Torus Dynamics: A Palimpsest

TORUS 2018: The Many Faces of AGN Obscuration

Jack Gallimore
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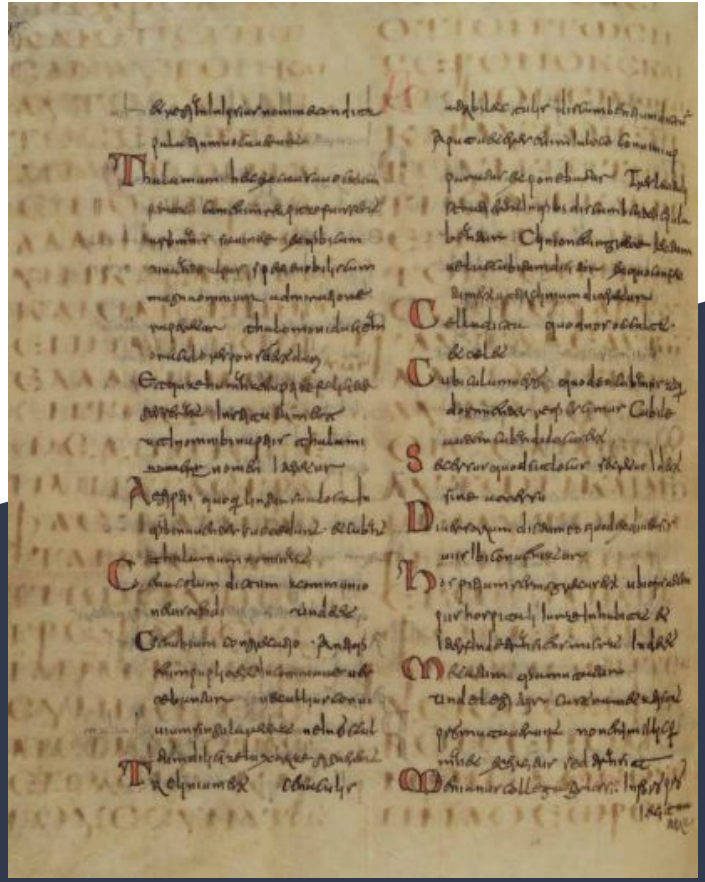


Codex Guelferbytanus A

The Geometry of AGN Obscuration - 1984

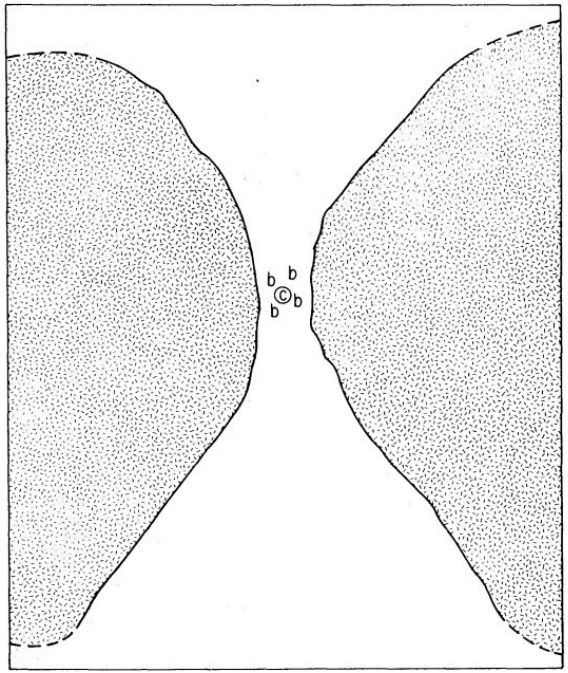
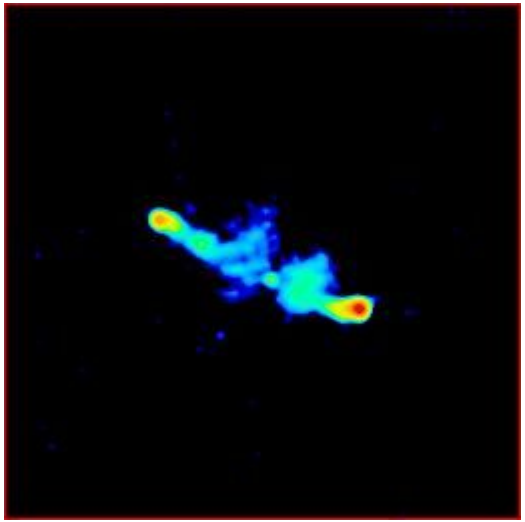
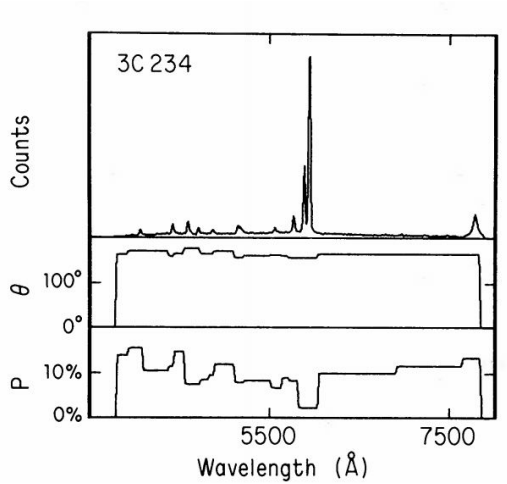


FIG. 12*a*

Cross-section schematic of a
“high perpendicular polarization source.”

3C 234 - Antonucci (1984)





Leahy, Pooley & Riley (1986)

The Geometry of AGN Obscuration - 1985

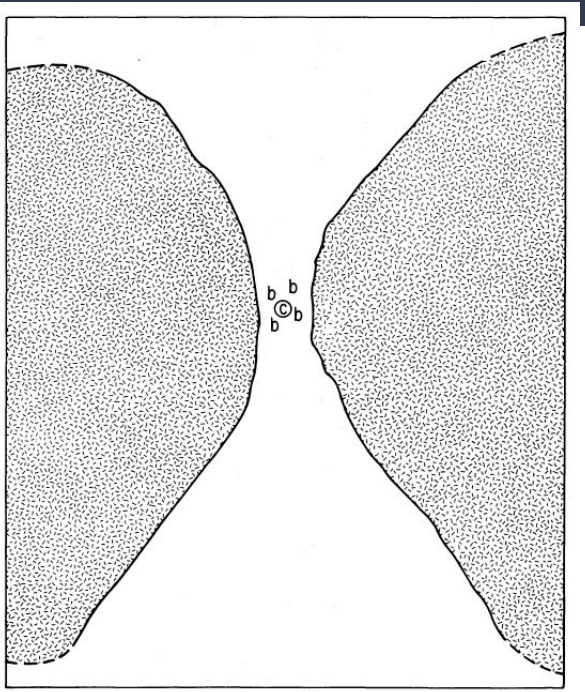
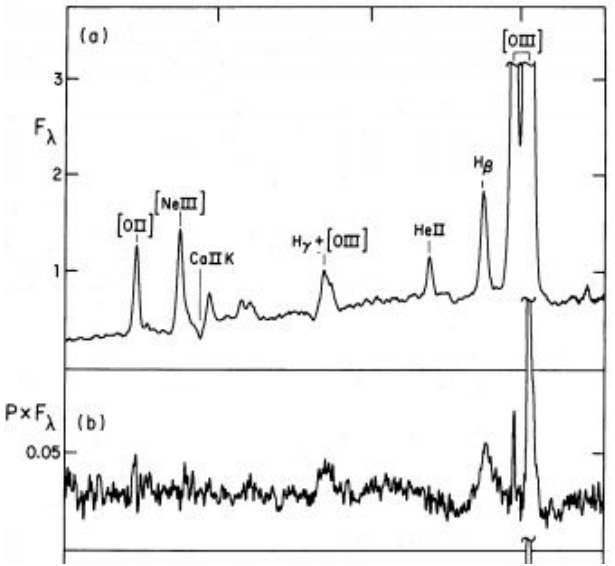


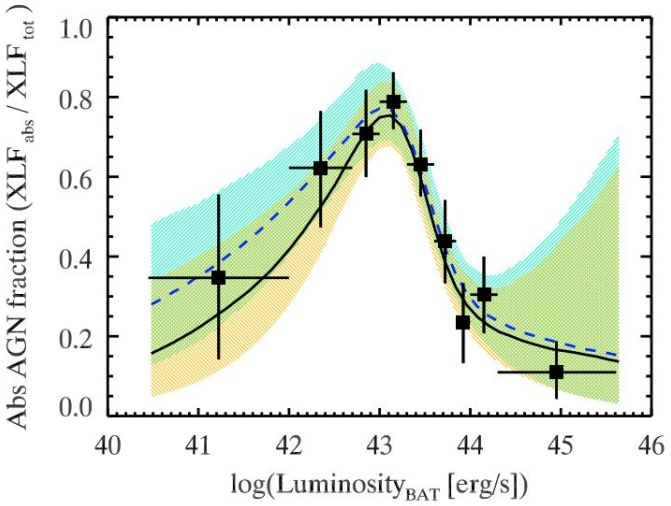
FIG. 5.—Cutaway drawing of a continuum source and broad-line clouds surrounded by a geometrically and optically thick disk. Only photons traveling out along the polar directions can scatter into the line of sight. We would observe a high polarization in the plane perpendicular to the symmetry axis, which we presume to be the radio structure axis.

Cross-section schematic model for NGC 1068.

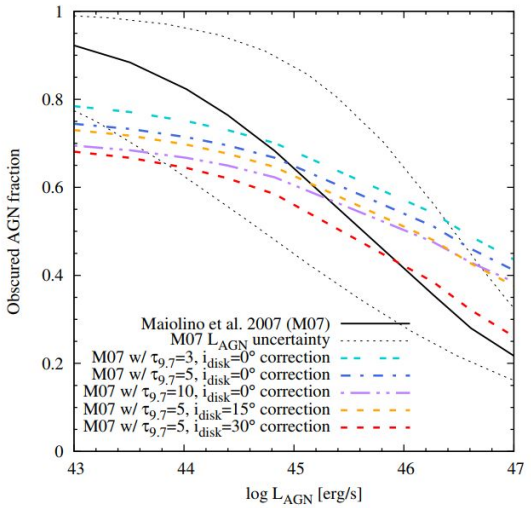
Antonucci & Miller (1985)

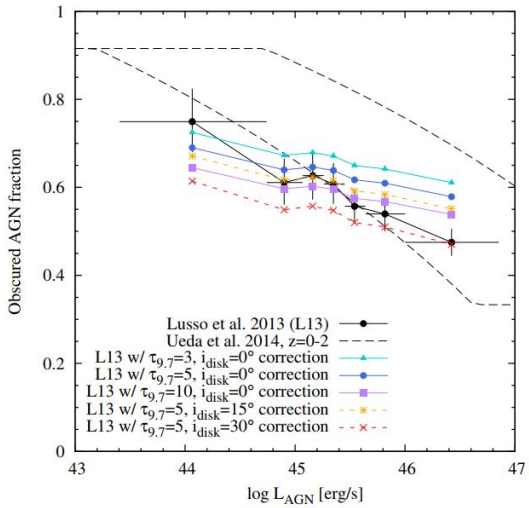


Torus Covering Fraction



X-rays: Burlon et al. (2011)





IR: Stalevski et al. (2016)

Torus Dynamics

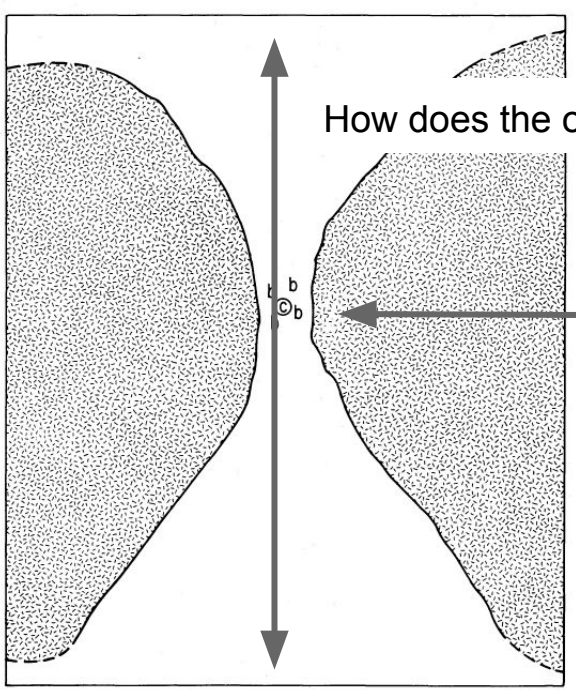


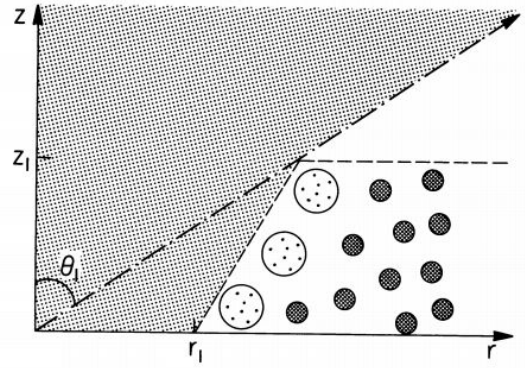
FIG. 5.—Cutaway drawing of a continuum source and broad-line clouds surrounded by a geometrically and optically thick disk. Only photons traveling out along the polar directions can scatter into the line of sight. We would observe a high polarization in the plane perpendicular to the symmetry axis, which we presume to be the radio structure axis.

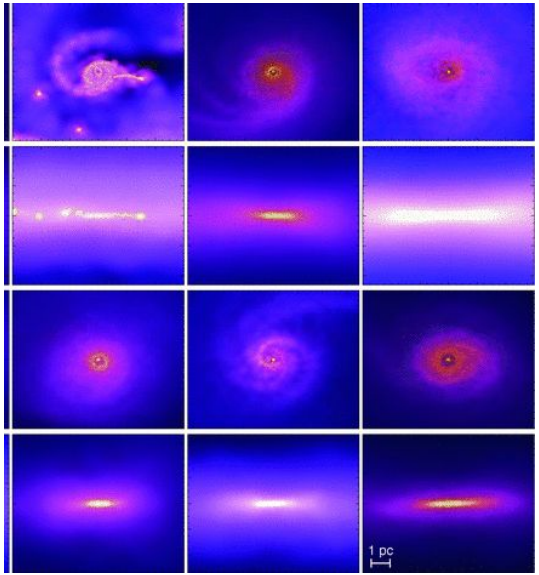
How does the obscuring region maintain its scale height?

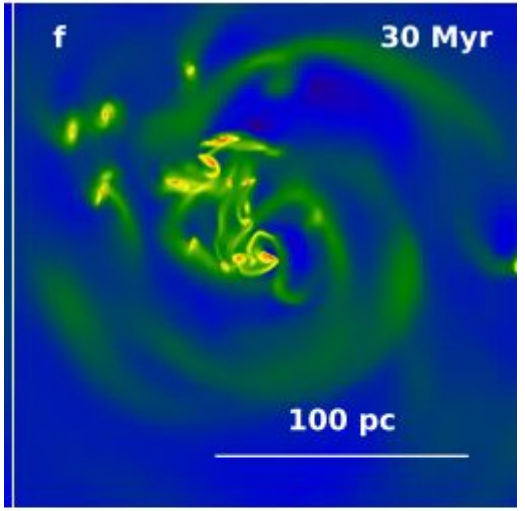
Accretion maintains the obscuring column / surface density

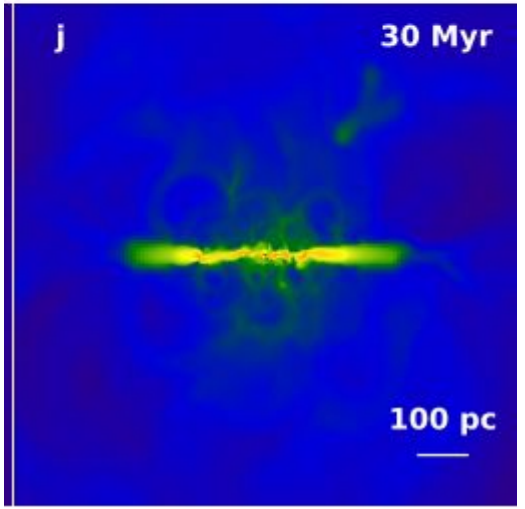
Clump Encounters of the Turbulent Kind

- Clump-Clump encounters
  - Krolik & Begelman (1986, 1988)
  - Schartmann et al. (2018)
- Kiloparsec-scale flows
  - Hopkins et al. (2012)



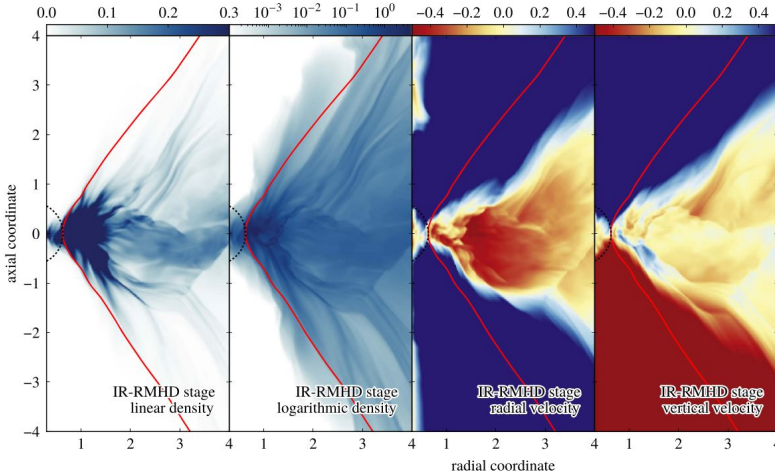


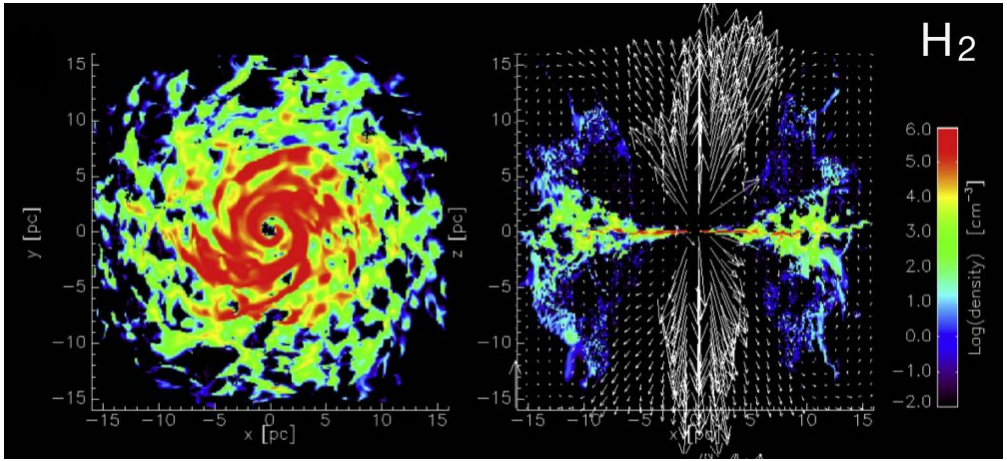




Radiation-Driven Outflows

- Photoionization Heating
  - Krolik & Begelman (1986)
- Infrared radiation pressure
  - Dorodnitsyn et al. (2016)
  - (+UV) Chan & Krolik (2017)
- X-ray heated fountains
  - Wada (2012, et al. 2016)





12:25	20 min	A.	A. Audibert	Nuclei of GAlaxies (NUGA) resolved by ALMA
12:45	105 min	LUNCH BREAK		
14:30	20 min	J. Braatz	T. Izumi	Circumnuclear Multi-phase Gas in the Circinus Galaxy Revealed with ALMA
14:50	20 min		K. Tristram	The compact molecular torus in the Circinus galaxy constrained by ALMA
15:10	25 min		C.-H. Chan	A new dynamical model of AGN tori
15:35	25 min		K. Wada	Dynamical pictures of tori and the multi-phase ISM
16:00	30 min	COFFEE BREAK		
16:30	25 min	M. Imanishi	A. Dorodnitsyn	Hydrodynamical models of obscuring accretion disks and winds
16:55	20 min		D. Williamson	Radiative hydrodynamics of dust and gas in the torus
17:15	20 min		D. Angles-Alcazar	Simulating nuclear fueling in realistic environments
17:35	20 min		E. Treister	Molecular Gas in the Nuclear Regions of Nearby Dual AGN
17:55	40 min		A. Alonso-Herrero	Discussion: Dynamics

Radiation-Driven Outflows

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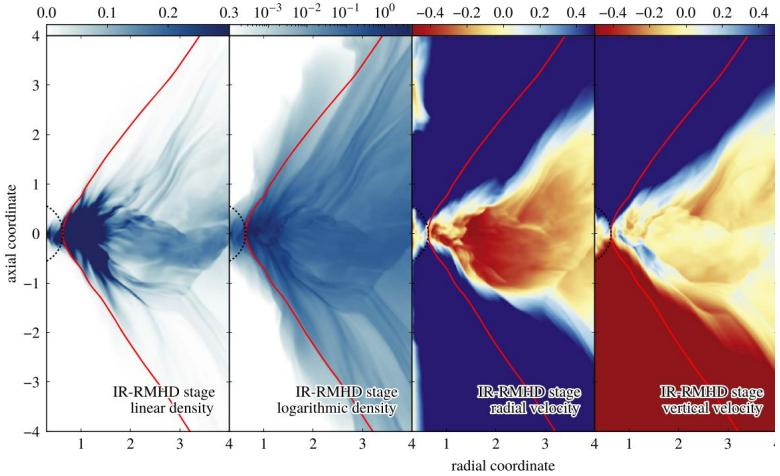
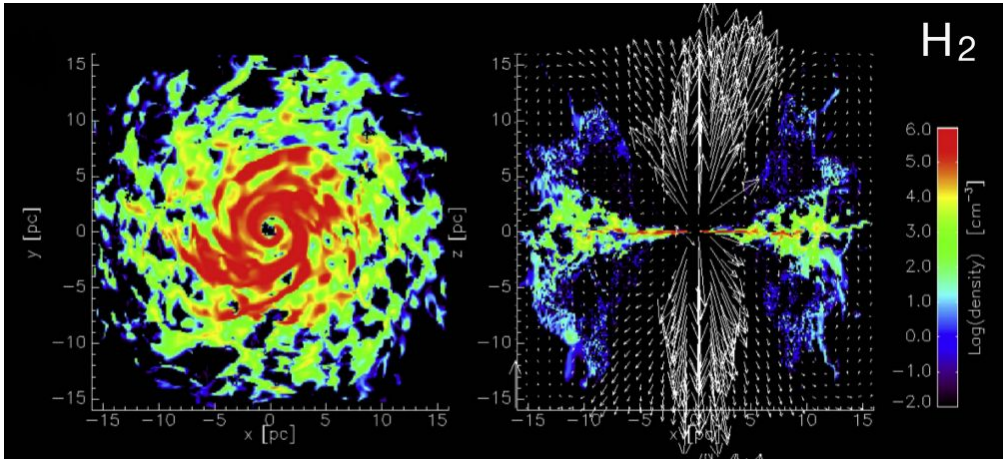
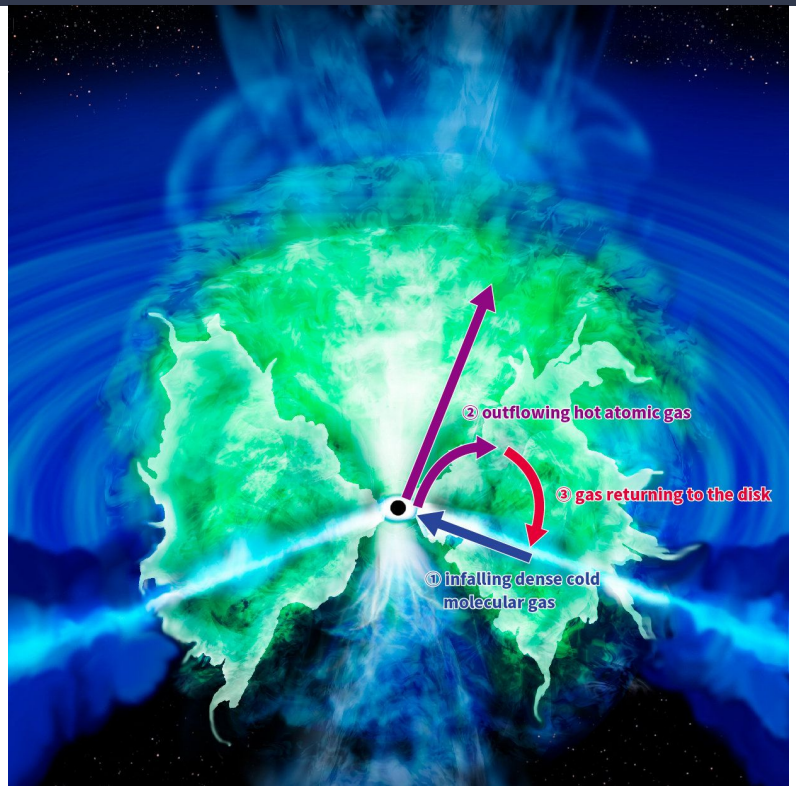




The Fountain Model



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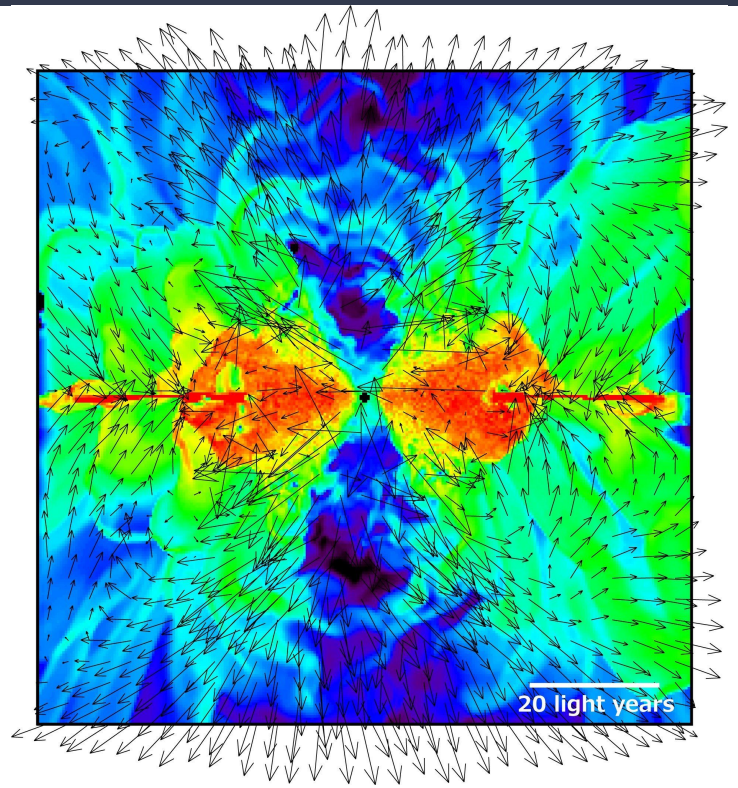

Wada et al.

12:25	20 min	A.	A. Audibert	Nuclei of GAlaxies (NUGA) resolved by ALMA
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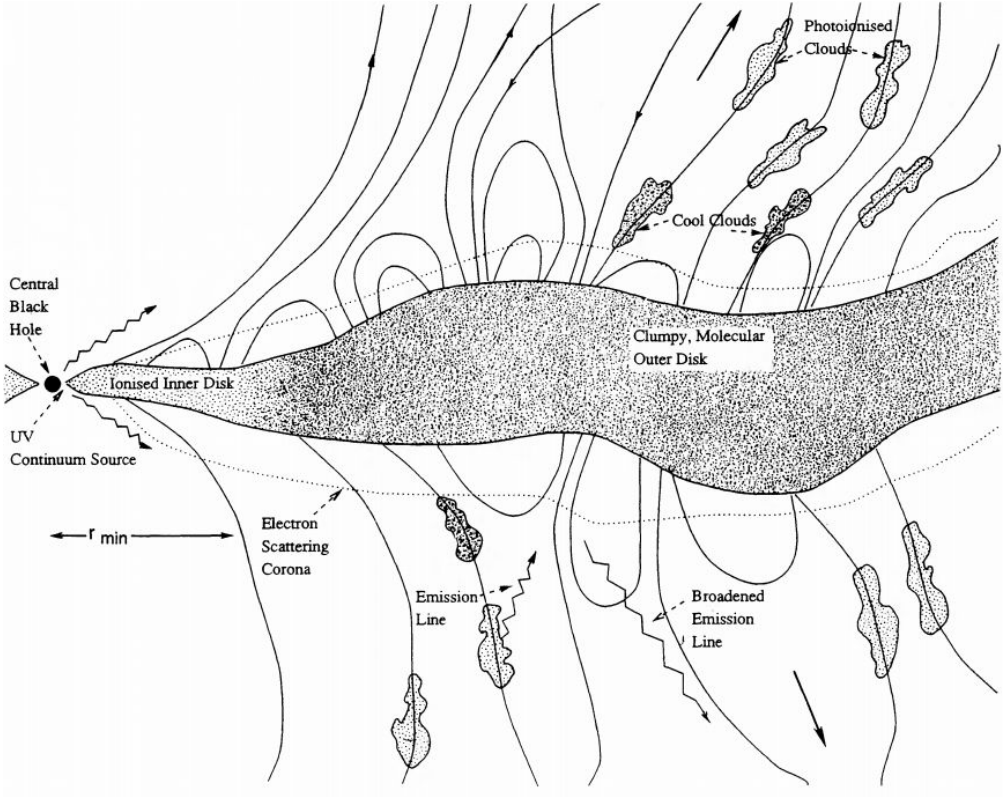
Hydromagnetic Winds

- Königl & Kartje (1994)
- Elitzur & Shlosman (2006)
- Elitzur & Ho (2009)
- Vollmer et al. (2018)



Emmering, Blandford, & Shlosman (1992)

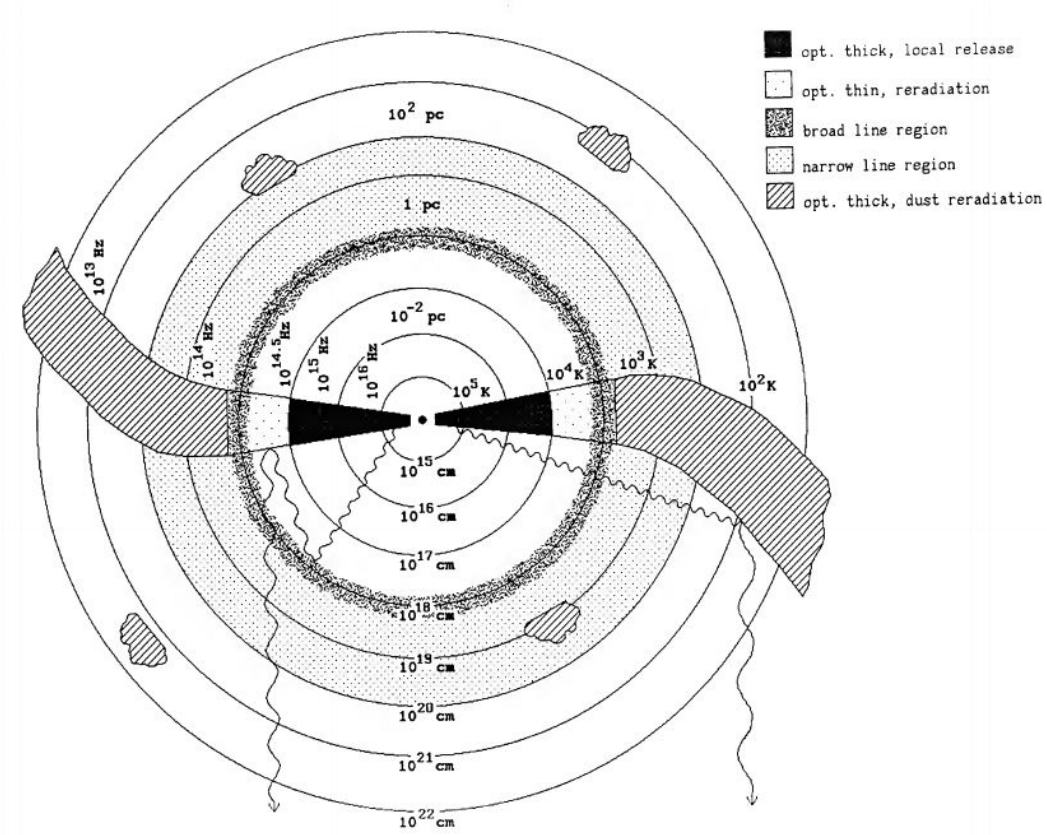
TUESDAY, 11. DECEMBER

R&V: REPROCESSING & VARIABILITY

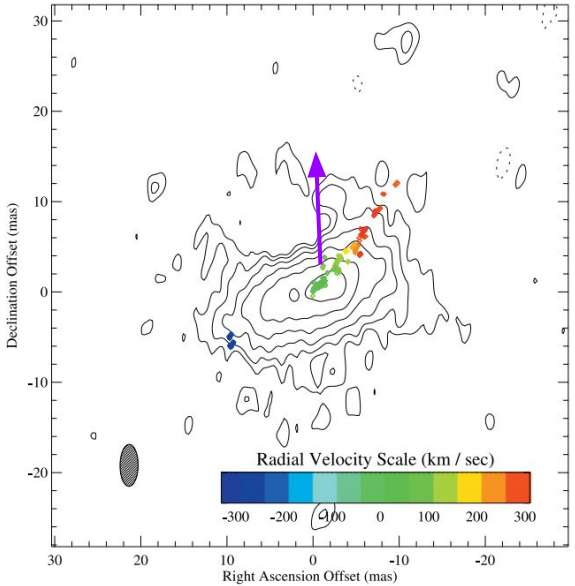
Time	Duration	Chair	Speaker	Title
09:00	25 min	M. Ward	B. Vollmer	Models of thick turbulent gas disks with magnetocentrifugal winds in AGN and their application to Circinus and NGC 1068
09:25	25 min		M. Stalevski	Towards a new paradigm of dust structure in AGN: Dissecting the mid-IR emission of Circinus galaxy
09:50	20 min		C. Andonie	Reconciling X-ray and IR observations of the Circinus Galaxy
10:10	20 min		M. Schartmann	The effect of circum-nuclear discs on the central gas and dust distribution
10:30	20 min		R. Nikutta	Hypercat - Hypercube of AGN tori

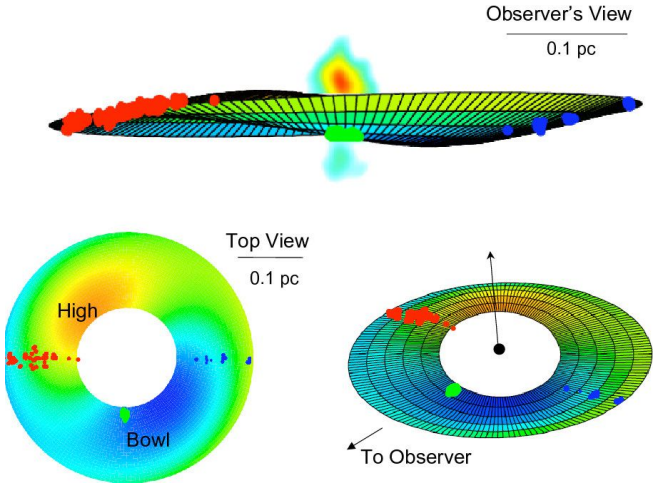
Warped Disks

- Phenomenology
  - Sanders et al. (1989)
- Water maser disks
  - NGC 4258
  - NGC 1068
  - Circinus
- Radiation-driven warps
  - Pringle (1996)
  - Maloney, Begelman, & Nowak (1997)
- Wind-driven warps
  - Quillen (2001)
- Damping
  - Sorathia et al. (2013)



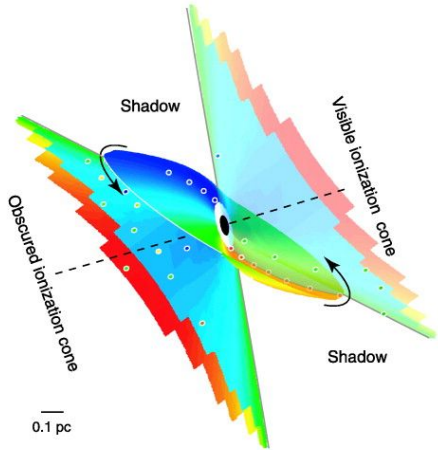
NGC 1068
Greenhill & Gwinn (1996)
Gallimore et al. (2004)





NGC 4258
Herrnstein et al. (2005)

Circinus
Greenhill et al. (2005)

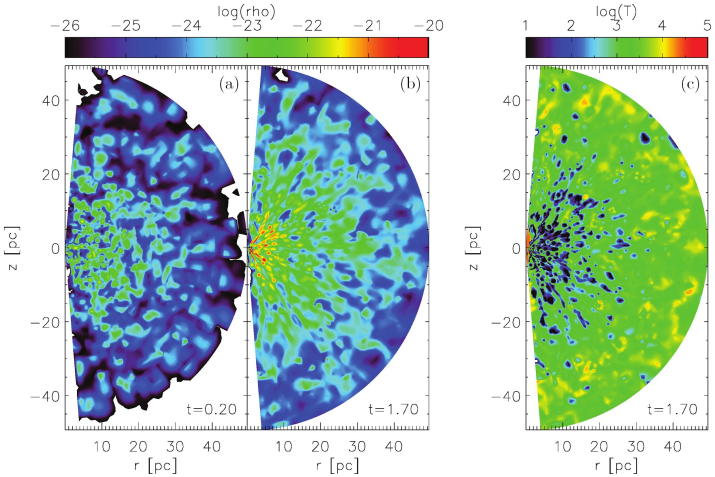


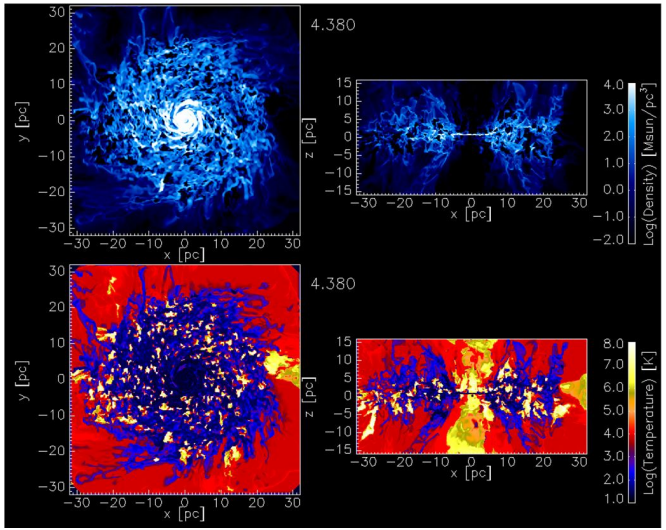
See also
Stalevski et al. (2017)

~~09:00~~	~~30 min~~		~~J. Gallimore~~	~~Review: Torus Dynamics~~
09:30	25 min		J. Braatz	Water Megamasers
~~09:55~~	~~25 min~~	T. Izumi	~~S. Kameno~~	~~A radio absorption study of AGN tori~~
10:20	20 min		A. Alonso-Herrero	The dusty molecular torus of Seyfert galaxies is full of surprises
10:40	10 min		Posters (Bianchin, Brum, Carpes, Ilha, Venanzi)	Dynamics

Star-formation

- Nuclear Star Cluster
  - Schartmann et al. (2010)
- Starburst Feedback
  - Wada & Norman (2002)
  - Wada et al. (2009)





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Das Eierlegende Wollmilchtorusmodel

Cloud-cloud interations

Radiation Pressure

Photoionization / Compton heating

MHD

Star formation

Turbulence

The Search for the Torus

11:20	25 min	R. Morganti	The complex nuclear regions of young radio galaxies

THE ASTRONOMICAL JOURNAL VOLUME 107, NUMBER 4 APRIL 1994

SEARCH FOR CO ABSORPTION FROM A MOLECULAR TORUS IN CYGNUS A

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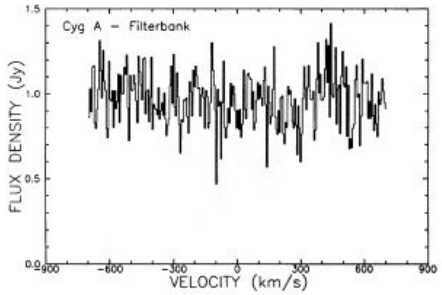
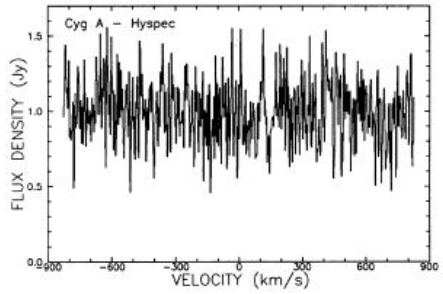
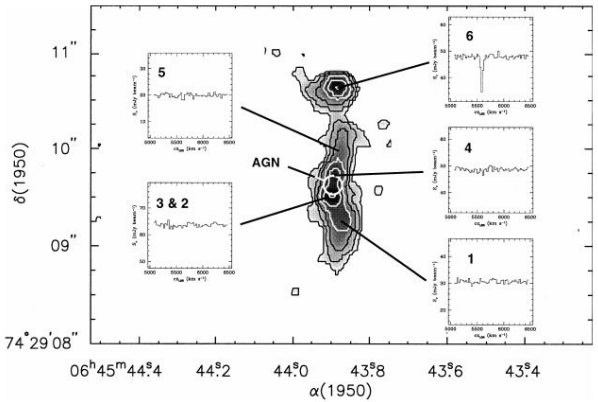
Received 1993 August 2; revised 1993 November 1

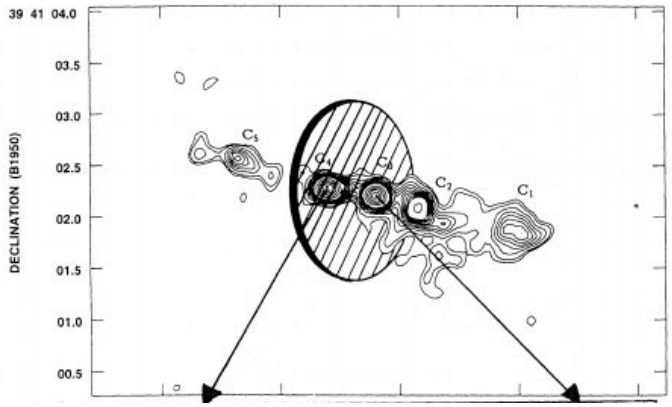




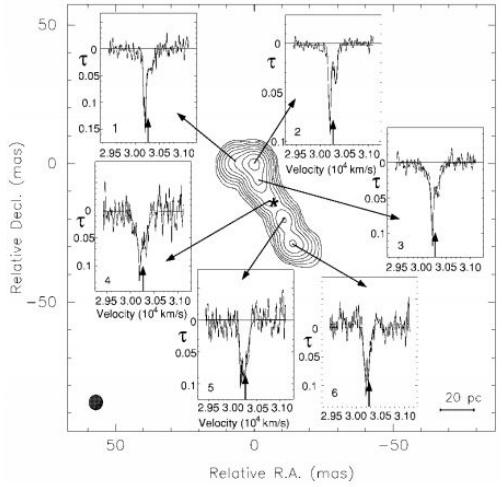
21 cm Absorption - Disks



MRK 6: Gallimore et al. (1998)

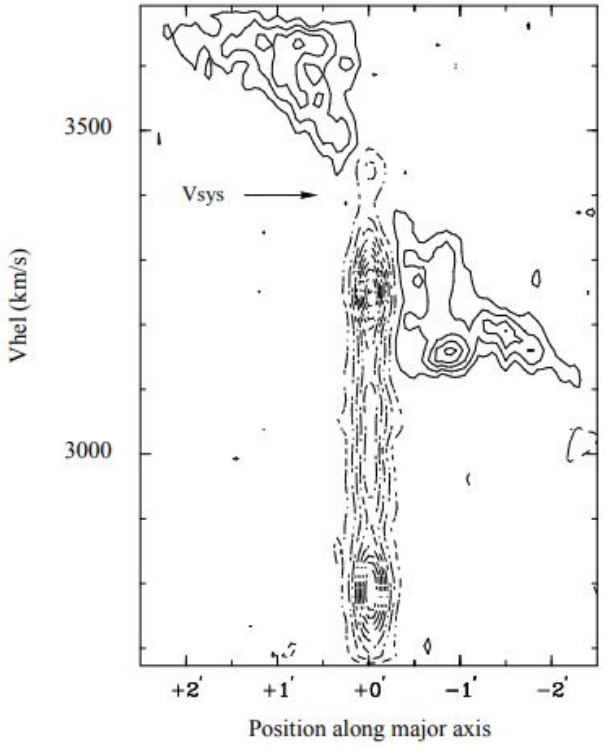


NGC4151: Mundell et al. (1995)



1946+708:
Peck & Taylor (2001)

21 cm Absorption – Outflows



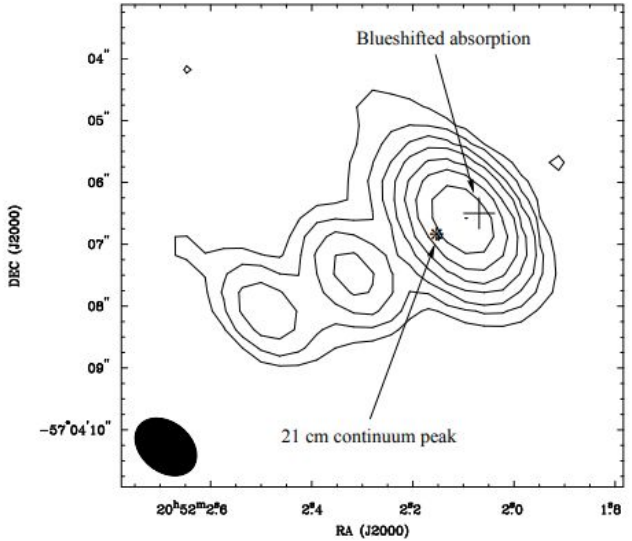
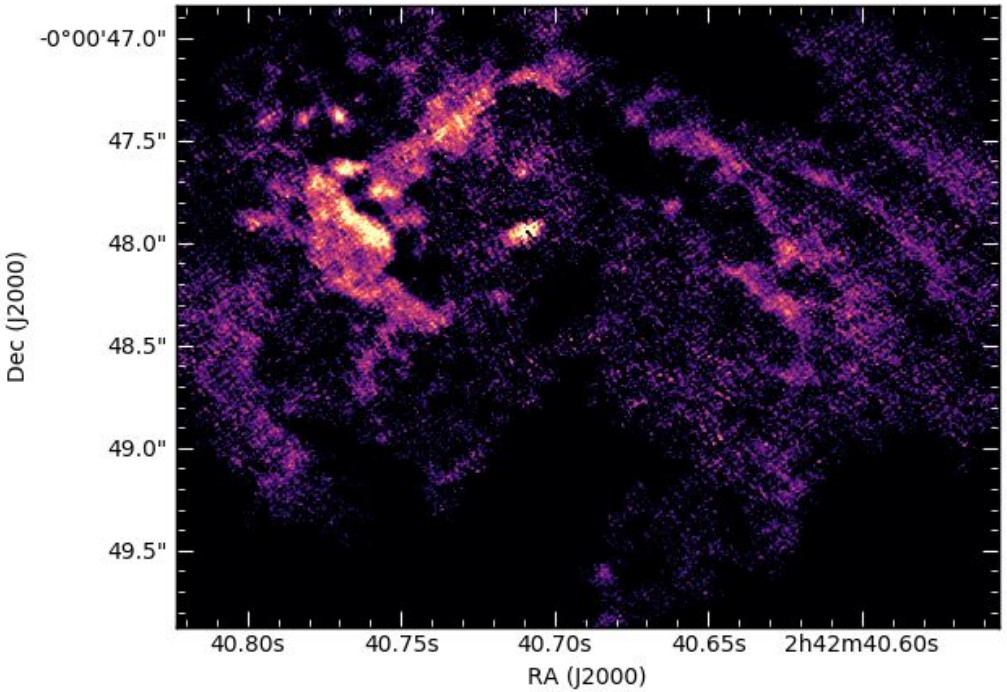


FIG. 1.—ATCA 8 GHz radio continuum image. The contour levels are 0.75, 1.5, 3, 6, 12, 24, 48, and 96 percent of the peak value of 163 mJy beam^{-1}. Positions of the 21 cm continuum peak and of the H I absorption are marked with crosses, with sizes representing the 1 σ error bar.

IC 5063: Morganti et al. (1998)

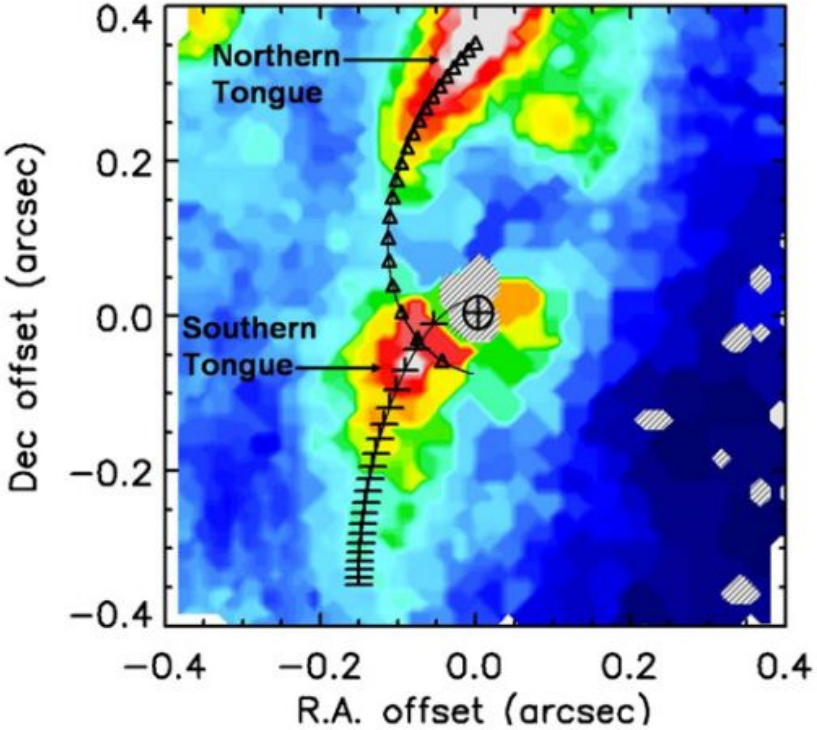
NGC 1068



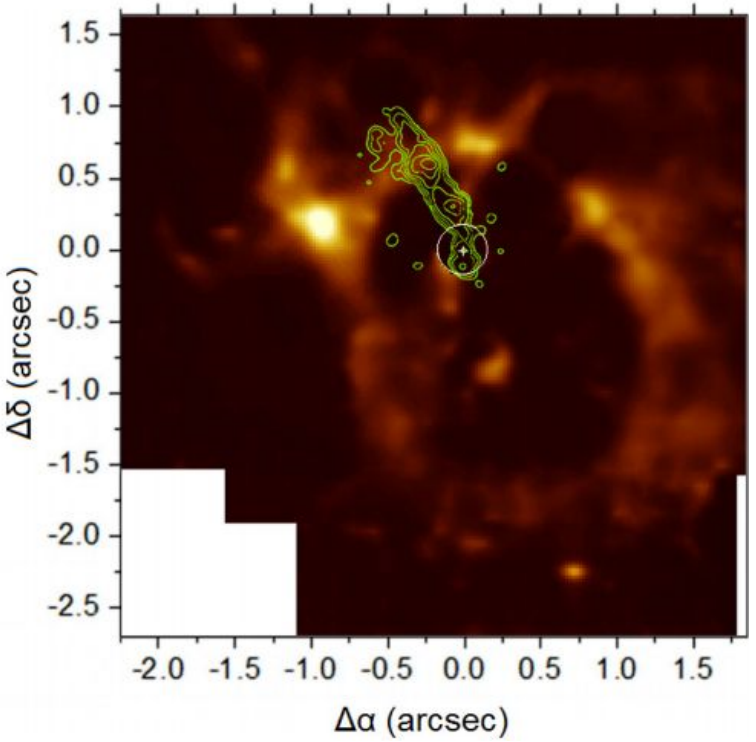
Impellizzeri et al. (in prep)

ALMA 1.4 pc resolution
HCN 3-2

NGC 1068 – Infall or Outflow?



Müller-Sánchez et al. (2009)

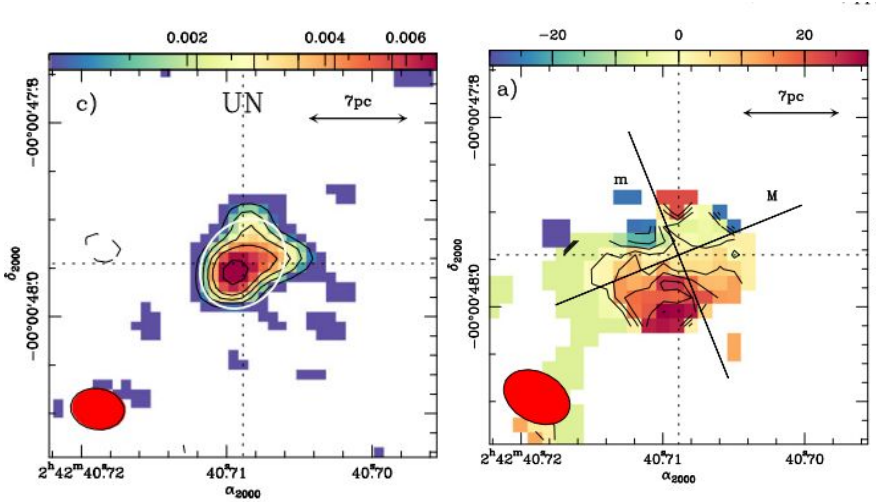


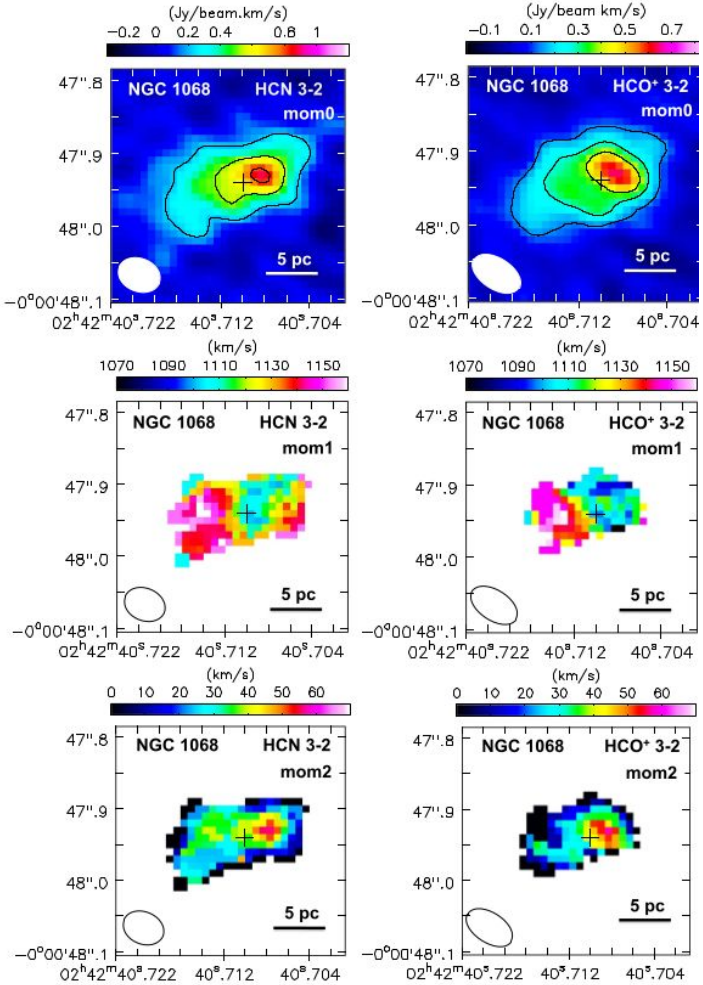
May & Steiner (2017); Barbosa et al. (2014)

NGC 1068

Imanishi et al. (2018)
ALMA 2.8 - 5 pc resolution

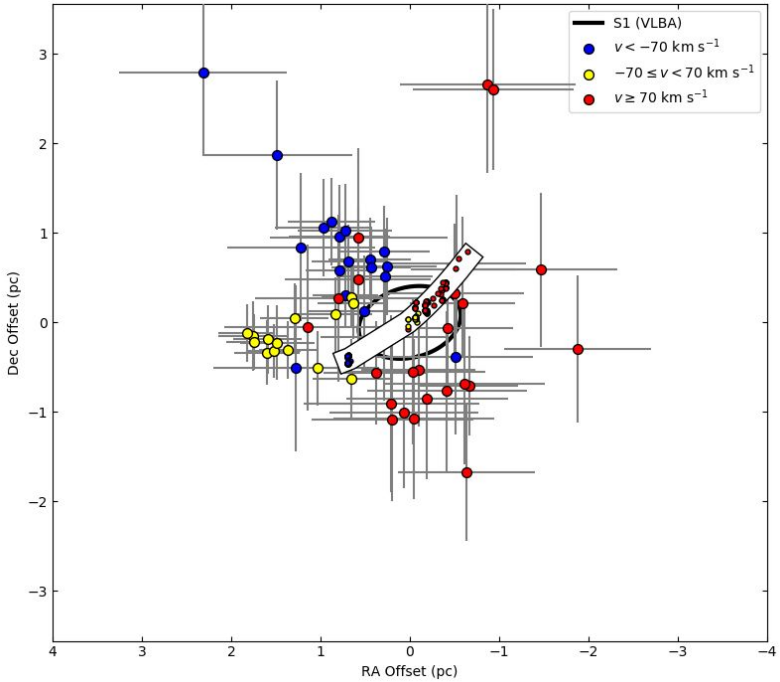
García-Burillo et al. (2016)
ALMA 4.5 - 5 pc resolution
CO (J=6→5)



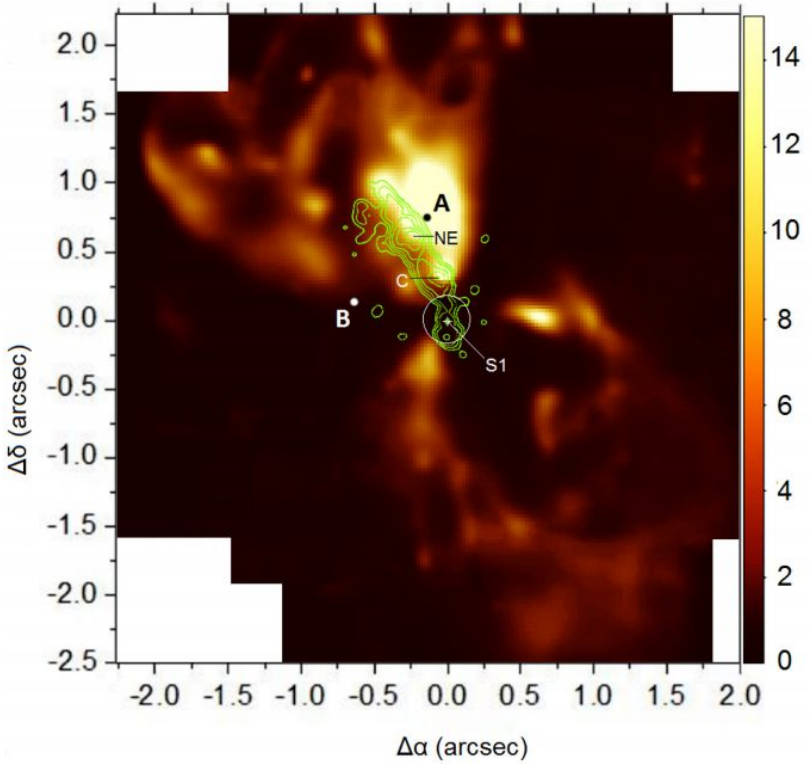


NGC 1068 – Outflow

May & Steiner (2017) - [Fe II]
Barbosa et al. (2014)
Cecil, Bland, & Tully (1990)

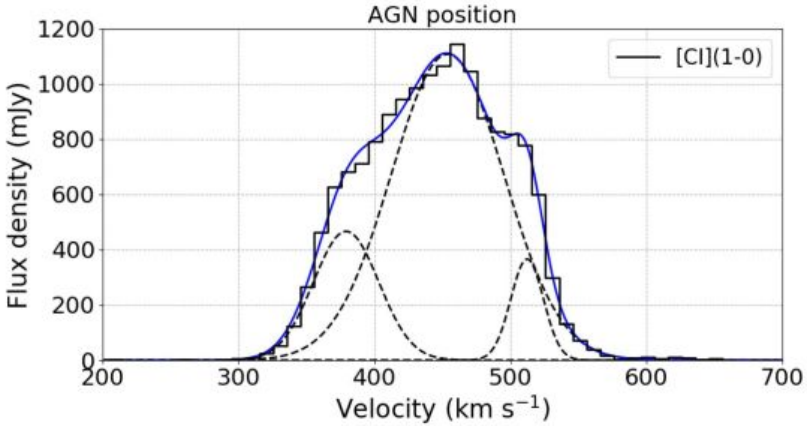


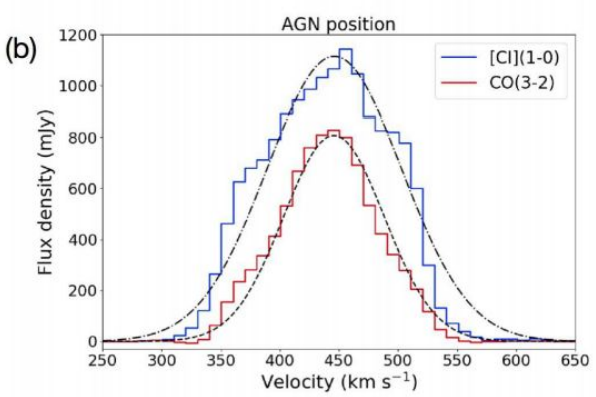
Gallimore et al. (2016) - CO 6-5



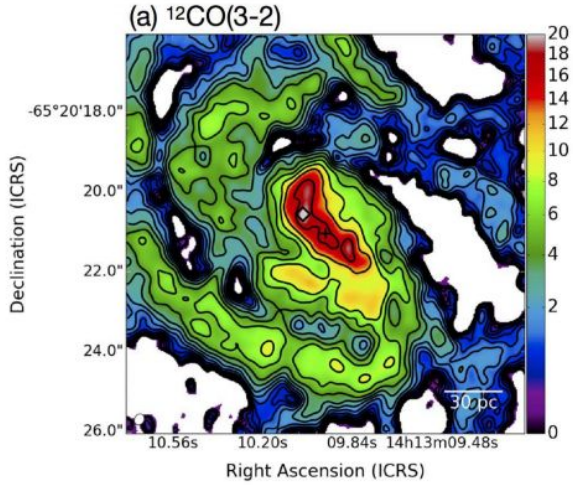
11:20	25 min	A. Constantin	S. Garcia-Burillo	The many 'faces' of the molecular torus of NGC1068
11:45	20 min		V. Impellizzeri	The counter rotating molecular torus in NGC1068
12:05	20 min		M. Imanishi	ALMA reveals a rotating dense molecular torus in NGC 1068
12:25	20 min		A. Audibert	NUclei of GAlaxies (NUGA) resolved by ALMA

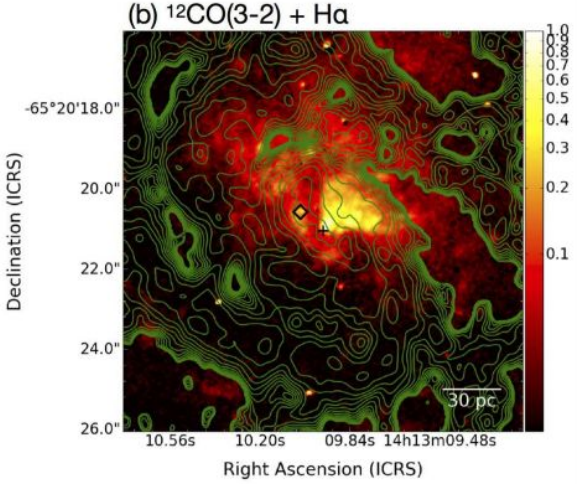
The Circinus Fountain





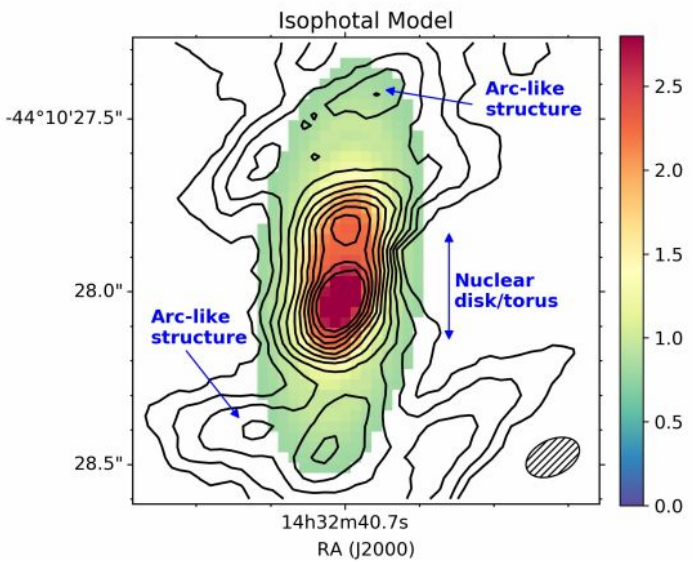
Izumi et al. (2018)

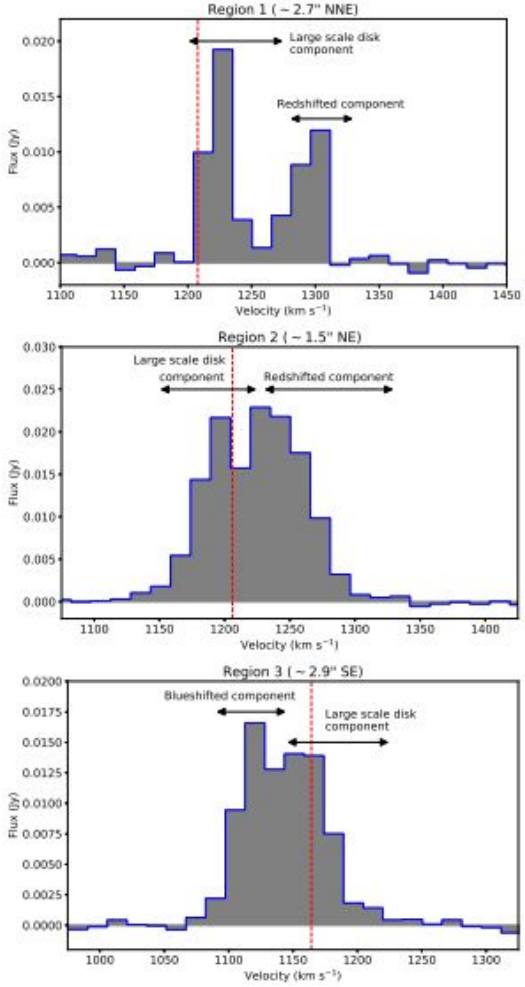




14:30	20 min	J. Braatz	T. Izumi	Circumnuclear Multi-phase Gas in the Circinus Galaxy Revealed with ALMA
14:50	20 min		K. Tristram	The compact molecular torus in the Circinus galaxy constrained by ALMA
15:10	25 min		C.-H. Chan	A new dynamical model of AGN tori
15:35	25 min		K. Wada	Dynamical pictures of tori and the multi-phase ISM

NGC 5643

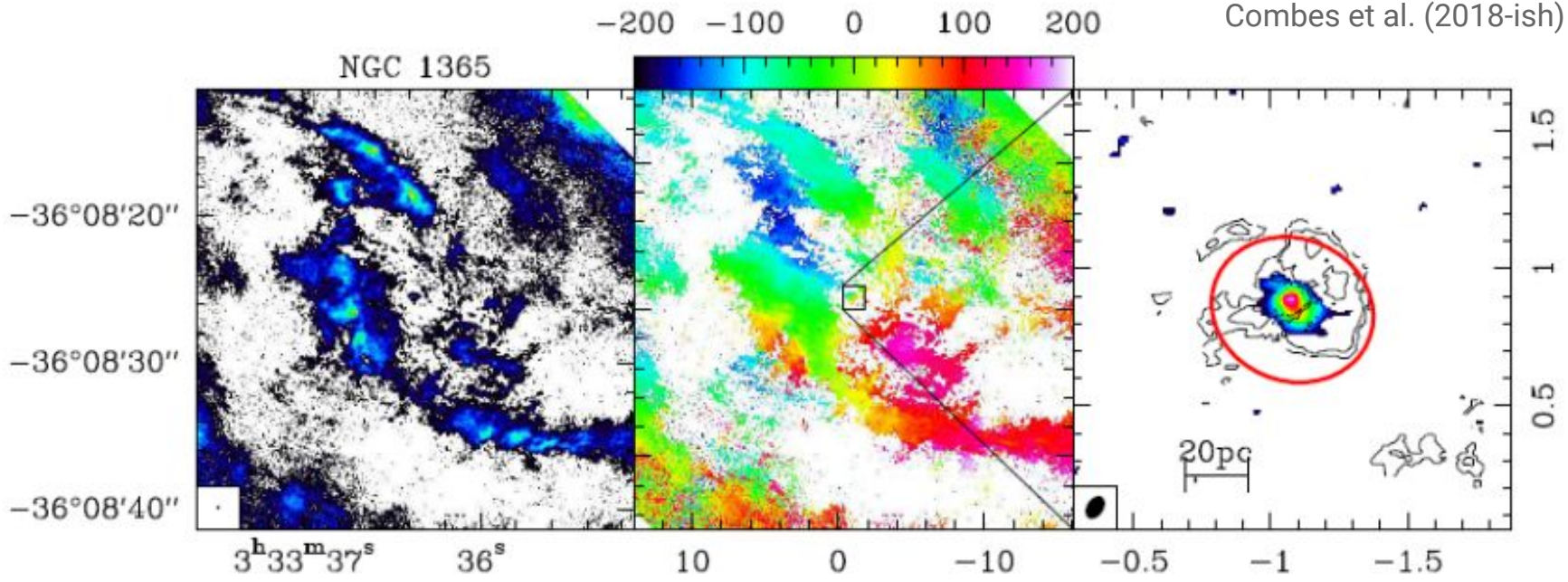




Alonso-Herrero et al. (2018)

The Torus in the Age of ALMA

Combes et al. (2018-ish)



12:25	20 min	A. Audibert		NUclei of GAlaxies (NUGA) resolved by ALMA