

# Vortex molecules in Bose-Einstein condensates

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Stable vortex dimers are known in coherently coupled two component Bose-Einstein condensates (BECs).<sup>1</sup> We construct stable vortex trimers in three component BECs and find that the shape can be controlled by changing the internal coherent (Rabi) couplings.<sup>2</sup> Stable vortex  $N$ -omers are also constructed in coherently coupled  $N$ -component BECs.<sup>3</sup> We classify all possible  $N$ -omers in terms of the mathematical graph theory. Next, we study effects of the Rabi coupling in vortex lattices in two-component BECs. We find how the vortex lattices without the Rabi coupling known before<sup>4</sup> are connected to the Abrikosov lattice of integer vortices with increasing the Rabi coupling.<sup>5</sup> In this process, we find various bound states of vortex dimers at small couplings and vortex dimers changing their partners in various ways at large couplings. We then find that the Abrikosov lattices are robust in three-component BECs.<sup>6</sup>

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