

# On polynomial automorphisms which commute with a simple derivation

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- ▶ **Notice:**  $e^{a\Delta}$  is the translation  $x_i + a$  if and only if  $\Delta =$  the partial derivative  $\partial/\partial x_i$ .

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“Algebraic” means the degree of polynomials defining elements in that subgroup is bounded (Kambayashi, 1979).



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- ▶ The results below are in collaboration with A. Rittatore and P.-L. Montgard. Assume  $D$  to be simple.
- ▶ **Theorem 1.** If  $\text{Aut}(D)$  is algebraic, then it is unipotent.
- ▶ **Theorem 2.**  $\text{Aut}(D)^0$  is algebraic of dimension  $\leq n - 2$ .
- ▶ **Theorem 3.** If  $n = 3$ , then  $\text{Aut}(D)^0 = 1$  or  $\text{Aut}(D)^0 = \text{Aut}(D) = \mathbb{k}$  (acting as translations).

# Sketch

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## List of references

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- ▶ Derksen, H., van den Essen, A., Finston, D. R., Maubach, S., *Unipotent group actions on affine varieties*, J. Algebra 336 (2011), 200–208.



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- ▶ A. Shamsuddin, *Ph.D. thesis*, Univesity of Leeds, 1977
- ▶ D. Yan, *Simple derivations in two variables*, Comm. in Algebra, vol. 47, Issue 9 (2019), pp.3881-3888.



**END**





# THANKS!