ECLEs in TDE hosts

None Assigned

ABSTRACT

Galaxies that display transient high ionization coronal lines are known as coronal line emitters (CLEs) or extreme coronal line emitters (ELCEs). One theory to explain the power source of these CLEs is that they are tidal disruption events (TDEs) in gas-rich environments. TDEs produce UV and X-ray emission that, if reprocessed by clouds of surrounding gas, can be re-emitted in the optical. We aim to compare the gas mass and gas concentrations between CL hosts and TDE hosts. The proposed observations will demonstrate another link (or lack thereof) between CLEs/ECLEs and TDEs, further improving our knowledge of the extreme environments surrounding black holes.

SCIENCE CATEGORY:	Galaxies and Galactic Nuclei				
ESTIMATED 12-M TIME:	**6.2 h**	**ESTIMATED 7-M TIME:**	**0.0 h**	**ESTIMATED TP TIME:**	**0.0 h**
DUPLICATE OBSERVATION JUSTIFICATION:					

REPRESENTATIVE SCIENCE GOALS (UP TO FIRST 30)

SCIENCE GOAL	CLUSTER	POSITION (ICRS)	BAND	ANG.RES.(")	LAS.(")	12m time (hrs)	7m time (hrs)	TP time (hrs)	Number of sources
AT 2022dsb	AT 2022dsb	15:42:21, -22:40:14	7	0.100	0.800	3.3	N/A	N/A	1
AT 2021dms	AT 2021dms	03:21:24, -11:08:45	7	0.100	0.600	1.9	N/A	N/A	1
SDSS J1342	SDSS J1342	13:42:44, 05:30:56	7	0.100	0.530	0.5	N/A	N/A	1
AT 2019ahk	AT 2019ahk	07:00:11, -66:02:24	7	0.100	0.750	0.5	N/A	N/A	1
Total # Science Goals : 4									

SCHEDULING TIME CONSTRAINTS	NONE	**TIME ESTIMATES OVERRIDDEN ?**	No	**JOINT PROPOSAL?**	No

1 Scientific justification

1.1 Tidal Disruption Events

Tidal disruption events (TDEs) are type of transient event where a flare is produced as a result of a star being torn apart by a black hole. A disruption occurs when a star enters the black hole's tidal radius, which is the distance from the black hole where the strength of the black hole's gravitational field is able to overcome the star's own self gravity [5].

TDEs have been observed in the X-ray, UV, optical, infrared, and radio bands, though not all TDEs have been observed in each of these bands. The precise source of the emission is unknown for TDEs. Proposed emission models include circularization shocks, accretion, and/or disk interactions. Observed emission may also come in the form of reprocessed emission and light echos as the light from the TDE interacts with gas and dust in the environment of the black hole [5].

TDE light curves typically decline on a timescale of months. However, it is not unusual for emission thought to be related to the TDE to reoccur at late times. For example, a subset of TDEs have displayed late-time MIR and radio flares, though the source of these emissions within the TDE (jets? shocks?) has not yet been determined [5]. Studying IR flares has been proposed as a way of identifying TDEs that occurred in dust-obscured environments [10].

1.2 (Extreme) Coronal Line Emitters

Coronal line emitters (CLEs), sometimes also called extreme coronal line emitters (ECLEs), are galaxies that exhibit transient properties in the form of spectra with strong coronal lines [6]. Coronal lines (CLs) are emission lines present in solar coronal spectra as well as the spectra of AGN, and they indicate the presence of highly ionized gas [3]. Some lines in question that have been observed in CLEs are [Fe x]λ6376, [Fe xi]λ7894, [Fe xiv]λ5304, [Ar xiv]λ4414, and [S xii]λ7612 [11, 6].

CLEs are specifically defined by line ratio strengths in the spectra. In [11], CLEs are selected by requiring that at least one CL in the spectrum has a line strength of at least 120% of the line strength of the [O iii]λ5007 line. [6] recommends that requiring that at least one CL in the spectrum has a line strength of at least 133% of the line strength of the [O iii]λ5007 line in order to better exclude non-transient sources.

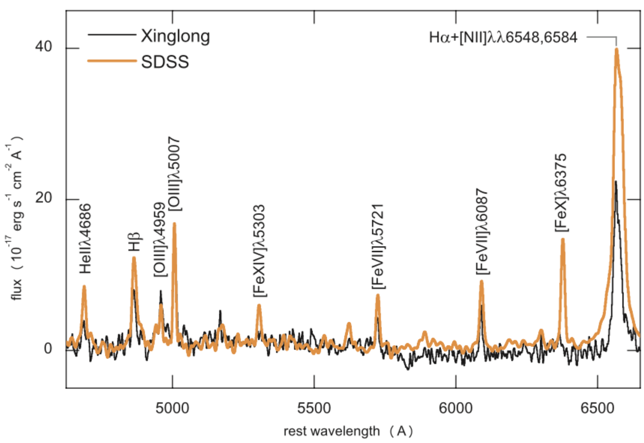

Figure 1: This figure from [7] shows the evolution of iron coronal lines in the CLE SDSS J0952. The SDSS spectrum (orange) was taken in 2005 while the follow-up spectrum (black) was taken in 2007. The coronal lines, especially [Fe x]λ6375, can be seen fading over time.

Additionally, the strength of these lines changes over time and they are not ever-present. A sample of CLEs presented in [2] have CLs with a variety of lifetimes, ranging from 2 months to 428 days. An example of CLs fading over time can be seen in Figure 1.

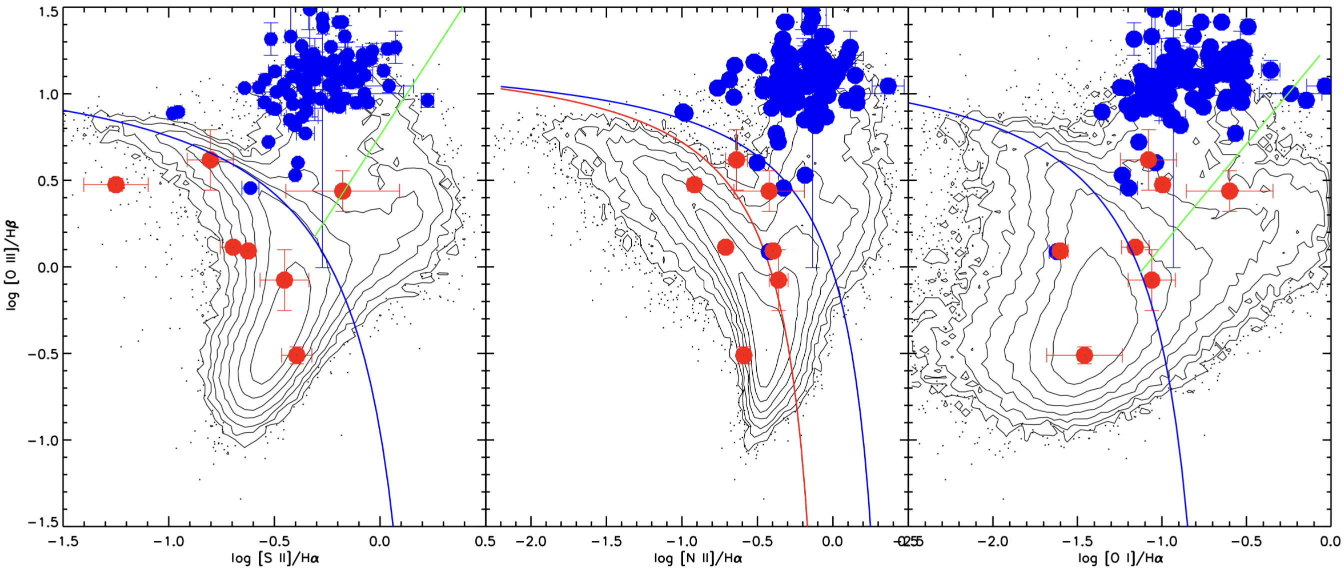

Figure 2: This figure from [11] is a BPT plot, which shows traditional line ratio diagnostics for certain populations of galaxies. The ECLE sample from [11] (red dots), non-ECLE galaxies with coronal line detections in SDSS DR4 (blue dots), and narrow emission-line galaxies from SDSS DR4 (gray number density contours) are plotted. The lack of overlap between these three populations show that ECLE galaxies probably are not Seyfert galaxies.

1.3 What links TDEs and CLEs?

There are multiple claims that CLEs arise from TDEs in gas-rich environments [1, 2, 6, 11]. Evidence comes in the form of spectral analysis over time, photometric analysis over time, and host galaxy analysis, all of which together show a variety of features in common with TDEs and a lack of similarity with AGN, leading to the conclusion that AGN do not make up the majority of the CLE population.

If a TDE indeed caused CLs, it would require that extreme UV and X-ray emission from the TDE ionized and then was reprocessed by gas in the surrounding environment. The resulting emission would be in the optical. These physical conditions can be found in both TDEs and AGN, though [12] shows that CLs from AGN are usually weaker than CLs from TDEs. However, [6] does not rule out AGN as a power source for CLEs.

Figure 2 from [11] shows that CLEs are preferentially not in Seyfert galaxies, as an indicator that the host galaxy populations of AGN and CLEs do not broadly share the same parameter space. While they may overlap some, all CLEs probably do not come from AGN. The lack of overlap between the ECLE sample from [11] (red points) and other SDSS galaxies with CLs that are not classified as CLEs (blue points) demonstrates this point. Additionally, the ECLEs do not fall in the AGN/Seyfert region of these BPT diagrams.

Figure 3 from [6] shows that CLE host galaxies and TDE host galaxies share similar properties as an indicator that CLEs and TDEs can be drawn from the same population of galaxies and that TDEs are a likely mechanism for the energy source of CLEs. This graph of star formation rate versus host galaxy stellar mass; displaying populations of CLEs, TDEs, galaxies with mid-IR outbursts, and galaxies in SDSS DR8; shows that the TDE host galaxies and CLEs share parameter space more closely with each other than with the mid-IR outburst population or the general sample of SDSS galaxies. Both the TDE host galaxy sample and the CLE sample tend to lie in the green valley, between the blue sequence and red sequence. Though the CLEs tend to have higher star formation rates than the sample of TDE hosts, this makes sense because an increased amount of gas is required to produce CLs.

If CLEs do arise from TDEs, [1] computes the CLE rate and compares it to TDE rates from the literature. They find that the CLE rate is 1-2 orders of magnitude lower than TDE rates, implying that only a subset of TDEs contribute to the CLE population.

Further solidifying the link between TDEs and CLEs would provide another way to identify TDEs and broaden our understanding of how the nuclear environment of a galaxy contributes to different emission processes.

1.4 Observational Tests

To test the claim that CLEs are TDEs in gas-rich environments, or are otherwise linked, we propose to observe CO in a sample consisting of TDE host galaxies and CLEs. In this way we can estimate the total gas mass in the galaxies and produce a measure of the gas concentration in the galaxies, in the style of Figure 18 from [4], to test the similarity of the TDE host galaxies and the CLEs. Gas is required to form CLs, and similar gas distribution profiles between the two populations may show that these two kinds of transient events arise from similar physical conditions.

Furthermore, not much is known about CLE host galaxies. The most recent comprehensive study of CLE host galaxies is [6], which does not involve any radio data. Gathering data on the radio properties of CLE galaxies is one step towards constraining their environment, emission mechanisms, and overall population properties.

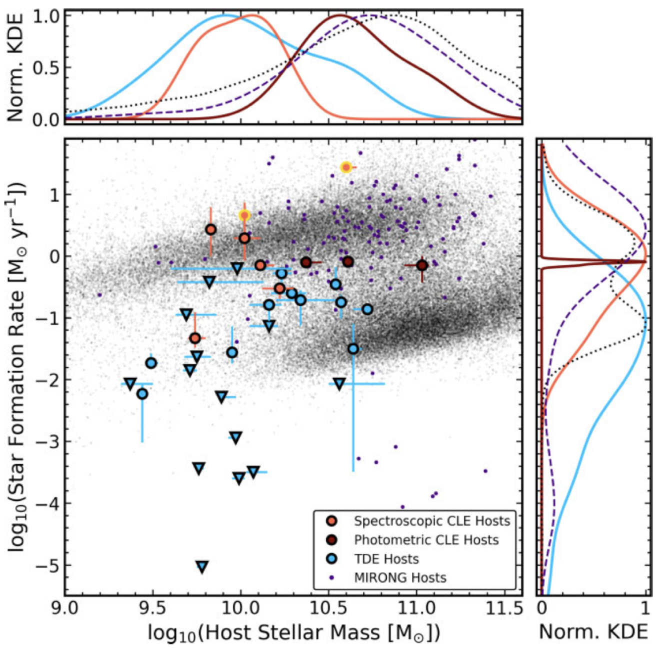

Figure 3: This figure from [6] is a plot of host galaxy stellar mass versus host galaxy star formation rate for CLE galaxies, TDE host galaxies, and MIRONG host galaxies (Mid-infrared Outbursts in Nearby Galaxies), with kernal density estimates for both axes. The gray points in the background are a sample of galaxies in SDSS DR8. CLE galaxies have more in common with TDE host galaxies than the general galaxy population.

Calculations from [1] suggest that only some TDEs produce CLEs. Discerning differences within TDE populations (likely differences in the environment surrounding the central black hole) that lead to the production of CLs will be important for understanding CL formation and evolution.

We intend to use observations of CO(3-2) as a tracer for molecular gas, providing an estimate for the total gas mass and the gas concentrations on circumnuclear scales in the galaxy. We will use these measurements to test whether or not there is any correlation of gas mass or concentration with the luminosity of the transient that occurred within the galaxy.

2 Description of observations

We propose to observe four targets (two known TDE hosts galaxies and two known CLE galaxies) with the purpose of measuring their total gas content and gas concentration. These galaxies were selected because of their low redshift and availability of complementary archival data to aid in our calculations. Observing two sources of each type will provide some protection against outliers. We will focus on the CO(3-2) transition (ν = 345.796 GHz at rest). Our beam size is 0.1 arcseconds following the experimental set-up of [4]. The largest angular structure we hope to resolve ranges from 0.5 to 0.8 arcseconds in order to recover most of the flux within the innermost 400 parsecs of each galaxy. We calculated the expected peak flux densities from MIR flux densities available in NED. These values were converted to expected CO(3-2) flux densities using the 22 μm $\rightarrow$ CO(1-0) conversion [8] and the CO(1-0) $\rightarrow$ CO(3-2) conversion [9]. The MIR flux densities came from the Wide-field Infrared Survey Explorer (WISE) W3 passband. We aim to observe the CO(3-2) line at a SNR > 5 and request sensitivities to achieve this ranging from 0.01 Jy/beam to 1.4 Jy/beam.

References

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[9] E. Schinnerer and A. K. Leroy. Molecular Gas and the Star-Formation Process on Cloud Scales in Nearby Galaxies. , 62(1):369–436, Sept. 2024.

[10] S. van Velzen et al. Reverberation in Tidal Disruption Events: Dust Echoes, Coronal Emission Lines, Multi-wavelength Cross-correlations, and QPOs. , 217(5):63, Aug. 2021.

[11] T.-G. Wang et al. Extreme Coronal Line Emitters: Tidal Disruption of Stars by Massive Black Holes in Galactic Nuclei? , 749(2):115, Apr. 2012.

[12] C.-W. Yang et al. Long-term Spectral Evolution of Tidal Disruption Candidates Selected by Strong Coronal Lines. , 774(1):46, Sept. 2013.

None Assigned

SG : 1 of 4 AT 2022dsb Band 7

TDE host galaxy

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.
0.1000"	0.8"	2 mJy, 2.1 K	1.386 km/s, 1.6 MHz	345.795990 GHz	33.228 µJy, 35.6 mK	5.625 GHz	XX,YY

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C-7)	t_total(C-4)	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
3.3 h	0.9 h	0.6 h	5.7 "	1	offset	17.2 "	3265.7 s	161.0 GB	19.8 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	345.795990	CO v=0 3-2	3840	1875.00 MHz	1.129 MHz	1663.6 km/s	1.002 km/s	4
3	334.000000	continuum 2	3840	1875.00 MHz	1.129 MHz	1722.4 km/s	1.037 km/s	3
4	332.000000	continuum 1	3840	1875.00 MHz	1.129 MHz	1732.8 km/s	1.043 km/s	3

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-AT_2022dsb	15:42:21, -22:40:14	6938.65 km/s,hel,RELATIVISTIC

Expected Source Properties

	Peak Flux	SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity	Pol.	Pol. SNR
Line	12.28 mJy	6.8	5 km/s	1.82 mJy, 1.9 K	3.61	0.0%	0.0
Continuum	2.46 mJy	73.9				0.0%	0.0

Dynamic range (cont flux/line rms): 1.2

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	337.883106	1.99 mJy, 2.1 K	1.99 mJy - 41.22 mJy

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

In order to achieve an ideal SNR greater than 5, we calculate the peak line flux from MIR observations in the WISE W3 passband (0.0071 Jy) and convert those values to expected CO(3-2) flux (0.01228 Jy/beam) using MIR-CO intensity relations.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

We select our angular resolution with the goal of obtaining moderate spatial resolution in our targets. The chosen angular resolution was selected to mirror the experimental set-up of Garcia-Burillo et al 2021. The largest angular scale was chosen in order to recover the flux within the innermost 400 parsecs (approximately) of the galaxy (z=0.023), so gas concentrations within that region can be calculated.

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

A wide bandwidth was chosen to observe both the CO(3-2) line and adjacent continuum emission.

None Assigned

SG : 2 of 4 AT 2021dms Band 7

Coronal line emitter

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.
0.1000"	0.6"	2.5 mJy, 2.7 K	1.397 km/s, 1.6 MHz	345.795990 GHz	41.586 µJy, 45.3 mK	5.625 GHz	XX,YY

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C-7)	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
1.9 h	0.5 h	0.0 h	5.8 "	1	offset	17.4 "	1778.0 s	94.3 GB	19.5 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	345.795990	CO v=0 3-2	3840	1875.00 MHz	1.129 MHz	1676.9 km/s	1.010 km/s	4
3	332.000000	continuum 1	3840	1875.00 MHz	1.129 MHz	1746.6 km/s	1.052 km/s	3
4	334.000000	continuum 2	3840	1875.00 MHz	1.129 MHz	1736.1 km/s	1.045 km/s	3

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-MCG_-02-09-033	03:21:24, -11:08:45	9324.00 km/s,hel,RELATIVISTIC

Expected Source Properties

	Peak Flux	SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity	Pol.	Pol. SNR
Line	14.28 mJy	6.3	5 km/s	2.28 mJy, 2.5 K	3.58	0.0%	0.0
Continuum	2.86 mJy	68.7				0.0%	0.0

Dynamic range (cont flux/line rms): 1.1

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	335.203371	2.5 mJy, 2.7 K	2.50 mJy - 13.28 mJy

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

In order to achieve an ideal SNR greater than 5, we calculate the peak line flux from MIR observations in the WISE W3 passband (0.00366 Jy) and convert those values to expected CO(3-2) flux (0.01428 Jy/beam) using MIR-CO intensity relations.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

We select our angular resolution with the goal of obtaining moderate spatial resolution in our targets. The chosen angular resolution was selected to mirror the experimental set-up of Garcia-Burillo et al 2021. The largest angular scale was chosen in order to recover the flux within the innermost 400 parsecs (approximately) of the galaxy (z=0.031), so gas concentrations within that region can be calculated.

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

A wide bandwidth was chosen to observe both the CO(3-2) line and adjacent continuum emission.

None Assigned

SG : 3 of 4 SDSS J1342 Band 7

Coronal line emitter

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.
0.1000"	0.5"	250 mJy, 274.7 K	1.404 km/s, 1.6 MHz	345.795990 GHz	107.259 µJy, 117.9 mK	5.625 GHz	XX,YY

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C-7)	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
0.5 h	0.1 h	0.0 h	5.8 "	1	offset	17.5 "	308.3 s	27.5 GB	20.2 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	345.795990	CO v=0 3-2	3840	1875.00 MHz	1.129 MHz	1685.1 km/s	1.015 km/s	4
3	332.000000	continuum 1	3840	1875.00 MHz	1.129 MHz	1755.1 km/s	1.057 km/s	3
4	334.000000	continuum 2	3840	1875.00 MHz	1.129 MHz	1744.6 km/s	1.050 km/s	3

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-2MASX_J13424...	13:42:44, 05:30:56	10783.29 km/s,hel,RELATIVISTIC

Expected Source Properties

	Peak Flux	SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity	Pol.	Pol. SNR
Line	1.35 Jy	229.3	5 km/s	5.91 mJy, 6.5 K	3.56	0.0%	0.0
Continuum	270.85 mJy	2525.2				0.0%	0.0

Dynamic range (cont flux/line rms): 42.1

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	333.573844	6.44 mJy, 7.1 K	6.44 mJy - 13.07 mJy

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

In order to achieve an ideal SNR greater than 5, we calculate the peak line flux from MIR observations in the WISE W3 passband (0.0281 Jy) and convert those values to expected CO(3-2) flux (1.3542 Jy/beam) using MIR-CO intensity relations.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

We select our angular resolution with the goal of obtaining moderate spatial resolution in our targets. The chosen angular resolution was selected to mirror the experimental set-up of Garcia-Burillo et al 2021. The largest angular scale was chosen in order to recover the flux within the innermost 400 parsecs (approximately) of the galaxy (z=0.0356), so gas concentrations within that region can be calculated.

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

A wide bandwidth was chosen to observe both the CO(3-2) line and adjacent continuum emission.

Very High Imaging or Spectral Dynamic Range. Please explain why this is required and how it can be achieved.

A linewidth lower than 5 km/s will result in a linewidth/bandwidth ratio less than 3, which is not ideal.

None Assigned

SG : 4 of 4 AT 2019ahk Band 7

TDE host galaxy

Science Goal Parameters

Ang.Res.	LAS	Requested RMS	RMS Bandwidth	Rep.Freq.	Cont. RMS	Cont. Bandwidth	Poln.Prod.
0.1000"	0.8"	7 mJy, 7.5 K	1.391 km/s, 1.6 MHz	345.795990 GHz	110.191 µJy, 118.7 mK	5.625 GHz	XX,YY

Use of 12m Array (43 antennas)

t_total(all configs)	t_science(C-7)	t_total()	Imaged area	#12m pointing	12m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate
0.5 h	0.1 h	0.0 h	5.8 "	1	offset	17.3 "	308.3 s	27.5 GB	20.2 MB/s

Use of ACA 7m Array (10 antennas) and TP Array

t_total(ACA)	t_total(7m)	t_total(TP)	Imaged area	#7m pointing	7m Mosaic spacing	HPBW	t_per_point	Data Vol	Avg. Data Rate

Spectral Setup : Spectral Line

BB	Center Freq Rest GHz	spw name	Eff #Ch p.p.	Bandwidth	Resolution	Vel. Bandwidth	Vel. Res.	Res. El. per FWHM
1	345.795990	CO v=0 3-2	3840	1875.00 MHz	1.129 MHz	1668.7 km/s	1.005 km/s	4
3	332.000000	continuum 1	3840	1875.00 MHz	1.129 MHz	1738.1 km/s	1.046 km/s	3
4	334.000000	continuum 2	3840	1875.00 MHz	1.129 MHz	1727.7 km/s	1.040 km/s	3

1 Target

No.	Target	Ra,Dec (ICRS)	V,def,frame --OR--z
1	1-2MASX_J07001...	07:00:11, -66:02:24	7858.00 km/s,hel,RELATIVISTIC

Expected Source Properties

	Peak Flux	SNR	Linewidth	RMS (over 1/3 linewidth)	linewidth / bandwidth used for sensitivity	Pol.	Pol. SNR
Line	40.85 mJy	6.8	5 km/s	6.04 mJy, 6.5 K	3.60	0.0%	0.0
Continuum	8.17 mJy	74.1				0.0%	0.0

Dynamic range (cont flux/line rms): 1.2

1 Tuning

Tuning	Target	Rep. Freq. Sky GHz	RMS (Rep. Freq.)	RMS Achieved
1	1	336.847904	6.61 mJy, 7.1 K	6.61 mJy - 290.41 mJy

Justification for requested RMS and resulting S/N (and for spectral lines the bandwidth selected) for the sensitivity calculation.

In order to achieve an ideal SNR greater than 5, we calculate the peak line flux from MIR observations in the WISE W3 passband (0.00718 Jy) and convert those values to expected CO(3-2) flux (0.04085 Jy/beam) using MIR-CO intensity relations.

Justification of the chosen angular resolution and largest angular scale for the source(s) in this Science Goal.

We select our angular resolution with the goal of obtaining moderate spatial resolution in our targets. The chosen angular resolution was selected to mirror the experimental set-up of Garcia-Burillo et al 2021. The largest angular scale was chosen in order to recover the flux within the innermost 400 parsecs (approximately) of the galaxy (z=0.0262), so gas concentrations within that region can be calculated.

Justification of the correlator set-up with particular reference to the number of spectral resolution elements per line width.

A wide bandwidth was chosen to observe both the CO(3-2) line and adjacent continuum emission.