SOFIA GREAT Observations of [OI] in the Circumnuclear Ring Region of the Galactic Center

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And the Central Molecular Zone of the Milky Way

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Key Players in the Work

- Mark Morris (UCLA); PI & Data Analysis
- Rolf Guesten (MPIfR Bonn); GREAT PI & Obtained the Data.
- Denise Riquelme (MPIfR Bonn); Data Reduction
- Eric Becklin (UCLA/SOFIA); Presenter

Outline of Material

- High level motivations for [OI] and [CII] observations in the CND
- Dust observations of the CNR (Disk) around Sgr A* with SOFIA/FORCAST
- The [OI] Observations with upGREAT on SOFIA

High Level Motivation for this Work

- Sgr A* is the closest Massive Black Hole 4E6 M(Sun)
- The history and future of accretion of mass unto the Black Hole is needed to understand Massive Black Hole physics
- Ionized gas [HII] has been the best studied, but its mass is only ~10% of the atomic gas mass inside the CND.
- Good [OI] and [CII] maps of the CND region with the highest special and spectral resolution are needed. Our maps cover the central 8 pc

The Circumnuclear Dust Ring around SgrA*: FORCAST imaging with SOFIA

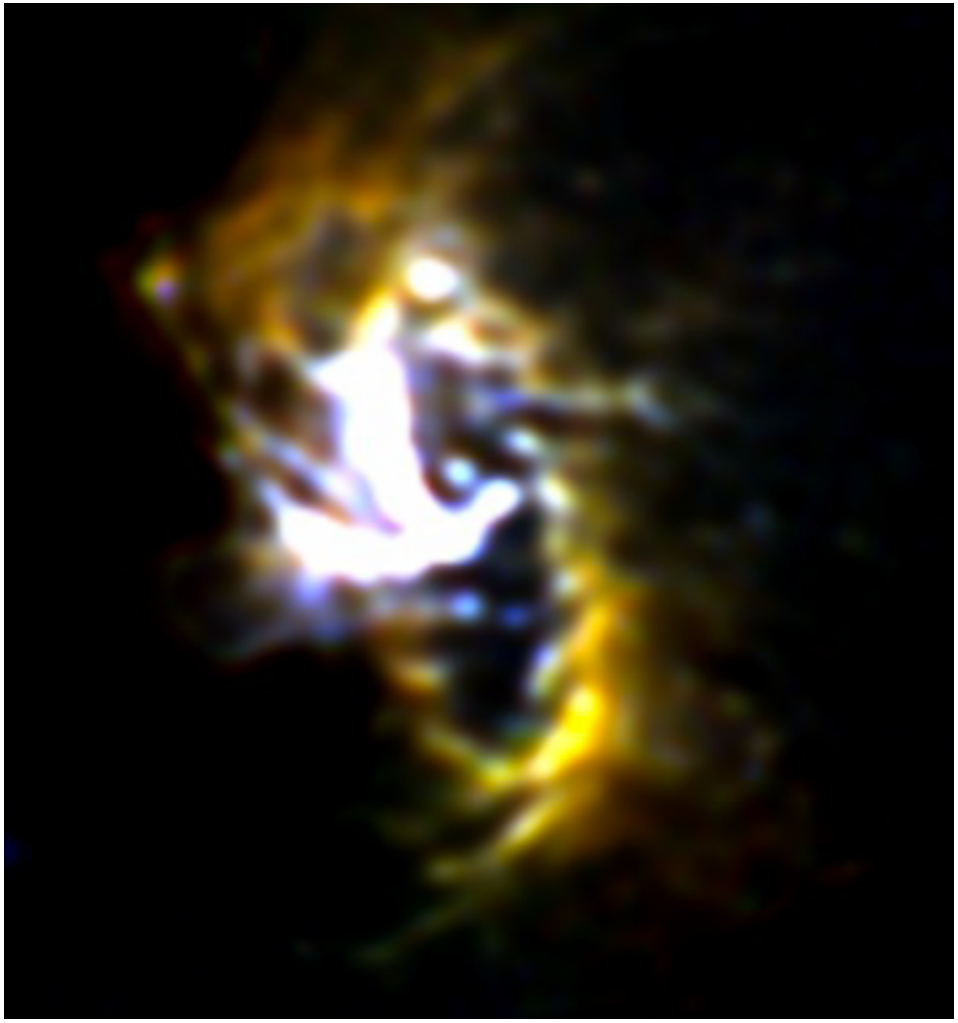
CNR at 19(blue), 31(green) and 37(red) microns

This is the highest resolution image of the Circumnuclear ring ever obtained with ~3 arcsec FWHM. (Lau etal 2013)

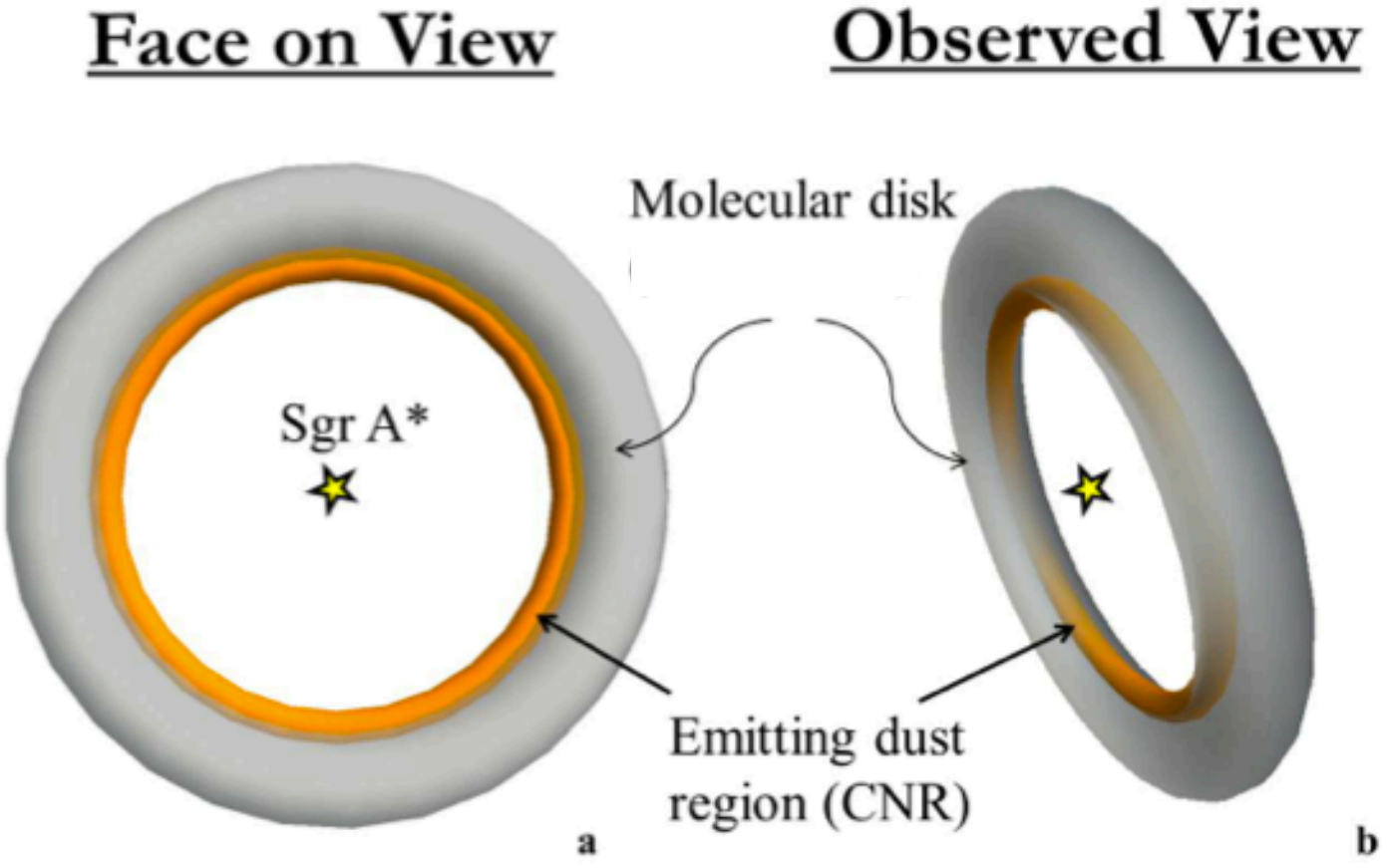
- White central emission is from the hot dust (T~200-300k) heated by ionized gas in the northern and eastern arms

- Almost perfect 1.5 pc radius ring is seen in cooler dust (T~100K) centered on the Massive Black Hole.
- Tilted about 23 degrees from the galactic plane.
- Heated by bright stars near the BH
- It is rotating in the direction of galactic rotation. (Guesten etal 1987)

- The ring is resolved with a width of about 0.3 pc.
- There is interesting small structures along the ring, almost periodic in nature.



Toy Model of the Dust Ring



Physics of [OI] in the CND Region

High Level Physics of [OI] and [CII]

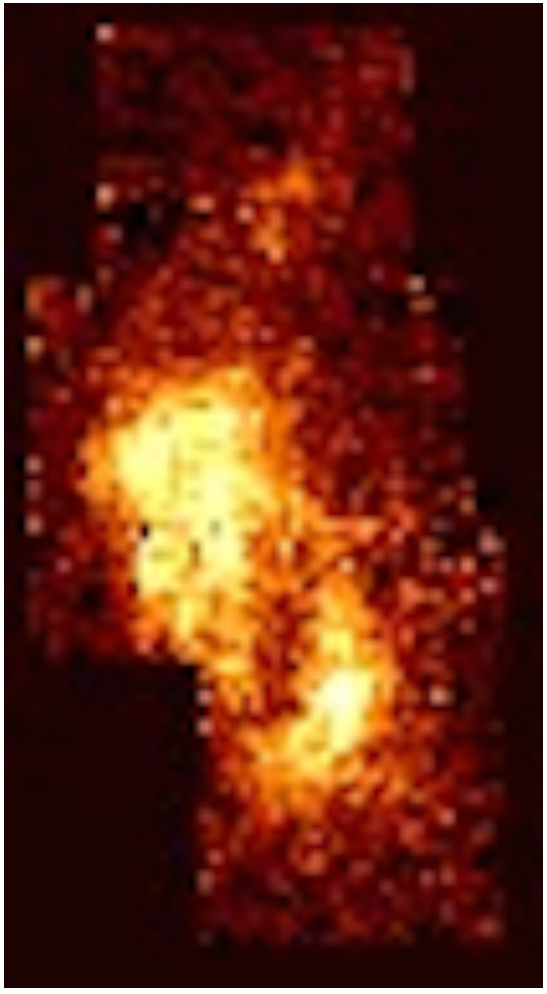
- [OI] at 63 microns and [CII] at 158 microns are two of the strongest cooling lines in the ISM
- Typically the emission occurs between a region of ionized Hydrogen [HII] and a Molecular region (H2) in a Photo-Dissociation Region (PDR).
- The [OI] line at 63 microns tends to be excited in high density regions >E5 cm(-3). [CII] excited at densities n>~E3 cm(-3).
- In the Galactic Center CNR region the PDR should occur between the ionized gas falling into the Black Hole region (Northern Arm, Eastern Arm and the Bar) and the Circum-Nuclear Ring.

[OI] Preliminary Results with SOFIA/GREAT

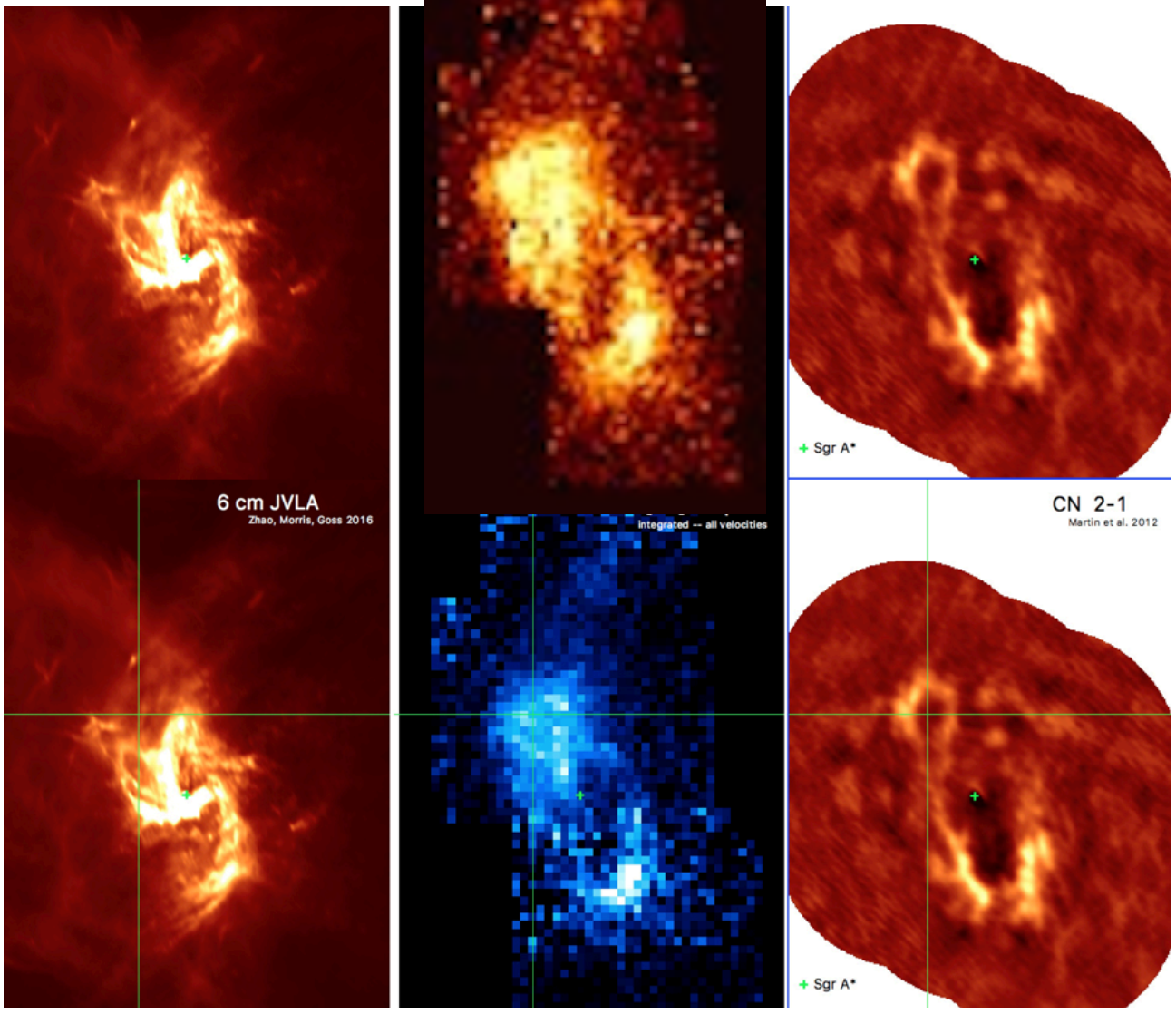
GREAT Heterodyne Instrument on SOFIA

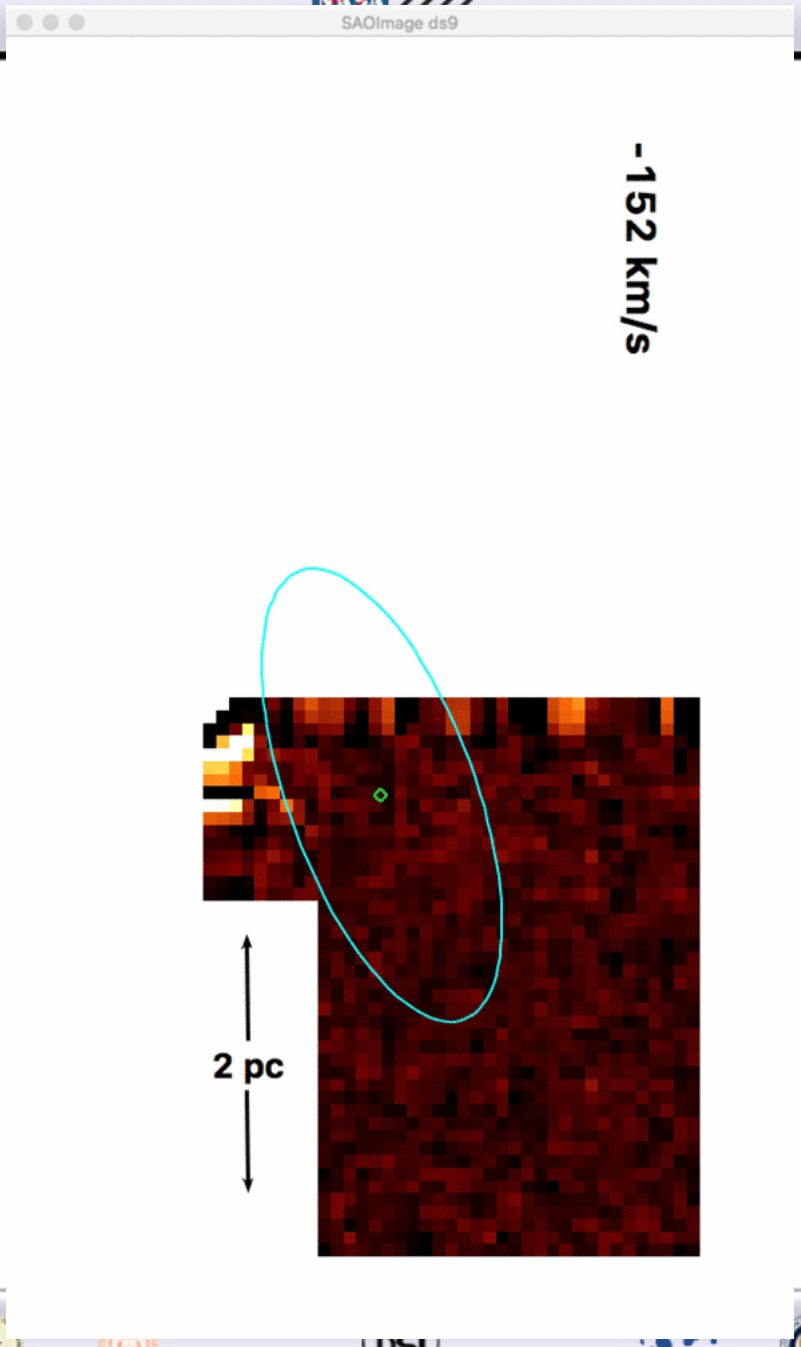
- UpGREAT does heterodyne observations at 63 to 540 microns with spectral resolving power of E6 (~0.3 km/sec)
- [CII] mapping is done with a 14 element array with two polarizations. 50 times faster than HIFI on Herschel for extended emission. T(noise)~1000K
- [OI] heterodyne mapping with 7 element array almost as sensitive at [CII]
- OI and CII observations carried out at the same time with a dichroic beamsplitter
- The [OI] line with SOFIA also has the smallest beam ~6 arcsec FWHM vs 14 arcsec for the [CII] line. The velocity resolution presented here is about 6 km/sec.

Total [OI] emission

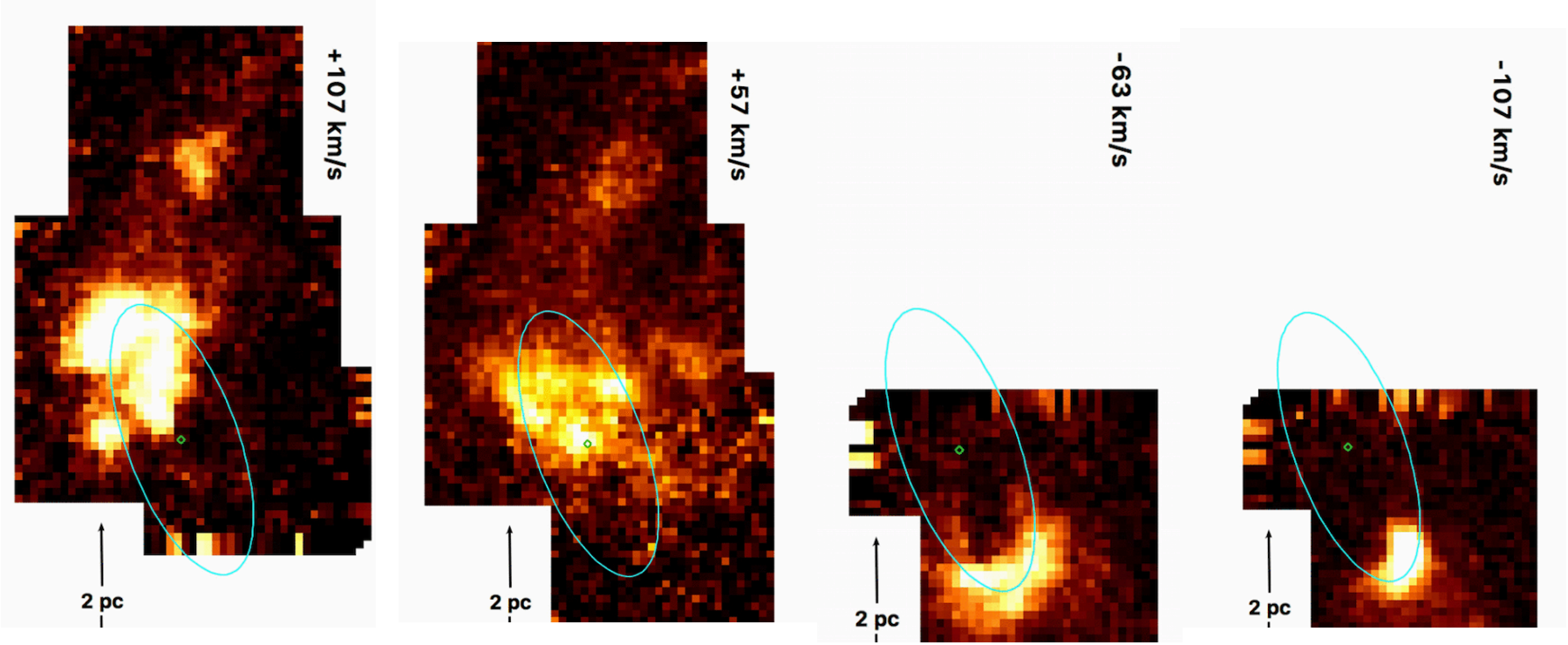


6 Cm [OI] E CN 2-1

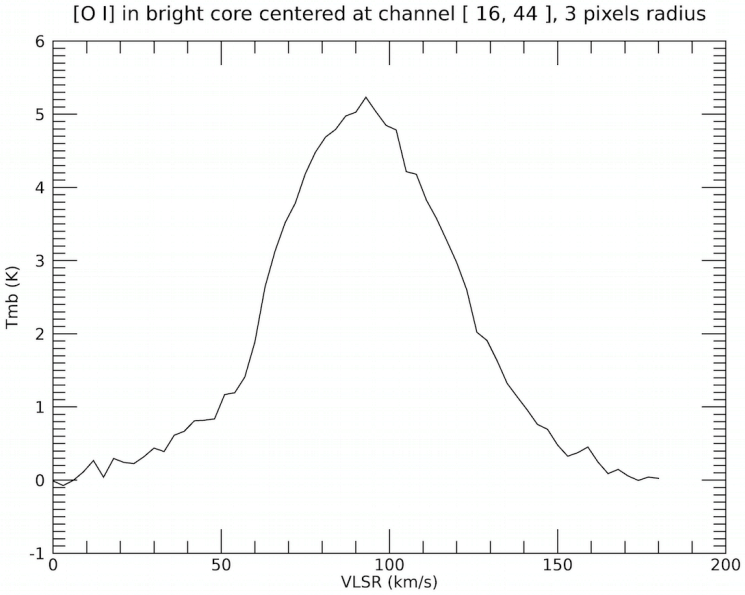

6 cm JVLA
Zhao, Morris, Goss 2016
integrated -- all velocities
Sgr A*
CN 2-1
Martin et al. 2012
Sgr A*

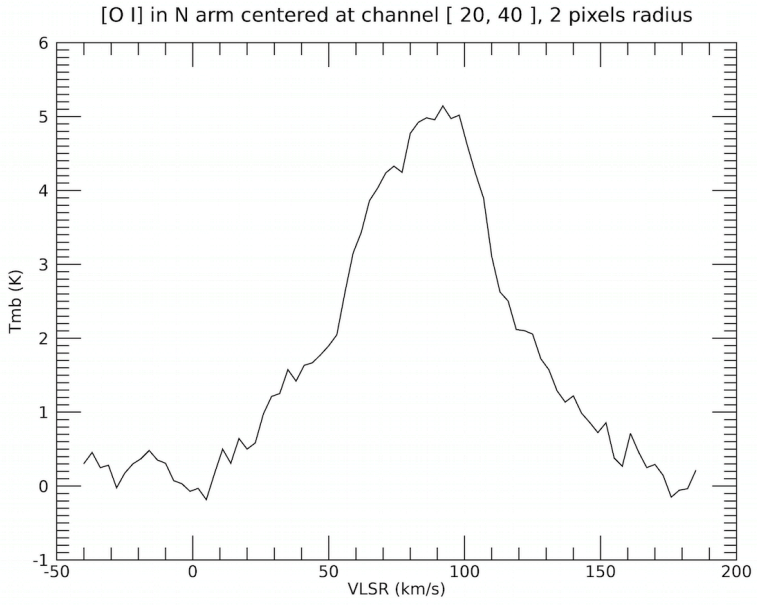

SAOImage ds9
-152 km/s
2 pc

[OI] at +107, +57,-63 & -107 Km/sec



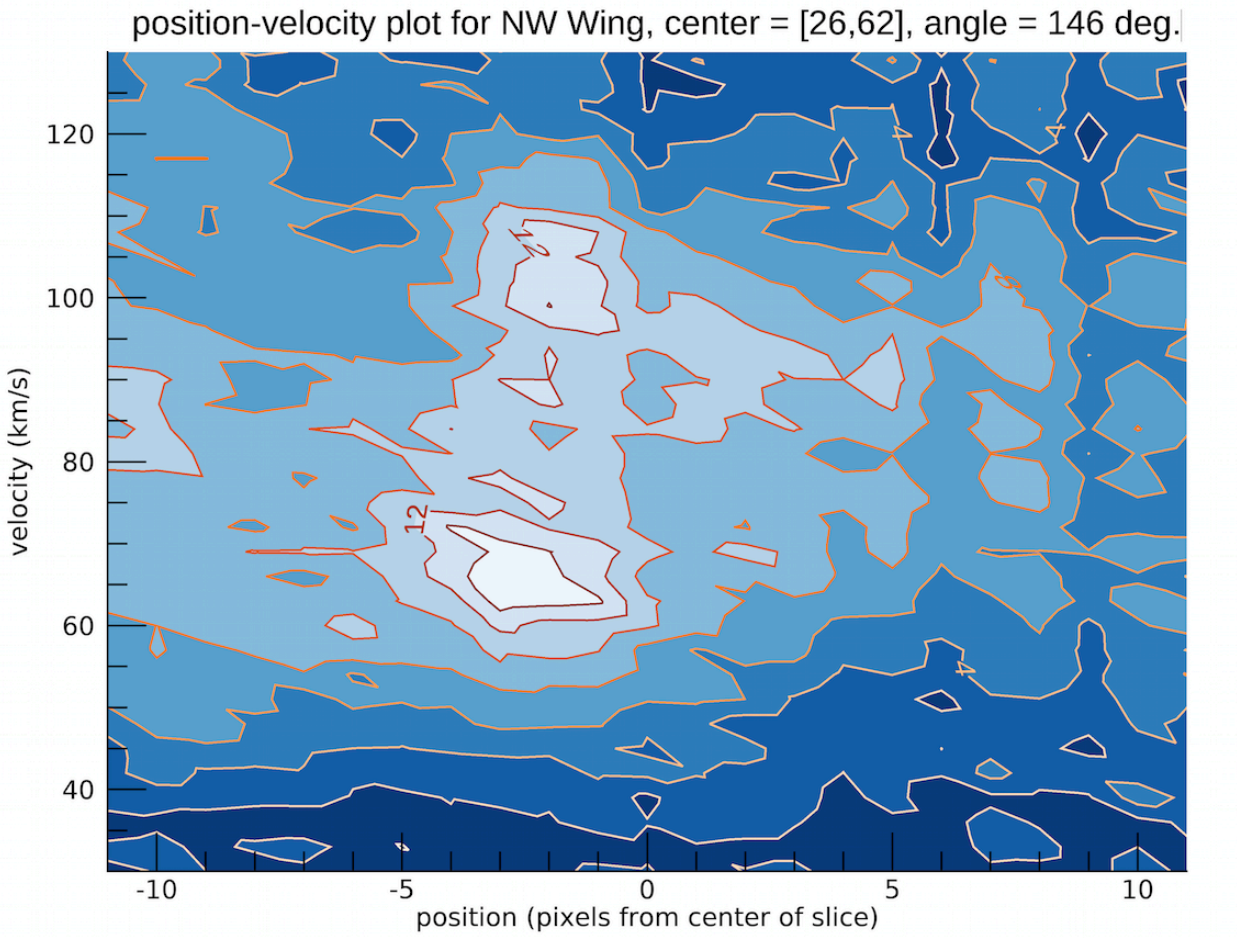
Spectrum of [O I] in Bright NE Core (left) and Northern Arm (right)





V_{LSR} (km/s)

Velocity vs Position along the NW Wing: OI shock?



Summary of Preliminary Results

- Strong extended [OI] associated with the entire inner edge of the CND. The emission is especially strong in the NE at positive velocities and in the SW at negative velocities.

- Strong Extended [OI] emission associated with the upper northern arm. Velocities similar to the [HII] (infalling)

- Several point sources of [OI]. One in Western Arm of CND del v~45 km/sec and another in the East Arm of CND near ionized Bar.

- Source in the Northwest Plume with del v~60 km/sec and a possible shock also seen at HAWC+ 53 microns.

Eric, Rolf and Mark on SOFIA: Dec 2018

Backup

FORCAST & Mag Vectors

6 cm