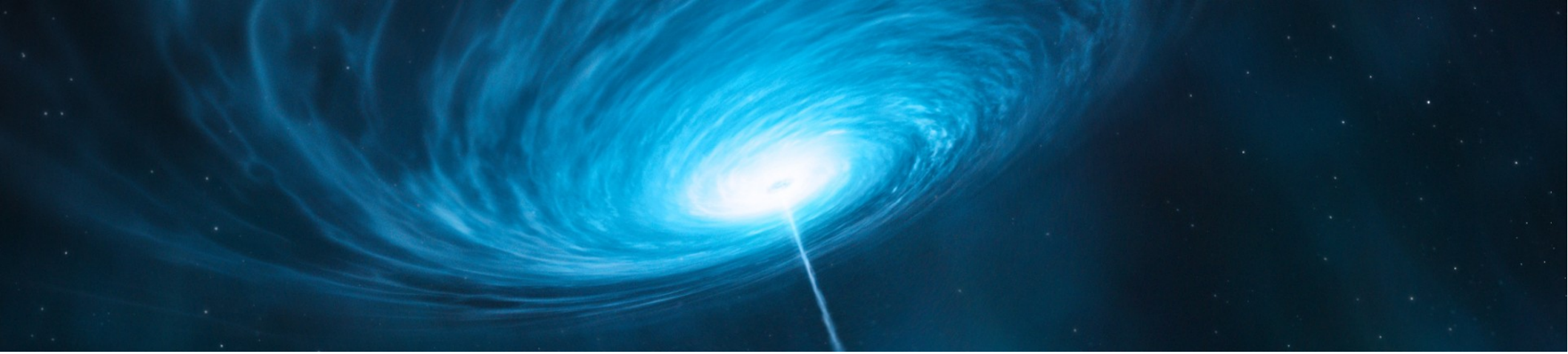
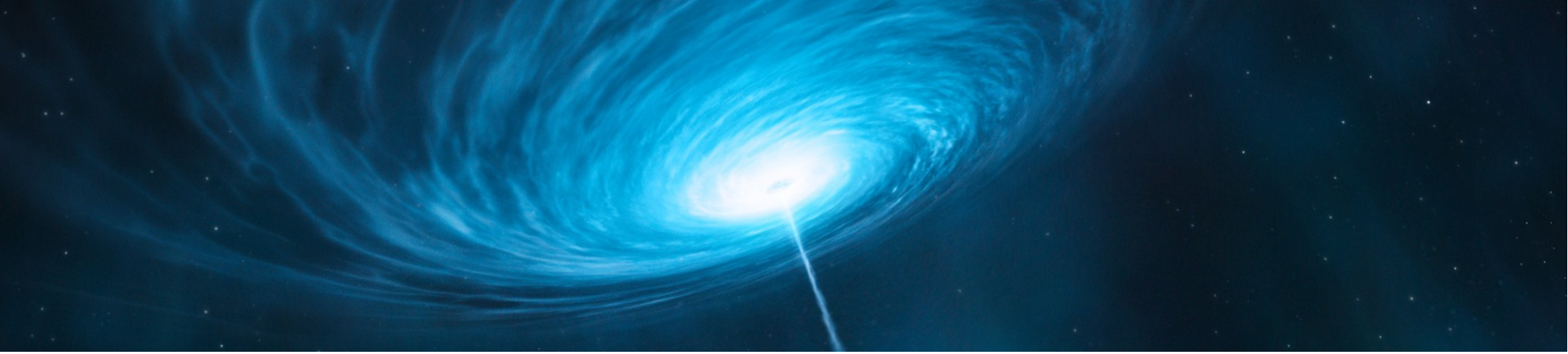


Investigating clumpy AGN models with UV/optical polarimetry

Frédéric Marin
René W. Goosmann

ASTRONOMICKÝ ÚSTAV
Akademie věd České republiky, v. v. i.



Introduction to Active Galactic Nuclei

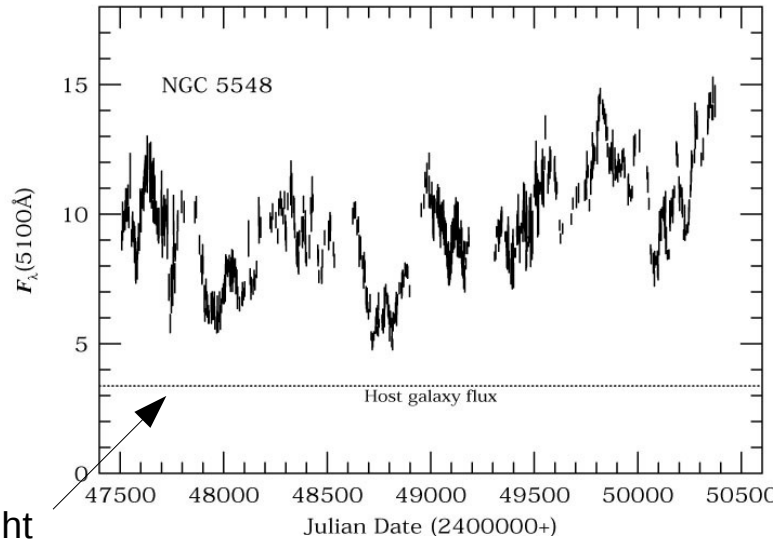
Characteristics:

- Extremely powerful, unresolved sources of optical/UV light
  → $L_{bol} \sim 10^{39\text{-}40}$ J/s (10^{13} times the L_{Sun}, 10^{4} times $L_{Milky\ Way}$)

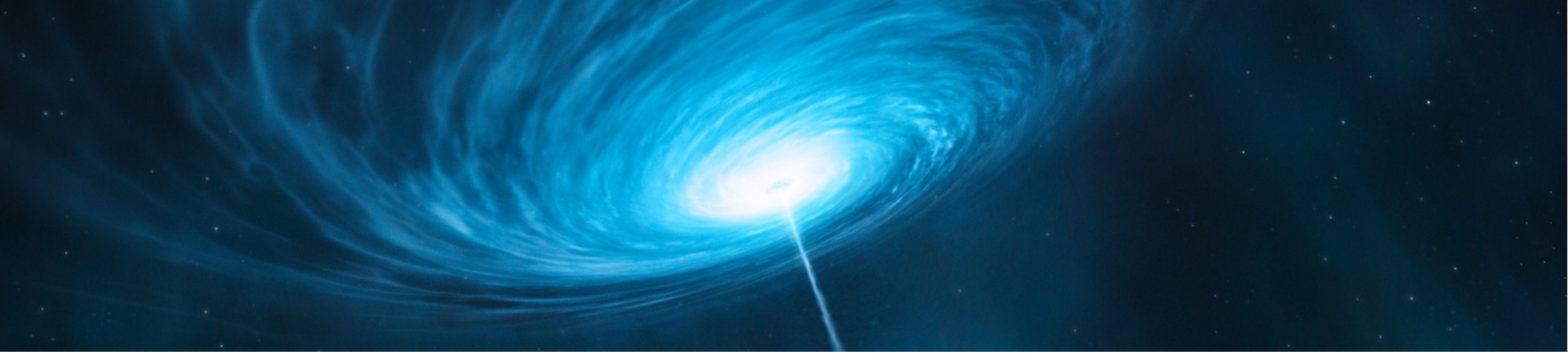
- Intrinsic, non-periodic, variable luminosity of unknown origin
  → even stronger in the X-ray domain
  → imprints of atomic features

- A fraction (10 – 25%) of quasars also emit large fluxes in the radio band
  → « radio-loud » objects
  (others are called « radio-quiet »)

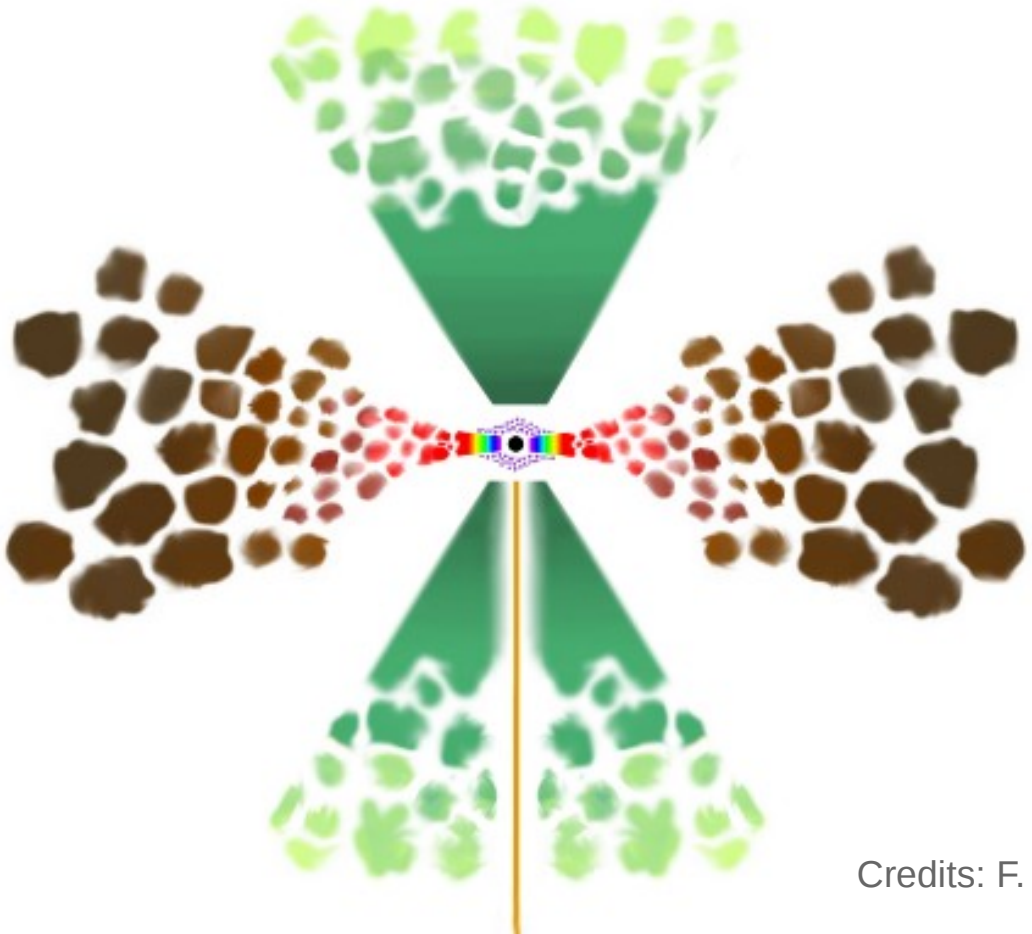
Peterson et al. (1999)



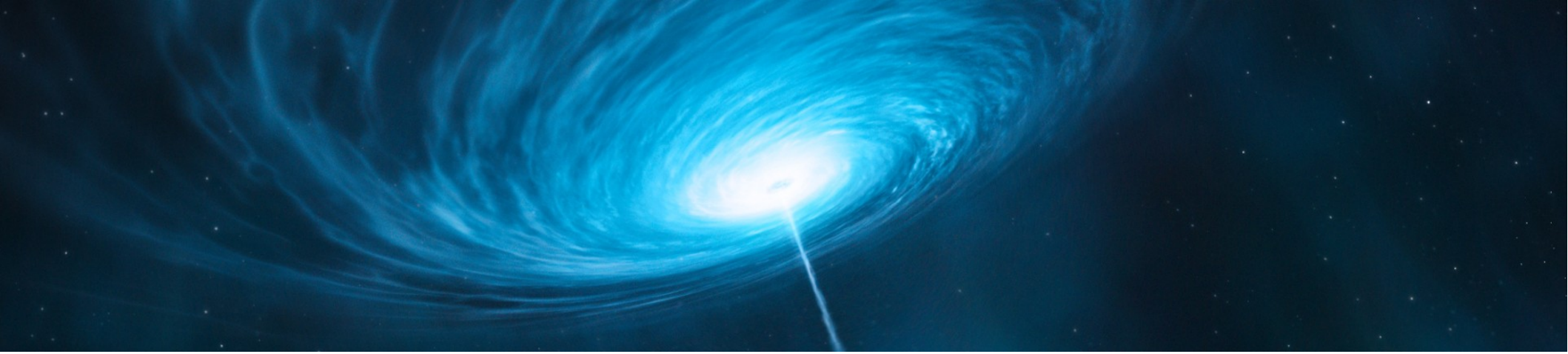
constant contribution from starlight



Introduction to Active Galactic Nuclei



Credits: F. Marin & J. Garreau



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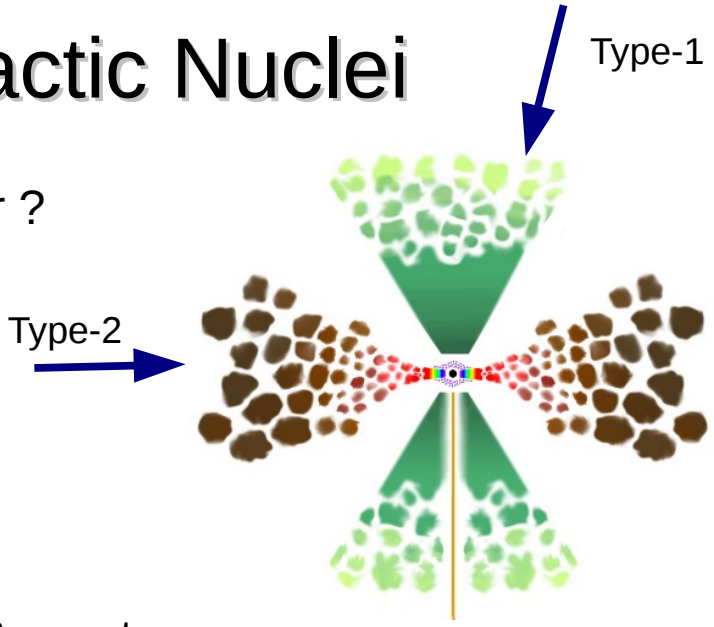
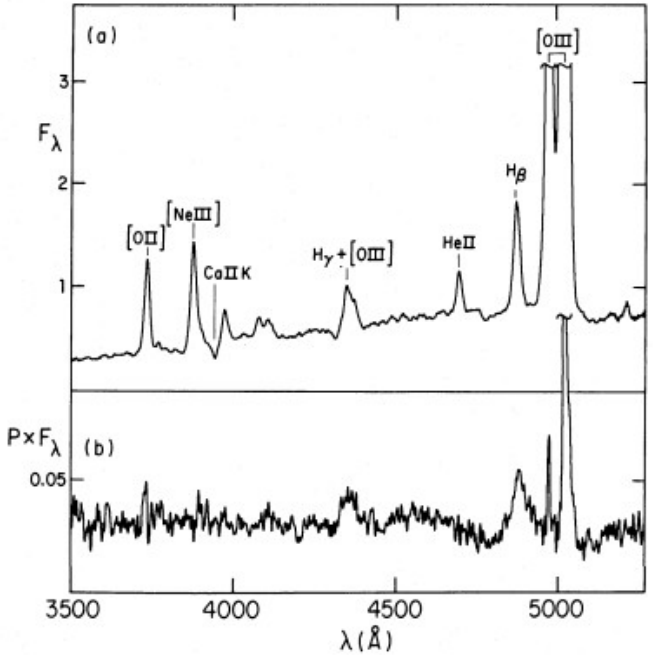


But how do we know that type-1 and type-2 AGN are similar ?

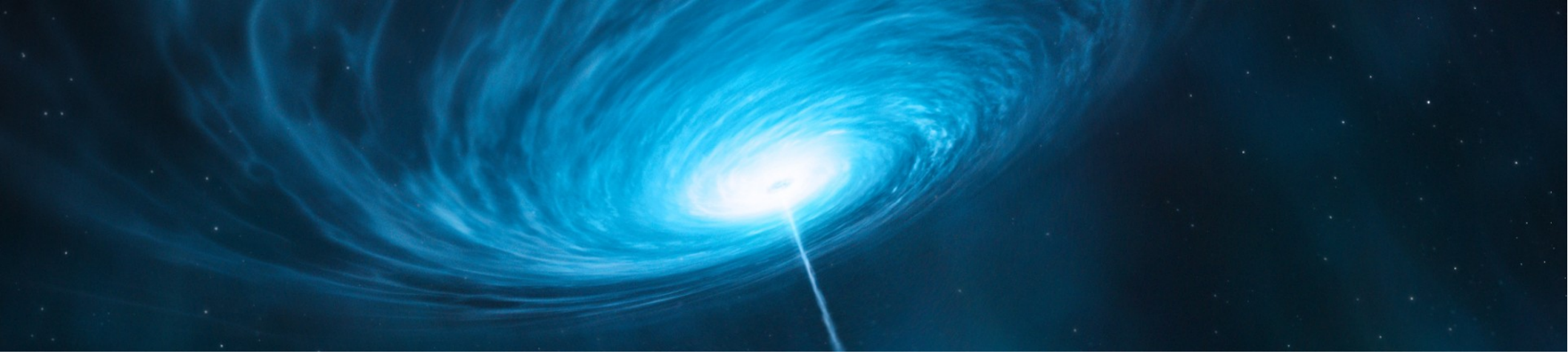
Observation of NGC 1068 (Seyfert-2)



→ Spectroscopy: type-2 spectrum
→ Polarimetry: broad Balmer lines (type-1 signature)

Through a periscopic view, we see the nuclear region of NGC 1068 scattered on the ionization cones

Antonucci & Miller (1985)



Polarization as a key mechanism

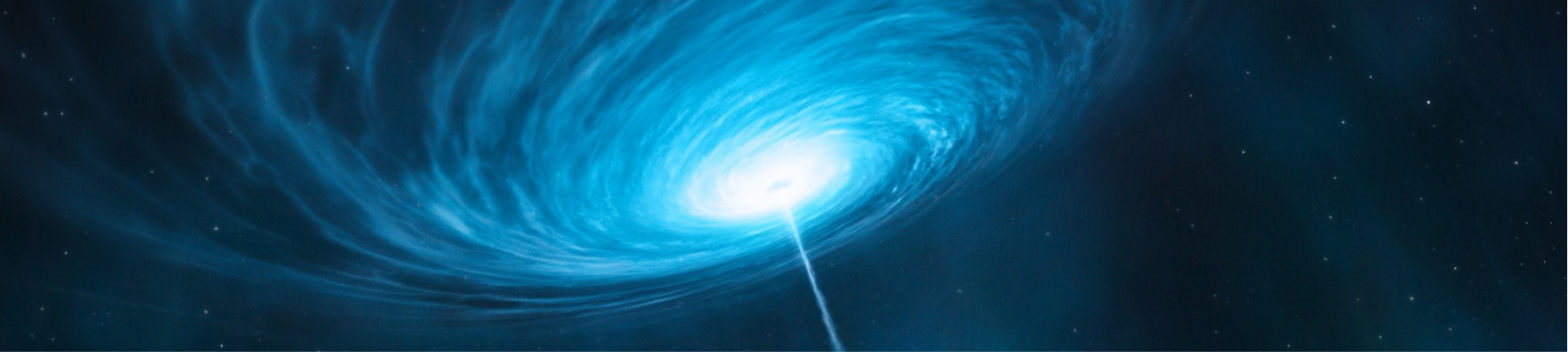
Why using polarimetry in AGN studies ?

The energetically dominant central engine radiation is « polluted » by the contributions from neighboring reprocessing regions

- atomic emission lines (disk, BLR)
- bound-free continua (Paschen, Balmer lines : BLR)
- infrared, thermal and nonthermal dust (re)emission (torus, NLR)
- starlight from the host galaxy

But we are lucky: all those components emit unpolarized light !

→ Polarization is a way to measure the true continuum emission of AGN



The STOKES code

Monte Carlo radiative transfer

In order to:

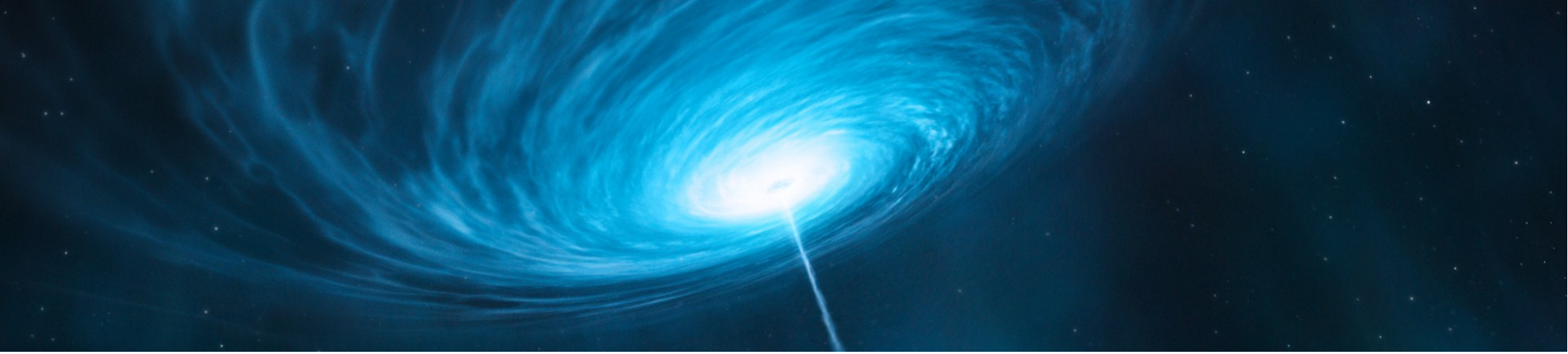
- reproduce / understand observed polarimetric spectra
- check the validity of on-going models
- predict observations

we need to achived state-of-the-art radiative transfer simulations

→ STOKES

(Goosmann & Gaskell 2007 ; Marin et al. 2012 ; Marin, Goosmann & Gaskell 2015)

Thanks to STSM !



The STOKES code

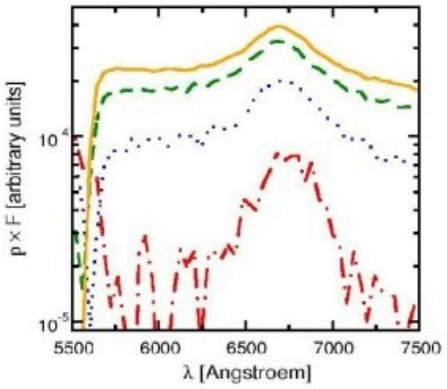
Monte Carlo radiative transfer

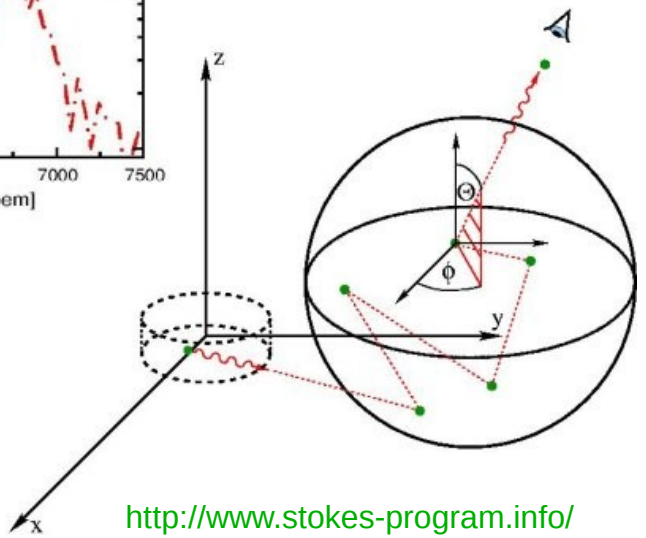
- Broadband MC code
  (from near IR to hard X-rays)
- 3D environment (any geometry)
- Radiative coupling
- Imaging algorithm
- Scattering on multiple media
  (dust, electrons, atoms, ions, molecules)
- 3D velocity field

+ coupling with other codes
  KY: GR effects (M. Dovciak)
  SKIRT: far-IR (M. Stalevski)
  TITAN: photo-ionization (A. Dumont)

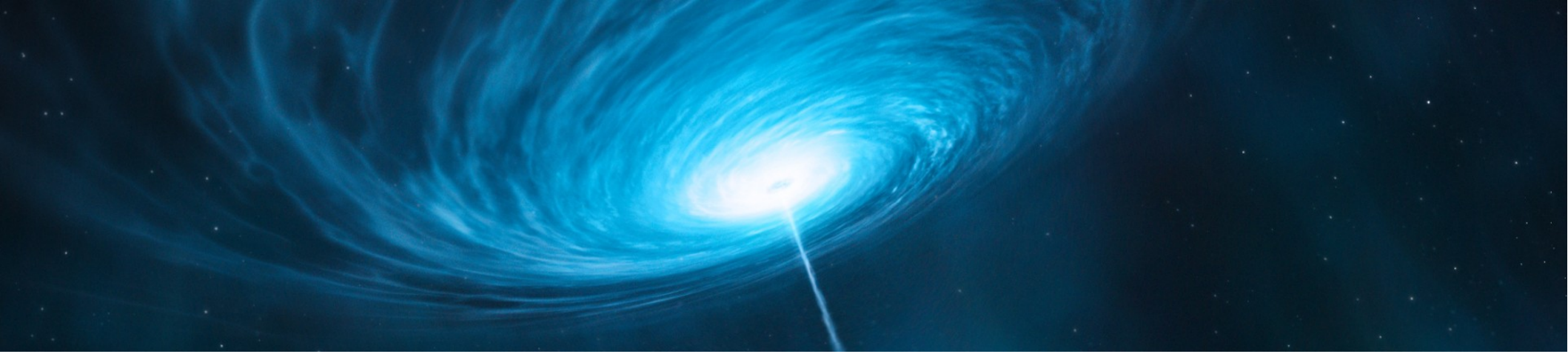
Another STSM !

Goosmann & Gaskell (2007)
Marin et al. (2012)
Marin et al. (submitted)





http://www.stokes-program.info/

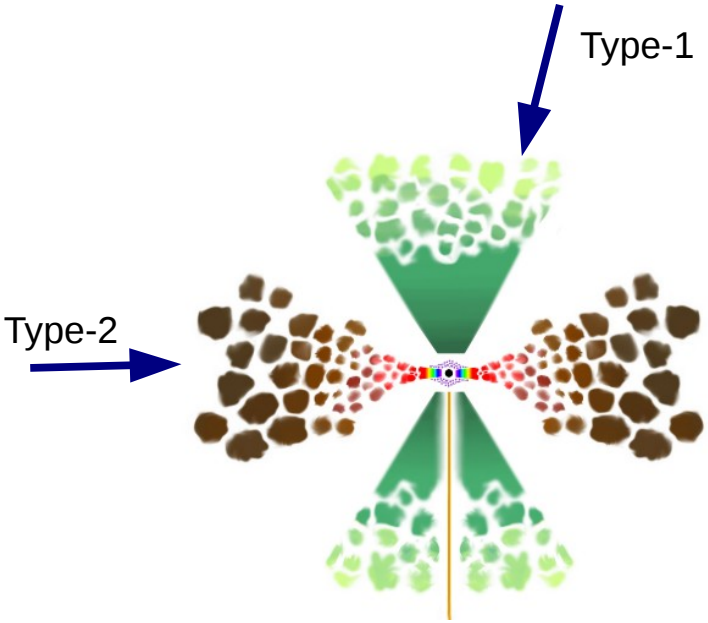


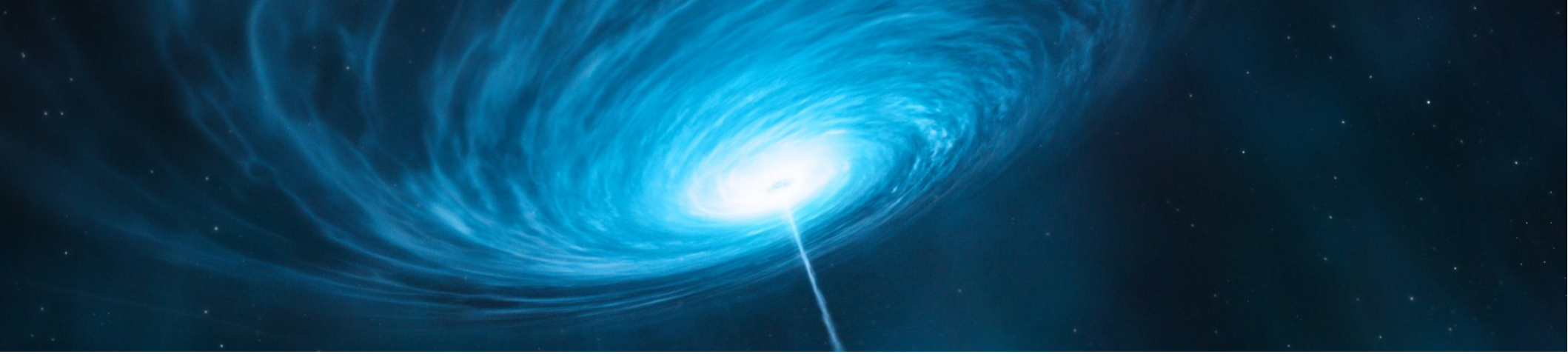
Multi-component simulations

The Unified Scheme

Most of the differences between type-1 and type-2 AGN can be explained by an orientation effect (Antonucci 1993)

→ different polarization signatures
→ investigation of the Unified Model
in the optical/UV band





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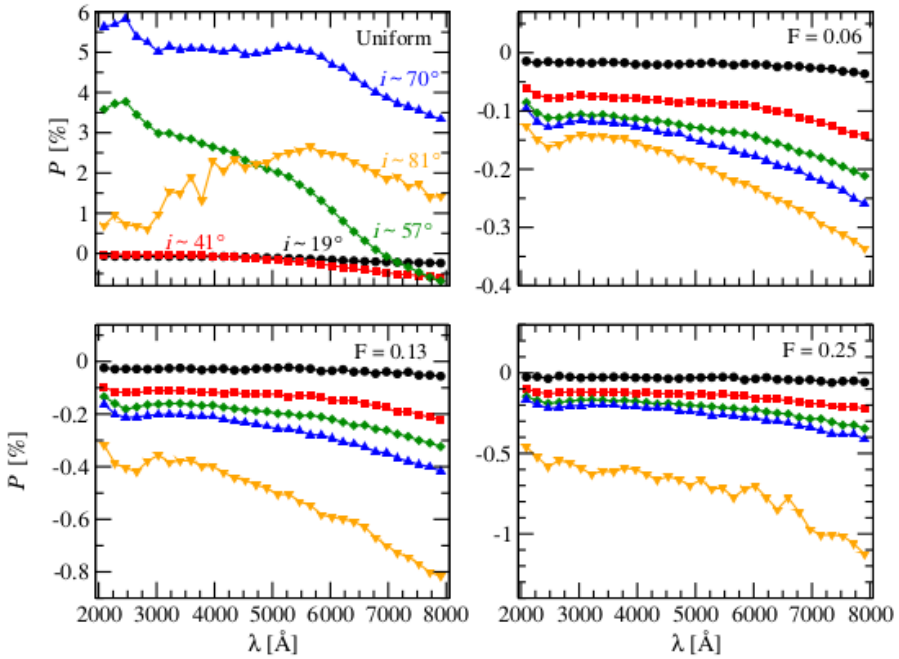
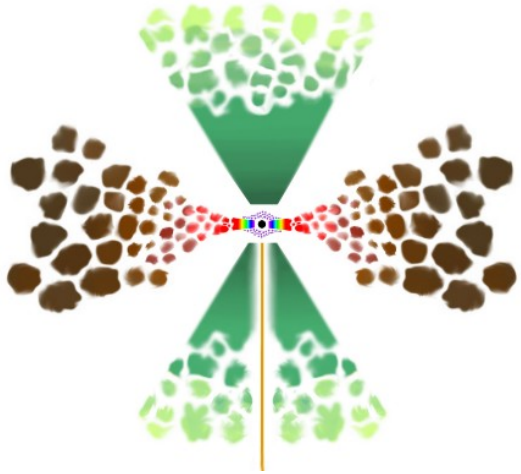
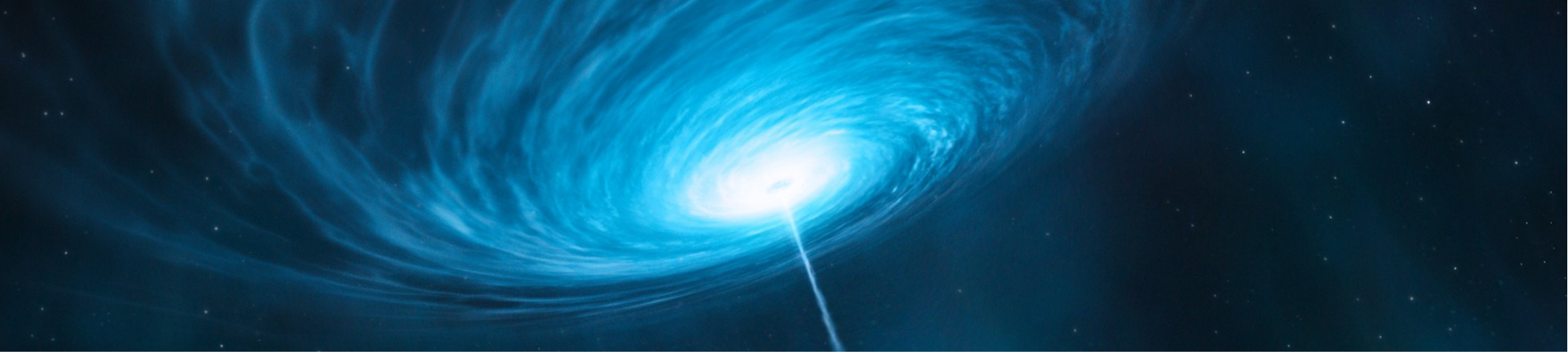


Extended torus

$\theta_0 = 45^o$



Marin, Goosmann & Gaskell (2015)



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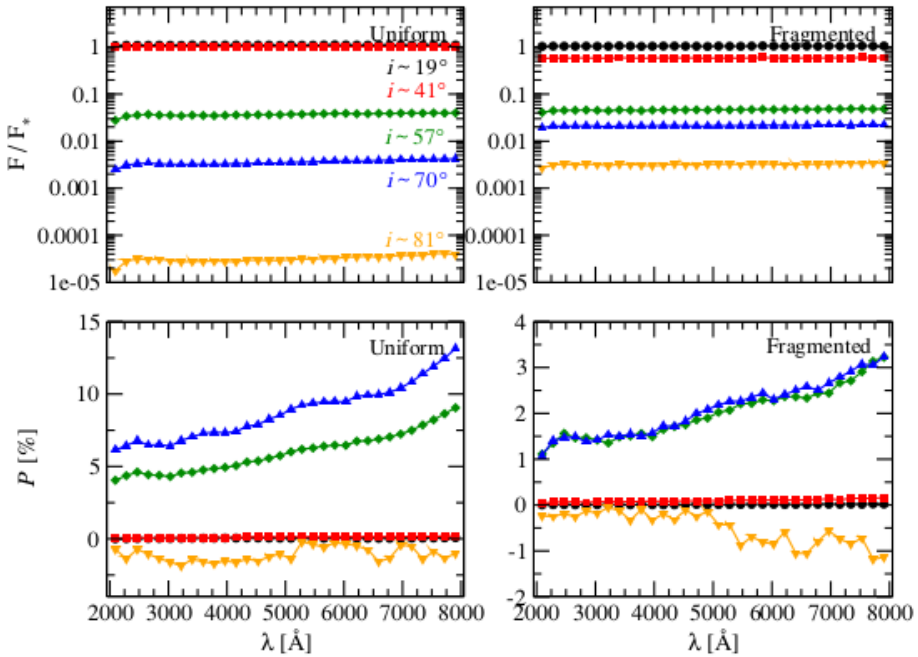

Compact torus

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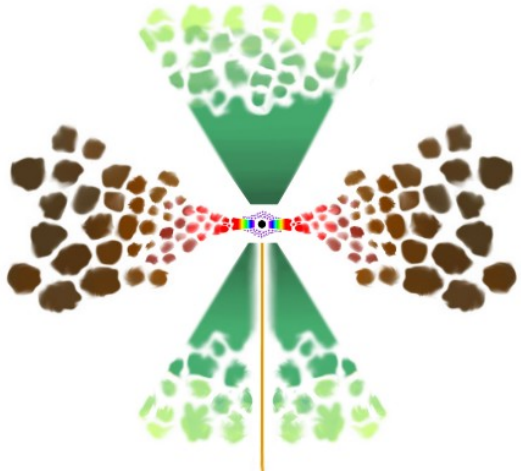

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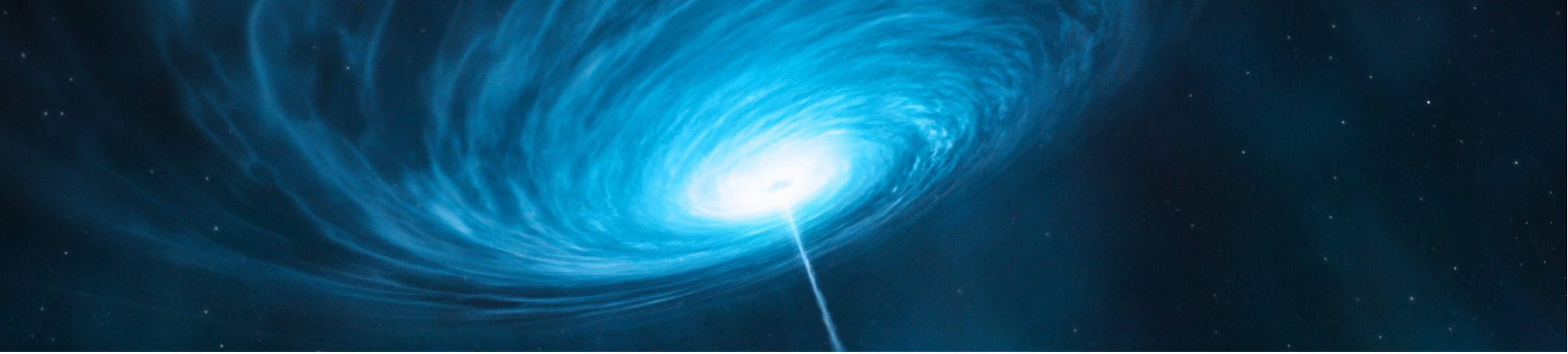

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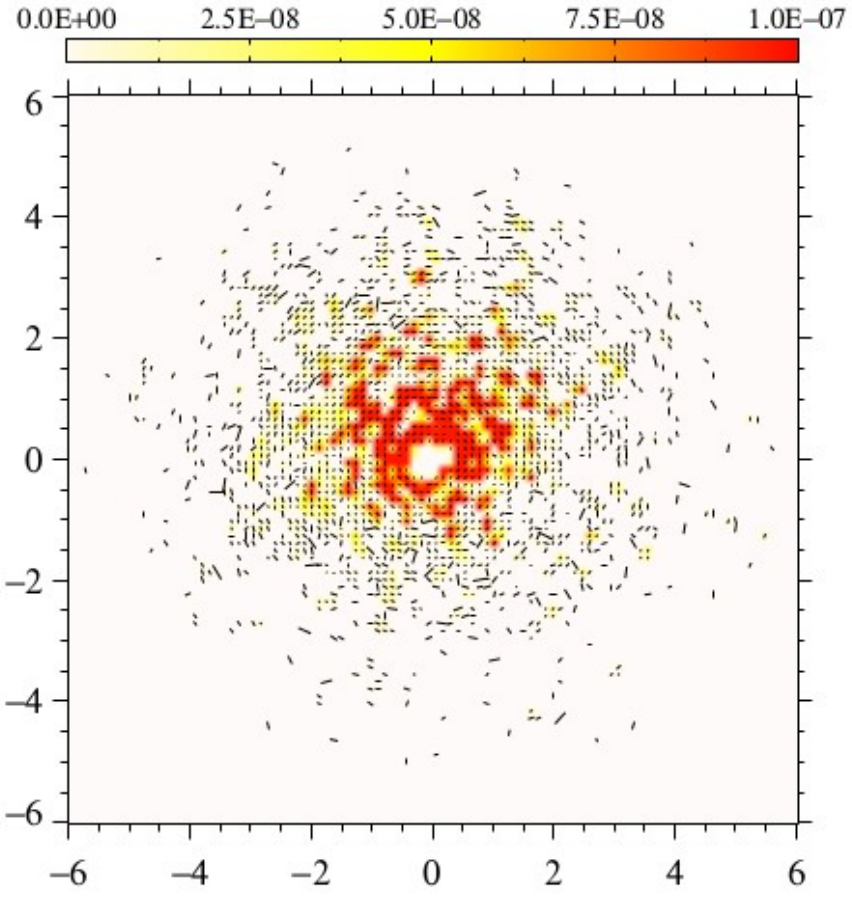

Illustrating the imaging capabilities of STOKES (2000 clumps, axes in parsecs, almost pole-on view)

Compact torus

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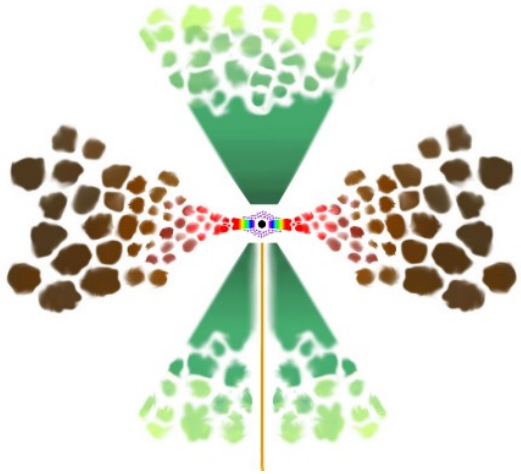

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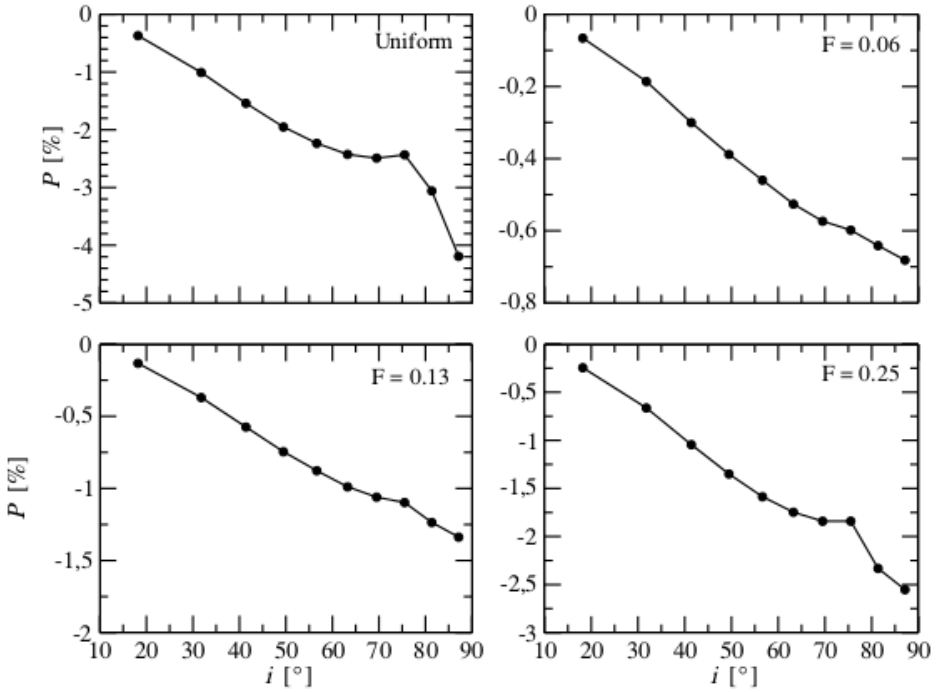
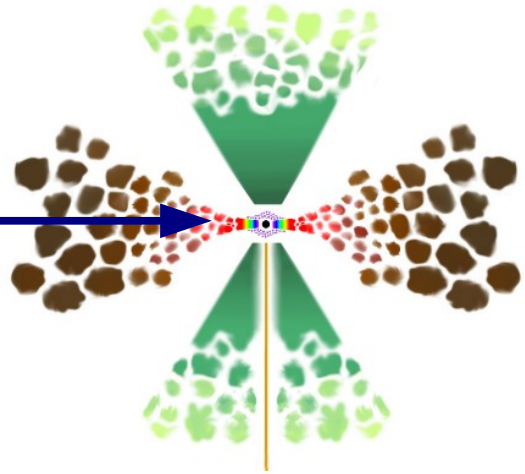
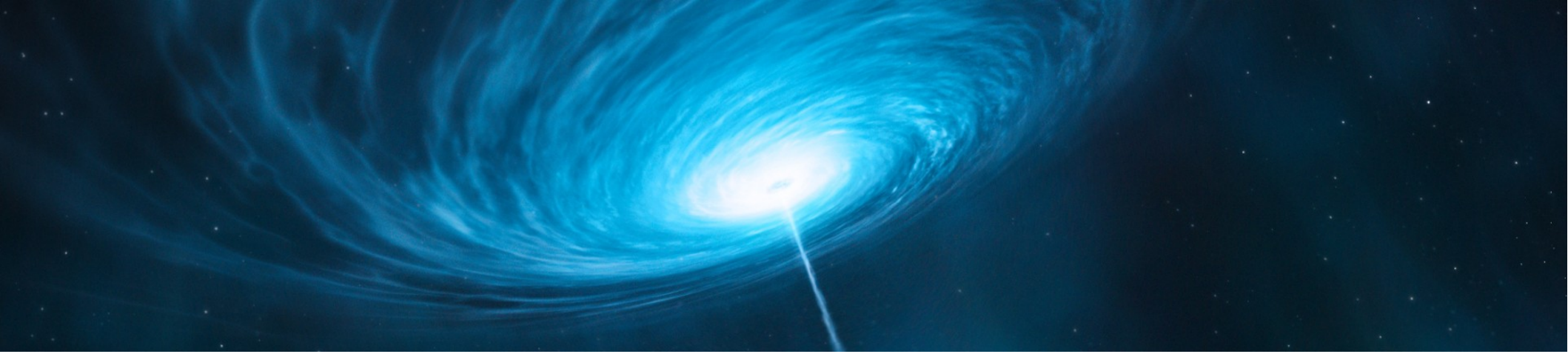


Radiation-supported disk



Marin, Goosmann & Gaskell (2015)



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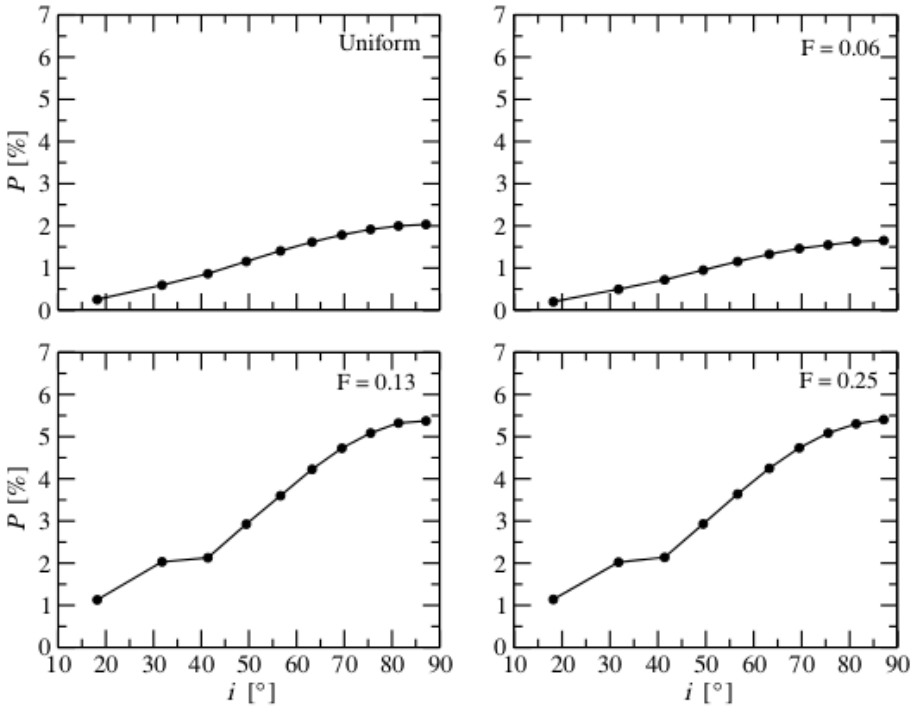
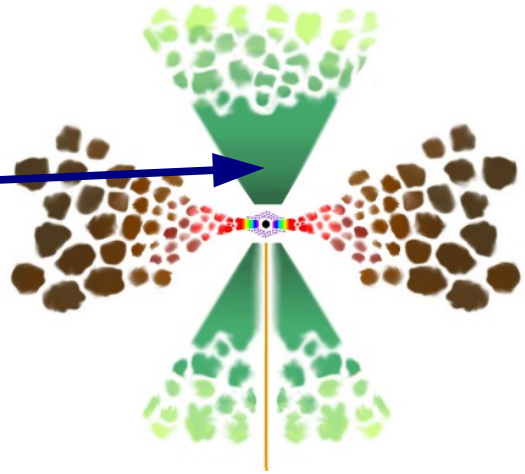


Ionized winds



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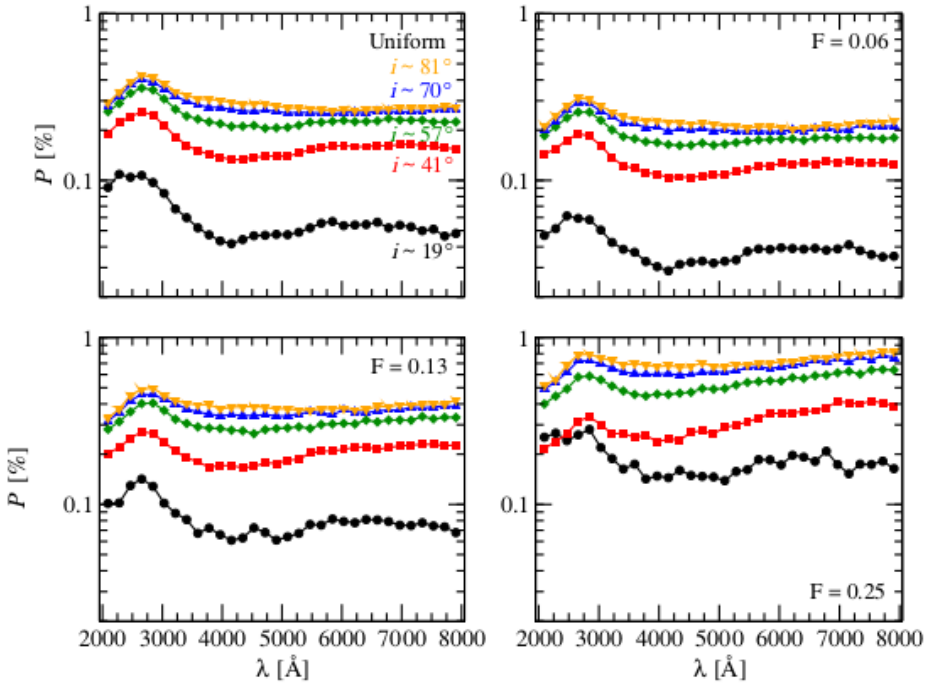

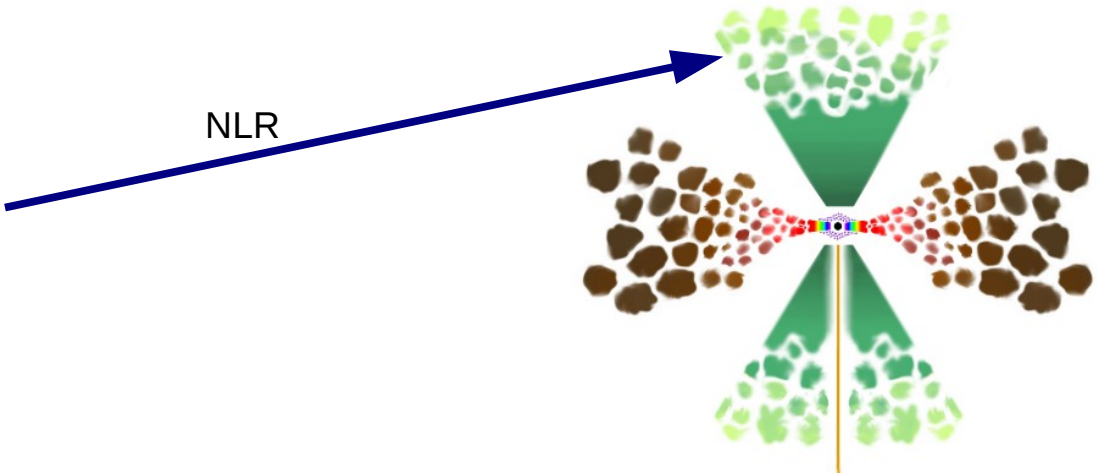

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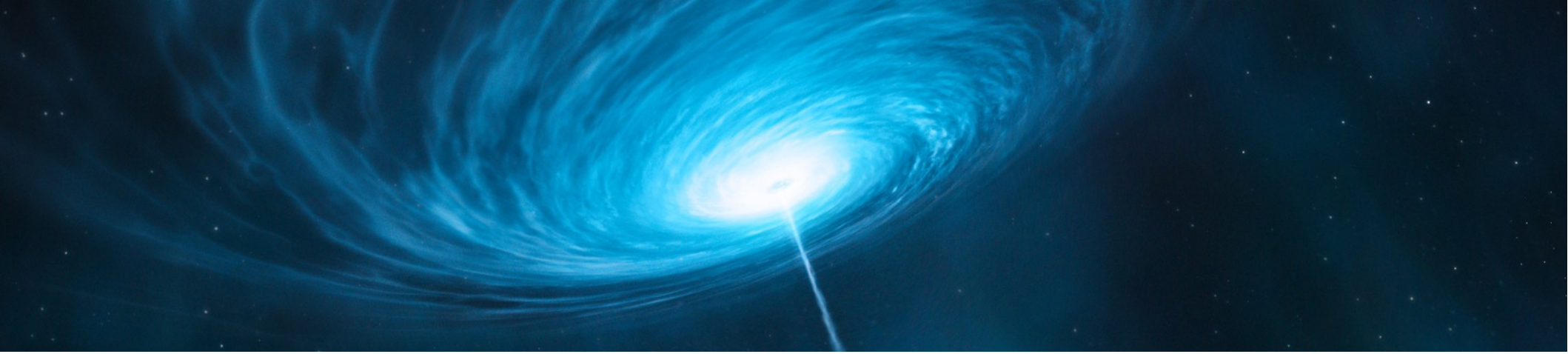

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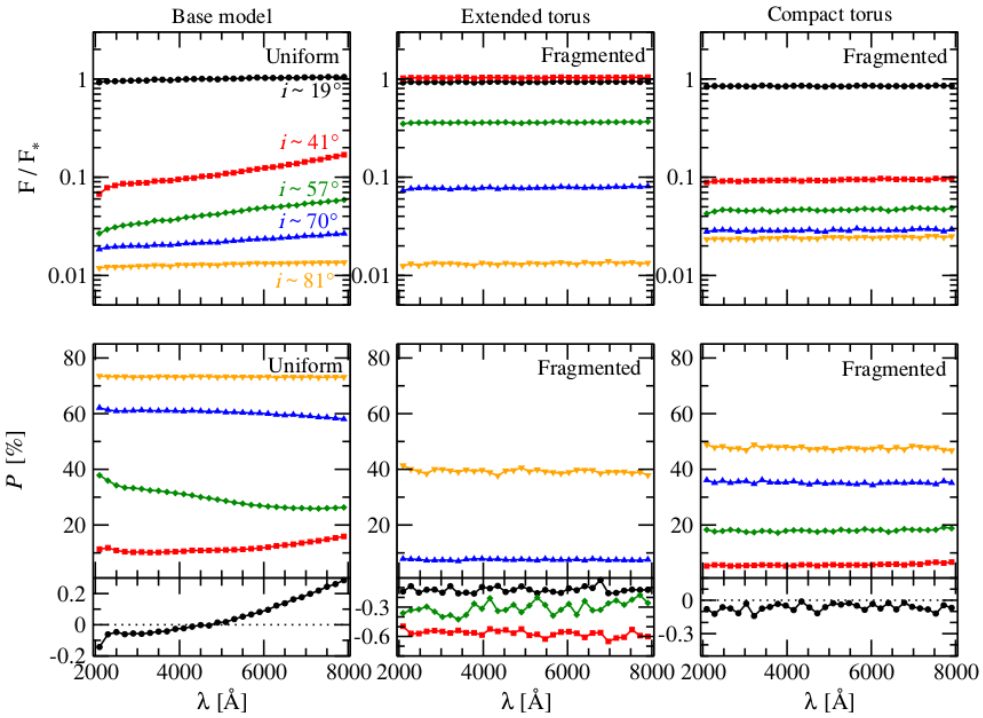
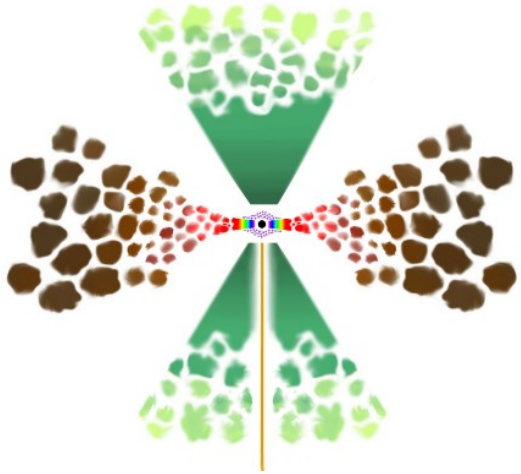


AGN



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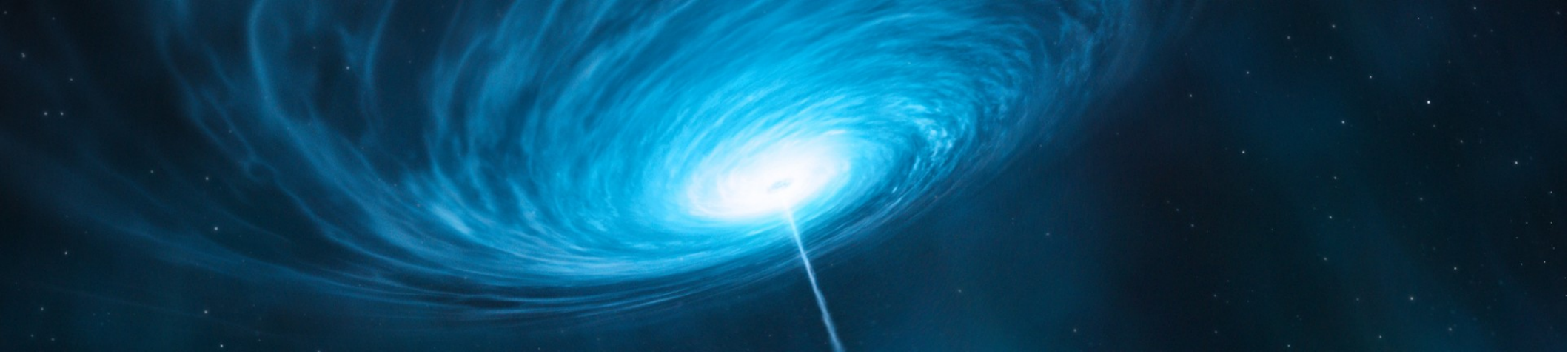


Conclusions

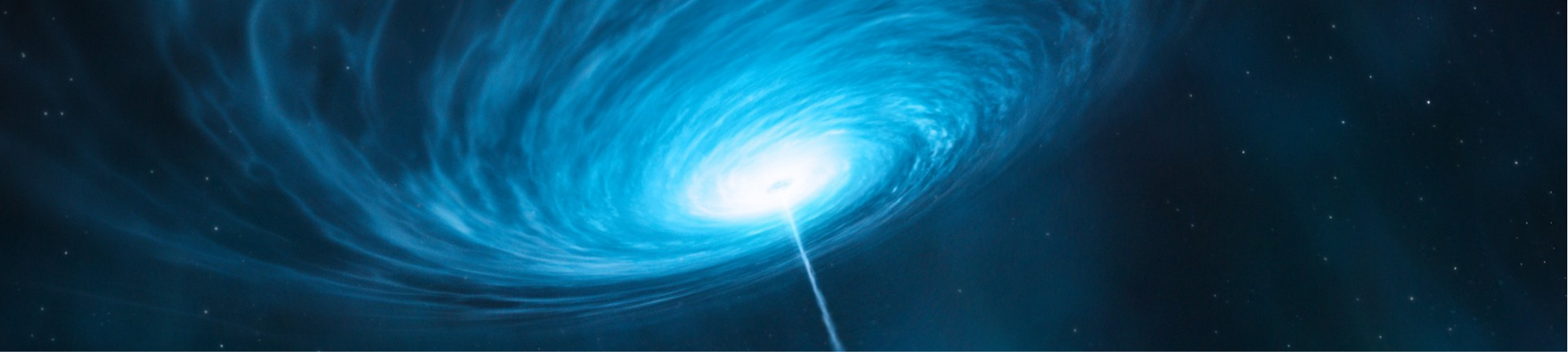
Optical/UV modeling of clumpy AGN
Achieved thanks to the STSM support

Tests of uniform-density versus fragmented models

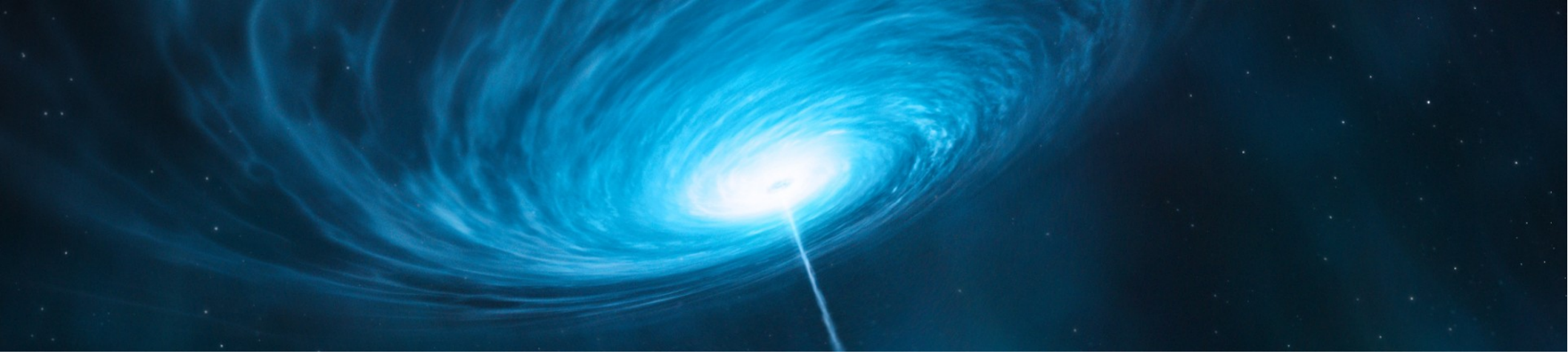
→ equatorial distributions of clumps, either for a dusty torus or an ionized accretion flow, decrease the net *P*, independently of the filling factor.

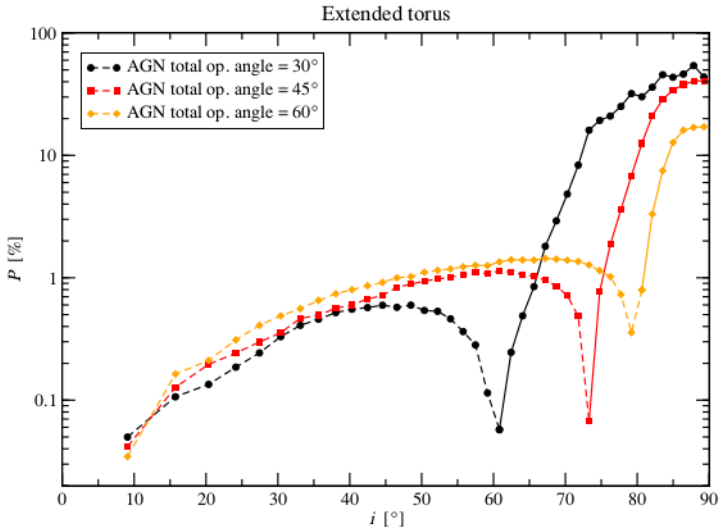
→ in the case of scattering regions distributed along the polar directions, the impact of fragmentation is reduced: a small number of clouds is able to properly reproduce the polarization behavior of uniform-density models

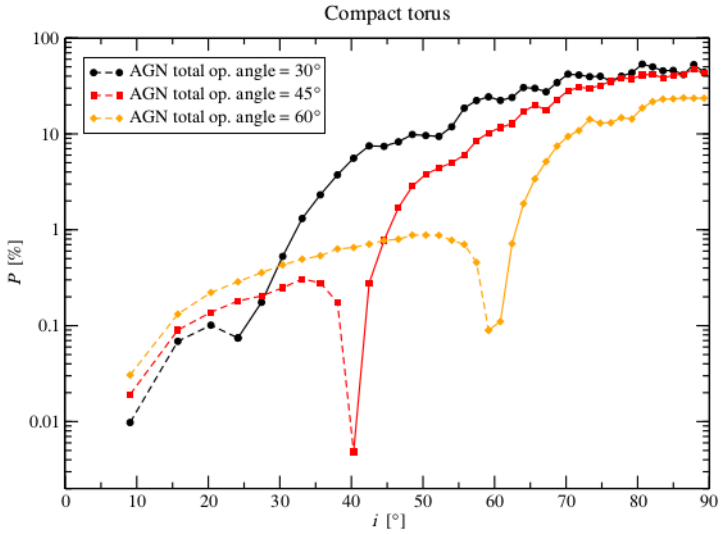
→ large, fragmented tori are not viable solutions to replace geometrically flat, uniform-density dust distributions regardless of their half-opening angle;
compact circumnuclear structures must be favored



Supplementary material







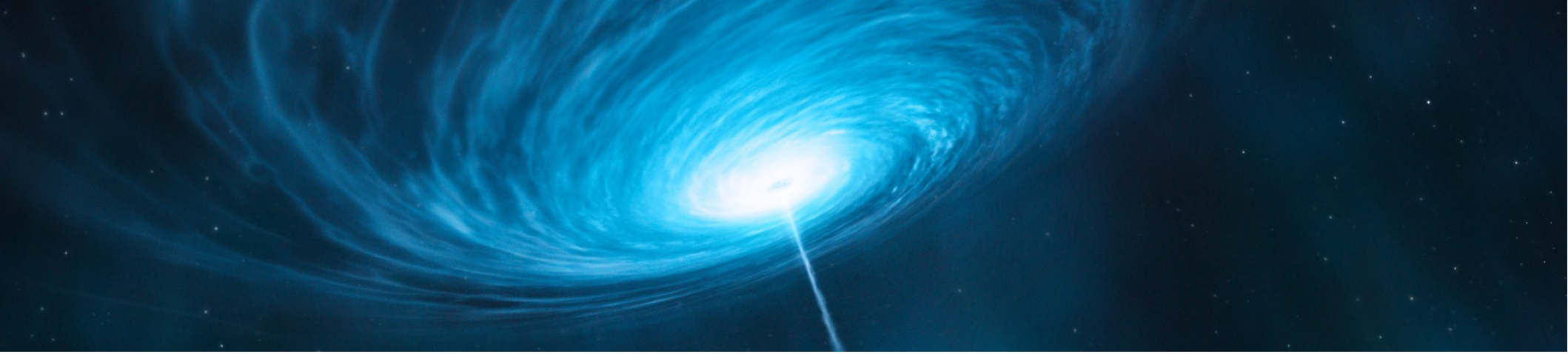
Investigating the opening angle of the system

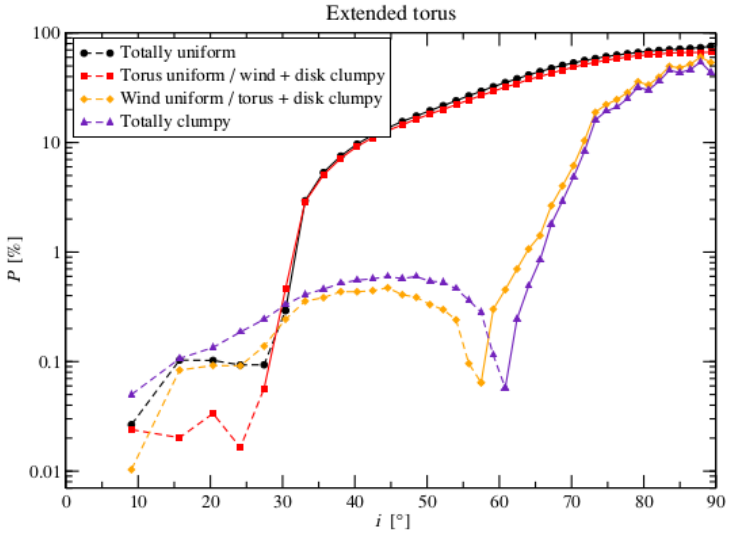
Opening angle of the system determined by the torus half-opening angle

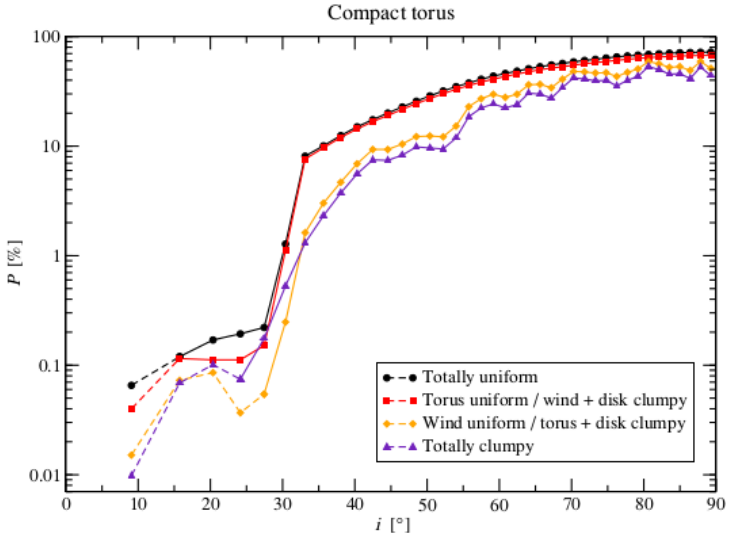
Ionized winds are collimated by the dusty funnel

Extended dusty tori predict a very large of type-1 AGN, independently of their opening angle

Marin, Goosmann & Gaskell (2015)







Investigating the clumpiness of the system

Can an AGN model being computed with a blend of uniform-density and fragmented regions ?

Extended tori deeply impact the resulting polarization degree and polarization position angle

Marin, Goosmann & Gaskell (2015)