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The image and kernel of Atkin's U_p operator modulo p

We determine the image of Atkin's U_p operator acting on $\pmod{p}$ reduced modular forms. In 1972, Serre showed that for level 1 modular forms, U_p was contractionary (i.e. the image has lower weight than the preimage.) We determine the exact weight of the space of images and generalize to all levels not divisible by p. As a consequence, we determine the dimension of the kernel of $U_p \pmod{p}$ for large weights. This contrasts with the situation for small weights, which is still confoundingly mysterious.