The Highly Polarized Infrared Core of Cygnus A

Lopez-Rodriguez, Enrique[1,2]; Antonucci, Robert[3]; Chari, Ranga-Ram[4]; Kishimoto, Makoto[5].

[1]SOFIA Science Center, [2]National Astronomical Observatory of Japan (NAOJ), [3]University of California Santa Barbara, [4]IPAC/Caltech, [5]Kyoto Sangyo University.

Lopez-Rodriguez et al. (2018, ApJ, 861, 23)

We report the detection of linearly polarized emission at 53 and 89 μm from the radio-loud active galactic nucleus (AGN) Cygnus A using HAWC+ onboard SOFIA. We measure a highly polarized core of 11±3% and 9±2% with a position angle (P.A.) of polarization of 43±8° and 39±7° at 53 and 89 μm, respectively. We find (1) a synchrotron dominated core with a flat spectrum (+0.21±0.05) and a turn-over at 543±120 μm, which implies synchrotron emission is insignificant in the infrared (IR), and (2) a 2-500 μm bump peaking at ~40 μm described by a blackbody component with color temperature of 107±9 K. The polarized SED has the same shape as the IR bump of the total flux SED. We observe a change in the P.A. of polarization of ~20° from 2 to 89 μm, which suggests a change of polarization mechanisms. The ultraviolet, optical and near-IR polarization has been convincingly attributed to scattering by polar dust, consistent with the usual torus scenario, though this scattered component can only be directly observed from the core in the near-IR. By contrast, the gradual rotation by ~20° towards the far-IR, and the near-perfect match between the total and polarized IR bumps, indicate that dust emission from aligned dust grains becomes dominant at 10-100 μm, with a large polarization of 10% at a nearly constant P.A. This result suggests that a coherent dusty and magnetic field structure dominates the 10-100 μm emission.

Cygnus A

At a redshift of 0.0562 (H_o = 73 km s^{-1} Mpc^{-1}, 1" ~ 1 kpc), Cygnus A is one of the most studied Faranoff-Riley class II radio galaxies. Cygnus A shows complex structures: an obscured core with a patchy dust lane, ionization cones and jets. Although optical total flux emission from the central engine (black hole and accretion disk) is not observed directly, due to the high visual extinction (A_v ~ 94 mag; Tadhunter et al. 1990), we see the broad lines of the hidden quasar in the polarized flux spectrum (e.g. Tadhunter et al. 1990, Ogle et al. 1997). This result proves the presence of broad polarized emission lines in the central engine scattered into our line of sight (LOS), which would otherwise be obscured by the geometrically and optically thick and dusty torus. Such interpretation is entirely consistent with the unified model (Antonucci 1993) of active galactic nuclei (AGN). Further high-angular resolution observations at IR wavelengths were necessary to study the core of Cygnus A. A highly polarized, ~10%, core at 2.0 μm with a position angle (PA) of polarization ,~21°. almost perpendicular to the direction of the radio jet (PA_{jet} ~104°) was observed using *HST*/NICMOS (Tadhunter et al. 2000). These authors suggested that the nuclear 2.0 μm polarization arises from an unresolved scattering region close to the central engine. We here report the detection of a highly polarized core in the 10-100 μm with a fairy constant degree of polarization and a change of ~20° in the PA of polarization, which indicates that another polarization mechanism from that at UV-Near-IR wavelengths may dominate at these wavelengths.

1 Synchrotron emission has a turn-over at 500 ± 120 μm. This component is insignificant at infrared wavelengths.

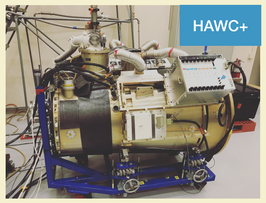
2 Total and Polarized infrared flux SED have the same shape, which indicates that the same physical component dominates the IR emission.

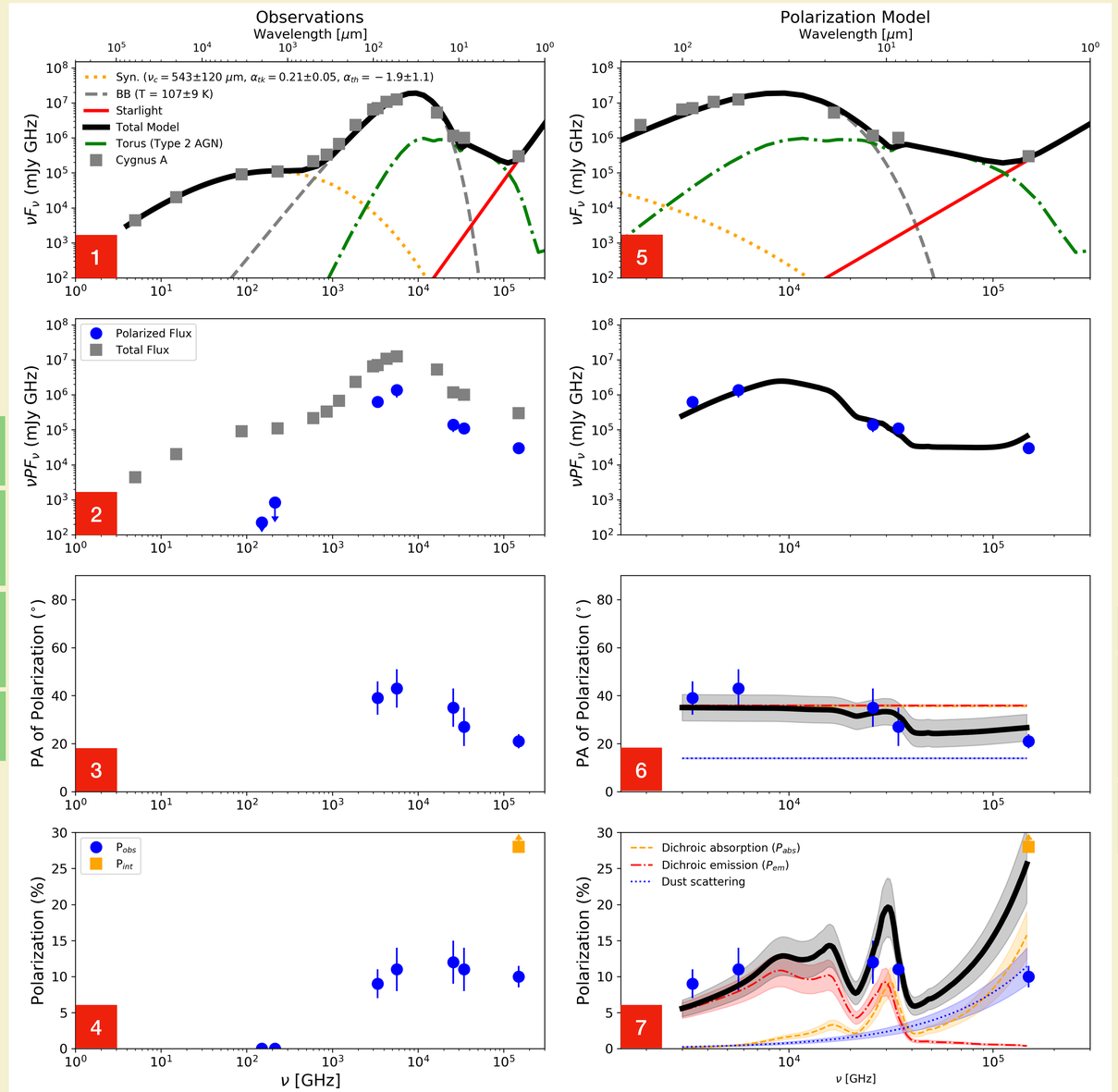
3 Position angle of polarization gradually changes with wavelength, which indicates the contribution of several polarization mechanisms.

4 Degree of polarization is fairly constant from 2 μm to 100 μm.

Far-infrared Polarimetric Observations with SOFIA

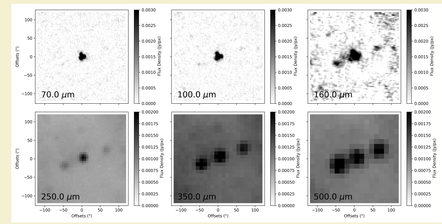
Cygnus A was observed with the newest SOFIA instrument, the High-resolution Airborne Wideband Camera-plus (HAWC+). We made observations using the chop-nod polarimetric mode at 53 and 89 μm with beam sizes of 4.85" and 7.80", respectively. Final observations provide a total exposure time of 1399s and 1483s at 53 and 89 μm, respectively. Polarimetric measurements within the beam size provide a single statistically significant polarization at the 4σ level in the degree of polarization.





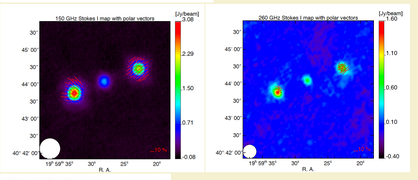
Supporting Observations

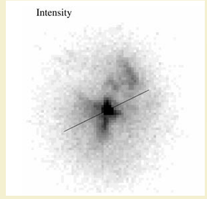
We compiled the total and polarized spectral energy distribution (SED) of Cygnus A with the best angular resolution from 2 μm to sub-mm wavelengths.

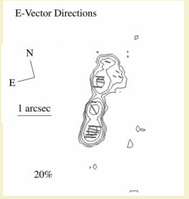


Herschel observations show an unresolved core from 70 to 500 μm. The jet power increase as wavelength increases (*Herschel* Archive).

NIKA2/IRAM30 polarimetric observations show an unresolved and unpolarized core at 150 and 260 GHz. Jets are highly polarized (Ritacco et al. 2017).







NICMOS/HST total intensity observations show a resolved core with an ionization bicone at 2 μm. The core is highly polarized and only one side of the bicone is polarized (Tadhunter et al. 2000).

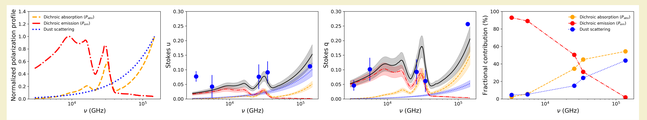
5 Total flux SED has an infrared bump peaking at ~40 μm.

6 2 μm polarization arises from dust scattering close to the core.
10-100 μm polarization arises from magnetically aligned dust grains.

7 20° change in the position angle of polarization can be explained by a change of polarization mechanisms.

Polarization Model

We use linear combinations of the dichroic absorption, emission and dust scattering profiles (first panel) to compute the Stokes qu (second and third panel). We find that polarization emission arising from aligned dust grains best describes the 10-100 μm measured polarization (fourth panel-red line). At 2 μm, dust scattering (fourth panel-blue line) is highly extinguished by dichroic absorption from the host galaxy (fourth panel-orange line).



Financial support for this work was provided by NASA through award #05 0071 (PI: Lopez-Rodriguez) issued by USRA. E.L.-R. acknowledges support from the Japanese Society for the Promotion of Science (JSPS) through award PE17783, the National Observatory of Japan (NAOJ) at Mitaka and the Thirty Meter Telescope (TMT) Office at NAOJ-Mitaka for providing a space to work and great collaborations during the short stay in Japan.

If you want to use SOFIA to observe your favorite radio galaxy, you have until September 7 to submit your proposal.

https://www.sofia.usra.edu/science/proposing-and-observing/proposal-calls/cycle-7

Antonucci et al. (1993, ARA&A, 31, 473)
Ogle et al. (1997, ApJ, 482, 320)
Ritacco et al. (2017, A&A, 599, 34)
Tadhunter et al. (1990, MNRAS, 246, 163)
Tadhunter et al. (2000, MNRAS, 313, 52)