[C II] in the cluster galaxies undergoing ram pressure stripping

1 Scientific Context

Context — Ram pressure stripping (RPS) is an important process in galaxy evolution. Recent data have revealed many examples of galaxies undergoing RPS, often accompanied with multi-phase tails. RPS galaxies thus are ideal objects to study multi-phase medium. Energy transfer in multi-phase medium is an outstanding question in astrophysics, important for galaxy formation. [C II] has been established as an important tracer of the cold gas. However, there has not been a systematical study for the [C II] emission from RPS galaxies (especially their tails).
Aims — The proposed *SOFIA*/FIFI-LS observations aim for the first sample study for the [C II] emission from galaxies undergoing strong RPS. The [C II] data will be combined with the FIR, CO and Hα data for multi-wavelength diagnostics and study. We will examine whether [C II] emission is enhanced in galaxies undergoing strong RPS and search for [C II] emission in the tails. [O I]$\lambda 63 \mu$m from galaxies is also expected to provide additional constraints.
Methods — We have selected a sample of RPS galaxies in nearby rich clusters Coma and A1367. The selection accounts for both the expected [C II] signal and the *SOFIA* transmission. We will use FIFI-LS to measure [C II] emission in these galaxies and the tails in the FOV. This can only be done by *SOFIA* now and has never been tried before. The FIR, CO, Hα, radio and X-ray data of these five galaxies are also available.
Synergies — RPS galaxies and their tails have been observed with telescopes from radio to X-rays. Particularly, more than five RPS galaxies have been observed with *ALMA* recently and one RPS galaxy is included in the GTO program of *JWST*. We also have access to the multi-wavelength data for these galaxies, from CO data from *ALMA*, IRAM-30m and *NOEMA*, optical data from *MUSE*, FIR continuum data from *Herschel* and radio continuum data from *VLA* to the X-ray data from *Chandra*. The proposed [C II] observations provide an important element in our multi-wavelength campaign.
Anticipated results — Detections of the total [C II] and [O I] emission from these RPS galaxies and likely the detections of [C II] from stripped tails in the field, which opens another window to probe the physical properties of the cold gas subject to RPS.

2 Scientific justification

2.1 Scientific rationale

Most baryons in galaxy clusters are in the hot intracluster medium (ICM). Cluster galaxies soar through the ICM and the interaction with the ICM plays a vital role in galaxy evolution, through ram pressure stripping (RPS) and turbulent/viscous stripping of the galactic cold gas. As the halo gas and the cold ISM are depleted, the galactic star formation (SF) will eventually be shut down and blue disk galaxies may turn into red galaxies (e.g., Quilis et al. 2000). Observational evidence of stripping in cluster late-type galaxies is present in HI, Hα, warm H_2, X-ray and CO observations (e.g., Gavazzi et al. 2001, 2017; Sun et al. 2007, 2010; Chung et al. 2007; Yagi et al. 2007, 2010; Sivanandam et al. 2010; Fossati et al. 2012; Jáchym et al. 2014, 2017, 2019; Poggianti et al. 2017a; Bellhouse et al. 2017). The stripping process has also been extensively studied in simulations (e.g., Quilis et al. 2000; Roediger & Brüggen 2008; Tonnesen & Bryan 2010). These simulations show that stripping has a significant impact on galaxy evolution (e.g., disk truncation, transformation of dwarf galaxies). While the cold ISM will be eventually depleted, an initial SF enhancement for galaxies undergoing strong RPS has been proposed and observed (e.g., Bekki & Couch 2003; Vulcani et al. 2018, 2020). RPS galaxies also appear to have a radio-to-FIR ratio higher than similar objects in the field (e.g., Chen et al. 2020), which may suggest compression of the ISM magnetic field. RPS has also been suggested to trigger AGN (e.g., Poggianti et al. 2017b). The significant effect of RPS on galaxy properties is not surprising, giving the strength of the ICM pressure (e.g., deflecting radio jets and confining galactic winds). [1]

Besides the impact on galaxy evolution, another significant question related to stripping is the evolution of the stripped ISM. The mixing of the stripped cold ISM with the hot ICM will produce multi-phase gas that can be observed in multiple bands. It is now known that some fraction of the stripped ISM can turn into stars in the galactic halo and the intracluster space, especially in high-ICM-pressure environments (e.g., Cortese et al. 2007; Sun et al. 2007; Smith et al. 2010; Yagi et al. 2010; Poggianti et al. 2016). Molecular gas has also begun to be discovered in the tail (Jáchym et al. 2014, 2017; Moretti et al. 2018). It is now believed that SF in the ISM stripped by ram pressure is a common phenomenon in rich clusters (e.g., Smith et al. 2010; Poggianti et al. 2016). As shown in the past 15 years, **RPS galaxies have emerge as ideal targets to study energy transfer in multi-phase medium**, including turbulence, cooling, SF conditions, stellar feedback and MHD effects.

While a lot of work has been done in optical emission lines (e.g., Hα), especially with MUSE (e.g., Fossati et al. 2016; Poggianti et al. 2017a), more work on cold gas is required to complete the picture on energy transfer and gas kinematics. CO observations still require a lot of time for mosaicing and can miss the so-called CO-dark molecular gas in low-metallicity systems. H I studies are still limited to very nearby clusters like the Virgo cluster (e.g., Oosterloo & van Gorkom 2005; Chung et al. 2007) as more sensitive H I telescopes than *VLA* are required for efficient studies of H I gas stripping in the nearby rich clusters like A3627, Coma and A1367 (e.g., Chen et al. 2020). On the other hand, we can also probe the cold gas with [C II].

Why study [C II]? Because it provides a bright tracer of the cold gas and SF. The [C II] fine structure line at 157.74 μm is the dominant coolant for neutral atomic gas in the ISM and can contribute up to a few per cent of the total FIR emission from a galaxy (Fig. 1). Because of its low ionization potential, this [C II] line can be produced in cold atomic ISM, molecular, and ionized gas. Recent studies have shown that most of the [C II] emission originates from neutral gas, most likely the photodissociation regions (PDRs) of molecular clouds at their outer layers (e.g., Pineda et al. 2013; Croxall et al. 2017). [C II] emission in galaxies is also considered a good SFR indicator (e.g., Herrera-Camus et al. 2015). More importantly, the [C II] data, combined with the data of other gas/dust tracers, offer important diagnostic on the multi-phase medium, e.g., PDA models (Fig. 1, Kaufman et al. 1999), SF detail (e.g., Narayanan & Krumholz 2017), additional pressure from turbulence and magnetic field (e.g. Canning et al. 2016).

Why study [C II] in RPS galaxies? Because such a study has never been systematically done for RPS galaxies (especially their tails). There were only published results on several Virgo cluster galaxies undergoing RPS (e.g., Leech et al. 1999; Boselli et al. 2002; Croxall et al. 2017), but the sample is very small and RPS in Virgo is at most moderate. There has been no studies on galaxies undergoing strong RPS. On the other hand, we do know that [C II] emission can be enhanced by additional pressure from shocks, turbulence and collisional heating, e.g., in Stephan's

[1] We all know that both radio jets and SN blastwaves are important ingredients in galaxy evolution and formation.

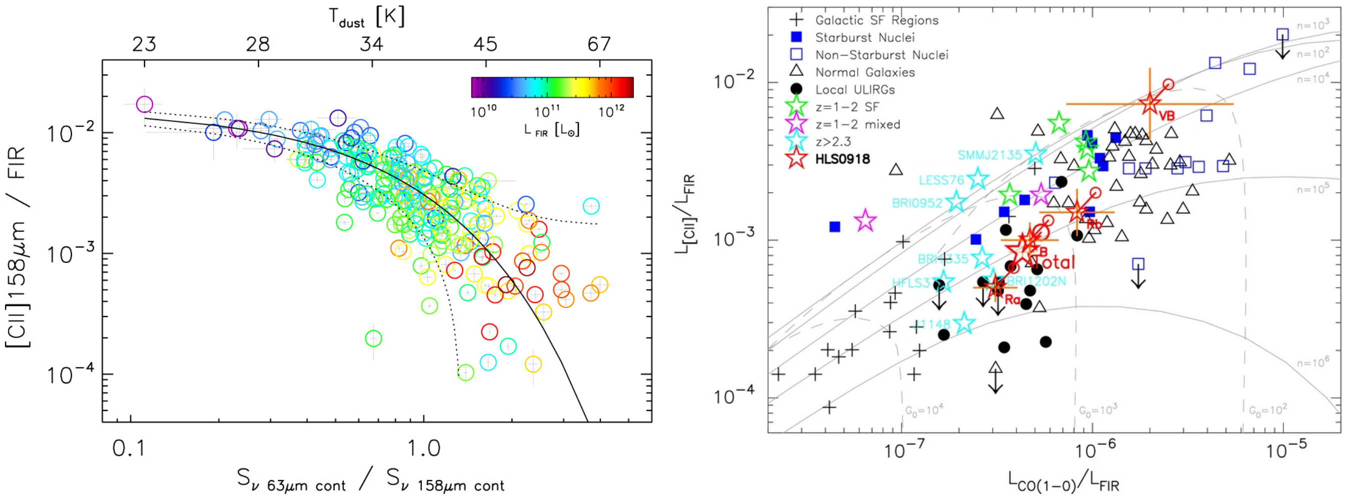

Figure 1: *Left*: Fig. 1 of Hemmati et al. (2017) to show the $L_{[\mathrm{C\,II}]}/L_{\mathrm{FIR}}$ ratio vs. the 63 μm - 158 μm FIR color (or dust temperature) for a large sample of Luminous Infrared Galaxies from *Herschel*. Galaxies are color-coded by the FIR luminosity. *Right*: Fig. 8 of Rawle et al. (2014) to show the $L_{[\mathrm{C\,II}]}/L_{\mathrm{FIR}}$ vs. $L_{\mathrm{CO(1-0)}}/L_{\mathrm{FIR}}$ diagnostic plot for various samples of galaxies. The gray lines represent the solar metallicity PDR models with varying gas density (n) and FUV field strength (G_0) from Kaufman et al. (1999). The G_0 and n degeneracy can be broken if the [O I]λ63μm / [C II]λ158μm ratio, which is density sensitive, is known. This diagnostic will be run on RPS galaxies proposed here, as we know their FIR and CO(1-0) luminosities.

Quintet and regions around jets in radio galaxies (e.g., Appleton et al. 2013, 2018; Peterson et al. 2018; Guillard et al. 2015). All these processes are ubiquitous in RPS galaxies! It is also intriguing to study the [C II] emission in the stripped tails, where the bulk of the ionization sources may not be UV photons of massive stars. For embedded cold gas in hot ICM, one would expect collisional heating like heat conduction and MHD wave can also create dissociation regions on the surface of molecular clouds. **Will the resulting [C II] emission be stronger?** Ferland et al. (2009) studied the resulting spectra from collisional heating by energetic particles or dissipative MHD wave, which allows us to use the observed [C II] 157.7 μm / Hα ratio to study the ionization source (e.g., the "Cosmic ray" model has a ratio 5.1 times larger than that from the "Extra heat" model and both have higher ratios than that from ionization from young stars). One may also compare the stripped tails with the intergalactic regions in the Stephen's Quintet and Taffy galaxies (Appleton et al. 2013; Peterson et al. 2018) where enhanced [C II] emission is observed (as well as enhanced warm H_2 emission). This proposal aims for **the first** systematic study of [C II] emission from galaxies undergoing strong RPS.

2.2 The sample of RPS galaxies for [C II] observations with *SOFIA*

We want to select RPS galaxies with strong [C II] signals expected from *SOFIA* FIFI-LS. While the Virgo cluster is the closest cluster, the average ram pressure and ambient ICM pressure in the Virgo cluster, as a poor cluster, is moderate. As gas stripping and cooling depend on the ambient pressure, the impact of RPS on the galaxy and the tail are not expected to be significant in Virgo-like clusters from simulations (e.g., Tonnesen et al. 2011) and observations (e.g., Jáchym et al. 2013; Verdugo et al. 2015). Thus, we focus on RPS galaxies in nearby rich clusters like Coma, A3627 and A1367, where RPS tails with bright Hα, CO and X-ray emission have been discovered (e.g., Gavazzi et al. 2001, 2017; Sun et al. 2007, 2010; Yagi et al. 2007, 2010, 2017; Yoshida et al. 2008; Jáchym et al. 2014, 2017, 2019). The best examples are ESO 137-001 (z=0.0156) in A3627 and D100 (z=0.0171) in the Coma cluster for their current comprehensive multi-wavelength coverage. However, ESO 137-001 is at the south (DEC = -60.8 deg). The atmospheric transmission for *SOFIA* also prevents [C II] observations at z = 0.0145 - 0.0204. Nevertheless, both Coma and A1367 host many other galaxies undergoing strong RPS.

We select RPS galaxies from the samples in the Coma cluster and A1367 from Gavazzi et al. (2001), Smith et al. (2010) and Yagi et al. (2010, 2017). The selection is based on the predicted [C II] signal from *SOFIA*, which is mainly the combination of the source flux and the atmospheric transmission for *SOFIA*. We use the FIR luminosity as the main proxy for the expected [C II] flux, based on the established [C II] — L_{FIR} correlation (Fig. 1 and Section

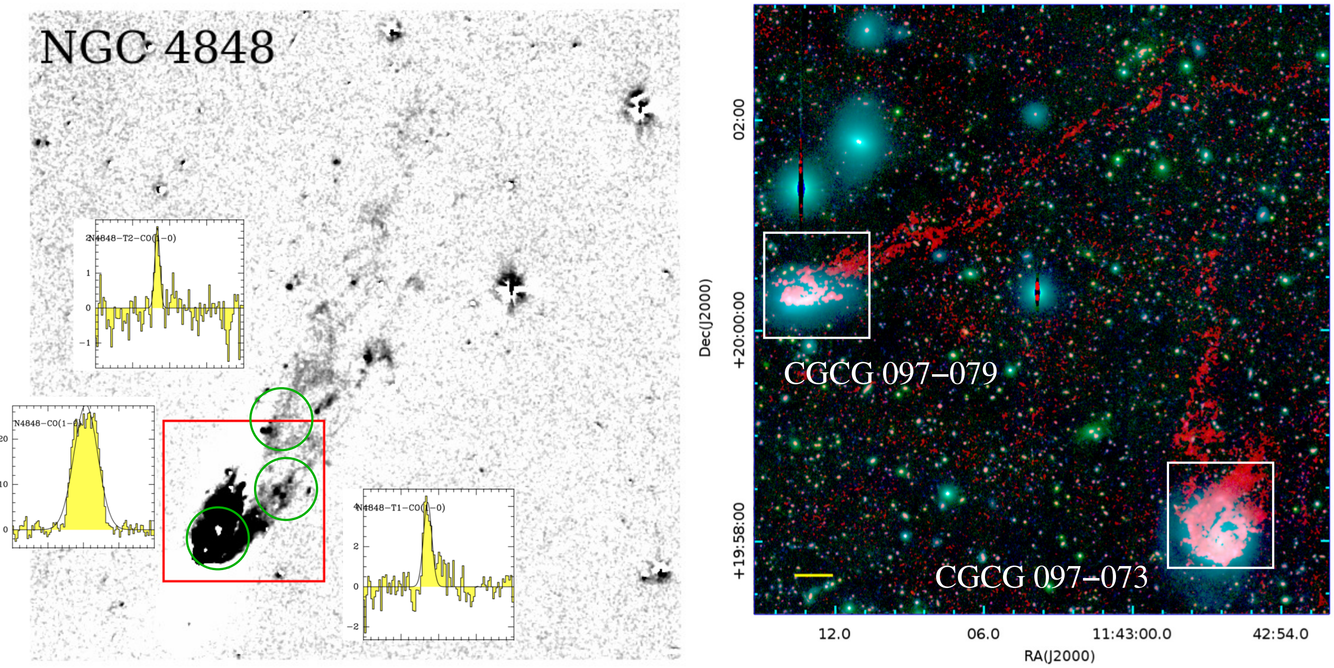

Figure 2: Hα images of three RPS galaxies in our sample (Yagi et al. 2017). The Hα images of the other two galaxies can be found in Yagi et al. (2010). The FOV of the FIFI-LS red channel ($1' \times 1'$) is also plotted, which covers some tail regions close to the galaxy. CO detections in NGC 4848's tail are also shown from new IRAM-30m data (private communication). $1'$ = 28.0 kpc in Coma and $1'$ = 26.7 kpc in A1367.

3). We also use another proxy, the CO luminosity, to verify the resulting sample from FIR, by assuming $L_{\rm [CII]}$ / $L_{\rm CO(1-0)}$ = 4000 (Accurso et al. 2017; Hemmati et al. 2017). By requesting the atmospheric transmission of at least 20%, the redshift window between 0.0145 and 0.0204 is not accessible from *SOFIA*. We also want to avoid strong absorption features at 161.28 μm, 161.89 μm, 162.04 μm and 162.71 μm. In the end, we have a sample of five RPS galaxies with the strongest [C II] signal expected from *SOFIA* FIFI-LS (Table 1). All these galaxies have *Herschel* photometry data and CO data from our work (one example shown in Fig. 2) and literature (Boselli et al. 1994, 1997; Lavezzi et al. 1999; Vollmer et al. 2001; Scott et al. 2013, 2015). The Hα tails of these five galaxies are also 3 - 10 times brighter than D100's (Yagi et al. 2010) so one may expect abundant molecular gas in their tails.

2.3 Science goals of the proposed *SOFIA*/FIFI-LS observations

1) The primary goal is the first-ever sample study of [C II] emission from the galaxies undergoing strong RPS. The total [C II] luminosity will be derived. Most galaxies should have compact [C II] emission, as their FIR emission, but [C II] spatial distribution will also be probed. The difference on the stellar luminosity and the FIR luminosity for galaxies in our sample is as large as $\sim$ 15 and $\sim$ 6 respectively, so the relation with the above two properties can also be examined. The [O I]λ63μm / [C II]λ158μm ratio will also be derived to constrain density, if the [O I] line in the blue channel is detected. For the rich supporting data for these galaxies (FIR, CO, Hα, X-ray etc.), multi-wavelength diagnostics (e.g., [C II]/FIR, [C II]/CO and [C II]/Hα) will be studied (e.g., Fig. 1). We will also run Cloudy to constrain the excitation and energy transfer mechanisms (e.g., Canning et al. 2016). We will also study kinematics from [C II] (velocity, dispersion and their distribution if possible) and compared it with kinematics of different tracers (mainly CO and Hα). These galaxies are in two clusters with mass different by a factor of $\sim$ 3.5 so the impact of the cluster environment can also be explored.

2) The [C II] emission from the tails near the galaxy in the FOV of FIFI-LS will also be searched for, as the [C II] emission in ram pressure stripped tails has **never** been detected before. This is just the by-product of the main goal, as detecting [C II] emission from the galaxy is much more feasible than that in diffuse tails. However, any detection would open a new wavelength window to the studies of stripped tails and [C II] is known to be enhanced in several intergalactic regions studied before (e.g., Appleton et al. 2018).

3 Feasibility and Path to Publication

The selected sample of five galaxies in Coma and A1367 presents the best sample of RPS galaxies in rich clusters to be studied by *SOFIA*/FIFI-LS on [C II]. They also give us the best chance for the first [C II] detection in stripped tails. All of them have *Herschel* FIR photometric data but none with the PACS spectral data (also true for any stripped tail). None of them, or any galaxies undergoing strong RPS, has been observed by *SOFIA*/FIFI-LS before. All galaxies are also close to the complementary sky positions.

For the conservative assumption of $L_{[\mathrm{C\,II}]}$ / $L_{\mathrm{FIR}} = 2\times10^{-3}$ (Fig. 1), these galaxies have [C II] flux of 3.2 - 16 $\times10^{-14}$ erg s^{-1} cm^{-2}. If we instead use the Hα - CO relation (or the previous CO detections) and the assumed $L_{[\mathrm{CII}]}$ / $L_{\mathrm{CO(1-0)}}$ ratio discussed above, the expected [C II] flux is $\sim 0.4 - 2\times10^{-13}$ erg s^{-1} cm^{-2} from these galaxies, consistent with the above estimates. Interestingly, with the Hα flux of their tails, we also expect $2-5\times10^{-14}$ erg s^{-1} cm^{-2} in the 10 kpc $\times$ 10 kpc (or $\sim 22'' \times 22''$; or about 4 FIFI-LS spaxels) regions of their tails.

We used the *SOFIA* Instrument Time Estimator (SITE) for FIFI-LS to derive the required exposure time. Conservatively, we assumed an observatory altitude of 39,000 ft, a telescope elevation of 40 deg and a bandwidth of 400 km/s in all simulations. The proposed observations are summarized in Table 1. The [C II] emission from these galaxies, at their distances, will be close to point-like for *SOFIA*, as their FIR emission seen by *Herschel*. We will be able to use Symmetric Chop as the observing mode, which is how the overhead time was estimated. Five pointings are proposed and the total requested time is 7.5 hours.

Table 1: The sample of the RPS galaxies to be studied in this proposal

Galaxy (Cluster)	z	$L_{\mathrm{W1}}{}^{a}$ (10^9 L$_\odot$)	$L_{\mathrm{FIR}}{}^{b}$ (10^9 L$_\odot$)	$T_{\mathrm{dust}}{}^{b}$ (K)	expected [C II] flux^c (10^{-14} erg s^{-1} cm^{-2})	time^d (minutes)
NGC 4848 (Coma)	0.02351	2.7	26.0±0.7	28.6±0.3	16	38.5/102.5
CGCG 097-073 (A1367)	0.02427	0.18	4.6±0.2	26.3±0.5	3.2	32.0/86.1
CGCG 097-079 (A1367)	0.02363	0.23	6.1±0.2	28.7±0.5	4.2	37.0/98.7
NGC 4853 (Coma)	0.02560	4.5	18.0±0.4	29.6±0.3	11.4	30.5/82.3
IC 3949 (Coma)	0.02525	2.2	7.6±0.2	23.9±0.3	4.8	29.5/79.7

Note: ^{a}: the *WISE* band1 (3.6 μm) luminosity; ^{b}: FIR luminosity and dust temperature from the modified blackbody fits (with mbb_emcee) based on the *Herschel* data from our analysis (assuming β=1.5); ^{c}: estimates by assuming $L_{[\mathrm{C\,II}]}$ / $L_{\mathrm{FIR}} = 2\times10^{-3}$; ^{d}: the required on-source time / total time to achieve a 5 σ flux limit of 3×10^{-14} erg s^{-1} cm^{-2} for the [C II] line.

The CO luminosities of these galaxies are known from literature (Boselli et al. 1997; Lavezzi et al. 1999; Vollmer et al. 2001; Scott et al. 2013, 2015) and we have new *IRAM*-30m data on three of them. The mass of the molecular gas ranges from $3\times10^8 - 4\times10^9 M_\odot$, with the second most luminous galaxy at the FIR (NGC 4853) being the galaxy with the least amount of CO signal. Thus, the variation of the $L_{[\mathrm{C\,II}]}$ / L_{FIR} ratio and the $L_{[\mathrm{C\,II}]}$ / L_{CO} ratio can be examined in this sample (e.g., Fig. 1).

Even for these five galaxies well selected, atmospheric absorption features exist, e.g., ∼ -360 km/s for NGC 4848 and ∼ ± 550 km/s for CGCG 097-073. This cannot be avoided by nearly all [C II] studies with *SOFIA*. The "missing" [C II] flux could also be recovered from the Hα emission with the IFU data (so velocities are known) and it is estimated the missed flux is always less than 15% of the total.

Our main goal is detecting [C II] line emission from these five galaxies, which is well justified (Table 1). We will also search for [C II] emission in the tails covered by the proposed pointings. On the other hand, in the blue channel, we will also be sensitive to the [O I]λ63.2μm line down to the flux limit of $\sim 4-7\times10^{-14}$ erg s^{-1} cm^{-2}. The collisional heating models by Ferland et al. (2009) predict [O I]λ63.2μm / [C II] ratio of 3 - 21, much higher than the values typically observed in cluster cool cores (e.g., 0.3 - 1, Canning et al. 2016). It is indeed known that the [O I]λ63.2μm / [C II] ratio can be enhanced in shock-heated media (e.g., Kaufman et al. 1999). Thus, detections of [O I] emission are very likely in galaxies and would help to constrain gas density and ionization models.

For our *SOFIA* analysis, we will focus our attention on measuring the line fluxes of [C II], as well as the distribution and kinematics if possible. We will start with the pipeline results. We also have rich experience on the IFU datacubes from our work with the *ALMA* and *MUSE* data. We will compare these far-infrared line intensities to those measured at other wavelengths, particularly CO and Hα. The $L_{[\mathrm{C\,II}]}$ / L_{FIR} ratio will also be derived. CO data for these galaxies are available from *IRAM*-30m and *NOEMA* (archives and private communications). All of them also have (or will have) [2] *MUSE* data with the same $1' \times 1'$ FOV (*ESO* archive and private communications). We also have access to the radio continuum data, FIR continuum and X-ray data. These line ratios will provide us with constraints on the temperature distribution, density, and mass of the coldest gas phases. We will measure the shapes of the strong [C II] lines, which will provide us with information about the kinematics of the line emitting gas. Comparison of the line ratios and line shapes obtained in the far infrared with those at other wavelengths will allow us to test models of heat input into the cold gas (e.g., Ferland et al. 2009). We plan at least two papers from this project, one on the [C II] emission from RPS galaxies and the other on the stripped tails and the multi-wavelength comparison.

We also want to emphasize that detecting [C II] in RPS galaxies and tails can indeed be easily done with *Herschel/PACS*. However, it has never been tried, also because the first detection of CO in stripped tails (Jáchym et al. 2014) was published after *Herschel* ceased operation in April 2013. **Luckily, this is still within *SOFIA*'s reach!**

Potential for Publicity This project focuses on science that has been little probed by the FIR data from existing telescopes and *SOFIA*. The main expected results include the [C II] emission from galaxies undergoing strong RPS and their near tails, a different environment from where [C II] is typically studied with *SOFIA*, in galaxies and ionized by young stars. The new data may also result in the first ever detection of [C II] in stripped tails. The results of the proposed observations will provide important diagnostics in combination with the existing multi-wavelength data, which further present important implications on energy transfer in multi-phase gas and galaxy evolution. We expect to publish at least two refereed paper from this project, one on the galaxies and another focussing on the stripped tails and the multi-wavelength comparison. We will promote the *SOFIA* results with a press release, public talks and presentations in professional conferences. RPS galaxies and their spectacular stripped tails have been the topic of many public releases recently, including at least three *Hubble* releases, at least four *NASA* releases and several *ESO* press releases. We expect the unique science probed with this proposal will ultimately open a new window on studies of ram pressure stripping and promote *SOFIA* and infrared astronomy to general public.

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University of Virginia, Deparment of Astronomy, Research Associate	2008 - 2012
Eureka Scientific, Scientist VI	2012 - 2013
University of Alabama in Huntsville, Deparment of Physics & Astronomy, Assistant Professor	2014 - 2018
University of Alabama in Huntsville, Deparment of Physics & Astronomy, Associate Professor	2018 - present

Research Interest:

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Publication Summary

95+ peer-reviewed publications (21 as the first author) — 4900+ citations -(Google Scholar), including 2000+ citations to the first-author papers (h-index: 39).

Selected Publications

Chen, H., **Sun, M.** et al., "The ram pressure stripped radio tails of galaxies in the Coma cluster", *MNRAS*, 496, 4654, (2020)

Jáchym, P., Kenney, J. D. P., **Sun, M.** et al., "ALMA Unveils Widespread Molecular Gas Clumps in the Ram Pressure Stripped Tail of the Norma Jellyfish Galaxy", *ApJ*, 883, 145, (2019)

Cramer, W. J., Kenney, J. D. P., **Sun, M.** et al., "Spectacular Hubble Space Telescope Observations of the Coma Galaxy D100 and Star Formation in Its Ram Pressure-stripped Tail", *ApJ*, 870, 63, (2019)

Jáchym, P., **Sun, M.** et al., "Molecular Gas Dominated 50 kpc Ram Pressure Stripped Tail of the Coma Galaxy D100", *ApJ*, 839, 114, (2017)

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List of co-inverstigators

Suresh Sivanandam is an assistant professor at the University of Toronto. He is an expert in ram-pressure stripping of galaxies within clusters, particularly in the use of mid-IR diagnostics to quantify the impact of the stripping process. He will provide near to far-IR coverage of the proposed sample.

Pavel Jáchym is a staff member at the Astronomical Institute of the Czech Academy of Sciences, Czech Republic. He is an expert in the astrophysics of galaxy evolution in galaxy clusters, and their millimeter and radio observations. He will provide millimeter spectroscopy and imaging of the proposed sample, and work on numerical modeling and interpretation of the observations.

Masafumi Yagi is is an assistant professor at the National Astronomical Observatory of Japan. He is an optical astronomer and is studying data processing and analyses to measure low surface brightness features. He observed most of the proposed samples using a wide field imager of the 8.3m Subaru telescope (Suprime-Cam). The deep Subaru data will also be used for the comparison with the [C II] distribution.

Michitoshi Yoshida is a distinguished professor at the Hiroshima University and the current director of the Subaru Telescope. He is an optical and near-infrared astronomer and an expert on galaxies. He will work with Dr. Yagi to assist this project.

Giuseppe Gavazzi is a full professor at the University of Milano (Italy). He is an expert in observational aspects of galaxy evolution. He is currently working on Hα observations of the Coma cluster and A1367.

Alessandro Boselli is research director for the French CNRS at the Laboratoire d'Astrophysique de Marseille. He is an expert in the study of the role of the environment on galaxy evolution through the analysis of multifrequency samples of galaxies in nearby clusters, including some initial works on the [C II] emission from nearby galaxies with the *ISO* and *Herschel* data. He has done a lot of work on RPS galaxies with optical, radio and IR data. He will provide multifrequency data spanning the whole range of the electromagnetic spectrum (imaging, spectroscopy).

Hao Chen is a postdoc at the South African Radio Astronomy Observatory. He worked with Dr. Sun as a postdoc at the UAH from 2017 to 2019. He has worked on sub-mm, IR and radio data of galaxies. He will lead the radio data analysis of these galaxies.

Rongxin Luo is a postdoc at the University of Alabama in Huntsville, working with Dr. Sun. He works on AGN and ram pressure stripping galaxies, mainly with the optical and NIR IFU data. He will lead the MUSE work of these galaxies and will also assist Dr. Sun on the *SOFIA* data analysis.