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THE EFFECT OF EPISODIC RADIATIVE FEEDBACK ON THE PROPERTIES OF YOUNG DISCS

FROM HYDRODYNAMIC SIMULATIONS TO OBSERVATIONS

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AND THE TRANSIENT TEAM (G.HERCZEG, D. JOHNSTONE, G.BAEK, J-E LEE, ...)

The structure of young embedded protostellar discs

MNRAS, 2017

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Observational signatures of outbursting protostars - I: From hydrodynamic simulations to observations

MNRAS, 2019

Benjamin MacFarlane,[1] Dimitris Stamatellos,[1★] Doug Johnstone,[2,3] Gregory Herczeg,[4] Giseon Baek,[5] Huei-Ru Vivien Chen,[6] Sung-Ju Kang[7] and Jeong-Eun Lee[5]

Observational signatures of outbursting protostars – II. Exploring a wide range of eruptive protostars

MNRAS, 2019

Benjamin MacFarlane,[1] Dimitris Stamatellos,[1★] Doug Johnstone,[2,3] Gregory Herczeg,[4] Giseon Baek,[5] Huei-Ru Vivien Chen,[6] Sung-Ju Kang[7] and Jeong-Eun Lee[5]

Radiative Transfer Modeling of EC 53: An Episodically Accreting Class I Young Stellar Object

APJ, 2020

Giseon Baek[1], Benjamin A. MacFarlane[2], Jeong-Eun Lee[1], Dimitris Stamatellos[2], Gregory Herczeg[3], Doug Johnstone[4,5], Carlos Contreras Peña[6], Watson Varricatt[7], Klaus W. Hodapp[7], Huei-Ru Vivien Chen[8], and Sung-Ju Kang[9]

MAIN QUESTIONS

(I) WHAT ARE THE OBSERVATIONAL PROPERTIES OF YSOS AND THEIR DISCS?

(II) HOW ARE THEY AFFECTED BY INFALL AND STELLAR FEEDBACK?

Stamatellos et al. 2011, 2012

RADIATIVE HYDRODYNAMIC SIMULATIONS

- **Radiative hydrodynamic simulations of a collapsing 5.4 $M_\odot$ molecular cloud**

- Stars (once they form) they are represented by "sink" particles that do not interact via pressure forces with the gas

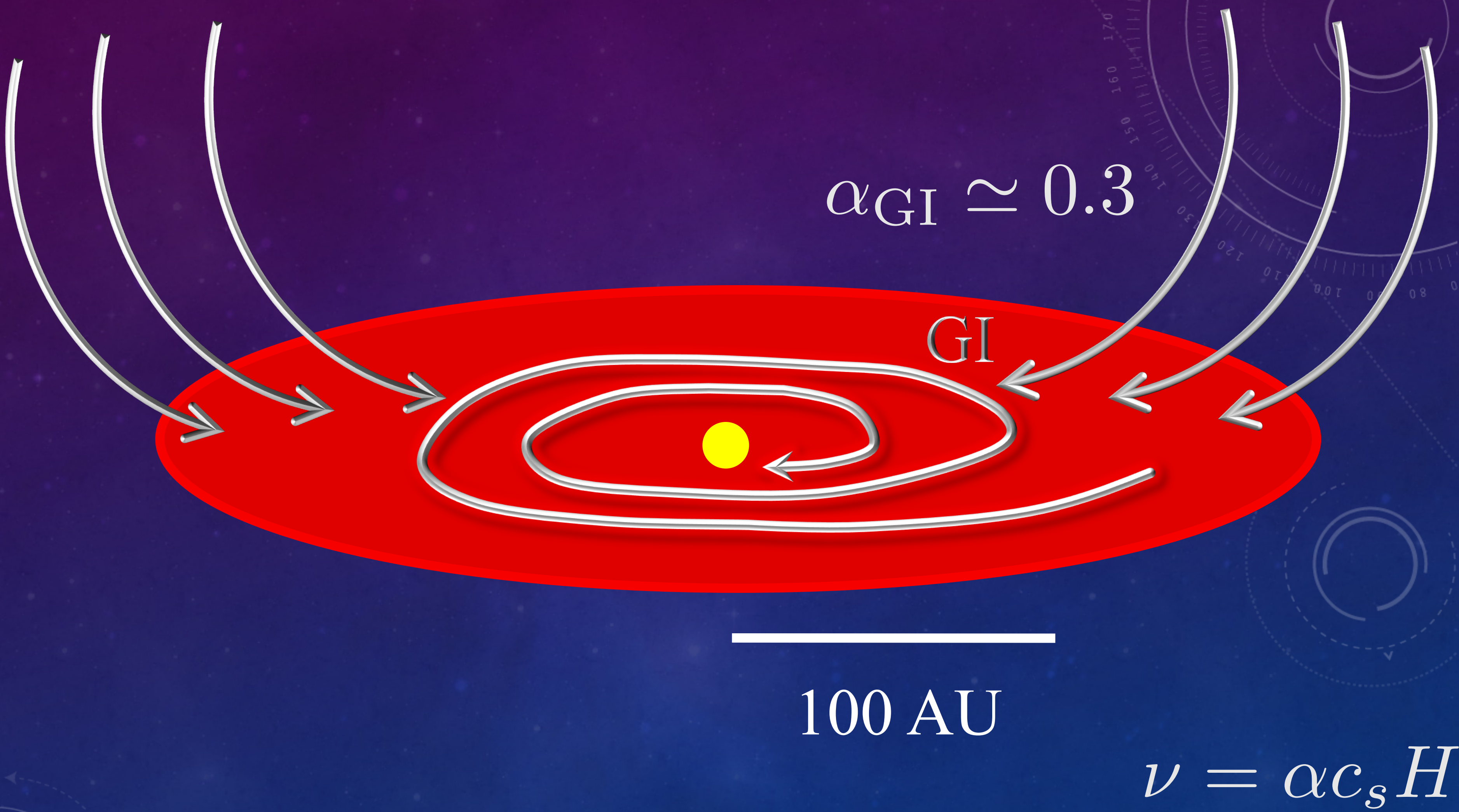
•**1st simulation:** no feedback from the forming stars

•**2nd simulation:** with continuous feedback

•**3rd simulation:** with episodic feedback (a combination of gravitational instability driving gas from the outer disc region to the inner disc region, and MRI driving accretion from the inner disc onto the star; e.g. Zhu et al. 2009+)

- The effect of magnetic fields is not included (directly)

EPISODIC ACCRETION: GI VS MRI

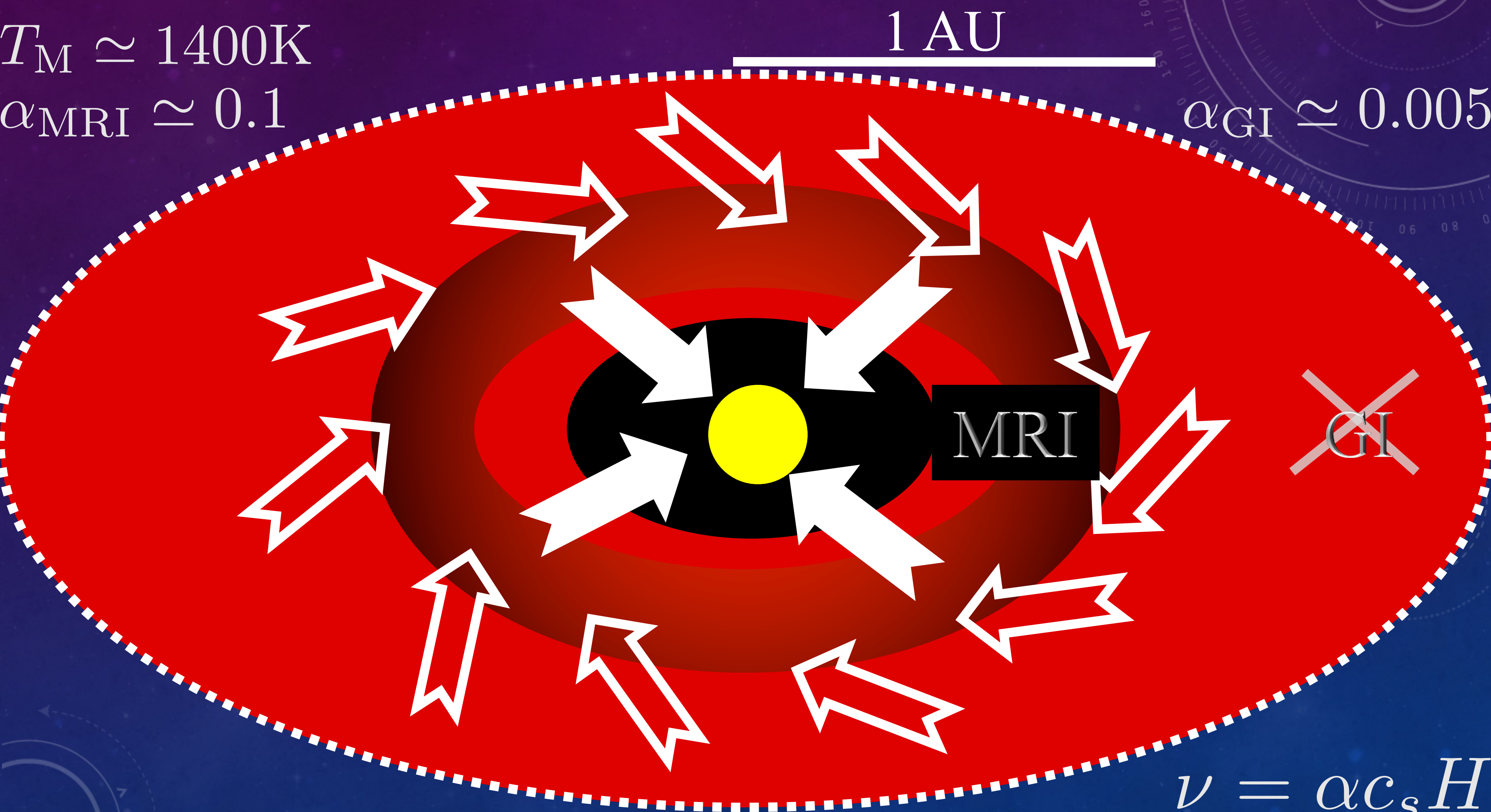


EPISODIC ACCRETION: GI VS MRI

$T_{\mathrm{M}} \simeq 1400\mathrm{K}$

$\alpha_{\mathrm{MRI}} \simeq 0.1$

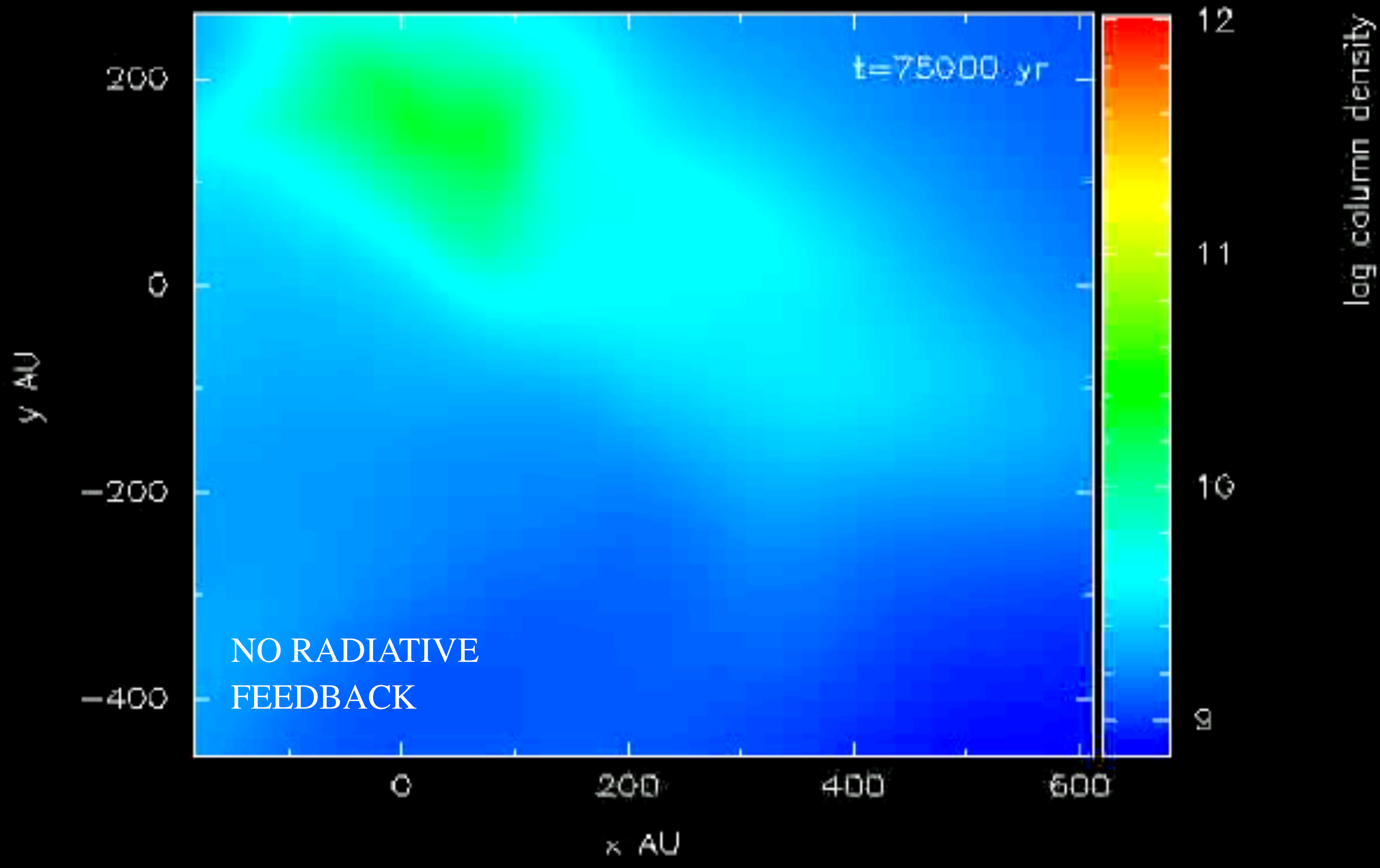
$\alpha_{\mathrm{GI}} \simeq 0.005$



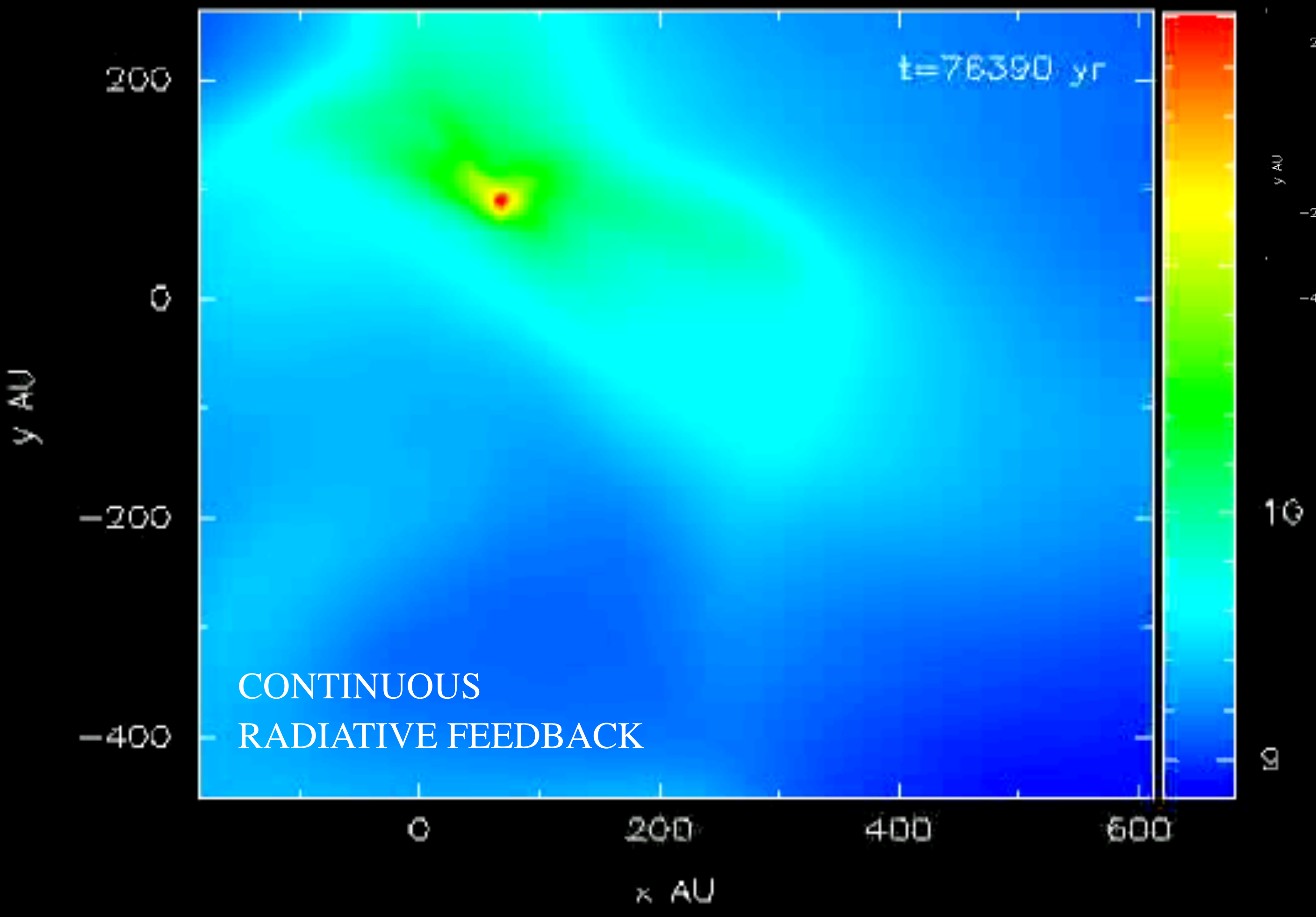
$\nu = \alpha c_s H$

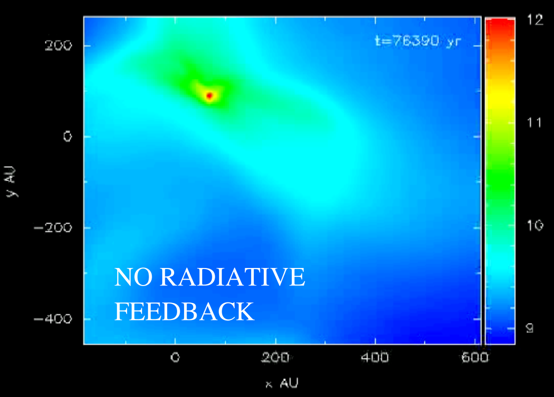
Zhou et al. 2009

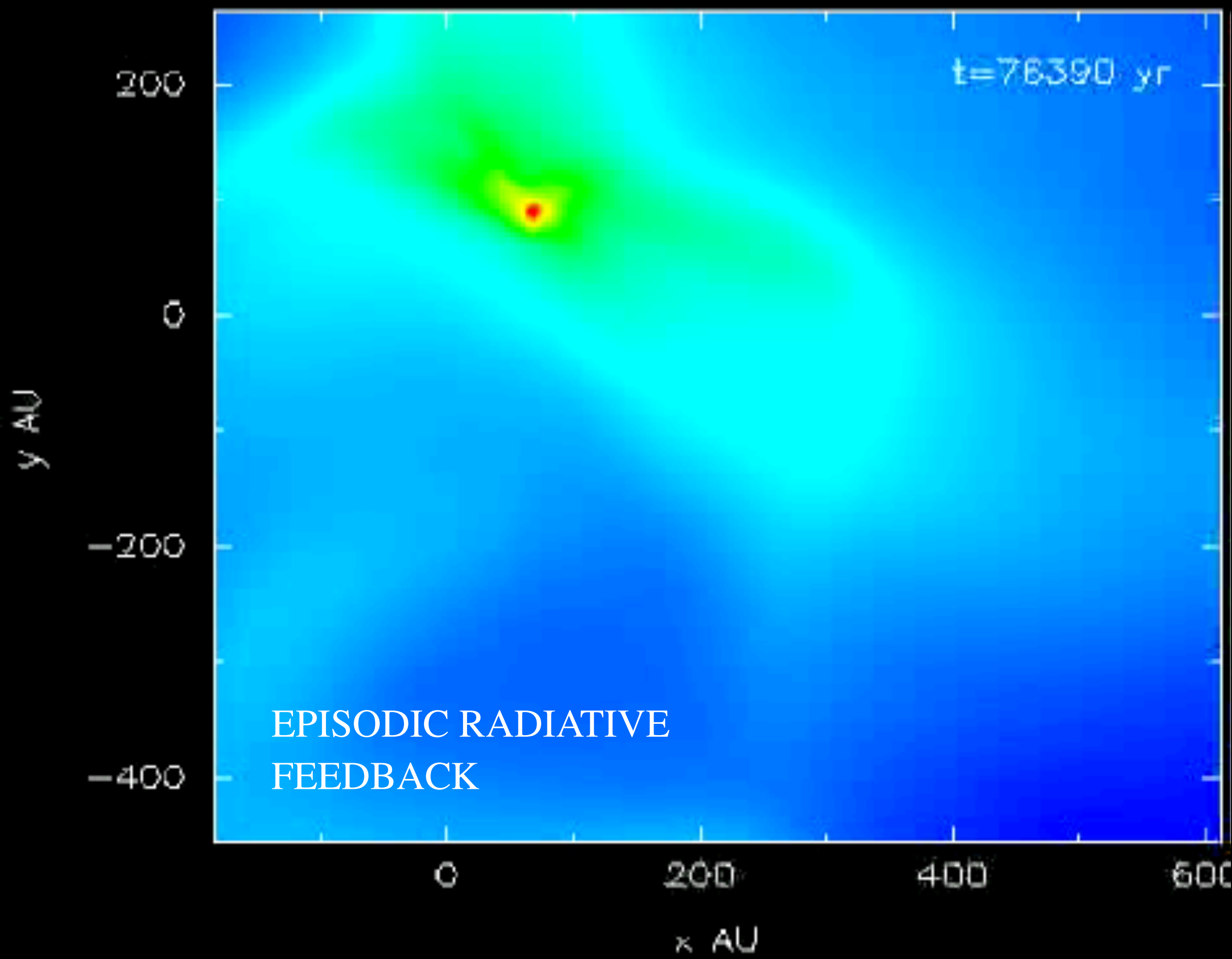
Stamatellos et al. 2011, 2012



Stamatellos et al. 2011, 2012



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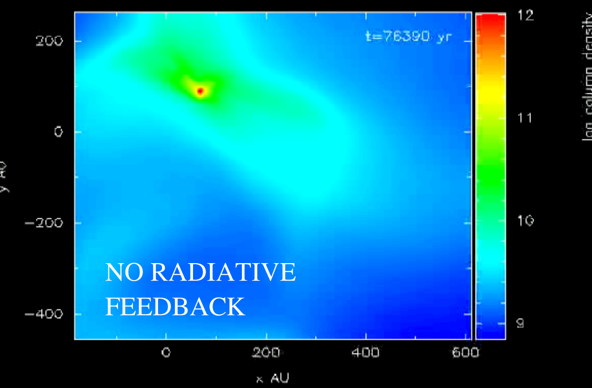
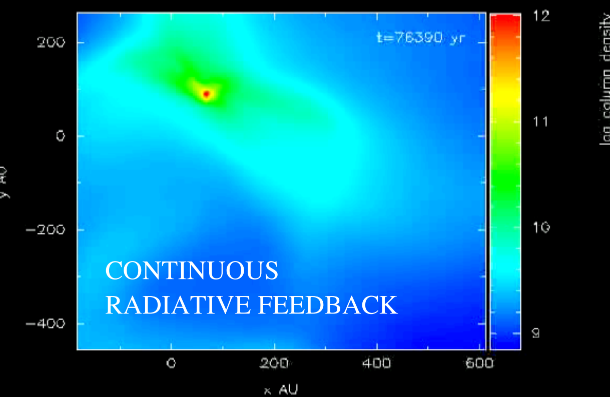
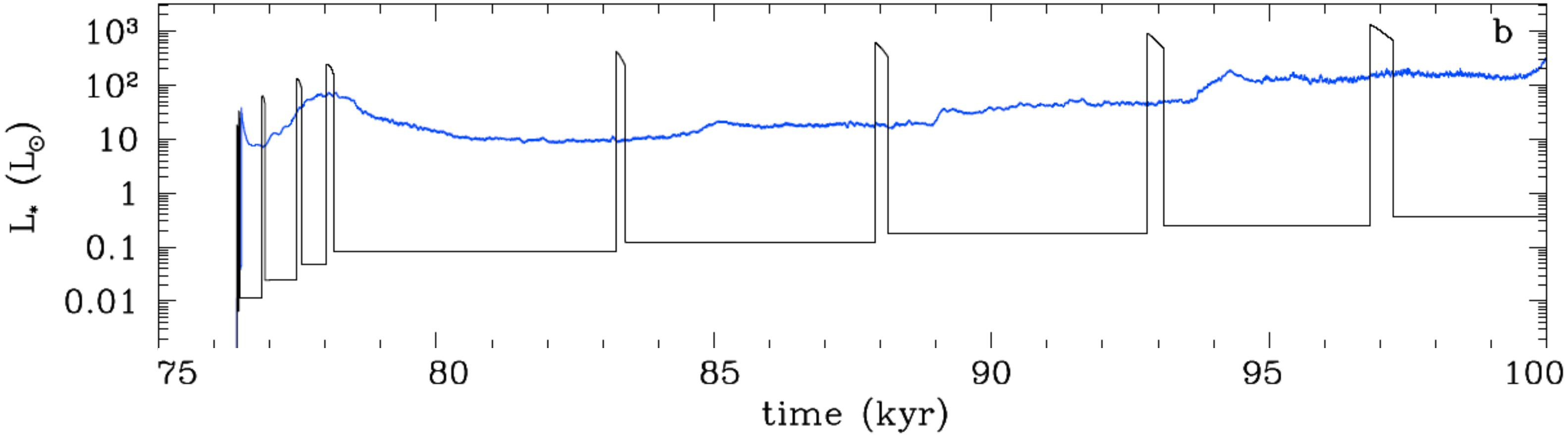
200
0
−200
−400
y AU
0
200
400
x AU
EPISODIC RADIATIVE
FEEDBACK


t=76390 yr
200
0
−200
−400
y AU
0
200
400
600
x AU
12
11
10
9
log column density
NO RADIATIVE
FEEDBACK


t=76390 yr
200
0
−200
−400
y AU
0
200
400
600
x AU
12
11
10
9
log column density
CONTINUOUS
RADIATIVE FEEDBACK

- The importance of radiative feedback depends on
  - duration of outburst (Δt_{MRI})
  - how often an outburst happens (T_{EA})

$t_{dyn} \sim 10^3$yr



Duration of episodic accretion event

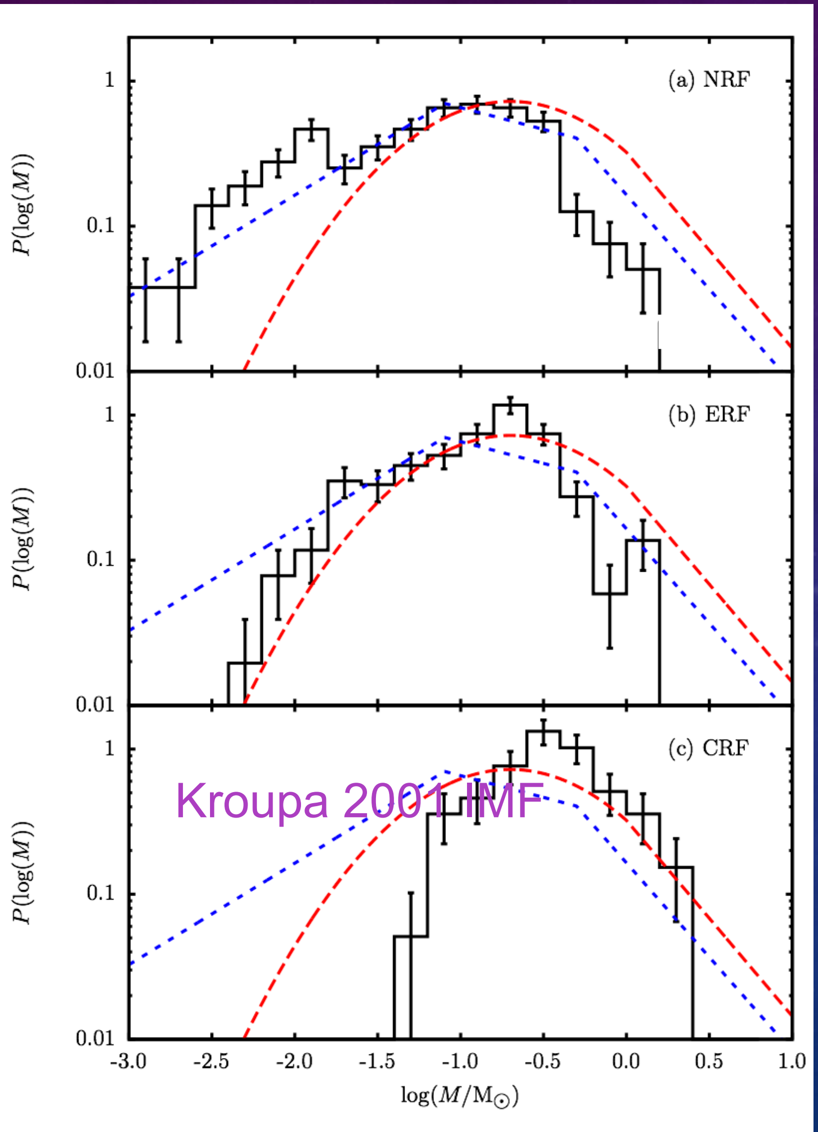
$$\Delta t_{\rm MRI} \simeq 0.25\,{\rm kyr}\,\left(\frac{\alpha_{\rm MRI}}{0.1}\right)^{-1}\left(\frac{M_{\rm MRI}}{0.13\,{\rm M}_\odot}\right)$$

Zhou et al. 2009

Time interval between successive episodic accretion events

$$T_{\rm EA} \simeq 13\,{\rm kyr}\,\left(\frac{M_\star}{0.2\,{\rm M}_\odot}\right)^{2/3}\left(\frac{\dot{M}_{\rm IAD}}{10^{-5}\,{\rm M}_\odot\,{\rm yr}^{-1}}\right)^{-8/9}$$

SIMULATING STAR FORMATION IN OPHIUCHUS
SIMULATED INITIAL MASS FUNCTION



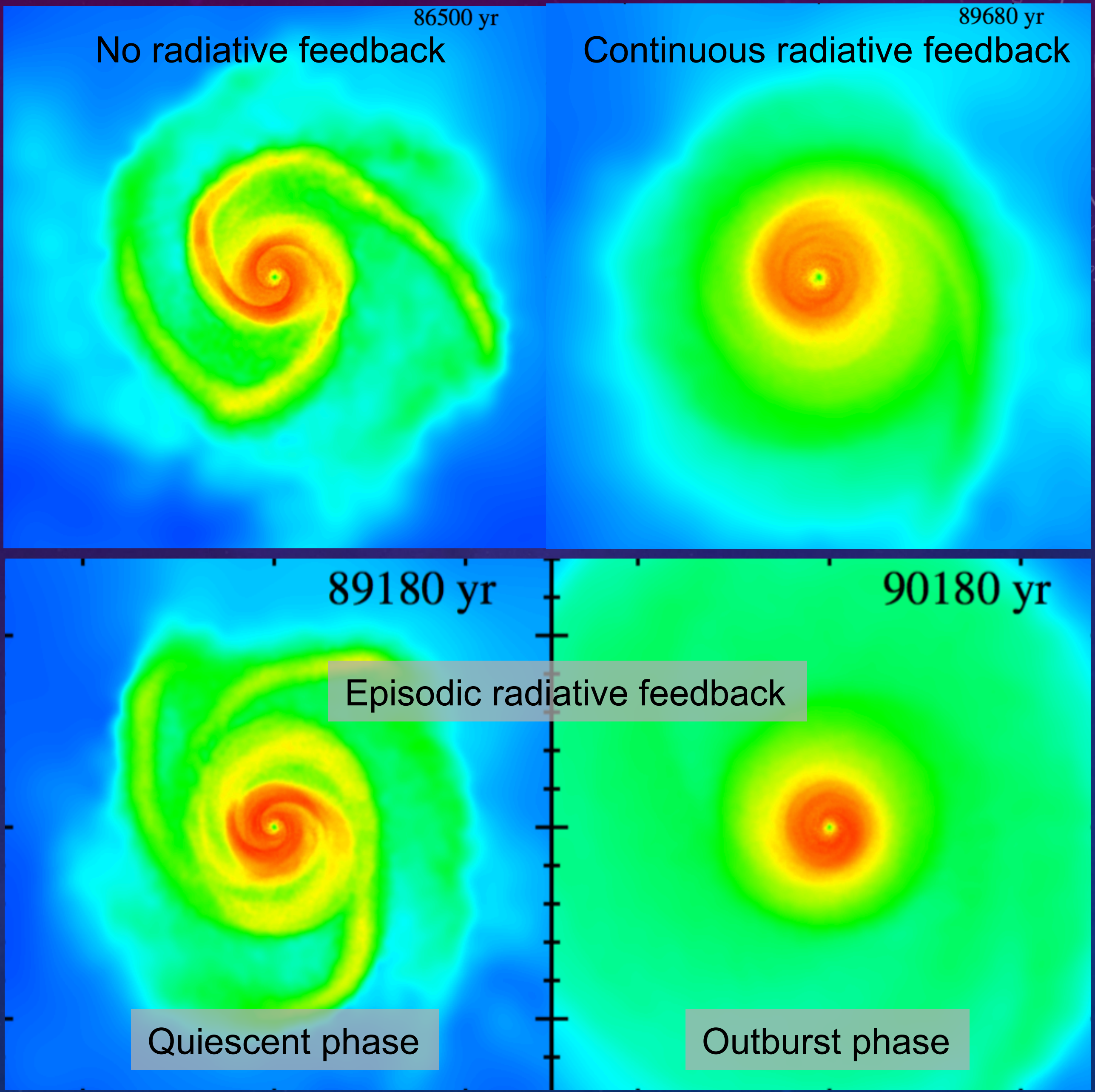
No radiative feedback

Episodic radiative feedback

Continuous radiative feedback

Lomax et al. 2014,2015; MNRAS

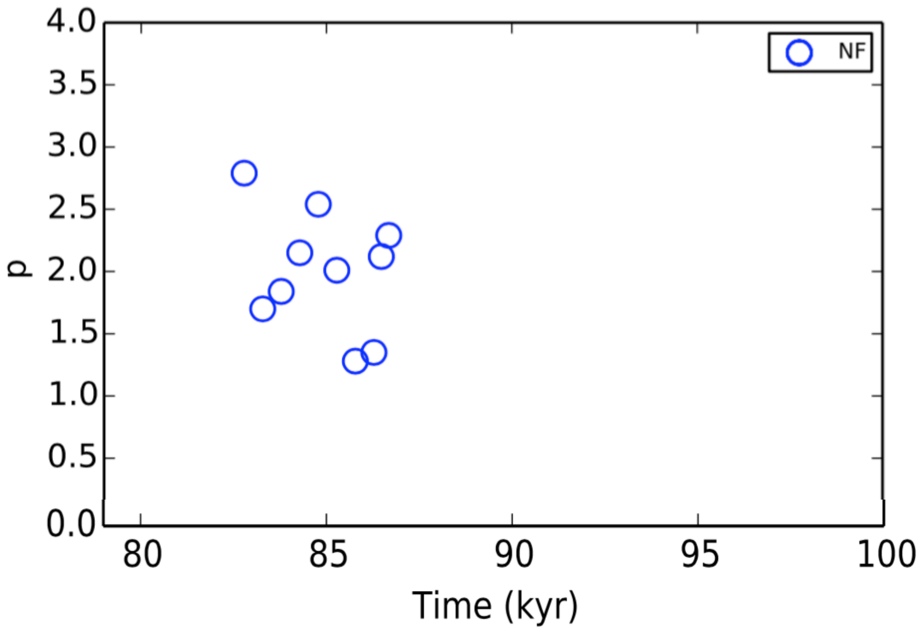
DIFFERENCES IN DISC MORPHOLOGIES/SPIRAL ARMS

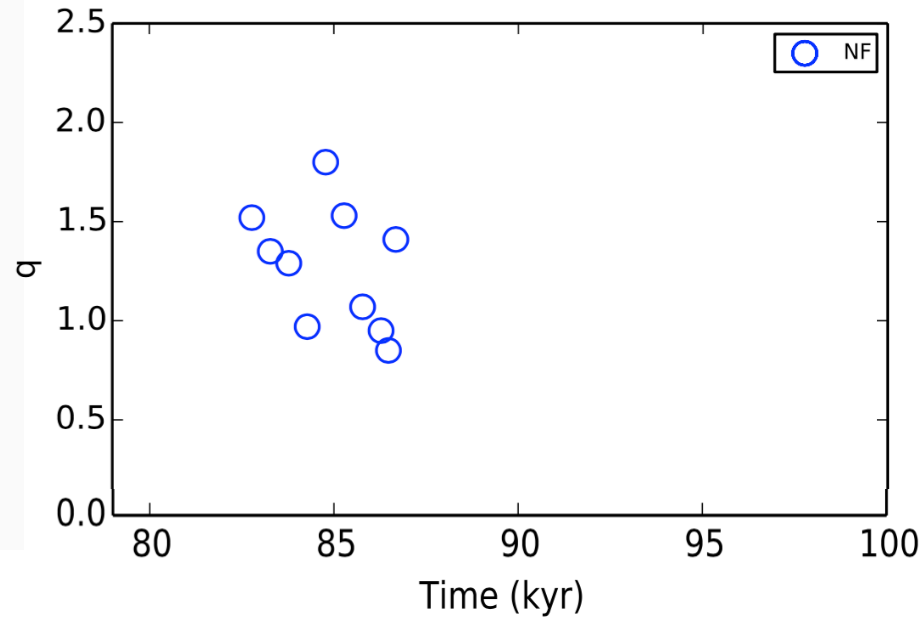


DENSITY AND TEMPERATURE PROFILES

p index (density) **$\Sigma \sim r^{-p}$**

q index (temperature) **$T \sim r^{-q}$**





No radiative feedback

Continuous radiative feedback

Episodic radiative feedback

DENSITY AND TEMPERATURE PROFILES

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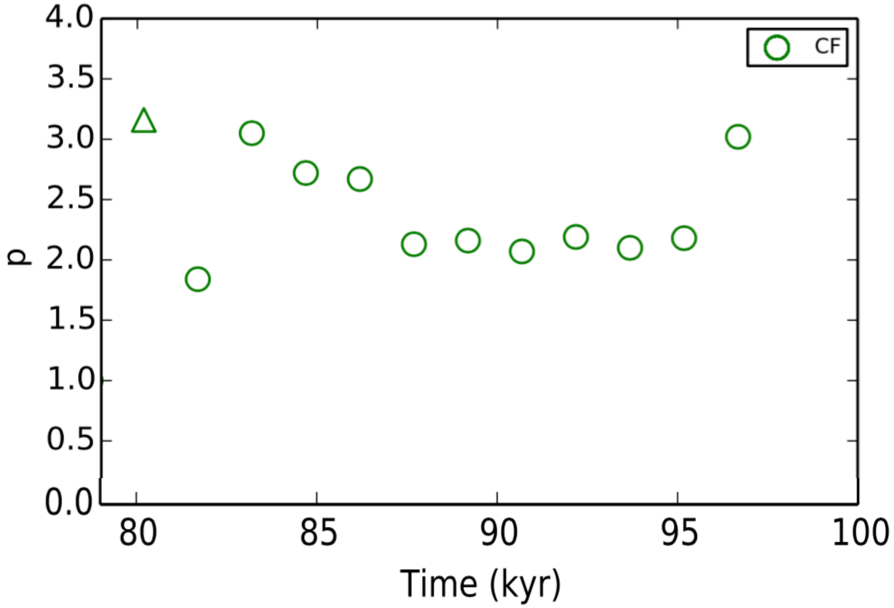
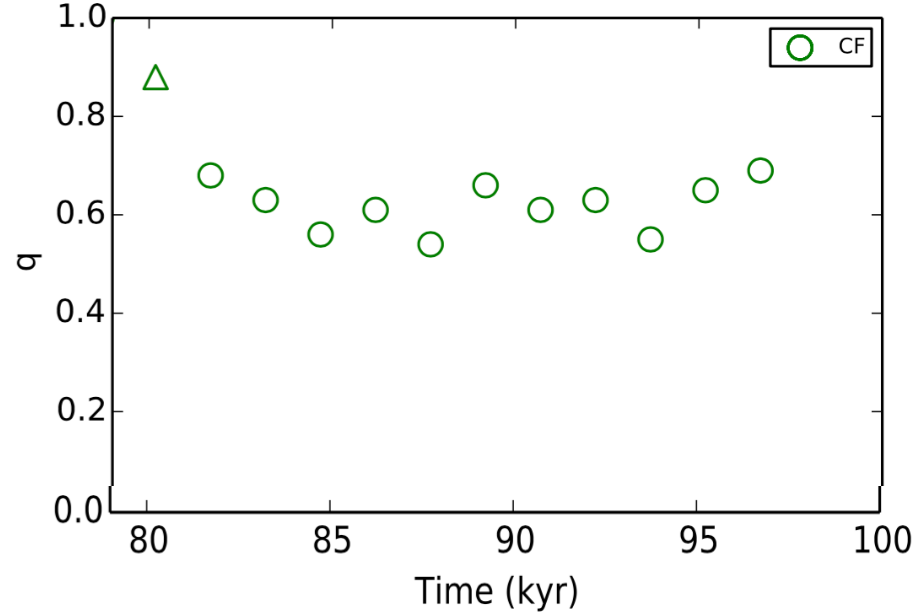


q index (temperature) **$T \sim r^{-q}$**



No radiative feedback

Continuous radiative feedback

Episodic radiative feedback

DENSITY AND TEMPERATURE PROFILES

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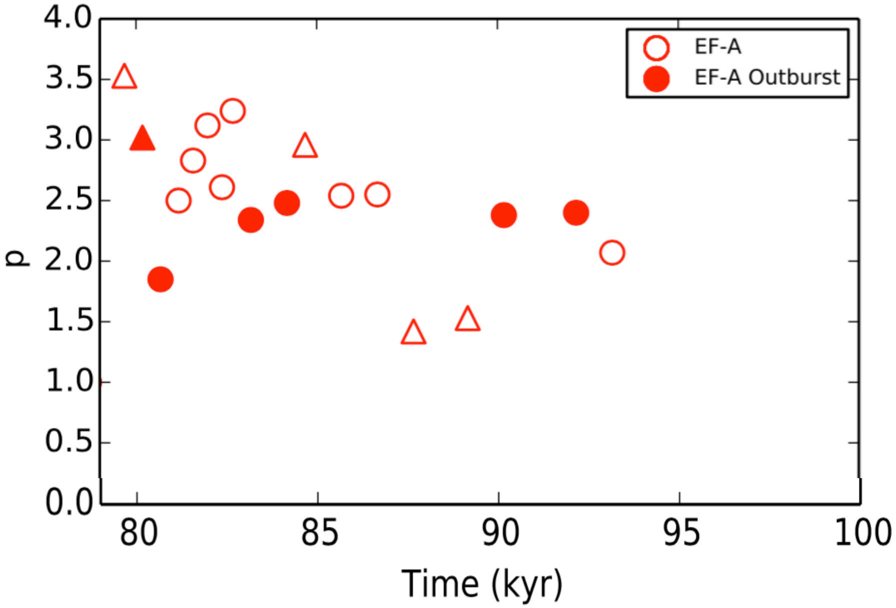
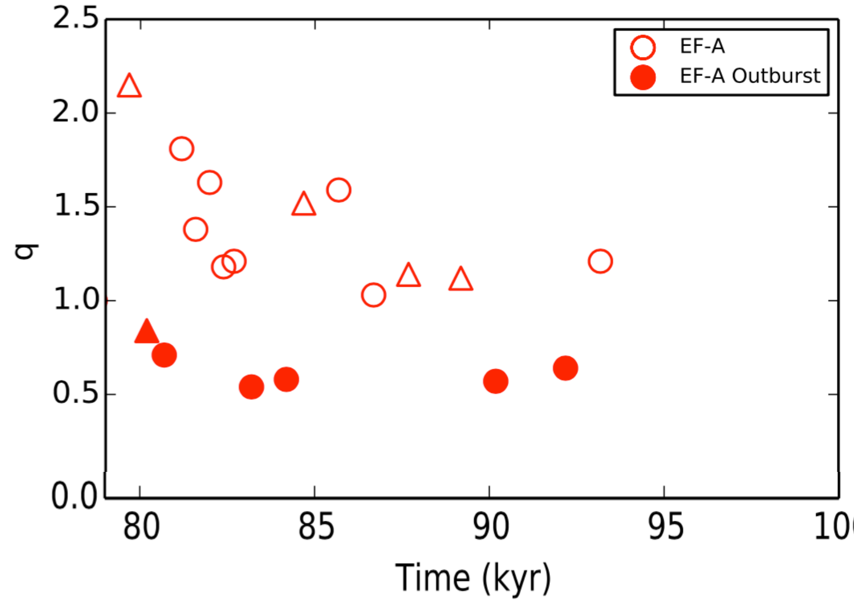




No radiative feedback

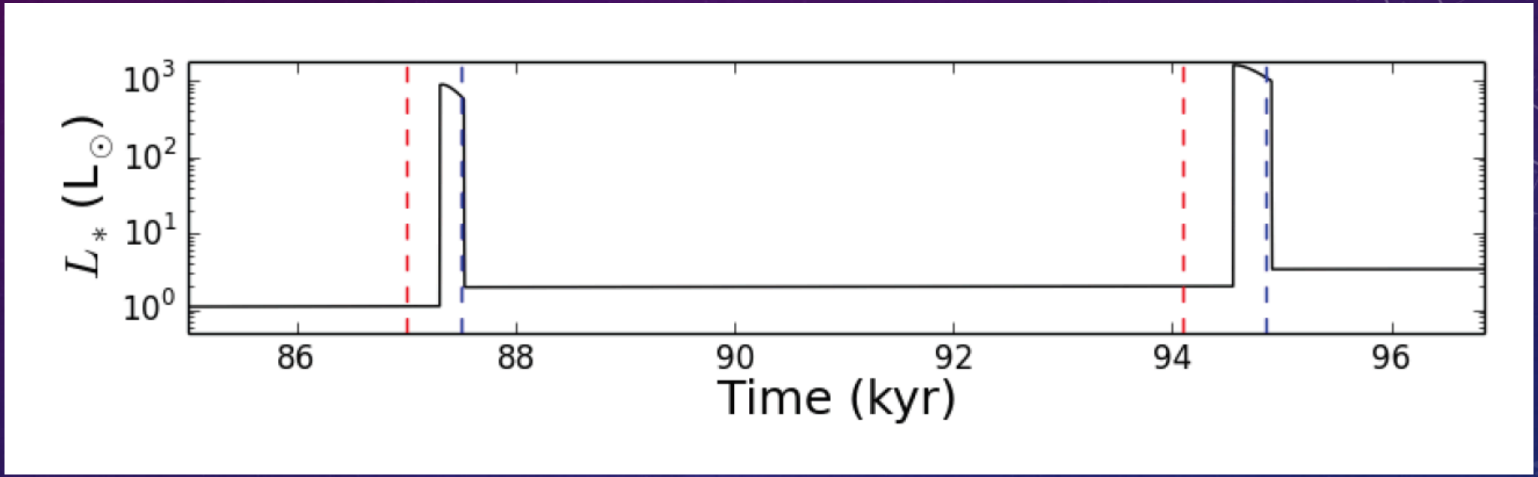
Continuous radiative feedback

Episodic radiative feedback

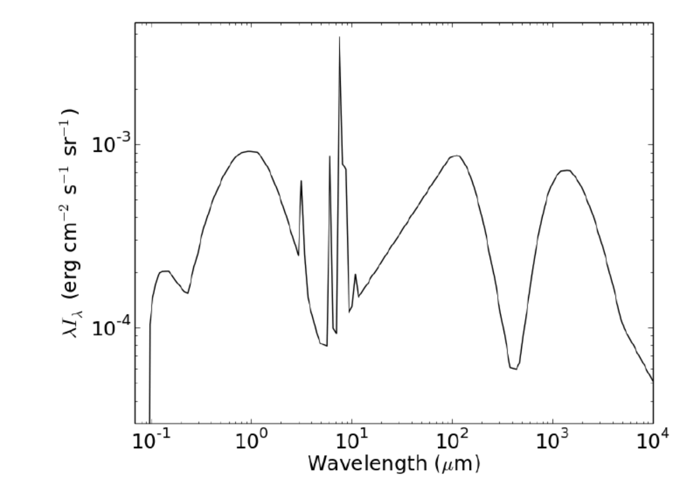
- Variable infall from the envelope modify the disc temperature and density profile
- The type of radiative feedback affects the disc morphology

RADIATIVE TRANSFER MODELLING OF SIMULATION SNAPSHOTS USING RADMC3D

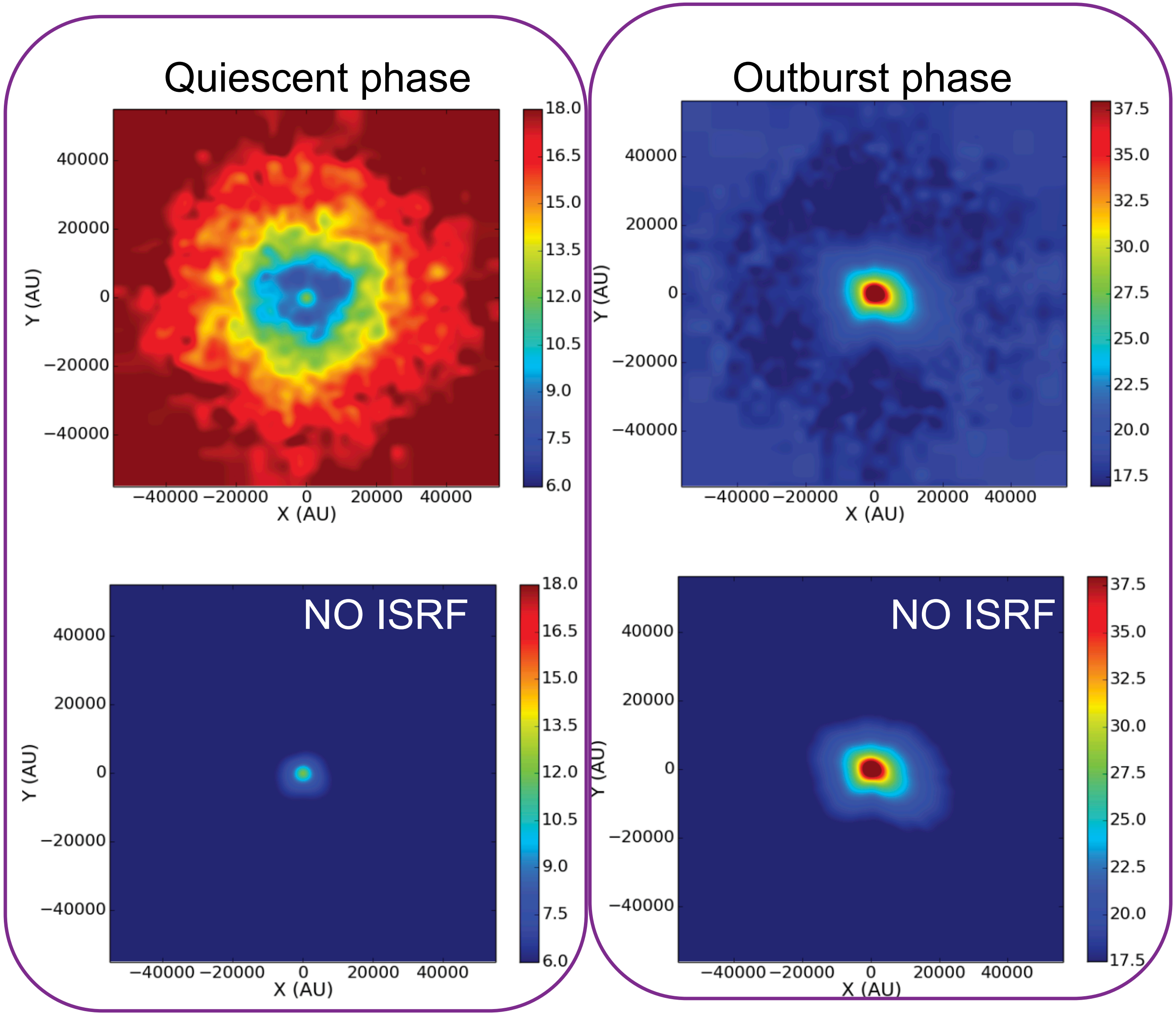
- Heating from the young protostar MacFarlane, Stamatellos et al. , 2019, a,b



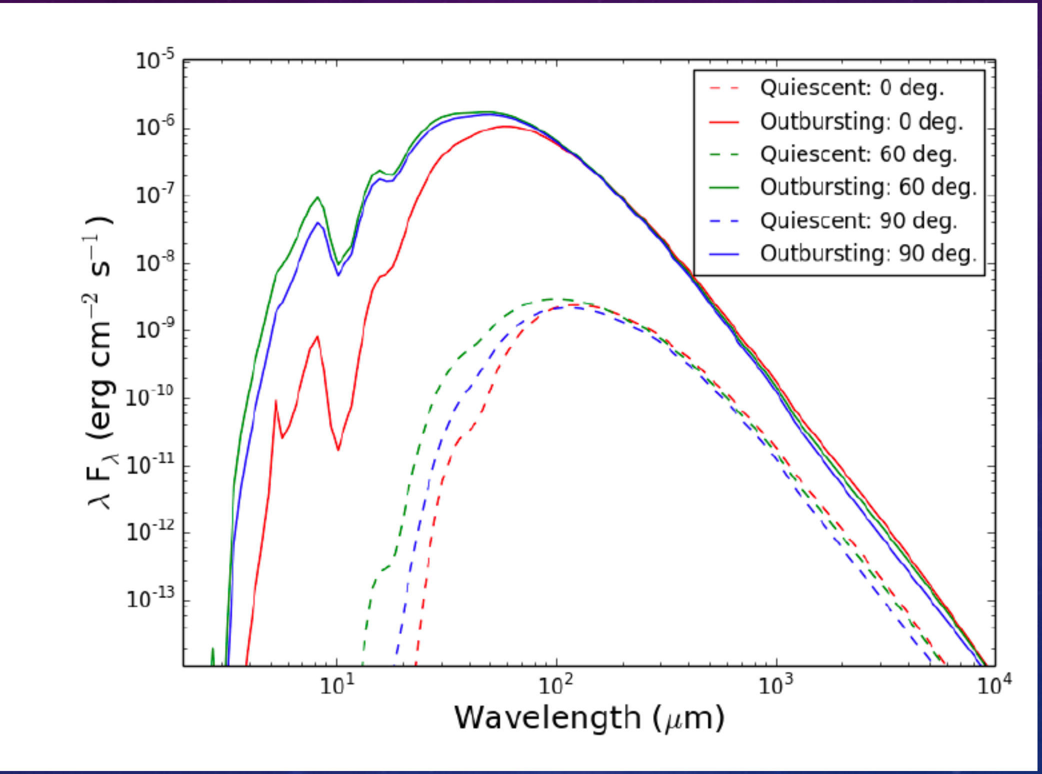
- Heating from the interstellar radiation field



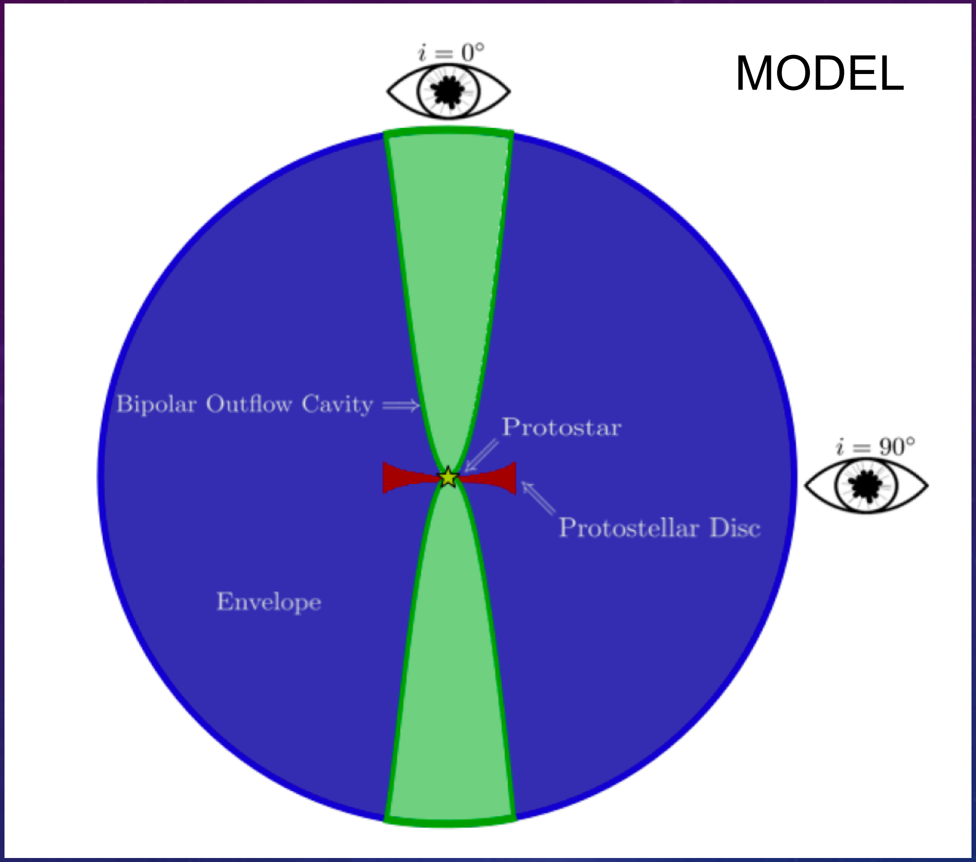
RADIATIVE TRANSFER MODELLING: TEMPERATURE PROFILES



RADIATIVE TRANSFER MODELLING: SEDS

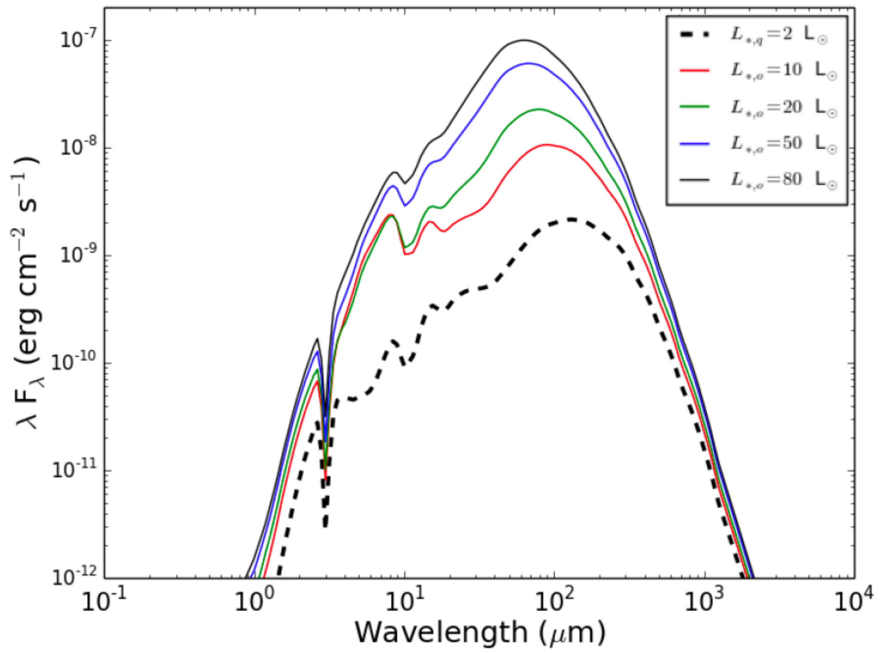


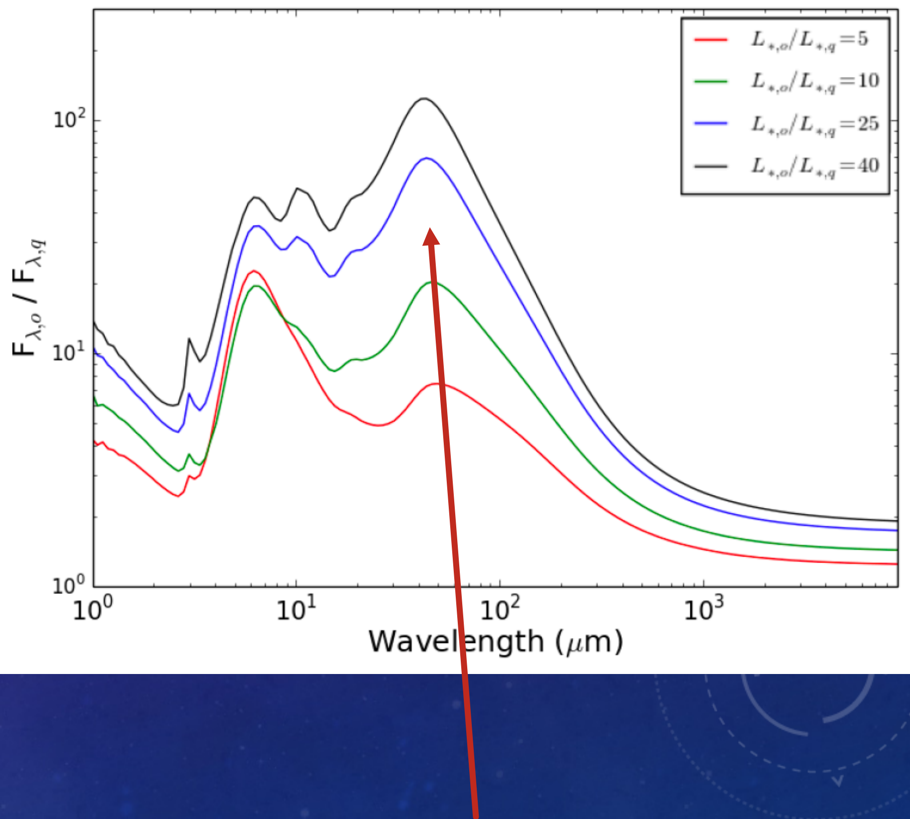
RADIATIVE TRANSFER MODELLING: EXPLORING THE PARAMETER SPACE



$M_d/M_\odot$	M_d/M_d^s	$M_e/M_\odot$	M_e/M_e^s	L_*
0.3	1	4	1	2, 10, 20, 50, 80
0.03	0.1	4	1	2, 10, 20, 50, 80
0.6	2	4	1	2, 10, 20, 50, 80
0.3	1	0.4	0.1	2, 10, 20, 50, 80
0.3	1	8	2	2, 10, 20, 50, 80

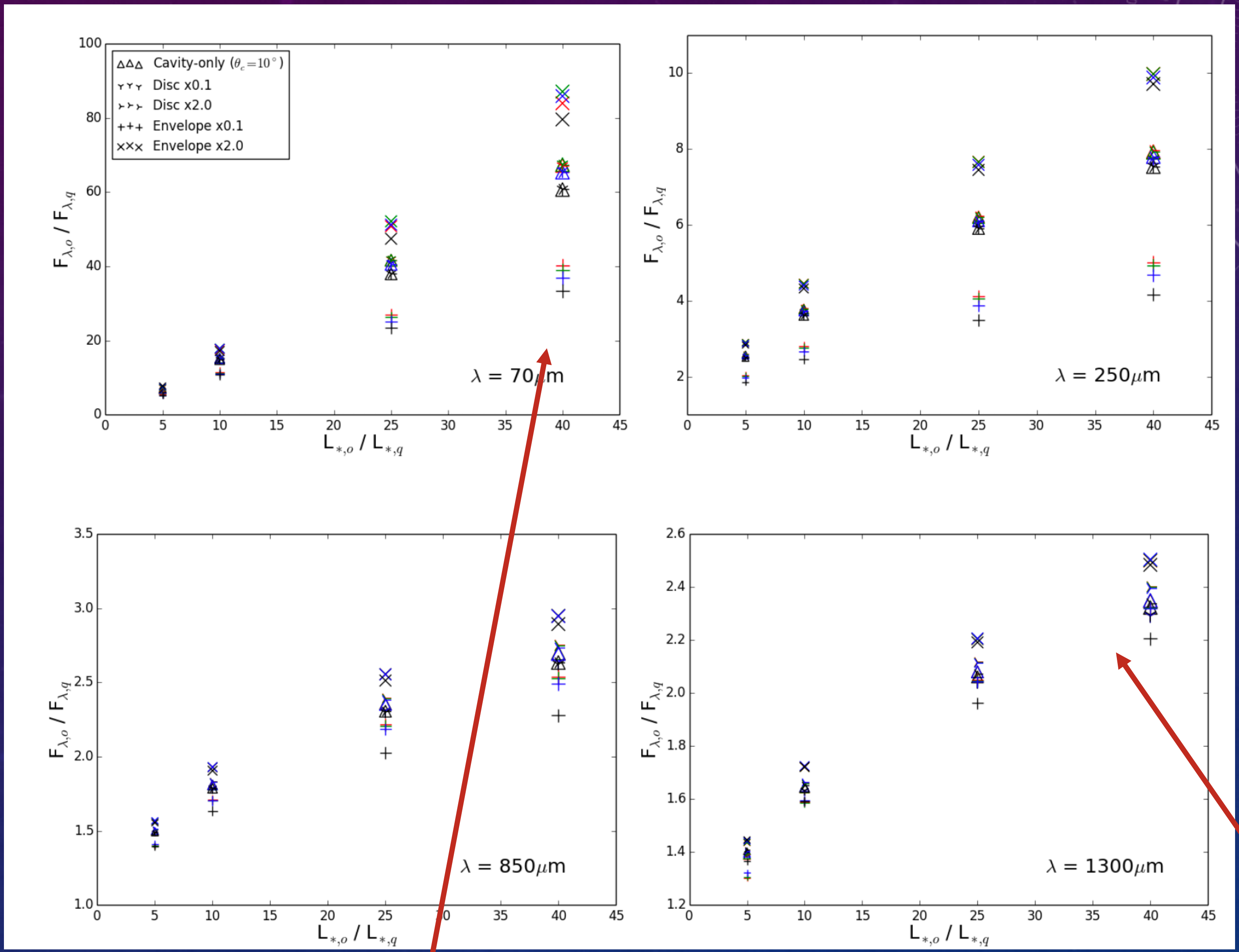
RADIATIVE TRANSFER MODELLING: SEDS





Maximum effect of outburst

RADIATIVE TRANSFER MODELLING: INCREASE IN FLUX VS WAVELENGTH



Increase dependence on the specific properties of YSO

Small dependence on the specific properties of YSO

CONCLUSIONS

- Combination of radiative transfer simulations with hydrodynamic simulations provide a powerful tool for interpreting observations
- We examined outbursts with increase in luminosity by a factor of up to 40
- Outbursts are easier seen in far IR wavelengths (an increase in flux by a factor of 10 to 90 at 70m) but the exact value of the flux increase depends strongly on the morphology of the YSO (cavity, disc, ...)
- Long wavelength emission shows only a small flux ratio increase during an outburst (an increase by a factor of 1.3 to 2.6 at 1.3mm) but it does not depend strongly on the morphology of the YSO