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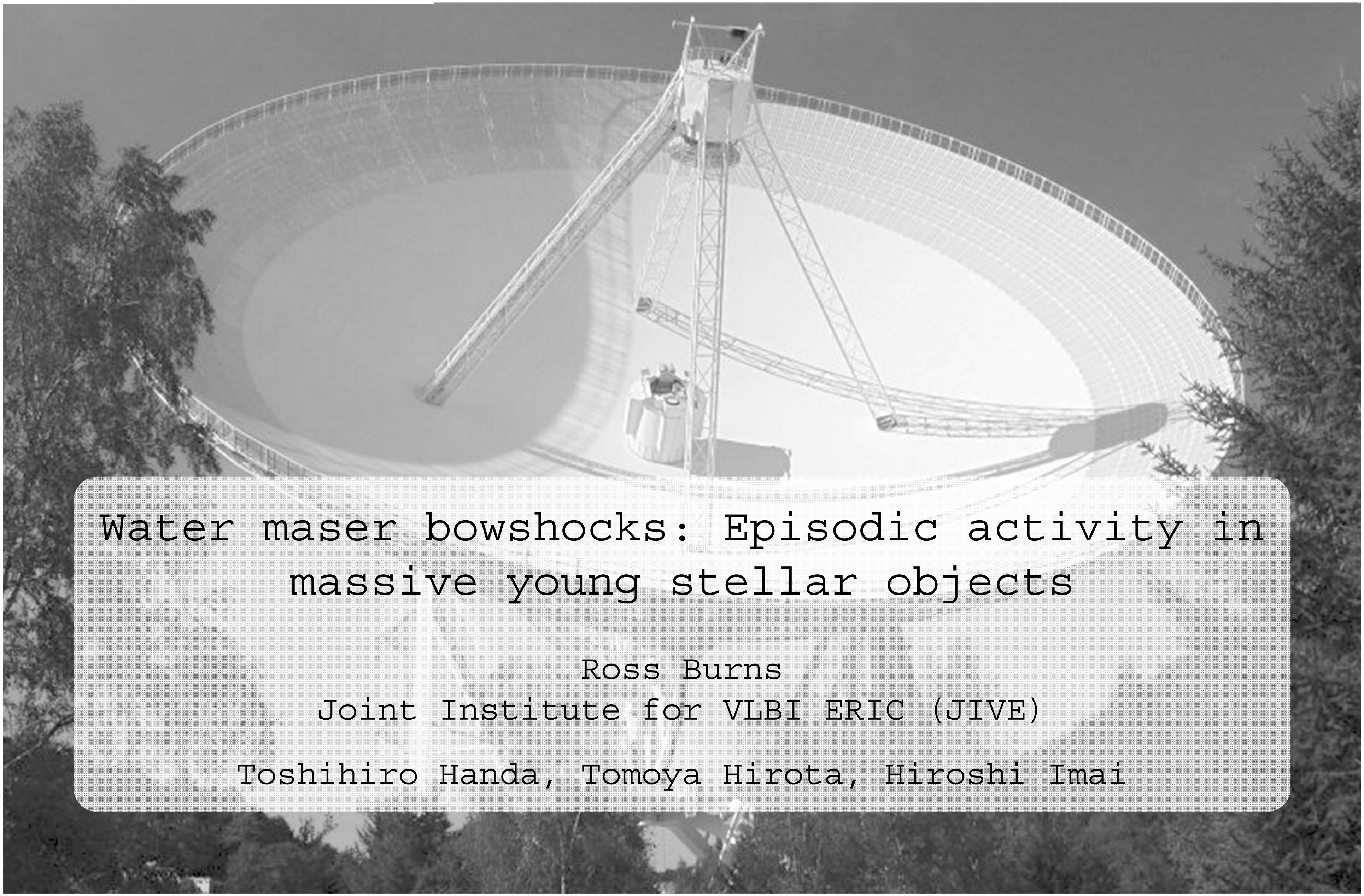

Water maser bowshocks: Episodic activity in massive young stellar objects

Ross Burns
Joint Institute for VLBI ERIC (JIVE)

Toshihiro Handa, Tomoya Hirota, Hiroshi Imai

Massive stars

- Enrich the ISM
  (produce elements >Fe)
- Inject turbulence
  (mechanical feedback)
- Ionizing radiation
  (raditative feedback)

- Angular momentum problem
- Radiation pressure problem
- Luminosity problem

Massive SF is not fully explained.

Massive stars

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- Inject turbulence
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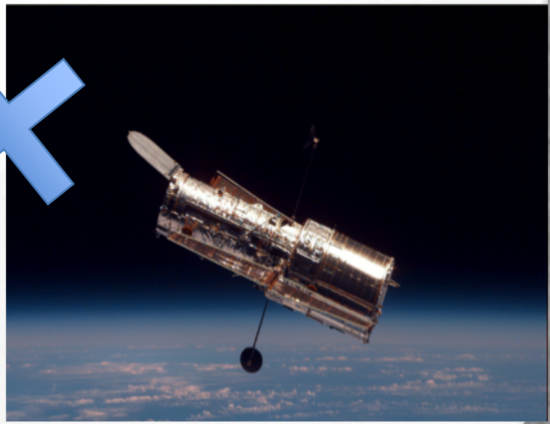
episodic accretion



Massive SF is not fully explained.

Episodic acc.: low mass YSOs

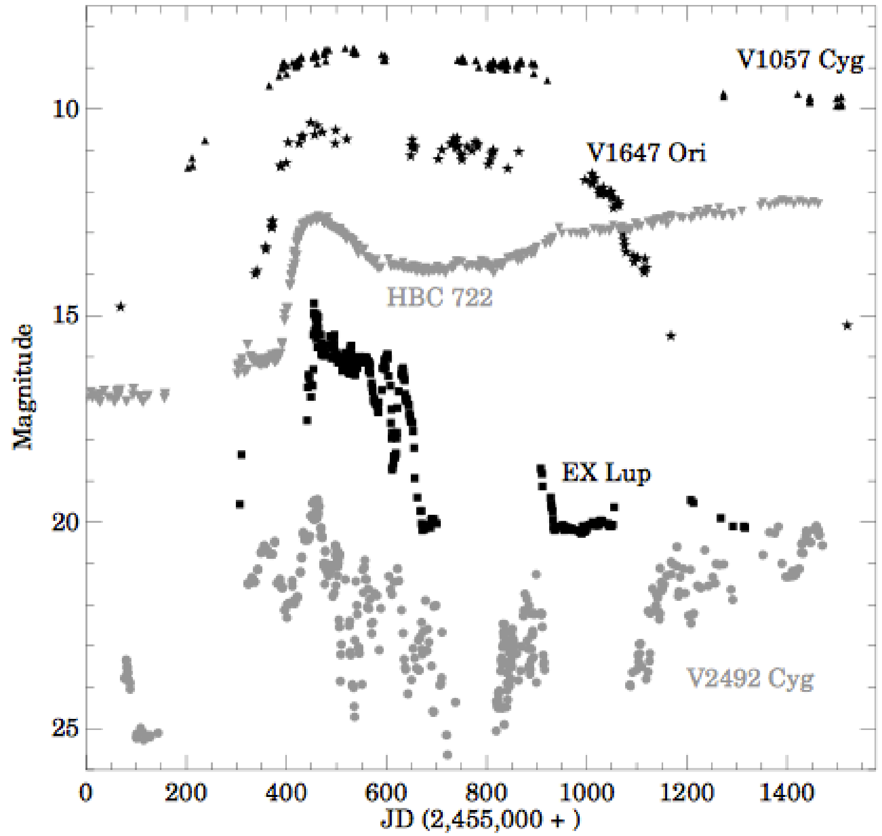


Fig. 2.— Comparison light curves for the FUor V1057 Cyg, the intermediate case V1647 Ori, the new sources HBC 722 and VSX J2025126.1+440523 (also known as PTF 10nvg or V2492 Cyg), and the classical EXor EX Lup, showing the continuum of outburst durations. Adapted from *Kóspál et al.,* (2011a).

Accretion burst

↓

Luminosity burst

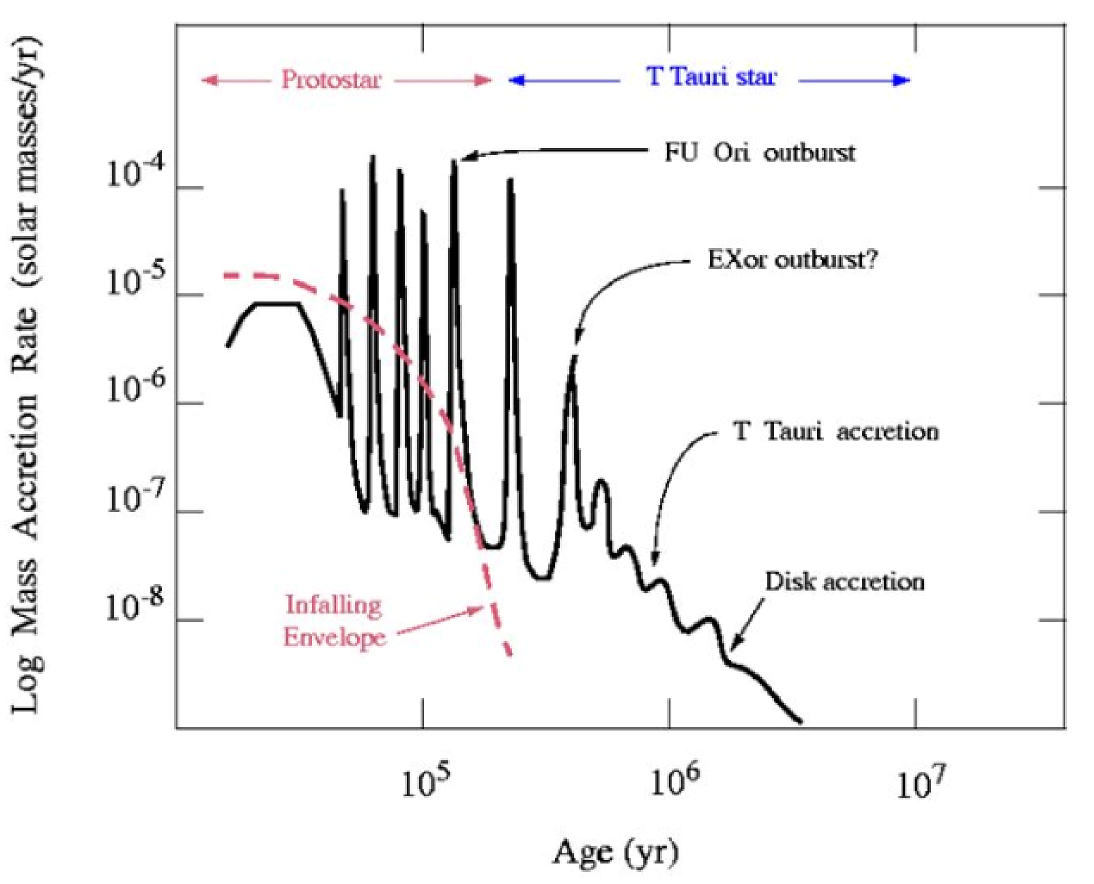
$L_{acc} < 100 L_\star$

FU Orionis
"FUors"
long-timescale

EX Lup
"EXors"
short-timescale

FUors = EXors?

Episodic acc.: low mass YSOs



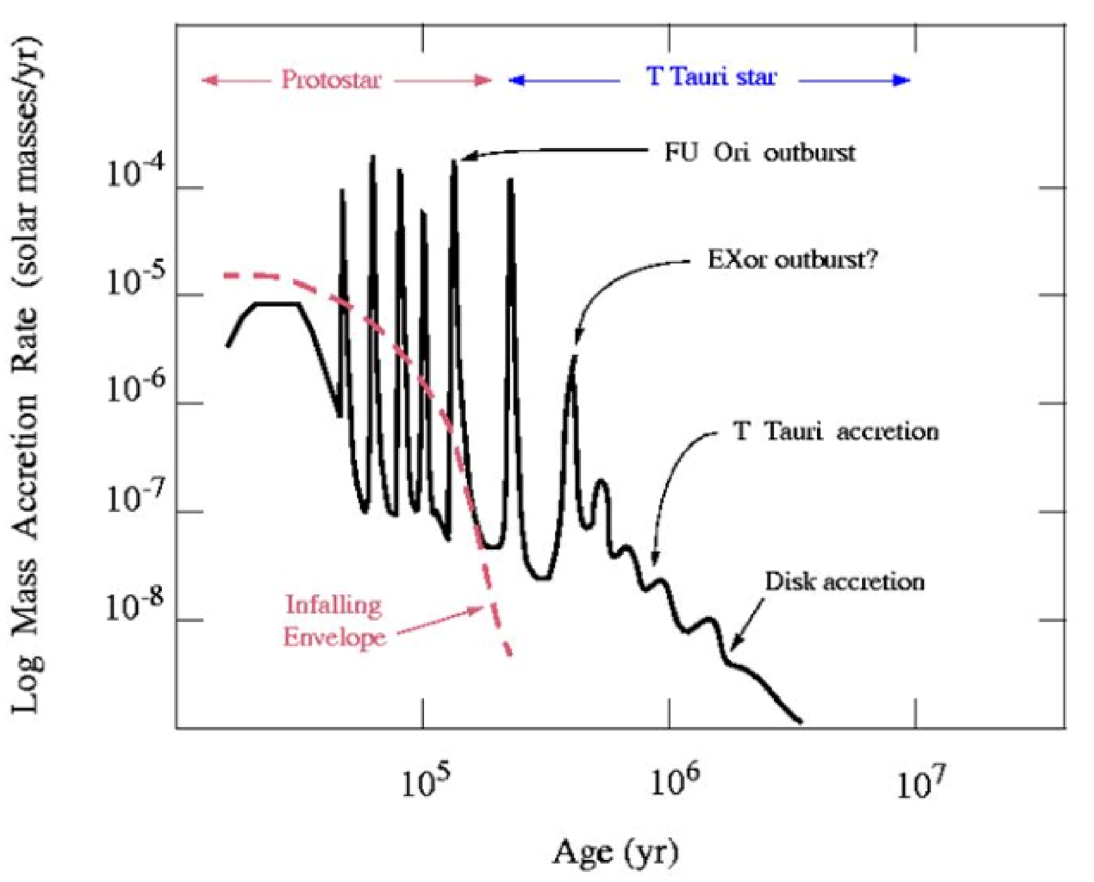
Photometric evidence (light curves)

Chemical evidence

Theoretically established

Solves "Luminosity problem"

Episodic acc.: low mass YSOs



Photometric evidence (light curves)

Chemical evidence

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FUori process present in massive YSOs?

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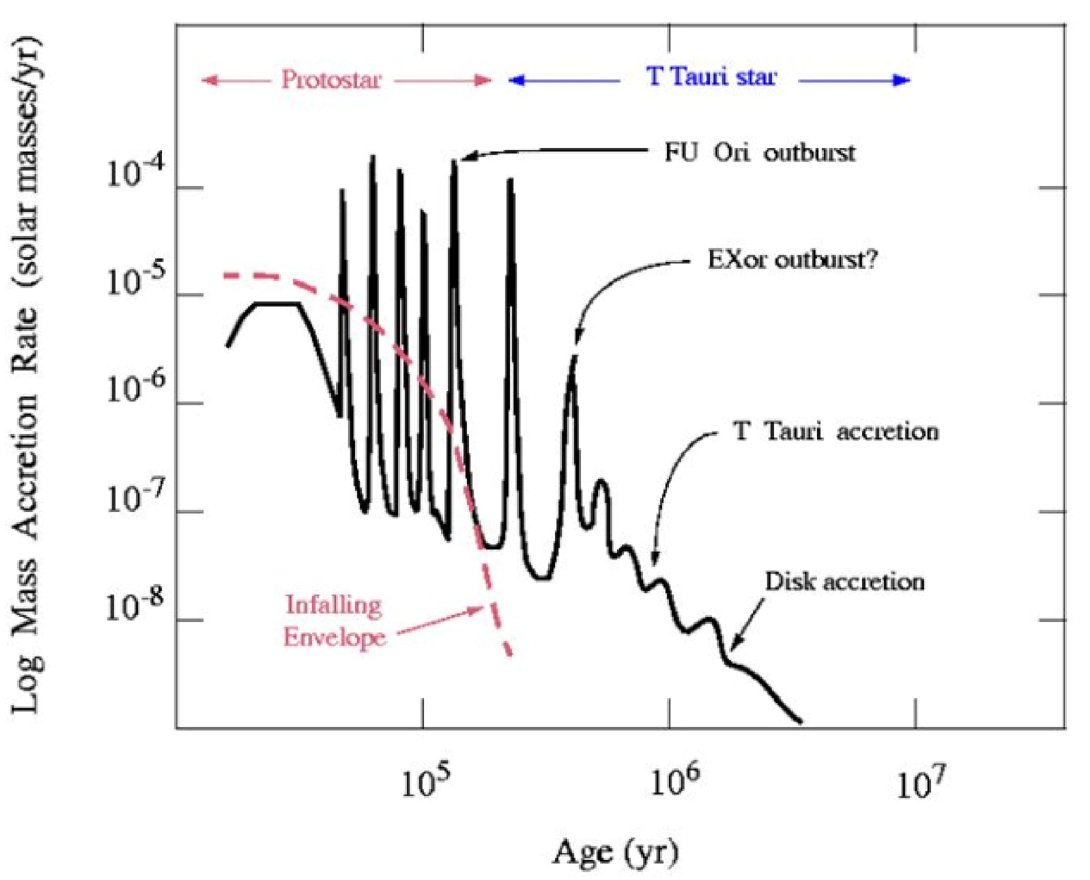
Episodic acc.: low mass YSOs



Photometric evidence (light curves)

Chemical evidence

Theoretically established

Solves "Luminosity problem"

FUori process present in massive YSOs? "MUors"?

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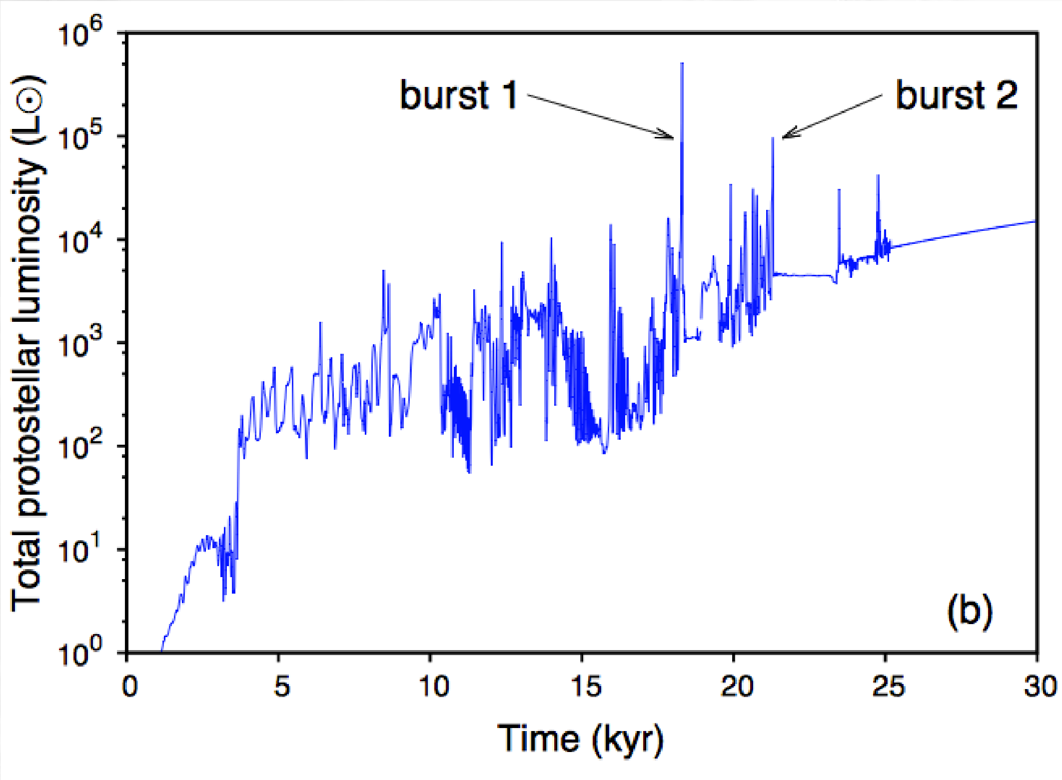
Episodic acc.: High mass YSOs

Simulations



Meyer+ 2017 Predict episodic accretion timescales of 10^4 yr

Similar to low-mass case (sim. and obs.)

How about the "Radiation pressure problem"?

In massive stars, radiation pressure is high enough that it should stop accretion beyond $8\,M_\odot$

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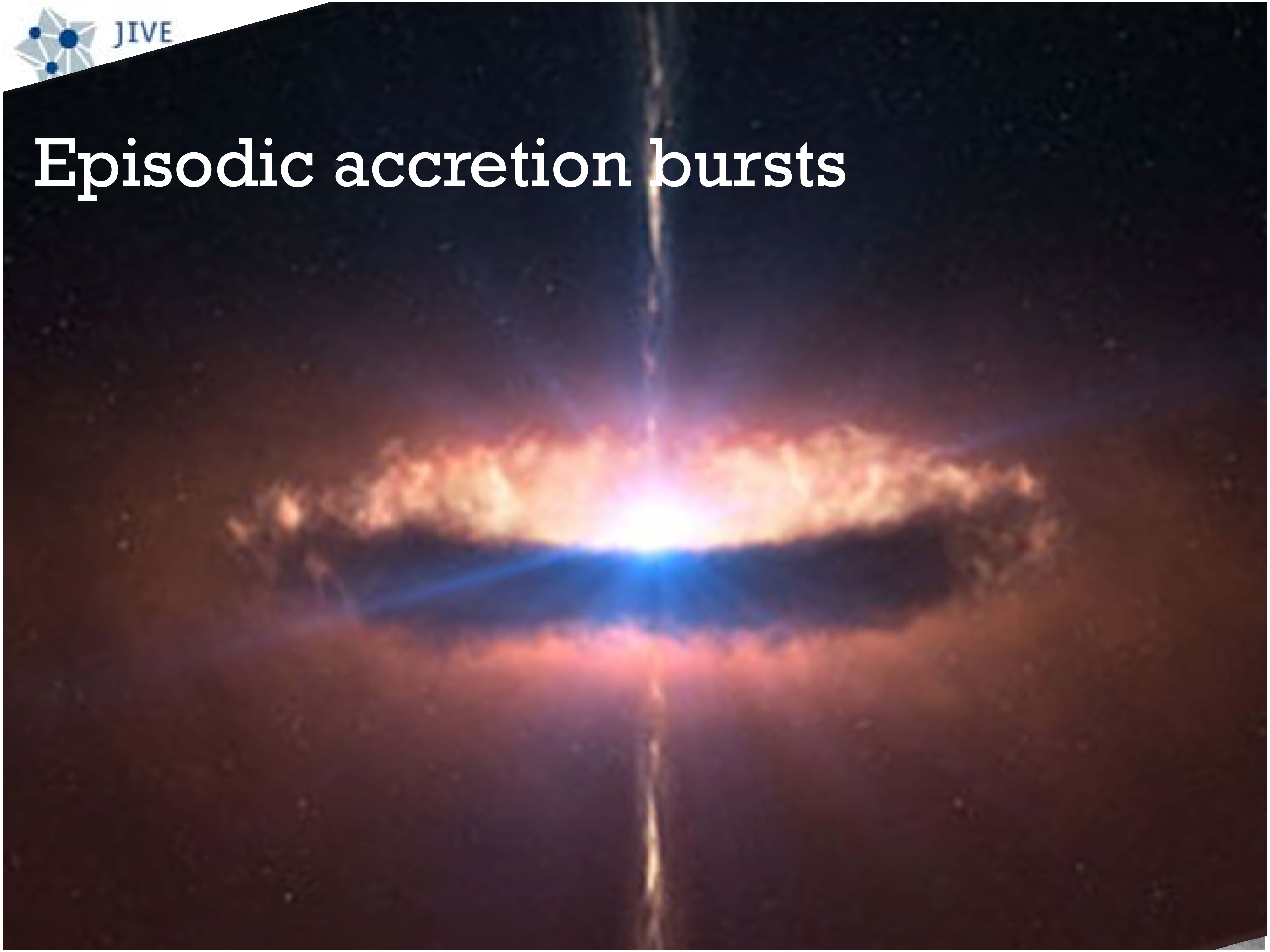
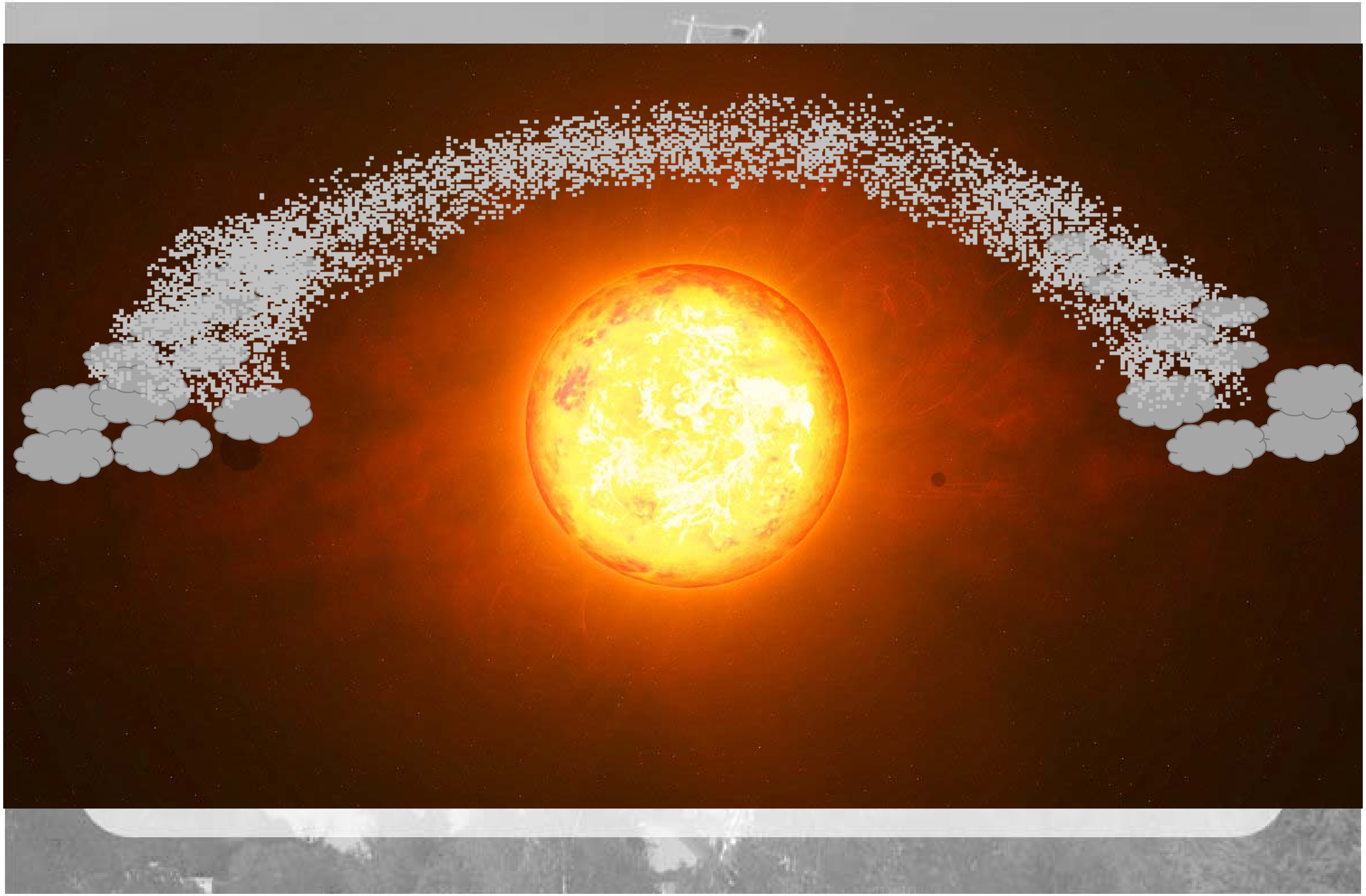
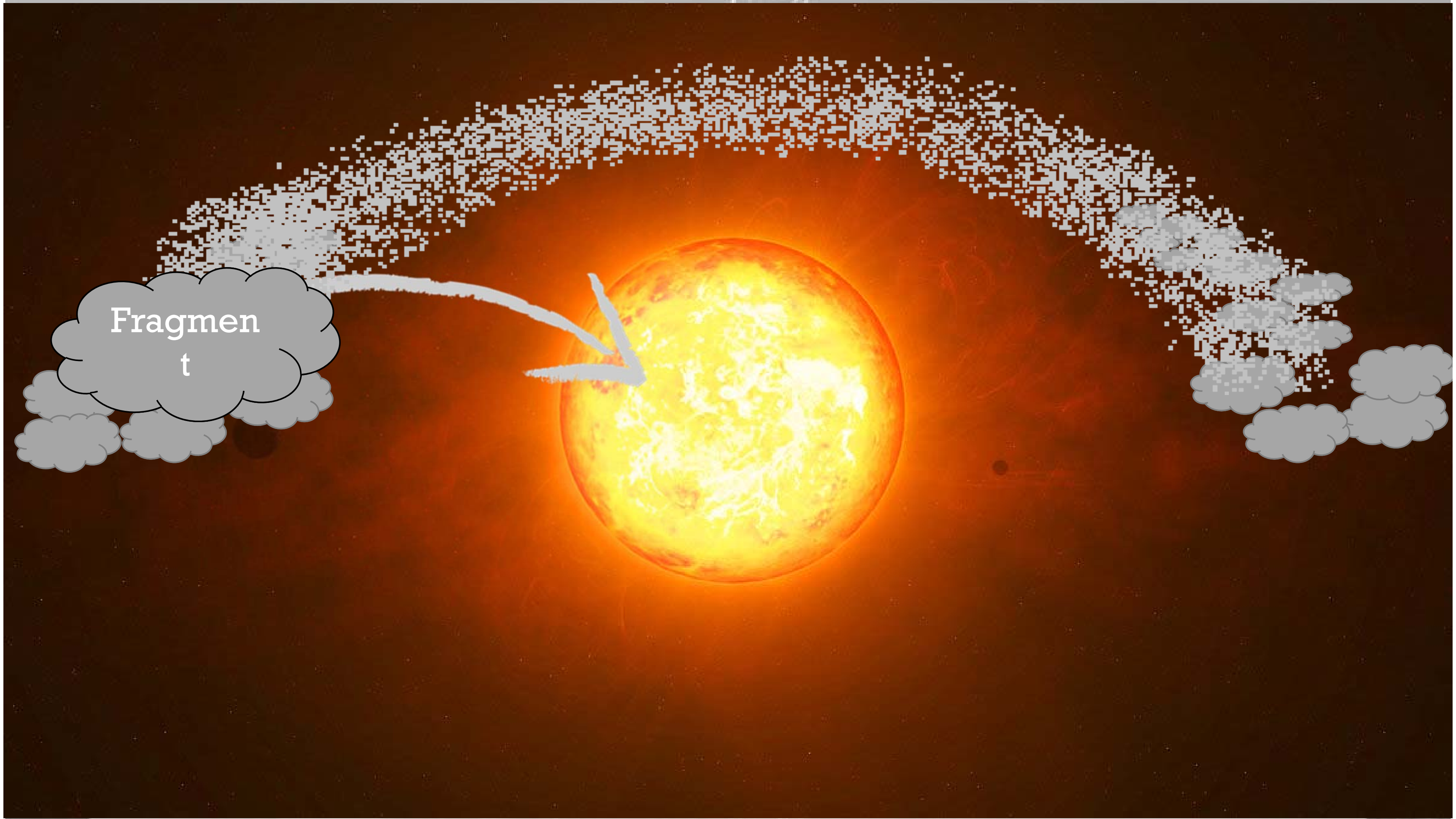
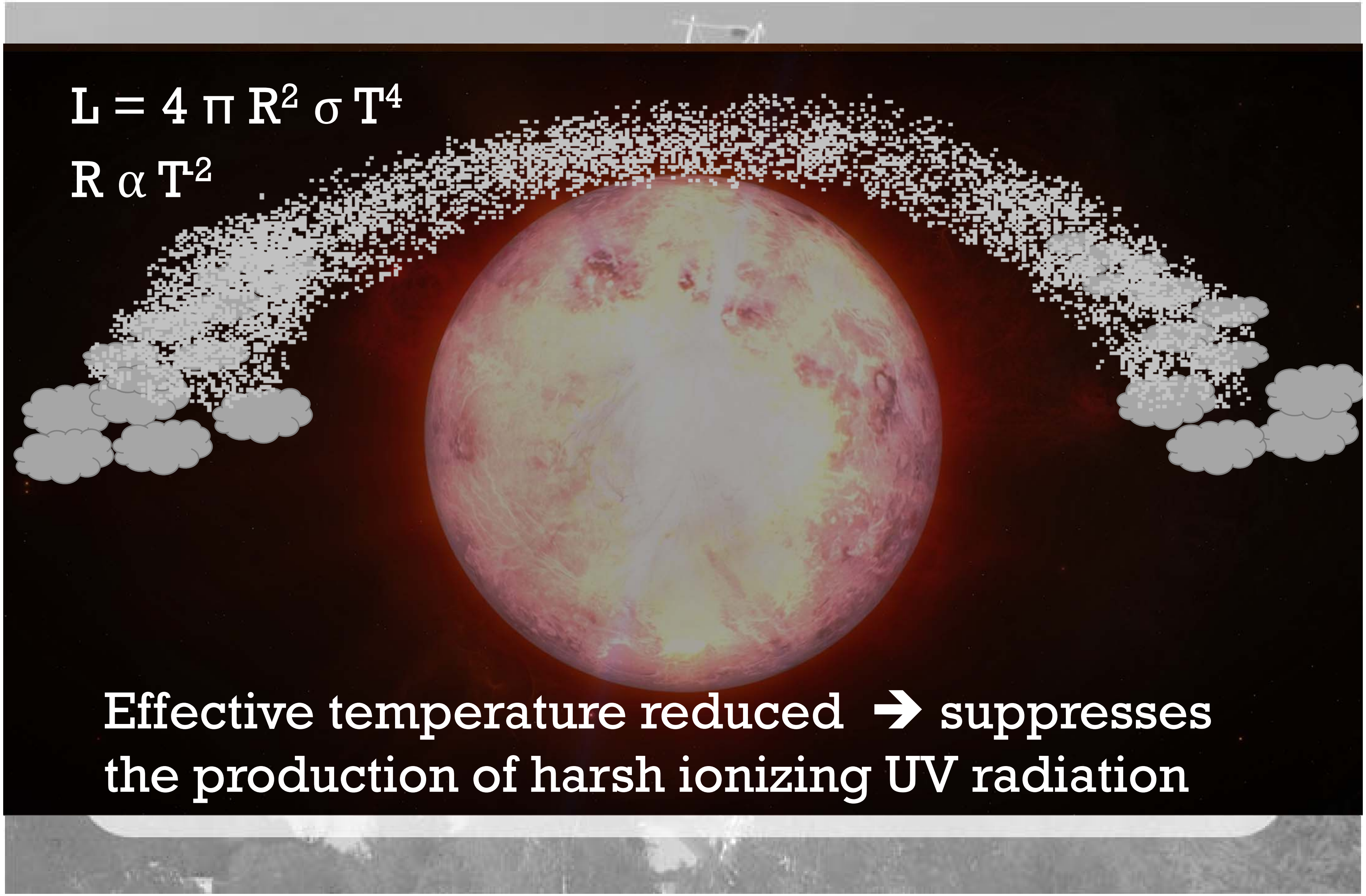
Episodic accretion bursts






Fragmen
t


$L = 4 \pi R^2 \sigma T^4$
$R \alpha T^{-2}$
Effective temperature reduced → suppresses the production of harsh ionizing UV radiation

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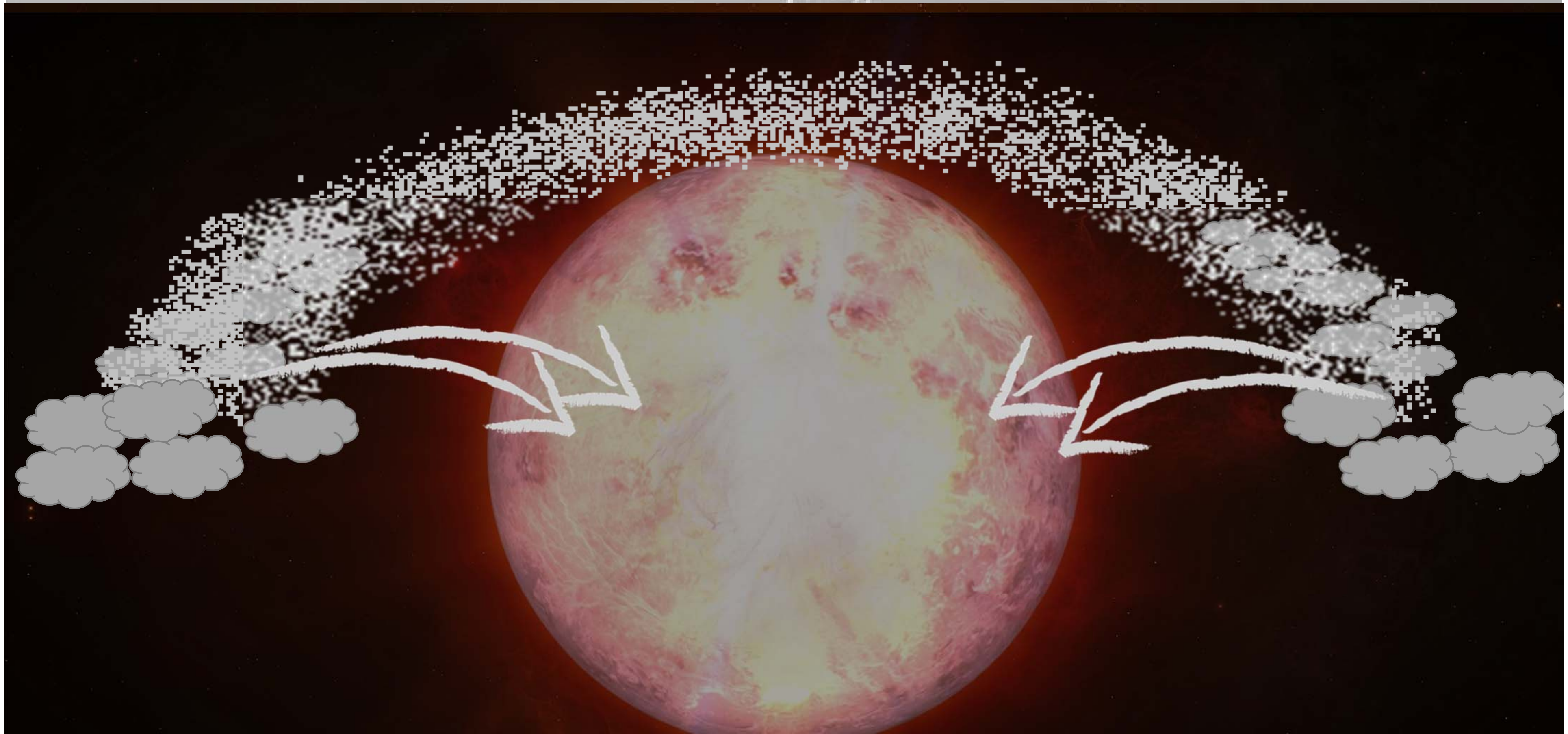
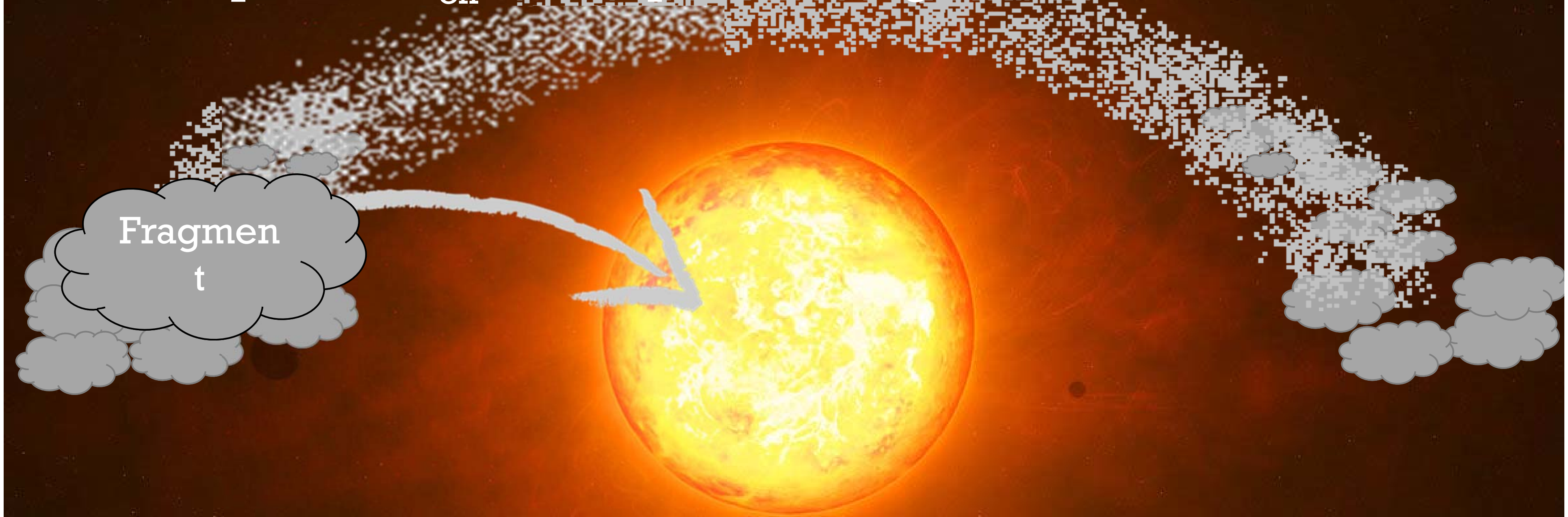


Star accretes from the disk without radiation pressure (like in low mass star formation)

After 10^4 years the star will contract gravitationally.
This pushes T_{eff} back up, restarting the UV radiation.



If another disk fragment is accreted before 10^4
the process repeats.

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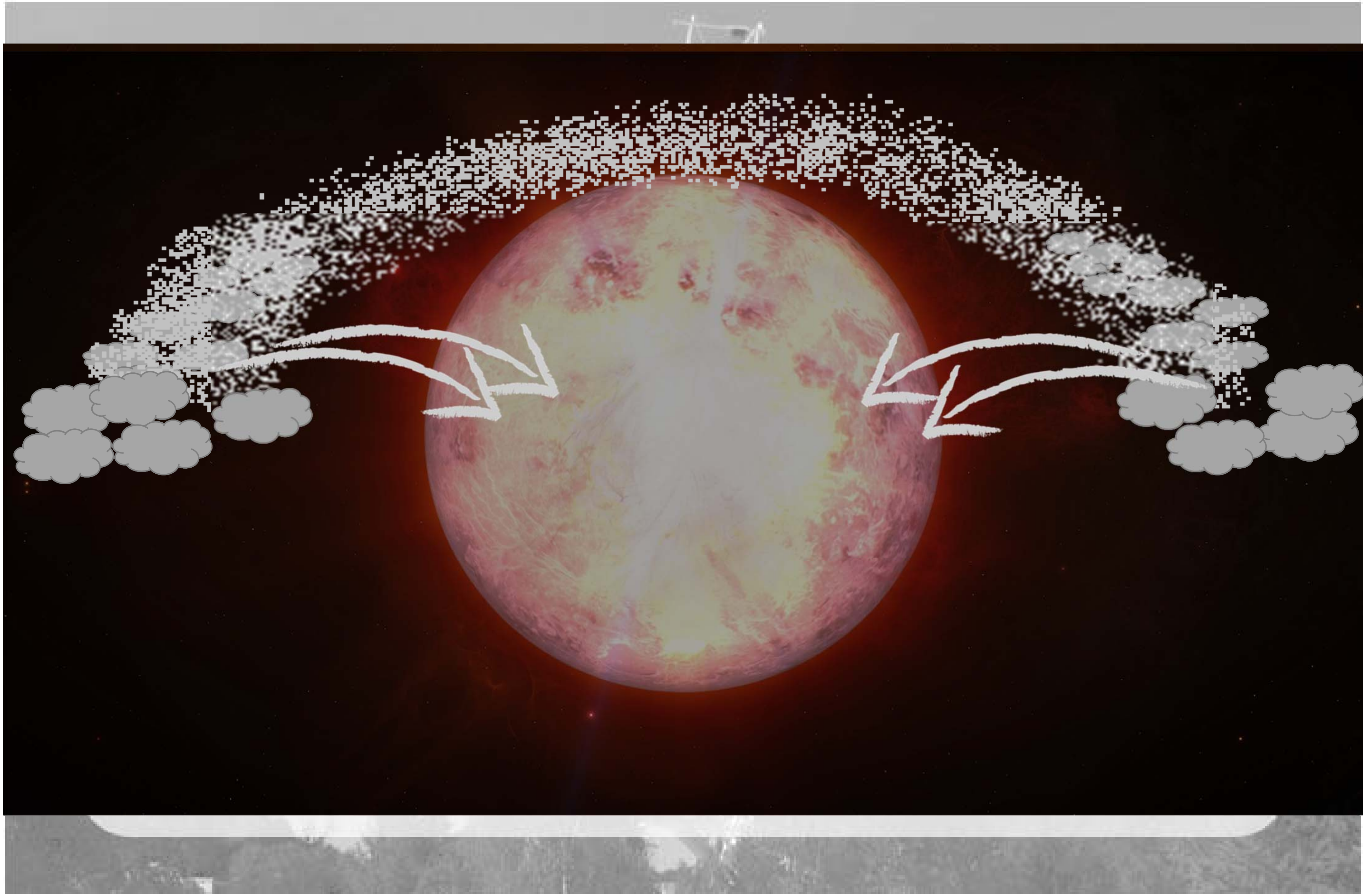
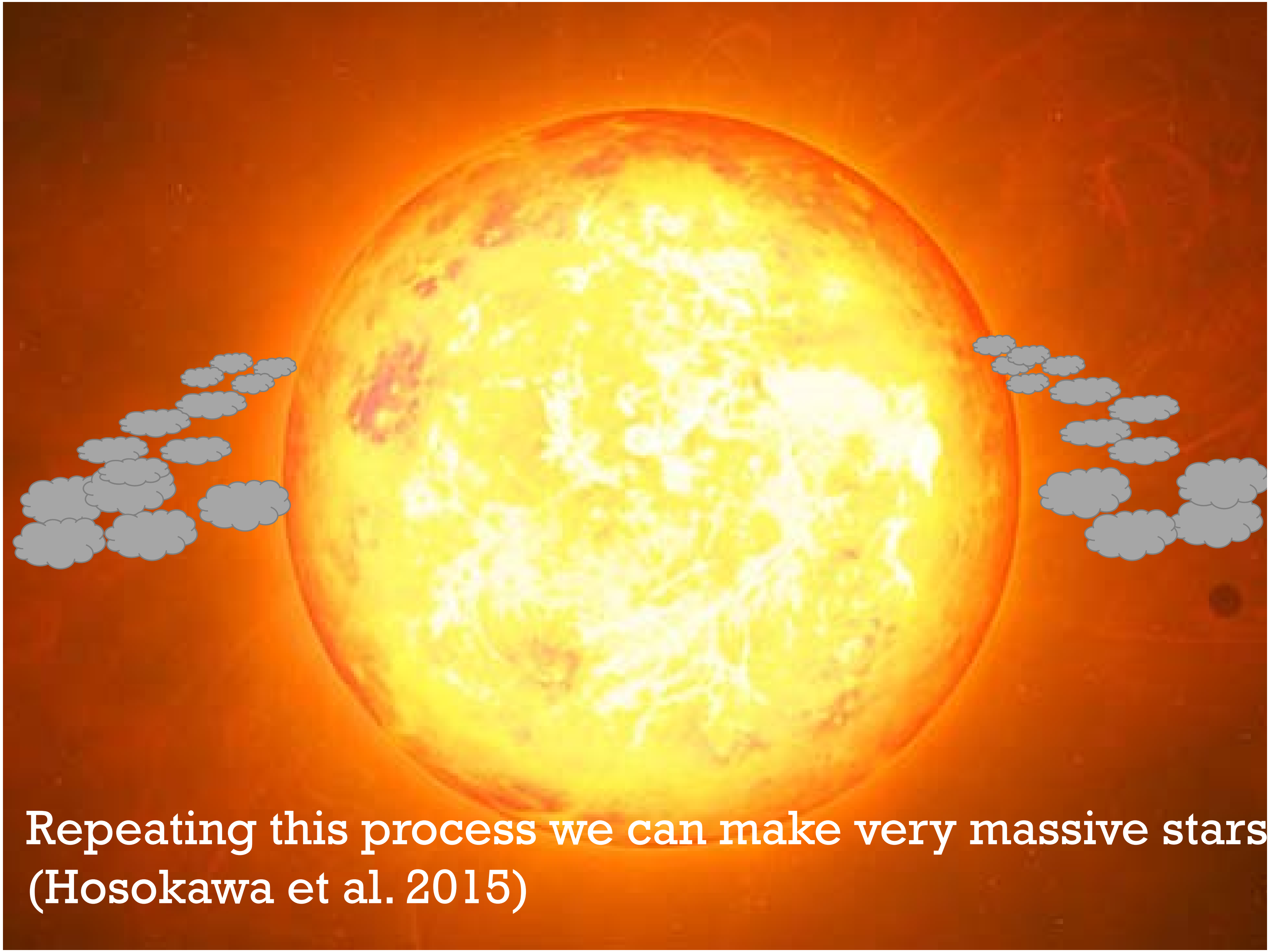
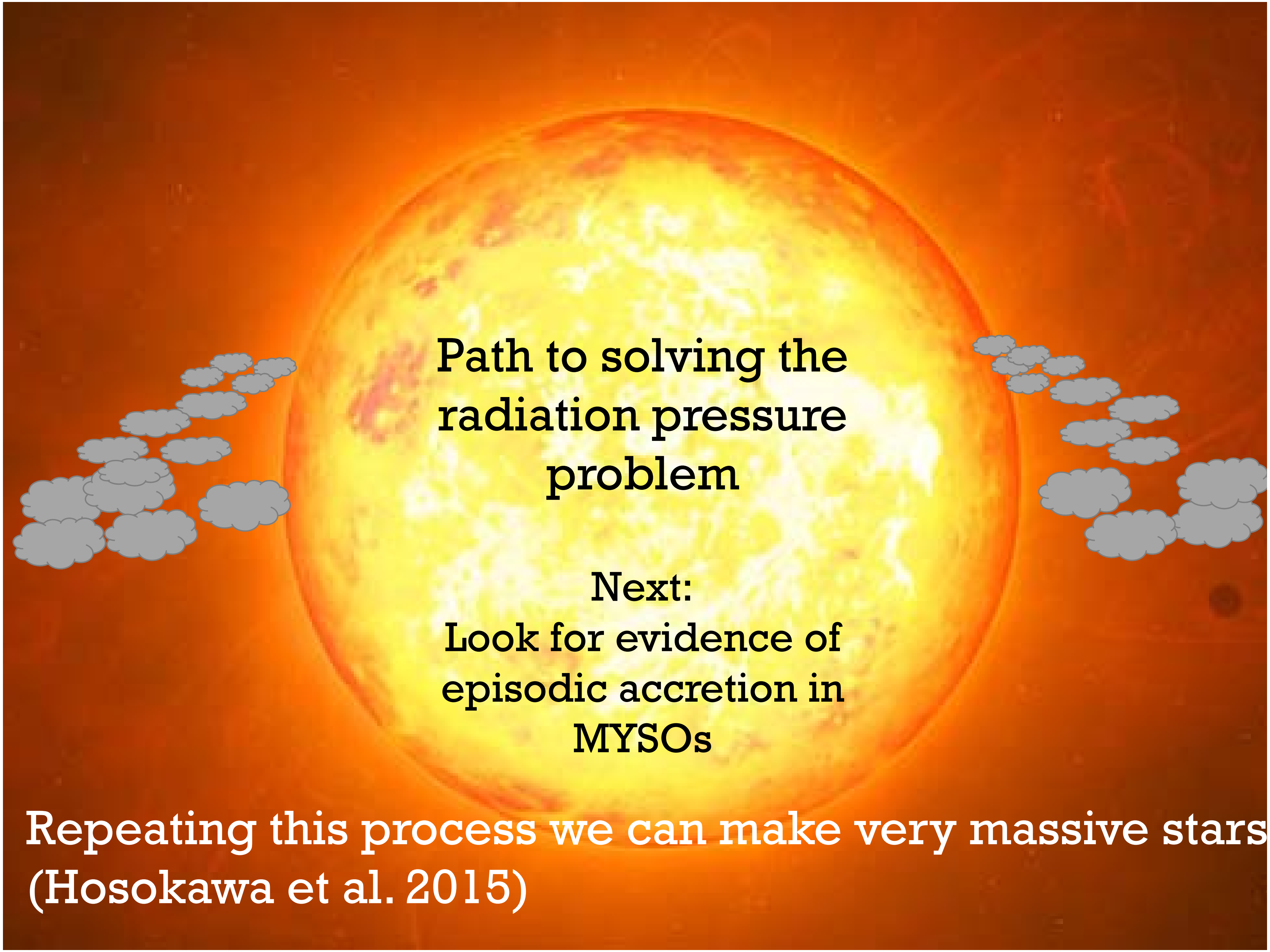



Repeating this process we can make very massive stars
(Hosokawa et al. 2015)



Path to solving the radiation pressure problem

Next:
Look for evidence of episodic accretion in MYSOs

Repeating this process we can make very massive stars (Hosokawa et al. 2015)

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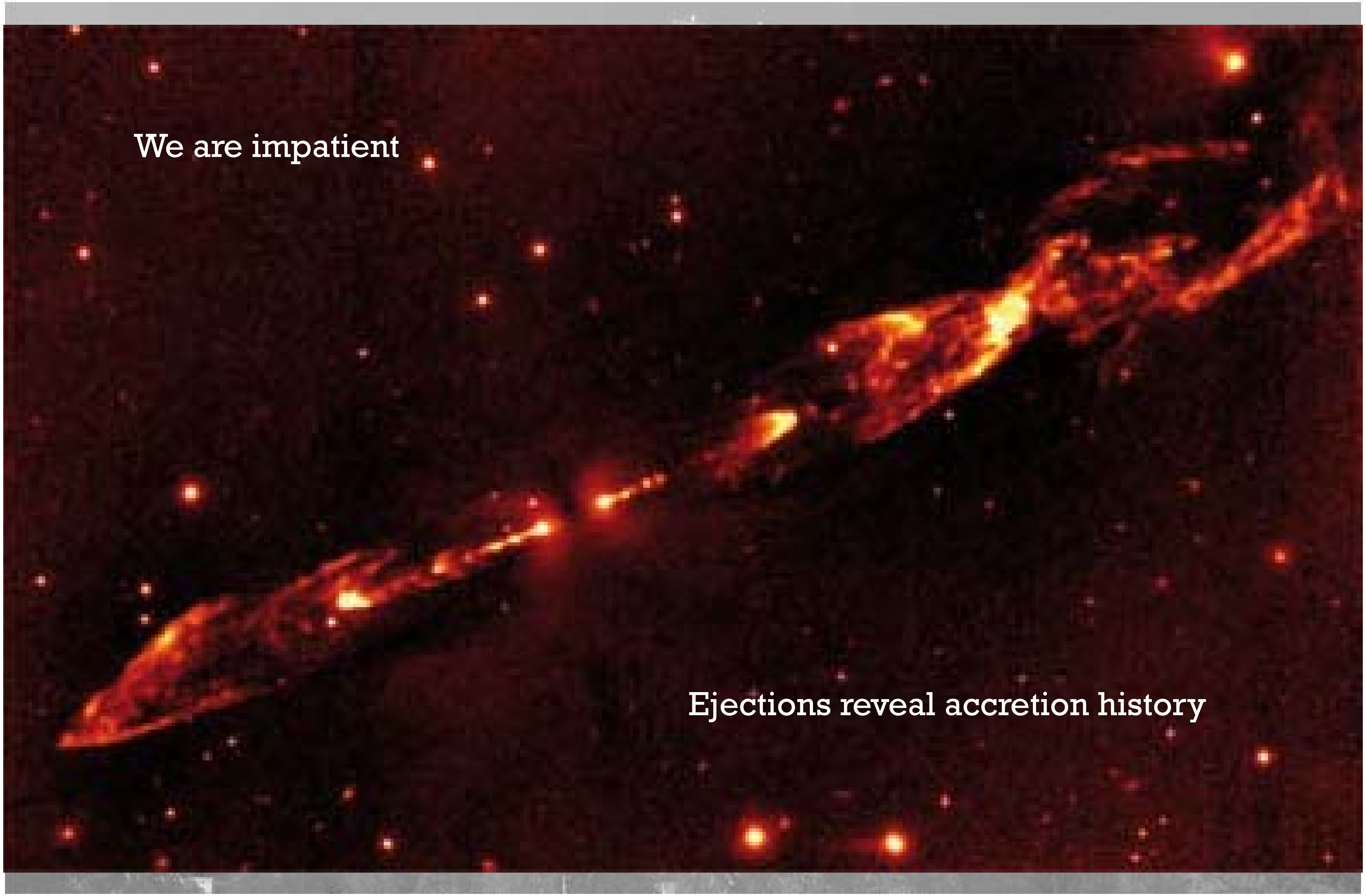
Bowshocks . . .



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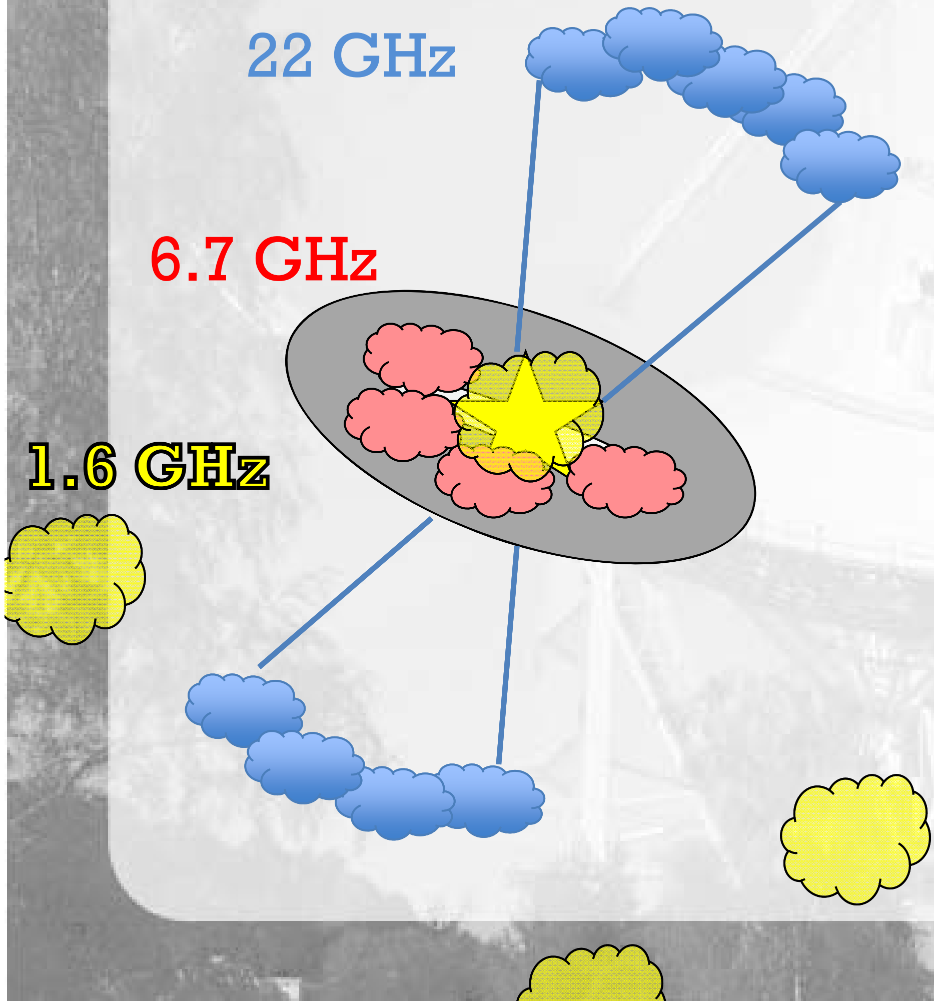
Masers trace...

- Many masers species exist.
  They trace different environments.



- 22 GHz Water masers trace shocks.
- 6.7 GHz Meth masers trace disks.
- 1.6 GHz OH masers trace envelope/shocks

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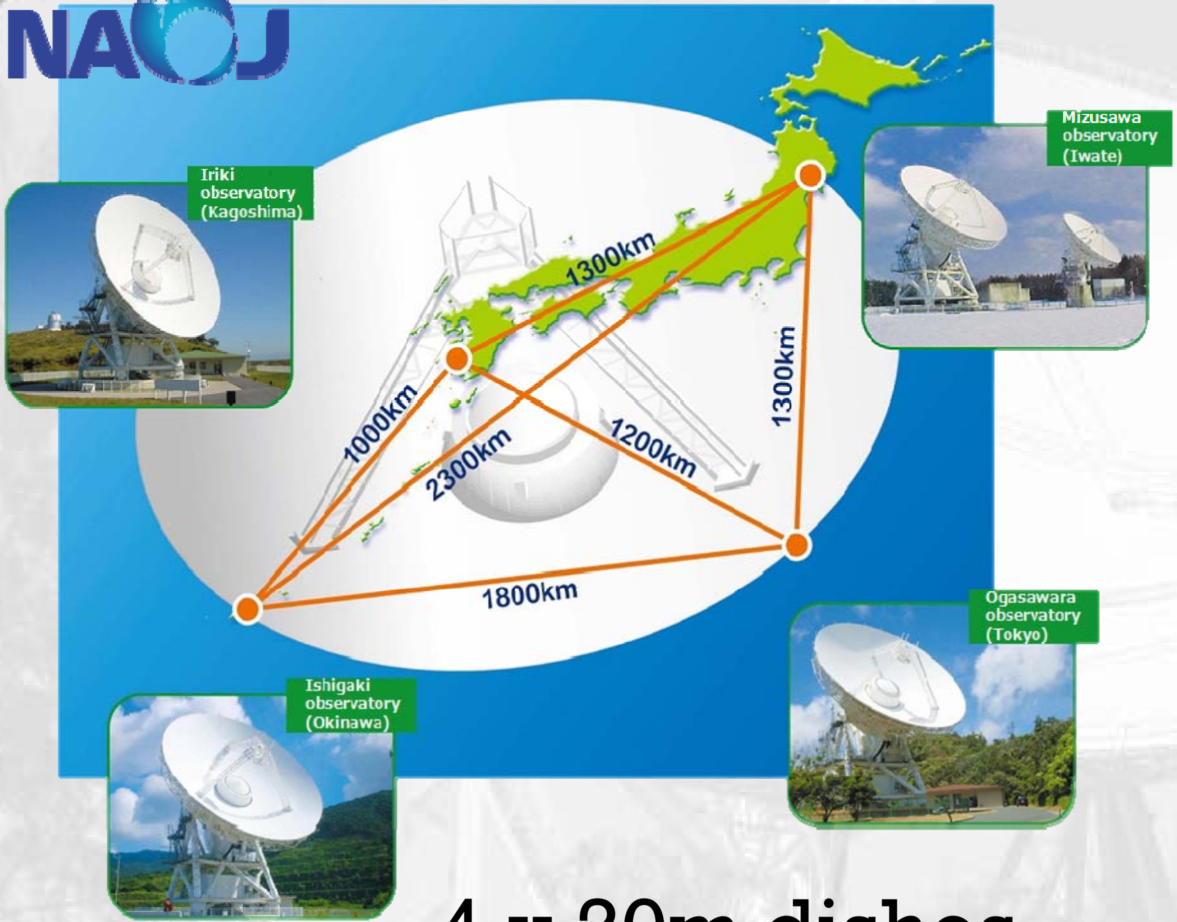
Observations: Maser VLBI



4 x 20m dishes
S,X,C,**K** (,Q)

Dual
Beam

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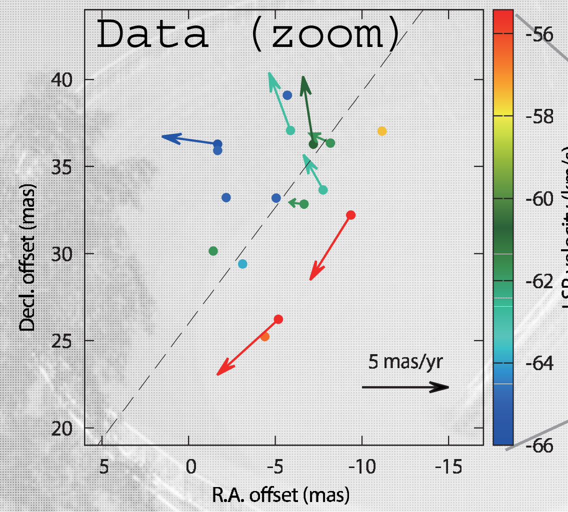
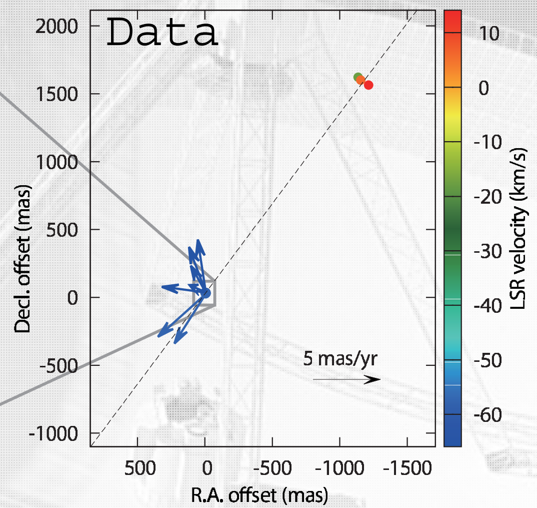
Power of maser VLBI

S235AB

Burns et al. 2015, MNRAS, 453, 3163

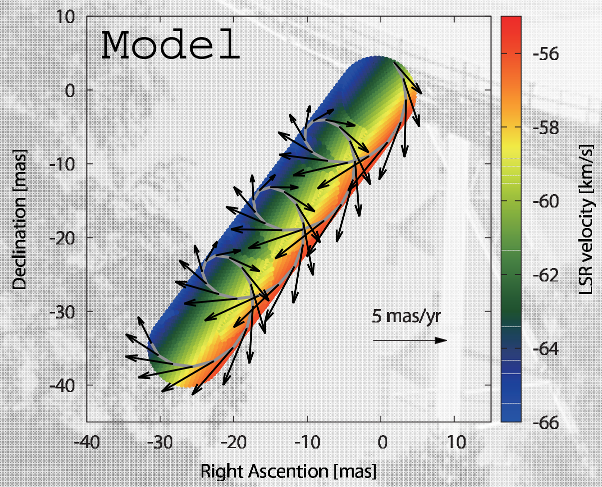




Proper motions
+
line of sight

↓

3D motion



Artist's impression

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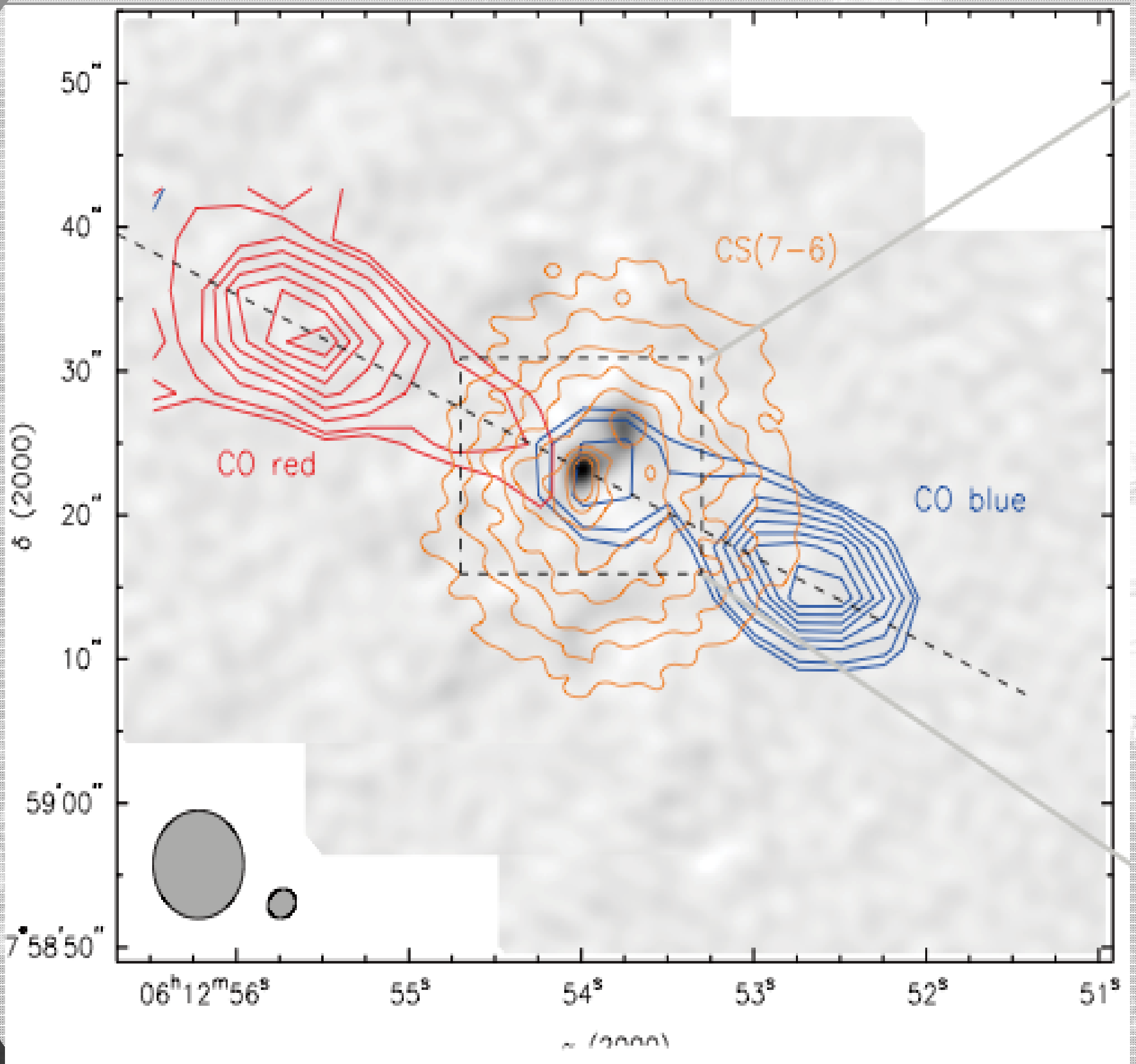
Results: S255IR



Massive YSO: 20 Mo

Large scale bipolar outflow

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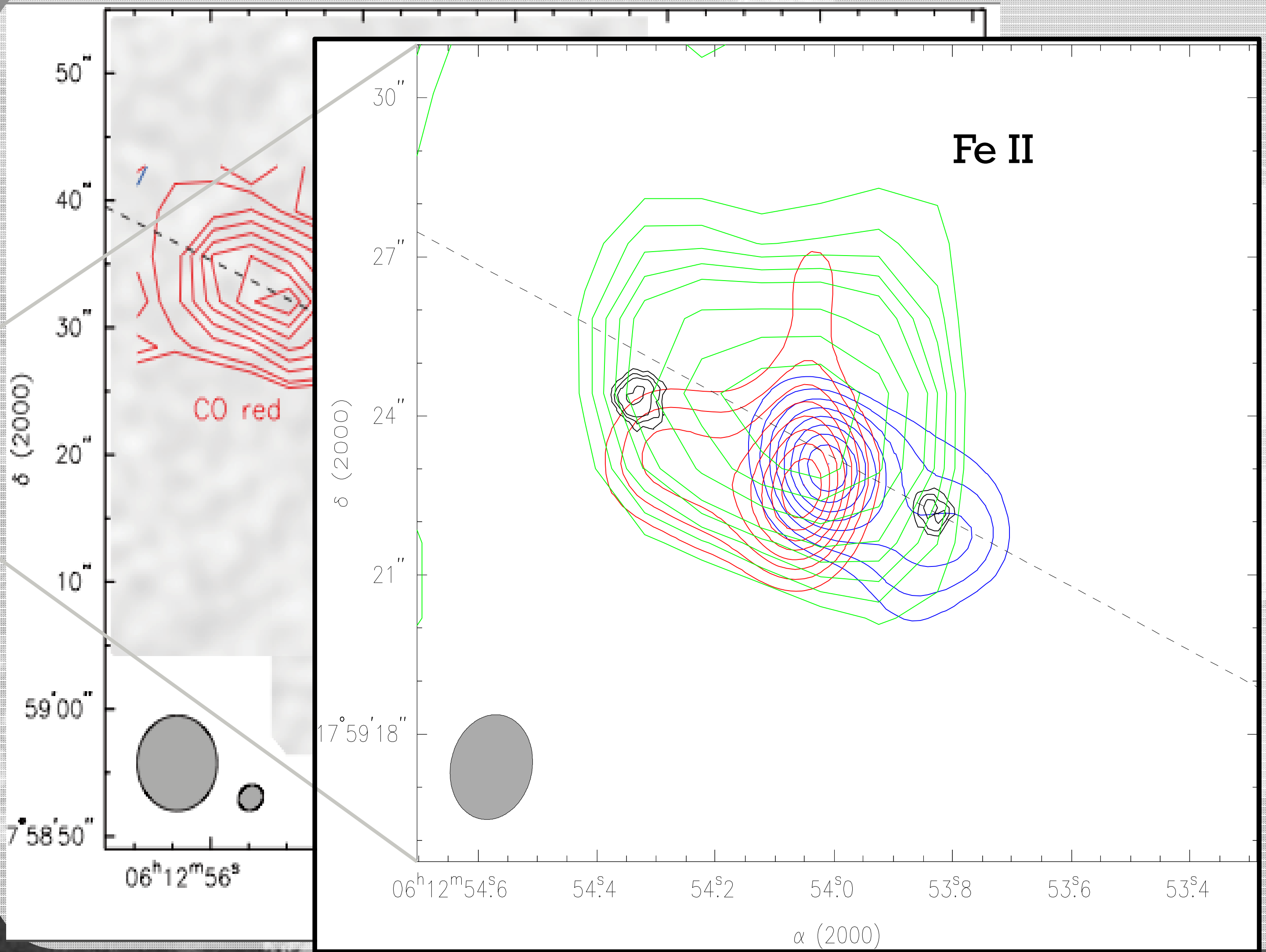
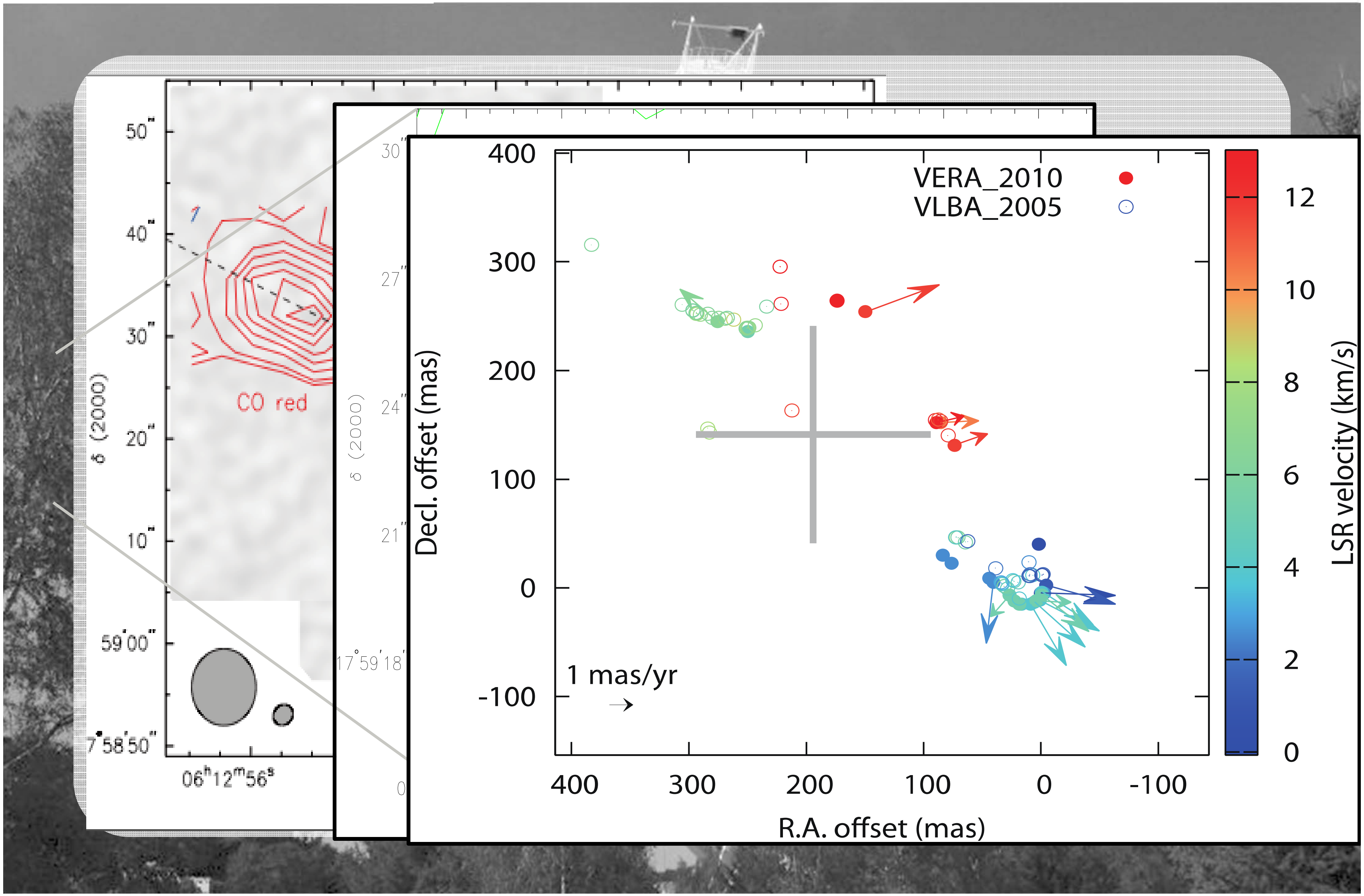
Results: S255IR



Results: S255IR



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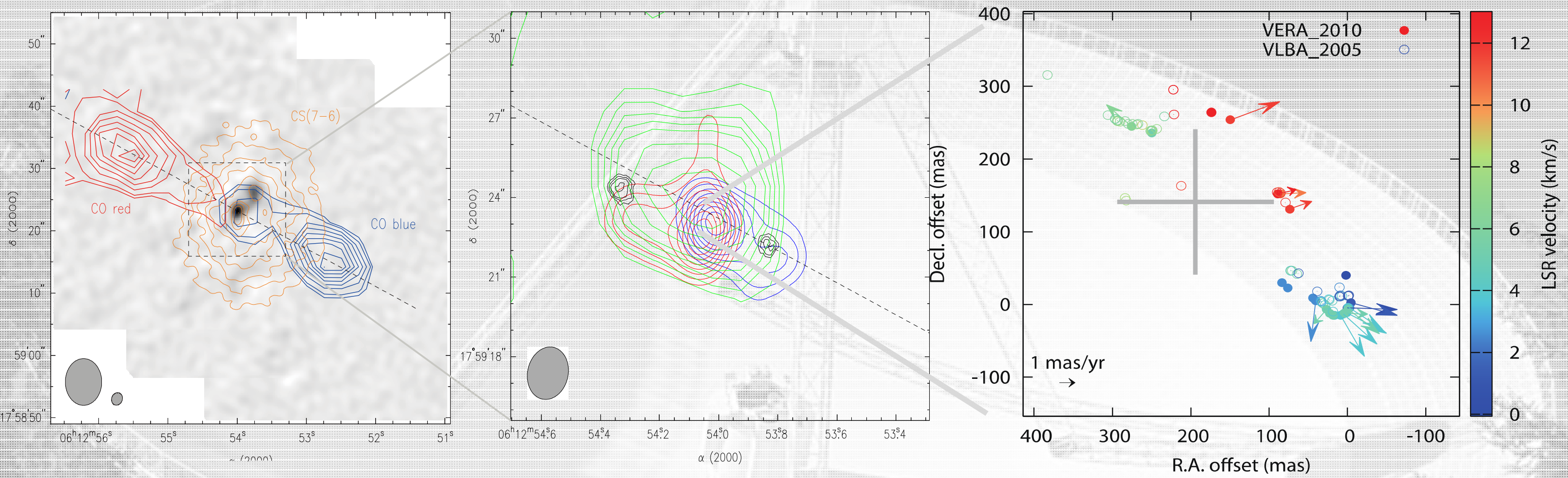
Results: S255IR



t_{dyn} = 7000 yr t_{dyn} = 1000 yr t_{dyn} < 130 yr

Fig 4. Multi-scale collimated ejections from S255IR-SMA1, showing: (Left) CO molecular outflow with a dynamic timescale of 7000, yrs from Zinchenko et al. (2015). (Middle) HCO+ emission (blue and red) and FeII bow shocks (black) tracing the 1000 yr old outflow from Wang et al. (2011). (Right) Combined (VERA + VLBA) view of water masers tracing the 130 yr old jet.

Episodic ejection suggests episodic accretion

10^4 yr timescales

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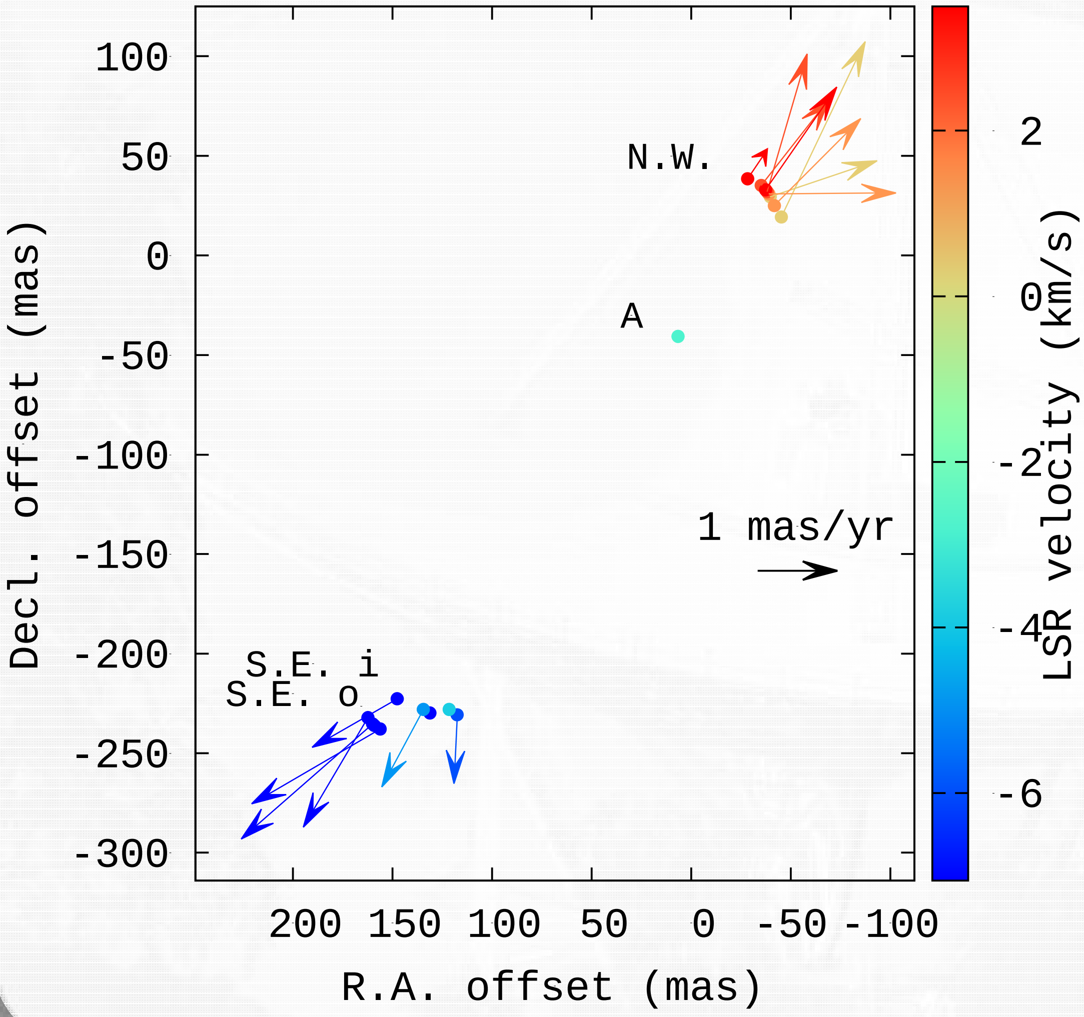
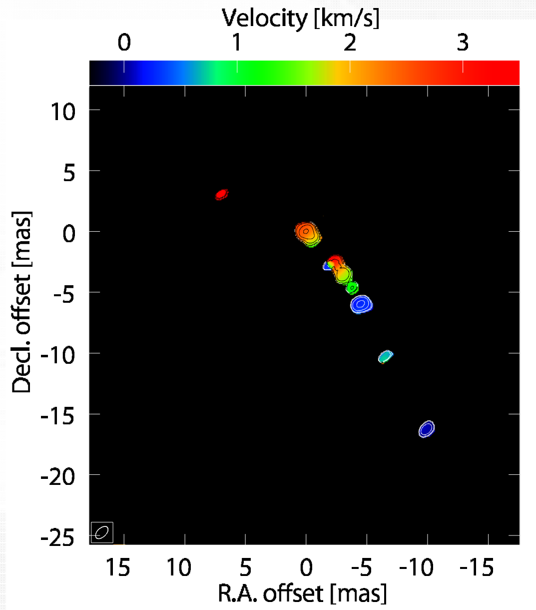
Results: AFGL5142

Burns et al, 2017, MNRAS, 467, 2376



Jet length: ~300 AU
Jet age: ~100 yr

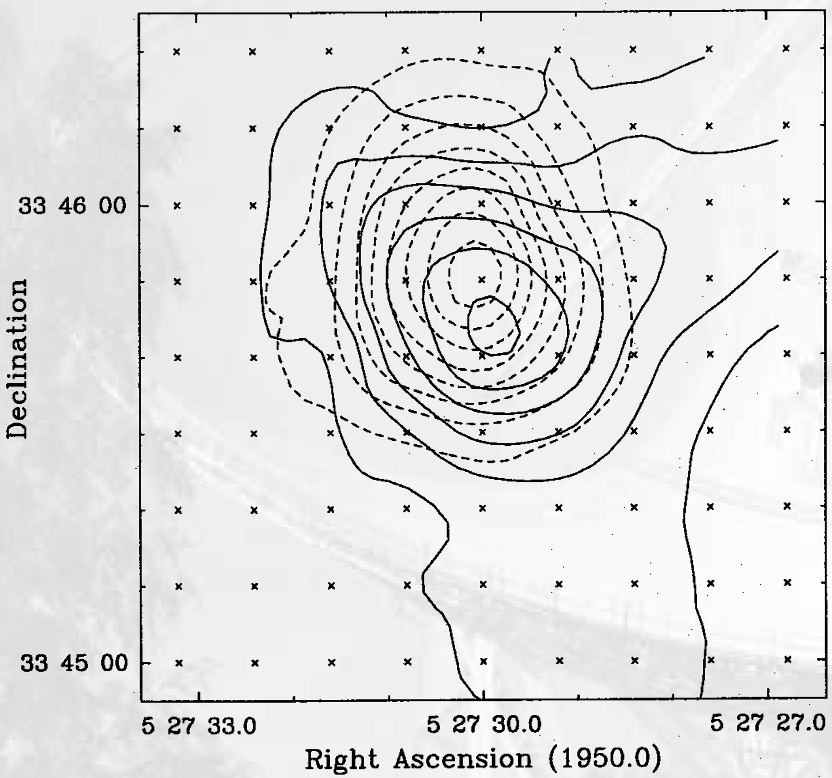
Outflow vel.: 14 km/s



J-shock:
new ejection

Episodic ejection: AFGL 5142

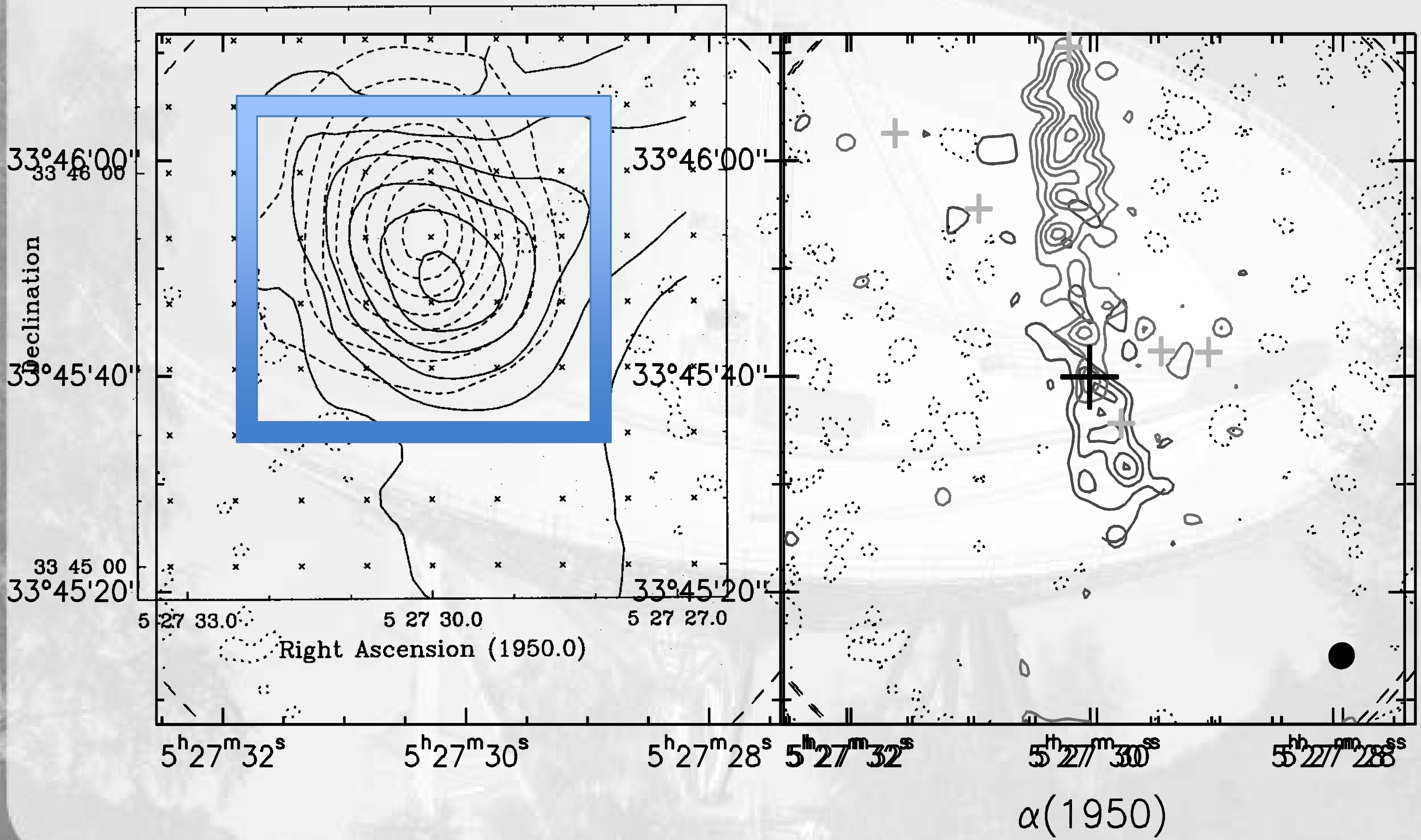
Hunter et al., 1995, A&A, 302, 249



Episodic ejection: AFGL 5142

Hunter et al., 1995, A&A, 302, 249

Hunter et al., 1999, AJ, 118, 477



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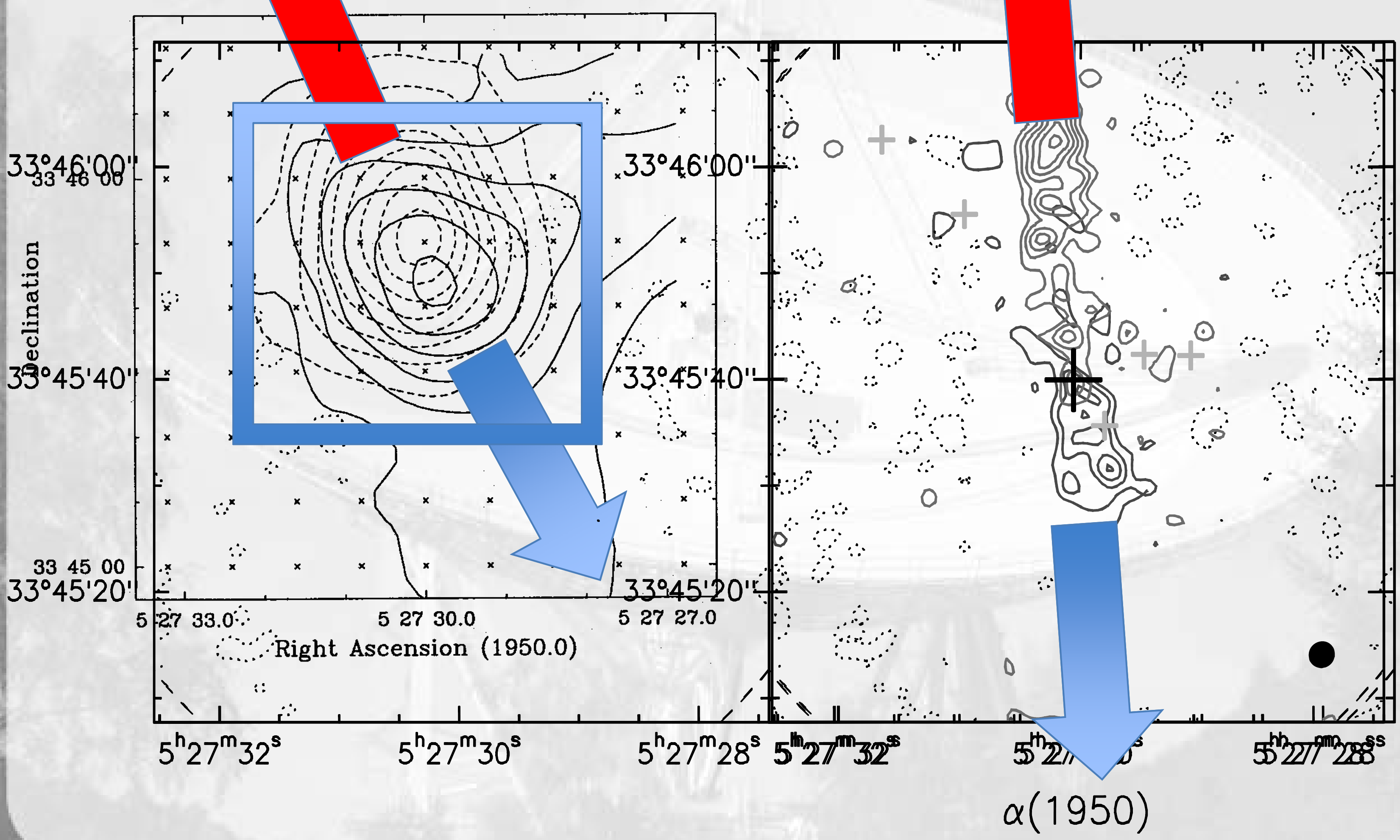
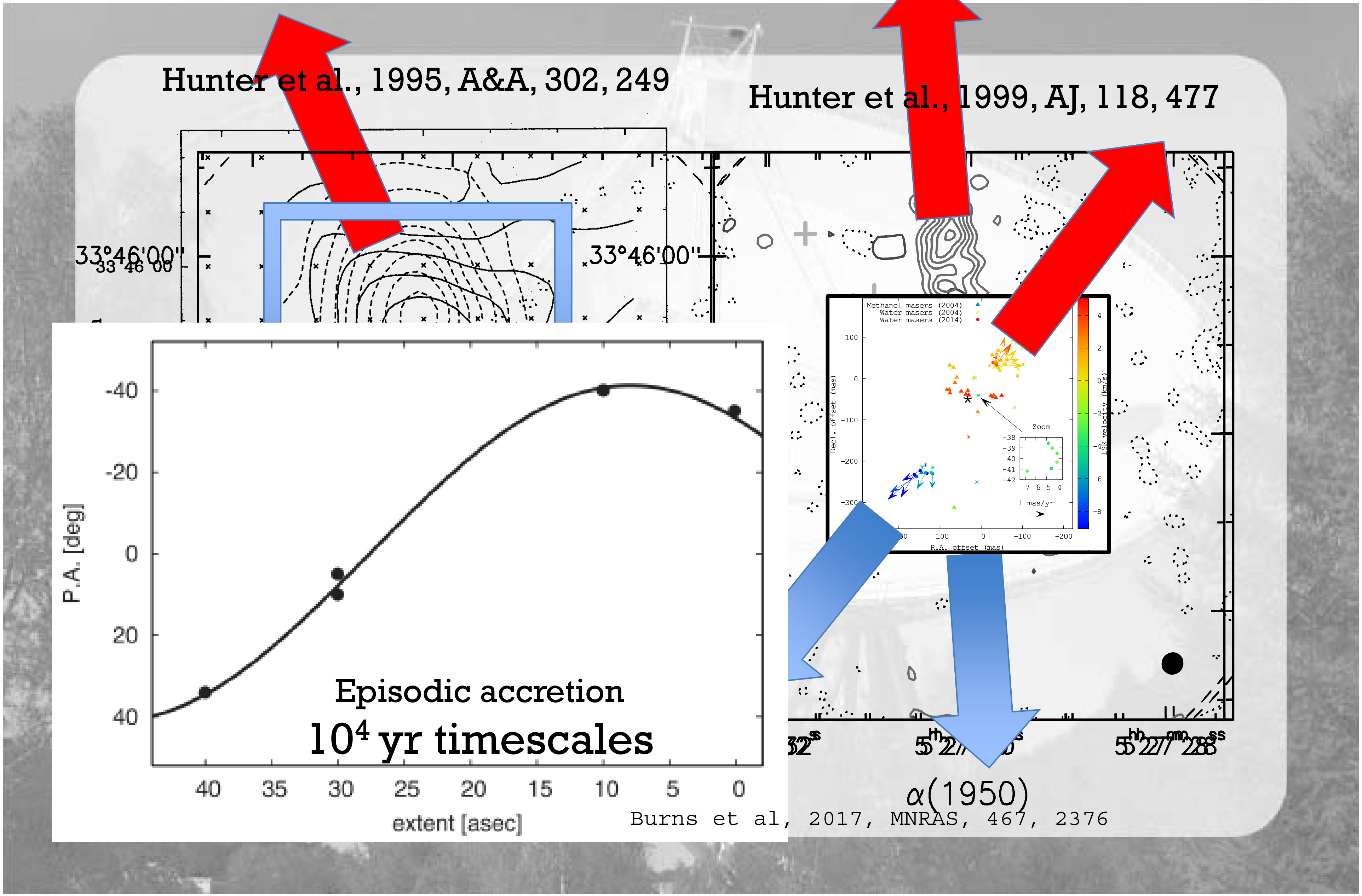
Episodic ejection: AFGL 5142

Hunter et al., 1995, A&A, 302, 249

Hunter et al., 1999, AJ, 118, 477



Episodic ejection: AFGL 5142



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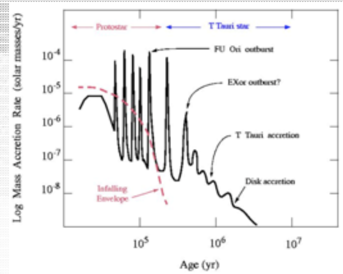
Conclusions

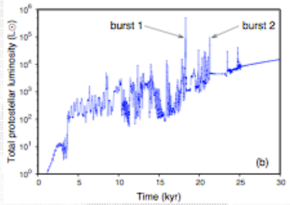
- Episodic accretion established for low mass YSOs

Solves luminosity problem

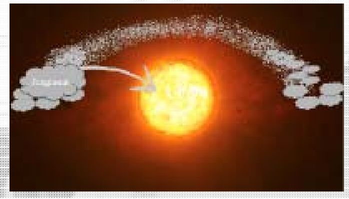


In Massive stars:

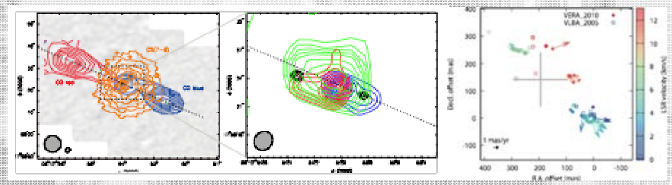
- Simulations predict episodic accretion on <10^4 yr timescales



- **Radiation pressure** problem solved by Bloating (<10^4 yr)



- VERA reveals episodic ejection in two **MYSOs**, S255IR and AFGL5142, <10^4 yr timescales



?“MUors”?

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Thanks for your attention

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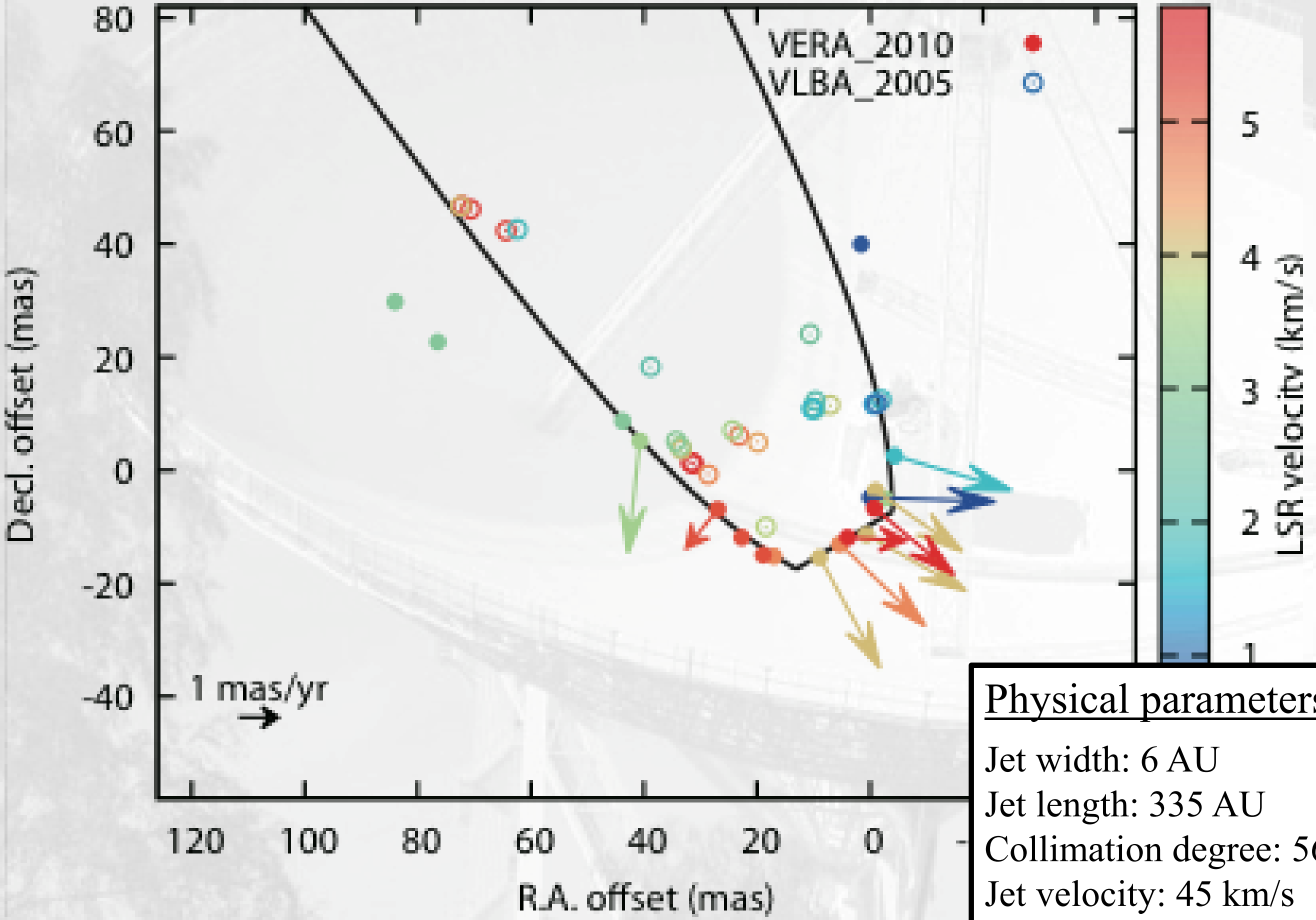
Results: S255IR



Burns et al., 2016, MNRAS, 460, 283

<u>Physical parameters of the bow-shock:</u>

Jet width: 6 AU
Jet length: 335 AU
Collimation degree: 56
Jet velocity: 45 km/s
Bow shock (maser) velocity: 25 km/s
Sound speed: 8 km/s
Jet age < 130 yrs

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S255IR, on my birthday!

NATURE PHYSICS | LETTER

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

A. Caratti o Garatti, B. Stecklum, R. Garcia Lopez, J. Eislöffel, T. P. Ray, A. Sanna, R. Cesaroni, C. M. Walmsley, R. D. Oudmaijer, W. J. de Wit, L. Moscadelli, J. Greiner, A. Krabbe, C. Fischer, R. Klein & J. M. Ibañez

Affiliations | Contributions | Corresponding author

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