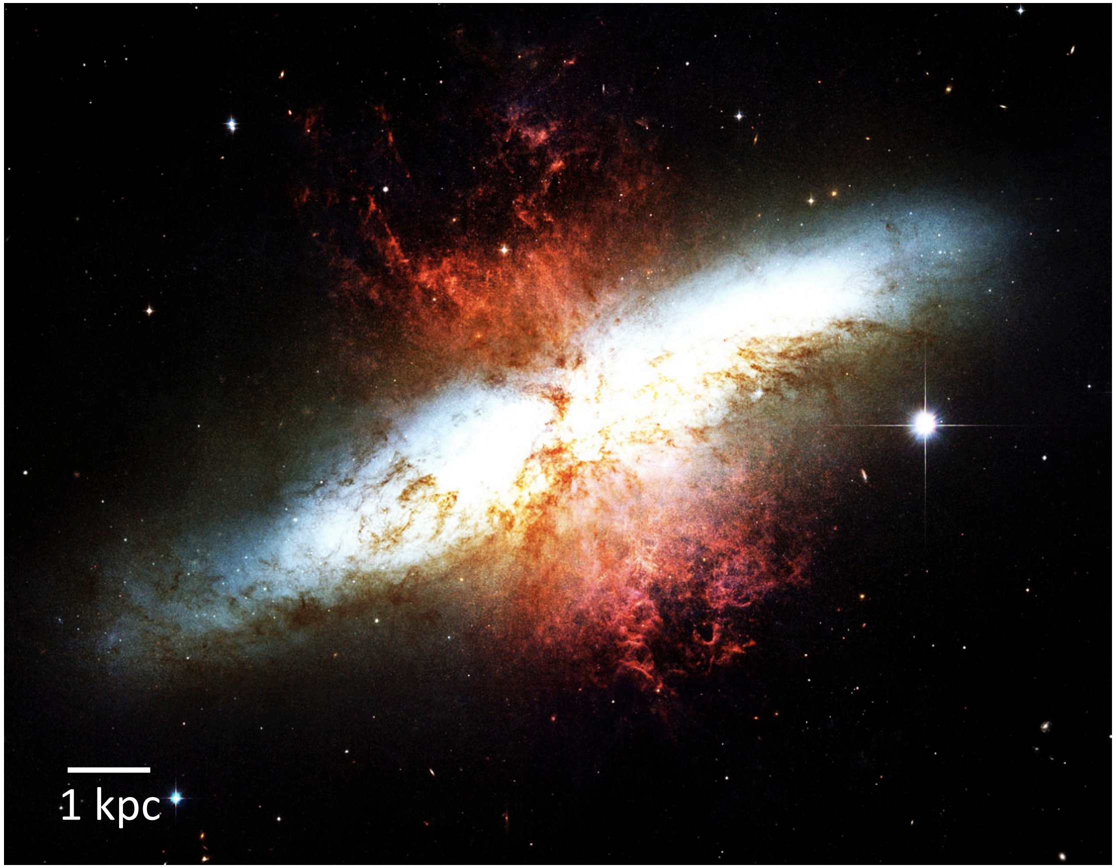
A far-IR and optical 3D view of the starburst driven superwind in NGC 2146

Kathryn Kreckel

Lee Armus (Caltech), Brent Groves (MPIA),
Mariya Lyubenov (Kapteyn), Tanio Diaz-Santos (Caltech)

Kreckel et al. 2014, submitted, arXiv:1403.2381

Galactic Winds and the ISM

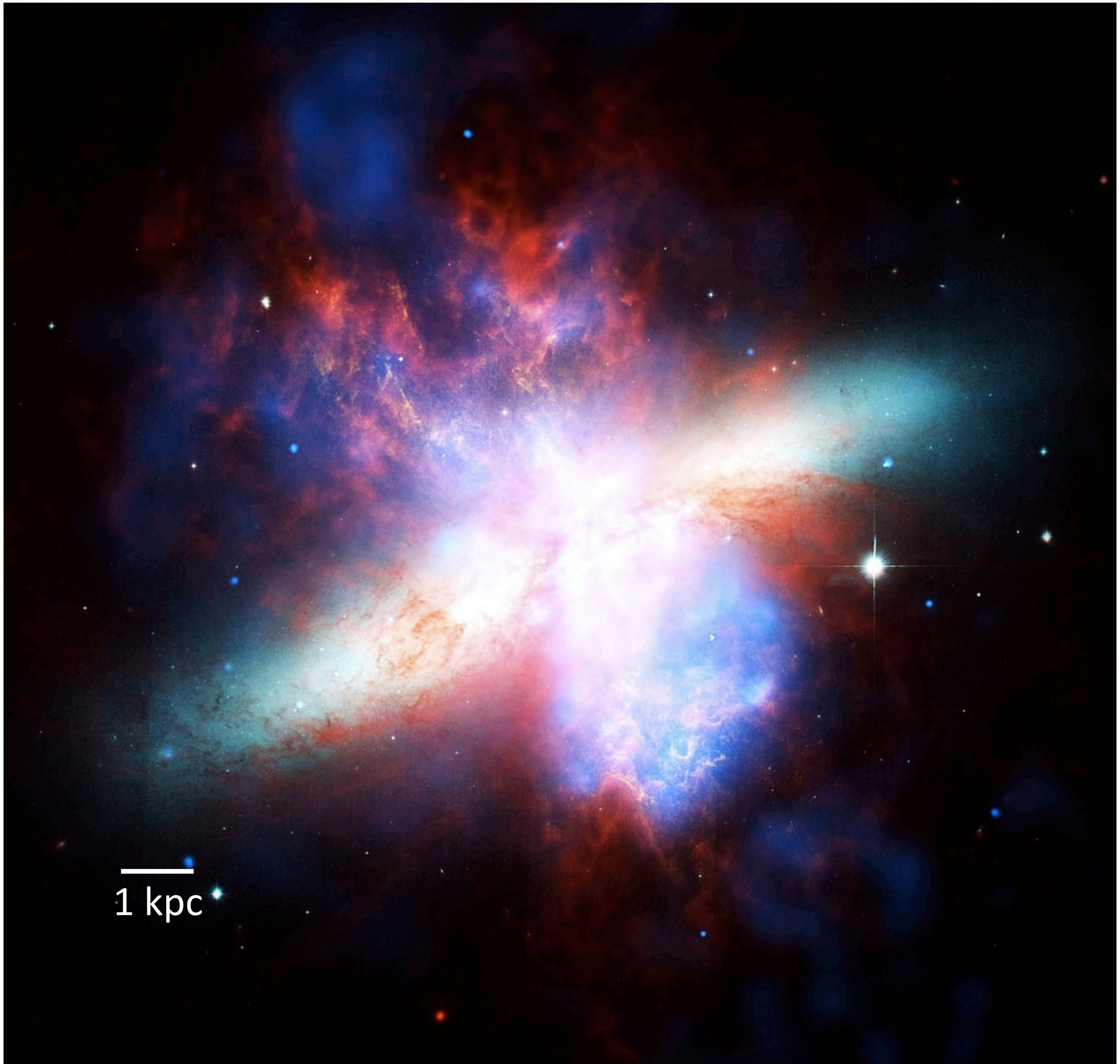


M82

Optical (stellar)

Hα (ionized gas)

Galactic Winds and the ISM



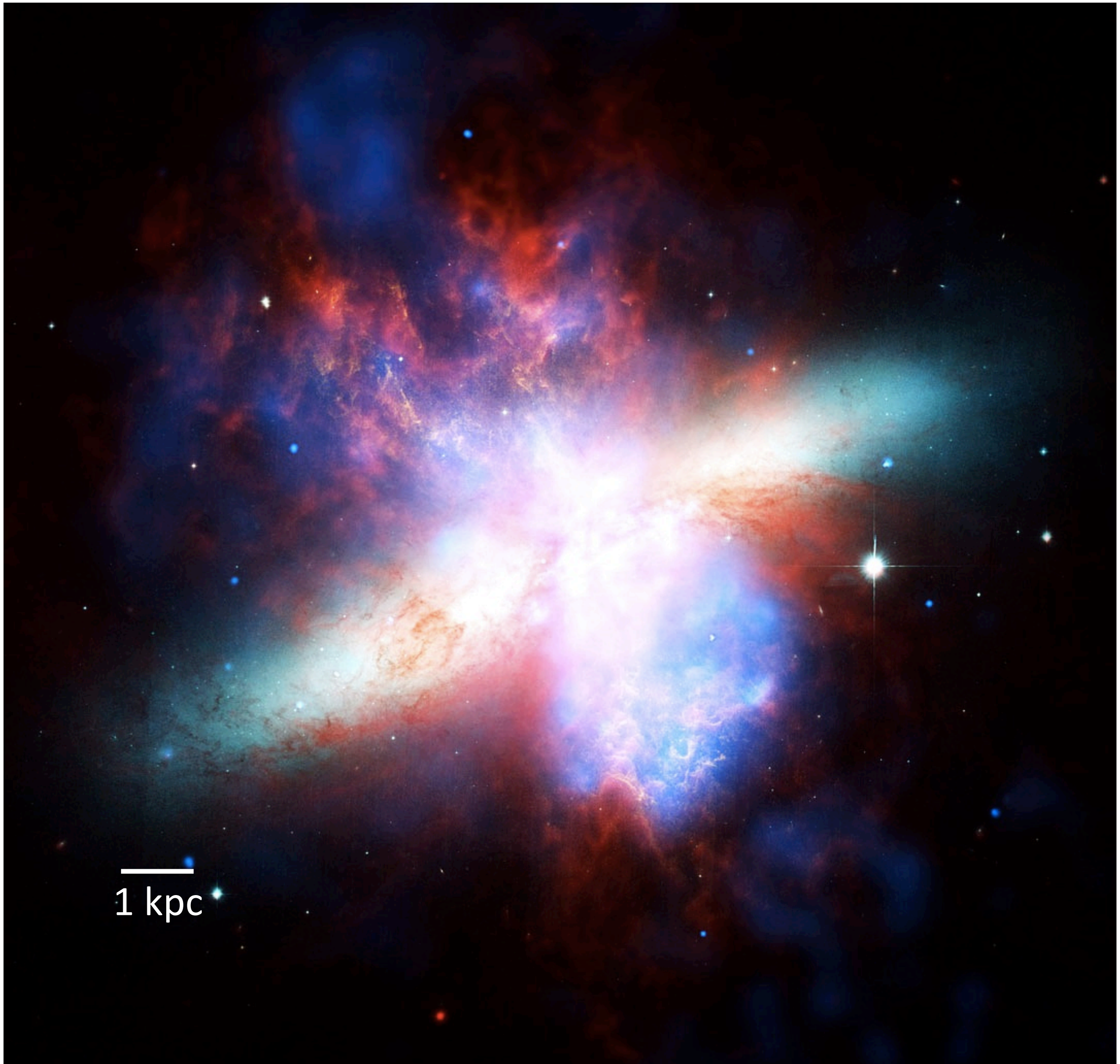
M82

Optical (stellar)

IR (cold gas & dust)

X-ray (hot gas)

Galactic Winds and the ISM



Responsible for:

- Metallicity evolution
- Depositing energy
- Multi-phase gas & dust entrainment
- Suppressing star formation
- Morphological transformation

M82

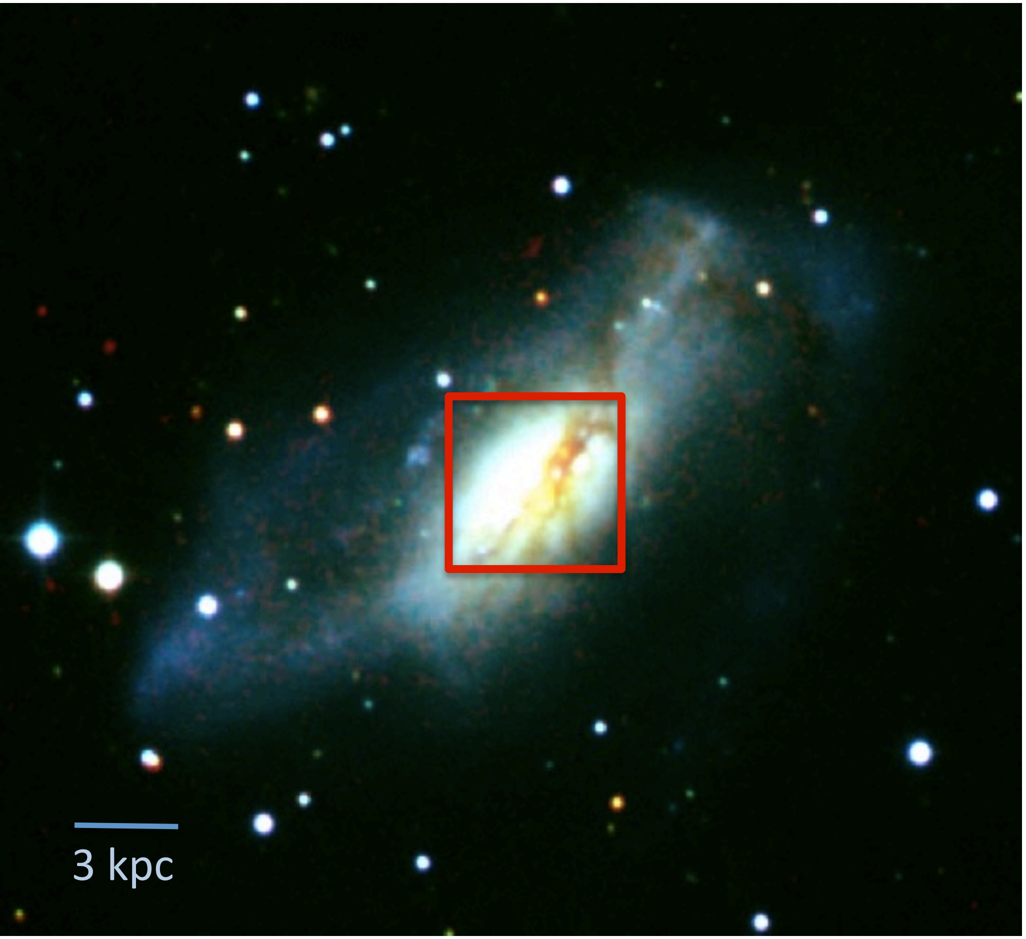
Optical (stellar)

IR (cold gas & dust)

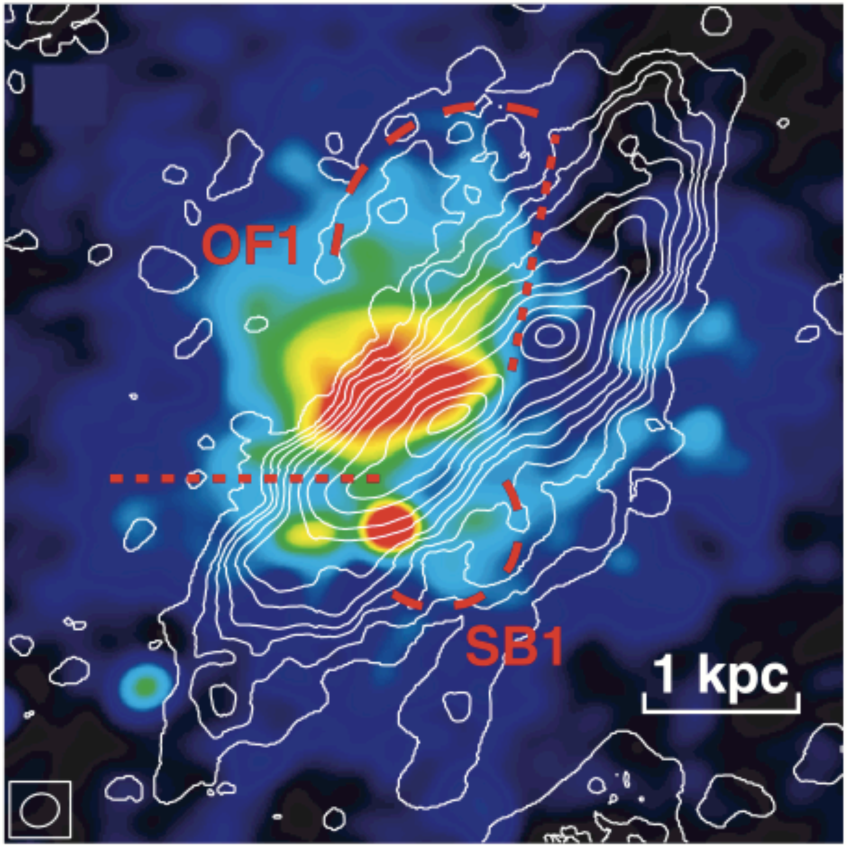
X-ray (hot gas)

$M_* = 2 \times 10^{10}\ M_{sun}$
$SFR = 7.9\ M_{sun}/year$
LIRG, $L_{IR} = 1.2 \times 10^{11}\ L_{sun}$

NGC 2146



Optical

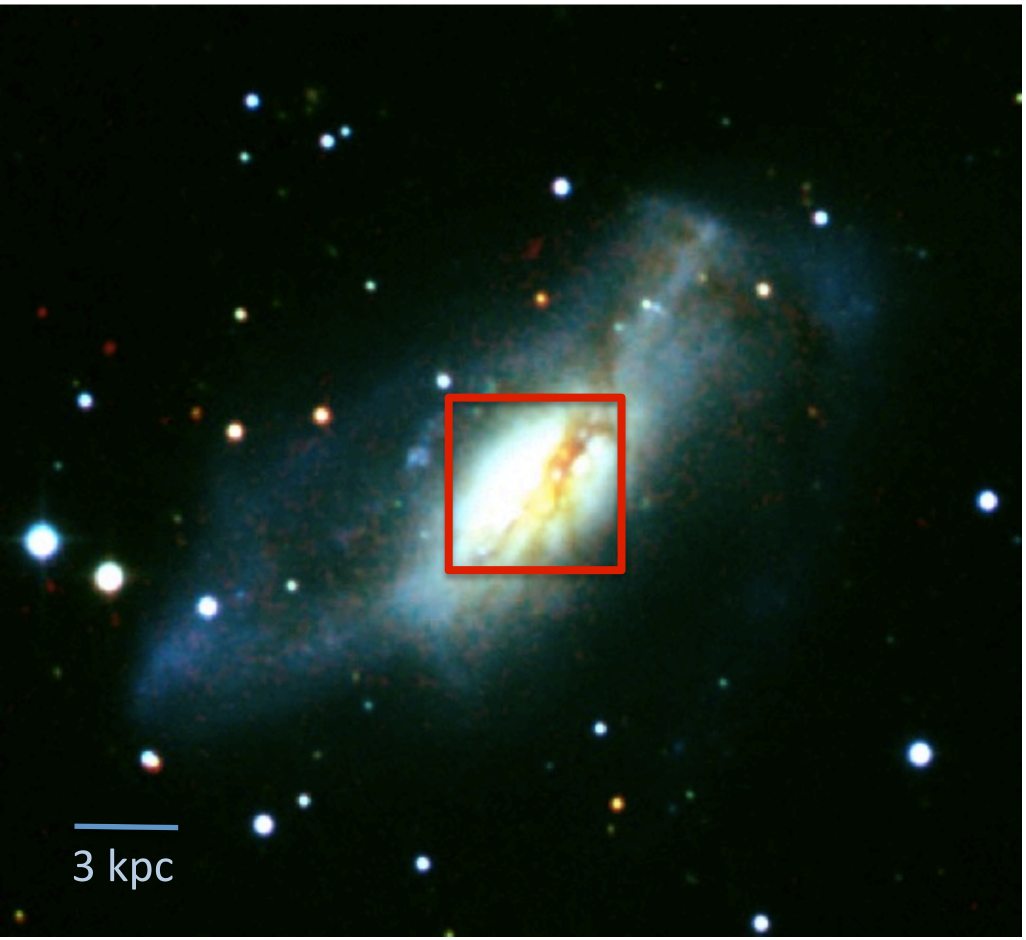


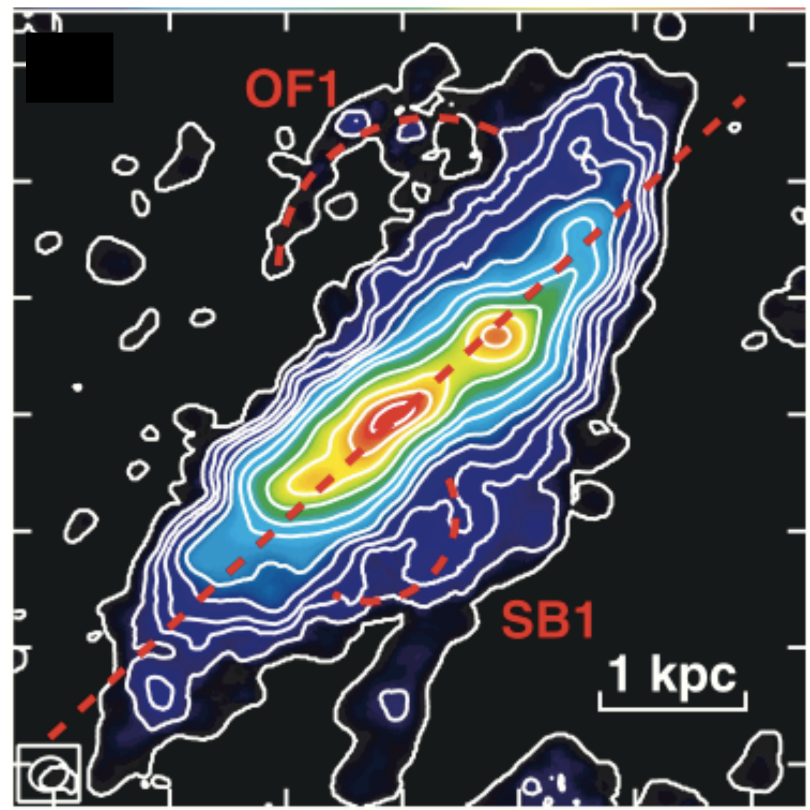
Soft X-ray

Armus et al. 1995
Inui et al. 2005
Tsai et al. 2009

$M_* = 2 \times 10^{10}\ M_{sun}$
$SFR = 7.9\ M_{sun}/year$
LIRG, $L_{IR} = 1.2 \times 10^{11}\ L_{sun}$

NGC 2146



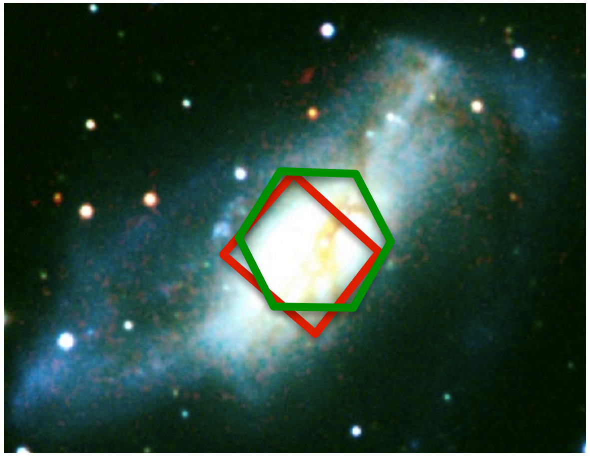


Optical

CO

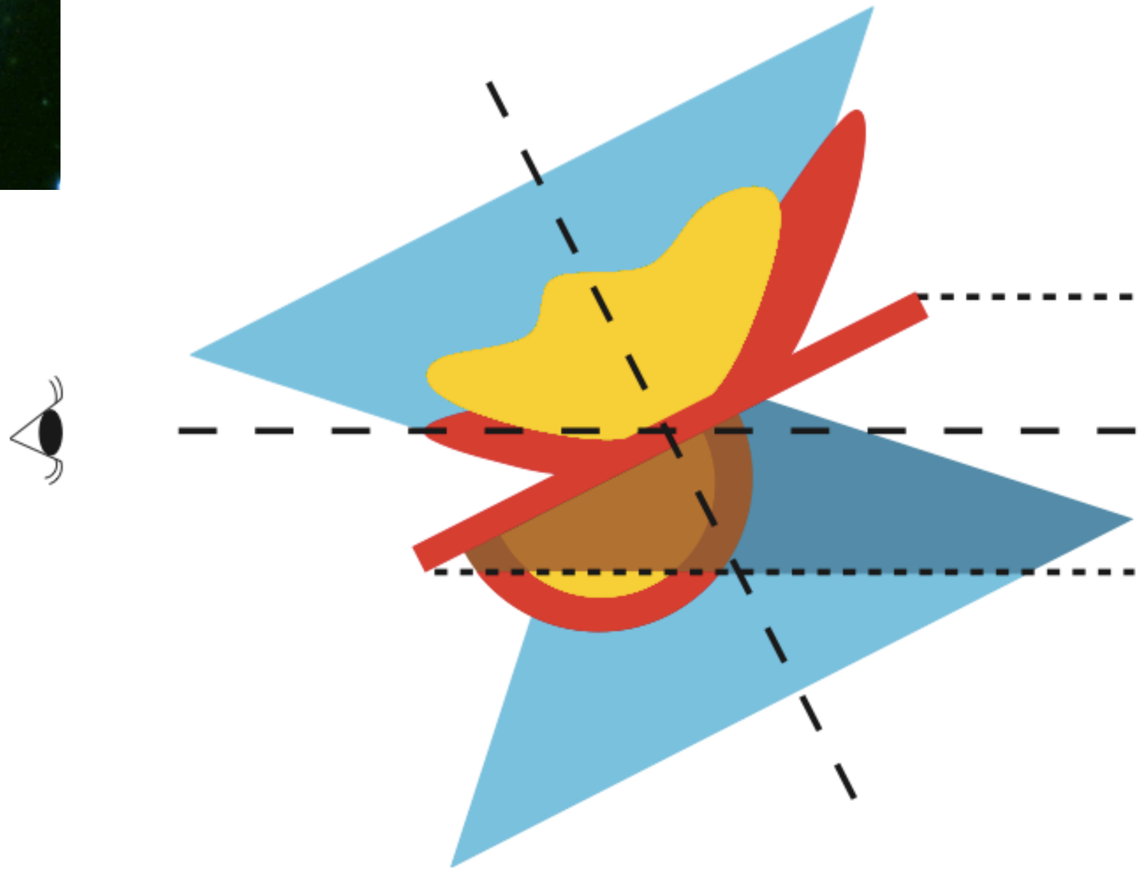
Tsai et al. 2009

Wind geometry



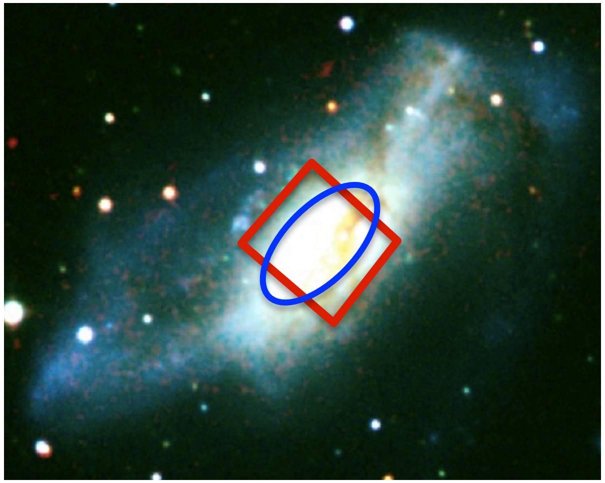
KINGFISH
Herschel PACS spectroscopy
- Unextincted view

FISHPPAK
PMAS/PPAK Optical IFS
- Map shock tracers



Tsai et al. 2009

Wind in far-IR lines

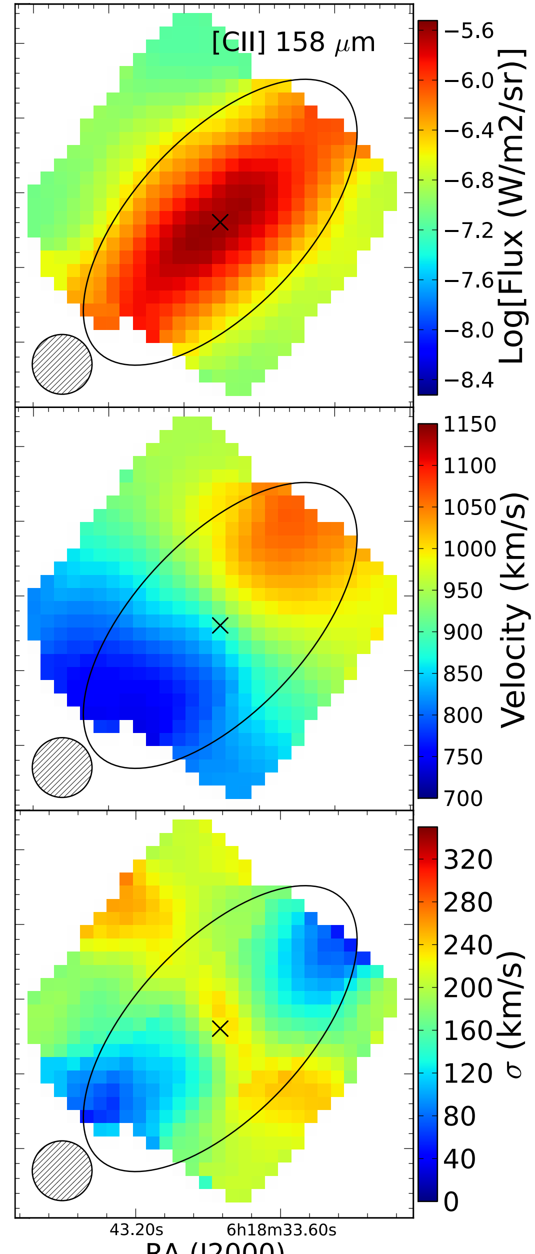


- Herschel PACS Spectroscopy
- 1’ field of view
- 9”-12” PSF (~1 kpc)
- 100-200 km/s FWHM
- Equivalent to ALMA at z=1-3

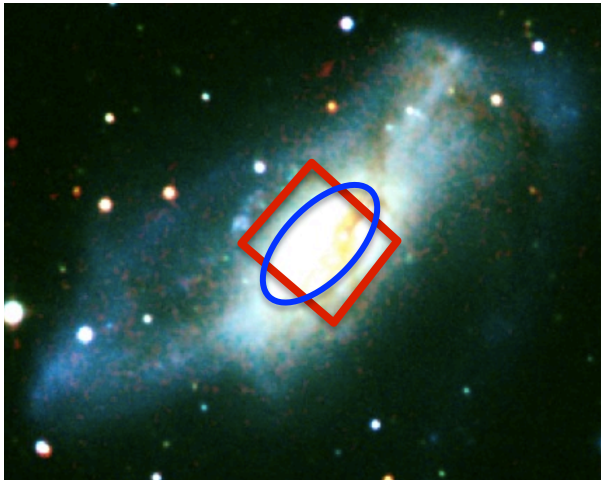
Intensity

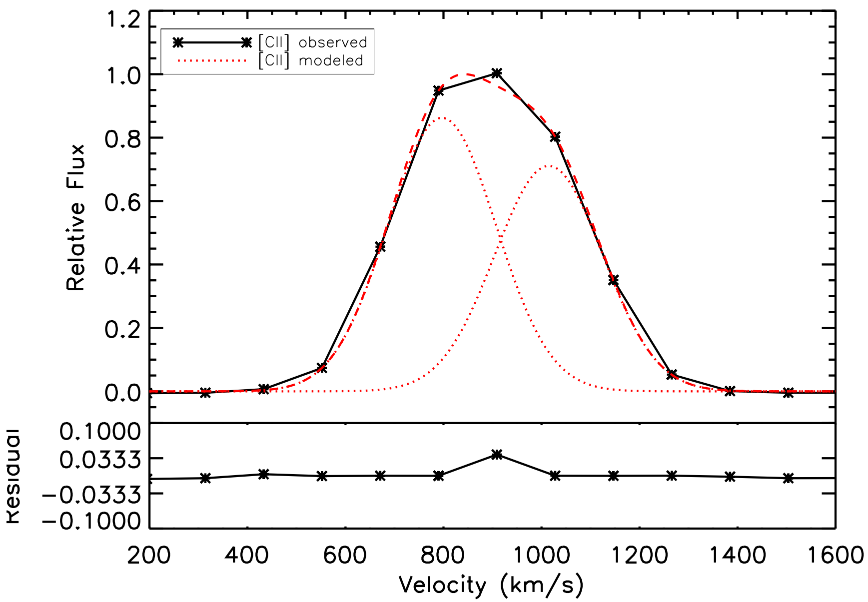
Velocity

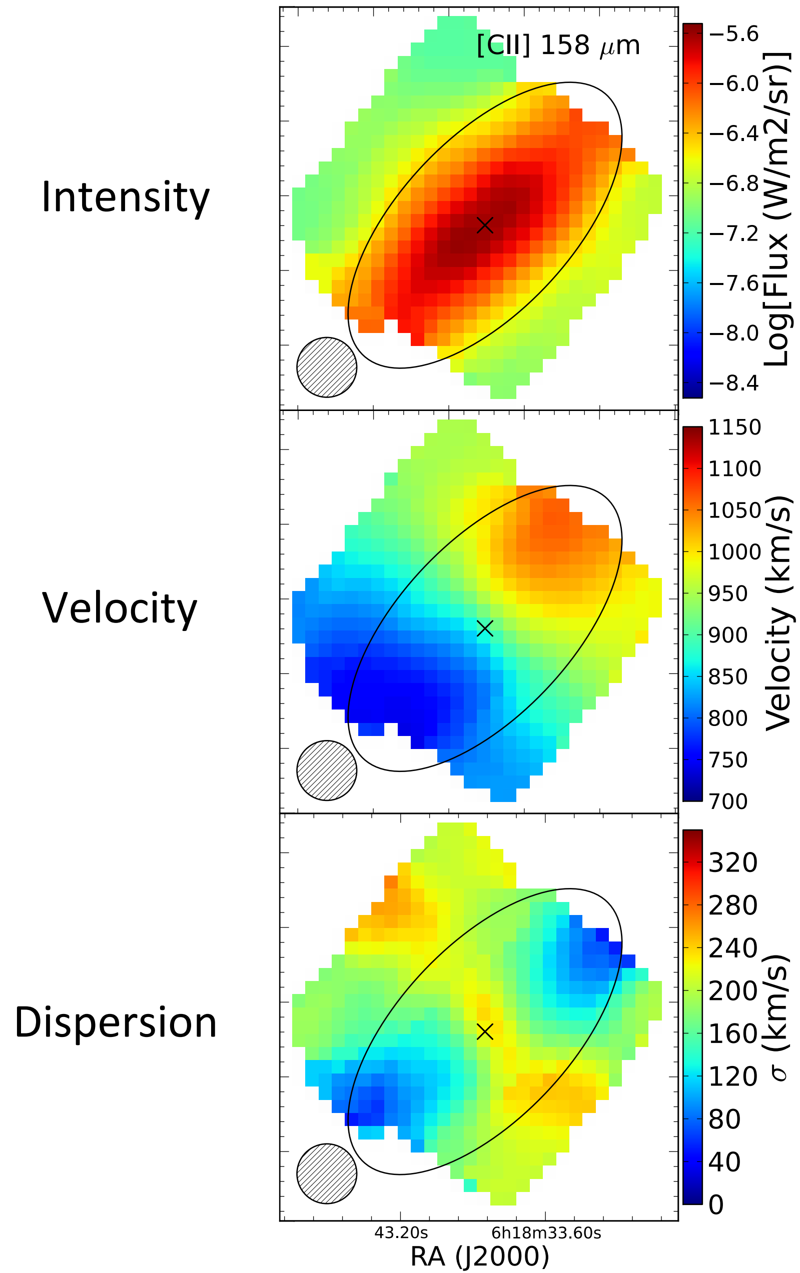
Dispersion



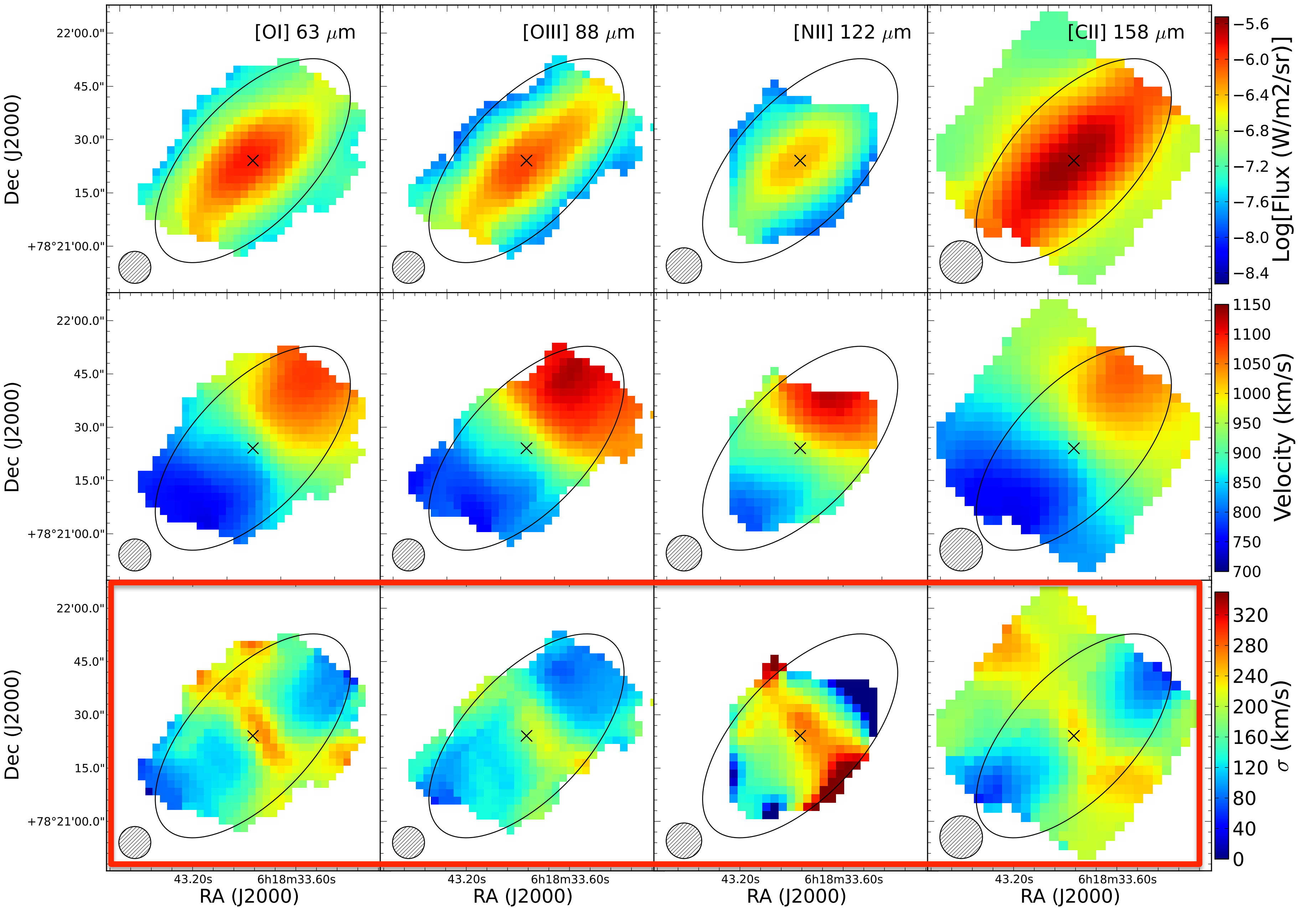
Wind in far-IR lines



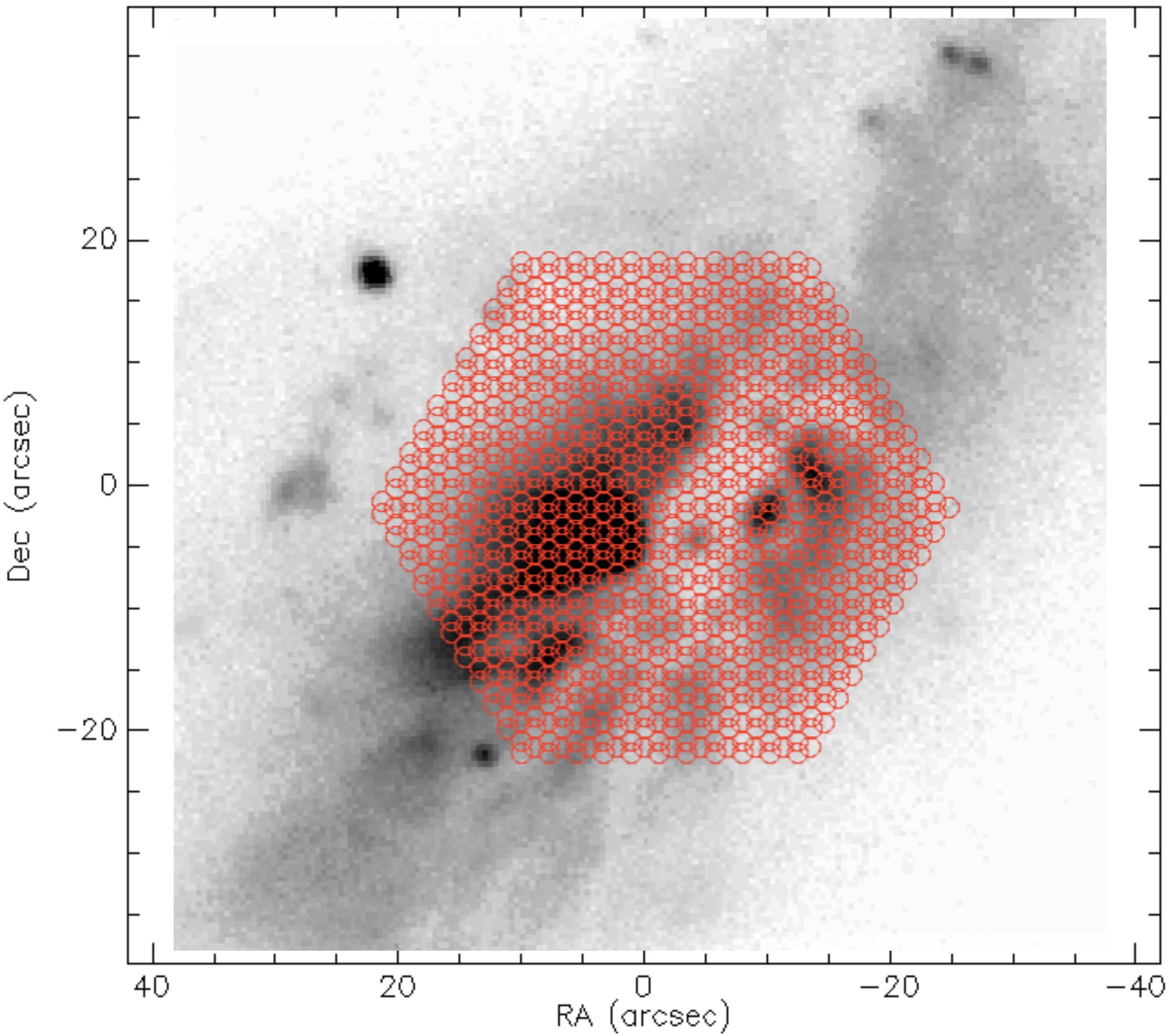




Wind in far-IR lines



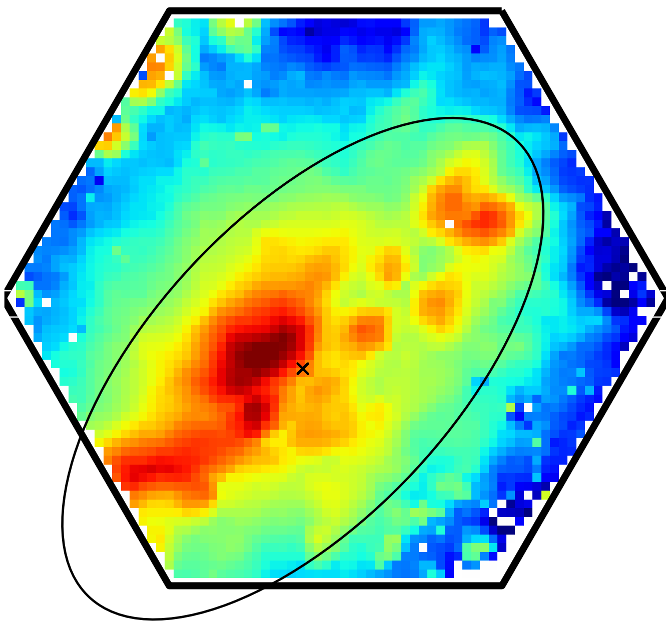
Optical IFS data



- PMAS/PPAK instrument at Calar Alto 3.5m
- 331 fibers x 3 dither positions
- 2.7'' diameter fibers
- 1' field of view
- 3700-7000 A
- 200 km/s FWHM

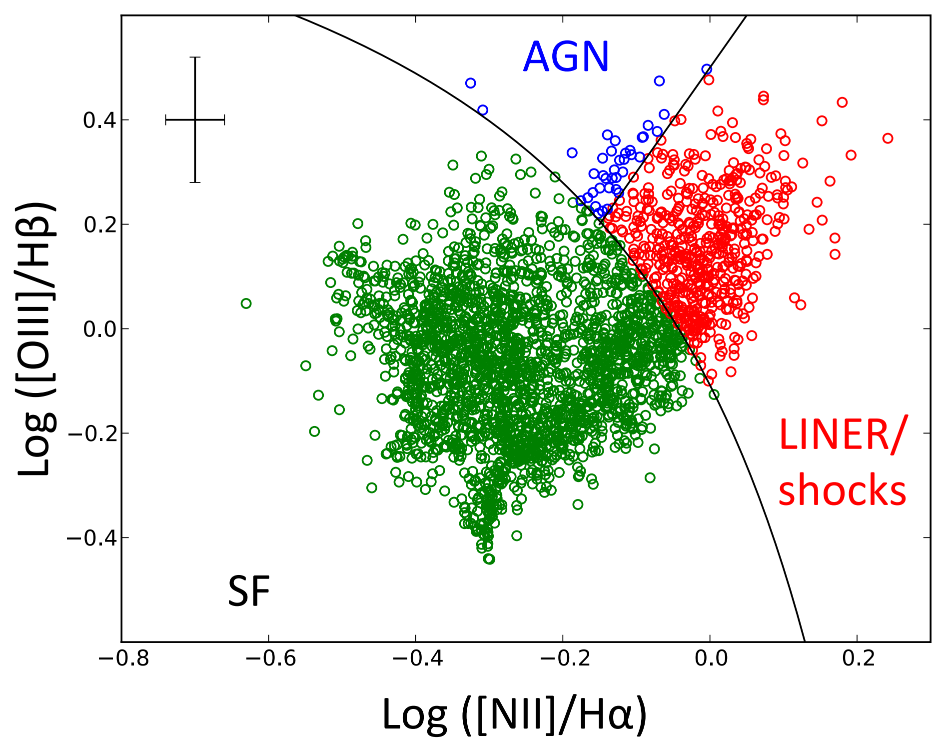
V band

Mapping the optical shock tracers

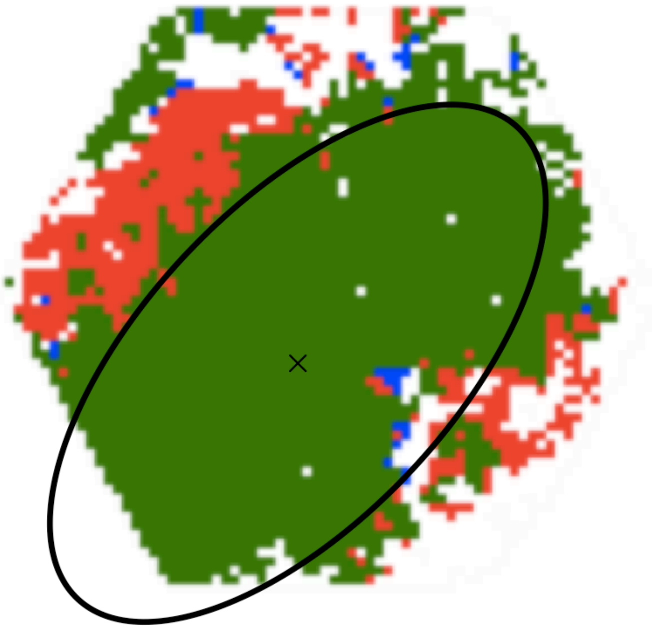


Hα line flux

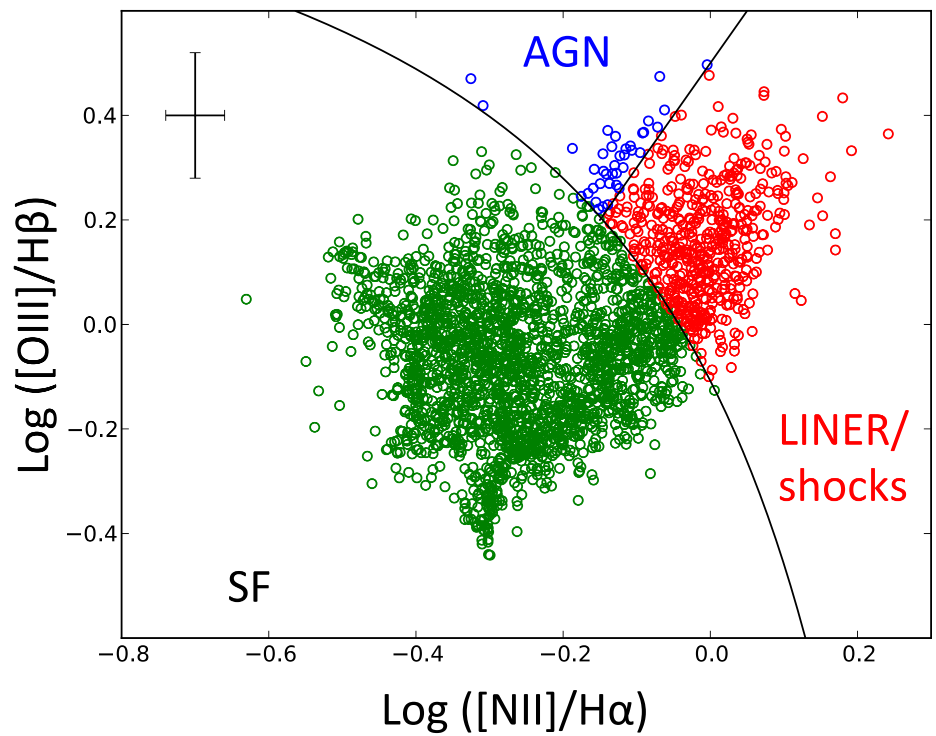
BPT Diagram



Mapping the optical shock tracers

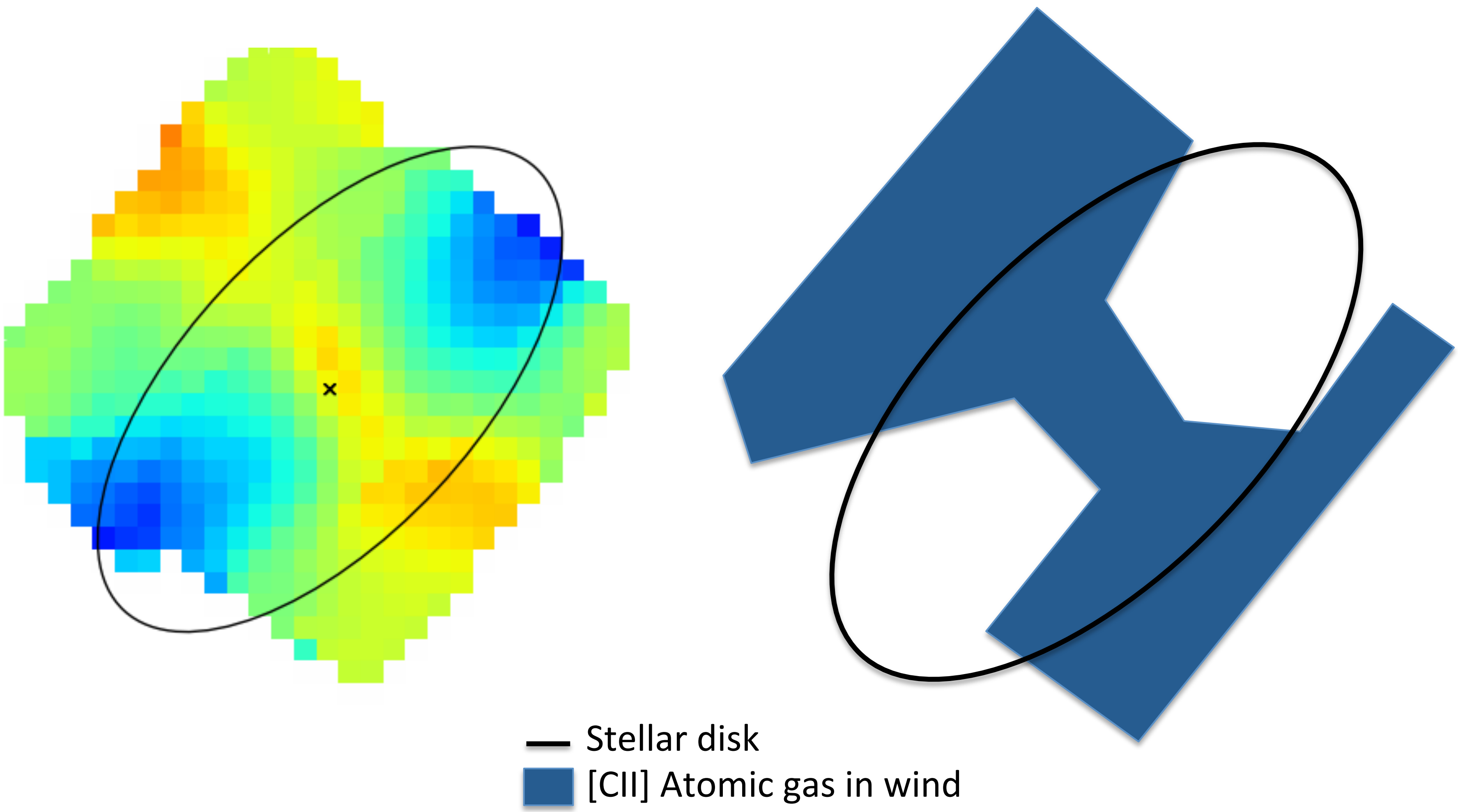


BPT Diagram

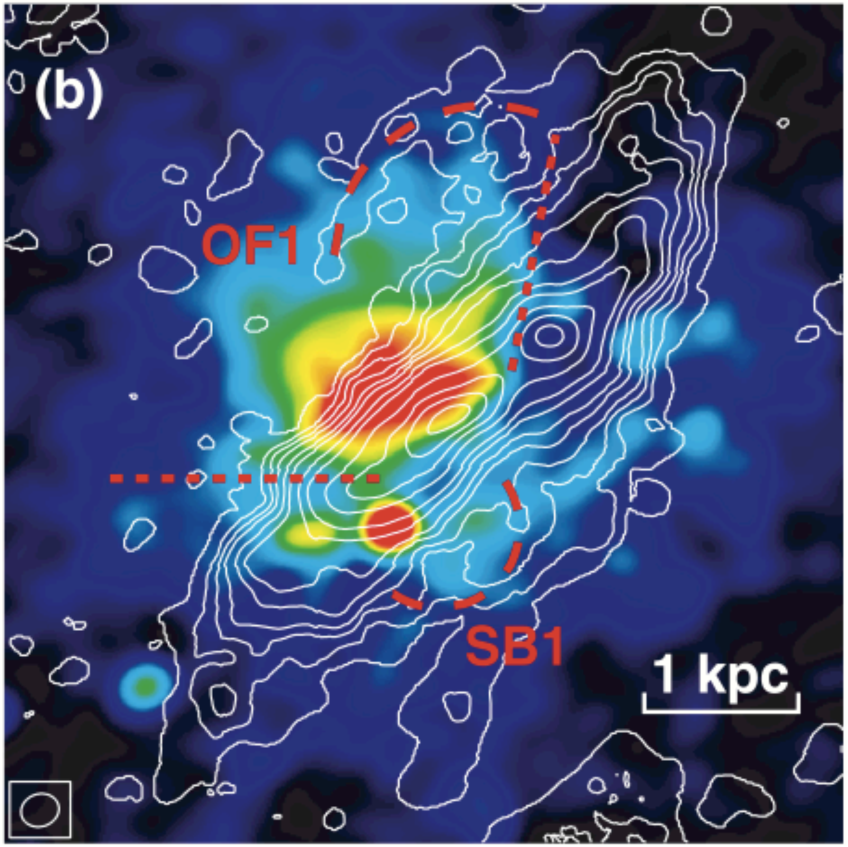


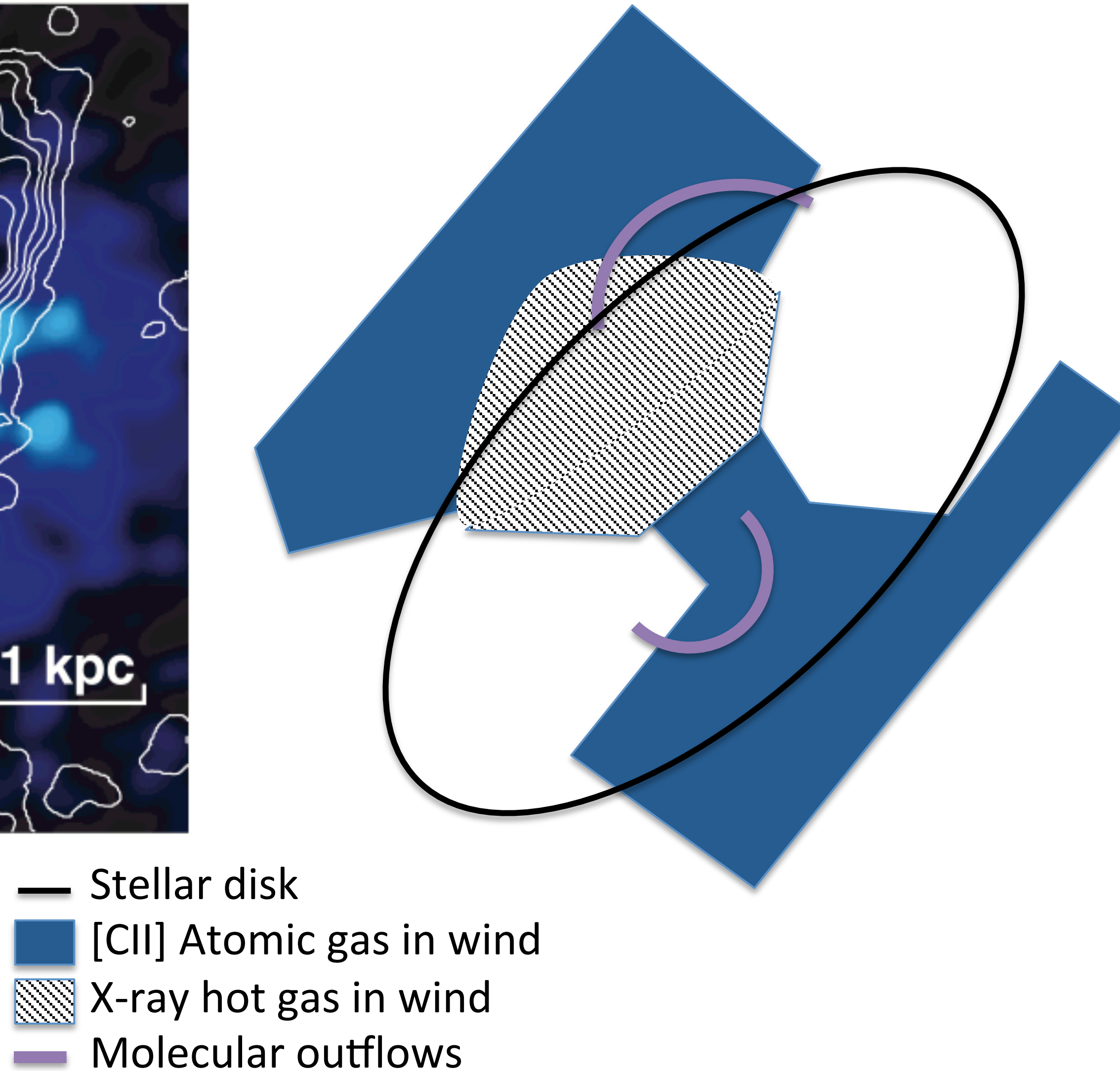
~200 km/s shock velocities

A spatial comparison of wind tracers

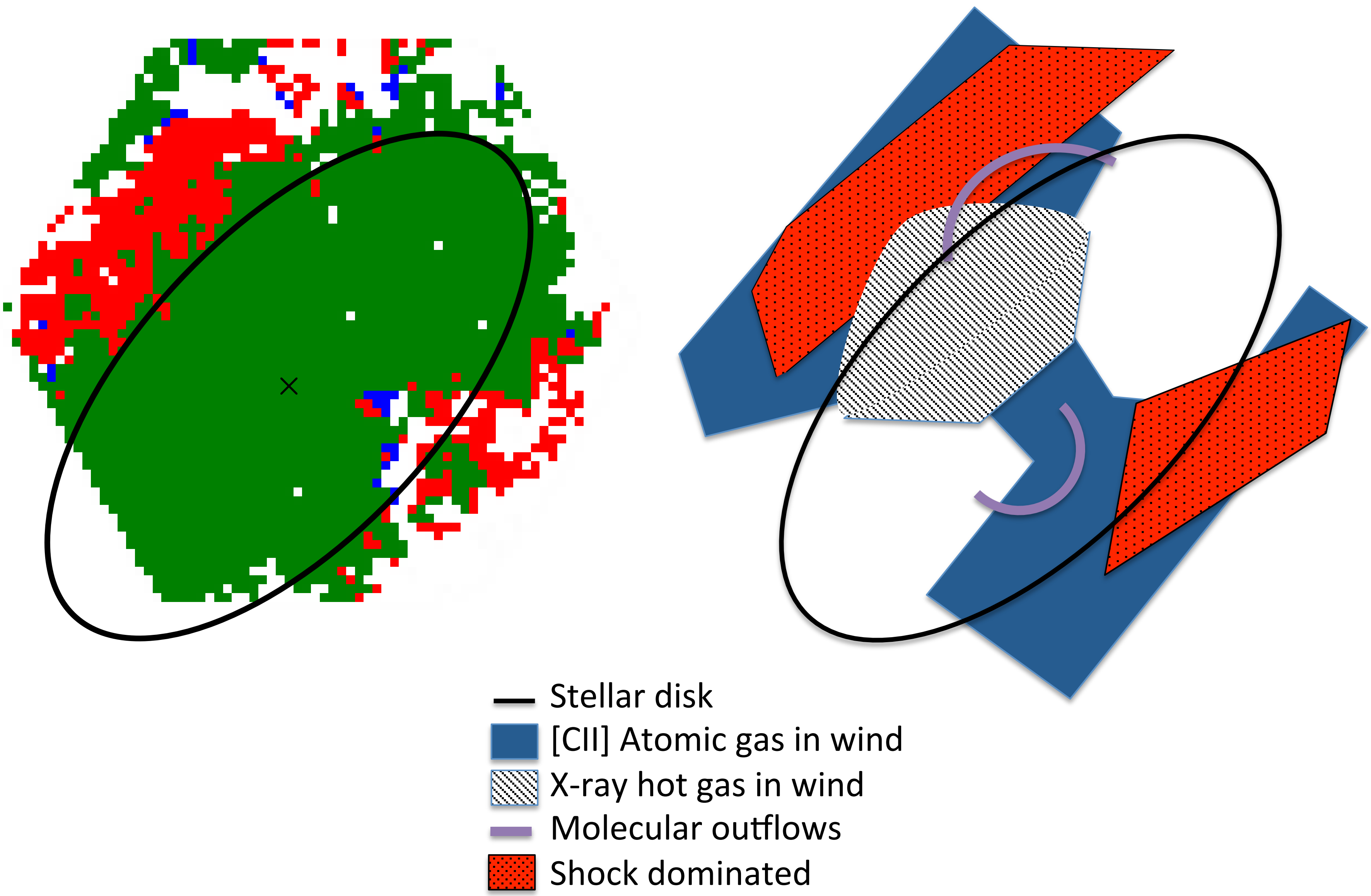


A spatial comparison of wind tracers



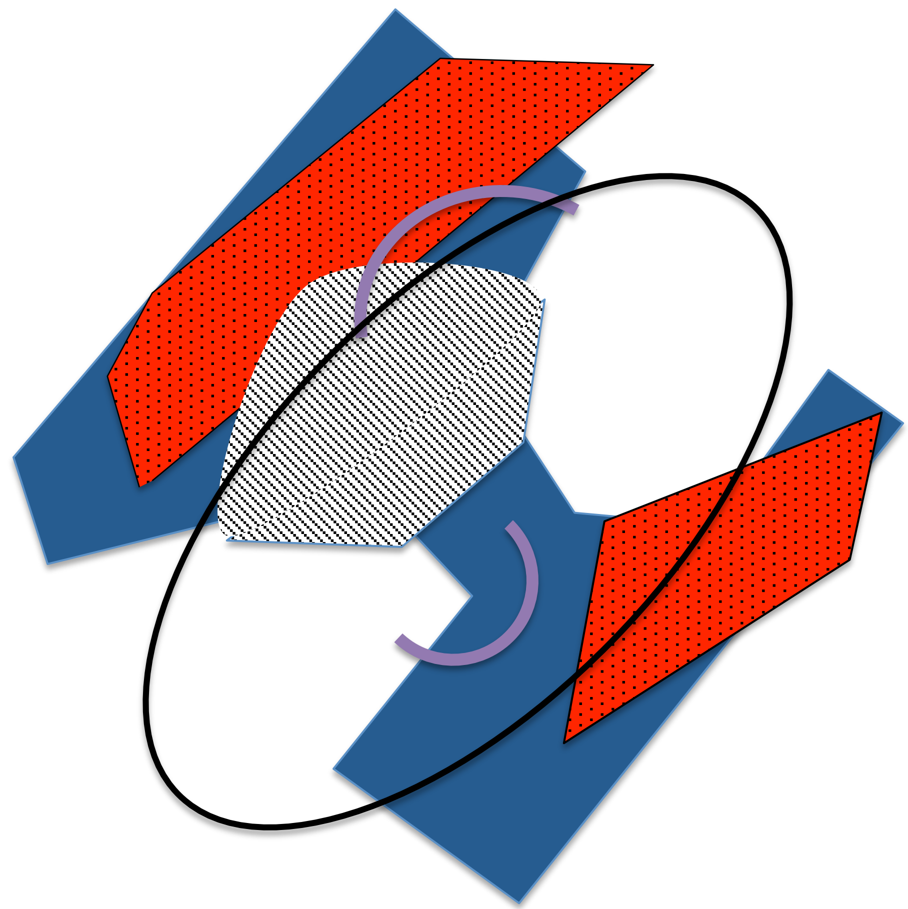


A spatial comparison of wind tracers



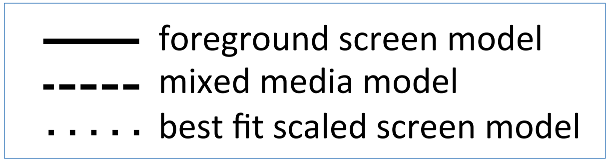
A spatial comparison of wind tracers

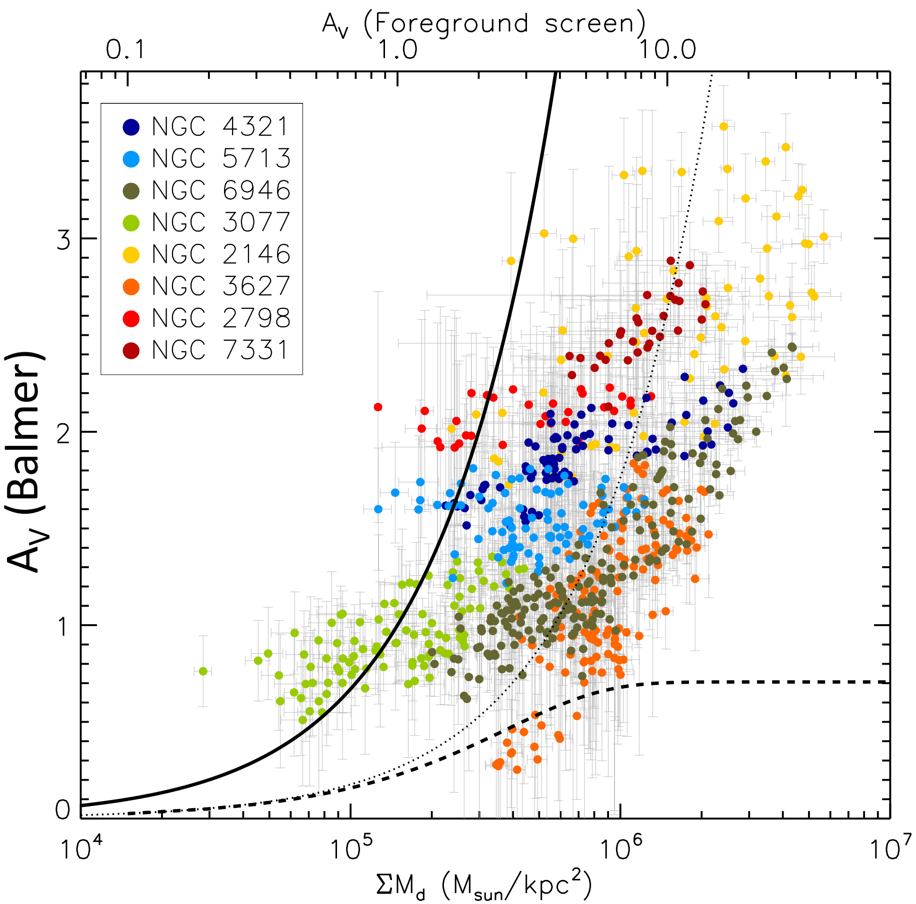
- Stellar disk
- [CII] Atomic gas in wind
- X-ray hot gas in wind
- Molecular outflows
- Shock dominated

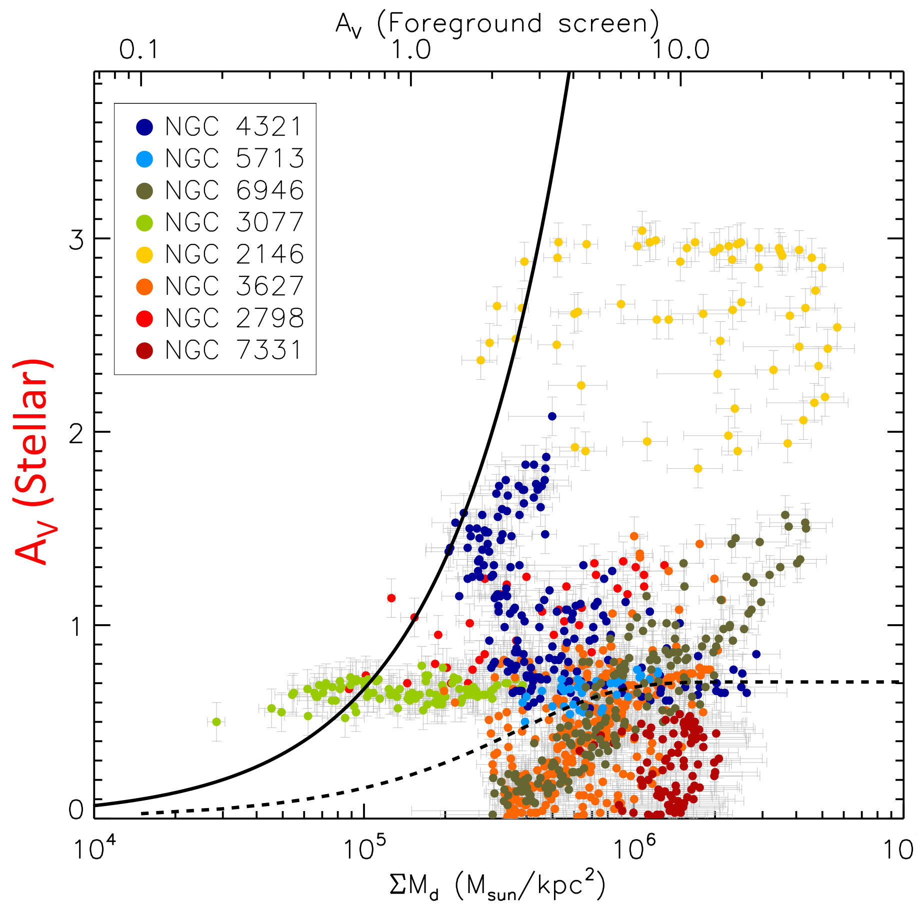


$M_{stars} \sim 2 \times 10^{10}\ M_{sun}$
$M_{CO,disk} \sim 2 \times 10^{9}\ M_{sun}$
$M_{CO,\ outflow} \sim 3 \times 10^{8}\ M_{sun}$
$M_{atomic,outflow} \sim 7 \times 10^{8}\ M_{sun}$

Connecting optical attenuation (A_V) with dust mass





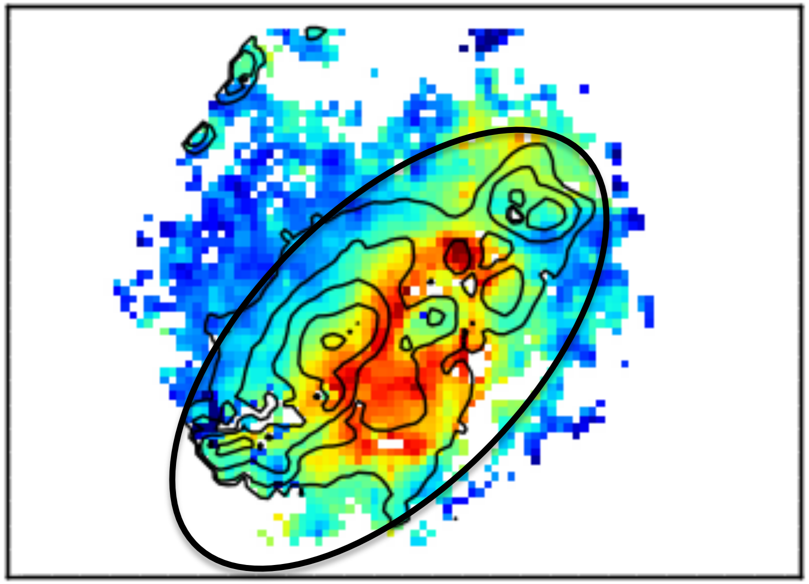


A_V (Balmer) = A_V (Foreground screen) / 3.8

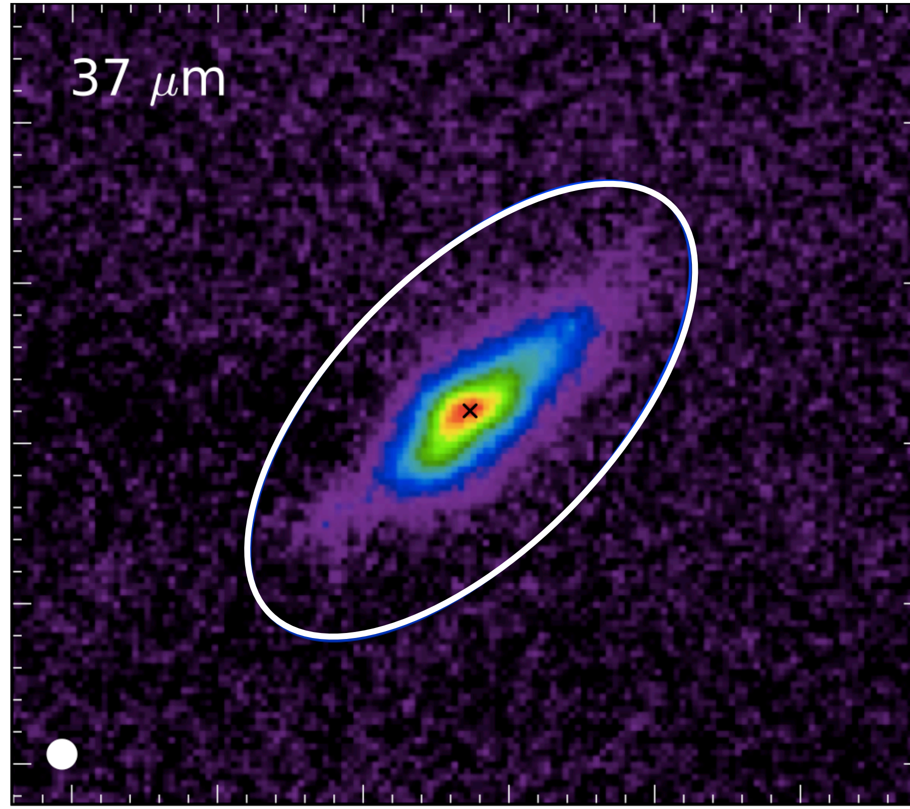
No clear correlation

Kreckel et al. 2013

No large scale dust entrainment

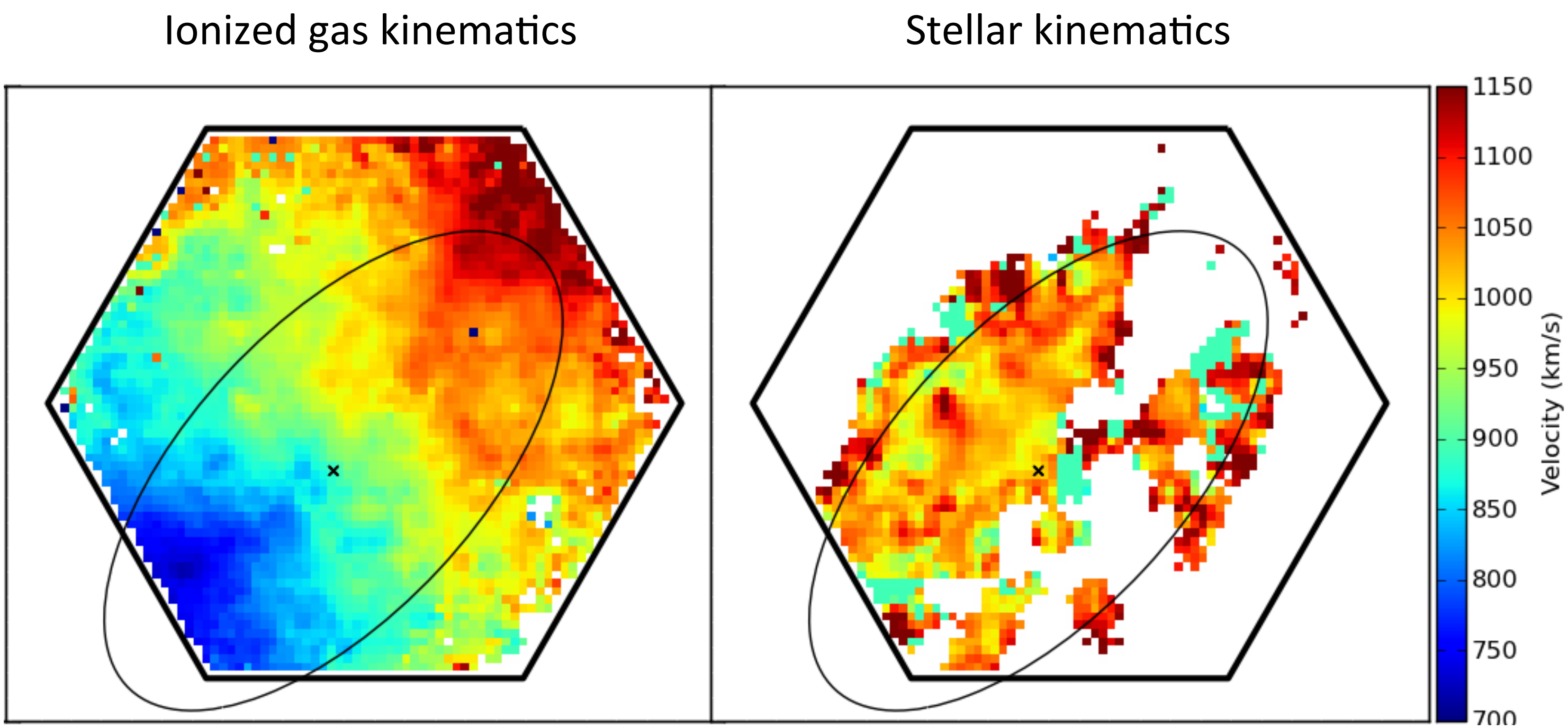


Cold dust, as traced by A_V with Hα contours



Warm dust, as traced by SOFIA FORCAST

Decoupled stellar and gas kinematics



Stellar continuum fit with pPXF (Cappellari & Emsellem 2004)
Emission lines simultaneously fit with GANDALF (Sarzi et al. 2006)

Impact of wind on final fate

Unimportant ⟷ Very important

High mass outflow rate in central starburst region

Can form stars for > 2.3 Gyr, double existing stellar mass

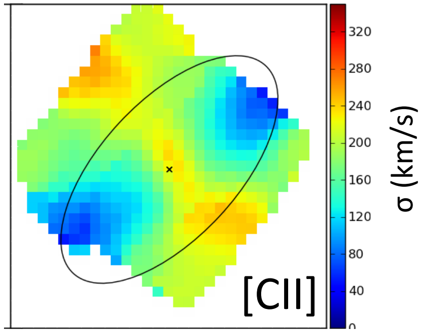
Dynamical quenching, shock heating of infalling gas

?

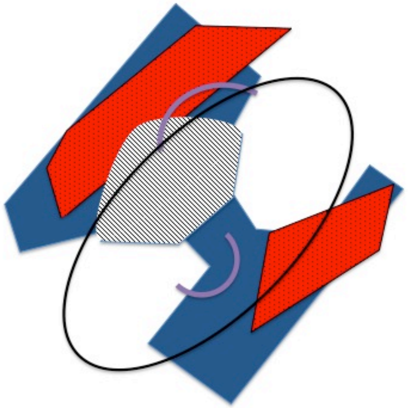
Rebuild a disk -> bulge dominated spiral

Exhaust/expel gas -> red and dead elliptical

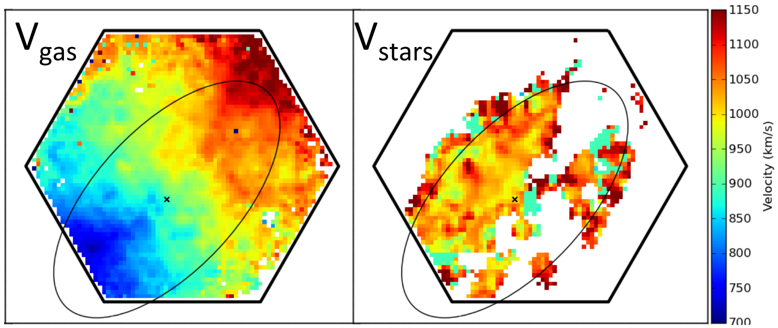
Summary



- Far-IR lines trace the wind



- Good spatial agreement between atomic wind and shocks, extends farther than the CO outflow & hot X-ray emission



- NGC 2146 is transitioning, wind is crucial in determining the final morphology