The Unique Outburst from S255IR-NIRS3
—
Clues for High-Mass Star Formation

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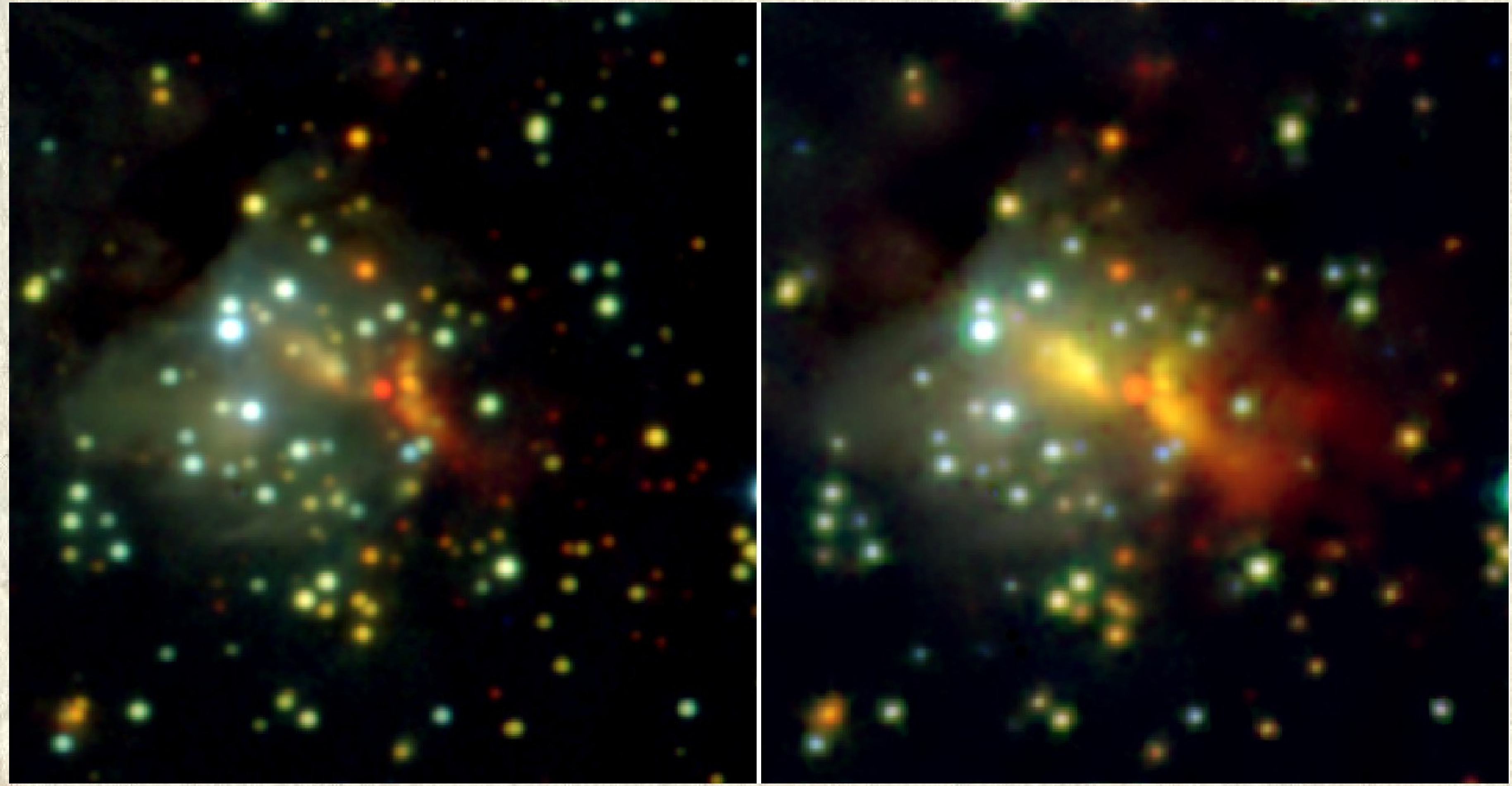
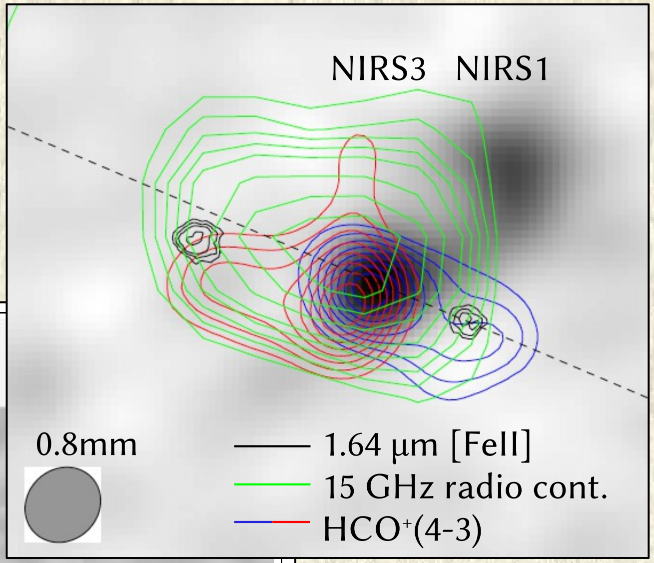
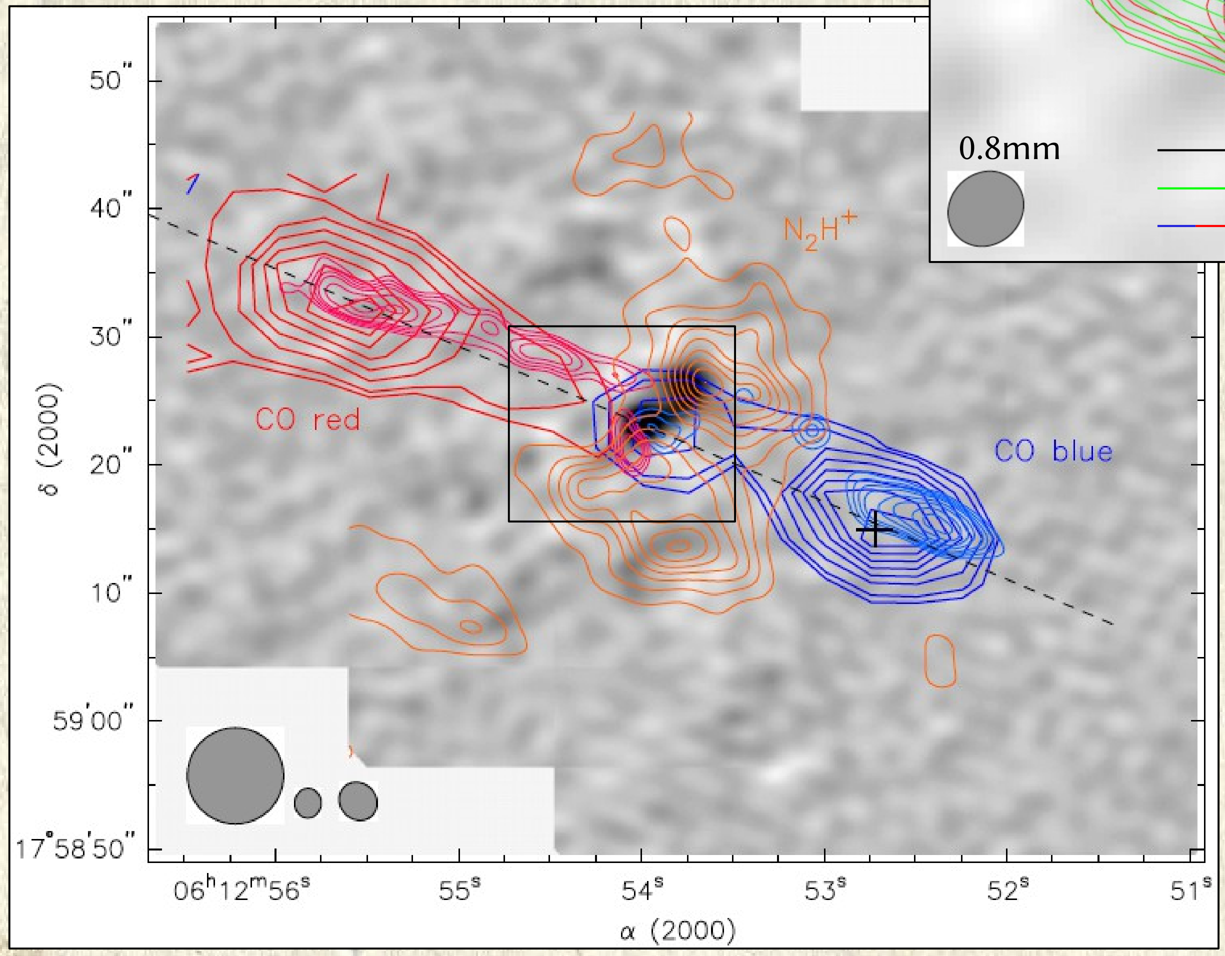


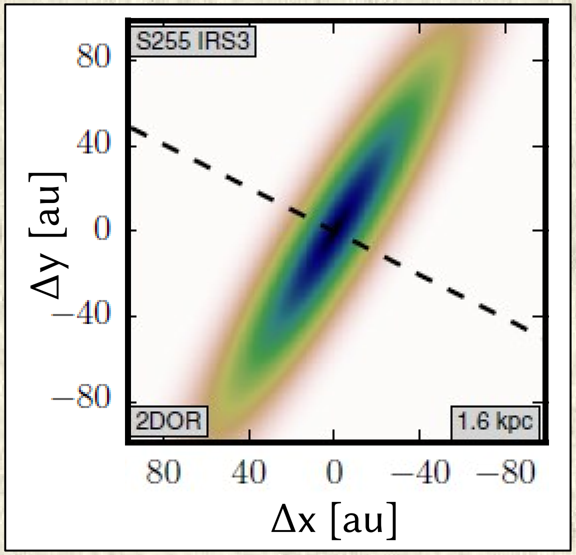
Introducing the HMYSO S255IR-NIRS3

Well-studied HMYSO, $L_*\sim2\times10^4 L_\odot$, $M_*\sim20M_\odot$, disk/outflow system (Zinchenko+ 2015) at 1.78±0.11kpc (Burns+ 2016), $A_V\sim46$mag (Simpson+ 2009), there is evidence for previous accretion/ejection events





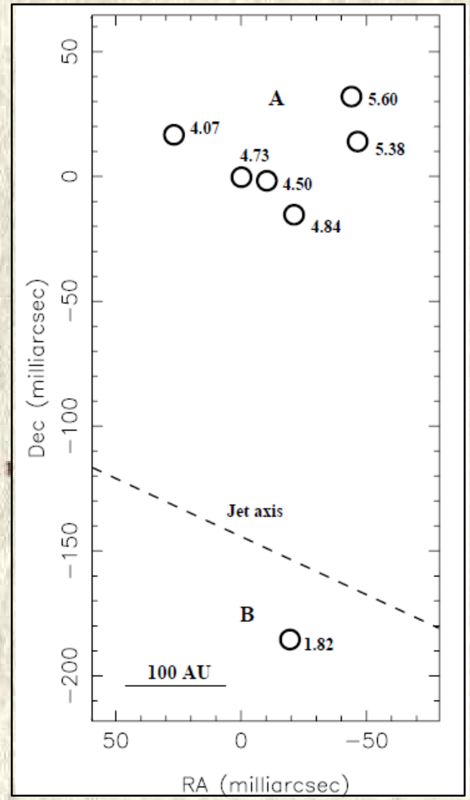
Brightness model for the 10.6μm VLTI visibilities (Boley+ 2013)



A Ringing Bell – The Methanol Maser Flare

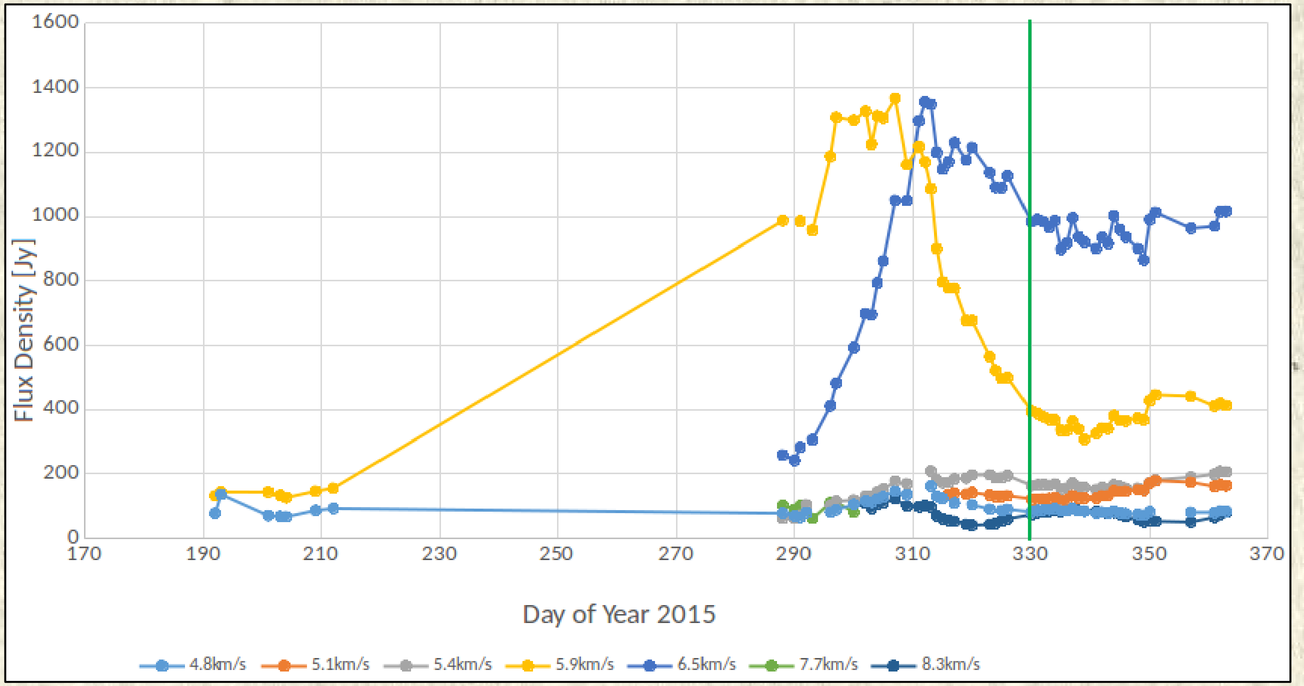
Class II 6.7GHz methanol masers, thought to be pumped by thermal IR emission (Sobolev+ 1997), trace embedded luminous YSOs (Breen+ 2013). They are generally variable, and some show regular flux changes (Goedhart+ 2014, Szymczak+ 2015). The methanol maser in S255IR was detected by Menten (1991).

Distribution of CH_3OH 6.7GHz maser spots (Minier+ 2001)



CH_3OH maser flux variation showing the **flare** of the 5.9km/s component and the **emergence** of a new one at **6.2km/s** (Fujisawa+ 2015).

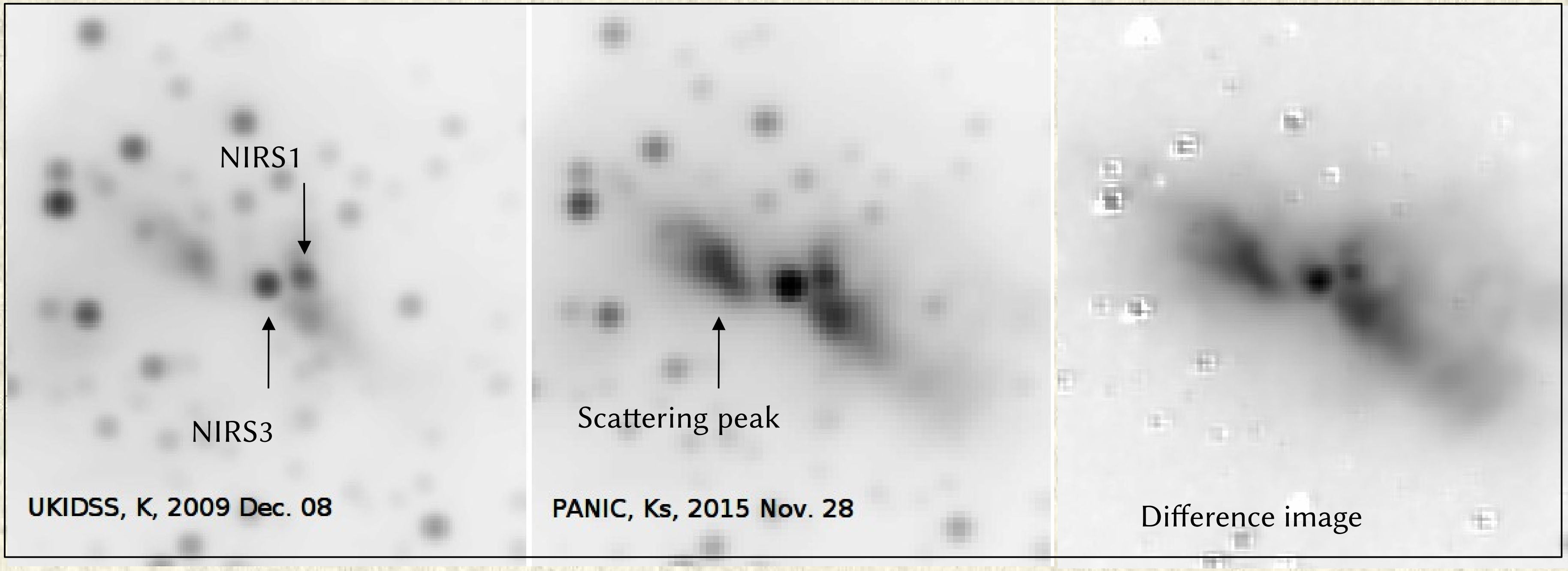
The vertical line marks the date of our first NIR imaging



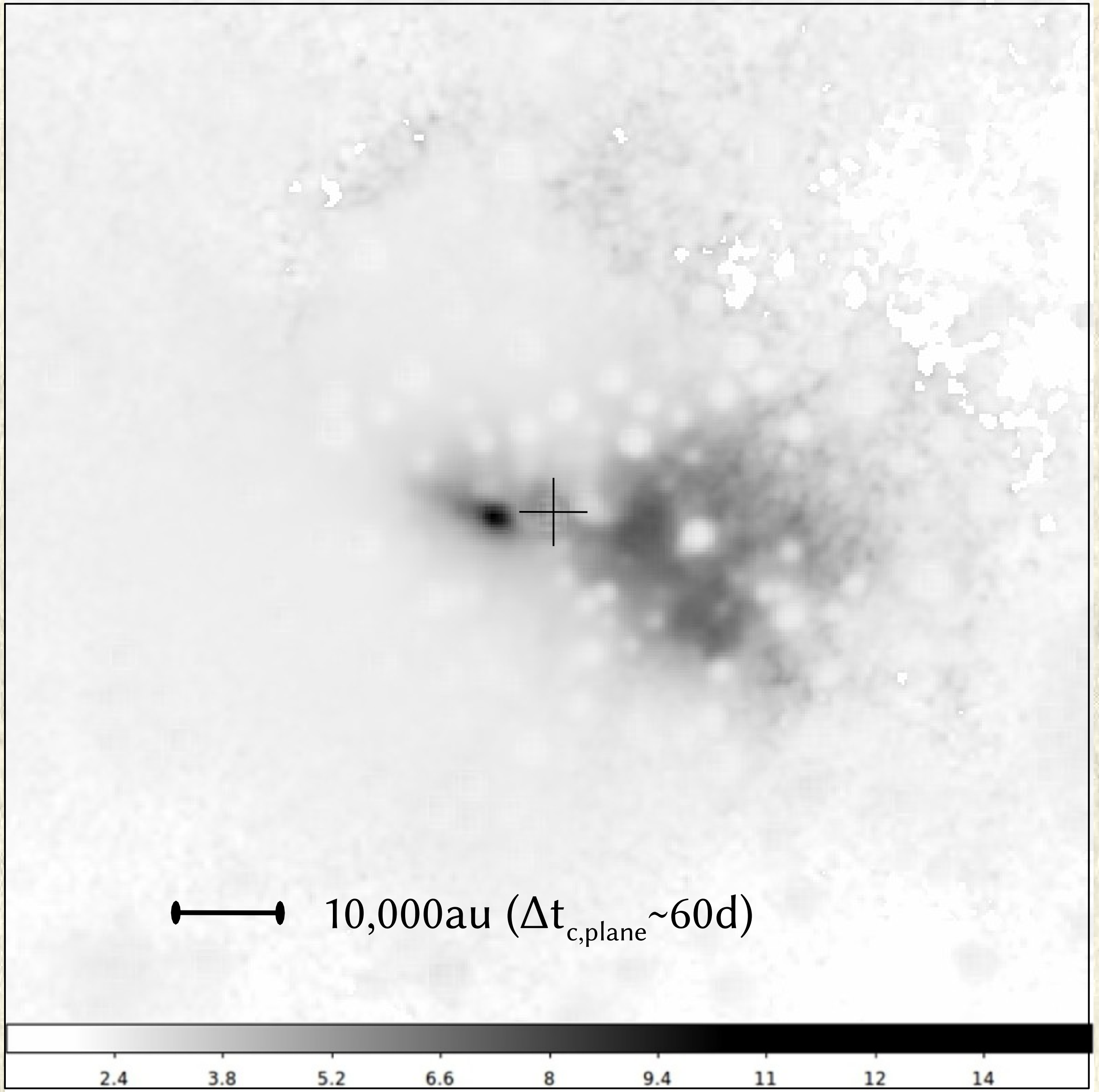
The outburst from S255IR-NIRS3

NIR imaging using PANIC at the Calar Alto 2.2-m telescope yielded evidence for the outburst from S255IR-NIRS3.

Stecklum+ (2016, ATel #8732)
Caratti o Garatti+, Nature, in press



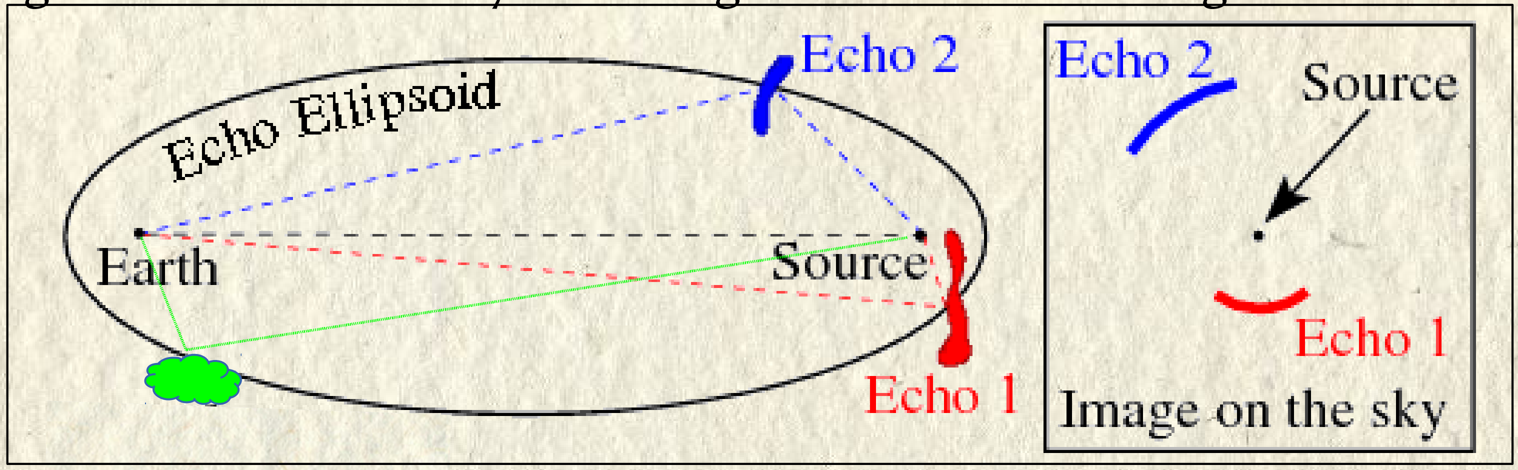
Light Echo Discovery



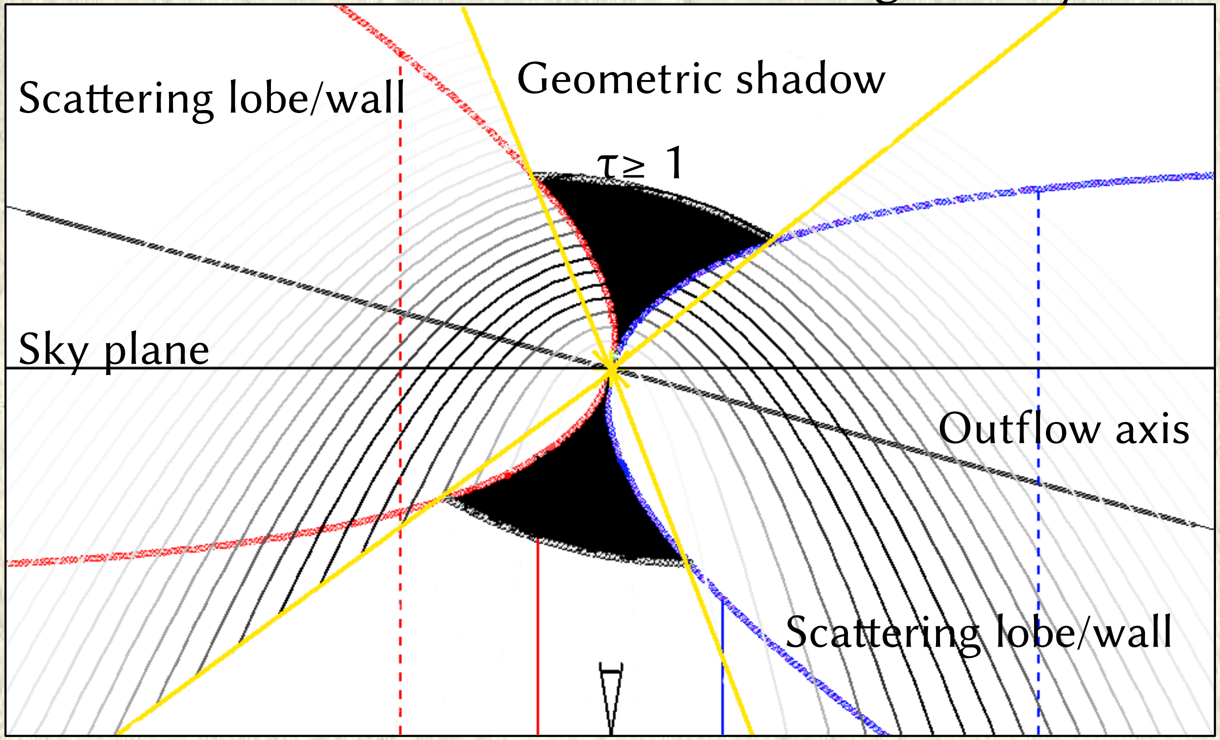
Ks/K-band ratio image(s)
PANIC(Nov 2015, Feb 2016)/UKIDSS(Dec 2009)

Light Echoes – Basics

light echo formation by scattering/re-emission © B. Sugerman



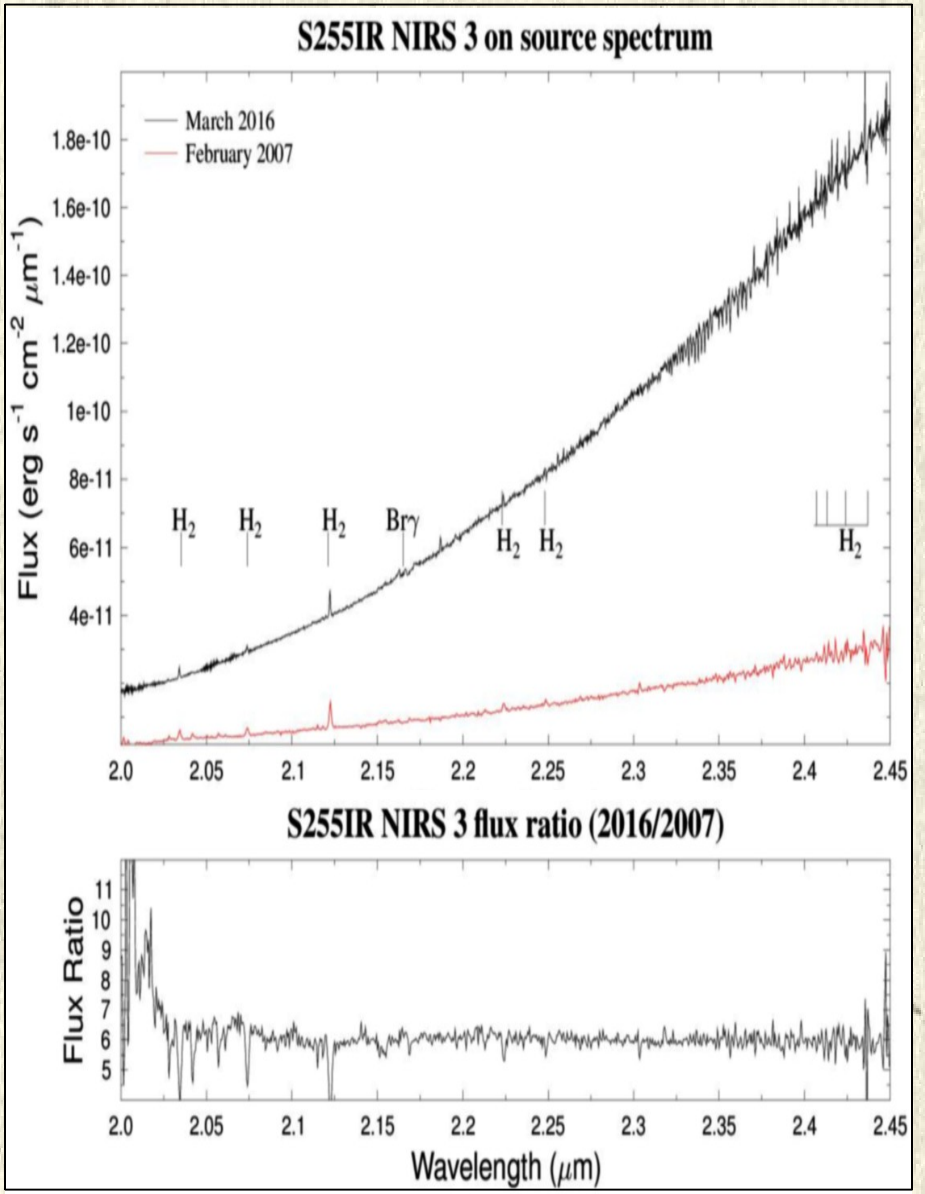
YSO echo geometry

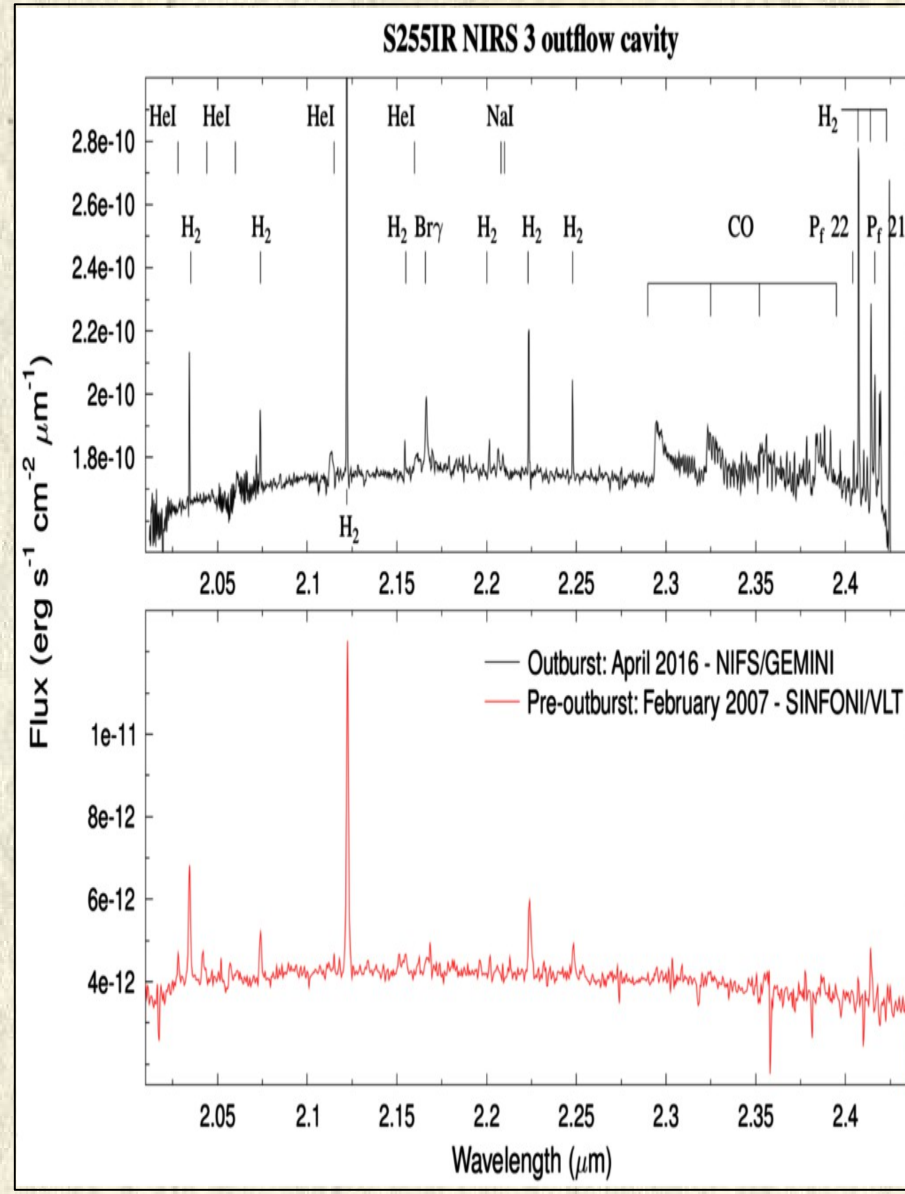


Schematic YSO morphology and light echo ellipses for a disk inclination of 75°

The ellipse gray shades indicate inverse brightness.

Integral Field Spectroscopy





On-source spectrum is very red and almost featureless, slope unaffected by the burst.

Light echo spectroscopy reveals an EXor-type spectrum.

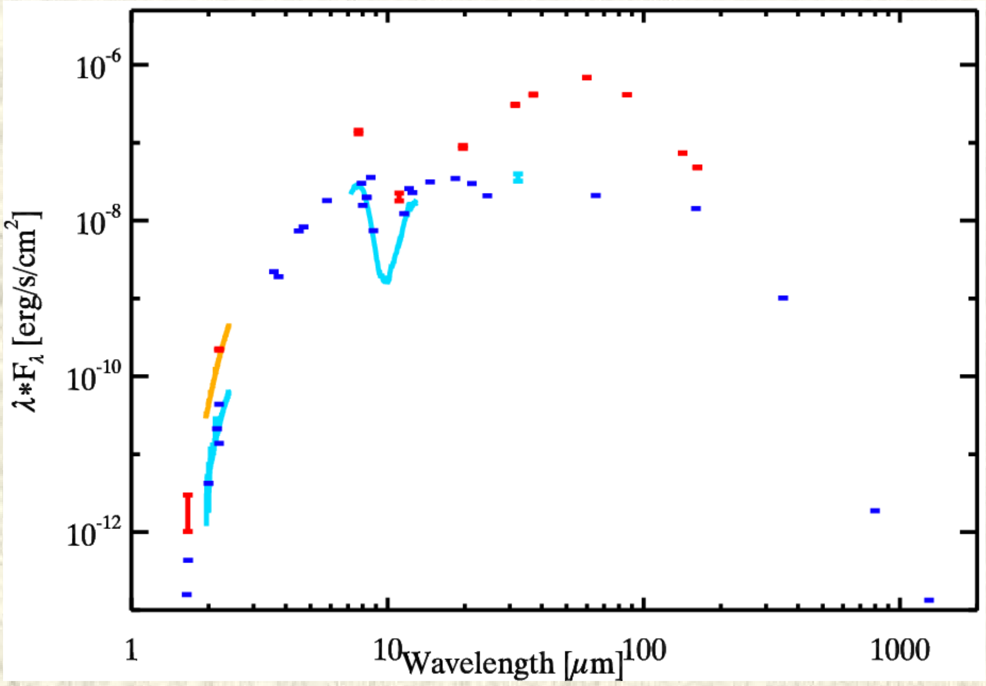
Pre-burst data ©Wang+ (2009)

Change of the Spectral Energy Distribution

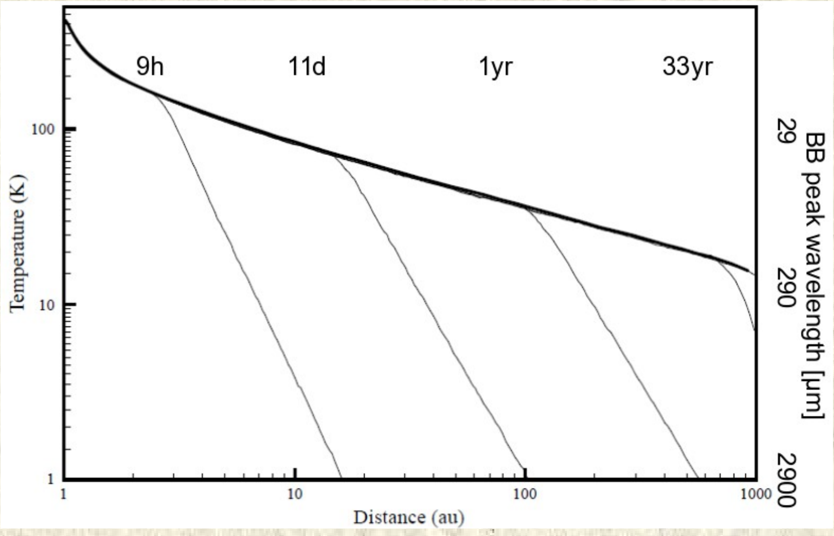
SOFIA observations (PI J. Eislöffel) reveal a drastic SED change.

SOFIA is of utmost importance in this regard since

- There is currently no other facility available for IR observations >25µm
- Space-based telescopes would suffer from saturation for bright targets



Pre- and burst SEDs (light lines are spectra) of S255IR-NIRS3



Disk mid-plane heat-up times for the Pascucci benchmark disk (Harries 2011) provide an idea on the thermal inertia

Outburst Parameters

Deriving output parameters requires reddening correction

The visual extinction towards NIRS3, derived from the H_2 lines detected in the outburst spectrum, amounts to $A_V = 44 \pm 16$mag.

The visual extinction towards the outflow lobes was derived using pairs of lines from [FeII] (2.016/2.254μm) and H_2 (2.034/2.437μm, 2.122/2.424μm, 2.223/2.413μm) that originate from the same upper level.

blueshifted lobe $A_V = 18 \pm 5$mag, redshifted lobe $A_V = 28 \pm 9$mag

The burst from S255IR-NIRS3 is the most luminous YSO outburst ever

$L_{pre\text{-}burst} \sim 2.9 \pm 0.8 \times 10^4\, L_\odot$, $L_{burst} \sim 1.6 \pm 0.4 \times 10^5\, L_\odot$

$$\Delta L_{burst} \sim 1.3 \pm 0.4 \times 10^5\, L_\odot$$

energy release during 9 months $(1.2 \pm 0.4) \times 10^{46}$ erg

$$\dot{M}_{acc} \sim 5 \times 10^{-3}\, M_\odot/yr$$

$$M_{acc} \sim 2\, M_{♃}$$

Conclusions

- The outburst confirms the presence of a circumstellar disk around the HMYSO which represents another piece of evidence for the formation of high-mass stars via accretion from circumstellar disks.
- The outburst demonstrated that accretion variability occurs in circumstellar disks of HMYSOs as well (cf. Meyer+ 2016).
- The methanol maser flare and the new maser spots which emerged due to the burst support the IR pumping theory for the excitation of 6.7GHz masers.
- Tracing the temporal response of circumstellar disks to accretion bursts with SOFIA opens up a new diagnostics – thermal disk screening.

Continuing follow-up...

- 2nd epoch SOFIA FORCAST/FIFI-LS observations were proposed to monitor the temporal evolution of the SED. Time-dependent radiative transfer shall yield a burst+disk model consistent with the SEDs.

- Ongoing NIR imaging to record both photometric variability and propagation/dilution of the light echo.

- 2nd epoch GEMINI/NIFS and VLT/SINFONI spectroscopy are scheduled to trace the decay of the scattered light as well as line-strength variations.

- Recently, JVLA monitoring yielded evidence for enhanced radio-continuum emission which shall be followed-up with ALMA (pending DDT proposal).

- Modeling the light echo will allow us to solve the inverse problem of retrieving both the burst light curve and the 3D dust distribution.