The user wants me to translate a Chinese academic paper title and some metadata. Let me analyze the input: "Star Formation Efficiency of Blue Compact Galaxies Through (O ii), (Hα), (IR), and 1.4 GHz Radio Continuum 后印本" This appears to be a title of a scientific paper. Let me break it down: - "Sta···

Authors: The user has provided a name "Gemechu Muleta Kumssa" and wants me to translate it from Simplified Chinese to English. However, this appears to be a name, likely of a person, and it' s not in Chinese characters. It' s already in Latin script.

Let me re-read the instructions carefully. The user wants me to translate from Simplified Chinese to English. But the input "Gemechu Muleta Kumssa" is not Chinese - it' s a name that appears to be of Ethiopian/Eritrean origin (likely Amharic or similar).

The instructions say: - Translate from Simplified Chinese to English - Preserve ALL LaTeX commands and placeholders - Preserve ALL ···paragraph wrapper tags EXACTLY - Maintain academic tone and formal scientific writing style - Use precise technical terminology - obey the glossary strictly - The glossary only contains: 机器学习 => machine learning, 深度学习 => deep learning

Since the input is just a name and not Chinese text, there' s nothing to translate. The name should remain as is. But the format requires tags.

Wait, let me check if there' s any context I' m missing. The user just provided "Gemechu Muleta Kumssa" with no tags or any other structure.

Given the strict requirements about tags, I should probably wrap this in a tag. But what ID? The instructions say "if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs" . Since there are NO paragraph tags in the input, I should not add any.

But that would mean returning just "Gemechu Muleta Kumssa" as is, which seems odd. Let me think about the purpose of this request.

Perhaps the user is testing if I understand that names should not be translated. Or perhaps this is part of a larger document where this name appears, and they want to know how to handle it.

Given the strict instructions: 1. The input is not Chinese, so there' s nothing to translate 2. There are no tags to preserve 3. The name is already in Latin script

The most appropriate response would be to return the name exactly as provided, since no translation is needed and there are no structural tags to preserve.

But wait - the user might have made a mistake and pasted the wrong text. Or perhaps they want me to treat this as

Date: 2025-03-11T00:00:00+00:00

Abstract

The user wants me to translate a Chinese academic text about star formation efficiency in blue compact galaxies. Let me analyze the requirements:

1. **Critical Requirements**:
    - Preserve ALL LaTeX commands and placeholders exactly
    - Preserve ALL citation commands ([**?**], **??**, (**??**), etc.) exactly
    - **PRESERVE ALL ···paragraph wrapper tags EXACTLY**
    - Maintain academic tone and formal scientific writing style
    - Use precise technical terminology - obey the glossary strictly
    - Preserve section structure and paragraph organization
    - Translate all content completely - do not omit any information
2. **Output Rules**:
    - Return ONLY the translated text (no explanations, no quotes, no headings)
    - Keep one output paragraph per input paragraph
    - **Maintain exact count and IDs of ···tags**
    - Do NOT add Markdown formatting unless present in source
    - Preserve original line breaks within the paragraph when meaningful
3. **Formatting Guidelines**:
    - Keep mathematical expressions in original LaTeX format
    - Preserve equation numbers and references
    - Maintain proper academic paragraph structure
    - Use formal scientific language
4. **Glossary**:
    - 机器学习 => machine learning
    - 深度学习 => deep learning

Wait, the glossary provided seems irrelevant to this astrophysics text. The text is about star formation efficiency, blue compact galaxies, etc. I should ignore the glossary since it doesn' t apply to this content. The user said “obey the

glossary strictly” but the glossary terms don’ t appear in the text. I should just translate the astrophysics terms accurately.

Let me look at the input text. It appears to be a single paragraph without any tags. But the instructions say I must preserve ···tags. This is confusing. Let me re-read the instructions.

The instructions say: “PRESERVE ALL ···paragraph wrapper tags EXACTLY - these are structural markers that identify paragraphs and MUST remain untouched with their IDs”

But the input text provided by the user doesn’ t contain any tags. It just says:

“This paper investigates the star formation efficiency (SFE) of blue compact galaxies (BCGs) by analyzing various indicators, including (O ii), (Hα), infrared emissions, and the 1.4 GHz radio continuum. The assessment of SFE was conducted using publicly accessible data that concentrated on star formation rates (SFRs) and depletion timescales. By employing the fundamental equation, I determined the SFE in relation to its freefall time, which highlighted variations in efficiencies associated with SFR masses derived from different spectra. The results demonstrated that the highest efficiency value was observed in the analysis of the 1.4 GHz radio continuum, emphasizing the importance of studying star-forming clouds across a range of electromagnetic wavelengths to achieve a comprehensive understanding of star formation mechanisms. The study’ s findings indicated a peak efficiency of star formation value of approximately 0.9

Full Text

Preamble

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Star Formation Efficiency of Blue Compact Galaxies Through [O II], Hα, IR, and 1.4 GHz Radio Continuum
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Abstract

This paper investigates the star formation efficiency (SFE) of blue compact galaxies (BCGs) by analyzing various indicators, including [O II], Hα, infrared emissions, and the 1.4 GHz radio continuum. The assessment of SFE was conducted using publicly accessible data that concentrated on star formation rates (SFRs) and depletion timescales. By employing the fundamental equation, I determined the SFE in relation to its free-fall time, which highlighted variations in efficiencies associated with SFR masses derived from different spectra. The results demonstrated that the highest efficiency value was observed in the analysis of the 1.4 GHz radio continuum, emphasizing the importance of studying star-forming clouds across a range of electromagnetic wavelengths to achieve a comprehensive understanding of star formation mechanisms. The study' s findings indicated a peak efficiency of star formation value of approximately 0.9%, while the relative minimum obtained from [O II] was around 0.42%, aligning with the range of SFEs documented in the existing literature. Additionally, investigating the factors that influence the variability in efficiency when examining clouds in BCGs across different wave bands is crucial for deepening our comprehension of the underlying processes of star formation.

Key words: catalogs -methods: analytical -turbulence -shock waves -accretion, accretion disks -stars: dwarf novae

1. Introduction

Blue compact dwarf galaxies, such as NGC 5253 in the southern constellation of Centaurus, represent some of the closest examples of this class, positioned approximately 12 million light-years from Earth (Kunth & Östlin 2000). These galaxies are distinguished by their notable feature of hosting highly active star-forming regions. BCD galaxies contain molecular clouds (MCs) that bear a striking resemblance to the pristine clouds that gave birth to the first stars in the early Universe, lacking significant dust or heavier elements. This is why astronomers view these galaxies as ideal laboratories for gaining deeper insights into star formation processes in the early stages of cosmic history.

BCGs exhibit distinct features such as their blue coloration, significant gas content, prominent condensed structure, nebular emission lines, and relatively low metallicity (Kunth & Östlin 2000). These blue, compact dwarf galaxies are known for their active star formation and youthful nature, serving as valuable tools for validating theories of galaxy formation, chemical evolution, and massive star development (Izotov et al. 1990). Observations reveal exceptionally low heavy element abundances in these systems; for instance, oxygen levels can be 77 times lower than solar values and 1.7 times lower than those in the previously most metal-poor galaxy, I Zw 18 (Izotov et al. 1990; Thuan et al. 1996). Additionally, the high electron temperature of 24,800 K suggests the presence of numerous massive stars with effective temperatures reaching up to 8×10^4 K. Based on these observations, galaxies like SBS0335-052 appear to be in their early evolutionary stages (Izotov et al. 1990; Thuan et al. 1996).

The inquiry into the star formation history of BCGs remains unresolved, as they could be either relatively young galaxies or older systems that have experienced a recent resurgence in star formation activity. In a study detailed by Kong (2004), an empirical population synthesis technique was employed utilizing a library of observed star cluster spectra. The findings indicate that BCGs typically comprise stellar systems of varying ages, with contributions from young, intermediate-age, and old stellar populations significantly impacting the 5870 Å continuum emission of most galaxies in the sample. Given the presence of old stars in all BCGs examined, the results point toward these being older galaxies with non-continuous star formation histories.

Understanding the star formation rate (SFR) is essential for unraveling the star formation history of galaxies across various redshifts and the overall evolution of the cosmos, as highlighted by Madau et al. (1996) and Steidel et al. (1999). To achieve this comprehension, it is imperative to have a dependable estimation of the SFR in individual galaxies. Several methods for estimating SFR rely on luminosity measurements at different wavelengths, such as radio, infrared (IR), ultraviolet (UV), optical spectral lines (like Hα, [O II] $ 3727), *andcontinuumemission*(*Kennicutt*1998).*UtilizingtheseSFRindicators*, *numerousinvestigationsha* [O II]3727, IR, radio (1.4 GHz) luminosities, and neutral hydrogen (H I) gas masses to calculate SFR and gas depletion timescales for a sample of 72 star-forming BCGs. However, that study did not calculate or estimate the star formation efficiency (SFE) or free-fall time (t_{ff}). Therefore, it is important to investigate the SFE in terms of free-fall time for these galaxies.

In order to evaluate potential systematic differences among various SFE indicators, I calculated the MC mass in BCGs using depletion timescales and the SFRs obtained from Hα, [O II]3727, IR, and radio luminosities from the catalog of Kong (2004). Additionally, I calculated t_{ff} and SFE by assuming a number density of star-forming MCs of n 10^3 cm^{-3} as suggested by Bertram et al. (2016). This paper examines the SFE of BCGs through the analysis of radio continuum emission, exploring the correlation between SFE and radio continuum. The assessment of SFR utilizing this approach is also addressed. The purpose of this work is to study the SFE of BCGs via [O II], Hα, IR emissions, and the 1.4 GHz radio continuum, and to investigate under which conditions we obtain SFE results consistent with values calculated in the literature.

2. Star Formation

There are many key processes influencing star formation on different scales (Evans et al. 2009), and the large-scale SFR is determined by physical processes covering a vast range of physical scales. The process of star formation is a fundamental aspect of galaxy formation and evolution, yet it remains inadequately understood within the field of astrophysics (Evans et al. 2009; Kumssa & Tessema 2021). Recent advancements in observational astronomy have yielded a wealth of data regarding star formation processes and their subsequent evolution. The intricate dynamics between gravitational forces and opposing pressure forces contribute to the complexity of star formation, making it challenging to achieve a comprehensive understanding of both the mechanisms involved and the SFE (Kumssa & Tessema 2022).

Without a robust theoretical framework for star formation, it is difficult to draw conclusions about the origins of planetary systems and their associated planets (Kumssa & Tessema 2022). Various physical processes and pressure forces play a role in star formation across different scales, whether galactic, extragalactic, or at both large and small scales. Notably, the majority of stars are birthed within interstellar clouds, specifically referred to as MCs. There exist numerous approaches to examining the SFE within galaxies, among which theoretical and observational methods serve as foundational elements. In this research, the observed luminosities of Hα, [O II]3727, IR, and radio emissions at 1.4 GHz from BCGs are utilized to analyze and assess the SFE of these galaxies.

These MCs are short-lived (10^7-10^8 yr) or long-lived (above 10^8 yr) (Fujii & Zwart 2016). Thus, not all mass in an MC may be converted to stars efficiently. Studying SFE in MCs represents an important input for developing a consistent star formation theory. Mo et al. (2010) inquired how MCs replace the mass that is converted to stars if the clouds' lifetime is too long and how they are recycled.

3. Star Formation Efficiency

The SFE, both in theoretical models and observational studies, is a topic of great interest and importance in astrophysics. Understanding how stars form and the factors that influence their formation is crucial for unraveling the mysteries of the Universe. By comparing theoretical predictions with observational data, scientists strive to gain insights into the processes that govern star formation and refine our understanding of this fundamental cosmic phenomenon. The SFR of BCGs was calculated by Kong (2004) using depletion timescales and the mass of neutral hydrogen. However, their SFE had not been calculated via this method. Therefore, I aimed to calculate the SFE of these clouds in terms of MC mass by obtaining it from assumed SFR and depletion timescales.

Various types of SFE exist, with some based on observational convenience and others on theoretical foundations. The definitions of SFE and the parameters used to calculate them are summarized here, with a focus on individual gas clouds rather than larger regions or entire galaxies. It is noted that the SFE at the scale of gas clouds can be independent of the SFE integrated over a broader area, as seen in feedback-regulated models related to the Kennicutt (1998) relation by various authors.

One of the cloud-scale SFEs is the "integrated" SFE, representing the proportion of gas mass transformed into stars throughout a cloud' s lifespan (Murray 2011):

$$\epsilon_{\text{int}} = \frac{M_*}{M_{\text{gas}}}$$

where M_* is the total mass in stars formed and M_{gas} is the total gas mass. ϵ_{int} is of particular interest because it is sensitive to the details of stellar feedback physics, as eventually a sufficient number of massive stars will form to expel the gas. ϵ_{int} ultimately determines the mapping between the MC and star cluster mass functions in a galaxy.

The determination of the instantaneous SFE (ϵ) can be achieved by quantifying the proportion of stars linked to the star-forming cloud at a specific moment in time, as stated by Myers et al. (1986). ϵ will evolve from 0 to some finite value during the star-forming lifetime of a cloud, so a certain amount of scatter in this quantity is expected even for a population of clouds with identical properties. As $t \to \infty$, $\epsilon \to \epsilon_{\text{int}}$. The natural timescale for the evolution of self-gravitating objects is the gravitational free-fall time, given by:

$$t_{\text{ff}} = \sqrt{\frac{3\pi}{32G\rho}}$$

where ρ is the volume-averaged density of the cloud, and G is the gravitational constant. Thus, the SFE per free-fall time as described by Krumholz & Tan (2007) is:

$$\epsilon_{\text{ff}} = \dot{M}_* \frac{t_{\text{ff}}}{M_{\text{gas}}}$$

where $\dot{M}_*$ represents the rate at which mass from the envelope is falling onto the core that is undergoing star formation. These theories typically predict $\epsilon_{\text{ff}} \sim 1\%$ for MCs with properties similar to those observed in local spiral galaxies (Bolatto et al. 2008), solely from the properties of isothermal supersonic turbulence plus a gravitational collapse criterion. Because these physics are scale-free, this could potentially explain the observation that $\epsilon_{\text{ff}} \sim 1\%$ on a wide range of scales from galaxies to dense star-forming clumps (Krumholz et al. 2011).

The study by Mac Low (2016) stated that gravitational collapse seems more dominant, but the question is how efficient it is, what parameters cause the fluctuation of SFE, and to what extent temperature and radius raise and reduce, respectively, to obtain a more efficient MC under its own gravity. Results from various studies show that efficiency ranges from $\epsilon = 0.030$–0.6 over giant molecular clouds (GMCs) regardless of the consideration of dense gas and diffuse gas in MCs, and $\epsilon \sim 0.5$ for dense gas with $n \sim 10^5$ cm^{-3}, as Evans et al. (2009) investigated in the Spitzer Legacy program for a set of five star-forming regions from cores to disks. Similar values were obtained by Heiderman et al. (2010)

in 15 additional clouds from the Gould' s Belt Survey, but some higher values of $\epsilon_{\text{ff}} \approx 0.14$–$0.24$ were obtained by Murray (2011). Most of the mass is in large MCs as mass spectra of GMCs show, which leads to lower densities with $\epsilon_{\text{ff}} \sim 0.001$–$0.003$ (Krumholz & Thompson 2013). Efficiencies obtained by different scholars vary. In this paper, we study what causes the difference in efficiencies mentioned in Section 1.

In this work, I apply the Hα, [O II]3727, IR, and radio (1.4 GHz) luminosities of star-forming BCGs estimated by Kong (2004). Studies by Murray (2011) and Robitaille & Whitney (2010) estimate SFR in the Milky Way and indicate the galactic SFR is 2 M yr^{-1}; as found by Solomon et al. (1987), the total molecular mass of the Milky Way is roughly 10^9 M , and efficiency is estimated to be $\epsilon_{\text{ff}} \sim 0.01$ (Krumholz & McKee 2005; Krumholz & Tan 2007). Furthermore, García-Burillo et al. (2012) analyzed observations and reported $\epsilon_{\text{ff}} \sim 0.01$ using tracers of dense gas with $n \sim 10^5$ cm^{-3} like HCN. Additionally, Murray (2011) obtained a galaxy-wide average SFE per t_{ff} of 0.0057 using the t_{ff} assumed by Krumholz & Tan (2007), which is $t_{\text{ff}} = 4.4$ Myr. As Evans et al. (2009) stated, clouds in higher-density regions subtend smaller volumes and include smaller masses. ϵ_{ff} is nearly constant because M_{gas} and $1/t_{\text{ff}}$ both fall with density at about the same rate.

4. Results and Analysis

Starting from the fundamental definition of SFE, I calculate the SFE of BCGs based on the data of Kong (2004). Here I consider the following formulations. In this context, τ represents the depletion timescale, M_c denotes the mass of the cloud, and $\dot{M}$ signifies the SFR. From this information, I derive the relationship shown in Figure 11, which indicates that as the duration of depletion extends, the ϵ_{ff} diminishes in both scenarios. This decline can be attributed to the potential dispersal of the cloud over an extended timeframe.

4.1. Mass of the MCs of BCGs from Depletion Timescale and SFR

The masses of the MCs can be obtained from depletion timescales and SFRs as described in Kong (2004) (Table 1). These include gas depletion timescales from [O II]3727, H$ 6563, $IR, and 1.4 GHz continuum, using SFRs derived from [OII]$3727, H $6563, IR luminosity, and 1.4 GHz radio continuum, respectively.

Following this, I calculated the MC mass from the depletion timescale and the SFR from the data as:

$$M_c(\text{O II}) = \text{SFR}(\text{O II}) \times \tau(\text{O II})$$

$$M_c(\text{H }) = \text{SFR}(\text{H }) \times \tau(\text{H })$$

$$M_c(\mathrm{IR}) = \mathrm{SFR}(\mathrm{IR}) \times \tau(\mathrm{IR})$$

$$M_c(1.4\,\mathrm{GHz}) = \mathrm{SFR}(1.4\,\mathrm{GHz}) \times \tau(1.4\,\mathrm{GHz})$$

where $M_c(\mathrm{O\,II})$, $M_c(\mathrm{H}\ )$, $M_c(\mathrm{IR})$, and $M_c(1.4\,\mathrm{GHz})$ are MC masses in the BCG calculated from the respective depletion timescales $\tau(\mathrm{O\,II})$, $\tau(\mathrm{H}\ )$, $\tau(\mathrm{IR})$, and $\tau(1.4\,\mathrm{GHz})$.

Now considering the particle number density of the cloud to be $n = 10^3\ \mathrm{cm}^{-3}$, we can obtain the initial density of the cloud by applying $\rho = n\mu m_{\mathrm{H}}$, where $\mu = 2.016$ is the mean molecular weight and m_{H} is the mass of hydrogen.

Figure 1 shows the location of the star-forming clouds in BCGs in terms of declination (J2000) and right ascension (J2000) from the data of Kong (2004). Figure 2 illustrates the average t_{ff} calculated from the assumed average density, which is approximately 3.625×10^7 yr, indicating that the density of star-forming galaxies can exhibit significant variation.

4.2. Star Formation Efficiency of Blue Compact Galaxy in Free-fall Time

In this section, I calculate the SFE of a BCG from the data by determining the t_{ff} from its assumed density. In light of this, and considering Equations (11) and (3), the t_{ff} is calculated for the above-obtained masses. Now using Equation (4) as a fundamental relation, I calculate the efficiency as:

$$\epsilon_{\mathrm{ff}}(\mathrm{O\,II}) = \frac{\mathrm{SFR}(\mathrm{O\,II}) \times t_{\mathrm{ff}}}{M_c(\mathrm{O\,II})}$$

$$\epsilon_{\mathrm{ff}}(\mathrm{H}\ ) = \frac{\mathrm{SFR}(\mathrm{H}\ ) \times t_{\mathrm{ff}}}{M_c(\mathrm{H}\ )}$$

$$\epsilon_{\mathrm{ff}}(\mathrm{IR}) = \frac{\mathrm{SFR}(\mathrm{IR}) \times t_{\mathrm{ff}}}{M_c(\mathrm{IR})}$$

$$\epsilon_{\mathrm{ff}}(1.4\,\mathrm{GHz}) = \frac{\mathrm{SFR}(1.4\,\mathrm{GHz}) \times t_{\mathrm{ff}}}{M_c(1.4\,\mathrm{GHz})}$$

where $\epsilon_{\mathrm{ff}}(\mathrm{O\,II})$, $\epsilon_{\mathrm{ff}}(\mathrm{H}\ )$, $\epsilon_{\mathrm{ff}}(\mathrm{IR})$, and $\epsilon_{\mathrm{ff}}(1.4\,\mathrm{GHz})$ are SFEs from the respective MC mass, t_{ff}, and SFR.

The cloud mass derived from [O II] illustrates the ϵ_{ff} of BCGs, as shown in Figure 3. This figure indicates a peak efficiency of 0.425%. Variations in the ϵ_{ff} values can arise from differences in observational methods. Therefore, it is essential to conduct observations from various angles and across different spectra to obtain a more comprehensive understanding of efficiency.

The ϵ_{ff} in BCGs, as represented by Figure 4, is measured in relation to cloud mass using Hα. The figure clearly indicates that the maximum ϵ_{ff} achieved is 0.675% in terms of cloud mass measured by Hα. The plot presented in Figure 5 illustrates the relationship between the ϵ_{ff} of BCGs and cloud mass as observed in the IR spectrum. It can be observed from Figure 5 that the highest efficiency recorded is 0.725% for the IR spectrum.

Figure 6 depicts the correlation between the ϵ_{ff} of BCGs and cloud mass as determined by radio continuum measurements. The data indicate that the peak ϵ_{ff} reaches 0.825% at a frequency of 1.4 GHz. Additionally, Figure 7 confirms that the maximum ϵ_{ff} occurs at the 1.4 GHz radio continuum, also around 0.825%. Furthermore, Figure 8 reinforces this finding, showing that the highest ϵ_{ff} is similarly recorded at a 1.4 GHz radio continuum of approximately 0.825%.

The data presented in Figure 9 reinforce the observation that the maximum SFR is achieved at a frequency of 1.4 GHz in the radio continuum. Additionally, Figures 7–9 indicate that the highest values of ϵ_{ff} and SFR coincide with the 1.4 GHz radio continuum, highlighting the significance of monitoring star-forming regions across different wavelengths of the electromagnetic spectrum. Figure 10 illustrates that the relationship between the efficiencies of star formation across different spectra can be analyzed from an alternative viewpoint.

The data presented in the figures demonstrate that the SFE of a cloud within a BCG, when assessed through various methodologies, yields results that are relatively consistent with one another, despite minor discrepancies arising from the differences in observational techniques employed. Figure 11 indicates that the maximum depletion time occurs at [O II]3727, which acts to decrease the ϵ_{ff}. The data demonstrate that the ϵ_{ff} of galaxies varies depending on the spectral range utilized for analysis, with the computed efficiencies also changing based on the particular type of spectrum observed in these galaxies.

5. Conclusion

The study of SFE of BCGs in free-fall time was carried out through an in-depth examination of observational data sourced from the catalog by Kong (2004), which included metrics on SFRs and depletion timescales. Utilizing this information, the remaining parameters, such as the mass of the cloud and the efficiencies of star formation, were subsequently computed. It is essential to note that the original data set did not include any calculations or forecasts related to the ϵ_{ff} of MCs in these galaxies. As a result, my aim was to determine the SFE during the free-fall time of the clouds by utilizing the spectrum through which the galaxy was observed.

This involved calculating the t_{ff} and MC masses using the SFR and depletion time available in the data set. Ultimately, I applied the fundamental equation to assess the SFE in relation to t_{ff}. Through this approach, I recognized the SFE in free-fall time associated with the MC masses derived from various spectra, suggesting that the ϵ_{ff} of star formation varies depending on the particular observation spectrum employed.

This paper utilized Hα, [O II]3727, IR, radio (1.4 GHz) luminosities, and neutral hydrogen (H I) gas masses to estimate the mass of the star-forming gas and to calculate the SFE of BCGs. Subsequently, it examined the variations in ϵ_{ff} derived from the aforementioned luminosities. The findings reveal that the ϵ_{ff} calculated from radio (1.4 GHz) luminosities tends to be somewhat higher than those derived from Hα, [O II]3727, and IR measurements. Therefore, it is advisable to investigate the SFE of these galaxies using a variety of spectral data. The calculation shows the peak value of ϵ_{ff} is attained for the cloud when observed at 1.4 GHz radio continuum spectrum, which is indicated in Figure 6, i.e., $\epsilon_{ff} \sim 0.825\%$.

These findings suggest that the efficiencies associated with star-forming clouds fluctuate across various wavelengths of the electromagnetic spectrum. Consequently, it is crucial to employ multi-wavelength telescopes to observe a particular star-forming region, as this approach facilitates the acquisition of comprehensive data necessary for the precise interpretation of the SFR and SFE.

The findings of this research reveal that the highest recorded value of ϵ_{ff} was 0.825%, with an average value near 0.66%. These figures (Figures 3-11) align with the range of SFEs referenced by multiple authors in the introductory section. It is imperative to explore the factors that influence the variability of ϵ_{ff} in a cloud when observed across different wave bands.

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Note: Figure translations are in progress. See original paper for figures.