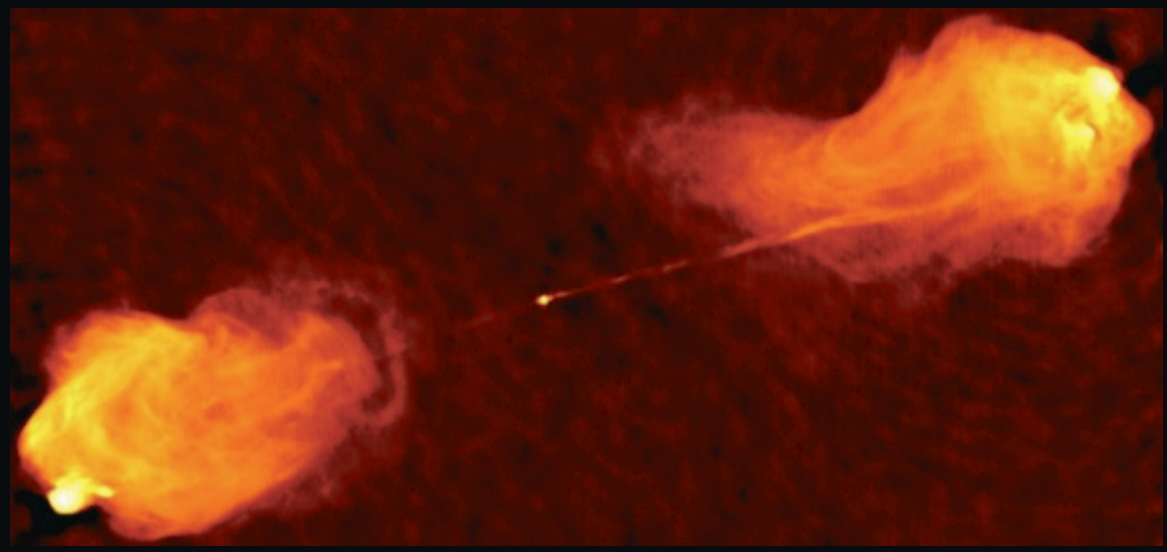
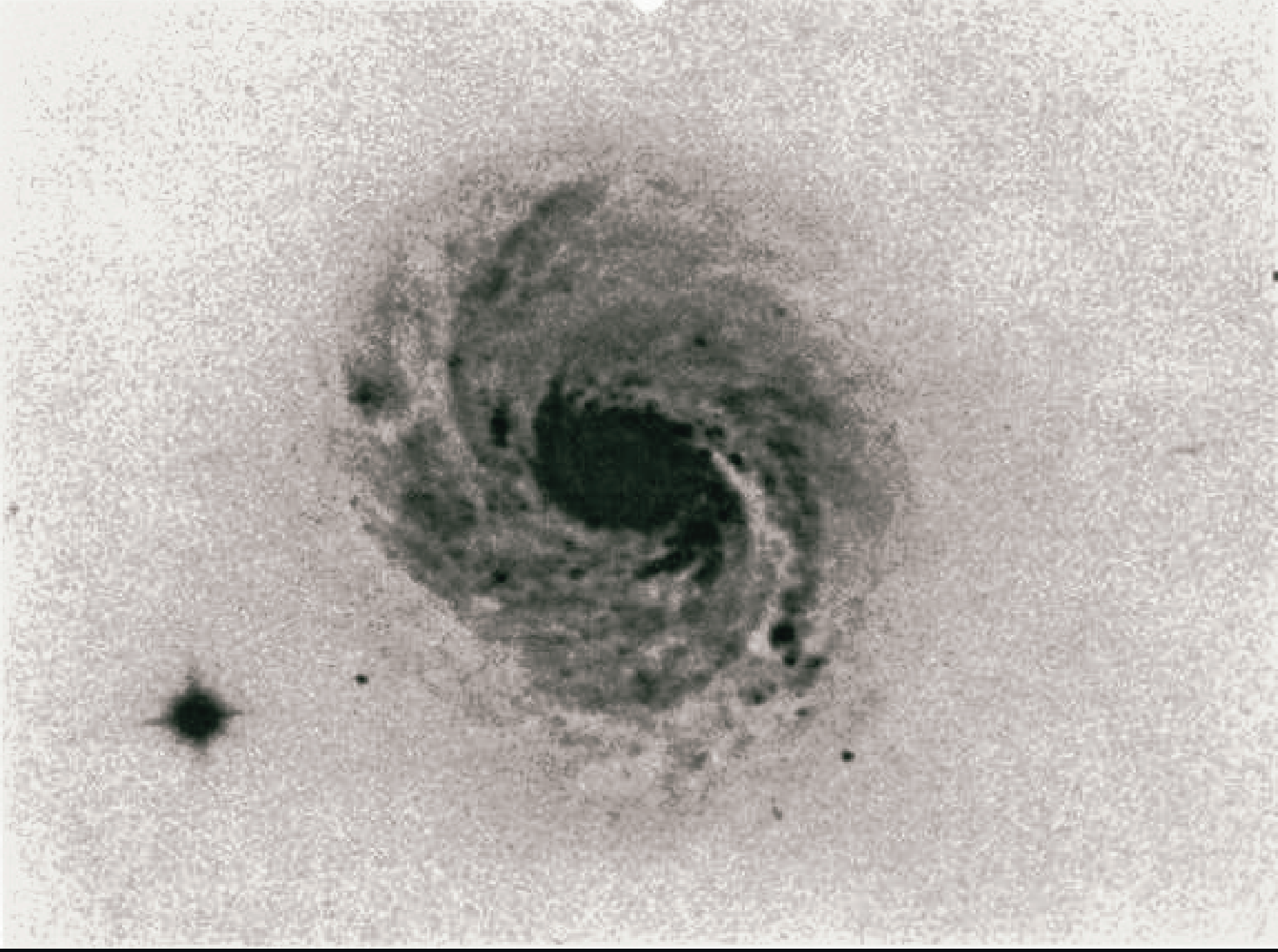
AGNs with the VLTI

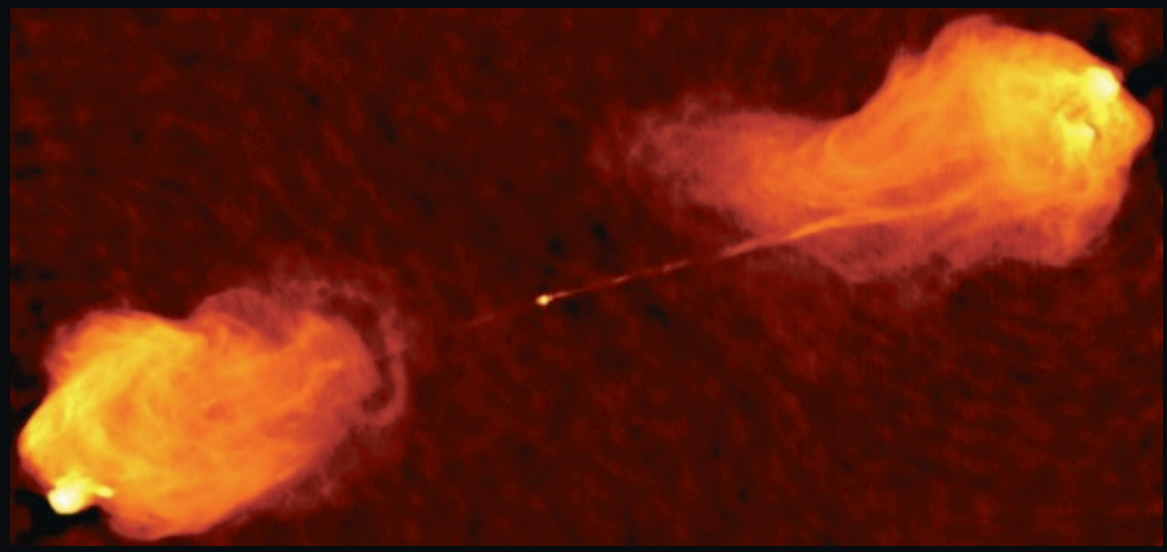
Cygnus A:I

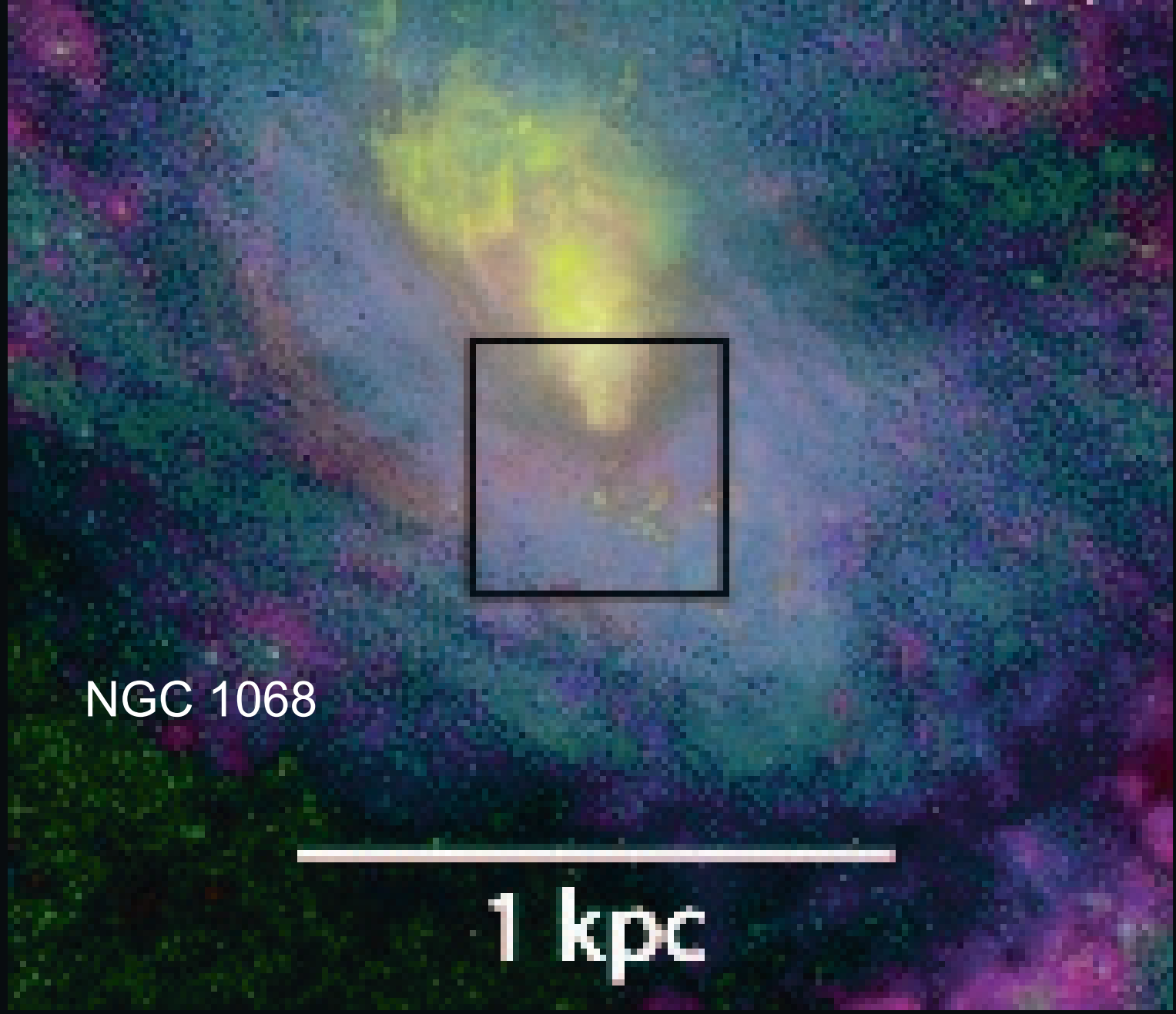


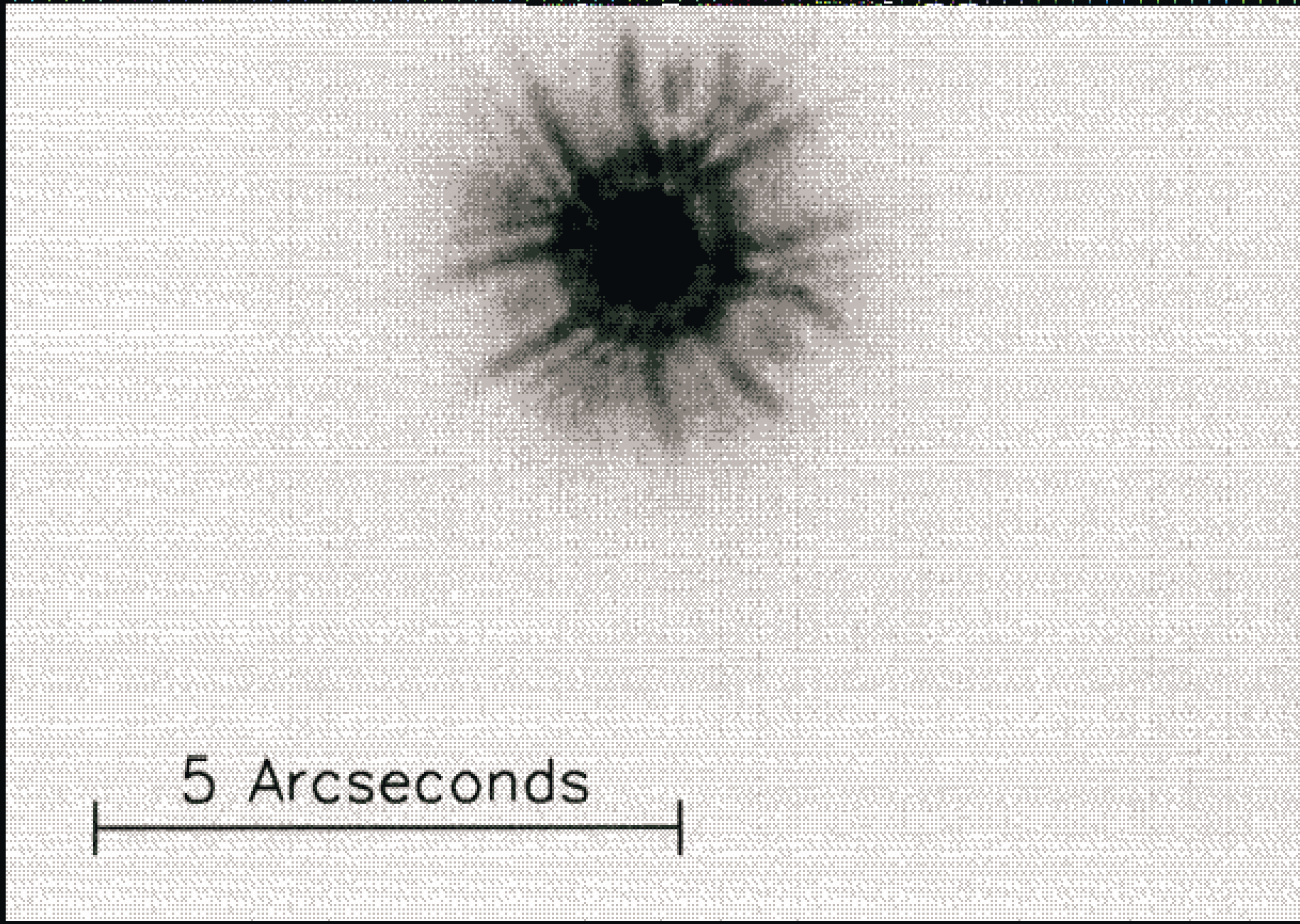
What's an AGN

- What's an AGN? (L = 10^46 erg/s)
- Radio Jet (sometimes) @ 300 kpc
- Narrow Line Region @ 1 kpc
- [dusty torus/disk@1pc]
- Broad Line Region (sometimes) @ 0.1 pc
- Hot Accretion disk (sometimes) @ 10 AU
- Black Hole (10^8 Mo) @ 1 AU






NGC 1068
1 kpc


5 Arcseconds

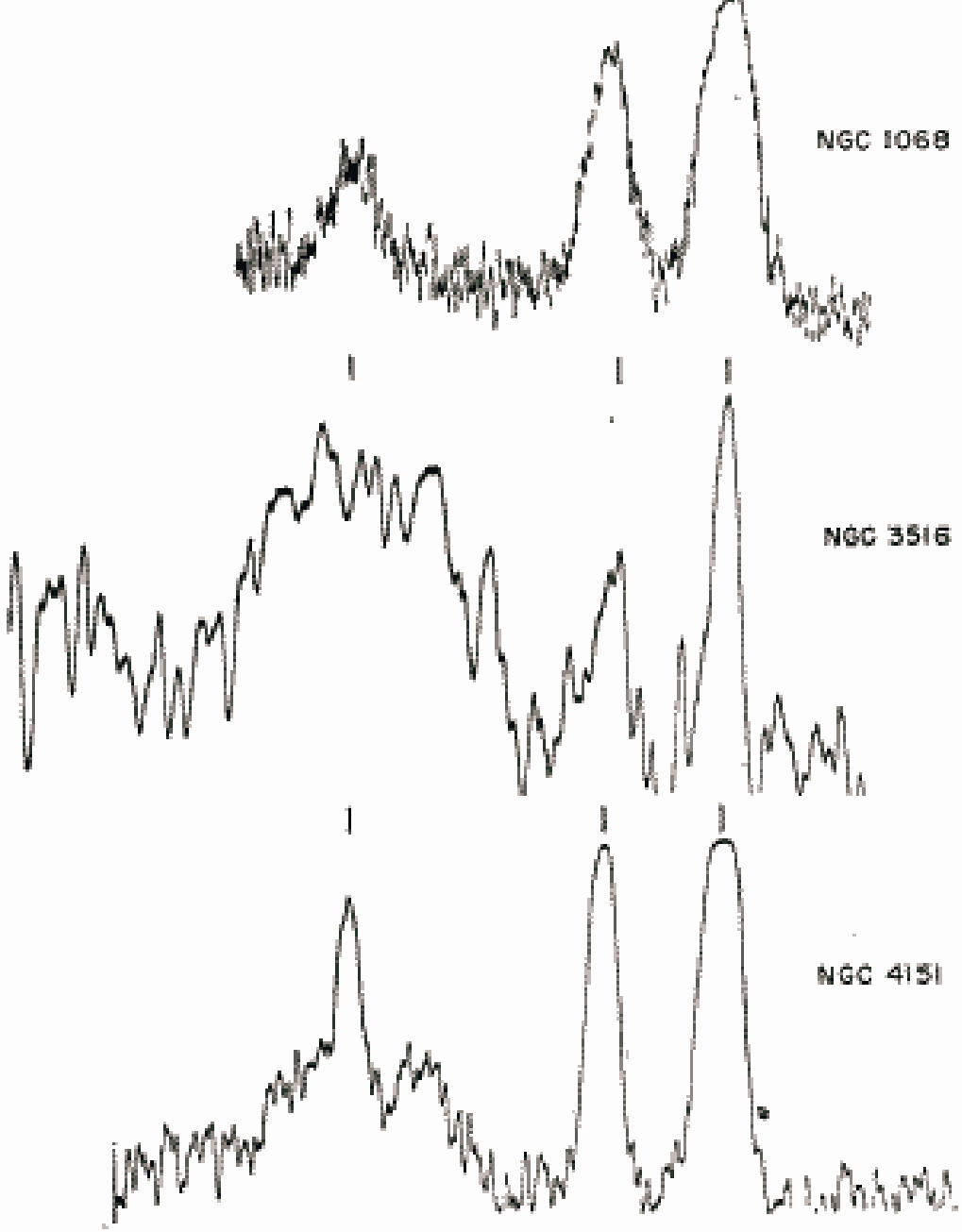
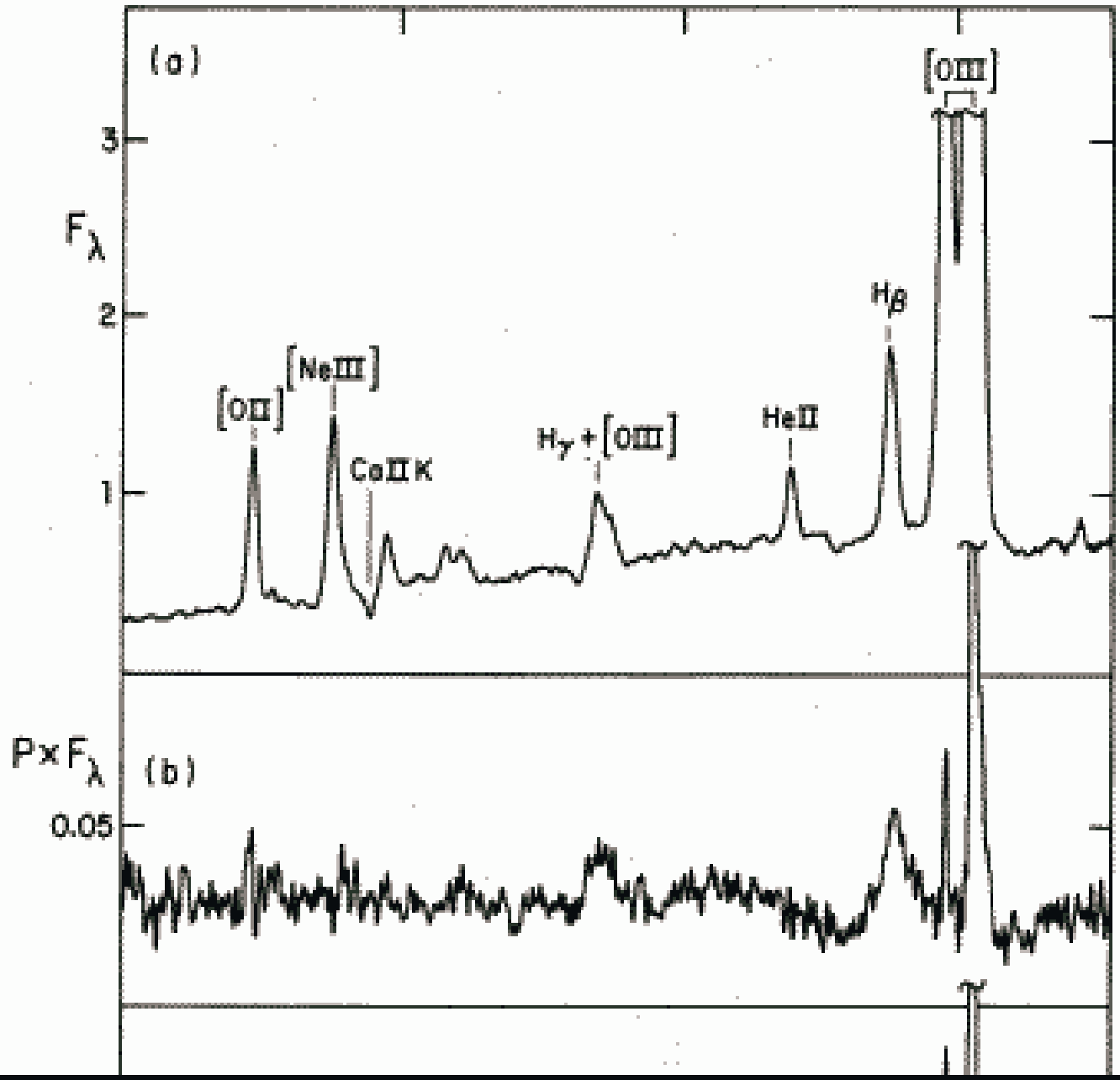
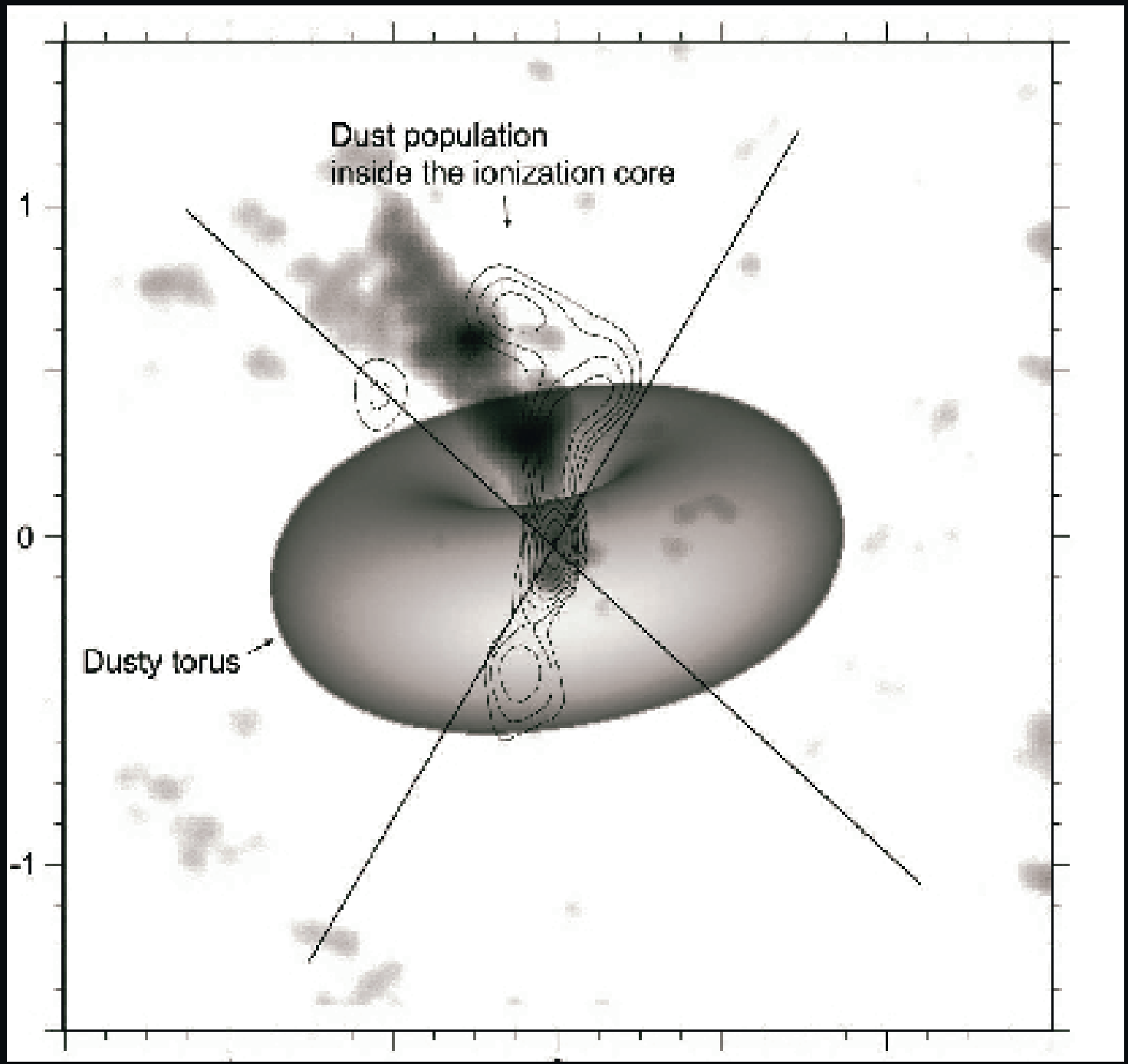
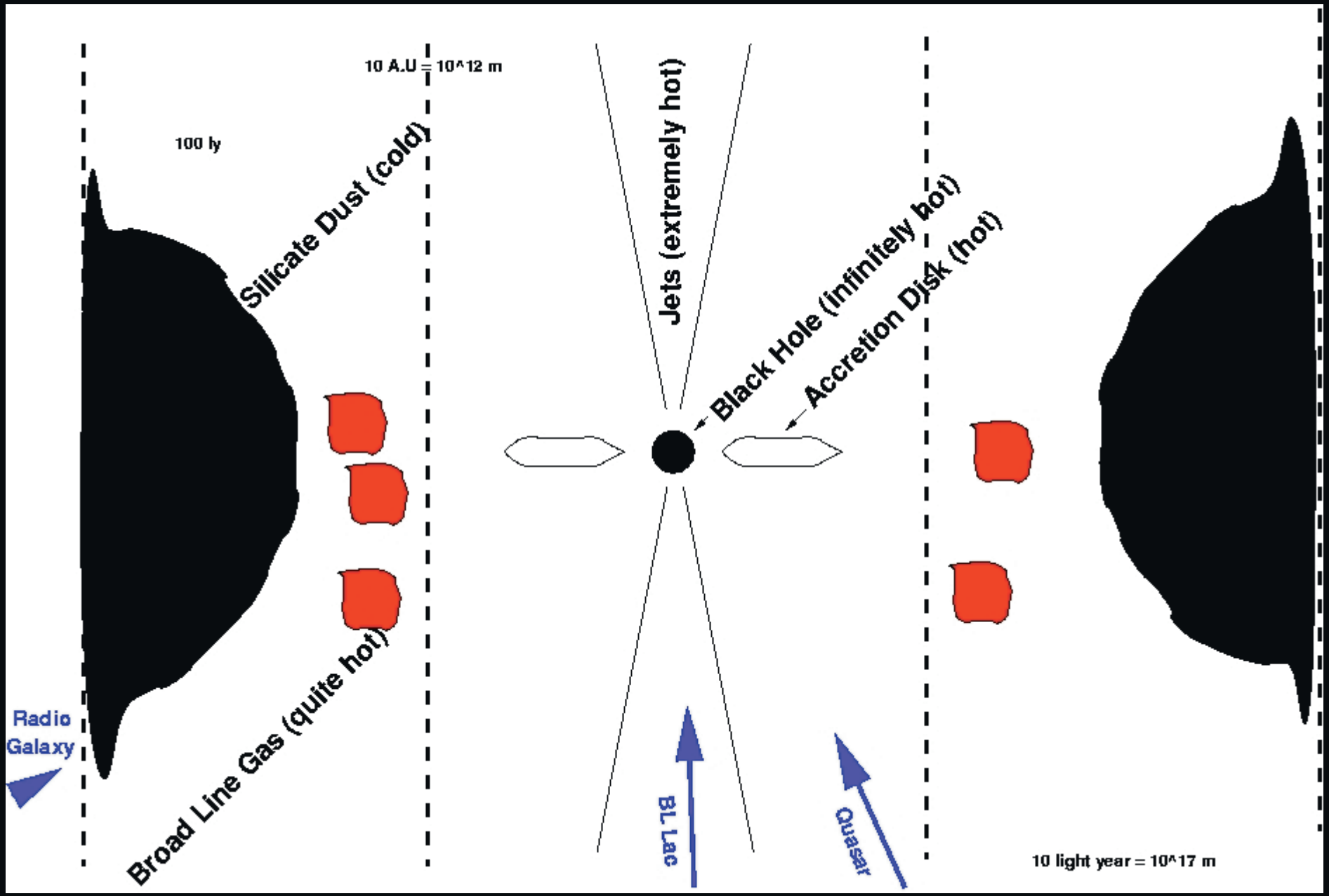


FIG. 1.—Microphotometer tracings of the emission lines λλ 4860 ($H\beta$), 4959 and 5007 [O III] in the nebulae NGC 1068, 3516, and 4151.


(a)
[OIII]
3
F_λ
2
Hβ
[NeIII]
[OII]
CaII K
Hγ + [OIII]
HeII
1
P x F_λ
(b)
0.05


Dust population
inside the ionization core
Dusty torus
1
0
-1


10 A.U = 10^12 m
100 ly
Silicate Dust (cold)
Broad Line Gas (quite hot)
Jets (extremely hot)
Black Hole (infinitely hot)
Accretion Disk (hot)
Radio Galaxy
BL Lac
Quasar
10 light year = 10^17 m

What do we see with VLTI

- What do we see with VLTI (~10 mas)
- at the distance of ~14 Mpc? (1”=70pc)

- Radio Jet (maybe optically thick core)
- Narrow Line Region @ 14” (too big)
- Dusty torus/disk @14 mas (!)
- Broad Line Region @ 1 mas (too small)
- Hot Accretion disk @ 1 microarcsec (“)
- Black Hole (10^8 Mo) @ 0.1 microarcsec

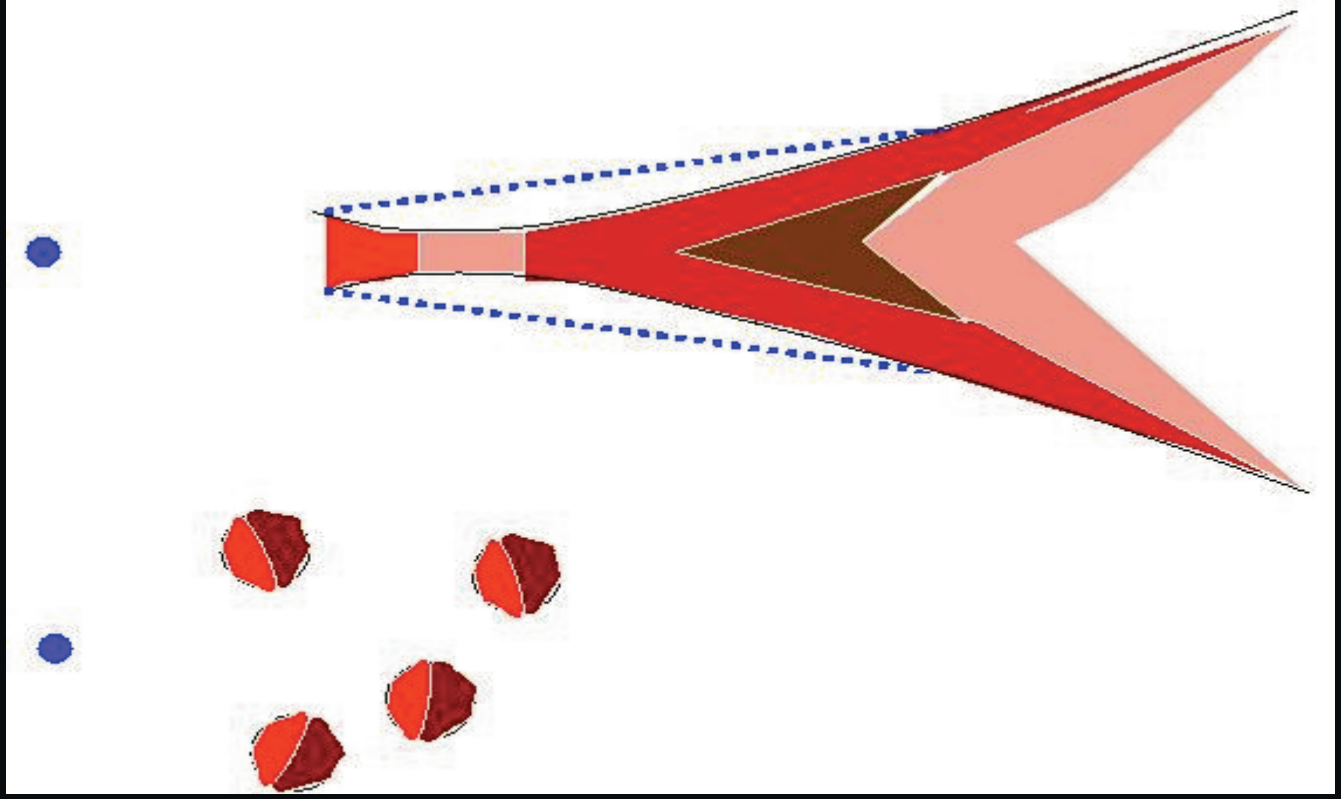
What do we see from dust?

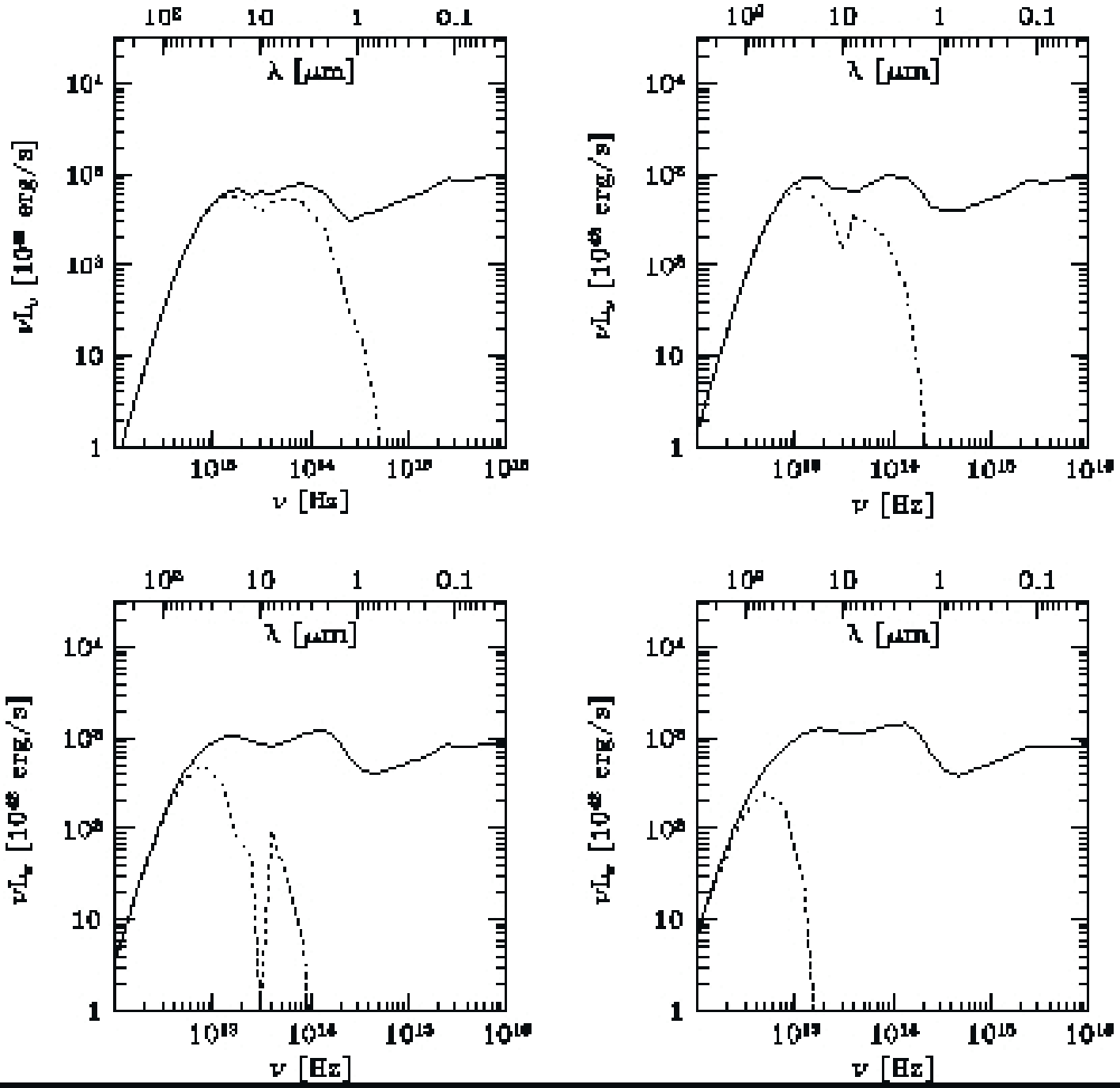
- What do we expect to see from dust?

- T= 1000-30 K (r=1 pc -> 200 pc)
- 1000 K ~ sublimation temperature
- λ =4 μ -> 100 μ

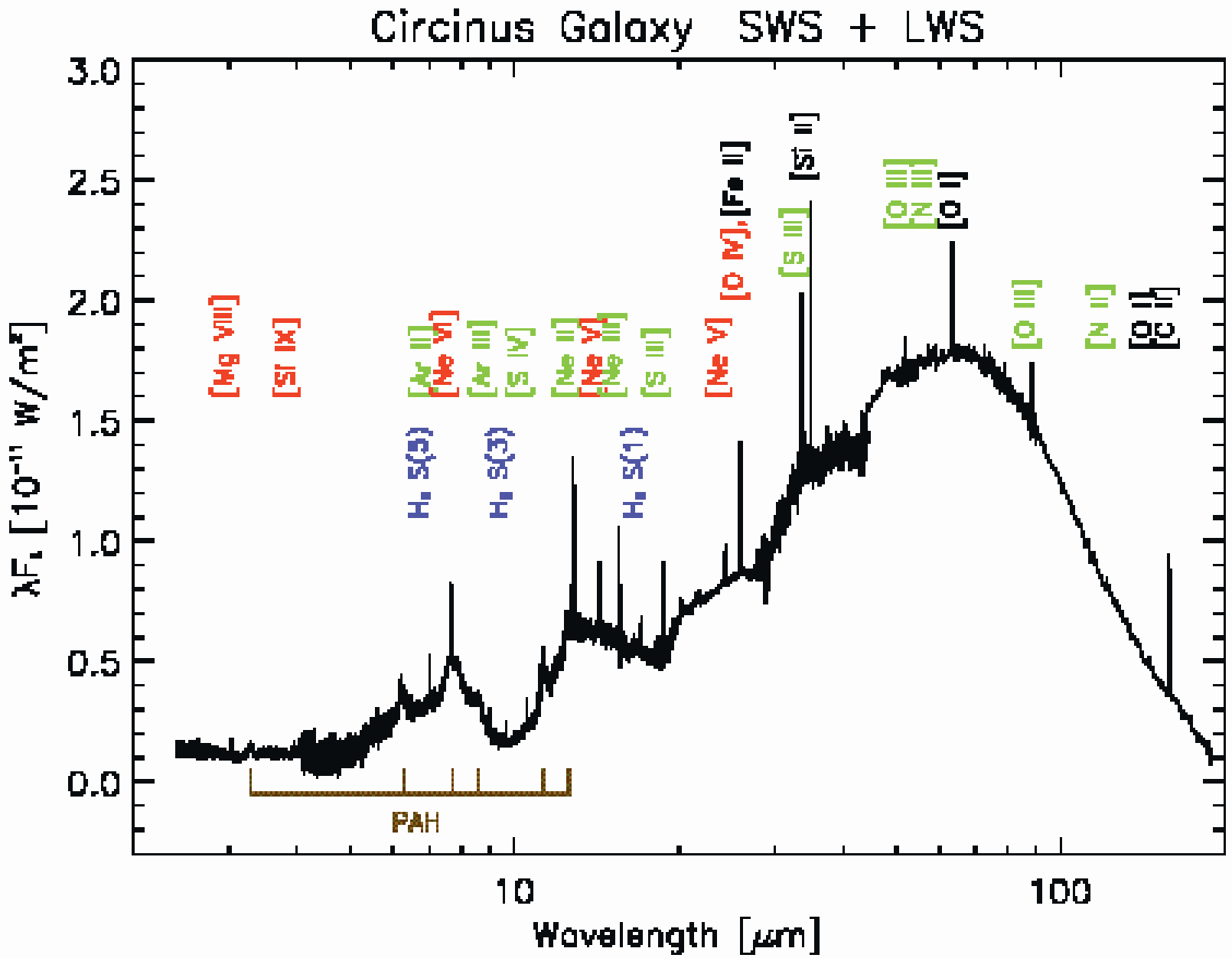
Model variants:

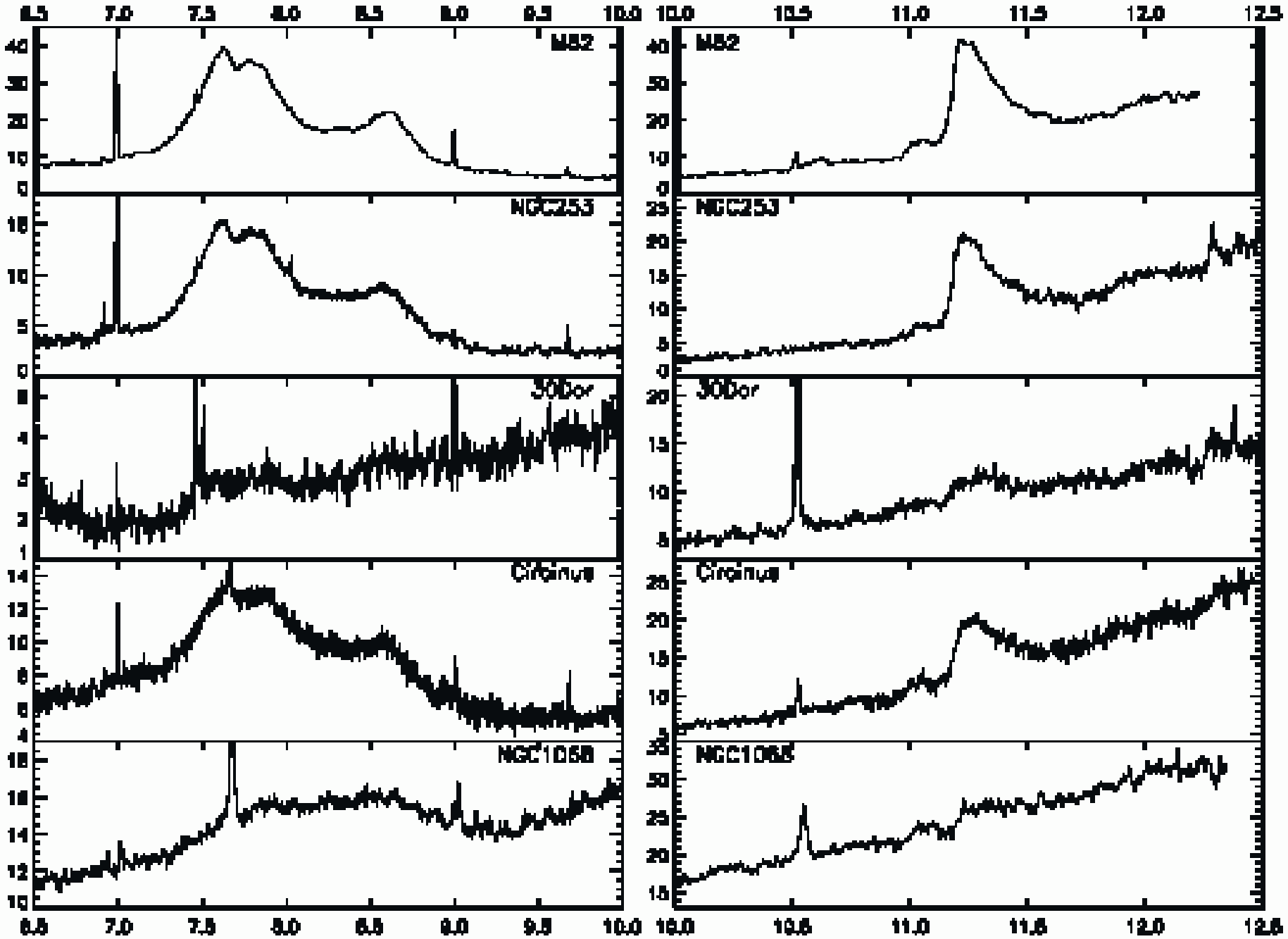
Optically thin (T ~ R^−1/2)
Optically thick (T ~ To (1−tau)^1/4)− leakage
Lumpy (locally optically thick, globally optically thin)





Gran
al 19


Circinus Galaxy SWS + LWS
λF_λ [10^-11 W/m^2]
Wavelength [μm]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10
100
[Mg VIII]
[Si IX]
[Ar II]
[Ne VI]
[Ar III]
[S IV]
[Ne V]
[Ne V]
[S III]
[O IV],[Fe II]
[Si II]
[S III]
[O III]
[N III]
[O I]
[O III]
[N II]
[O I]
H2 S(5)
H2 S(3)
H2 S(1)
PAH


M82
NGC253
30Dor
Circinus
NGC1068
M82
NGC253
30Dor
Circinus
NGC1068

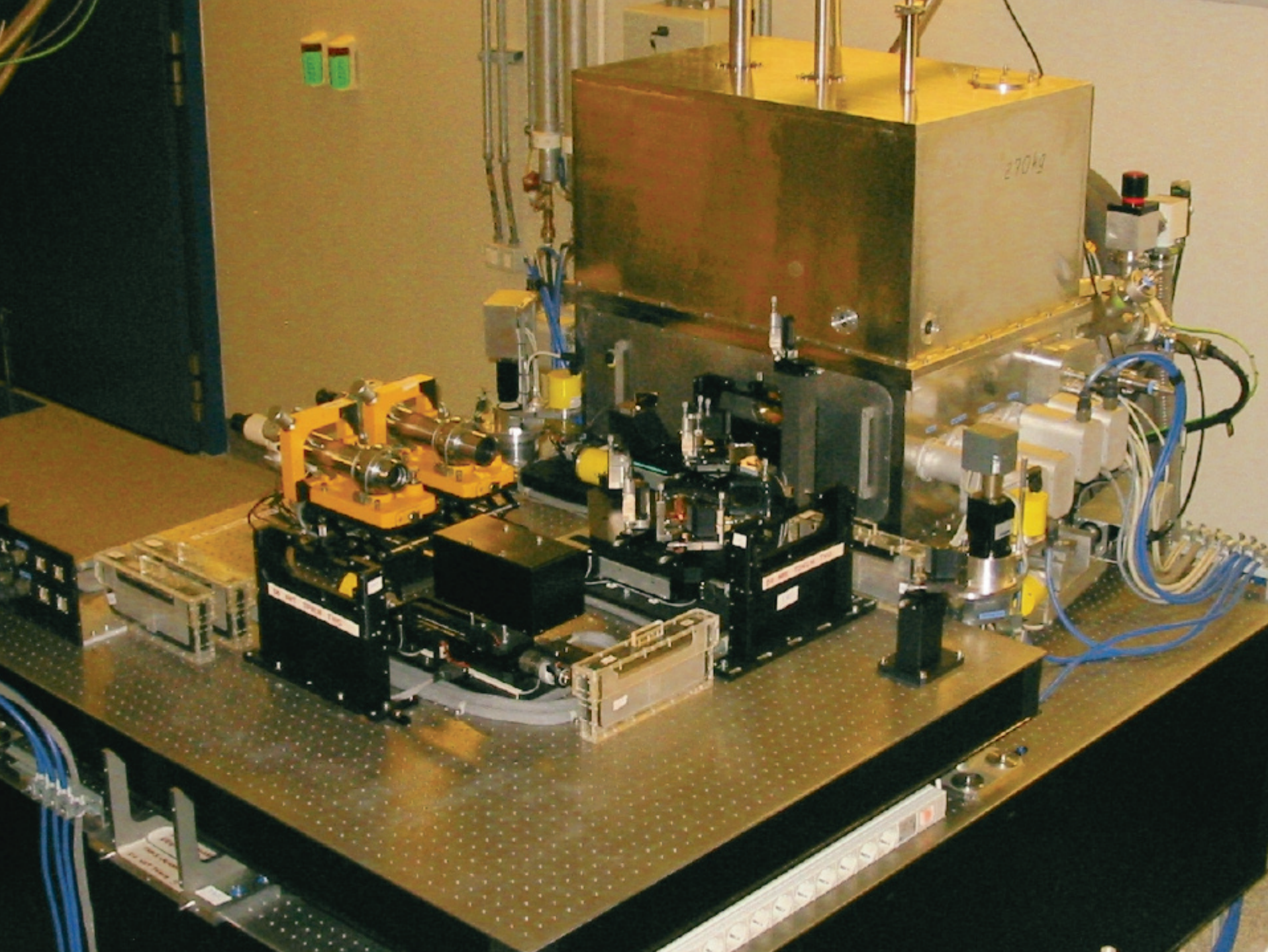
What do we see from dust?

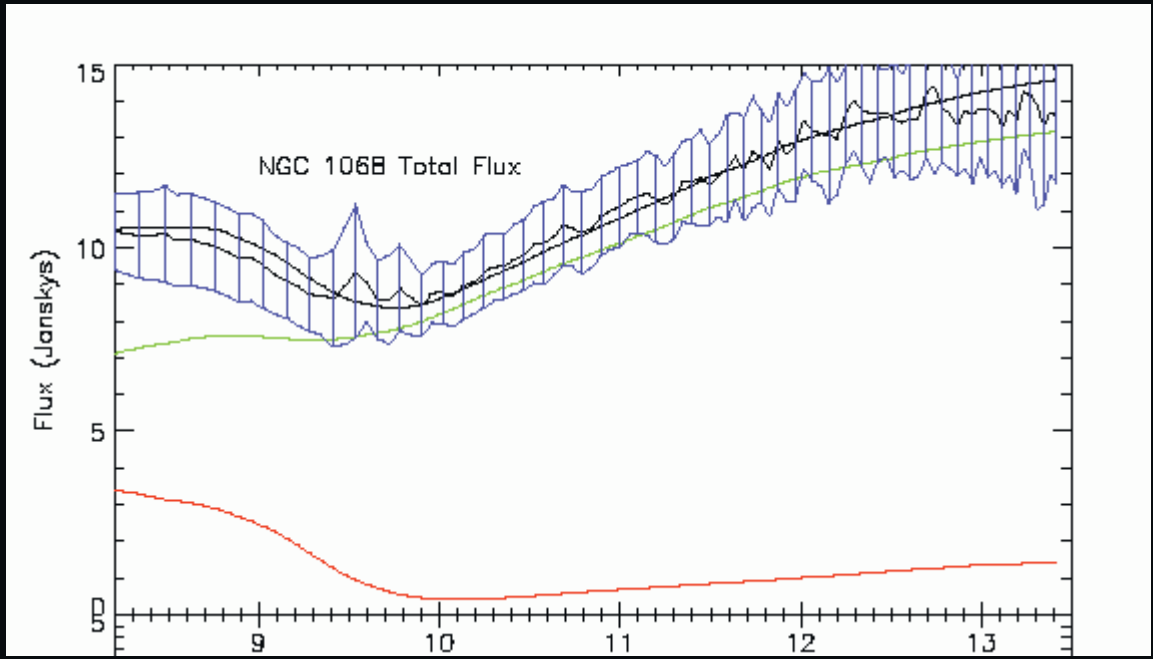
Seyfert 1	Seyfert 2
Round	Flattened
If optically thick:	
Core dominated?	Extended
Silicate emission?	Silicate absorption

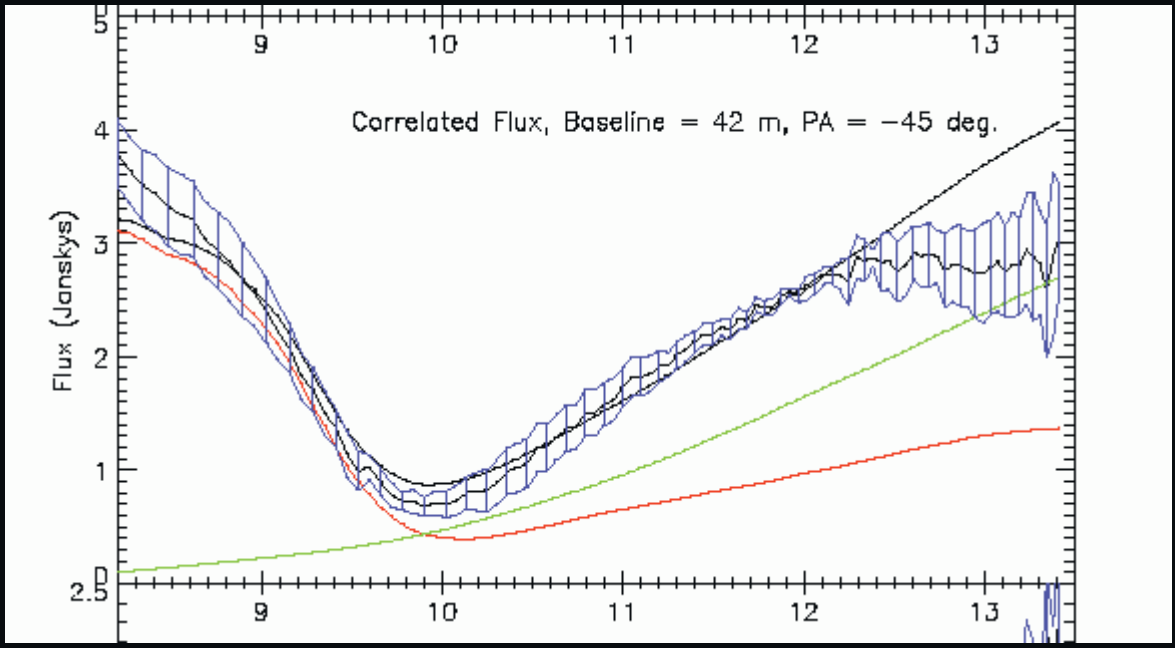
Prime Questions:

- Do obscuring torii really exist?
  - if so:
    - shape
    - size
    - orientation
    - temperature
    - clumpiness
    - chemistry

What supports thick disk/torus?


270kg


NGC 1068 Total Flux
Flux (Janskys)
15
10
5
0
-5
9
10
11
12
13


Correlated Flux, Baseline = 42 m, PA = −45 deg.
Flux (Janskys)
5
4
3
2
1
0
2.5
9
10
11
12
13

MIDI Prime Targets:

Close, big, bright:

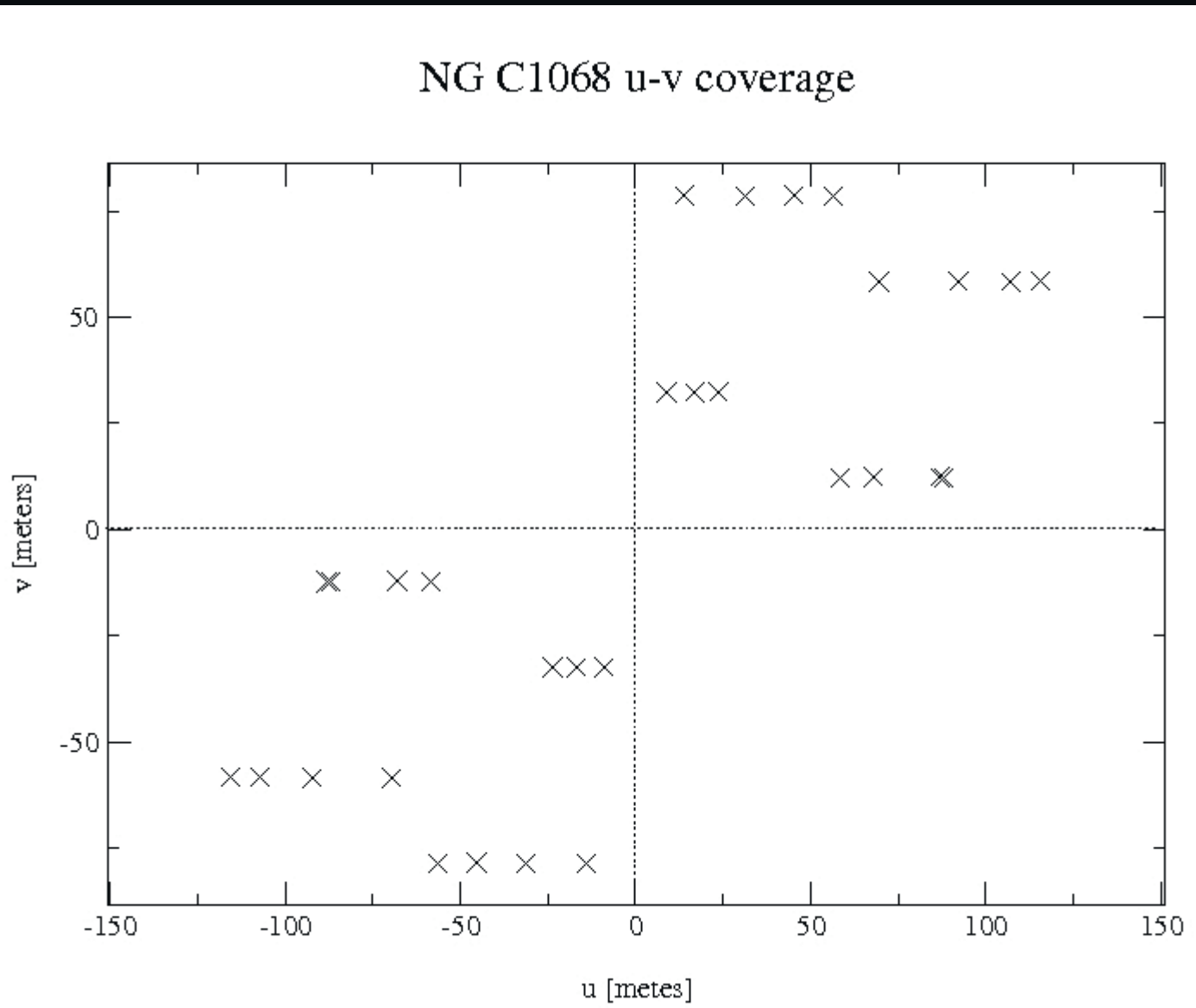
NGC 1068, Circinus, Cen A

Secondary Targets:

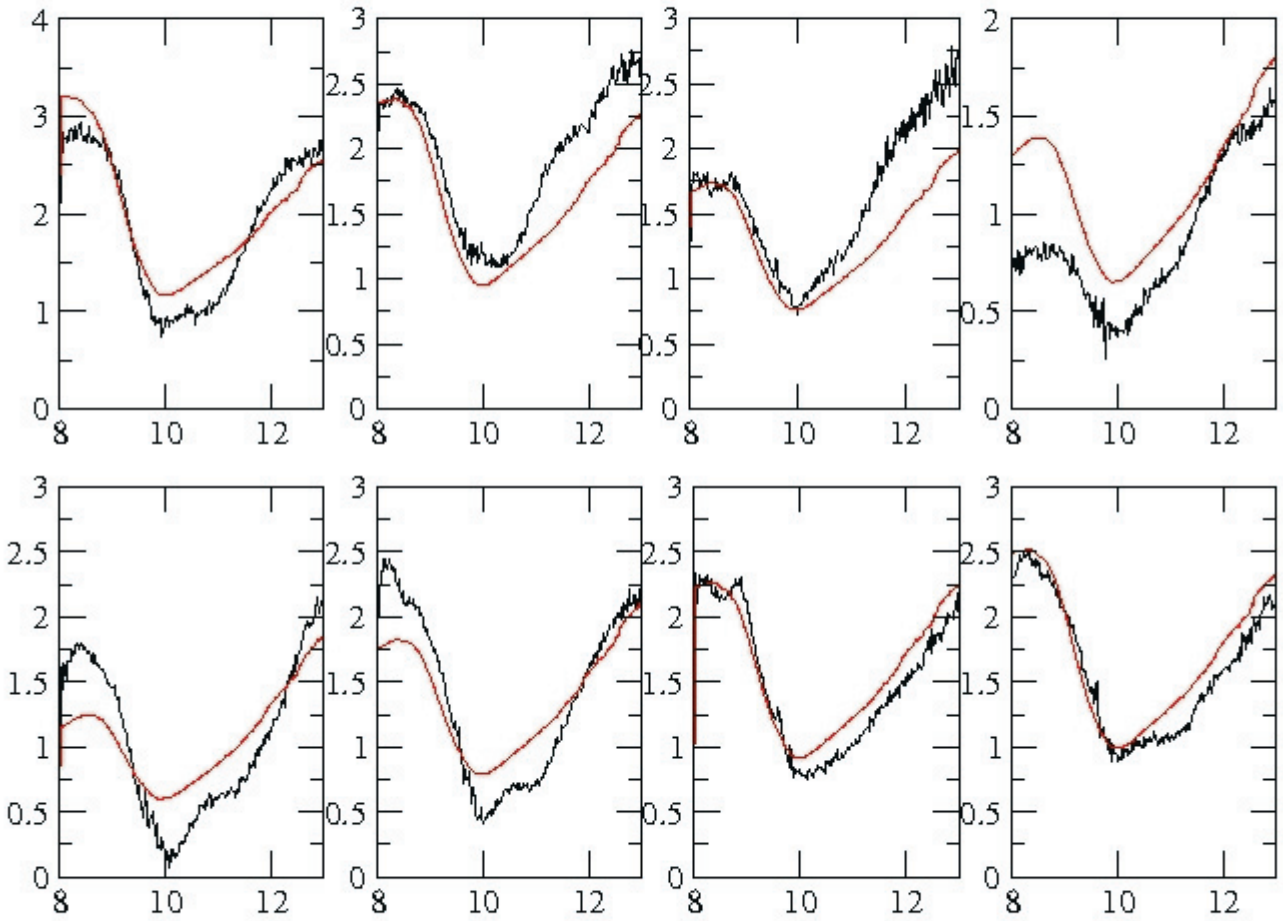
not so close/big/bright

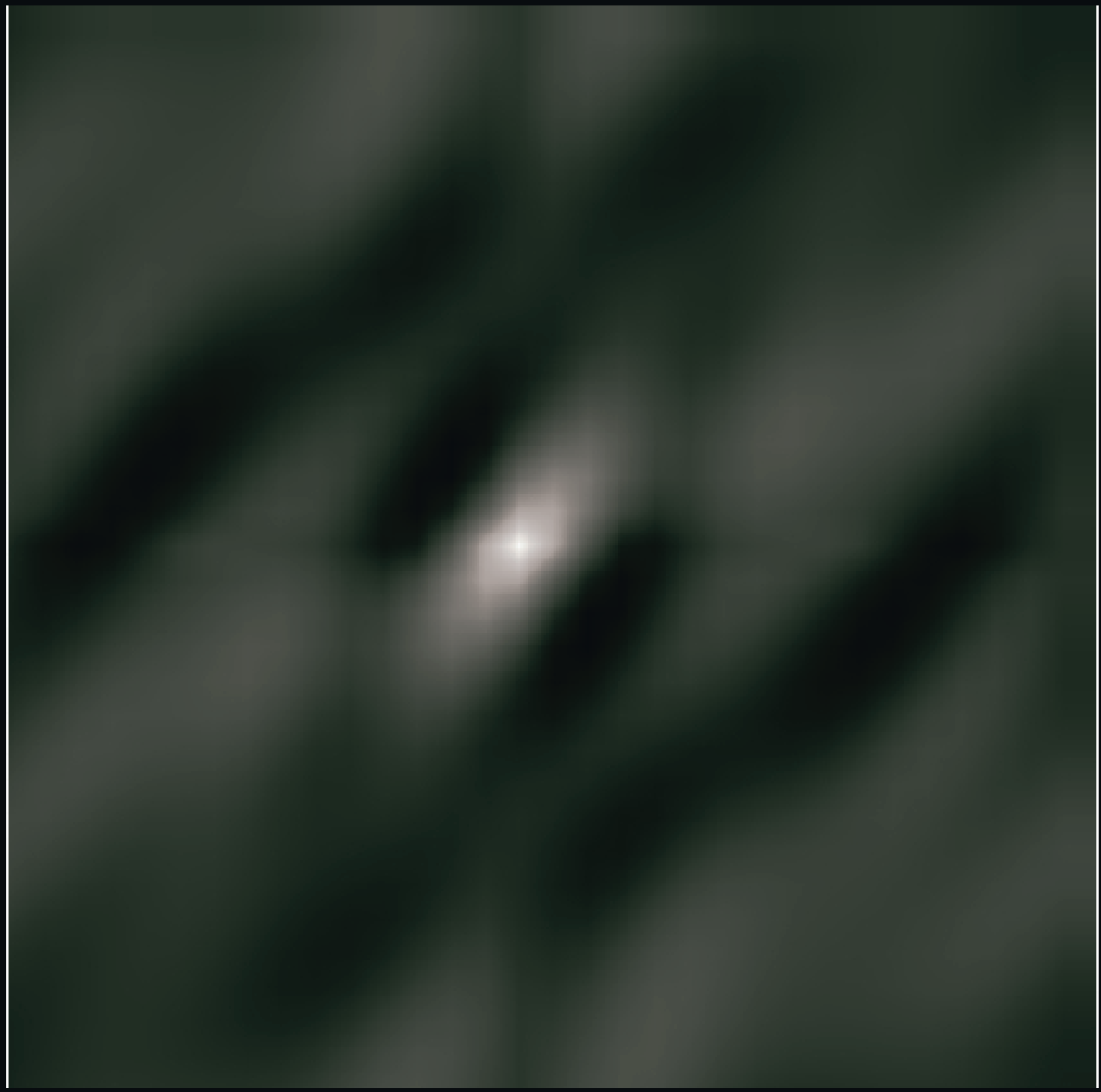
~10 Sy 1+2 ; 1 quasar (3c273)

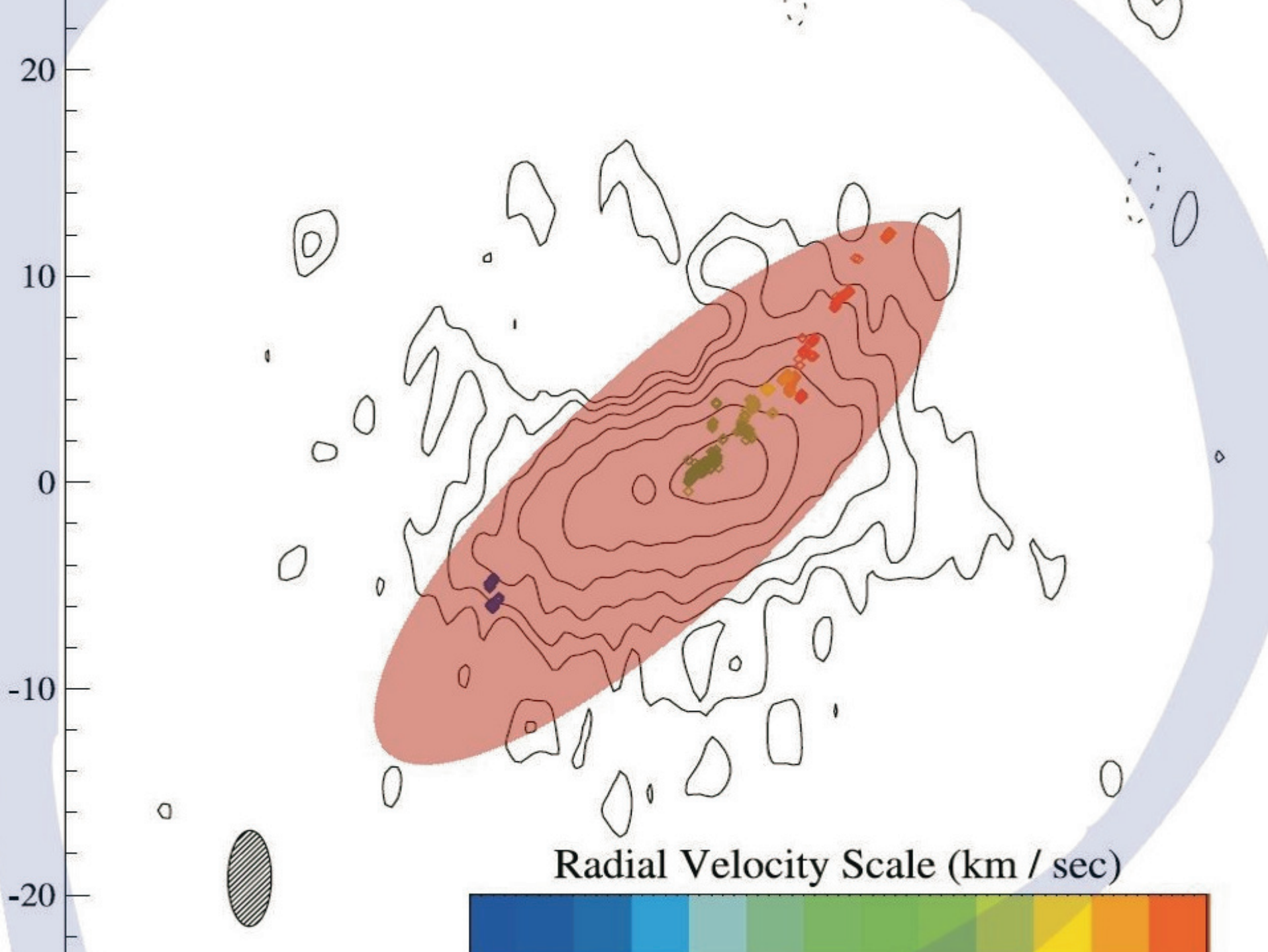
1 Starburster

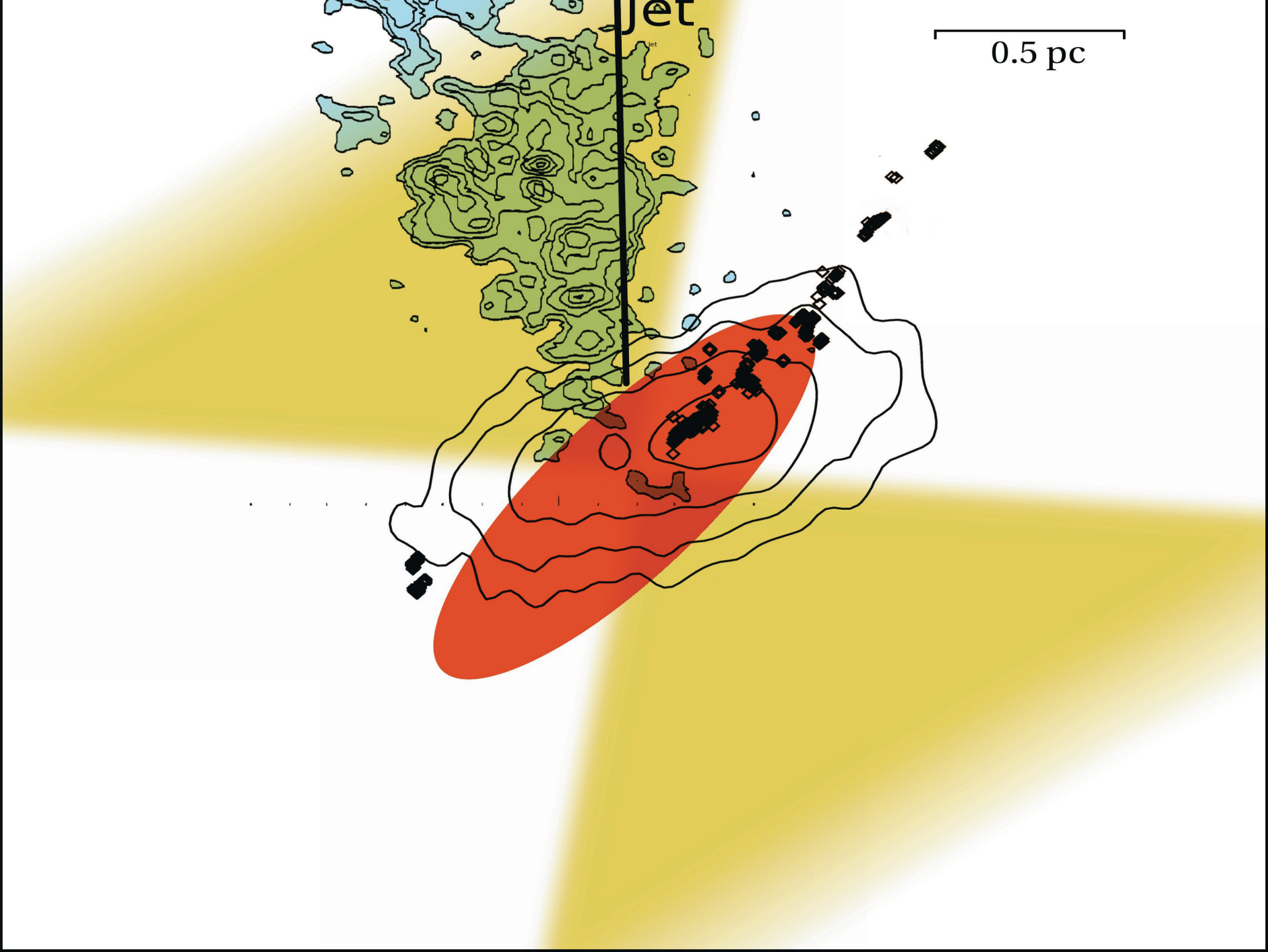

NG C1068 u-v coverage
v [meters]
u [metes]
50
0
-50
-150
-100
-50
0
50
100
150

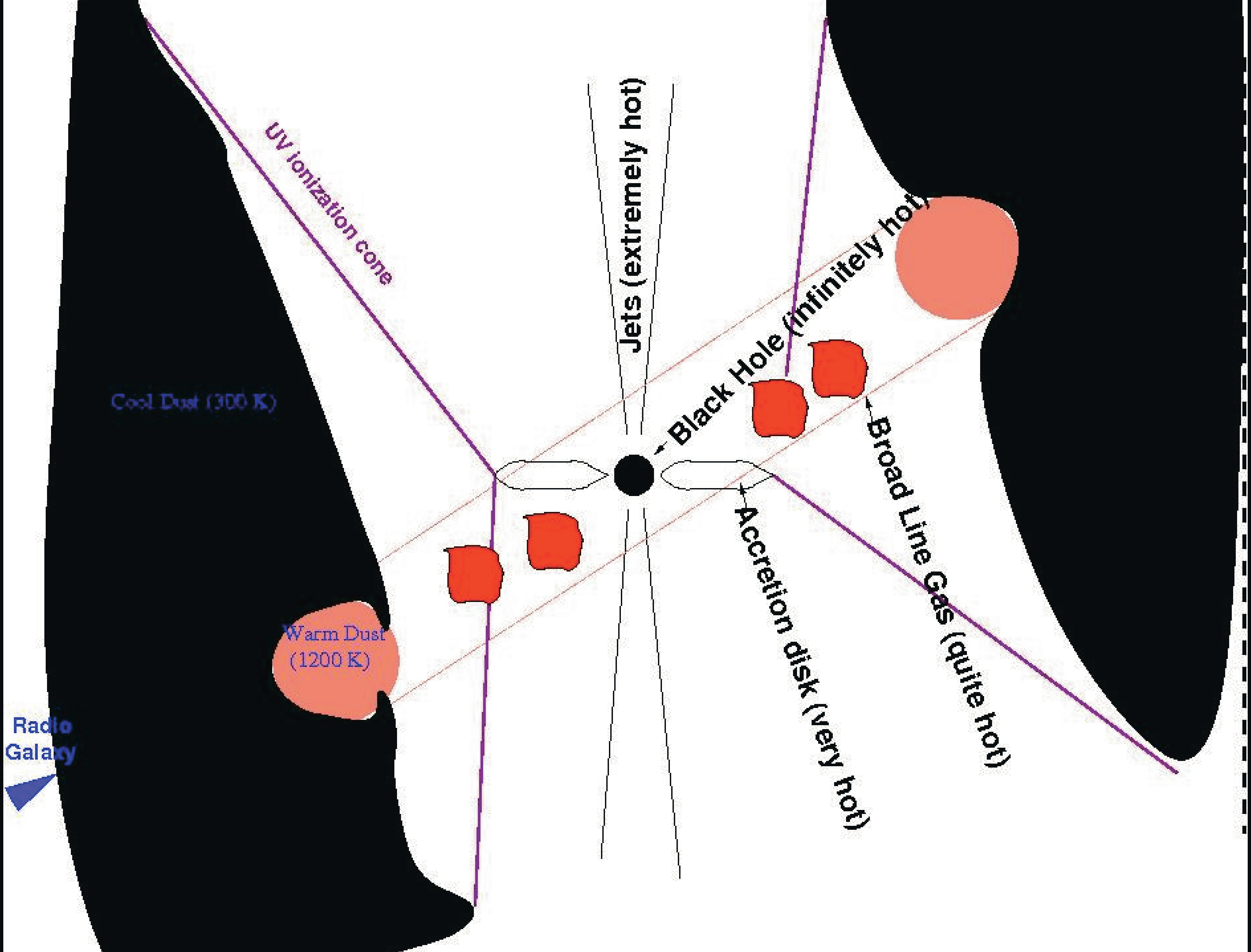
NGC 1068 correlated flux






20
10
0
-10
-20
Radial Velocity Scale (km / sec)


Jet
0.5 pc


UV ionization cone
Jets (extremely hot)
Black Hole (infinitely hot)
Cool Dust (300 K)
Broad Line Gas (quite hot)
Accretion disk (very hot)
Warm Dust (1200 K)
Radio Galaxy

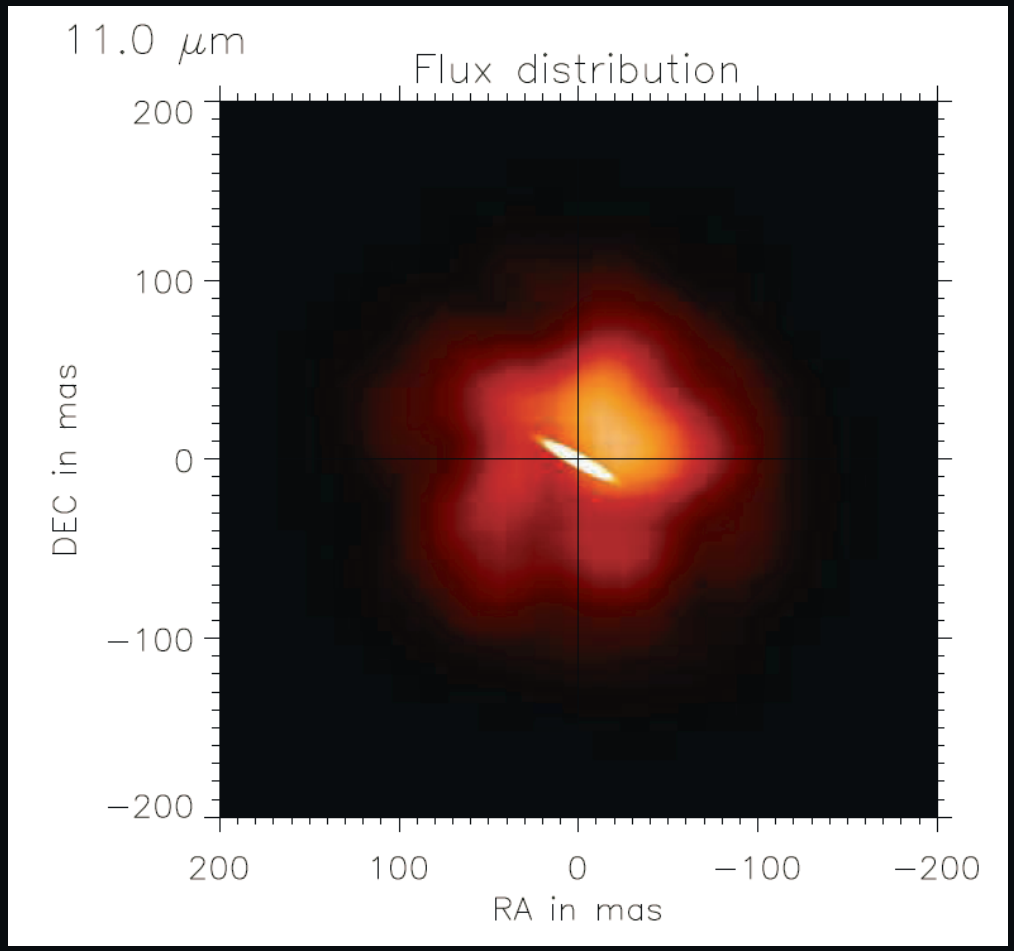
Circinus: the galaxy

- Spiral galaxy SA(s)b, i = ~65°
- RA = 14h 13m, DEC = - 65° 20’
- Seyfert type 2
- 4×10^6 $M_\odot$ nucleus
- Distance ~4 Mpc ? 50 mas ~ 1 pc
- unresolved in MIR

2MASS J, H, K_s colour mosaic

Circinus: Gaussian fit

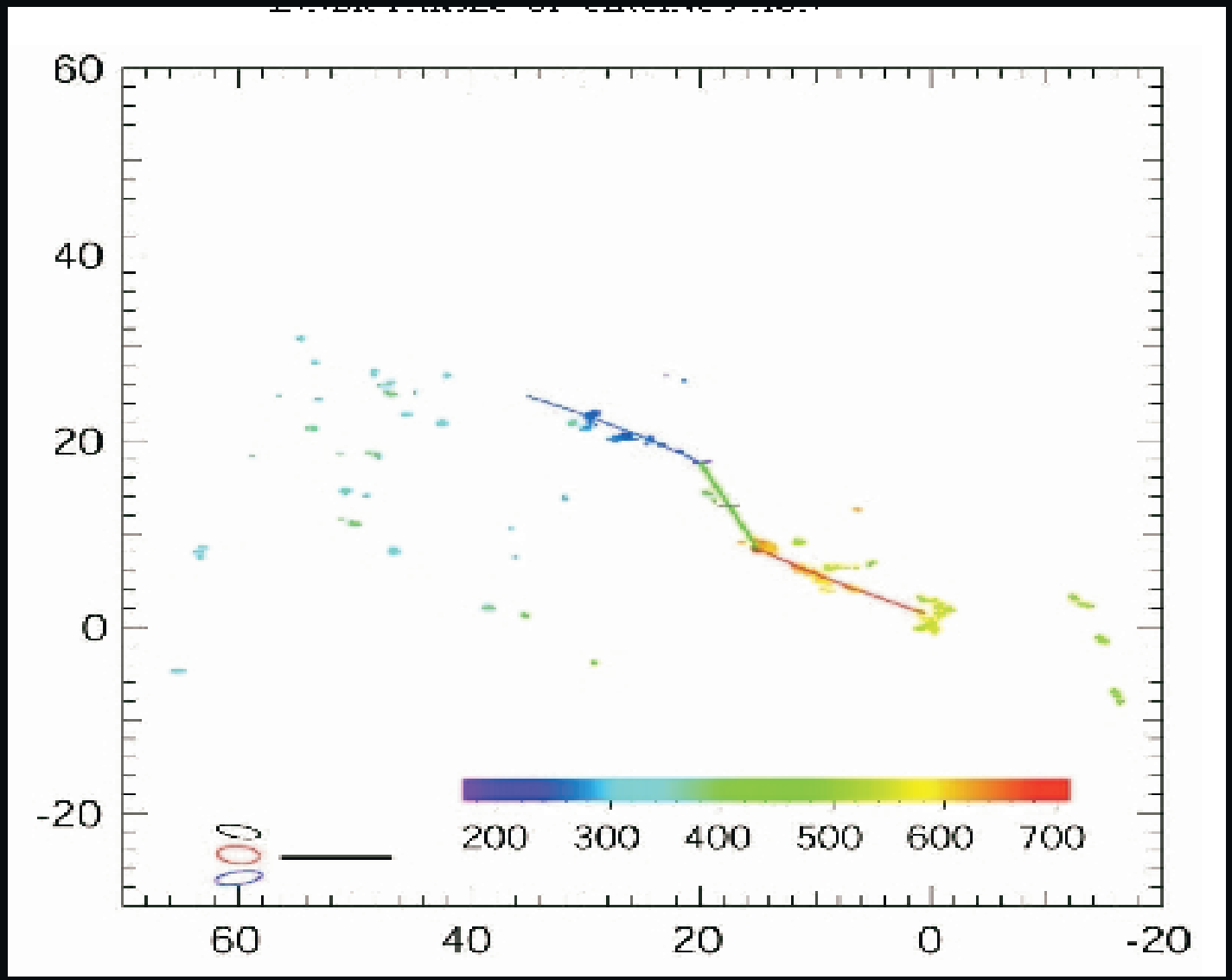
Two blackbody Gaussians:



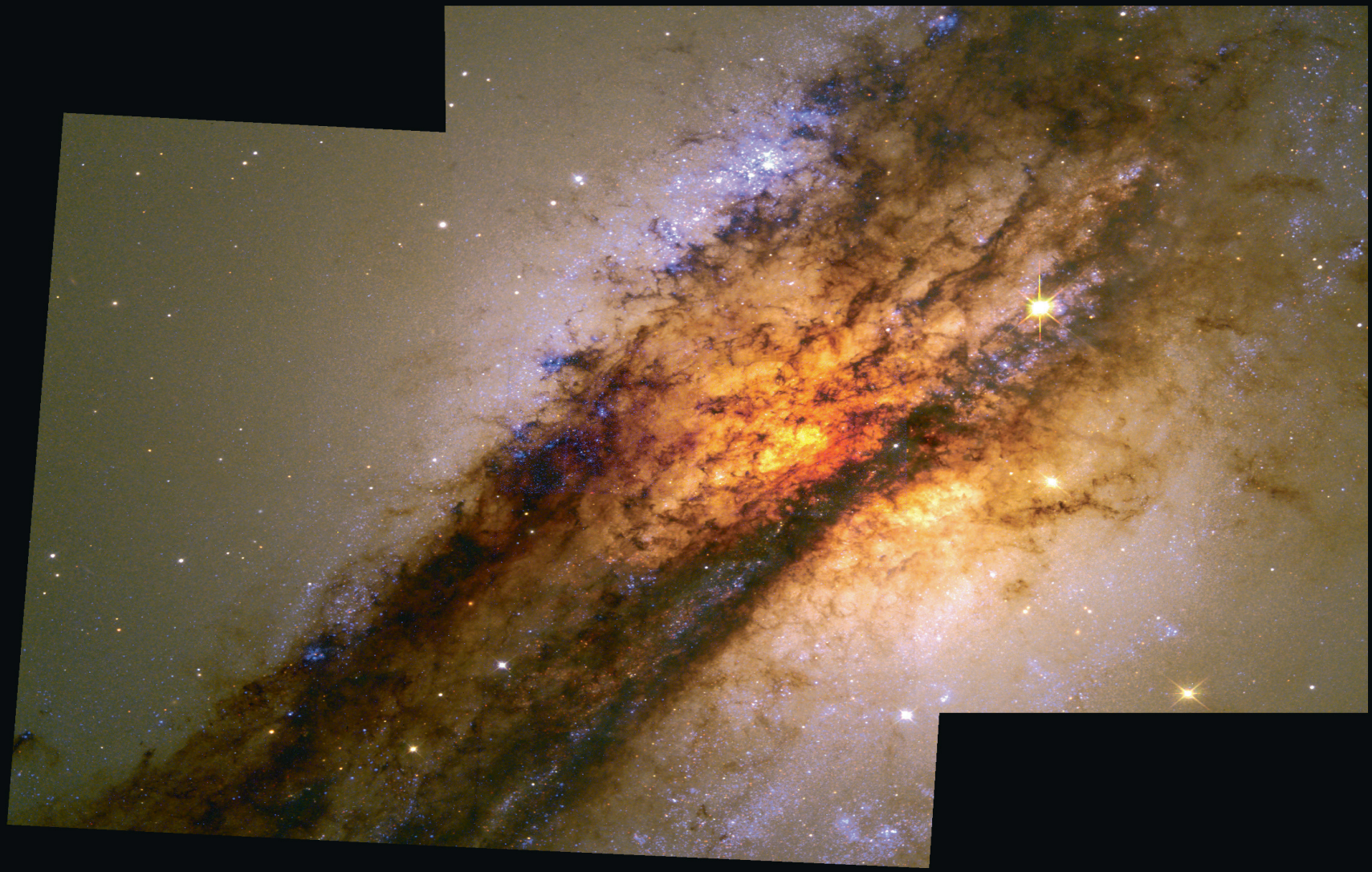
Log of model flux distribution at 11μm

Tristram et al. 2007

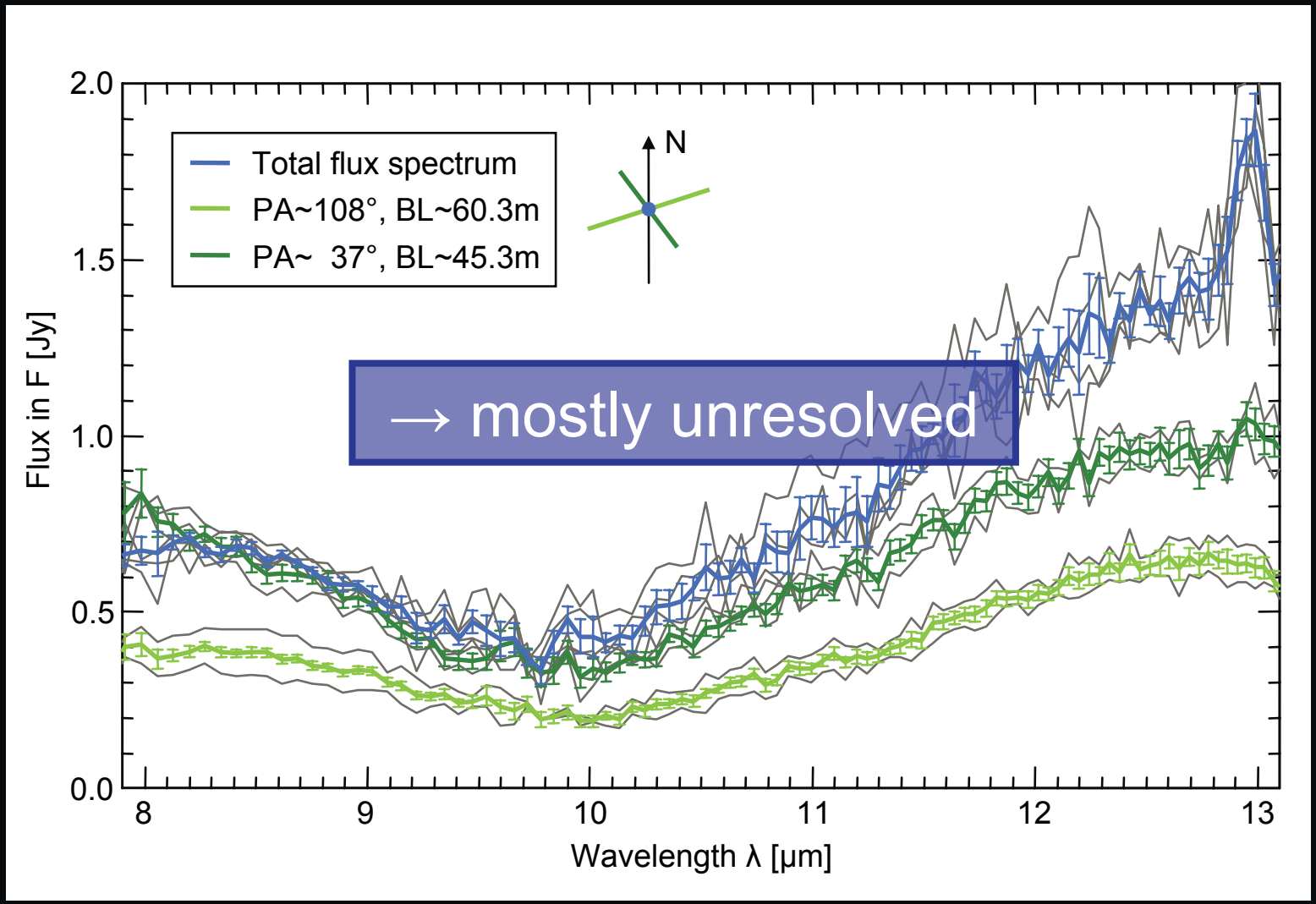
Greenhill 2003: Water Masers

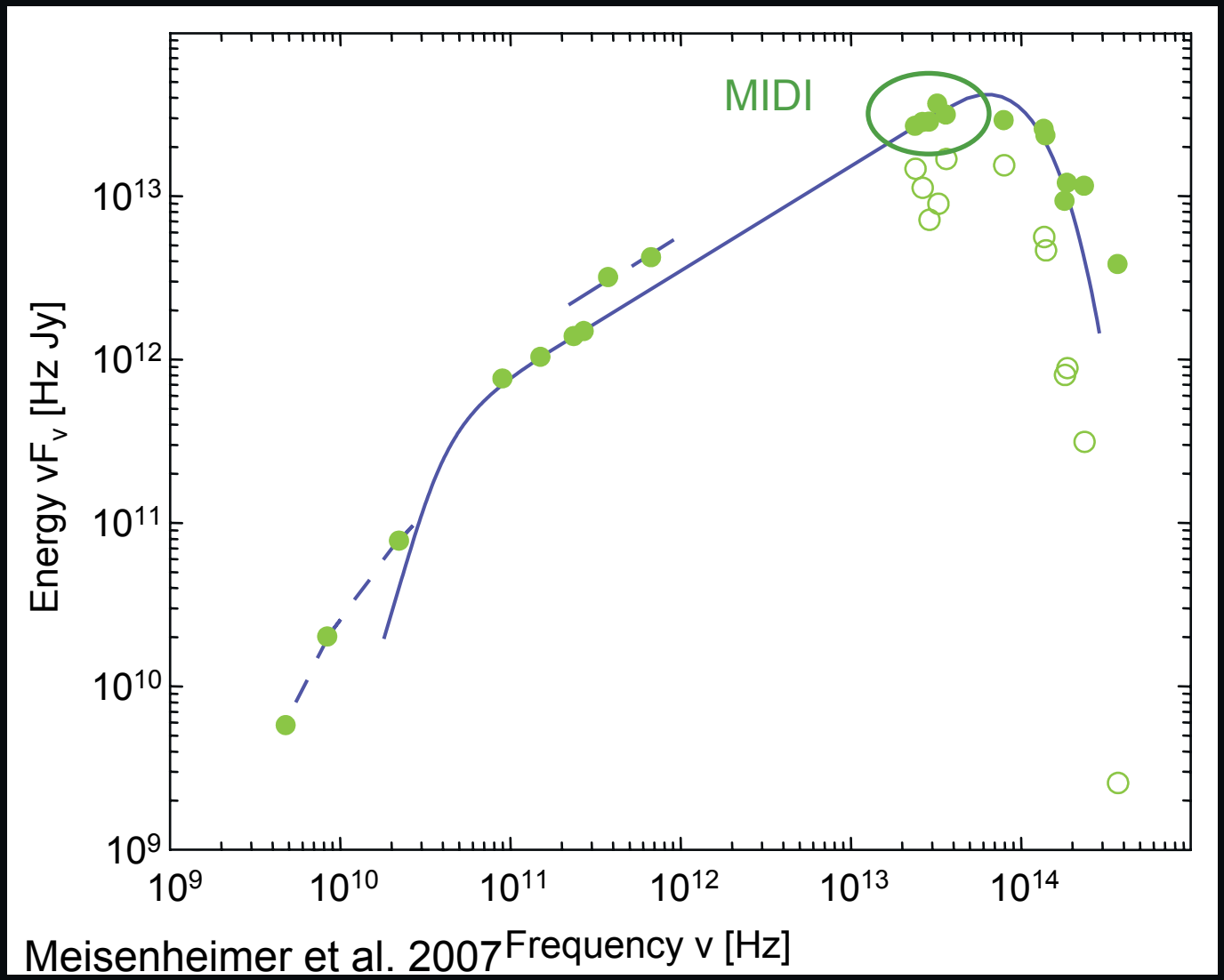


Cen A = NGC 5128



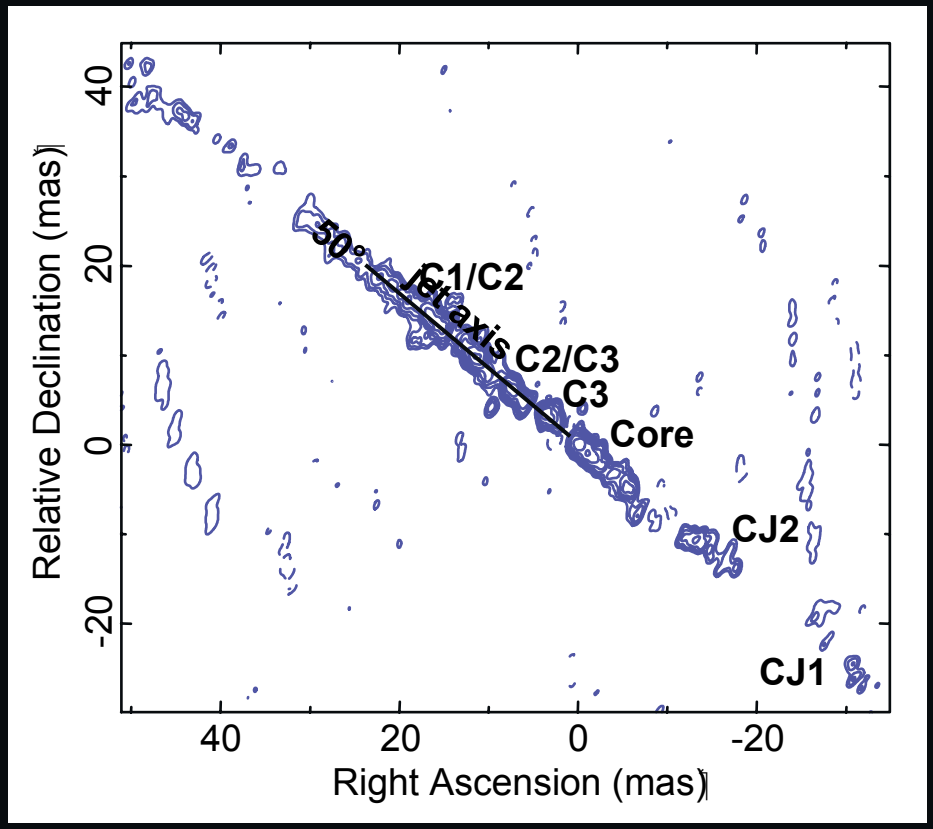
Centaurus A: Fluxes

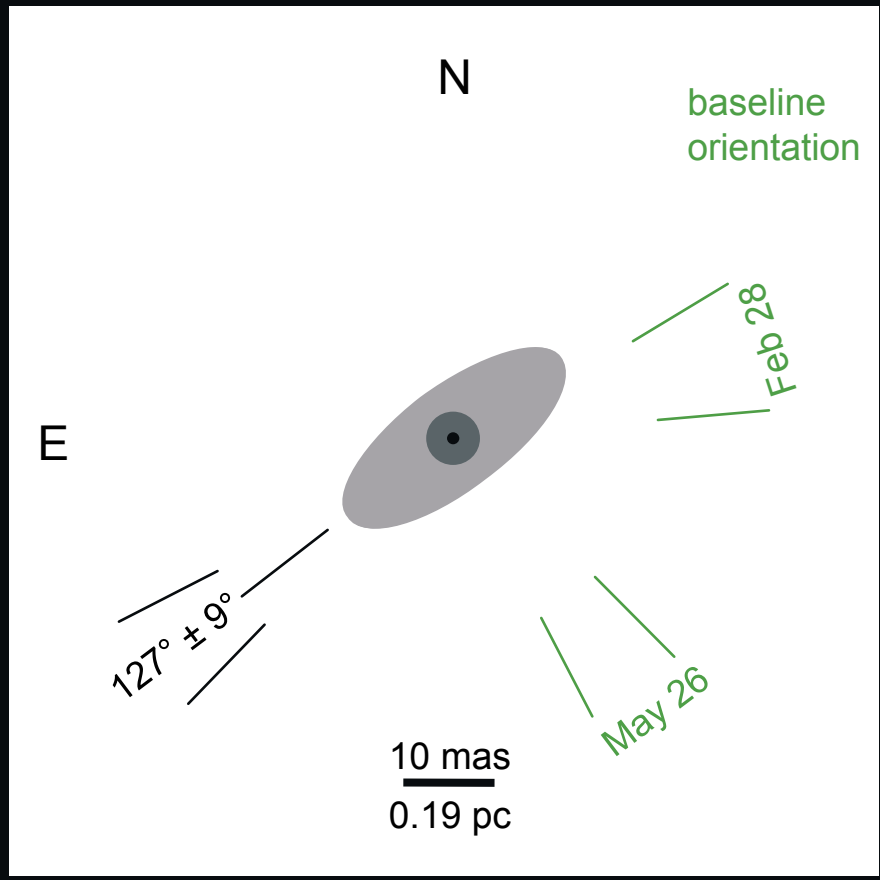




Meisenheimer et al. 2007

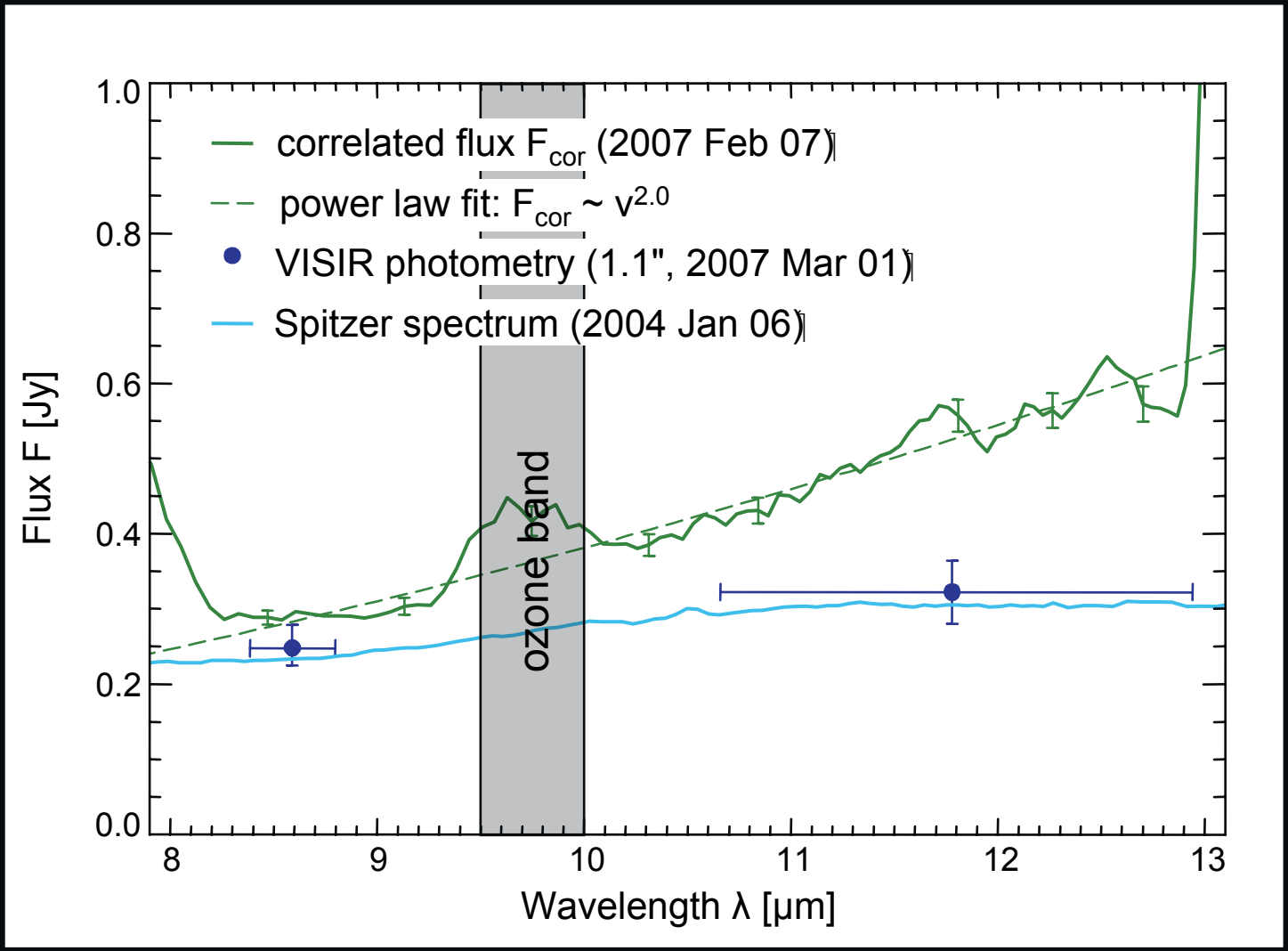
Bulk of the MIR radiation is synchrotron emission

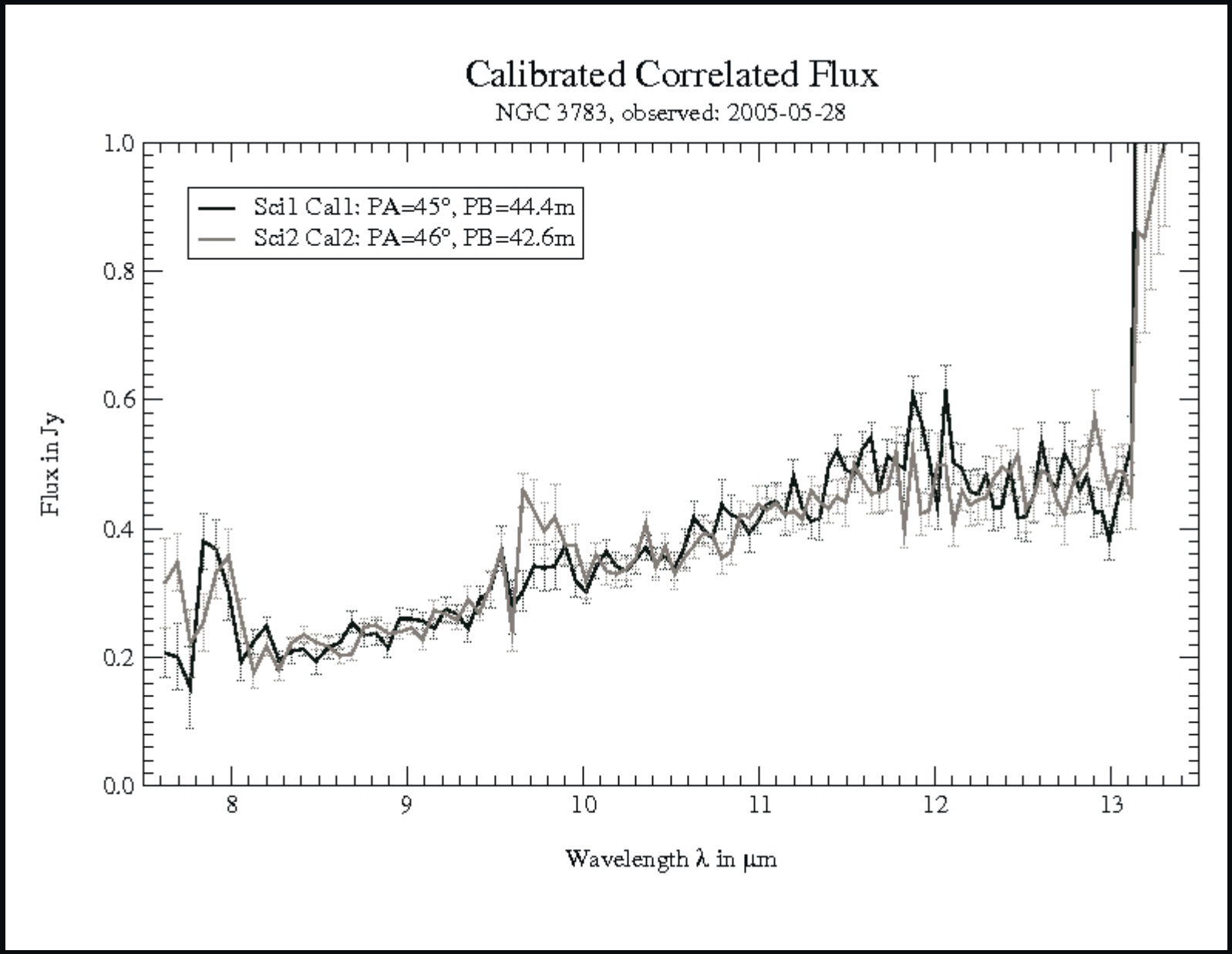




Name	Flux (10 μm)	Type	Detect?
NGC 1068	13 Jy	Sy 2	X+VINCI
Circinus	5 Jy	Sy 2	X
Cen A	0.6 Jy	RG	X
NGC 3783	0.5 Jy	Sy 1	X
Mrk 1239	0.4 Jy	Sy 1	X
MCG -05-23-016	0.3 Jy	Sy 2	X
NGC 7469	0.4 Jy	Sy 1	X
NGC 1365	0.6 Jy	Sy 2	X
IC 4329A	0.6 Jy	Sy 1	X (res?)
NGC 253	?	StarB/Sy 2	0
NGC 7582	?	Sy 2	0
NGC 7479	?	Sy 2	NA
NGC 5253	?	StarB	NA
NGC 4151	~1Jy	Sy 1	X
3C 273	0.3 Jy	QSO	X

3C 273


correlated flux F_{cor} (2007 Feb 07)
power law fit: $F_{cor} \sim \nu^{2.0}$
VISIR photometry (1.1", 2007 Mar 01)
Spitzer spectrum (2004 Jan 06)
ozone band
Flux F [Jy]
Wavelength λ [μm]
1.0
0.8
0.6
0.4
0.2
0.0
8
9
10
11
12
13


Calibrated Correlated Flux
NGC 3783, observed: 2005-05-28
Sci1 Cal1: PA=45°, PB=44.4m
Sci2 Cal2: PA=46°, PB=42.6m
Flux in Jy
1.0
0.8
0.6
0.4
0.2
0.0
8
9
10
11
12
13
Wavelength λ in μm

Conclusions:

conclusions

Best studied dust disks:

Agree in size/orientation with H2O masers.

Disks are smaller than (some) SED predictions, and probably clumpy

NGC1068 disk is tipped wrt both jet and ionization cone.

Interesting dust chemistry.

NONUNIFIED TORI:
conclusions

Some are tipped wrt natural axes;
Some aren't.

Some have inner edge at sublimation radius. Some don't.

Some have strong MIR emission (Sy 2, quasar). Some don't (RG).

Basic Sy1/2 unification not yet tested but see NGC 4151.

AGN Survey Conclusions:

conclusions

- Weak but nonzero dust emission in Radio Galaxy (Cen A)
- Most Seyferts show “optically thin” spectra, little SiO abs.
- 1(2) Sy1 resolved(?); no SiO emission

Homework: conclusions

What diameter telescopes are needed to measure 10 μ flux from optically thick 300 K dust on 1000 meter baseline? Assume noise comes from photon noise from optical train (50% absorption) and integration/coherence time is 1 second.