Molecular gas in the starburst galaxy NGC 1808 revealed with ALMA

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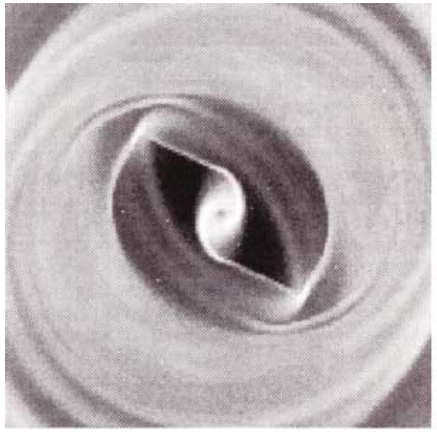
Outline

- Bars, starbursts, and galaxy evolution
- Case study: galaxy NGC 1808
- Overview of ALMA observations of molecular gas in NGC 1808: from 5 kpc to 50 pc scales
- Galaxy-scale inflow
- Central starburst region

Inflows and outflows in galaxies

Gas orbits in bars



Athanassoula 1992

Galaxy interactions
Bars (~50% of disk galaxies)

Feeding: cold gas inflow

Starburst

Feedback: outflow

High-resolution CO studies of barred galaxies are sparse (e.g., Sheth+ 2002, Hirota+ 2014)

Murray+ 2005, Veilleux+ 2005, Fabian+ 2012, etc.

Quench star formation

Transport metals to halo

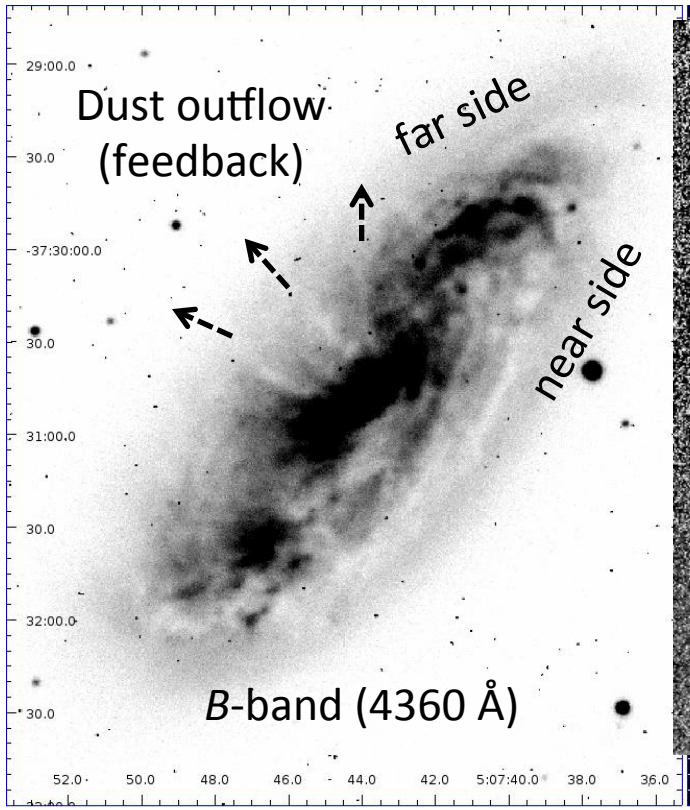
Famous nearby starbursts: M82 and NGC 253 (e.g., Bolatto+ 2013); many starbursts/AGN over a wide redshift range (e.g., Cicone+ 2014)

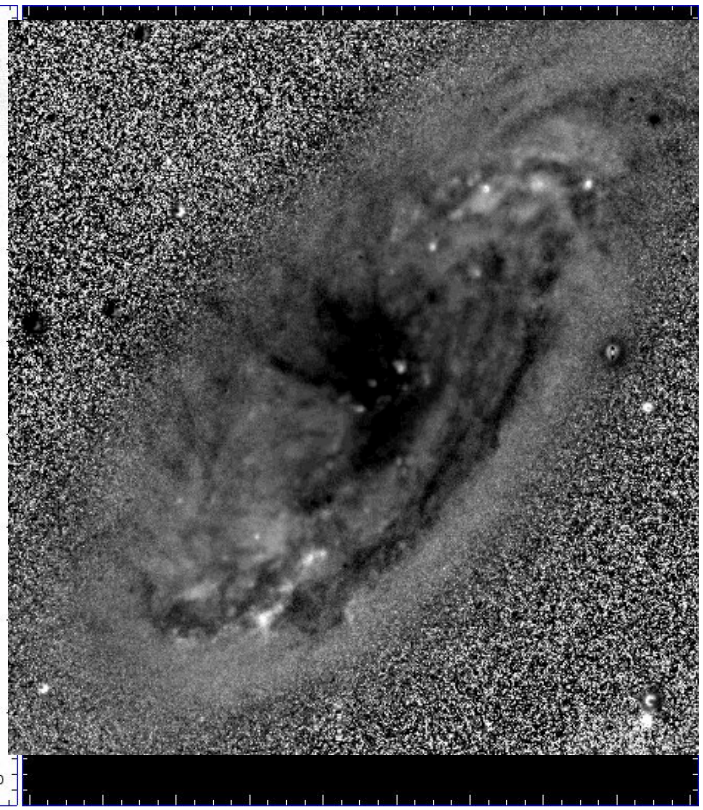
Case study: galaxy NGC 1808

Morphology	(R)SAB(s)a (de Vaucouleurs+ 1991)
Distance	10.8 Mpc (Tully 1988)
Central activity	Starburst

Outflow from spectral data: **Na I D** absorption/ emission (Phillips 1993)

CGS data: color index *B*-*R*





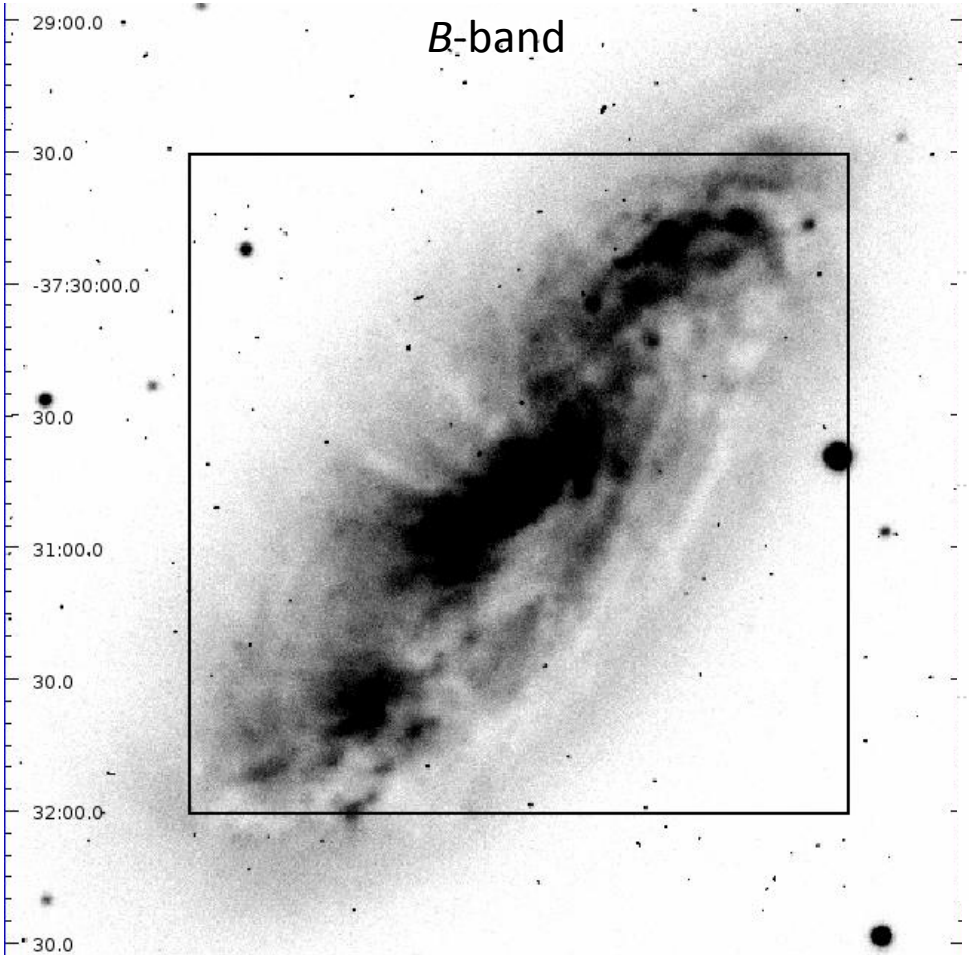
Eskridge+ 2002

HLA

Science with ALMA

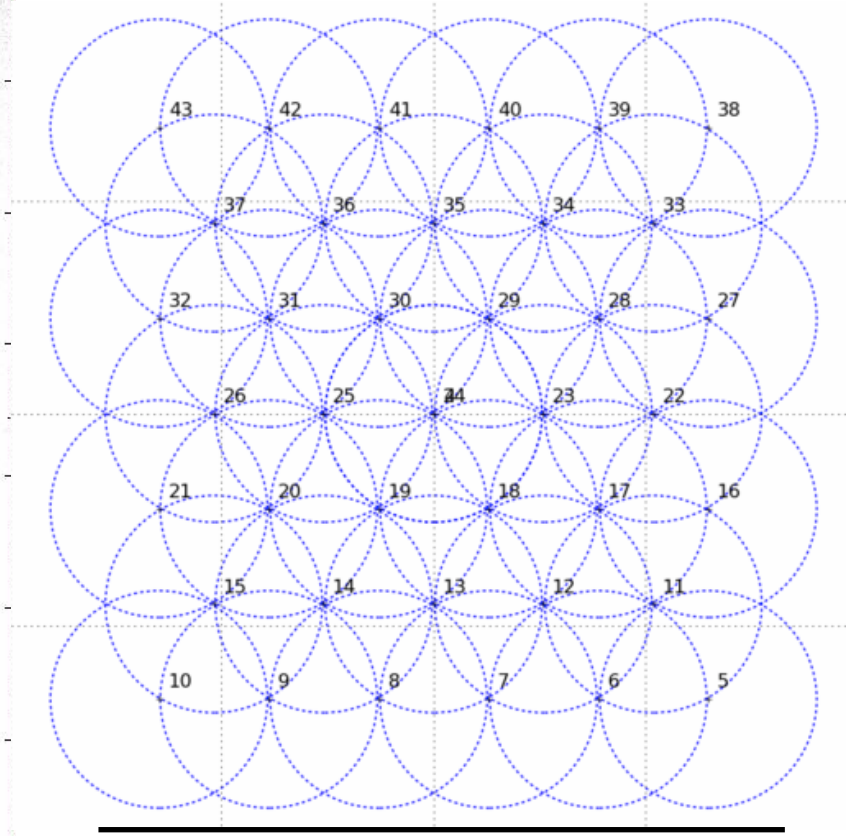
How is the molecular gas organized in the disk (bar) and starburst nucleus?

ALMA observations: CO (J=1-0)



B-band

39-field Nyquist-sampled mosaic



150” (7.5 kpc)

Observing time = 41 min. w/27 antennas

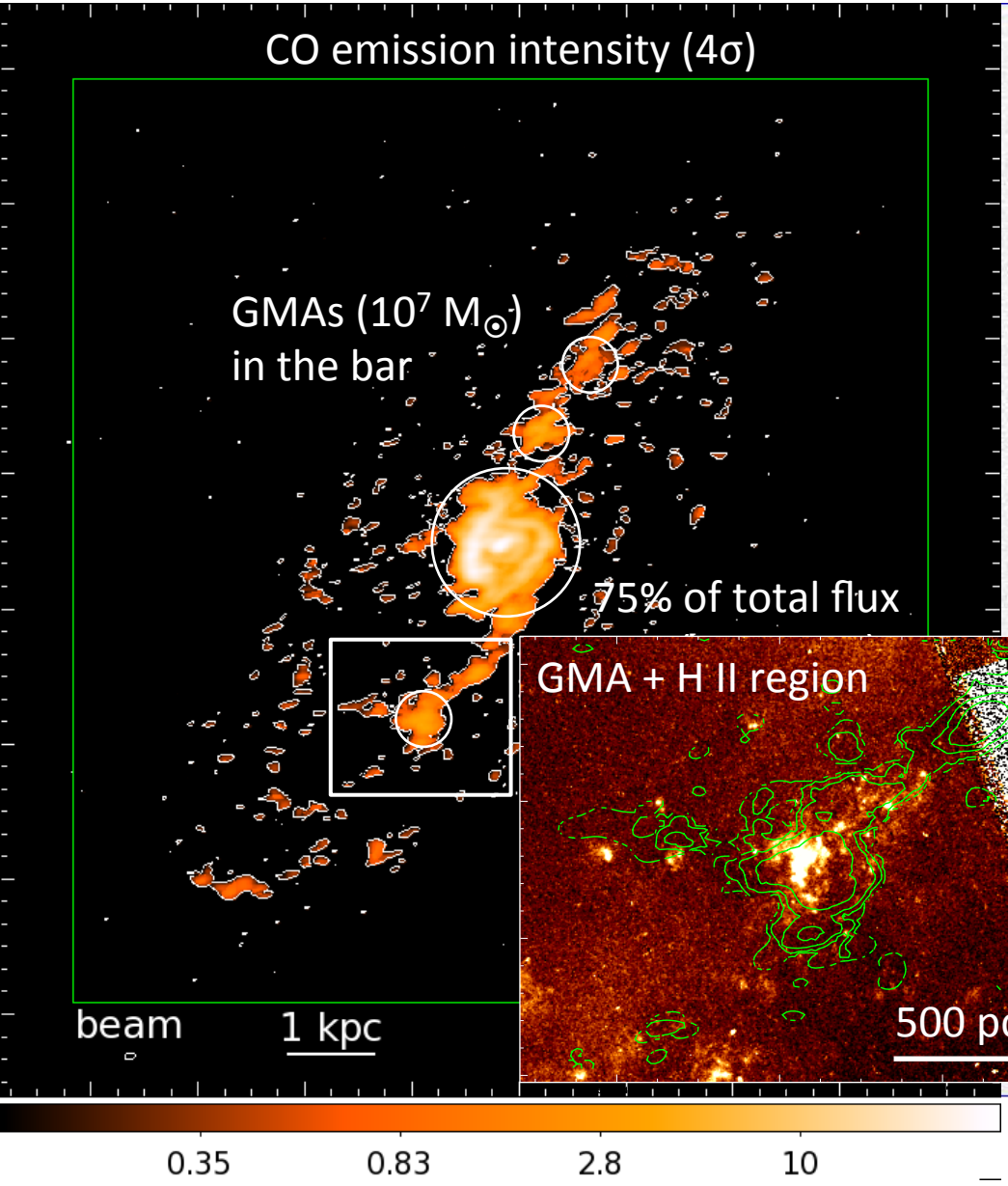
Spatial resolution = 2.5” x 1.4” (130 x 73 pc^2)

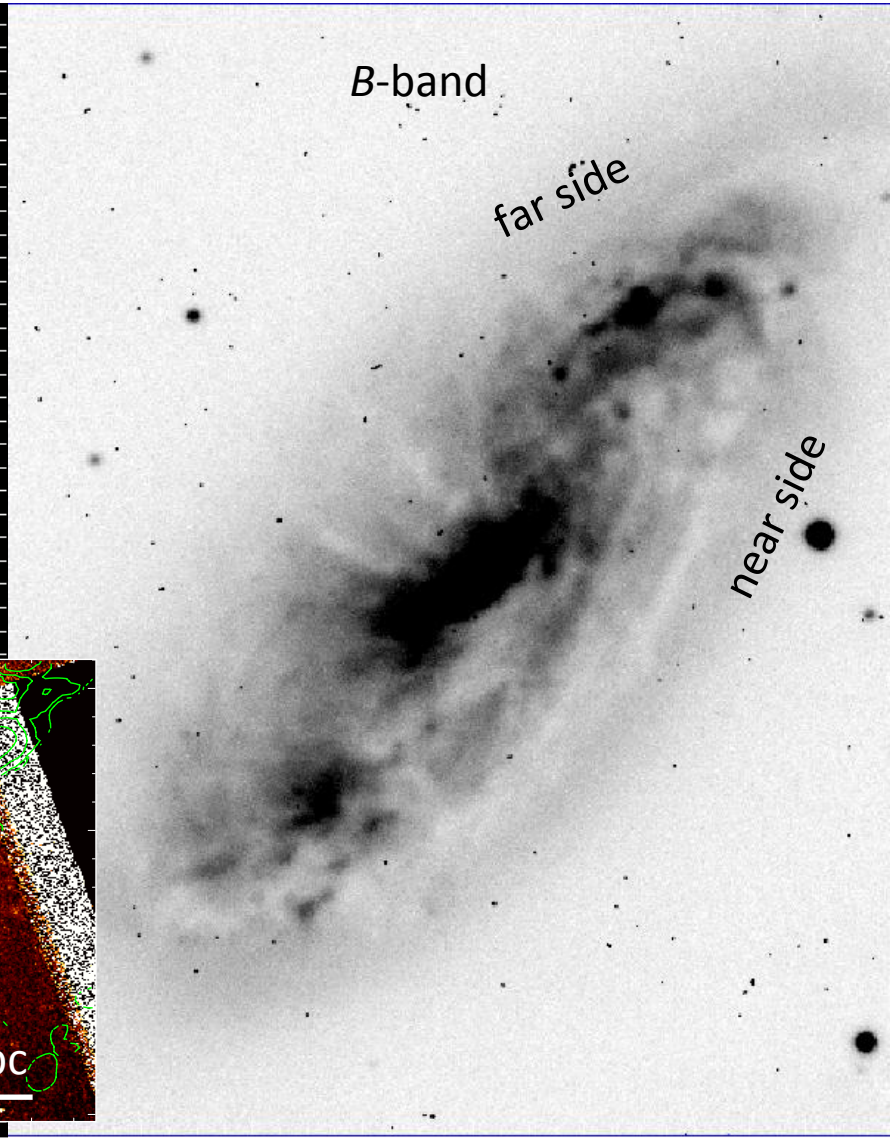
1σ r.m.s. = 5.5 mJy $beam^{-1}$ (10.2 km s^{-1} channel), $M > 7 \times 10^4$ $M_\odot$

cf. Galactic GMCs: 4×10^5 $M_\odot$, 40 pc; Scoville & Sanders 1987

Results

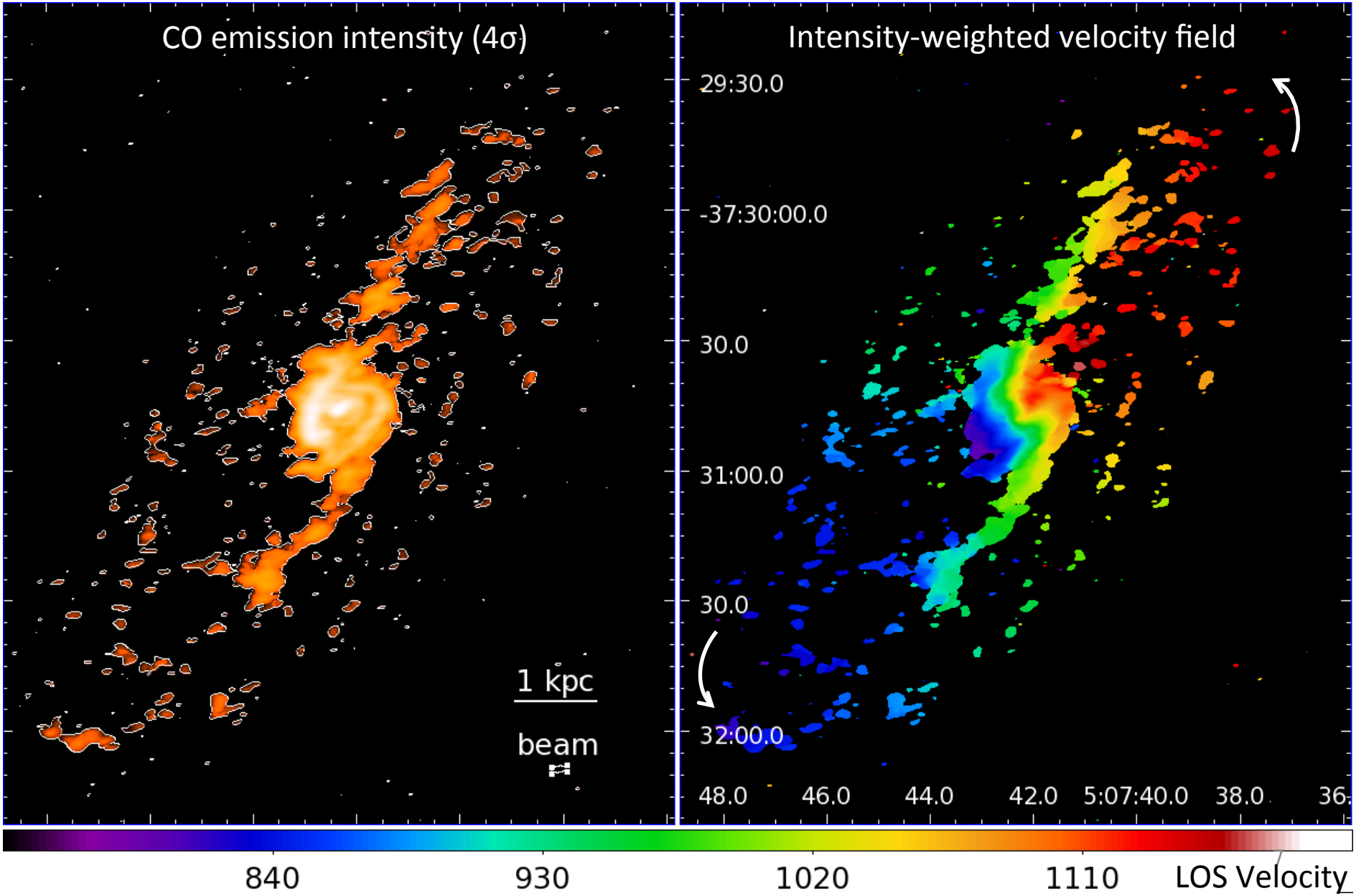
Salak+ (in prep.)



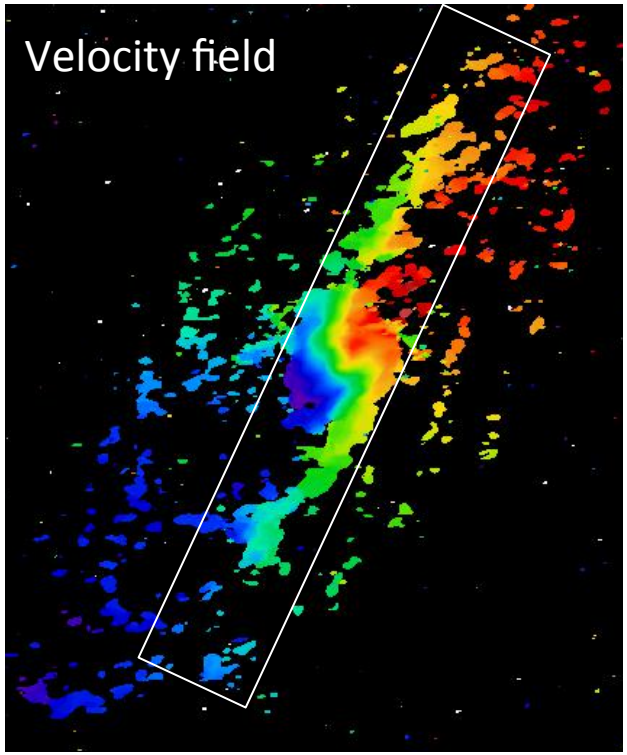


Galactic rotation

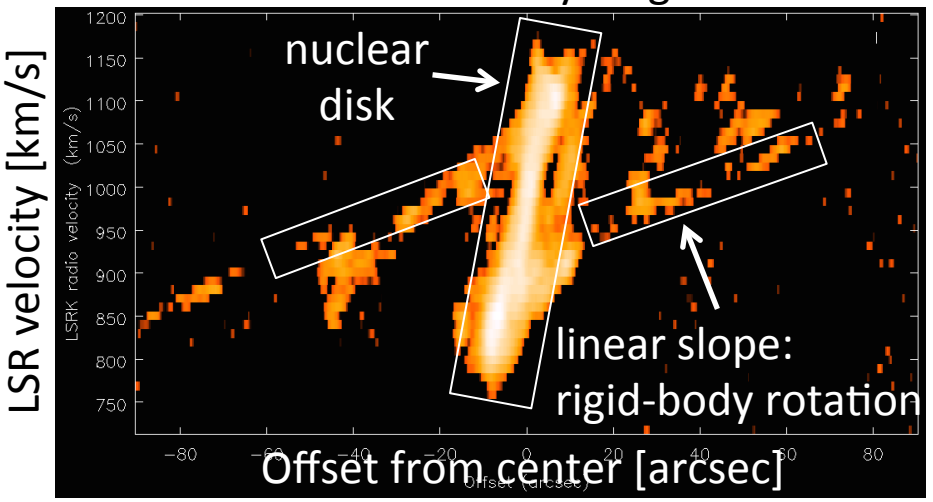
Salak+ (in prep.)

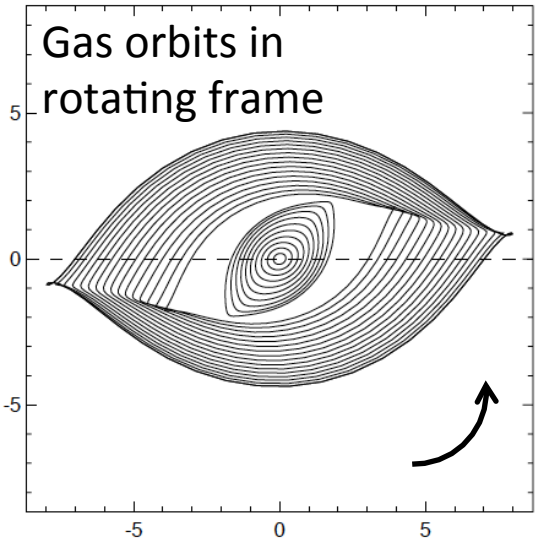


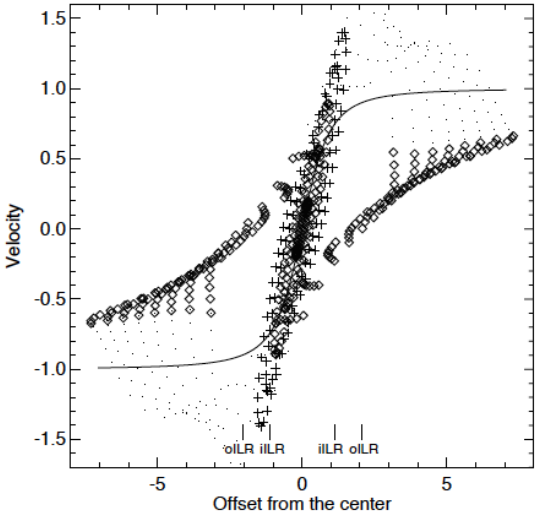
Bar dynamics



Position-velocity diagram



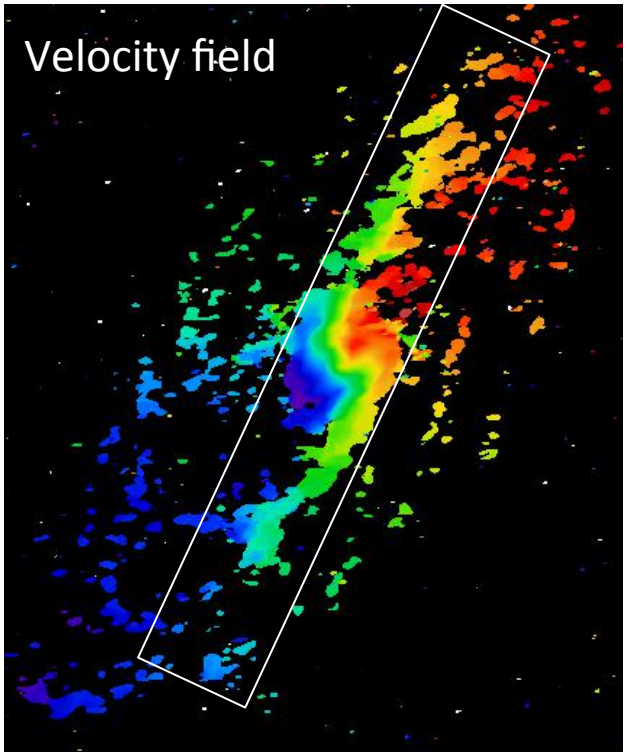




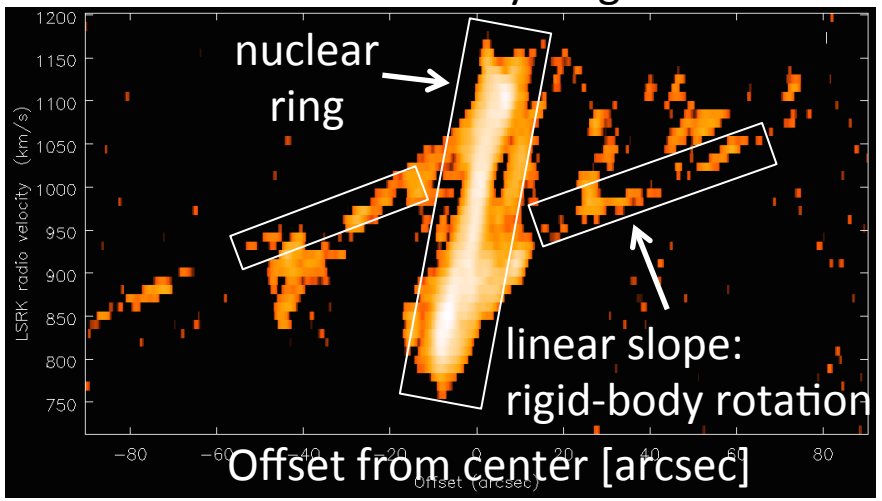
Salak+ (in prep.)

Sakamoto+ 2000, Wada 1994

Bar pattern speed



Position-velocity diagram

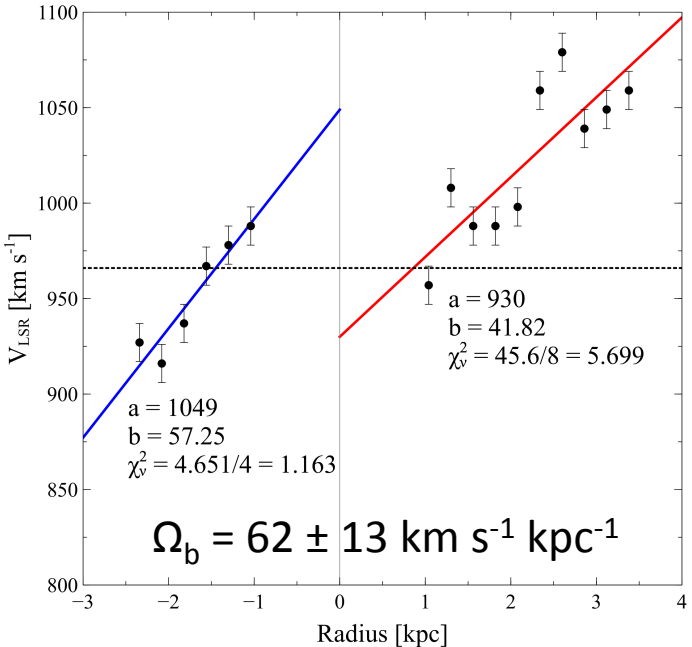


$$V_{\rm obs} = V_{\rm sys} + R\Omega_{\rm b}\sin(i)\cos(\Delta{\rm PA})$$

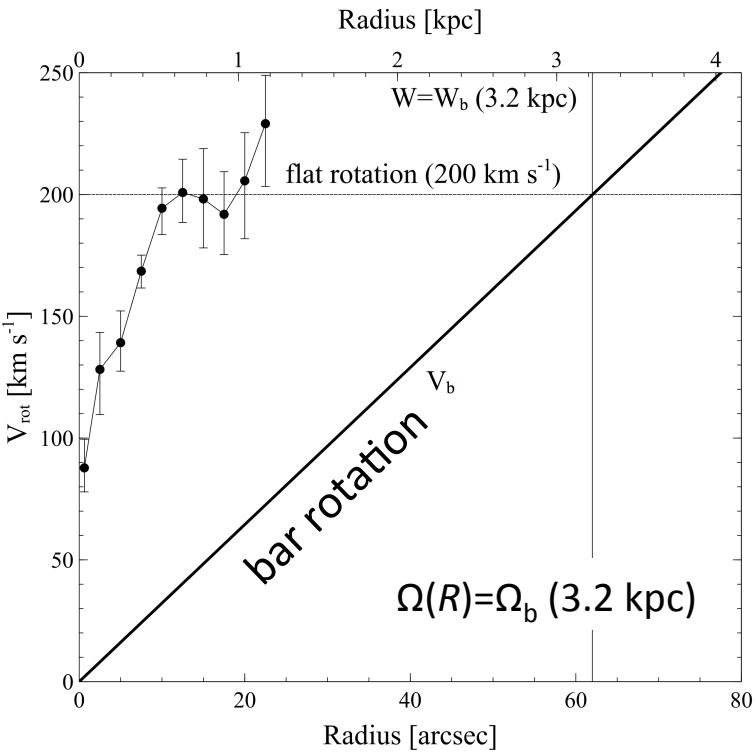
$i = 57^\circ$: inclination

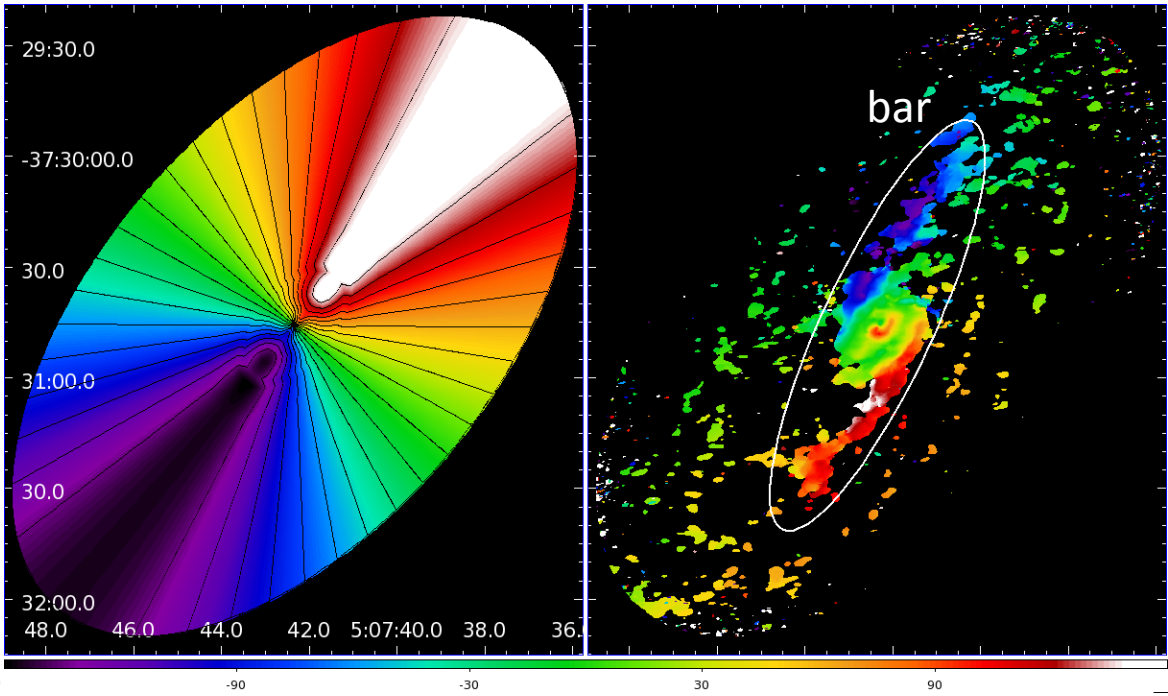
$\Delta{\rm PA} = 20^\circ$: position angle offset

$V_{\rm sys} = 966$ km s^{-1} : systemic velocity



Non-circular motions





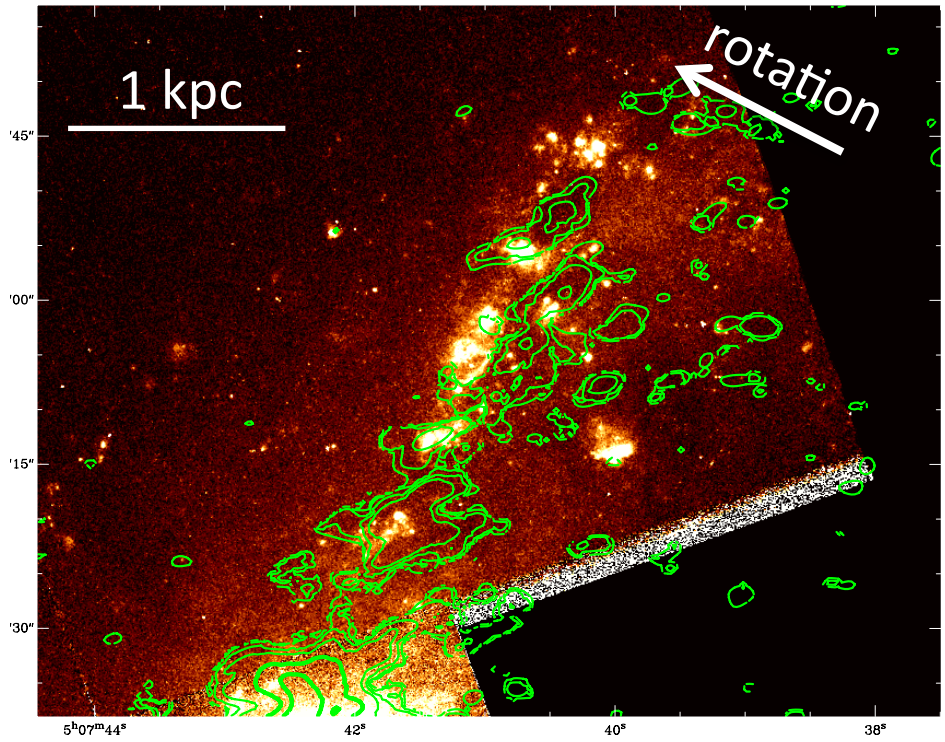
model velocity field (circular motion)

data – model = residual velocity field

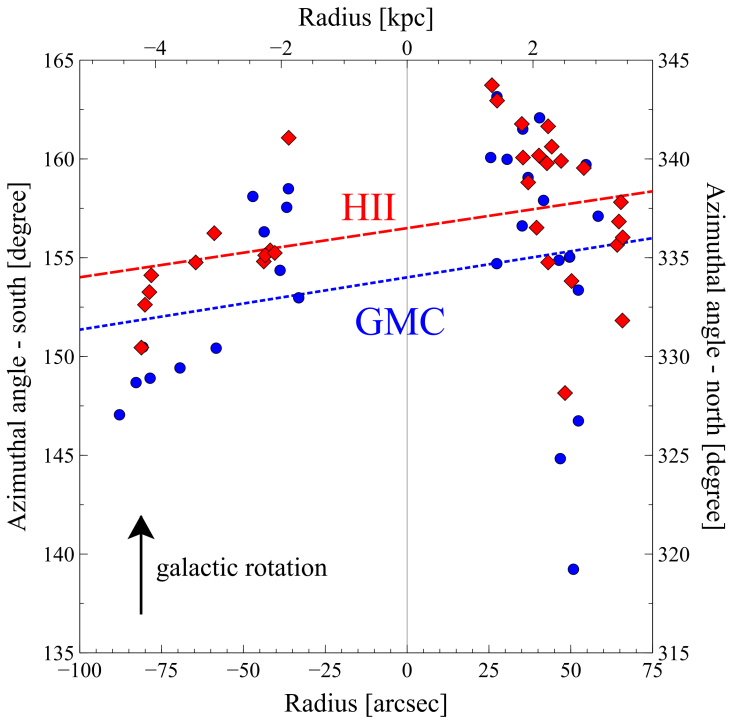
- Large azimuthal velocity gradients at the upstream side of the bar.
- Gas streaming motion inside the bar.

GMCs and H II regions in the bar

Giant molecular associations (GMAs; 10^7 $M_\odot$) and star-forming regions (Hα) in the bar.



Offset between H II regions and molecular clouds – GMCs "lag" behind?

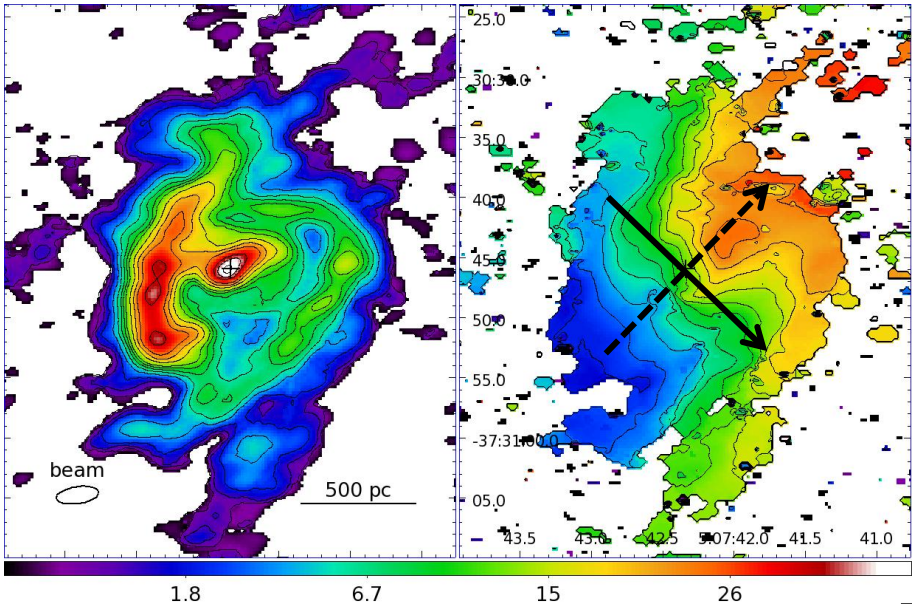


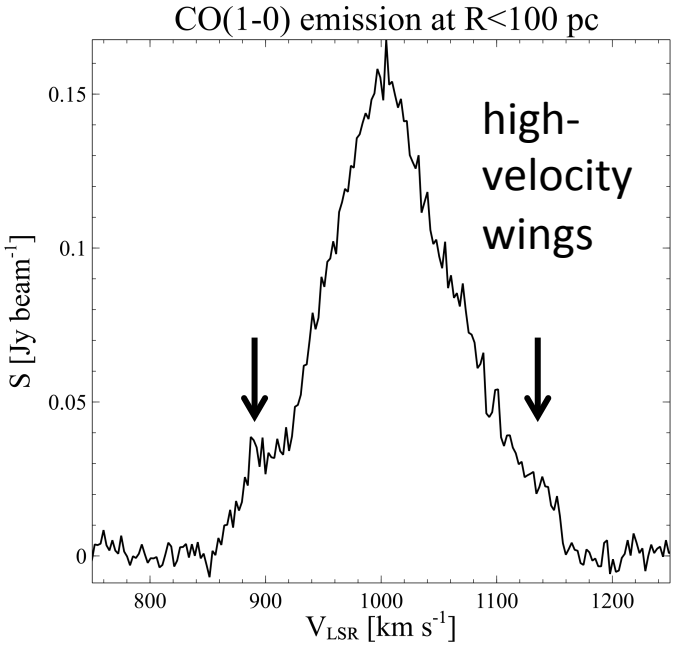
- CO-Hα offset timescale:

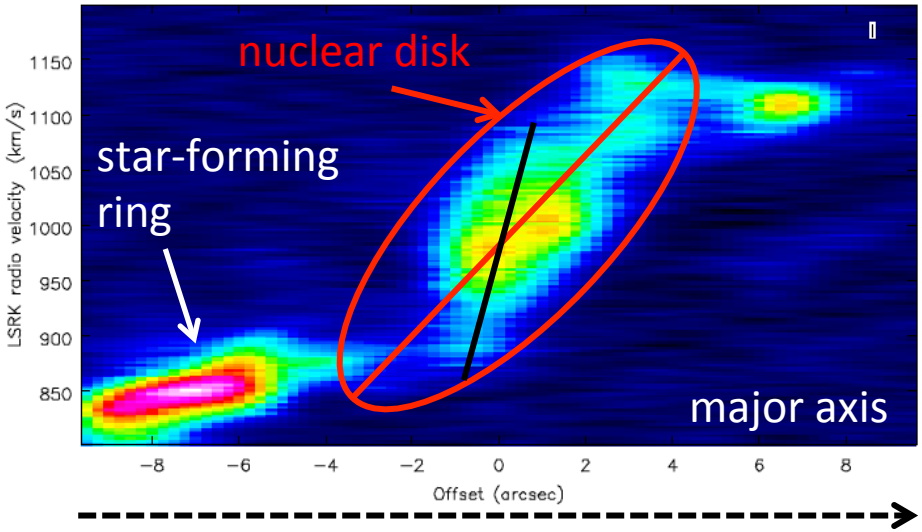
$$t_{\mathrm{drift}} = \frac{\Delta\varphi}{\Omega(R) - \Omega_{\mathrm{b}}} \sim 10^6 \text{ years}$$

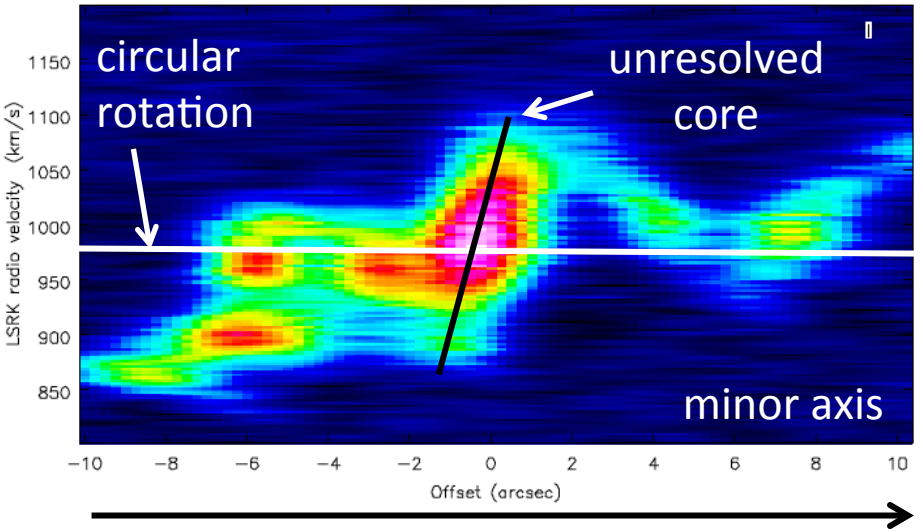
Galactic core

Salak+ (in prep.)









Galactic core

- New ALMA data: 40-pc resolution

Preliminary data… Under construction…

Summary

- ALMA observations of the barred starburst galaxy NGC 1808
- Discovery of a circumnuclear disk in the galactic center, 500-pc ring, and GMAs and GMCs in the bar and disk
- Global cold gas inflow (streaming) driven by bar dynamics
- Azimuthal offset between GMCs and HII regions in the bar

Thank you!