Poster Pop Session

I. Physikalisches Institut - Universität zu Köln

Observations of Dusty S-cluster Object (DSO/G2)

Detection of significant polarized continuum emission in K_s-band

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Bonn-Cologne Graduate School of Physics and Astronomy

STRONGGRAVITY EU FP7-SPACE research project 312789 2013 - 2017

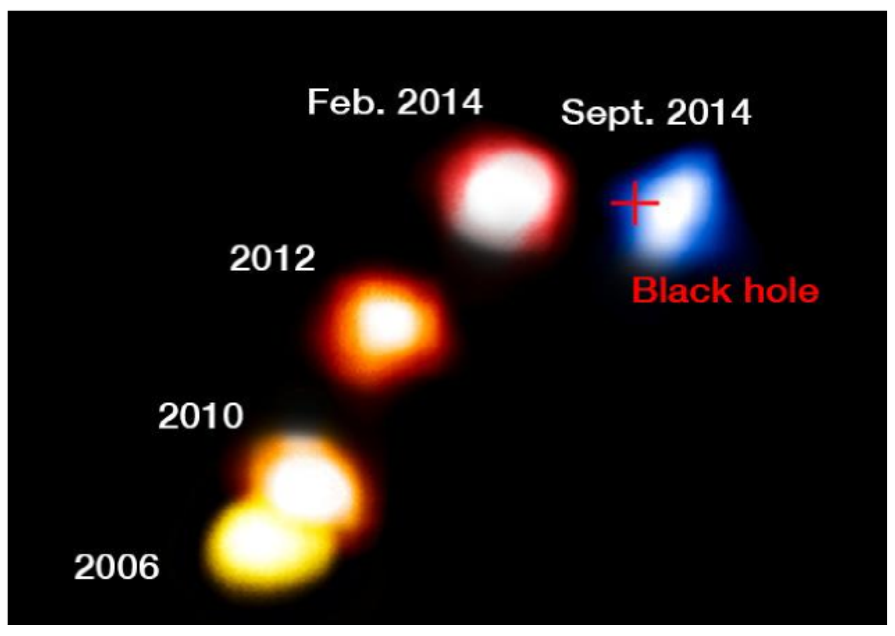
IMPRS astronomy & astrophysics Bonn and Cologne

Introduction

An infrared-excess source called G2 or Dusty S-cluster Object (DSO) passed on a highly eccentric orbit around the Galaxy's central supermassive black hole, SgrA*. The nature of the DSO/G2 has been disputed mainly because of the lack of any information about the geometry of the source. **For the first time, we use, near-infrared polarimetric imaging data to determine the nature and the geometrical properties of the DSO, and to obtain an improved K_s-band identification of this source in median polarimetry images of different years.** Measurements of the DSO polarization degree and angle in 2008 - 2012 indicate that it is **intrinsically polarized source (~30%)** with a varying polarization angle as it approaches Sgr A* position. DSO shows a near-infrared excess of K_s-L'>3 and **remains compact** close to the pericentre of its orbit. Its observed properties and significant linear polarization suggests that the DSO might be a **dust-enshrouded young star** with bipolar outflows that forms a dense bow-shock layer due to its supersonic motion upon approaching Sgr A*.

DSO/G2 as compact, stable K_S-band source

The faint DSO was found in 2011 on its way towards SgrA* (Gillessen+ 2012). The object can be primarily tracked in L'-band and recombination line emission (e.g. Brγ) in K-band.



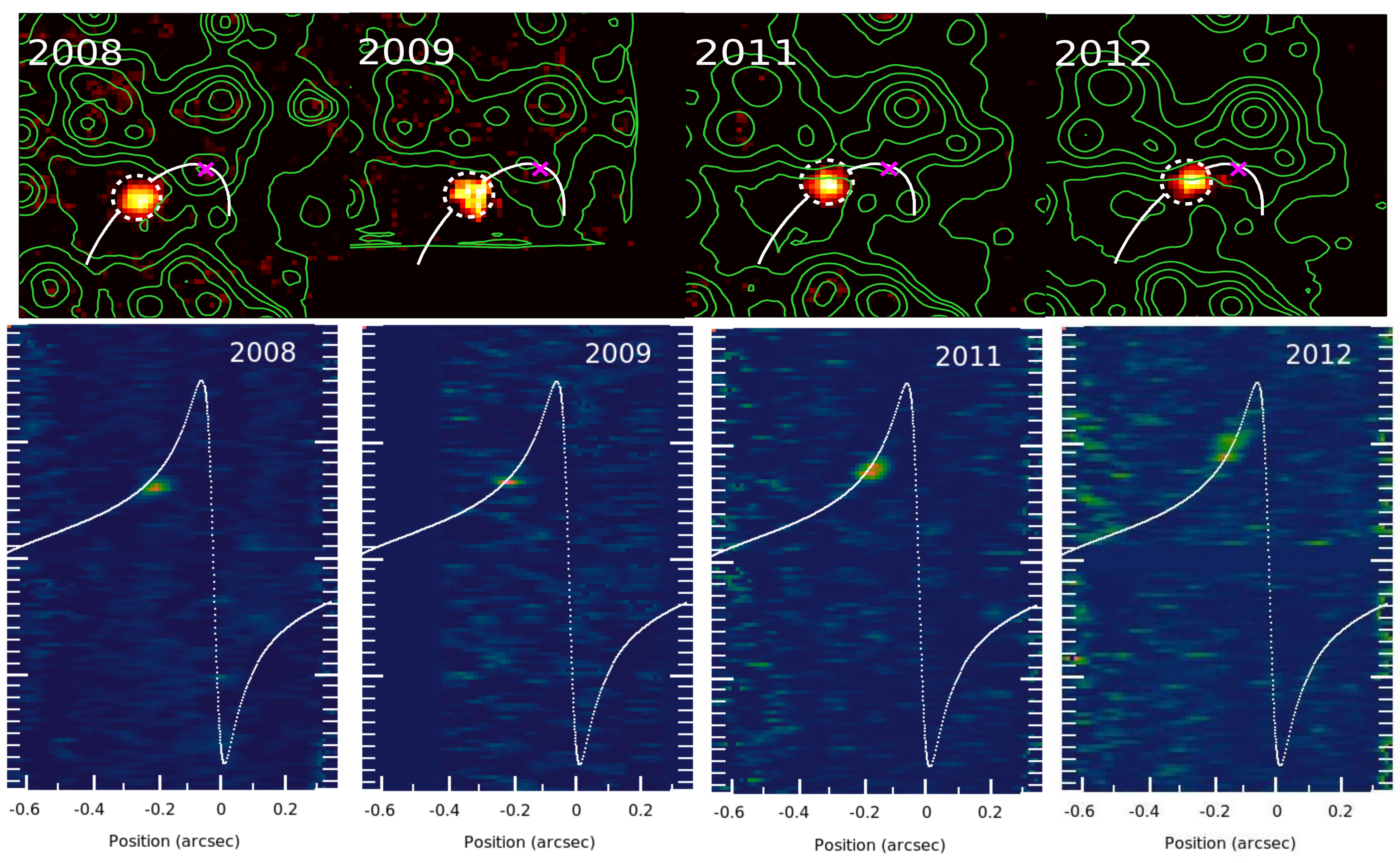
The **DSO remained compact in the Brγ line emission both before and after the periapse passage** (which occured in spring 2014; Valencia-S.+ 2015).

Credit: ESO/ A. Eckart

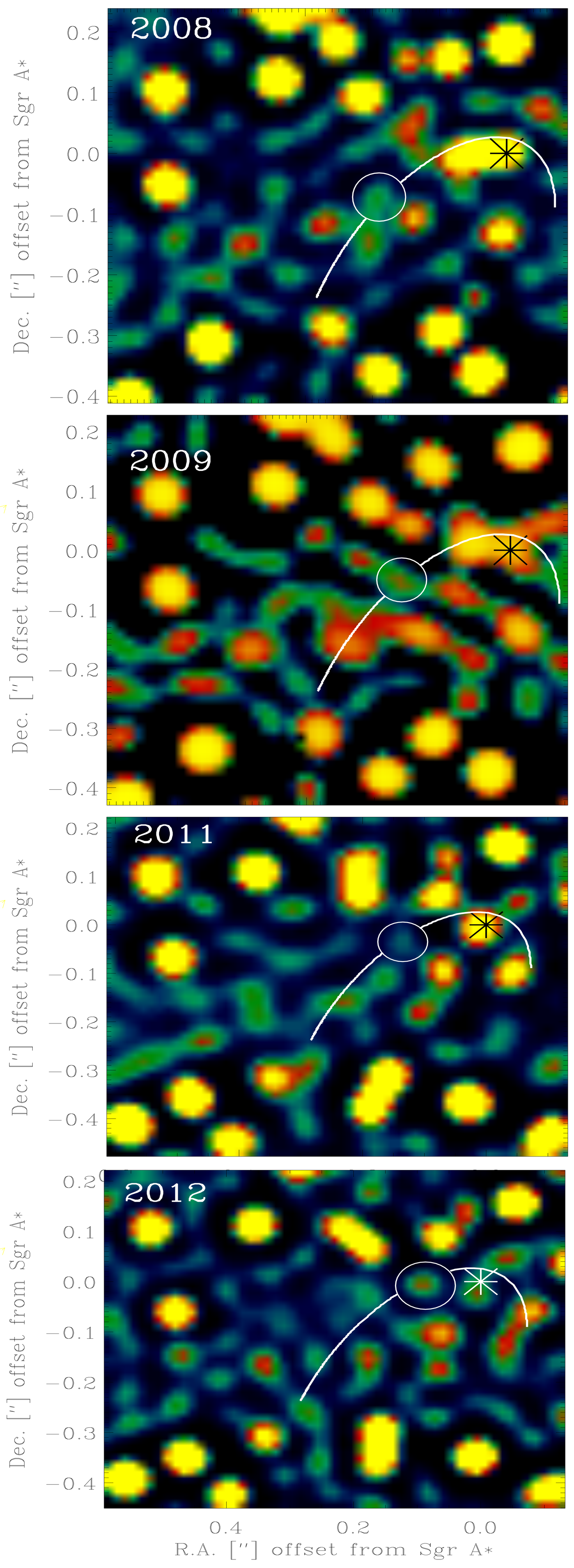
Combined with the compact continuum L-band emission (Witzel+ 2014) the observations have showed that **the source did neither stretch nor disintegrate** as was previously stated (Gillessen+ 2012, Pfuhl+ 2015).

In **Shahzamanian+ (2016) ,** we revisit the analysis of the DSO emission in K_S-band continuum in more detail. Using the aperture photometry we determine the flux density in each of four polarimetry channels. By adding the resulting flux density in two orthogonal polarimetry channels, we obtained the total flux density (see Table). The DSO does not show any intrinsic continuum flux density variability in the K_S-band based our data set.

Top: *The Brγ line maps in years 2008-2012 obtained with SINFONI/ VLT confirm the compact character of the DSO. Line shows the best fit orbit. Green contours: K-band continuum.* ***Bottom****: Corresponding Position-Velocity diagrams (Peissker+, tbs).*



Detection of polarized emission



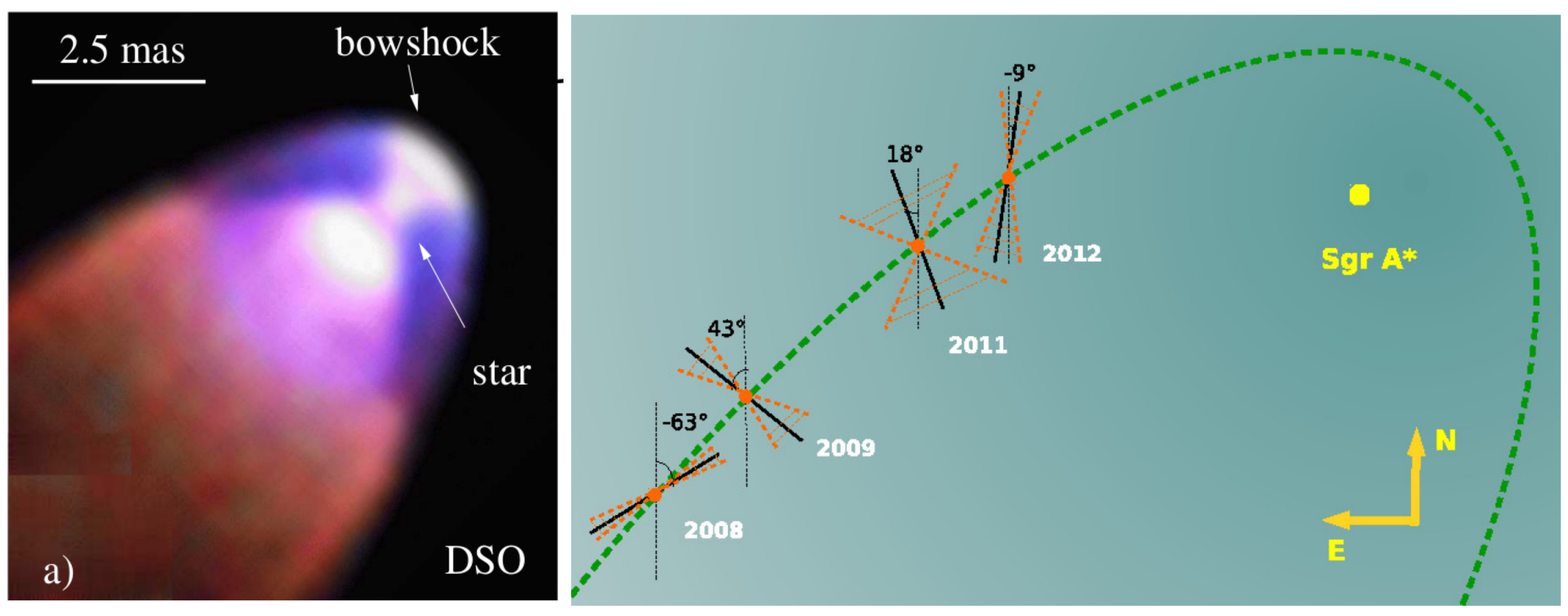
Ks-band deconvolved median images of the central arcsecond at the GC in polarimetry mode in 2008, 2009, 2011 and 2012 (from top to bottom).

Shahzamanian et al. (2016) use the near-infrared polarimetric imaging data to determine the polarization of the DSO for the first time. Observations indicate that:

- The DSO is an **intrinsically polarized source** with the polarization degree ~ 30%.
- The polarization degree stays approximately constant within uncertainties (see Table). The significance of the linear polarization measurements from Monte Carlo simulations is larger than 1/100 000.
- The polarization angle varies while the source moves towards the periapse (Fig. bottom, right).
- Significant polarized emission as well as a large infrared excess may be explained by the model of a dust-enshrouded star that deviates from a spherical symmetry.
- The total and polarized flux density are matched by a composite stellar model consisting of the **Star +envelope+bipolar cavities+bow shock (Zajaček+ 2014, 2015, 2016)**

We summarize the **observed polarization degree** and the angle for individual epochs in the following Table:

Year	Flux density (mJy)	p_{obs} (%)	ϕ_{obs} (degrees)
2008	0.25	30.1	−62.9
2009	0.19	32.6	42.9
2011	0.23	29.9	18.1
2012	0.25	37.6	−9.7



Left*: RGB image of the source model of DSO. Blue colour - K_S band, green - L' band and red - M band.* ***Right****: Sketch of the evolution of the DSO polarization angle while it approaches SgrA*.*

References

Eckart+ 2013, A&A 551 • Eckart+ 2014, Proc. of IAUS 303 • Gillessen+ 2012, Nature 481 • Peissker+, tbs • Pfuhl+ 2015, ApJ 798 • **Shahzamanian+ 2016, A&A accepted (ArXiv #)** • **Valencia-S.+ 2015, ApJ 800** • Witzel+ 2014, ApJL 796 • Zajaček+ 2014, A&A, 565 A17 • Zajaček+ 2015, Proc. of 24th WDS • **Zajaček+ 2016, MNRAS 455**

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I. Physikalisches Institut - Universität zu Köln

Formation and properties of near-infrared excess sources in the Galactic centre

On the nature of the Dusty S-cluster Object (DSO/G2)

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STRONGGRAVITY EU FP7-SPACE research project 312789 2013 - 2017

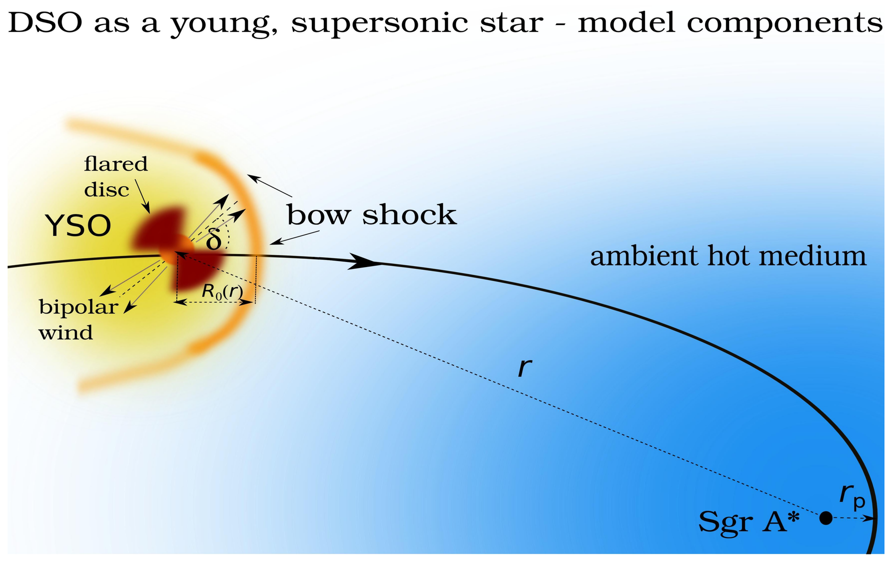
IMPRS astronomy & astrophysics Bonn and Cologne

Introduction

Near-infrared observations reveal a large number of young stars in the innermost parsec of the Galactic centre, with estimated ages of a few million years. Recently, **a group of near-infrared excess sources with emission lines** located in the S-cluster has been studied and the basic characteristics of their continuum and spectra have been determined. One of the objects, **DSO/G2**, has recently passed the pericentre at approx. 160 AU from the supermassive black hole and remained compact, which implies that at least in this case it is a dust-enshrouded star, potentially even younger than massive OB stars in the region. Here we present details of **the model of a young, supersonic star** and compare its properties with the infrared observations of the DSO/G2.

DSO as a young enshrouded star

Based on the observed DSO/G2 compactness and the detected near-infrared excess, as well as the significant linear polarization (Shahzamanian+ 2016; Witzel+ 2014; Peissker+,tbs), we propose a model of a dust-enshrouded star that consists of a star with a dusty envelope, bipolar cavities, and a dense bow-shock layer.

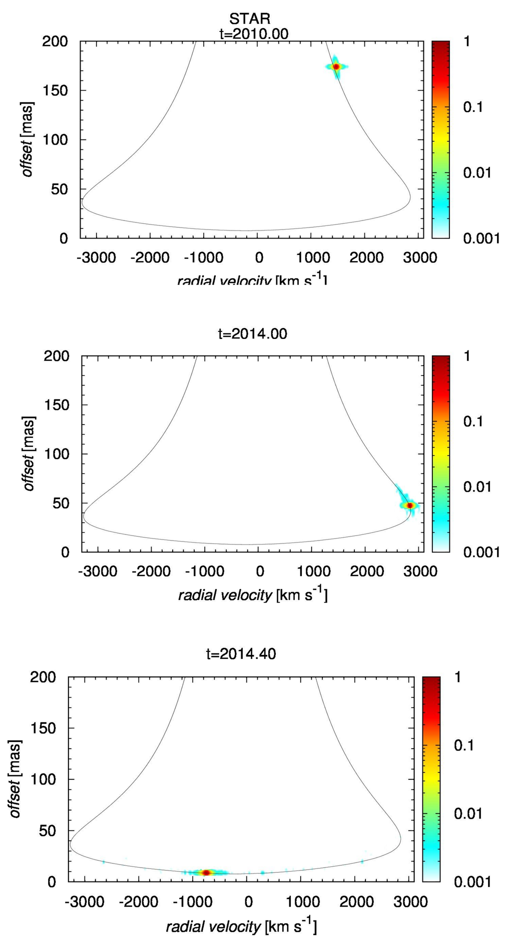


Compactness

The structure of the circumstellar envelope can be complex, with both inflow and outflow responsible for emission lines (Valencia-S+ 2015; Zajaček +2015). The density of the circumstellar matter increases towards the star - emitting material may be present in the accretion disc, columns and stellar wind.

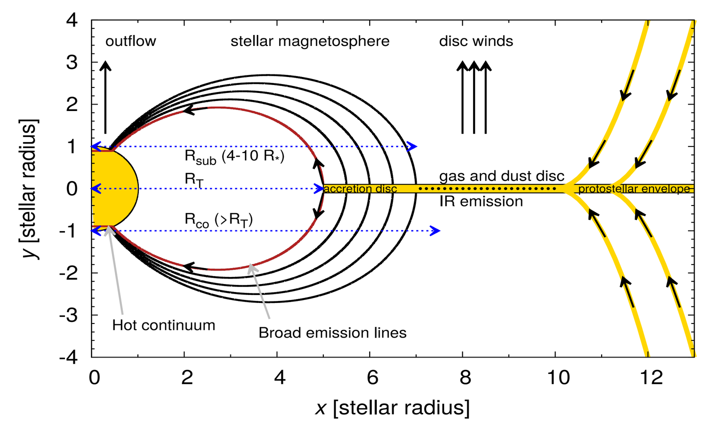
The compact emission in position-velocity plots (Peissker et al., tbs) indicates that most of the emitting material must by located within the Roche lobe of the star associated with the DSO. The consistency with such a scenario is also demonstrated by a simulation of the evolution of a circumstellar material around 1 Solar mass star.

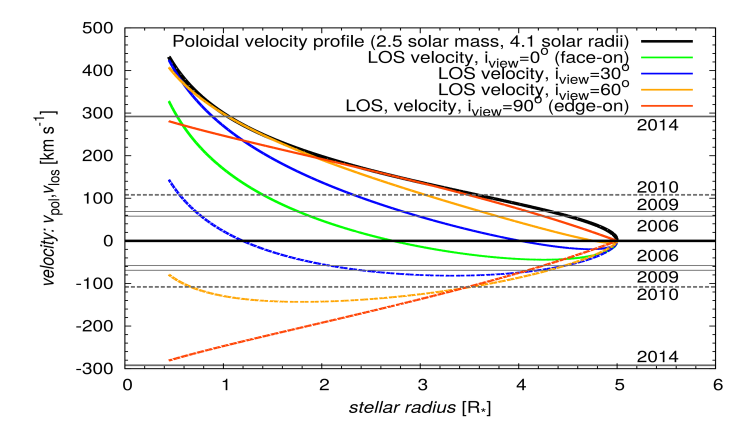
Simulated position-velocity plots for a dust-enshrouded star



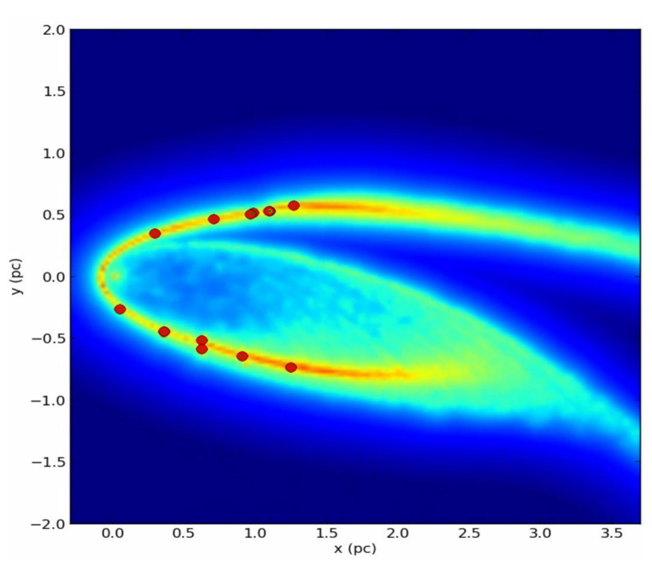
Compact broad emission line

Broad emission lines in young protostars can be explained to arise in the process of magnetospheric accretion (Fig. below, left). The gas is channeled from the inner region of an accretion disc along magnetic field lines. The projected velocities may reach several hundred km/s (see the poloidal velocity profile and the line-of-sight velocities for different inclinations below). This effectively results in the Doppler broadening of emission lines, in particular Brγ recombination line.





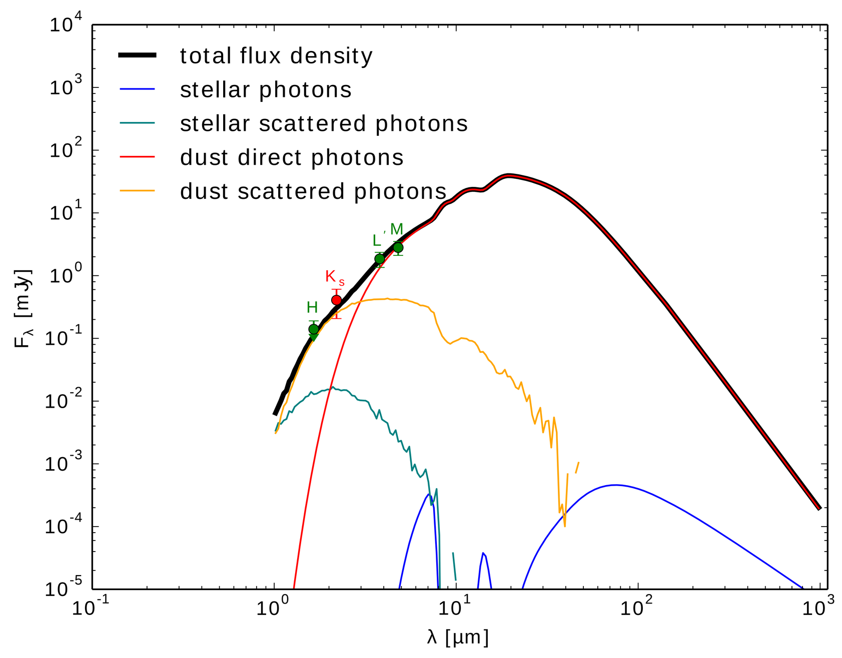
Plausible mechanism of star formation close to Sgr A*

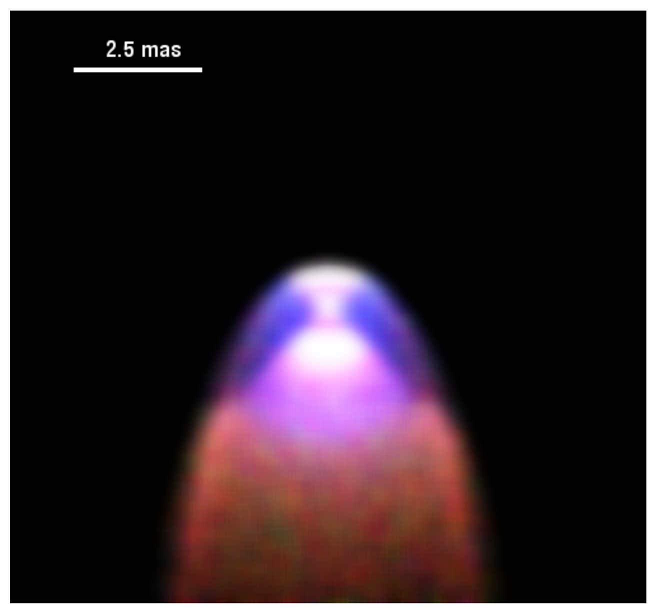


A scenario of infalling molecular clump (100 solar masses; 0.2 pc, isothermal - 50 K) in which star-formation can take place due to tidal focusing (Jalali+2014). Each red circle in the Figure denotes an ensemble of stars similar to IRS 13N association observed in the Galactic centre. DSO/G2 could have formed recently via a similar process, 10^5 - 10^6 yrs ago.

Spectral energy distribution

We perform 3D Monte-Carlo radiative-transfer simulations using the *Hyperion* code (Robitaille+ 2011). A star with L =30 Lsun enshrouded by a non-spherical dusty envelope fits the SED of the DSO/G2.



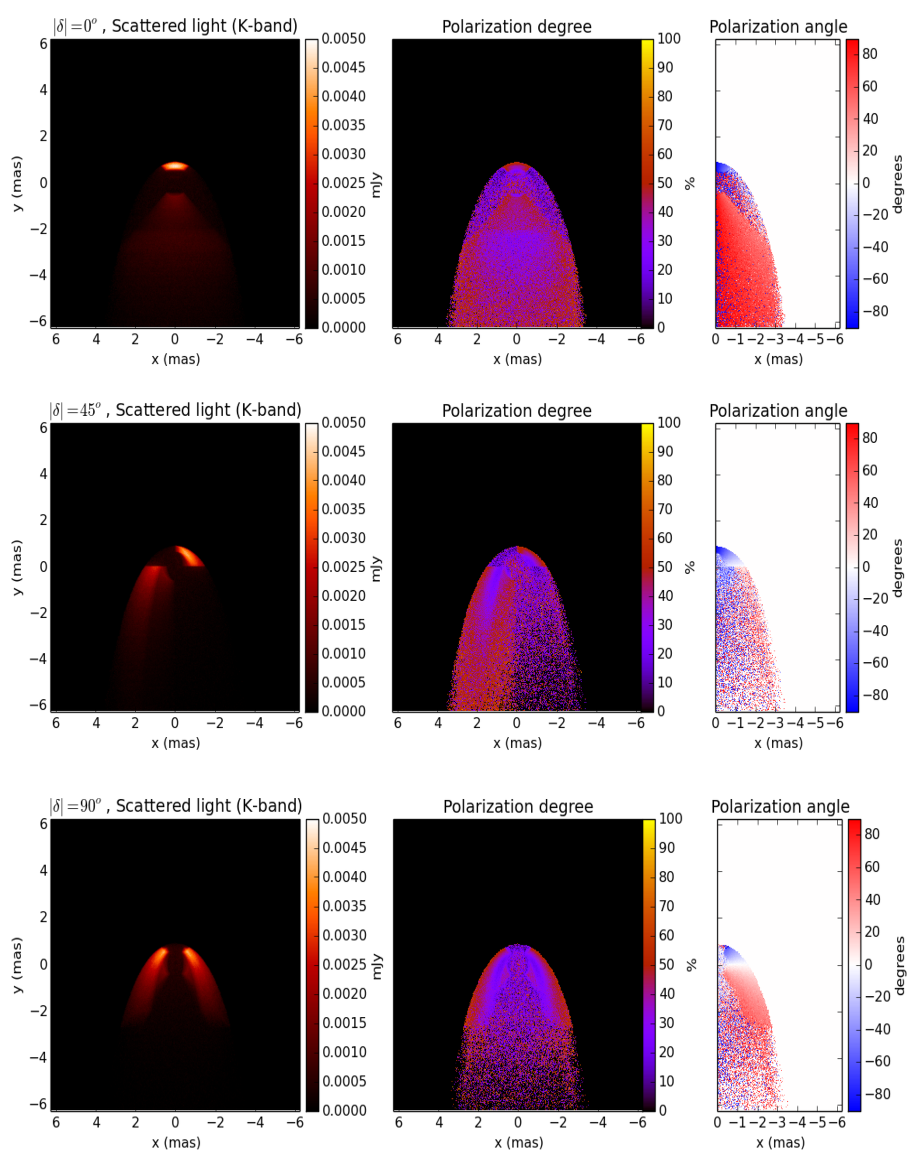


Left: Simulated SED of the DSO/G2 with observed values. Right: RGB image of the source model of the DSO (K_s, L' and M bands).

Polarized emission

We also construct synthetic images of the DSO model in K_s band. The significant observed linear polarization degree of approx. 30% can be reproduced. Mie scattering on spherical dust grains produces the polarized emission in the model. Due to the non-spherical nature of the dusty envelope (because of bipolar cavities and dense bow shock) individual contributions do not cancel each other and the simulated total degree reaches 25-30%.

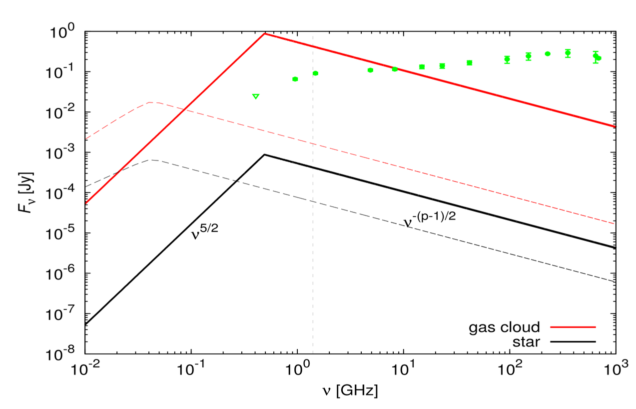
From top to bottom: images of scattered light in K_s band and the distributions of the polarization degree and the angle for different orientation of the bipolar outflow

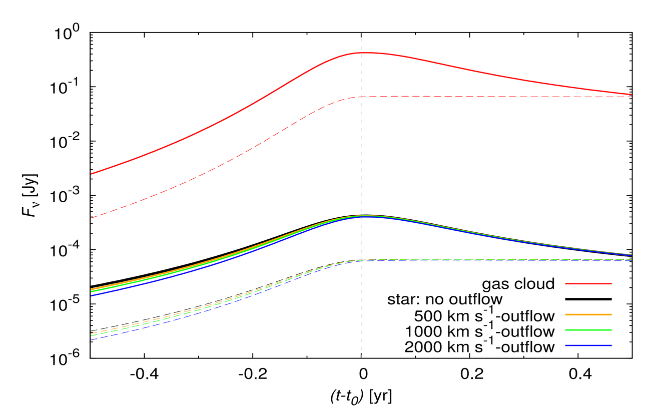


Non-detection of Non-thermal emission

Alongside the thermal emission of the star, dust and the emission scattered on dust grains, the dense bow shock may be a source of non-thermal synchrotron emission. We calculate the potential emission for the expected cross-sections of the gas cloud (Gillessen+ 2012) and the star (Zajaček +2016). The stellar scenario typically produces synchrotron emission below the quiescent emission of Sgr A*.

Left: Calculated spectrum of the synchrotron emission of the bow shock for the estimated cross-section of the gas cloud (red line) and a wind-blowing star (black line). Right: A light curve for both scenarious at 1.4 GHz.





References

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Robitaille 2011, A&A 536 A79 • **Shahzamanian+ 2016, A&A accepted (ArXiv #)** • **Valencia-S.+ 2015, ApJ 800** • Witzel+ 2014, ApJL 796
Zajaček+ 2014, A&A, 565 A17 • Zajaček+ 2015, Proc. of 24th WDS • **Zajaček+ 2016, MNRAS 455**

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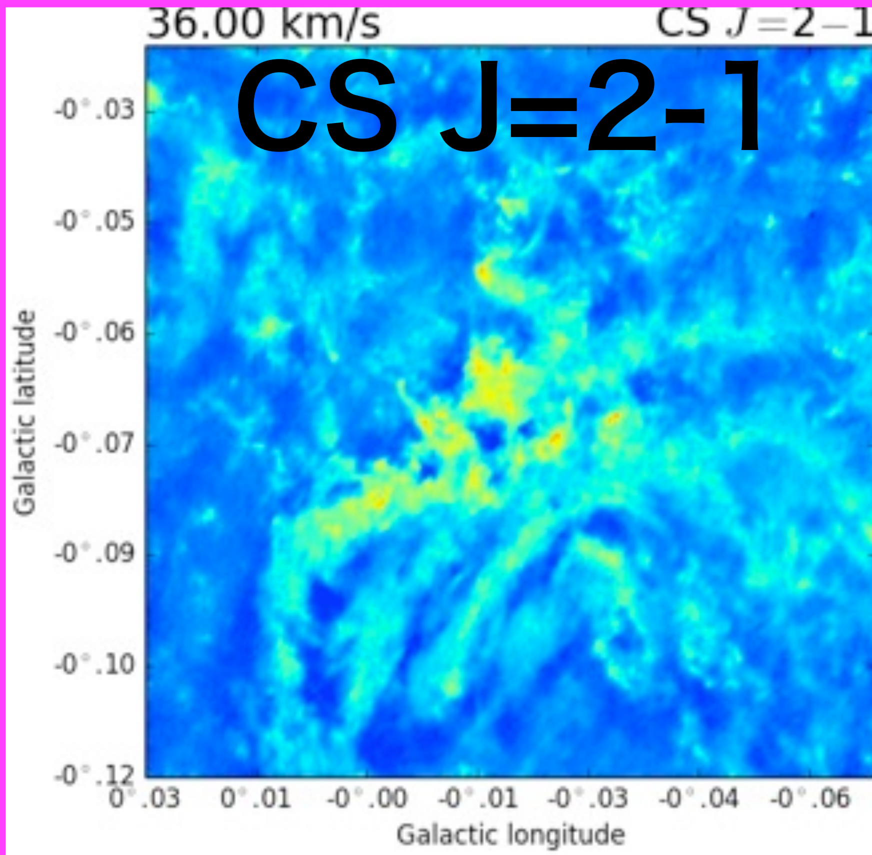
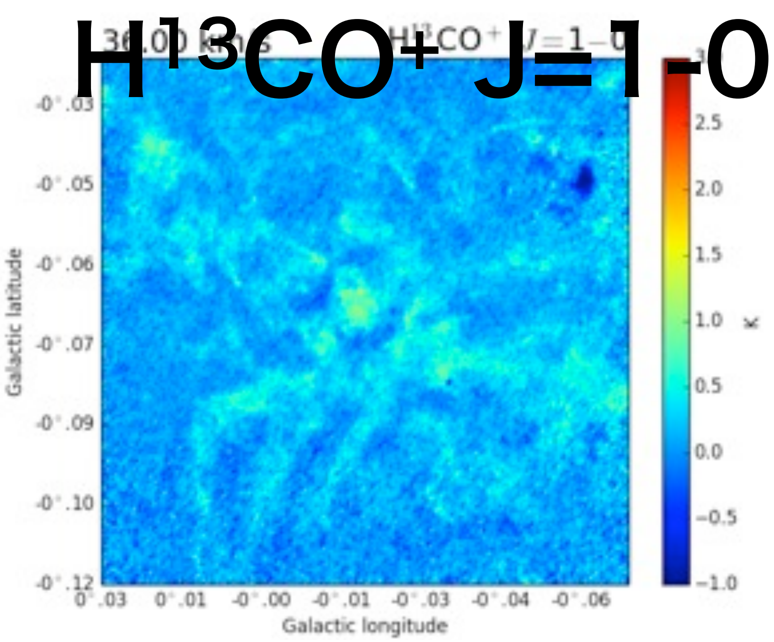
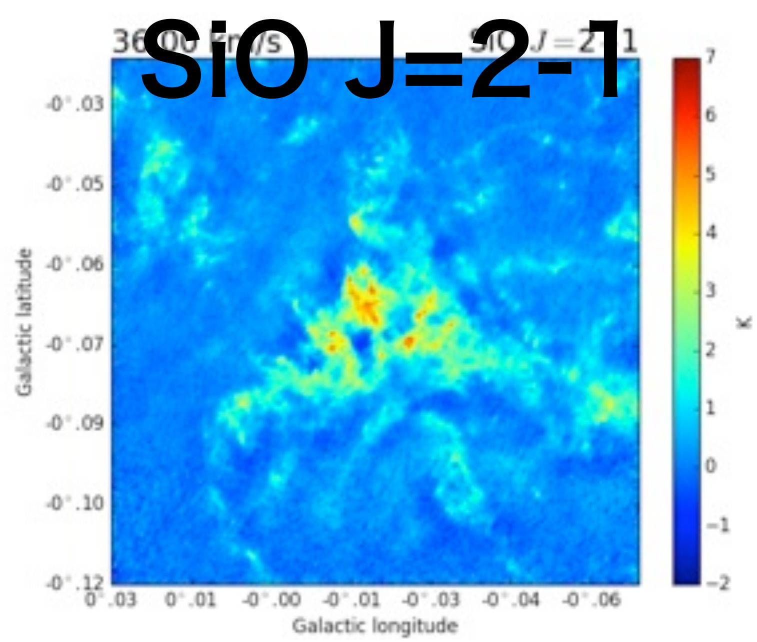
ALMA view of the Galactic Center 50km/s molecular cloud (P05)

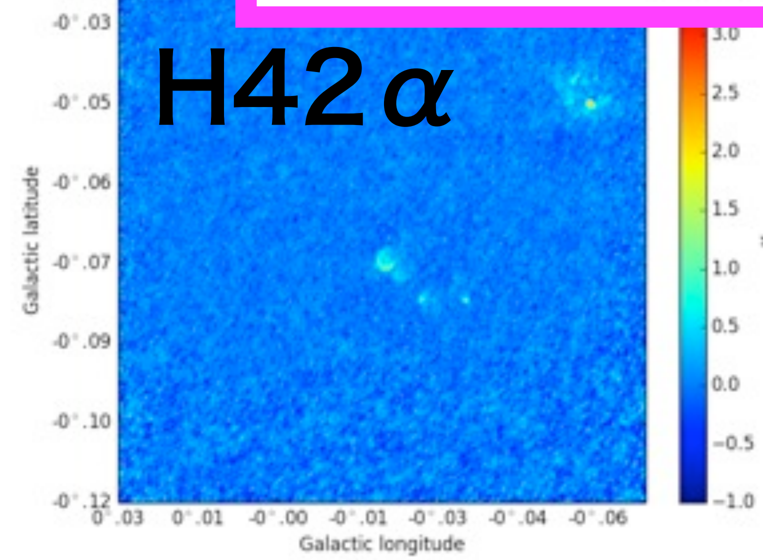
Kenta Uehara (the Univ. Tokyo), Masato Tsuboi,Yoshimi Kitamura(ISAS/JAXA), Ryosuke Miyawaki (J. F. Oberlin Univ.),Atsushi Miyazaki (NAOJ/JSF)

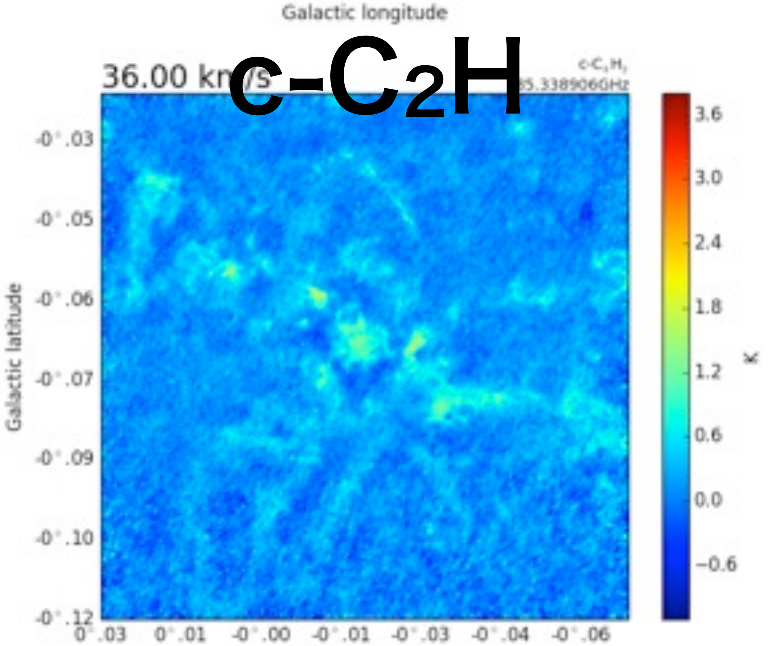


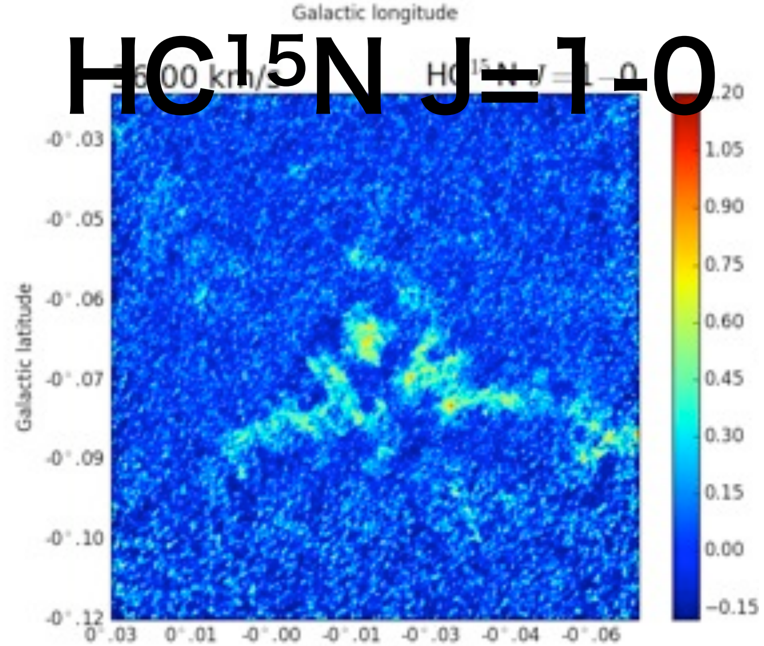
We observed the 50MC in the Sgr A region with ALMA cycle 1. This observation include many emission lines and re-combination lines. The 50MC was resolved into fine structures up to the size of ~0.1pc. In my poster, I present the result of the CS J=2-1 emission line and of the identified filaments.

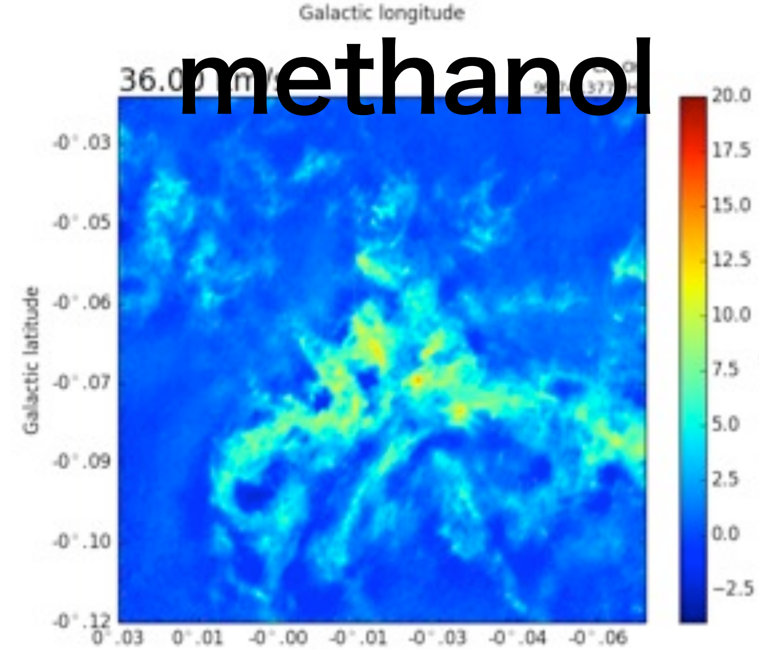










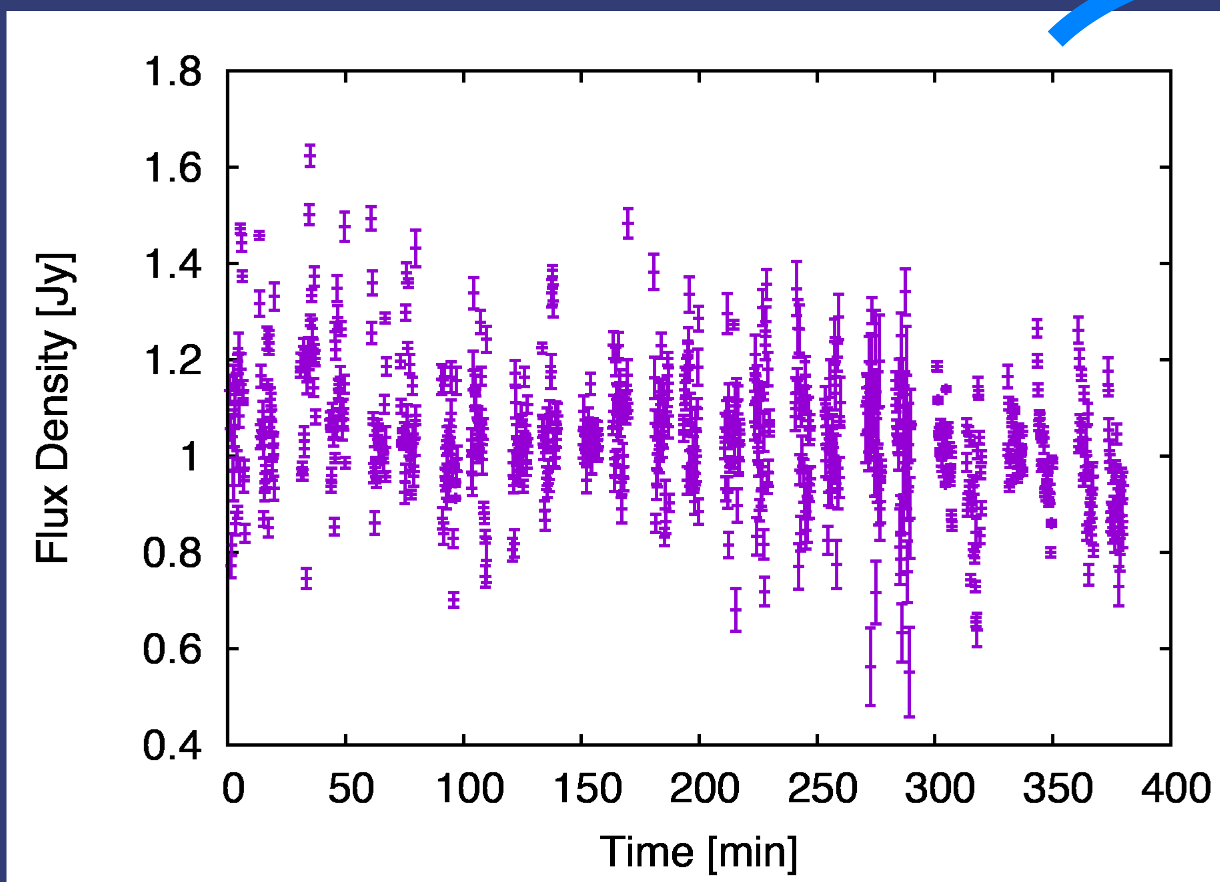


Possible Detection of Quasi-Periodic Oscillations from Sgr A* at 43 GHz

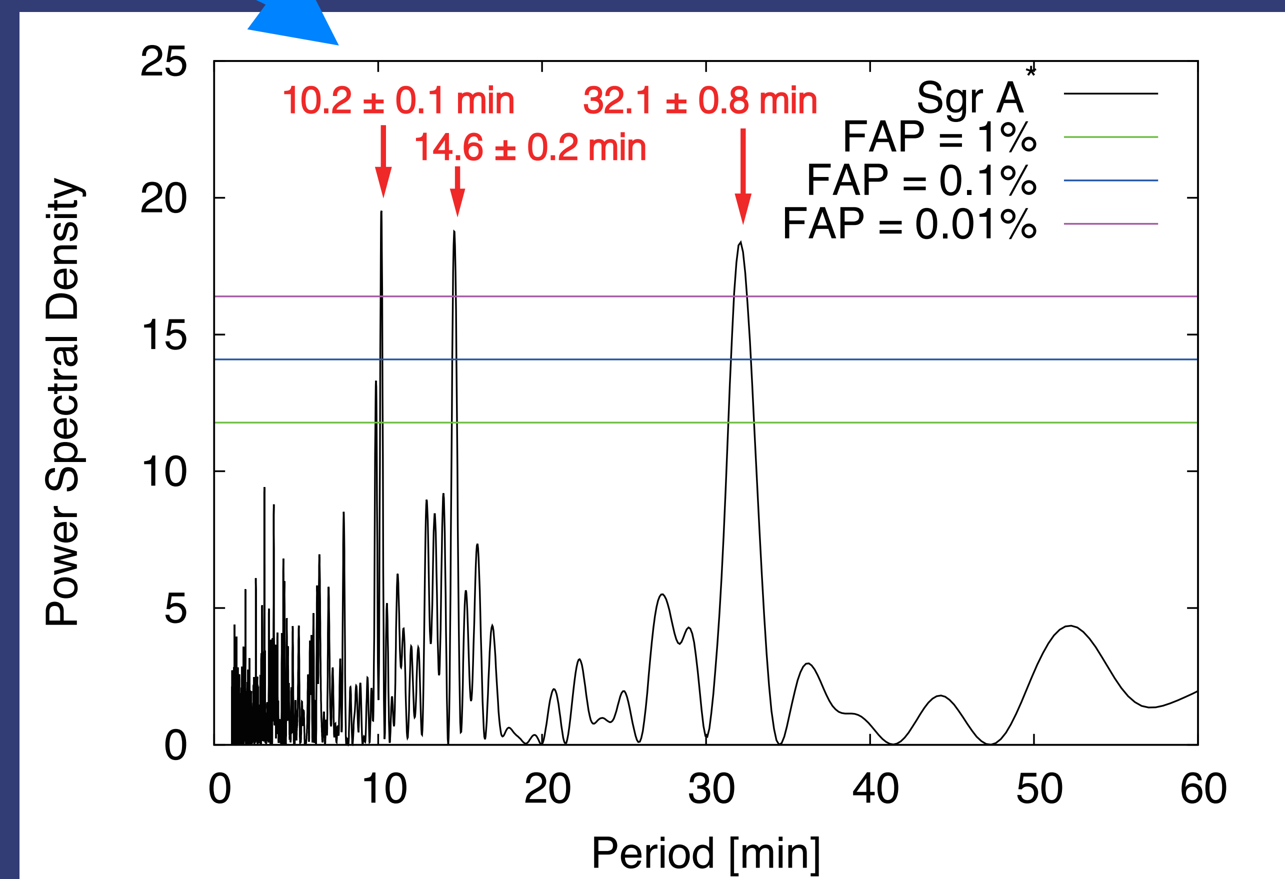
Yuhei Iwata, et al. (Keio Univ.)

We reanalyzed VLBA 43 GHz data more conservatively. ← tentative detection was reported (Miyoshi et al. 2011).

Light Curve at 43 GHz



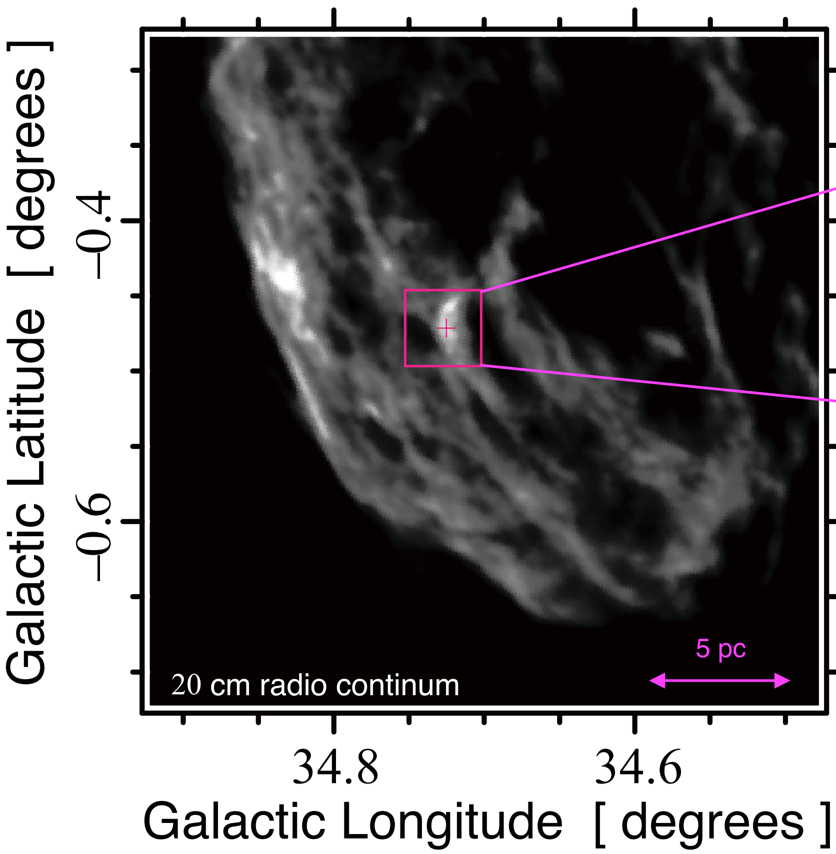
Periodic Analysis

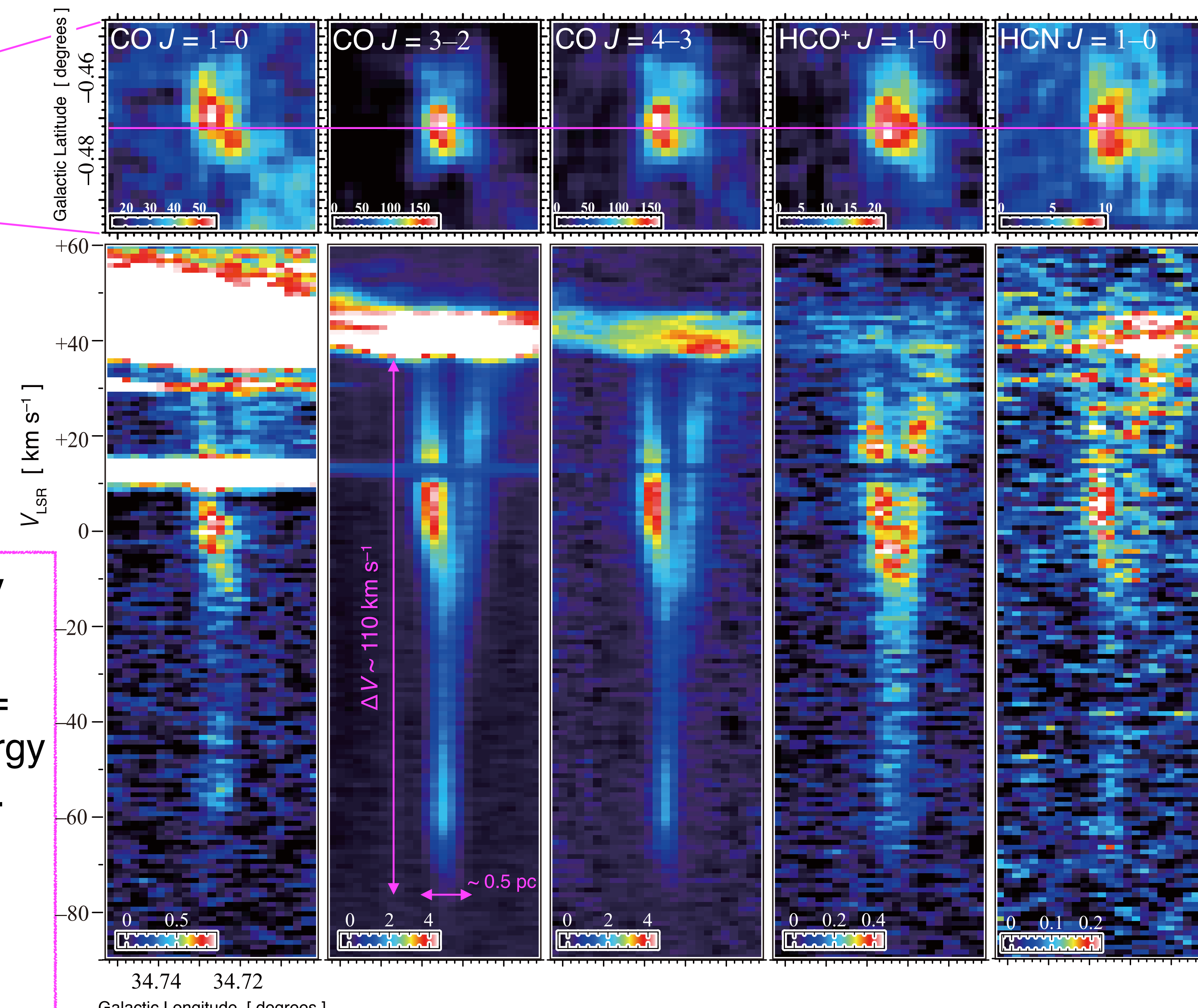


Three characteristic periods were detected!

Kinematics of the Ultra-High-Velocity Gas in the Expanding Molecular Shell Adjacent to the W44 Supernova Remnant

Masaya Yamada, et al. (Keio University)

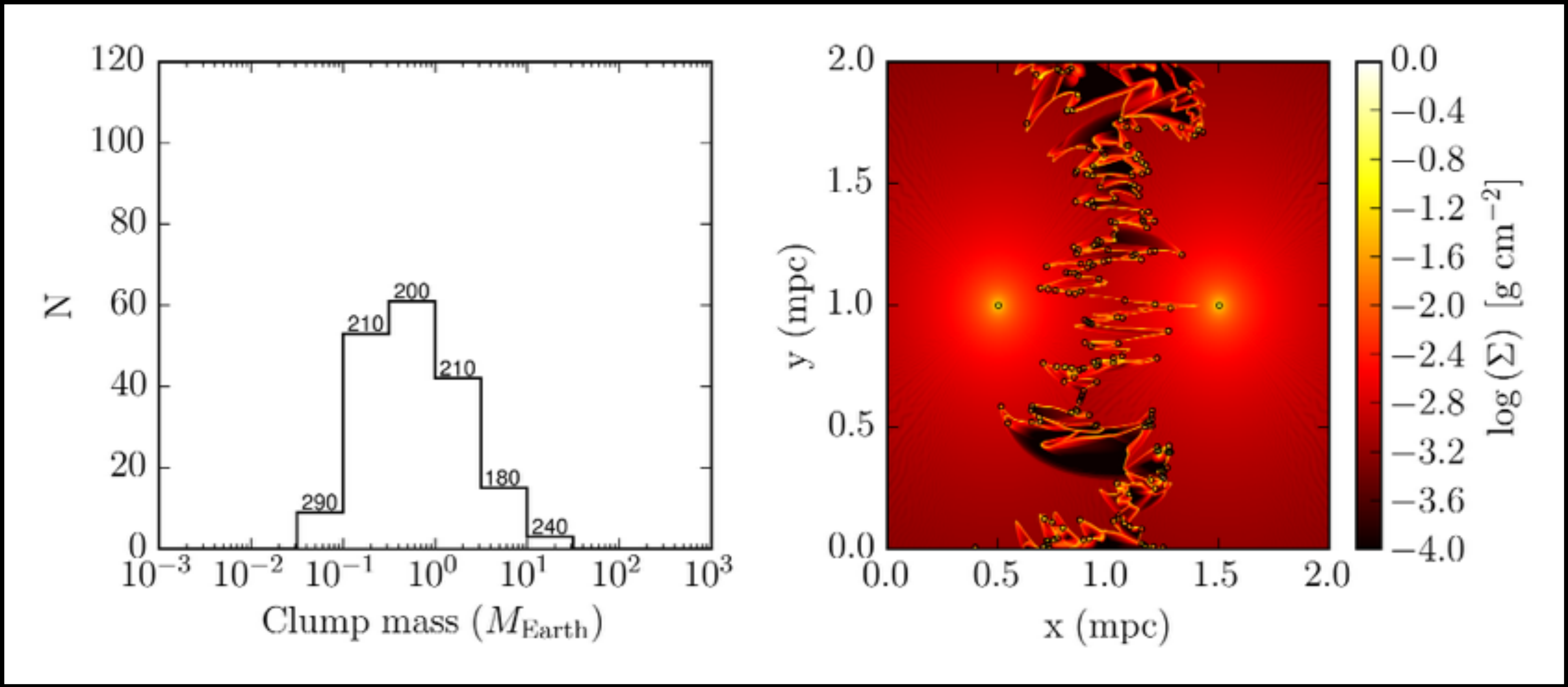




1. We mapped the ultra-high-velocity feature (the'Bullet').
2. The 'Bullet' is most intense CO J = 3–2 emission, and the kinetic energy of the Bullet amounts to $10^{48.0}$ erg.
3. The Bullet might have been accelerated by a plunge of a compact object, likely an isolated stellar mass black hole.

Clump formation through colliding stellar winds in the Galactic Centre

Diego Calderón, J. Cuadra, A. Ballone, M. Schartmann, et al



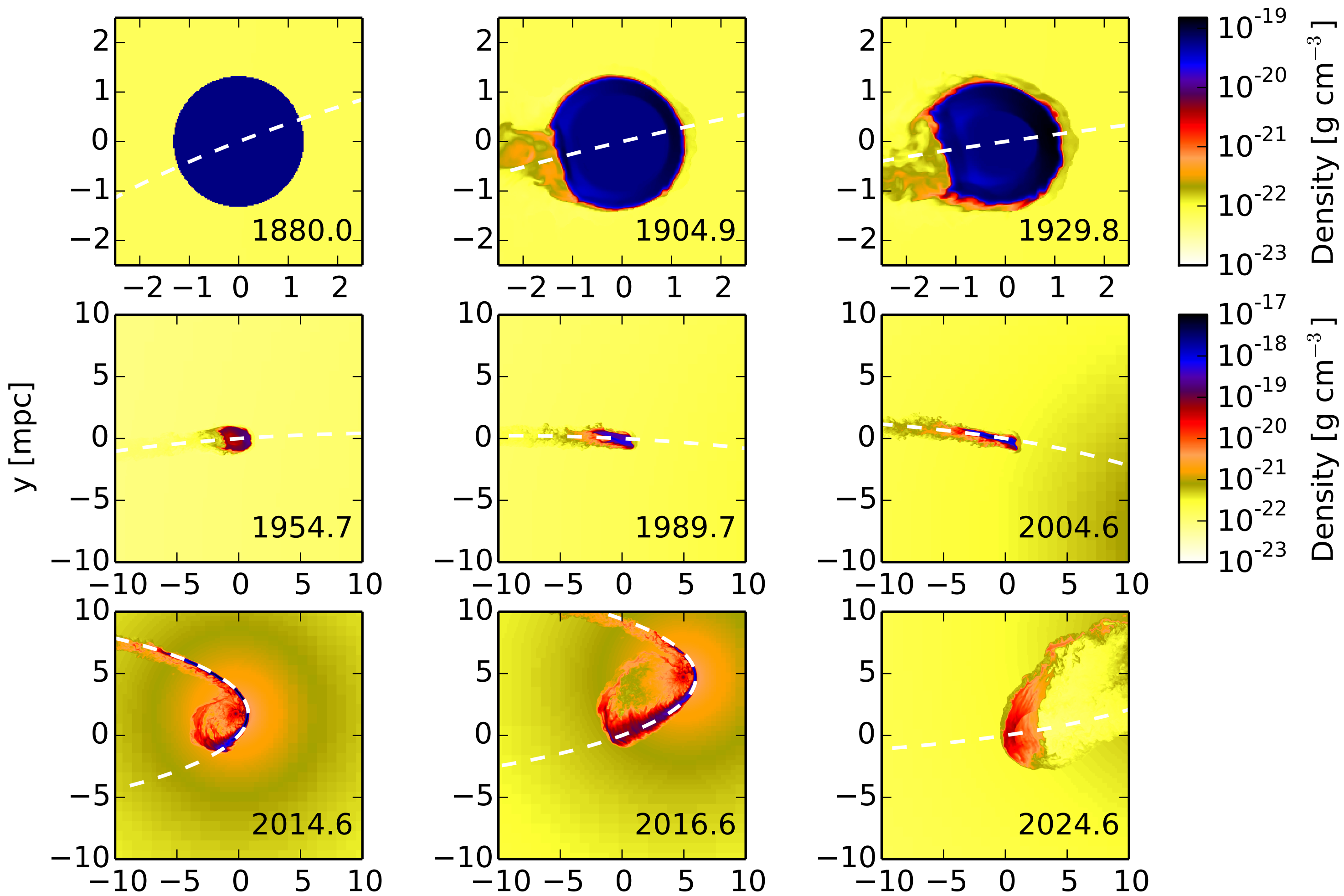
- Could G1 and G2 be gas clumps formed in wind collisions?
- **Gas clumps up to 100M_{Earth}** can be formed in wind collisions (G2 ~ 3M_{Earth},, if purely gaseous)
- To do so, winds have to be **slow (<750km s^{-1})** and stars need to be **close (<2000 AU)**.

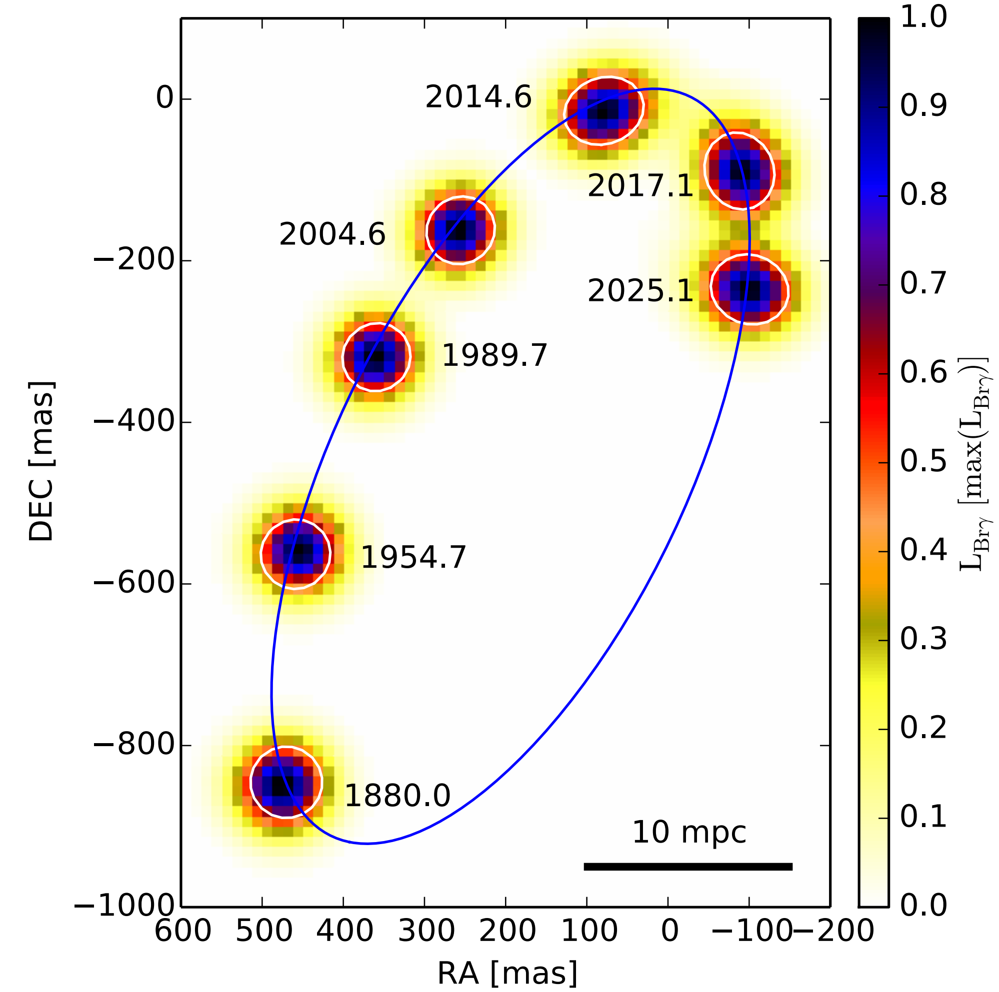
Massive binaries (3 known so far) IRS 16 SW?

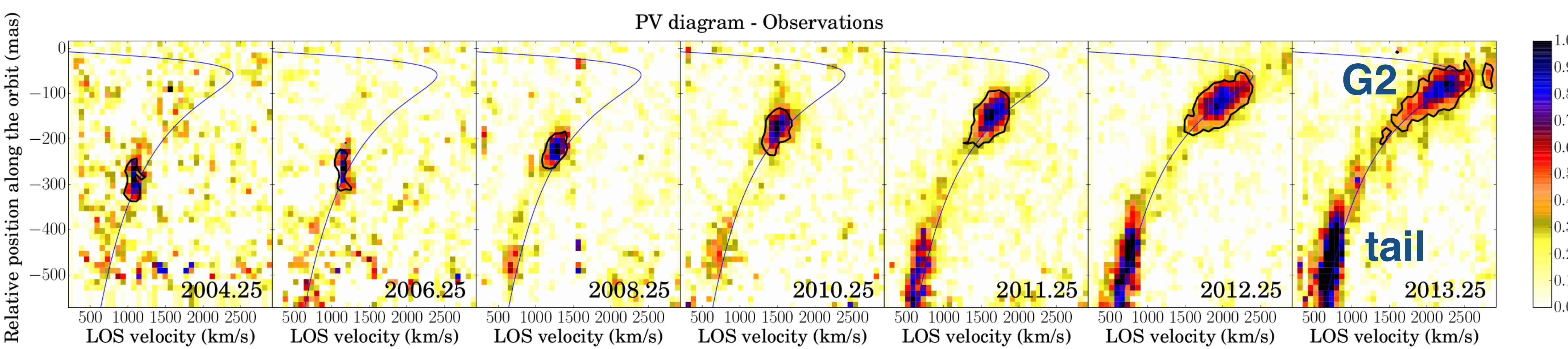
For more details check Calderón et al. (2016)

3D AMR simulations of the evolution of the diffuse gas cloud G2 in the Galactic Centre

M. Schartmann, A. Ballone, A. Burkert, S. Gillessen, R. Genzel, O. Pfuhl,
F. Eisenhauer, P.M. Plewa, T. Ott, E.M. George, M. Habibi

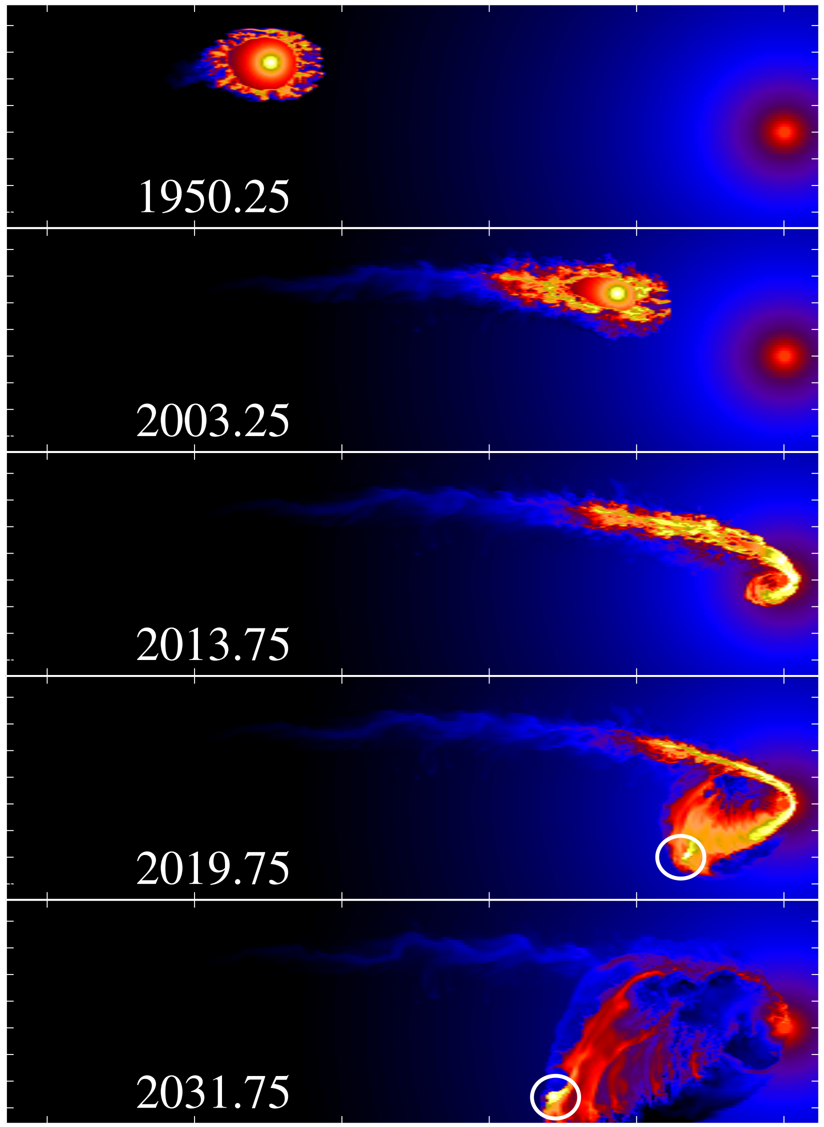






3D AMR simulations of G2 as an outflow

Ballone et al. (in prep.)



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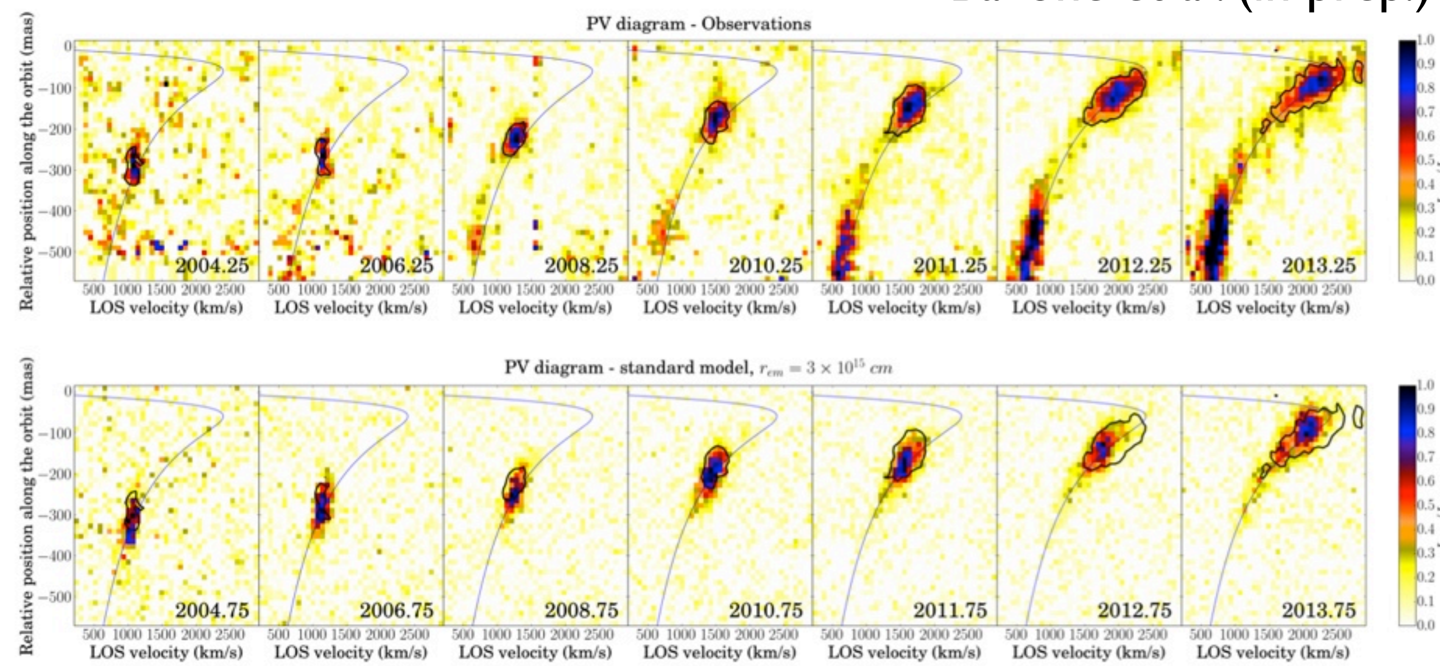
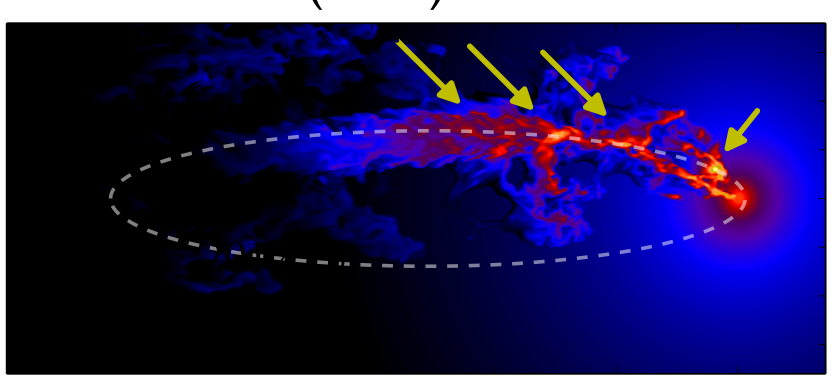


An outflow can reasonably match the PV diagrams, as in the case of the diffuse cloud model (see Marc Schartmann's poster)! But we have to wait some more years to understand...

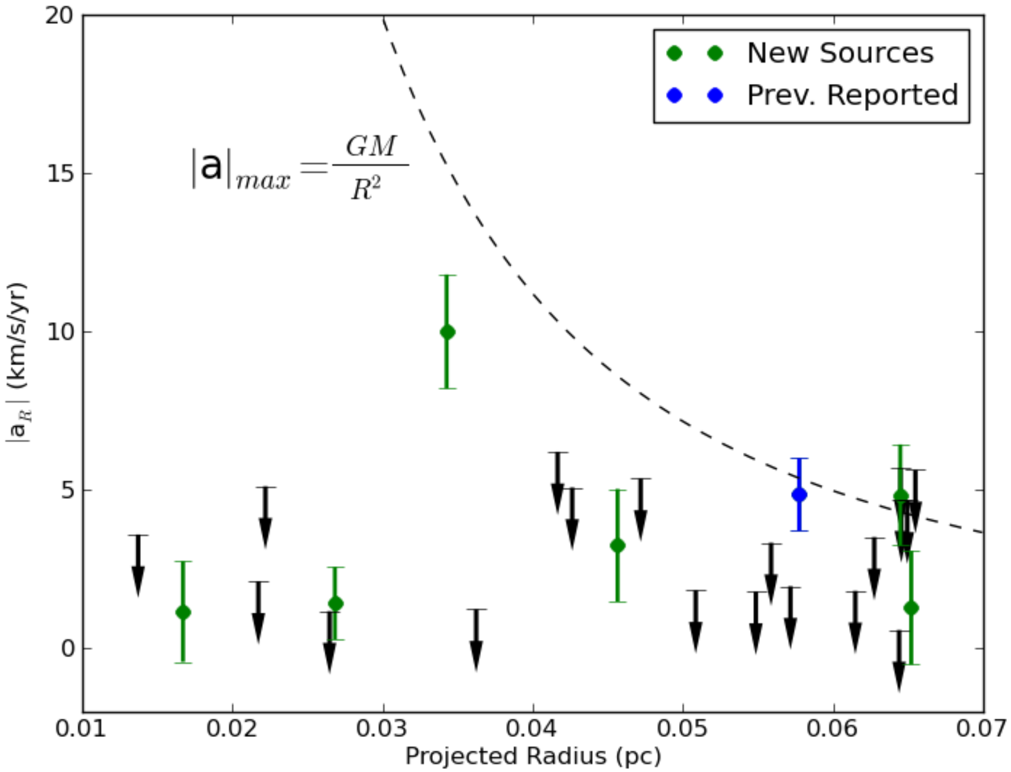
Ballone et al. (2016)



On the other hand, can a faster outflow simultaneously reproduce G2 and its trailing material?

A. Ballone, M. Schartmann, A. Burkert, S. Gillessen, P. M. Plewa, R. Genzel, O. Pfuhl, F. Eisenhauer, T. Ott, E. M. George, M. Habibi

The Late-type Stellar Density Profile in the GC: Statistical Approach

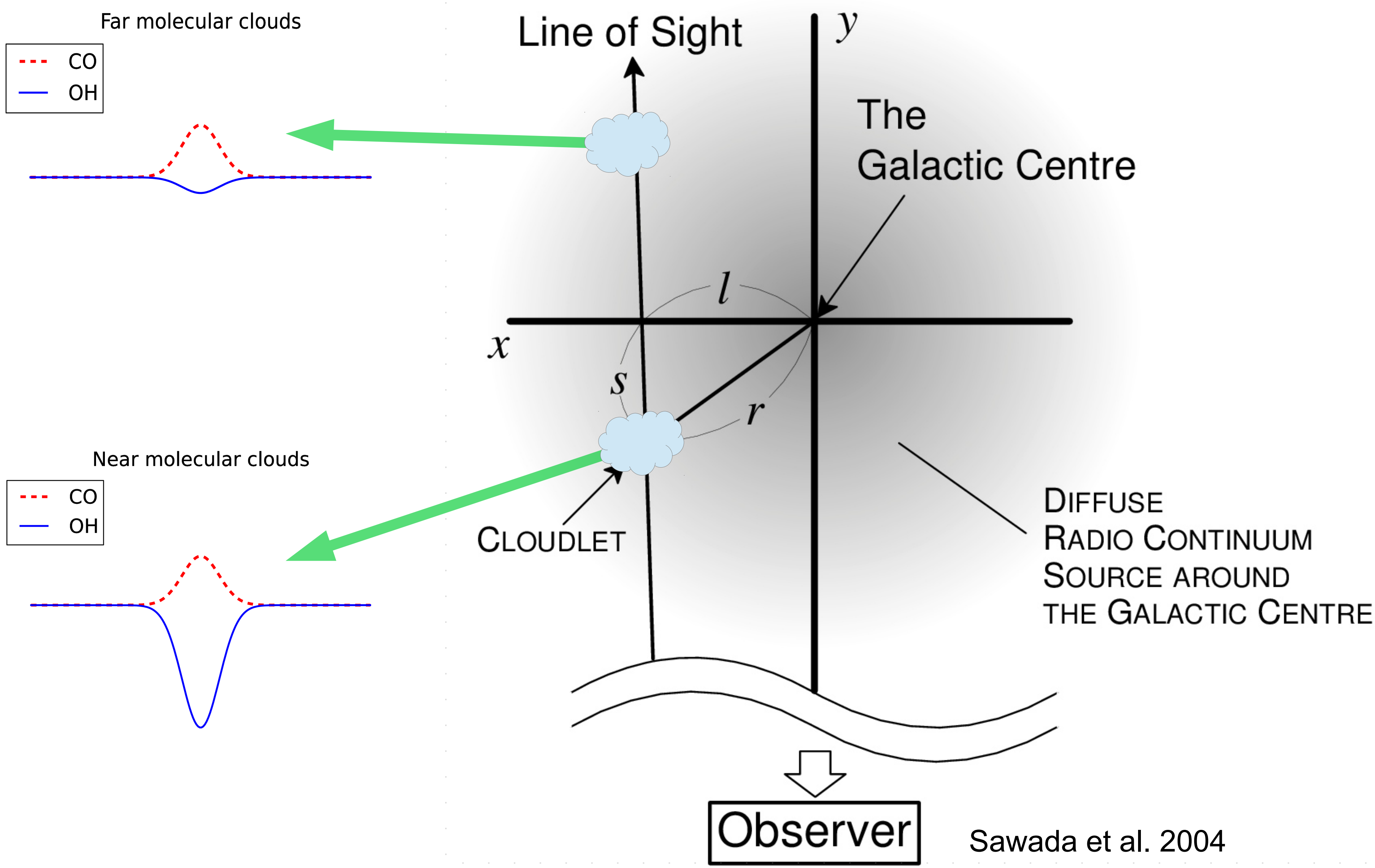


- ○Initial theory: γ be between 3/2 and 7/4
- ○Previous observation: γ ~ 0
    - ○Assumptions to correct for projection effects
- ○New: 3D positions from accelerations

S. Chappell, UCLA

3D model of the Galactic Centre

Qingzeng Yan, Andrew Walsh

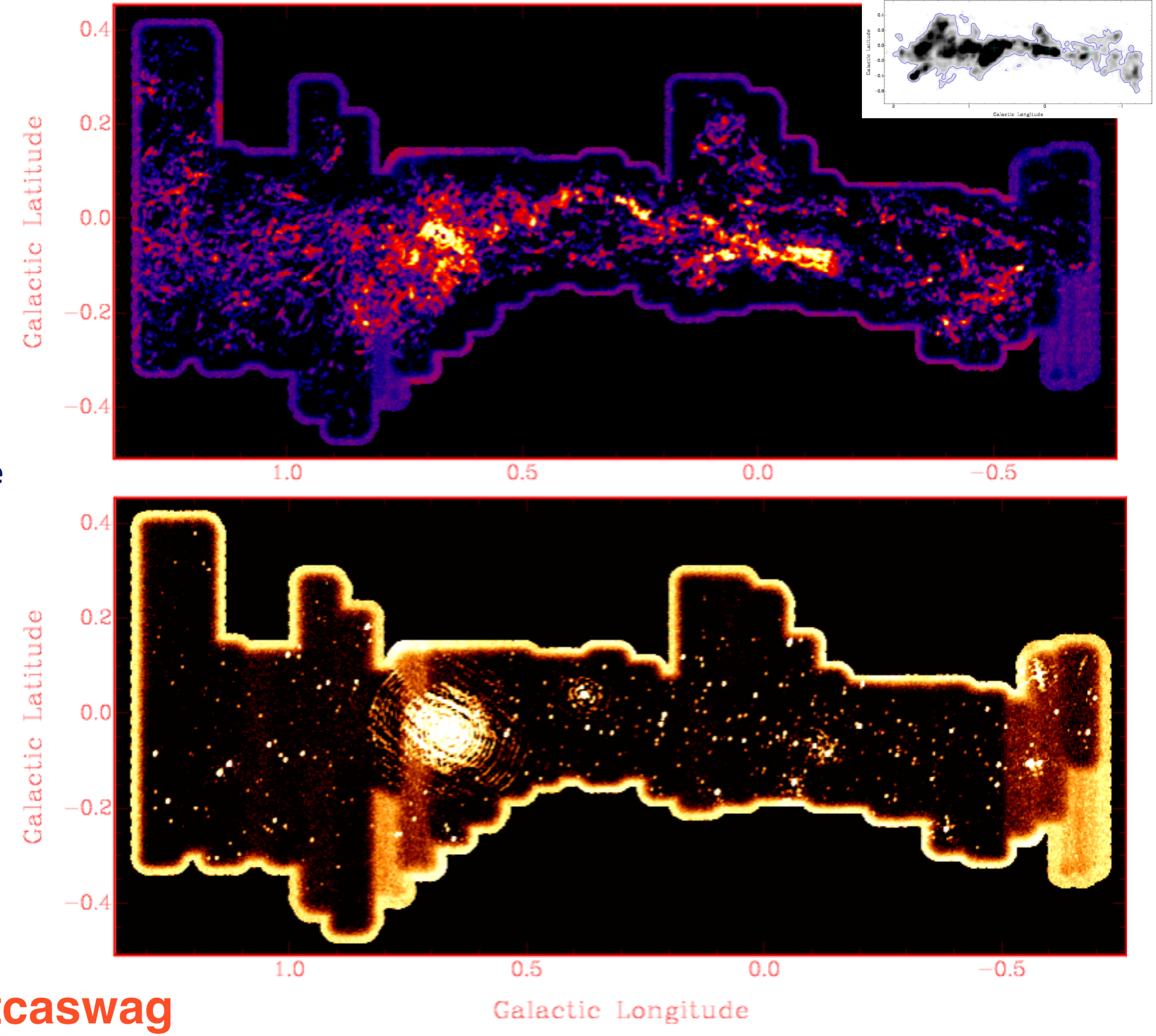


Survey of Water and Ammonia in the Galactic Center

Survey of Water and Ammonia in the Galactic Center

500h ATCA compact configuration. (PI: Ott)
21-26GHz, 42 spectral lines + continuum,
~6500 pointings,
0.8pc (28”) 0.4km/s resolution
Observations ongoing as we speak, might be finished this season

- Maps of temperature, opacity , formation temperature
- Water maser (YSO, AGB), PDR, shock tracers, RRLs
- o(10^4) Clump properties (masses, pressures, densities, sizes, dynamics …
- Continuum: synchrotron, free-free, polarization, (dust/spinning dust)
- Dynamics-temperature connection: poster by Nico Krieger



https://sites.google.com/site/atcaswag

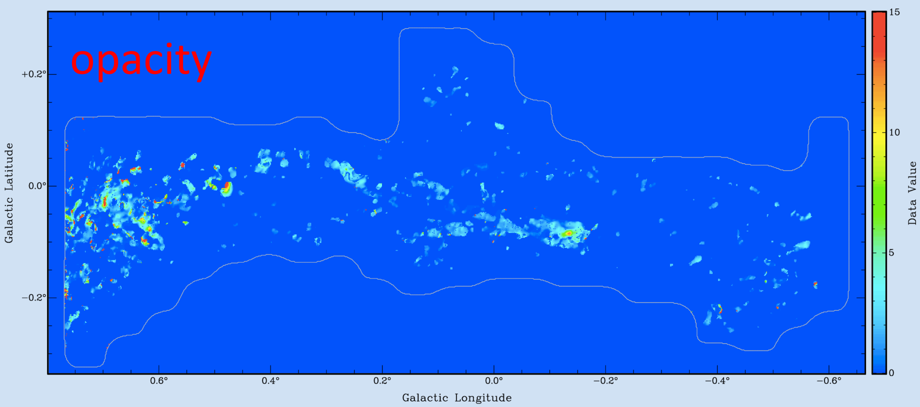
Molecular Cloud Temperatures in the Central Molecular Zone

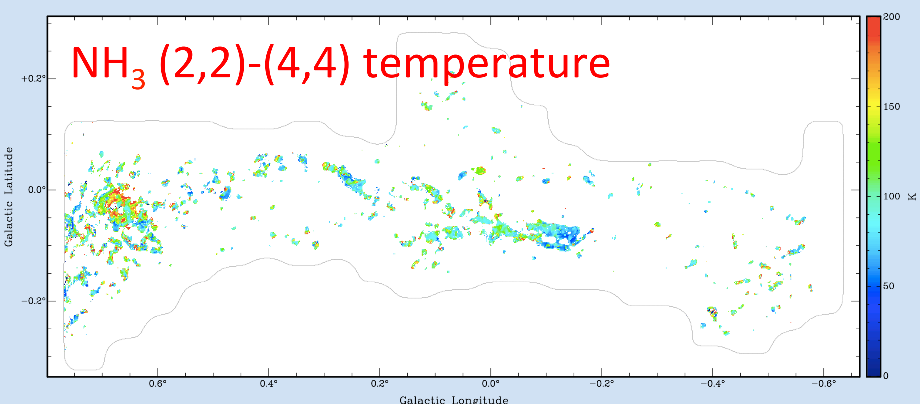
N. Krieger (MPIA), J. Ott, F. Walter, D. Kruijssen, H. Beuther

SWAG

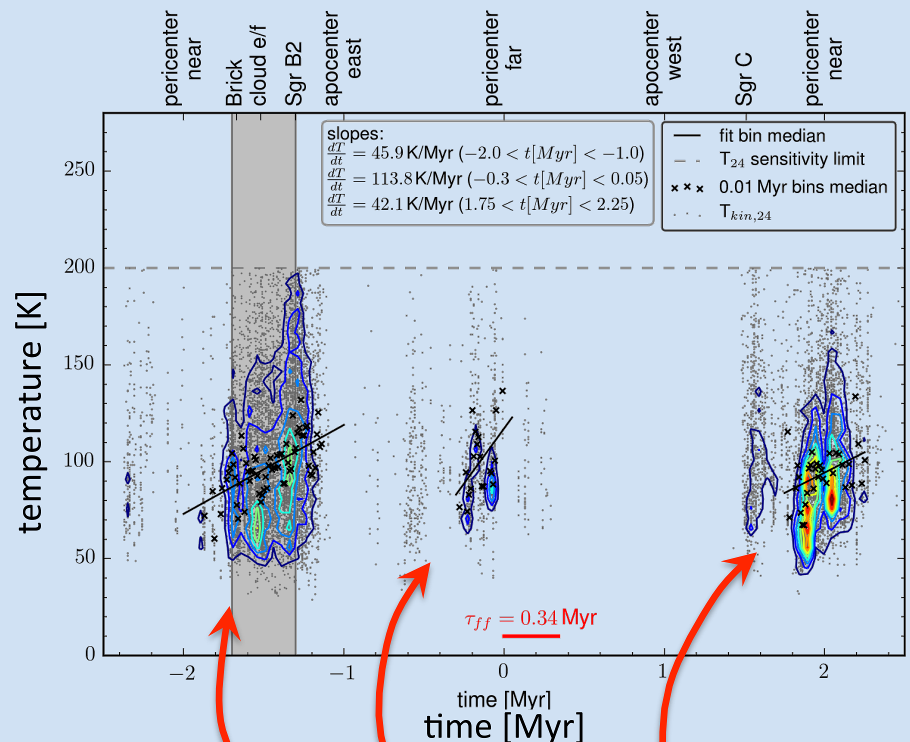
Survey of Water and Ammonia in the Galactic Center

SWAG (2014 obs. only): Pixel-by-pixel ammonia hyperfine structure fitting





fit CMZ clouds for absolute time assuming stream model



time [Myr]

increasing T in dust ridge and pericenter passages

Hydrodynamic Simulations of the Central Molecular Zone with a Realistic Galactic Potential

Jihye Shin (Korea Institute for Advanced Study) & Sungsoo S. Kim (Kyung Hee University)

< Method >

3D SPH simulations with

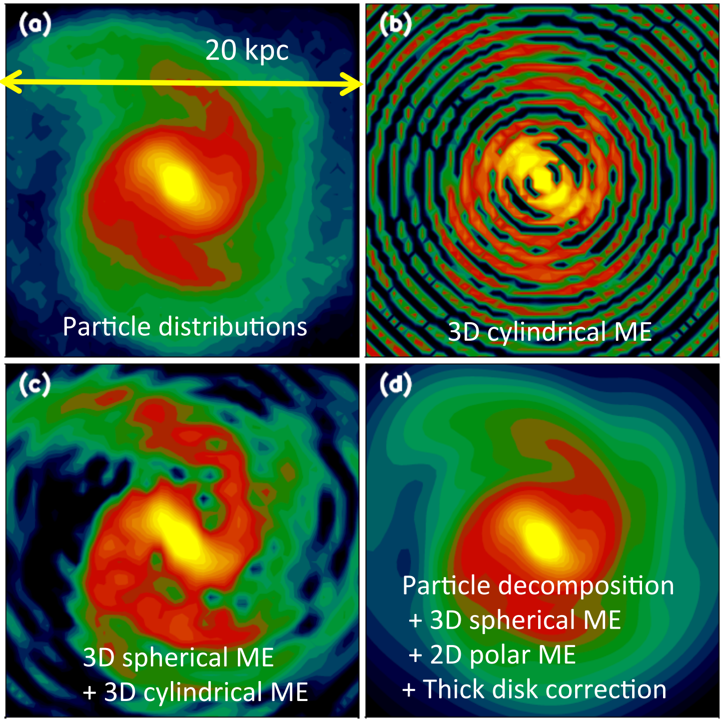
1) realistic astrophysical processes (heating/cooling, SF, and SN feedback)

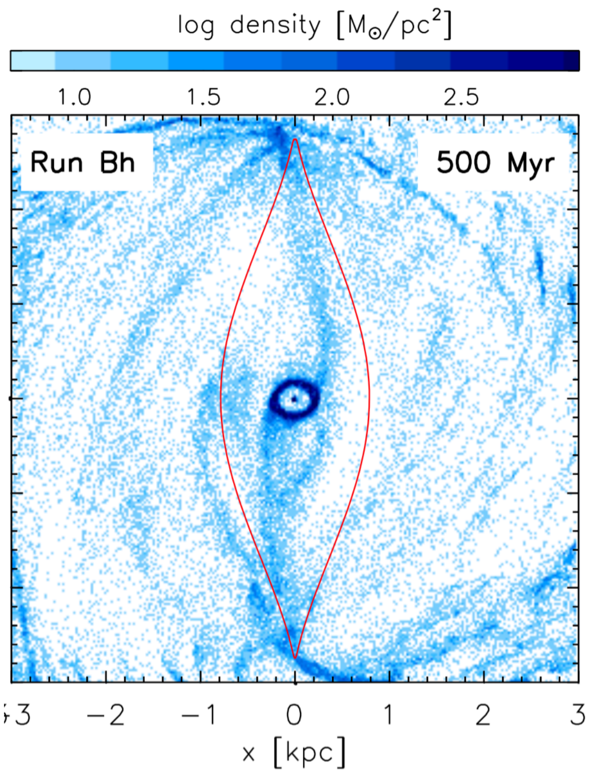
2) realistic Galactic structures

- adopting a snapshot of a self-consistent, high-resolution simulation targeted for the Milky Way (Baba 2015)
- developing a procedure based on the multipole expansion (ME) technique to describe the detailed density distribution of Baba 2015

-> 30 times faster than the self-consistent Galaxy simulation of Baba 2015

-> easily obtain density distribution that are slightly different from the original density distribution by modifying the expansion coefficients





< Results >

1) Through non-axisymmetric Galactic structures of an elongated bar and spiral arms, gas clouds in the disk inflow to the nuclear region and form a central molecular zone (CMZ)-like nuclear ring.

2) SFR and gas inflow rate in the nuclear ring are equilibrated to ~ 0.02 M_{sun}/yr.

3) Simulated nuclear ring well reproduces observed properties of the CMZ; asymmetric mass distribution, compact-sized of ~150 pc, and infinity-shaped feature.

-> Interestingly, our results give a new scope that the CMZ may form quite recently.

Low-end mass function of the Arches and Quintuplet clusters

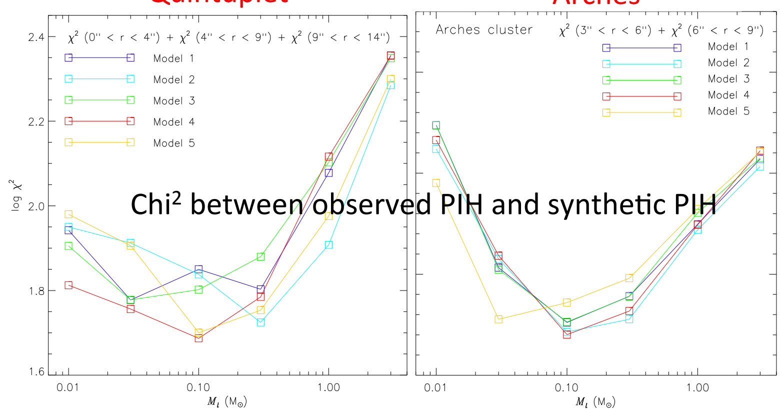
Jihye Shin (Korea Institute for Advanced Study) & Sungsoo S. Kim (Kyung Hee University)

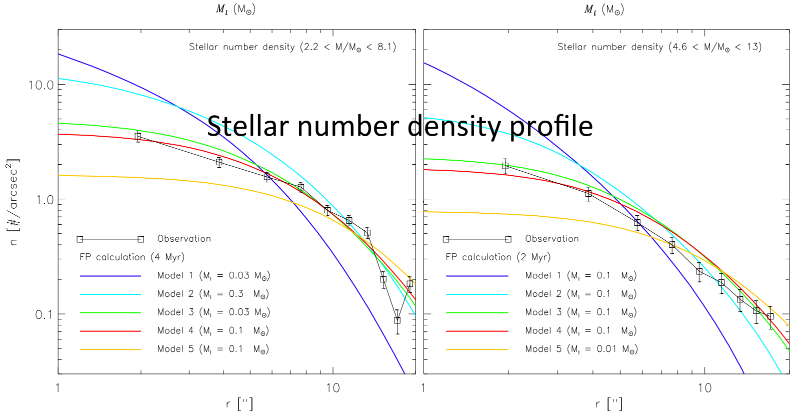
< Method >

We devise a new photometric method to estimate the shape of the low-end mass function (MF) where the individual stars are not resolved.

- Using **pixel intensity histogram of observed images**
- why? fainter stars are more abundant, so they have a non-negligible contribution to the pixel intensities and number distributions of pixel intensities.

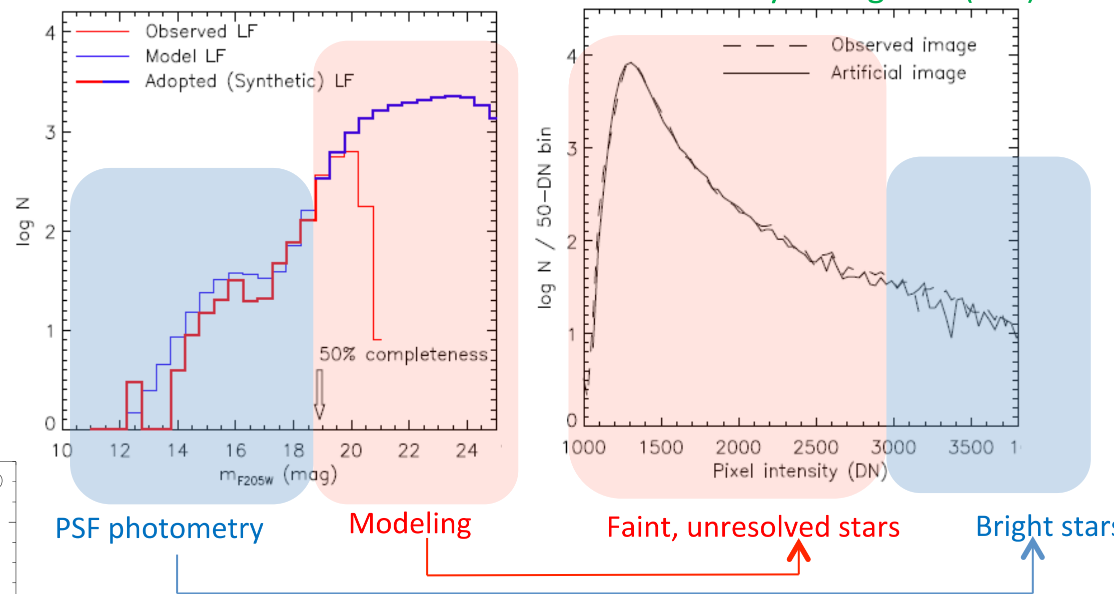
Quintuplet Arches





Luinosity function

Pixel intensity histograim (PIH)



< Results >

Chi² between observed PIH and synthetic PIH

-> Arches & Quintuplet contain unresolved, low-mass stars below 1M$_\odot$.

-> Best-fit Ml with Kroupa MF : M$_l$=0.01-0.3 M$_\odot$

Stellar number density profile

-> Best-fit density profile: **R$_g$=100pc, R$_t$=2.5pc with M$_l$=0.1M$_\odot$** reproduces the observed PIHs and observed number density profile, simultaneously.

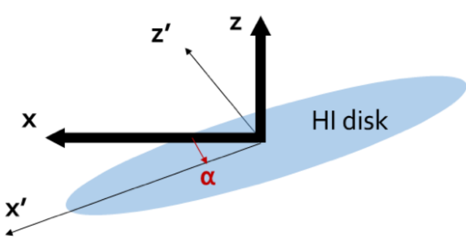
-> MFs of Arches and Quintuplet clusters are not so different from the IMF found in the Galactic disk.

(Shin & Kim 2015, 2016)

Hydrodynamic Simulations of HI Disk in the Galactic Center : Preliminary Report

Joowon Lee (joowon.lee@khu.ac.kr) and Sungsoo S. Kim / Kyung Hee University, Korea

Previous HI survey data have shown that the central **HI gas** in the Milky Way that resides within **~1.5 kpc** of the Galactic Centre (GC) is **tilted by ~15° with respect to the Galactic plane**. Although several models, such as a tilted disk model, have been suggested to interpret the observed morphology of the HI layer, it is still unknown what causes and how it preserves its tilted structure. We study the behavior of a gas disk near the GC using an N-body / SPH code.



Burton & Liszt (1978)

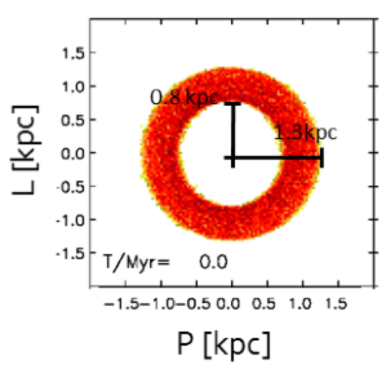
- Axisymmetric disk
- r : 1.3 kpc
- Thickness : ~ 200 pc
- Tilt angle : 22°
- HI mass : $1.1 \times 10^{7}\ M_{\odot}$

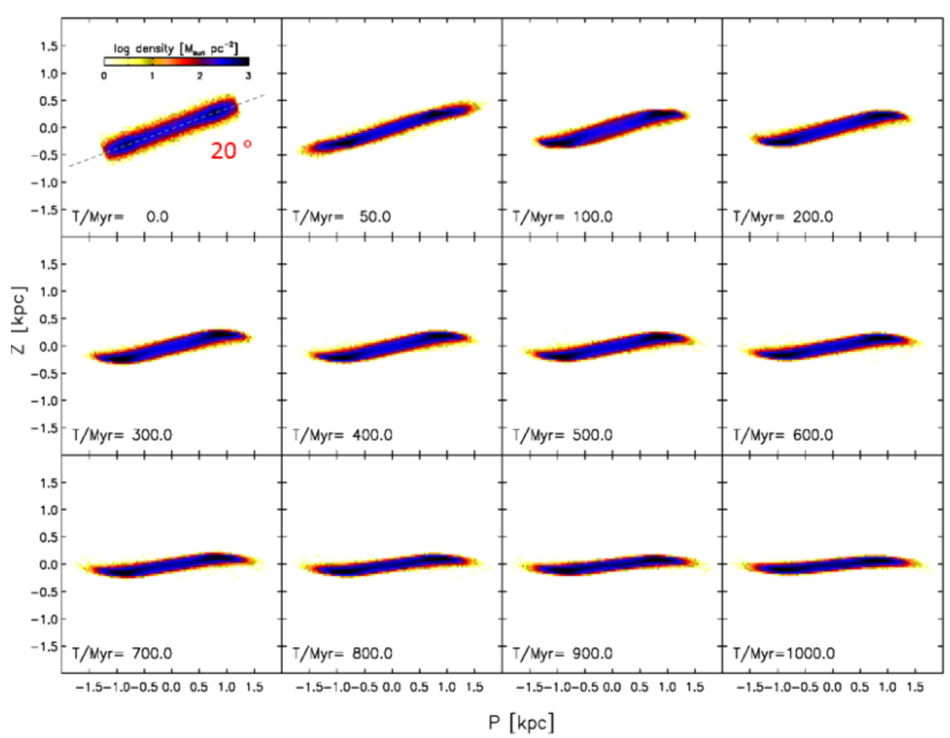
Liszt & Burton (1980)

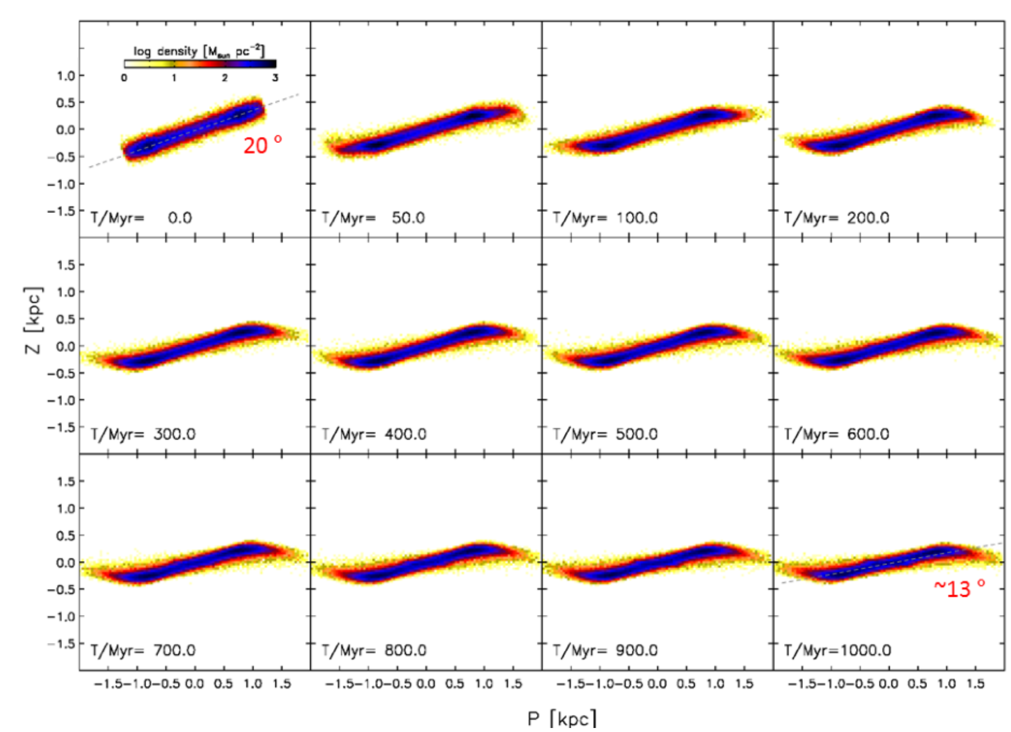
- Elliptical disk
- Semi-major axis : 1.6 kpc
- Axis ratio 3.1 : 1
- Tilt angle : 13.5 °
- HI mass : $5.2 \times 10^{6}\ M_{\odot}$

Ferrière, Gillard & Jean (2007)

- Holed elliptical disk
- Semi-major axis : 1.6 kpc
- Axis ratio 3 : 1
- Inner boundary : 800 pc × 258 pc
- Thickness : ~ 120 pc
- Tilt angle : 13.5 °
- HI mass : $3.5 \times 10^{6}\ M_{\odot}$







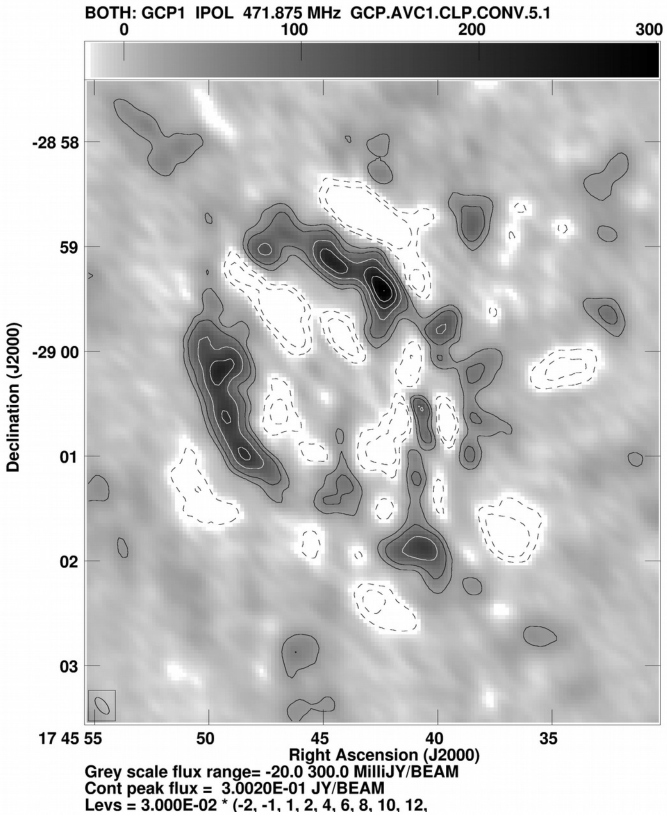
Low radio frequency spectrum of Sgr-A*

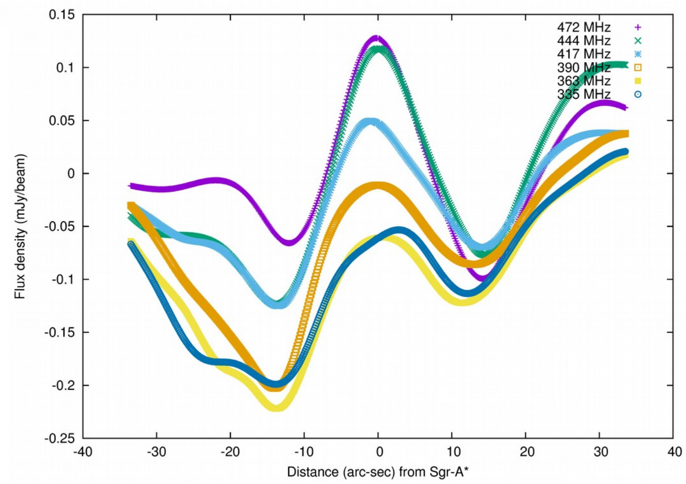
Subhashis Roy (NCRA, Pune, India)

Motivation: Low frequency spectrum important to constrain Sgr-A* emission models.

Galactic centre observed at 250–500 MHz using new wideband system of GMRT.

Preliminary results: Sgr-A* clearly detected till 450 MHz. Cross-cuts indicate Sgr-A* total flux density 0.4 Jy across the band.
Lack of absorption from Sgr-A West. Spectral index ~0.3.

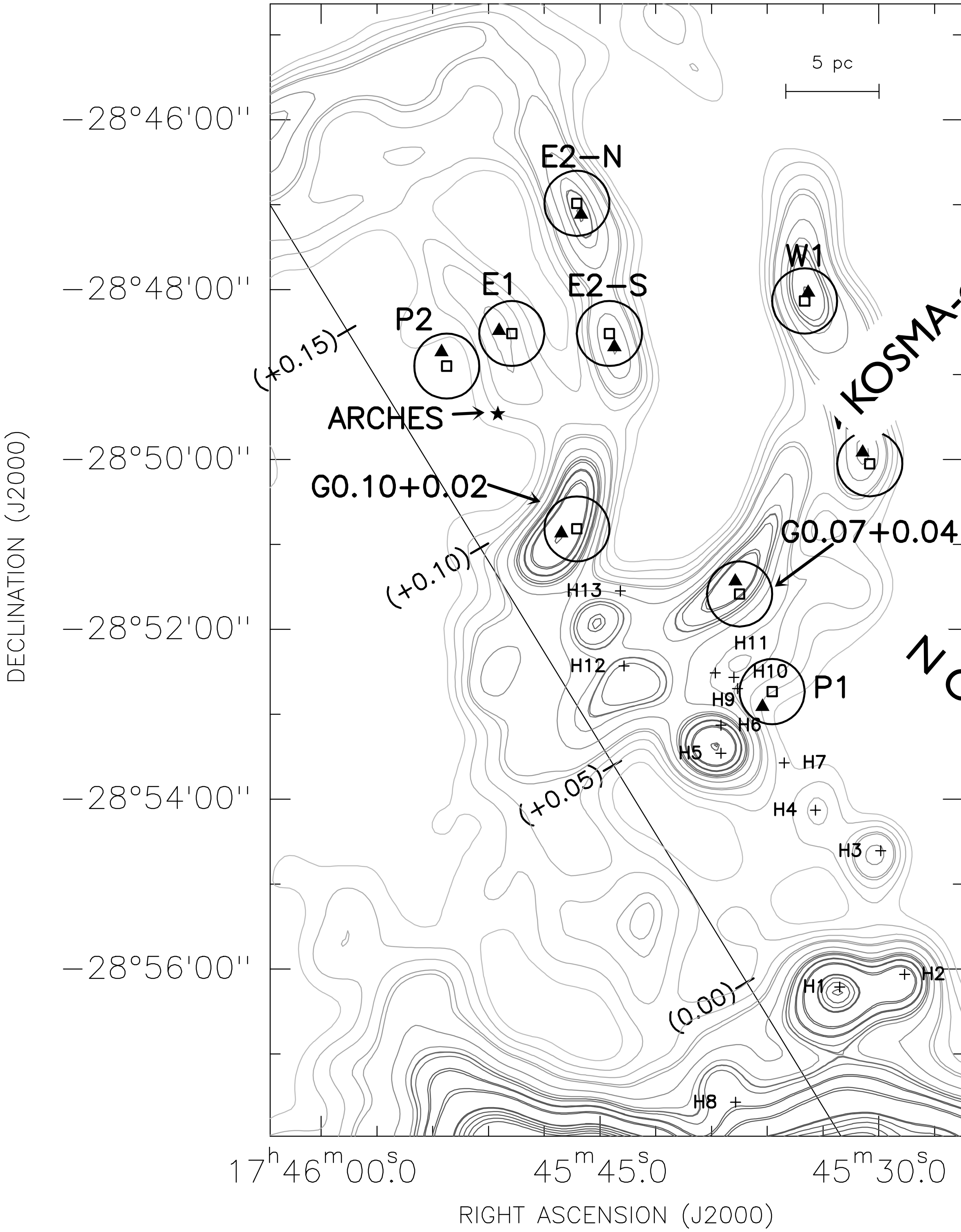




Warm ISM in the Sgr A Complex. II.: PDR Emission from the Arched-Filaments and Nearby Positions

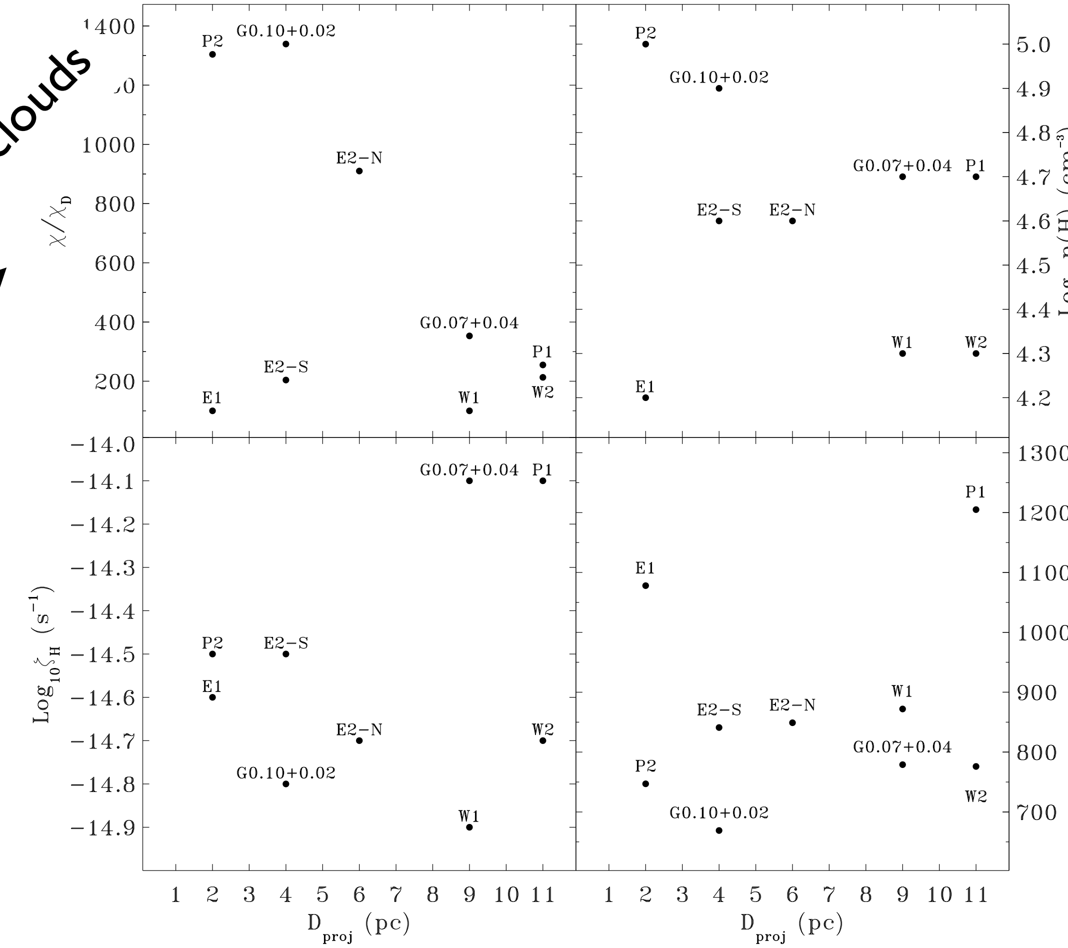
García P. (pgarcia@iram.es), Röllig M., Abel N., Steinke M., Burton M., Backwell R.

P06: García +2016, in prep.



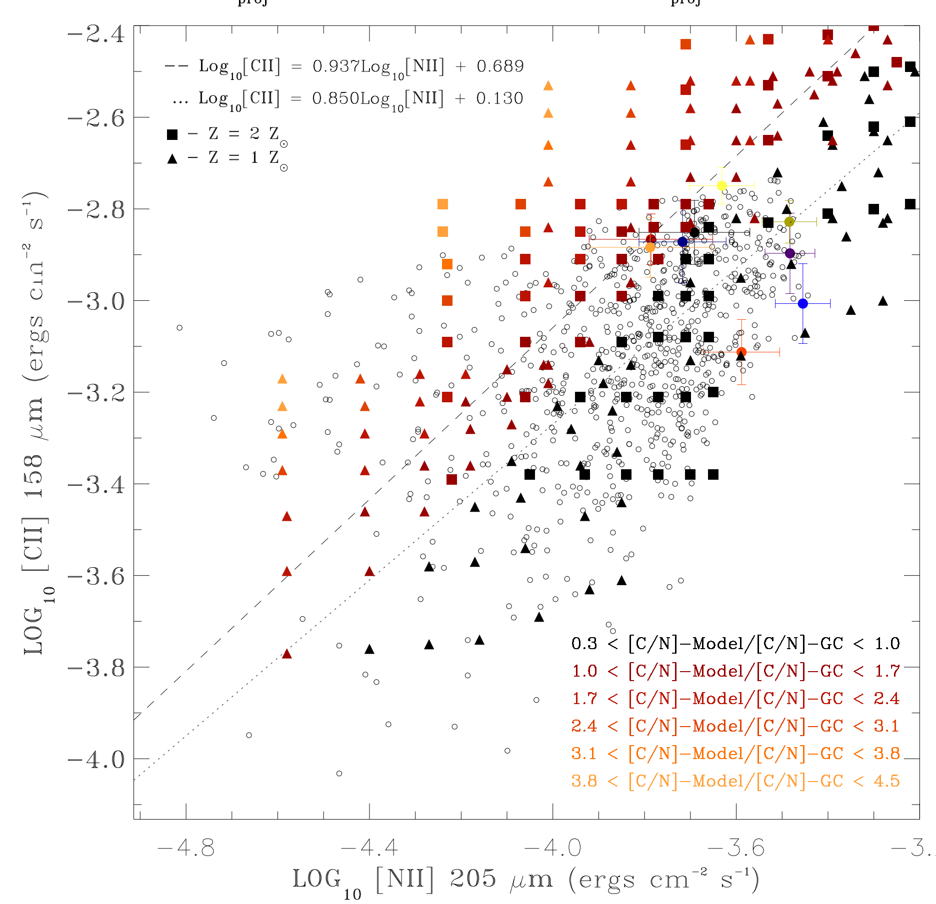
KOSMA-τ PDR model of clumpy clouds

3D Structure



CII 158 μm vs NII 205 μm

N Overabundance in the GC



Sub-mm Obs. of Sgr A GMC in García et al. 2016