

RENDICONTI *del* SEMINARIO MATEMATICO *della* UNIVERSITÀ DI PADOVA

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Rendiconti del Seminario Matematico della Università di Padova,
tome 72 (1984), p. 45-48

http://www.numdam.org/item?id=RSMUP_1984__72__45_0

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A Remark on the Spectra of Rings with Gabriel Dimension.

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All rings considered in this Note will be commutative and unitary. For such a ring $\mathfrak{J}(A)$ will denote the lattice of ideals of A and $\text{Spec}(A)$ the topological space (endowed with the Zariski topology) of prime ideals of A .

Năstăsescu [N] has proved that if A and B are two commutative Noetherian rings having the lattices $\mathfrak{J}(A)$ and $\mathfrak{J}(B)$ isomorphic, then $\text{Spec}(A)$ and $\text{Spec}(B)$ are homeomorphic topological spaces. He gives also a counter-example to show that the result fails for arbitrary commutative rings.

The aim of this Note is to present a very short proof of the above result in a more general setting: A or B has a Gabriel dimension, and $\mathfrak{J}(A)$ is isomorphic to $\mathfrak{J}(B)$ not necessarily as lattices but only as partially ordered sets.

Denote by $\text{Spec}(A)_0$ the set of maximal ideals of A , and if $\alpha > 0$ is an ordinal, denote by $\text{Spec}(A)_\alpha$ the set of prime ideals P of A such that each prime ideal Q of A properly containing P belongs to $\text{Spec}(A)_\beta$ for some $\beta < \alpha$. If A has a Gabriel dimension then it is well-known that $\text{Spec}(A) = \text{Spec}(A)_\alpha$ for an ordinal α ; in this case the least such α is called the classical Krull dimension of A , denoted by $\text{cl } K \dim A$. If the ring A has a Gabriel dimension as defined in [G-R], this dimension will be denoted by $G \dim A$.

LEMMA [G-R]. If the ring A has a Gabriel dimension, then A is Gabriel simple if and only if A is a domain. ■

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THEOREM. Let A and B two commutative rings with unit element such that there exists an isomorphism

$$\varphi: \mathfrak{J}(A) \rightarrow \mathfrak{J}(B)$$

of partially ordered sets. Suppose that A has a Gabriel dimension. If P is an ideal of A and $\alpha \geq 0$ is an ordinal, then:

- (1) B has a Gabriel dimension and $G \dim B = G \dim A$.
- (2) B is Gabriel simple if and only if A is Gabriel simple.
- (3) $P \in \text{Spec}(A)$ if and only if $\varphi(P) \in \text{Spec}(B)$.
- (4) $P \in \text{Spec}(A)_\alpha$ if and only if $\varphi(P) \in \text{Spec}(B)_\alpha$.
- (5) $\text{cl } K \dim B = \text{cl } K \dim A$.

PROOF. (1) and (2) follow at once from the inductive noncategorical definition of the Gabriel dimension of a module, sketched in [G] and explicitied in [L]. A proof that this definition is indeed the same with the original definition of the Gabriel definition by means of quotient categories may be found in [A].

(3) Suppose that $P \in \text{Spec}(A)$; then A/P is a domain with Gabriel dimension, and by the Lemma, A/P is Gabriel simple. But the isomorphism

$$\varphi: \mathfrak{J}(A) \rightarrow \mathfrak{J}(B)$$

of posets induces an isomorphism

$$\varphi_P: \mathfrak{J}(A/P) \rightarrow \mathfrak{J}(B/\varphi(P))$$

of posets. According to (2), $B/\varphi(P)$ is Gabriel simple, and so, by Lemma, $B/\varphi(P)$ is a domain. Consequently $\varphi(P) \in \text{Spec}(B)$.

(4) We proceed by transfinite induction. If $\alpha = 0$ and $P \in \text{Spec}(A)_0$ then P is a maximal ideal of A , and then, since φ is an isomorphism of posets, $\varphi(P)$ has the same property; so $\varphi(P) \in \text{Spec}(B)_0$. Let now $\alpha > 0$ and suppose that $P \in \text{Spec}(A)_\alpha$. Denote $P' = \varphi(P)$ and let $Q' \in \text{Spec}(B)$ with $Q' \supsetneq P'$. Then $Q' = \varphi(Q)$ for some $Q \in \mathfrak{J}(A)$ with $Q \supsetneq P$. By (3), $Q \in \text{Spec}(A)$, hence $Q \in \text{Spec}(A)_\beta$ for some $\beta < \alpha$.

By the induction hypothesis $\varphi(Q) = Q' \in \text{Spec}(B)_\beta$, and consequently $P' = \varphi(P) \in \text{Spec}(B)_\alpha$.

(5) follows immediately from (4). ■

COROLLARY 1. If the rings A and B are as in the theorem above then $\text{Spec}(A)$ and $\text{Spec}(B)$ are homeomorphic.

PROOF. The isomorphism $\varphi: \mathfrak{J}(A) \rightarrow \mathfrak{J}(B)$ of posets induces by the theorem a bijective map

$$\bar{\varphi}: \text{Spec}(A) \rightarrow \text{Spec}(B)$$

which is clearly bicontinuous. ■

COROLLARY 2 [N]. If A and B are commutative Noetherian rings with unit element for which there exists an isomorphism $\varphi: \mathfrak{J}(A) \rightarrow \mathfrak{J}(B)$ of lattices, then $\text{Spec}(A)$ and $\text{Spec}(B)$ are homeomorphic. ■

REMARKS. (1) The proof of Corollary 2 given in [N] uses essentially both the Noetherian condition on A and the fact that $\varphi: \mathfrak{J}(A) \rightarrow \mathfrak{J}(B)$ is a lattice isomorphism.

(2) The condition « A has a Gabriel dimension » is essential for Corollary 1 to be true. To see this it is sufficient to consider the example given in [N]:

Let A be a rank 1 nondiscrete valuation ring with value group the additive group \mathbf{R} of real numbers; if $v: A \rightarrow \mathbf{R} \cup \{\infty\}$ is the valuation on A and $I = \{x \in A \mid v(x) \geq \pi/2\}$, then I is a nonzero ideal of A , $\mathfrak{J}(A)$ and $\mathfrak{J}(A/I)$ are isomorphic lattices, but $\text{Spec}(A) = \{0, M\}$ and $\text{Spec}(A/I) = \{M/I\}$, where M is the unique maximal ideal of A . Note that A has not Gabriel dimension. ■

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Manoscritto pervenuto in redazione il 28 febbraio 1983.