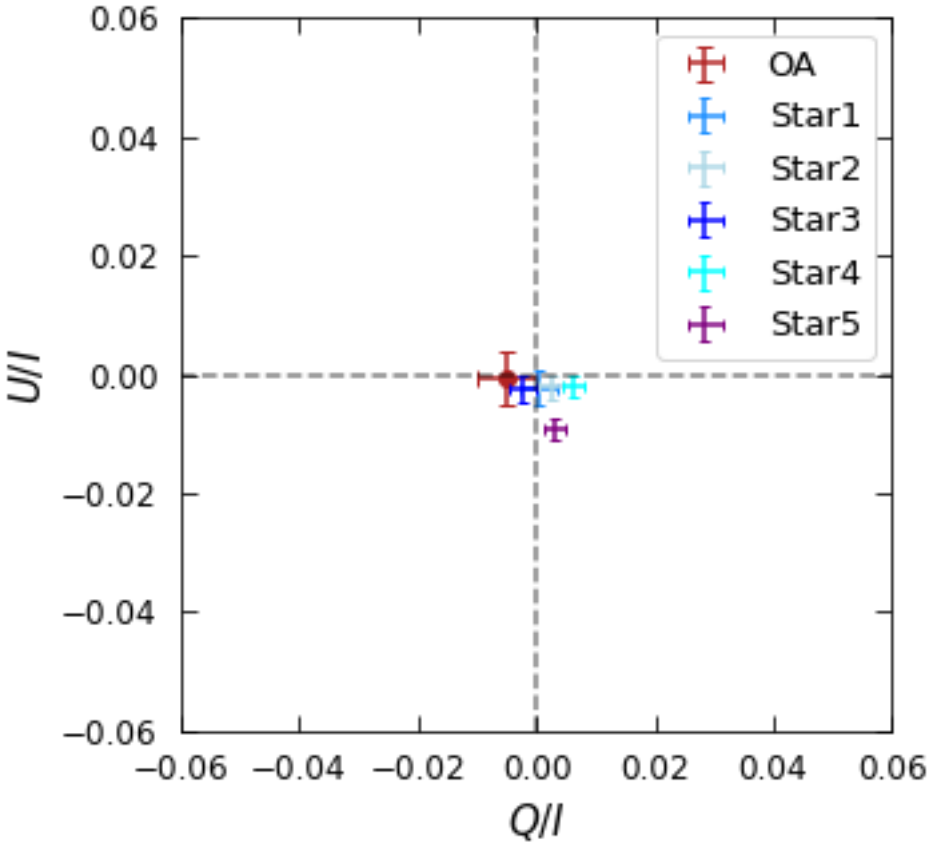
Rossi A. et al (2011)

$$\mathbf{P_{OA} < 1.57\ \%}$$

$$\mathbf{P_{HG} \leq 1.1\ \%}$$

IMAGING POLARIMETRY RESULTS

1st night – $t - t_0 \sim 0.62$ d



$\mathbf{P_{OA} < 1.99\ \%}$

IMAGING POLARIMETRY RESULTS

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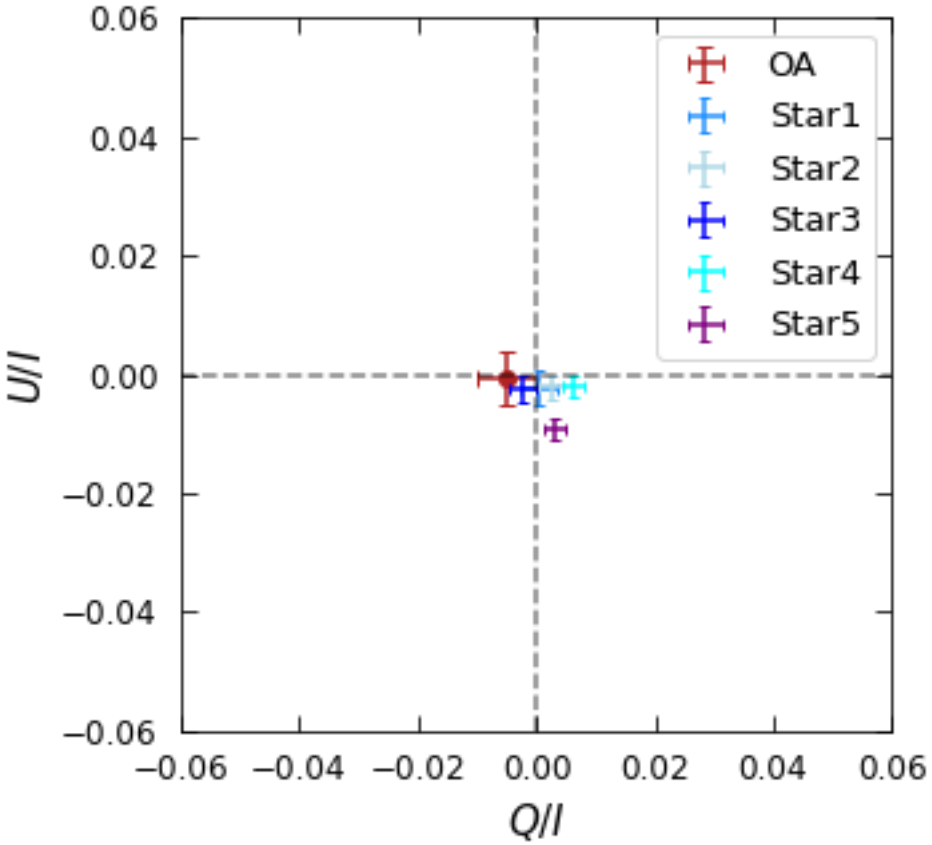
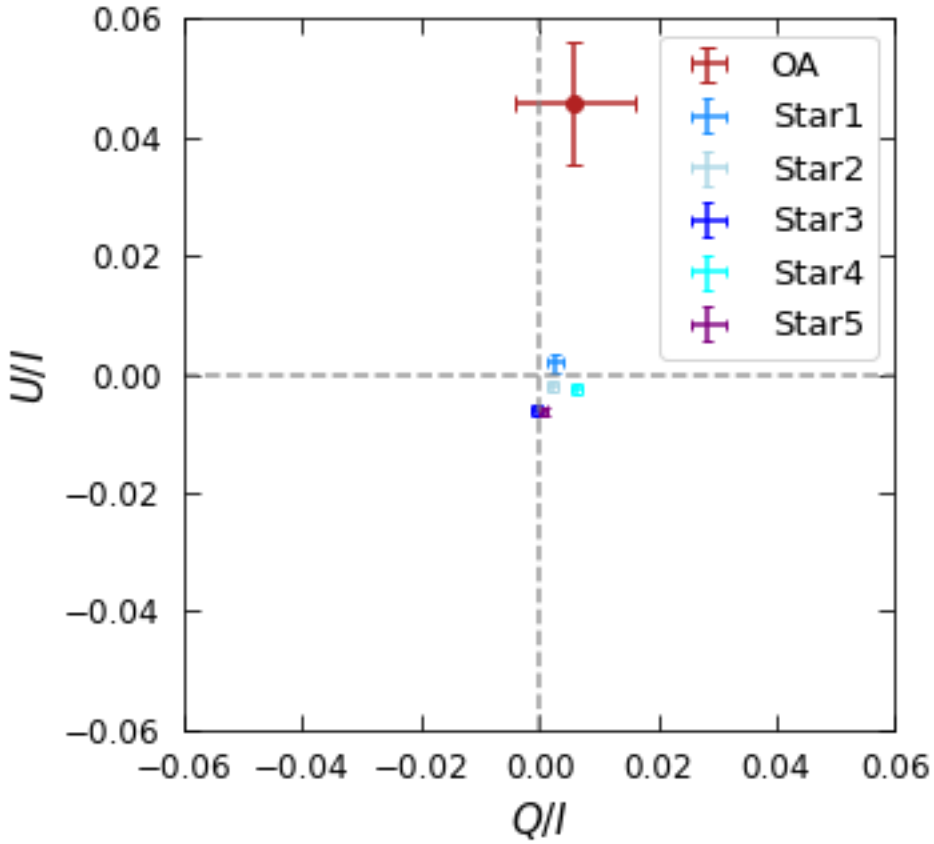


$\mathbf{P_{OA} < 1.99\ \%}$

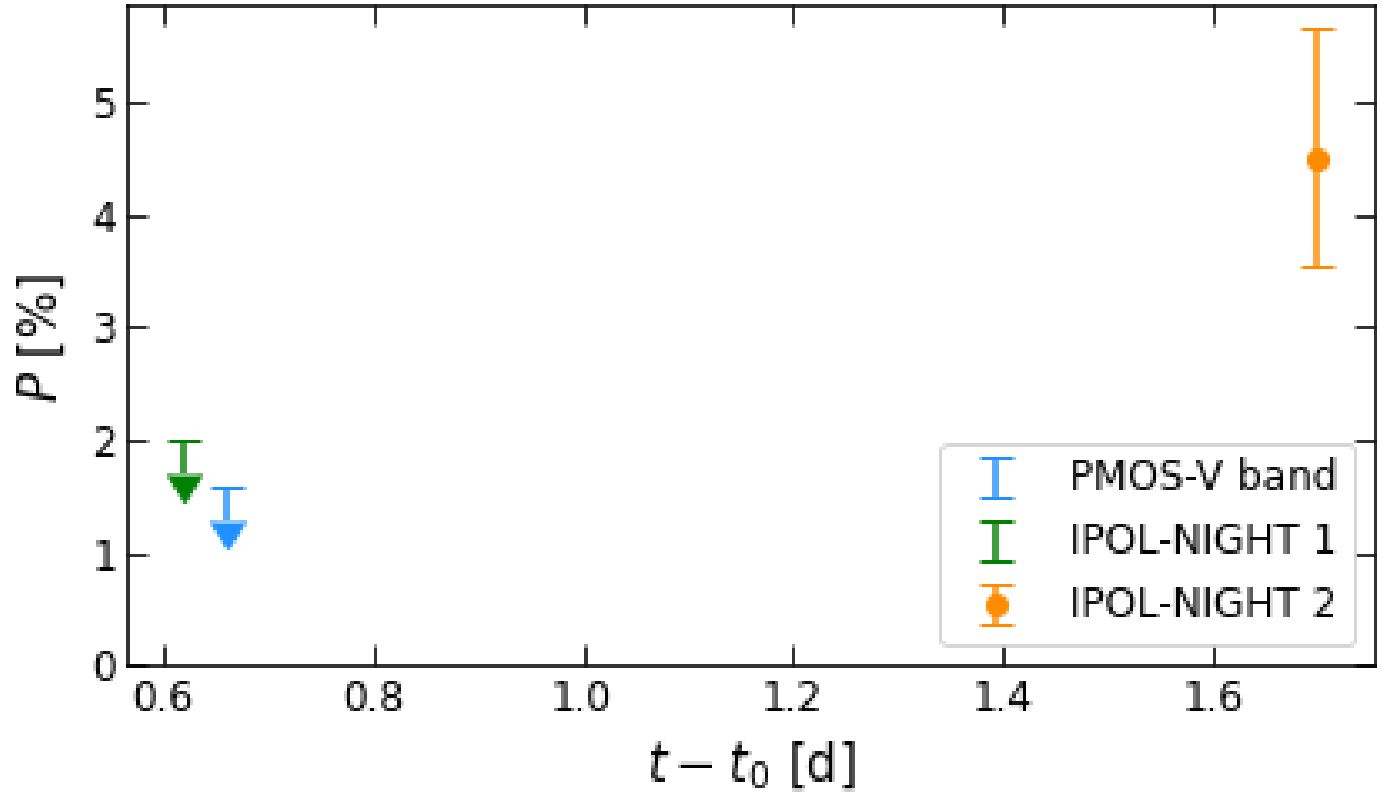
2nd night – $t - t_0 \sim 1.70$ d



$\mathbf{P_{OA} = 4.49^{+1.16}_{-0.96}\ \%}$

POLARISATION CURVE

$t - t_0$ [d]	MODE	Q/I	U/I	P [%]	θ [°]
0.62	IPOL	-0.0049 ± 0.0050	-0.0008 ± 0.0045	< 1.99	–
0.66	PMOS	0.0031 ± 0.0034	0.0037 ± 0.0038	< 1.57	–
1.70	IPOL	0.0059 ± 0.0101	0.0457 ± 0.0104	$4.49^{+1.16}_{-0.96}$	41.3 ± 6.3

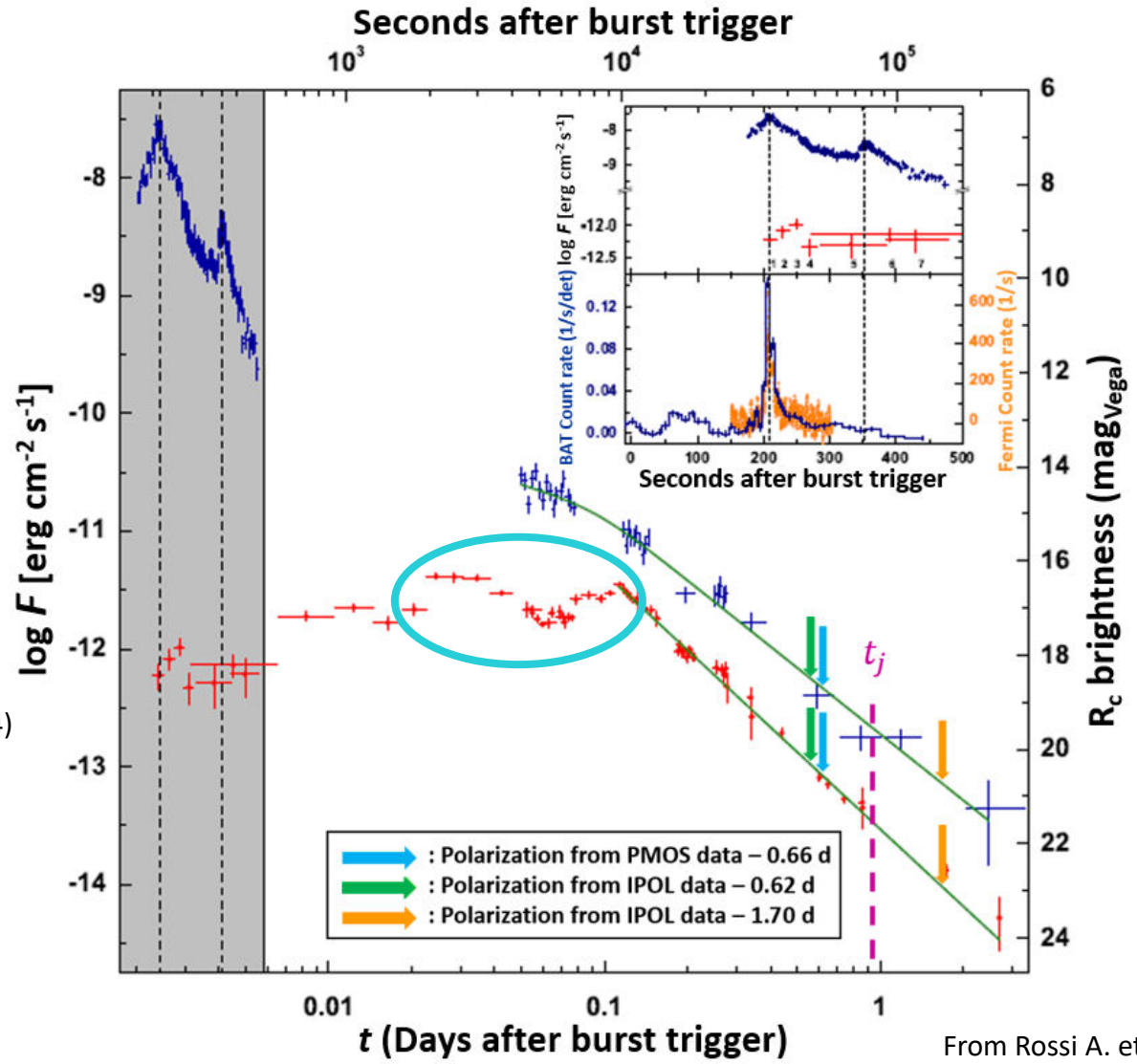


COMPARISON WITH MODELS

LONG-LIVED ENGINE?

$t_j = 0.93$ d

Leventis et al (2014)



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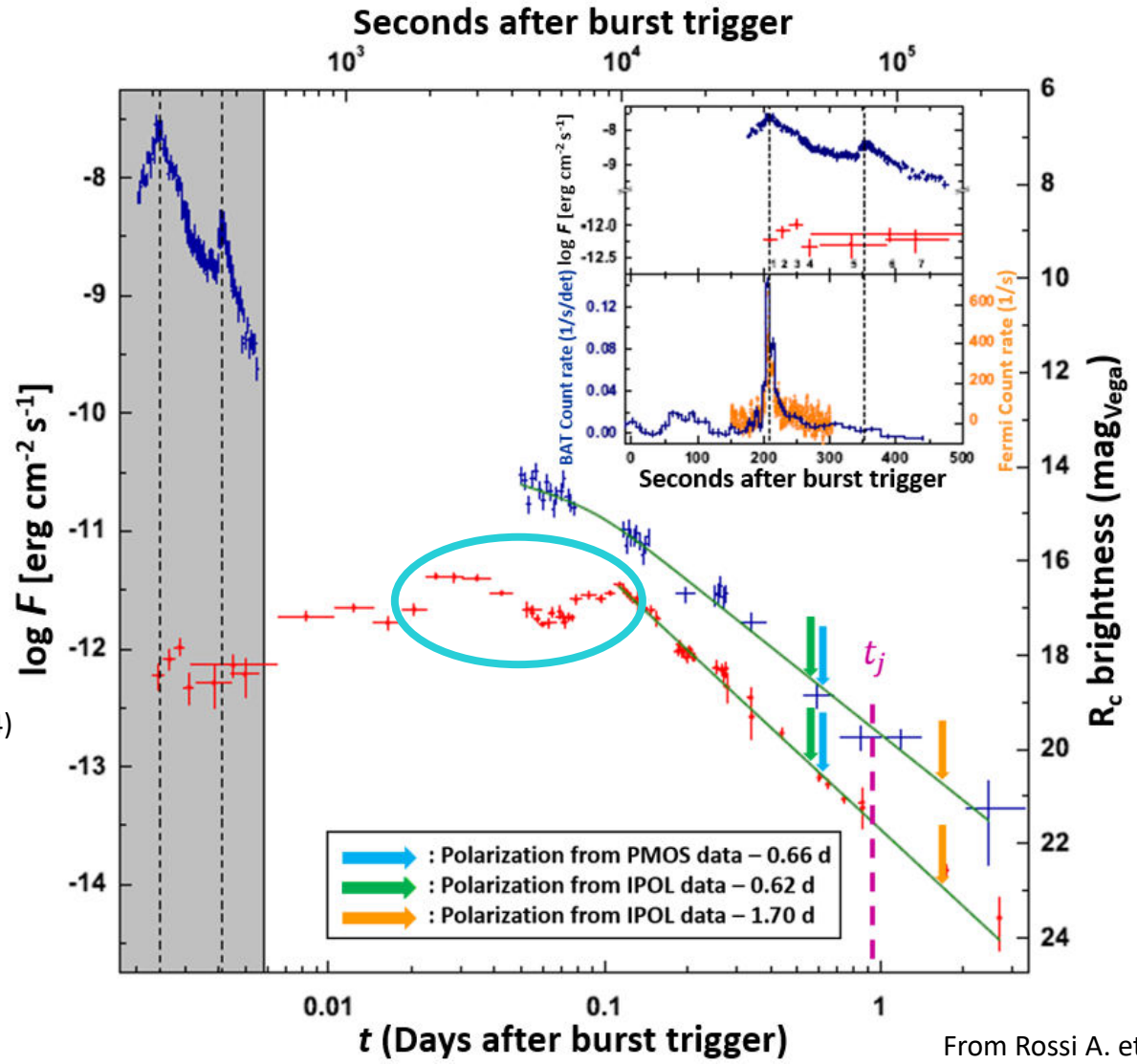

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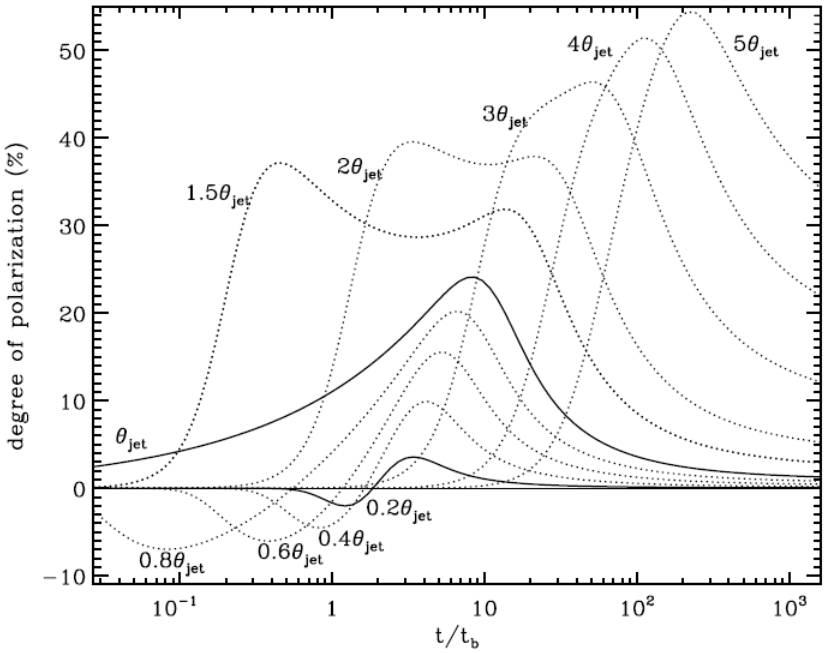
EXPECTED POLARISATION CURVES FOR HOMOGENEOUS JET



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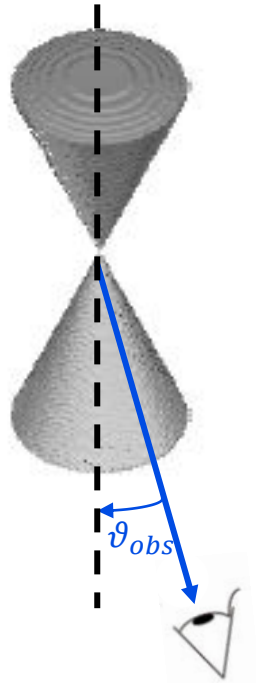
CONCLUSIONS

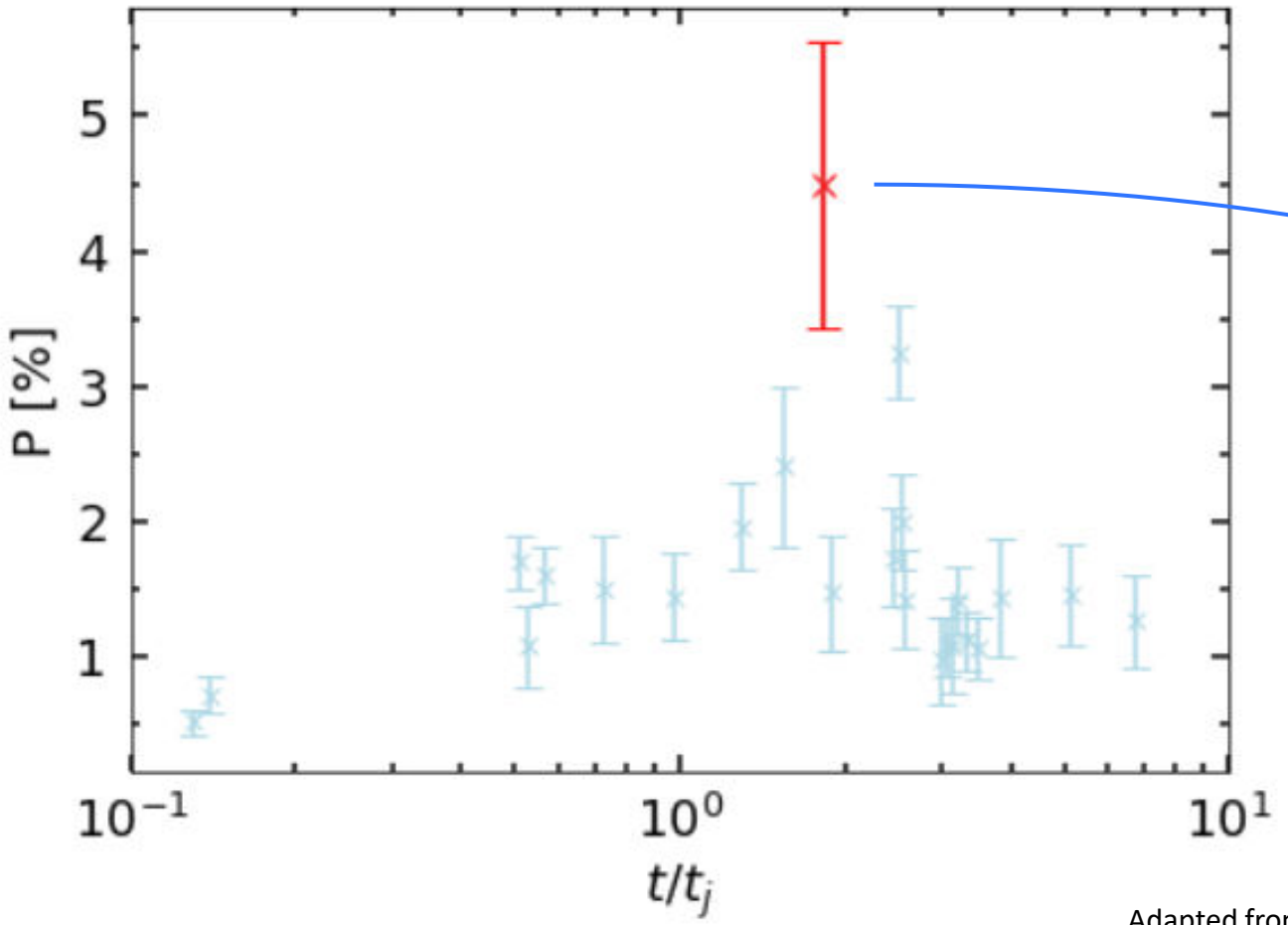


- If $t_j = 0.93$ d GRB 080928 was probably characterized by an homogeneous jet. Structured and Gaussian jets have been excluded after comparison with models;
- Polarisation degree results are consistent with $0.6 < \vartheta_{obs}/\vartheta_{jet} < 0.8$. Polarisation detection coincides with the second rise in the curve;
- The fifth GRB spectro-polarimetric analysis overall, one of the relatively few GRB polarisation detections;
- The same method can be applied to more GRBs to increase the sample and look for similarities and differences.


Thank you for
the attention!

BACK-UP SLIDES

POLARISATION DETECTION vs. JET BREAK TIME



Largest P of the sample.
1σ errors..

Adapted from Stringer&Lazzati (2020)