Transition Region Cool Loops: the case of optically thick radiative losses

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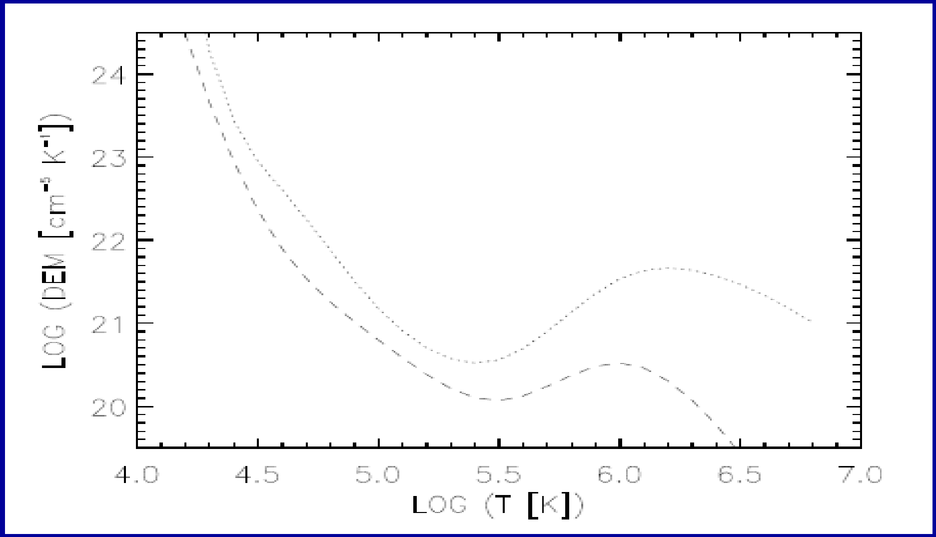
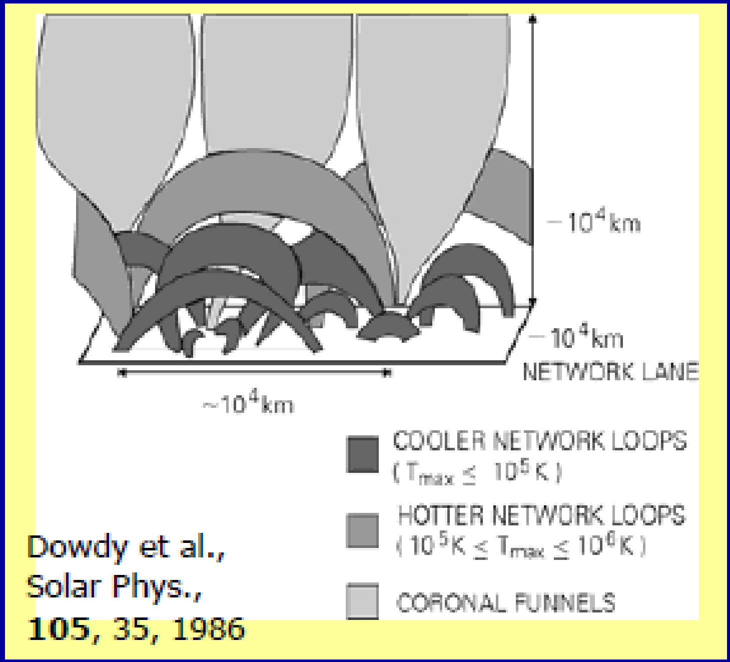
Introduction: Theory

- 80's: TR emission originates from the bases of coronal loops (L ~ 10 Mm, T ~ MK) but DEM predicted << observed (for T < 10^5 K)





- Dowdy et al. (1986): lower TR emission originates from small cool loops (h ≤ 8 Mm, T ≤ 10^5 K), insulated from the corona.
- Antiochos & Noci (1986): a mixture of quasi-static cool loops with different temperatures can account for the missing lower TR DEM.

Introduction: Theory

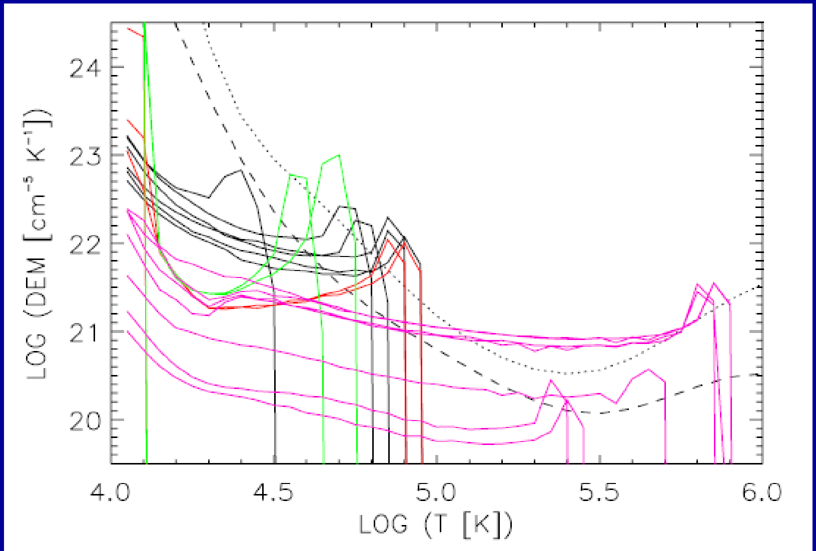
The general properties of static cool loops were first discussed by Hood & Priest (1979) and then by Antiochos & Noci (1986)

Properties:
– low-lying (h = 1.1–5 Mm), nearly isobaric, $T_{max} < 10^5$ K, energy balance: heating rate ≈ radiative losses

Cally & Robb (1991) treated the stability, structure and evolution of static cool loops both analytically and numerically

Conclusions:
– The shape of $\Lambda(T)$ poses restrictive conditions on their existence: if $\Lambda(T) \sim T^a$ then $a > 2$ (E_h = const), in the presence of the H Ly-α losses peak around $T = 2 \times 10^4$ K, strictly static cool loops do not exist, static cool loops exist assuming a T^3 dependence of $\Lambda(T)$ below $T = 10^5$ K

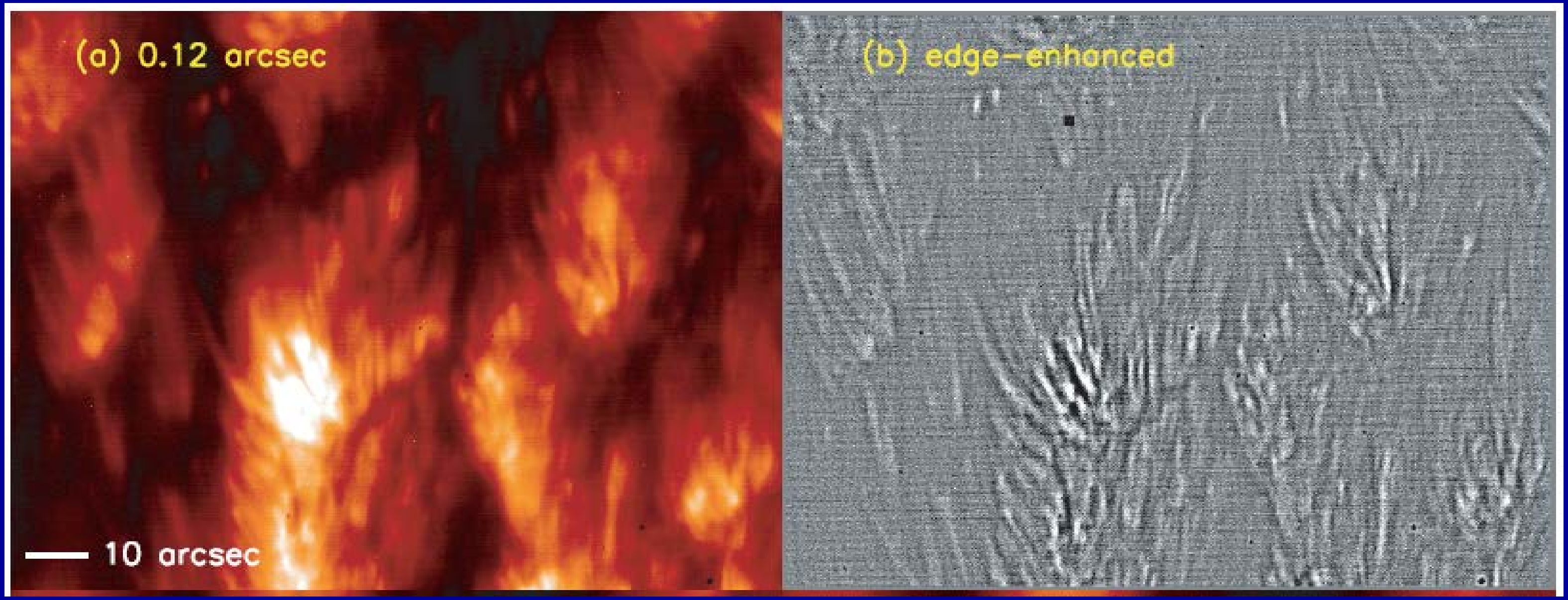
We obtained through hydrodynamic simulations stable, quasi-static low-lying cool loops, under different and more realistic assumptions on the optically thin radiative loss function with respect to previous works. We thus showed that their emission, plus the emission of intermediate temperature loops (0.1 < T < 1 MK), can account for the observed radiative output below 1 MK. (Sasso et al., 2012)



Observations

VAULT (2007): First observations of subarcsecond-scale Ly-α looplike structures

$T=10^4$-$3x10^4$ K and $P=0.1$-0.3 dyne cm^2



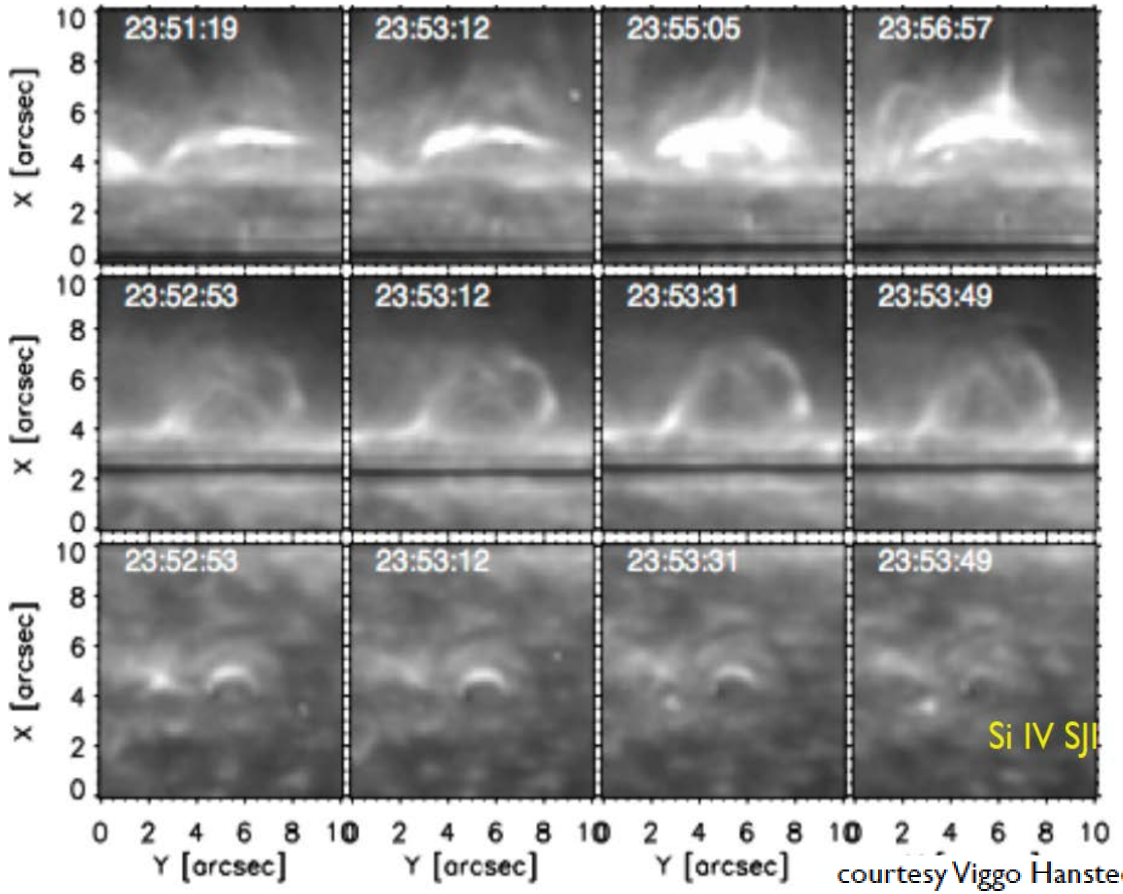
Patsourakos et al. (2007)

Are these threads cool loops?
(Centeno & Judge, 2008 - Judge, 2008)

Observations

IRIS - Interface Region Imaging Spectrograph

There are many low lying, short lived, cool
loops in the C II '1330' and Si IV '1400' slit jaw images.
"UFS" (unresolved fine structure) resolved



courtesy Viggo Hansteen

Hansteen et al. (2014)

Optically Thick Radiative Losses

AN: Antiochos & Noci (1986)

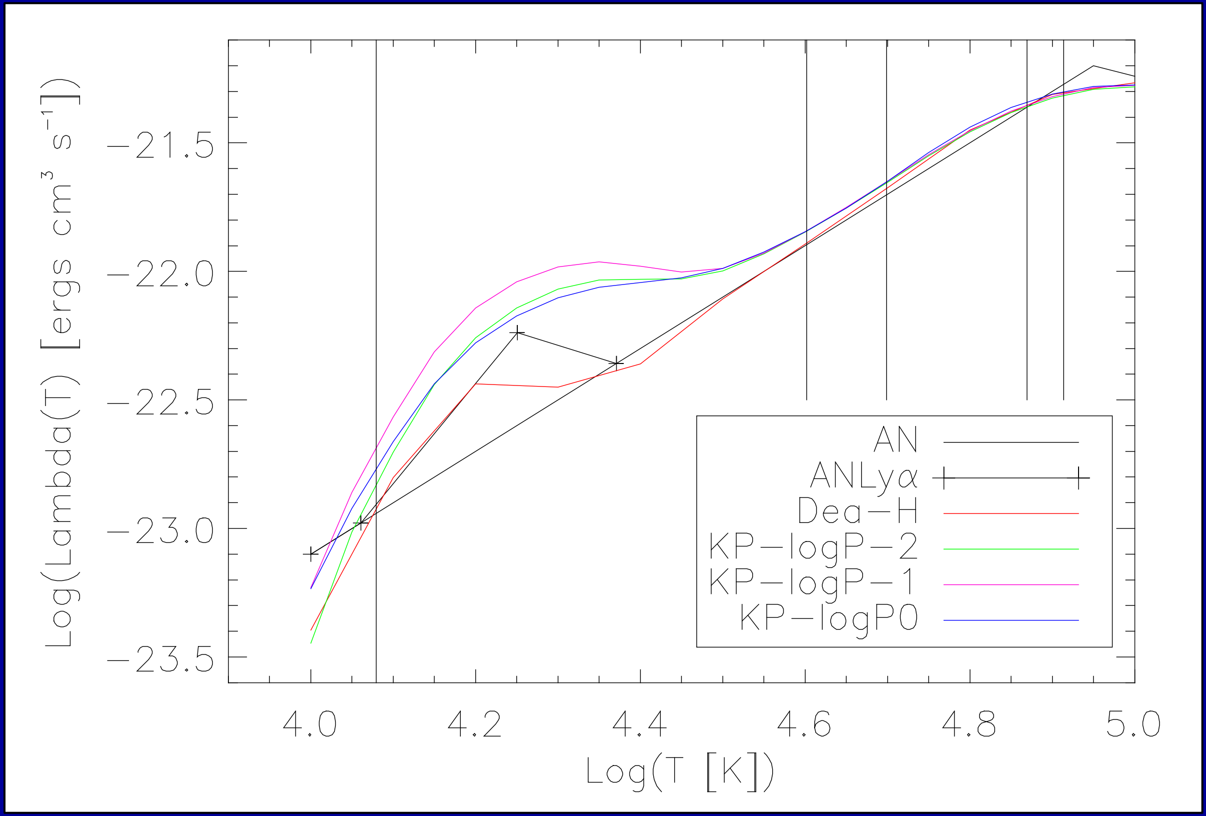
T^2 for logT < 4.95

T^{-1} for logT > 4.95

ANLyα: AN+Ly α peak

Dea-H: Dere et al. (2009) without H contribution

KP: Kuin & Poland for different pressure values

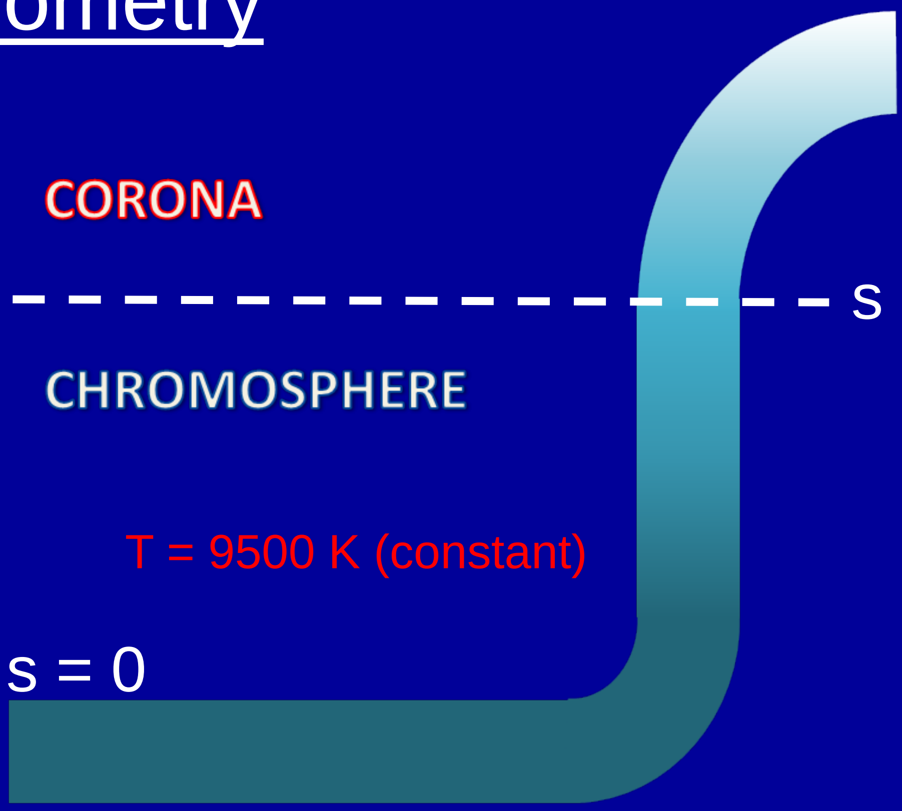


Loop model

- <u>ARGOS</u> with PARAMESH package:

1D hydrodynamic code with adaptive grid (essential to resolve the thin chromospheric-coronal transition region section of the loop for coronal loops, or shocks in dynamical simulations)

- <u>Geometry</u>



Simulations start from quasi-static cool loops obtained previously (optically thin radiative losses and constant heating)

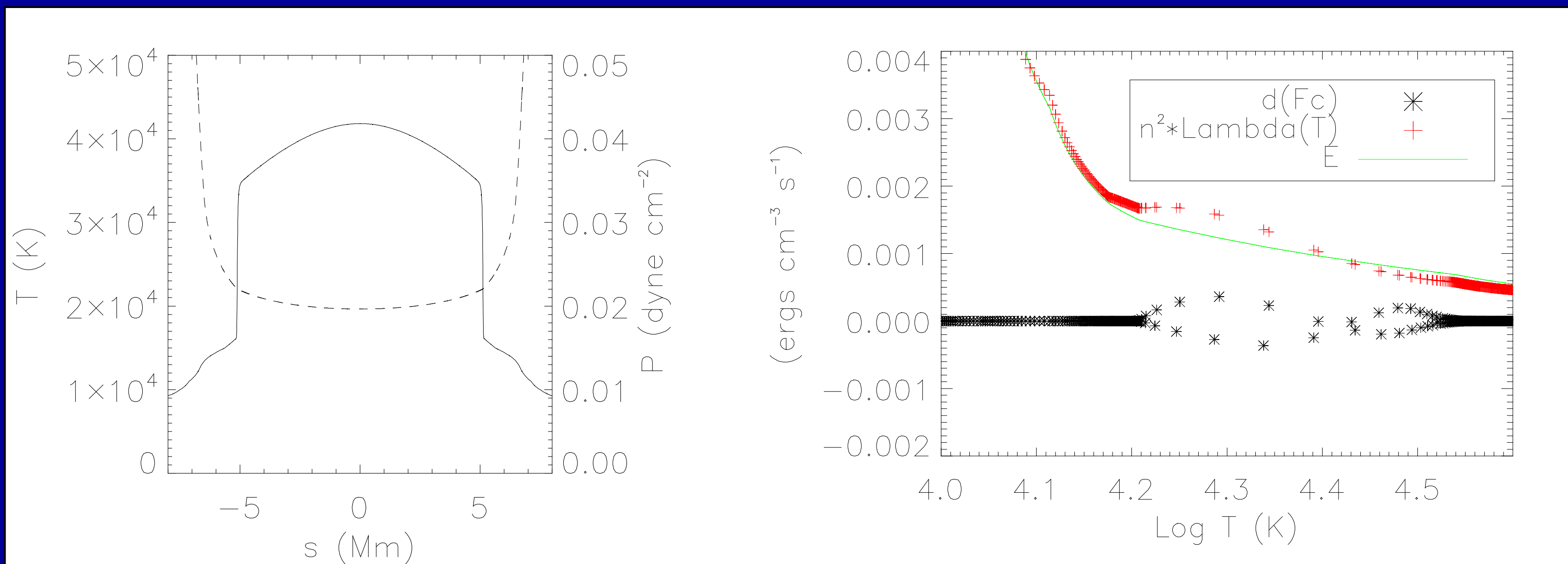
Results

Cool loops from constant heating rate & optically thick radiative losses

“Loop0” stays for 42 min in a cool state (T< 10^5 K) even if not a stable one. The mean temperature of the loop oscillates between 1-2x10^4 K for 38 min and then in 4 min reaches much higher values.
During these 4 minutes the simulation records three states characterized by maximum temperatures of 5, 7 and 9x10^4 K, progressively.

Results

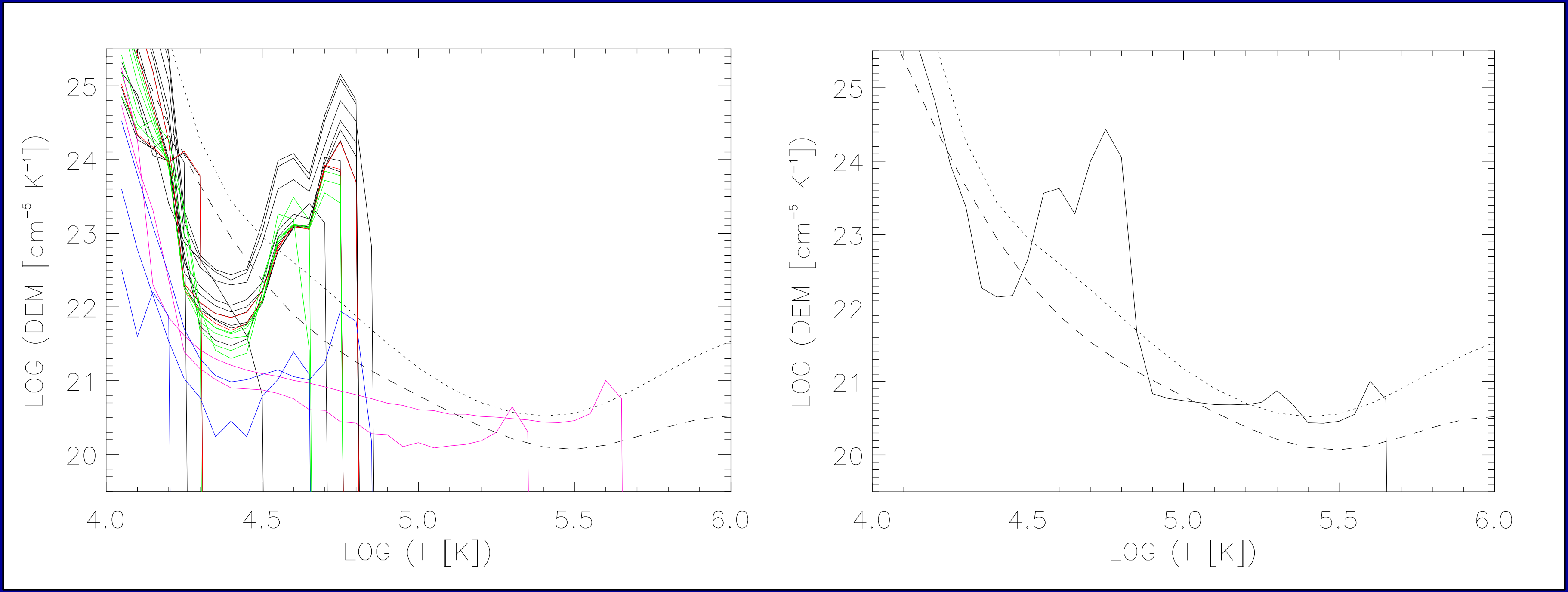
Loops from constant heating rate per particle (dependent on density) & optically thick radiative losses



Maximum temperatures: 1.5 - 6.2 × 10^4 K
Small (L/2 = 7.5−8.8 Mm, h = 1.67−3.05 Mm)
Nearly isobaric
Balance between the heating rate and radiative losses
– Quasi-static cool loops, predicted by Antiochos & Noci (1986) –

DEMs

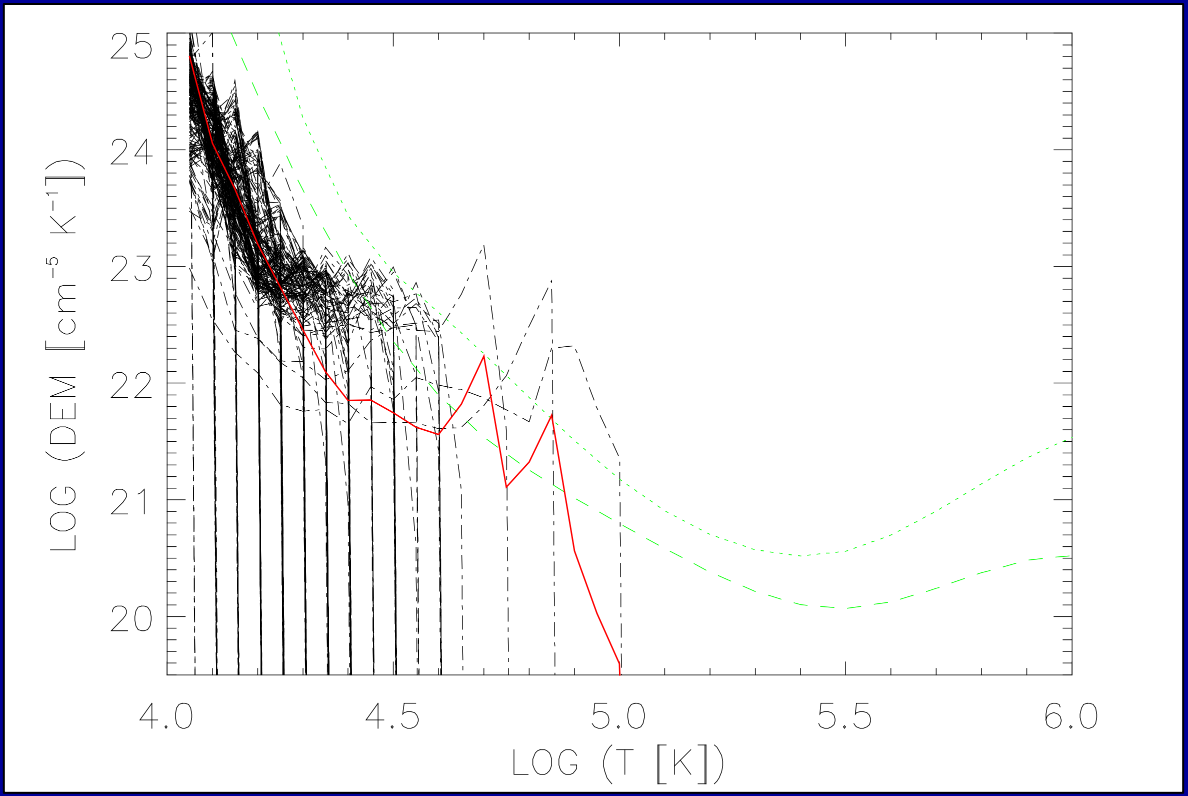
Loops from constant heating rate per particle (dependent on density) & optically thick radiative losses



Total DEM resulting from the combination of the DEMs of the single loops (shown in the left panel)

DEMs

Cool loops from constant heating rate & optically thick radiative losses



DEM of one meta-stable cool loop “Loop0” over the whole simulation (DEMs of each loop at each step of the simulation) → It is like to average the DEMs produced by different loops in a different phase of their evolution.

Conclusions

- We have studied the conditions of existence and stability of cool loops with $T<10^5$ K through hydrodynamic simulations, introducing a calculated, <u>optically thick radiative loss function</u>.
- We found that it is possible to obtain quasi-static cool loops in these conditions stable over hours or more by using a constant heating rate per particle.
- We analyzed the contributions of these cool loops, plus the intermediate temperature loops we also obtained, to the TR DEM.
- We also found meta-stable cool loops and analyzed their contribution to the TR DEM.

- IRIS observations → dynamic loops (impulsive heating, …)