C-CWEL – Continuing Cool WISE ExpLoration of BRC 38: A NITARP 2013 search for YSOs using primarily WISE data

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Abstract

Stars are born in clusters within cold clouds of interstellar gas and dust known as giant molecular clouds. Once high-mass stars form, they can move the material around, and create HII regions. Bright rimmed clouds (BRCs) are dense clumps of gas and dust within HII regions at the edges of molecular clouds; the clouds themselves are dark but their rims are bright in the optical from illumination by the nearby bright O or B stars. These BRCs may be host to lower-mass star formation triggered by these massive stars. The young stellar objects (YSOs) that may be found in the BRCs are often hidden by the dark cloud.

The central ~5’x5’ region of BRC 38 (21h40m02.2s +58d20m43s [J2000]) has been studied in many wavelengths from X-rays with Chandra (Getman et al. 2007) to Spitzer bands

(Choudhury et al. 2010). These authors have identified confirmed YSOs and candidate YSOs. Our investigation seeks to look for more YSOs by including WISE (Widefield Infrared Survey Explorer) data in a 20 arcminute radius centered on BRC 38. The primary WISE data set will be supplemented with data from the Two-micron All Sky Survey (2MASS; JHK_s bands), the Isaac Newton Telescope and Photometric H-Alpha Survey (IPHAS; riHα bands), and other data available in the literature in the central region. We will include the Spitzer data discussed in Choudhury et al. (2010), but also serendipitously obtained Spitzer data flanking the region but unreported by Choudhury et al. (2010). We will identify objects as potential candidate YSOs from their infrared (IR) colors; we will examine images of the objects, construct color-color and color-magnitude diagrams, and construct spectral energy distributions (SEDs) to assess each candidate object individually. We will compare the lists of YSO candidates from the literature with the YSO candidates that we find in the BRC 38 region, and we expect to find more YSO candidates in the greater BRC 38 region.

1. Science Background and Context

1.1 Star Formation

The study of the formation and evolution of stars is important because it leads us to a better understanding of some of the physical mechanisms that guide the evolution of the universe, as well as the origins of our own Solar System. Since the process of star formation takes place on timescales of millions of years, we are only able to obtain brief glimpses into each stellar story. Therefore, it is important to observe as many formation events, in as many wavelengths as possible, so that we can analyze a wide range of environmental conditions, ages, and masses, which will allow us to constrain and refine the theory of stellar formation.

Star formation begins when large clouds of interstellar dust and gas collapse. Within the arms of our Milky Way Galaxy there are regions in which the density of gas and dust is significantly greater than that typical of the interstellar medium. These regions are known as giant molecular clouds (GMCs). Stars are typically formed in clusters within GMCs. GMCs are largely composed of molecular hydrogen (70%), helium (28%), and a small percentage of heavier elements. A typical GMC is dozens of parsecs in length, and has a mass of hundreds of thousands of solar masses. The internal temperature of a GMC is cold, generally in the 10 - 30K range, and its average density on the order of 300 molecules per cubic centimeter, although there is substantial variability of temperature and density within a GMC.

The life of a GMC is a battle between the inward force of gravity and the outward force of thermal gas pressure. Stars only form when the force of gravity exceeds the gas pressure within of a portion (or fragment) of a GMC. The force of gravity depends on mass, and gas pressure on temperature. The greater the mass within a fragment, the more likely it will collapse. On the other hand, higher temperatures reduce the likelihood of collapse. If mass (and density) is great enough and temperature low enough, the fragment will collapse and star formation can proceed without outside influence. However, star formation can likely be triggered by an outside stimulus such as ionizing radiation and stellar wind from a nearby massive star, a shockwave from a supernovae explosion, a collision between molecular clouds, or a density wave moving within the Galaxy's spiral arms. These external triggering mechanisms work by compressing the material within a fragment, thus increasing density.

Once gas and dust within a cloud fragment becomes compressed and clumped, the gravitational force exerted within the fragment increases, which, in turn, attracts additional material. In time, enough material is accreted onto the central object within the fragment that a glowing protostar is formed. The protostar exists within a cocoon of gas and dust. Dust absorbs most visible light produced by the glowing protostar. As a result, the dust gets warmer and re-radiates the energy in infrared (IR) wavelengths. Observing the protostar using the infrared thus provides a view of the incubating protostar. Additional mass accretes onto the protostar until the supply of material runs out, or winds and jets from the protostar blow away the remaining material. Meanwhile, the protostar will continue contracting from self-gravity.

Because of random motions of gas particles within the GMC (and any net motion of the entire GMC), a collapsing cloud fragment will have an overall rotation. This rotation (plus conservation of angular momentum) prevents all the infalling material from settling directly onto the protostar. Instead, the material forms a spinning circumstellar disk. Some of the disk material gradually spirals inward due to friction, thus continuing to increase the mass of the protostar, while other matter may condense into planetary bodies. During the latter stages, protostellar winds and jets will clear away the gas and dust cocoon, thus ending the accretion of additional mass onto the protostar. Low mass stars at this stage are known as T Tauri stars.

Although accretion of additional mass has stopped, the protostar continues to contract. This causes its interior temperature, density and pressure to rise until thermonuclear fusion begins. Fusion generates enough thermal energy that the outward force of gas pressure offsets the inward force of gravity, which stops further contraction. Hydrostatic equilibrium is established and maintained. The protostar has transitioned into a main sequence star, a state in which it will remain for 90% of its lifetime.

The process of star formation can occur in numerous locations within a GMC and can produce many thousands of stars until the mass of the GMC is consumed or dispersed.

1.2 Bright Rimmed Clouds

Research during the past two decades has shown that bright rimmed clouds (BRCs), fragments of molecular clouds located at the edges of relatively old (>10^6 yr) HII regions, are areas of active star formation. An HII region is an emission nebula within a GMC, the illumination of which results from the recombination of previously ionized hydrogen. The source of ionization is ultraviolet (UV) radiation emitted by nearby massive and hot O and B type stars. BRCs are relatively dense clumps of gas and dust where much of the surrounding material has been blown away by the intense radiation and strong stellar winds from these stars. Over time, the less dense material is dispersed, gradually revealing the dense regions that become the BRC. BRCs are "bright" due to recombination of the ionized layer at the edge of the HII region, which is visible in the optical regime. The O and B stars not only illuminate the BRC, but their intense radiation and winds provide a mechanism for triggering or accelerating the collapse of GMC fragments, a process known as radiation driven implosion (RDI), thus initiating the process of star formation (Sugitani et al. 1991).

Sugitani et al. (1991) provided the first catalog of 44 BRCs, including BRC 38, the subject of this project. They classified BRCs based on their rim morphology: type A, B, and C with moderately curved, tightly curved, and cometary curved rims, respectively. They noted that BRCs are denser in the direction toward their ionizing source, thus indicating the influence of stellar wind on the shape of BRCs. A typical BRC has a radius of less than 0.5 parsecs, with an average mass of about 100 solar masses.

1.3 Young Stellar Objects (YSOs)

"Young stellar object" (YSO) is a collective term for any object in the early stage of star development. A given BRC (plus the region around it) may contain YSOs exhibiting a wide range of developmental stages. Because the bulk of radiation emitted by a protostar is absorbed by the surrounding circumstellar dusty cocoon and/or protostellar disk, YSOs characteristically display excess IR radiation as the dust is warmed, an excess as compared to emissions from a plain, dust-free star of comparable temperature (which can be approximated as a blackbody). The amount and wavelength of the excess IR emissions is suggestive of the amount of circumstellar dust, and therefore the stage of development for a given YSO.

A spectral energy distribution (SED) plots energy (y-axis) against wavelength (x-axis), a sort of low-resolution spectrum. SEDs are constructed by measuring the amount of energy emitted by an object at specific wavelengths. The developmental stage of YSOs can be estimated based upon the shape of their SED (connected to the size of the IR excess); see Figure 1. Large positive slopes between ~2 and ~24 μm on an SED suggest a large IR excess, suggesting the presence of a dusty cocoon or protostellar disk. As a YSO matures, the amount of dust surrounding the star decreases (from accretion or from being blown away). Consequently, the level of IR excess also decreases, and the slope of the SED decreases. The slope of the SED allows us to place these objects into classes, as in Figure 1. A Class 0 is the earliest and most embedded phase of protostellar development; the SED is similar to that of a cold blackbody from the circumstellar envelope. Class I is the next phase; this SED is a composite of a warmer blackbody (the central object) plus significant IR excess from the surrounding dusty cocoon, hence a positive slope. (The "bite" at about 10 μm comes from silicates in the dust around the star.) Figure 1 comes from Bachiller (1996); since then, another class, "Flat" has been added after Class I. This SED has a nearly 0 slope between ~2 and ~24 μm. Class II represents a young ("Classical") T Tauri star; most of the energy comes from the central object, but there is still some IR excess from the optically thick disk. Class III represents an older ("Weak-Lined") T Tauri star. The SED is beginning to resemble that of a young main sequence star with little IR excess because the

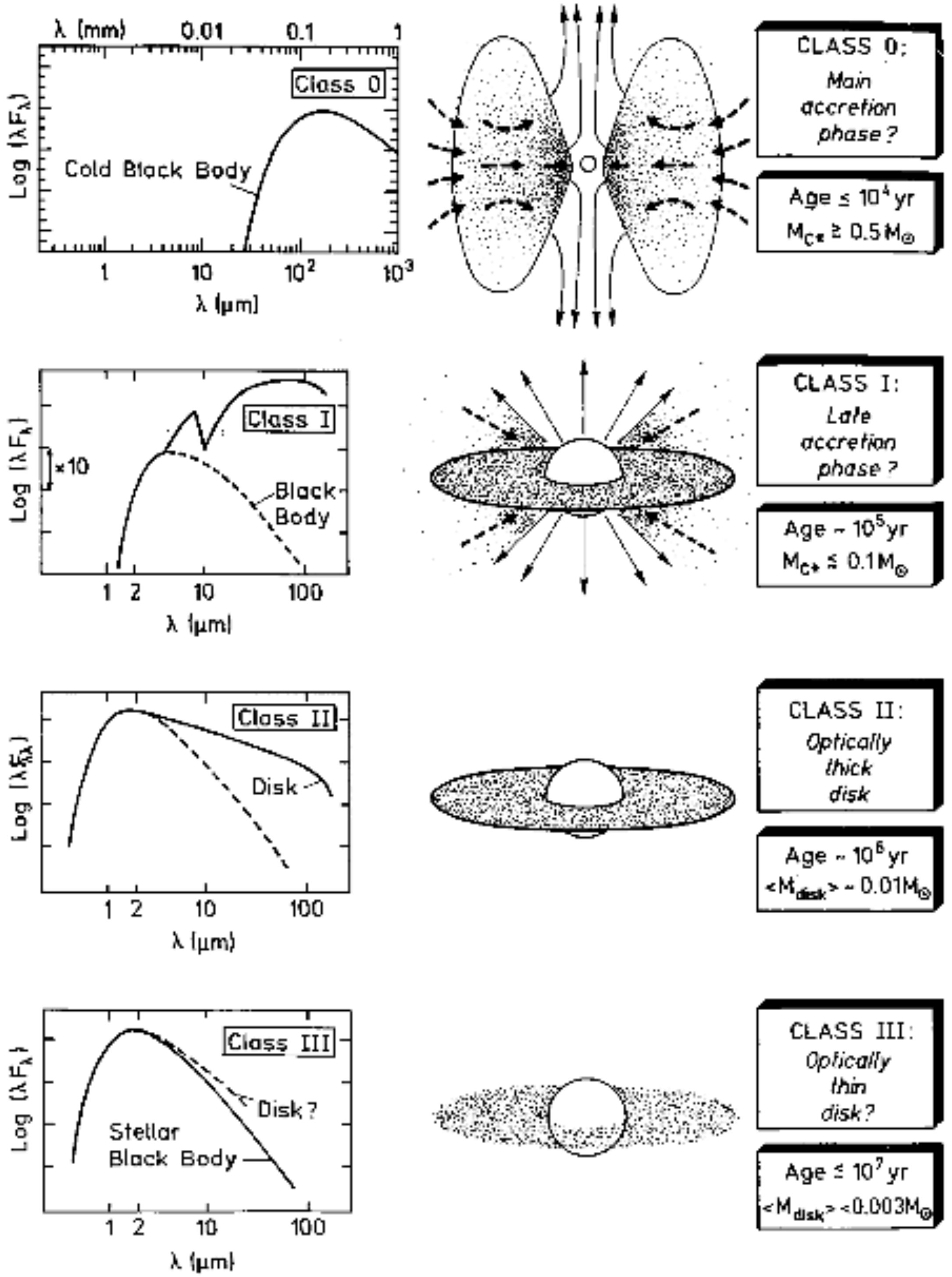

Figure 1: Stages of YSO Development (Bachiller 1996 Figure 11, citing Andre 1994)

bulk of the surrounding dust has been blown away. The optically thin disk has a mass of only about 0.003 Msun. A “transition disk” class is sometimes inserted between classes II and III, to indicate a transition between an object having a disk and not having one. There may also be a “debris disk” class after class III to indicate a second generation of dust formed from colliding protoplanetesimals in the protostellar disk.

There are a number caveats that should be kept in mind when interpreting the class sequence described above. The ages indicated are more suggestive of the sequence of stellar development than empirically determined ages. Because class 0 stars do not remain at that stage for long periods, they are difficult to find. The above sequence applies only to low mass stars. High mass stars evolve so quickly that the stages become blurred. The orientation of a YSO can produce a false classification. For example, an edge-on Class III YSO could appear like a face-on Class II.

Sugitanti et al. (1991) and Ogura et al. (2002) postulated that the amount of IR excess may also be related to the location of the YSO within the BRC and thus its proximity and exposure to the radiation of the nearby O or B type star. According to this model, star formation is triggered by radiation from these massive and hot stars, a process known as radiation-driven implosion (RDI). The radiation compresses the cloud material, triggering star formation in the interior, while evaporating the cloud's outer layers. In RDI, the farther a YSO is away from the radiating O or B star, the younger it is. Since younger YSOs tend to have IR-radiating disks, the prevalence of sources with excess IR emissions should increase with distance from the O or B star.

1.4 BRC 38

The region we are planning to study is BRC 38, located at 21:40:42 +58:16:13. (BRC 38 is also sometimes known as SFO 38 and IC 1396N within the literature. BRC 38 is part of the IC 1396 HII region located within the constellation Cepheus (Figure 2). IC 1396 is a target-rich region of triggered star formation, and BRC 38 is one of 11 named BRCs within the IC 1396 complex (several of the other BRCs are easily visible as black “fingers” in Figure 3). BRC 38 has been selected for study because there is a wide variety of available data including WISE, Spitzer, and 2MASS. Analysis of these data is likely to result in numerous new YSO candidates within the region, as well as the “rediscovery” of previously known YSOs listed in the literature. This study will complement the study of BRC 34, also located within IC 1396, conducted by the NITARP BRC team in 2011. Our work, along with that of the 2011 BRC team, will allow us to better understand the rate, and the likely triggering mechanism, of star-formation within the whole IC 1396 complex.

The ionizing star within IC 1396 is HD 206267, an O6.5V star approximately 0°47” south of BRC 38 (see Figure 3), a projected distance of 11 pc. BRC 38 is located within the Cepheus OB2 association, measured to be at a distance between 615 pc (de Zeeuw et al. 1999) and 750 pc (Matthews 1979). We will use 750 pc here to be consistent with most other studies, although doing so may overestimate luminosities by 40% and physical sizes by 20% (Choudhury et al. 2010). BRC 38 exhibits B-type morphology (Sugitani et al. 1991), with the southern edge being the brightest part in the optical.

Our work as proposed here will allow us to better understand the larger environment around BRC 38, and is a step en route to a better understanding of the whole IC1396 complex.

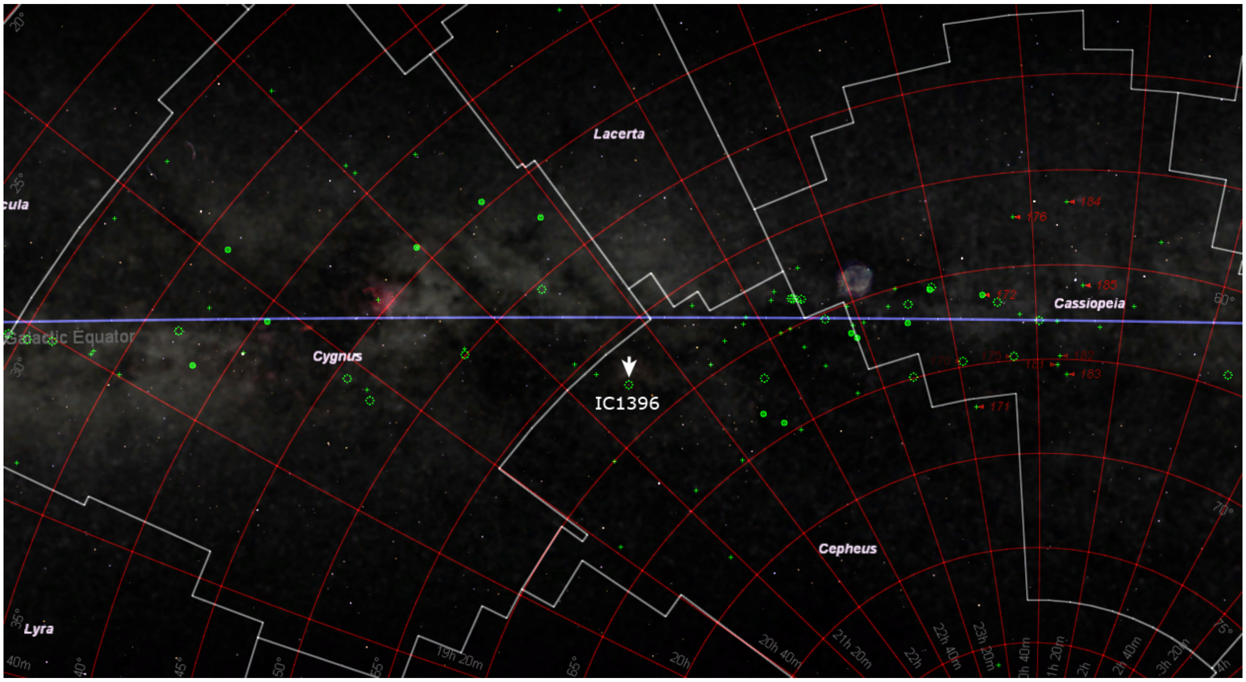

Figure 2: StarryNight image showing the Galactic plane (blue line) and location of local emission nebulae (green circles) within the Milky Way spiral arms. IC 1396 is labeled in the center of the image, and is located in the constellation Cepheus.

The central ~5'x5' region of BRC 38 has been extensively studied at a number of wavelengths with the goal of identifying potential YSOs. Choudhury et al. (2010) conducted a very thorough investigation of the YSO population in the central portion of BRC 38 using Spitzer IRAC (InfraRed Array Camera; 3.6-8 μm) and MIPS (Multiband Imaging Photometer) (24-70 μm) observations, as well as ground based-optical photometry and spectroscopy (Hα emissions, indicative of T Tauri stars). They identified 58 YSOs within BRC 38. The majority of the YSOs were located in the southern rim of BRC 38. Most of these are identified as class II, with a clear evolutionary sequence of YSOs from this rim inward to the core of the BRC 38, where star formation is progressing away from the dense bright rim. This also fits the Ogura et al. (2002) model that more evolved YSOs will be found closest to O or B type stars, which energize and shape the entire emission nebula. Using Hα grism spectroscopy and narrowband imaging, Ogura et al. (2002) identified 16 Hα emission stars around BRC 38 as part of a larger study of several BRCs. Beltrán et al. (2009) studied the central region of BRC 38 using deep J, H, and K bands, and narrow-band H2 observations to study the morphology of the region. They identified a complex structure of knots and chains of molecular hydrogen as well as outflows supporting recent star formation in the region. Getman et al. (2007), using the ACIS (AXAF CCD Imaging

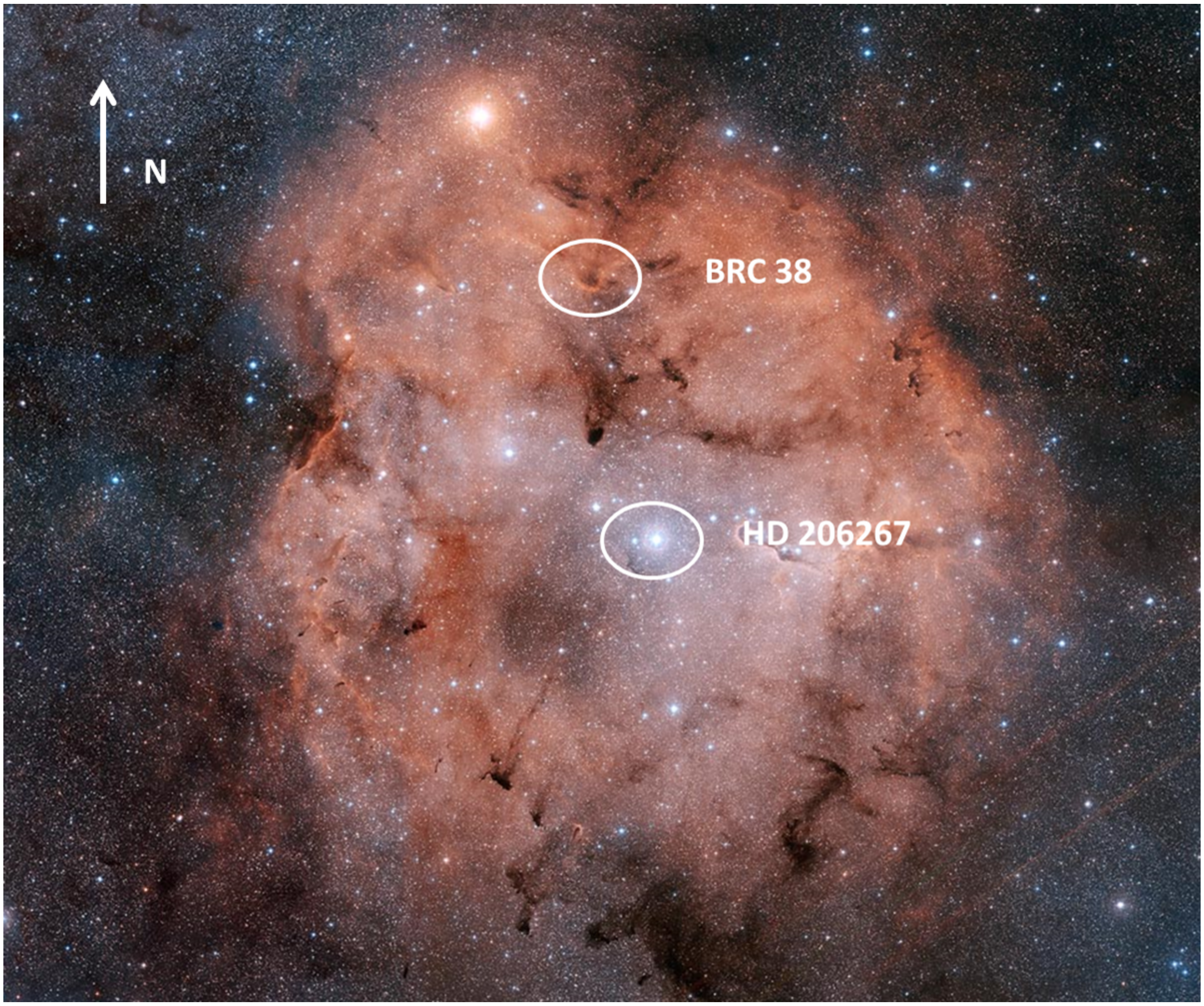

Figure 3: Optical composite image of IC 1396, taken with red and blue emulsion from Oschin Telescope at Palomar Observatory. This imagespans about 5 degrees on the sky. Circles indicate locations of BRC 38 and HD 206267. Other BRCs can be seen as black "fingers" on the edge of the HII region. (The underlying image comes from APOD, specifically http://apod.nasa.gov/apod/ap120805.html)

Spectrometer) instrument on the Chandra X-Ray Observatory to identify sources exhibiting violent magnetic reconnection flares (also indicative of T Tauri stars), found 25 YSOs within BRC 38.

There are two recent optical (r,i,Hα) studies of the entire IC 1396 complex. Nakano et al. (2012) identified 25 probable Hα emission line stars in the vicinity of BRC 38. Barentsen et al. (2011) used the Isaac Newton Telescope Photometric H-Alpha Survey (IPHAS), Hα and broad-band Sloan r' and i' filters, they identified 158 pre-main-sequence candidates in IC 1396. Several of these candidates were clustered around BRC 38. They also found evidence of an age gradient in star formation, providing additional evidence for triggered star formation in BRC 38 from the nearby HD206267.

2. Analysis Plan

Our methodology is similar to that for previous NITARP teams mentored by L. Rebull. Last year's C-WAYS team proposed to do this sort of analysis on three BRCs, including BRC 38; they decided to downscale once they got into the analysis, and in the end, they focused just on BRC 27 (Novatne et al. 2013). We will build on the work started by the CWAYS team, which is why our team is called C-CWEL (pronounced 'sequel'). Our methodology is somewhat similar to that in Rebull et al. (2011), which used WISE data to look for new members of the Taurus star-forming region, and to that in Rebull et al. (2013), which was a paper originating from a NITARP 2011 team, and which used primarily Spitzer data to look for new young stars in two other BRCs (27 and 34).

There are substantial data available in the literature for the central ~5'x5' region of BRC 38. The focus of our work will be a region ~20' in radius (~40' in diameter) centered on this region. We will start from data available over the entire region and include data in the central region, as available.

Beginning with the WISE (3.5, 4.6, 12, and 22 μm; Wright et al. 2010)and 2MASS (JHK_s, or 1.25, 1.65, and 2.17μm, respectively; Skrutskie et al. 2006) catalogs in the region of interest, we will first select YSO candidates from combinations of WISE and 2MASS colors. We will use the color selection scheme developed by Koenig et al. (2012) for WISE data. This scheme is modeled after the method developed by Gutermuth et al. (2008, 2009) for Spitzer data that allows for the reliable identification of YSO candidates while excluding extragalactic contamination. By running this selection algorithm, we will identify a subset of objects which we will investigate further, e.g., a set of IR-selected YSO candidates, or objects that appear to be YSOs with an IR excess.

The team will also assemble a list of YSO candidates and supporting ancillary data available from the literature and surveys, including (see Figure 4):

- Chandra X-ray data from Getman et al. (2007) – whole catalog published
- Optical data from Choudhury et al. (2010) – BVI data for selected objects
- Optical data from Chauhan et al. (2009)– photometry, spectra for selected objects
- Optical data from Ogura et al. (2002) – Hα data for selected objects
- Optical data from Barentsen et al. (2011) – r', i', Hα (IPHAS) for selected objects
- Optical data from IPHAS, the entire catalog in the region
- Optical data from Nakano et al. (2012) – i', Hα datafor selected objects
- Near infrared (NIR) data from 2MASS,the entire catalog in the region
- NIR data from Beltrán et al. (2009) – JHK data (~2 mags fainter than 2MASS) for the central region published, all objects they detected
- Mid-infrared (MIR) from WISE, the entire catalog in the region
- MIR from Japanese Akari (Astro-F), the entire catalog in the region (NB: data for one object in the region included in Nakano et al. 2012)
- MIR from Spitzer – central 4-band IRAC region for objects detected in 5.8 and 8 μm published by Choudhury et al. (2010); we will use their catalog, augmented by our photometry (including serendipitous IRAC and all MIPS data); more on this below.

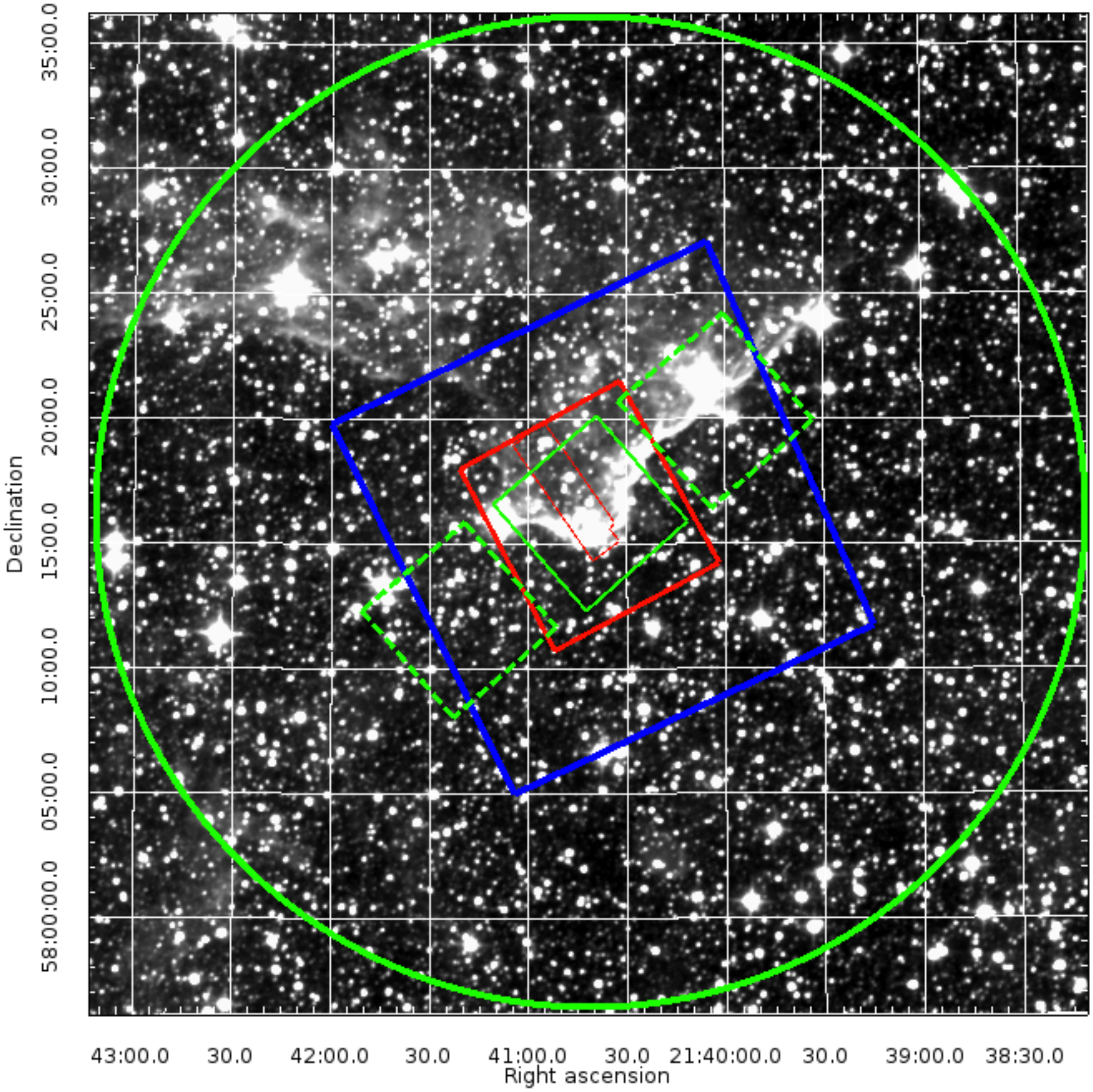

Figure 4: This WISE-4 (22μm) greyscale image of the BRC 38 region(~40' on a side) is the region of proposed study; the green circle is 20' in radius (~40' diameter). The central green square is the region covered by all four Spitzer IRAC bands. The green dashed-line square to the lower left is the serendipitous IRAC 2 & 4 (4.8 & 8 μm) data and the green dashed-line square in the upper right isthe serendipitous IRAC 1 & 3 (3.6 & 5.8 μm) data. The red square shows the Spitzer MIPS -24 μm coverage and the red rectangle is MIPS-70 μm coverage. The large blue box in the center is the Chandra field of view for the observation discussed in Getman et al. (2007). The optical data from Chauhan et al. (2011), Choudhury et al. (2010), and Ogura et al. (2002) are largely within the region of IRAC 4-band coverage. The deep JHK data from Beltrán et al. (2009) are in a region comparable to the IRAC 4-band coverage.

Some authors have published whole catalogs of their region of interest, and some have simply published lists of objects they have identified as YSOs or YSO candidates. As seen in Figure 4, most authors have data in just the central region of BRC 38. By combining the data for every point source in this region that we can identify in the literature, we will have a multiband, merged catalog that we can use in our analysis. We will identify the subset of these objects in our catalog. This will serve as the literature-identified YSOs and YSO candidates for our study.

We will merge the complete catalog of all point sources in the literature with the list ofpreviously identified YSOs and with the newly IR-selected YSOs. This will allow the team to:

- identify which of the YSOs/candidates from the literature were also recovered by the Koenig et al. (2012) selection algorithm, and which have additional data beyond what was originally published;
- identify which of the YSOs/candidates from the literature were NOT recovered by the Koenig et al. (2012) selection algorithm;
- identify which objects (not necessarily YSOs) from the literature that were recovered by the Koenig et al. (2012) selection algorithm, and which have additional data beyond WISE and 2MASS.

The objects of interest in this region, therefore, consist of the combination of objects selected by the Koenig et al. (2012) selection algorithm, plus the objects identified in the literature as YSOs and YSO candidates, whether or not they were selected independently by the Koenig et al. (2012) selection algorithm.

The Koenig et al. (2012) selection algorithm is not perfect, and can be fooled by background (or foreground) stars that only appear to have an IR excess due to contamination by nearby (in projection, e.g., apparently nearby on the sky) sources, or by background galaxies that have colors that are similar to YSOs in the IR. As such, each object needs to be inspected and assessed to see if any of the amassed evidence can rule it out (or confirm it) as a YSO. For each object identified as a potential YSO candidate or previously identified YSO, the team will proceed to do the following:

- visually inspect the object in as many images, from as many bands, as we can access to determine if it is a point source, assess the influence of extended emission on existing photometry catalogs, and discard objects that are obviously resolved galaxies;
- generate color-magnitude diagrams (CMD) and color-color diagrams (CCD) and identify the location of each of the objects in each diagram to determine if they are located in the regions associated with YSOs;
- construct an SED for each object using photometry from as many bands as we can access from the literature or from additional photometry done by our team (see below), identify the SED class of the YSO candidates, and discard objects that have SEDs inconsistent with YSOs;
- compare the spatial distribution of the YSOs by class to determine if there is an age gradient supporting the idea of triggered star formation in the region.

Using this process, our team will determine the final list of objects that are identified as new potential YSO candidates that we have discovered, and discuss properties of objects identified in the literature as YSOs or YSO candidates.

The photometry for most of the available data and catalogs is already available, except for the Spitzer data. There is only one Spitzer observation in this region in the Spitzer Heritage Archive. Choudhury et al (2010) worked only with the IRAC 4-band region, and only published data for objects detected in the last two channels in IRAC, and only did photometry in MIPS-24 for objects in the IRAC 4-band region. As such, there are some serendipitous 2-band IRAC data, some MIPS-24 data, and the MIPS-70 data that have not been published yet; there may be some objects of interest even in the 4-band region of IRAC that have data in <4 channels that may be of interest to our study. We will need to do photometry ourselves on these Spitzer data. The Spitzer data for BRC 38 will be obtained from the Spitzer Heritage Archive (SHA), specifically Astronomical Observation Request Key (AORKEY) 6032640 for IRAC bands, and 6032896 for MIPS bands. We will do photometry on the pipeline-produced mosaics of with the Aperture Photometry Tool (APT) developed by R. Laher, as described in Laher et al (2012a,b).

We will compile all of the photometry data using a Microsoft Excel spreadsheet, where we can perform the necessary calculations, such as flux density, energy density and magnitude conversions, as well as to produce color-color and color-magnitude diagrams, and also generate the SEDs.

We anticipate some challenges in keeping track of all the information on each source (previous NITARP teams have shared that difficulty with us). Due to the different spatial resolutions between all of these instruments and therefore catalogs, we will pay special attention to the spatial resolution of each catalog as we identify the point sources across bands.

3. Educational Outreach

NITARP is a unique program in the STEM education field, providing authentic research, expert guidance by practicing astrophysicists, and an interactive professional learning community to support educators as they work to simultaneously learn to conduct new astronomical research and create learning programs that connect other educators and secondary students to the research process. One of the factors for the program's success is that scientists and teachers work together recognizing each others' expertise and towards the creation of new STEM learning opportunities. As a result, there will be three education outreach products from this work in addition to the astronomical research. We outline below our proposed plan for an education poster, individual educator plans for reaching secondary students and our proposed outreach efforts to support educator professional development.

3.1 Education Methodologies

Learning takes place in a complex web of interactions during a NITARP research project. This means that at any given time we may be learning astronomical content knowledge, field specific research methodology, computer programs or devising teaching methods. As a result, there will be critical junctures where we need support as we work to develop our teaching with the additional of authentic astronomy research opportunities. We will utilize previously established education research methodologies (Laurence et al, 2006; Laurence et al, 2007 & Slavit et al, 2009) to document our learning process and the effective supports that allow us to continue this work.

Recently, the field of educational research has used several methodologies to trace teacher learning, interactions with supports and subsequent changes in teaching. Documenting teachers' questions, choices of supports and learning patterns through reflection and dialogic inquiry has allowed for deeper understanding of teacher learning needs, resource access patterns and usefulness of individual supports (e.g., Laurence et al 2007; Slavit et al, 2009). Given the short time period we have to work with, we will use a simplified methodology grounded in the conceptual frameworks of self-explanation (Chi, Slotta & de Leeuw, 1994 & de Leeuw & Chi, 2003); the use of dialogic inquiry to understand knowledge negotiation between teachers and scientists (Nelson, 2005) and the documentation of teacher questions and supports (Laurence, et al 2007). For the purposes of this work we will individually track our questions that need to be addressed as we progress through the project. Through individual journals, group discussions and Journal Club discussions, we will keep track of our questions and the resources that support our learning and address our questions. A final group reflection by the group on the learning process will allow us to code our questions and resources to determine successful patterns of support based on the identified critical junctures in our learning. By tracking our questions, critical junctures, and the effective supports, we can give back to the NITARP project a series of supports that can assist the program as it continues its ground-breaking work.

3.2 Secondary Student Learning Opportunities

The C-CWEL team is comprised of both traditional and non-traditional educators. Three members are high school classroom teachers. Two members provide educational opportunities to visitors of observatories and science centers or provide assistance to teachers looking for research based science partnerships in their classrooms. The sixth member provides professional development for educators and designs curriculum for NASA's Aerospace Educators Service Program. All members are looking for an opportunity to experience the process of authentic astronomical research for the benefits it will bring to their unique work situations but they also united in an effort to improve the education and opportunities for the next generation of scientists. Below we discuss our plans for reaching secondary students in formal classrooms and through informal learning in planetariums or government outreach programs.

3.3 Classroom-Based Educators

Conducting authentic research is a key initiative in science education at the secondary and undergraduate level. It is also an activity eagerly sought by educators. Using real astronomical data provides educators and students an opportunity to experience the process of project development, teamwork, data collection and analysis, interpretation of results, and formal scientific presentations. These results of these activities will be shared through presentations at state, regional and national conferences and community events.

Glencoe High School (J. Gibbs)

Students at Glencoe High School will have the opportunity to participate in the C-CWEL research with Mr. Gibbs. Currently, Glencoe has a team of five sophomores which meets once a week to work on astronomical projects. The Glencoe Team will continue to meet in the Spring of 2013 and will begin to transition to the C-CWEL Team's project and exploration of BRC 38. To prepare we will review several background concepts such as the process of star formation and evolution, electromagnetic radiation and the relationship of temperature to wavelength (Wien's Law) of a blackbody curve and the current body of literature related to BRC 38. As these students progress in their astronomical understanding, they will be able to mentor and teach these concepts to the new students who join the team thus creating a sustainable astronomy program. In addition to presenting our research at the American Astronomical Society (AAS) winter meeting in 2014, students will make a presentation to the Glencoe High School staff and later to the Hillsboro School District school board.

Ravenscroft School (M. Murphy)

Ravenscroft School students will participate in the NITARP research project as an extracurricular activity during the spring and summer of 2013, and as a semester long research-based independent study course for credit during the fall of 2013. Participating students, all of whom are enrolled in Ravenscroft's astronomy course, were selected via an application process in March 2013. Participants will learn about the scientific research process, as well as gain a deeper understanding of the physics of stellar formation. Activities will include reviewing and discussing relevant journal articles; accessing, sorting, and reducing data from NASA archives; conducting photometric analysis of infrared and optical sources; performing astronomic image processing; and preparing to present results of scientific research to the professional community and the public through papers and posters. After the January 2014 AAS meeting, participants will present their research to the Honors Astronomy (Stellar and Galactic) class, as well as at other venues and outreach activities.

Ukiah High School (L. Orr)

The students in Ukiah High school will be given the opportunity to participate in the NITARP C-CWEL research project as a part of an extracurricular club in astronomy and research science during the fall, summer, and spring of 2013. The student team will be comprised of upper high school students from both Ukiah School and nearby Pilot Rock High School. Over the course of the year, the students will learn about the research process, gain additional instruction and guided application of the physics related to stellar formation, expand on their knowledge and understanding of stellar evolution and astronomy, and participate in the data analysis of this investigation, and gain experience in scientific communication. The students will give a presentation of the experience and their results to the staff of Ukiah School, the school board, and during a public outreach event in the community as well as during the January AAS in 2014.

Laura Orr, as a NITARP researcher, will use the experience to gain a better understanding of astronomical research as well as the process of proposing, conducting, and presenting authentic research. She will share the experience and skills with other middle and high school teachers in her region and state via workshops and professional development presentations given at a local, state, regional and national level.

3.4 University- and Planetarium-Based Educators

Buhl Planetarium & Observatory at Carnegie Science Center (R. Marshall)

At Carnegie Science Center, presentations of multiple variations will be shared with staff, visitors, Pittsburgh Regional Science and Engineering Fair (PRSEF) students, and special audiences during the course of this research project. Full dome visuals of the location of BRC 38 in the Buhl Planetarium have already been programmed and will be continually shared with the public. A student/teacher lab packaged workshop will be created after the completion of this project. Additional presentations may include venues such as the National Science Teacher Association (NSTA) conferences.

Pisgah Astronomical Research Institute (PARI) (C. Whitworth)

Ms. Whitworth will develop opportunities for gifted high school students, adult learners and other interested researchers to pursue team-based and individual research endeavors through Pisgah Astronomical Research Institute. These research opportunities will focus on developing astronomical research skills for participants. The research project opportunities will be based on the skills and software used in this research. Topics may include detecting potential YSOs in other regions, validating YSO detection found in other research, and reviewing new data sets for continued validation of YSO detection. PARI participants will learn about infrared properties of light as compared to other wavelengths, develop astronomy research topics using other wavelength sources, utilize IPAC data sets to investigate research questions, manage and manipulate data in MS Excel and study early life cycles of stars.

3.5 Professional Development Outreach

NASA Aerospace Education Services Project (W. Laurence)

Wendi's professional work includes teaching graduate education courses in curriculum and instructional theory, providing teacher professional development and designing curriculum for in-person and on-line learning. Her outreach for this program will include supporting a NASA Summer of Innovation National Awardee, the South Dakota Discovery Center, in their implementation of astronomy camps and support of educator professional developmentin both astronomy content and STEM pedagogy and resources. A series of on-line webinars will take place during the spring of 2013 and will be augmented by two on-site professional development programs in March and May of 2013. In addition, lessons learned during the NITARP experience will be included in a presentation at the National Science Teachers Association Annual meeting in San Antonio, Texas in April. This presentation looks at ways to teach across the curriculum using NASA materials and NITARP will be included at the intersection of STEAM and the arts.

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