Insight on quasar changing-look physics from optical polarimetry

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TORUS 2018. The many faces of the AGN obscuration
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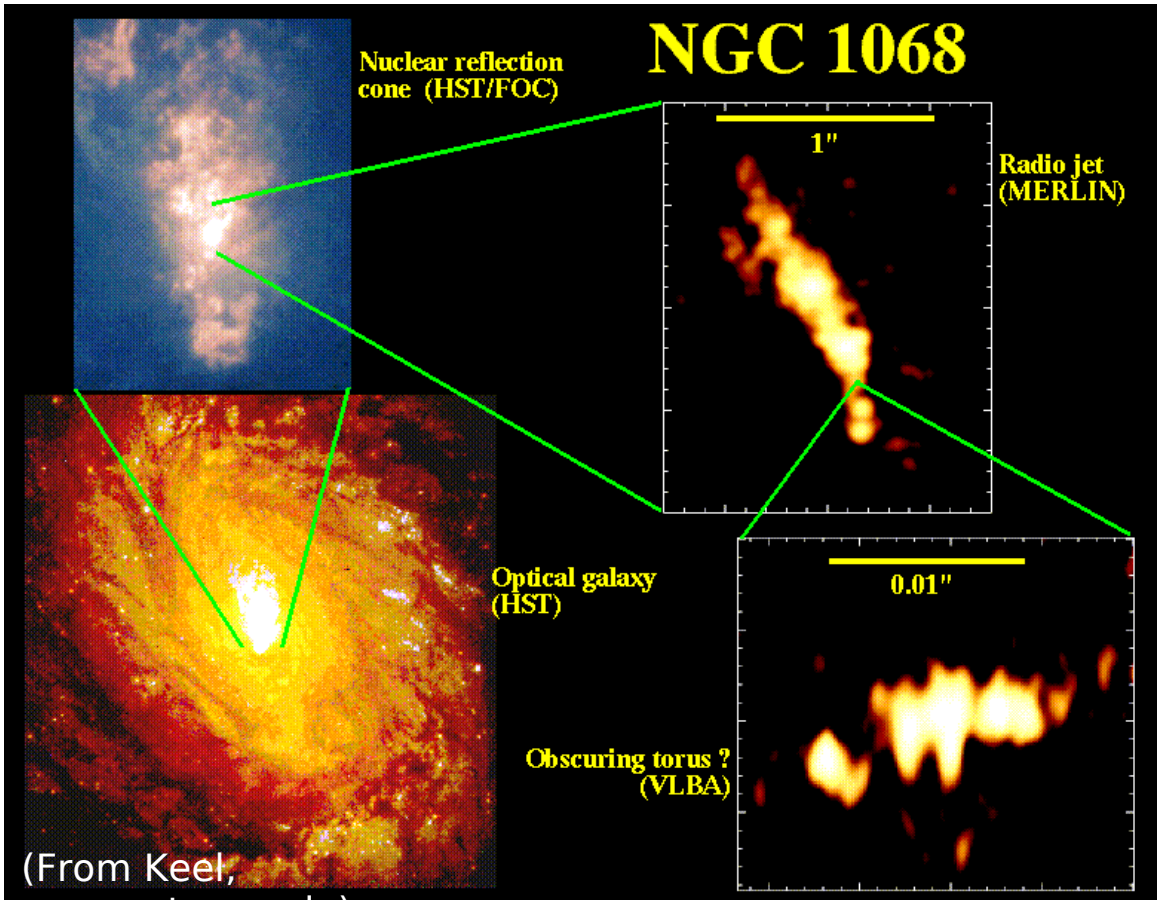
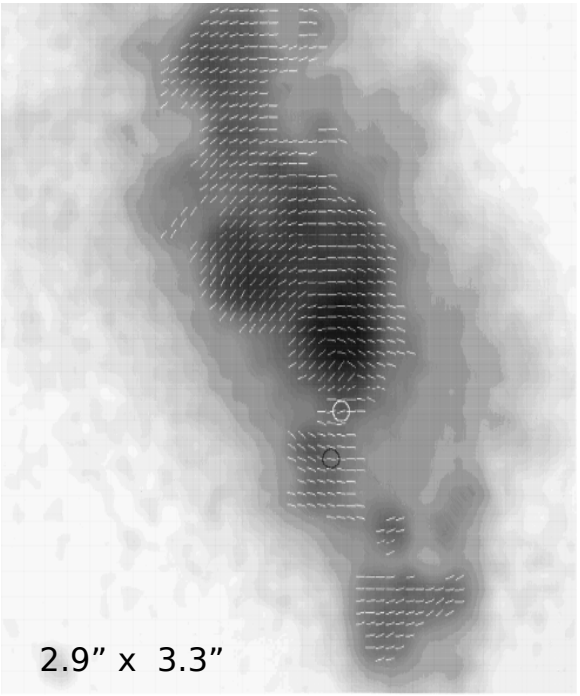
Outline

- Optical linear polarization in radio-quiet AGNs : overview (Seyferts and quasars)
- Changing-look quasars
- Polarization in changing-look quasars : expectations, measurements, and results

Polarization in the nearby Seyfert 2 NGC 1068

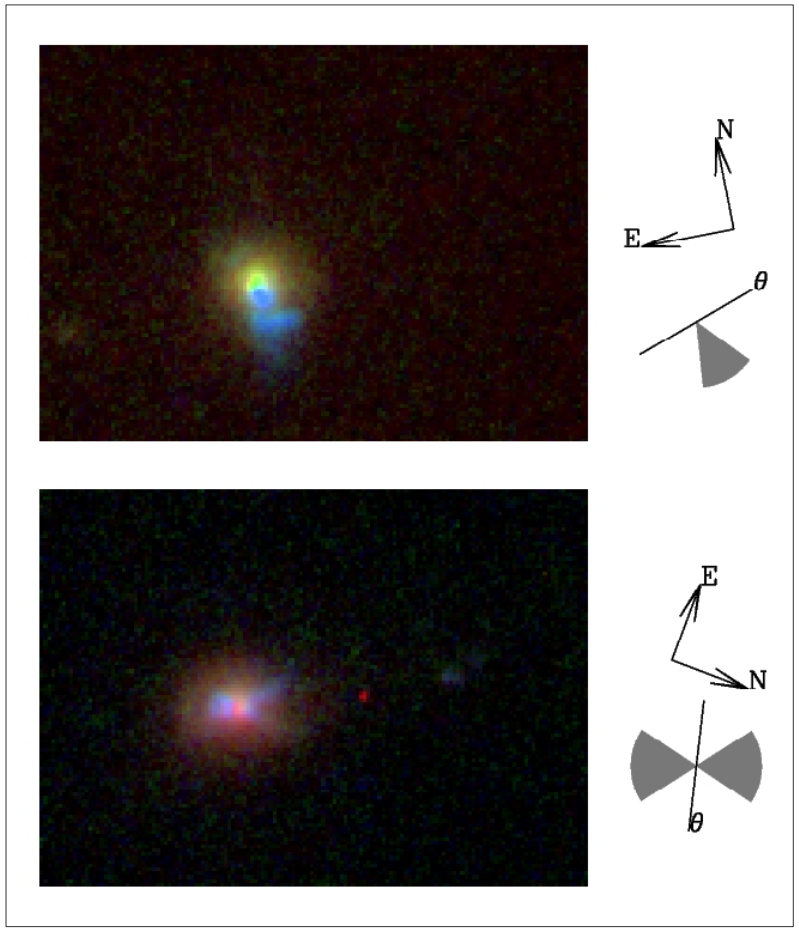




Centrosymmetric polarization due to dust scattering
(HST UV observations, Capetti et al. 1995)

- polarization (> 10%) due to scattering of nuclear light
- caused by electrons inside the NLR and dust in external regions
- polarization vectors are perpendicular to the radio jet / ionization cones

Polarization in Type 2 quasars at z ~ 0.5

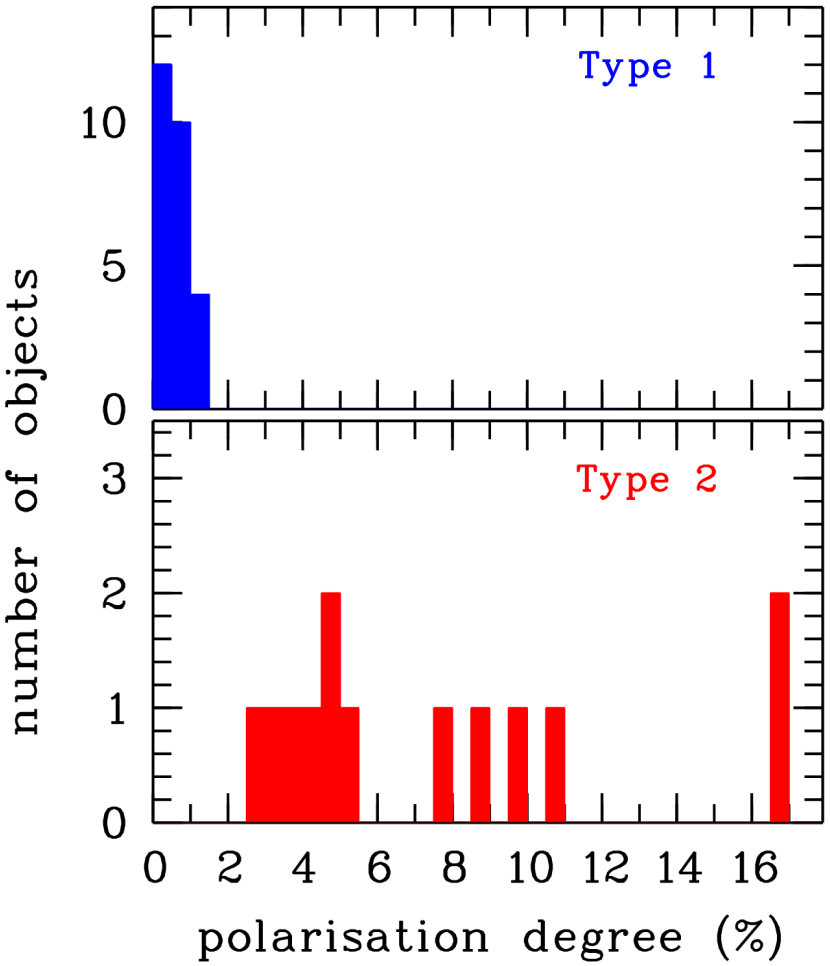


Three-band HST color-composite images of Type 2 quasars. The irregularly shaped blue spot is identified as a one-sided scattering region (top) or as a fairly symmetric bi-conical region (bottom). (From Zakamska et al. 2005)

The UV-blue polarization of Type 2 quasars is typically 3-15% and perpendicular to the extended UV continuum (Zakamska et al. 2005)

[Note: Those Type 2 quasars are selected on the basis of their high [OIII] luminosity]

Type 1 / Type 2 polarization dichotomy



Rest-frame UV-blue linear polarization in Type 1 and Type 2 quasars at 0.2 < z < 0.7 (From Hutsemékers et al. 2017)

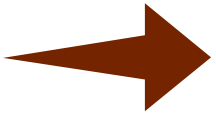
- Type 1 quasars have p < 2% and Type 2 quasars have p > 2%

  (Type 2 quasar polarization measurements are still scarce !)

- Similar dichotomy in Seyferts but less clear due to dilution of the polarization by the host starlight

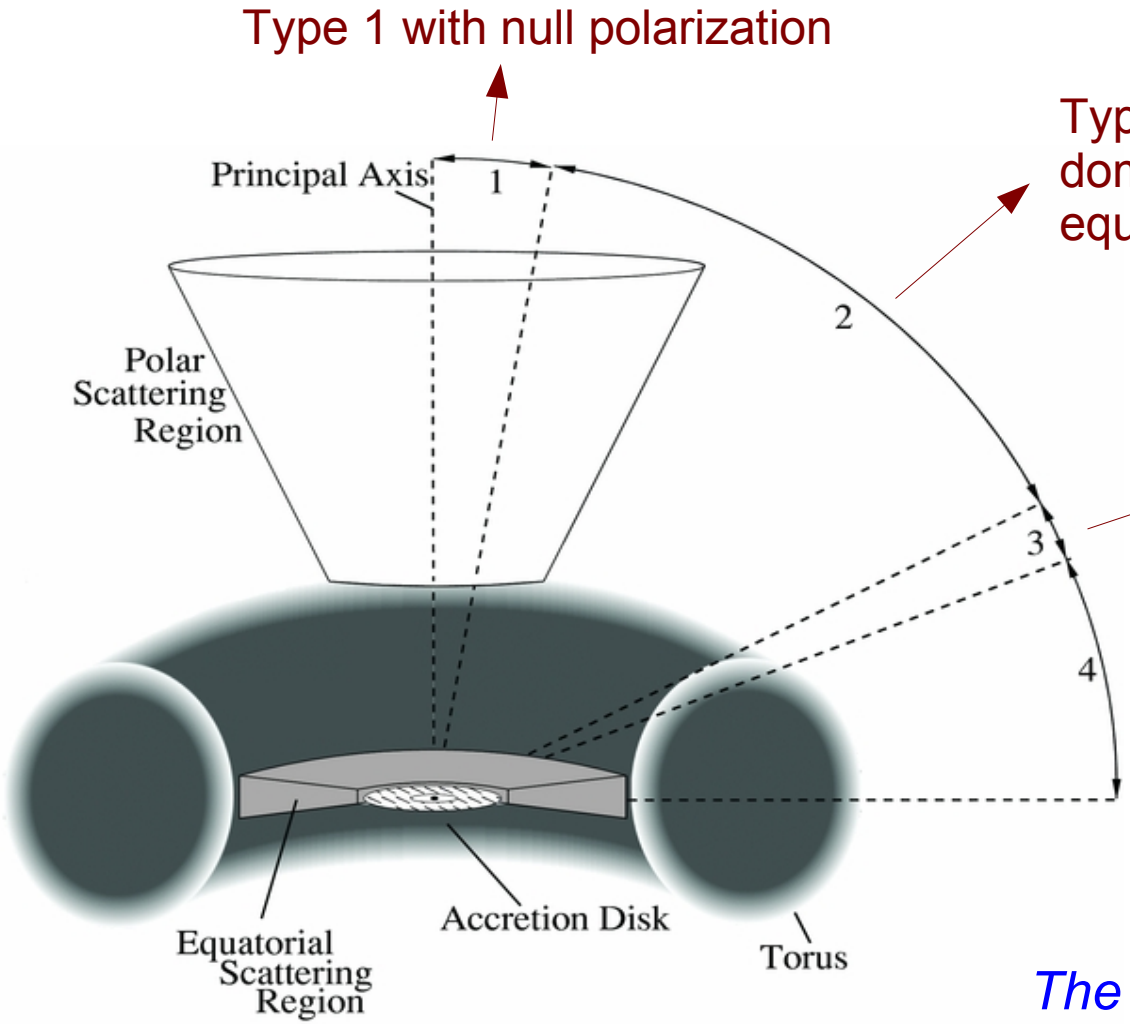
Polarization in AGNs: main characteristics

- Electron scattering is likely the main polarization mechanism. Dust in the torus and the NLR can also contribute
- Type 2 AGNs show high optical polarization > 2%. The polarization is perpendicular to the radio axis and/or to the ionization cones (e.g., Zakamska et al. 2003, 2005). This suggests polar scattering
- Type 1 AGNs have low optical polarization ~ 0.6%, a minority (~ 1/100) showing p > 3%. The polarization is most often parallel to the radio axis / ionization cones but perpendicular polarization is also observed (Stockman et al. 1979, Berriman et al. 1990, Kishimoto et al. 2004, Borguet et al. 2008). This suggests equatorial and polar scattering



A two-component polar + equatorial scattering model can explain most observations

Polarization in AGNs : the unified view



Type 1 with polarization dominated by equatorial scattering

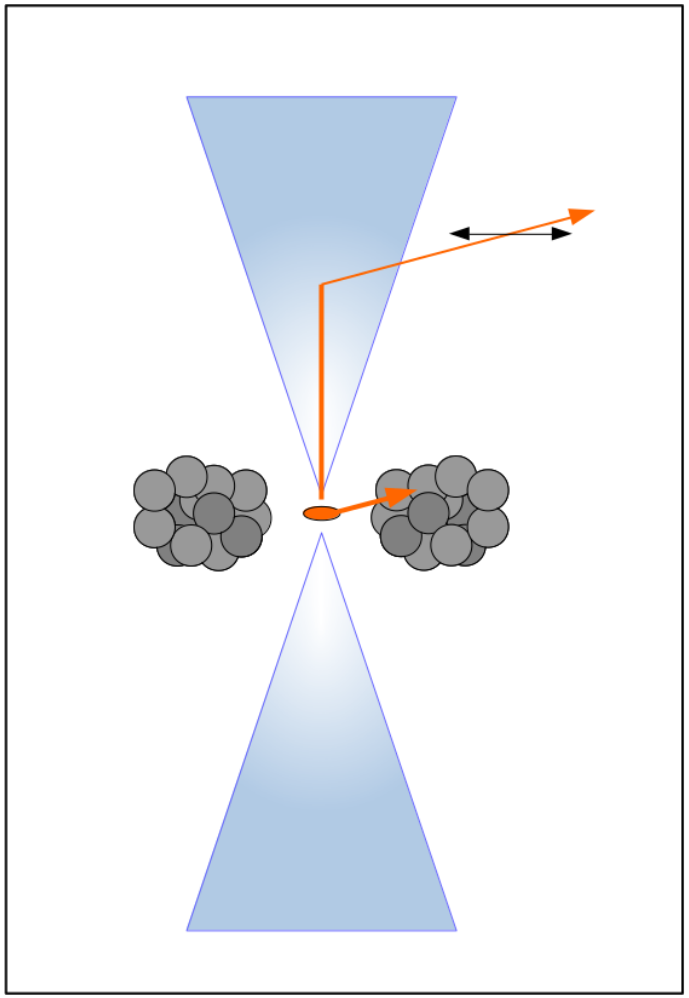
Type 1 with polarization dominated by polar scattering

Type 2 with polarization from polar scattering

The relative importance of extended polar scattering and compact equatorial scattering is determined by inclination

(Smith et al. 2004, Batcheldor et al. 2011)

Hidden BLR in Type 2 AGNs



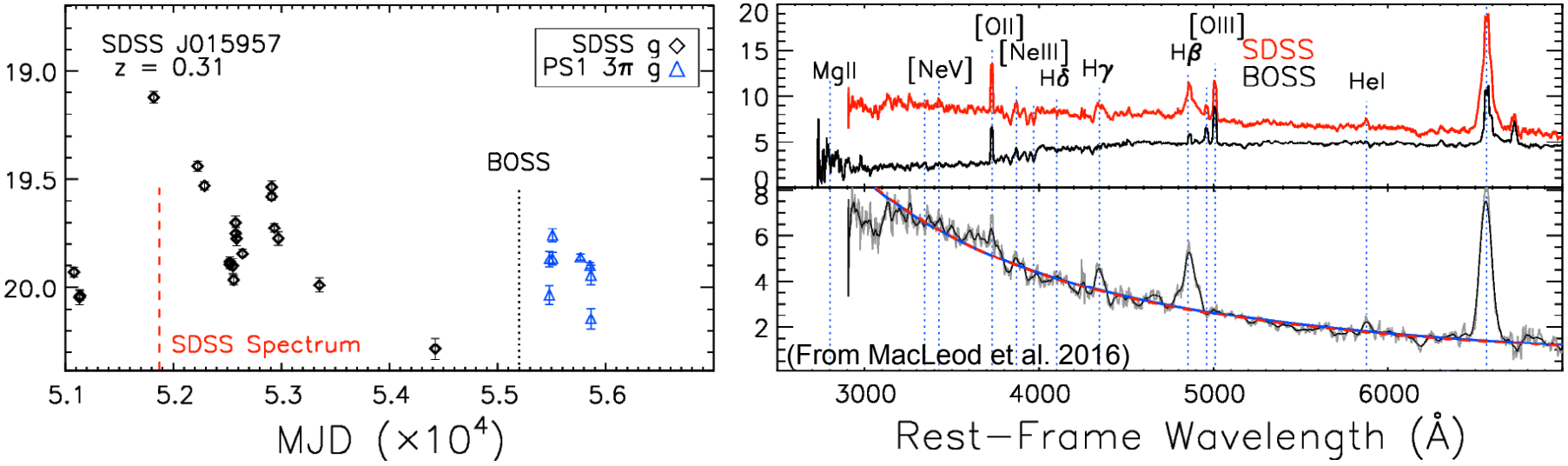
Type 2 AGN

The polarized scattered light shows BELs revealing the Type 1 AGN core (periscopic view)

The direct light is obscured; only NELs are seen leading to a Type 2 AGN classification

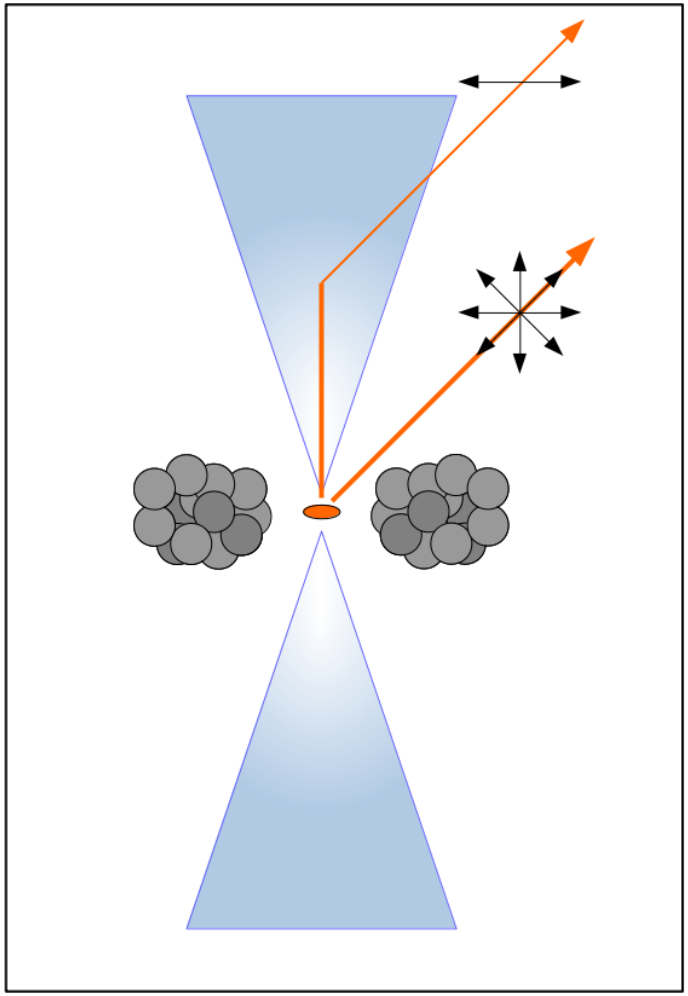
Strong support to the Unification Model: Type 1 and Type 2 AGNs only differ by their inclination w.r.t. the line of sight
(Antonucci & Miller 1985)

Changing-look quasars

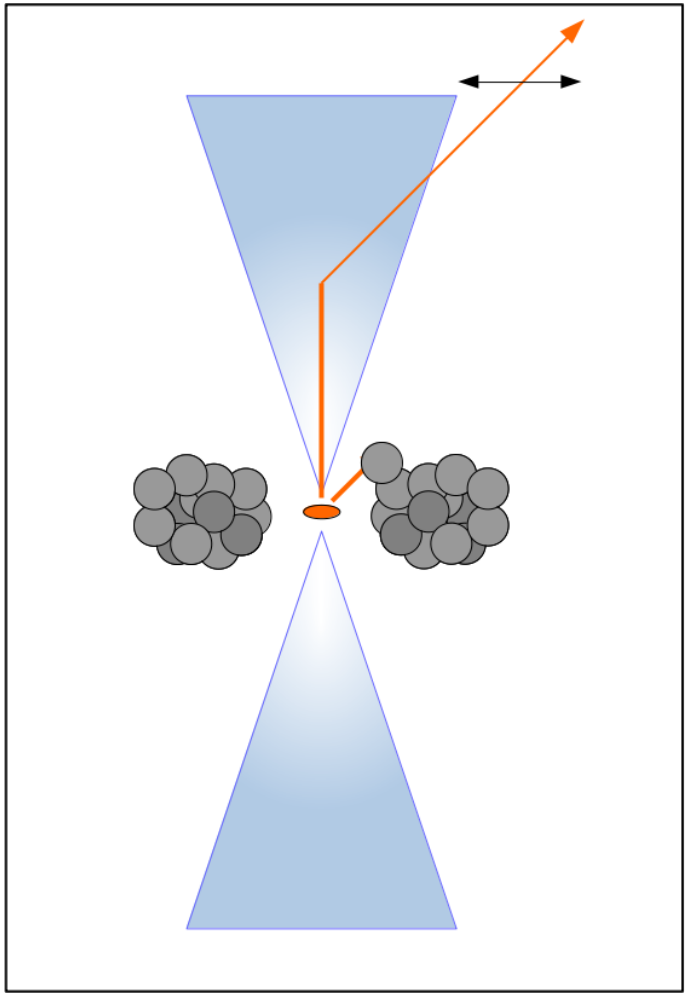


- A dozen quasars are known to change from Type 1 to Type 2 or vice-versa, together with 1-2 mag variations on timescales of years (LaMassa et al. 2015, Runnoe et al. 2016, Ruan et al. 2016, MacLeod et al. 2016)
- Cause: variable obscuration (moving dust cloud in the torus) or dimming / brightening of the ionization source (variable accretion rate)
- Variable obscuration is disfavored : the crossing time of torus dust clouds is too long and optical luminosity variations are followed by mid-IR variations (LaMassa et al. 2015, Sheng et al. 2017)

Expected polarization in changing-look quasars



Type 1 AGN



Type 1 → Type 2
due to obscuration

High polarization typical of Type 2 quasars is expected if the change of look Type 1 → Type 2 is due to variable obscuration

Polarization of changing-look quasars

Object	z	Observation Date yyyy-mm-dd	p %	σ_p %	p_0 %	θ °	σ_θ °	g mag	Trend / Δg mag	Status
J101152.98+544206.4	0.246	2017-02-19	0.15	0.22	0.00	-	-	19.6±0.2	−−	faint
J015957.62+003310.5	0.312	2018-01-13/14/15	0.47	0.27	0.41	158	16	20.5±0.2	+0.5	faint
J100220.17+450927.3	0.400	2018-01-13/15	0.61	0.17	0.59	68	8	19.4±0.1	−1.0	bright
J102152.34+464515.7	0.204	2018-01-14	0.16	0.23	0.00	-	-	19.4±0.1	−−	faint
J132457.29+480241.2	0.272	2018-01-14	0.17	0.13	0.13	158	22	18.4±0.1	−1.5	bright
J214613.31+000930.8	0.621	2018-09-13	0.28	0.43	0.00	-	-	20.8±0.2	−−	intermediate
J225240.37+010958.7	0.534	2018-09-13	1.10	0.66	0.94	115	20	21.2±0.1	−−	faint
J233317.38−002303.4	0.513	2018-09-13	0.59	0.51	0.38	138	39	21.2±0.1	+1.5	faint
J233602.98+001728.7	0.243	2018-09-13	0.21	0.12	0.18	47	19	20.3±0.1	−−	intermediate
J002311.06+003517.5	0.422	2018-09-13	0.31	0.09	0.30	131	9	18.8±0.1	−−	faint
J012648.08−083948.0	0.198	2018-09-13	0.13	0.07	0.11	24	18	19.1±0.1	−−	intermediate
J022556.07+003026.7	0.504	2018-09-13	0.48	0.13	0.46	147	8	20.7±0.1	−−	intermediate
J022652.24−003916.5	0.625	2018-09-13	6.87	0.64	6.84	71	3	22.8±0.2	+1.0	faint

(Hutsemékers et al. 2018, submitted)

→ Sample: all changing-look quasars from LaMassa et al. (2015), Runnoe et al. (2016), Ruan et al. (2016), MacLeod et al. (2016)

→ Measurements: g-band with FORS2 @ VLT and ISIS+ACAM @ WHT

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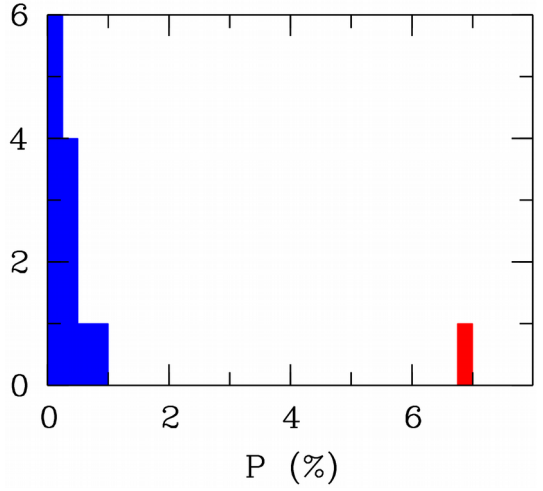
→ Photometry reveals strong variations since last published data (~2015) that indicates new changes of look

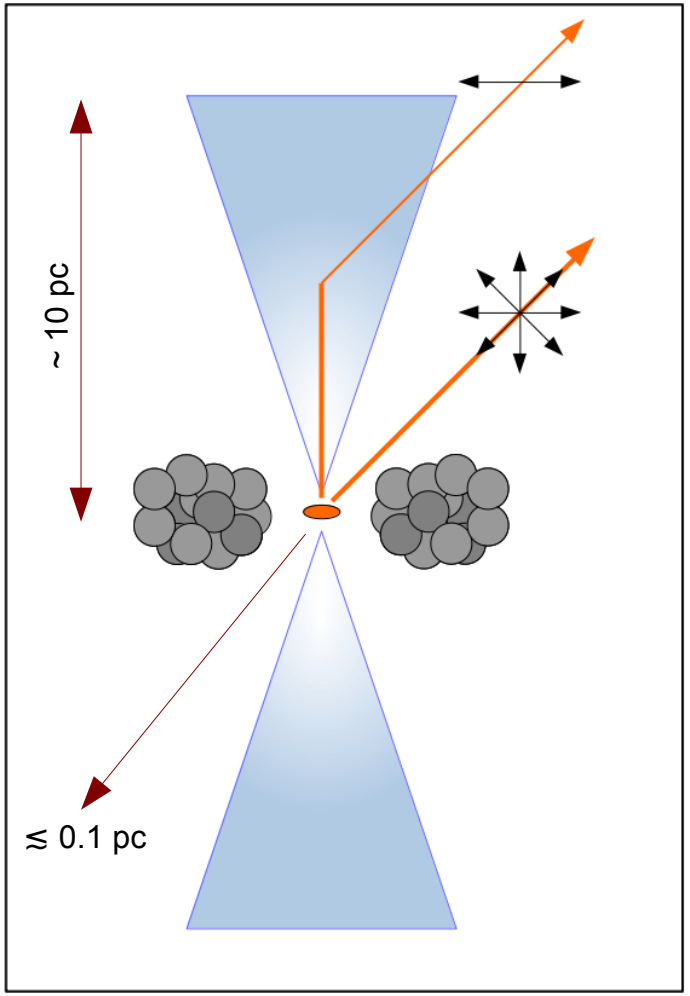
→ All targets but one have polarization < 1%



Results

- All quasars but one, including six in Type 2 state, have low polarization p < 1% => no evidence that dust obscuration causes Type 1→Type 2
- All quasars with p < 1% should be seen at inclinations < 15° according to simulations with STOKES (Marin 2017)
- One quasar in a Type 2 state has a high polarization p ~ 7%. This can be due to obscuration but this is unlikely. Indeed, in that object, the time for a dust cloud from the torus to eclipse the BLR is 80 years, more than one order of magnitude the timescale of the change of look (6 years)
- Alternatively we could see the polarization echo of a switched off Type 1 quasar seen at intermediate inclination

Polarization echo in a switched off quasar



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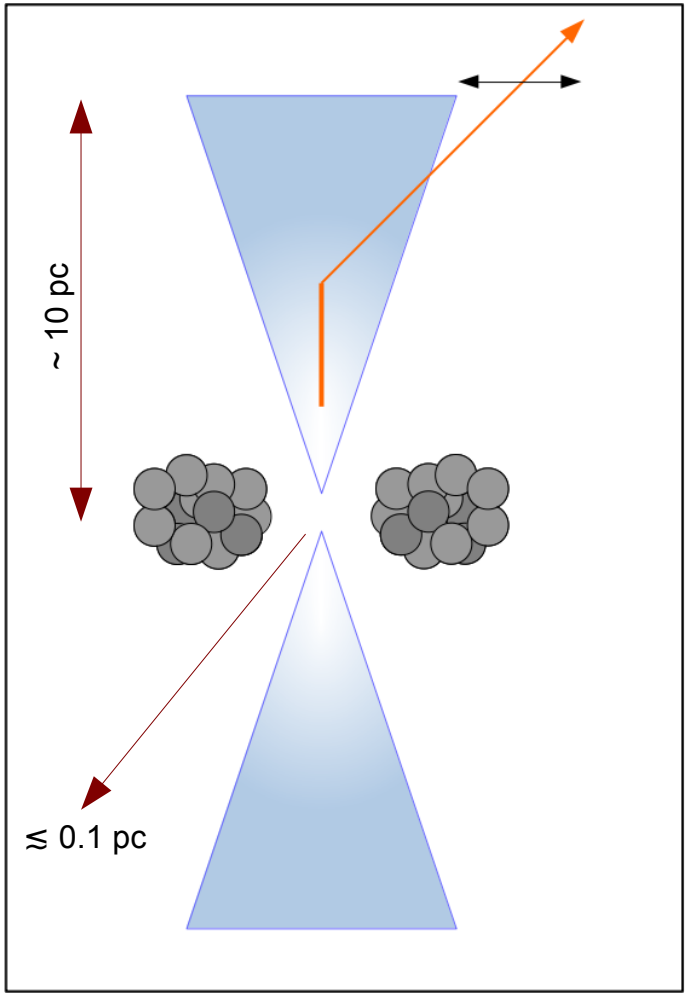

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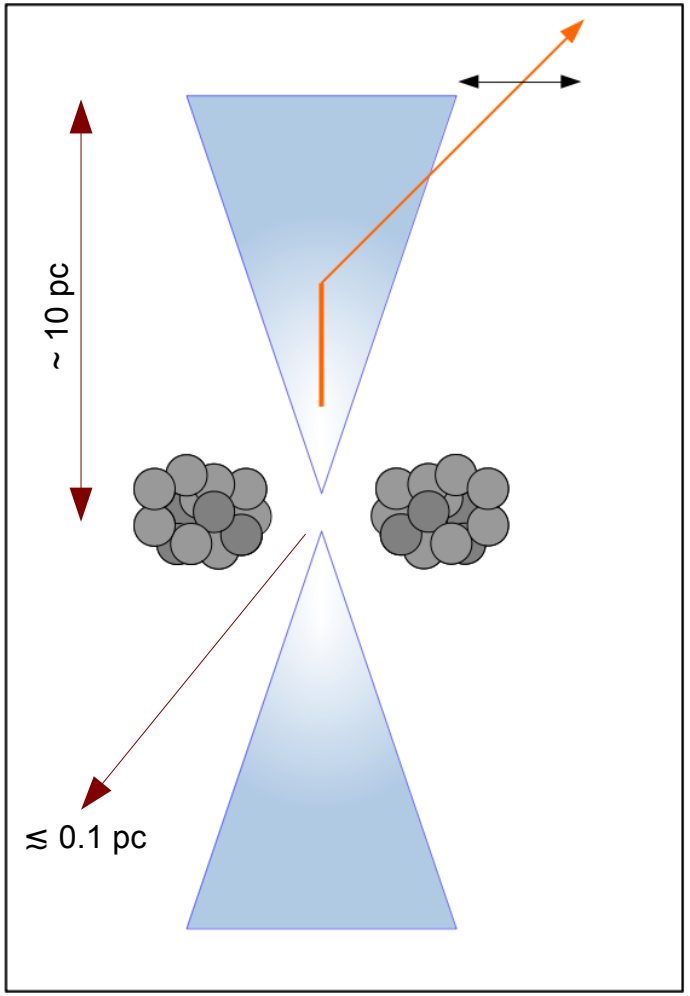

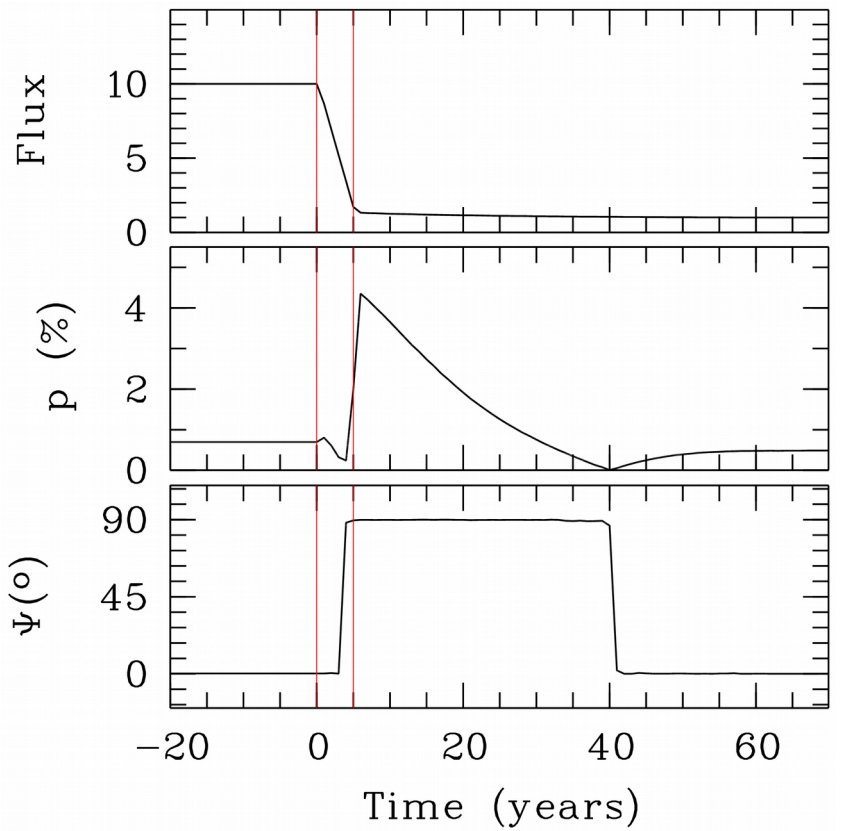

Simulation with STOKES of a Type 1 quasar fading out in five years and the subsequent polarization echo (Hutsemékers et al. 2018, submitted)

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- Alternatively we could see the polarization echo of a switched off Type 1 quasar seen at intermediate inclination
- An echo of the past BLR emission is also expected in the polarized scattered light → fake hidden BLRs
- All results do agree with dimming/brightening of the ionizing source
- *Based on the assumption that scattering regions are also present in those quasars*

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