IMPRS astronomy & astrophysics Bonn and Cologne

Polarization properties of bow shock sources close to the Galactic centre

RAGtime meeting 19

Author: **Michal Zajaček**

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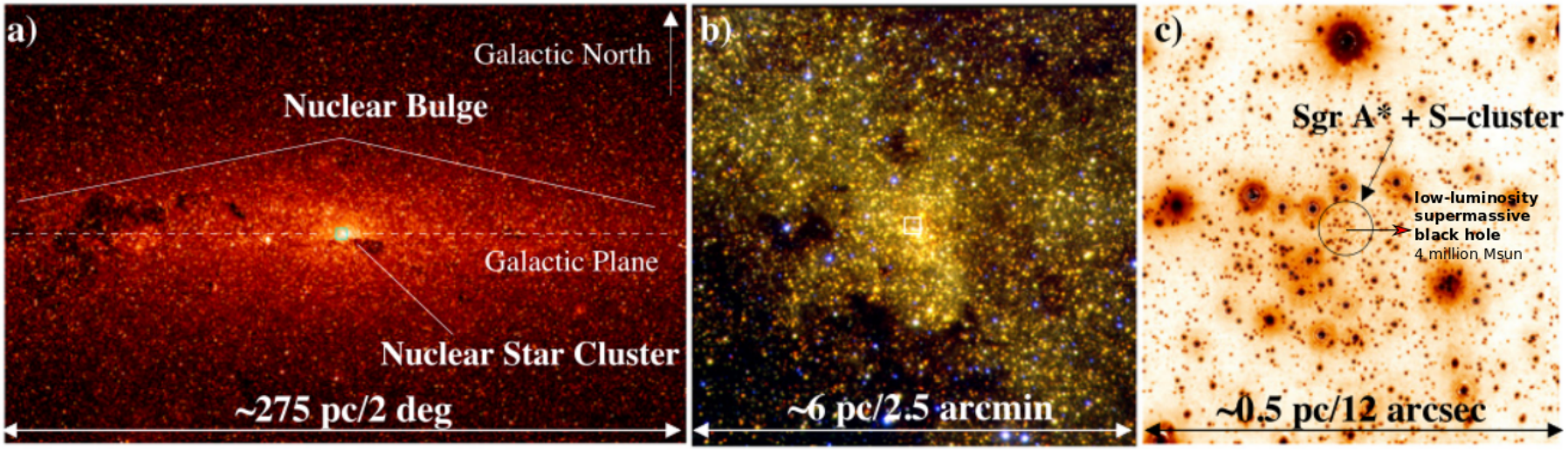
Director of the MPIfR: **Prof. Dr. J. Anton Zensus**

Advisory board: **Priv-Doz. Dr. Silke Britzen (PI)**, **Prof. Dr. Vladimír Karas**, **Dr. Mónica Valencia-S.**

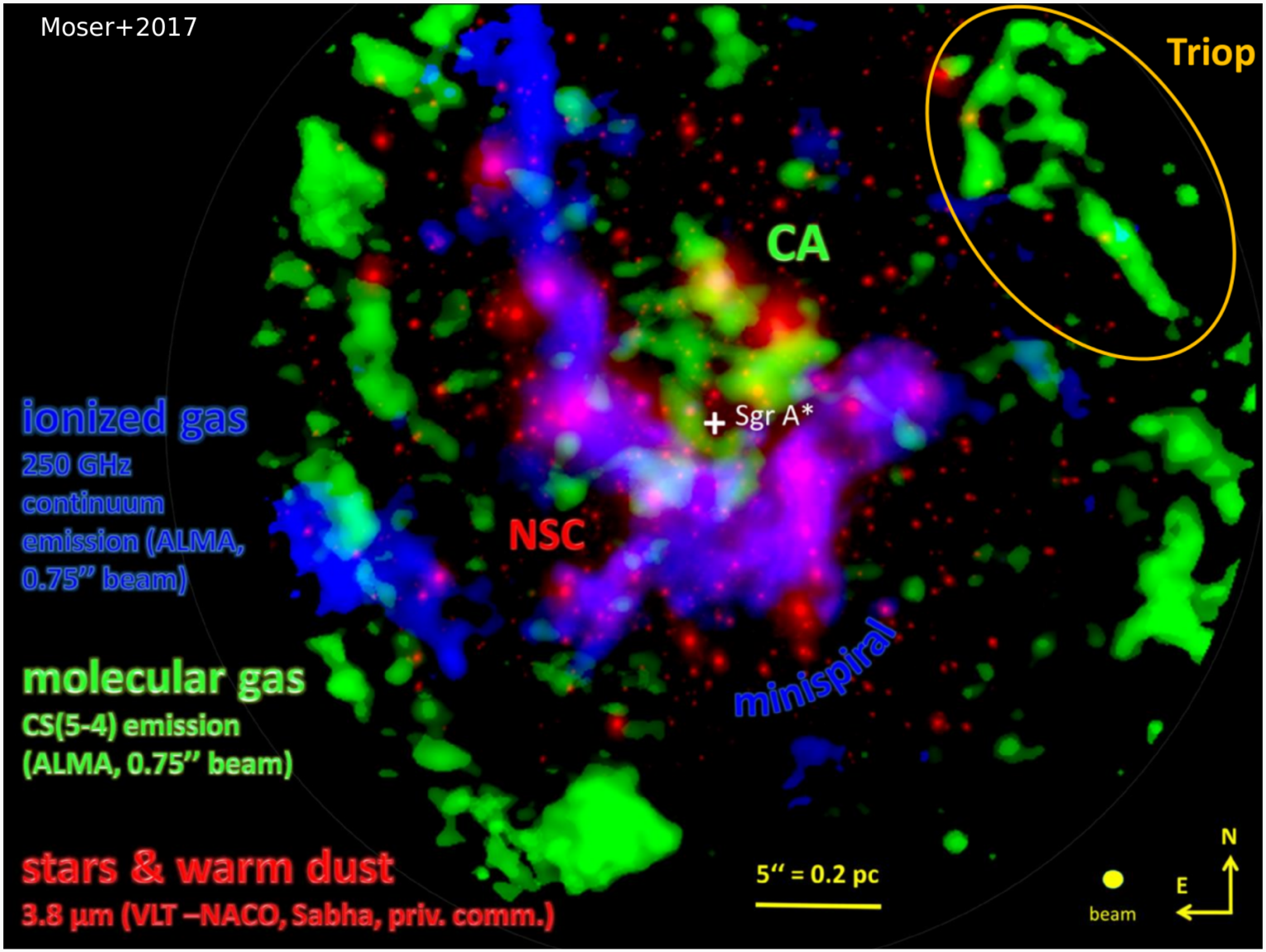
October 24, 2017, Silesian University in Opava

Approaching the Galactic center



- zoom-in towards the compact radio source (Sgr A*) – NIR wavelengths (Schödel+14): (a) Spitzer/IRAC, (b) ISAAC multicolor, (c) NACO/VLT
- **Nuclear Star Cluster**: one of the densest clusters in the Galaxy $\Longleftrightarrow$ **(super)massive black hole (SMBH)** of $4 \times 10^6\ M_\odot$ (Eckart+17, Genzel+10)
- enables monitoring individual objects as well as study cluster properties as a whole

Approaching the Galactic center – a unique laboratory



- the inner 1 pc: unique laboratory – a mutual interaction of stars, gas and dust in the potential of the SMBH

Our group - Recent results

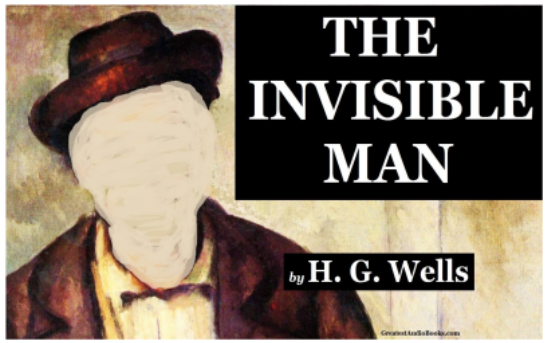
The Milky Way's Supermassive Black Hole: How good a case is it?

A Challenge for Astrophysics & Philosophy of Science

Andreas Eckart[a,b] Andreas Hüttemann[c], Claus Kiefer[d], Silke Britzen[b], Michal Zajaček[a,b], Claus Lämmerzahl[e], Manfred Stöckler[f], Monika Valencia-S.[a], Vladimir Karas[g], Macarena García-Marín[h]

Received: date / Accepted: date

Principle of The Invisible Man



Abstract The compact and, with $4.3 \pm 0.3 \times 10^6 M_\odot$, very massive object located at the center of the Milky Way is currently the very best candidate for a supermassive black hole (SMBH) in our immediate vicinity. The strongest evidence for this is provided by measurements of stellar orbits, variable X-ray emission, and

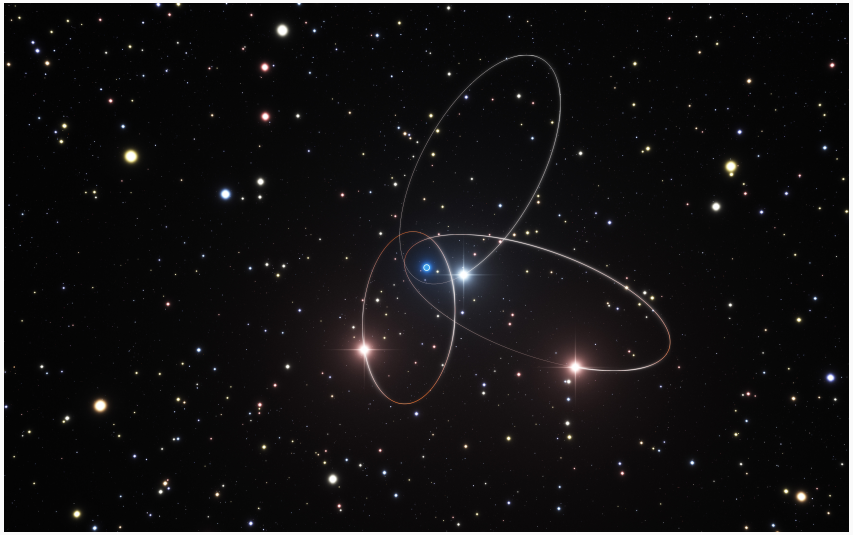
Our group - Recent results

Eckart+17 **arXiv:1703.09118**

label	necessary condition
N_1	Is object at nominal position of SgrA*?
N_2	Is size of emitting region in SgrA* sufficiently small?
N_3	Is mass of SgrA* in agreement with SMBH masses?
N_4	Does the distance to SgrA* place it at the center of the Milky Way?
N_5	Is the manipulative success for SgrA* similar to other SMBH candidates?
N_6	Is a bright fast jet originating from SgrA*?
N_7	Do we detect a merger ringing signal in gravitational waves from SgrA*?
N_8	Do we detect an exceptionally bright flare from SgrA*?
N_9	Do stars and pulsars close to SgrA* give indications for a SMBH?
N_{10}	Is the spectrum of the surroundings of SgrA* what es expect from a SMBH?
N_{11}	Do we detect a photon ring in SgrA* in addition to orbiting matter?
N_{12}	Do VLBI images of SgrA* show a shadow as expected for a SMBH?
N_{13}	Do we detect photo-center motion of SgrA* with NIR- and/or mm-radio-interferometry?
N_{14}	Can we differentiate fo SgrA* between jet components and hot-spot?

Some of these can be tested in the near future...

Our group - Recent results



Credit: ESO/M. Parsa/L. Calçada

Parsa, Eckart, Shahzamanian, Karas, Zajaček, Zensus and Straubmeier

ApJ 845, 2017

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  4. **Sgr A*** – Is it really a black hole? Do we know all the parameters (mass, spin, charge)?

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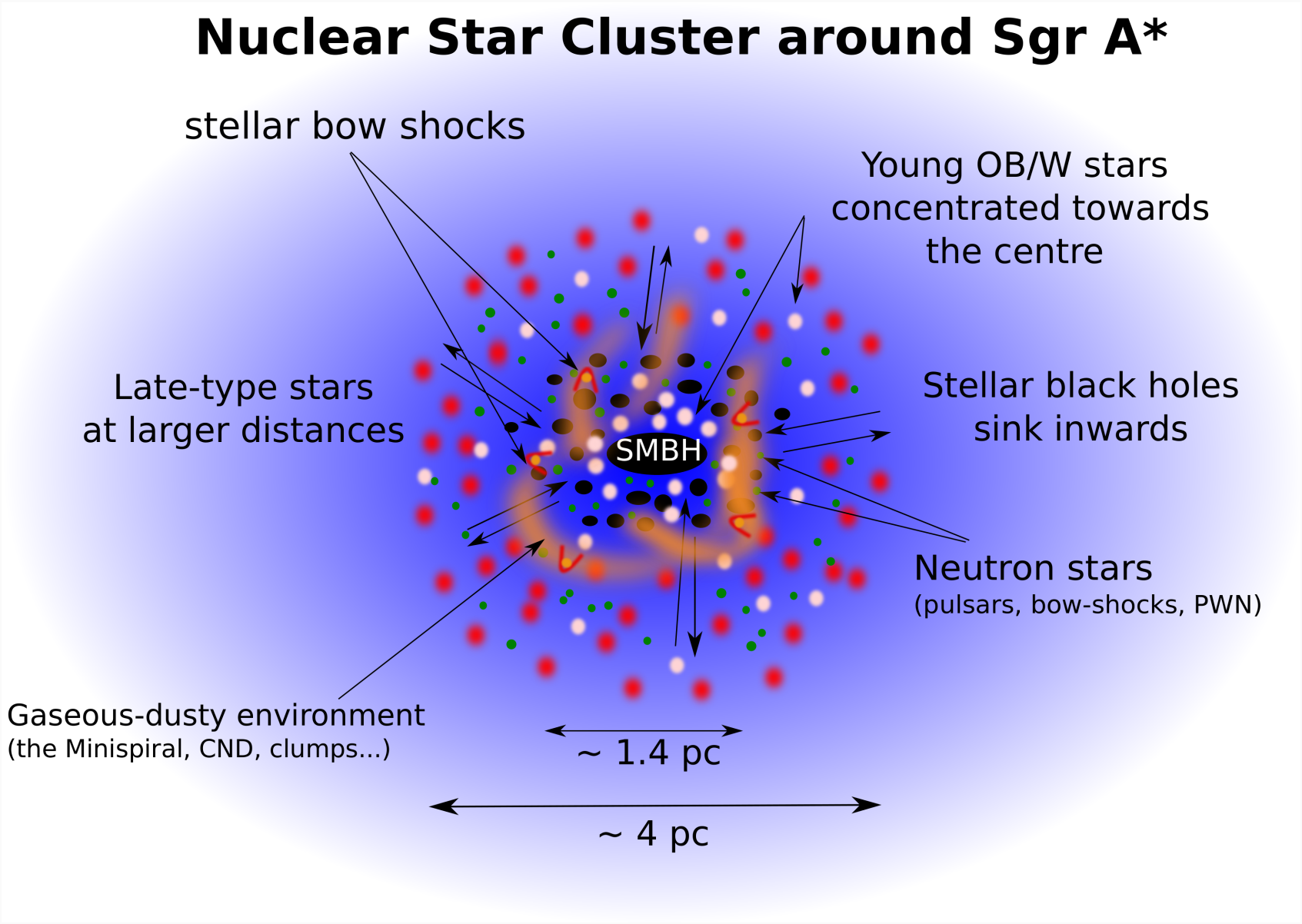
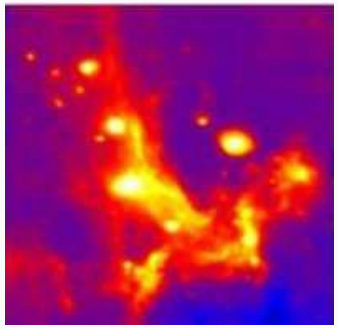


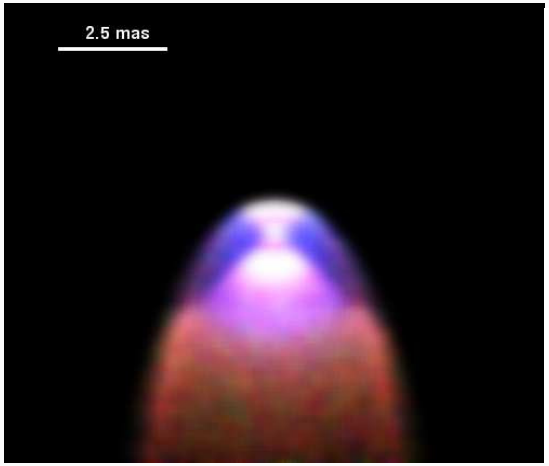
Research topics

Interaction

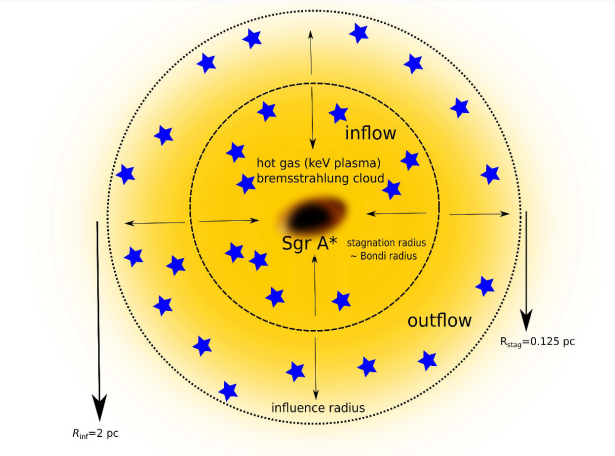
between  and 

gravitational — electromagnetic — magnetohydrodynamic

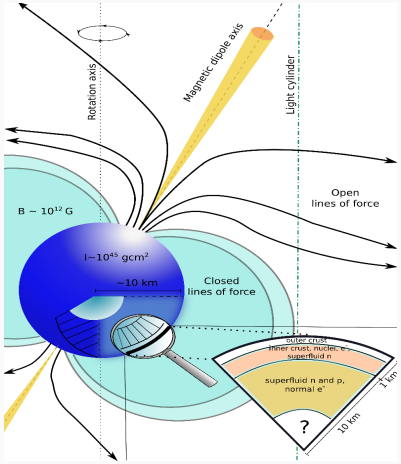
Modelling DSO/G2



Charge of the SMBH



Interaction modes of neutron stars



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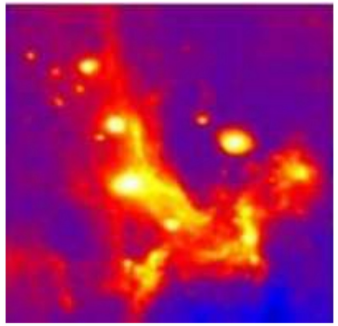
between  and 

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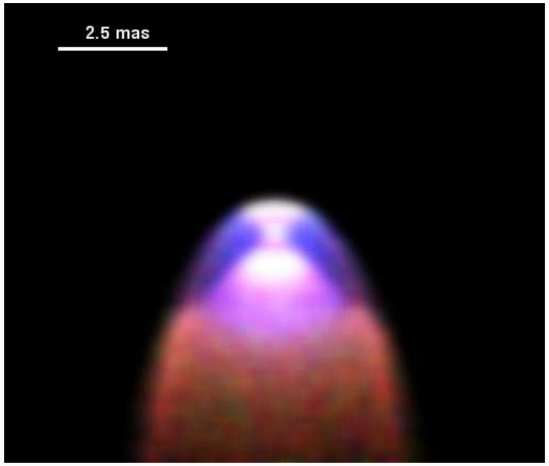

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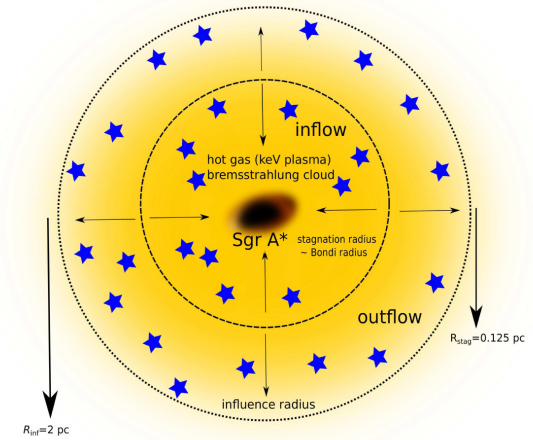

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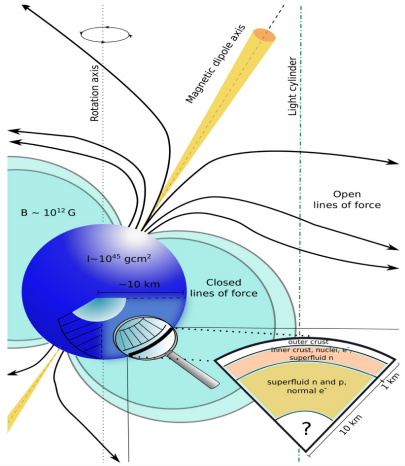
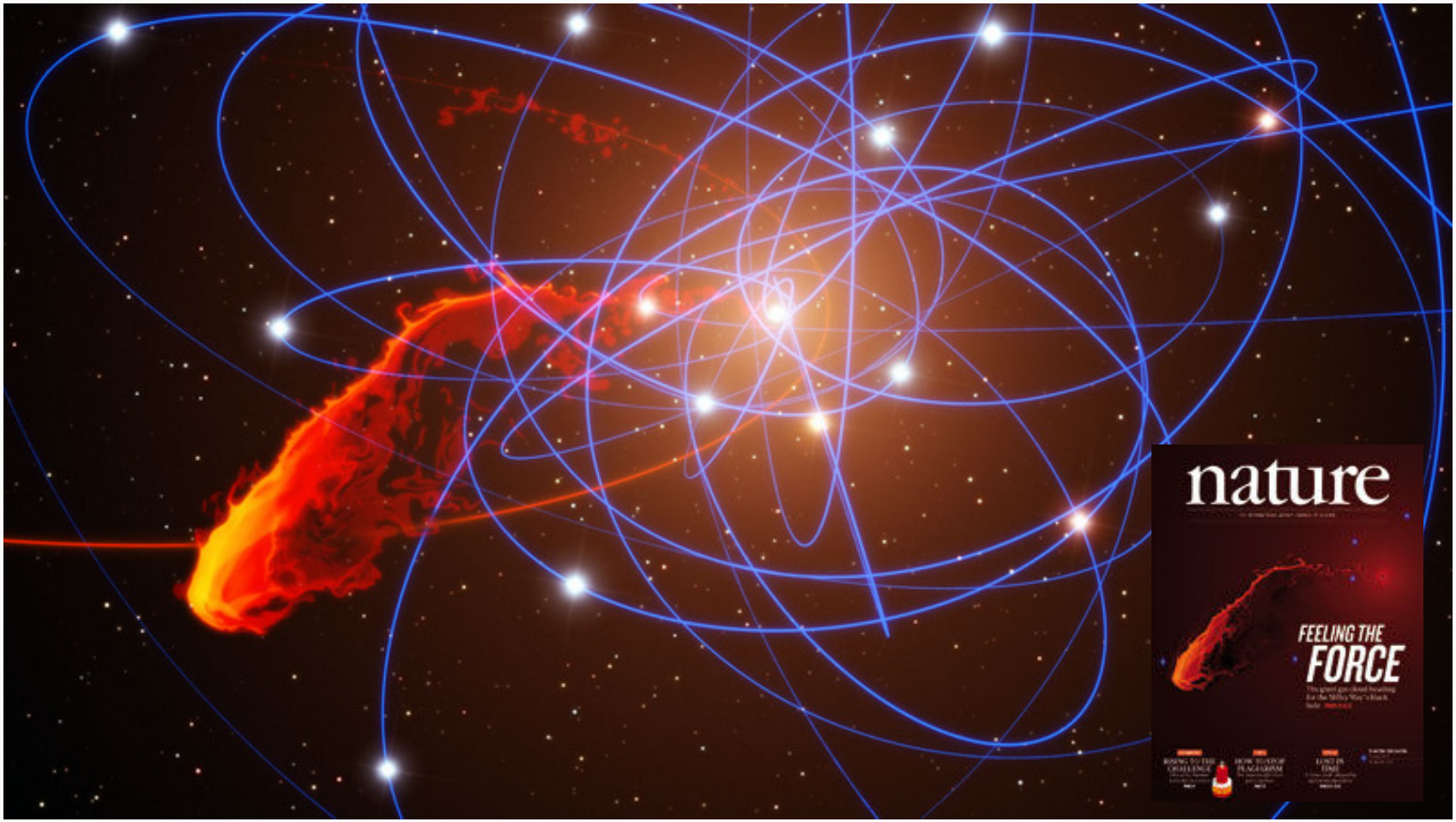


Modelling Dusty S-cluster Object(s)

Observational motivation

Originally known as the **gas cloud G2** that is going to "feed" the starved black hole...



ESO/MPE/Marc Schartmann

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  (d) Can some of the dusty material detach from the object and reach the black hole?

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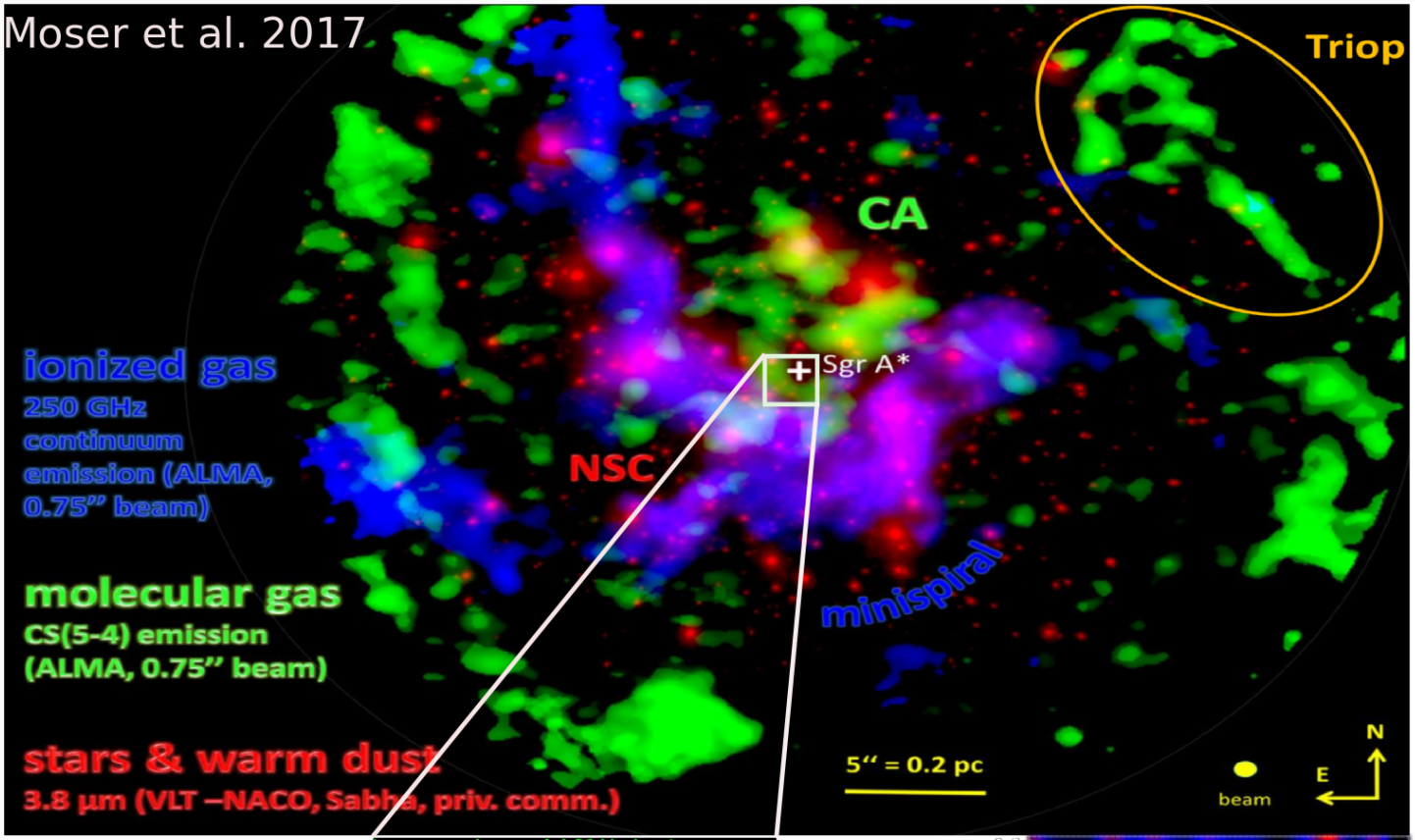
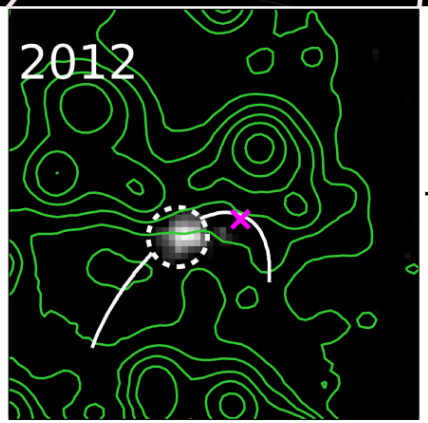
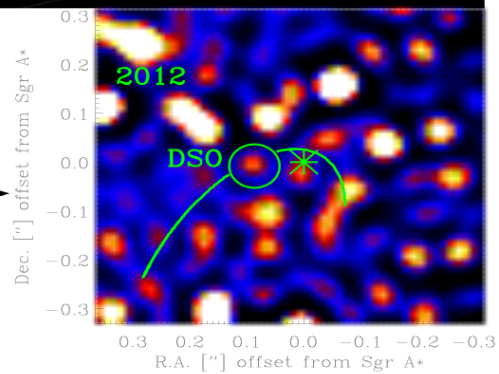


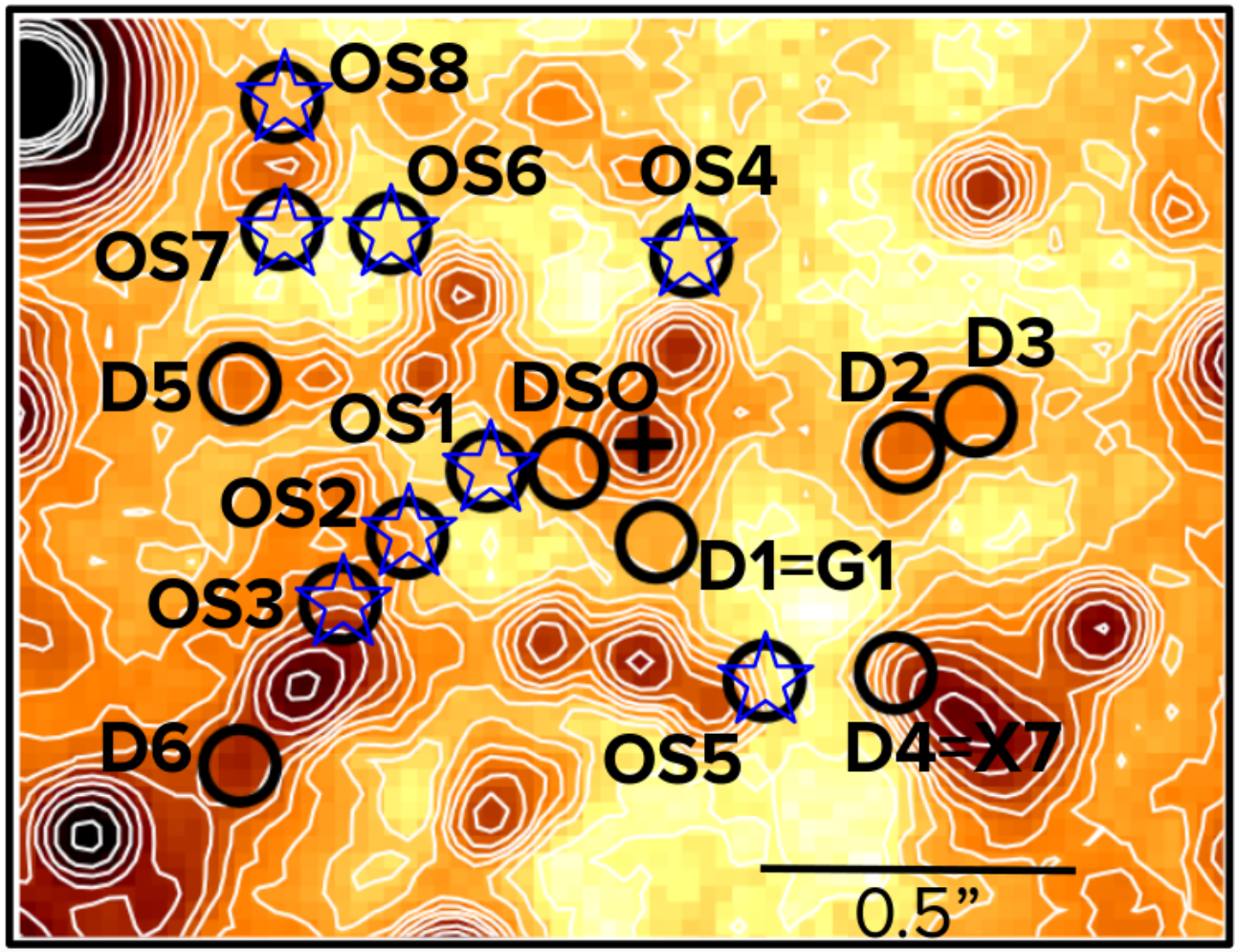
Brγ emission
(Peissker, Valencia-S.
in prep.)





K_S-band continuum (Shahzamanian et al. 2016)

Observational motivation–More similar dusty sources



Very young stellar objects ($\sim 0.1\,\mathrm{Myr}$) close to Sgr A*? (Peissker, Valencia-S. et al., in prep)

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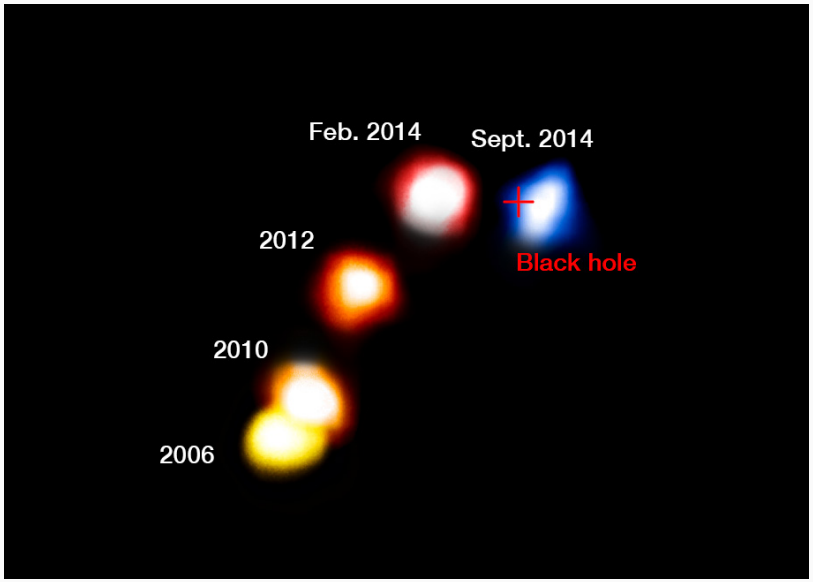
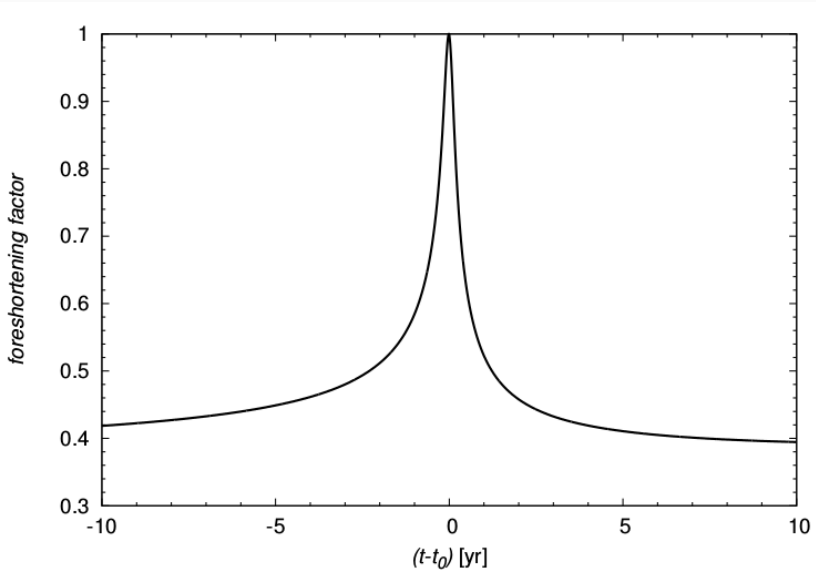
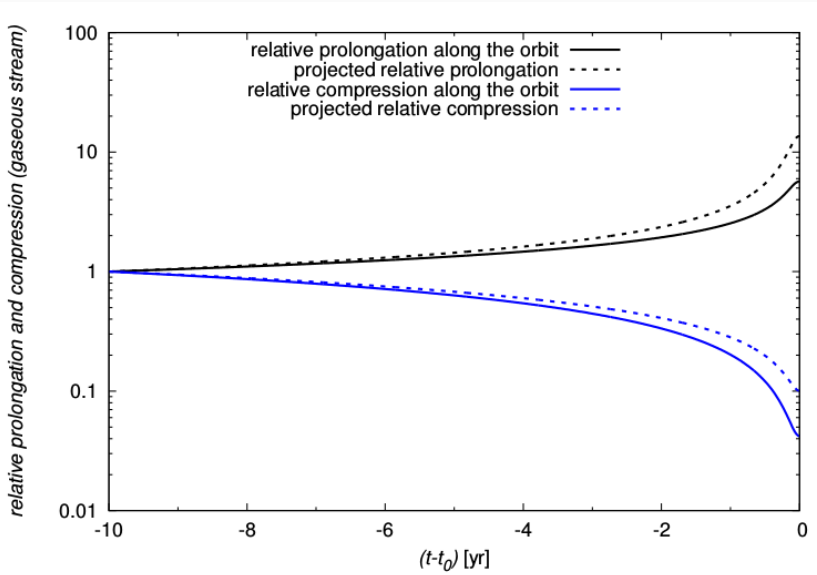


Figure 1: Brγ line emission maps – does not behave as a gas cloud. **Valencia-S., M.; Eckart, A.; Zajaček, M.+15**.

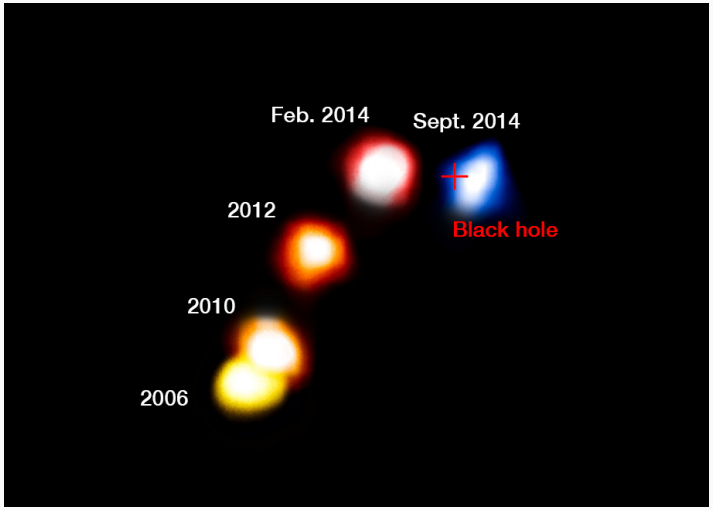
Arguments for the compactness

Behaviour of a Core-less Cloud

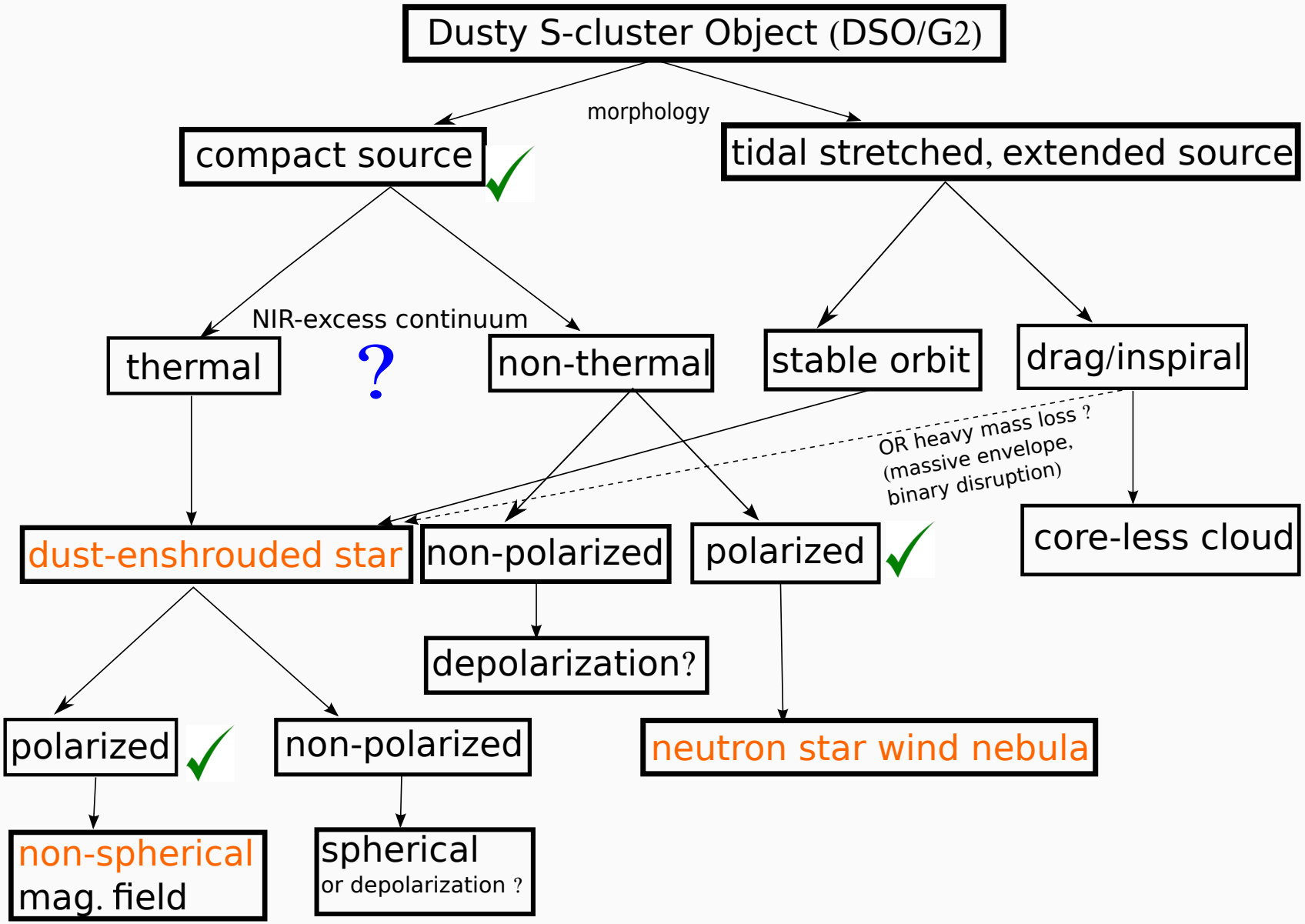




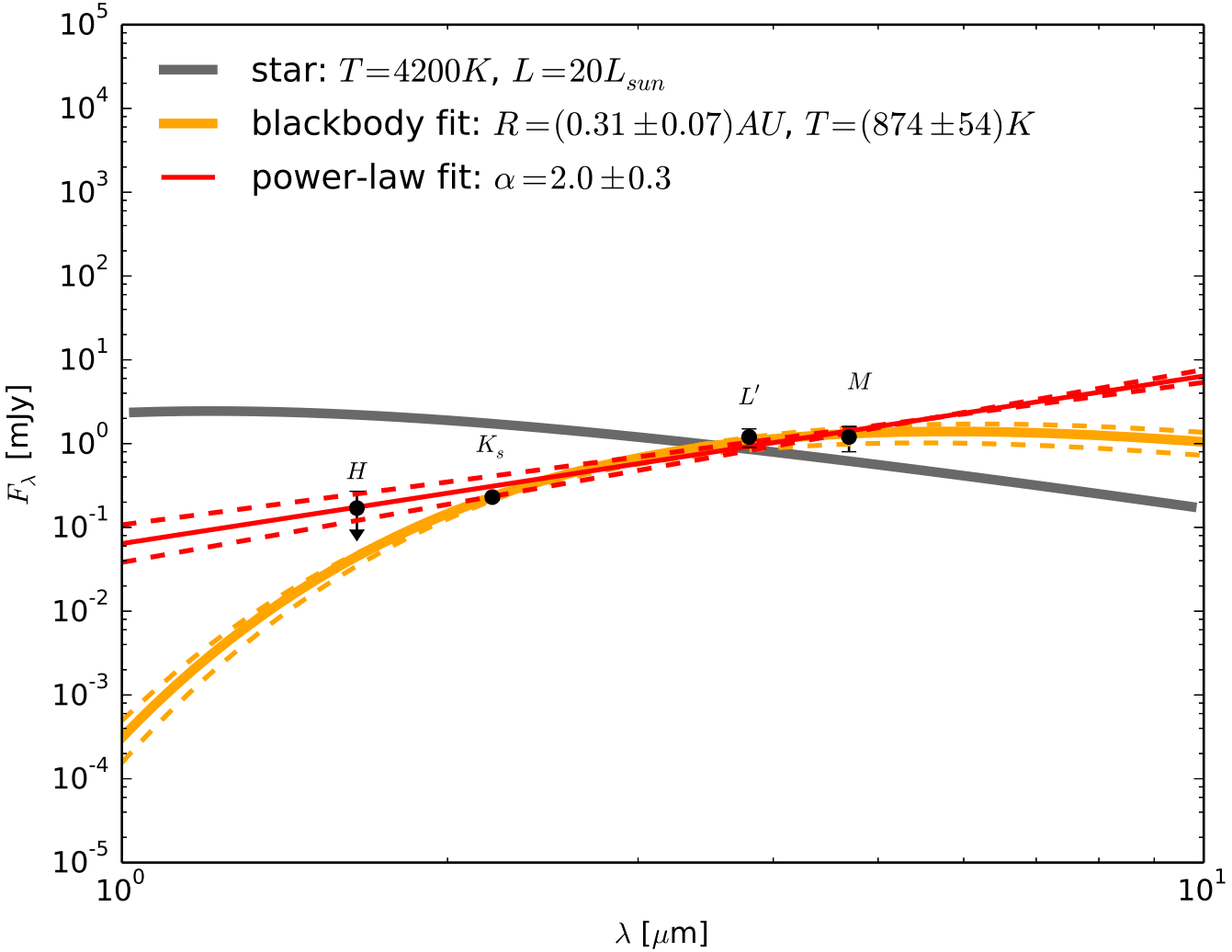
Observations (Brγ recombination line)



Roadmap for solving DSO nature

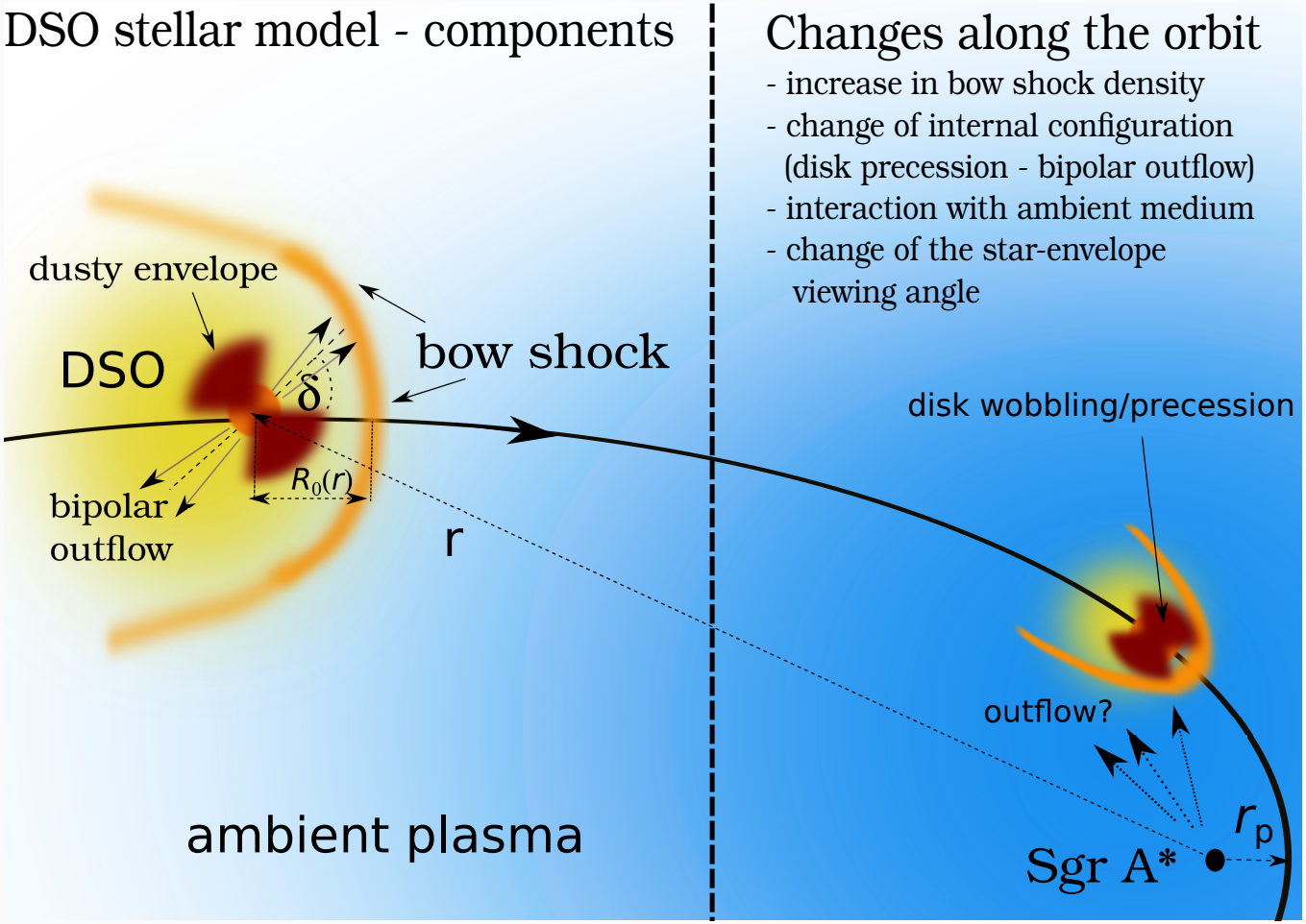


Spectral Energy Distribution: simple power-law and blackbody fit



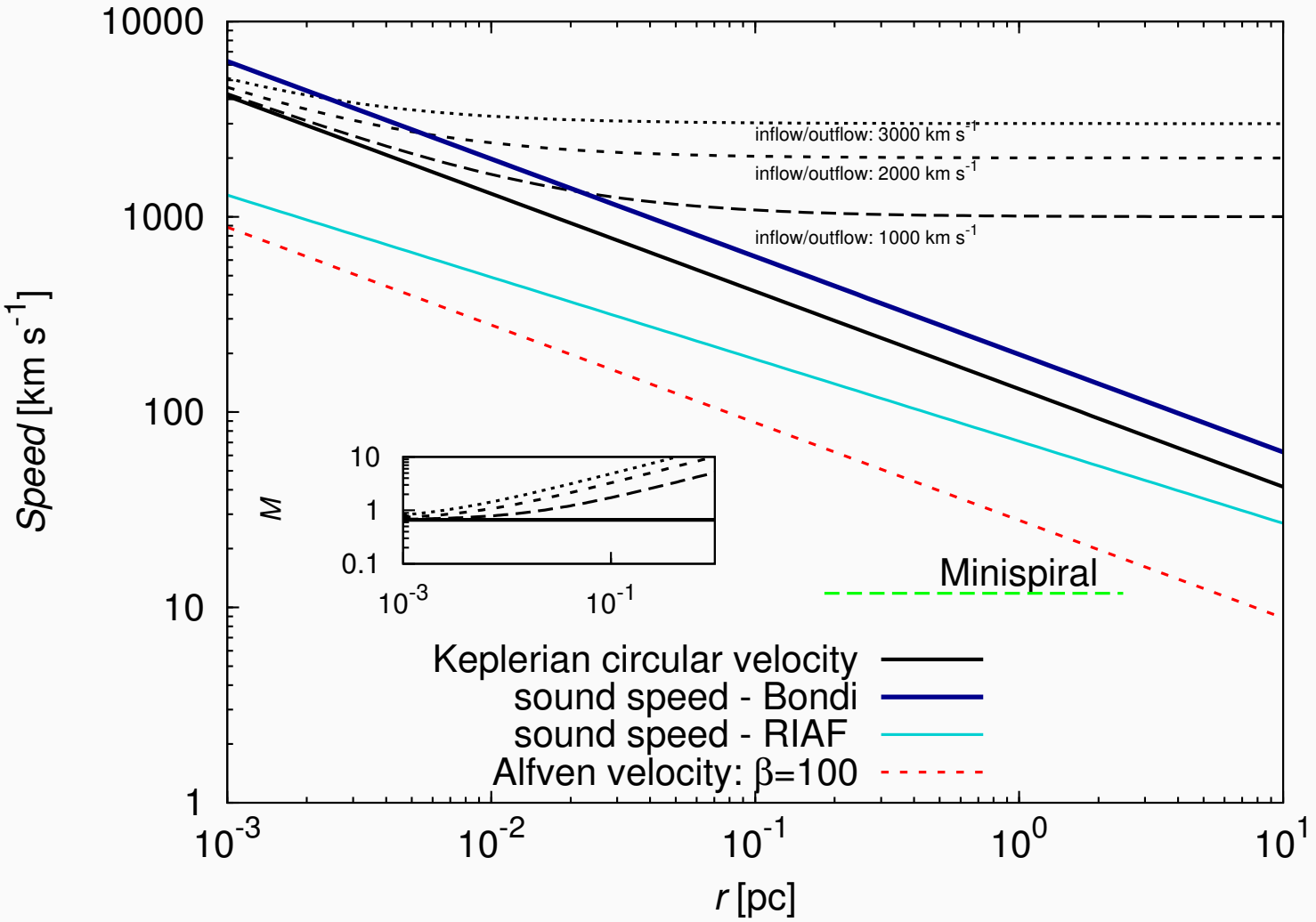
DSO/G2 as a dust-enshrouded star

The model of **a young star in accretion phase** - Several possible contributions to the continuum and line emission:



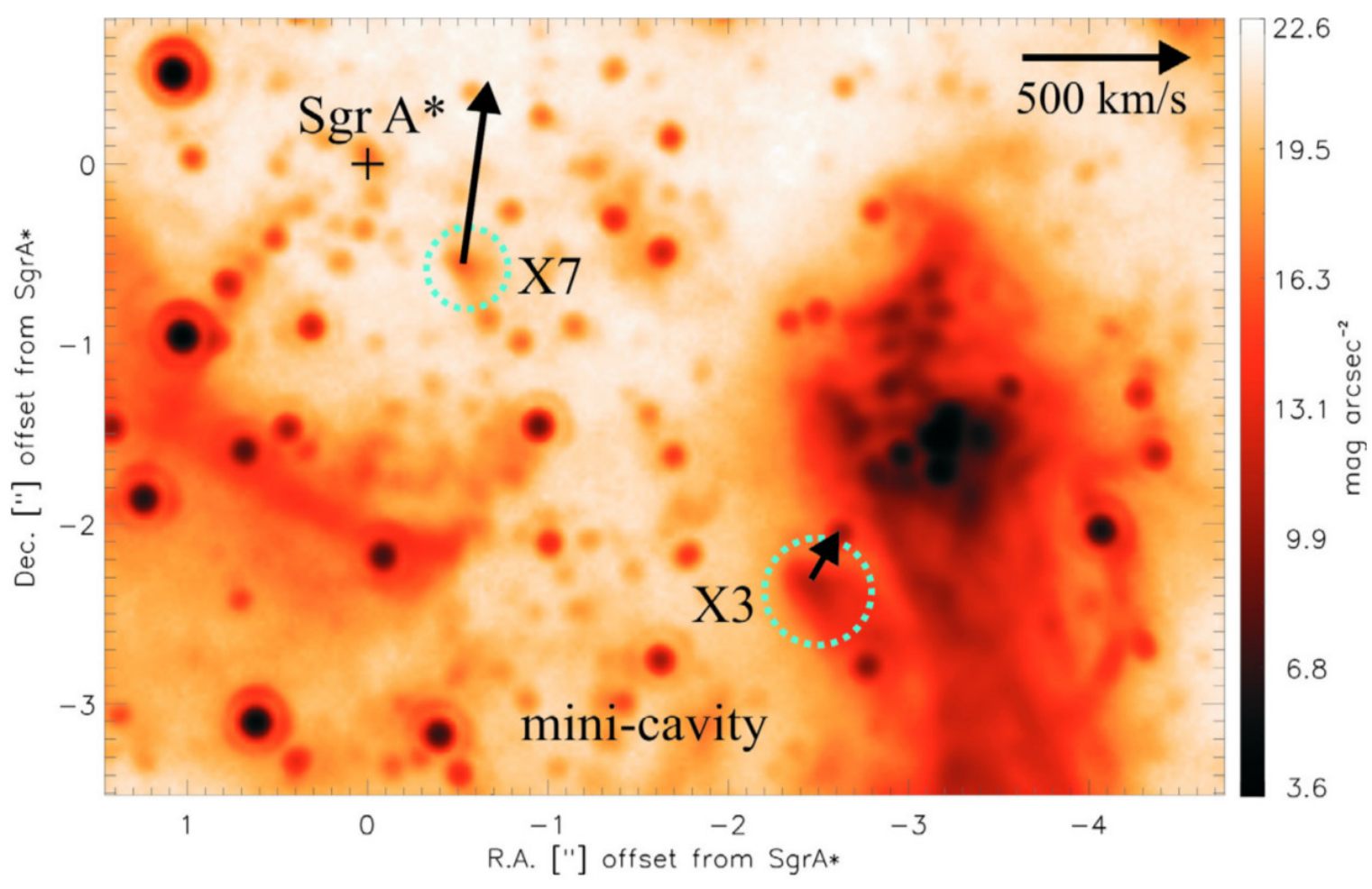
Bow shocks close to the Galactic centre

Relative stellar velocities $\mathbf{v}_{\rm rel} = \mathbf{v}_\star - \mathbf{v}_{\rm a}$ mostly supersonic, $\mathcal{M} \equiv v_{\rm rel}/c_{\rm s} > 1$

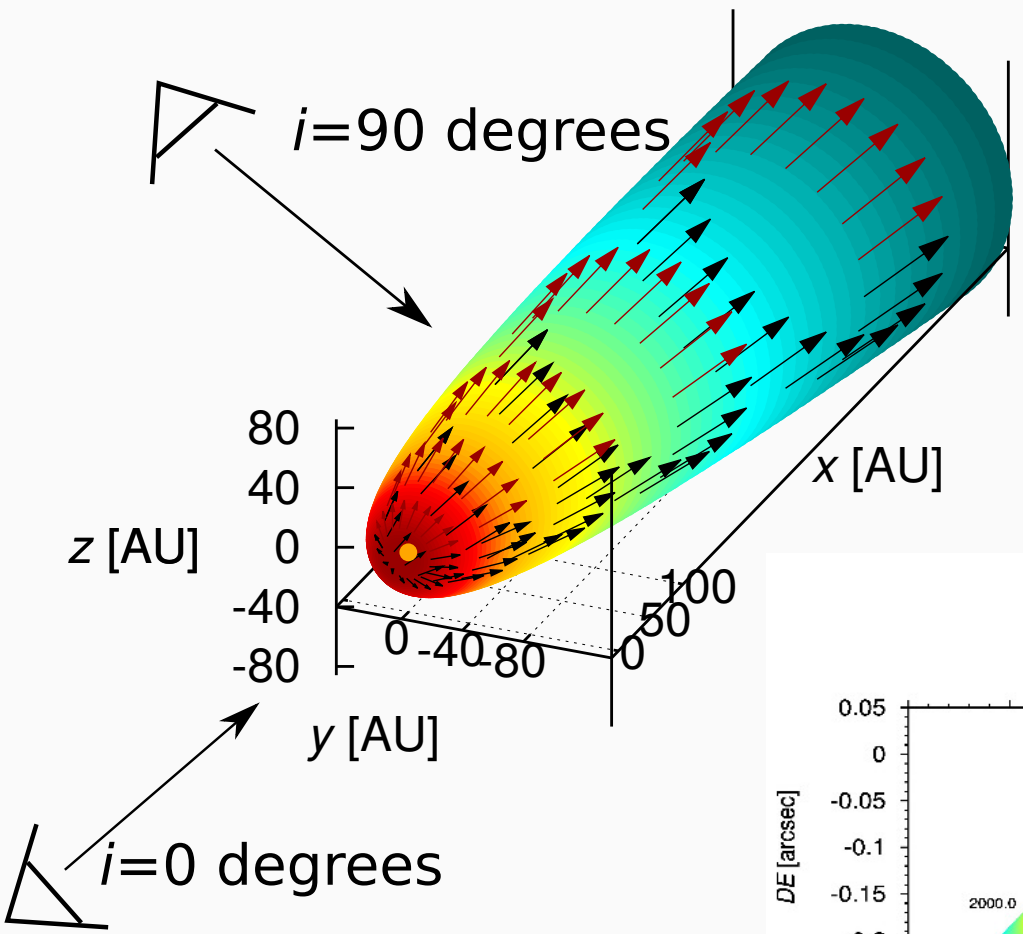


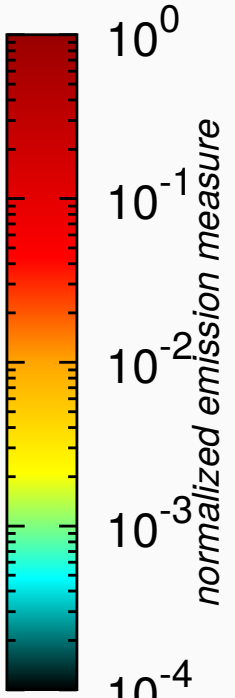
Bow shocks close to the Galactic centre

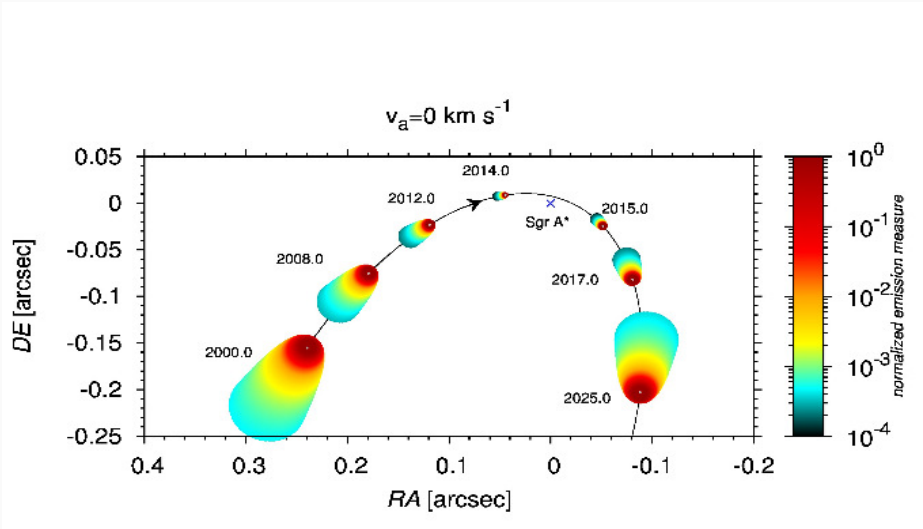
Observed comet-shaped structures (X3 and X7) close to the GC: Muzic+10:



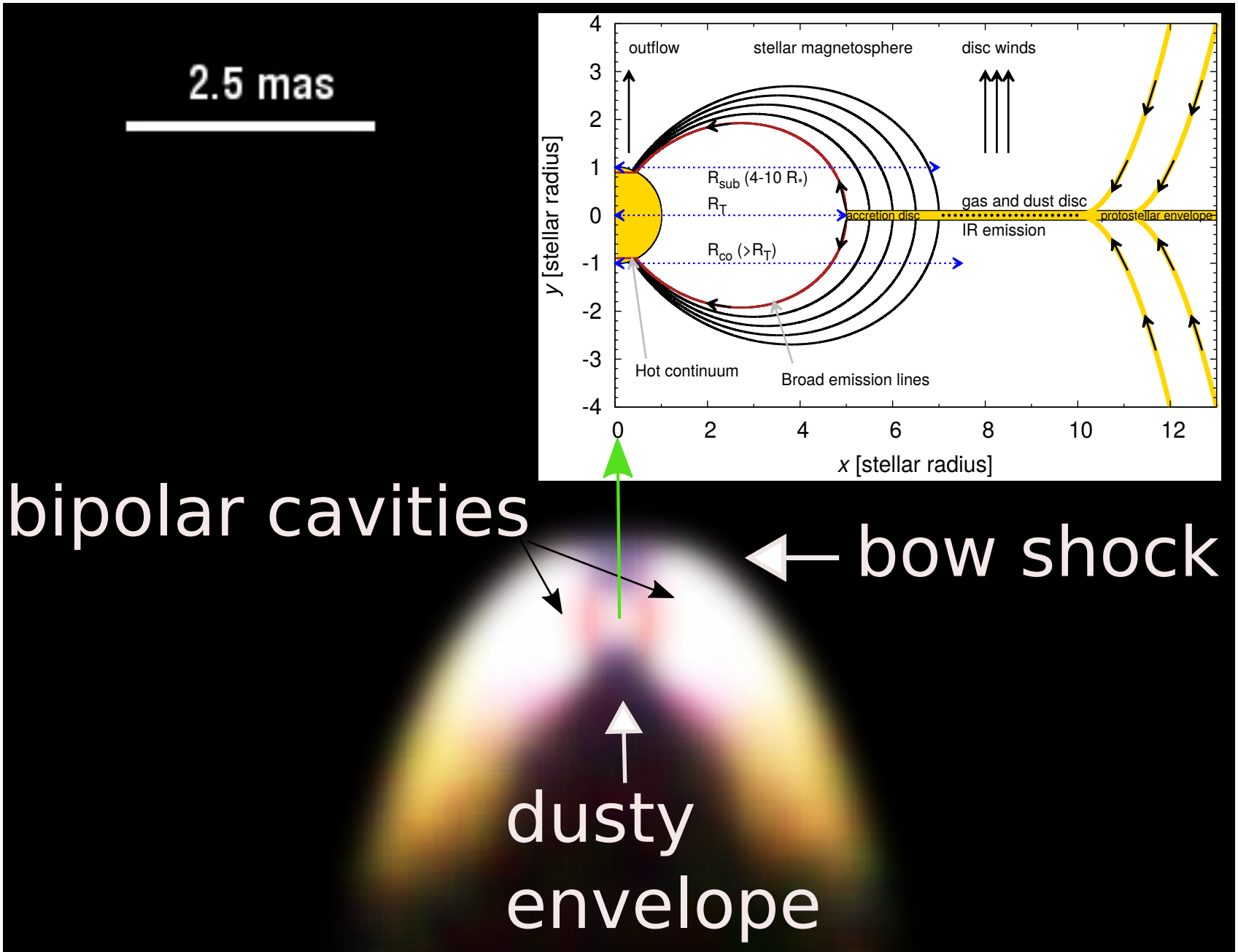
DSO/G2 as a dust-enshrouded star: Basic geometry



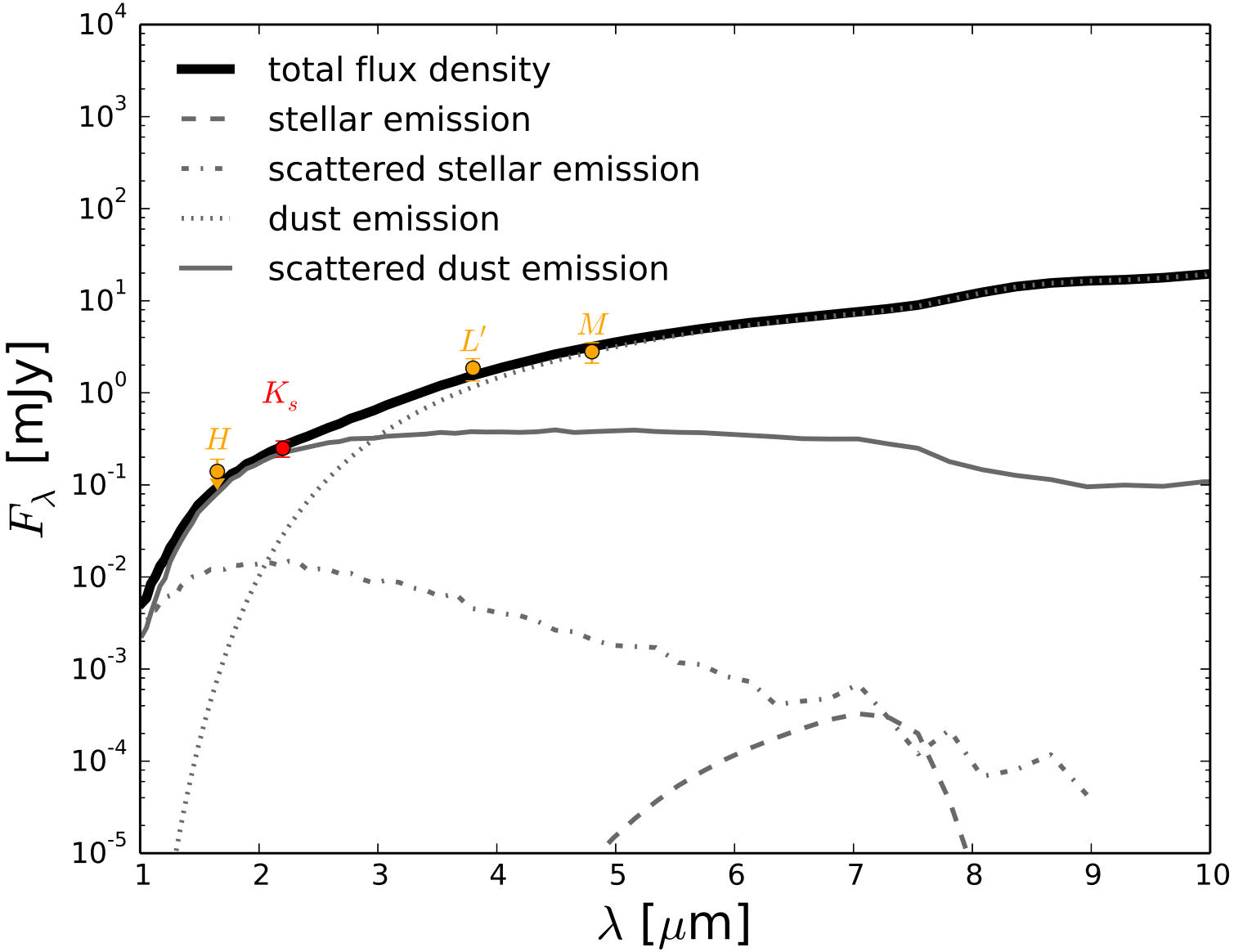




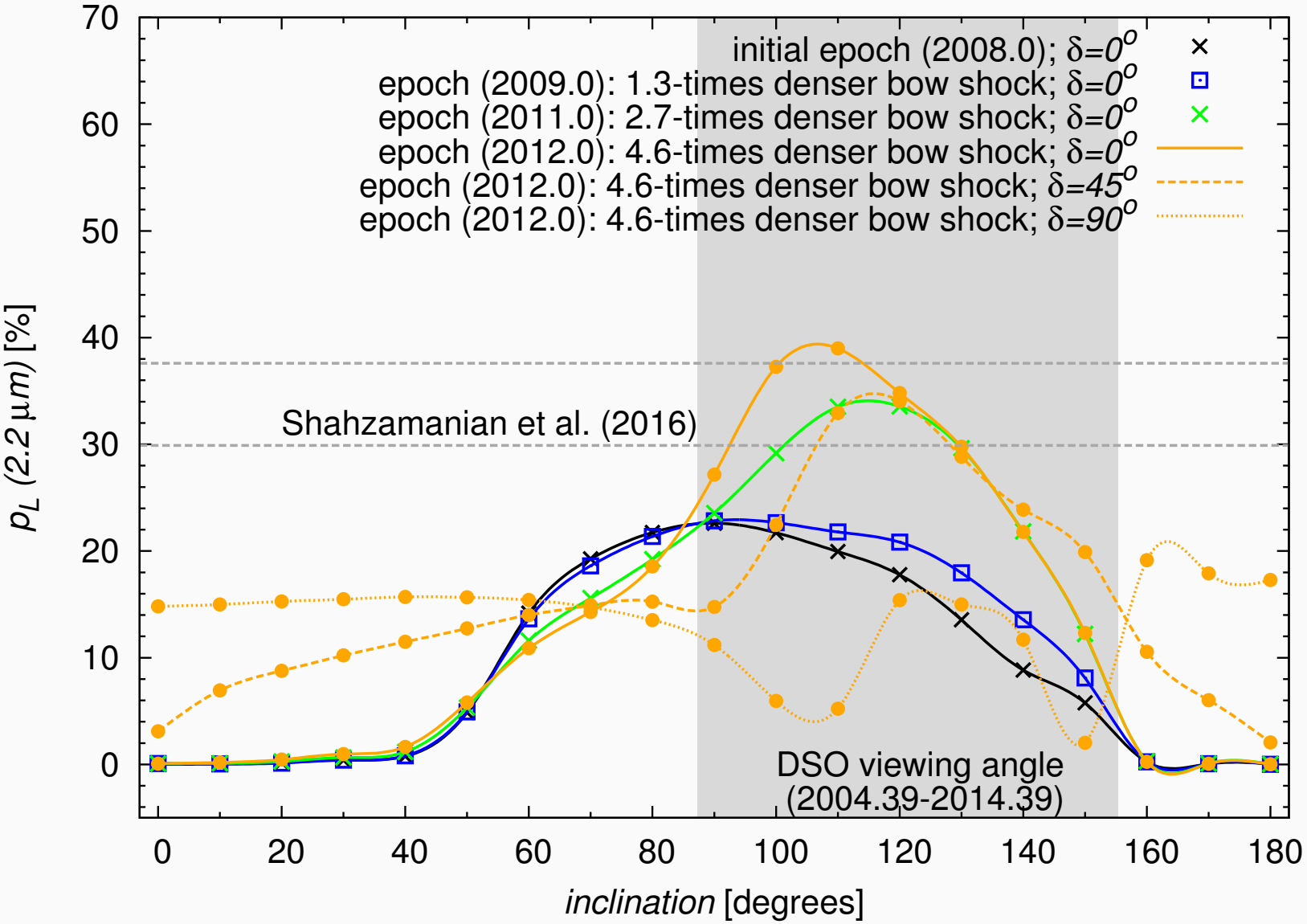
Radiative transfer model: Simulated image



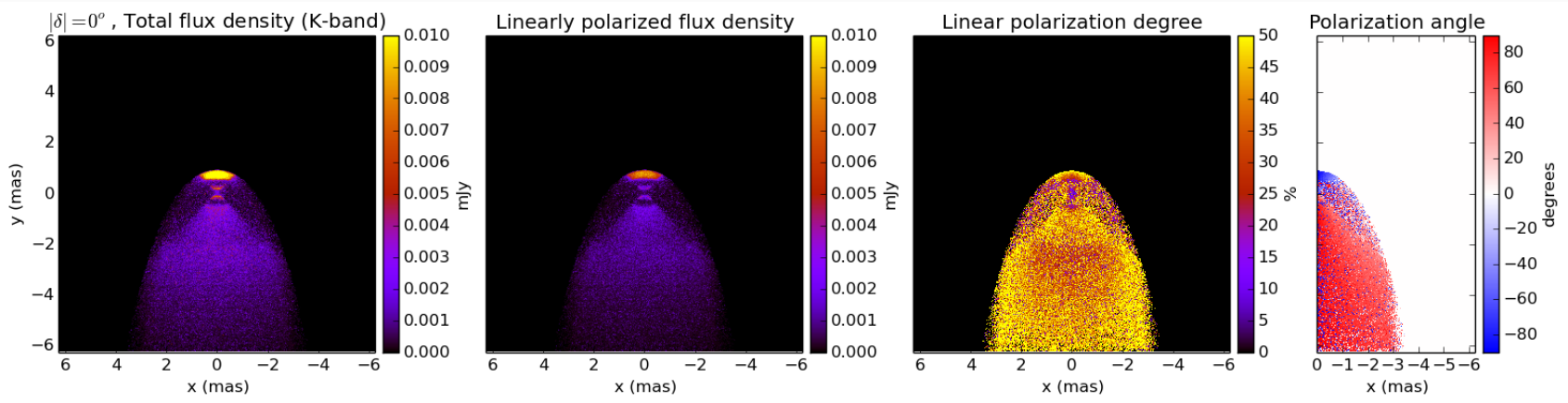
Radiative transfer model: Model Spectral Energy Distribution



Radiative transfer model: Linear polarization in K_s band as function of inclination



Modelling Dusty S-cluster Objects: Summary



The model of a dust-enshrouded star can explain:

- the NIR continuum emission

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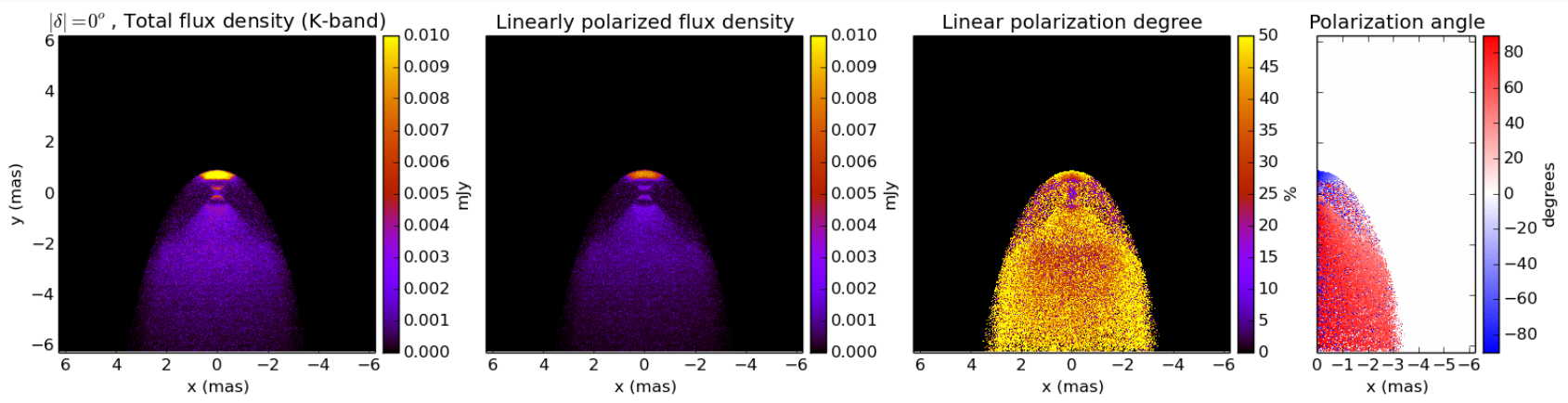

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- *H*- and K_s-band emission dominated by scattered dust emission

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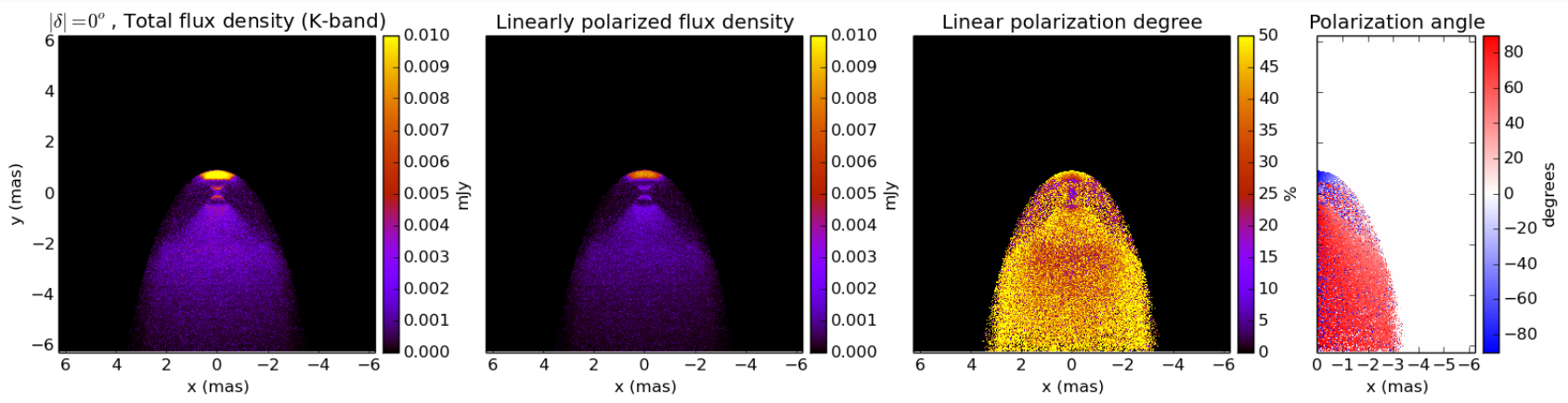

The model of a dust-enshrouded star can explain:

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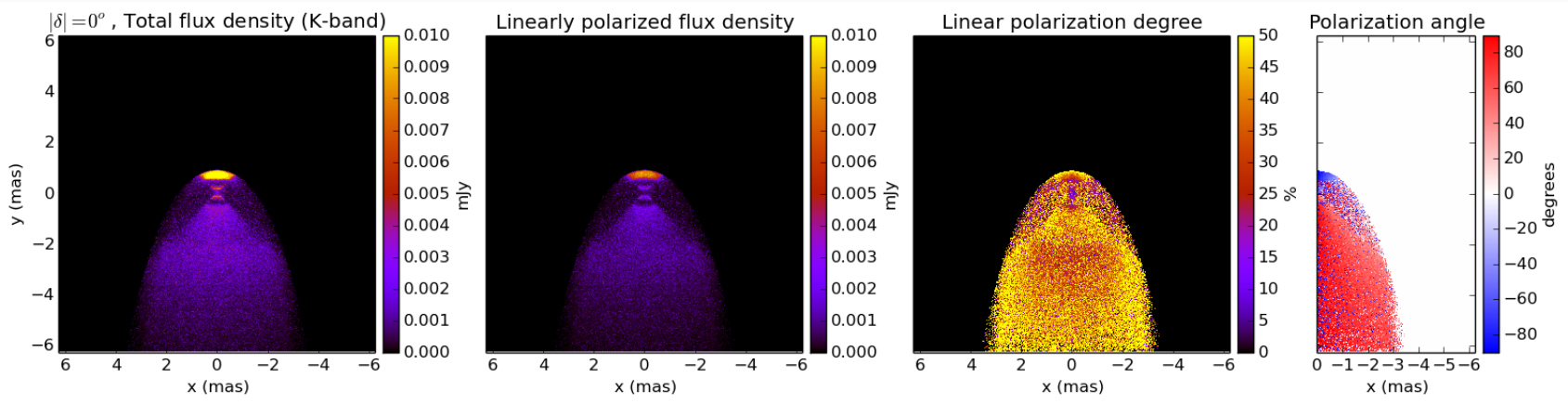
- H- and K_S-band emission dominated by scattered dust emission
- L'- and M-band emission dominated by thermal dust emission

Modelling Dusty S-cluster Objects: Summary



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- the NIR continuum emission
- H- and K_s-band emission dominated by scattered dust emission
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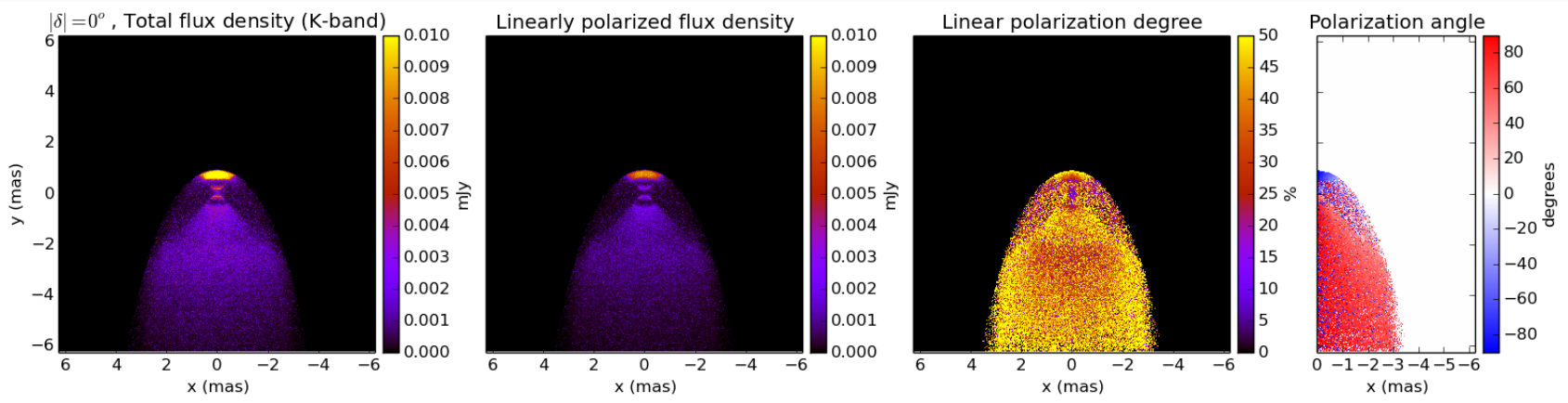
- Doppler-broadened emission lines (Brγ, Paα, HeI) by inflow or outflow to/from the star

Modelling Dusty S-cluster Objects: Summary



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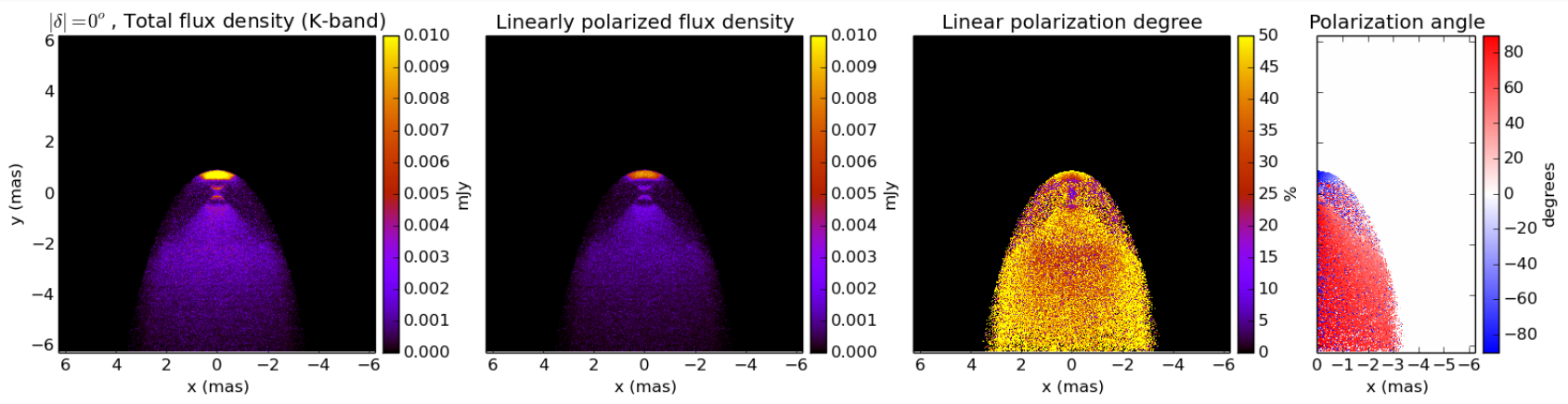

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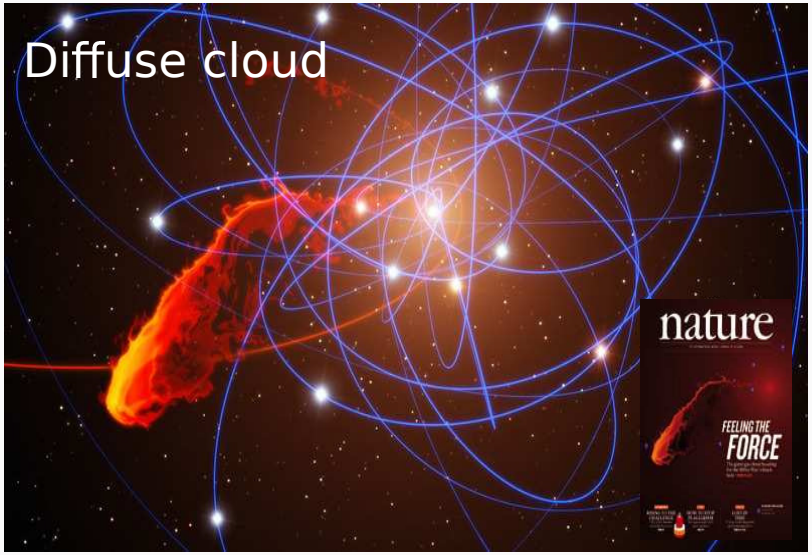
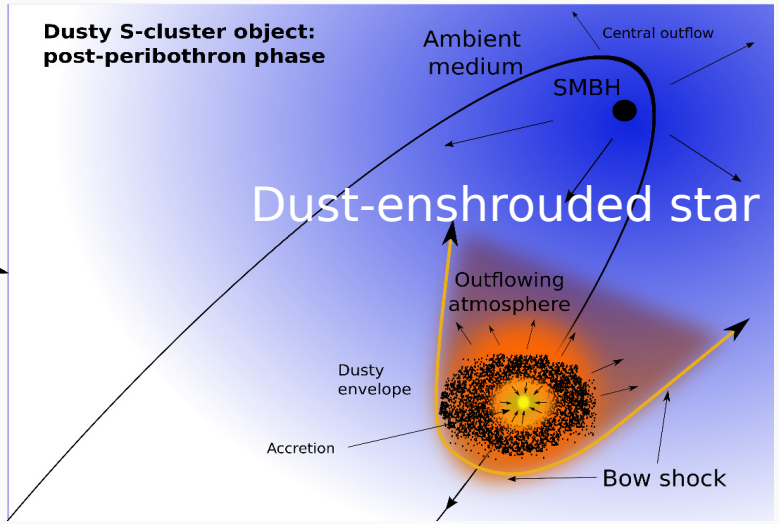
- in the end the source does not disintegrate and "survives" (unlike the gas cloud)

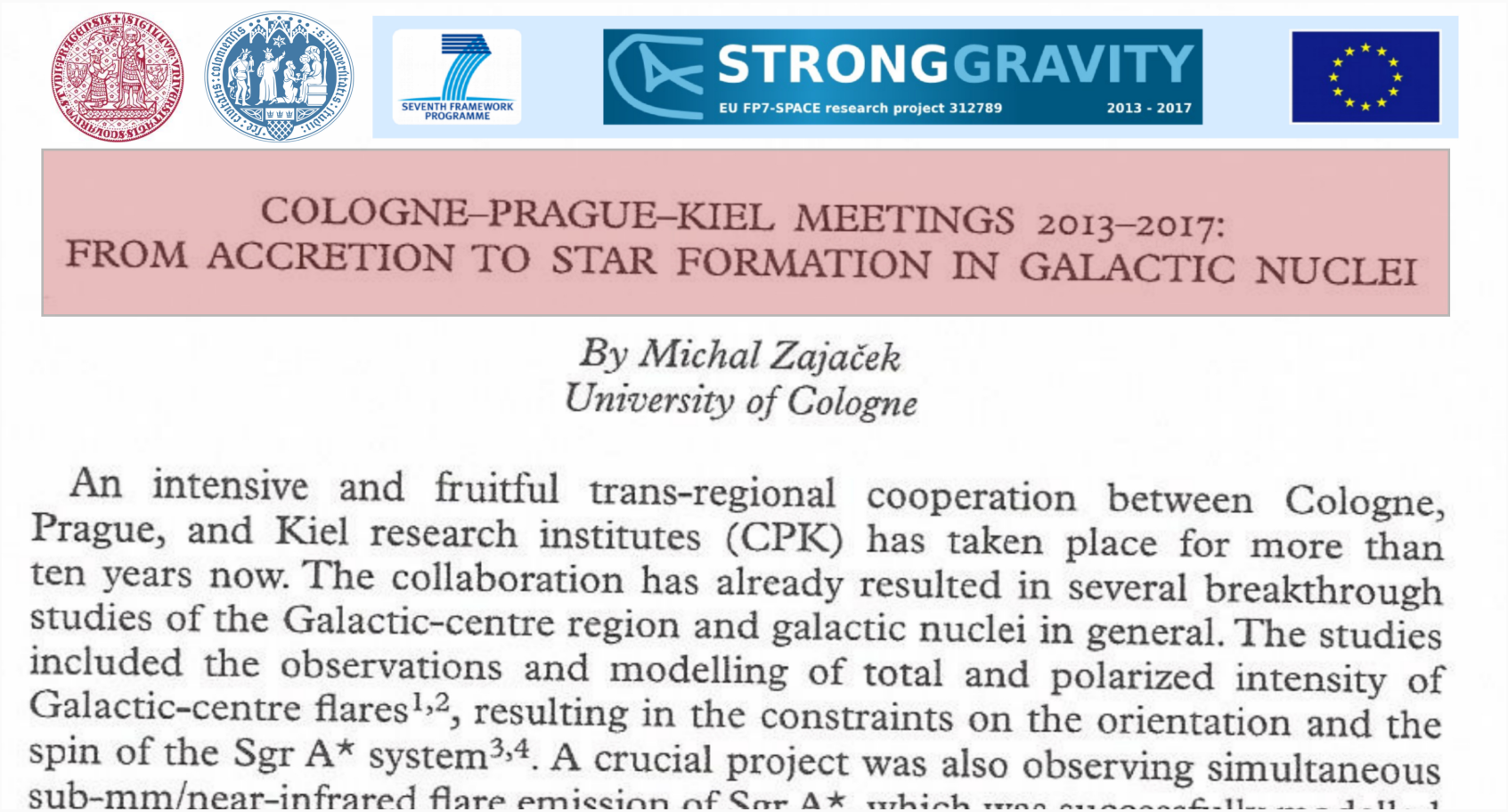
Modelling Dusty S-cluster Objects: Summary





Cologne-Prague-Kiel meetings 2013-2017

Read the final report in the **Observatory** magazine in December:



SEVENTH FRAMEWORK PROGRAMME

STRONGGRAVITY

EU FP7-SPACE research project 312789 2013 - 2017

COLOGNE–PRAGUE–KIEL MEETINGS 2013–2017:
FROM ACCRETION TO STAR FORMATION IN GALACTIC NUCLEI

By Michal Zajaček
University of Cologne

An intensive and fruitful trans-regional cooperation between Cologne, Prague, and Kiel research institutes (CPK) has taken place for more than ten years now. The collaboration has already resulted in several breakthrough studies of the Galactic-centre region and galactic nuclei in general. The studies included the observations and modelling of total and polarized intensity of Galactic-centre flares[1,2], resulting in the constraints on the orientation and the spin of the Sgr A* system[3,4]. A crucial project was also observing simultaneous sub-mm/near-infrared flare emission of Sgr A*, which

Radiative transfer model: Inclination dependence