Interferometric observations of the nuclear dust in active galactic nuclei

Obscured AGN Across Cosmic Time

Konrad R. W. Tristram

Collaborators:
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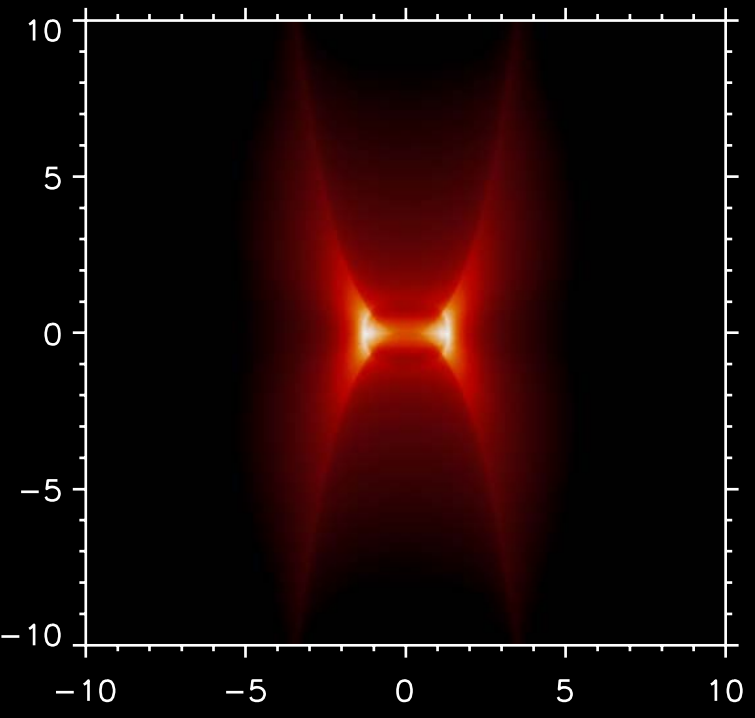
W. Jaffe, D. Raban (Sterrewacht Leiden), Bill Cotton (NRAO)

Introduction: Which instrument?

- Torus size: ~ 1 pc
  - ↳ Angular sizes for the nearest AGN: < 20 mas



continuous torus model
λ=10 μm, i=60°
Schartmann (2005)

Introduction: Which instrument?

- Torus size: ~ 1 pc
  - ↳ Angular sizes for the nearest AGN: < 20 mas
- Need MIR instruments with highest resolution!
  - ↳ Find this only at the VLTI: MIDI

VLT with the Residencia
February 2005

Introduction: Which instrument?

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- Need MIR instruments with highest resolution!
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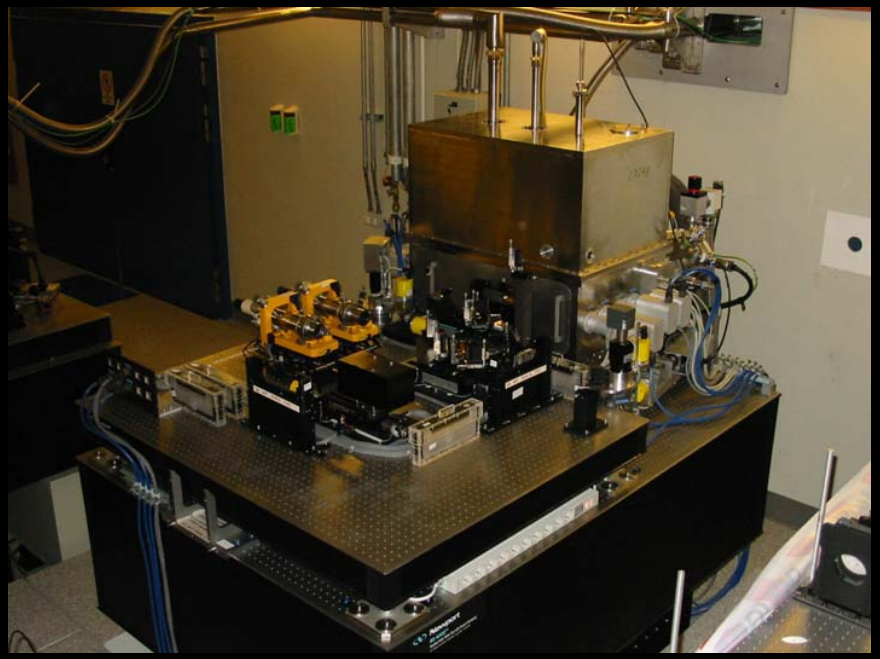
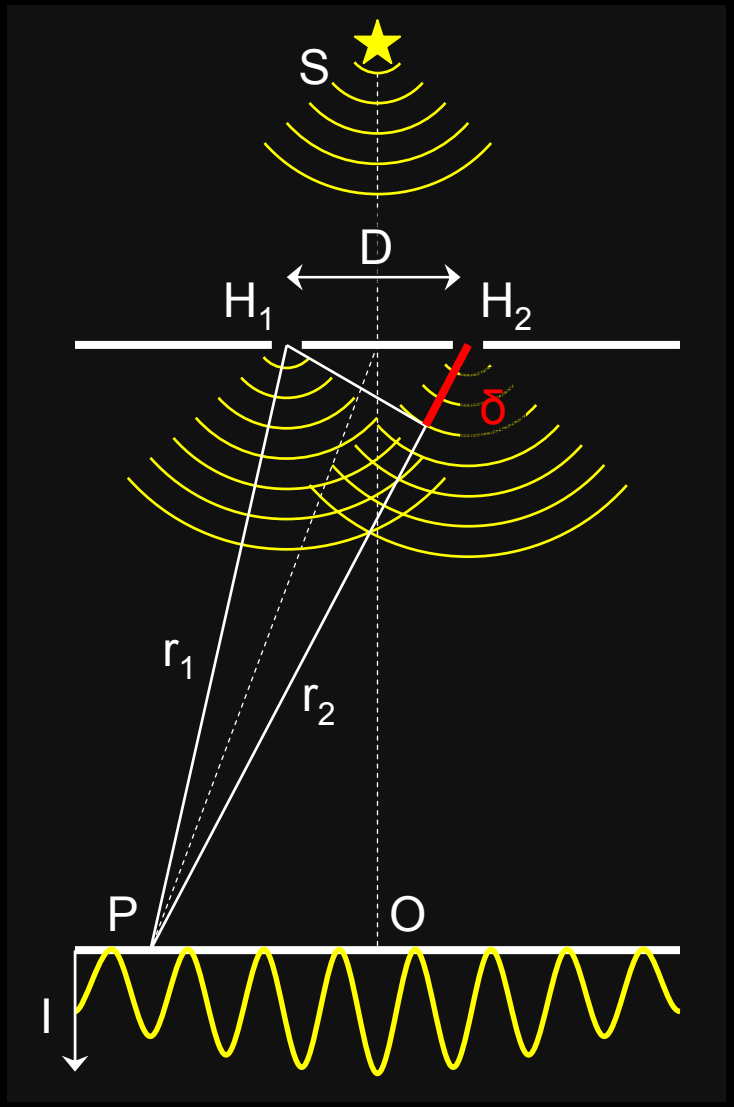
- MIDI
  - Dispersed fringes in the N-band (8 to 13 µm)
  - NaCl prism (R ~ 30)
  - Grism (R ~ 240)



MIDI in the VLTI lab

Introduction: MIR interferometry

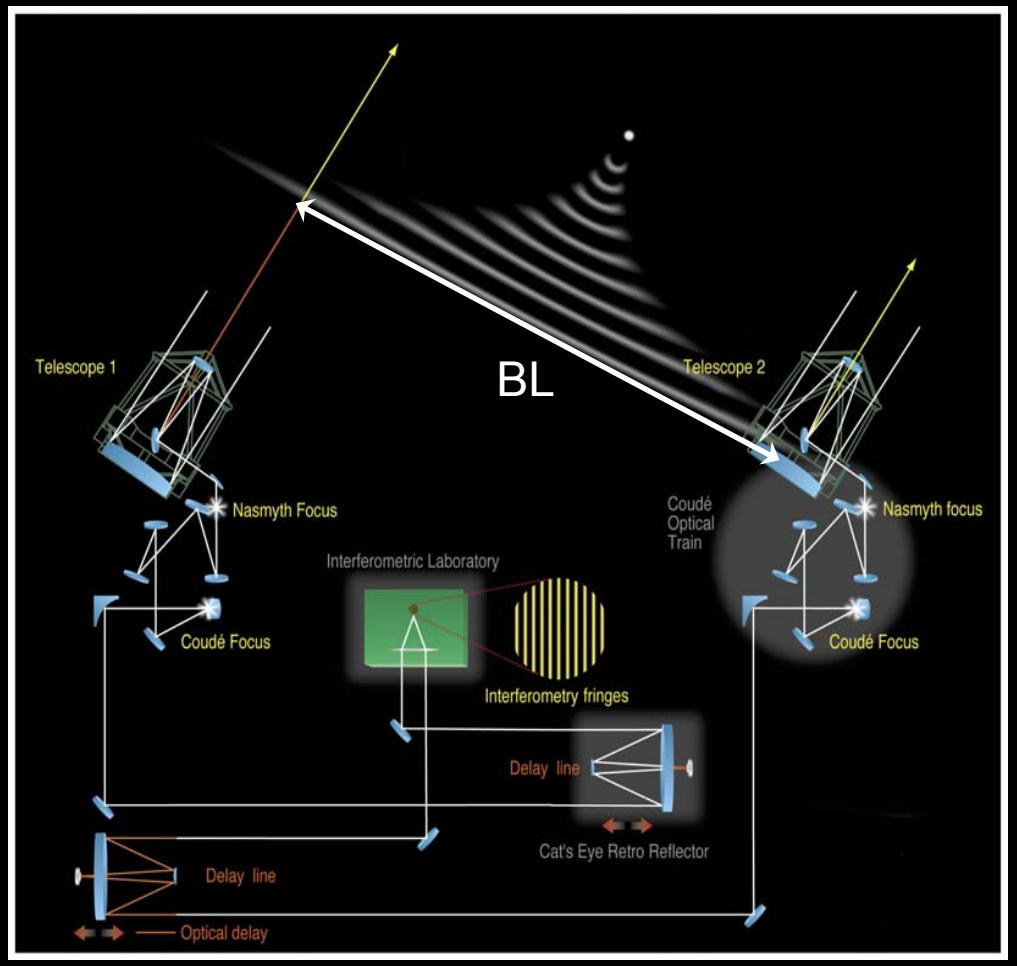
- Essentially Young's experiment



Introduction: MIR interferometry

- Essentially Young's experiment
- Correlated flux F_{cor}: flux in fringes
- Resolution:

$$\varphi = \frac{\lambda}{2 \cdot BL}$$



The VLTI interferometer

Introduction: Target list

List of all AGN observed to date:

Name	Flux (10 µm)	Time
Circinus	5.0 Jy	GTO
NGC 1068 (M77)	13.0 Jy	SDT / OT
NGC 5128 (Centaurus A)	0.6 Jy	GTO
NGC 3783	0.5 Jy	OT
Mrk 1239	0.4 Jy	GTO
MCG -05-23-016	0.3 Jy	GTO
NGC 7469	0.4 Jy	GTO
NGC 1365	0.6 Jy	GTO
IC 4329A	0.6 Jy	GTO
3C 273	0.3 Jy	GTO

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Circinus: General properties

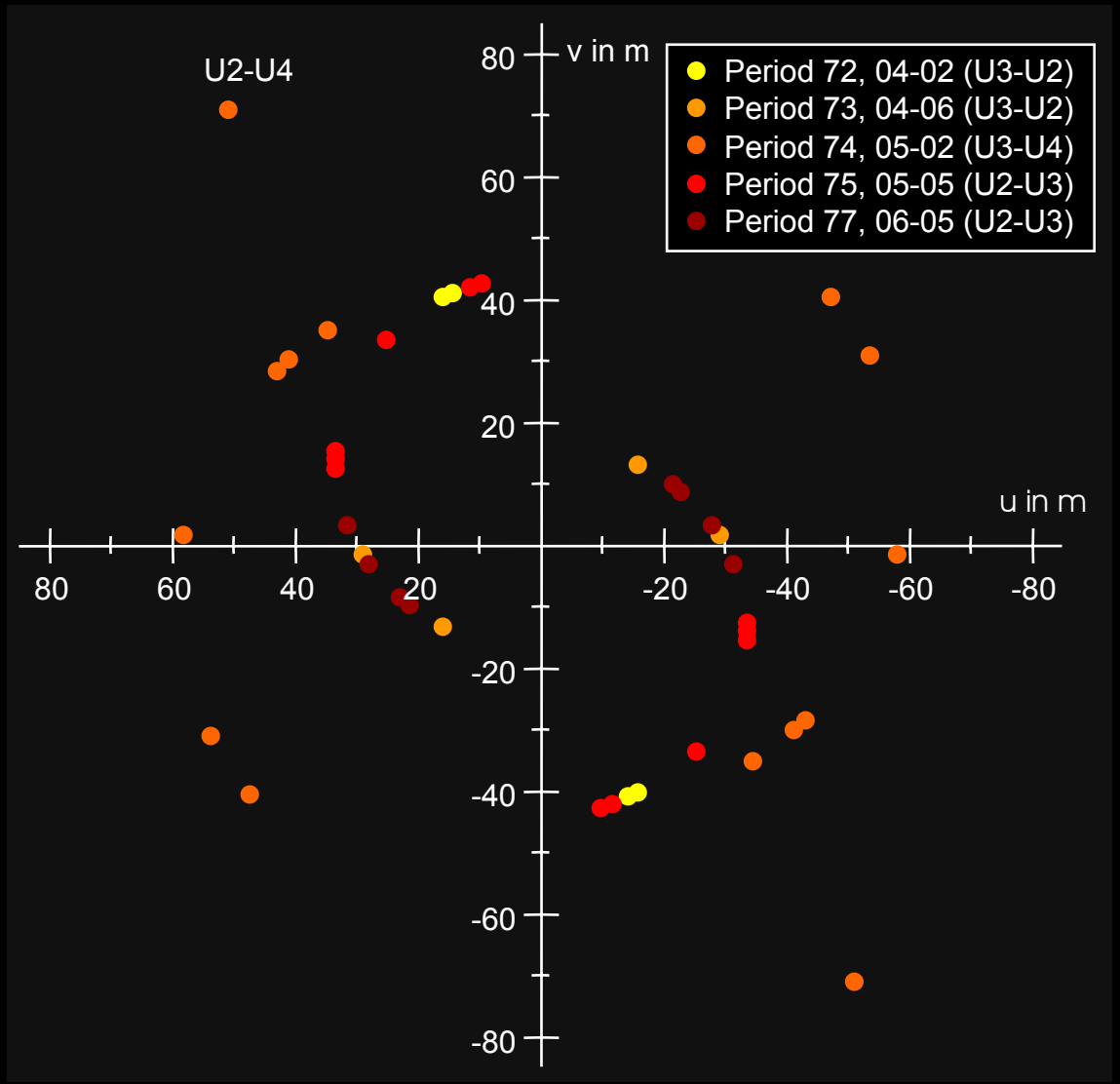
- Spiral galaxy SA(s)b, i = 65°
- Seyfert type 2
- $4 \times 10^6\ M_\odot$ nucleus
- Distance ~4 Mpc
  - ↳ 50 mas ~ 1 pc
- Circumnuclear starburst

2MASS J, H, K_s colour mosaic

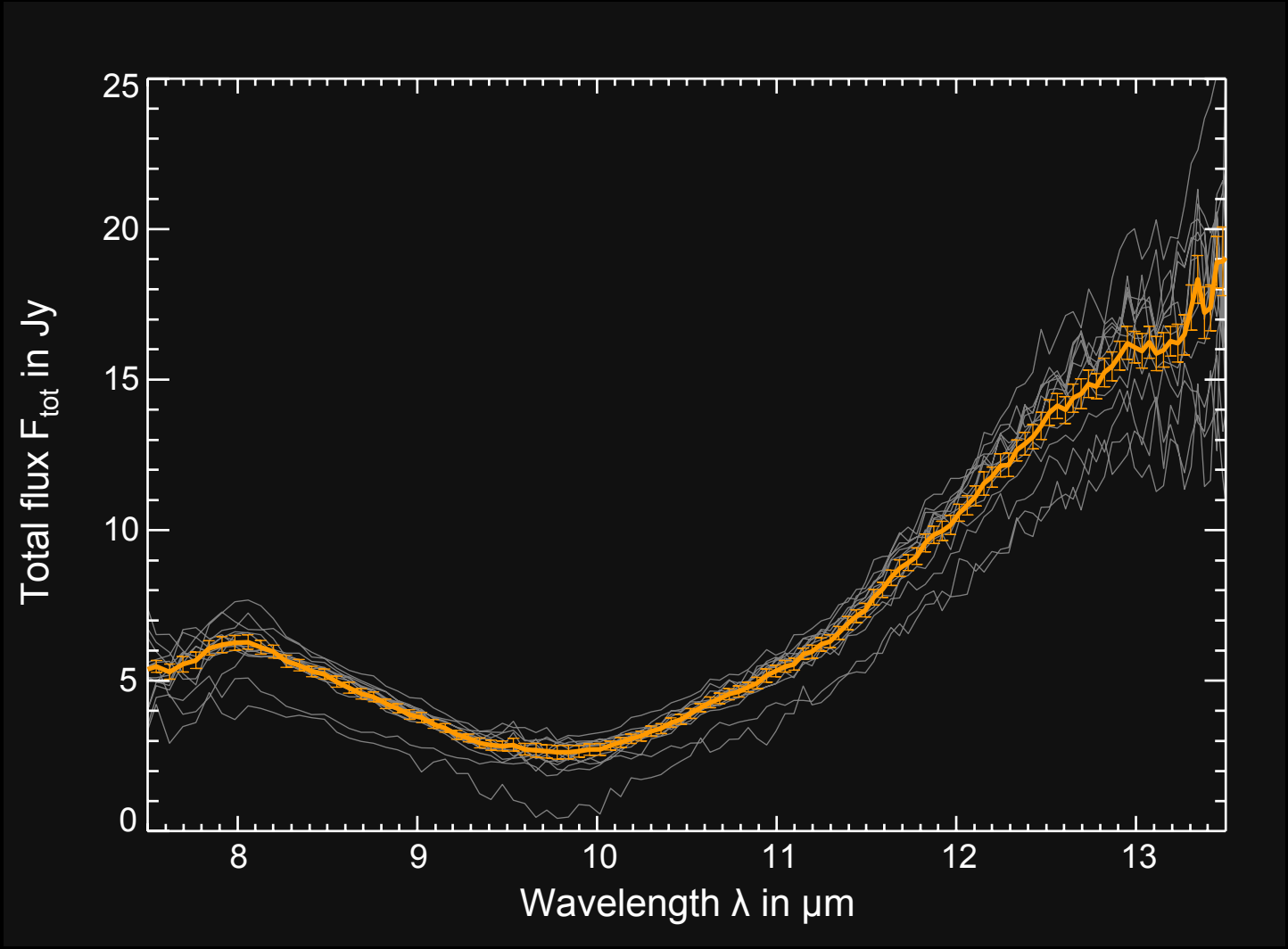
Circinus: UV coverage

GTO observations from P72 to P77:

- 21 fringe tracks
- 16 photometries



Circinus: Total flux



Circinus: UV coverage

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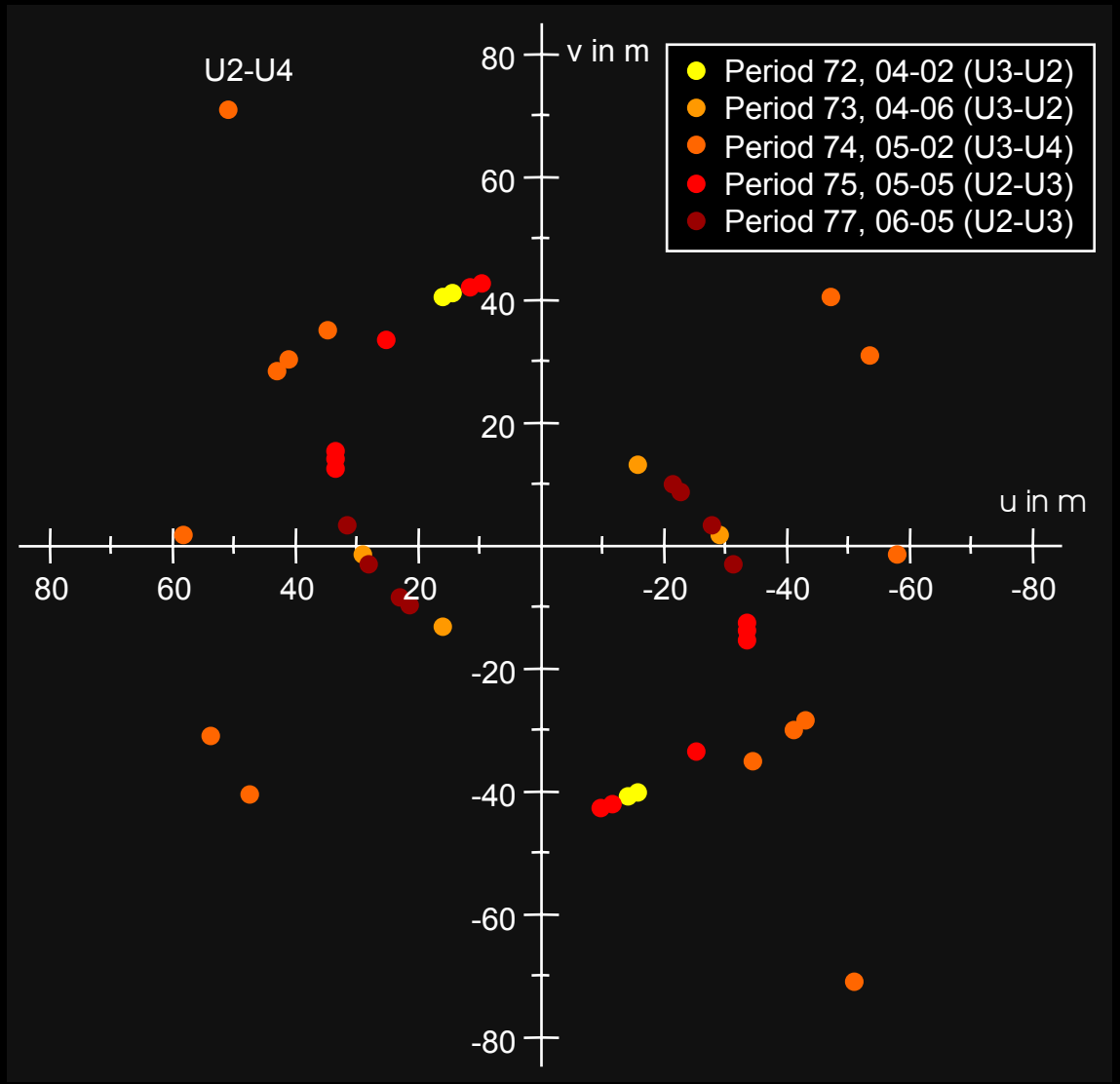
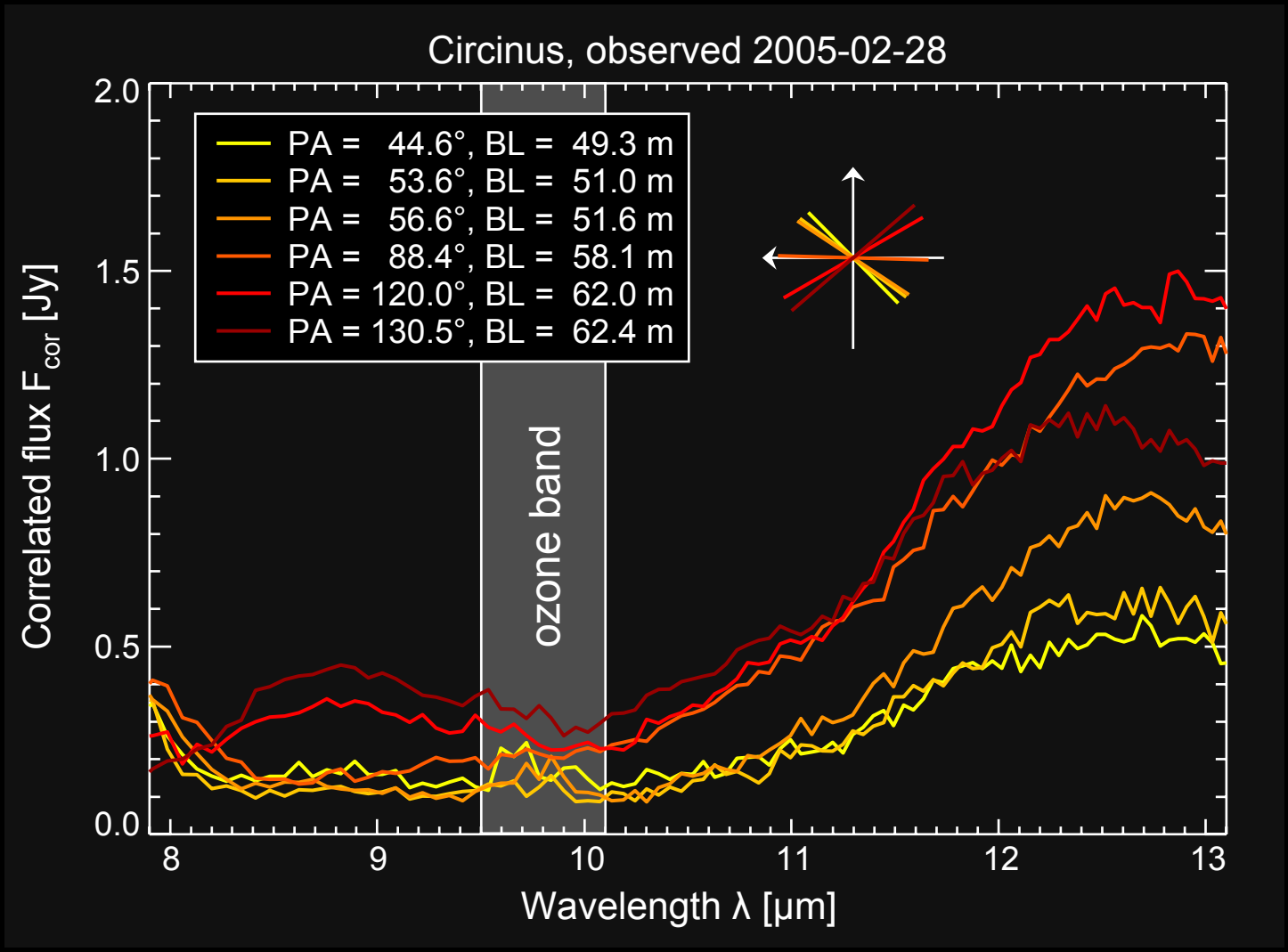
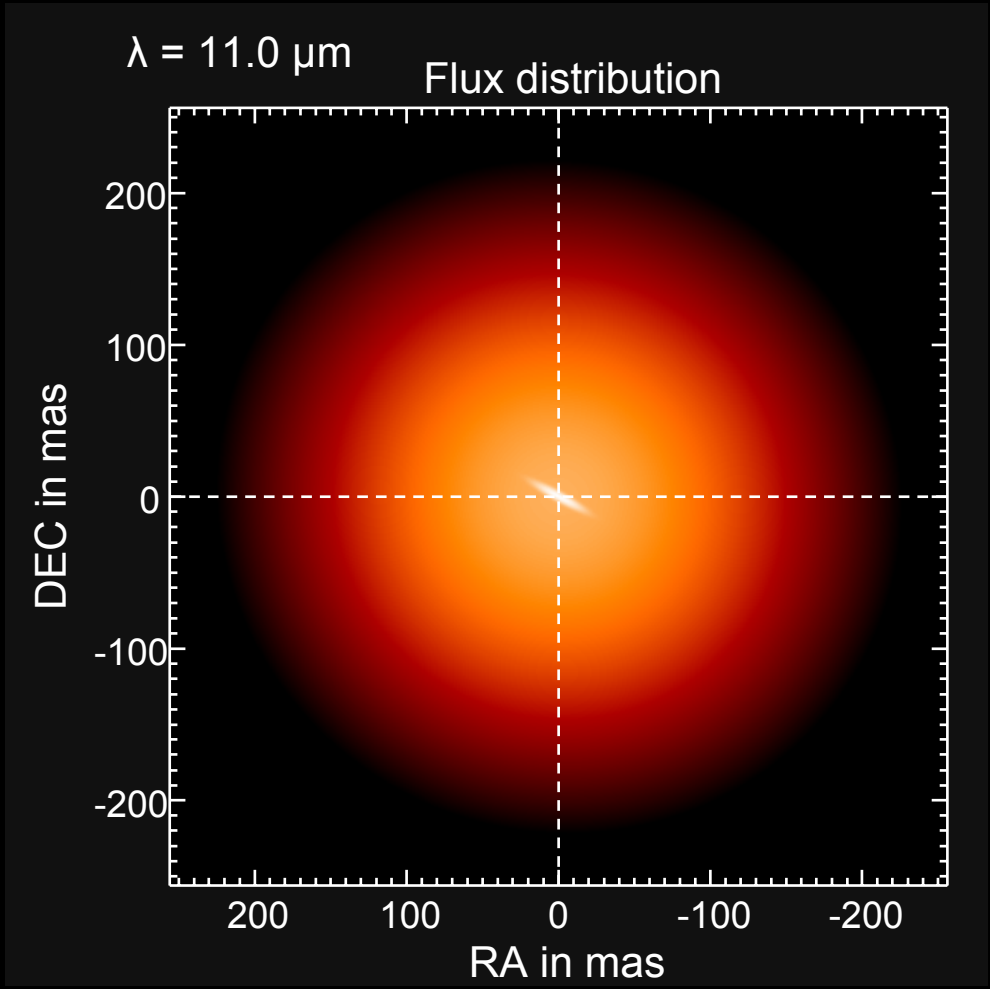


Circinus: Correlated flux



Circinus: Gaussian fit



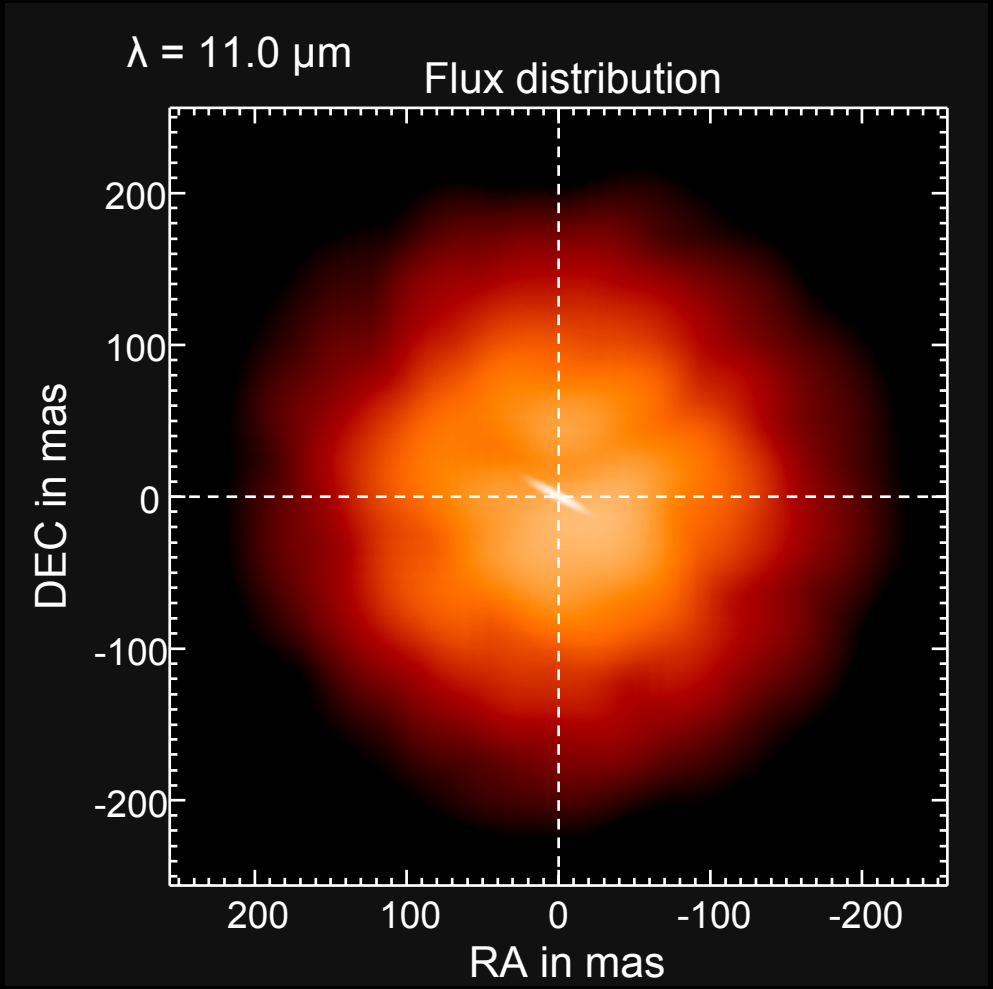
Two blackbody Gaussians:

Size:	Δ_1 = 21 mas
Axis ratio:	r_1 = 0.21
Silicate depth:	τ_1 = 1.18
Temperature:	T_1 = 334 K
Covering factor:	f_1 = 1.0
Size:	Δ_2 = 97 mas
Axis ratio:	r_2 = 0.97
Silicate depth:	τ_2 = 2.21
Temperature:	T_2 = 298 K
Covering factor:	f_2 = 0.20
Position angle:	α = 61°

Log of model flux distribution at 11μm

Tristram et al.

Circinus: Clumpiness



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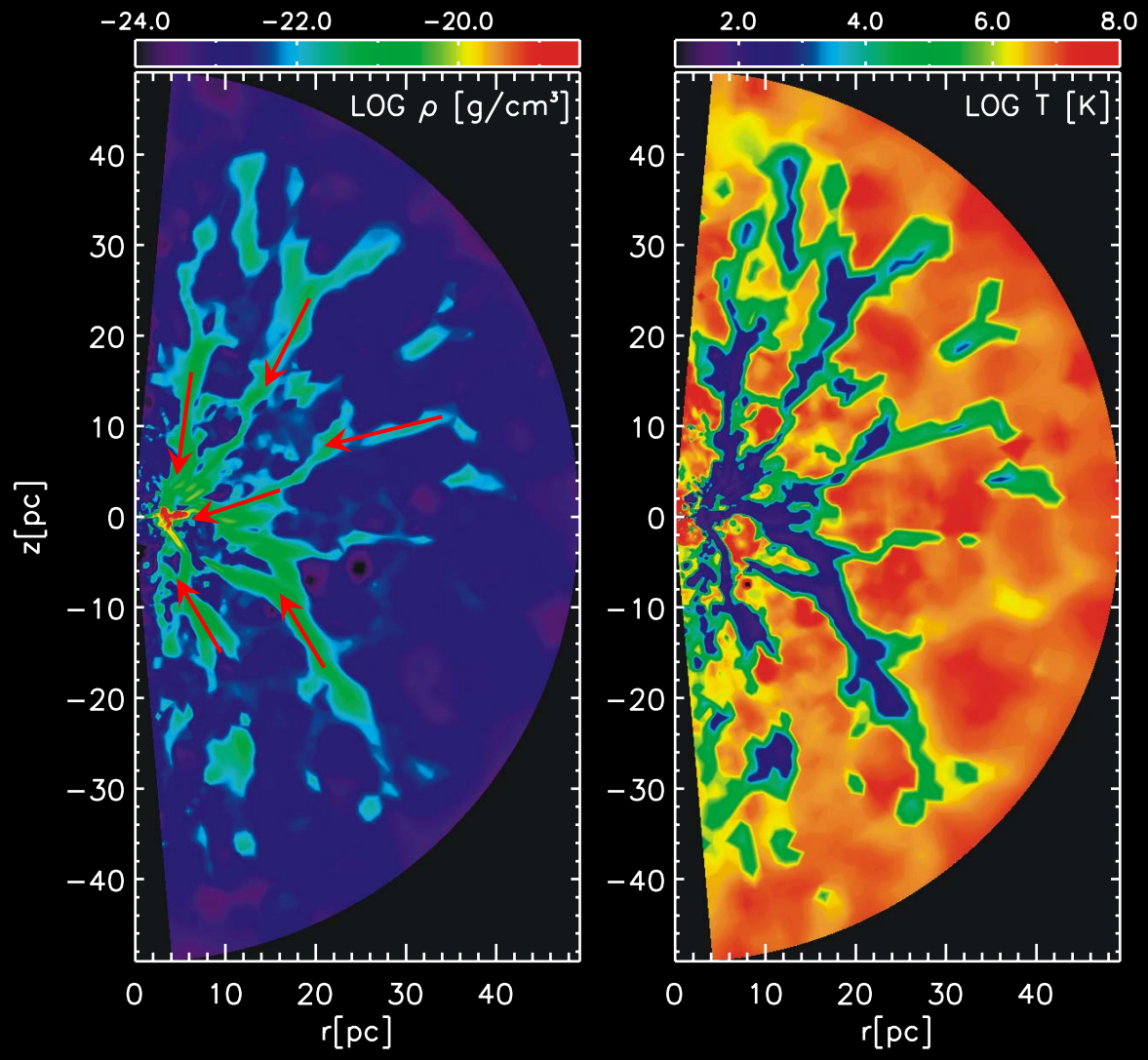
Tristram et al.

Simulations of AGN tori

Hydrodynamical torus model

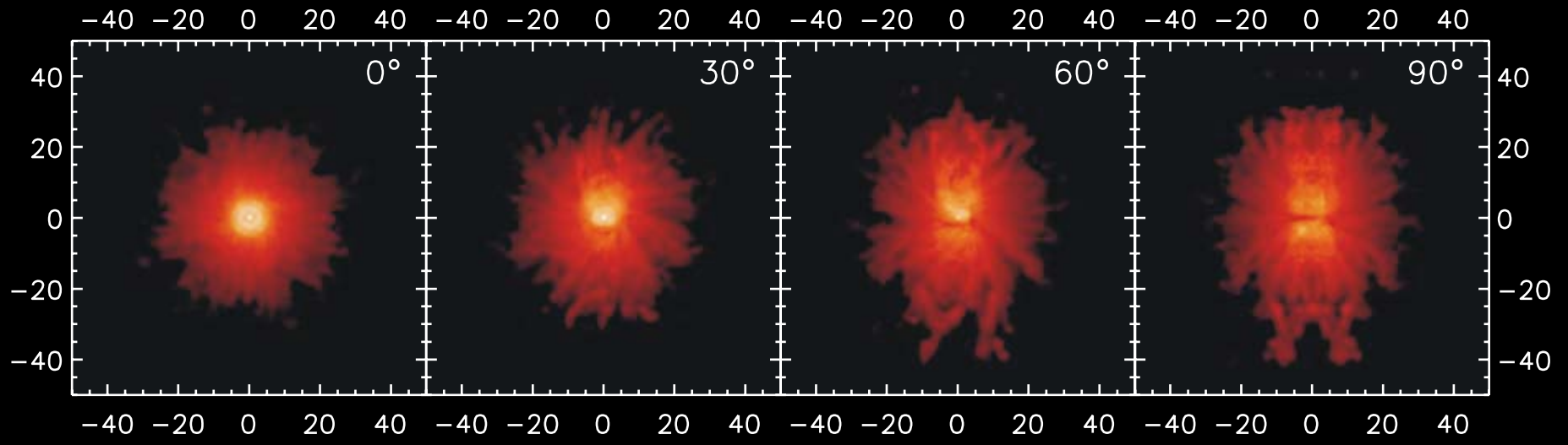


Schartmann et al.

Simulations of AGN tori

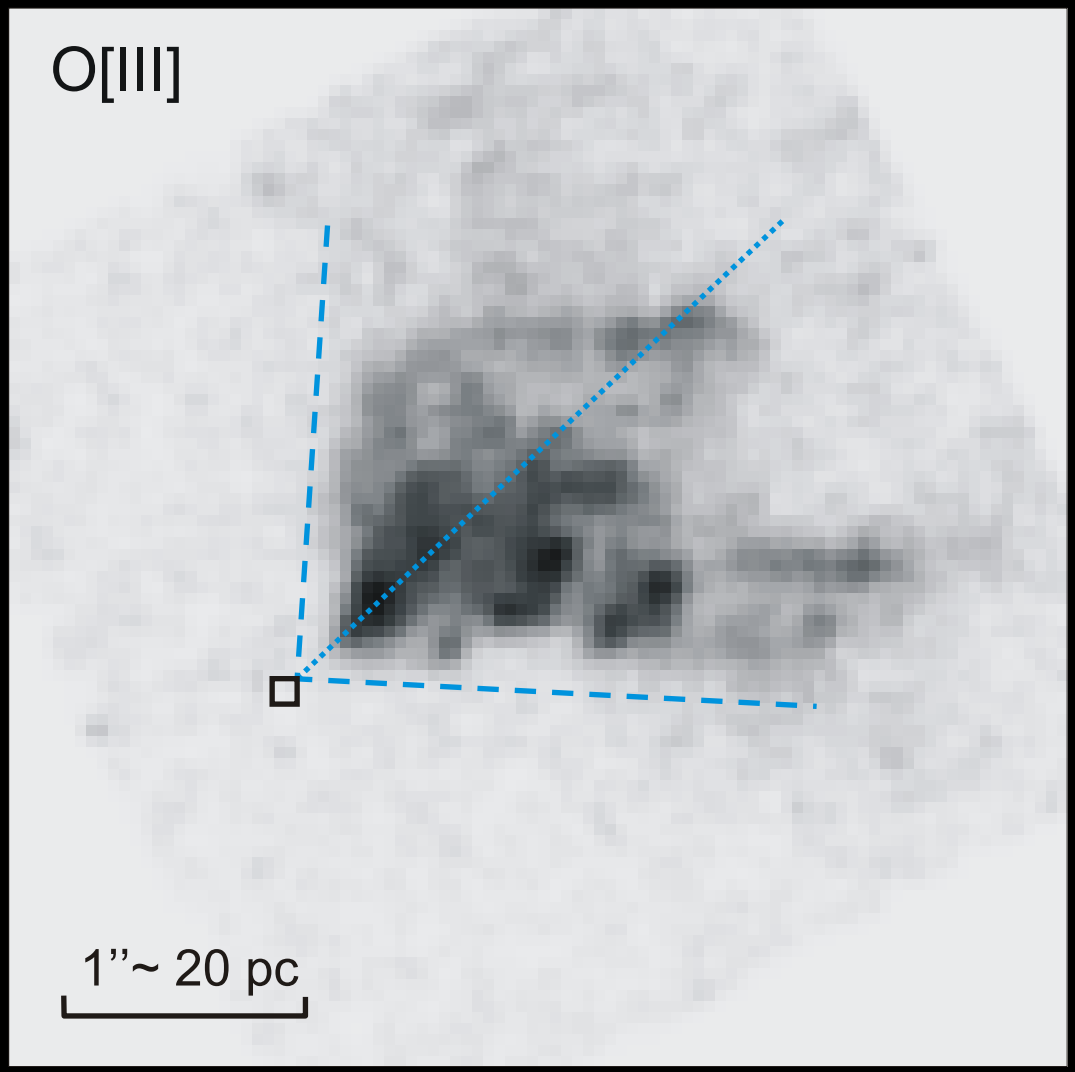
Hydrodynamical torus model

Brightness distribution (in logarithmic scaling, axis in pc):



Schartmann et al.

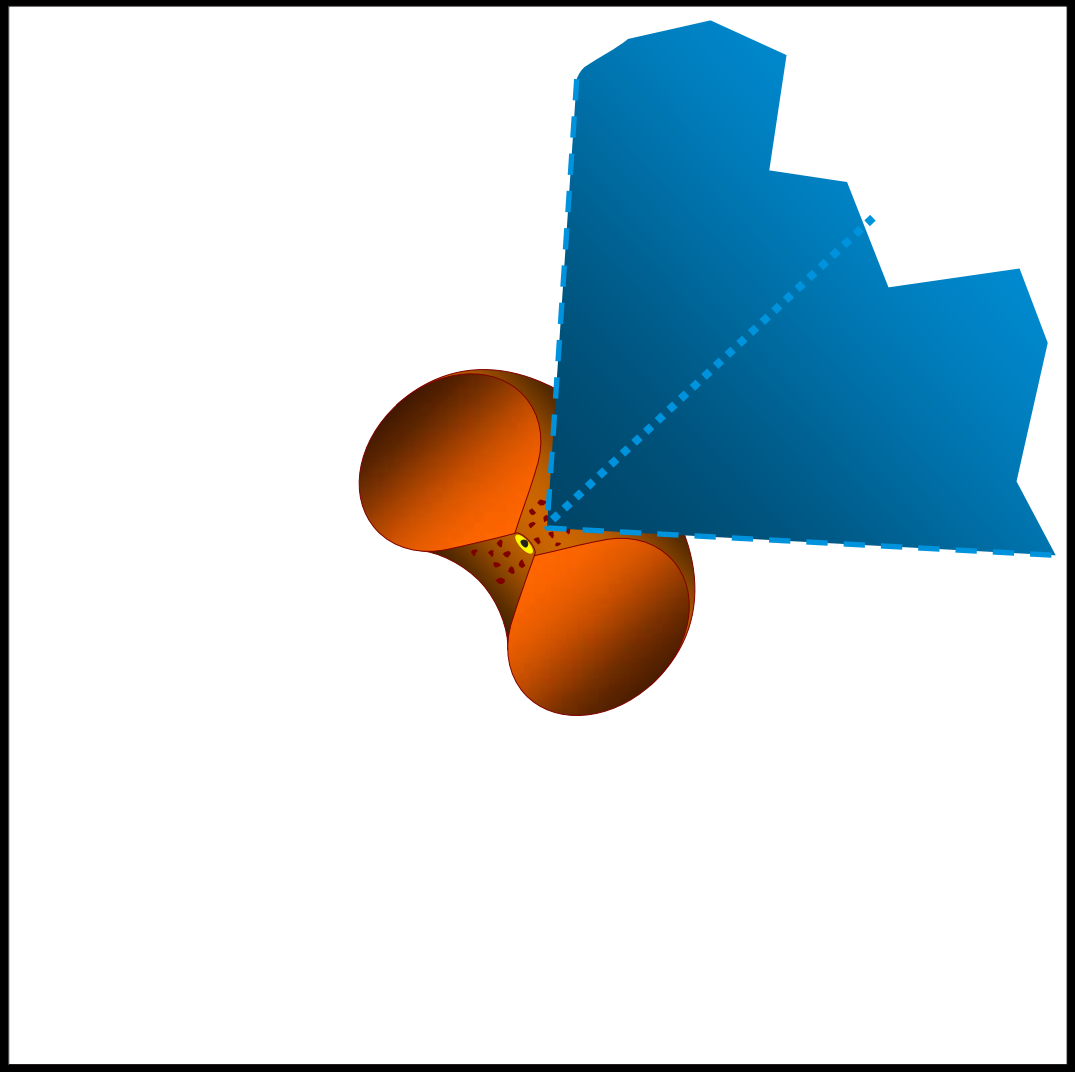
Circinus: Geometry



Known geometry

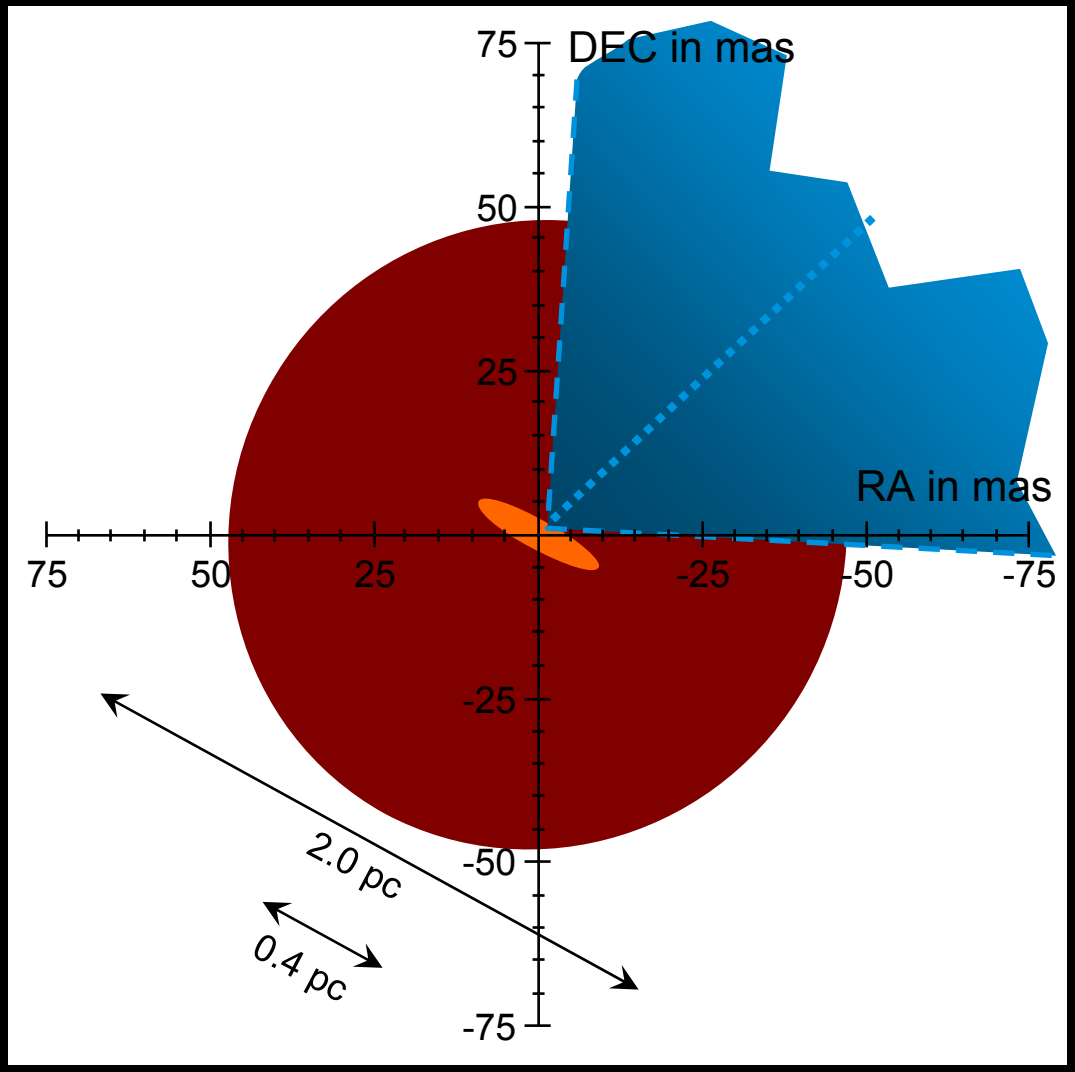
Wilson et al. 2000

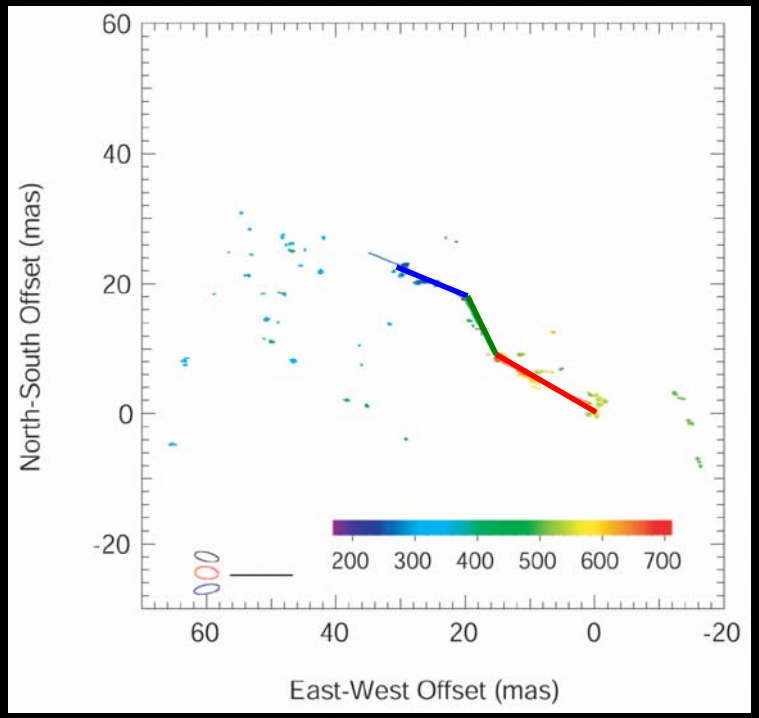
Circinus: Geometry



Expected torus configuration

Circinus: Geometry





Greenhill et al. 2000

NGC 1068: General properties

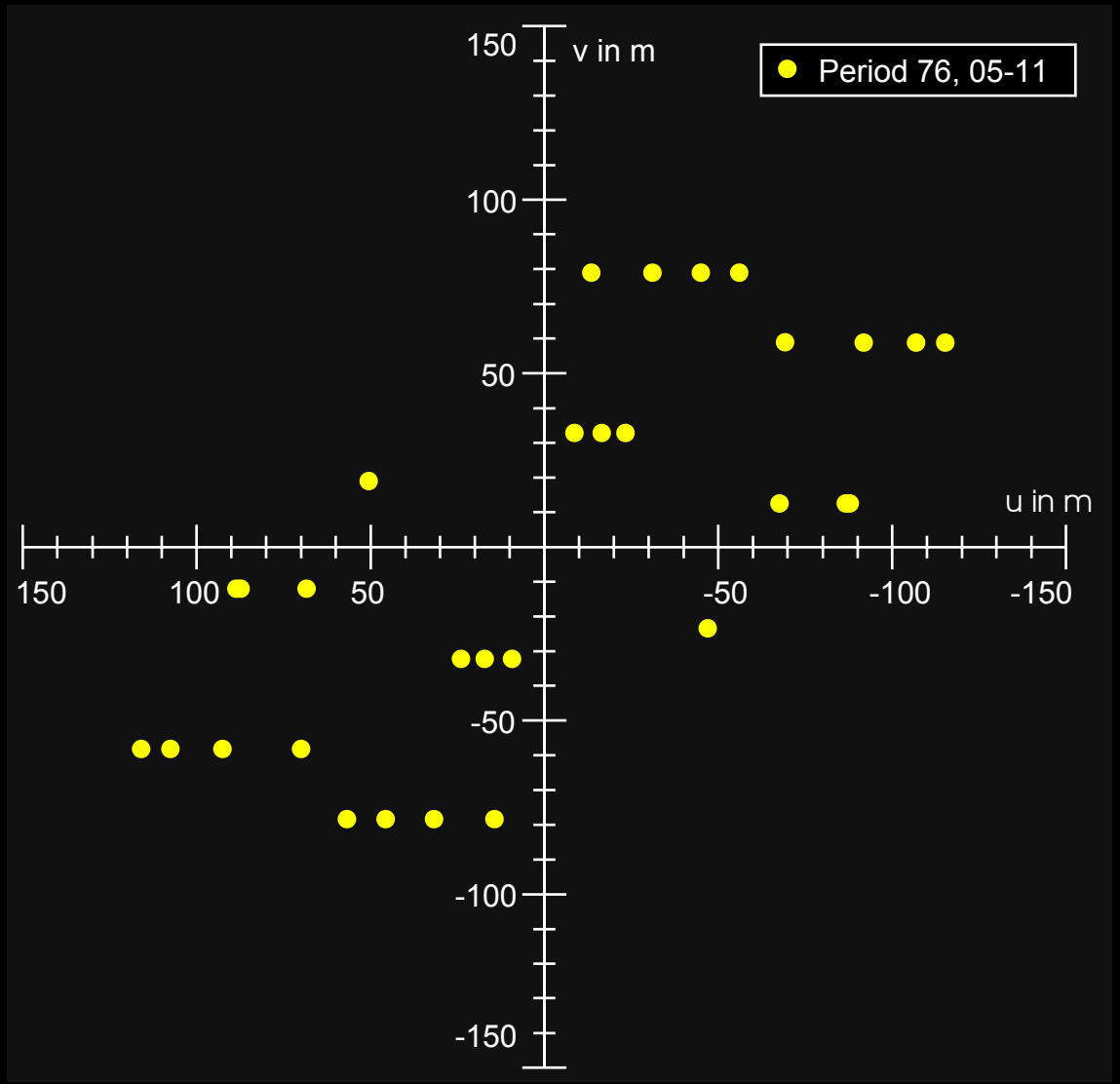
- Messier M77
- barred spiral galaxy (R)SA(rs)b, i = 51°
- Seyfert type 2
- 1×10^7 $M_\odot$ nucleus
- Distance ~14 Mpc
  - ↳ 14 mas ~ 1 pc

SDSS (http://www.wikisky.org)

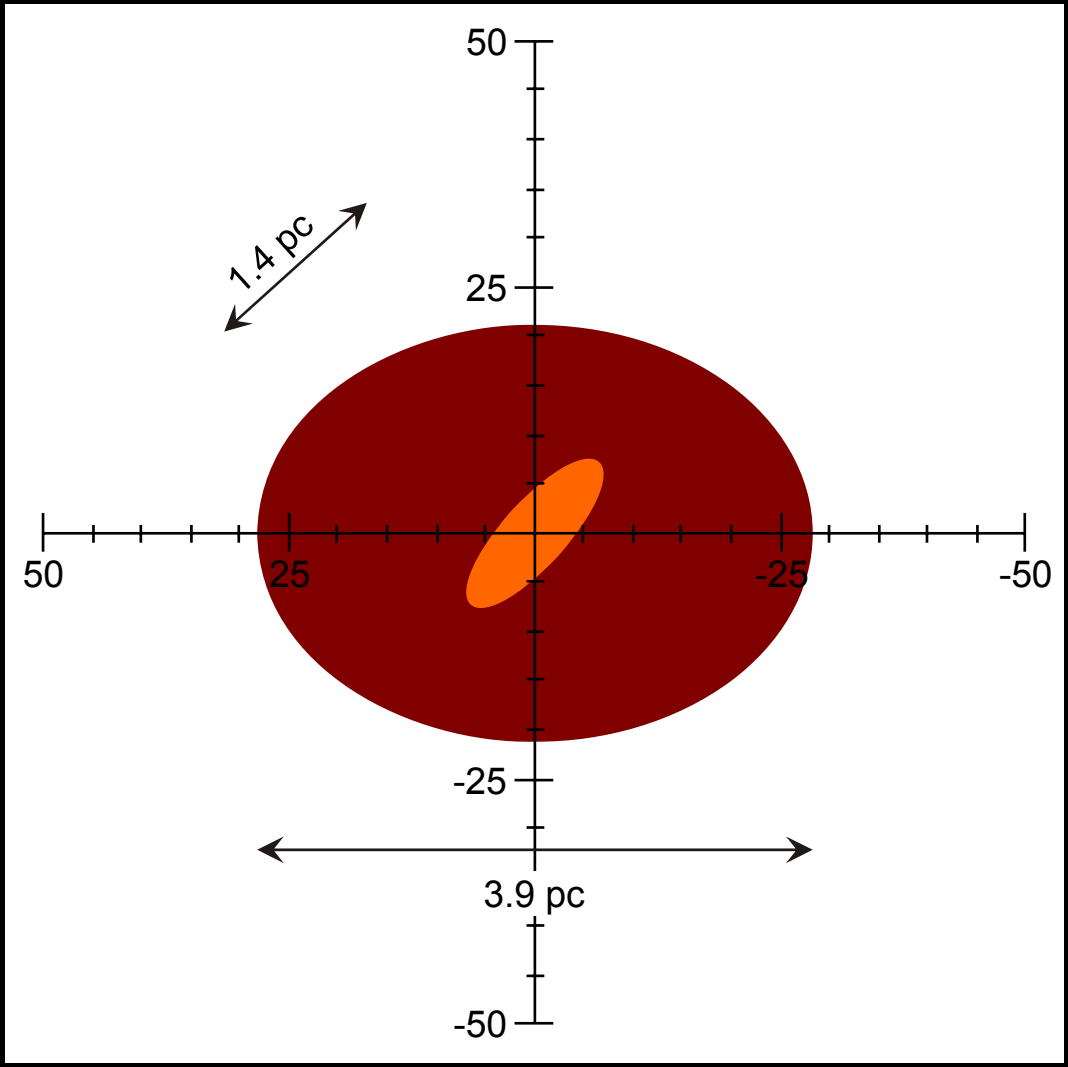
NGC 1068: UV coverage

OT observations in period P76:

- grism
- 15 fringe tracks



NGC 1068: Modelling

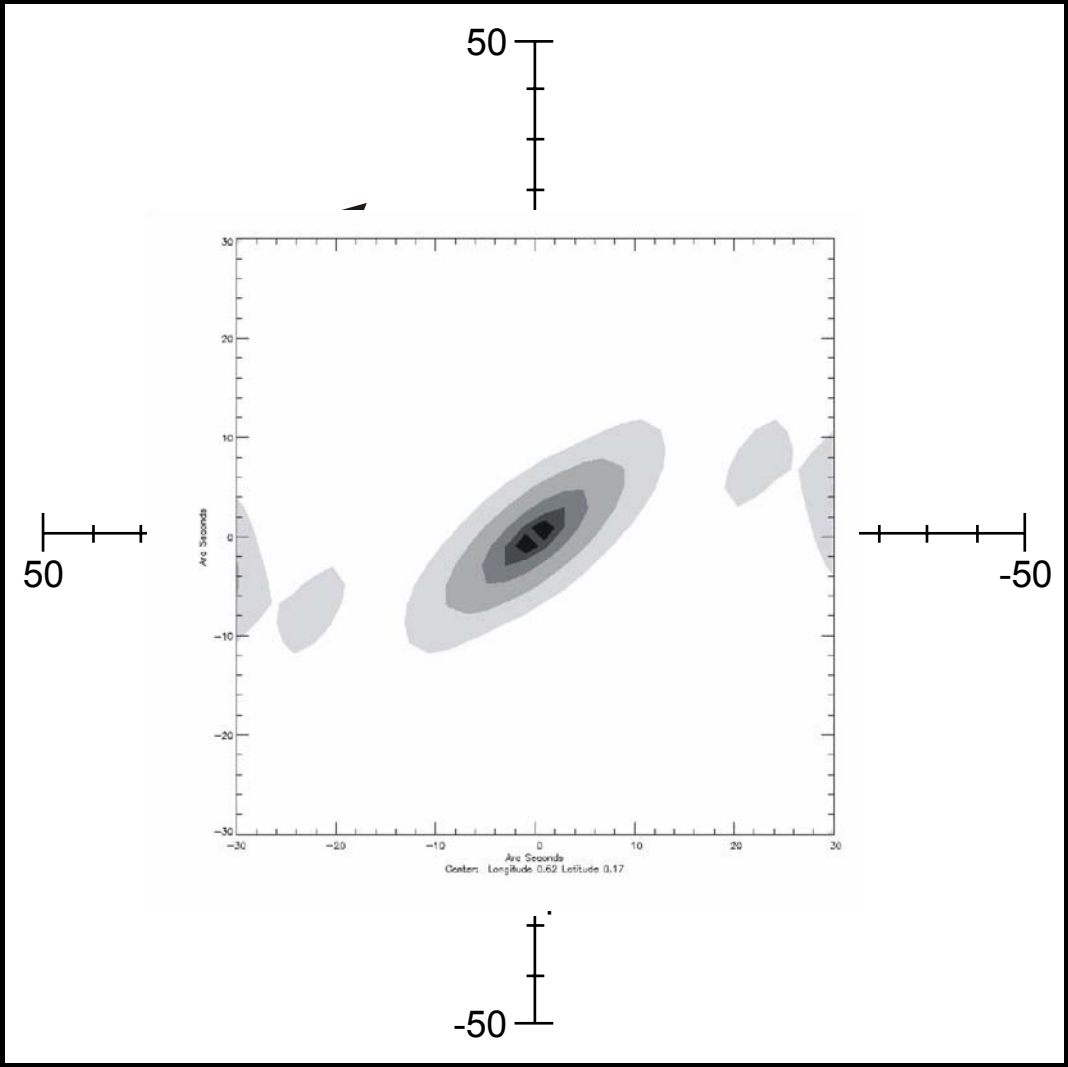


2 blackbody Gaussians:

Size:	$\Delta_1 = 20$ mas
Axis ratio:	$r_1 = 0.34$
Silicate depth:	$\tau_1 \approx 5$
Temperature:	$T_1 \approx 700$ K
Position angle:	$\alpha_1 = -42°$
Size:	$\Delta_2 = 57$ mas
Axis ratio:	$r_2 = 0.75$
Silicate depth:	$\tau_2 \approx 4$
Temperature:	$T_2 \approx 300$ K
Position angle:	$\alpha \approx 0°$

Raban et al.

NGC 1068: Modelling

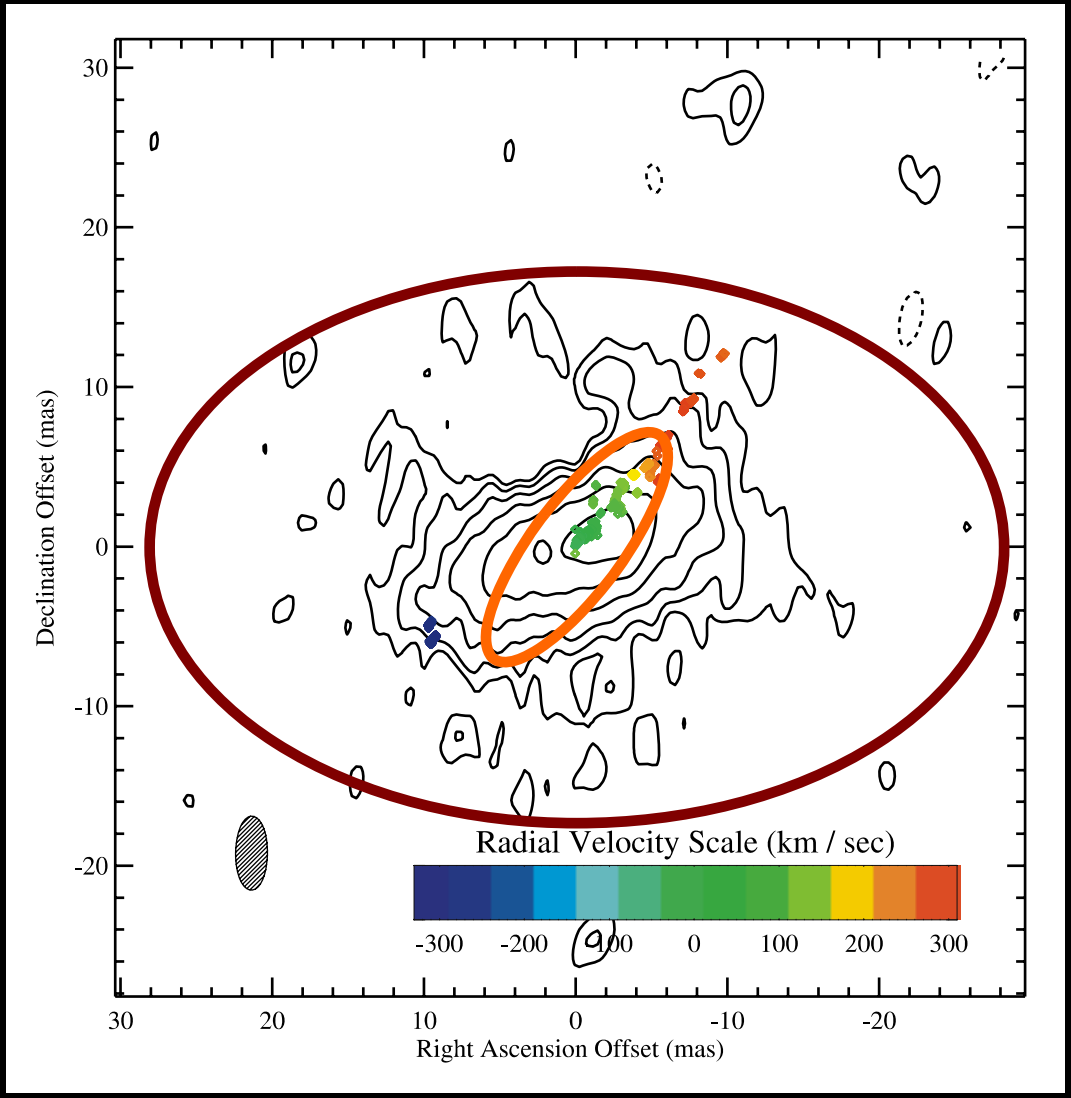


2 blackbody Gaussians:

Size:	$\Delta_1 =$ 20 mas
Axis ratio:	$r_1 =$ 0.34
Silicate depth:	$\tau_1 \approx$ 5
Temperature:	$T_1 \approx$ 700 K
Position angle:	$\alpha_1 =$ −42°
Size:	$\Delta_2 =$ 57 mas
Axis ratio:	$r_2 =$ 0.75
Silicate depth:	$\tau_2 \approx$ 4
Temperature:	$T_2 \approx$ 300 K
Position angle:	$\alpha \approx$ 0°

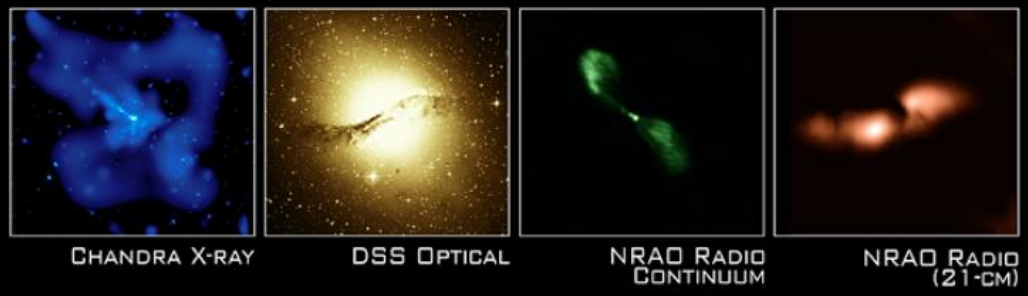
Raban et al.

NGC 1068: Geometry



Gallimore et al. 2004

Centaurus A: Properties

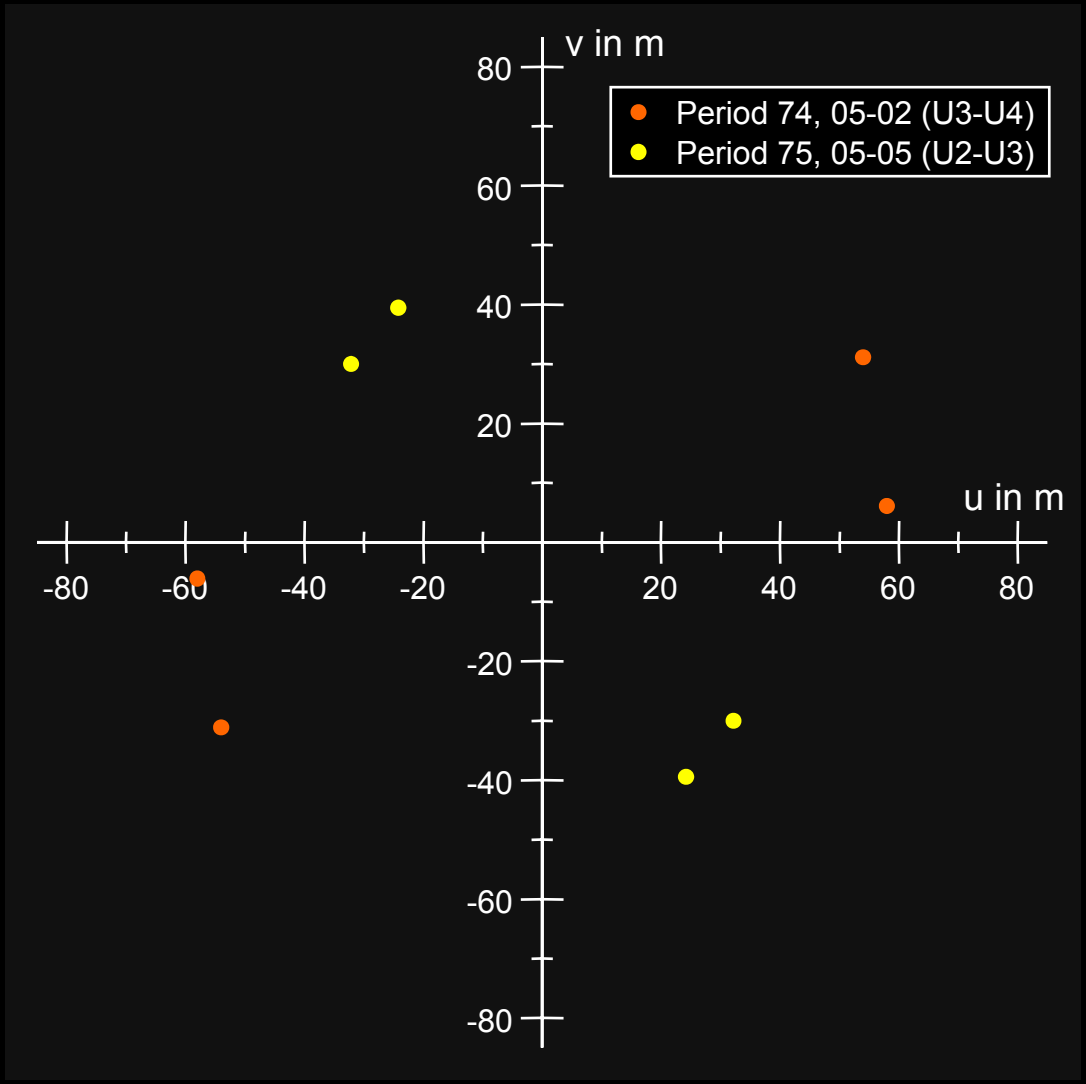


- elliptical galaxy
- recent merger
- dust lane, edge-on
- FR 1 radio galaxy
- narrow line RG
- $6 \times 10^7\ M_\odot$ nucleus
- distance ~4 Mpc
  - ↳ 50 mas ~ 1 pc

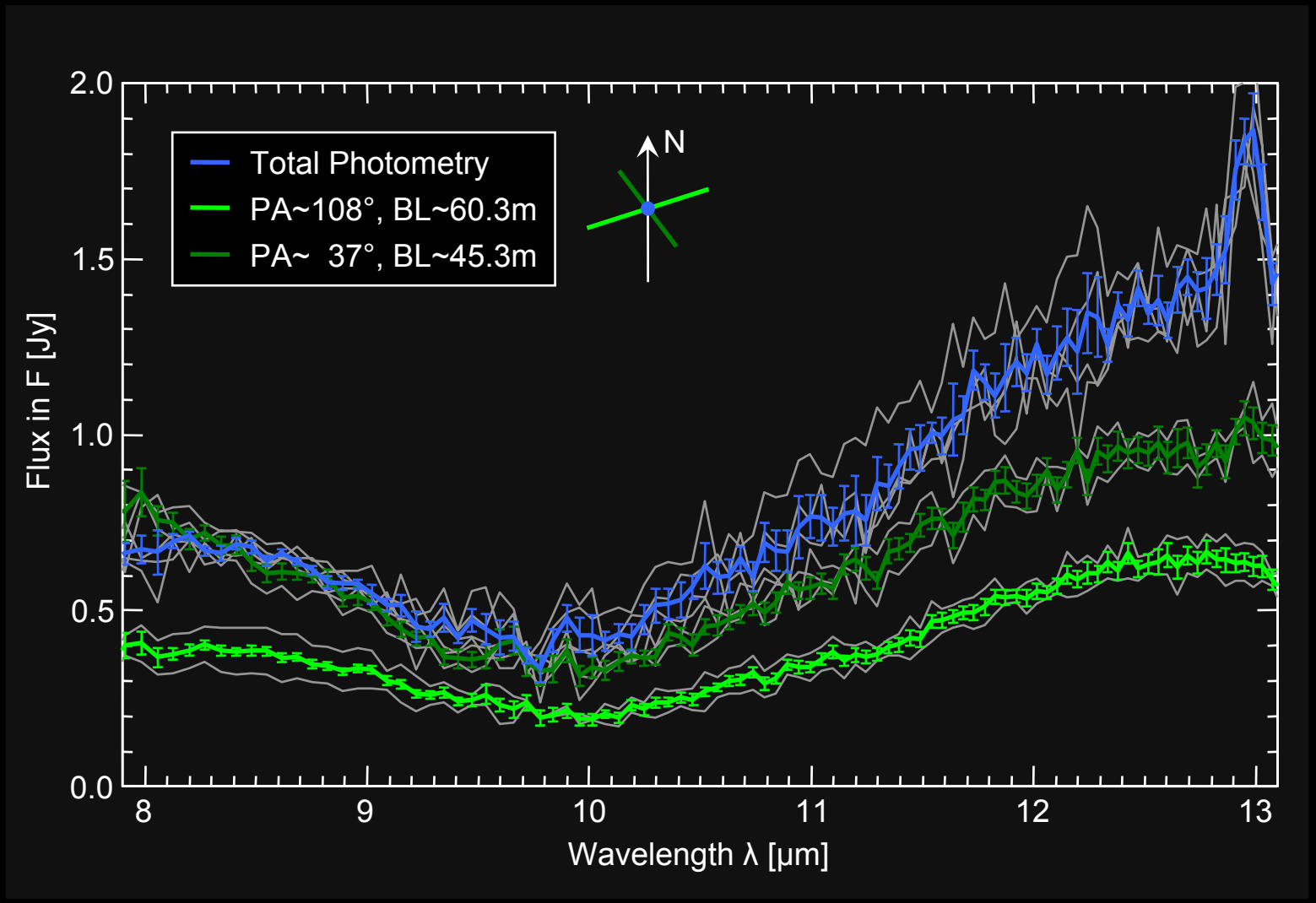
Centaurus A: UV coverage

GTO observations in P74 and P75:

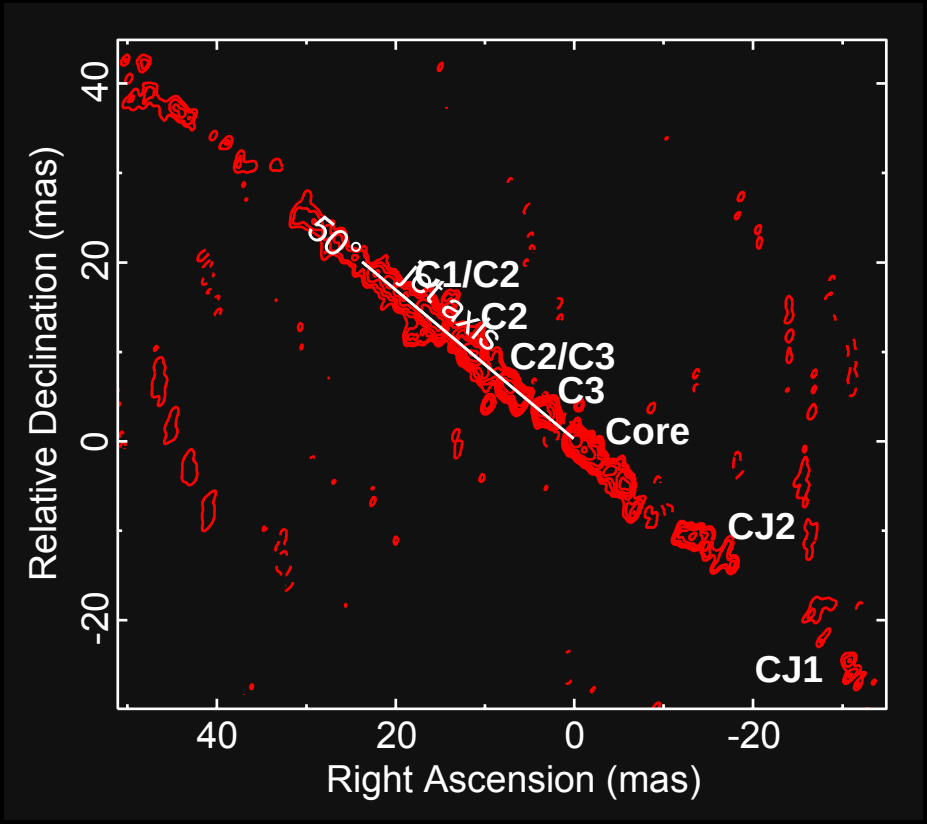
- 4 independent visibility points
- problems with photometry



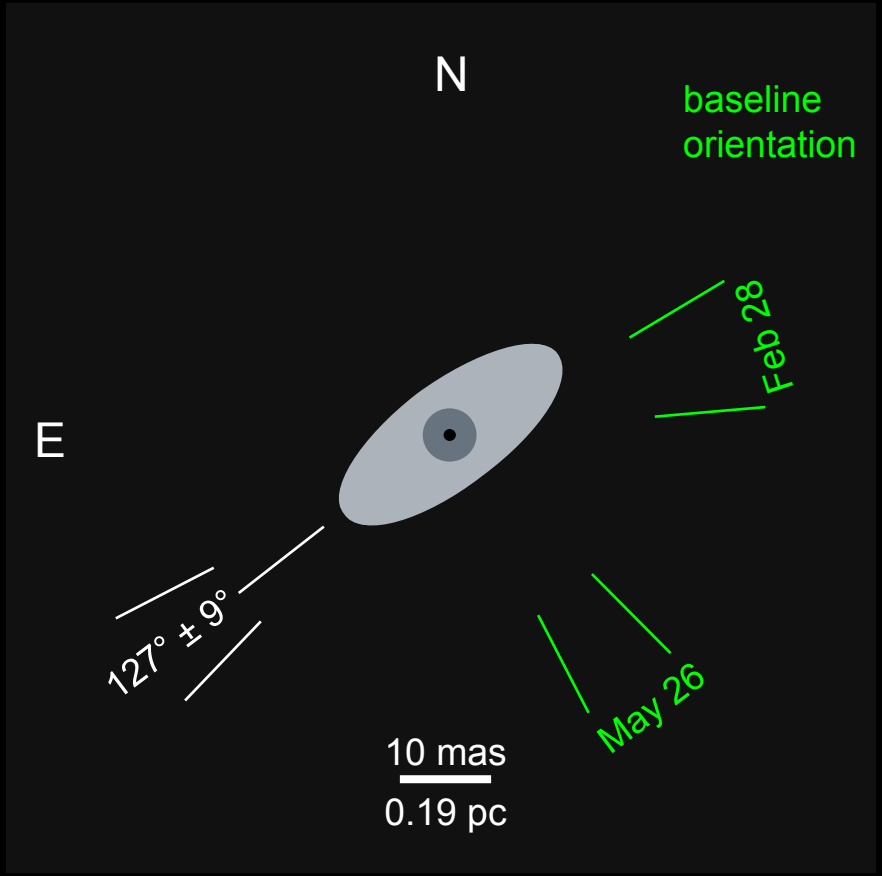
Centaurus A: Fluxes



Centaurus A: Results



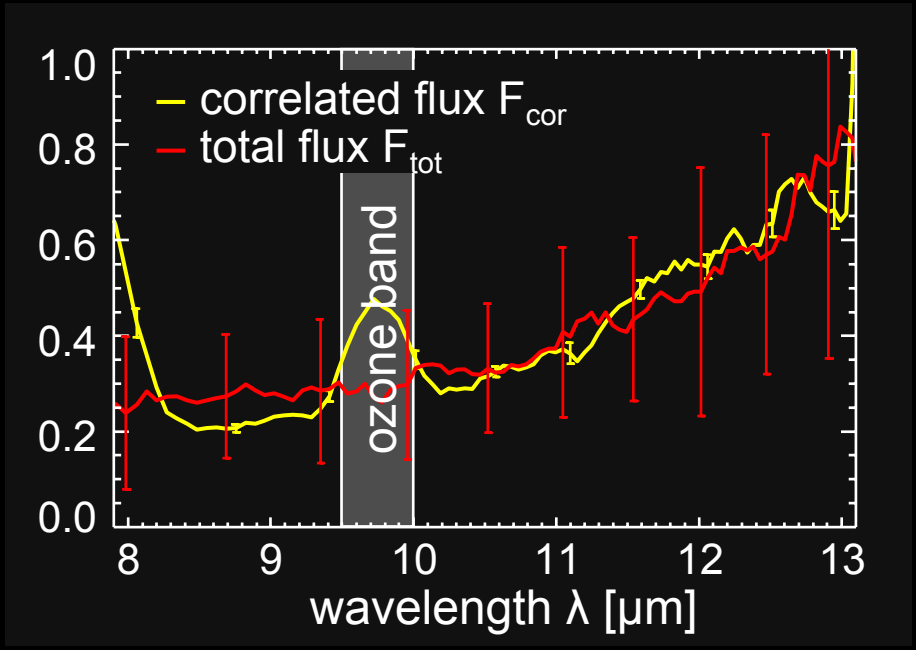
Horiuchi et al. 2006



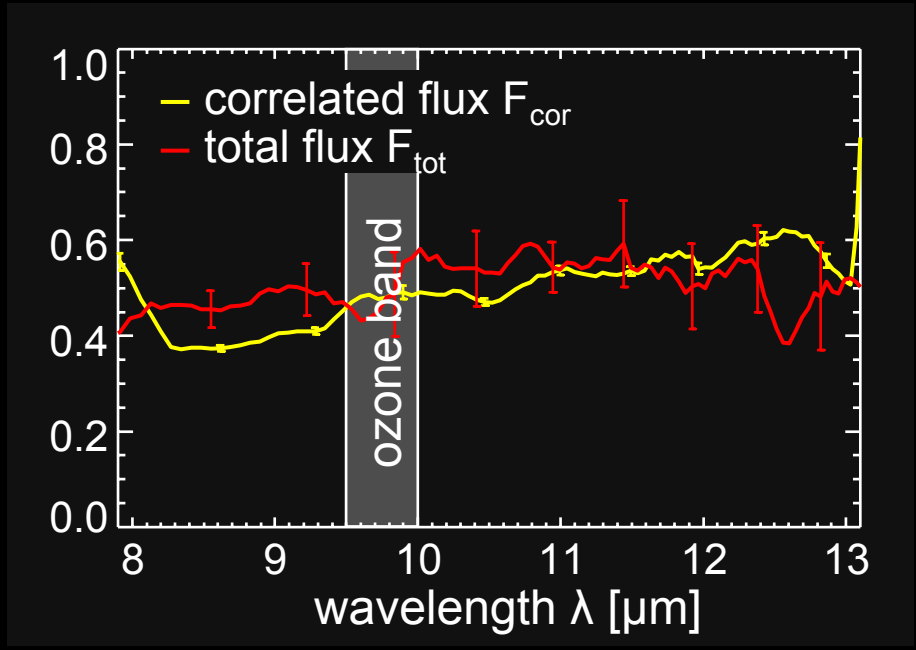
Meisenheimer et al. 2007

Other targets: Mrk 1239, MCG -05-..

MCG -05-23-016 (Seyfert 2)

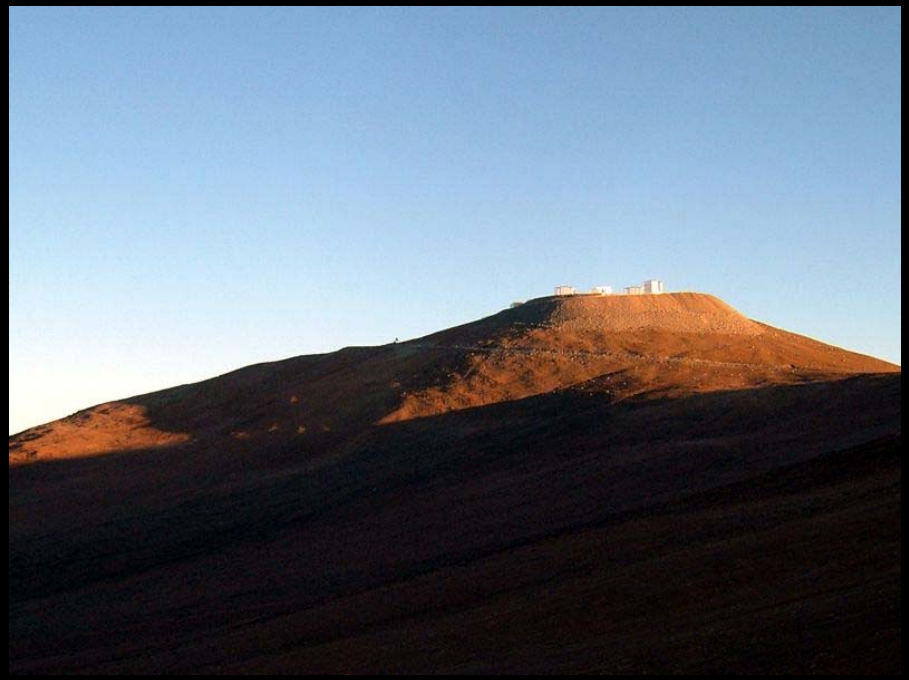


Mrk 1239 (Seyfert 1)



Conclusions

- Circinus & NGC 1068:
  - dusty tori perpendicular to ionisation cone
  - trace maser locations
- Centaurus A
  - dust disk
  - synchrotron source
- Weaker targets:
  - hardly resolved



VLT on Cerro Paranal, May 2005

Prospects

- Long baselines for unresolved targets
- Shorter baselines for highly resolved targets
- Look at the phases
  - ↳ imaging
- Comparison to simulations
- Extension of sample

One of the galaxies to be observed: NGC 1365