Star Formation Newsletter
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野村英子 (国立天文台)

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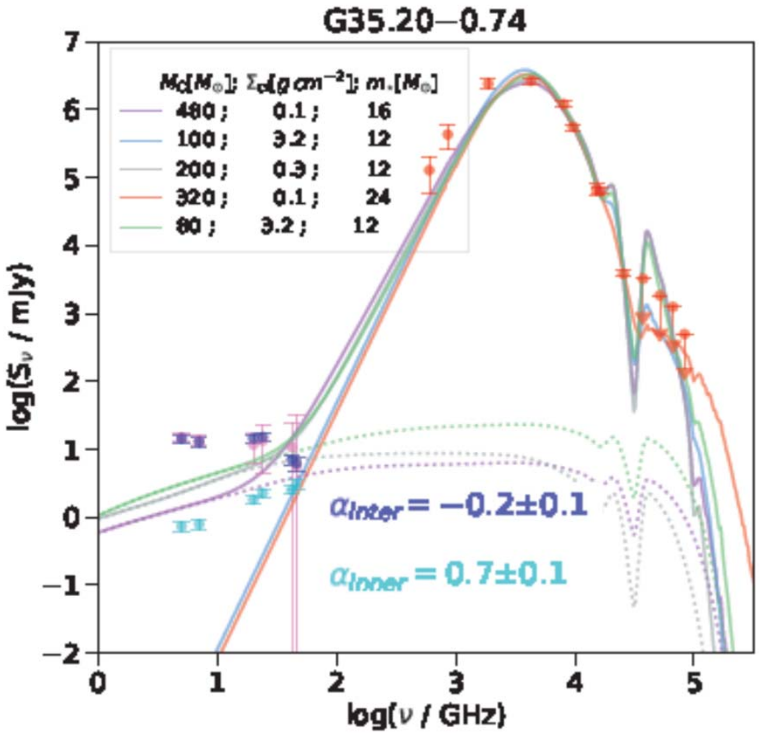
65. The SOMA Radio Survey. I. Comprehensive SEDs Of High-Mass Protostars From Infrared To Radio And The Emergence Of Ionization Feedback

V. Rosero[1,2,3], K. E. I. Tanaka[4,5,3], J. C. Tan[6,2], J. Marvil[1], M. Liu[2,3], Y. Zhang[7], J. M. De Buizer[8], M. T. Beltrán[9]

- SOFIA Massive (SOMA) Star Formation Surveyのサンプル８天体のFIRからセンチ波までのSEDを調べた。
- Tanaka, Tan & Zhang (2016; TTZ16)の輻射&円盤風フィードバックモデルと比較し、よい一致が得られた。
- FIR-センチ波SEDとモデルより、中心星質量によい制限が得られた。
- 大質量星周囲の小質量星も検出した



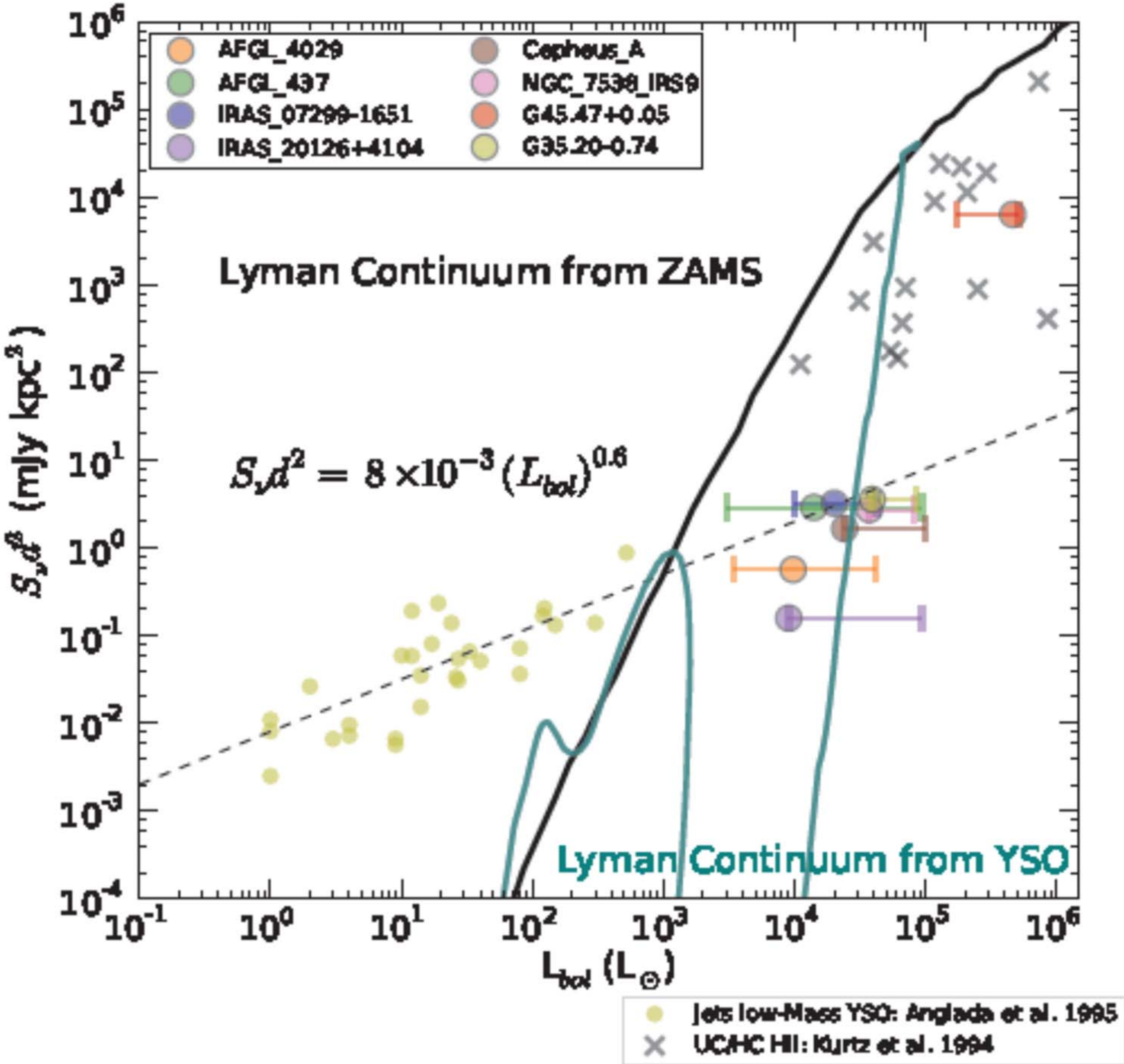
- データ
  SOFIA-FORCAST (~10-40um)
  + VLA 0.7, 1.3 & 6 cm
- ターゲット天体
  L~10^4-10^5 L_sun, d~2 kpc (0.7, 8.4 kpc)

・今回のターゲット天体のセンチ波-前放射強度の関係は、主に小質量星YSOジェット天体の関係とよい一致。また、TTZ16モデル(青線)ともよい一致。

・G45.47に関しては、UC/HC HII領域の関係とよい一致。(TTZ16モデルともよい一致。)

・数天体では、大質量星周囲に若い小質量星と考えられる時間変動する天体が見つかった。ただし、数は多くない。

- 検出限界？
- competitive accretion model との関連？

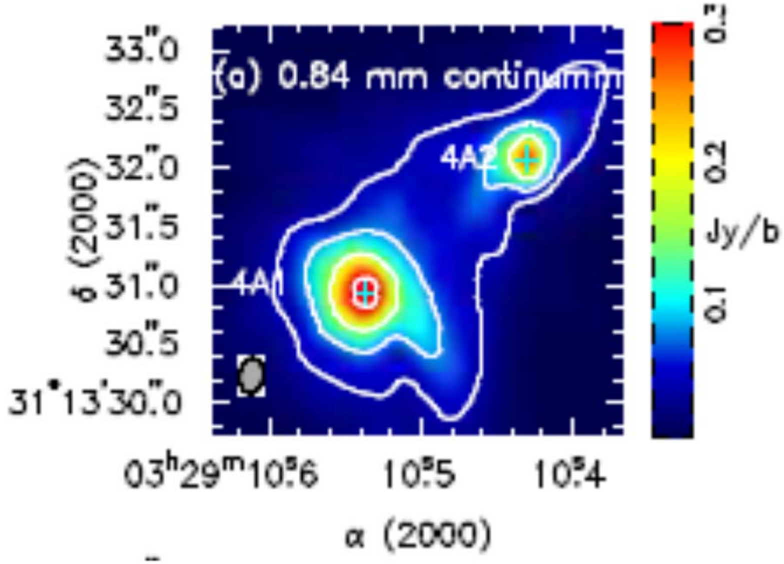


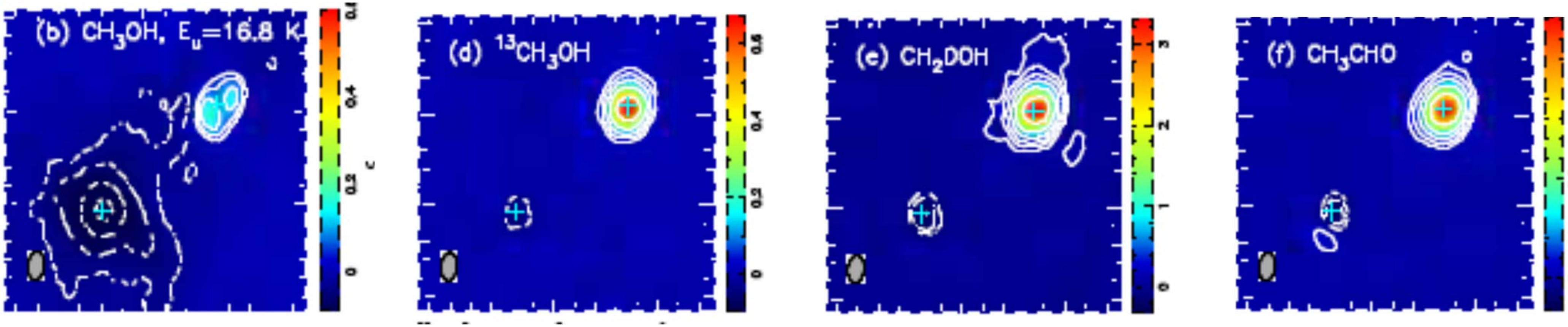
66. **Implications of a hot atmosphere/corino from ALMA observations towards NGC1333 IRAS 4A1**

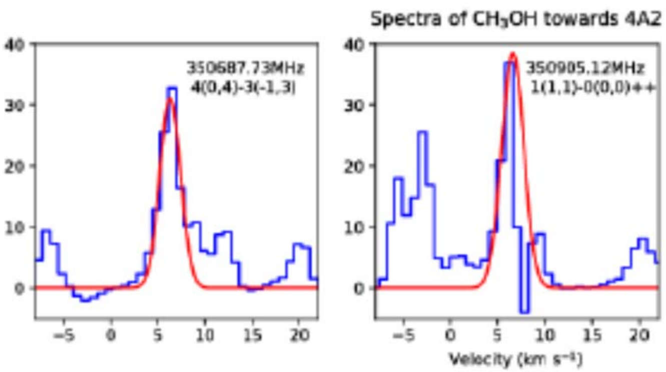
DIPEN SAHU,[1,*] SHENG-YUAN LIU,[2] YU-NUNG SU,[2] ZHI-YUN LI,[3] CHIN-FEI LEE,[2] NAOMI HIRANO,[2] AND SHIGEHISA TAKAKUWA[4,2]

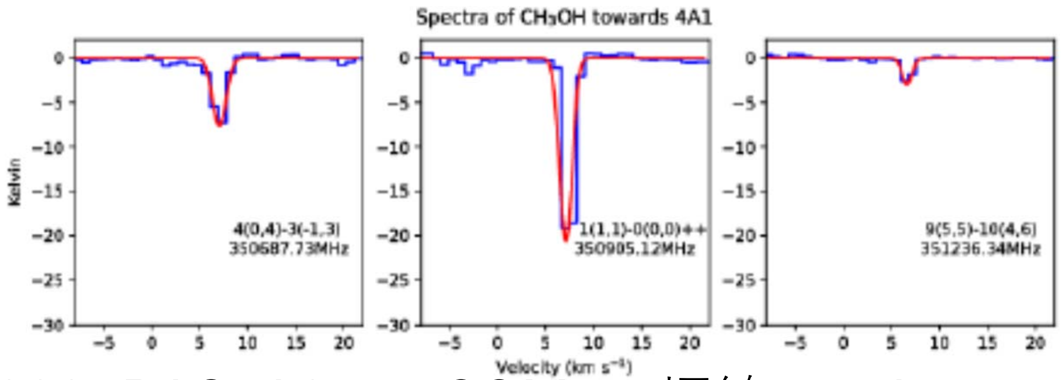
・ALMAにより、若い連星系NGC1333 IRAS4Aを観測した。
・天体A1よりCOMs (CH3OH, 13CH3OH, CH2DOH, CH3CHO)を吸収線で検出した。
・吸収線は、A1に付随する円盤上層部もしくは、エンベロープ中の分子を見ていると考えられる。

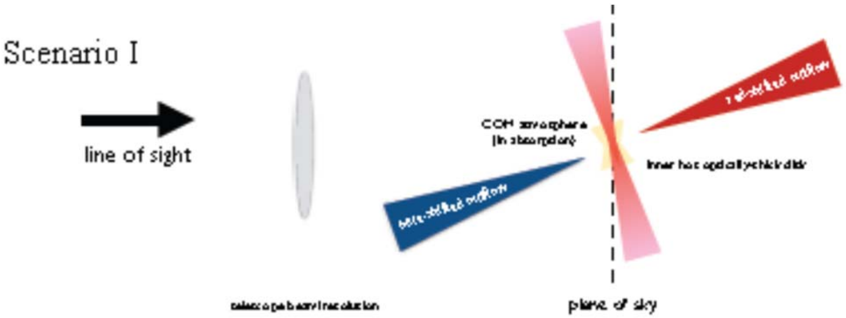
・データ：ALMA cycle 3, Band 7, angular res. ~0.3”
・ターゲット天体
NGC1333 IRAS4A2: 有名なhot corino天体
A1ではこれまでCOMsの検出報告はなかった
ダスト連続波は、4A1の方が強い











- NGC1333 IRAS4A2ではCOMsは輝線で、A1では吸収線で検出された
- ダスト放射はA2は光学的に薄く、A1は厚いと考えられる
- A1, A2どちらも CH_2DOH/CH_3OH ~0.01

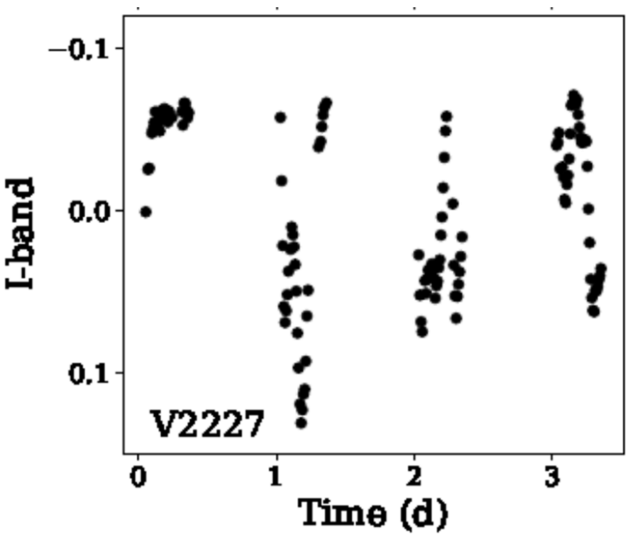
69. Clumpy dust rings around non-accreting young stars

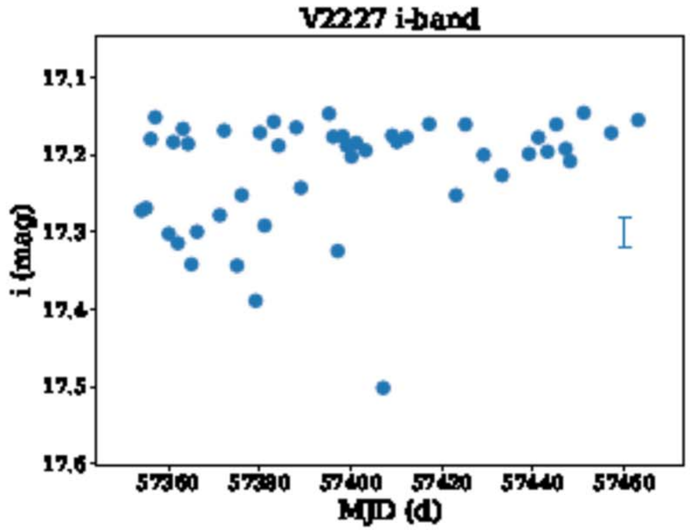
Aleks Scholz[1*], Antonella Natta[2], Inna Bozhinova[1], Maya Petkova[1,4], Howard Relles[1], Jochen Eislöffel[3]

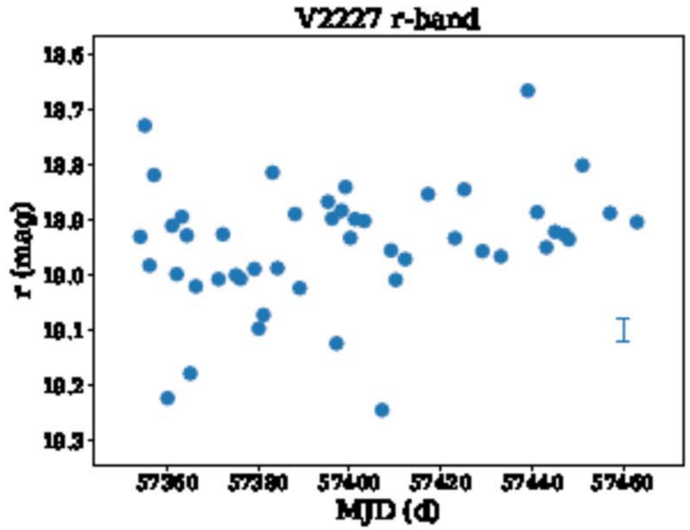
・若いが降着の兆候を示さない４つの天体より、可視光３バンドで変則的なeclipseを見つけた。
・eclipse源は、ダストによる減光とconsistentなreddeningを示した。
・eclipse源は、半径0.01AUから40AUに存在する、光学的に薄いダスト・クランプで原始惑星系円盤から残骸円盤へ移行するフェーズを見ているのかもしれない。

・ターゲット天体
ε Ori中の不規則な変動を示す天体４天体を選んだ。
中心質量は0.3-0.5M_sun。Hα のEWは小さい(3-14Å)。
8, 12, 24umでexcessを示すが、非常に弱い。

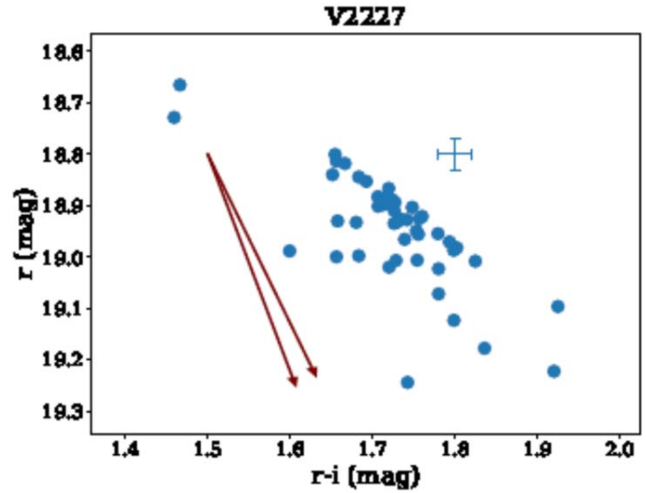
・データ
i, r, Vバンドの光度曲線を解析。WISE 3.6 & 4.5 umも解析したが、こちらは優位な変動は確認できなかった。



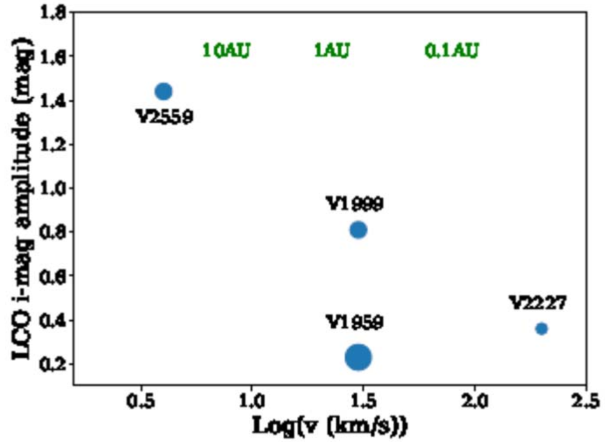


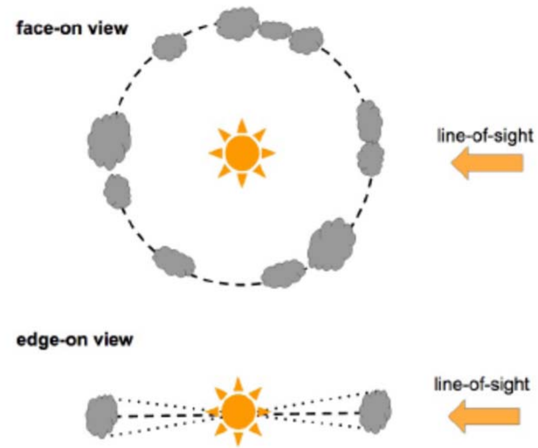


光度曲線



減光(赤化)





ダスト雲の速度・軌道超半径

61. **The Gaia-ESO Survey: age spread in the star forming region NGC 6530 from the HR diagram and gravity indicators**

L. Prisinzano[1], F. Damiani[1], V. Kalari[2,3], R. Jeffries[4], R. Bonito[1], G. Micela[1], N. J. Wright[4], R. J. Jackson[4], E. Tognelli[5], M. G. Guarcello[1], J. S. Vink[3], A. Klutsch[6], F. M. Jiménez-Esteban[7], V.

In very young clusters, the stellar age distribution is the empirical proof of the duration of star cluster formation and thus it gives indications of the physical mechanisms involved in the star formation process. Determining the amount of interstellar extinction and the correct reddening law are crucial steps to derive fundamental stellar parameters and in particular accurate ages from the HR diagram. In this context, we derived accurate stellar ages for NGC 6530, the young cluster associated with the Lagoon Nebula to infer the star formation history of this region. We use the *Gaia*-ESO survey observations of the Lagoon Nebula, together with photometric literature data and *Gaia* DR2 kinematics, to derive cluster membership and fundamental stellar parameters. Using spectroscopic effective temperatures, we analyze the reddening properties of all objects and derive accurate stellar ages for cluster members. We identified 652 confirmed and 9 probable members. The reddening inferred for members and non-members allows us to distinguish foreground objects, mainly main-sequence (MS) stars, and background objects, mainly giants. This classification is in agreement with the distances inferred from *Gaia* DR2 parallaxes for these objects. The foreground and background stars show a spatial pattern that allows us to trace the three-dimensional structure of the nebular dust component. Finally, we derive stellar ages for 382 confirmed cluster members for which we obtained the individual reddening values. In addition, we find that the gravity-sensitive γ index distribution for the M-type stars is correlated with stellar age. For all members with $T_{eff} < 5500$ K, the mean logarithmic age is 5.84 (units of years) with a dispersion of 0.36 dex. The age distribution of stars with accretion and/or disk (CTTSe) is similar to that of stars without accretion and without disk (WTTSp). We interpret this dispersion as evidence of a real age spread since the total uncertainties on age determinations, derived from Monte Carlo simulations, are significantly smaller than the observed spread. This conclusion is supported by the evidence of a decreasing of the gravity-sensitive γ index as a function of stellar ages. The presence of a small age spread is also supported by the spatial distribution and the kinematics of old and young members. In particular, members with accretion and/or disk, formed in the last 1 Myr, show evidence of subclustering around the cluster center, in the Hourglass Nebula and in the M8-E region, suggesting a possible triggering of star formation events by the O-type star ionization fronts.

Accepted by Astronomy and Astrophysics

62. **The HH34 jet/counterjet system at 1.5 and 4.5 μm**

A. C. Raga[1], B. Reipurth[2], A. Noriega-Crespo[3]

We present a (previously unpublished) 1.5 μm archival HST image of the HH 34 Herbig-Haro jet, in which the northern counterjet is seen at an unprecedented angular resolution of $\sim 0.1''$ (this counterjet had only been imaged previously at lower resolution with Spitzer). The jet/counterjet structure observed in this image shows evidence of low-amplitude, point-symmetric deviations from the outflow axis, indicating the presence of a precession in the ejection direction. We use the ratios between the 1.5 and 4.5 μm intensities of the emitting knots (from the HST image and from a previously published 4.5 μm Spitzer image) to obtain an estimate of the spatial dependence of the optical extinction to the HH 34 jet/counterjet system. We find evidence for extinction from a central, dense core surrounding the outflow source and from a more extended region in the foreground of the HH 34 counterjet.

Accepted by RMxAA

63. MHD simulations of the formation and propagation of protostellar jets to observational length scales

Jon P. Ramsey[1,3] and David A. Clarke[2]

We present 2.5-D global, ideal MHD simulations of magnetically and rotationally driven protostellar jets from Keplerian accretion discs, wherein only the initial magnetic field strength at the inner radius of the disc, $B_{\rm i}$, is varied. Using the AMR-MHD code AZEuS, we self-consistently follow the jet evolution into the observational regime ($> 10^3$ AU) with a spatial dynamic range of $\sim 6.5 \times 10^5$. The simulations reveal a three-component outflow: 1) A hot, dense, super-fast and highly magnetised 'jet core'; 2) a cold, rarefied, trans-fast and highly magnetised 'sheath' surrounding the jet core and extending to a tangential discontinuity; and 3) a warm, dense, trans-slow and weakly magnetised shocked ambient medium entrained by the advancing bow shock. The simulations reveal power-law relationships between $B_{\rm i}$ and the jet advance speed, $v_{\rm jet}$, the average jet rotation speed, $\langle v_\varphi \rangle$, as well as fluxes of mass, momentum, and kinetic energy. Quantities that do not depend on $B_{\rm i}$ include the plasma-β of the transported material which, in all cases, seems to asymptote to order unity. Jets are launched by a combination of the 'magnetic tower' and 'bead-on-a-wire' mechanisms, with the former accounting for most of the jet acceleration—even for strong fields—and continuing well beyond the fast magnetosonic point. At no time does the leading bow shock leave the domain and, as such, these simulations generate large-scale jets that reproduce many of the observed properties of protostellar jets including their characteristic speeds and transported fluxes.

Accepted by MNRAS

64. **The G332 molecular cloud ring: I. Morphology and physical characteristics**

Domenico Romano[1,2], Michael G. Burton[1,3], Michael C.B. Ashley[1], Sergio Molinari[2], David Rebolledo[4,5], Catherine Braiding[1] and Eugenio Schisano[2,6]

We present a morphological and physical analysis of a Giant Molecular Cloud (GMC) using the carbon monoxide isotopologues (^{12}CO, ^{13}CO, C^{18}O $^3P_2 \rightarrow {}^3P_1$) survey of the Galactic Plane (Mopra CO Southern Galactic Plane Survey), supplemented with neutral carbon maps from the HEAT telescope in Antarctica. The giant molecular cloud structure (hereinafter the ring) covers the sky region $332° < l < 333°$ and $b = \pm0.°5$ (hereinafter the G332 region). The mass of the ring and its distance are determined to be respectively $\sim 2 \times 10^5$ $M_\odot$ and ~3.7 kpc from Sun. The dark molecular gas fraction, estimated from the ^{13}CO and [CI] lines, is ~17% for a CO $T_{\rm ex}$ between [10, 20 K]. Comparing the [CI] integrated intensity and N(H$_2$) traced by ^{13}CO and ^{12}CO, we define an $X^{809}_{\rm CI}$ factor, analogous to the usual $X_{\rm CO}$, through the [CI] line. $X^{809}_{\rm CI}$ ranges between $[1.8, 2.0] \times 10^{21}$ cm^{-2} K^{-1} km^{-1} s. We examined local variation in $X_{\rm CO}$ and $T_{\rm ex}$ across the cloud, and find in regions where the star formation activity is not in an advanced state, an increase in the mean and dispersion of the $X_{\rm CO}$ factor as the excitation temperature decreases. We present a catalogue of C^{18}O clumps within the cloud. The star formation (SF) activity ongoing in the cloud shows a correlation with $T_{\rm ex}$, [CI] and CO emissions, and anti-correlation with $X_{\rm CO}$, suggesting a North-South spatial gradient in the SF activity. We propose a method to disentangle dust emission across the Galaxy, using HI and ^{13}CO data. We describe Virtual Reality (VR) and Augmented Reality (AR) data visualisation techniques for the analysis of radio astronomy data.

Accepted by MNRAS

67. Discovery of a sub-Keplerian disk with jet around a 20 $M_\odot$ young star. ALMA observations of G023.01-00.41

A. Sanna[1], A. Koelligan[2], L. Moscadelli[3], R. Kuiper[2], R. Cesaroni[3], T. Pillai[1], K.M. Menten[1], Q. Zhang[4], A. Caratti o Garatti[5], C. Goddi[6], S. Leurini[7] and C. Carrasco-Gonzalez[8]

It is well established that Solar-mass stars gain mass via disk accretion, until the mass reservoir of the disk is exhausted and dispersed, or condenses into planetesimals. Accretion disks are intimately coupled with mass ejection via polar cavities, in the form of jets and less collimated winds, which allow mass accretion through the disk by removing a substantial fraction of its angular momentum. Whether disk accretion is the mechanism leading to the formation of stars with much higher masses is still unclear. Here, we are able to build a comprehensive picture for the formation of an O-type star, by directly imaging a molecular disk which rotates and undergoes infall around the central star, and drives a molecular jet which arises from the inner disk regions. The accretion disk is truncated between 2000–3000 au, it has a mass of about a tenth of the central star mass, and is infalling towards the central star at a high rate ($6 \times 10^{-4}\,M_\odot\,yr^{-1}$), as to build up a very massive object. These findings, obtained with the Atacama Large Millimeter/submillimeter Array at 700 au resolution, provide observational proof that young massive stars can form via disk accretion much like Solar-mass stars.

Accepted by Astronomy & Astrophysics

68. **Protostellar Outflows at the EarliesT Stages (POETS). II. A possible radio synchrotron jet associated with the EGO G035.02+0.35**

A. Sanna[1], L. Moscadelli[2], C. Goddi[3], M. Beltrán[2], C.L. Brogan[4], A. Caratti o Garatti[5], C. Carrasco-González[6], T.R. Hunter[4], F. Massi[2] and M. Padovani[2]

Centimeter continuum observations of protostellar jets have revealed the presence of knots of shocked gas where the flux density decreases with frequency. This spectrum is characteristic of nonthermal synchrotron radiation and implies the presence of both magnetic fields and relativistic electrons in protostellar jets. Here, we report on one of the few detections of nonthermal jet driven by a young massive star in the star-forming region G035.02+0.35. We made use of the NSF's Karl G. Jansky Very Large Array (VLA) to observe this region at C, Ku, and K bands with the A- and B-array configurations, and obtained sensitive radio continuum maps down to a rms of $10\,\mu$Jy beam^{-1}. These observations allow for a detailed spectral index analysis of the radio continuum emission in the region, which we interpret as a protostellar jet with a number of knots aligned with extended $4.5\,\mu$m emission. Two knots clearly emit nonthermal radiation and are found at similar distances, of approximately 10,000 au, each side of the central young star, from which they expand at velocities of hundreds km s^{-1}. We estimate both the mechanical force and the magnetic field associated with the radio jet, and infer a lower limit of $0.4 \times 10^{-4}\,M_{\odot}\,yr^{-1}\,km\,s^{-1}$ and values in the range 0.7–1.3 mG, respectively.

Accepted by Astronomy & Astrophysics

70 **Is Molecular Cloud Turbulence Driven by External Supernova Explosions?**

D. Seifried[1], S. Walch[1], S. Haid[1], P. Girichidis[2,3] and T. Naab[4]

We present high-resolution ($\sim$ 0.1 pc), hydrodynamical and magneto-hydrodynamical simulations to investigate whether the observed level of molecular cloud (MC) turbulence can be generated and maintained by external supernova (SN) explosions. The MCs are formed self-consistently within their large-scale galactic environment following the non-equilibrium formation of H_2 and CO including (self-) shielding and important heating and cooling processes. The MCs inherit their initial level of turbulence from the diffuse ISM, where turbulence is injected by SN explosions. However, by systematically exploring the effect of individual SNe going off outside the clouds, we show that at later stages the importance of SN driven turbulence is decreased significantly. This holds for different MC masses as well as MCs with and without magnetic fields. The SN impact also decreases rapidly with larger distances. Nearby SNe ($d \sim 25$ pc) boost the turbulent velocity dispersions of the MC by up to 70 per cent (up to a few km s^{-1}). For $d > 50$ pc, however, their impact decreases fast with increasing d and is almost negligible. For all probed distances the gain in velocity dispersion decays rapidly within a few 100 kyr. This is significantly shorter than the average timescale for a MC to be hit by a nearby SN under solar neighbourhood conditions ($\sim$ 2 Myr). Hence, at these conditions SNe are not able to sustain the observed level of MC turbulence. However, in environments with high gas surface densities and SN rates like the Central Molecular Zone, observed elevated MC dispersions could be triggered by external SNe.

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