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

Eric Becklin, Mark Morris, Rolf Guesten, Denise Riquelme, etal
USRA/UCLA/MPIfR

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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
This is the highest resolution image of the Circumnuclear ring ever obtained with ~3 arcsec FWHM. (Lau et al. 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 et al. 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

Face on View

Oberved View

Molecular disk

Sgr A*

Emitting dust region (CNR)
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 $>10^5$ cm$^{-3}$. [CII] excited at densities $n>\sim 10^3$ 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

CN 2-1  
Martin et al. 2012
[O\textsc{i}] at +107, +57, -63 & -107 Km/sec
Spectrum of [O I] in Bright NE Core (left) and Northern Arm (right)
Velocity vs Position along the NW Wing: OI shock?

position-velocity plot for NW Wing, center = [26,62], angle = 146 deg.
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.
Backup
FORCAST & Mag Vectors

6 cm