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Circumnuclear *Multi-phase* Gas in the Circinus Galaxy Revealed with ALMA

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Radiation-driven "fountain"



Wada 2012, ApJ, 758, 66

Radiation-driven "fountain"



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Dust rad. transfer

One snapshot from RHD \rightarrow 3D Monte Carlo



Schartmann et al. (2014)

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- Successfully reproduced the MIR polar elongation! (Schartmann et al. 2014)
- And observed SED can be reproduced relatively well

Multi-phase & multi-species gas distribution





- Target: <u>The Circinus galaxy</u>
- M_{BH}, λ_{Edd}, CND-scale M_{gas}: matched to the values of Circinus
- Hydrodynamic simulation + XDR chemistry + radiative transfer

Multi-phase Obscuring Structures



Multi-phase circumnuclear obscuring structures studied with ALMA

→ T. Izumi et al. 2018, ApJ, 867, 48

 Atomic vs molecular gas <u>dynamics</u>?
 → Can we see different dynamical/ geometrical structures?

Is that difference due to outflows?

ALMA Cycle 4 Observations (Band 7 + 8) 7



- Compton-thick AGN (Arevalo+2014)
 - N_H ~(6-10) × 10²⁴ cm⁻²
 - $L_{2-10keV} \sim (2-5) \times 10^{42} \text{ erg/s}$
- <u>Clearest MIR polar elongation</u>
 - → Test the fountain scheme
- Low SFR
 - → Weak stellar feedback
- High resolution <u>CO(3-2)</u> + [CI](1-0)
 @ALMA Cycle 4

Why we observed CO & CI?



Cold dust emission (ALMA: 860µm cont.)





⁽ALMA: 860µm cont.)

9



- Double-Gaussian fit to the visibility data → CND + core
- Consistent with the MIR elongation?? Or just a jet?

Declination (ICRS)

Right Ascension (ICRS)

Molecular & Atomic gas distributions



Right Ascension (ICRS)

• CND (D ~70 pc) + Spirals

- M_{H2} ~ 3×10⁶ M_{sun} (CND)
 - c.f., M_{BH} ~ 2×10⁶ M_{sun}

- beam-averaged
- N_H (Xray) ~ 6×10²⁴ сm⁻²
- 6 Cold gas (CND-scale)
 - contributes
 - significantly to the nuclear obscuration!

Molecular & Atomic gas distributions



Right Ascension (ICRS)

140

60

- First extragalactic
 high spatial resolution imaging (~15 pc)
 - Similar 2D distribution to the CO(3-2)
- But we don't know <u>3D</u> structures!

Decomposition of Cold Gas Dynamics

CO(3-2)



- Global motion is dominated by rotation
- (**d**) We decomposed the dynamics with tilted-ring models <u>V_{rot}</u>, *σ*, inclination, P.A.



(e)

3D Barolo code
 (Di Teodoro & Fraternali 2015)

Decomposition of Cold Gas Dynamics

CO(3-2)



Right Ascension (ICRS)

Decomposition of Cold Gas Dynamics





CI vs CO: Multi-phase Torus Structures





- Geometrically thin mol. & atomic disks at
 r > 20 pc (c.f., low-SFR in Circinus)
- Geometrically thicker atomic disk than the dense molecular disk (r < 10 pc)
 - → <u>Multi-phase structures!</u>

What makes the geometrical thickness? ¹⁴



- Nuclear [CI](1-0) spectrum clearly shows a larger FWHM than CO(3-2).
- [CI](1-0) profile = Multiple Gaussians
- Almost symmetric (coherent) blue- and red-components → <u>Outflows</u>
- V_{wind} < V_{esc}: will fall back to the disk (Failed wind) → Fountain

thickness? 14







) spectrum clearly shows than CO(3-2).

= Multiple Gaussians

ric (coherent) blue- and

s → <u>Outflows</u>

I fall back to the disk Fountain

Comparison with our model



- Hydrodynamic simulation + XDR chemistry + rad. transfer
- $CO(3-2) \rightarrow mid-plane of the CND$
- [CI](1-0) → mid-plane + puffed-up component due to outflows







[CI](1-0)
stand out!
imulation
n of the "torus" !?

Summary: Multi-phase Obscuring Structures

