Уральский федеральный университет имени первого Президента России Б.Н.Ельцина

Мазеры в протозвездных дисках (феноменология)

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Коуровская астрономическая обсерватория,

Уральский федеральный университет

(работа поддержана грантом РФФИ 20-52-53054)

Динамическая и химическая эволюция протопланетных дисков
3-4 марта 2021

- Sanna A., Moscadelli L., Surcis G. et al. 2017, A&A, 603, A94
  "Planar infall of CH_3OH gas around Cepheus A HW2"
- Sobolev A.M., Ladeyschikov D.A., Nakashima J.I. 2019, RAA, 19, 34
  "Database of molecular masers and variable stars"
- Meyer D.M.-A., Vorobyov E.I., Elbakyan V.G. et al. 2019, MNRAS, 482, 5459
  "Burst occurrence in young massive stellar objects"
- Brogan C.L., Hunter T.R., Towner A.P.M. et al. 2019, ApJL, 881, L39
  "Sub-arcsecond (Sub)millimeter Imaging of the Massive Protocluster G358.93-0.03: Discovery of 14 New Methanol Maser Lines Associated with a Hot Core"
- Burns R.A., Sugiyama K., Hirota T. et al. 2020, Nature Astronomy, 4, 506
  "A heatwave of accretion energy traced by masers in the G358-MM1 high-mass protostar"
- Chen Xi et al., Sobolev A.M., Breen S.L. et al. 2020, ApJL, 876, 22C
  "$^{13}CH_3OH$ Masers Associated With a Transient Phenomenon in a High-mass Young Stellar Object"
- Chen Xi, Sobolev A.M., Ren Z.-Y. et al. 2020, Nature Astronomy, tmp.. 144C
  "New maser species tracing spiral-arm accretion flows in a high-mass young stellar object"
- Stecklum B., Wolf V., Linz H. et al. 2021, A&A, 646, 161
  "Infrared observations of the flaring maser source G358.93-0.03.
  SOFIA confirms an accretion burst from a massive young stellar object"

Astrophysical Masers and their Environments
Proceedings IAU Symposium No. 242, 2007
J.M. Chapman & W.A. Baan, eds.

doi:10.1017/S1743921307012999

Investigating high-mass star formation through maser surveys

S. P. Ellingsen[1], M. A. Voronkov[2], D. M. Cragg[3], A. M. Sobolev[4], S. L. Breen[1] and P. D. Godfrey[3]

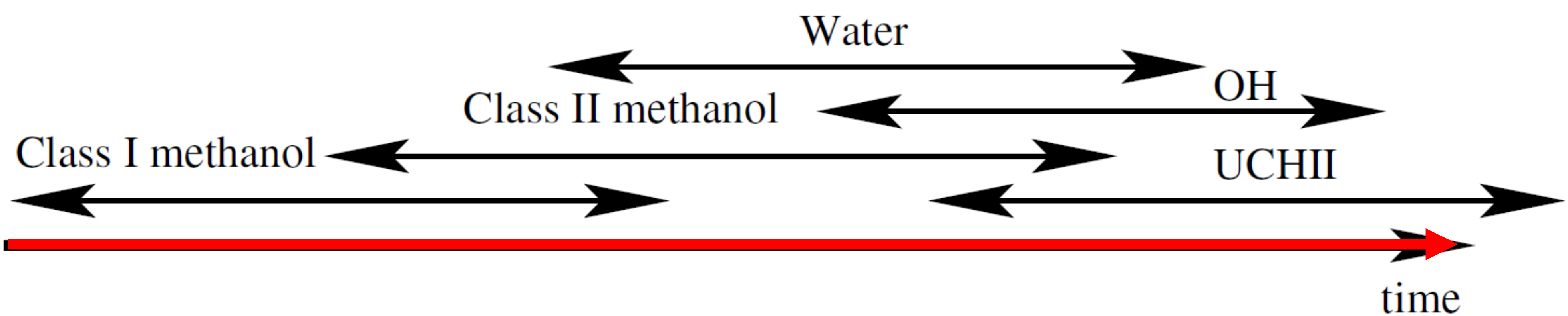
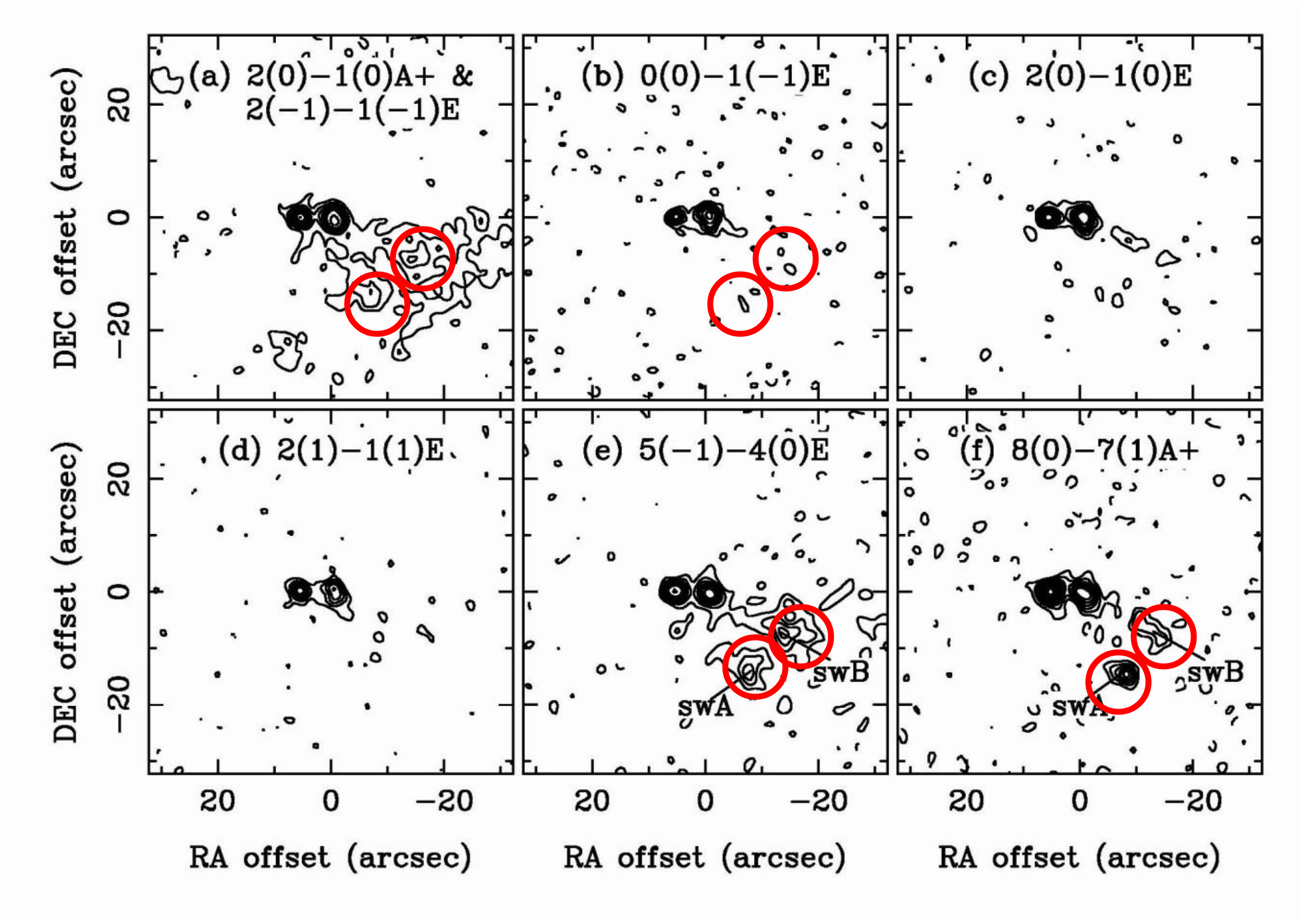


Figure 2. A "straw man" evolutionary sequence for masers in high-mass star formation regions.

Class I methanol masers have potential to trace the youngest stages of the massive protostar formation

(Strelnitskij 1982), (Sobolev & Strelnitskij 1983)



(Sutton, Sobolev, Salii, Malyshev, Ostrovskii, Zinchenko 2004)

The masing environment of star forming object IRAS 00338+6312: Disk, outflow, or both ?

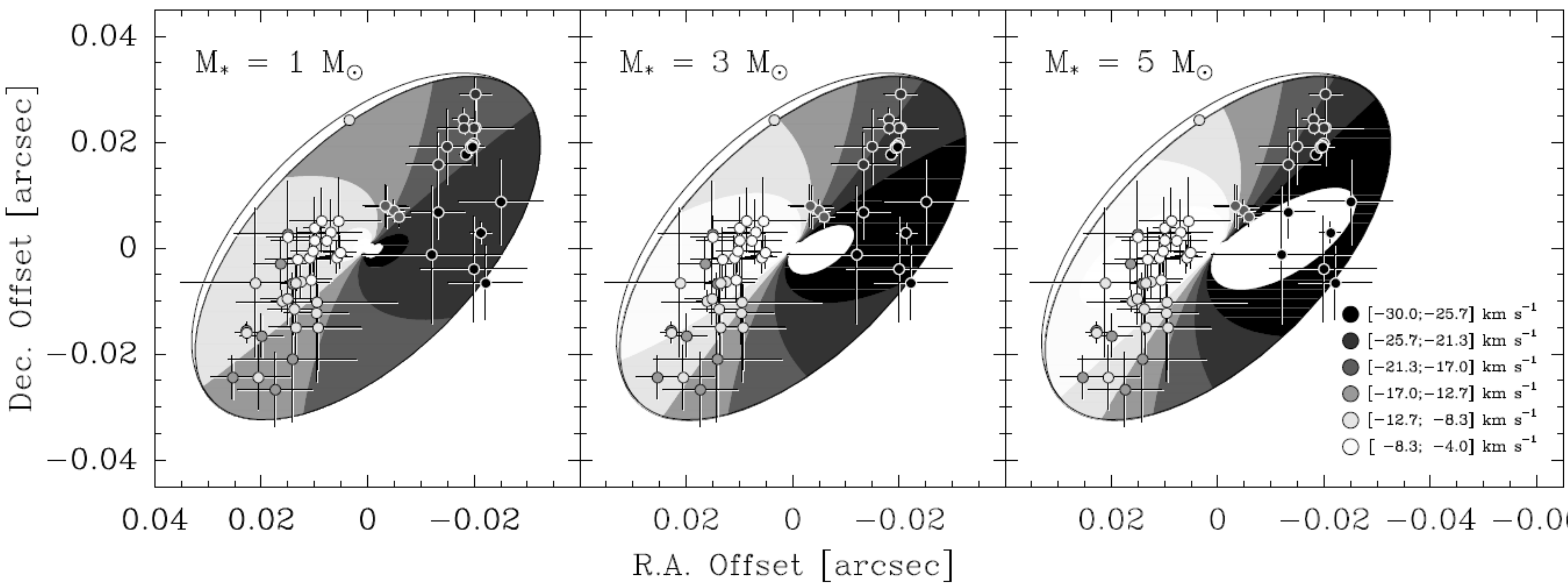
Astron. Astrophys. 310, 199–210 (1996)

D. Fiebig[1]*, W.J. Duschl[1,2], K.M. Menten[3], and W.M. Tscharnuter[1]

L 1287 (H_2O): accretion disk-impinging-clumps traced by masers?

D. Fiebig

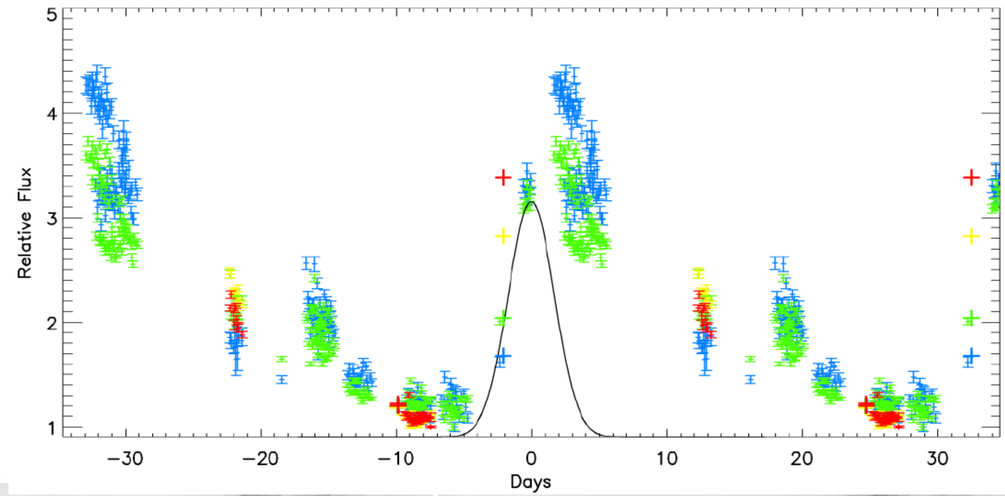
Astron. Astrophys. 327, 758–770 (1997)

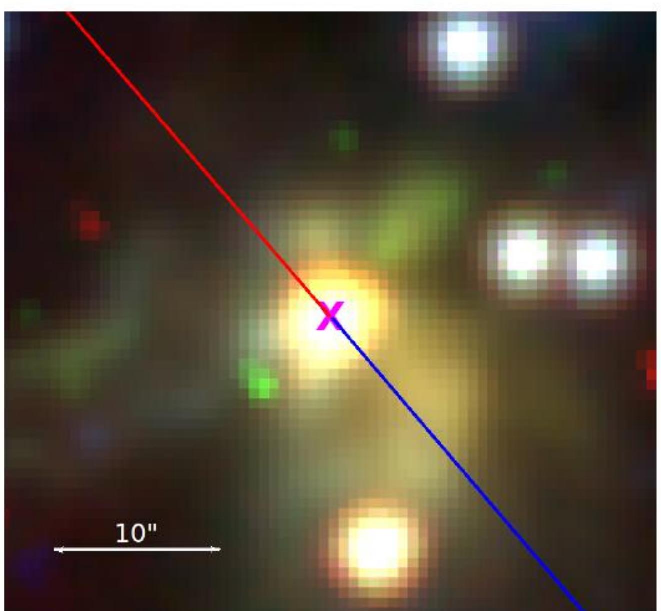


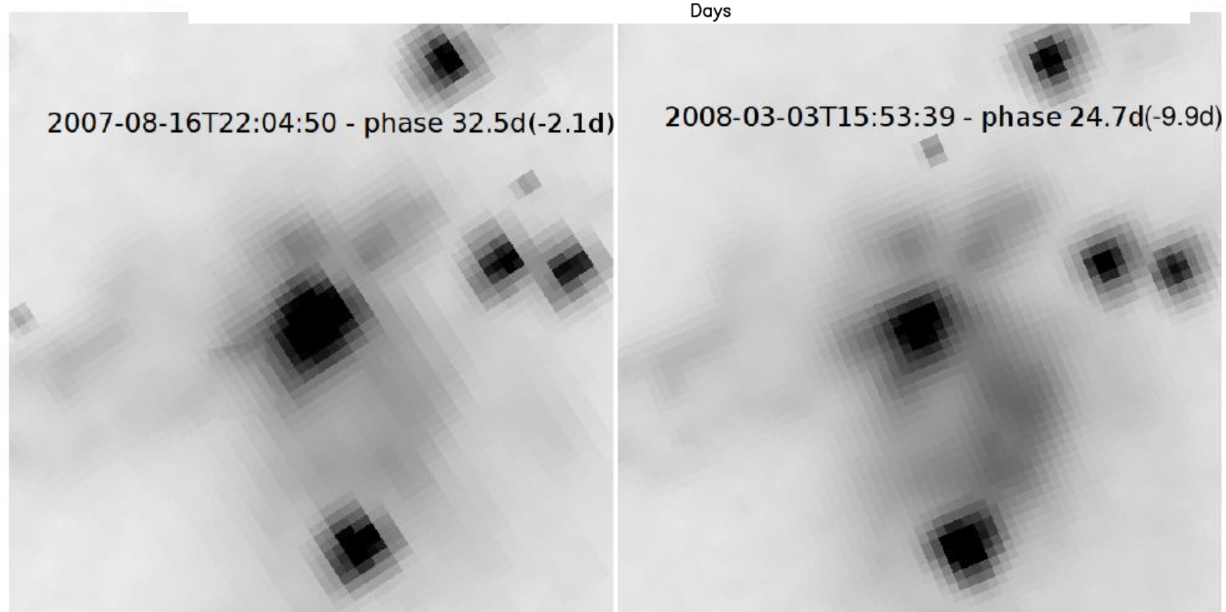
Infrared variability, maser activity, and accretion of massive young stellar objects

Bringfried Stecklum[1], Alessio Caratti o Garatti[2], Klaus Hodapp[3], Hendrik Linz[4], Luca Moscadelli[5], and Alberto Sanna[6]

G107.30+5.64







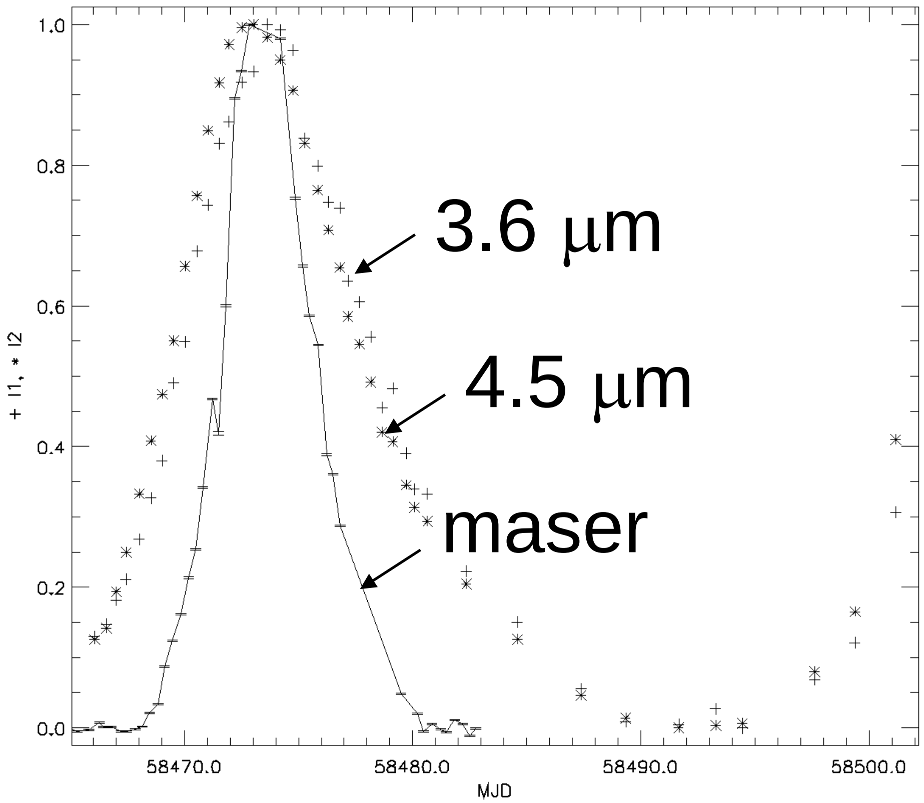
Готовится статья в A&A

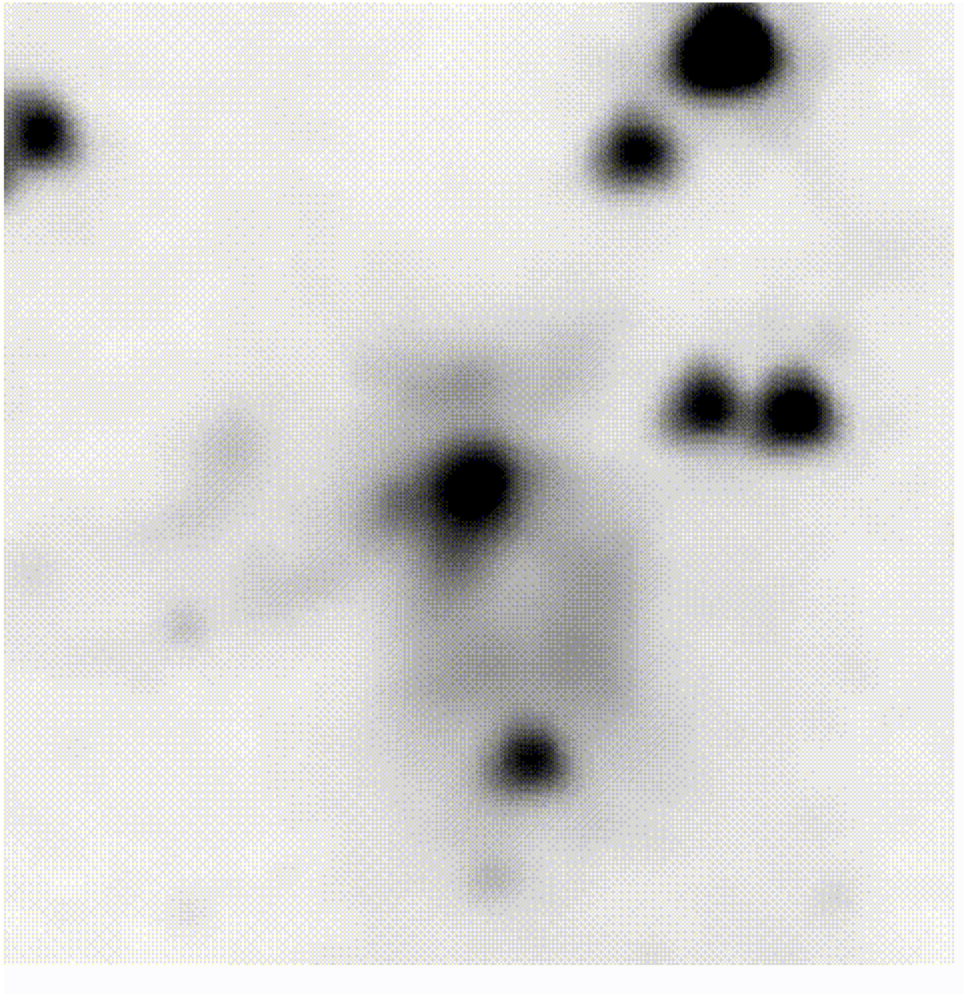
Spitzer

3.6 μm, 4.5 μm

Torun 32m, Irbene 16m

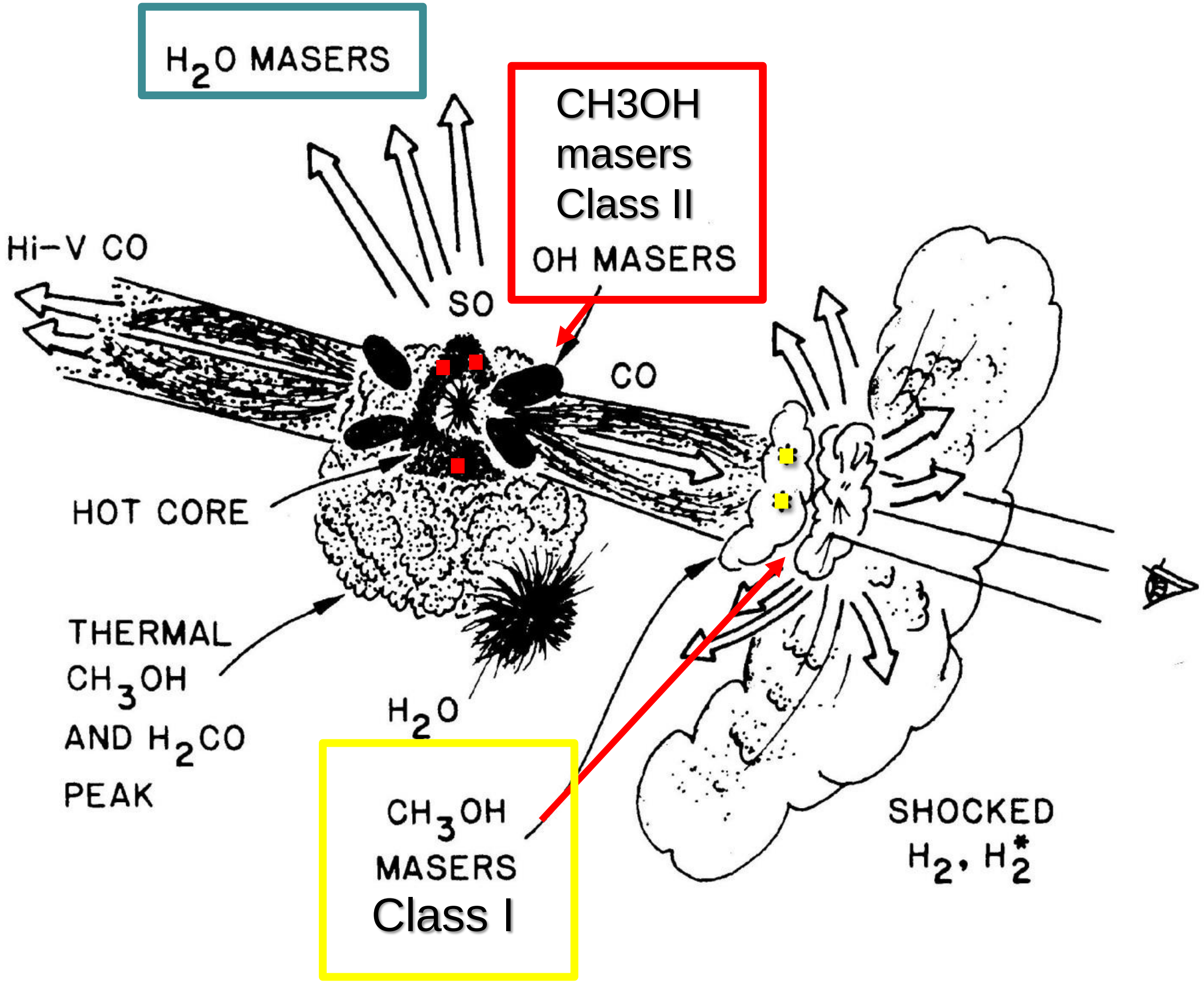
6.7 GHz maser





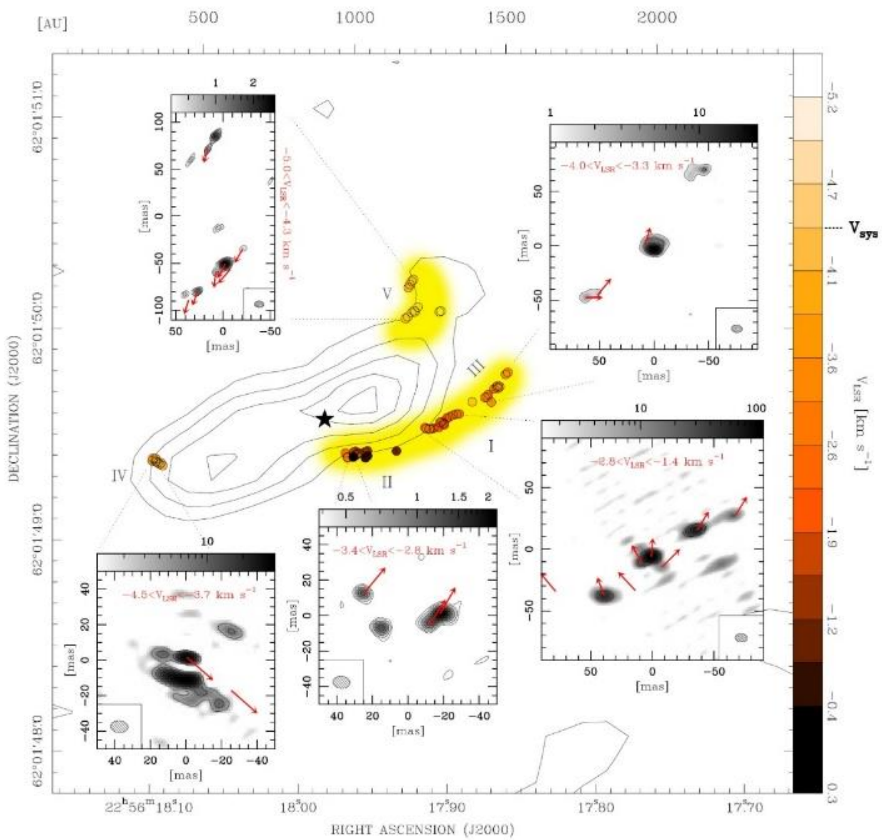
G107.30+5.64

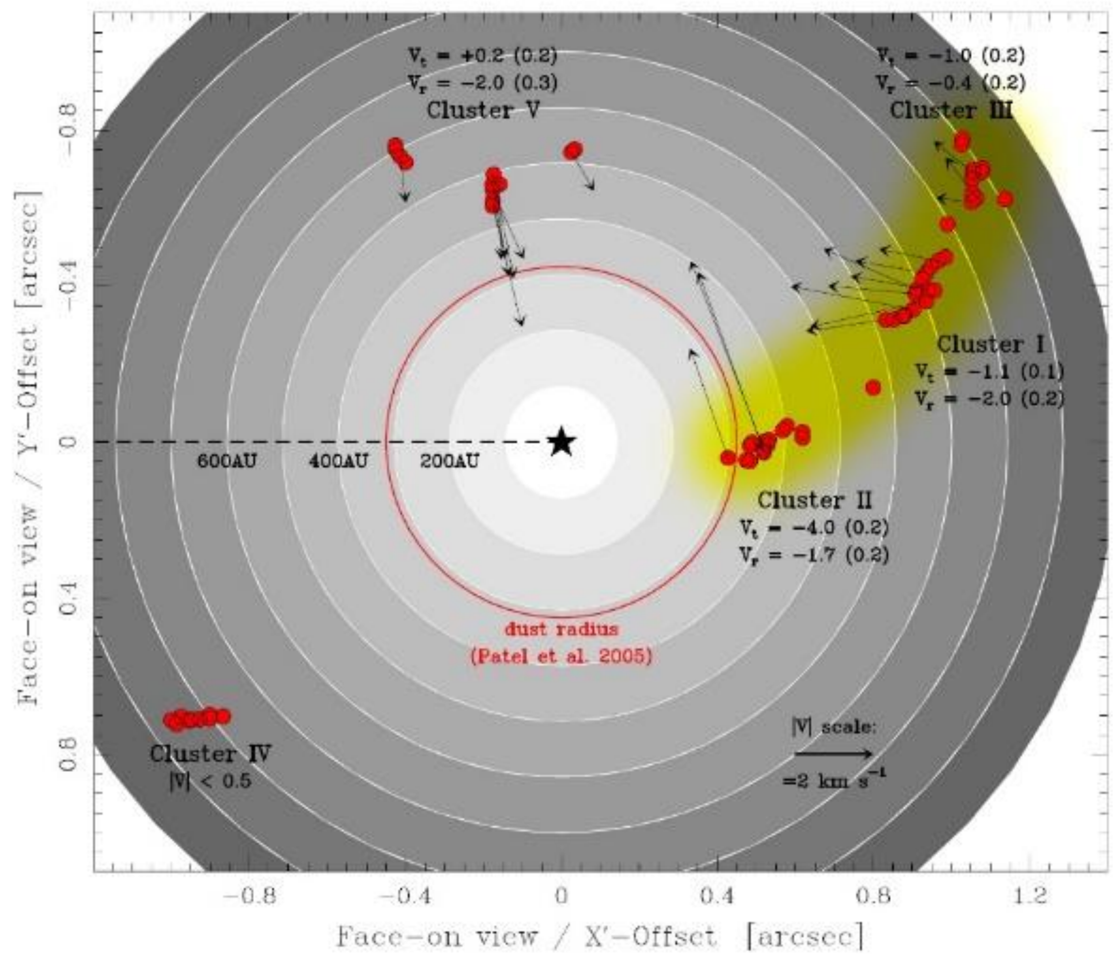
Мазеры в окрестностях массивных звезд



Johnston et al. (1992ApJ...385..232J)

Аккреционные структуры
(диски, кольца и др.)





Cep A HW2 Sanna et al. (2017)

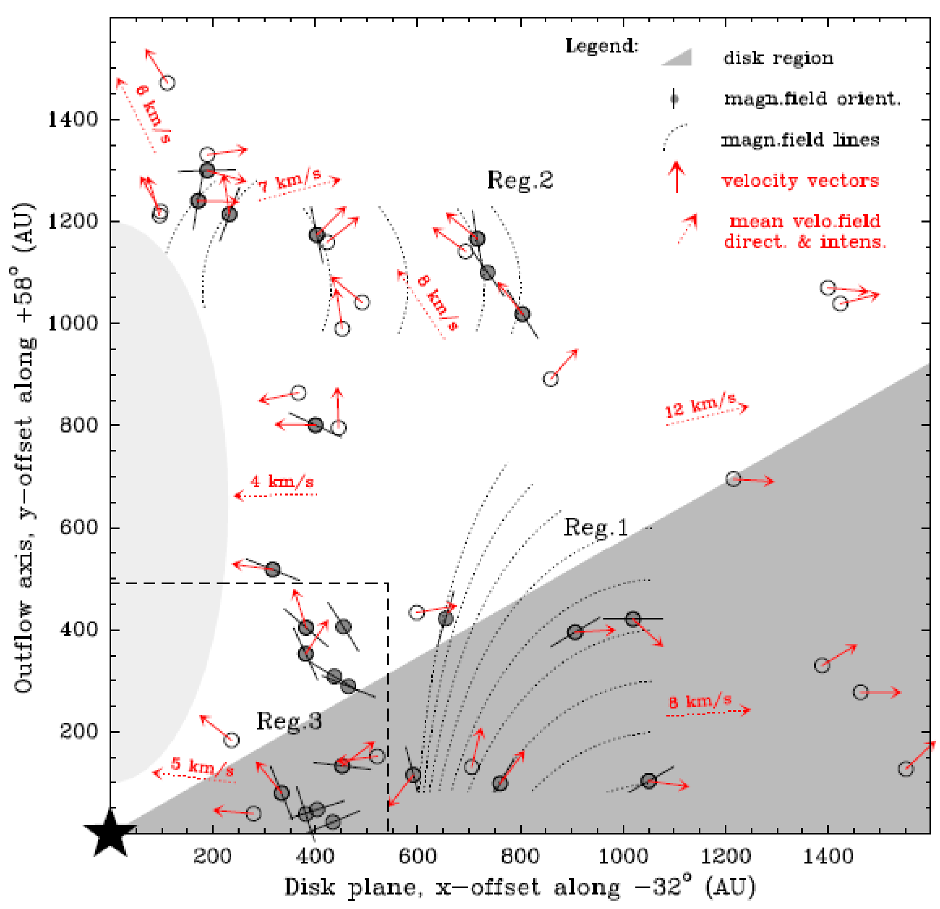
A&A 583, L3 (2015)

the 5_1-6_0 A^+ CH_3OH maser transition 6668.519 MHz toward G023.01−00.41

Velocity and magnetic fields within 1000 AU of a massive YSO*

A. Sanna[1], G. Surcis[2], L. Moscadelli[3], R. Cesaroni[3], C. Goddi[4], W. H. T. Vlemmings[5], and A. Caratti o Garatti[6]

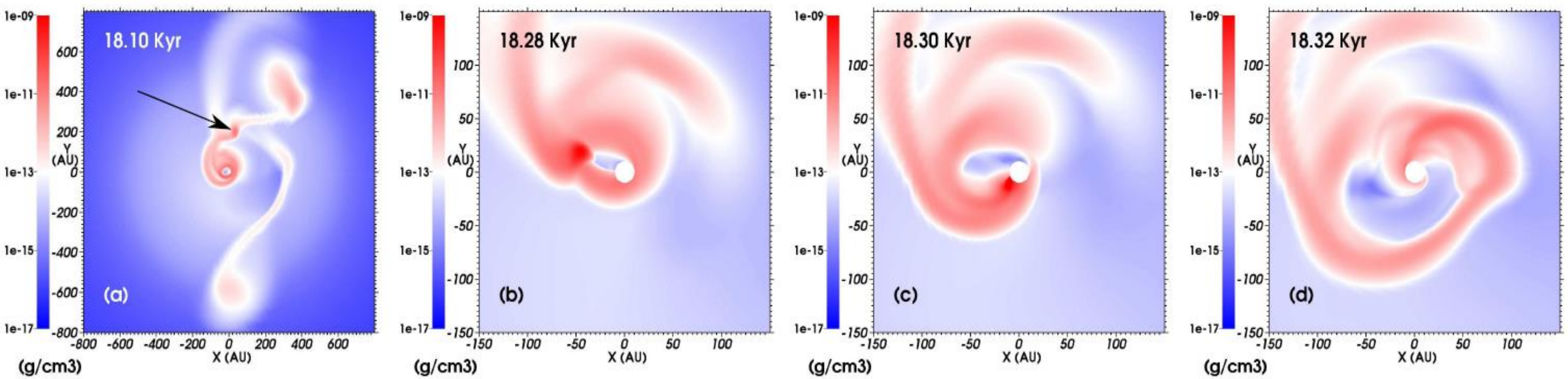
A&A 583, L3 (2015)

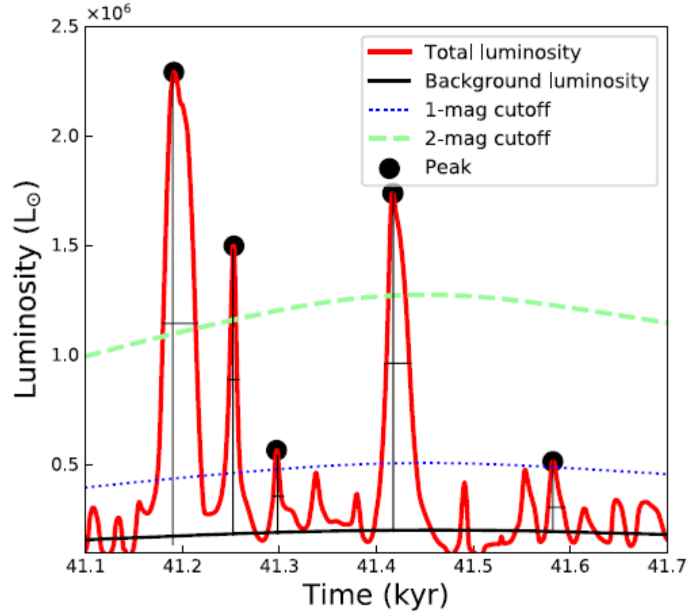


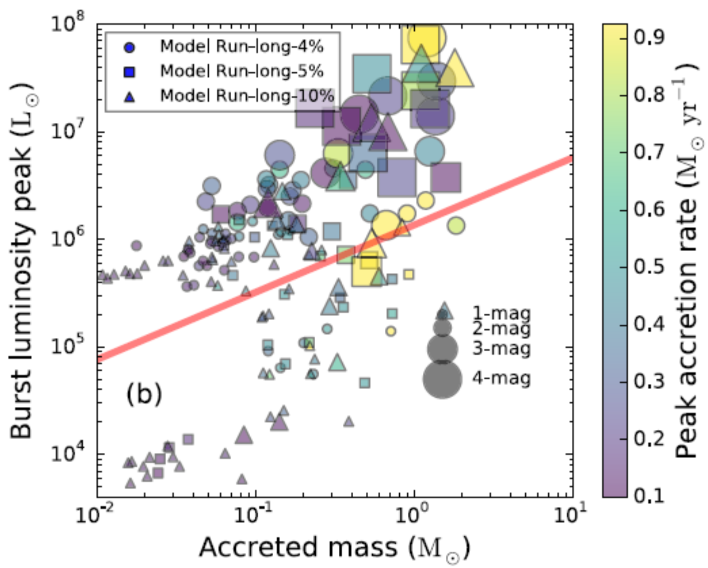
MNRAS **464,** L90–L94 (2017)
Advance Access publication 2016 September 15
doi:10.1093/mnrasl/slw187

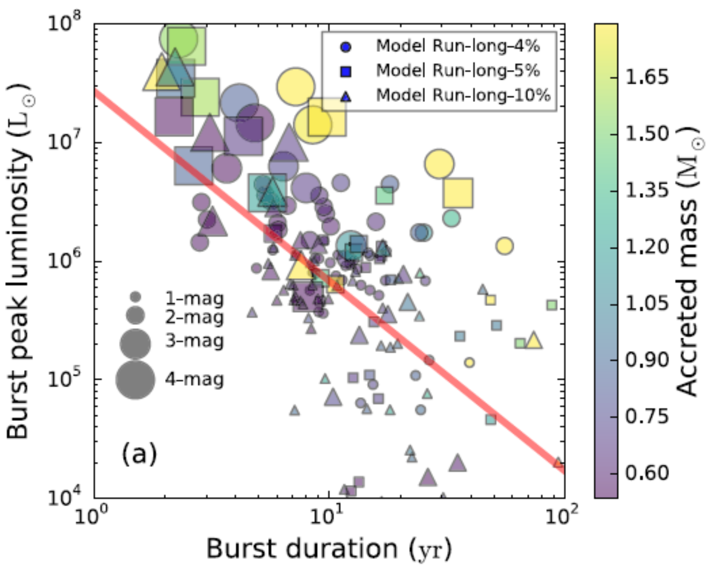
On the existence of accretion-driven bursts in massive star formation

D. M.-A. Meyer,[1★] E. I. Vorobyov,[2,3] R. Kuiper[1] and W. Kley[1]









Burst occurrence in young massive stellar objects

D. M.-A. Meyer,[1★] E. I. Vorobyov,[2,3] V. G. Elbakyan,[3] B. Stecklum,[4] J. Eislöffel[4] and A. M. Sobolev[5]

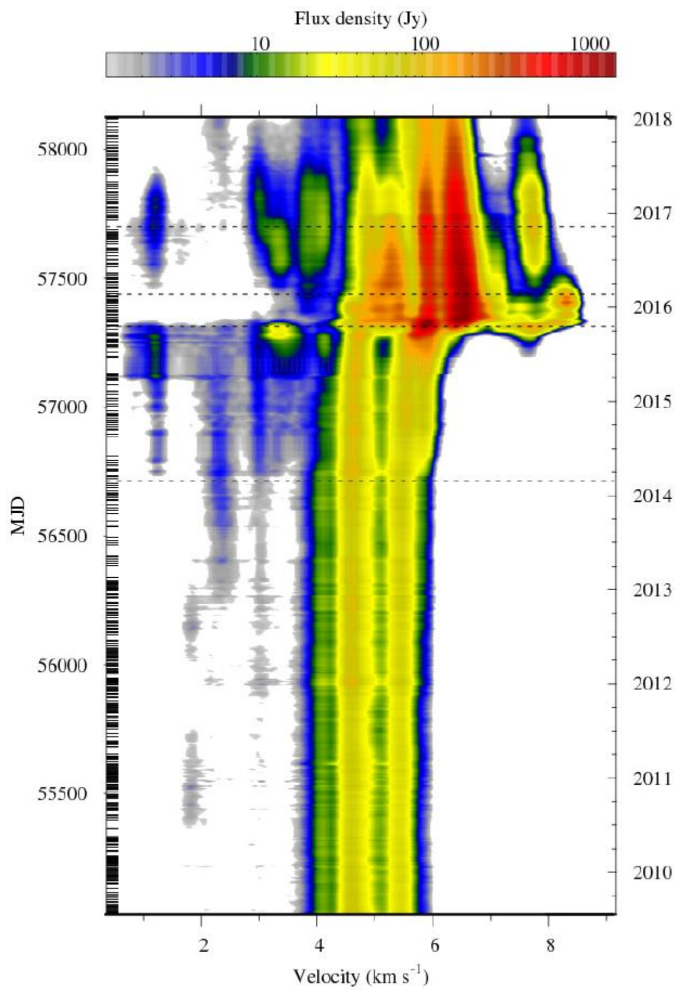
MNRAS **482,** 5459–5476 (2019)

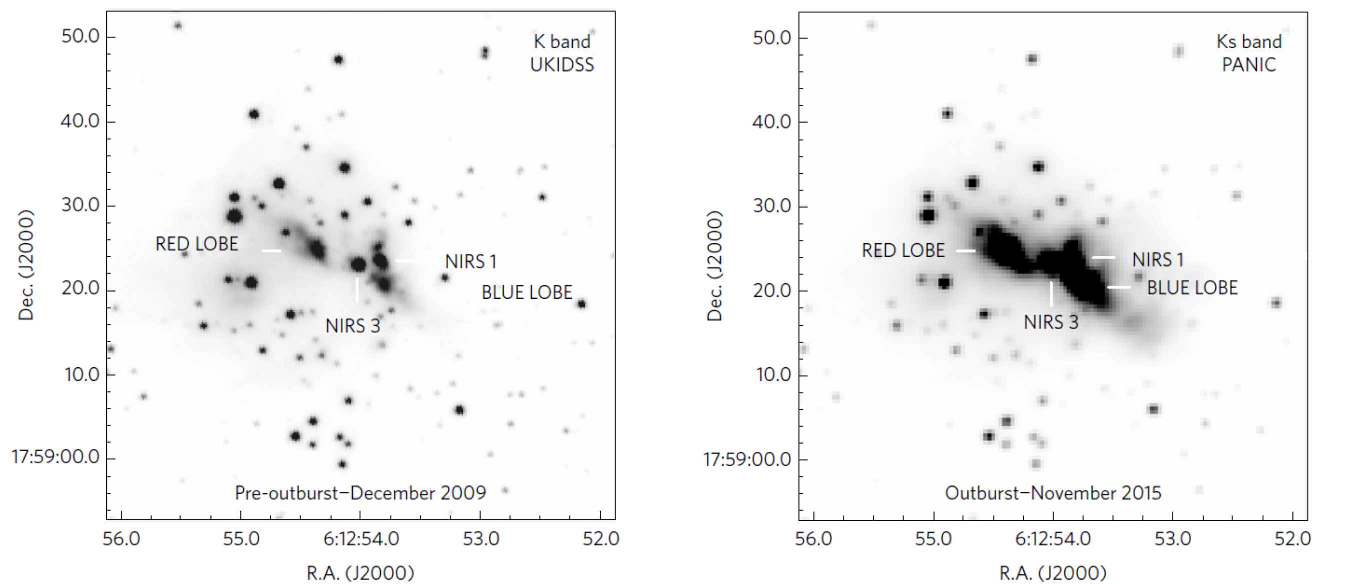
S255IR-NIRS3 flare

nature physics
LETTERS
PUBLISHED ONLINE: 14 NOVEMBER 2016 | DOI: 10.1038/NPHYS3942

Disk-mediated accretion burst in a high-mass young stellar object

A. Caratti o Garatti[1*], B. Stecklum[2], R. Garcia Lopez[1], J. Eislöffel[2], T. P. Ray[1], A. Sanna[3], R. Cesaroni[4], C. M. Walmsley[1,4], R. D. Oudmaijer[5], W. J. de Wit[6], L. Moscadelli[4], J. Greiner[7], A. Krabbe[8], C. Fischer[8], R. Klein[9] and J. M. Ibañez[10]





Giant burst of methanol maser in S255IR-NIRS3

M. Szymczak[1], M. Olech[1], P. Wolak[1], E. Gérard[2], and A. Bartkiewicz[1]

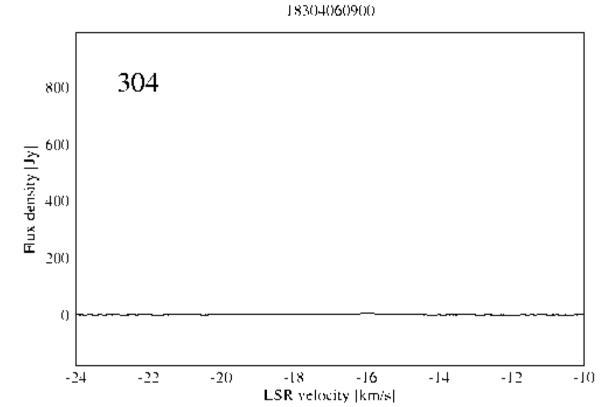
A&A 617, id.A80, 2018

Maser Monitoring Organization (M2O)

(2017 IAUS336)

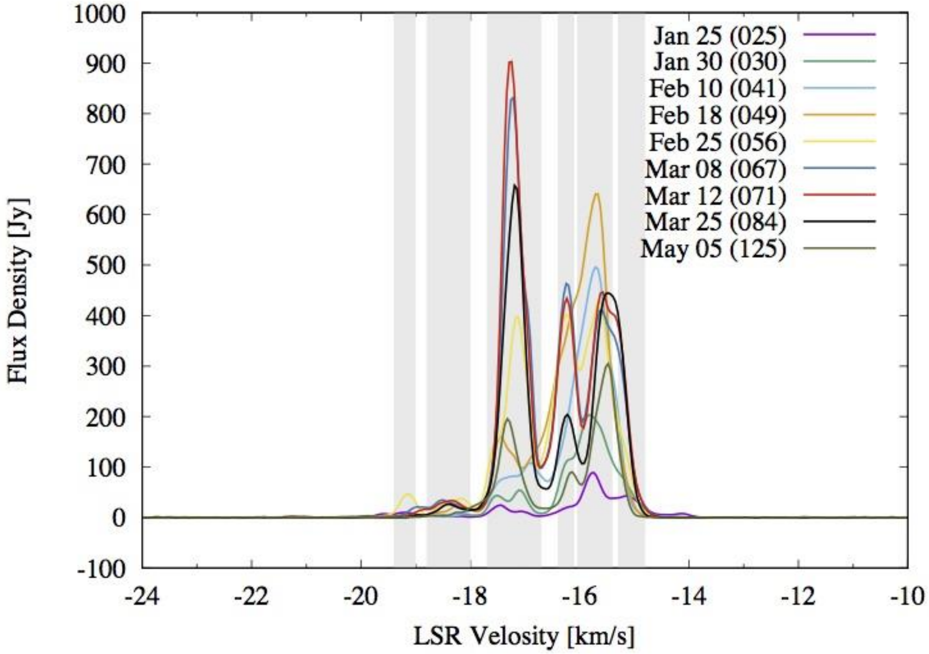
- **Formation of a network of MASER monitoring telescopes:**
  - **Independently, groups thought it useful to collaborate.**
  - **Expressed interest in formalisation of coordinated observing**
  - **Creation of a network of communications**
- **Functions:**
  - **Provide calibration and confirmation services to each**
  - **Create catalogue of interesting and monitored sources**
  - **Develop triggering methodologies**
  - **Operate as a 24 hour monitoring service when required**
  - **Inform other facilities of interesting phenomena**
  - **Provide fast follow-up observation services.**
- **Longer term**
  - **Provide multi-wavelength monitoring,**
    - **millimeter, optical/IR, etc.**
- **Countries represented:**

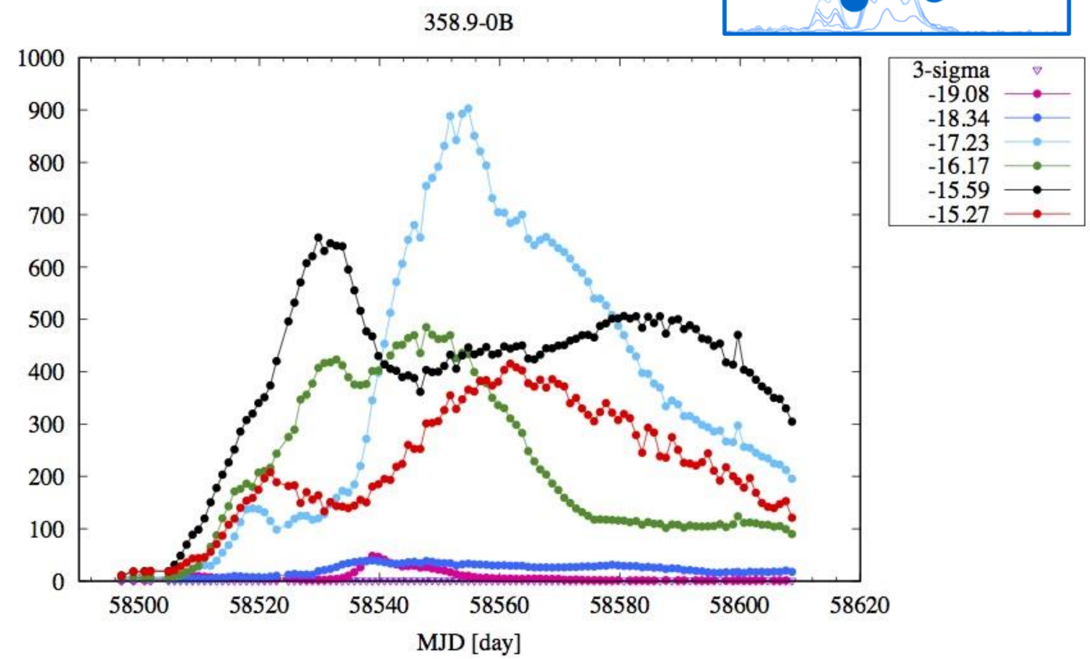
Australia, Canada, China, France, Germany, Italy, Japan, Korea, Latvia, Poland, Russia, South Africa, Thailand, USA



G358.931-0.030
March 2019

https://www.masermonitoring.com/





Sugiyama, Saito, Yonekura, Momose, Munetake

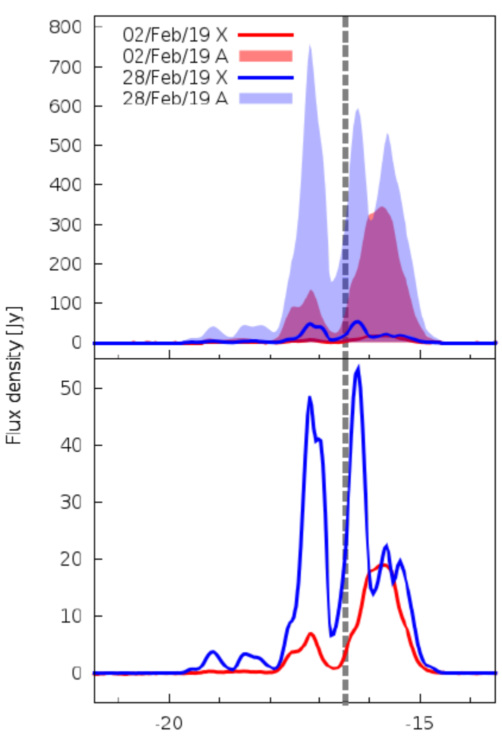
Bursting activity of the 6.668-GHz CH3OH maser detected in G 358.93-00.03 using the Hitachi 32-m

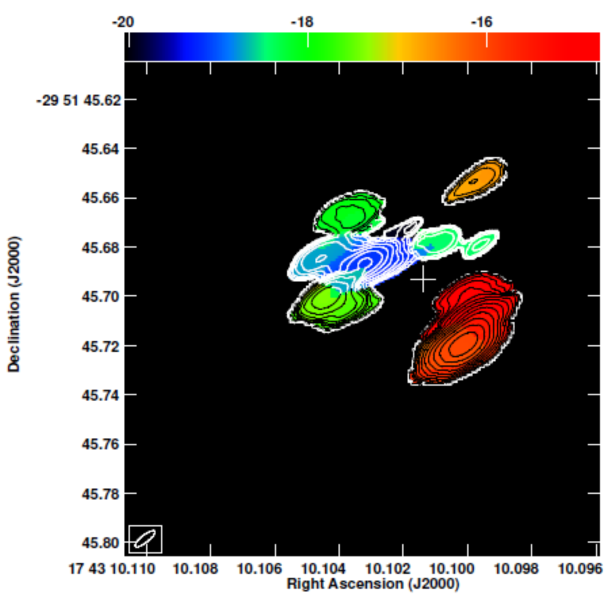
2019ATel12446....1S

2020, Nature Astronomy, 4, 506

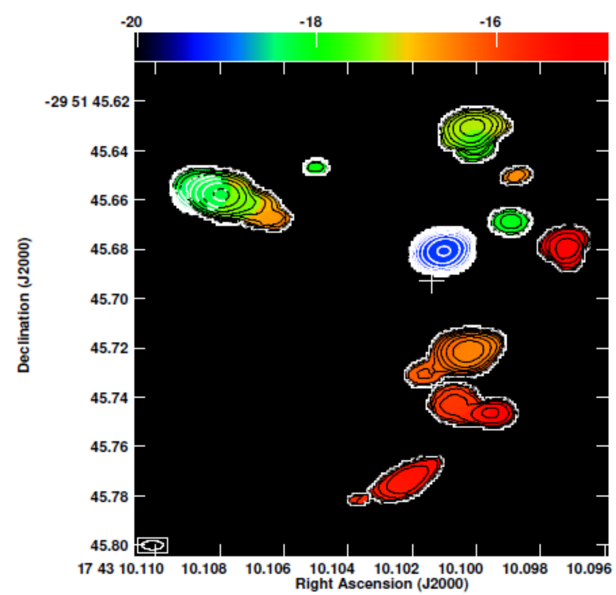
A heatwave of accretion energy traced by masers in the G358-MM1 high-mass protostar

R. A. Burns[1,2★], K. Sugiyama[1,3], T. Hirota[1], Kee-Tae Kim[2,4], A. M. Sobolev[5], B. Stecklum[6], G. C. MacLeod[7,8], Y. Yonekura[9], M. Olech[10], G. Orosz[11,12], S. P. Ellingsen[11], L. Hyland[11], A. Caratti o Garatti[13], C. Brogan[14], T. R. Hunter[14], C. Phillips[15], S. P. van den Heever[8], J. Eislöffel[6], H. Linz[16], G. Surcis[17], J. O. Chibueze[18,19], W. Baan[20] and B. Kramer[3,21]





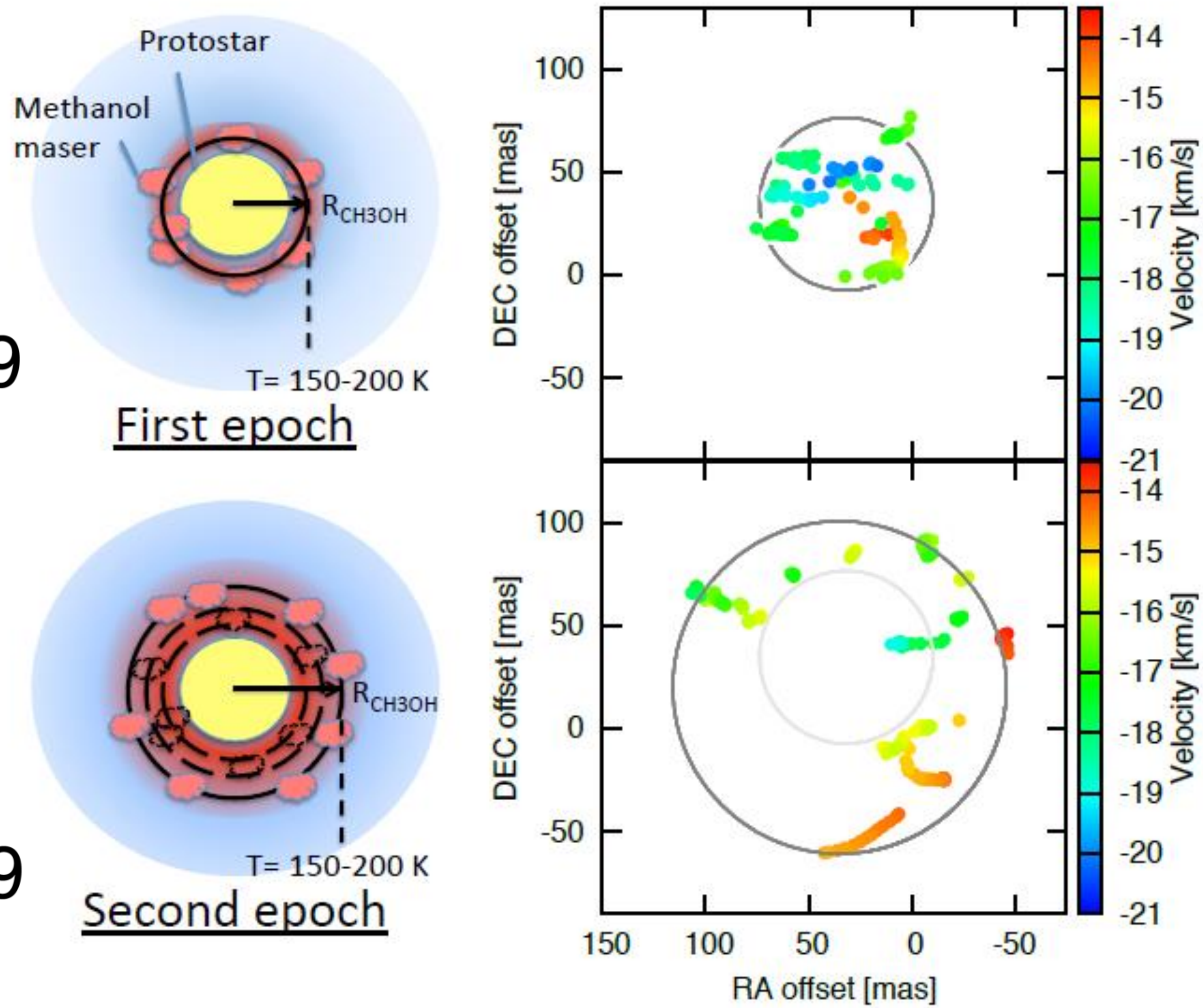
02 Feb 2019



28 Feb 2019

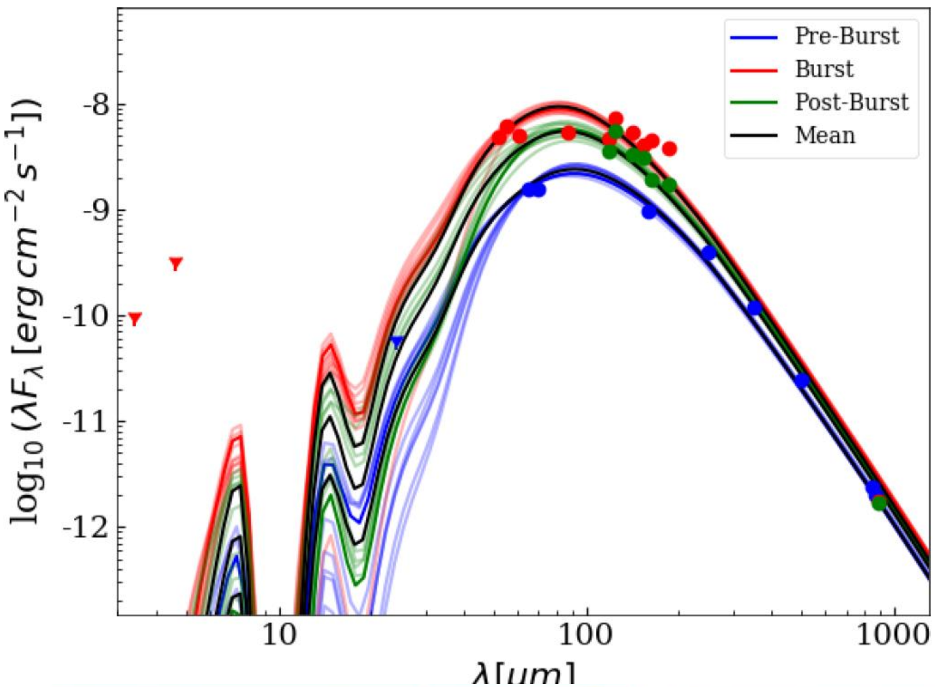
02 Feb 2019

28 Feb 2019



Distribution translocates with 4-8% the speed of light

This means that excitation goes through structures with very high density material



Stecklum B., Wolf V., Linz H. et al. 2021, A&A, 646, 161

"Infrared observations of the flaring maser source G358.93-0.03. SOFIA confirms an accretion burst from a massive young stellar object"

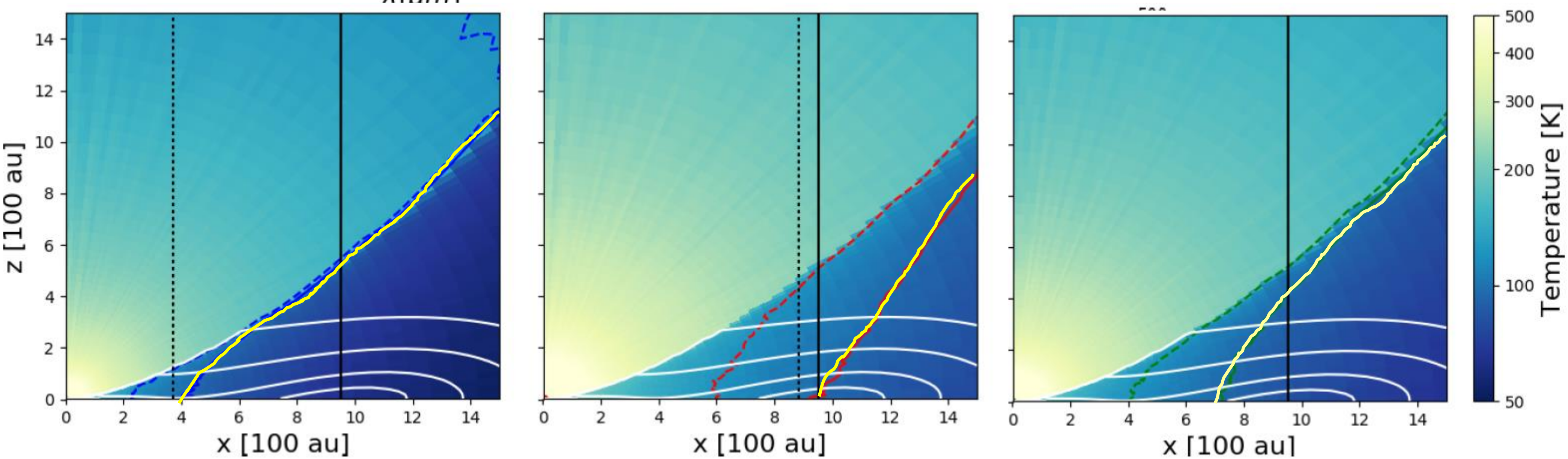
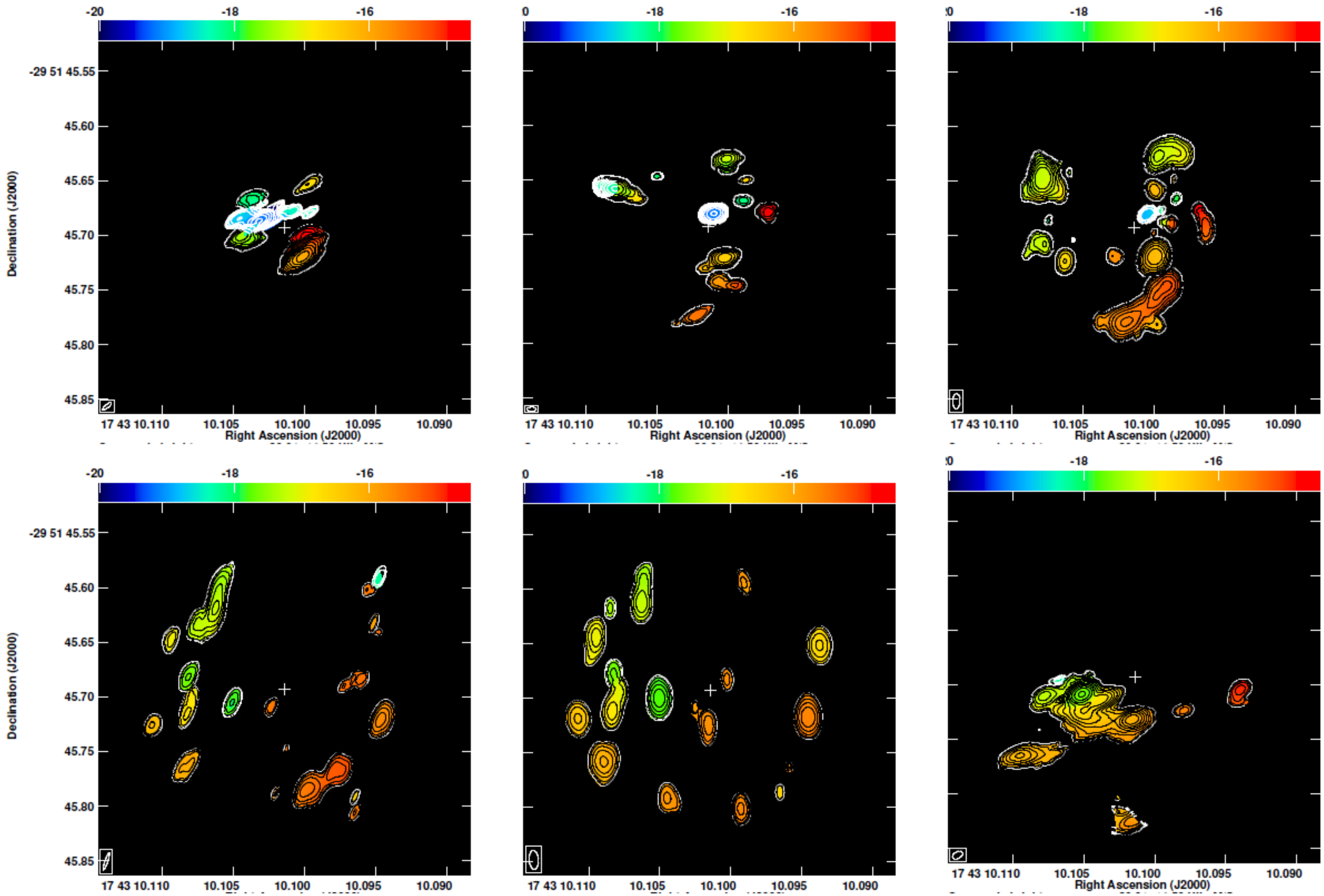
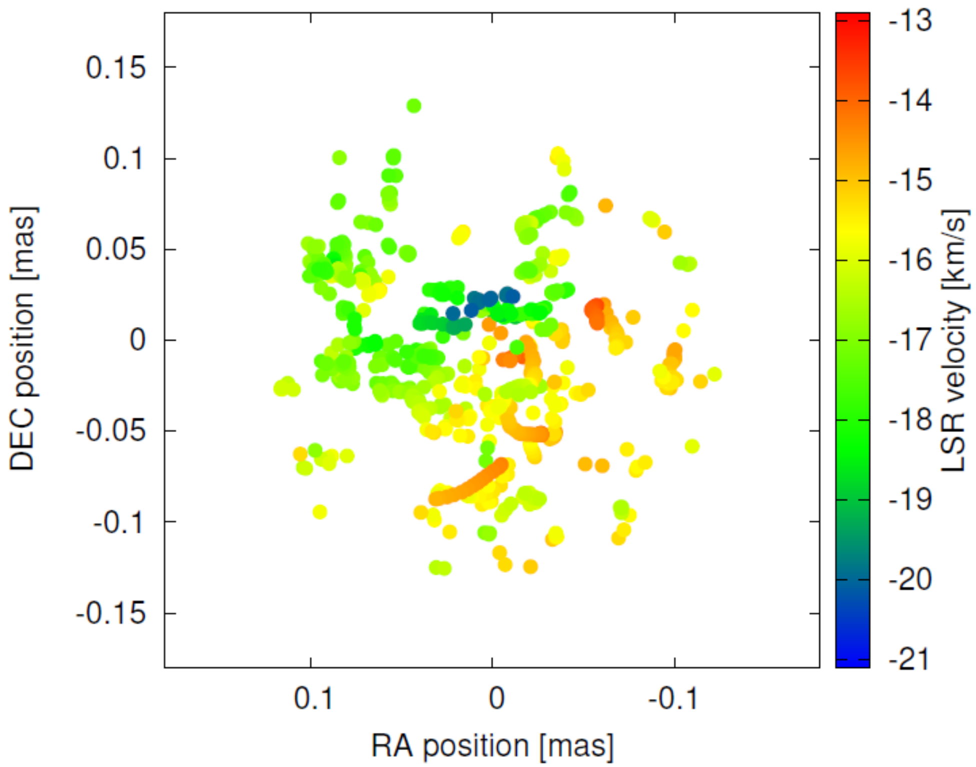


Fig. 8. Temperature distribution of the mean model in the x-z plane (innermost part of first quadrant) for the pre-burst (**left**), burst- (**center**) and post-burst epochs (**right**). The blue, red, and green lines enclose the temperature range from 94 K (solid) to 120 K (dashed) during the pre- and burst epochs, respectively. The white contours mark gas particle volume densities of $n_H = [0.2, 0.3, 0.5, 1] \times 10^8\ cm^{-3}$ which decrease with increasing z. The vertical solid black line indicates the outer radius of the disk. The dashed black lines mark the radius of the maser ring from the first and 4th epoch of the VLBI observations (Burns et al., in prep.; Burns et al. 2020b). The length of the black bar corresponds to 50 mas.



Burns et al. (2021, in preparation)



A combined view of all maser spotmaps in derived from VLBI monitoring

Burns et al. (2021, in preparation)

nature astronomy
LETTERS
https://doi.org/10.1038/s41550-020-1144-x

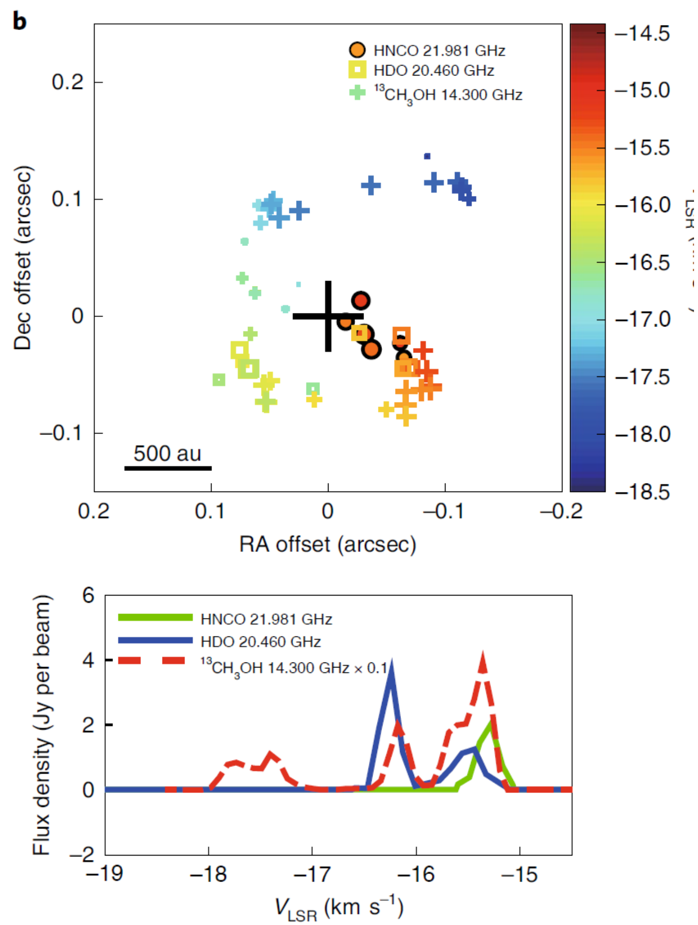
New maser species tracing spiral-arm accretion flows in a high-mass young stellar object

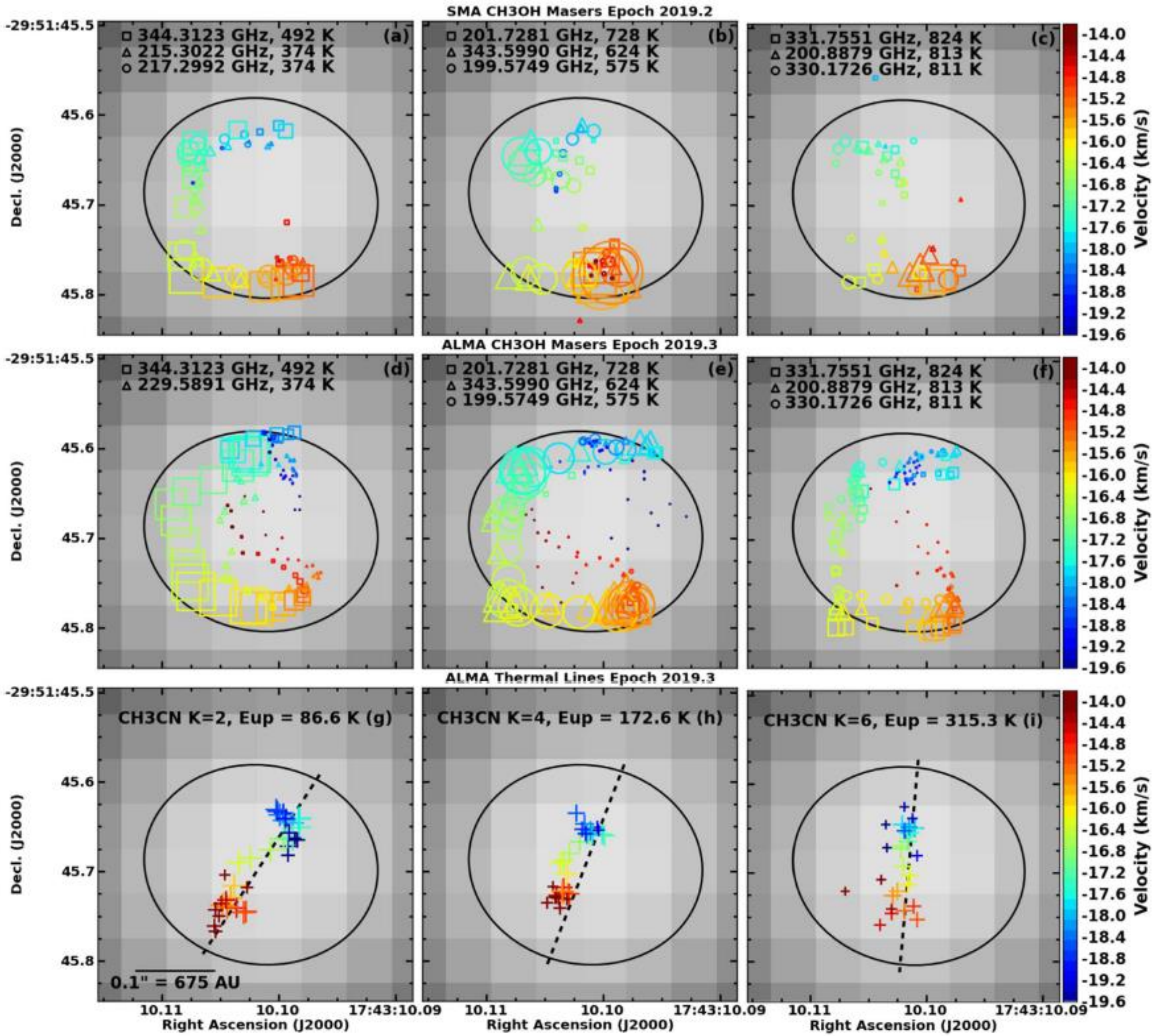
Xi Chen[1,2,3] ✉, Andrej M. Sobolev[4] ✉, Zhi-Yuan Ren[5], Sergey Parfenov[4], Shari L. Breen[6], Simon P. Ellingsen[7], Zhi-Qiang Shen[2,3], Bin Li[2,3], Gordon C. MacLeod[8,9], Willem Baan[10], Crystal Brogan[11], Tomoya Hirota[12,13], Todd R. Hunter[11], Hendrik Linz[14], Karl Menten[15], Koichiro Sugiyama[13,16], Bringfried Stecklum[17], Yan Gong[15] and Xingwu Zheng[18]

HNCO 21.981 GHz

HDO 20.460 GHz

$^{13}CH_3OH$ 14.300 GHz





Brogan C.L., Hunter T.R., Towner A.P.M. et al. 2019, ApJL, 881, L39

"Sub-arcsecond (Sub)millimeter Imaging of the Massive Protocluster G358.93-0.03: Discovery of 14 New Methanol Maser Lines Associated with a Hot Core"

- Исследования мазеров имеют высокий потенциал для изучения структуры околозвездных дисков массивных молодых звездных объектов, в том числе кинематики и магнитных полей. Этот потенциал ещё не используется в полной мере
- Наблюдения показывают, что структура околозвездных дисков массивных молодых звездных объектов существенно неоднородна
- В них присутствуют когерентные структуры с размерами до 1000 а.е.
- Вдоль некоторых структур происходит аккреция вещества на молодую звезду, эти структуры могут иметь форму спиралей
- Вещество аккреционных структур состоит из сгустков, выпадение которых на молодую звезду приводит к аккреционным вспышкам различной интенсивности
- В структурах диска присутствует большое количество вещества высокой плотности, приводящее к существенному замедлению распространения света
- После аккреционной вспышки физическо-химическое состояние вещества диска изменяется и, вероятно, не возвращается в предыдущее состояние

Благодарю!

работа поддержана грантом РФФИ 20-52-53054