Constraining **giant planet formation** with synthetic **ALMA** images of the **Solar System**'s natal protoplanetary disk

Bergez-Casalou C.[1], Bitsch B.[1], Kurtovic N.[1], Pinilla P. [1,2]

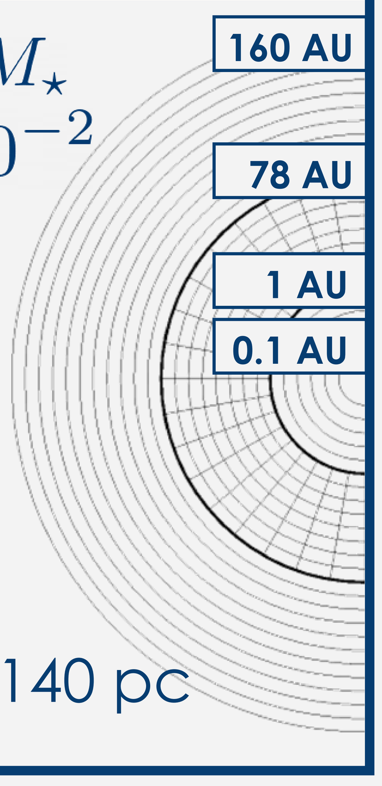
[1] Max Planck Institute for Astronomy, Heidelberg, Germany   [2] Mullard Space Science Laboratory, Holmbury St Mary, UK

OBJECTIVES

Recent observations of protoplanetary disks as, e.g. in the DSHARP Survey[1], can be used to derive constraints on planet formation. On the other hand, observations of our own Solar System bring a completely different kind of constraints. The goal of this study is to better link the observations of dust in disks to the Solar System by estimating how its likely natal disk could have looked like if we observed it with ALMA. An hypothetic exoplanetary system is also tested for comparison. The synthetic images can be compared to the observed disks and help to better constrain planet formation.

NUMERICAL SETUP

- **Gas:** Fargo2D1D[2] - Isothermal - $M_{disk} = 10\% M_\star$
  $\Sigma = (836.1 \text{ g/cm}^2)\ r^{-1} \quad \alpha = 10^{-4}; 10^{-3}; 10^{-2}$
  $h = H/r = (0.025; 0.033) \times r^{2/7}$
- **Dust:** Twopoppy[3] - 1D radial growth
  Integrated for 1Myr - $a_0 = 2.5 \times 10^{-6}$cm
  $\Sigma_{d,0} = 0.01 \times \Sigma_{g,1D} \quad v_f(\alpha) = (1, 3, 10)$m/s
- **Flux:** Radmc3D[4] - 1.3mm - DSHARP opacities - 140 pc

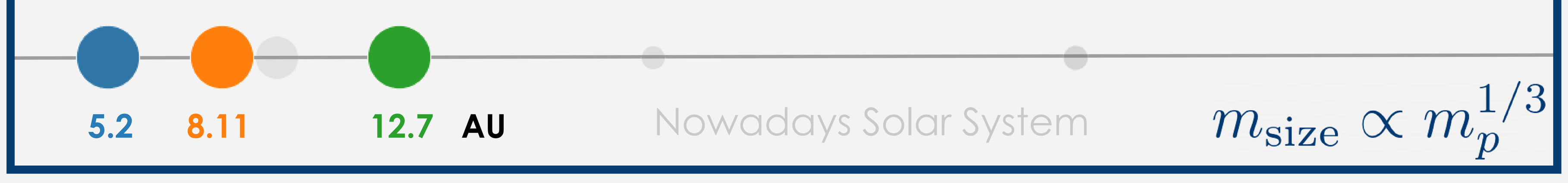


PLANETS SETUP

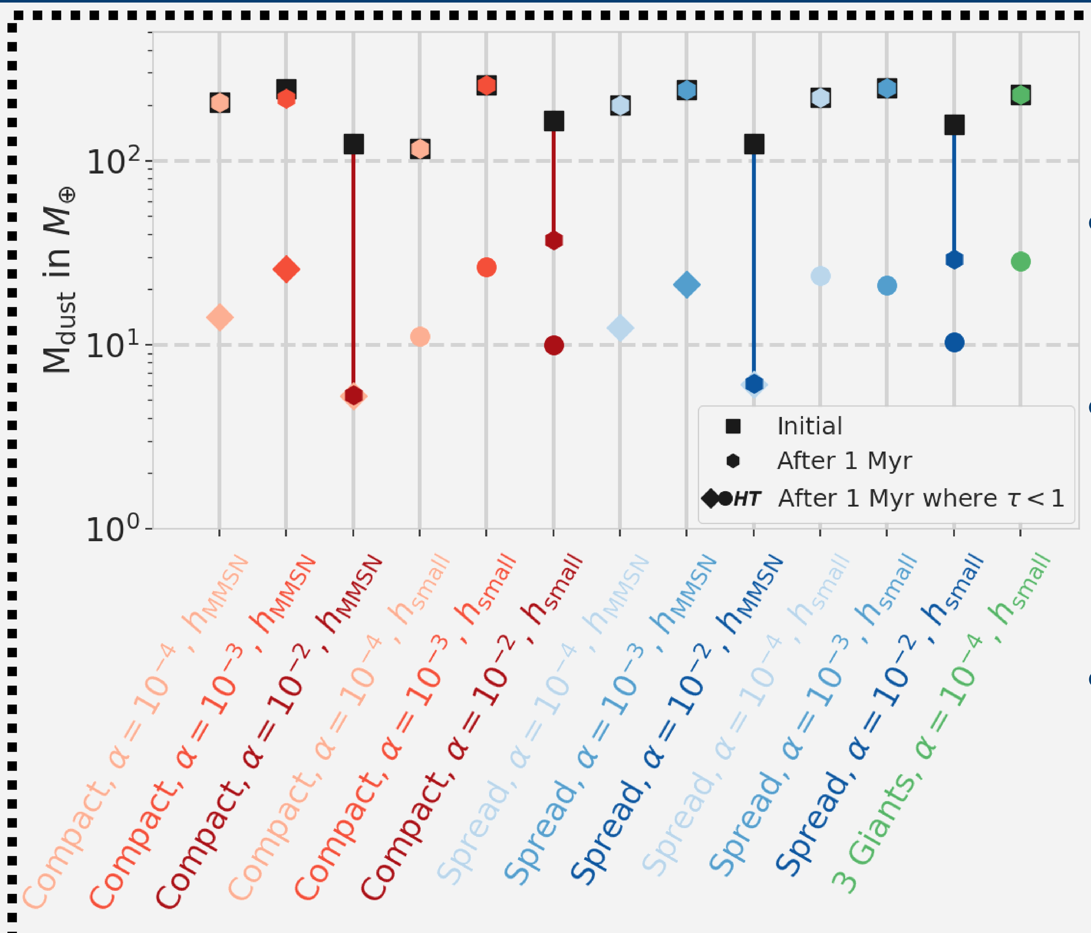
- Compact Solar System - Nice instability model[5]

- Spread Solar System - Inward migration model

- 3 Giants of 1Mj - Exoplanet comparison

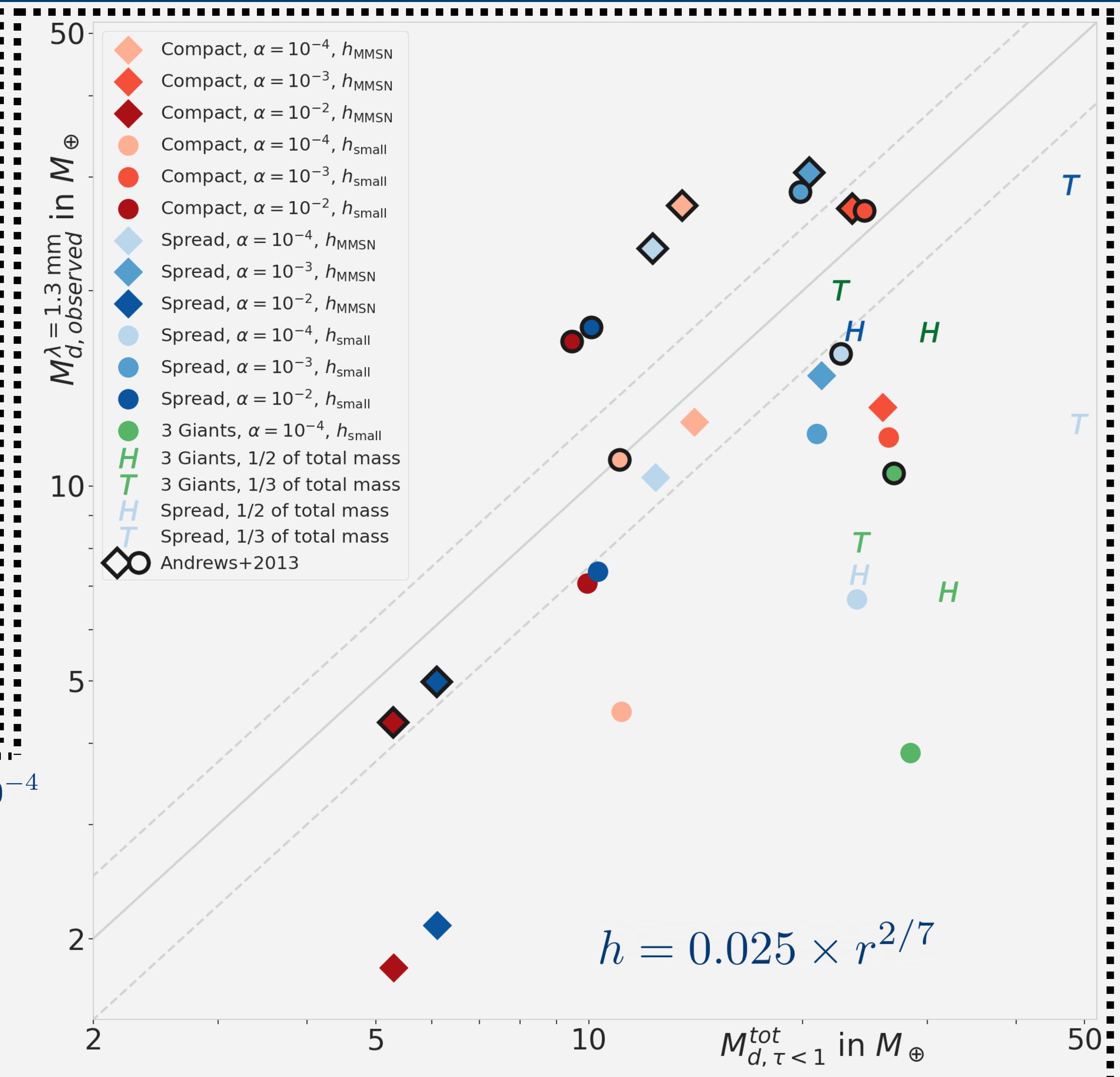


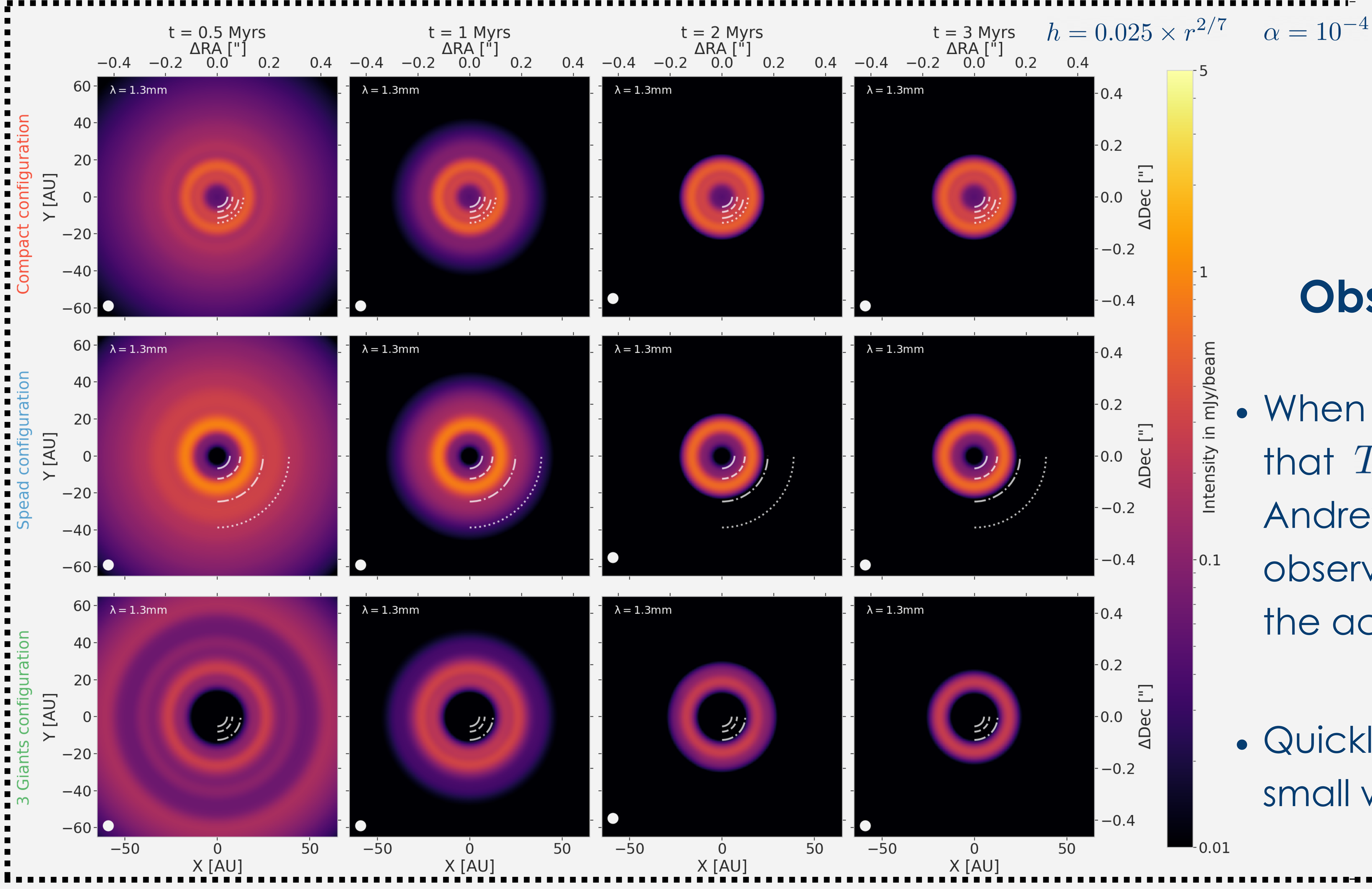
RESULTS



Dust growth

- At *high* viscosity, dust grains drift through the planets pressure bumps.
- At *low* viscosity, dust grains are trapped in the pressure bumps and become optically thick.
- Then, optically thin dust represents only **~10%** of the total dust mass.





Observing dust in protoplanetary disks

- When observing dust in disks, most studies assume that $T_{dust} = 20\text{K}$ and $\kappa_\nu^{abs} = 2.3 \text{ cm}^2/\text{g}$ as in Andrews+2013. Following this, the resulting observed masses are overestimated compared to the actual optically thin dust mass.
- Quickly (< 1 Myrs), our observed dust disks become small with all substructures within 60 AU.

CONCLUSION

camille.bergez@obspm.fr

Compared to known protoplanetary disks, the Solar System's disk would look like a small compact disk without substructures at large radii (<60 AU). Dust rings quickly become optically thick, hiding the majority of the dust. An accurate estimate of the dust properties (opacity, temperature) is necessary to determine the amount of solids available for planet formation.

References : [1]Andrews+2018 [2]Crida+2007 [3] Birnstiel+2012,2015 [4] Dullemond+2012 [5]Gomes+2005